emFile

CPU-independent file system
for embedded applications

User Guide & Reference Manual

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Manual versions

This manual describes the current software version. If any error occurs, inform us, and we will try to assist you as soon as possible. Contact us for further information on topics or routines not yet specified.

Print date: October 1, 2026

Software	Revision	Date	By	Description
5.44.0	0	261001	MD	Added -e option to File Encrypter utility. Corrected spelling and grammar errors. Added FS_CRYPT_FILE_INFO structure. Added FS_CRYPT_EncodeFileHeaderEx() API function. Added FS_CRYPT_DecodeFileHeaderEx() API function. Added FS_CRYPT_GetFileExtraDataSize() API function. Added FS_CRYPT_ReadFileExtraData() API function. Added FS_CRYPT_SetFileExtraDataSize() API function. Added FS_CRYPT_WriteFileExtraData() API function. Added FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE configuration define. Added FS_STORAGE_GetConfig() API function. Updated the list of supported NAND flash devices. Added FS_NOR_SPIFI_Allow8bitMode() API function. Updated the list of supported NOR flash devices. Added FS_NAND_HW_TYPE_QSPI_WRITE_MULTIPLE function. Added FS_DATA_ITEM_CONST structure. Updated the list of supported NAND flash devices. Added FS_SUPPORT_FILE_BUFFER_RELOCATABLE configuration define.
5.42.0	0	260521	MD	Added FS_NAND_PHY_ReadCASNPara() API function. Added FS_NAND_PHY_SetHWTypeSPI() API function. Added FS_NAND_PHY_SetHWTypeDataFlash() API function. Added FS_NAND_PHY_SetHWTypeQSPI() API function. Added FS_MEMORY_ALIGNMENT configuration define. Added FS_MMC_CM_ReadSCR() API function. Added FS_MMC_CM_ReadSSR() API function. Updated the list of supported NOR flash devices. Updated the list of supported NAND flash devices. Added FS_FileTimeToTimeStampEnhanced() API function. Added FS_TimeStampEnhancedToFileTime() API function. Added FS_SetTimeDateEnhancedCallback() API function. Added FS_TIME_DATE_ENHANCED_CALLBACK function definition. Added FS_SUPPORT_TIME_DATE_ENHANCED configuration define. Added FS_GetFileTimeEnhanced() API function. Added FS_SetFileTimeEnhanced() API function.
5.40.0	0	260223	MD	Updated the list of supported NAND flash devices.
5.38.1	1	251117	MD	Added “importimage” command to Storage Image Creator. Added “formatexfat” command to Storage Image Creator.
5.38.1	0	251027	MD	Added FS_NOR_READ_ALIGNMENT configuration define. Added FS_NOR_SUPPORT_ACCESS_ALIGNMENT configuration define. Added FS_NOR_SFDP_SetReadAlignment() API function. Added FS_NOR_SPIFI_SetReadAlignment() API function.
5.38.0	0	250814	MD	Updated the list of supported NOR flash devices. Added “seteccsupport” command to NOR Image Creator. Updated information about the File Encrypter utility. Added FS_CRYPT_DecodeFileHeader() API function. Added FS_CRYPT_EncodeFileHeader() API function. Added information about the maximum storage capacities. Updated the list of supported NAND flash devices. Added FS_FindMatch() API function. Added FS_FindMatch64() API function.
5.36.0	0	250526	MD	Added FS_MEMMOVE() macro. Added FS_EXFAT_MAX_NUM_OEM_PARA configuration define. Added FS_EXFAT_WriteOEMPara() API function. Added FS_EXFAT_ReadOEMPara() API function. Added section about reducing RAM usage of Universal NAND driver. Added section about improving performance of Universal NAND driver. Added section about block grouping of Universal NAND driver. Added section about reducing RAM usage of Block Map NOR driver. Added section about improving performance of Block Map NOR driver.

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Software	Revision	Date	By	Description
				Added FS_STORAGE_FormatLow() API function. Added FS_STORAGE_IsLLFormatted() API function. Updated section about running emFile on target hardware. Updated the list of supported NOR flash devices. Updated the list of supported NAND flash devices. Added FS_FormatEx() function.
5.34.0	0	250213	MD	Updated information about running on target hardware. Added FS_GetFileName() API function. Added FS_NAND_HW_TYPE_QSPI_READ_EX function. Added FS_NAND_QSPI_AllowDTRMode() function. Updated the list of supported NOR flash devices. Updated the list of supported NAND flash devices.
5.32.1	0	241104	MD	Updated the list of supported NOR flash devices. Added FS_CRYPT_SetSectorBufferSize() function.
5.32.0	0	241002	MD	Added FS_EXFAT_UPDATE_SPACE_USAGE configuration define. Added FS_EXFAT_UPDATE_DIRTY_FLAG configuration define. Added FS_EXFAT_SUPPORT_FREE_CLUSTER_CACHE configuration define. Added FS_EXFAT_PERMIT_RO_FILE_MOVE configuration define. Added FS_EXFAT_OPTIMIZE_LINEAR_ACCESS configuration define. Added FS_EXFAT_FILE_NAME_CONV_DEFAULT configuration define. Added FS_SUPPORT_LARGE_FILES configuration define. Added FS_SUPPORT_EXFAT configuration define. Updated the list of supported NOR flash devices. Added FS_Truncate64() API function. Added FS_FindFirstFile64() API function. Added FS_FindNextFile64() API function. Added FS_FindClose64() API function. Added FS_FIND_DATA64 structure. Added FS_GetFileSize64() function. Added FS_SetFileSize64() function. Added FS_Seek64() function. Added FS_FTell64() function. Added FS_GetFileInfo64() function. Added FS_FILE_INFO64 structure. Added FS_EXFAT_ConfigDirtyFlagUpdate() function. Added FS_EXFAT_ConfigSpaceUsageUpdate() function. Added FS_EXFAT_ConfigROFileMovePermission() function. Added FS_EXFAT_FormatSD() function. Added FS_EXFAT_GetConfig() function. Added FS_EXFAT_GetFileNameConverter() function. Added FS_EXFAT_GrowRootDir() function. Added FS_EXFAT_SetFileNameConverter() function. Added FS_EXFAT_LAYOUT structure. Added FS_EXFAT_CONFIG structure. Added FS_SetEncryptionObjectEx() function. Added FS_CRYPT_AES_OPTIMIZE_MIX_SUBST configuration define. Added FS_CRYPT_AES_OPTIMIZE_MIX_COLUMNS configuration define. Added FS_CRYPT_AES_SUPPORT_INPLACE_CALC configuration define. Added FS_CRYPT_AUTH_TAG_BUFFER_SIZE configuration define. Added FS_CRYPT_DES_SUPPORT_INPLACE_CALC configuration define. Added FS_CRYPT_SUPPORT_ENHANCED_MODE configuration define. Added FS_CRYPT_SUPPORT_STANDARD_MODE configuration define.
5.30.0	0	240617	MD	Added section for the Authenticated Encryption driver. Added FS_MMC_NOTIFY_EVENT configuration define. Added FS_MMC_SUPPORT_ERROR_RECOVERY configuration define. Updated the list of supported NAND flash devices. Updated the list of supported NOR flash devices. Added FS_CRYPT_EncryptEx() function. Added FS_CRYPT_DecryptEx() function. Added FS_GetPathBaseName() function. Added FS_GetPathDirName() function. Added FS_GetPathExtension() function. Added FS_GetPathVolumeName() function. Added FS_MakePath() function. Added new functions to the SPIFI NOR physical layer. Added FS_CopyDir() function. Added formatting flags. Added FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST configuration define. Added FS_NOR_MIN_SECTOR_SIZE_SHIFT configuration define.

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Software	Revision	Date	By	Description
				Added FS_NOR_MAX_NUM_SECTOR_SIZES configuration define. Added FS_IsFileBufferSet() function. Added FS_GetFileBufferInfo() function. Added FS_UnsetFileBuffer() function. Added FS_SUPPORT_FILE_BUFFER_LIST configuration define. Added CRC function replacement macros.
5.28.0	0	240212	MD	Added FS_NAND_SUPPORT_FAIL_SAFE_ERASE configuration define. Added freesectors command to Storage Image Creator. Added FS_FILEDISK_WORK_BUFFER_SIZE configuration define. Added FS_GetFirstCluster() function. Added FS_GetATInfo() function. Added FS_GetClusterInfo() function. Added FS_GetDiskLayout() function. Added FS_WINDRIVE_AllowImageFile() function. Added read-only versions of the device drivers.
5.26.0	0	231117	MD	Added section for the Storage Image Creator utility. Added FS_GetFileSizeEx() function. Added FS_STORAGE_SyncEx() function. Added FS_STORAGE_FindVolumeByDevice() function. Added FS_STORAGE_FindVolumeByIndex() function. Added FS_STORAGE_FreeSectorsEx() function. Added FS_STORAGE_CleanEx() function. Added FS_STORAGE_CleanOneEx() function. Added FS_STORAGE_GetCleanCntEx() function. Added FS_STORAGE_GetSectorUsageEx() function. Added FS_STORAGE_RefreshSectorsEx() function. Added FS_STORAGE_SyncSectorsEx() function. Added FS_STORAGE_Mount() function. Added FS_STORAGE_MountEx() function. Added FS_STORAGE_SetAutoMountType() function. Added FS_STORAGE_GetAutoMountType() function. Added FS_STORAGE_GetMountType() function. Added FS_STORAGE_SetAutoMountTypeEx() function. Added FS_STORAGE_GetAutoMountTypeEx() function. Added FS_STORAGE_GetMountTypeEx() function. Added FS_STORAGE_SUPPORT_MOUNT configuration define.
5.24.0	0	230828	MD	Updated section about Encryption usage. Updated the list of supported NAND flash devices. Added FS_MMC_CM_ReadSectors() function. Added FS_MMC_CM_WriteSectors() function. Added FS_LOGVOL_SUPPORT_CLEAN configuration define. Added FS_LOGVOL_SUPPORT_TRIM configuration define. Added FS_MMC_CM_ReadCSD() function. Added section for the File Disk driver. Added FS_NOR_OPTIMIZE_EMPTY_CHECK configuration define. Added exportimage command to NOR Image Creator. Updated the list of supported NOR flash devices. Updated the list of supported FRAM devices. Added exportfolder command to NAND Image Creator. Added /R option to rd command of the NAND Image Creator. Added /S option to addfolder command of the NAND Image Creator.
5.22.0	0	230216	MD	Added section for Universal RAM Disk driver. Updated the list of supported NAND flash devices. Updated the list of supported NOR flash devices. Added FS_NOR_DMB() configuration define. Added FS_NOR_REVERSE_ENDIANESS configuration define. Added FS_STORAGE_FillSectors() API function. Added FS_STORAGE_FillSectorsEx() API function. Added FS_MMC_CM_ReadGeneral() API function. Added FS_MMC_CM_WriteGeneral() API function.
5.20.0	0	221114	MD	Updated the list of supported NOR flash devices. Added section for partitioning functions. Updated the list of supported NAND flash devices. Added FS_FGets() function. Added FS_CreateGPT() function. Added FS_SUPPORT_GPT configuration define. Added FS_GetPartitioningScheme() function. Added FS_GetGPTInfo() function. Added FS_GPT_INFO structure.

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				Added FS_GetPartitionInfoGPT() function. Added FS_PARTITION_INFO_GPT structure. Renamed FS_GetPartitionInfo() function to FS_GetPartitionInfoMBR(). Renamed FS_PARTITION_INFO structure to FS_PARTITION_INFO_MBR. Added FS_SUPPORT_SECTOR_BUFFER_BURST configuration define. Added FS_MMC_DISABLE_DAT3_PULLUP configuration define. Added missing configuration defines for Card Mode MMC/SD driver.
5.18.0	0	220727	MD	Added FS_MMC_CM_AllowCacheActivation() function. Added FS_NOR_SPIFI_AllowDTRMode() function. Added FS_NOR_HW_TYPE_SPIFI_MAP_EX, FS_NOR_HW_TYPE_SPIFI_MAP_EX, FS_NOR_HW_TYPE_SPIFI_READ_EX, FS_NOR_HW_TYPE_SPIFI_WRITE_EX and FS_NOR_HW_TYPE_SPIFI_POLL_EX functions. Added FS_NOR_SPIFI_AllowOctalMode() function. Updated the list of supported NOR flash devices.
5.16.2	0	220725	MD	Changed the name of BigFile component to BigFAT.
5.16.0	0	220428	MD	Added sample for disk checking in the background. Added FS_FPuts() function. Added FS_NAND_UNI_SetMaxPageSize() function. Added FS_NAND_UNI_SetMaxSpareAreaSize() function. Added FS_FPrintf() function. Added FS_OPTIMIZATION_TYPE configuration define. Extended the Storage layer API. Updated the list of supported NAND flash devices. Added FS_NOR_ErasePhySector() function. Added FS_NOR_WriteOff() function. Added FS_NOR_OPTIMIZE_DATA_WRITE configuration define. Added FS_NOR_SUPPORT_TRIM configuration define.
5.14.0	0	220307	MD	Added FS_NOR_HW_TYPE_SPI_READ_EX and FS_NOR_HW_TYPE_SPI_WRITE_EX functions. Added FS_FAT_CHECK_UNUSED_DIR_ENTRIES configuration define. Added FS_BIGFILE_CheckDisk() function. Updated the list of supported NOR flash devices. Added FS_NAND_2048X8_SetDeviceList() function. Added FS_MMC_GetCardInfo() function. Updated the list of supported NAND flash devices. Added FS_JOURNAL_OPTIMIZE_SPACE_USAGE configuration define. Added FS_NOR_SUPPORT_FORMAT configuration define.
5.12.0	0	211130	MD	Added FS_FAT_GetLFNConverter() function. Updated the list of features. Added FS_GetAutoMount() function. Added FS_FAT_GetConfig() function. Added FS_EFS_GetConfig() function. Added FS_NOR_SPIFI_ExecCmd() function.
5.10.0	0	210824	MD	Updated the list of supported NAND flash devices. Added setnumworkblocks command to NOR Image Creator.
5.8.1	0	210618	MD	Added FS_NAND_QSPI_SetDeviceList() function. Added information about the compile time and runtime configuration of the NAND physical layers. Added information about resource usage of NAND physical layers.
5.8.0	0	210517	MD	Added FS_CACHE_GetType() function. Added FS_NAND_UNI_GetBlockInfoEx() function. Added FS_NAND_ONFI_SetDeviceList() function. Updated the list of supported NOR flash devices. Updated the list of supported NAND flash devices. Added information about the compile time configuration of the NOR physical layers. Added information about creating a custom device or logical driver. Updated the list of file system configuration defines.
5.6.0	0	210127	MD	Added FS_NOR_BM_Mount() function. Added FS_MMC_CM_SetDriverStrength() function. Added information about the compile time configuration of the Block Map NOR driver. Added information about the compile time configuration of the Sector Map NOR driver. Updated the list of supported NOR flash devices. Added FS_NOR_BM_EnableECC() function. Added FS_NOR_BM_DisableECC() function.

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				Added FS_NOR_BM_SetECCHook() function. Added FS_NOR_BM_IsECCEnabled() function. Added FS_NOR_ECC_HOOK structure. Added FS_NOR_ECC_HOOK_CALC function. Added FS_NOR_ECC_HOOK_APPLY function. Improved the section about the RAM usage of the file system.
5.4.0	0	201029	MD	Added FS_GetVolumeAlias() function. Added FS_NOR_SFDP_Configure() function. Added FS_MMC_CM_AllowAccessModeDDR50() function. Added FS_MMC_CM_AllowAccessModeHS200() function. Added FS_MMC_CM_AllowAccessModeHS400() function. Added FS_MMC_CM_AllowAccessModeHS_DDR() function. Added FS_MMC_CM_AllowAccessModeSDR104() function. Added FS_MMC_CM_AllowAccessModeSDR50() function. Added FS_MMC_CM_AllowVoltageLevel1V8() function. Added FS_MMC_CM_SetHS200Tuning() function. Added FS_MMC_CM_SetSDR104Tuning() function. Added FS_MMC_CM_SetSDR50Tuning() function. Added information about the compile time configuration of the Card Mode MMC/SD driver.
5.2.0	1	200630	MD	Added FS_NAND_UNI_Mount() function.
5.2.0	0	200527	MD	Improved wording of the FAQs chapter. Added description of the BigFileMerger utility. Added FS_NOR_BM_SetInvalidSectorError() function.
5.1.0	1	200411	MD	Updated the resource usage of EFS.
5.1.0	0	200504	MD	Added FS_GetMountType() function. Added FS_NOR_SPIFI_SetSectorSize() function. Updated the list of supported NOR flash devices. Added FS_EFS_SUPPORT_FREE_CLUSTER_CACHE configuration define. Added FS_SUPPORT_SECTOR_BUFFER_CACHE configuration define. Added FS_GetMemInfo() function. Added more information about the fail-safety of the NOR drivers. Added compile time configuration information for the Block Map NOR driver.
5.0.1	1	200317	MD	Corrected a sample.
5.0.1	0	200316	MD	Corrected structure member names.
5.0.0	0	200301	MD	Reworked version of the manual.

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About this document

Assumptions

This document assumes that you already have a solid knowledge of the following:

- The software tools used for building your application (assembler, linker, C compiler).
- The C programming language.
- The target processor.
- The DOS command line.

If you feel that your knowledge of C is not sufficient, we recommend *The C Programming Language* by Kernighan and Ritchie (ISBN 0--13--1103628), which describes the standard in C programming and, in newer editions, also covers the ANSI C standard.

How to use this manual

This manual explains all the functions and macros that the product offers. It assumes you have a working knowledge of the C language. Knowledge of assembly programming is not required.

Typographic conventions for syntax

This manual uses the following typographic conventions:

Style	Used for
Body	Body text.
`Keyword`	Text that you enter at the command prompt or that appears on the display (that is, system functions, file- or pathnames).
`Parameter`	Parameters in API functions.
`Sample`	Sample code in program examples.
`Sample comment`	Comments in program examples.
Reference	Reference to chapters, sections, tables, and figures or other documents.
GUIElement	Buttons, dialog boxes, menu names, menu commands.
Emphasis	Very important sections.

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Chapter 1

Introduction to emFile

This section presents an overview of emFile, its structure, and its capabilities.

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1.1 What is emFile

emFile is a file system design for embedded applications which supports NAND, DataFlash, NOR and SPI Flash, SD and MMC Memory Cards, RAM and USB mass storage devices. emFile is a high-performance library optimized for high speed, versatility, and a minimal memory footprint of both RAM and ROM. It is written in ANSI C and can be used on any CPU.

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1.2 Features

The main features of emFile are:

- Two file system variants: FAT and SEGGER's proprietary Embedded File System (EFS).
- FAT is MS DOS/MS Windows-compatible, including FAT12, FAT16 and FAT32.
- Optional support for long file name (LFN) for FAT.
- EFS comes with native support for long file names.
- Multiple device driver support; the same driver can support multiple storage media.
- Multiple media support; device drivers allow concurrent access to different storage media types.
- Cache support via RAM for optimized performance.
- Fail-safe and task-safe, works with any operating system.
- ANSI C stdio.h-like API. Applications using standard C I/O library can easily be ported to emFile.
- Simple device driver structure, sample code trial versions and extensive API documentation.
- NAND driver for SLC and MLC NAND Flash and DataFlash with ECC and wear leveling.
- NOR driver for parallel and serial NOR flash with wear leveling.
- Driver for Memory Card devices such as MMC, SD, SDHC, eMMC that supports bus and SPI modes.
- Driver for IDE and Compact Flash that supports True-IDE and memory-mapped modes.
- Journaling, RAID1 and RAID5 options to enhance data integrity.
- Encryption at volume and file level with optional support for authentication.
- Profiling via SEGGER SystemView.
- Image creator tools for NOR and NAND.
- NAND flash evaluation board available.
- SQLite integration.
- MISRA C:2012 compliant.
- Support for Shift-JIS encoded Japanese file names.
- Support for GBK and Big5 encoded Chinese file names.
- Support for UHC encoded Korean file names.
- Support for files larger than 4 GBytes via BigFAT and exFAT components.

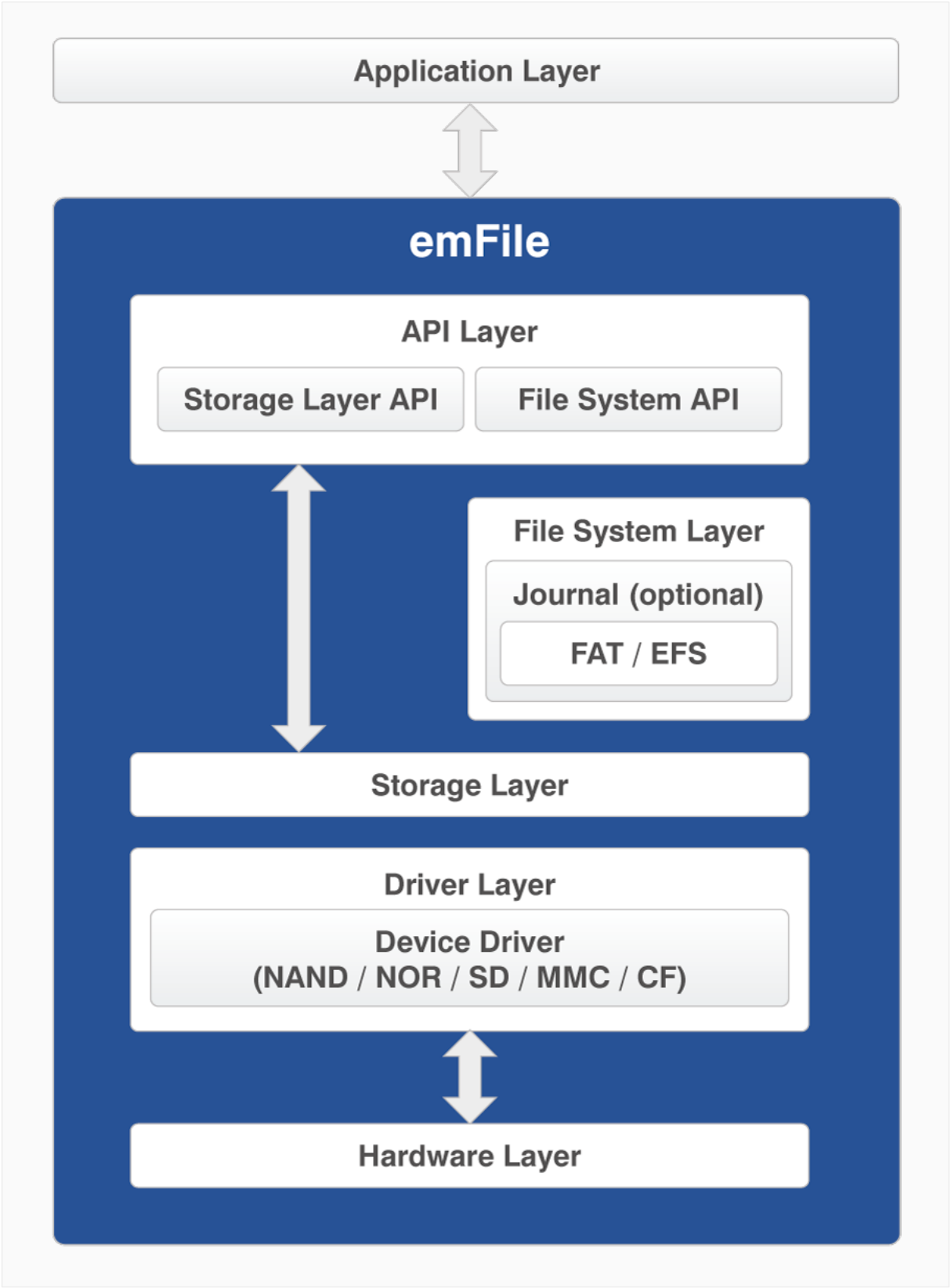
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1.3 Basic concepts

This section describes the software structure of emFile as well as other general concepts such as fail safety and wear leveling.

1.3.1 emFile structure

emFile is organized in different layers as illustrated in the following diagram. A short description of each layer's functionality follows below.



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File system structure

1.3.1.1 API layer

The API layer is the interface between emFile and the user application. It is divided into two parts: the storage API and the file system API. The file system API declares file functions in ANSI C standard I/O style, such as `FS_FOpen()`, `FS_FWrite()` etc. The API layer transfers any calls to these functions to the file system layer. Currently, the FAT file system or an optional file system, called EFS, are available for emFile. Both file systems can be used simultaneously. The storage API declares the functions which are required to initialize and access a storage medium. The storage API allows sector read and write operations. The API layer transfers these calls to the storage layer. The storage API is optimized for applications which do not require file system functionality like file and directory handling. A typical application which uses the storage API could be a USB mass storage device, where data has to be stored on a medium, but all file system functionality is handled by the host PC.

1.3.1.2 File system layer

The file system layer translates file operations to logical block (sector) operations. After such a translation, the file system calls the logical block layer and specifies the corresponding device driver for a device.

1.3.1.3 Storage layer

The main purpose of the Storage Layer is to synchronize accesses to a device driver. Furthermore, it provides a simple interface for the File System API. The Storage Layer calls a device driver to perform a block operation. It also contains the cache mechanism.

1.3.1.4 Driver layer

Device drivers are low-level routines that are used to access sectors of the device and to check status. They are hardware independent but depend on the storage medium.

1.3.1.5 Hardware layer

This layer contains the low-level routines to access your hardware. These routines simply read and store fixed-length sectors. The structure of the device driver is simple in order to allow easy integration of your own hardware.

1.3.2 Choice of file system type: FAT vs. EFS

Within emFile, there is a choice among two different file systems. The first, the FAT file system, is divided into three different subtypes, FAT12, FAT16 and FAT32. The other file system, EFS, is a proprietary file system developed by SEGGER. The choice of a suitable file system depends on the environment in which the end application is to operate.

The FAT file system was developed by Microsoft to manage file segments, locate available clusters and reassemble files for use. Released in 1976, the first version of the FAT file system was FAT12, which is no longer widely used. It was created for extremely small storage devices. (The early version of FAT12 did not support managing directories).

FAT16 is good for use on multiple operating systems because it is supported by all versions of Microsoft Windows, as well as by DOS and Linux. The newest version, FAT32, improves upon the FAT16 file system by utilizing a partition/disk much more efficiently. It is supported by all Microsoft Windows versions newer than Windows 98 as well as on Linux-based systems.

The EFS file system was added to emFile as an alternative to the FAT file system and was specifically designed for embedded devices. This file system uses the storage space dedicated to the file and directory names more efficiently while still offering faster access to embedded storage devices. Another benefit of EFS is that there are no issues concerning long file name (LFN) support. The FAT file system was not designed for long file name

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support, limiting names to twelve characters (8.3 format). LFN support may be added to any of the FAT file systems. Long file names are inherent to this proprietary file system.

1.3.3 Fail safety

Fail safety is the feature of emFile that ensures the consistency of data in case of unexpected loss of power during a write access to a storage medium. emFile will be fail-safe only when both the file system (FAT/EFS) and the device driver are fail-safe. The journaling add-on of emFile makes the FAT/EFS file systems fail-safe. The device drivers of emFile are all fail-safe by design. You can find detailed information about how the fail-safety works in chapter *Journaling* on page 1453 and as part of the description of individual device drivers.

1.3.4 Wear leveling

This is a feature of the NAND and NOR flash device drivers that increase the lifetime of a storage medium by ensuring that all the storage blocks are equally well used. The flash storage memories have a limited number of program/erase cycles, typically around 100,000. The manufacturers do not guarantee that the storage device will work properly once this limit is exceeded. The wear leveling logic implemented in the device drivers tries to keep the number of program-erase cycles of a storage block as low as possible. You can find additional information in the description of the respective device drivers.

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1.4 Implementation notes

This section provides information about the implementation of emFile.

1.4.1 File system configuration

The file system is designed to be configurable at runtime. This has various advantages. Most of the configuration is done automatically; the linker builds in only code that is required. This concept allows the file system to be put in a library. The file system does not need to be recompiled when the configuration changes, e.g., a different driver is used. Compile-time configuration is kept to a minimum, primarily to select the level of multitasking support and the level of debug information. For detailed information about configuration of emFile, refer to *Configuration of emFile* on page 1371.

1.4.2 Runtime memory requirements

Because the configuration is selected at runtime, the amount of memory required is not known at compile-time. For this reason, a mechanism for runtime memory assignment is required. Runtime memory is typically allocated when required during initialization and, in most embedded systems, never freed.

1.4.3 Initializing the file system

The first thing that needs to be done after the system start-up and before any file system function can be used is to call the function `FS_Init()`. This routine initializes the internals of the file system. While initializing the file system, you have to add your target device to the file system. The function `FS_X_AddDevices()` adds and initializes the device.

```
FS_Init()
  |
  +-> FS_X_AddDevices()
        |
        +-> FS_AssignMemory()
        |
        +-> FS_AddDevice()
        |
        +-> Optional: Other configuration functions
```

1.4.4 Development environment (compiler)

The CPU used is of no importance; only an ANSI-compliant C compiler complying with at least one of the following international standards is required:

- ISO/IEC/ANSI 9899:1990 (C90) with support for C++ style comments (//)
- ISO/IEC 9899:1999 (C99)
- ISO/IEC 14882:1998 (C++)

If your compiler has some limitations, let us know, and we will inform you if these will be a problem when compiling the software. Any compiler for 16/32/64-bit CPUs or DSPs that we know of can be used; most 8-bit compilers can be used as well. A C++ compiler is not required, but can be used. The application program can therefore also be programmed in C++ if desired.

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Chapter 2

Getting started

This chapter provides an introduction to using emFile. It explains how to use the Windows sample, which is an easy way to get a first project with emFile up and running.

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2.1 Package content and installation

emFile is provided in source code and contains everything needed to compile it on any platform. The following table shows the contents of the emFile package:

Files	Description
`Application`	Sample applications.
`BSP`	Support files for different evaluation boards.
`Config`	Configuration header files.
`Doc`	emFile documentation.
`FS`	emFile source code.
`Inc`	Global header files.
`Linux`	Utility applications for Linux.
`Sample`	Sample drivers and applications.
`SEGGER`	Utility source code.
`Simulation`	Support files for PC simulation.
`Windows`	Utility applications for Windows.
`FS_Start.*`	PC simulation project MS Visual Studio / C++ and FAT.
`FS_EFS_Start.*`	PC simulation project MS Visual Studio / C++ and EFS.
`FS_STORAGE_Start.*`	PC simulation project MS Visual Studio / C++ and storage layer.

emFile is shipped in electronic form in a `.zip` file. In order to install it, extract the `.zip` file to any folder of your choice, preserving the directory structure of the `.zip` file.

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2.2 Using the Windows sample application

If you have MS Visual C++ 6.00 or any later version available, you will be able to work with a Windows sample project using emFile. Even if you do not have the Microsoft compiler, you should read this chapter in order to understand how an application can use emFile.

2.2.1 Building the sample application

Open the workspace `FS_Start.sln` with MS Visual Studio (for example, by double-clicking it). There is no further configuration necessary. You should be able to build the application without any error or warning message.

2.2.2 Overview of the sample application

The sample project uses the RAM disk driver for demonstration. The main function of the sample application `Start.c` calls the function `MainTask()`. `MainTask()` initializes the file system and executes some basic file system operations. The sample application `Start.c` is described step by step:

```
void main(void);
void main(void) {
  MainTask();                                                    ❶
}
```

```
void MainTask(void) {
  U32          v;
  FS_FILE    * pFile;
  char         ac[256];
  char         acFileName[32];
  const char * sVolumeName = "";

  FS_X_Log("Start\n");
  //
  // Initialize file system
  //
  FS_Init();                                                     ❷
  //
  // Check if low-level format is required
  //
  FS_FormatLLIfRequired(sVolumeName);                            ❸
  //
  // Check if volume needs to be high level formatted.
  //
  if (FS_IsHLFormatted(sVolumeName) == 0) {                      ❹
    FS_X_Log("High-level format\n");
    FS_Format(sVolumeName, NULL);
  }
  sprintf(ac, "Running sample on \"%s\"\n", sVolumeName);
  FS_X_Log(ac);                                                  ❺
  v = FS_GetVolumeFreeSpaceKB(sVolumeName);                      ❻
  if (v < 0x8000) {
    sprintf(ac, "  Free space: %lu KBytes\n", v);
  } else {
    v >>= 10;
    sprintf(ac, "  Free space: %lu MBytes\n", v);
  }
  FS_X_Log(ac);
  sprintf(acFileName, "%s\\File.txt", sVolumeName);
  sprintf(ac, "  Write test data to file %s\n", acFileName);
  FS_X_Log(ac);
  pFile = FS_FOpen(acFileName, "w");                             ❼
  if (pFile) {
    FS_Write(pFile, "Test", 4);                                  ❽
    FS_FClose(pFile);
```

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```
  } else {
    sprintf(ac, "Could not open file: %s to write.\n", acFileName);
    FS_X_Log(ac);
  }
  v = FS_GetVolumeFreeSpaceKB(sVolumeName);                    ❾
  if (v < 0x8000) {
    sprintf(ac, "  Free space: %lu KBytes\n", v);
  } else {
    v >>= 10;
    sprintf(ac, "  Free space: %lu MBytes\n", v);
  }
  FS_X_Log(ac);
  FS_Unmount(sVolumeName);
  FS_X_Log("Finished\n");                                      ❿
  while (1) {
    ;
  }
}
```

❶ Application start

`main.c` calls `MainTask()`.

❷ File system initialization

`MainTask()` initializes and adds a device to emFile.

❸ Low-level formatting

Checks if the volume is low-level formatted and formats it if required.

❹ High-level formatting

Checks if the volume is high-level formatted and formats it if required.

❺ Volume name

Outputs the volume name.

❻ Free space before operation

Calls `FS_GetVolumeFreeSpace()` and outputs the return value - the available free space of the RAM disk - to the console window.

❼ File creation

Creates and opens a test file with write access (`File.txt`) on the device.

❽ File write

Writes 4 bytes into the file and closes the file handle or outputs an error message.

❾ Free space after operation

Calls `FS_GetVolumeFreeSpace()` and outputs the return value - the available free space of the RAM disk - again to the console window.

❿ End of application

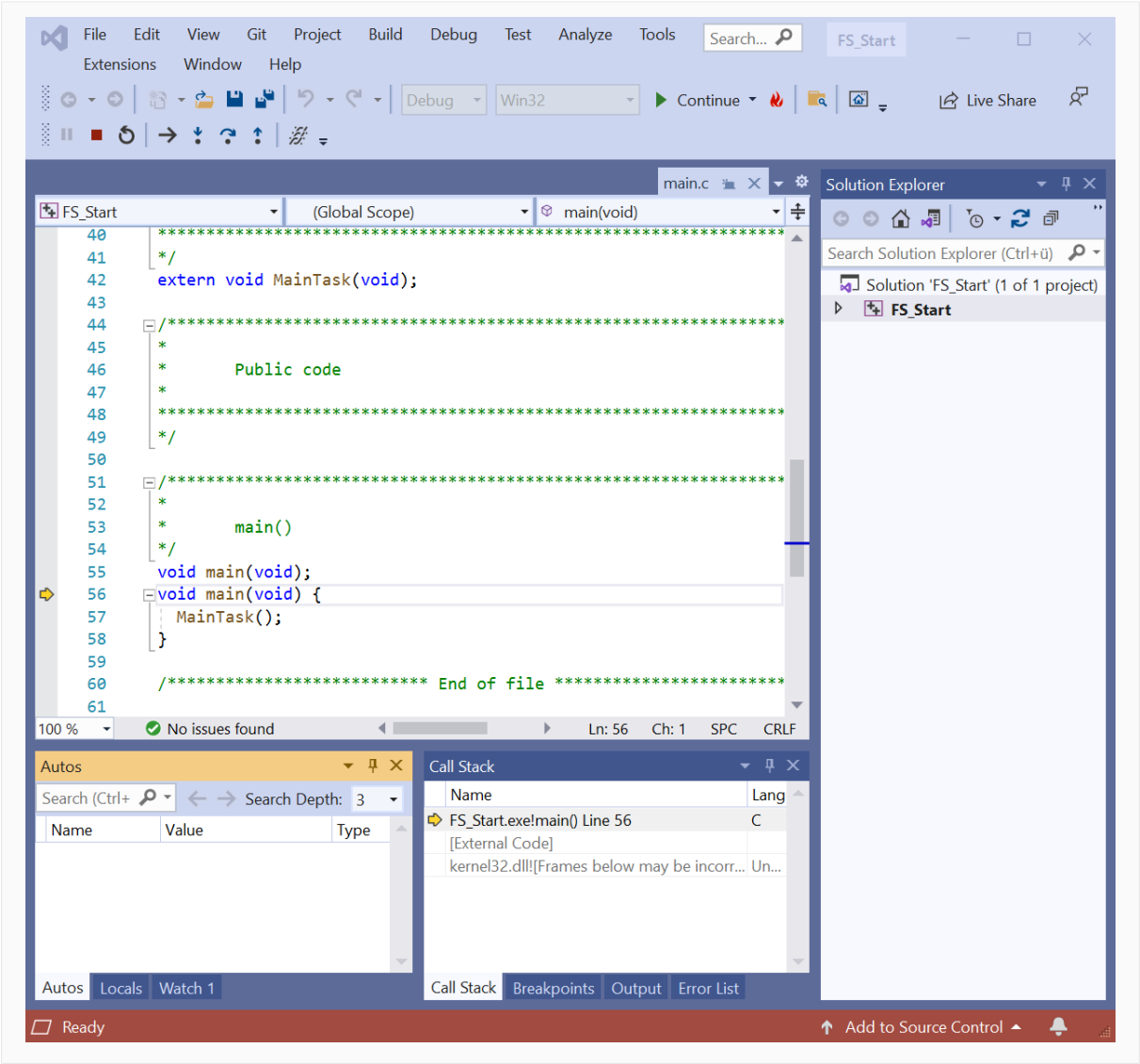
Outputs a quit message and enters an endless loop.

2.2.3 Stepping through the sample application

❶ Application start

After starting the debugger by stepping into the application, your screen should look like the screenshot below. The main function calls `MainTask()`.

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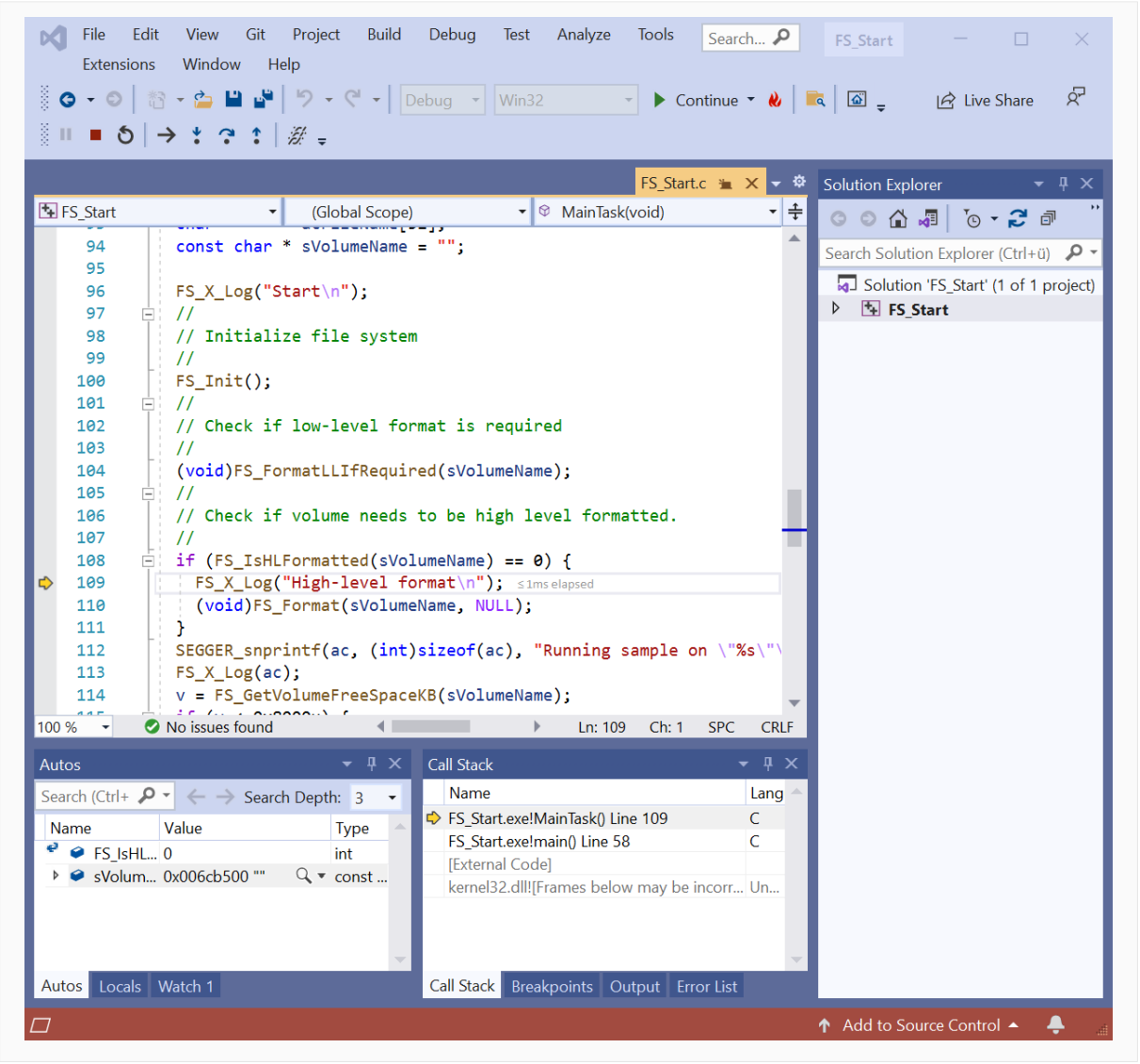


Application start

❷ File system initialization

The first thing called from `MainTask()` is the emFile function `FS_Init()`. This function initializes the file system and calls `FS_X_AddDevices()`. The function `FS_X_AddDevices()` is used to add and configure the used device drivers to the file system. In the example configuration, only the RAM disk driver is added. `FS_Init()` must be called before using any other emFile function. You should step over this function.

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File system initialization

❸ Low-level formatting

If the initialization was successful, `FS_FormatLLIfRequired()` is called. It checks if the volume is low-level formatted and formats the volume if required. You should step over this function.

❹ High-level formatting

Afterward, `FS_IsHLFormatted()` is called. It checks if the volume is high-level formatted and formats the volume if required. You should step over this function.

❺ Volume name

The volume name is printed in the console window.

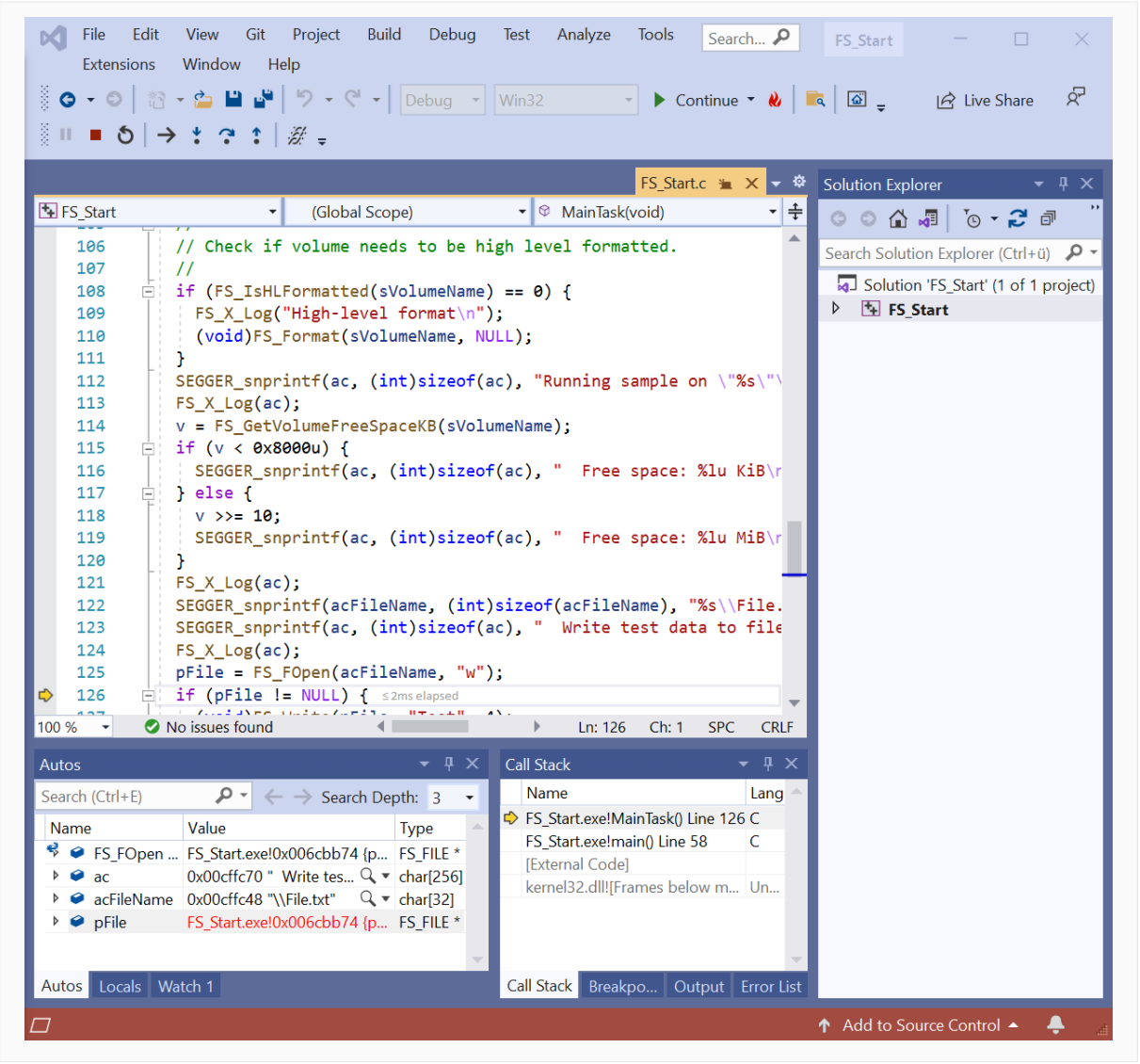
❻ Free space before operation

The emFile function `FS_GetVolumeFreeSpace()` is called, and the return value is written into the console window.

❼ File creation

Afterward, you should get to the emFile function call `FS_FOpen()`. This function creates a file named `File.txt` in the root directory of your RAM disk. Stepping over this function should return the address of an `FS_FILE` structure. In case of any error, it would return 0, indicating that the file could not be created.

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File creation

❽ File write

If `FS_FOpen()` returns a valid pointer to an `FS_FILE` structure, the sample application will write a small ASCII string to this file by calling the emFile function `FS_Write()`. Step over this function. If a problem occurs, compare the return value of `FS_Write()` with the length of the ASCII string, which should be written. `FS_Write()` returns the number of elements which have been written. If no problem occurs, the emFile function `FS_FClose()` should be reached. `FS_FClose()` closes the file handle for `File.txt`. Step over this function.

❾ Free space after operation

Continue stepping over until you reach the place where the function `FS_GetVolumeFreeSpace()` is called. The emFile function `FS_GetVolumeFreeSpace()` returns available free drive space in bytes. After you step over this function, the variable v should have a value greater than zero.

❿ End of application

The return value is written in the console window.

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End of application

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2.3 Further source code examples

Further source code examples which demonstrate directory operations and performance measuring are available. All emFile source code examples are located in the `Sample/FS/Application` folder of the emFile shipment.

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2.4 Recommended project structure

We recommend keeping emFile separate from your application files. It is good practice to keep all the program files (including the header files) together in the FS subdirectory of your project's root directory. This practice makes it very easy to update to newer versions of emFile by simply replacing the FS directory. Your application files can be stored anywhere.

> **Warning**
>
> When updating to a newer emFile version, as files may have been added, moved, or deleted, the project directories may need to be updated accordingly.

> **Warning**
>
> Always make sure that you have only one version of each file!

It is frequently a major problem when updating to a new version of emFile if you have old files included and therefore mix different versions. If you keep emFile in the directories as suggested (and only in these), this type of problem cannot occur. When updating to a newer version, you should be able to keep your configuration files and leave them unchanged. For safety reasons, we recommend backing up (or at least renaming) the FS directories before updating.

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Chapter 3

Running emFile on target hardware

This chapter explains how to integrate and run emFile on your target hardware. It explains this process step-by-step.

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3.1 Integrating emFile

The default configuration of emFile contains a single storage device: a RAM disk. This should always be the first step to check if emFile functions properly on your target hardware. We assume that you are familiar with the tools you have selected for your development (compiler, project manager, linker, etc.). You should therefore be able to add files, add directories to the include search path, and so on. It is also assumed that you are familiar with the OS that you will be using on your target system (if you are using one). The SEGGER Embedded Studio IDE (https://www.segger.com/embedded-studio.html) is used in this document for all examples and screenshots, but every other ANSI C toolchain can also be used. It is also possible to use makefiles; in this case, when we say “add to the project”, this translates into “add to the makefile”.

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3.2 Procedure to follow

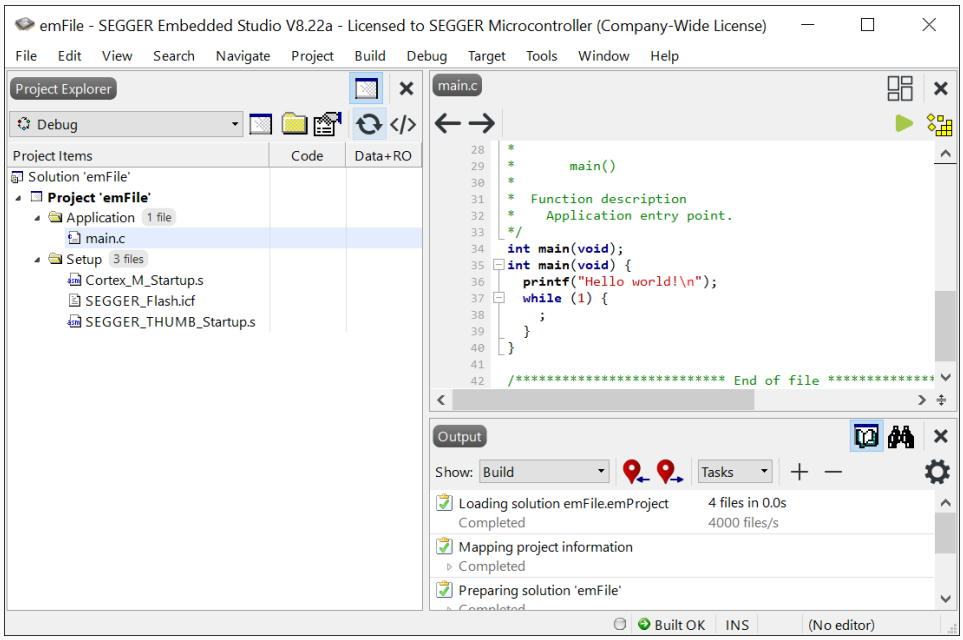
Integration of emFile is a relatively simple process, which consists of the following steps:

- Step 1: Creating a start project without emFile.
- Step 2: Adding emFile to the start project.
- Step 3: Adding the device driver.
- Step 4: Activating the driver.
- Step 5: Adjusting the RAM usage.

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3.3 Step 1: Creating a simple project without emFile

We recommend that you create a small "hello world" program for your system. That project should already use your OS and there should be a way to display text on a screen or serial port. If you are using the SEGGER embOS (https://www.segger.com/products/rtos/embos/), you can use the start project shipped with the embOS for this purpose.



Start project

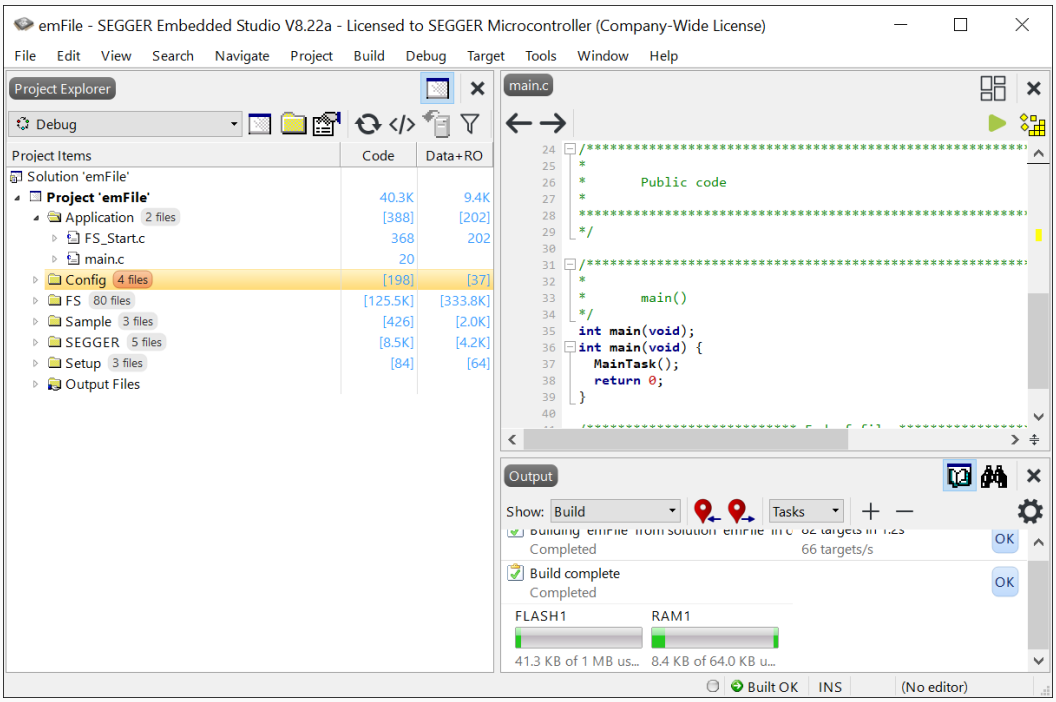
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3.4 Step 2: Adding emFile to the start project

Add all source files from the following directories (and their subdirectories) to your project:

- `Application` (Only one file located in this directory in addition to `main.c` has to be included)
- `Config`
- FS
- `Sample/FS/OS` (Only one file located in this directory has to be included and only if the application uses an RTOS. The included file must be compatible with the RTOS used).
- SEGGER

It is recommended to keep the provided folder structure.



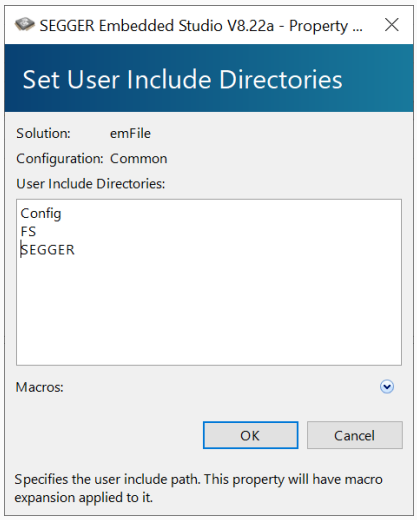
Add source files

3.4.1 Configuring the include path

The include path is the path in which the compiler looks for include files. In cases where the included files (typically header files, `.h`) do not reside in the same directory as the C file to compile, an include path needs to be set. In order to build the project with all added files, you will need to add the following directories to your include path:

- `Config`
- FS
- SEGGER

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Include paths

3.4.2 Select the start application

For quick and easy testing of your emFile integration, start with the code found in the `Application` folder of the shipment. Exclude all files in the `Application` folder of your project except the supplied `main.c` and `FS_Start.c` files. The application performs the following steps:

- `main.c` calls `MainTask()`.
- `MainTask()` initializes and adds a device to the file system.
- Checks if the volume is low-level formatted and formats it if required.
- Checks if the volume is high-level formatted and formats it if required.
- Outputs the volume name.
- Calls `FS_GetVolumeFreeSpace()` and outputs the return value (the available total space of the RAM disk) to the console window.
- Creates and opens a test file with write access (`File.txt`) on the storage device.
- Writes 4 bytes of data into the file and closes the file handle or outputs an error message.
- Calls `FS_GetVolumeFreeSpace()` and outputs the return value (the available free space of the RAM disk) again to the console window.
- Outputs a quit message and enters an endless loop.

3.4.3 Build the project and test it

Build the project. It should compile without errors and warnings. If you encounter any problem during the build process, check your include path and your project configuration settings. The start application should print out the storage space of the device twice, once before a file has been written to the device and once afterward.

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3.5 Step 3: Adding the device driver

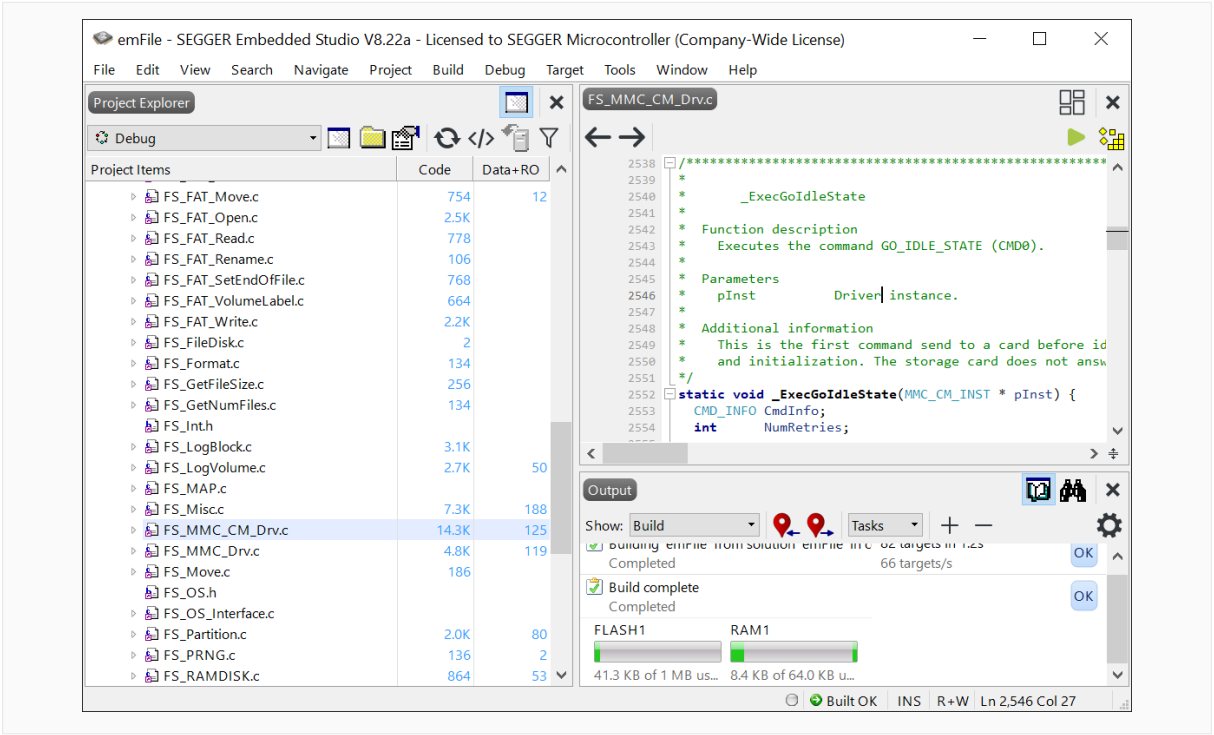
To configure emFile with a device driver, two modifications have to be performed:

- Adding the device driver source to the project.
- Adding the hardware routines to the project.

Each step is explained in the following sections. For example, the implementation of the MMC/SD driver is shown, but all steps can easily be adapted to every other device driver implementation.

3.5.1 Adding the device driver source to the project

Add the driver sources to the project and add the directory to the include path.



Add device driver

Most drivers require additional hardware routines to work with the specific hardware. If your driver requires low-level I/O routines to access the hardware, you will have to provide them.

Drivers that require hardware routines are:

- NAND drivers
- NOR drivers using external serial NOR flash as storage
- MMC/SD drivers
- Compact Flash/IDE driver
- RAM Disk driver using external serial memory as storage

Drivers that do not require hardware routines are:

- NOR driver using CPI-compatible NOR flash as storage
- RAM Disk driver using system memory as storage

Nearly all drivers have to be configured before they can be used. The runtime configuration functions which specify, for example, the memory addresses and the size of memory are located in the configuration file of the respective driver. All required configurations are explained in the configuration section of the respective driver. If you use one of the drivers which do not require hardware routines, skip the next section and refer to *Step 4: Activating the driver* on page 64.

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3.5.2 Adding hardware routines to the project

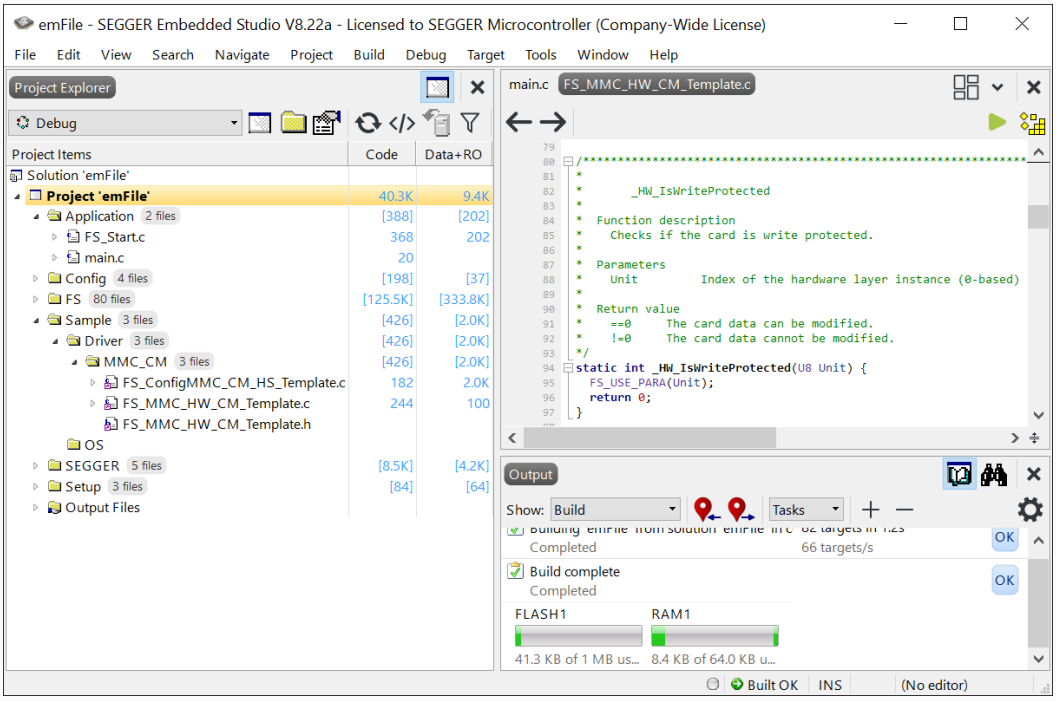
A template with empty function bodies and in most cases one or more sample implementations are supplied for every driver that requires hardware routines. The easiest way to start is to use one of the ready-to-use samples. The ready-to-use samples can be found in the subfolders `Sample/FS/Driver/<DRIVER_DIR>` of the emFile shipment where `DRIVER_DIR` is the type of the device driver. You should check the `Readme.txt` file located in the driver directory to see which samples are included. If there is one which is a good or close match for your hardware, it should be used. Otherwise, use the template to implement the hardware routines. The template is a skeleton driver which contains empty implementations of the required functions and is the ideal base to start the implementation of hardware specific I/O routines. What to do Copy the compatible hardware function sample or the template into a subdirectory of your work directory and add it to your project. The template file is located in the `Sample/FS/Driver/<DRIVER_DIR>` folder; the example implementations are located in the respective directories. If you start the implementation of hardware routines with the hardware routine template, refer to *Device drivers* on page 479 for detailed information about the implementation of the driver-specific hardware functions, else refer to section *Step 4: Activating the driver* on page 64.

> **Note**
>
> You cannot run and test the project with the new driver on your hardware as long as you have not added the proper configuration file for the driver to your project. Refer to section *Step 4: Activating the driver* on page 64 for more information about the activation of the driver with the configuration file.

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3.6 Step 4: Activating the driver

After adding the driver source and, if required, the hardware function implementation, copy the FS_Config<DRIVER_NAME>.c file (for example, FS_ConfigMMC_CardMode.c for the MMC/SD card driver using card mode) into the Config folder of your emFile work directory and add it to your project.



Add template driver

The configuration files contain all the runtime configuration functions of the file system. The configuration files include a start configuration which allows a quick and easy start with every driver. The most important function for the beginning is FS_X_AddDevices(). It activates and configures the driver, if required. A driver which does not require hardware routines has to be configured before it can be used.

3.6.1 Modifying the runtime configuration

The following example adds a single CFI-compliant NOR flash chip with a 16-bit interface and a size of 256 Mbytes to the file system. The base address, the start address and the size of the NOR flash are defined using the macros NOR_BASE_ADDR, NOR_START_ADDR and NOR_SIZE. Normally, only the "Defines, configurable" section of the configuration files requires changes for typical embedded systems. The "Public code" section, which includes the time and date functions and FS_X_AddDevices(), does not require modifications on most systems.

```
/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define ALLOC_SIZE          0x10000         // Size of memory pool provided
                                            // to the file system for
                                            // semi-dynamic memory allocation.
                                            // This value should be fine-tuned
                                            // according to your system.
#define NOR_BASE_ADDR       0x40000000      // Base address of the NOR flash
                                            // device to be used as storage
#define NOR_START_ADDR      0x40000000      // Address of the first NOR physical
                                            // sector to be used as storage.
                                            // If the entire NOR flash device
```

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```
                                        // has to be used by the file system,
                                        // then this value is identical
                                        // to the base address.
#define NOR_SIZE           0x200000     // Number of bytes to be used
                                        // as storage.

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static U32 _aMemBlock[ALLOC_SIZE / 4];     // Memory pool used for semi-dynamic
                                           // allocation of the file system.

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    Configures the file system.
*
*  Additional information
*    This function is called during the file system initialization.
*/
void FS_X_AddDevices(void) {
  //
  // Provide the file system memory to work with.
  //
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add and configure the NOR driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, NOR_BASE_ADDR, NOR_START_ADDR, NOR_SIZE);
  //
  // Configure a read buffer for the file data.
  //
  FS_ConfigFileBufferDefault(512, 0);
}
```

After the driver has been added, the configuration functions (in this example `FS_NOR_SetPhyType()` and `FS_NOR_Configure()`) should be called. Detailed information about the driver configuration can be found in the configuration section of the respective driver. Refer to section *Runtime configuration* on page 485 for detailed information about the other runtime configurations of the file system. Before compiling and running the sample application with the added driver, you have to exclude `FS_ConfigRAMDisk.c` from the project.

> **Note**
>
> For the drivers which require hardware access routines, if you have only added the template with empty function bodies until now, the project should compile without errors or warning messages. But you can only run the project on your hardware if you have finished the implementation of the hardware functions.

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3.7 Step 5: Adjusting the RAM usage

The file system needs RAM for management purposes in various places. The amount of RAM required depends primarily on the configuration, especially the drivers used. The drivers which have their own level of management (such as NOR / NAND drivers) generally require more RAM than the "simple" drivers such as those for hard drives, compact flash, or MMC/SD cards. Every driver needs to allocate RAM. The file system allocates RAM in the initialization phase and holds it while the file system is running. The macro `ALLOC_SIZE`, which is located in the respective driver configuration file, specifies the size of RAM used by the file system. This value should be fine-tuned according to the requirements of your target system.

By default, `ALLOC_SIZE` is set to a value which should be appropriate for most target systems. Nevertheless, you should adjust it in order to avoid wasting too much RAM. Once your file system project is up and running, you can check the real RAM requirement of the driver via the public variable `FS_Global.MemManager.NumBytesAllocated`. Check the value of `FS_Global.MemManager.NumBytesAllocated` after the initialization of the file system and after a volume has been mounted. At this point `FS_Global.MemManager.NumBytesAllocated` can be used as a reference for the dynamic memory usage of emFile. You should reserve a few more bytes for emFile than the value of `FS_Global.MemManager.NumBytesAllocated` is at this point, since every file which is opened needs dynamic memory for maintenance information. For more information about resource usage of the file handlers, please refer to *Dynamic RAM usage* on page 487.

> **Note**
>
> If you define `ALLOC_SIZE` with a value which is smaller than the appropriate size, the file system will run into `FS_X_Panic()`. If you define `ALLOC_SIZE` with a value which is above the limits of your target system, the linker will give an error during the build process of the project.

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3.8 Step 6: Testing the storage device access

The access to the storage device can be tested by using the example applications located in the Sample/FS/Application folder of the emFile shipment.

Particularly helpful is the FS Commander application (`FS_Commander.c`) that supports the interactive execution of different file system operations via text commands similar to a command line application on a PC. By default, the FS Commander application supports the input of commands and the output of results either via SEGGER Real Time Transfer (https://kb.segger.com/RTT) or via semihosting (https://kb.segger.com/Semihosting). The way the FS Commander application interacts with the host PC can be easily adapted to any other means of transferring the data that are available on the target hardware such as UART or Ethernet.

The simplest way to test the basic access to the storage device is by running the `TestAccessSWR` in the FS Commander application. This command fills each logical sector of the storage device with data, and then it verifies that the data was stored correctly. It works with any storage device supported by emFile. An error is reported in case of a data mismatch, which is typically an indication that the access to the storage device does not work correctly. Please note that the command may take a relatively long time to complete on a storage device with a large capacity such as an SD card and a USB drive. In such a case, it is recommended to reduce the range of the tested sectors via the `StartSector` and `NumSectors` parameters.

The NAND and NOR device drivers provide additional means for testing the access to the storage device via the verification of write and erase operations. Additional information about the usage of these features can be found in the “Runtime configuration” section that is included in the description of each device driver.

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Chapter 4

API functions

This chapter provides a detailed description of the emFile API layer.

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4.1 General information

Any functions or data structures that are not described in this chapter but are exposed through inclusion of the FS.h header file must be considered private and subject to change.

4.1.1 Volume, file, and directory names

A volume, file, or directory name is a 0-terminated string the application can use as a parameter to an API function (such as FS_FOpen()) to identify a volume, file, or directory the API function has to operate on.

A file or directory name contains the following mandatory and optional elements where the optional elements are surrounded by []:

```
[VolumeName:[UnitNo:]][DirPath]FileName|DirName
```

- VolumeName is the name of the volume on which the file or directory is located. If not specified, the first configured volume is assumed.
- UnitNo is the index of the volume on which the file or directory is located. If not specified, the index 0 is assumed. It is not allowed to specify a unit number if the volume name has not been specified.
- DirPath is the complete directory path to an already existing subdirectory. DirPath has to start and end with a directory delimiter character. The names of directories in the path are also separated by a directory delimiter. The directory delimiter character can be configured at compile time via FS_DIRECTORY_DELIMITER configuration define. The default directory delimiter is the '\' character. The root directory is assumed if DirPath is not specified. emFile does not support relative file or directory names; therefore, the application has to always specify the full path to a file or directory.
- FileName or DirName is the name of the file or directory that has to be accessed by the file system. If the volume is formatted as FAT and the support for long file names is not enabled, all file and directory names have to follow the standard FAT 8.3 naming convention. The same applies to the directory names in DirPath. EFS comes with native support for long file names.

The maximum length of a file or directory name can be configured via the FS_MAX_PATH configuration define.

A volume name contains the following mandatory and optional elements where the optional elements are surrounded by []:

```
VolumeName:[UnitNo:]
```

VolumeName and UnitNo have the same meaning as described above.

Examples

The following examples specify the same file name assuming that the first driver added to the file system is the NAND driver.

- "DirName\FileName.txt"
- "nand:\DirName\FileName.txt"
- "nand:0:\DirName\FileName.txt"

The following examples specify the same volume name assuming that the first driver added to the file system is the NOR driver.

- ""
- "nor"
- "nor:0:"

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4.2 API function overview

The table below lists the available API functions within their respective categories.

Function	Description
File system control functions	
FS_Init()	Starts the file system.
FS_DeInit()	Frees allocated resources.
FS_Mount()	Initializes a volume in default access mode.
FS_MountEx()	Initializes a volume in a specified access mode.
FS_SetAutoMount()	Sets the automatic mount behavior.
FS_Sync()	Saves cached information to storage.
FS_Unmount()	Synchronizes the data and marks the volume as not initialized.
FS_UnmountForced()	Marks the volume as not initialized.
File system configuration functions	
FS_AddDevice()	Adds a driver to file system.
FS_AddPhysDevice()	Adds a device to the file system without assigning a volume to it.
FS_AssignMemory()	Assigns a memory pool to the file system.
FS_ConfigFileBufferDefault()	Configures the size and flags for the file buffer.
FS_LOGVOL_Create()	Creates a driver instance.
FS_LOGVOL_AddDevice()	Adds a storage device to a logical volume.
FS_SetFileBufferFlags()	Changes the operating mode of the file buffer.
FS_SetFileBufferFlagsEx()	Changes the operating mode of the file buffer.
FS_SetFileWriteMode()	Configures the file write mode.
FS_SetFileWriteModeEx()	Configures the write mode of a specified volume.
FS_SetMemHandler()	Configures functions for memory management.
FS_SetMaxSectorSize()	Configures the maximum size of a logical sector.
File access functions	
FS_FClose()	Closes an opened file.
FS_FGets()	Reads a line of text from file.
FS_FOpen()	Opens an existing file or creates a new one.
FS_FOpenEx()	Opens an existing file or creates a new one.
FS_FPrintf()	Writes a formatted string to a file.
FS_FPuts()	Writes a 0-terminated string to a file.
FS_FRead()	Reads data from file.
FS_FSeek()	Sets the current position in file.

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Function	Description
FS_FSeek64()	Modifies the current position in a file.
FS_FWrite()	Writes data to file.
FS_FTell()	Returns current position in file.
FS_FTell64()	Returns current position in a file.
FS_GetFileSize()	Obtains the size of a file.
FS_GetFileSizeEx()	Obtains the size of a file.
FS_GetFileSize64()	Returns the size of a file.
FS_Read()	Reads data from a file.
FS_SetEndOfFile()	Sets the file size to current file position.
FS_SetFileSize()	Sets the file size to the specified number of bytes.
FS_SetFileSize64()	Sets the file size to the specified number of bytes.
FS_SyncFile()	Synchronizes file to storage device.
FS_Truncate()	Changes the size of a file.
FS_Truncate64()	Changes the size of a file.
FS_Verify()	Verifies the file contents.
FS_Write()	Writes data to file.
Operations on files	
FS_CopyFile()	Copies a file.
FS_CopyFileEx()	Copies a file.
FS_GetFileAttributes()	Queries the attributes of a file or directory.
FS_GetFileBufferInfo()	Obtains information about a file buffer.
FS_GetFileInfo()	Returns information about a file or directory.
FS_GetFileInfo64()	Obtains information about a file or directory.
FS_GetFileName()	Obtains the name of a file.
FS_GetFileTime()	Obtains the creation time of a file or directory.
FS_GetFileTimeEnhanced()	Obtains the timestamp of a file or directory.
FS_GetFileTimeEx()	Obtains the timestamp of a file or directory.
FS_IsFileBufferSet()	Checks if a file buffer is configured for the specified file.
FS_ModifyFileAttributes()	Sets / clears the attributes of a file or directory.
FS_Move()	Moves a file or directory to another location.
FS_Remove()	Removes a file.
FS_Rename()	Changes the name of a file or directory.
FS_SetFileAttributes()	Modifies all the attributes of a file or directory.
FS_SetFileBuffer()	Assigns a file buffer to an opened file.

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Function	Description
FS_SetFileTime()	Modifies the creation time of a file or directory.
FS_SetFileTimeEnhanced()	Modifies the timestamp of a file or directory.
FS_SetFileTimeEx()	Modifies the timestamp of a file or directory.
FS_UnsetFileBuffer()	Frees the file buffer assigned to specified file.
FS_WipeFile()	Overwrites the contents of a file with random data.
Directory functions	
FS_CopyDir()	Copies a directory and its contents to a different location.
FS_CreateDir()	Creates a directory including any missing directories in the path.
FS_DeleteDir()	Removes a directory and its contents.
FS_FindClose()	Ends a directory scanning operation.
FS_FindClose64()	Ends a directory scanning operation.
FS_FindFirstFile()	Initiates a directory scanning operation.
FS_FindFirstFile64()	Initiates a directory scanning operation.
FS_FindNextFile()	Returns information about the next file or directory in a directory scanning operation.
FS_FindNextFileEx()	Returns information about the next file or directory in a directory scanning operation.
FS_FindNextFile64()	Returns information about the next file or directory in a directory scanning operation.
FS_FindMatch()	Checks if the file name matches the specified pattern.
FS_FindMatch64()	Checks if the file name matches the specified pattern.
FS_MkDir()	Creates a directory.
FS_RmDir()	Removes a directory.
Formatting functions	
FS_Format()	Performs a high-level format.
FS_FormatEx()	Performs a high-level format.
FS_FormatLLIfRequired()	Performs a low-level format.
FS_FormatLow()	Performs a low-level format.
FS_IsHLFormatted()	Checks if a volume is high-level formatted or not.
FS_IsLLFormatted()	Returns whether a volume is low-level formatted or not.
Partitioning functions	
FS_CreateGPT()	Partitions the specified volume using a GPT (GUID Partition Table) partition scheme.
FS_CreateMBR()	Partitions the specified volume using a MBR (Master Boot Record) partition scheme.

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Function	Description
FS_GetGPTInfo()	Returns information about the GPT partitioning.
FS_GetPartitionInfoMBR()	Returns information about a MBR partition.
FS_GetPartitionInfoGPT()	Returns information about a GPT partition.
FS_GetPartitioningScheme()	Returns information about how a storage device is partitioned.
File system checking functions	
FS_CheckAT()	Verifies the consistency of the allocation table.
FS_CheckDir()	Verifies the consistency of a single directory.
FS_CheckDisk()	Checks the consistency of the file system structure.
FS_CheckDisk_ErrCode2Text()	Returns a human-readable text description of a disk checking error code.
FS_GetATInfo()	Obtains information about the allocation table.
FS_GetClusterInfo()	Obtains information about a storage allocation unit.
FS_GetDiskLayout()	Obtains information about the data layout of a volume.
FS_GetFirstCluster()	Obtains the id of the first cluster assigned to a file or directory.
FS_InitCheck()	Initializes a non-blocking disk checking operation.
File system extended functions	
FS_ConfigEOFErrorSuppression()	Enables / disables the reporting of end-of-file condition as error.
FS_ConfigPOSIXSupport()	Enables / disables support for the POSIX-like behavior.
FS_FileTimeToTimeStamp()	Converts a broken-down date and time representation into a timestamp.
FS_FileTimeToTimeStampEnhanced()	Converts a broken-down date and time representation into a timestamp.
FS_FreeSectors()	Informs the device driver about unused sectors.
FS_GetAutoMount()	Returns information about how a volume is automatically mounted.
FS_GetFileId()	Calculates a value that uniquely identifies a file.
FS_GetFileWriteMode()	Returns the write mode.
FS_GetFileWriteModeEx()	Returns the write mode configured for a specified volume.
FS_GetFSType()	Returns the type of file system assigned to volume.
FS_GetMaxSectorSize()	Queries the maximum configured logical sector size.
FS_GetMemInfo()	Returns information about the memory management.

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Function	Description
FS_GetMountType()	Returns information about how a volume is mounted.
FS_GetNumFilesOpen()	Queries the number of opened file handles.
FS_GetNumFilesOpenEx()	Queries the number of opened file handles on a volume.
FS_GetNumVolumes()	Queries the number of configured volumes.
FS_GetVolumeAlias()	Returns the alternative name of a volume.
FS_GetVolumeFreeSpace()	Returns the free space available on a volume.
FS_GetVolumeFreeSpaceFirst()	Initiates the search for free space.
FS_GetVolumeFreeSpaceKB()	Returns the free space available on a volume.
FS_GetVolumeFreeSpaceNext()	Continues the search for free space.
FS_GetVolumeInfo()	Obtains information about a volume.
FS_GetVolumeInfoEx()	Obtains information about a volume.
FS_GetVolumeLabel()	Returns the label of the volume.
FS_GetVolumeName()	Obtains the name of a volume.
FS_GetVolumeSize()	Returns the size of a volume.
FS_GetVolumeSizeKB()	Returns the size of a volume.
FS_GetVolumeStatus()	Returns the presence status of a volume.
FS_IsVolumeMounted()	Checks if a volume is mounted.
FS_Lock()	Claims exclusive access to file system.
FS_LockVolume()	Claims exclusive access to a volume.
FS_SetBusyLEDCallback()	Registers a callback for busy status changes of a volume.
FS_SetCharSetType()	Configures the character set that is used for the file and directory names.
FS_SetFSType()	Sets the type of file system a volume.
FS_SetMemCheckCallback()	Registers a callback for checking of 0-copy operations.
FS_SetTimeDateCallback()	Configures a function that the file system can use to get the current time and date.
FS_SetTimeDateEnhancedCallback()	Configures a function that the file system can use to get the current time and date.
FS_SetVolumeAlias()	Assigns an alternative name for a volume.
FS_SetVolumeLabel()	Modifies the label of a volume.
FS_TimeStampEnhancedToFileTime()	Converts a timestamp to a broken-down date and time representation.
FS_TimeStampToFileTime()	Converts a timestamp into a broken-down date and time representation.
FS_Unlock()	Releases the exclusive access to file system.
FS_UnlockVolume()	Releases the exclusive access to a volume.
Storage layer functions	
FS_STORAGE_Clean()	Performs garbage collection on a volume.

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Function	Description
FS_STORAGE_CleanEx()	Performs garbage collection on a volume.
FS_STORAGE_CleanOne()	Performs garbage collection on a volume.
FS_STORAGE_CleanOneEx()	Performs garbage collection on a volume.
FS_STORAGE_DeInit()	Frees the resources allocated by the storage layer.
FS_STORAGE_FillSectors()	Writes the same sector data to one or more logical sectors.
FS_STORAGE_FillSectorsEx()	Writes the same sector data to one or more logical sectors.
FS_STORAGE_FindVolume()	Searches for a volume instance by name.
FS_STORAGE_FindVolumeByDevice()	Searches for a volume instance by index.
FS_STORAGE_FindVolumeByIndex()	Searches for a volume instance by index.
FS_STORAGE_FormatLow()	Performs a low-level format.
FS_STORAGE_FormatLowEx()	Formats the storage device.
FS_STORAGE_FreeSectors()	Informs the driver about unused sectors.
FS_STORAGE_FreeSectorsEx()	Informs the driver about unused sectors.
FS_STORAGE_GetAutoMountType()	Returns information about how a volume is automatically mounted.
FS_STORAGE_GetAutoMountTypeEx()	Returns information about how a volume is automatically mounted.
FS_STORAGE_GetCleanCnt()	Calculates the number of garbage collection sub-operations.
FS_STORAGE_GetCleanCntEx()	Calculates the number of garbage collection sub-operations.
FS_STORAGE_GetConfig()	Returns information about how the storage layer is configured to operate.
FS_STORAGE_GetCounters()	Returns the values of statistical counters.
FS_STORAGE_GetDeviceInfo()	Returns information about the storage device.
FS_STORAGE_GetDeviceInfoEx()	Returns information about the storage device.
FS_STORAGE_GetMountType()	Returns information about how a volume is mounted.
FS_STORAGE_GetMountTypeEx()	Returns information about how a volume is mounted.
FS_STORAGE_GetSectorUsage()	Returns information about the usage of a logical sector.
FS_STORAGE_GetSectorUsageEx()	Returns information about the usage of a logical sector.
FS_STORAGE_GetVolumeStatusEx()	Returns the presence status of a volume.
FS_STORAGE_Init()	Initializes the storage layer.
FS_STORAGE_IsLLFormatted()	Returns whether a volume is low-level formatted or not.
FS_STORAGE_IsLLFormattedEx()	Checks if a storage device is low-level formatted.
FS_STORAGE_Mount()	Initializes a volume in a specified access mode.

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Function	Description
FS_STORAGE_MountEx()	Initializes a volume in a specified access mode.
FS_STORAGE_ReadSector()	Reads the data of one logical sector.
FS_STORAGE_ReadSectorEx()	Reads the contents of one logical sector from the storage device.
FS_STORAGE_ReadSectors()	Reads the data of one or more logical sectors.
FS_STORAGE_ReadSectorsEx()	Reads the contents of multiple logical sectors from a storage device.
FS_STORAGE_RefreshSectors()	Reads the contents of a logical sector and writes it back.
FS_STORAGE_RefreshSectorsEx()	Reads the contents of a logical sector and writes it back.
FS_STORAGE_ResetCounters()	Sets all statistical counters to 0.
FS_STORAGE_SetAutoMountType()	Sets the automatic mount behavior.
FS_STORAGE_SetAutoMountTypeEx()	Sets the automatic mount behavior.
FS_STORAGE_SetOnDeviceActivityCallback()	Registers a function to be called on any logical sector read or write operation.
FS_STORAGE_SetWriteVerification()	Enables or disables the verification of written sector data.
FS_STORAGE_Sync()	Writes cached information to storage device.
FS_STORAGE_SyncEx()	Writes cached information to storage device.
FS_STORAGE_SyncSectors()	Synchronizes the contents of one or more logical sectors.
FS_STORAGE_SyncSectorsEx()	Synchronizes the contents of one or more logical sectors.
FS_STORAGE_Unmount()	Synchronizes a volume and marks it as not initialized.
FS_STORAGE_UnmountEx()	Synchronizes the volume and marks it as not initialized.
FS_STORAGE_UnmountForced()	Marks a volume it as not initialized.
FS_STORAGE_UnmountForcedEx()	Marks the volume as not initialized without synchronizing it.
FS_STORAGE_WriteSector()	Modifies the data of a logical sector.
FS_STORAGE_WriteSectorEx()	Writes a logical sector to the storage device.
FS_STORAGE_WriteSectors()	Modifies the data of one or more logical sectors.
FS_STORAGE_WriteSectorsEx()	Writes multiple logical sectors to the storage device.
FAT related functions	
FS_FAT_ConfigDirtyFlagUpdate()	Enables / disables the update of the flag that indicates if the volume has been unmounted correctly.
FS_FAT_ConfigFATCopyMaintenance()	Enables / disables the update of the second allocation table.

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Function	Description
FS_FAT_ConfigFSInfoSectorUse()	Enables / disables the usage of information from the FSInfo sector.
FS_FAT_ConfigROFileMovePermission()	Enables / disables the permission to move (and rename) files and directories with the read-only file attribute set.
FS_FAT_DisableLFN()	Disables the support for long file names.
FS_FAT_FormatSD()	Performs a high-level format as per SD Specification.
FS_FAT_GetConfig()	Returns information about how the FAT component is configured to operate.
FS_FAT_GetLFNConverter()	Returns the type of configured file name converter.
FS_FAT_GrowRootDir()	Increases the size of the root directory.
FS_FAT_SetLFNConverter()	Configures how long file names are to be encoded and decoded.
FS_FAT_SupportLFN()	Enables the support for long file names.
EFS related functions	
FS_EFS_ConfigCaseSensitivity()	Configures how the file names are compared.
FS_EFS_ConfigStatusSectorSupport()	Enables or disables the usage of information from the status sector.
FS_EFS_GetConfig()	Returns information about how the EFS component is configured to operate.
FS_EFS_SetFileNameConverter()	Configures how file names are to be encoded.
exFAT related functions	
FS_EXFAT_ConfigDirtyFlagUpdate()	Enables or disables the update of the flag that indicates if the volume has been unmounted correctly.
FS_EXFAT_ConfigROFileMovePermission()	Enables / disables the permission to move (and rename) files and directories with the read-only file attribute set.
FS_EXFAT_ConfigSpaceUsageUpdate()	Enables or disables the update of the storage usage.
FS_EXFAT_FormatSD()	Performs a high-level format as per SD Specification.
FS_EXFAT_GetConfig()	Returns information about how the exFAT component is configured to operate.
FS_EXFAT_GetFileNameConverter()	Returns the type of configured file name converter.
FS_EXFAT_GrowRootDir()	Increases the size of the root directory.
FS_EXFAT_ReadOEMPara()	Obtains information about one or more OEM parameters.
FS_EXFAT_SetFileNameConverter()	Configures how long file names are to be encoded and decoded.
FS_EXFAT_WriteOEMPara()	Modifies the information of one or more OEM parameters.
Error handling functions	
FS_ClearErr()	Clears error status of a file handle.

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Function	Description
FS_ErrorNo2Text()	Returns a human-readable text description of an API error code.
FS_FEof()	Returns if end of file has been reached.
FS_FError()	Returns error status of a file handle.
Configuration checking functions	
FS_CONF_GetDebugLevel()	Returns the level of debug information configured for the file system.
FS_CONF_GetDirectoryDelimiter()	Returns the character that is configured as delimiter between the directory names in a file path.
FS_CONF_GetMaxPath()	Returns the configured maximum number of characters in a path to a file or directory.
FS_CONF_GetNumVolumes()	Returns the maximum number of volumes configured for the file system.
FS_CONF_GetOSLocking()	Returns the type of task locking configured for the file system.
FS_CONF_IsCacheSupported()	Checks if the file system is configured to support the sector cache.
FS_CONF_IsDeInitSupported()	Checks if the file system is configured to support deinitialization.
FS_CONF_IsEFSSupported()	Checks if the file system is configured to support the EFS file system.
FS_CONF_IsEncryptionSupported()	Checks if the file system is configured to support encryption.
FS_CONF_IsFATSupported()	Checks if the file system is configured to support the FAT file system.
FS_CONF_IsFreeSectorSupported()	Checks if the file system is configured to support the “free sector” command.
FS_CONF_IsJournalSupported()	Checks if the file system is configured to support journaling.
FS_CONF_IsTrialVersion()	Checks if the file system has been configured as a trial (limited) version.
FS_GetVersion()	Returns the version number of the file system.
Path processing functions	
FS_GetPathBaseName()	Returns the name of the target file or directory with the extension removed.
FS_GetPathDirName()	Returns the path to a target file or directory with the volume name, base name, and extension removed.
FS_GetPathExtension()	Returns the extension of a file or directory.
FS_GetPathVolumeName()	Returns the name of the volume from a path.
FS_MakePath()	Creates a path to a file or directory from individual components.
Obsolete functions	
FS_AddOnExitHandler()	Registers a deinitialization callback.
FS_CloseDir()	Closes a directory.

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Function	Description
FS_ConfigOnWriteDirUpdate()	Configures if the directory entry has be updated after writing to file.
FS_DirEnt2Attr()	Loads attributes of a directory entry.
FS_DirEnt2Name()	Loads the name of a directory entry.
FS_DirEnt2Size()	Loads the size of a directory entry.
FS_DirEnt2Time()	Loads the time stamp of a directory entry.
FS_GetNumFiles()	Obtains the number of files in a directory.
FS_OpenDir()	API function.
FS_ReadDir()	Reads next directory entry in directory.
FS_RewindDir()	Sets pointer for reading the next directory entry to the first entry in the directory.

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4.3 File system control functions

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4.3.1 FS_Init()

Description

Starts the file system.

Prototype

```
void FS_Init(void);
```

Additional information

`FS_Init()` initializes the file system and creates resources required for the access of the storage device in a multi-tasking environment. This function has to be called before any other file system API function.

Example

```
#include "FS.h"

void SampleInit(void) {
  FS_Init();
  //
  // Access file system
  //
}
```

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4.3.2 FS_DeInit()

Description

Frees allocated resources.

Prototype

```
void FS_DeInit(void);
```

Additional information

This function is optional. `FS_DeInit()` frees all resources that are allocated by the file system after initialization. Also, all static variables of all file system layers are reset in order to guarantee that the file system remains in a known state after deinitialization. The application can call this function only after it called `FS_Init()`.

This function has to be used when the file system is reset at runtime. For example this is the case if the system uses a software reboot which reinitializes the target application.

This function is available if the emFile sources are compiled with the `FS_SUPPORT_DEINIT` configuration define set to 1.

Example

```
#include "FS.h"

void SampleDeInit(void) {
  FS_Init();
  //
  // Access the file system...
  //
  FS_DeInit();
  //
  // The file system cannot be accessed anymore.
  //
}
```

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4.3.3 FS_Mount()

Description

Initializes a volume in default access mode.

Prototype

```
int FS_Mount(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	The name of a volume. If the empty string is specified, the first device in the volume table is used.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only.
= FS_MOUNT_RW	Volume is mounted read/write.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

The storage device has to be mounted before being accessed for the first time after file system initialization. The file system is configured by default to automatically mount the storage device at the first access in read / write mode. This function can be used to explicitly mount the storage device if the automatic mount behavior has been disabled via FS_SetAutoMount(). Refer to FS_SetAutoMount() for an overview of the different automatic mount types.

Example

```
#include "FS.h"

void SampleMount(void) {
  FS_Init();
  //
  // Mount default volume in read / write mode.
  //
  FS_Mount("");
  //
  // Access the data stored on the file system.
  //
}
```

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4.3.4 FS_MountEx()

Description

Initializes a volume in a specified access mode.

Prototype

```
int FS_MountEx(const char * sVolumeName,
               U8     MountType);
```

Parameters

Parameter	Description
sVolumeName	The name of the volume. If the empty string is specified, the first device in the volume table is used.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Read only access. • FS_MOUNT_RW Read / write access.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only.
= FS_MOUNT_RW	Volume is mounted read/write.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

Performs the same operation as FS_Mount() while it allows the application to specify how the storage device has to be mounted.

Example

```
#include "FS.h"

void SampleMountEx(void) {
  FS_Init();
  //
  // Mount default volume in read-only mode.
  //
  FS_MountEx("", FS_MOUNT_RO);
  //
  // Access the data stored on the file system.
  //
}
```

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4.3.5 FS_SetAutoMount()

Description

Sets the automatic mount behavior.

Prototype

```
void FS_SetAutoMount(const char * sVolumeName,
                     U8     MountType);
```

Parameters

Parameter	Description
sVolumeName	Pointer to a string containing the name of the volume. If the empty string is specified, the first device in the volume table is used.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Allows to automatically mount the volume in read only mode. • FS_MOUNT_RW Allows to automatically mount the volume in read / write mode. • 0 Disables the automatic mount operation for the volume.

Additional information

By default, the file system is configured to automatically mount all volumes in read / write mode and this function can be used to change the default automatic mount type or to disable the automatic mounting.

Example

```
#include "FS.h"

void SampleSetAutoMount(void) {
  FS_SetAutoMount("", FS_MOUNT_R);    // Mount default volume in read-only mode.
}
```

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4.3.6 FS_Sync()

Description

Saves cached information to storage.

Prototype

```
int FS_Sync(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Pointer to a string containing the name of the volume to be synchronized. If the empty string is specified, the first configured volume is used.

Return value

= 0 OK, volume synchronized
≠ 0 Error code indicating the failure reason. Refer to `FS_ErrorNo2Text()` for more information.

Additional information

The function write the contents of write buffers and updates the management information of all opened file handles to storage device. All the file handles are left open. If configured, `FS_Sync()` also writes to storage the changes present in the write cache and in the journal. `FS_Sync()` can be called from the same task as the one writing data or from a different task.

Example

```
#include "FS.h"

void SampleSync(void) {
  FS_Sync("");      // Synchronize the default volume.
}
```

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4.3.7 FS_Unmount()

Description

Synchronizes the data and marks the volume as not initialized.

Prototype

```
void FS_Unmount(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Pointer to a string containing the name of the volume to be unmounted. If the empty string is specified, the first device in the volume table is used. Can not be NULL.

Additional information

This function closes all open files and synchronizes the volume, that is writes all cached data to storage device. FS_Unmount() hast to be called before a storage device is removed to make sure that all the information cached by the file system is updated to storage device. This function is also useful when shutting down a system.

The volume is initialized again at the next call to any other file system API function that requires access to storage device. The application can also explicitly initialize the volume via FS_Mount() or FS_MountEx().

Example

```
#include "FS.h"

void SampleUnmount(void) {
  FS_Unmount("");     // Unmount the default volume.
}
```

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4.3.8 FS_UnmountForced()

Description

Marks the volume as not initialized.

Prototype

```
void FS_UnmountForced(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Pointer to a string containing the name of the volume to be unmounted. If the empty string is specified, the first device in the volume table is used.

Additional information

This function performs the same operations as FS_Unmount(). FS_UnmountForced() has to be called if a storage device has been removed before it could be regularly unmounted. When using FS_UnmountForced() there is no guarantee that the information cached by the file system is updated to storage.

The volume is initialized again at the next call to any other file system API function that requires access to storage device. The application can also explicitly initialize the volume via FS_Mount() or FS_MountEx().

Opened file handles are only marked as invalid but they are not closed. The application has to close them explicitly by calling FS_FClose().

Example

```
#include "FS.h"
#include "FS_OS.h"

void SampleUnmountForced(void) {
  int IsPresentNew;
  int IsPresent;

  IsPresent = FS_GetVolumeStatus("");
  while (1) {
    IsPresentNew = FS_GetVolumeStatus("");
    //
    // Check if the presence status of the storage device has been changed.
    //
    if (IsPresentNew != IsPresent) {
      if (IsPresentNew == FS_MEDIA_IS_PRESENT) {
        FS_Mount("");
      } else  {
        FS_UnmountForced("");
      }
      IsPresent = IsPresentNew;
    }
    FS_X_OS_Delay(500);
  }
}
```

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4.3.9 Volume mounting modes

Description

Modes for mounting a volume.

Definition

```
#define FS_MOUNT_RO    FS_MOUNT_R
#define FS_MOUNT_RW    (FS_MOUNT_R | FS_MOUNT_W)
```

Symbols

Definition	Description
FS_MOUNT_RO	Read-only. Data can only be read from storage device.
FS_MOUNT_RW	Read / Write. Data can be read form and written to storage device.

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4.4 File system configuration functions

The file system configuration functions listed in this section can only be used in the run-time configuration phase. This means in practice that they can only be called from within `FS_X_AddDevices()`.

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4.4.1 FS_AddDevice()

Description

Adds a driver to file system.

Prototype

```
FS_VOLUME *FS_AddDevice(const FS_DEVICE_TYPE * pDevType);
```

Parameters

Parameter	Description
pDevType	in Pointer to a function table identifying the driver that has to be added.

Return value

≠ 0 OK, driver added.
= 0 An error occurred.

Additional information

This function can be used to add a device or a logical driver to the file system. The application has to add at least one driver to file system.

The function performs the following operations:

- Adds a physical device. This initializes the driver, allowing the driver to identify the storage device if required and to allocate memory for driver level management of the storage device. This makes sector operations possible.
- Assigns a logical volume to physical device. This makes it possible to mount the storage device, making it accessible for the file system and allowing file operations to be performed on it.

Example

```
#include "FS.h"

void FS_X_AddDevices(void) {
  //
  // Basic configuration of the file system...
  //

  //
  // Add and configure a device driver for NAND flash.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);

  //
  // Additional configuration of the file system...
  //
}
```

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4.4.2 FS_AddPhysDevice()

Description

Adds a device to the file system without assigning a volume to it.

Prototype

```
int FS_AddPhysDevice(const FS_DEVICE_TYPE * pDevType);
```

Parameters

Parameter	Description
pDevType	in Pointer to a function table identifying the driver that has to be added.

Return value

= 0 OK, storage device added.
≠ 0 An error occurred.

Additional information

This function can be used to add a device or a logical driver to file system. It works similarly to `FS_AddDevice()` with the difference that it does not assign a logical volume to storage device. This means that the storage device is not directly accessible by the application via the API functions of the file system. An additional logical driver is required to be added via `FS_AddDevice()` to make the storage device visible to application.

`FS_AddPhysDevice()` initializes the driver, allowing the driver to identify the storage device as far as required and allocate memory required for driver level management of the device. This makes sector operations possible.

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4.4.3 FS_AssignMemory()

Description

Assigns a memory pool to the file system.

Prototype

```
void FS_AssignMemory(U32 * pData,
                     U32   NumBytes);
```

Parameters

Parameter	Description
pData	in A pointer to the start of the memory region assigned to file system.
NumBytes	Size of the memory pool assigned.

Additional information

emFile comes with a simple semi-dynamic internal memory manager that is used to satisfy the runtime memory requirements of the file system. `FS_AssignMemory()` can be used to provide a memory pool to the internal memory manager of the file system. If not enough memory is assigned, the file system calls `FS_X_Panic()` in debug builds which by default halts the execution of the application. The actual number of bytes allocated is stored in the global variable `FS_Global.MemManager.NumBytesAllocated`. This variable can be used to fine-tune the size of the memory pool.

emFile supports also the use of an external memory manager (e.g. via malloc() and free() functions of the standard C library). The selection between the internal and the external memory management has to be done at compile time via the `FS_SUPPORT_EXT_MEM_MANAGER` define. The configuration of the memory management functions is done via `FS_SetMemHandler()`.

This function has to be called in the initialization phase of the file system; typically in `FS_X_AddDevices()`. The support for internal memory management has to be enabled at compile time by setting the `FS_SUPPORT_EXT_MEM_MANAGER` define to 0. `FS_AssignMemory()` does nothing if the `FS_SUPPORT_EXT_MEM_MANAGER` define is set to 1.

Example

```
#include "FS.h"

#define ALLOC_SIZE    0x1000

static U32 _aMemBlock[ALLOC_SIZE / 4];

void FS_X_AddDevices(void) {
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Perform additional file system configuration.
  //
}
```

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4.4.4 FS_ConfigFileBufferDefault()

Description

Configures the size and flags for the file buffer.

Prototype

```
int FS_ConfigFileBufferDefault(int BufferSize,
                               int Flags);
```

Parameters

Parameter	Description
BufferSize	Size of the file buffer in bytes.
Flags	File buffer operating mode.

Return value

= 0 OK, the file buffer has been configured.
≠ 0 Error code indicating the failure reason.

Additional information

The function has to be called only once, in FS_X_AddDevices(). If called after FS_Init() the function does nothing and generates a warning.

Flags is a bitwise-or combination of *File buffer flags* on page 166. If Flags is set to 0 then the file buffer caches only the data read from the file.

The file system allocates a file buffer of BufferSize bytes for each file the application opens. The operating mode of the file buffer can be changed at runtime via FS_SetFileBuffer-Flags(). If file buffers of different sizes are required FS_SetFileBuffer() should be used instead.

For best performance it is recommended to set the size of the file buffer to be equal to the size of the logical sector. Smaller file buffer sizes can also be used to reduce the RAM usage.

FS_SetFileBuffer() is available if the emFile sources are compiled with the FS_SUP-PORT_FILE_BUFFER configuration define set to 1.

Example

```
#include "FS.h"

#define ALLOC_SIZE    0x1000

static U32 _aMemBlock[ALLOC_SIZE / 4];

void FS_X_AddDevices(void) {
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Set the file buffer of 512 bytes for read and write operations.
  // The file buffer is allocated at runtime for each opened file
  // from _aMemBlock.
  //
#if (FS_USE_FILE_BUFFER || FS_SUPPORT_FILE_BUFFER)
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif
}
```

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4.4.5 FS_LOGVOL_Create()

Description

Creates a driver instance.

Prototype

```
int FS_LOGVOL_Create(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to create.

Return value

= 0 OK, volume has been created.
≠ 0 An error occurred.

Additional information

This function creates an instance of a logical volume. A logical volume is the representation of one or more physical devices as a single device. It allows treating multiple physical devices as one larger device. The file system takes care of selecting the correct location on the correct physical device when reading from or writing to the logical volume. Logical volumes are typically used if multiple flash devices (NOR or NAND) are present, but they should be presented to the application in the same way as a single device with the combined capacity of both.

sVolumeName is the name that has to be assigned to the logical volume. This is the volume name that is passed to some of the FS API functions and that has to be used in a file path.

FS_LOGVOL_Create() does nothing if the module is configured to work in driver mode by setting the FS_LOGVOL_SUPPORT_DRIVER_MODE define option to 1. In this case a logical driver is created by adding it via FS_AddDevice() to file system.

Normally, all devices are added individually using FS_AddDevice(). This function adds the devices physically as well as logically to the file system. In contrast to adding all devices individually, all devices can be combined in a logical volume with a total size of all combined devices. To create a logical volume the following steps have to be performed: 1. The storage device has to be physically added to the file system using FS_AddPhysDevice(). 2. A logical volume has to be created using FS_LOGVOL_Create(). 3. The devices which are physically added to the file system have to be added to the logical volume using FS_LOGVOL_AddDevice().

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4.4.6 FS_LOGVOL_AddDevice()

Description

Adds a storage device to a logical volume.

Prototype

```
int FS_LOGVOL_AddDevice(const char           * sVolumeName,
                        const FS_DEVICE_TYPE * pDeviceType,
                              U8               DeviceUnit,
                              U32              StartSector,
                              U32              NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the logical volume.
pDeviceType	Type of the storage device that has to be added.
DeviceUnit	Index of the storage device that has to be added (0-based).
StartSector	Index of the first sector that has to be used as storage (0-based).
NumSectors	Number of sectors that have to be used as storage.

Return value

= 0 OK, storage device added.
≠ 0 An error occurred.

Additional information

Only devices with an identical sector size can be combined to a logical volume. All additionally added devices need to have the same sector size as the first physical device of the logical volume.

This function does nothing if FS_LOGVOL_SUPPORT_DRIVER_MODE is set to 1.

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4.4.7 FS_SetFileBufferFlags()

Description

Changes the operating mode of the file buffer.

Prototype

```
int FS_SetFileBufferFlags(FS_FILE * pFile,
                          int       Flags);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
Flags	File buffer operating mode.

Return value

= 0 OK, file buffer flags changed.
≠ 0 Error code indicating the failure reason.

Additional information

This function can only be called immediately after the file is opened and before performing any operation on the file.

Flags is a bitwise-or combination of *File buffer flags* on page 166. If Flags is set to 0 then the file buffer caches only the data read from the file.

FS_SetFileBufferFlags() is only available if the file system is built with the FS_SUPPORT_FILE_BUFFER configuration define set to 1.

Example

```
#include "FS.h"

void SampleSetFileBufferFlags(void) {
  FS_FILE * pFile;
  U8        abData[16];

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    memset(abData, 'a', sizeof(abData));
    FS_SetFileBufferFlags(pFile, FS_FILE_BUFFER_WRITE);
    FS_Write(pFile, abData, sizeof(abData));
    FS_FClose(pFile);
  }
}
```

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4.4.8 FS_SetFileBufferFlagsEx()

Description

Changes the operating mode of the file buffer.

Prototype

```
int FS_SetFileBufferFlagsEx(const char * sVolumeName,
                            int    Flags);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which to set the flags.
Flags	File buffer operating mode.

Return value

= 0 OK, operating mode changed.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to change the operating mode of the file buffer for the files that are located on a specific volume.

Flags is a bitwise-or combination of *File buffer flags* on page 166. If Flags is set to 0 then the file buffer caches only the data read from the file.

FS_SetFileBufferFlagsEx() is available if the emFile sources are compiled with the FS_SUPPORT_FILE_BUFFER configuration define set to 1.

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4.4.9 FS_SetFileWriteMode()

Description

Configures the file write mode.

Prototype

```
void FS_SetFileWriteMode(FS_WRITEMODE WriteMode);
```

Parameters

Parameter	Description
WriteMode	Specifies how to write to file: • FS_WRITEMODE_SAFE Updates the allocation table and the directory entry at each write to file operation. • FS_WRITEMODE_MEDIUM Updates the allocation table at each write to file operation. • FS_WRITEMODE_FAST The allocation table and directory entry are updated when the file is closed.

Additional information

This function can be called to configure which mode the file system has to use when writing to a file. The file system uses by default FS_WRITEMODE_SAFE which allows the maximum fail-safe behavior, since the allocation table and the directory entry is updated on every write operation to file.

If FS_WRITEMODE_FAST is set, the update of the allocation table is performed using a special algorithm. When writing to the file for the first time, the file system checks how many clusters in series are empty starting with the first one occupied by the file. This cluster chain is remembered, so that if the file grows and needs an additional cluster, the allocation doesn't have to be read again in order to find the next free cluster. The allocation table is only modified if necessary, which is the case when:

- All clusters of the cached free-cluster-chain are occupied.
- The volume or the file is synchronized that is when FS_Sync(), FS_FClose(), or FS_SyncFile() is called.
- A different file is written.

Especially when writing large amounts of data, FS_WRITEMODE_FAST allows maximum performance, since usually the file system has to search for a free cluster in the allocation table and link it with the last one occupied by the file. In worst case, multiple sectors of the allocation table have to be read in order to find a free cluster.

Example

```
#include "FS.h"

void FS_X_AddDevices(void) {
  //
  // Configure the file system to write as fast as possible
  // to all files on all volumes.
  //
  FS_SetFileWriteMode(FS_WRITEMODE_FAST);
  //
  // Perform other file system configuration...
  //
}
```

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4.4.10 FS_SetFileWriteModeEx()

Description

Configures the write mode of a specified volume.

Prototype

```
int FS_SetFileWriteModeEx(      FS_WRITEMODE   WriteMode,
                          const char         * sVolumeName);
```

Parameters

Parameter	Description
WriteMode	Specifies how to write to file: • FS_WRITEMODE_SAFE Updates the allocation table and the directory entry at each write to file operation. • FS_WRITEMODE_MEDIUM Updates the allocation table at each write to file operation. • FS_WRITEMODE_FAST The allocation table and directory entry are updated when the file is closed.
sVolumeName	Identifies the volume for which the write mode has to be changed.

Return value

= 0 OK, write mode set.
≠ 0 Error code indicating the failure reason.

Additional information

When not explicitly set using this function the write mode of a volume is the write mode set via FS_SetFileWriteMode() or the default write mode (FS_WRITEMODE_SAFE). FS_SetFileWriteModeEx() is typically on file system configurations using multiple volumes that require different write modes. For example on a file system configured to use two volumes where one volume has to be configured for maximum write performance (FS_WRITEMODE_FAST) while on the other volume the write operation has to be fail-safe (FS_WRITEMODE_SAFE).

Refer to FS_SetFileWriteMode() for detailed information about the different write modes.

Example

```
#include "FS.h"

void FS_X_AddDevices(void) {
  //
  // Configure the file system to write as fast as possible
  // to all files on the "nand:0:" volume.
  //
  FS_SetFileWriteModeEx(FS_WRITEMODE_FAST, "nand:0");
  //
  // Perform other file system configuration...
  //
}
```

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4.4.11 FS_SetMemHandler()

Description

Configures functions for memory management.

Prototype

```
void FS_SetMemHandler(FS_MEM_ALLOC_CALLBACK * pfAlloc,
                      FS_MEM_FREE_CALLBACK  * pfFree);
```

Parameters

Parameter	Description
pfAlloc	Pointer to a function that allocates memory (e.g. malloc()). It cannot be NULL.
pfFree	Pointer to a function that frees memory (e.g. free()). It cannot be NULL.

Additional information

The application can use this function to configure functions for the memory management. The file system calls pfAlloc to allocate memory and pfFree to release the allocated memory.

This function has to be called in the initialization phase of the file system; typically in FS_X_AddDevices(). The support for external memory management has to be enabled at compile time by setting the FS_SUPPORT_EXT_MEM_MANAGER define to 1. FS_SetMemHandler() does nothing if FS_SUPPORT_EXT_MEM_MANAGER is set to 0 (default).

Example

```
#include <stdlib.h>
#include "FS.h"

void FS_X_AddDevices(void) {
#if FS_SUPPORT_EXT_MEM_MANAGER
  //
  // Configure functions for dynamic memory allocation.
  //
  FS_SetMemHandler((FS_MEM_ALLOC_CALLBACK *)malloc, free);
#endif // FS_SUPPORT_EXT_MEM_MANAGER
  //
  // Configure the file system...
  //
}
```

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4.4.12 FS_SetMaxSectorSize()

Description

Configures the maximum size of a logical sector.

Prototype

```
int FS_SetMaxSectorSize(unsigned MaxSectorSize);
```

Parameters

Parameter	Description
MaxSectorSize	Number of bytes in the logical sector.

Return value

= 0 OK, the sector size had been set.
≠ 0 Error code indicating the failure reason.

Additional information

The file system uses internal RAM buffers to store the data of logical sectors it accesses. The storage devices added to file system can have different logical sector sizes. Since the size of the logical sectors is not known at the time the internal RAM buffers are allocated the application has to call `FS_SetMaxSectorSize()` to specify the size of the largest logical sector used by the configured drivers.

The default value for the maximum size of a logical sector is 512 bytes. The size of the logical sector supported by a driver can be found in the section that describes the specific driver.

`FS_SetMaxSectorSize()` can be called only at file system initialization in `FS_X_AddDevices()`.

Example

```
#include "FS.h"

void FS_X_AddDevices(void) {
  //
  // This function call is typically required when
  // a NAND flash with 2048 byte pages is used as
  // storage device.
  //
  FS_SetMaxSectorSize(2048);
}
```

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4.4.13 FS_MEM_ALLOC_CALLBACK

Description

Type of function called by the file system to allocate memory dynamically.

Type definition

```
typedef void * FS_MEM_ALLOC_CALLBACK(U32 NumBytes);
```

Parameters

Parameter	Description
NumBytes	Number of bytes to be allocated.

Return value

≠ NULL OK, pointer to the allocated memory block.
= NULL Error, could not allocate memory.

Additional information

The callback function has the same signature as the malloc() standard C function. The application can register the callback function via FS_SetMemHandler().

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4.4.14 FS_MEM_FREE_CALLBACK

Description

Type of function called by the file system to release dynamically allocated memory.

Type definition

```
typedef void FS_MEM_FREE_CALLBACK(void * pData);
```

Parameters

Parameter	Description
pData	Memory block to be released.

Additional information

The callback function has the same signature as the free() standard C function. The application can register the callback function via `FS_SetMemHandler()`. `pMem` points to a memory block that was allocated using a call to `pfAlloc` callback function registered via `FS_SetMemHandler()`.

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4.4.15 FS_WRITEMODE

Description

Modes of writing to file.

Type definition

```
typedef enum {
  FS_WRITEMODE_SAFE,
  FS_WRITEMODE_MEDIUM,
  FS_WRITEMODE_FAST,
  FS_WRITEMODE_UNKNOWN
} FS_WRITEMODE;
```

Enumeration constants

Constant	Description
FS_WRITEMODE_SAFE	Allows maximum fail-safe behavior. The allocation table and the directory entry are updated after each write access to file. This write mode provides the slowest performance.
FS_WRITEMODE_MEDIUM	Medium fail-safe. The allocation table is updated after each write access to file. The directory entry is updated only if file is synchronized that is when FS_Sync(), FS_FClose(), or FS_SyncFile() is called.
FS_WRITEMODE_FAST	This write mode provided the maximum performance. The directory entry is updated only if the file is synchronized that is when FS_Sync(), FS_FClose(), or FS_SyncFile() is called. The allocation table is modified only if necessary.
FS_WRITEMODE_UNKNOWN	End of enumeration (for internal use only)

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4.5 File access functions

The functions in this section can be used to access the data stored in a file.

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4.5.1 FS_FClose()

Description

Closes an opened file.

Prototype

```
int FS_FClose(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to the file to be closed.

Return value

= 0 OK, file handle has been successfully closed.
≠ 0 Error code indicating the failure reason. Refer to `FS_ErrorNo2Text()`.

Example

```
#include "FS.h"

void SampleFClose(void) {
  FS_FILE * pFile;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    //
    // Access file.
    //
    FS_FClose(pFile);
  }
}
```

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4.5.2 FS_FGets()

Description

Reads a line of text from file.

Prototype

```
char *FS_FGets(char    * sData,
               int       SizeOfData,
               FS_FILE * pFile);
```

Parameters

Parameter	Description
sData	out Buffer that receives the data read from file. It cannot be NULL.
SizeOfData	Number of bytes in sData. It cannot be 0.
pFile	Handle to opened file. It cannot be NULL.

Return value

≠ NULL OK, data read successfully. The returned value is sData buffer.
= NULL An error occurred.

Additional information

This function starts reading from the current position in the file and advances the current file position by the number of bytes read.

FS_FGets() returns when either a line terminator is read from file and stored to sData, SizeOfData - 1 bytes are stored to sData or the end of file is reached. The data stored to sData is 0-terminated.

A line terminator can be either a single Line Feed character (0x0A), a single Carriage Return character (0x0D) or a Carriage Return and Line Feed character sequence (0x0D 0x0A).

The file to read from has to be opened with read permissions. For more information about open modes refer to FS_FOpen().

The application can check for the actual error using FS_FError().

Example

```
#include "FS.h"

void SampleFGets(void) {
  FS_FILE * pFile;
  char      ac[128];
  char    * s;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile != NULL) {
    for (;;) {
      s = FS_FGets(ac, sizeof(ac), pFile);
      if (s == NULL) {
        break;
      }
    }
    FS_FClose(pFile);
  }
}
```

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4.5.3 FS_FOpen()

Description

Opens an existing file or creates a new one.

Prototype

```
FS_FILE *FS_FOpen(const char * sFileName,
                  const char * sMode);
```

Parameters

Parameter	Description
sFileName	Name of the file to be opened or created. It is a 0-terminated string that cannot be NULL.
sMode	Indicates how the file should be opened. It is a 0-terminated string that cannot be NULL.

Return value

≠ 0 OK, pointer to a file handle that identifies the opened file.
= 0 Error, unable to open the file.

Additional information

The sMode parameter can take one of the following values:

sMode
"r" or "rb"
"w" or "wb"
"a" or "ab"
"r+", "r+b" or "rb+"
"w+", "w+b" or "wb+"
"a+", "a+b" or "ab+"

For more details about FS_FOpen(), refer to the ANSI C documentation of the fopen() function.

The file system does not distinguish between binary and text mode; the files are always accessed in binary mode.

In order to use long file names with FAT, the FS_FAT_SupportLFN() has to be called before after the file system is initialized.

FS_FOpen() accepts file names encoded in UTF-8 format. This feature is disabled by default. To enable it the file system has to be compiled with the FS_FAT_SUPPORT_UTF8 configuration define to 1. Additionally, the support for long file names has to be enabled for volumes formatted as FAT.

Example

```
#include "FS.h"

void SampleOpenFile(void) {
  FS_FILE * pFile;

  //
  // Opens for reading a file on the default volume.
  //
  pFile = FS_FOpen("Test.txt", "r");
  //
```

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```
  // Opens for writing a file on the default volume.
  //
  pFile = FS_FOpen("Test.txt", "w");
  //
  // Opens for reading a file in folder "SubDir" on the default volume.
  // The directory delimiter is the '\' character.
  //
  pFile = FS_FOpen("\\SubDir\\Test.txt", "r");
  //
  // Opens for reading a file on the first RAM disk volume.
  //
  pFile = FS_FOpen("ram:Test.txt", "r");
  //
  // Opens for reading a file on the second RAM disk volume.
  //
  pFile = FS_FOpen("ram:1:Test.txt", "r");
  //
  // Opens for writing a file with a long name for writing.
  //
  FS_FAT_SupportLFN();
  pFile = FS_FOpen("Long file name.text", "w");
  //
  // Opens for writing a file with a name encoded in UTF-8 format.
  // The file system has to be compiled with FS_FAT_SUPPORT_UTF8 define
  // set to 1. The name contains the following characters:
  //   small a, umlaut mark
  //   small o, umlaut mark
  //   small sharp s
  //   small u, umlaut mark
  //   '.'
  //   't'
  //   'x'
  //   't'
  //
  FS_FAT_SupportLFN();
  pFile = FS_FOpen("\xC3\xA4\xC3\xB6\xC3\x9F\xC3\xBC.txt", "w");
}
```

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4.5.4 FS_FOpenEx()

Description

Opens an existing file or creates a new one.

Prototype

```
int FS_FOpenEx(const char     * sFileName,
               const char     * sMode,
                     FS_FILE ** ppFile);
```

Parameters

Parameter	Description
sFileName	Name of the file to be opened or created. It is a 0-terminated string that cannot be NULL.
sMode	Indicates how the file should be opened. It is a 0-terminated string that cannot be NULL.
ppFile	Pointer to a file handle pointer that receives the opened file handle.

Return value

= 0 OK, file opened.
≠ 0 Error code indicating the failure reason.

Additional information

For additional information about the sMode parameter refer to FS_FOpen().

Example

```
#include <stdio.h>
#include "FS.h"

FS_FILE * pFile;

/*********************************************************************
*
*       SampleFOpenEx
*
*  Function description
*    Opens for reading a file on the default volume.
*/
void SampleFOpenEx(void) {
  int  r;
  char ac[100];

  r = FS_FOpenEx("Test.txt", "r", &pFile);
  if (r) {
    SEGGER_snprintf(ac, sizeof(ac), "Could not open file (Reason: %s)\n",
      FS_ErrorNo2Text(r));
    FS_X_Log(ac);
  }
}
```

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4.5.5 FS_FPrintf()

Description

Writes a formatted string to a file.

Prototype

```
int FS_FPrintf(      FS_FILE * pFile,
               const char    * sFormat,
                               ...);
```

Parameters

Parameter	Description
pFile	Opened file handle. It cannot be NULL.
sFormat	Format of the data to be written (0-terminated string). It cannot be NULL.

Return value

≥ 0 OK, number of bytes written to file.
< 0 Error code indicating the failure reason.

Additional information

This function works in the same way as the fprintf() standard C library function. It formats the data according to sFormat and then writes the formatted string to pFile. The format specification is identical to that of fprintf(). FS_FPrintf() relies on SEGGER_vsnprintfEx() to perform the actual formatting.

The file position is advanced by the number of bytes written.

FS_FPrintf() uses a buffer allocated on the stack for the formatting of the data. The size of this buffer can be configured via FS_BUFFER_SIZE_FILE_PRINT.

FS_FPrintf() is available only when the file system is built with FS_BUFFER_SIZE_FILE_PRINT set to a value greater than 0.

Example

```
#include "FS.h"

void SampleFPrintf(void) {
  FS_FILE * pFile;
  int       i;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    for (i = 0; i < 10; ++i) {
      FS_FPrintf(pFile, "Counter value: %d\n", i);
    }
    FS_FClose(pFile);
  }
}
```

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4.5.6 FS_FPuts()

Description

Writes a 0-terminated string to a file.

Prototype

```
int FS_FPuts(const char    * sData,
             FS_FILE * pFile);
```

Parameters

Parameter	Description
sData	Data to be written (0-terminated string). It cannot be NULL.
pFile	Opened file handle. It cannot be NULL.

Return value

= 0 OK, data written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function works in the same way as the fputs() standard C library function. It writes the 0-terminated string sData to the file pFile. The 0-terminator is not written to file. The file position is advanced by the number of bytes written.

Example

```
#include "FS.h"

const char acText[] = "Hello world\n";

void SampleFPuts(void) {
  FS_FILE * pFile;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    FS_FPuts(acText, pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.7 FS_FRead()

Description

Reads data from file.

Prototype

```
U32 FS_FRead(void    * pData,
             U32       ItemSize,
             U32       NumItems,
             FS_FILE * pFile);
```

Parameters

Parameter	Description
pData	Buffer that receives the data read from file.
ItemSize	Size of one item to be read from file (in bytes).
NumItems	Number of items to be read from the file.
pFile	Handle to opened file. It cannot be NULL.

Return value

Number of items read.

Additional information

The file has to be opened with read permissions. For more information about open modes refer to FS_FOpen().

The application has to check for possible errors using FS_FError() if the number of items actually read is different than the number of items requested to be read by the application.

The data is read from the current position in the file that is indicated by the file pointer. FS_FRead() moves the file pointer forward by the number of bytes successfully read.

Example

```
#include "FS.h"

char acBuffer[100];

void SampleFRead(void) {
  FS_FILE * pFile;
  U32       NumItems;
  int       ErrCode;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    NumItems = FS_FRead(acBuffer, 1, sizeof(acBuffer), pFile);
    if (NumItems != sizeof(acBuffer)) {
      ErrCode = FS_FError(pFile);
      if (ErrCode) {
        //
        // An error occurred during the read operation.
        //
      }
    }
    FS_FClose(pFile);
  }
}
```

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4.5.8 FS_FSeek()

Description

Sets the current position in file.

Prototype

```
int FS_FSeek(FS_FILE * pFile,
             I32       Offset,
             int       Origin);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
Offset	Byte offset for setting the file pointer position.
Origin	Indicates how the file pointer has to be moved.

Return value

= 0 OK, file pointer has been positioned according to the specified parameters.
≠ 0 Error code indicating the failure reason.

Additional information

FS_FSeek() moves the file pointer to a new location by a number of bytes relative to the position specified by the Origin parameter. The Origin parameter can take the values specified by *File positioning reference* on page 135.

The file pointer can be repositioned anywhere in the file. It is also possible to reposition the file pointer beyond the end of the file. This feature is used together with FS_SetEndOfFile() to reserve space for a file (preallocate the file).

Alternative name

FS_SetFilePos

Example

```
#include "FS.h"

const char acText[]="Some text will be overwritten";

void SampleFSeek(void) {
  FS_FILE * pFile;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    //
    // Write the data to file.
    //
    FS_FWrite(acText, 1, strlen(acText), pFile);
    //
    // Move the file pointer back 4 bytes from the current
    // position in file. The data stored in the file looks
    // like this: "Some text will be overwritten"
    //
    FS_FSeek(pFile, -4, FS_SEEK_CUR);
    //
    // The write operation overwrites the last
    // 4 characters that is "tten" of the data
    // written in the previous call to FS_FWrite().
    //
    FS_FWrite(acText, 1, strlen(acText), pFile);
    //
    // The data in the file looks now like this:
```

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```
    // "Some text will be overwriSome text will be overwritten"
    //
    FS_FClose(pFile);
  }
}
```

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4.5.9 FS_FSeek64()

Description

Modifies the current position in a file.

Prototype

```
int FS_FSeek64(FS_FILE * pFile,
               I64       Offset,
               int       Origin);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
Offset	Byte offset for setting the file pointer position.
Origin	Indicates how the file pointer has to be moved.

Return value

= 0 OK, file pointer has been positioned according to the specified parameters.
≠ 0 Error code indicating the failure reason.

Additional information

This function moves the file pointer to a new location by a number of bytes specified via the Offset parameter and relative to a position specified via the Origin parameter. The Origin parameter can take the values specified by *File positioning reference* on page 135.

The file pointer can be repositioned anywhere in the file. It is also possible to reposition the file pointer beyond the end of the file. This feature can be used together with FS_SetEndOfFile() to reserve space for a file, also known as file preallocation.

This function performs the same operation as FS_FSeek() with the difference that the set file position can be greater than or equal to 2^{32}. This makes FS_Seek64() suitable for setting the position in a file that is larger than or equal to 4 GB.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include "FS.h"

const char acText[]="Some text will be overwritten";

void SampleFSeek64(void) {
  FS_FILE * pFile;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    //
    // Write the data to file.
    //
    FS_FWrite(acText, 1, strlen(acText), pFile);
    //
    // Move the file pointer back 4 bytes from the current
    // position in file. The data stored in the file looks
    // like this: "Some text will be overwritten"
    //
    FS_FSeek64(pFile, -4, FS_SEEK_CUR);
    //
    // The write operation overwrites the last
    // 4 characters that is "tten" of the data
    // written in the previous call to FS_FWrite().
    //
```

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```
    FS_FWrite(acText, 1, strlen(acText), pFile);
    //
    // The data in the file looks now like this:
    // "Some text will be overwriSome text will be overwritten"
    //
    FS_FClose(pFile);
  }
}
```

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4.5.10 FS_FWrite()

Description

Writes data to file.

Prototype

```
U32 FS_FWrite(const void    * pData,
              U32       ItemSize,
              U32       NumItems,
              FS_FILE * pFile);
```

Parameters

Parameter	Description
pData	Data to be written to file.
ItemSize	Size of an item to be written to file (in bytes).
NumItems	Number of items to be written to file.
pFile	Handle to opened file. It cannot be NULL.

Return value

Number of elements written.

Additional information

The file has to be opened with write permissions. For more information about open modes refer to FS_FOpen().

The application has to check for possible errors using FS_FError() if the number of items actually written is different from the number of items requested to be written by the application.

The data is written at the current position in the file that is indicated by the file pointer. FS_FWrite() moves the file pointer forward by the number of bytes successfully written.

Example

```
#include "FS.h"

const char acText[] = "Hello world\n";

void SampleFWrite(void) {
  FS_FILE * pFile;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    FS_FWrite(acText, 1, strlen(acText), pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.11 FS_FTell()

Description

Returns current position in file.

Prototype

```
I32 FS_FTell(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

≠ 0xFFFFFFFF	OK, current position of the file pointer.
= 0xFFFFFFFF	An error occurred.

Additional information

The function returns the file position as a signed value for compatibility reasons. The return value has to be treated as a 32-bit unsigned with the value 0xFFFFFFFF indicating an error.

FS_FTell() does not perform any access to the storage device. The position is calculated by using the data stored in the file handle.

In addition, FS_FTell() can be used to calculate the file size by setting the file position to the end of the file using FS_FSeek(). Alternatively, FS_GetFileSize() can be used instead.

FS_FTell() returns 0xFFFFFFFF if the file system is built with FS_SUPPORT_LARGE_FILES set to 1 and the position in the file is greater than 0xFFFFFFFF.

Alternative name

FS_GetFilePos

Example

```
#include "FS.h"

const char acText[]="Hello world\n";

void SampleFTell(void) {
  FS_FILE * pFile;
  I32       FilePos;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_FWrite(acText, 1, strlen(acText), pFile);
    FilePos = FS_FTell(pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.12 FS_FTell64()

Description

Returns current position in a file.

Prototype

```
I64 FS_FTell64(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

≠ 0xFFFFFFFFFFFFFFFF	OK, current position of the file pointer.
= 0xFFFFFFFFFFFFFFFF	An error occurred.

Additional information

This function performs the same operation as FS_FTell() with the difference that the returned file position can be greater than or equal to 2^{32}. This makes FS_FTell64() suitable for getting the position in a file that is larger than or equal to 4 GB.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include "FS.h"

const char acText[]="Hello world\n";

void SampleFTell64(void) {
  FS_FILE * pFile;
  I64       FilePos;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_FWrite(acText, 1, strlen(acText), pFile);
    FilePos = FS_FTell64(pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.13 FS_GetFileSize()

Description

Obtains the size of a file.

Prototype

```
U32 FS_GetFileSize(const FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to the file to be queried.

Return value

≠ 0xFFFFFFFF	File size of the file in bytes.
= 0xFFFFFFFF	An error occurred.

Additional information

The file has to be opened with read or write access mode.

FS_GetFileSize() returns 0xFFFFFFFF if the file system is built with FS_SUPPORT_LARGE_FILES set to 1 and the size of the file is greater than 0xFFFFFFFF.

Example

```
#include "FS.h"

void SampleGetFileSize(void) {
  FS_FILE * pFile;
  U32       FileSize;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    FileSize = FS_GetFileSize(pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.14 FS_GetFileSizeEx()

Description

Obtains the size of a file.

Prototype

```
int FS_GetFileSizeEx(FS_FILE * pFile,
                     U32     * pNumBytes);
```

Parameters

Parameter	Description
pFile	Handle to the file to be queried.
pNumBytes	out Size of the file in bytes.

Return value

= 0 OK, file size returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_GetFileSize() with the difference that it returns an error code in case of an error.

The file has to be opened with read or write access mode.

FS_GetFileSizeEx() returns 0xFFFFFFFF via pNumBytes if the file system is built with FS_SUPPORT_LARGE_FILES set to 1 and the size of the file is greater than 0xFFFFFFFF.

Example

```
#include "FS.h"

void SampleGetFileSizeEx(void) {
  FS_FILE * pFile;
  U32       FileSize;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    FileSize = 0;
    FS_GetFileSizeEx(pFile, &FileSize);
    FS_FClose(pFile);
  }
}
```

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4.5.15 FS_GetFileSize64()

Description

Returns the size of a file.

`pFile` Handle to opened file. `pNumBytes` out Size of the file.

Prototype

```
int FS_GetFileSize64(FS_FILE * pFile,
                     U64     * pNumBytes);
```

Return value

= 0 OK, file size returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened with read or write access.

This function performs the same operation as `FS_GetFileSize()` with the difference that the returned file size can be greater than or equal to 2^{32}. This makes `FS_GetFileSize64()` suitable for getting the size of a file that is larger than or equal to 4 GB.

This function is available only when the file system is built with `FS_SUPPORT_LARGE_FILES` set to 1.

Example

```
#include "FS.h"

void SampleGetFileSize64(void) {
  FS_FILE * pFile;
  U64       FileSize;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    FileSize = 0;
    FS_GetFileSize64(pFile, &FileSize);
    FS_FClose(pFile);
  }
}
```

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4.5.16 FS_Read()

Description

Reads data from a file.

Prototype

```
U32 FS_Read(FS_FILE * pFile,
            void    * pData,
            U32       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to an opened file. It cannot be NULL.
pData	Buffer to receive the read data.
NumBytes	Number of bytes to be read.

Return value

Number of bytes read.

Additional information

The file has to be opened with read permissions. For more information about open modes refer to FS_FOpen().

The application has to check for possible errors using FS_FError() if the number of bytes actually read is different than the number of bytes requested to be read by the application.

The data is read from the current position in the file that is indicated by the file pointer. FS_Read() moves the file pointer forward by the number of bytes successfully read.

Example

```
#include "FS.h"

U8 abBuffer[100];

void SampleRead(void) {
  FS_FILE * pFile;
  U32       NumBytesRead;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    NumBytesRead = FS_Read(pFile, abBuffer, sizeof(abBuffer));
    if (NumBytesRead != sizeof(abBuffer)) {
      //
      // An error occurred.
      //
    }
    FS_FClose(pFile);
  }
}
```

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4.5.17 FS_SetEndOfFile()

Description

Sets the file size to current file position.

Prototype

```
int FS_SetEndOfFile(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

= 0 OK, new file size has been set.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened with write permissions. Refer to `FS_FOpen()` for more information about the file open modes.

`FS_SetEndOfFile()` can be used to truncate as well as to extend a file. If the file is extended, the contents of the file between the old end-of-file and the new one are not defined. Extending a file (preallocation) can increase the write performance when the application writes large amounts of data to file as the file system is not required anymore to access the allocation table.

Example

```
#include "FS.h"

void SampleSetEndOfFile(void) {
  FS_FILE * pFile;

  //
  // Reserve space for a file of 20000 bytes.
  //
  pFile = FS_FOpen("Test.bin", "r+");
  if (pFile) {
    FS_FSeek(pFile, 20000, FS_SEEK_SET);
    FS_SetEndOfFile(pFile);
    FS_FClose(pFile);
  }
}
```

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4.5.18 FS_SetFileSize()

Description

Sets the file size to the specified number of bytes.

Prototype

```
int FS_SetFileSize(FS_FILE * pFile,
                   U32       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to an opened file.
NumBytes	New file size.

Return value

= 0 OK, new file size has been set.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened with write permissions. Refer to `FS_FOpen()` for more information about the file open modes. `FS_SetFileSize()` can be used to extend as well as truncate a file. The file position is preserved if the new file size is larger than or equal to the current file position. Else the file position is set to the end of the file.

Example

```
#include "FS.h"

void SampleSetFileSize(void) {
  FS_FILE * pFile;

  //
  // Create a file 20000 bytes large.
  //
  pFile = FS_FOpen("Test.bin", "r+");
  if (pFile) {
    FS_SetFileSize(pFile, 20000);
    FS_FClose(pFile);
  }
}
```

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4.5.19 FS_SetFileSize64()

Description

Sets the file size to the specified number of bytes.

Prototype

```
int FS_SetFileSize64(FS_FILE * pFile,
                     U64       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to an opened file.
NumBytes	New file size.

Return value

= 0 OK, new file size has been set.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened with write permissions. Refer to FS_FOpen() for more information about the file open modes.

FS_SetFileSize64() can be used to extend as well as truncate a file. The file position is preserved if the new file size is larger than or equal to the current file position. Otherwise the file position is set to the end of the file.

This function performs the same operation as FS_SetFileSize() with the difference that the set file size can be greater than or equal to 2^{32}. This makes FS_SetFileSize64() suitable for setting a file size that is larger than or equal to 4 GB.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include "FS.h"

void SampleSetFileSize64(void) {
  FS_FILE * pFile;

  //
  // Create a file that is about 8GB bytes large.
  //
  pFile = FS_FOpen("Test.bin", "r+");
  if (pFile) {
    FS_SetFileSize64(pFile, 8000000000uLL);
    FS_FClose(pFile);
  }
}
```

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4.5.20 FS_SyncFile()

Description

Synchronizes file to storage device.

Prototype

```
int FS_SyncFile(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	File pointer identifying the opened file. It can be NULL.

Return value

= 0 OK, file(s) synchronized.
≠ 0 Error code indicating the failure reason.

Additional information

The function synchronizes all the opened files if a NULL is passed as pFile parameter.

FS_SyncFile() cleans the write buffer if configured and updates the management information to storage device. The function performs basically the same operations as FS_FClose() with the only difference that it leaves the file open. FS_SyncFile() is used typically with fast or medium file write modes to make sure that the data cached by the file system for the file is written to storage medium.

The function can also be called from a different task than the one that writes to file if the support for multi-tasking is enabled in the file system. The support for multi-tasking can be enabled by compiling the file system sources with the FS_OS_LOCKING define is set to value different than 0.

Example

```
#include "FS.h"

void SampleFileSync(void) {
  FS_FILE * pFile;

  FS_SetFileWriteMode(FS_WRITEMODE_FAST);
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    //
    // Write to file...
    //
    FS_SyncFile(pFile);
    //
    // Write to file...
    //
    FS_SyncFile(pFile);
    //
    // Write to file...
    //
    FS_FClose(pFile);
  }
}
```

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4.5.21 FS_Truncate()

Description

Changes the size of a file.

Prototype

```
int FS_Truncate(FS_FILE * pFile,
                U32       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to an opened file.
NumBytes	The new size of the file.

Return value

= 0 OK, file size successfully modified.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened in write mode. For more information about open modes refer to FS_FOpen().

An error is returned if NumBytes is larger than the actual file size and the support for POSIX operation is disabled.

If the support for POSIX operation is enabled, then this function can also be used to increase the size of the file. The extra bytes are initialized with 0. The application can enable the support for POSIX operation by building the file system with FS_SUPPORT_POSIX set to 1 and by calling at runtime FS_ConfigPOSIXSupport() with the OnOff parameter set to 1.

FS_Truncate() allocates FS_BUFFER_SIZE_TRUNCATE bytes on the stack with the support for the POSIX operation enabled.

Example

```
#include "FS.h"

void SampleTruncate(void) {
  FS_FILE * pFile;
  U32       FileSize;
  int       r;

  pFile = FS_FOpen("Test.bin", "r+");
  if (pFile) {
    FileSize = FS_GetFileSize(pFile);
    //
    // Reduce the size of the file by 200 bytes.
    //
    r = FS_Truncate(pFile, FileSize - 200);
    if (r) {
      //
      // An error occurred while truncating file.
      //
    }
  }
  FS_FClose(pFile);
}
```

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4.5.22 FS_Truncate64()

Description

Changes the size of a file.

Prototype

```
int FS_Truncate64(FS_FILE * pFile,
                  U64       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to an opened file.
NumBytes	The new size of the file.

Return value

= 0 OK, file size successfully modified.
≠ 0 Error code indicating the failure reason.

Additional information

The file has to be opened in write mode. For more information about open modes refer to FS_FOpen().

An error is returned if NumBytes is larger than the actual file size and the support for POSIX operation is disabled.

If the support for POSIX operation is enabled, then this function can also be used to increase the size of the file. The extra bytes are initialized with 0. The application can enable the support for POSIX operation by building the file system with FS_SUPPORT_POSIX set to 1 and by calling at runtime FS_ConfigPOSIXSupport() with the OnOff parameter set to 1.

FS_Truncate64() allocates FS_BUFFER_SIZE_TRUNCATE bytes on the stack with the support for the POSIX operation enabled.

This function performs the same operation as FS_Truncate() with the difference that the set file size can be greater than or equal to 2^{32}. This makes FS_Truncate64() suitable for setting a file size that is larger than or equal to 4 GB.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include "FS.h"

void SampleTruncate64(void) {
  FS_FILE * pFile;
  U64       FileSize;
  int       r;

  pFile = FS_FOpen("Test.bin", "r+");
  if (pFile) {
    r = FS_GetFileSize64(pFile, &FileSize);
    if (r == 0) {
      //
      // Reduce the size of the file by 200 bytes.
      //
      r = FS_Truncate64(pFile, FileSize - 200);
      if (r != 0) {
        //
        // An error occurred while truncating file.
        //
      }
```

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```
    }
  }
  FS_FClose(pFile);
}
```

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4.5.23 FS_Verify()

Description

Verifies the file contents.

Prototype

```
int FS_Verify(      FS_FILE * pFile,
              const void    * pData,
                    U32       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pData	Data to be checked against.
NumBytes	Number of bytes to be checked.

Return value

= 0 Verification was successful.
≠ 0 Verification failed.

Additional information

The function starts checking at the current file position. That is the byte read from file position + 0 is checked against the byte at pData + 0, the byte read from file position + 1 is checked against the byte at pData + 1 and so on. FS_Verify() does not modify the file position.

Example

```
#include "FS.h"

const U8 abVerifyData[4] = { 1, 2, 3, 4 };

void SampleVerify(void) {
  FS_FILE * pFile;
  int       r;

  //
  // Open file and write data into it.
  //
  pFile = FS_FOpen("Test.bin", "w+");
  if (pFile) {
    FS_Write(pFile, abVerifyData, sizeof(abVerifyData));
    //
    // Set file pointer to the start of the data that has to be verified.
    //
    FS_FSeek(pFile, 0, FS_SEEK_SET);
    //
    // Verify data.
    //
    r = FS_Verify(pFile, abVerifyData, sizeof(abVerifyData));
    if (r == 0) {
      FS_X_Log("Verification was successful.\n");
    } else {
      FS_X_Log("Verification failed.\n");
    }
    FS_FClose(pFile);
  }
}
```

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4.5.24 FS_Write()

Description

Writes data to file.

Prototype

```
U32 FS_Write(      FS_FILE * pFile,
             const void    * pData,
                   U32       NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pData	The data to be written to file.
NumBytes	Number of bytes to be written to file.

Return value

Number of bytes written.

Additional information

The file has to be opened with write permissions. For more information about open modes refer to FS_FOpen().

The application has to check for possible errors using FS_FError() if the number of bytes actually written is different from the number of bytes requested to be written by the application.

The data is written at the current position in the file that is indicated by the file pointer. FS_Write() moves the file pointer forward by the number of bytes successfully written.

Example

```
#include "FS.h"

void SampleWrite(void) {
  FS_FILE    * pFile;
  const char   acText[] = "Hello world\n";

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_Write(pFile, acText, strlen(acText));
    FS_FClose(pFile);
  }
}
```

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4.5.25 File positioning reference

Description

Reference point when changing the file position.

Definition

```
#define FS_SEEK_SET    0
#define FS_SEEK_CUR    1
#define FS_SEEK_END    2
```

Symbols

Definition	Description
FS_SEEK_SET	The reference is the beginning of the file.
FS_SEEK_CUR	The reference is the current position of the file pointer.
FS_SEEK_END	The reference is the end-of-file position.

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4.6 Operations on files

The functions in this section can be used by an application to manipulate files.

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4.6.1 FS_CopyFile()

Description

Copies a file.

Prototype

```
int FS_CopyFile(const char * sFileNameSrc,
                const char * sFileNameDest);
```

Parameters

Parameter	Description
sFileNameSrc	Name of the source file (fully qualified).
sFileNameDest	Name of the destination file (fully qualified).

Return value

= 0 OK, the file has been copied
≠ 0 Error code indicating the failure reason

Additional information

The copy process uses an internal temporary buffer of 512 bytes that is allocated on the stack. The size of this buffer can be configured via FS_BUFFER_SIZE_FILE_COPY. Alternatively, FS_CopyFileEx() can be used that lets the application specify a copy buffer of an arbitrary size.

FS_CopyFile() overwrites the destination file if it exists. The destination file has to be writable, that is the FS_ATTR_READ_ONLY flag is set to 0.

Example

```
#include "FS.h"

void SampleCopyFile(void) {
  FS_CopyFile("Src.txt", "ram:\\Dest.txt");
}
```

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4.6.2 FS_CopyFileEx()

Description

Copies a file.

Prototype

```
int FS_CopyFileEx(const char * sFileNameSrc,
                  const char * sFileNameDest,
                        void * pBuffer,
                        U32    NumBytes);
```

Parameters

Parameter	Description
sFileNameSrc	Name of the source file (fully qualified).
sFileNameDest	Name of the destination file (fully qualified).
pBuffer	Buffer to temporary store the copied data. It cannot be NULL.
NumBytes	Size of the buffer in bytes.

Return value

= 0 OK, the file has been copied.
≠ 0 Error code indicating the failure reason.

Additional information

The copy process uses an external buffer provided by the application. FS_CopyFile() overwrites the destination file if it exists. The destination file has to be writable, that is the FS_ATTR_READ_ONLY flag is set to 0.

The best performance is achieved when the copy buffer is a multiple of sector size and is 32-bit aligned. For example using a 7 KB copy buffer to copy 512 byte sectors is more efficient than using a copy buffer of 7.2 KB, therefore the function rounds down the size of the copy buffer to a multiple of sector size. If the application specifies a copy buffer smaller than the sector size a warning is generated in debug builds indicating that the performance of the copy operation is not optimal.

Example

```
#include "FS.h"

static U32 _aBuffer[1024 / 4];    // Buffer to be used as temporary storage.

void SampleCopyFileEx(void) {
  FS_CopyFileEx("Src.txt", "Dest.txt", _aBuffer, sizeof(_aBuffer));
}
```

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4.6.3 FS_GetFileAttributes()

Description

Queries the attributes of a file or directory.

Prototype

```
U8 FS_GetFileAttributes(const char * sName);
```

Parameters

Parameter	Description
sName	Name of the file or directory to be queried.

Return value

= 0xFF An error occurred.
≠ 0xFF Bit mask containing the attributes of file or directory.

Additional information

The return value is an or-combination of the following attributes: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileAttributes(void) {
  U8   Attr;
  char ac[100];

  Attr = FS_GetFileAttributes("Test.txt");
  if (Attr == 0xFF) {
    FS_X_Log("ERROR: Could not get the file attributes.\n");
  } else {
    SEGGER_snprintf(ac, sizeof(ac),
      "File attributes: %c%c%c%c%c\n",
      (Attr & FS_ATTR_READ_ONLY) ? 'R' : '-',
      (Attr & FS_ATTR_HIDDEN)    ? 'H' : '-',
      (Attr & FS_ATTR_SYSTEM)    ? 'S' : '-',
      (Attr & FS_ATTR_ARCHIVE)   ? 'A' : '-',
      (Attr & FS_ATTR_DIRECTORY) ? 'D' : '-');
    FS_X_Log(ac);
  }
}
```

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4.6.4 FS_GetFileBufferInfo()

Description

Obtains information about a file buffer.

Prototype

```
int FS_GetFileBufferInfo(FS_FILE             * pFile,
                         FS_FILE_BUFFER_INFO * pInfo);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pInfo	out Information about the file buffer.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function returns an error if the specified file does not have a file buffer. `FS_IsFileBufferSet()` can be used to check if a file buffer is configured.

`FS_GetFileBufferInfo()` is available only if the file system is built with the `FS_SUPPORT_FILE_BUFFER` configuration define set to 1.

This function does not perform any access to the storage device.

Example

```
#include "FS.h"

void SampleGetFileBufferInfo(void) {
  FS_FILE             * pFile;
  FS_FILE_BUFFER_INFO   Info;
  int                   r;
  char                  ac[100];

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != 0) {
    r = FS_IsFileBufferSet(pFile);
    if (r > 0) {
      memset(&Info, 0, sizeof(Info));
      r = FS_GetFileBufferInfo(pFile, &Info);
      if (r == 0) {
        FS_X_Log("File buffer info:\n");
        FS_X_Log("  Allocated by application: ");
        if (Info.IsExternal != 0) {
          FS_X_Log("yes\n");
        } else {
          FS_X_Log("no\n");
        }
        SEGGER_snprintf(ac, sizeof(ac),
          "  Buffer size:             %d bytes\n", Info.BufferSize);
        FS_X_Log(ac);
        FS_X_Log("  Operating mode:          READ");
        if (Info.Flags & FS_FILE_BUFFER_WRITE) {
          FS_X_Log(" WRITE");
        }
        if (Info.Flags & FS_FILE_BUFFER_ALIGNED) {
          FS_X_Log(" ALIGNED");
        }
        FS_X_Log("\n");
      }
    }
```

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```
    FS_FClose(pFile);
  }
}
```

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4.6.5 FS_GetFileInfo()

Description

Returns information about a file or directory.

Prototype

```
int FS_GetFileInfo(const char         * sName,
                   FS_FILE_INFO * pInfo);
```

Parameters

Parameter	Description
sName	Name of the file or directory.
pInfo	out Information about file or directory.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function can be used to obtain information about a file or directory such as attributes, size or time stamps. For more information refer to FS_FILE_INFO.

FS_GetFileInfo() returns 0xFFFFFFFF via the FileSize member of pInfo if the file system is built with FS_SUPPORT_LARGE_FILES set to 1 and the size of the file is greater than 0xFFFFFFFF. If sName specifies the name of a structured file such as a file that stores data encrypted with authentication then the FileSize member represents the size of the regular file and not the number of bytes accessible to the application.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileInfo(void) {
  int          r;
  FS_FILE_INFO FileInfo;
  char         ac[100];
  FS_FILETIME  FileTime;

  r = FS_GetFileInfo("Test.txt", &FileInfo);
  if (r == 0) {
    FS_X_Log("File info:\n");
    SEGGER_snprintf(ac, sizeof(ac), "  Attributes:    0x%x\n", FileInfo.Attributes);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Size:          %ld bytes\n", FileInfo.FileSize);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.CreationTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Creation time: %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastAccessTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Access time:   %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastWriteTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Write time:    %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
```

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```
}
```

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4.6.6 FS_GetFileInfo64()

Description

Obtains information about a file or directory.

Prototype

```
int FS_GetFileInfo64(const char           * sName,
                     FS_FILE_INFO64 * pInfo);
```

Parameters

Parameter	Description
sName	Name of the file or directory.
pInfo	out Information about file or directory.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

The function returns information about the attributes, size and time stamps of the specified file or directory. For more information refer to FS_FILE_INFO64.

This function performs the same operation as FS_GetFileInfo() with the difference that the size of the queried file or directory can be greater than or equal to 4GB.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileInfo64(void) {
  int            r;
  FS_FILE_INFO64 FileInfo;
  char           ac[100];
  FS_FILETIME    FileTime;
  U32            FileSizeLow;
  U32            FileSizeHigh;

  r = FS_GetFileInfo64("Test.txt", &FileInfo);
  if (r == 0) {
    FileSizeLow  = (U32)(FileInfo.FileSize % 1000000000uLL);
    FileSizeHigh = (U32)(FileInfo.FileSize / 1000000000uLL);
    FS_X_Log("File info:\n");
    SEGGER_snprintf(ac, sizeof(ac), "  Attributes:    0x%x\n", FileInfo.Attributes);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Size:          %ld%ld bytes\n", FileSizeHigh, FileSizeLow);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.CreationTime.TimeDate, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Creation time: %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastAccessTime.TimeDate, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Access time:   %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastWriteTime.TimeDate, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "  Write time:    %d-%.2d-%.2d %.2d:%.2d:%.2d\n",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
```

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```
}
```

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4.6.7 FS_GetFileName()

Description

Obtains the name of a file.

Prototype

```
int FS_GetFileName(FS_FILE   * pFile,
                   char      * pFileName,
                   unsigned    SizeOfFileName);
```

Parameters

Parameter	Description
pFile	Handle to the opened file.
pFileName	out Receives the name of the file as 0-terminated string. It cannot be NULL.
SizeOfFileName	Number of bytes in pFileName.

Return value

> 0	Number of bytes in the file name or number of bytes required to store the volume name.
< 0	Error code indicating the failure reason.

Additional information

If pFileName is sufficiently large to store the entire file name and the 0-terminator then the function returns the number of bytes in the file name without the 0-terminator. If pFileName is not sufficiently large to store the entire file name and the 0-terminator then the function returns the minimum buffer size required to store the entire file name including the 0-terminator. In this case, the function does not store any data to pFileName.

FS_GetFileName() stores at most SizeOfFileName - 1 bytes to pFileName and it terminates the string by a 0.

This function is present only when the file system is built with FS_MULTI_HANDLE_SAFE set to 1.

```
#include "FS.h"

void SampleGetFileName(void) {
  FS_FILE  * pFile;
  unsigned   SizeOfBuffer;
  int        NumBytes;
  char       acFileName[32];

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    memset(acFileName, 0, sizeof(acFileName));
    SizeOfBuffer = sizeof(acFileName);
    NumBytes = FS_GetFileName(pFile, acFileName, SizeOfBuffer);
    if ((NumBytes > 0) && (NumBytes < (int)SizeOfBuffer)) {
      FS_X_Log("File name: ");
      FS_X_Log(acFileName);
      FS_X_Log("\n");
    }
    FS_FClose(pFile);
  }
}
```

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4.6.8 FS_GetFileTime()

Description

Obtains the creation time of a file or directory.

Prototype

```
int FS_GetFileTime(const char * sName,
                   U32  * pTimeStamp);
```

Parameters

Parameter	Description
sName	File or directory name.
pTimeStamp	out Read timestamp value.

Return value

= 0 OK, timestamp read successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The date and time encoded in the timestamp using the following format:

Bit field
0 to 4
5 to 10
11 to 15
16 to 20
21 to 24
25 to 31

The last modification and the last access timestamps can be read via `FS_GetFileTimeEx()`.

Actual year can be calculated by adding 1980 to the encoded year value.

`FS_TimeStampToFileTime()` can be used to convert the returned timestamp into a broken-down date and time representation.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileTime(void) {
  char        ac[100];
  U32         TimeStamp;
  FS_FILETIME FileTime;
  int         r;

  r = FS_GetFileTime("Test.txt", &TimeStamp);
  if (r == 0) {
    FS_TimeStampToFileTime(TimeStamp, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Creation time: %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
}
```

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4.6.9 FS_GetFileTimeEnhanced()

Description

Obtains the timestamp of a file or directory.

Prototype

```
int FS_GetFileTimeEnhanced(const char         * sName,
                           FS_TIMESTAMP * pTimeStamp,
                           int            TimeType);
```

Parameters

Parameter	Description
sName	File or directory name.
pTimeStamp	out Read timestamp value.
TimeType	Type of timestamp to return.

Return value

= 0 OK, timestamp read successfully.
≠ 0 Error code indicating the failure reason.

Additional information

EFS maintains only one timestamp that is updated when the file is created. Therefore, the same timestamp value is returned for all time types.

TimeType can be set to one of the *File time types* on page 171 values.

FS_TimeStampEhnancedToFileTime() can be used to convert the returned timestamp into a broken-down date and time representation.

FS_GetFileTimeEnhanced() always sets to 0 the members Milliseconds and Offset of pTimeStamp if the file system is built with FS_SUPPORT_TIME_DATE_ENHANCED set to 0 or if the specified file or directory is located on a volume formatted as FAT or EFS.

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4.6.10 FS_GetFileTimeEx()

Description

Obtains the timestamp of a file or directory.

Prototype

```
int FS_GetFileTimeEx(const char * sName,
                           U32  * pTimeStamp,
                           int    TimeType);
```

Parameters

Parameter	Description
sName	File or directory name.
pTimeStamp	out Read timestamp value.
TimeType	Type of timestamp to read.

Return value

= 0 OK, timestamp read successfully.
≠ 0 Error code indicating the failure reason.

Additional information

Refer to FS_GetFileTime() for a description of the timestamp format.

TimeType can be set to one of the *File time types* on page 171 values. EFS maintains only one timestamp that is updated when the file is created. Therefore, the same timestamp value is returned for all the time types.

FS_TimeStampToFileTime() can be used to convert the timestamp returned by FS_GetFileTimeEx() into a broken-down date and time representation.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileTimeEx(void) {
  char        ac[100];
  U32         TimeStamp;
  FS_FILETIME FileTime;
  int         r;

  r = FS_GetFileTimeEx("Test.txt", &TimeStamp, FS_FILETIME_MODIFY);
  if (r == 0) {
    FS_TimeStampToFileTime(TimeStamp, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Modify time: %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
}
```

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4.6.11 FS_IsFileBufferSet()

Description

Checks if a file buffer is configured for the specified file.

Prototype

```
int FS_IsFileBufferSet(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

= 1 OK, file buffer set.
= 0 OK, file buffer not set.
≠ 0 Error code indicating the failure reason.

Additional information

`FS_IsFileBufferSet()` is available only if the file system is built with the `FS_SUPPORT_FILE_BUFFER` configuration define set to 1.

Example

```
#include "FS.h"

void SampleIsFileBufferSet(void) {
  FS_FILE * pFile;
  int       r;

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != 0) {
    r = FS_IsFileBufferSet(pFile);
    if (r < 0) {
      FS_X_Log("ERROR: Could not get file buffer status.\n");
    } else {
      if (r != 0) {
        FS_X_Log("File buffer set\n");
      } else {
        FS_X_Log("File buffer not set\n");
      }
    }
    FS_FClose(pFile);
  }
}
```

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4.6.12 FS_ModifyFileAttributes()

Description

Sets / clears the attributes of a file or directory.

Prototype

```
U8 FS_ModifyFileAttributes(const char * sName,
                           U8     SetMask,
                           U8     ClrMask);
```

Parameters

Parameter	Description
sName	Name of the file or directory.
SetMask	Bit mask of the attributes to be set.
ClrMask	Bit mask of the attributes to be cleared.

Return value

= 0xFF An error occurred.
≠ 0xFF Bit mask containing the old attributes of the file or directory.

Additional information

This function can be used to set and clear at the same time the attributes of a file or directory. The FS_ATTR_DIRECTORY attribute cannot be modified using this function.

The return value is an or-combination of the following attributes: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY.

The attributes that are specified in the SetMask are set to 1 while the attributes that are specified in the ClrMask are set to 0. SetMask and ClrMask values are an or-combination of the following attributes: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, or FS_ATTR_ARCHIVE. The attributes that are not specified in either SetMask or ClrMask are not modified.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleModifyFileAttributes(void) {
  U8   Attr;
  char ac[100];

  //
  // Set the read-only and the hidden flags. Clear archive flag.
  //
  Attr = FS_ModifyFileAttributes("Test.txt",
                                 FS_ATTR_READ_ONLY | FS_ATTR_HIDDEN,
                                 FS_ATTR_ARCHIVE);
  SEGGER_snprintf(ac, sizeof(ac), "Old file attributes: %c%c%c%c%c\n",
    (Attr & FS_ATTR_READ_ONLY) ? 'R' : '-',
    (Attr & FS_ATTR_HIDDEN)    ? 'H' : '-',
    (Attr & FS_ATTR_SYSTEM)    ? 'S' : '-',
    (Attr & FS_ATTR_ARCHIVE)   ? 'A' : '-',
    (Attr & FS_ATTR_DIRECTORY) ? 'D' : '-');
  FS_X_Log(ac);
  Attr = FS_GetFileAttributes("Test.txt");
  SEGGER_snprintf(ac, sizeof(ac), "New file attributes: %c%c%c%c%c\n",
    (Attr & FS_ATTR_READ_ONLY) ? 'R' : '-',
    (Attr & FS_ATTR_HIDDEN)    ? 'H' : '-',
    (Attr & FS_ATTR_SYSTEM)    ? 'S' : '-',
    (Attr & FS_ATTR_ARCHIVE)   ? 'A' : '-',
    (Attr & FS_ATTR_DIRECTORY) ? 'D' : '-');
```

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```
  FS_X_Log(ac);
}
```

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4.6.13 FS_Move()

Description

Moves a file or directory to another location.

Prototype

```
int FS_Move(const char * sNameSrc,
            const char * sNameDest);
```

Parameters

Parameter	Description
sNameSrc	Name of the source file or directory (partially qualified). It cannot be NULL.
sNameDest	Name of the destination file or directory (partially qualified). It cannot be NULL.

Return value

= 0 OK, file or directory move successfully.
≠ 0 Error code indicating the failure reason.

Additional information

FS_Move() can be used to change the location of a file or directory in the directory tree of the file system.

If the source and the destination file are located on the same volume, then only the directory entry assigned to the moved file is relocated. Otherwise the contents of the file is copied to the destination volume and the source file is deleted.

The function is able to move entire directory trees when the source and destination are located on the same volume. Moving an entire directory tree on a different volume is not supported. This operation has to be performed in the application by iterating over the files and directories and by copying them one-by-one.

By default, the source files and directories that have the FS_ATTR_READ_ONLY attribute set and that are located on a volume formatted as FAT cannot be moved. This behavior can be changed by compiling the file system sources with FS_FAT_PERMIT_RO_FILE_MOVE configuration define to 1. FS_FAT_ConfigROFileMovePermission() can be used to change the behavior at runtime.

Source files and directories located on an EFS formatted volume can be moved even if they have the FS_ATTR_READ_ONLY attribute set.

The operation fails if the destination file or directory already exists.

FS_Move() preserves the timestamps of the moved file or directory.

Example

```
#include "FS.h"

void SampleMove(void) {
  //
  // File tree before the operation.
  //
  // <root>
  //   |
  //   +->SubDir2
  //        |
  //        +->SubDir3
  //
  FS_Move("SubDir1", "SubDir2\\SubDir3");
  //
```

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```
  // File tree after the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //   |
  //   +->SubDir2
  //
}
```

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4.6.14 FS_Remove()

Description

Removes a file.

Prototype

```
int FS_Remove(const char * sFileName);
```

Parameters

Parameter	Description
sFileName	Name of the file to be removed.

Return value

= 0 OK, file has been removed.
≠ 0 Error code indicating the failure reason.

Additional information

The function removes also files that have the FS_ATTR_READ_ONLY attribute set. The remove operation fails if the file to be deleted is open.

Example

```
#include "FS.h"

void SampleRemove(void) {
  FS_Remove("Test.txt");
}
```

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4.6.15 FS_Rename()

Description

Changes the name of a file or directory.

Prototype

```
int FS_Rename(const char * sNameOld,
              const char * sNameNew);
```

Parameters

Parameter	Description
sNameOld	Old file or directory name (including the path).
sNameNew	New file or directory name (without path).

Return value

= 0 OK, file or directory has been renamed.
≠ 0 Error code indicating the failure reason.

Additional information

The function can rename either a file or a directory.

By default, the files and directories that have the FS_ATTR_READ_ONLY attribute set and that are located on a volume formatted as FAT cannot be renamed. This behavior can be changed by compiling the file system sources with the FS_FAT_PERMIT_RO_FILE_MOVE configuration define to 1. FS_FAT_ConfigROFileMovePermission() can be used to change the behavior at runtime.

Source files and directories located on an EFS formatted volume can be moved even if they have the FS_ATTR_READ_ONLY attribute set.

Example

```
#include "FS.h"

void SampleRename(void) {
  //
  // File tree before the operation.
  //
  // <root>
  //   |
  //   +->SubDir2
  //        |
  //        +->SubDir3
  //
  FS_Rename("SubDir2\\SubDir3", "SubDir1");
  //
  // File tree after the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //        |
  //        +->SubDir3
  //
}
```

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4.6.16 FS_SetFileAttributes()

Description

Modifies all the attributes of a file or directory.

Prototype

```
int FS_SetFileAttributes(const char * sName,
                         U8     AttrMask);
```

Parameters

Parameter	Description
sName	Pointer to a name of the file/directory.
AttrMask	Bit mask of the attributes to be set.

Return value

= 0 OK, attributes have been set.
≠ 0 Error code indicating the failure reason.

Additional information

The FS_ATTR_DIRECTORY attribute cannot be modified using this function. The value of AttrMask parameter is an or-combination of the following attributes: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY. The attributes that are not set in AttrMask are set to 0.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleFileAttributes(void) {
  U8   Attr;
  char ac[100];

  FS_SetFileAttributes("Test.txt", FS_ATTR_HIDDEN);
  Attr = FS_GetFileAttributes("Test.txt");
  SEGGER_snprintf(ac, sizeof(ac), "File attributes: %c%c%c%c%c\n",
    (Attr & FS_ATTR_READ_ONLY) ? 'R' : '-',
    (Attr & FS_ATTR_HIDDEN)    ? 'H' : '-',
    (Attr & FS_ATTR_SYSTEM)    ? 'S' : '-',
    (Attr & FS_ATTR_ARCHIVE)   ? 'A' : '-',
    (Attr & FS_ATTR_DIRECTORY) ? 'D' : '-');
  FS_X_Log(ac);
}
```

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4.6.17 FS_SetFileBuffer()

Description

Assigns a file buffer to an opened file.

Prototype

```
int FS_SetFileBuffer(FS_FILE * pFile,
                     void    * pData,
                     I32       NumBytes,
                     int       Flags);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pData	Pointer to the to memory area which should be used as buffer.
NumBytes	Number of bytes in the buffer.
Flags	Specifies the operating mode of the file buffer.

Return value

= 0 OK, buffer assigned.
≠ 0 Error code indicating the failure reason.

Additional information

This function can only be called immediately after the file is opened and before performing any operation on the file.

Flags is a bitwise-or combination of *File buffer flags* on page 166. If Flags is set to 0 then the file buffer caches only the data read from the file.

If the file buffer is configured in write mode the data of any operation that writes fewer bytes at once than the size of the file buffer is stored to file buffer. The contents of the file buffer is written to file in the following cases:

- when the file buffer is full.
- when place is required for new data read from file.
- when closing the file via FS_FClose().
- when synchronizing the file to storage via FS_SyncFile().
- when unmounting the file system via FS_Unmount() or FS_UnmountForced().
- when the file system is synchronized via FS_Sync().

In case of a read operation if the data is not present in the file buffer the file system fills the entire file buffer with the data from file.

FS_SetFileBuffer() reports an error if the file system is configured to automatically allocate a file buffer for each file it opens via FS_ConfigFileBufferDefault().

The data required to manage the file buffer is allocated from pData. The FS_SIZEOF_FILE_BUFFER() define can be used to calculate the amount of RAM required to store a specified number of data bytes in the file buffer.

If the file is opened and closed in the same function the file buffer can be allocated locally on the stack. Otherwise the buffer has to be globally allocated. After the file is closed the memory allocated for the file buffer is no longer accessed by the file system and can be safely deallocated or used to store other data.

FS_SetFileBuffer() is available only if the file system is built with the FS_SUPPORT_FILE_BUFFER configuration define set to 1.

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Example

```
#include "FS.h"

void SampleSetFileBuffer(void) {
  FS_FILE * pFile;
  U32       aBuffer[FS_SIZEOF_FILE_BUFFER(512) / 4];

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    //
    // Set the file buffer for read and write operation.
    // The file buffer is allocated on the stack since the file
    // is closed before the function returns.
    //
    FS_SetFileBuffer(pFile, aBuffer, sizeof(aBuffer), FS_FILE_BUFFER_WRITE);
    //
    // Data is written to file buffer.
    //
    FS_Write(pFile, "Test", 4);
    //
    // Write the data from file buffer to storage and close the file.
    //
    FS_FClose(pFile);
  }
}
```

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4.6.18 FS_SetFileTime()

Description

Modifies the creation time of a file or directory.

Prototype

```
int FS_SetFileTime(const char * sName,
                   U32    TimeStamp);
```

Parameters

Parameter	Description
sName	File or directory name.
TimeStamp	Timestamp value to be written.

Return value

= 0 OK, timestamp written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

Refer to FS_GetFileTime() for a description of the timestamp format.

FS_FileTimeToTimeStamp() can be used to create a timestamp value that can be passed to FS_SetFileTime() from a broken-down date and time representation.

This function is optional. The file system updates automatically the timestamps of file or directories.

Example

```
#include "FS.h"

void SampleSetFileTime(void) {
  U32         TimeStamp;
  FS_FILETIME FileTime;

  FileTime.Year   = 2005;
  FileTime.Month  = 03;
  FileTime.Day    = 26;
  FileTime.Hour   = 10;
  FileTime.Minute = 56;
  FileTime.Second = 14;
  FS_FileTimeToTimeStamp (&FileTime, &TimeStamp);
  FS_SetFileTime("Test.txt", TimeStamp);
}
```

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4.6.19 FS_SetFileTimeEnhanced()

Description

Modifies the timestamp of a file or directory.

Prototype

```
int FS_SetFileTimeEnhanced(const char         * sName,
                           const FS_TIMESTAMP * pTimeStamp,
                                 int            TimeType);
```

Parameters

Parameter	Description
sName	File or directory name.
pTimeStamp	in Timestamp value to be written.
TimeType	Type of timestamp to be written.

Return value

= 0 OK, timestamp written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

TimeType can be set to one of the *File time types* on page 171 values. EFS maintains only one timestamp. Therefore, TimeType is ignored for files and directories stored on an EFS volume.

FS_FileTimeToTimeStampEnhanced() can be used to create a suitable timestamp value that can be passed to this function from a broken-down date and time representation.

This function is optional. The file system updates automatically the timestamps of file or directories.

FS_SetFileTimeEnhanced() always sets to 0 the members Milliseconds and Offset of pTimeStamp if the file system is built with FS_SUPPORT_TIME_DATE_ENHANCED set to 0 or if the specified file or directory is located on a volume formatted as FAT or EFS.

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4.6.20 FS_SetFileTimeEx()

Description

Modifies the timestamp of a file or directory.

Prototype

```
int FS_SetFileTimeEx(const char * sName,
                     U32    TimeStamp,
                     int    TimeType);
```

Parameters

Parameter	Description
sName	File or directory name.
TimeStamp	Timestamp value to be written.
TimeType	Type of timestamp to be written.

Return value

= 0 OK, timestamp written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

Refer to FS_GetFileTime() for a description of the timestamp format.

TimeType can be set to one of the *File time types* on page 171 values. EFS maintains only one timestamp. Therefore, TimeType is ignored for files and directories stored on an EFS volume.

FS_FileTimeToTimeStamp() can be used to create a timestamp value that can be passed to FS_SetFileTimeEx() from a broken-down date and time representation.

This function is optional. The file system updates automatically the timestamps of file or directories.

Example

```
#include "FS.h"

void SampleSetFileTime(void) {
  U32         TimeStamp;
  FS_FILETIME FileTime;

  FileTime.Year   = 2017;
  FileTime.Month  = 07;
  FileTime.Day    = 07;
  FileTime.Hour   = 14;
  FileTime.Minute = 48;
  FileTime.Second = 14;
  FS_FileTimeToTimeStamp(&FileTime, &TimeStamp);
  //
  // Set the access time of the file.
  //
  FS_SetFileTimeEx("Test.txt", TimeStamp, FS_FILETIME_ACCESS);
}
```

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4.6.21 FS_UnsetFileBuffer()

Description

Frees the file buffer assigned to specified file.

Prototype

```
int FS_UnsetFileBuffer(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

= 0 OK, file buffer freed successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can only be called immediately after the file is opened and before performing any operation on the file. An error is returned if an attempt is made to unset a file buffer allocated by the file system with FS_SUPPORT_FILE_BUFFER_LIST set to 0.

FS_UnsetFileBuffer() is available only if the file system is built with the FS_SUPPORT_FILE_BUFFER configuration define set to 1.

This function does not perform any access to the storage device.

Example

```
#include "FS.h"

void SampleUnsetFileBuffer(void) {
  FS_FILE * pFile;
  int       r;
  U8        abData[4];

  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != 0) {
    if (FS_IsFileBufferSet(pFile)) {
      FS_UnsetFileBuffer(pFile);
    }
    //
    // The following write operation is performed
    // without a file buffer.
    //
    memset(abData, 0, sizeof(abData));
    FS_Write(pFile, abData, sizeof(abData));
    FS_FClose(pFile);
  }
}
```

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4.6.22 FS_WipeFile()

Description

Overwrites the contents of a file with random data.

Prototype

```
int FS_WipeFile(const char * sFileName);
```

Parameters

Parameter	Description
sFileName	Name of the file to overwrite.

Return value

= 0 Contents of the file overwritten.
≠ 0 Error code indicating the failure reason.

Additional information

When a file is removed, the file system marks the corresponding directory entry and the clusters in the allocation table as free. The contents of the file is not modified and it can be in theory restored by using a disk recovery tool. This can be a problem if the file stores sensitive data. Calling `FS_WipeFile()` before the file is removed makes the recovery of data impossible.

This function allocates `FS_BUFFER_SIZE_FILE_WIPE` bytes on the stack.

Example

```
#include "FS.h"

void SampleWipeFile(void) {
  FS_FILE * pFile;

  //
  // Create a file and write data to it.
  //
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_Write(pFile, "12345", 5);
    FS_FClose(pFile);
  }
  //
  // Overwrite the file contents with random data.
  //
  FS_WipeFile("Test.txt");
  //
  // Delete the file from storage medium.
  //
  FS_Remove("Test.txt");
}
```

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4.6.23 File attributes

Description

Attributes of files and directories.

Definition

```
#define FS_ATTR_READ_ONLY    0x01u
#define FS_ATTR_HIDDEN       0x02u
#define FS_ATTR_SYSTEM       0x04u
#define FS_ATTR_ARCHIVE      0x20u
#define FS_ATTR_DIRECTORY    0x10u
```

Symbols

Definition	Description
FS_ATTR_READ_ONLY	The file is read-only. Applications can read the file but cannot write to it.
FS_ATTR_HIDDEN	The file or directory is marked as hidden. Most of operating systems do not include these files in an ordinary directory listing. This flag is not evaluated by emFile.
FS_ATTR_SYSTEM	The file or directory is part of, or is used exclusively by, the operating system. This flag is not evaluated by emFile.
FS_ATTR_ARCHIVE	The file or directory is an archive file or directory. Applications can use this attribute to mark files for backup or removal. This flag is not evaluated by emFile.
FS_ATTR_DIRECTORY	The file is actually a directory.

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4.6.24 File buffer flags

Description

File buffer operating options.

Definition

```
#define FS_FILE_BUFFER_WRITE      (1uL << 0)
#define FS_FILE_BUFFER_ALIGNED    (1uL << 1)
```

Symbols

Definition	Description
FS_FILE_BUFFER_WRITE	Data written to file is cached.
FS_FILE_BUFFER_ALIGNED	Cached data is kept aligned to logical sector boundary.

Additional information

A file buffer always caches the data read from the file. This operating mode is always enabled and cannot be disabled.

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4.6.25 File buffer size

Description

Calculates the file buffer size.

Definition

```
#define FS_SIZEOF_FILE_BUFFER(NumBytes)    (FS_SIZEOF_FILE_BUFFER_STRUCT + (NumBytes))
```

Additional information

This define can be used in an application to calculate the number of bytes that have to be allocated in order to store the specified number of bytes in the file buffer. `NumBytes` is typically a multiple of logical sector size.

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4.6.26 FS_FILE_BUFFER_INFO

Description

Information about a file buffer.

Type definition

```
typedef struct {
  U32  BufferSize;
  U8   Flags;
  U8   IsExternal;
} FS_FILE_BUFFER_INFO;
```

Structure members

Member	Description
BufferSize	Maximum number of bytes that can be stored in the file buffer.
Flags	Operating mode of the file buffer.
IsExternal	Specifies where the file buffer was allocated.

Additional information

The Flags member is a bitwise-or combination of *File buffer flags* on page 166 values.

The IsExternal member is set to 1 if the file buffer is provided by the application via FS_SetFileBuffer(). If the file buffer is allocated by the file system then IsExternal is set to 0.

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4.6.27 FS_FILE_INFO

Description

Information about a file or directory.

Type definition

```
typedef struct {
  U8   Attributes;
  U32  CreationTime;
  U32  LastAccessTime;
  U32  LastWriteTime;
  U32  FileSize;
} FS_FILE_INFO;
```

Structure members

Member	Description
Attributes	File or directory attributes.
CreationTime	Date and time when the file was created.
LastAccessTime	Date and time when the file was accessed last.
LastWriteTime	Date and time when the file was written to last.
FileSize	Size of the file in bytes.

Additional information

The Attributes member is a bitwise-or combination of the following flags: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY.

The FileSize member is always set to 0 for directories located on FAT and EFS volumes.

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4.6.28 FS_FILE_INFO64

Description

Information about a file or directory.

Type definition

```
typedef struct {
  U8            Attributes;
  FS_TIMESTAMP  CreationTime;
  FS_TIMESTAMP  LastAccessTime;
  FS_TIMESTAMP  LastWriteTime;
  U64           FileSize;
} FS_FILE_INFO64;
```

Structure members

Member	Description
Attributes	File or directory attributes.
CreationTime	Date and time when the file was created.
LastAccessTime	Date and time when the file was accessed last.
LastWriteTime	Date and time when the file was written to last.
FileSize	Size of the file in bytes.

Additional information

The Attributes member is a bitwise-or combination of the following flags: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY.

The FileSize member is always set to 0 for directories located on FAT and EFS volumes.

This structure can store the size of a file that is greater than or equal to 4GB.

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4.6.29 File time types

Description

Types of timestamps available for a file or directory.

Definition

```
#define FS_FILETIME_CREATE    0
#define FS_FILETIME_ACCESS    1
#define FS_FILETIME_MODIFY    2
```

Symbols

Definition	Description
FS_FILETIME_CREATE	Date and time when the file or directory was created.
FS_FILETIME_ACCESS	Date and time of the last read access to file or directory.
FS_FILETIME_MODIFY	Date and time of the last write access to file or directory.

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4.7 Directory functions

This section describes functions that operate on directories. API functions are provided for creating, deleting and listing directories.

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4.7.1 FS_CopyDir()

Description

Copies a directory and its contents to a different location.

Prototype

```
int FS_CopyDir(const char * sDirNameSrc,
               const char * sDirNameDest,
                     int    MaxRecursionLevel);
```

Parameters

Parameter	Description
sDirNameSrc	Name of the source directory (0-terminated string).
sDirNameDest	Name of the destination directory (0-terminated string).
MaxRecursionLevel	Maximum depth of the directory tree.

Return value

= 0 OK, directory copied successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The function uses recursion to process the directory tree and it requires about 100 bytes of stack for each directory level it processes. The MaxRecursionLevel parameter can be used to prevent a stack overflow if the directory tree is too deep.

This function allocates on the stack two buffers of FS_MAX_PATH bytes and one buffer of FS_BUFFER_SIZE_FILE_COPY bytes.

Following are some examples of the values that can be passed to MaxRecursionLevel.

- MaxRecursionLevel=0 Creates an empty destination directory. If any files or directories are present in the source directory then an error is reported.
- MaxRecursionLevel=1 Copies the source directory and all the files stored in it to the destination directory. If a subdirectory is present in the source directory then the copy operation is aborted and an error is reported. In this case, the destination directory will contain an incomplete copy of the source directory.
- MaxRecursionLevel=2 Copies the source directory and all the files and subdirectories stored in it to the destination directory. If the subdirectories contain other subdirectories in them then the copy operation is aborted and an error is reported. The destination directory will contain an incomplete copy of the source directory.

If present, the destination directory including its contents is removed before the copy operation. The destination directory is created if missing.

Example

```
#include "FS.h"

void SampleCopyDir(void) {
  FS_CopyDir("SubDir", "CopyDir", 5);
}
```

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4.7.2 FS_CreateDir()

Description

Creates a directory including any missing directories in the path.

Prototype

```
int FS_CreateDir(const char * sDirName);
```

Parameters

Parameter	Description
sDirName	Directory name.

Return value

= 0 Directory path has been created.
= 1 Directory path already exists.
< 0 Error code indicating the failure reason.

Additional information

The function creates automatically any subdirectories that are specified in the path but do not exist on the storage.

FS_CreateDir() uses a work buffer of FS_MAX_PATH bytes that is allocated on the stack. This buffer is used for parsing the path to the created directory.

Example

```
#include "FS.h"

void SampleCreateDir(void) {
  //
  // File tree before the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //
  FS_CreateDir("SubDir1\\SubDir2\\SubDir3");
  //
  // File tree after the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //        |
  //        +->SubDir2
  //             |
  //             +->SubDir3
  //
}
```

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4.7.3 FS_DeleteDir()

Description

Removes a directory and its contents.

Prototype

```
int FS_DeleteDir(const char * sDirName,
                 int    MaxRecursionLevel);
```

Parameters

Parameter	Description
sDirName	Directory name.
MaxRecursionLevel	Maximum depth of the directory tree.

Return value

= 0 OK, directory has been removed
≠ 0 Error code indicating the failure reason

Additional information

The function uses recursion to process the directory tree and it requires about 100 bytes of stack for each directory level it processes. The MaxRecursionLevel parameter can be used to prevent a stack overflow if the directory tree is too deep.

Following are some examples of the values that can be passed to MaxRecursionLevel.

- MaxRecursionLevel=0 Deletes the directory only if empty else an error is reported and the directory is not deleted.
- MaxRecursionLevel=1 Deletes the directory and all the files in it. If a subdirectory is present an error is reported and the directory is not deleted.
- MaxRecursionLevel=2 Deletes the directory and all the files and subdirectories in it. If the subdirectories contain other subdirectories an error is reported and the directory is not deleted.

Example

```
#include "FS.h"

void SampleDeleteDir(void) {
  //
  // File tree before the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //   |
  //   +->SubDir2
  //        |
  //        +->File1.txt
  //        |
  //        +->File2.txt
  //
  FS_DeleteDir("SubDir2", 1);
  //
  // File tree after the operation.
  //
  // <root>
  //   |
  //   +->SubDir1
  //
}
```

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4.7.4 FS_FindClose()

Description

Ends a directory scanning operation.

Prototype

```
void FS_FindClose(FS_FIND_DATA * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Additional information

This function has to be called at the end of the directory scanning operation to clear the used context. After calling this function the same context can be used for a different directory scanning operation.

Example

```
#include "FS.h"

void SampleFindClose(void) {
  FS_FIND_DATA fd;
  int          r;
  char         acFileName[32];

  //
  // List the files from the root directory.
  //
  r = FS_FindFirstFile(&fd, "", acFileName, sizeof(acFileName));
  if (r == 0) {
    do {
      //
      // Process file or directory...
      //
    } while (FS_FindNextFile(&fd));
  }
  FS_FindClose(&fd);
  //
  // List the files from the "SubDir1" directory.
  //
  r = FS_FindFirstFile(&fd, "SubDir1", acFileName, sizeof(acFileName));
  if (r == 0) {
    do {
      //
      // Process file or directory...
      //
    } while (FS_FindNextFile(&fd));
  }
  FS_FindClose(&fd);
}
```

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4.7.5 FS_FindClose64()

Description

Ends a directory scanning operation.

Prototype

```
int FS_FindClose64(FS_FIND_DATA64 * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

= 0 OK, directory scanning closed successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called at the end of the directory scanning operation to clear the used context. After calling this function the same context can be used for a different directory scanning operation.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include "FS.h"

void SampleFindClose64(void) {
  FS_FIND_DATA64 fd;
  int            r;
  char           acFileName[32];

  //
  // List the files from the root directory.
  //
  r = FS_FindFirstFile64(&fd, "", acFileName, sizeof(acFileName));
  if (r == 0) {
    for (;;) {
      //
      // Process file or directory...
      //
      r = FS_FindNextFile64(&fd);
      if (r != 0) {
        break;
      }
    }
  }
  (void)FS_FindClose64(&fd);
  //
  // List the files from the "SubDir1" directory.
  //
  r = FS_FindFirstFile64(&fd, "SubDir1", acFileName, sizeof(acFileName));
  if (r == 0) {
    for (;;) {
      //
      // Process file or directory...
      //
      r = FS_FindNextFile64(&fd);
      if (r != 0) {
        break;
      }
    }
  }
  (void)FS_FindClose64(&fd);
```

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```
}
```

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4.7.6 FS_FindFirstFile()

Description

Initiates a directory scanning operation.

Prototype

```
int FS_FindFirstFile(      FS_FIND_DATA * pFD,
                     const char         * sDirName,
                           char         * sFileName,
                           int            SizeOfFileName);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.
sDirName	Name of the directory to search in.
sFileName	Buffer that receives the name of the file found.
SizeOfFileName	Size in bytes of the sFileName buffer.

Return value

= 0 OK, directory scanning initialized successfully.
= 1 No files or directories available in directory.
< 0 Error code indicating the failure reason.

Additional information

This function returns information about the first file or directory found in the directory. This is typically the special directory name ".." when searching in a directory other than root. FS_FindFirstFile() and FS_FindNextFile() can be used to list all the files and directories in a directory.

The name of the file or directory is returned in sFileName. FS_FindFirstFile() stores at most SizeOfFileName - 1 characters in the buffer and it terminates the name of file or directory by a 0 character. The file or directory name is truncated if it contains more characters than the number of characters that can be stored in sFileName. For files or directories stored on a FAT volume with LFN support the name is truncated by returning the short version (8.3 format) of the file or directory name.

Alternatively, the file name can be accessed via the sFileName member of the pFD structure. Additional information about the file or directory such as size, attributes and timestamps are returned via the corresponding members of pFD structure. For more information refer to FS_FIND_DATA.

The returned file or directory does not necessarily be the first file or directory created in the root directory. The name of the first file or directory can change as files are deleted and created in the root directory.

The file system is able to handle a sFileName buffer with a maximum size of 32767 bytes.

FS_FindFirstFile() returns 0xFFFFFFFF via the FileSize member of pFD if the file system is built with FS_SUPPORT_LARGE_FILES set to 1 and the size of the file is greater than 0xFFFFFFFF.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleFindFirstFile(void) {
  FS_FIND_DATA fd;
  int          r;
  char         acFileName[32];
```

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```
  char         ac[100];
  FS_FILETIME  FileTime;

  //
  // List the files from the "SubDir1" directory.
  //
  r = FS_FindFirstFile(&fd, "SubDir1", acFileName, sizeof(acFileName));
  if (r == 0) {
    do {
      //
      // Ignore "." and ".." entries.
      //
      if (fd.sFileName[0] == '.') {
        continue;
      }
      //
      // Show information about the file.
      //
      if (fd.Attributes & FS_ATTR_DIRECTORY) {
        SEGGER_snprintf(ac, sizeof(ac), "Directory name: %s\n", fd.sFileName);
      } else {
        SEGGER_snprintf(ac, sizeof(ac), "File name:      %s\n", fd.sFileName);
      }
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "File size:      %lu\n", fd.FileSize);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "Attributes:     %c%c%c%c%c\n",
        (fd.Attributes & FS_ATTR_READ_ONLY) ? 'R' : '-',
        (fd.Attributes & FS_ATTR_HIDDEN)    ? 'H' : '-',
        (fd.Attributes & FS_ATTR_SYSTEM)    ? 'S' : '-',
        (fd.Attributes & FS_ATTR_ARCHIVE)   ? 'A' : '-',
        (fd.Attributes & FS_ATTR_DIRECTORY) ? 'D' : '-');
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.CreationTime, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Creation time:  %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.LastAccessTime, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Access time:    %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.LastWriteTime, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Write time:     %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_X_Log("--\n");
    } while (FS_FindNextFile(&fd));
  }
  FS_FindClose(&fd);
}
```

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4.7.7 FS_FindFirstFile64()

Description

Initiates a directory scanning operation.

Prototype

```
int FS_FindFirstFile64(      FS_FIND_DATA64 * pFD,
                       const char           * sDirName,
                             char           * sFileName,
                             int              SizeOfFileName);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.
sDirName	Name of the directory to search in.
sFileName	Buffer that receives the name of the file found.
SizeOfFileName	Size in bytes of the sFileName buffer.

Return value

= 1 OK, no files or directories available in directory.
= 0 OK, directory scanning initialized successfully.
< 0 Error code indicating the failure reason.

Additional information

This function returns information about the first file or directory found in the directory. This is typically the special directory name "." when searching in a directory other than root. FS_FindFirstFile64() and FS_FindNextFile64() can be used to list all the files and directories that are located in a specified directory.

The name of the file or directory is returned via sFileName. FS_FindFirstFile64() stores at most SizeOfFileName - 1 characters in the buffer and it terminates the name of file or directory by a 0-character. The file or directory name is truncated if it contains more characters than the number of characters that can be stored in sFileName. For files or directories stored on a FAT volume with LFN support the name is truncated by returning the short version (8.3 format) of the file or directory name.

Alternatively, the file name can be accessed via the sFileName member of the pFD structure. Additional information about the file or directory such as size, attributes and timestamps are returned via the corresponding members of pFD structure. For more information refer to FS_FIND_DATA.

If the file name is truncated then value of the FileNameLen member of the pFD structure is greater than the length of the 0-terminated string stored in the sFileName member of the same structure.

The returned file or directory does not necessarily be the first file or directory created in the root directory. The name of the first file or directory can change as files are deleted and created in the root directory.

The file system is able to handle a sFileName buffer with a maximum size of 32767 bytes.

This function is available only when the file system is built with FS_SUPPORT_LARGE_FILES set to 1.

Example

```
#include <stdio.h>
#include "FS.h"
```

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```
void SampleFindFirstFile64(void) {
  FS_FIND_DATA64 fd;
  int            r;
  char           acFileName[32];
  char           ac[100];
  FS_FILETIME    FileTime;

  //
  // List the files from the "SubDir1" directory.
  //
  r = FS_FindFirstFile64(&fd, "SubDir1", acFileName, sizeof(acFileName));
  if (r == 0) {
    for (;;) {
      //
      // Skip over system directory entries.
      //
      if ((fd.sFileName[0] == '.') && (fd.sFileName[1] == '\0')) {
        continue;
      }
      if ((fd.sFileName[0] == '.') && (fd.sFileName[1] == '.') && (fd.sFileName[2] == '\0')) {
        continue;
      }
      //
      // Show information about the file.
      //
      if (fd.Attributes & FS_ATTR_DIRECTORY) {
        SEGGER_snprintf(ac, sizeof(ac), "Directory name: %s\n", fd.sFileName);
      } else {
        SEGGER_snprintf(ac, sizeof(ac), "File name:      %s\n", fd.sFileName);
      }
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "File size:      %lu\n", fd.FileSize);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "Attributes:     %c%c%c%c%c\n",
        (fd.Attributes & FS_ATTR_READ_ONLY) ? 'R' : '-',
        (fd.Attributes & FS_ATTR_HIDDEN)    ? 'H' : '-',
        (fd.Attributes & FS_ATTR_SYSTEM)    ? 'S' : '-',
        (fd.Attributes & FS_ATTR_ARCHIVE)   ? 'A' : '-',
        (fd.Attributes & FS_ATTR_DIRECTORY) ? 'D' : '-');
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.CreationTime.TimeDate, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Creation time:  %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.LastAccessTime.TimeDate, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Access time:    %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_TimeStampToFileTime(fd.LastWriteTime.TimeDate, &FileTime);
      SEGGER_snprintf(ac, sizeof(ac), "Write time:     %d-%.2d-%.2d %.2d:%.2d:%.2d",
        FileTime.Year, FileTime.Month,  FileTime.Day,
        FileTime.Hour, FileTime.Minute, FileTime.Second);
      FS_X_Log(ac);
      FS_X_Log("--\n");
      r = FS_FindNextFile64(&fd);
      if (r != 0) {
        break;
      }
    }
  }
  (void)FS_FindClose64(&fd);
}
```

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4.7.8 FS_FindNextFile()

Description

Returns information about the next file or directory in a directory scanning operation.

Prototype

```
int FS_FindNextFile(FS_FIND_DATA * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

1 OK, information returned successfully.
0 Error occurred or end of directory reached.

Additional information

`FS_FindNextFile()` returns information about the next file or directory located after the file or directory returned via a previous call to `FS_FindFirstFile()` or `FS_FindNextFile()` within the same listing context.

The name of the file or directory is returned in sFileName member of `pFD`. `FS_FindNextFile()` stores at most one less than the buffer size characters in the buffer and it terminates the name of the file or directory by a 0 character. The buffer for the file or directory name is specified in the call to `FS_FindFirstFile()`. The file or directory name is truncated if it contains more characters than the number of characters that can be stored in sFileName. For files or directories stored on a FAT volume with LFN support the name is truncated by returning the short version (8.3 format) of the file or directory name.

Additional information about the file or directory such as size, attributes and timestamps are returned via the corresponding members of `pFD` structure. For more information refer to `FS_FIND_DATA`.

`FS_FindFirstFile()` has to be called first to initialize the listing operation. It is allowed to perform operations on files or directories (creation, deletion, etc.) within the listing loop.

`FS_FindNextFile()` returns `0xFFFFFFFF` via the FileSize member of `pFD` if the file system is built with `FS_SUPPORT_LARGE_FILES` set to 1 and the size of the file is greater than `0xFFFFFFFF`.

Example

Refer to the example of `FS_FindFirstFile()`

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4.7.9 FS_FindNextFileEx()

Description

Returns information about the next file or directory in a directory scanning operation.

Prototype

```
int FS_FindNextFileEx(FS_FIND_DATA * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

= 1 No files or directories available in directory.
= 0 OK, information returned successfully.
< 0 Error code indicating the failure reason.

Additional information

`FS_FindNextFileEx()` performs the same operation as `FS_FindNextFile()` with the difference that its return value is consistent with the return value of the other emFile API functions.

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4.7.10 FS_FindNextFile64()

Description

Returns information about the next file or directory in a directory scanning operation.

Prototype

```
int FS_FindNextFile64(FS_FIND_DATA64 * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

= 1 OK, no files or directories available in directory.
= 0 OK, information returned successfully.
< 0 Error code indicating the failure reason.

Additional information

This function can be called only after an initial call to the `FS_FindFirstFile64()` with the same directory scanning context.

This function is available only when the file system is built with `FS_SUPPORT_LARGE_FILES` set to 1.

Example

Refer to the example of `FS_FindFirstFile64()`

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4.7.11 FS_FindMatch()

Description

Checks if the file name matches the specified pattern.

Prototype

```
int FS_FindMatch(      FS_FIND_DATA * pFD,
                 const char         * sPattern);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.
sPattern	in Pattern to be matched (0-terminated string).

Return value

> 0	File name does not match the pattern.
= 0	File name matches pattern.
< 0	Error code indicating the failure reason.

Additional information

Permitted wildcard characters in pattern are '?' and '*'. '?' matches a single character. '*' matches none or any number of characters. Any other characters are compared for equality. The compare operation is case insensitive for file names that are located on a volume formatted as FAT or exFAT. The compare operation is case sensitive for file names that are located on a volume formatted as EFS and the file name case sensitivity is enabled via FS_EFS_ConfigCaseSensitivity() and FS_EFS_CASE_SENSITIVE. For multi-byte characters and characters encoded as UTF-8 the comparison is performed on the decoded value.

Example

```
#include "FS.h"

void SampleFindMatch(void) {
  FS_FIND_DATA fd;
  int          r;
  char         acFileName[32];

  //
  // List the names of the files and directories with ".txt" extension
  // that are located in the "SubDir1" directory.
  //
  r = FS_FindFirstFile(&fd, "SubDir1", acFileName, sizeof(acFileName));
  if (r == 0) {
    for (;;) {
      if (FS_FindMatch(&fd, "*.txt") == 0) {
        FS_X_Log(fd.sFileName);
        FS_X_Log("\n");
      }
      r = FS_FindNextFileEx(&fd);
      if (r != 0) {
        break;
      }
    }
  }
  FS_FindClose(&fd);
}
```

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4.7.12 FS_FindMatch64()

Description

Checks if the file name matches the specified pattern.

Prototype

```
int FS_FindMatch64(      FS_FIND_DATA64 * pFD,
                   const char           * sPattern);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.
sPattern	in Pattern to be matched (0-terminated string).

Return value

> 0	File name does not match the pattern.
= 0	File name matches pattern.
< 0	Error code indicating the failure reason.

Additional information

Refer to `FS_FindMatch()` for more information.

Example

Refer to the example of `FS_FindMatch()`

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4.7.13 FS_MkDir()

Description

Creates a directory.

Prototype

```
int FS_MkDir(const char * sDirName);
```

Parameters

Parameter	Description
sDirName	Directory name.

Return value

= 0 OK, directory has been created
≠ 0 Error code indicating the failure reason

Additional information

The function fails if a directory with the same name already exists in the target directory. `FS_MkDir()` expects that all the directories in the path to the created directory exist. Otherwise the function returns with an error. `FS_CreateDir()` can be used to create a directory along with any missing directories in the path.

Example

```
#include "FS.h"

void SampleMkDir(void) {
  FS_MkDir("SubDir1");
}
```

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4.7.14 FS_RmDir()

Description

Removes a directory.

Prototype

```
int FS_RmDir(const char * sDirName);
```

Parameters

Parameter	Description
sDirName	Directory name.

Return value

= 0 OK, directory has been removed
≠ 0 Error code indicating the failure reason

Additional information

The function fails if the directory is not empty. `FS_DeleteDir()` can be used to remove a directory and its contents.

Example

```
#include "FS.h"

void SampleRmDir(void) {
  FS_RmDir("SubDir1");
}
```

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4.7.15 FS_FIND_DATA

Description

Information about a file or directory.

Type definition

```
typedef struct {
  U8      Attributes;
  U32     CreationTime;
  U32     LastAccessTime;
  U32     LastWriteTime;
  U32     FileSize;
  char  * sFileName;
  U16     SizeofFileName;
  FS_DIR  Dir;
} FS_FIND_DATA;
```

Structure members

Member	Description
Attributes	Attributes of the file or directory.
CreationTime	Date and time when the file or directory was created.
LastAccessTime	Date and time when the file or directory was accessed last.
LastWriteTime	Date and time when the file or directory was modified last.
FileSize	Size of the file in bytes.
sFileName	Name of the file or directory as 0-terminated string.
SizeofFileName	Internal. Not to be used by the application.
Dir	Internal. Not to be used by the application.

Additional information

sFileName points to the buffer passed as argument to FS_FindFirstFile().

This structure contains also the context for the file listing operation. These members are considered internal and should not be used by the application. FS_FIND_DATA is used as context by the FS_FindFirstFile(), FS_FindNextFile(), FS_FindNextFileEx() and FS_FindClose() set of functions.

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4.7.16 FS_FIND_DATA64

Description

Information about a file or directory.

Type definition

```
typedef struct {
  U8            Attributes;
  FS_TIMESTAMP  CreationTime;
  FS_TIMESTAMP  LastAccessTime;
  FS_TIMESTAMP  LastWriteTime;
  U64           FileSize;
  char        * sFileName;
  U16           FileNameLen;
  U16           SizeOfFileName;
  FS_DIR        Dir;
} FS_FIND_DATA64;
```

Structure members

Member	Description
Attributes	Attributes of the file or directory.
CreationTime	Date and time when the file or directory was created.
LastAccessTime	Date and time when the file or directory was accessed last.
LastWriteTime	Date and time when the file or directory was modified last.
FileSize	Size of the file in bytes.
sFileName	Name of the file or directory as 0-terminated string.
FileNameLen	Actual length of the file name in bytes.
SizeOfFileName	Internal. Not to be used by the application.
Dir	Internal. Not to be used by the application.

Additional information

sFileName points to the buffer passed as argument to FS_FindFirstFile64().

This structure contains also the context for the file listing operation. These members are considered internal and should not be used by the application. FS_FIND_DATA64 is used as context by the FS_FindFirstFile64(), FS_FindNextFile64() and FS_FindClose64() set of functions.

If FileNameLen is greater than the length of the 0-terminated string stored to sFileName then the file name was truncated.

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4.8 Formatting functions

A storage device has to be formatted before it can be used to write data to it. SD and MMC memory cards as well as USB drives are usually already preformatted. Normally, the NAND and NOR flash devices have to be reformatted. These storage devices require a low-level format first, followed by a high-level format. The low-level format is device-specific while the high-level format depends on the type of file system.

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4.8.1 FS_Format()

Description

Performs a high-level format.

Prototype

```
int FS_Format(const char           * sVolumeName,
              const FS_FORMAT_INFO * pFormatInfo);
```

Parameters

Parameter	Description
sVolumeName	Volume name.
pFormatInfo	in Additional format information. It can be set to NULL.

Return value

= 0 OK, storage device formatted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The high-level format operation prepares a storage device for the access via the file system. It has to be performed once before writing any data to the storage device.

The term "high-level" indicates that the format operation is performed at the file system level in comparison with a "low-level" format operation that is performed at the device driver level that is located below the file system level in the file system stack. A low-level format operation can be performed via FS_FormatLow().

The high-level format operation writes to the storage device basic management information that is required by the file system to operate correctly. This includes the initialization of the allocation table and of the root directory, as well as of the BIOS Parameter Block (BPB) for a volume formatted as FAT and of the Information Sector for a volume formatted as EFS. The amount of data written during the high-level format operation is typically smaller than 1 percent of the capacity of the storage device.

The type of file system can be selected at compile time via FS_SUPPORT_FAT and FS_SUPPORT_EFS defines. If both file systems are enabled at compile time the type of file system can be configured via FS_SetFSType().

pFormatInfo can be used to specify how the storage device has to be formatted such as the cluster size and the number of entries in the root directory. For a typical application, this parameter can safely be set to NULL. If set to NULL, the file system uses reasonable format parameters that are calculated based on the capacity of the storage device.

For increased performance it is recommended to format the storage device with clusters as large as possible. In this way the number of accesses to the allocation table the file system has to perform during a read or write operation is kept to a minimum. For more information about format parameters see FS_FORMAT_INFO.

After performing a high-level format operation all the files and directory that were present on the storage device are lost.

An application can check if a storage device is high-level formatted by calling FS_IsHLFormatted().

Example

```
#include <string.h>
#include "FS.h"

void SampleFormat(void) {
```

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```
  FS_FORMAT_INFO FormatInfo;
  //
  // Format default volume using reasonable defaults.
  //
  FS_Format("", NULL);
  //
  // Format the "mmc:0:" volume using 32 Kbyte clusters
  // assuming that the size of the logical sector used
  // by the storage device is 512 bytes.
  //
  memset(&FormatInfo, 0, sizeof(FormatInfo));
  FormatInfo.SectorsPerCluster = 64;
  FS_Format("mmc:0:", &FormatInfo);
}
```

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4.8.2 FS_FormatEx()

Description

Performs a high-level format.

Prototype

```
int FS_FormatEx(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Volume name.

Return value

= 0 OK, storage device formatted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The high-level format operation prepares a storage device for the access via the file system. It has to be performed once before writing any data to the storage device.

This function performs the same operation as `FS_Format()` with the difference that it uses the same format parameters irrespective of the file system type. The selection of the cluster size based on the capacity of the storage device in bytes. The selection algorithm is summarized in the following table.

Capacity
< 256 MB
≥ 256 MB and < 1 GB
≥ 1 GB and < 32 GB
≥ 32 GB

After performing a high-level format operation all the files and directory that were present on the storage device are lost.

An application can check if a storage device is high-level formatted by calling `FS_IsHLFormatted()`.

Example

```
#include "FS.h"

void SampleFormatEx(void) {
  FS_FormatEx("");
}
```

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4.8.3 FS_FormatLLIfRequired()

Description

Performs a low-level format.

Prototype

```
int FS_FormatLLIfRequired(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be formatted.

Return value

= 0 OK, low-level format successful.
= 1 Low-level format not required.
< 0 Error code indicating the failure reason.

Additional information

This function performs a low-level format of a storage device if it is not already low-level formatted. `FS_FormatLLIfRequired()` does nothing if the storage device is already low-level formatted. A storage device has to be low-level formatted once before the file system can perform any data access. All the data present on the storage device is lost after a low-level format.

The low-level format operation is required only for the storage devices that are managed by the file system such as NAND and NOR flash devices. SD cards and e.MMC devices do not require a low-level format.

Example

```
#include "FS.h"

void SampleFormatLLIfRequired(void) {
  FS_Init();
  //
  // Perform a low-level format if required.
  // Equivalent to the following sequence:
  //
  // if (FS_IsLLFormatted("nand:0:") == 0) {
  //   FS_FormatLow("nand:0:");
  // }
  //
  FS_FormatLLIfRequired("nand:0:");
}
```

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4.8.4 FS_FormatLow()

Description

Performs a low-level format.

Prototype

```
int FS_FormatLow(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be formatted.

Return value

= 0 OK, low-level format successful.
≠ 0 Error code indicating the failure reason.

Additional information

The low-level format operation prepares a storage device for the data access. It has to be performed once before writing any data to the storage device.

This operation is performed by the device driver that is used to access the storage device. The low-level format operation has to be performed only for a storage device that is managed by the file system such as NAND and NOR flash. SD cards and eMMC devices do not support and do not require a low-level format.

The term "low-level" indicates that the format operation is performed at the device driver level in comparison with a high-level format operation that is performed at the file system level that is located above the device driver level in the file system stack. A high-level format operation can be performed either via `FS_Format()` or `FS_FAT_FormatSD()`.

The low-level format operation writes to the storage device basic management information that is required by the device driver to operate correctly. A typical low-level format operation erases all the blocks in the partition that is used as storage and then stores format information in the first block of the partition.

The file system reports an error if an attempt is made to access a storage device that is not low-level formatted. The application can check if a storage device is low-level formatted by calling `FS_IsLLFormatted()`.

All the data present on the storage device is lost after a low-level format.

Typically, a low-level format operation has to be followed by a high-level format operation if a file system is used for accessing the storage device. If the storage device is accessed only via the functions of the storage layer such as when the contents of the storage device is exposed via USB Mass Storage then a high-level format operation is not required.

This function performs the same operation as `FS_STORAGE_FormatLow()`.

Example

```
#include "FS.h"

void SampleFormatLow(void) {
  FS_Init();
  //
  // Performs a low-level format of the NOR flash.
  //
  FS_FormatLow("nor:0:");
}
```

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4.8.5 FS_IsHLFormatted()

Description

Checks if a volume is high-level formatted or not.

Prototype

```
int FS_IsHLFormatted(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked.

Return value

= 1 Volume is formatted.
= 0 Volume is not formatted.
< 0 Error code indicating the failure reason.

Additional information

This function can be use to determine if the format of a volume is supported by the file system. If the volume format is unknown the function returns 0.

Example

```
#include "FS.h"

void SampleIsHLFormatted(void) {
  FS_Init();
  //
  // Perform a high-level format if required.
  //
  if (FS_IsHLFormatted("") == 0) {
    FS_Format("", NULL);
  }
}
```

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4.8.6 FS_IsLLFormatted()

Description

Returns whether a volume is low-level formatted or not.

Prototype

```
int FS_IsLLFormatted(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked. It cannot be NULL.

Return value

= 1 Volume is low-level formatted.
= 0 Volume is not low-level formatted.
< 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_IsLLFormatted().

Example

```
#include "FS.h"

void SampleIsLLFormatted(void) {
  FS_Init();
  //
  // Perform a low-level format if required.
  // Equivalent to the following sequence:
  //
  // FS_FormatLLIfRequired("nor:0:");
  //
  if (FS_IsLLFormatted("nor:0:") == 0) {
    FS_FormatLow("nor:0:");
  }
}
```

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4.8.7 FS_FORMAT_INFO

Description

Parameters for the high-level format.

Type definition

```
typedef struct {
  U16           SectorsPerCluster;
  U16           NumRootDirEntries;
  FS_DEV_INFO * pDevInfo;
  U8            Flags;
  U16           SectorsPerClusterHigh;
} FS_FORMAT_INFO;
```

Structure members

Member	Description
SectorsPerCluster	Number of sectors in a cluster.
NumRootDirEntries	Number of directory entries in the root directory.
pDevInfo	Information about the storage device.
Flags	Formatting options.
SectorsPerClusterHigh	High-order 16-bits of the number of sectors in a cluster.

Additional information

This structure can be passed to FS_Format() to specify additional information about how the storage device has to be formatted.

A cluster is the allocation unit of the file system that consists of one or more consecutive logical sectors. The size of the cluster can be specified in number of sectors via SectorsPerCluster that has to be a power of 2 value. Using large clusters can help improve the performance of the file system because this reduces the number of accesses to the allocation table. Using small clusters makes more efficient use of disk space. Permitted values for SectorsPerCluster are:

- 0-128 for FAT
- 0-32768 for EFS
- 0-65536 for exFAT

A value of 0 means that the file system has to determine the size of the cluster automatically.

NumRootDirEntries represents the number of directory entries in the root directory should have. This is only a proposed value. The actual value depends on the FAT type. This value is typically used for FAT12 or FAT16 formatted volume that have a fixed number of entries in the root directory. On FAT32 formatted volume the root directory can grow dynamically. The file system uses a default value of 256 if NumRootDirEntries is set to 0.

pDevInfo should be typically set to NULL unless some specific information about the storage device has to be passed to format function. The file system requests internally the information from storage device if pDevInfo is set to NULL.

Flags is a bitwise-or combination of *Formatting flags* on page 201 values.

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4.8.8 Formatting flags

Description

Options for formatting a storage device.

Definition

```
#define FS_FORMAT_FLAG_IGNORE_PARTITIONING    0x01u
```

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4.9 Partitioning functions

The functions in this section can be used to manage separate volumes on the same storage device.

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4.9.1 FS_CreateGPT()

Description

Partitions the specified volume using a GPT (GUID Partition Table) partition scheme.

Prototype

```
int FS_CreateGPT(const char                 * sVolumeName,
                 FS_GPT_INFO                * pGPTInfo,
                 FS_PARTITION_INFO_GPT      * pPartInfo,
                 int                          NumPartitions);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be partitioned.
pGPTInfo	in Information about the GPT partitioning. It cannot be NULL.
pPartInfo	in List of the partitions to be created. It cannot be NULL.
NumPartitions	Number of partitions to be created. It cannot be 0 or negative.

Return value

= 0 OK, volume partitioned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The partition information is stored starting with the first logical sector of the storage device. The number of logical sectors occupied by the partitioning information depends on the number of partitions created. The partitioning information requires at least three logical sectors that is one logical sector for the protective MBR, one logical sector for the GPT header and one logical sector for the partition table. In addition, a copy of the GPT header and of the partition table is stored for redundancy purposes at the end of the storage device. For this reason, FS_CreateGPT() overwrites any information present in these logical sectors of the specified volume.

The partition entries are stored in the order specified in the pPartInfo array: the information found in pPartInfo[0] is stored to first partition entry, the information found in pPartInfo[1] is stored to the second partition entry, and so on.

The actual number of created partition entries is calculated as the maximum of NumPartitions and pGPTInfo::NumPartitions If pGPTInfo::NumPartitions is greater than NumPartitions then FS_CreateGPT() creates empty partitions for partition indexes greater than or equal to NumPartitions.

FS_CreateGPT() calculates the values of pGPTInfo::StartSector and pGPTInfo::NumSectors based on the capacity of the storage device if these members are set to 0. If pPartInfo::StartSector is set to 0 then FS_CreateGPT() set is to the next available sector that immediately follows the previous partition entry. pPartInfo::NumSectors can be set to 0 only for the last partition in the list in which case the last partition occupies the remaining free space on the storage device. For any other partitions pPartInfo::NumSectors must be different than 0.

FS_CreateGPT() checks the validity of values in pGPTInfo and pPartInfo. Any misconfiguration such as overlapping partitions is reported as an error and the partition table is not created.

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The partitioning information such as the disk id and the number of partitions can be queried via `FS_GetGPTInfo()`. The information about individual partitions can be obtained via `FS_GetPartitionInfoGPT()`.

The DISKPART logical driver can be used to access the data of the created partitions.

Example

```
#include <string.h>
#include "FS.h"

static const U8 _abDiskId[FS_NUM_BYTES_GUID] = {            // FB223EF0-C45C-D24A-4787-F2E856469D59
  0xFB, 0x22, 0x3E, 0xF0,
  0xC4, 0x5C,
  0xD2, 0x4A,
  0x47, 0x87,
  0xF2, 0xE8, 0x56, 0x46, 0x9D, 0x59
};

static const U8 _abTypeBasicData[FS_NUM_BYTES_GUID] = {     // A2A0D0EB-E5B9-3344-87C0-68B6B72699C7
  0xA2u, 0xA0u, 0xD0u, 0xEBu,
  0xE5u, 0xB9u,
  0x33u, 0x44u,
  0x87u, 0xC0u,
  0x68u, 0xB6u, 0xB7u, 0x26u, 0x99u, 0xC7
};

static const U8 _abPartId0[FS_NUM_BYTES_GUID] = {           // E633CD2E-2D08-7C46-5E97-7283101E324D
  0xE6, 0x33, 0xCD, 0x2E,
  0x2D, 0x08,
  0x7C, 0x46,
  0x5E, 0x97,
  0x72, 0x83, 0x10, 0x1E, 0x32, 0x4D
};

static const U8 _abPartId1[FS_NUM_BYTES_GUID] = {           // 6D8195A2-A800-3442-4007-999793ECE605

  0x6D, 0x81, 0x95, 0xA2,
  0xA8, 0x00,
  0x34, 0x42,
  0x40, 0x07,
  0x99, 0x97, 0x93, 0xEC, 0xE6, 0x05
};

static const U8 _abPartId2[FS_NUM_BYTES_GUID] = {           // 621D39CB-6DD4-6448-7539-487394C67FCF
  0x62, 0x1D, 0x39, 0xCB,
  0x6D, 0xD4,
  0x64, 0x48,
  0x75, 0x39,
  0x48, 0x73, 0x94, 0xC6, 0x7F, 0xCF
};

static const char _acPartName0[] = "Partition 0";
static const char _acPartName1[] = "Partition 1";
static const char _acPartName2[] = "Partition 2";

void SampleCreateGPT(void) {
  FS_PARTITION_INFO_GPT aPartInfo[3];
  FS_GPT_INFO           gptInfo;

  //
  // This example creates a GUID partition table with three partitions.
  // The position and size of first partition is configured explicitly.
  // The position of the second partition is calculated by FS_CreateGPT()
  // and it starts right after the first partition.
  // The third partition occupies the remaining of the storage device.
  //
  memset(aPartInfo, 0, sizeof(aPartInfo));
  memset(&gptInfo, 0, sizeof(gptInfo));
  //
  // We fill here only the disk id. The information related to
  // the partition location and the number of partitions is
  // calculated by FS_CreateGPT();
  //
  memcpy(gptInfo.abId, _abDiskId, FS_NUM_BYTES_GUID);
```

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```
  //
  // First partition.
  //
  aPartInfo[0].StartSector = 32;
  aPartInfo[0].NumSectors  = 5000;
  memcpy(aPartInfo[0].abId, _abPartId0, FS_NUM_BYTES_GUID);
  memcpy(aPartInfo[0].abType, _abTypeBasicData, FS_NUM_BYTES_GUID);
  strncpy(aPartInfo[0].acName, _acPartName0, FS_MAX_NUM_BYTES_PART_NAME - 1);
  aPartInfo[0].acName[FS_MAX_NUM_BYTES_PART_NAME - 1] = '\0';
  //
  // Second partition.
  //
  aPartInfo[1].StartSector = 0;
  aPartInfo[1].NumSectors  = 10000;
  memcpy(aPartInfo[1].abId, _abPartId1, FS_NUM_BYTES_GUID);
  memcpy(aPartInfo[1].abType, _abTypeBasicData, FS_NUM_BYTES_GUID);
  strncpy(aPartInfo[1].acName, _acPartName1, FS_MAX_NUM_BYTES_PART_NAME - 1);
  aPartInfo[1].acName[FS_MAX_NUM_BYTES_PART_NAME - 1] = '\0';
  //
  // Third partition.
  //
  aPartInfo[2].StartSector = 0;
  aPartInfo[2].NumSectors  = 0;
  memcpy(aPartInfo[2].abId, _abPartId1, FS_NUM_BYTES_GUID);
  memcpy(aPartInfo[2].abType, _abTypeBasicData, FS_NUM_BYTES_GUID);
  strncpy(aPartInfo[2].acName, _acPartName2, FS_MAX_NUM_BYTES_PART_NAME - 1);
  aPartInfo[2].acName[FS_MAX_NUM_BYTES_PART_NAME - 1] = '\0';
  //
  // Create the partition table.
  //
  FS_CreateGPT("", &gptInfo, aPartInfo, 3);
}
```

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4.9.2 FS_CreateMBR()

Description

Partitions the specified volume using a MBR (Master Boot Record) partition scheme.

Prototype

```
int FS_CreateMBR(const char                 * sVolumeName,
                 FS_PARTITION_INFO_MBR * pPartInfo,
                 int                      NumPartitions);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be partitioned.
pPartInfo	in List of the partitions to be created.
NumPartitions	Number of partitions to be created.

Return value

= 0 OK, volume partitioned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

The Master Boot Record is a special logical sector that contains information about how the storage device is partitioned. This partitioning information is located on the first logical sector of a storage device (sector index 0). The MBR information can be queried via FS_GetPartitionInfoMBR(). FS_CreateMBR() overwrites any information present in the first logical sector of the specified volume.

The partition entries are stored in the order specified in the pPartInfo array: the information found in pPartInfo[0] is stored to first partition entry, the information found in pPartInfo[1] is stored to the second partition entry, and so on.

If the Type member of the FS_PARTITION_INFO_MBR structure is set to 0 then FS_CreateMBR() automatically calculates the partition type and the CHS (Cylinder/Head/Sector) addresses (Type, StartAddr and EndAddr) based on the values stored in the StartSector and NumSector members.

The data of the created partitions can be accessed using the DISKPART logical driver.

Example

```
#include <string.h>
#include "FS.h"

void SampleCreateMBR(void) {
  FS_PARTITION_INFO_MBR aPartInfo[2];

  //
  // This example creates a MBR with two partitions.
  // The first partition is configured to be bootable.
  // All parameters are explicitly configured.
  // The second partition is configured not to be bootable.
  // The partition type and CHS address are calculated
  // automatically by FS_CreateMBR().
  //
  memset(aPartInfo, 0, sizeof(aPartInfo));
  //
  // First partition.
  //
  aPartInfo[0].IsActive           = 1;
  aPartInfo[0].StartSector        = 10;
  aPartInfo[0].NumSectors         = 100000;
```

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```
  aPartInfo[0].Type               = 6;
  aPartInfo[0].StartAddr.Cylinder = 0;
  aPartInfo[0].StartAddr.Head     = 0;
  aPartInfo[0].StartAddr.Sector   = 11;
  aPartInfo[0].EndAddr.Cylinder   = 538;
  aPartInfo[0].EndAddr.Head       = 1;
  aPartInfo[0].EndAddr.Sector     = 10;
  //
  // Second partition.
  //
  aPartInfo[1].StartSector = 200000;
  aPartInfo[1].NumSectors  = 10000;
  FS_CreateMBR("", aPartInfo, 2);
}
```

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4.9.3 FS_GetGPTInfo()

Description

Returns information about the GPT partitioning.

Prototype

```
int FS_GetGPTInfo(const char        * sVolumeName,
                  FS_GPT_INFO * pGPTInfo);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the partition is located.
pGPTInfo	out Information about the GPT partitioning.

Return value

= 0 OK, partition information read.
≠ 0 Error code indicating the failure reason.

Example

```
#include <string.h>
#include "FS.h"

void SampleGetGPTInfo(void) {
  char        ac[100];
  int         r;
  FS_GPT_INFO gptInfo;

  memset(&gptInfo, 0, sizeof(gptInfo));
  r = FS_GetGPTInfo("", &gptInfo);
  if (r == 0) {
    FS_X_Log("GPT partitioning info:\n");
    SEGGER_snprintf(ac, sizeof(ac), "  StartSector:   %lu\n",
      (U32)gptInfo.StartSector);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  NumSectors:    %lu\n",
      (U32)gptInfo.NumSectors);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  NumPartitions: %u\n", gptInfo.NumPartitions);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  IsValidMain:   %u\n", gptInfo.IsValidMain);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  IsValidBackup: %u\n", gptInfo.IsValidBackup);
    FS_X_Log(ac);
    FS_X_Log("  Id:            ");
    SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X",
      gptInfo.abId[0], gptInfo.abId[1],
      gptInfo.abId[2], gptInfo.abId[3]);
    FS_X_Log(ac);
    FS_X_Log("-");
    SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
      gptInfo.abId[4], gptInfo.abId[5]);
    FS_X_Log(ac);
    FS_X_Log("-");
    SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
      gptInfo.abId[6], gptInfo.abId[7]);
    FS_X_Log(ac);
    FS_X_Log("-");
    SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
      gptInfo.abId[8], gptInfo.abId[9]);
    FS_X_Log(ac);
    FS_X_Log("-");
    SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X%02X%02X",
      gptInfo.abId[10], gptInfo.abId[11], gptInfo.abId[12],
      gptInfo.abId[13], gptInfo.abId[14], gptInfo.abId[15]);
    FS_X_Log(ac);
```

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```
    FS_X_Log("\n");
  }
}
```

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4.9.4 FS_GetPartitionInfoMBR()

Description

Returns information about a MBR partition.

Prototype

```
int FS_GetPartitionInfoMBR(const char                 * sVolumeName,
                           FS_PARTITION_INFO_MBR * pPartInfo,
                           U8                       PartIndex);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the partition is located.
pPartInfo	out Information about the partition.
PartIndex	Index of the partition to query.

Return value

= 0 OK, partition information read.
≠ 0 Error code indicating the failure reason.

Additional information

The function reads the information from the Master Boot Record (MBR) that is stored on the first sector (the sector with the index 0) of the specified volume. An error is returned if no MBR information is present on the volume. If the Type member of the FS_PARTITION_INFO_MBR structure is 0, the partition entry is not valid.

Permitted values for PartIndex are 0 to 3.

Example

```
#include <string.h>
#include "FS.h"

void SampleGetPartitionInfoMBR(void) {
  int                   iPart;
  FS_PARTITION_INFO_MBR PartInfo;
  char                  ac[100];

  //
  // Show the contents of the partition list stored in the Master
  // Boot Record. Only the valid entries are displayed.
  //
  FS_X_Log("MBR partition list:\n");
  for (iPart = 0; iPart < FS_MAX_NUM_PARTITIONS_MBR; ++iPart) {
    memset(&PartInfo, 0, sizeof(PartInfo));
    FS_GetPartitionInfoMBR("", &PartInfo, iPart);
    if (PartInfo.Type != 0) {
      SEGGER_snprintf(ac, sizeof(ac), "  Index:         %u\n", iPart);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  StartSector:   %lu\n", PartInfo.StartSector);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  NumSectors:    %lu\n", PartInfo.NumSectors);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  Type:          %u\n", PartInfo.Type);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  IsActive:      %u\n", PartInfo.IsActive);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  FirstCylinder: %u\n", PartInfo.StartAddr.Cylinder);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  FirstHead:     %u\n", PartInfo.StartAddr.Head);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  FirstSector:   %u\n", PartInfo.StartAddr.Sector);
      FS_X_Log(ac);
```

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```
      SEGGER_snprintf(ac, sizeof(ac), "  LastCylinder:  %u\n", PartInfo.EndAddr.Cylinder);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  LastHead:      %u\n", PartInfo.EndAddr.Head);
      FS_X_Log(ac);
      SEGGER_snprintf(ac, sizeof(ac), "  LastSector:    %u\n", PartInfo.EndAddr.Sector);
      FS_X_Log(ac);
      FS_X_Log("\n");
    }
  }
}
```

Deprecated name

`FS_GetPartitionInfo`

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4.9.5 FS_GetPartitionInfoGPT()

Description

Returns information about a GPT partition.

Prototype

```
int FS_GetPartitionInfoGPT(const char                 * sVolumeName,
                           FS_PARTITION_INFO_GPT * pPartInfo,
                           unsigned                 PartIndex);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the partition is located.
pPartInfo	out Information about the partition.
PartIndex	Index of the partition to query.

Return value

= 0 OK, partition information read.
≠ 0 Error code indicating the failure reason.

Example

```
#include <string.h>
#include "FS.h"

void SampleGetPartitionInfoGPT(void) {
  int                  iPart;
  FS_PARTITION_INFO_GPT PartInfo;
  char                 ac[100];
  int                  r;
  FS_GPT_INFO          gptInfo;
  int                  IsEmpty;
  unsigned             i;

  //
  // Show the contents of a GUID partition table.
  // Only the valid entries are displayed.
  //
  memset(&gptInfo, 0, sizeof(gptInfo));
  r = FS_GetGPTInfo("", &gptInfo);
  if (r == 0) {
    FS_X_Log("GPT partition list:\n");
    for (iPart = 0; iPart < gptInfo.NumPartitions; ++iPart) {
      memset(&PartInfo, 0, sizeof(PartInfo));
      r = FS_GetPartitionInfoGPT("", &PartInfo, iPart);
      IsEmpty = 1;
      //
      // An empty partition entry has all the bytes in the GUID type set to 0;
      //
      for (i = 0; i < sizeof(PartInfo.abType); ++i) {
        if (PartInfo.abType[i] != 0) {
          IsEmpty = 0;
        }
      }
      if (IsEmpty == 0) {
        SEGGER_snprintf(ac, sizeof(ac), "  Index:         %u\n", iPart);
        FS_X_Log(ac);
        SEGGER_snprintf(ac, sizeof(ac), "  StartSector:   %lu\n",
          (U32)PartInfo.StartSector);
        FS_X_Log(ac);
        SEGGER_snprintf(ac, sizeof(ac), "  NumSectors:    %lu\n",
          (U32)PartInfo.NumSectors);
        FS_X_Log(ac);
        SEGGER_snprintf(ac, sizeof(ac), "  Attr:          0x%08X%08X\n",
          (U32)(PartInfo.Attributes >> 32), (U32)(PartInfo.Attributes & 0xFFFFFFFFuL));
```

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```
        FS_X_Log(ac);
        SEGGER_snprintf(ac, sizeof(ac), "  Name:          %s\n", PartInfo.acName);
        FS_X_Log(ac);
        FS_X_Log("  Type:        ");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X",
          PartInfo.abType[0], PartInfo.abType[1],
          PartInfo.abType[2], PartInfo.abType[3]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abType[4], PartInfo.abType[5]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abType[6], PartInfo.abType[7]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abType[8], PartInfo.abType[9]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X%02X%02X",
          PartInfo.abType[10], PartInfo.abType[11], PartInfo.abType[12],
          PartInfo.abType[13], PartInfo.abType[14], PartInfo.abType[15]);
        FS_X_Log(ac);
        FS_X_Log("  Unique:      ");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X",
          PartInfo.abId[0], PartInfo.abId[1],
          PartInfo.abId[2], PartInfo.abId[3]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abId[4], PartInfo.abId[5]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abId[6], PartInfo.abId[7]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X",
          PartInfo.abId[8], PartInfo.abId[9]);
        FS_X_Log(ac);
        FS_X_Log("-");
        SEGGER_snprintf(ac, sizeof(ac), "%02X%02X%02X%02X%02X%02X",
          PartInfo.abId[10], PartInfo.abId[11], PartInfo.abId[12],
          PartInfo.abId[13], PartInfo.abId[14], PartInfo.abId[15]);
        FS_X_Log(ac);
        FS_X_Log("\n");
        FS_X_Log("\n");
      }
    }
  }
}
```

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4.9.6 FS_GetPartitioningScheme()

Description

Returns information about how a storage device is partitioned.

Prototype

```
int FS_GetPartitioningScheme(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the partition is located.

Return value

≥ 0	OK, partitioning type. It can be set to one of the *Partitioning schemes* on page 218 values.
≠ 0	Error code indicating the failure reason.

Example

```
#include "FS.h"

void SampleGetPartitioningScheme(void) {
  int Scheme;

  Scheme = FS_GetPartitioningScheme("");
  if (Scheme >= 0) {
    switch (Scheme) {
    case FS_PARTITIONING_SCHEME_NONE:
      FS_X_Log("The storage device is not partitioned.\n");
      break;
    case FS_PARTITIONING_SCHEME_MBR:
      FS_X_Log("The storage device is partitioned via MBR.\n");
      break;
    case FS_PARTITIONING_SCHEME_GPT:
      FS_X_Log("The storage device is partitioned via GPT.\n");
      break;
    default:
      FS_X_Log("Unknown partitioning scheme.\n");
      break;
    }
  }
}
```

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4.9.7 FS_GPT_INFO

Description

Information about a GUID partition table.

Type definition

```
typedef struct {
  U64  StartSector;
  U64  NumSectors;
  U16  NumPartitions;
  U8   IsValidMain;
  U8   IsValidBackup;
  U8   abId[];
} FS_GPT_INFO;
```

Structure members

Member	Description
StartSector	Index of the first logical sector that can be used for partition data (FirstUsableLBA field).
NumSectors	Index of the last logical sector that can be used for partition data (LastUsableLBA field - FirstUsableLBA field + 1).
NumPartitions	Number of partitions present on the storage device (NumberOfPartitionEntries field).
IsValidMain	Indicates if the main partition table is valid.
IsValidBackup	Indicates if the backup partition table is valid.
abId	GUID that uniquely identifies the storage device (DiskGUID field)

Additional information

The partitioning information can be obtained via `FS_GetGPTInfo()`.

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4.9.8 FS_PARTITION_INFO_MBR

Description

Information about a MBR partition.

Type definition

```
typedef struct {
  U32          NumSectors;
  U32          StartSector;
  FS_CHS_ADDR  StartAddr;
  FS_CHS_ADDR  EndAddr;
  U8           Type;
  U8           IsActive;
} FS_PARTITION_INFO_MBR;
```

Structure members

Member	Description
NumSectors	Total number of sectors in the partition.
StartSector	Index of the first sector in the partition relative to the beginning of the storage device.
StartAddr	Address of the first sector in the partition in CHS format.
EndAddr	Address of the last sector in the partition in CHS format.
Type	Type of the partition.
IsActive	Set to 1 if the partition is bootable.

Example

For an example usage, refer to FS_GetPartitionInfoMBR().

Deprecated name

FS_PARTITION_INFO_MBR

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4.9.9 FS_PARTITION_INFO_GPT

Description

Information about a GPT partition.

Type definition

```
typedef struct {
  U8    abType[];
  U8    abId[];
  U64   StartSector;
  U64   NumSectors;
  U64   Attributes;
  char  acName[];
} FS_PARTITION_INFO_GPT;
```

Structure members

Member	Description
abType	Partition type as GUID (PartitionTypeGUID field).
abId	Unique id of the partition as GUID (UniquePartitionGUID field).
StartSector	Index of the first logical sector in the partition (StartingLBA field).
NumSectors	Index of the last logical sector in the partition (EndingLBA field - StartingLBA field + 1).
Attributes	Partition attributes (Attributes field).
acName	Partition name as 0-terminated string, UTF-8 encoded (PartitionName field).

Additional information

The name of the partition returned via acName member is a 0-terminated string encoded as UTF-8. The size of this member can be configured via FS_MAX_NUM_BYTES_PART_NAME.

Example

For an example usage, refer to FS_GetPartitionInfoGPT().

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4.9.10 Partitioning schemes

Description

Methods for partitioning a storage device.

Definition

```
#define FS_PARTITIONING_SCHEME_NONE    0
#define FS_PARTITIONING_SCHEME_MBR     1
#define FS_PARTITIONING_SCHEME_GPT     2
```

Symbols

Definition	Description
FS_PARTITIONING_SCHEME_NONE	The storage device is not partitioned.
FS_PARTITIONING_SCHEME_MBR	The storage device is partitioned as MBR.
FS_PARTITIONING_SCHEME_GPT	The storage device is partitioned as GPT.

Example

Refer to `FS_GetPartitioningScheme()` for an example usage.

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4.10 File system checking functions

The functions in this section can be used by an application to check the consistency of the file system structure.

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4.10.1 FS_CheckAT()

Description

Verifies the consistency of the allocation table.

Prototype

```
int FS_CheckAT(FS_CHECK_DATA * pCheckData);
```

Parameters

Parameter	Description
pCheckData	in Checking context. It cannot be NULL.

Return value

= FS_CHECKDISK_RETVAL_OK	No errors found or the callback returned FS_CHECKDISK_ACTION_DO_NOT_REPAIR.
= FS_CHECKDISK_RETVAL_RETRY	An error has been found. The error has been corrected since the callback function returned FS_CHECKDISK_ACTION_SAVE_CLUSTERS or FS_CHECKDISK_ACTION_DELETE_CLUSTERS. FS_CheckDir() has to be called again to check for the next error.
= FS_CHECKDISK_RETVAL_ABORT	The application requested the abort of disk checking operation through the callback returning FS_CHECKDISK_ACTION_ABORT.
= FS_CHECKDISK_RETVAL_CONTINUE	Indicates that not all the allocation table has been checked. The entire volume has to be checked again using FS_CheckDir().
< 0	Error code indicating the failure reason.

Additional information

FS_CheckAT() has to be called in combination with FS_InitCheck() and FS_CheckDir() to check the consistency of the file system.

pCheckData has to be initialized via a call to FS_InitCheck().

Example

Refer to FS_InitCheck() for a usage example.

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4.10.2 FS_CheckDir()

Description

Verifies the consistency of a single directory.

Prototype

```
int FS_CheckDir(      FS_CHECK_DATA * pCheckData,
                const char          * sPath);
```

Parameters

Parameter	Description
pCheckData	in Checking context. It cannot be NULL.
sPath	Path to the directory to be checked. It cannot be NULL.

Return value

= FS_CHECKDISK_RETVAL_OK	No errors found or the callback returned FS_CHECKDISK_ACTION_DO_NOT_REPAIR.
= FS_CHECKDISK_RETVAL_RETRY	An error has been found. The error has been corrected since the callback function returned FS_CHECKDISK_ACTION_SAVE_CLUSTERS or FS_CHECKDISK_ACTION_DELETE_CLUSTERS. FS_CheckDir() has to be called again to check for the next error.
= FS_CHECKDISK_RETVAL_ABORT	The application requested the abort of disk checking operation through the callback returning FS_CHECKDISK_ACTION_ABORT.
= FS_CHECKDISK_RETVAL_MAX_RECURSE	Maximum recursion level reached. The disk checking operation has been aborted.
< 0	Error code indicating the failure reason.

Additional information

FS_CheckDir() has to be called in combination with FS_InitCheck() and FS_CheckAT() to check the consistency of the file system.

pCheckData has to be initialized via a call to FS_InitCheck(). In order to check the entire file system structure, the application will have to call FS_CheckDir() with every different directory path present on the file system.

Example

Refer to FS_InitCheck() for a usage example.

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4.10.3 FS_CheckDisk()

Description

Checks the consistency of the file system structure.

Prototype

```
int FS_CheckDisk(const char                          * sVolumeName,
                 void                                * pBuffer,
                 U32                                   BufferSize,
                 int                                   MaxRecursionLevel,
                 FS_CHECKDISK_ON_ERROR_CALLBACK      * pfOnError);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked.
pBuffer	Work buffer to be used for checking the allocation table.
BufferSize	Size of the work buffer in bytes. It cannot be NULL.
MaxRecursionLevel	The maximum directory depth the function is allowed to check.
pfOnError	Function that has to be called when an error is found. It cannot be NULL.

Return value

= FS_CHECKDISK_RETVAL_OK	No errors found or the callback returned FS_CHECKDISK_ACTION_DO_NOT_REPAIR.
= FS_CHECKDISK_RETVAL_RETRY	An error has been found. The error has been corrected since the callback function returned FS_CHECKDISK_ACTION_SAVE_CLUSTERS or FS_CHECKDISK_ACTION_DELETE_CLUSTERS. FS_CheckDisk() has to be called again to check for the next error.
= FS_CHECKDISK_RETVAL_ABORT	The application requested the abort of disk checking operation through the callback returning FS_CHECKDISK_ACTION_ABORT.
= FS_CHECKDISK_RETVAL_MAX_RECURSE	Maximum recursion level reached. The disk checking operation has been aborted.
< 0	Error code indicating the failure reason.

Additional information

This function can be used to check if any errors are present on a specific volume and, if necessary, to repair these errors. Ideally, the work buffer has to be large enough to store the usage information of all the clusters in the allocation table. FS_CheckDisk() uses one bit to store the usage state of a cluster. The typical size of the work buffer is about 2 KBytes. Additional iterations are performed if the work buffer is not large enough to check the whole allocation table in one step.

FS_CheckDisk() can detect and correct the following file system errors:

- Invalid directory entries.
- Lost clusters or cluster chains.
- Cross-linked clusters.
- Clusters are associated to a file with size of 0.
- Too few clusters are allocated to a file.

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- Cluster is not marked as end-of-chain, although it should be.

The contents of a lost cluster chain is saved during the repair operation to files named FILE<FileIndex>.CHK that are stored in directories named FOUND.<DirIndex>. FileIndex is a 0-based 4-digit decimal number that is incremented by one for each cluster chain saved. DirIndex is a 0-based 3-digit decimal number that is incremented by one each time FS_CheckDisk() is called. For example the first created directory has the name FOUND.000, the second FOUND.001, and so on while the first file in the directory has the name FILE0000.CHK, the second FILE0001.CHK, and so on.

The callback function is used to notify the application about the errors found by FS_CheckDisk() during the disk checking operation. FS_CheckDisk() uses the return value of the callback function to decide if the error hast to be repaired or not. For more information refer to FS_CHECKDISK_ON_ERROR_CALLBACK.

FS_CheckDisk() closes all opened files before it starts the disk checking operation. The application is not allowed to access the storage device from a different task as long as the operation is in progress.

Example

```
#include <stdio.h>
#include <stdarg.h>
#include <string.h>
#include "FS.h"

static U32 _aBuffer[1024 / 4];
static int _NumErrors;

/*********************************************************************
*
*       _OnError
*/
static int _OnError(int ErrCode, ...) {
  va_list      ParamList;
  const char * sFormat;
  char         c;
  char         ac[256];

  (void)memset(&ParamList, 0, sizeof(ParamList));
  sFormat = FS_CheckDisk_ErrCode2Text(ErrCode);
  if (sFormat) {
    va_start(ParamList, ErrCode);
    vsprintf(ac, sFormat, ParamList);
    FS_X_Log(ac);
    FS_X_Log("\n");
  }
  if (ErrCode != FS_CHECKDISK_ERRCODE_CLUSTER_UNUSED) {
    FS_X_Log("  Do you want to repair this? (y/n/a) ");
  } else {
    FS_X_Log("  * Convert lost cluster chain into file (y)\n");
    FS_X_Log("  * Delete cluster chain                 (d)\n");
    FS_X_Log("  * Do not repair                        (n)\n");
    FS_X_Log("  * Abort                                (a)\n");
  }
  _NumErrors++;
  c = getchar();
  FS_X_Log("\n");
  if ((c == 'y') || (c == 'Y')) {
    return FS_CHECKDISK_ACTION_SAVE_CLUSTERS;
  } else if ((c == 'a') || (c == 'A')) {
    return FS_CHECKDISK_ACTION_ABORT;
  } else if ((c == 'd') || (c == 'D')) {
    return FS_CHECKDISK_ACTION_DELETE_CLUSTERS;
  }
  return FS_CHECKDISK_ACTION_DO_NOT_REPAIR;     // Do not repair anything.
}

/*********************************************************************
*
*       SampleCheckDisk
*/
```

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```
void SampleCheckDisk(void) {
  int r;

  while (1) {
    r = FS_CheckDisk("", _aBuffer, sizeof(_aBuffer), 5, _OnError);
    if (r != FS_CHECKDISK_RETVAL_RETRY) {
      break;
    }
  }
  if (_NumErrors == 0) {
    FS_X_Log("No errors were found.\n");
  } else {
    FS_X_Log("Errors were found.\n");
  }
}
```

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4.10.4 FS_CheckDisk_ErrCode2Text()

Description

Returns a human-readable text description of a disk checking error code.

Prototype

```
const char *FS_CheckDisk_ErrCode2Text(int ErrCode);
```

Parameters

Parameter	Description
ErrCode	Error code for which the text description has to be returned.

Return value

Text description as 0-terminated string.

Additional information

This function can be invoked inside the callback for `FS_CheckDisk()` to format the error information in human-readable format. The text description includes format specifiers for the printf() family of functions that can be used to show additional information about the file system error.

Refer to `FS_CheckDisk()` for more information about how to use this function.

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4.10.5 FS_GetATInfo()

Description

Obtains information about the allocation table.

Prototype

```
int FS_GetATInfo(const char       * sVolumeName,
                 FS_AT_INFO * pATInfo);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume that stores the allocation table. It cannot be NULL.
pATInfo	out Allocation table information. It cannot be NULL.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This is an optional function that can be used to get information about the allocation table. The allocation table is a data structure maintained by the file system that stores information about how the clusters are allocated.

Example

```
#include "FS.h"

void SampleGetATInfo(void) {
  int        r;
  FS_AT_INFO ATInfo;
  char       ac[100];

  memset(&ATInfo, 0, sizeof(ATInfo));
  r = FS_GetATInfo("", &ATInfo);
  if (r == 0) {
    FS_X_Log("Allocation table info:");
    SEGGER_snprintf(ac, sizeof(ac), "  First cluster: %u\n", ATInfo.FirstClusterId);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Last cluster:  %u\n", ATInfo.LastClusterId);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Write count:   %u\n", ATInfo.WriteCnt);
    FS_X_Log(ac);
  }
}
```

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4.10.6 FS_GetClusterInfo()

Description

Obtains information about a storage allocation unit.

Prototype

```
int FS_GetClusterInfo(const char            * sVolumeName,
                      U32                     ClusterId,
                      FS_CLUSTER_INFO       * pClusterInfo);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume that stores the cluster. It cannot be NULL.
ClusterId	Id of the cluster to be queried.
pClusterInfo	out Cluster information. It cannot be NULL.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This is an optional function that can be used to get detailed information about a storage allocation unit (cluster).

The file system reserves the first entries in the allocation table for internal usage. These entries of the allocation table do not have any associated cluster. The id of the first and of the last valid cluster can be obtain via FS_GetATInfo().

Example

```
#include "FS.h"

void SampleGetClusterInfo(void) {
  int             r;
  FS_CLUSTER_INFO ClusterInfo;
  char            ac[100];

  memset(&ClusterInfo, 0, sizeof(ClusterInfo));
  r = FS_GetClusterInfo("", 2, &ClusterInfo);
  if (r == 0) {
    FS_X_Log("Cluster info:");
    SEGGER_snprintf(ac, sizeof(ac), "  Sector index: %u\n", ClusterInfo.SectorIndex);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Status:       %s\n",
      ClusterInfo.IsFree ? "free" : "allocated");
    FS_X_Log(ac);
    if (ClusterInfo.IsFree == 0) {
      if (ClusterInfo.IsEOC != 0) {
        SEGGER_snprintf(ac, sizeof(ac), "  Next cluster: <end of chain>\n");
      } else {
        SEGGER_snprintf(ac, sizeof(ac), "  Next cluster: %u\n", ClusterInfo.NextClusterId);
      }
      FS_X_Log(ac);
    }
  }
}
```

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4.10.7 FS_GetDiskLayout()

Description

Obtains information about the data layout of a volume.

Prototype

```
int FS_GetDiskLayout(const char           * sVolumeName,
                     FS_DISK_LAYOUT * pDiskLayout);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried. It cannot be NULL.
pDiskLayout	out Layout information. It cannot be NULL.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This is an optional function that can be used to get detailed information about where the file system stores the data on a volume. The information is provided in a form of logical sector ranges.

Example

```
#include "FS.h"

void SampleGetDiskLayout(void) {
  int            r;
  FS_DISK_LAYOUT DiskLayout;
  U32            aBuffer[512 / 4];
  U32            SectorIndex;

  memset(&DiskLayout, 0, sizeof(DiskLayout));
  r = FS_GetDiskLayout("", &DiskLayout);
  if (r == 0) {
    //
    // Read the first logical sector of the root directory.
    // Works only for volumes formatted as FAT12 or FAT16.
    //
    if (   (DiskLayout.FSType == FS_TYPE_FAT12)
        || (DiskLayout.FSType == FS_TYPE_FAT16)) {
      SectorIndex = DiskLayout.FSLayout.fat.SectorIndexRootDir;
      (void)FS_STORAGE_ReadSector("", aBuffer, SectorIndex);
    }
  }
}
```

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4.10.8 FS_GetFirstCluster()

Description

Obtains the id of the first cluster assigned to a file or directory.

Prototype

```
int FS_GetFirstCluster(const char * sName,
                       U32  * pClusterId);
```

Parameters

Parameter	Description
sName	Name of the file or directory to query.
pClusterId	out Id of the first cluster.

Return value

= 0 OK, cluster id returned successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This is an optional function that can be used to get the id of the first cluster assigned to a file or directory for analysis purposes.

Empty files do not have any cluster assigned to them. In this case the returned cluster id is 0.

Subdirectories always have a cluster id assigned to them because they are never empty since the system directory entries ".” and "..” are always present and cannot be deleted.

The root directory of a FAT32 and EFS formatted storage device always have a cluster id assigned to them that is set when the storage device is formatted.

The root directory of a FAT12 and FAT16 formatted storage device is allocated on a special area of the file system and has a fixed size. For this reason, such a root directory does not have any cluster allocated to it. `FS_GetFirstCluster()` returns an error in this case.

Example

```
#include "FS.h"

void SampleGetFirstCluster(void) {
  char ac[100];
  U32  ClusterId;
  int  r;

  r = FS_MkDir("SubDir1");
  if (r == 0) {
    r = FS_GetFirstCluster("SubDir1", &ClusterId);
    if (r == 0) {
      SEGGER_snprintf(ac, sizeof(ac), "%u is the first cluster in the chain\n", ClusterId);
      FS_X_Log(ac);
    }
  }
}
```

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4.10.9 FS_InitCheck()

Description

Initializes a non-blocking disk checking operation.

Prototype

```
int FS_InitCheck(      FS_CHECK_DATA                  * pCheckData,
                 const char                           * sVolumeName,
                       void                           * pBuffer,
                       U32                              BufferSize,
                       FS_CHECKDISK_ON_ERROR_CALLBACK * pfOnError);
```

Parameters

Parameter	Description
pCheckData	out Checking context. It cannot be NULL.
sVolumeName	Name of the volume on which the checking is performed. It cannot be NULL.
pBuffer	in Working buffer. It cannot be NULL.
BufferSize	Number of bytes in pBuffer.
pfOnError	Callback function to be invoked in case of a file system damage. It cannot be NULL.

Return value

= FS_CHECKDISK_RETVAL_OK	OK, disk checking has been initialized.
< 0	Error code indicating the failure reason.

Additional information

FS_InitCheck() has to be called in combination with FS_CheckDir() and FS_CheckAT() to check the consistency of the file system. These functions perform the same operation as FS_CheckDisk() with the difference that the access to the file system is blocked only for a limited period of time.

It is mandatory to call FS_InitCheck() before any call to FS_CheckDir() or FS_CheckAT(). The purpose of FS_InitCheck() is to prepare the checking context pCheckData for the operation. This context must be passed to FS_CheckDir() and FS_CheckAT().

The parameters sVolumeName, pBuffer, BufferSize and pfOnError have the same meaning as the corresponding parameters of FS_CheckDisk(). Refer to FS_CheckDisk() for more information about the usage of these parameters.

In a typical usage the application calls FS_InitCheck() once followed by multiple calls to FS_CheckDir() and FS_CheckAT(). In addition, each time FS_CheckDir() and FS_CheckAT() find and correct an error FS_InitCheck() has to be called again to re-initialize the operation.

Example

The following example demonstrates how the consistency of the file system structure can be checked while the application performs normal file system operations.

```
#include <stdarg.h>
#include <stdio.h>
#include <string.h>
#include "FS.h"

#define VOLUME_NAME       ""
#define MAX_RECURSION     5

static U32 _aBuffer[1024 / 4];
static int _NumErrors;
```

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```
/*********************************************************************
*
*       _IsSystemDir
*/
static int _IsSystemDir(const char * sDirName) {
  if (((*sDirName == '.') && (*(sDirName + 1) == '\0'))) {
    return 1;
  }
  if (((*sDirName == '.') && (*(sDirName + 1) == '.')  && (*(sDirName + 2) == '\0'))) {
    return 1;
  }
  return 0;
}

/*********************************************************************
*
*       _cbOnError
*/
static int _cbOnError(int ErrCode, ...) {
  va_list      ParamList;
  const char * sFormat;
  int          c;
  char         ac[1000];

  //lint --e{438} -esym(530, ParamList)
  sFormat = FS_CheckDisk_ErrCode2Text(ErrCode);
  if (sFormat) {
    va_start(ParamList, ErrCode);
    SEGGER_vsnprintf(ac, sizeof(ac), sFormat, ParamList);
    va_end(ParamList);
    FS_X_Log(ac);
    FS_X_Log("\n");
  }
  if (ErrCode != FS_CHECKDISK_ERRCODE_CLUSTER_UNUSED) {
    FS_X_Log("  Do you want to repair this error? (y/n/a) ");
  } else {
    FS_X_Log("  * Convert lost cluster chain into file (y)\n");
    FS_X_Log("  * Delete cluster chain                 (d)\n");
    FS_X_Log("  * Do not repair                        (n)\n");
    FS_X_Log("  * Abort                                (a)\n");
  }
  ++_NumErrors;
  c = getchar();
  FS_X_Log("\n");
  if ((c == 'y') || (c == 'Y')) {
    return FS_CHECKDISK_ACTION_SAVE_CLUSTERS;
  } else if ((c == 'a') || (c == 'A')) {
    return FS_CHECKDISK_ACTION_ABORT;
  } else if ((c == 'd') || (c == 'D')) {
    return FS_CHECKDISK_ACTION_DELETE_CLUSTERS;
  }
  return FS_CHECKDISK_ACTION_DO_NOT_REPAIR;
}

/*********************************************************************
*
*       _CheckDir
*
*  Function description
*    Checks the consistency of a directory tree.
*
*  Notes
*    (1) This function calls itself recursively.
*/
static int _CheckDir(FS_CHECK_DATA * pCheckData, char * sDirPath,
                     unsigned SizeOfDirPath, int MaxRecursionLevel) {
  int            r;
  int            Result;
  FS_FIND_DATA   FindData;
  char           acDirName[32];
  unsigned       LenPath;
  unsigned       LenName;
  char         * p;
  char         * pEnd;
  unsigned       NumBytes;
```

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```
  r = FS_CheckDir(pCheckData, sDirPath);
  if (r == FS_CHECKDISK_RETVAL_OK) {
    //
    // Search for subdirectories and descend into them.
    //
    memset(&FindData, 0, sizeof(FindData));
    Result = FS_FindFirstFile(&FindData, sDirPath, acDirName, sizeof(acDirName));
    if (Result == 0) {
      while (1) {
        //
        // Descend into any directory other than "." and "..".
        //
        if (FindData.Attributes & FS_ATTR_DIRECTORY) {
          if (_IsSystemDir(FindData.sFileName) == 0) {
            if (MaxRecursionLevel == 0) {
              r = FS_CHECKDISK_RETVAL_MAX_RECURSE;        // Error, deepest directory
                                                          // level reached.
              break;
            }
            //
            // Create the path to the directory.
            //
            LenPath = strlen(sDirPath);
            if (LenPath >= (SizeOfDirPath - 1)) {
              r = FS_ERRCODE_BUFFER_TOO_SMALL;            // Error, cannot create path
                                                          // to directory.
              break;
            }
            NumBytes = SizeOfDirPath - LenPath;
            LenName  = strlen(FindData.sFileName);
            if ((LenName + 1 + 1) >= NumBytes) {
              r = FS_ERRCODE_BUFFER_TOO_SMALL;            // Error, cannot create path
                                                          // to directory.
              break;
            }
            pEnd  = sDirPath + LenPath;
            p     = pEnd;
            strcpy(p, FindData.sFileName);                // Add the directory name.
            p    += LenName;
            *p++  = FS_DIRECTORY_DELIMITER;               // Separate the path from
                                                          // directory name.
            *p    = '\0';
            r = _CheckDir(pCheckData, sDirPath, SizeOfDirPath, MaxRecursionLevel - 1);
            *pEnd = '\0';                                 // Restore the path to parent
                                                          // directory.
            if (r != FS_CHECKDISK_RETVAL_OK) {
              break;
            }
          }
        }
        Result = FS_FindNextFile(&FindData);
        if (Result == 0) {
          break;                                          // End of directory reached
                                                          // or error.
        }
      }
    }
  }
  if (r == FS_CHECKDISK_RETVAL_SKIP) {
    r = FS_CHECKDISK_RETVAL_OK;                           // Make sure that we return
                                                          // the same value as FS_CheckDisk()
  }
  return r;
}

/*********************************************************************
*
*       _CheckDisk
*
*  Function description
*    Checks the consistency of the file system.
*/
static int _CheckDisk(void) {
  int           r;
  char          acDirName[FS_MAX_PATH];
```

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```
  FS_CHECK_DATA CheckData;

  memset(&CheckData, 0, sizeof(CheckData));
  for (;;) {
    //
    // Initialize the operation.
    //
    r = FS_InitCheck(&CheckData, VOLUME_NAME, _aBuffer, sizeof(_aBuffer), _cbOnError);
    if (r != 0) {
      break;                                            // Error, could not initialize
                                                        // the operation.
    }
    for (;;) {
      memset(acDirName, 0, sizeof(acDirName));          // Begin the checking with the
                                                        // root directory.
      strncpy(acDirName, VOLUME_NAME, sizeof(acDirName) - 1);
      //
      // Check the directory structure.
      //
      r = _CheckDir(&CheckData, acDirName, sizeof(acDirName), MAX_RECURSION);
      if (r != FS_CHECKDISK_RETVAL_OK) {
        break;                                          // An error occurred.
      }
      //
      // Check the allocation table.
      //
      r = FS_CheckAT(&CheckData);
      if (r != FS_CHECKDISK_RETVAL_CONTINUE) {
        break;                                          // No more checks are required
                                                        // or an error was found and corrected.
      }
    }
    if (r != FS_CHECKDISK_RETVAL_RETRY) {
      break;                                            // Operation completed.
    }
  }
  return r;
}

/*************************************************************************
*
*       SampleCheckDiskBG
*/
void SampleCheckDiskBG(void) {
  FS_CHECK_DATA CheckData;
  FS_CHECK_DATA CheckDataOld;
  int           r;

  //
  // Initialize the check context.
  //
  memset(&CheckDataOld, 0, sizeof(CheckDataOld));
  memset(&CheckData, 0, sizeof(CheckData));
  for (;;) {
    //
    // Wait for a file system change.
    //
    for (;;) {
      r = FS_InitCheck(&CheckData, VOLUME_NAME, _aBuffer, sizeof(_aBuffer), _cbOnError);
      if (r == 0) {
        r = memcmp(&CheckData, &CheckDataOld, sizeof(FS_CHECK_DATA));
        if (r != 0) {
          break;
        }
      }
      //
      // TBD: Delay execution using a RTOS function.
      //
    }
    _NumErrors = 0;
    //
    // Check and correct file system errors.
    //
    r = _CheckDisk();
    if (r != 0) {
      FS_X_Log("Disk checking operation failed.\n");
```

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```
    } else {
      if (_NumErrors == 0) {
        FS_X_Log("File system structure is consistent.\n");
      }
    }
    memcpy(&CheckDataOld, &CheckData, sizeof(FS_CHECK_DATA));
  }
}
```

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4.10.10 FS_AT_INFO

Description

Information about the allocation table.

Type definition

```
typedef struct {
  U32  FirstClusterId;
  U32  LastClusterId;
  U32  WriteCnt;
} FS_AT_INFO;
```

Structure members

Member	Description
FirstClusterId	Id of the first cluster used as storage.
LastClusterId	Id of the last cluster used as storage.
WriteCnt	Number of times the allocation table was modified since mounting the file system.

Additional information

The information can be obtained using `FS_GetATInfo()`.

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4.10.11 FS_CLUSTER_INFO

Description

Information about a storage allocation unit.

Type definition

```
typedef struct {
  U32  SectorIndex;
  U32  NextClusterId;
  U8   IsFree;
  U8   IsEOC;
} FS_CLUSTER_INFO;
```

Structure members

Member	Description
SectorIndex	Index of the first sector in the cluster.
NextClusterId	Id of the linked cluster.
IsFree	Usage status.
IsEOC	End of chain status.

Additional information

NextClusterId is valid only if IsFree and IsEOC are set to 0.

IsFree is set to 1 if the cluster is not allocated to any file or directory.

IsEOC is set to 1 if the cluster is the last in the chain. If the cluster is linked to another cluster then IsEOC is set to 0. In this case NextClusterId stores the index of the linked cluster.

Information about a cluster can be obtained using FS_GetClusterInfo().

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4.10.12 FS_DISK_LAYOUT

Description

Layout of the data stored on the volume.

Type definition

```
typedef struct {
  U32           SectorIndexPart;
  U32           NumSectorsPart;
  U16           FSType;
  FS_FS_LAYOUT  FSLayout;
} FS_DISK_LAYOUT;
```

Structure members

Member	Description
SectorIndexPart	Index of the logical sector that stores the first data in the file system partition.
NumSectorsPart	Number of logical sectors in the file system partition.
FSType	Type of the file system stored on the volume.
FSLayout	Information about the layout of the file system data.

Additional information

SectorIndexPart is set to 0 if the storage device is not partitioned. The sector indexes in the FSLayout.fat and FSLayout.efs structures are relative to SectorIndexPart.

FSType indicates the type of file system stored on the volume. It can be set to one of the *Format types* on page 298 values. If FSType is set to either FS_TYPE_FAT12, FS_TYPE_FAT16 or FS_TYPE_FAT32 then the layout information is stored in FSLayout.fat. If FSType is set to FS_TYPE_EFS then the layout information is stored in FSLayout.efs.

The data layout of a volume can be obtained using FS_GetVolumeLayout().

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4.10.13 FS_EFS_LAYOUT

Description

Data layout of an EFS partition.

Type definition

```
typedef struct {
  U32  SectorIndexInfo;
  U32  SectorIndexStatus;
  U32  SectorIndexAT;
  U32  NumSectorsAT;
  U32  SectorIndexData;
  U32  NumSectorsData;
} FS_EFS_LAYOUT;
```

Structure members

Member	Description
SectorIndexInfo	Index of the logical sector that stores the format information.
SectorIndexStatus	Index of the logical sector that stores information about the status of file system.
SectorIndexAT	Index of the logical sector that stores the beginning of the allocation table.
NumSectorsAT	Number of logical sectors in the allocation table.
SectorIndexData	Index of the logical sector that stores the beginning of the area reserved for files and directories.
NumSectorsData	Number of logical sectors available for file and directories.

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4.10.14 FS_FAT_LAYOUT

Description

Data layout of a FAT partition.

Type definition

```
typedef struct {
  U32  SectorIndexBPB;
  U32  SectorIndexBPBBackup;
  U32  SectorIndexFSInfo;
  U32  SectorIndexFSInfoBackup;
  U32  NumSectorsReserved;
  U32  SectorIndexAT;
  U32  SectorIndexATBackup;
  U32  NumSectorsAT;
  U32  SectorIndexRootDir;
  U32  NumSectorsRootDir;
  U32  SectorIndexData;
  U32  NumSectorsData;
} FS_FAT_LAYOUT;
```

Structure members

Member	Description
SectorIndexBPB	Index of the logical sector that stores the format information.
SectorIndexBPBBackup	Index of the logical sector that stores a copy of the format information.
SectorIndexFSInfo	Index of the logical sector that stores information about the status of file system.
SectorIndexFSInfoBackup	Index of the logical sector that stores a copy of the data stored at SectorIndexFSInfo.
NumSectorsReserved	Number of reserved logical sectors.
SectorIndexAT	Index of the logical sector that stores the beginning of the allocation table.
SectorIndexATBackup	Index of the logical sector that stores the beginning of the copy of the allocation table.
NumSectorsAT	Number of logical sectors in the allocation table.
SectorIndexRootDir	Index of the logical sector that stores the beginning of the root directory.
NumSectorsRootDir	Number of logical sectors allocated for the root directory.
SectorIndexData	Index of the logical sector that stores the beginning of the area reserved for files and directories.
NumSectorsData	Number of logical sectors available for file and directories.

Additional information

SectorIndexBPB is typically set to 0.

SectorIndexBPBBackup is typically set to 6. This member is valid only for FAT32 formatted volumes.

SectorIndexFSInfo is typically set to 1. This member is valid only for FAT32 formatted volumes.

SectorIndexFSInfoBackup is typically set to 7. This member is valid only for FAT32 formatted volumes.

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`NumSectorsReserved` is never set to 0 because it includes at least the BPB sector and the FSInfo sector.

`SectorIndexATBackup` is set to 0 if the backup AT is not present.

`SectorIndexRootDir` is valid only for FAT12 and FAT16 formatted volumes. For FAT32 formatted volumes this member is set to 0 to indicate that the root directory is dynamically allocated at runtime.

`NumSectorsRootDir` is valid only for FAT12 and FAT16 formatted volumes. For FAT32 formatted volumes this member is set to 0 to indicate that the root directory is dynamically allocated at runtime.

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4.10.15 FS_EXFAT_LAYOUT

Description

Data layout of an exFAT partition.

Type definition

```
typedef struct {
  U32  SectorIndexBoot;
  U32  SectorIndexBootBackup;
  U32  SectorIndexBootEx;
  U32  SectorIndexBootExBackup;
  U32  NumSectorsBootEx;
  U32  SectorIndexOEMPara;
  U32  SectorIndexOEMParaBackup;
  U32  SectorIndexReserved;
  U32  SectorIndexReservedBackup;
  U32  SectorIndexCheckSum;
  U32  SectorIndexCheckSumBackup;
  U32  SectorIndexAT;
  U32  SectorIndexATBackup;
  U32  NumSectorsAT;
  U32  SectorIndexData;
  U32  NumSectorsData;
  U32  SectorIndexRootDir;
  U32  SectorIndexAB;
  U32  NumSectorsAB;
  U32  SectorIndexUT;
  U32  NumSectorsUT;
} FS_EXFAT_LAYOUT;
```

Structure members

Member	Description
SectorIndexBoot	Index of the logical sector that stores the format information.
SectorIndexBootBackup	Index of the logical sector that stores a copy of the format information.
SectorIndexBootEx	Index of the first logical sector that stores extended boot information.
SectorIndexBootExBackup	Index of the first logical sector that stores a copy of the extended boot information.
NumSectorsBootEx	Number of sectors that store extended boot information.
SectorIndexOEMPara	Index of the logical sector that stores OEM parameters.
SectorIndexOEMParaBackup	Index of the logical sector that stores a copy of the OEM parameters.
SectorIndexReserved	Index of the logical sector that stores reserved information.
SectorIndexReservedBackup	Index of the logical sector that stores a copy of the reserved information.
SectorIndexCheckSum	Index of the logical sector that stores checksum information.
SectorIndexCheckSumBackup	Index of the logical sector that stores a copy of the checksum information.
SectorIndexAT	Index of the logical sector that stores the beginning of the allocation table.
SectorIndexATBackup	Index of the logical sector that stores the beginning of the copy of the allocation table.
NumSectorsAT	Number of logical sectors in the allocation table.

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Member	Description
SectorIndexData	Index of the logical sector that stores the beginning of the area reserved for files and directories.
NumSectorsData	Number of logical sectors available for file and directories.
SectorIndexRootDir	Index of the first logical sector of the root directory.
SectorIndexAB	Index of the first logical sector of the Allocation Bitmap.
NumSectorsAB	Number of logical sectors in the Allocation Bitmap.
SectorIndexUT	Index of the first logical sector of the Up-case Table.
NumSectorsUT	Number of logical sectors in the Up-case Table.

Additional information

SectorIndexBoot is typically set to 0.

SectorIndexBootBackup is typically set to 12.

SectorIndexATBackup is set to 0 if the backup AT is not present.

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4.10.16 FS_FS_LAYOUT

Description

Data layout of the file system.

Type definition

```
typedef union {
  FS_FAT_LAYOUT    fat;
  FS_EFS_LAYOUT    efs;
  FS_EXFAT_LAYOUT  exFAT;
} FS_FS_LAYOUT;
```

Structure members

Member	Description
fat	Information about the layout of the FAT file system data.
efs	Information about the layout of the EFS file system data.
exFAT	Information about the layout of the exFAT file system data.

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4.11 File system extended functions

This section describes API functions that do not fall into any other category. It includes functions that operate on volumes, utility functions as well as functions for locking the file system against concurrent access from different tasks.

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4.11.1 FS_ConfigEOFErrorSuppression()

Description

Enables / disables the reporting of end-of-file condition as error.

Prototype

```
void FS_ConfigEOFErrorSuppression(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 EOF is reported as error. • 1 EOF is not reported as error.

Additional information

The end-of-file indicator of a file handle is set to 1 as soon as the application tries to read more bytes than available in the file. This function controls if an error is reported via FS_FError() when the end-of-file indicator is set for a file handle. The default is to report the end-of-file condition as error. The configuration has effect on all the opened file handles.

This function is available only when the file system is built with FS_SUPPRESS_EOF_ERROR set to 1.

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4.11.2 FS_ConfigPOSIXSupport()

Description

Enables / disables support for the POSIX-like behavior.

Prototype

```
void FS_ConfigPOSIXSupport(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 POSIX behavior is disabled. • 1 POSIX behavior is enabled.

Additional information

The end-of-file indicator of a file handle is set to 1 as soon as the application tries to read more bytes than available in the file. This function controls if an error is reported via FS_FError() when the end-of-file indicator is set for a file handle. The default is to report the end-of-file condition as error. The configuration has effect on all the opened file handles.

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4.11.3 FS_FileTimeToTimeStamp()

Description

Converts a broken-down date and time representation into a timestamp.

Prototype

```
void FS_FileTimeToTimeStamp(const FS_FILETIME * pFileTime,
                            U32         * pTimeStamp);
```

Parameters

Parameter	Description
pFileTime	in Broken-down date and time to be converted. It cannot be set to NULL.
pTimeStamp	out Converted timestamp. It cannot be set to NULL.

Additional information

This function can be used to convert a broken-down date and time representation into a timestamp that can be passed to FS_SetFileTime() or FS_SetFileTimeEx().

For a description of the timestamp format refer to FS_GetFileTime().

Example

```
#include "FS.h"

void SampleSetFileTime(void) {
  U32         TimeStamp;
  FS_FILETIME FileTime;

  FileTime.Year   = 2005;
  FileTime.Month  = 03;
  FileTime.Day    = 26;
  FileTime.Hour   = 10;
  FileTime.Minute = 56;
  FileTime.Second = 14;
  FS_FileTimeToTimeStamp (&FileTime, &TimeStamp);
  FS_SetFileTime("Test.txt", TimeStamp);
}
```

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4.11.4 FS_FileTimeToTimeStampEnhanced()

Description

Converts a broken-down date and time representation into a timestamp.

Prototype

```
int FS_FileTimeToTimeStampEnhanced(const FS_FILETIME  * pFileTime,
                                   FS_TIMESTAMP * pTimeStamp);
```

Parameters

Parameter	Description
pFileTime	in Broken-down date and time to be converted. It cannot be set to NULL.
pTimeStamp	out Converted timestamp. It cannot be set to NULL.

Return value

= 0 OK, file time converted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to convert a broken-down date and time representation into a timestamp that can be passed to FS_SetFileTimeEnhanced()

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4.11.5 FS_FreeSectors()

Description

Informs the device driver about unused sectors.

Prototype

```
int FS_FreeSectors(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which to perform the operation.

Return value

= 0 OK, sectors have been freed.
≠ 0 Error code indicating the failure reason.

Additional information

The function visits each entry of the allocation table and checks if the cluster is used to store data. If the cluster is free, informs the storage layer that the sectors assigned to the cluster do not store valid data. This information is used by the NAND and NOR device drivers to optimize the internal wear-leveling process.

`FS_FreeSectors()` is available only when the support for the free sector operation is enabled. The support for the free sector operation can be enabled or disabled via `FS_SUPPORT_FREE_SECTOR`.

Example

```
#include "FS.h"

void SampleFreeSectors(void) {
  FS_FreeSectors("nand:0:");
}
```

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4.11.6 FS_GetAutoMount()

Description

Returns information about how a volume is automatically mounted.

Prototype

```
int FS_GetAutoMount(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

= 0	Volume is not mounted automatically.
= FS_MOUNT_RO	Volume is mounted automatically in read only mode.
= FS_MOUNT_RW	Volume is mounted automatically in read/write mode.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

After the initialization of the file system all the volumes are configured to be automatically mounted as read/write at the first access to the file system. The type of mount operation can be configured via FS_SetAutoMount().

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4.11.7 FS_GetFileId()

Description

Calculates a value that uniquely identifies a file.

Prototype

```
int FS_GetFileId(const char * sFileName,
                 U8   * pId);
```

Parameters

Parameter	Description
sFileName	Name of the file for which to calculate the id.
pId	A 16-byte array where the id is stored.

Return value

= 0 Id returned OK.
≠ 0 Error code indicating the failure reason.

Additional information

The calculated value is a combination of the sector number that stores the directory entry assigned to file combined with the index of the directory index. Typically used by USB MTP component of SEGGER emUSB-Device to create an unique object id to the file.

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4.11.8 FS_GetFileWriteMode()

Description

Returns the write mode.

Prototype

```
FS_WRITEMODE FS_GetFileWriteMode(void);
```

Return value

WriteMode Specifies how to write to file:

- `FS_WRITEMODE_SAFE` Updates the allocation table and the directory entry at each write to file operation.
- `FS_WRITEMODE_MEDIUM` Updates the allocation table at each write to file operation.
- `FS_WRITEMODE_FAST` The allocation table and directory entry are updated when the file is closed.
- `FS_WRITEMODE_UNKNOWN` An error occurred.

Additional information

This function can be used to query the write mode configured for the entire file system. The write mode for the entire file system can be configured via `FS_SetFileWriteMode()`. The write mode is set by default to `FS_WRITEMODE_SAFE` when the file system is initialized.

Refer to `FS_SetFileWriteMode()` for detailed information about the different write modes.

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4.11.9 FS_GetFileWriteModeEx()

Description

Returns the write mode configured for a specified volume.

Prototype

```
FS_WRITEMODE FS_GetFileWriteModeEx(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Identifies the volume that have to be queried.

Return value

WriteMode Specifies how to write to file:

- FS_WRITEMODE_SAFE Updates the allocation table and the directory entry at each write to file operation.
- FS_WRITEMODE_MEDIUM Updates the allocation table at each write to file operation.
- FS_WRITEMODE_FAST The allocation table and directory entry are updated when the file is closed.
- FS_WRITEMODE_UNKNOWN An error occurred.

Additional information

This function can be used to query the write mode configured for the specified volume. The write mode of the volume can be configured via FS_SetFileWriteModeEx(). If the write mode is not explicitly configured by the application for the volume via FS_SetFileWriteModeEx() then the write mode configured for the entire file system is returned. The write mode for the entire file system can be configured via FS_SetFileWriteMode(). The write mode is set by default to FS_WRITEMODE_SAFE when the file system is initialized.

Refer to FS_SetFileWriteMode() for detailed information about the different write modes.

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4.11.10 FS_GetFSType()

Description

Returns the type of file system assigned to volume.

Prototype

```
int FS_GetFSType(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried. It cannot be NULL.

Return value

≥ 0 File system type.
< 0 Error code indicating the failure reason.

Additional information

This function is optional and available only when the file system is built with support for multiple file system types. The support for multiple file system types is activated when more than two of the following configuration defines are set to 1:

- FS_SUPPORT_FAT
- FS_SUPPORT_EFS
- FS_SUPPORT_EXFAT

The return value can be one of the value specified by *File system types* on page 296

Example

```
#include "FS.h"

void SampleGetFSType(void) {
  int FSType;

#if FS_SUPPORT_MULTIPLE_FS
  FSType = FS_GetFSType("");
#else
  FSType = FS_FAT;
#endif
  FS_X_Log("File system type: ");
  switch (FSType) {
  case FS_FAT:
    FS_X_Log("FAT");
    break;
  case FS_EFS:
    FS_X_Log("EFS");
    break;
  default:
    FS_X_Log("<unknown>");
    break;
  }
  FS_X_Log("\n");
}
```

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4.11.11 FS_GetMaxSectorSize()

Description

Queries the maximum configured logical sector size.

Prototype

```
U32 FS_GetMaxSectorSize(void);
```

Return value

Maximum logical sector size in bytes.

Additional information

Default value of the maximum logical sector size is 512 bytes. Refer to `FS_SetMaxSectorSize()` for more information about the maximum logical sector size.

Example

```
#include "FS.h"

void SampleGetMaxSectorSize(void) {
  U32 MaxSectorSize;

  MaxSectorSize = FS_GetMaxSectorSize();
}
```

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4.11.12 FS_GetMemInfo()

Description

Returns information about the memory management.

Prototype

```
int FS_GetMemInfo(FS_MEM_INFO * pMemInfo);
```

Parameters

Parameter	Description
pMemInfo	out Returned information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

The application can use this function to obtain information about the memory management such as number of bytes allocated by the file system, type of memory management used, etc.

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4.11.13 FS_GetMountType()

Description

Returns information about how a volume is mounted.

Prototype

```
int FS_GetMountType(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only.
= FS_MOUNT_RW	Volume is mounted read/write.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

sVolumeName is the name of a volume that already exists. If the volume name is not known to file system then an error is returned. Alternatively, the application can call FS_IsVolumeMounted() if the information about how the volume is actually mounted is not important. After the file system initialization all volumes are in unmounted state.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetMountType(void) {
  int          r;
  const char * sMountType;
  char         ac[100];

  r = FS_GetMountType("");
  switch (r) {
  case 0:
    sMountType = "not mounted";
    break;
  case FS_MOUNT_RO:
    sMountType = "read only";
    break;
  case FS_MOUNT_RW:
    sMountType = "read/write";
    break;
  default:
    sMountType = FS_ErrorNo2Text(r);
    break;
  }
  SEGGER_snprintf(ac, sizeof(ac), "Mount type: %s\n", sMountType);
  FS_X_Log(ac);
}
```

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4.11.14 FS_GetNumFilesOpen()

Description

Queries the number of opened file handles.

Prototype

```
int FS_GetNumFilesOpen(void);
```

Return value

Total number of file handles that are open.

Additional information

This function counts the number of file handles that were opened by the application via `FS_FOpen()` or `FS_FOpenEx()` and that were not closed yet via `FS_FClose()`.

The returned value is not the actual number of files opened because the same file can be opened by an application more than one time. For example, `FS_GetNumFilesOpen()` returns 2 if the same file is opened by the application twice.

Example

```
#include "FS.h"

void SampleGetNumFilesOpen(void) {
  FS_FILE * pFile1;
  FS_FILE * pFile2;
  int       NumFileHandles;

  FS_Init();
  //
  // The number of opened files is 0 at this stage.
  //
  NumFileHandles = FS_GetNumFilesOpen();
  //
  // Open the first file.
  //
  pFile1 = FS_FOpen("File1.txt", "w");
  //
  // The number of opened files is 1 at this stage.
  //
  NumFileHandles = FS_GetNumFilesOpen();
  //
  // Open the second file.
  //
  pFile2 = FS_FOpen("File2.txt", "w");
  //
  // The number of opened files is 2 at this stage.
  //
  NumFileHandles = FS_GetNumFilesOpen();
  //
  // Close first file.
  //
  FS_FClose(pFile1);
  //
  // The number of opened files is 1 at this stage.
  //
  NumFileHandles = FS_GetNumFilesOpen();
  //
  // Close second file.
  //
  FS_FClose(pFile2);
  //
  // The number of opened files is 0 at this stage.
  //
  NumFileHandles = FS_GetNumFilesOpen();
}
```

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4.11.15 FS_GetNumFilesOpenEx()

Description

Queries the number of opened file handles on a volume.

Prototype

```
int FS_GetNumFilesOpenEx(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume (0-terminated string). NULL is permitted.

Return value

≥ 0 Total number of file handles that are open on the volume.
< 0 Error code indicating the failure reason.

Additional information

This function counts the number of file handles that were opened by the application via FS_FOpen() or FS_FOpenEx() and that were not closed yet via FS_FClose() on a specified volume.

The returned value is not the actual number of files opened because the same file can be opened by an application more than one time. For example, FS_GetNumFilesOpenEx() returns 2 if the same file is opened by the application twice.

FS_GetNumFilesOpenEx() works in the same way as FS_GetNumFilesOpen() if sVolumeName is set to NULL.

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4.11.16 FS_GetNumVolumes()

Description

Queries the number of configured volumes.

Prototype

```
int FS_GetNumVolumes(void);
```

Return value

Number of volumes.

Additional information

This function can be used to check how many volumes are configured in the file system. Each call to `FS_AddDevice()` creates a separate volume. Calling `FS_AddPhysDevice()` does not create a volume. The maximum number of volumes is limited only by available memory.

`FS_GetNumVolumes()` can be used together with `FS_GetVolumeName()` to list the names of all configured volumes.

Example

```
#include "FS.h"

void SampleGetVolumeName(void) {
  int  NumVolumes;
  int  iVolume;
  int  BufferSize;
  int  NumBytesStored;
  char acVolumeName[32];

  BufferSize = sizeof(acVolumeName);
  NumVolumes = FS_GetNumVolumes();
  FS_X_Log("Available volumes:\n");
  for (iVolume = 0; iVolume < NumVolumes; iVolume++) {
    NumBytesStored = FS_GetVolumeName(iVolume, acVolumeName, BufferSize);
    if (NumBytesStored < BufferSize) {
      FS_X_Log("  ");
      FS_X_Log(acVolumeName);
      FS_X_Log("\n");
    }
  }
}
```

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4.11.17 FS_GetVolumeAlias()

Description

Returns the alternative name of a volume.

Prototype

```
const char *FS_GetVolumeAlias(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	in Name of the volume to be queried. It cannot be set to NULL.

Return value

= NULL No volume alias configure or an error occurred.
≠ NULL Configured volume alias.

Additional information

This function is optional. It can be used by an application to obtain the alternative name of a volume if configured. For more information about the volume alias refer to FS_SetVolumeAlias().

This function is available only when FS_SUPPORT_VOLUME_ALIAS is set to 1.

The alias of a volume can also be queried either via FS_GetVolumeInfo() or FS_GetVolumeInfoEx(). The sAlias member of the FS_DISK_INFO structure stores the configured alias.

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4.11.18 FS_GetVolumeFreeSpace()

Description

Returns the free space available on a volume.

Prototype

```
U32 FS_GetVolumeFreeSpace(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked.

Return value

≠ 0 Number of bytes available on the volume.
= 0 An error occurred.

Additional information

This function returns the free space available to application to store files and directories.

A free space larger than four Gbytes is reported as `0xFFFFFFFF` because this is the maximum value that can be represented in an unsigned 32-bit integer. The function `FS_GetVolumeFreeSpaceKB()` can be used instead if the available free space is larger than four Gbytes.

`FS_GetVolumeFreeSpace()` can sill be reliably used if the application does not need to know if there is more than four GBytes of free space available.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVolumeFreeSpace(void) {
  U32  NumBytes;
  char ac[100];

  NumBytes = FS_GetVolumeFreeSpace("");
  if (NumBytes < 0x8000) {
    SEGGER_snprintf(ac, sizeof(ac), "Free space: %lu Kbytes\n", NumBytes);
  } else {
    NumBytes >>= 10;
    SEGGER_snprintf(ac, sizeof(ac), "Free space: %lu Mbytes\n", NumBytes);
  }
  FS_X_Log(ac);
}
```

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4.11.19 FS_GetVolumeFreeSpaceFirst()

Description

Initiates the search for free space.

Prototype

```
int FS_GetVolumeFreeSpaceFirst(      FS_FREE_SPACE_DATA * pFSD,
                               const char               * sVolumeName,
                                     void               * pBuffer,
                                     int                  SizeOfBuffer);
```

Parameters

Parameter	Description
pFSD	Context of the free space search.
sVolumeName	Name of the volume to search on.
pBuffer	Work buffer.
SizeOfBuffer	Size of the work buffer in bytes.

Return value

= 1 OK, the entire allocation table has been searched.
= 0 OK, search is not completed.
< 0 Error code indicating the failure reason.

Additional information

FS_GetVolumeFreeSpaceFirst() together with FS_GetVolumeFreeSpaceNext() can be used to calculate the amount of available free space on a volume. This pair of functions implement the same functionality as FS_GetVolumeFreeSpace() with the difference that they block the access to the file system for a very short time.

Typically, FS_GetVolumeFreeSpace() uses the information stored to the FSInfo sector of a FAT file system or to the Status sector of an EFS file system to get the number of free clusters on the volume. If this information is not available then FS_GetVolumeFreeSpace() calculates the free space by reading and evaluating the entire allocation table. The size of the allocation table depends on the size of the volume with sizes of a few tens of Mbytes for a volume pf 4 Gbytes or larger. Reading such amount of data can take a relatively long time to complete during which the application is not able to access the file system. FS_GetVolumeFreeSpaceFirst() and FS_GetVolumeFreeSpaceNext() can be used in such cases by calculating the available free space while the application is performing other file system accesses.

FS_GetVolumeFreeSpaceFirst() is used by the application to initiate the search process followed by one or more calls to FS_GetVolumeFreeSpaceNext(). The free space is returned in the NumClustersFree member of pFSD. The cluster size can be determined by calling FS_GetVolumeInfoEx() with the Flags parameter set to 0.

The specified work buffer is used by the file system for the read operations only when FS_SUPPORT_SECTOR_BUFFER_BURST is set to 1. The file system is able to use the work buffer for burst operations only if pBuffer is aligned according to the value configured via FS_DRIVER_ALIGNMENT.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVolumeFreeSpace(void) {
  char               ac[100];
  FS_FREE_SPACE_DATA fsd;
```

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```
  int                r;
  FS_DISK_INFO       VolumeInfo;
  U32                BytesPerCluster;
  U32                NumKBytesFree;

  r = FS_GetVolumeFreeSpaceFirst(&fsd, "", NULL, 0);
  if (r < 0) {
    SEGGER_snprintf(ac, sizeof(ac), "Could not initiate searching (%s)\n",
      FS_ErrorNo2Text(r));
    FS_X_Log(ac);
  } else {
    if (r == 0) {
      for (;;) {
        r = FS_GetVolumeFreeSpaceNext(&fsd);
        if (r < 0) {
          SEGGER_snprintf(ac, sizeof(ac), "Could not continue searching (%s)\n",
            FS_ErrorNo2Text(r));
          FS_X_Log(ac);
          break;
        }
        if (r == 1) {
          // End of allocation table reached.
          break;
        }
      }
    }
  }
  FS_GetVolumeInfoEx("", &VolumeInfo, 0);
  BytesPerCluster = (VolumeInfo.BytesPerSector * VolumeInfo.SectorsPerCluster);
  NumKBytesFree   = fsd.NumClustersFree * (BytesPerCluster >> 10);
  SEGGER_snprintf(ac, sizeof(ac), "Free space: %lu Kbytes\n", NumKBytesFree);
  FS_X_Log(ac);
}
```

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4.11.20 FS_GetVolumeFreeSpaceKB()

Description

Returns the free space available on a volume.

Prototype

```
U32 FS_GetVolumeFreeSpaceKB(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked.

Return value

≠ 0 The space available on the volume in Kbytes.
= 0 An error occurred.

Additional information

This function returns the free space available to application to store files and directories.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVolumeFreeSpaceKB(void) {
  U32  NumKBytes;
  char ac[100];

  NumKBytes = FS_GetVolumeFreeSpaceKB("");
  SEGGER_snprintf(ac, sizeof(ac), "Free space: %lu Kbytes\n", NumKBytes);
  FS_X_Log(ac);
}
```

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4.11.21 FS_GetVolumeFreeSpaceNext()

Description

Continues the search for free space.

Prototype

```
int FS_GetVolumeFreeSpaceNext(FS_FREE_SPACE_DATA * pFSD);
```

Parameters

Parameter	Description
pFSD	Context of the free space search.

Return value

= 1 OK, the entire allocation table has been searched.
= 0 OK, search is not completed.
< 0 Error code indicating the failure reason.

Additional information

pFSD has to be initialized via a call to `FS_GetVolumeFreeSpaceFirst()`. One or more calls to `FS_GetVolumeFreeSpaceNext()` are required in order to determine the available free space. For more information refer to `FS_GetVolumeFreeSpaceFirst()`.

Example

Refer to `FS_GetVolumeFreeSpaceFirst()` for an example usage.

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4.11.22 FS_GetVolumeInfo()

Description

Obtains information about a volume.

Prototype

```
int FS_GetVolumeInfo(const char         * sVolumeName,
                     FS_DISK_INFO * pInfo);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to query. It cannot be NULL.
pInfo	out Volume information. It cannot be NULL.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function returns the information about a volume such as volume size, available free space, format type, etc.

Example

```
#include <stdio.h>
#include <string.h>
#include "FS.h"

void SampleGetVolumeInfo(void) {
  FS_DISK_INFO   VolumeInfo;
  int            r;
  char           ac[100];
  const char   * sFSType;

  memset(&VolumeInfo, 0, sizeof(VolumeInfo));
  r = FS_GetVolumeInfo("", &VolumeInfo);
  if (r == 0) {
    SEGGER_snprintf(ac, sizeof(ac), "Total number of clusters:         %lu\n",
      VolumeInfo.NumTotalClusters);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Number of free clusters:          %lu\n",
      VolumeInfo.NumFreeClusters);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Sectors per cluster:              %d\n",
      VolumeInfo.SectorsPerCluster);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Bytes per sector:                 %d\n",
      VolumeInfo.BytesPerSector);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Number of root directory entries: %d\n",
      VolumeInfo.NumRootDirEntries);
    FS_X_Log(ac);
    switch (VolumeInfo.FSType) {
    case FS_TYPE_FAT12:
      sFSType = "FAT12";
      break;
    case FS_TYPE_FAT16:
      sFSType = "FAT16";
      break;
    case FS_TYPE_FAT32:
      sFSType = "FAT32";
      break;
    case FS_TYPE_EFS:
      sFSType = "EFS";
```

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```
      break;
    default:
      sFSType = "<Unknown>";
      break;
    }
    SEGGER_snprintf(ac, sizeof(ac), "File system type:                %s\n",
      sFSType);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Formatted acc. to SD spec.:      %s\n",
      VolumeInfo.IsSDFormatted ? "Yes" : "No");
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Has been modified:               %s\n",
      VolumeInfo.IsDirty ? "Yes" : "No");
    FS_X_Log(ac);
  }
}
```

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4.11.23 FS_GetVolumeInfoEx()

Description

Obtains information about a volume.

Prototype

```
int FS_GetVolumeInfoEx(const char         * sVolumeName,
                       FS_DISK_INFO * pInfo,
                       int            Flags);
```

Parameters

Parameter	Description
sVolumeName	The volume name.
pInfo	out Volume information.
Flags	Specifies what type of information the function has to return.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_GetVolumeInfo() with the difference it gives the application more control about what type of information it has to return. The type of information that has to be returned can be controlled via the Flags parameter.

Flags is a bitwise-or combination of *Volume information flags* on page 311.

Example

```
#include <stdio.h>
#include <string.h>
#include "FS.h"

void SampleGetVolumeInfoEx(void) {
  FS_DISK_INFO   VolumeInfo;
  int            r;
  char           ac[100];
  const char   * sFSType;

  memset(&VolumeInfo, 0, sizeof(VolumeInfo));
  //
  // Return also the available free space.
  //
  r = FS_GetVolumeInfoEx("", &VolumeInfo, FS_DISKINFO_FLAG_FREE_SPACE);
  if (r == 0) {
    SEGGER_snprintf(ac, sizeof(ac), "Number of total clusters:         %lu\n",
      VolumeInfo.NumTotalClusters);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Number of free clusters:          %lu\n",
      VolumeInfo.NumFreeClusters);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Sectors per cluster:              %d\n",
      VolumeInfo.SectorsPerCluster);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Bytes per sector:                 %d\n",
      VolumeInfo.BytesPerSector);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Number of root directory entries: %d\n",
      VolumeInfo.NumRootDirEntries);
    FS_X_Log(ac);
    switch (VolumeInfo.FSType) {
    case FS_TYPE_FAT12:
      sFSType = "FAT12";
```

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```
      break;
    case FS_TYPE_FAT16:
      sFSType = "FAT16";
      break;
    case FS_TYPE_FAT32:
      sFSType = "FAT32";
      break;
    case FS_TYPE_EFS:
      sFSType = "EFS";
      break;
    default:
      sFSType = "<Unknown>";
      break;
    }
    SEGGER_snprintf(ac, sizeof(ac), "File system type:                %s\n",
      sFSType);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Formatted acc. to SD spec.:      %s\n",
      VolumeInfo.IsSDFormatted ? "Yes" : "No");
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Has been modified:               %s\n",
      VolumeInfo.IsDirty ? "Yes" : "No");
    FS_X_Log(ac);
  }
}
```

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4.11.24 FS_GetVolumeLabel()

Description

Returns the label of the volume.

Prototype

```
int FS_GetVolumeLabel(const char     * sVolumeName,
                      char     * sVolumeLabel,
                      unsigned   SizeOfVolumeLabel);
```

Parameters

Parameter	Description
sVolumeName	Identifies the volume to be queried. It cannot be NULL.
sVolumeLabel	Buffer that receives the volume label. It cannot be NULL.
SizeOfVolumeLabel	Number of characters in pVolumeName buffer.

Return value

= 0 OK, volume label read.
≠ 0 Error code indicating the failure reason.

Additional information

The function stores at most SizeOfVolumeLabel - 1 bytes to pVolumeLabel buffer. The returned volume label is 0-terminated. The volume label is truncated if it contains more characters than the number of characters that can be stored to pVolumeLabel.

EFS does not have a volume label. FS_GetVolumeLabel() returns with an error if the application tries to read the volume label of a volume formatted as EFS.

Example

```
#include "FS.h"

void SampleGetVolumeName(void) {
  char acVolumeLabel[16];
  int  r;

  r = FS_GetVolumeLabel("", acVolumeLabel, sizeof(acVolumeLabel));
  if (r == 0) {
    FS_X_Log("Volume label: ");
    FS_X_Log(acVolumeLabel);
    FS_X_Log("\n");
  }
}
```

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4.11.25 FS_GetVolumeName()

Description

Obtains the name of a volume.

Prototype

```
int FS_GetVolumeName(int    VolumeIndex,
                     char * pVolumeName,
                     int    SizeOfVolumeName);
```

Parameters

Parameter	Description
VolumeIndex	0-based index of the volume to be queried.
pVolumeName	out Receives the name of the volume as 0-terminated string. It cannot be NULL.
SizeOfVolumeName	Number of bytes in pVolumeName.

Return value

> 0	Number of bytes in the volume name or number of bytes required to store the volume name.
< 0	Error code indicating the failure reason.

Additional information

If pVolumeName is sufficiently large to store the entire volume name and the 0-terminator then the function returns the number of bytes in the volume name without the 0-terminator. If pVolumeName is not sufficiently large to store the entire volume name and the 0-terminator then the function returns the minimum buffer size required to store the entire volume name and the 0-terminator. In this case the function does not store any data to pVolumeName.

FS_GetVolumeName() stores at most SizeOfVolumeName - 1 bytes to pVolumeName and it terminates the string by a 0.

VolumeIndex specifies the position of the volume in the internal volume list of the file system. The first volume added to file system in FS_X_AddDevices() via FS_AddDevice() is stored at index 0 in the volume list, the second volume added via FS_AddDevice() is store at the index 1 in the volume list and so on. The total number of volumes can be queried via FS_GetNumVolumes().

Example

```
#include "FS.h"

void SampleGetVolumeName(void) {
  int  NumVolumes;
  int  iVolume;
  int  BufferSize;
  int  NumBytesStored;
  char acVolumeName[32];

  BufferSize = sizeof(acVolumeName);
  NumVolumes = FS_GetNumVolumes();
  FS_X_Log("Available volumes:\n");
  for (iVolume = 0; iVolume < NumVolumes; iVolume++) {
    NumBytesStored = FS_GetVolumeName(iVolume, acVolumeName, BufferSize);
    if (NumBytesStored < BufferSize) {
      FS_X_Log("  ");
      FS_X_Log(acVolumeName);
      FS_X_Log("\n");
    }
  }
```

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```
}
```

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4.11.26 FS_GetVolumeSize()

Description

Returns the size of a volume.

Prototype

```
U32 FS_GetVolumeSize(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

≠ 0 Total number of bytes available to file system.
= 0 An error occurred.

Additional information

This function returns the total number of bytes available to file system as data storage. The actual number of bytes available to application for files and directories is smaller than the value returned by `FS_GetVolumeSize()` since the file system requires some space for the boot sector and the allocation table.

A size larger than four Gbytes is reported as `0xFFFFFFFF` because this is the maximum value that can be represented in an unsigned 32-bit integer. The function `FS_GetVolumeSizeKB()` can be used instead if the volume size is larger than four Gbytes.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVolumeSize(void) {
  U32  NumBytes;
  char ac[100];

  NumBytes = FS_GetVolumeSize("");
  if (NumBytes < 0x8000) {
    SEGGER_snprintf(ac, sizeof(ac), "Volume size: %lu Kbytes\n", NumBytes);
  } else {
    NumBytes >>= 10;
    SEGGER_snprintf(ac, sizeof(ac), "Volume size: %lu Mbytes\n", NumBytes);
  }
  FS_X_Log(ac);
}
```

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4.11.27 FS_GetVolumeSizeKB()

Description

Returns the size of a volume.

Prototype

```
U32 FS_GetVolumeSizeKB(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

≠ 0 Storage available to file system in Kbytes.
= 0 An error occurred.

Additional information

This function returns the total number of bytes available to file system as data storage. The actual number of bytes available to application for files and directories is smaller than the value returned by `FS_GetVolumeSize()` since the file system requires some space for the boot sector and the allocation table.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVolumeSizeKB(void) {
  U32  NumKBytes;
  char ac[100];

  NumKBytes = FS_GetVolumeSizeKB("");
  SEGGER_snprintf(ac, sizeof(ac), "Volume size: %lu Kbytes\n", NumKBytes);
  FS_X_Log(ac);
}
```

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4.11.28 FS_GetVolumeStatus()

Description

Returns the presence status of a volume.

Prototype

```
int FS_GetVolumeStatus(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume. It cannot be NULL.

Return value

FS_MEDIA_NOT_PRESENT	Storage device is not present.
FS_MEDIA_IS_PRESENT	Storage device is present.
FS_MEDIA_STATE_UNKNOWN	Presence status is unknown.

Additional information

This function can be used to check if a removable storage device that is assigned to a volume is present or not. FS_GetVolumeStatus() is typically called periodically from a separate task to handle the insertion and removal of a removable storage device.

Example

```
#include "FS.h"
#include "FS_OS.h"

void SampleUnmountForced(void) {
  int IsPresentNew;
  int IsPresent;

  IsPresent = FS_GetVolumeStatus("");
  while (1) {
    IsPresentNew = FS_GetVolumeStatus("");
    //
    // Check if the presence status of the storage device has been changed.
    //
    if (IsPresentNew != IsPresent) {
      if (IsPresentNew == FS_MEDIA_IS_PRESENT) {
        FS_Mount("");
      } else  {
        FS_UnmountForced("");
      }
      IsPresent = IsPresentNew;
    }
    FS_X_OS_Delay(500);
  }
}
```

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4.11.29 FS_IsVolumeMounted()

Description

Checks if a volume is mounted.

Prototype

```
int FS_IsVolumeMounted(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

1 Volume is mounted.
0 Volume is not mounted or does not exist.

Additional information

The function returns 1 if the volume is mounted either in read-only mode or in read / write mode.

Example

```
#include "FS.h"

void SampleIsVolumeMounted(void) {
  int IsMounted;

  IsMounted = FS_IsVolumeMounted("");
  if (IsMounted) {
    FS_X_Log("Volume is mounted.\n");
  } else {
    FS_X_Log("Volume is not mounted.\n");
  }
}
```

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4.11.30 FS_Lock()

Description

Claims exclusive access to file system.

Prototype

```
void FS_Lock(void);
```

Additional information

The execution of the task that calls this function is suspended until the file system grants it exclusive access. After the task gets exclusive access to file system the other tasks that try to perform file system operations are blocked until the task calls `FS_Unlock()`.

`FS_Lock()` is typically used by applications that call device driver functions from different tasks. These functions are usually not protected against concurrent accesses. Additionally, `FS_Lock()` can be used to protect a group of file system operations against concurrent access.

`FS_Lock()` is available if `FS_OS_LOCKING` set to 1. The function does nothing if `FS_OS_LOCKING` set to 0 or 2. The calls to `FS_Lock()` / `FS_Unlock()` cannot be nested.

The API functions of the file system are multitasking safe. It is not required to explicitly lock these function calls via `FS_Lock()` / `FS_Unlock()`. All API functions call internal versions of `FS_Lock()` and `FS_Unlock()` on function entry and exit respectively.

Example

```
#include "FS.h"

void SampleLock(void) {
  FS_FILE           * pFile;
  FS_NAND_DISK_INFO   DiskInfo;

  //
  // The device driver functions are not protected against concurrent
  // access from different tasks. Make sure that only one task can access
  // the file system.
  //
#if (FS_OS_LOCKING == 1)
  FS_Lock();
#endif // FS_OS_LOCKING == 1
  FS_NAND_UNI_GetDiskInfo(0, &DiskInfo);
#if (FS_OS_LOCKING == 1)
  FS_Unlock();
#endif // FS_OS_LOCKING == 1
  //
  // Make sure that the write operation is not interrupted
  // by a different task.
  //
#if (FS_OS_LOCKING == 1)
  FS_Lock();
#endif // FS_OS_LOCKING == 1
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test", 4);
    FS_FClose(pFile);
  }
#if (FS_OS_LOCKING == 1)
  FS_Unlock();
#endif // FS_OS_LOCKING == 1
}
```

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4.11.31 FS_LockVolume()

Description

Claims exclusive access to a volume.

Prototype

```
void FS_LockVolume(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume that has to be locked.

Additional information

The execution of the task that calls this function is suspended until the file system grants it exclusive access to the specified volume. After the task gets exclusive access to volume the other tasks that try to perform file system operations on that volume are blocked until the task calls FS_UnlockVolume() with the same volume name as in the call to FS_LockVolume().

FS_LockVolume() is typically used by applications that call device driver functions from different tasks. These functions are usually not protected against concurrent accesses. Additionally, FS_LockVolume() can be used to protect a group of file system operations against concurrent access.

FS_LockVolume() is available if FS_OS_LOCKING set to 2. The function does nothing if FS_OS_LOCKING set to 0 or 1. The calls to FS_LockVolume() / FS_UnlockVolume() cannot be nested.

The API functions of the file system are multitasking safe. It is not required to explicitly lock these function calls via FS_LockVolume() / FS_UnlockVolume(). All API functions call internal versions of FS_LockVolume() and FS_UnlockVolume() on function entry and exit respectively.

Example

```
#include "FS.h"

void SampleLockVolume(void) {
  FS_FILE           * pFile;
  FS_NAND_DISK_INFO   DiskInfo;

  //
  // The device driver functions are not protected against concurrent
  // access from different tasks. Make sure that only one task can access
  // the file system.
  //
#if (FS_OS_LOCKING == 2)
  FS_LockVolume("nand:0:");
#endif // FS_OS_LOCKING == 2
  FS_NAND_UNI_GetDiskInfo(0, &DiskInfo);
#if (FS_OS_LOCKING == 2)
  FS_UnlockVolume("nand:0:");
#endif // FS_OS_LOCKING == 2
  //
  // Make sure that the write operation is not interrupted
  // by a different task.
  //
#if (FS_OS_LOCKING == 2)
  FS_LockVolume("nand:0:");
#endif // FS_OS_LOCKING == 2
  pFile = FS_FOpen("nand:0:\\Test.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test", 4);
    FS_FClose(pFile);
  }
#if (FS_OS_LOCKING == 2)
  FS_UnlockVolume("nand:0:");
```

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```
#endif // FS_OS_LOCKING == 2
}
```

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4.11.32 FS_SetBusyLEDCallback()

Description

Registers a callback for busy status changes of a volume.

Prototype

```
int FS_SetBusyLEDCallback(const char                * sVolumeName,
                          FS_BUSY_LED_CALLBACK * pfBusyLED);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the callback has to be registered. It cannot be NULL.
pfBusyLED	Function to be called when the busy status changes. It cannot be NULL.

Return value

= 0 OK, callback registered.
≠ 0 Error code indicating the failure reason.

Additional information

The application can use this FS_SetBusyLEDCallback() to register a function that is called by the file system each time the busy status of a volume changes. The volume becomes busy when it starts an access to storage device. When the access to storage device ends the volume becomes ready. The busy status of a volume can change several times during a single file system operation.

FS_SetBusyLEDCallback() is available if the FS_SUPPORT_BUSY_LED configuration define is set to 1. The function does nothing if FS_SUPPORT_BUSY_LED is set to 0.

Example

```
#include "FS.h"

static void _cbBusyLED(U8 OnOff) {
  if (OnOff) {
    //
    // Set LED on.
    //
  } else {
    //
    // Set LED off.
    //
  }
}

void SampleSetBusyLEDCallback(void) {
  FS_FILE * pFile;

  FS_SetBusyLEDCallback("nand:0:", _cbBusyLED);
  pFile = FS_FOpen("nand:0:\\File.txt", "w");
  FS_FClose(pFile);
}
```

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4.11.33 FS_SetCharSetType()

Description

Configures the character set that is used for the file and directory names.

Prototype

```
void FS_SetCharSetType(const FS_CHARSET_TYPE * pCharSetType);
```

Parameters

Parameter	Description
pCharSetType	Type of character set used.

Additional information

Permitted values of pCharSetType are:

Identifier
FS_CHARSET_CP437
FS_CHARSET_CP932
FS_CHARSET_CP936
FS_CHARSET_CP949
FS_CHARSET_CP950

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4.11.34 FS_SetFSType()

Description

Sets the type of file system a volume.

Prototype

```
int FS_SetFSType(const char * sVolumeName,
                 int    FSType);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the type of the file system has to be set. It cannot be NULL.
FSType	Type of file system.

Return value

= 0 OK, file system type set.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional and available only when the file system is built with support for multiple file system types. The support for multiple file system types is activated when more than two of the following configuration defines are set to 1:

- FS_SUPPORT_FAT
- FS_SUPPORT_EFS
- FS_SUPPORT_EXFAT

FSType can be one of the value specified by *File system types* on page 296

In a multi-volume configuration the application has to call FS_SetFSType() before formatting a volume that was never formatted or when the volume was formatted using a different file system type.

Example

```
#include "FS.h"

void SampleSetFSType(void) {
  //
  // Format the "nand:0:" volume as EFS.
  //
#if FS_SUPPORT_MULTIPLE_FS
  FS_SetFSType("nand:0:", FS_EFS);
#endif // FS_SUPPORT_MULTIPLE_FS
  FS_Format("nand:0:", NULL);
  //
  // Format the "nor:0:" volume as FAT.
  //
#if FS_SUPPORT_MULTIPLE_FS
  FS_SetFSType("nor:0:", FS_FAT);
#endif // FS_SUPPORT_MULTIPLE_FS
  FS_Format("nor:0:", NULL);
}
```

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4.11.35 FS_SetMemCheckCallback()

Description

Registers a callback for checking of 0-copy operations.

Prototype

```
int FS_SetMemCheckCallback(const char                 * sVolumeName,
                           FS_MEM_CHECK_CALLBACK * pfMemCheck);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the callback has to be registered. It cannot be NULL.
pfMemCheck	Function to be called before a 0-copy operation is executed. It cannot be NULL.

Return value

= 0 OK, callback registered.
≠ 0 Error code indicating the failure reason.

Additional information

FS_SetMemCheckCallback() can be used by an application to register a function that is called by the file system before any read or write operation to check if a data buffer can be used in 0-copy operation. In a 0-copy operation, a pointer to the data is passed directly to the device driver instead of the data being copied first in an internal buffer and then being passed it to device driver.

Example

```
#include "FS.h"

#if FS_SUPPORT_CHECK_MEMORY

static int _cbMemCheck(void * p, U32 NumBytes) {
  if ((U32)p > 0x100000uL) {
    return 1;   // 0-copy allowed.
  } else {
    return 0;   // 0-copy not allowed
  }
}

#endif // FS_SUPPORT_CHECK_MEMORY

void SampleSetMemCheckCallback(void) {
  FS_FILE * pFile;

#if FS_SUPPORT_CHECK_MEMORY
  FS_SetMemCheckCallback("", _cbMemCheck);
#endif // FS_SUPPORT_CHECK_MEMORY
  pFile = FS_FOpen("File.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test\n", 5);
  }
  FS_FClose(pFile);
}
```

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4.11.36 FS_SetTimeDateCallback()

Description

Configures a function that the file system can use to get the current time and date.

Prototype

```
void FS_SetTimeDateCallback(FS_TIME_DATE_CALLBACK * pfTimeDate);
```

Parameters

Parameter	Description
pfTimeDate	Function to be invoked.

Additional information

By default the callback function is initialized to point to `FS_X_GetTimeDate()`.

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4.11.37 FS_SetTimeDateEnhancedCallback()

Description

Configures a function that the file system can use to get the current time and date.

Prototype

```
void FS_SetTimeDateEnhancedCallback(FS_TIME_DATE_ENHANCED_CALLBACK * pfTimeDate);
```

Parameters

Parameter	Description
pfTimeDate	Function to be invoked.

Additional information

By default, the callback function is initialized to point to NULL.

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4.11.38 FS_SetVolumeAlias()

Description

Assigns an alternative name for a volume.

Prototype

```
int FS_SetVolumeAlias(const char * sVolumeName,
                      const char * sVolumeAlias);
```

Parameters

Parameter	Description
sVolumeName	in Name of the volume to which the alternative name has to be assigned. It cannot be set to NULL.
sVolumeAlias	in Alternative name as 0-terminated string. Can be set to NULL.

Return value

= 0 OK, the alternative name has been assigned.
< 0 Error code indicating the failure reason.

Additional information

The assigned alias can be used as replacement in any path to a file or directory that contains a volume name and it can be passed instead of a volume name to any API function that requires one. The alias replaces the volume and the unit number. When used as a volume name the volume separator character (':') has to be added to the end of the alias otherwise it is not recognized as a valid volume name by the file system.

Valid characters in an alias are ASCII capital and small letters, digits and the underscore character. The comparison applied to alias is case sensitive and is performed after the file system checks the real volume names.

The alias name is copied to the internal instance of the volume. The function fails with an error if the alias is longer that the space available in the internal buffer. The size of the internal buffer for the alias can be configured at compile time via FS_MAX_LEN_VOLUME_ALIAS. The alias can be removed by either passing a NULL or an empty string as sVolumeAlias parameter. If FS_MAX_LEN_VOLUME_ALIAS is set to 0 then only the pointer to the volume alias is stored. The application has to make sure that the memory region that stores the volume alias remains valid until the file system is deinitialized via FS_DeInit().

This function is available only when FS_SUPPORT_VOLUME_ALIAS is set to 1.

The alias of a volume can be queried either via FS_GetVolumeInfo() or FS_GetVolumeInfoEx(). The sAlias member of the FS_DISK_INFO structure stores the configured alias. In addition, the volume alias can be obtained via FS_GetVolumeAlias().

Example

```
#include "FS.h"

void SampleSetVolumeAlias(void) {
  FS_SetVolumeAlias("nor:0:", "flash");
}
```

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4.11.39 FS_SetVolumeLabel()

Description

Modifies the label of a volume.

Prototype

```
int FS_SetVolumeLabel(const char * sVolumeName,
                      const char * sVolumeLabel);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the label has to be modified. It cannot be NULL.
sVolumeLabel	Volume label as 0-terminated ASCII string. The volume label is deleted if set to NULL.

Return value

= 0 OK, volume label set.
≠ 0 Error code indicating the failure reason.

Additional information

The volume label is an ASCII string that can be assigned to a volume. It is not evaluated by the file system and it cannot be used as volume name. A Windows PC shows the volume label of a removable storage device in the "Computer" window when it is mounted via USB MSD. The volume label can be read via FS_GetVolumeLabel().

The volume label of a FAT-formatted volume can contain at most 11 characters. The following characters are not allowed in a volume name: '^', '&', '*', '+', '-', ',', '.', '/', ':', ';', '<', '=', '>', '?', '[', ']', '\'.

EFS does not have a volume label. FS_GetVolumeLabel() returns with an error if the application tries to read the volume label of a volume formatted as EFS.

Example

```
#include "FS.h"

void SampleSetVolumeName(void) {
  FS_SetVolumeLabel("", "SEGGER");
}
```

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4.11.40 FS_TimeStampEnhancedToFileTime()

Description

Converts a timestamp to a broken-down date and time representation.

Prototype

```
int FS_TimeStampEnhancedToFileTime(const FS_TIMESTAMP * pTimeStamp,
                                   FS_FILETIME  * pFileTime);
```

Parameters

Parameter	Description
pTimeStamp	in Timestamp to be converted. It cannot be set to NULL.
pFileTime	out Converted broken-down date and time. It cannot be set to NULL.

Return value

= 0 OK, timestamp converted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to convert a timestamp as returned by FS_GetFileTimeEnhanced() into a broken-down date and time representation.

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4.11.41 FS_TimeStampToFileTime()

Description

Converts a timestamp into a broken-down date and time representation.

Prototype

```
void FS_TimeStampToFileTime(U32           TimeStamp,
                            FS_FILETIME * pFileTime);
```

Parameters

Parameter	Description
TimeStamp	Timestamp to be converted.
pFileTime	out Converted broken-down date and time. It cannot be set to NULL.

Additional information

This function can be used to convert a timestamp as returned by FS_GetFileTime() and FS_GetFileTimeEx() into a broken-down date and time representation.

For a description of the timestamp format refer to FS_GetFileTime().

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetFileTime(void) {
  char        ac[100];
  U32         TimeStamp;
  FS_FILETIME FileTime;
  int         r;

  r = FS_GetFileTime("Test.txt", &TimeStamp);
  if (r == 0) {
    FS_TimeStampToFileTime(TimeStamp, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Creation time: %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
}
```

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4.11.42 FS_Unlock()

Description

Releases the exclusive access to file system.

Prototype

```
void FS_Unlock(void);
```

Additional information

This function has to be called in pair with `FS_Lock()` to allow other tasks to access the file system. For each call to `FS_Lock()` the application has to call `FS_Unlock()`.

`FS_Unlock()` is available if `FS_OS_LOCKING` set to 1. The function does nothing if `FS_OS_LOCKING` set to 0 or 2. The calls to `FS_Lock()` / `FS_Unlock()` cannot be nested.

Example

Refer to `FS_Lock()` for an example usage.

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4.11.43 FS_UnlockVolume()

Description

Releases the exclusive access to a volume.

Prototype

```
void FS_UnlockVolume(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume that has to be locked.

Additional information

This function has to be called in pair with FS_LockVolume() to allow other tasks to access the volume. For each call to FS_LockVolume() the application has to call FS_UnlockVolume() with the same volume name as parameter.

FS_UnlockVolume() is available if FS_OS_LOCKING set to 2. The function does nothing if FS_OS_LOCKING set to 0 or 1. The calls to FS_LockVolume() / FS_UnlockVolume() cannot be nested.

Example

Refer to FS_LockVolume() for an example usage.

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4.11.44 Disk checking error codes

Description

Error codes reported by `FS_CheckDisk()` during operation.

Definition

```
#define FS_CHECKDISK_ERRCODE_0FILE                      0x10
#define FS_CHECKDISK_ERRCODE_SHORTEN_CLUSTER            0x11
#define FS_CHECKDISK_ERRCODE_CROSSLINKED_CLUSTER        0x12
#define FS_CHECKDISK_ERRCODE_FEW_CLUSTER                0x13
#define FS_CHECKDISK_ERRCODE_CLUSTER_UNUSED             0x14
#define FS_CHECKDISK_ERRCODE_CLUSTER_NOT_EOC            0x15
#define FS_CHECKDISK_ERRCODE_INVALID_CLUSTER            0x16
#define FS_CHECKDISK_ERRCODE_INVALID_DIRECTORY_ENTRY    0x17
#define FS_CHECKDISK_ERRCODE_SECTOR_NOT_IN_USE          0x18
#define FS_CHECKDISK_ERRCODE_INVALID_FILE               0x19
```

Symbols

Definition	Description
FS_CHECKDISK_ERRCODE_0FILE	A cluster chain is assigned to a file that does not contain any data.
FS_CHECKDISK_ERRCODE_SHORTEN_CLUSTER	The cluster chain assigned to a file is longer than the size of the file.
FS_CHECKDISK_ERRCODE_CROSSLINKED_CLUSTER	A cluster is assigned to more than one file or directory.
FS_CHECKDISK_ERRCODE_FEW_CLUSTER	The size of the file is larger than the cluster chain assigned to file.
FS_CHECKDISK_ERRCODE_CLUSTER_UNUSED	A cluster is marked as in use, but not assigned to any file or directory.
FS_CHECKDISK_ERRCODE_CLUSTER_NOT_EOC	A cluster is does not have end-of-chain marker.
FS_CHECKDISK_ERRCODE_INVALID_CLUSTER	Invalid cluster id.
FS_CHECKDISK_ERRCODE_INVALID_DIRECTORY_ENTRY	Invalid directory entry.
FS_CHECKDISK_ERRCODE_SECTOR_NOT_IN_USE	A logical sector that stores data is not marked as in use in the device driver.
FS_CHECKDISK_ERRCODE_INVALID_FILE	A fragment file was found that does not belong to any big file.

Additional information

The error codes are reported via the ErrCode parameter of the callback function.

Example

Refer to `FS_CheckDisk()` for an example usage.

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4.11.45 Disk checking return values

Description

Error codes returned by `FS_CheckDisk()`.

Definition

```
#define FS_CHECKDISK_RETVAL_OK             0
#define FS_CHECKDISK_RETVAL_RETRY          1
#define FS_CHECKDISK_RETVAL_ABORT          2
#define FS_CHECKDISK_RETVAL_MAX_RECURSE    3
#define FS_CHECKDISK_RETVAL_CONTINUE       4
#define FS_CHECKDISK_RETVAL_SKIP           5
```

Symbols

Definition	Description
FS_CHECKDISK_RETVAL_OK	OK, file system not in corrupted state
FS_CHECKDISK_RETVAL_RETRY	An error has be found and repaired, retry is required.
FS_CHECKDISK_RETVAL_ABORT	User aborted operation via callback or API call
FS_CHECKDISK_RETVAL_MAX_RECURSE	Maximum recursion level reached, operation aborted
FS_CHECKDISK_RETVAL_CONTINUE	`FS_CheckAT()` returns this value to indicate that the allocation table has not been entirely checked.
FS_CHECKDISK_RETVAL_SKIP	`FS_CheckDir()` returns this value to indicate that the directory entry does not have to be checked.

Example

Refer to `FS_CheckDisk()` for an example usage.

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4.11.46 Disk checking action codes

Description

Values returned by the FS_CheckDisk() callback function.

Definition

```
#define FS_CHECKDISK_ACTION_DO_NOT_REPAIR      0
#define FS_CHECKDISK_ACTION_SAVE_CLUSTERS      1
#define FS_CHECKDISK_ACTION_ABORT              2
#define FS_CHECKDISK_ACTION_DELETE_CLUSTERS    3
```

Symbols

Definition	Description
FS_CHECKDISK_ACTION_DO_NOT_REPAIR	The error does not have to be repaired.
FS_CHECKDISK_ACTION_SAVE_CLUSTERS	The data stored in the clusters of a faulty cluster chain has to be saved to a file.
FS_CHECKDISK_ACTION_ABORT	The disk checking operation has to be aborted.
FS_CHECKDISK_ACTION_DELETE_CLUSTERS	The data stored in the clusters of a faulty cluster chain has to be deleted.

Additional information

These values indicate FS_CheckDisk() how to handle a file system error.

Example

Refer to FS_CheckDisk() for an example usage.

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4.11.47 File system types

Description

Types of file systems supported.

Definition

```
#define FS_FAT      0
#define FS_EFS      1
#define FS_EXFAT    2
```

Symbols

Definition	Description
FS_FAT	File Allocation Table (FAT).
FS_EFS	SEGGER Embedded File System (EFS).
FS_EXFAT	Extensible File Allocation Table (exFAT).

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4.11.48 File time limits

Description

Limits for the members of FS_FILETIME structure.

Definition

```
#define FS_FILETIME_YEAR_MIN            1980u
#define FS_FILETIME_YEAR_MAX            2108u
#define FS_FILETIME_MONTH_MIN           1u
#define FS_FILETIME_MONTH_MAX           12u
#define FS_FILETIME_DAY_MIN             1u
#define FS_FILETIME_DAY_MAX             31u
#define FS_FILETIME_HOUR_MIN            0u
#define FS_FILETIME_HOUR_MAX            23u
#define FS_FILETIME_MINUTE_MIN          0u
#define FS_FILETIME_MINUTE_MAX          59u
#define FS_FILETIME_SECOND_MIN          0u
#define FS_FILETIME_SECOND_MAX          59u
#define FS_FILETIME_MILLISECONDS_MIN    0u
#define FS_FILETIME_MILLISECONDS_MAX    999u
#define FS_FILETIME_TIMEZONE_MIN        (-60 * 16)
#define FS_FILETIME_TIMEZONE_MAX        (60 * 16)
#define FS_FILETIME_TIMEZONE_INVALID    0x7FFF
```

Symbols

Definition	Description
FS_FILETIME_YEAR_MIN	Minimum value of Year member (Epoch).
FS_FILETIME_YEAR_MAX	Maximum value of Year member.
FS_FILETIME_MONTH_MIN	Minimum value of Month member (January).
FS_FILETIME_MONTH_MAX	Maximum value of Month member (December).
FS_FILETIME_DAY_MIN	Minimum value of Day member.
FS_FILETIME_DAY_MAX	Maximum value of Day member.
FS_FILETIME_HOUR_MIN	Minimum value of Hour member.
FS_FILETIME_HOUR_MAX	Maximum value of Hour member.
FS_FILETIME_MINUTE_MIN	Minimum value of Minute member.
FS_FILETIME_MINUTE_MAX	Maximum value of Minute member.
FS_FILETIME_SECOND_MIN	Minimum value of Second member.
FS_FILETIME_SECOND_MAX	Maximum value of Second member.
FS_FILETIME_MILLISE-CONDS_MIN	Minimum value of Milliseconds member.
FS_FILETIME_MILLISE-CONDS_MAX	Maximum value of Milliseconds member.
FS_FILETIME_TIME-ZONE_MIN	Minimum value of TimeZone member.
FS_FILETIME_TIME-ZONE_MAX	Maximum value of TimeZone member.
FS_FILETIME_TIME-ZONE_INVALID	Value indicating that the TimeZone is not valid.

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4.11.49 Format types

Description

Types of format supported.

Definition

```
#define FS_TYPE_FAT12    0x000Cu
#define FS_TYPE_FAT16    0x0010u
#define FS_TYPE_FAT32    0x0020u
#define FS_TYPE_EFS      0x0120u
#define FS_TYPE_EXFAT    0x0220u
```

Symbols

Definition	Description
FS_TYPE_FAT12	FAT with 12-bit allocation table entries.
FS_TYPE_FAT16	FAT with 16-bit allocation table entries.
FS_TYPE_FAT32	FAT with 32-bit allocation table entries.
FS_TYPE_EFS	SEGGER Embedded File System (EFS) with 32-bit allocation table entries.
FS_TYPE_EXFAT	exFAT with 32-bit allocation table entries.

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4.11.50 FS_BUSY_LED_CALLBACK

Description

Type of function called by the file system to report a change in the busy status of a volume.

Type definition

```
typedef void FS_BUSY_LED_CALLBACK(U8 OnOff);
```

Parameters

Parameter	Description
OnOff	Indicates if the volume is busy or not. • 1 The volume is busy. • 0 The volume is ready.

Additional information

A function of this type can be registered with the file system via FS_SetBusyLEDCallback(). FS_BUSY_LED_CALLBACK() is called by the file system each time the volume changes the busy status from busy to ready and reverse. Therefore, an application can use FS_BUSY_LED_CALLBACK()to indicate the busy / ready status of a volume via LED or by other means.

The file system calls FS_BUSY_LED_CALLBACK() with OnOff set to 1 when the volume goes busy. When the volume becomes ready FS_BUSY_LED_CALLBACK() is called again with OnOff set to 0.

Example

Refer to FS_SetBusyLEDCallback() for an example usage.

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4.11.51 FS_CHECKDISK_ON_ERROR_CALLBACK

Description

Type of function called by FS_CheckDisk() to report an error.

Type definition

```
typedef int FS_CHECKDISK_ON_ERROR_CALLBACK(int ErrCode,
                                           ... ...);
```

Parameters

Parameter	Description
ErrCode	Code of the reported error.

Return value

Value that indicates FS_CheckDisk() how the error should be handled.

Additional information

ErrCode is one of the FS_CHECKDISK_ERRCODE_... defines. The value returned by FS_CHECKDISK_ON_ERROR_CALLBACK() can be one of the FS_CHECKDISK_ACTION_... defines.

In addition to ErrCode FS_CheckDisk() can pass other parameters FS_CHECKDISK_ON_ERROR_CALLBACK() providing information about the reported error. These parameters can be directly passed to a printf()-style function along with the format returned by FS_CheckDisk_ErrCode2Text() to create a text description of the error in human-readable format.

Example

Refer to FS_CheckDisk() for an example usage.

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4.11.52 FS_CHS_ADDR

Description

Address of physical block on a mechanical drive.

Type definition

```
typedef struct {
  U16  Cylinder;
  U8   Head;
  U8   Sector;
} FS_CHS_ADDR;
```

Structure members

Member	Description
Cylinder	Cylinder number (0-based)
Head	Read / write head (0-based)
Sector	Index of the sector on a cylinder.

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4.11.53 FS_DISK_INFO

Description

Information about a volume.

Type definition

```
typedef struct {
  U32          NumTotalClusters;
  U32          NumFreeClusters;
  U16          SectorsPerCluster;
  U16          BytesPerSector;
  U16          NumRootDirEntries;
  U16          FSType;
  U8           IsSDFormatted;
  U8           IsDirty;
  const char * sAlias;
  void       * pBuffer;
  int          SizeOfBuffer;
  U16          SectorsPerClusterHigh;
} FS_DISK_INFO;
```

Structure members

Member	Description
NumTotalClusters	Total number of clusters on the storage device.
NumFreeClusters	Number of clusters that are not in use.
SectorsPerCluster	Number of sectors in a cluster.
BytesPerSector	Size of the logical sector in bytes.
NumRootDirEntries	Number of directory entries in the root directory.
FSType	Type of file system.
IsSDFormatted	Set to 1 if the volume was formatted according to SD Specification.
IsDirty	Set to 1 if the volume was not unmounted correctly or the file system modified the storage.
sAlias	Alternative name of the volume (0-terminated).
pBuffer	Buffer to be used for the access to the storage device.
SizeOfBuffer	Number of bytes in pBuffer.
SectorsPerClusterHigh	High-order 16-bits of the number of sectors in a cluster.

Additional information

IsDirty can be used to check if the volume formatted as FAT has been correctly unmounted before a system reset. IsDirty is set to 1 at file system initialization if the file system was not properly unmounted.

NumRootDirEntries is valid only for volumes formatted FAT12 or FAT16.

FSType can be set to one of *Format types* on page 298 values.

IsSDFormatted and IsDirty are valid only for volumes formatted as FAT.

sAlias is set to NULL if the volume alias feature is disabled.

The members pBuffer and SizeOfBuffer can be used to specify a work buffer for the operation that calculates the available free space. This work buffer is used by the file system to read data from the allocation table of the file system. Specifying a work buffer larger than a logical sector size can help increasing the performance of the operation when using a storage device that can efficiently perform read burst operations such as SD card, eMMC

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device or USB drive. The file system is able to use the work buffer for burst operations only if pBuffer is aligned according to the value configured via FS_DRIVER_ALIGNMENT. The work buffer is used only when the flag FS_DISKINFO_FLAG_WORK_BUFFER is set in the Flags parameter passed to FS_GetVolumeInfoEx() and the file system is built with FS_SUPPORT_SECTOR_BUFFER_BURST set to 1. The file system uses an internal sector buffer for the operation if either pBuffer is set to NULL or SizeOfBuffer is set to 0.

Example

Refer to FS_GetVolumeInfo() for an example usage.

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4.11.54 FS_FILETIME

Description

Time and date representation.

Type definition

```
typedef struct {
  U16  Year;
  U8   Month;
  U8   Day;
  U8   Hour;
  U8   Minute;
  U8   Second;
  U16  Milliseconds;
  I16  TimeZone;
} FS_FILETIME;
```

Structure members

Member	Description
Year	Year value.
Month	Month of the year.
Day	Day of the month.
Hour	Hour of the day.
Minute	Minute of the hour.
Second	Second of the minute.
Milliseconds	Number of milliseconds in the current second.
TimeZone	Offset from UTC of the timezone in minutes.

Additional information

FS_FILETIME represents a timestamp using individual members for the month, day, year, weekday, hour, minute, and second values. This can be useful for getting or setting a time-stamp of a file or directory.

Positive values of TimeZone indicate that the local time is ahead of UTC.

The conversion between a timestamp in U32 format and a FS_FILETIME structure can be done using FS_FileTimeToTimeStamp() and FS_TimeStampToFileTime()

The conversion between a time stamp in FS_TIMESTAMP format and a FS_FILETIME structure can be done using FS_FileTimeToTimeStampEnhanced() and FS_TimeStampEnhancedToFile-Time()

The range of valid values are defined by *File time limits* on page 297.

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4.11.55 FS_FREE_SPACE_DATA

Description

Information the number of free space available on a volume.

Type definition

```
typedef struct {
  U32         NumClustersFree;
  int         SizeOfBuffer;
  void      * pBuffer;
  FS_VOLUME * pVolume;
  U32         FirstClusterId;
} FS_FREE_SPACE_DATA;
```

Structure members

Member	Description
NumClustersFree	Number of unallocated clusters found.
SizeOfBuffer	Internal. Do not use. Number of bytes in the work buffer.
pBuffer	Internal. Do not use. Work buffer.
pVolume	Internal. Do not use. Volume information.
FirstClusterId	Internal. Do not use. Id of the first cluster to be checked.

Additional information

This structure stores the result and context of the operation that calculates the amount of free space available on a volume. The amount of free space is returned as a number of clusters via the NumClustersFree member. The members of the search context are considered internal and should not be used by the application. FS_FREE_SPACE_DATA is used by the FS_GetVolumeFreeSpaceFirst() FS_GetVolumeFreeSpaceNext() pair of API functions.

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4.11.56 FS_MEM_CHECK_CALLBACK

Description

Type of function called by the file system to check if a memory region can be used in a 0-copy operation.

Type definition

```
typedef int FS_MEM_CHECK_CALLBACK(void * pMem,
                                  U32    NumBytes);
```

Parameters

Parameter	Description
pMem	Points to the first byte in the memory area to be checked.
NumBytes	Size of the memory area in bytes.

Return value

≠ 0 The memory region can be used in a 0 copy operation.
= 0 The memory region cannot be used in a 0 copy operation.

Additional information

A function of this type is called by the file system before any read or write operation performed by the application. The function has to check if the memory region defined by pMem and NumBytes can be passed directly to the device driver during a 0-copy operation.

The callback function is typically required on a system where the device driver uses DMA to transfer data to and from the storage device and where not all the memory regions can be accessed by the DMA. If the memory region cannot be accessed by DMA the callback function has to return 0. The file system copies then the data to an internal buffer that is accessible to DMA and performs the data transfer. The callback has to return a value different than 0 if the DMA can access the specified memory region. In this case the memory region is passed directly to device driver to perform the data transfer and the internal copy operation of the file system is skipped.

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4.11.57 FS_MEM_INFO

Description

Information about the memory management.

Type definition

```
typedef struct {
  U8   IsExternal;
  U32  NumBytesTotal;
  U32  NumBytesAllocated;
  U8   NumBytesAlignment;
} FS_MEM_INFO;
```

Structure members

Member	Description
IsExternal	Memory allocator type.
NumBytesTotal	Size of the memory pool in bytes.
NumBytesAllocated	Number of bytes allocated from the memory pool.
NumBytesAlignment	Alignment of the allocated memory in bytes.

Additional information

The information can be queried via FS_GetMemInfo().

IsExternal contains the value of the FS_SUPPORT_EXT_MEM_MANAGER configuration define.

If the file system is configured to use the internal memory allocator (FS_SUPPORT_EXT_MEM_MANAGER set to 0) then NumBytesTotal stores the value passed as second parameter to FS_AssignMemory(). NumBytesTotal is set to 0 if the file system is configured to use an external memory allocator (FS_SUPPORT_EXT_MEM_MANAGER set to 1) because this value is not known to the file system.

The value of NumBytesAllocated stores the number of bytes allocated by the file system at the time FS_GetMemInfo() is called. In emFile versions older than 5.xx this information was stored in the global variable FS_NumBytesAllocated.

NumBytesAlignment is set to 0 if the file system is built with FS_SUPPORT_EXT_MEM_MANAGER set to 1 to indicate that the alignment is unknown.

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4.11.58 FS_TIME_DATE_CALLBACK

Description

Type of function called by the file system to get the local time and date.

Type definition

```
typedef U32 FS_TIME_DATE_CALLBACK(void);
```

Return value

Current time and date in a format suitable for the file system.

Additional information

The time and date have to be encoded as follows: Bit 0-4: 2-second count (0-29) Bit 5-10: Minutes (0-59) Bit 11-15: Hours (0-23) Bit 16-20: Day of month (1-31) Bit 21-24: Month of year (1-12) Bit 25-31: Count of years from 1980 (0-127) The callback function can be registered via `FS_SetTimeDateCallback()`. `FS_X_GetTimeDate()` is set as default callback function at the file system initialization. The application has to provide the implementation of `FS_X_GetTimeDate()`.

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4.11.59 FS_TIME_DATE_ENHANCED_CALLBACK

Description

Type of function called by the file system to get the local time and date with timezone information.

Type definition

```
typedef void FS_TIME_DATE_ENHANCED_CALLBACK(FS_TIMESTAMP * pTimeStamp);
```

Parameters

Parameter	Description
pTimeStamp	out Local time and date.

Additional information

The callback function can be registered with the file system via `FS_SetTimeDateEnhanced-Callback()`.

Example

Refer to `FS_SetTimeDateEnhancedCallback()` for an example usage.

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4.11.60 FS_TIMESTAMP

Description

Recorded time of an operation performed on a file or directory.

Type definition

```
typedef struct FS_TIMESTAMP {
  U32  TimeDate;
  U8   Milliseconds;
  U8   Offset;
} FS_TIMESTAMP;
```

Structure members

Member	Description
TimeDate	Local time and date.
Milliseconds	Number of milliseconds.
Offset	Time difference to UTC.

Additional information

TimeDate is encoded as documented in the description of FS_GetFileTime().

Milliseconds is stored in 10-millisecond units. The valid value range for Milliseconds is 0-199.

Offset stores information about the timezone and is encoded in the same way as the UtcOffset field of an exFAT timestamp.

Bit field
0 to 6
7

Example values for the offset field:

Value
0x00
0x04
0x3F
0x40

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4.11.61 Volume information flags

Description

Flags that control the information returned by `FS_GetVolumeInfoEx()`.

Definition

```
#define FS_DISKINFO_FLAG_FREE_SPACE     0x01
#define FS_DISKINFO_FLAG_WORK_BUFFER    0x02
```

Symbols

Definition	Description
FS_DISKIN-FO_FLAG_FREE_SPACE	Returns the available free space on the storage device.
FS_DISKIN-FO_FLAG_WORK_BUFFER	Specifies a working buffer for the read operations.

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4.12 Storage layer functions

The functions described in this section can be used to access and to manage the data at the logical sector level, effectively bypassing the file system. These functions are typically used when the application comes with its own file system or when the storage device has to be mounted as a mass storage device via USB.

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4.12.1 FS_STORAGE_Clean()

Description

Performs garbage collection on a volume.

Prototype

```
int FS_STORAGE_Clean(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which to perform the garbage collection.

Return value

= 0 OK, volume cleaned.
≠ 0 Error code indicating the failure reason.

Additional information

The application can call this function to convert storage blocks that contain invalid data to free space that can be used to store new data. This operation is supported only by storage devices that are managed by the file system such as NAND and NOR flash.

`FS_STORAGE_Clean()` is optional since the device drivers perform the garbage collection operation automatically. The function can be used to increase the write performance by preparing the storage device in advance of the write operation.

The actions executed by `FS_STORAGE_Clean()` depend on the device driver used. For example, the Sector Map NOR driver converts all logical blocks that contain invalid data into free (writable) logical blocks. As a consequence, the following write operation will run faster because physical sectors does not have to be erased.

`FS_STORAGE_Clean()` can potentially take a long time to complete, preventing the access of other tasks to the file system. How long the execution takes depends on the type of storage device and on the number of storage blocks that contain invalid data. The file system provides an alternative function `FS_STORAGE_CleanOne()` that completes in a shorter period of time than `FS_STORAGE_Clean()`. This is realized by executing only one sub-operation of the entire garbage collection operation at a time. For more information refer to `FS_STORAGE_CleanOne()`.

Additional information about the garbage collection operation can be found in the “Garbage collection” section of the NAND and NOR drivers of the emFile manual.

Example

```
#include "FS.h"

void SampleStorageClean(void) {
  FS_FILE * pFile;

  //
  // Perform garbage collection on the storage device.
  //
  FS_STORAGE_Clean("nor:0:");
  //
  // The write to file is fast since the NOR driver does not have to perform
  // any garbage collection during the write operation.
  //
  pFile = FS_FOpen("nor:0:\\File.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test", 4);
    FS_FClose(pFile);
  }
```

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```
}
```

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4.12.2 FS_STORAGE_CleanEx()

Description

Performs garbage collection on a volume.

Prototype

```
int FS_STORAGE_CleanEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume on which to perform the garbage collection.

Return value

= 0 OK, volume cleaned.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as `FS_STORAGE_Clean()` with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.3 FS_STORAGE_CleanOne()

Description

Performs garbage collection on a volume.

Prototype

```
int FS_STORAGE_CleanOne(const char * sVolumeName,
                        int  * pMoreToClean);
```

Parameters

Parameter	Description
sVolumeName	Name of the storage volume on which to perform the garbage collection.
pMoreToClean	out Indicates if the storage device has been cleaned completely or not. It can be NULL. • ≠0 Not cleaned completely. • =0 Completely clean.

Return value

= 0 OK, clean operation executed.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_Clean() with the difference that it executes only one sub-operation of the garbage collection operation at a time. This is practical if other tasks of the application require access to the file system before the garbage collection operation is completed. The completion of the garbage collection operation is indicated via pMoreToClean. FS_STORAGE_CleanOne() returns a value different than 0 via pMoreToClean if the operation is not completed.

Additional information about the garbage collection operation can be found in the "Garbage collection" section of the NAND and NOR drivers.

Example

```
#include "FS.h"

void SampleStorageCleanOne(void) {
  FS_FILE * pFile;
  int       MoreToClean;

  //
  // Perform garbage collection on the storage device.
  //
  MoreToClean = 0;
  do {
    FS_STORAGE_CleanOne("nand:0:", &MoreToClean);
  } while (MoreToClean);
  //
  // The write to file is fast since the NAND driver does not have to perform
  // any garbage collection during the write operation.
  //
  pFile = FS_FOpen("nand:0:\\File.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test", 4);
    FS_FClose(pFile);
  }
}
```

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4.12.4 FS_STORAGE_CleanOneEx()

Description

Performs garbage collection on a volume.

Prototype

```
int FS_STORAGE_CleanOneEx(FS_VOLUME * pVolume,
                          int       * pMoreToClean);
```

Parameters

Parameter	Description
pVolume	Instance of the storage volume on which to perform the garbage collection.
pMoreToClean	out Indicates if the storage device has been cleaned completely or not. It can be NULL. • ≠0 Not cleaned completely. • =0 Completely clean.

Return value

= 0 OK, clean operation executed.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_CleanOne() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.5 FS_STORAGE_DeInit()

Description

Frees the resources allocated by the storage layer.

Prototype

```
void FS_STORAGE_DeInit(void);
```

Additional information

This function is optional. `FS_STORAGE_DeInit()` frees all resources that are allocated by the storage layer after initialization. The application can call this function only after it called `FS_STORAGE_Init()`.

This function is available if the emFile sources are compiled with the `FS_SUPPORT_DEINIT` configuration define set to 1.

Example

```
#include "FS.h"

void SampleStorageDeInit(void) {
  FS_STORAGE_Init();
#if FS_SUPPORT_DEINIT
  //
  // Access the storage layer...
  //
  FS_STORAGE_DeInit();
#endif // FS_SUPPORT_DEINIT
  //
  // The storage layer cannot be accessed anymore.
  //
}
```

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4.12.6 FS_STORAGE_FillSectors()

Description

Writes the same sector data to one or more logical sectors.

Prototype

```
int FS_STORAGE_FillSectors(const char * sVolumeName,
                           const void * pData,
                                 U32    SectorIndex,
                                 U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to write to. It cannot be NULL.
pData	in Buffer that contains the sector data to be written. It cannot be NULL.
SectorIndex	Index of the first sector to be written.
NumSectors	Number of sectors to be written.

Return value

= 0 OK, sector data modified.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to write the same sector data to multiple consecutive logical sectors. pData has to point to a memory region that stores the contents of a single logical sector that has to be written.

The size of the logical sector depends on the type of storage device used. The application can query the size of the logical sector as well as the number of logical sectors of a storage device via FS_STORAGE_GetDeviceInfo(). Typically, the size of a logical sector is 512 bytes.

SectorIndex is a 0-based index that identifies the first logical sector to be written. The range of the logical sectors modified by this function is SectorIndex to SectorIndex + NumSectors - 1.

FS_STORAGE_FillSectors() reports an error and does not perform any operation if the specified range of logical sectors exceeds the size of the storage device.

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4.12.7 FS_STORAGE_FillSectorsEx()

Description

Writes the same sector data to one or more logical sectors.

Prototype

```
int FS_STORAGE_FillSectorsEx(      FS_VOLUME * pVolume,
                             const void      * pData,
                                   U32         SectorIndex,
                                   U32         NumSectors);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to write to.
pData	in Contents of the logical sector.
SectorIndex	Index of the logical sector to be written.
NumSectors	Number of logical sectors to be written.

Return value

= 0 OK, logical sectors written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_FillSectors() with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling FS_STORAGE_FindVolume().

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4.12.8 FS_STORAGE_FindVolume()

Description

Searches for a volume instance by name.

Prototype

```
FS_VOLUME *FS_STORAGE_FindVolume(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume.

Return value

≠ NULL Pointer to the volume instance.
= NULL Volume not found.

Additional information

This function returns the volume instance assigned to the specified volume name. The return value can be passed as parameter to the API functions of the Storage layer that identify a volume by instance and not by name.

The returned volume instance is no longer valid after the file system is deinitialized via a call to FS_DeInit(). The application must call FS_STORAGE_FindVolume() to get a new volume instance after the file system is reinitialized.

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4.12.9 FS_STORAGE_FindVolumeByDevice()

Description

Searches for a volume instance by index.

Prototype

```
FS_VOLUME *FS_STORAGE_FindVolumeByDevice(FS_DEVICE * pDevice);
```

Parameters

Parameter	Description
pDevice	Device instance assigned to the volume.

Return value

≠ NULL Pointer to the volume instance.
= NULL Volume not found.

Additional information

This function performs the same operation as FS_STORAGE_FindVolumeByIndex() with the difference that the volume to be searched for is specified via device instance instead of volume index.

A device index can be obtained via the callback of the function registered via FS_STORAGE_SetOnDeviceActivityCallback() or FS_STORAGE_SetOnDeviceActivityCallbackEx().

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4.12.10 FS_STORAGE_FindVolumeByIndex()

Description

Searches for a volume instance by index.

Prototype

```
FS_VOLUME *FS_STORAGE_FindVolumeByIndex(int VolumeIndex);
```

Parameters

Parameter	Description
VolumeIndex	Index of the volume.

Return value

≠ NULL Pointer to the volume instance.
= NULL Volume not found.

Additional information

This function returns the volume instance assigned to the volume with the specified index. The first volume added to the file system via FS_AddDevice() has the index 0, the second index 1 and so on. The total number of configured volumes can be queried via FS_GetNumVolumes().

The return value of this function can be passed as parameter to the API functions of the Storage layer that identify a volume by instance and not by name.

The returned volume instance is no longer valid after the file system is deinitialized via a call to FS_DeInit(). The application must call FS_STORAGE_FindVolumeByIndex() to get a new volume instance after the file system is reinitialized.

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4.12.11 FS_STORAGE_FormatLow()

Description

Performs a low-level format.

Prototype

```
int FS_STORAGE_FormatLow(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be formatted.

Return value

= 0 OK, low-level format successful.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as `FS_FormatLow()`. Refer to `FS_FormatLow()` for more information.

Example

```
#include "FS_Storage.h"

void SampleStorageFormatLow(void) {
  FS_STORAGE_Init();
  //
  // Performs a low-level format of a NAND flash device.
  //
  FS_STORAGE_FormatLow("nand:0:");
}
```

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4.12.12 FS_STORAGE_FormatLowEx()

Description

Formats the storage device.

Prototype

```
int FS_STORAGE_FormatLowEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be formatted.

Return value

= 0 OK, low	level format was successful.
≠ 0	Error code indicating the failure reason.

Additional information

This function performs the same operation as `FS_FormatLow()` with the difference that the volume to be queried is identified by a volume instance instead a volume name. The application can get a volume instance from a volume name by calling `FS_STORAGE_FindVolume()`.

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4.12.13 FS_STORAGE_FreeSectors()

Description

Informs the driver about unused sectors.

Prototype

```
int FS_STORAGE_FreeSectors(const char * sVolumeName,
                           U32    SectorIndex,
                           U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which to perform the operation.
SectorIndex	Index of the first logical sector to be marked as invalid (0-based).
NumSectors	Number of sectors to be marked as invalid starting with SectorIndex.

Return value

= 0 OK, sectors freed.
≠ 0 Error code indicating the failure reason

Additional information

Typically, this function is called by the application to inform the driver which logical sectors are no longer used for data storage. The NAND and NOR drivers can use this information to optimize the internal relocation of data blocks during the wear-leveling operation. The data of the logical sectors marked as not in use is not copied anymore that can typically lead to an improvement of the write performance.

FS_STORAGE_FreeSectors() performs a similar operation as the trim command of SSDs (Solid-State Drives). The data stored to a logical sector is no longer available to an application after the logical sector has been freed via FS_STORAGE_FreeSectors(),

Example

```
#include "FS.h"

void SampleStorageFreeSectors(void) {
  //
  // Inform the NAND driver that the logical sectors
  // with the indexes 2, 3, and 4 are no longer in use.
  //
  FS_STORAGE_FreeSectors("nand:0:", 2, 3);
}
```

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4.12.14 FS_STORAGE_FreeSectorsEx()

Description

Informs the driver about unused sectors.

Prototype

```
int FS_STORAGE_FreeSectorsEx(FS_VOLUME * pVolume,
                             U32         SectorIndex,
                             U32         NumSectors);
```

Parameters

Parameter	Description
pVolume	Instance of the volume on which to perform the operation.
SectorIndex	Index of the first logical sector to be marked as invalid (0-based).
NumSectors	Number of sectors to be marked as invalid starting with SectorIndex.

Return value

= 0 OK, sectors freed.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_FreeSectors() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.15 FS_STORAGE_GetAutoMountType()

Description

Returns information about how a volume is automatically mounted.

Prototype

```
int FS_STORAGE_GetAutoMountType(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

= 0	Volume is not mounted automatically.
= FS_MOUNT_RO	Volume is mounted automatically in read only mode.
= FS_MOUNT_RW	Volume is mounted automatically in read and write mode.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.16 FS_STORAGE_GetAutoMountTypeEx()

Description

Returns information about how a volume is automatically mounted.

Prototype

```
int FS_STORAGE_GetAutoMountTypeEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.

Return value

= 0	Volume is not mounted automatically.
= FS_MOUNT_RO	Volume is mounted automatically in read only mode.
= FS_MOUNT_RW	Volume is mounted automatically in read and write mode.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

This function performs the same operation as FS_STORAGE_GetAutoMountType() with the difference that the volume is specified via a volume instance instead of a volume name.

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.17 FS_STORAGE_GetCleanCnt()

Description

Calculates the number of garbage collection sub-operations.

Prototype

```
int FS_STORAGE_GetCleanCnt(const char * sVolumeName,
                           U32  * pCleanCnt);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.
pCleanCnt	out Number of sub-operations left.

Return value

= 0 OK, clean count returned.
≠ 0 Error code indicating the failure reason.

Additional information

FS_STORAGE_GetCleanCnt() calculates and returns the number of sub-operations that the application has to perform until the garbage collection operation is completed. The value returned via pCleanCnt is the number of times FS_STORAGE_CleanOne() has to be called to complete the garbage collection. FS_STORAGE_GetCleanCnt() is supported only for volumes mounted on a storage device managed by emFile such as NAND or NOR flash.

Example

```
#include "FS.h"

void SampleStorageGetCleanCnt(void) {
  U32 CleanCnt;

  CleanCnt = 0;
  FS_STORAGE_GetCleanCnt("nor:0:", &CleanCnt);
  if (CleanCnt) {
    do {
      FS_STORAGE_CleanOne("nor:0:", NULL);
    } while (--CleanCnt);
  }
}
```

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4.12.18 FS_STORAGE_GetCleanCntEx()

Description

Calculates the number of garbage collection sub-operations.

Prototype

```
int FS_STORAGE_GetCleanCntEx(FS_VOLUME * pVolume,
                             U32       * pCleanCnt);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.
pCleanCnt	out Number of sub-operations left.

Return value

= 0 OK, clean count returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_GetCleanCnt() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.19 FS_STORAGE_GetConfig()

Description

Returns information about how the storage layer is configured to operate.

Prototype

```
int FS_STORAGE_GetConfig(FS_STORAGE_CONFIG * pConfig);
```

Parameters

Parameter	Description
pConfig	out Configuration information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

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4.12.20 FS_STORAGE_GetCounters()

Description

Returns the values of statistical counters.

Prototype

```
void FS_STORAGE_GetCounters(FS_STORAGE_COUNTERS * pStat);
```

Parameters

Parameter	Description
pStat	out Current values of statistical counters.

Additional information

This function returns the values of the counters that indicate how many operations the storage layer executed since the file system initialization or the last call to `FS_STORAGE_ResetCounters()`.

The statistical counters are updated only on debug builds if the file system sources are compiled with `FS_DEBUG_LEVEL` greater than or equal to `FS_DEBUG_LEVEL_CHECK_PARA` or `FS_STORAGE_ENABLE_STAT_COUNTERS` set to 1.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleStorageGetCounters(void) {
  FS_STORAGE_COUNTERS StatCnt;
  char                ac[100];

  FS_STORAGE_GetCounters(&StatCnt);
  SEGGER_snprintf(ac, sizeof(ac), "Num. read operations:                %lu\n",
    StatCnt.ReadOperationCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors read:                   %lu\n",
    StatCnt.ReadSectorCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors read (from cache):      %lu\n",
    StatCnt.ReadSectorCachedCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors read (alloc. table):    %lu\n",
    StatCnt.ReadSectorCntMan);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors read (dir. entry):      %lu\n",
    StatCnt.ReadSectorCntDir);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. write operations:               %lu\n",
    StatCnt.WriteOperationCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors written:                %lu\n",
    StatCnt.WriteSectorCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors written (by cache):     %lu\n",
    StatCnt.WriteSectorCntCleaned);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors written (alloc. table): %lu\n",
    StatCnt.WriteSectorCntMan);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors written (dir. entry):   %lu\n",
    StatCnt.WriteSectorCntDir);
  FS_X_Log(ac);
}
```

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4.12.21 FS_STORAGE_GetDeviceInfo()

Description

Returns information about the storage device.

Prototype

```
int FS_STORAGE_GetDeviceInfo(const char        * sVolumeName,
                             FS_DEV_INFO * pDeviceInfo);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried. It cannot be NULL.
pDeviceInfo	out Information about the storage device. It cannot be NULL.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function returns information about the logical organization of the storage device such as the number of logical sectors and the size of the logical sector supported. FS_STORAGE_GetDeviceInfo() requests the information directly from the device driver.

Deprecated name

FS_GetDeviceInfo

Example

```
#include <stdio.h>
#include "FS.h"

void SampleStorageGetDeviceInfo(void) {
  FS_DEV_INFO DeviceInfo;
  char        ac[100];

  FS_STORAGE_GetDeviceInfo("", &DeviceInfo);
  SEGGER_snprintf(ac, sizeof(ac), "Total num. sectors:      %lu\n",
    DeviceInfo.NumSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. bytes per sector:   %d\n",
    DeviceInfo.BytesPerSector);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. read / write heads: %d\n",
    DeviceInfo.NumHeads);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Num. sectors per track:  %d\n",
    DeviceInfo.SectorsPerTrack);
  FS_X_Log(ac);
}
```

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4.12.22 FS_STORAGE_GetDeviceInfoEx()

Description

Returns information about the storage device.

Prototype

```
int FS_STORAGE_GetDeviceInfoEx(FS_VOLUME    * pVolume,
                               FS_DEV_INFO * pDeviceInfo);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.
pDeviceInfo	out Information about the storage device.

Return value

= 0 OK, volume information returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_GetDeviceInfo() with the difference that the volume to be queried is identified by a volume instance instead a volume name. The application can get a volume instance from a volume name by calling FS_STORAGE_FindVolume().

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4.12.23 FS_STORAGE_GetMountType()

Description

Returns information about how a volume is mounted.

Prototype

```
int FS_STORAGE_GetMountType(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be queried.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only.
= FS_MOUNT_RW	Volume is mounted read/write.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.24 FS_STORAGE_GetMountTypeEx()

Description

Returns information about how a volume is mounted.

Prototype

```
int FS_STORAGE_GetMountTypeEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only.
= FS_MOUNT_RW	Volume is mounted read/write.
< 0	Error code indicating the failure reason. Refer to FS_ErrorNo2Text().

Additional information

This function performs the same operation as FS_STORAGE_GetMountType() with the difference that the volume is specified via a volume instance instead of a volume name.

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.25 FS_STORAGE_GetSectorUsage()

Description

Returns information about the usage of a logical sector.

Prototype

```
int FS_STORAGE_GetSectorUsage(const char * sVolumeName,
                              U32    SectorIndex);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume.
SectorIndex	Index of the sector to be queried.

Return value

= FS_SECTOR_IN_USE	The sector contains valid data.
= FS_SECTOR_NOT_USED	The sector contains invalid data.
= FS_SECTOR_USAGE_UNKNOWN	The usage of the sector is unknown or the operation is not supported.
< 0	Error code indicating the failure reason.

Additional information

After a low-level format all the logical sectors contain invalid information. The data of a logical sector becomes valid after the application performs a write operation to that sector. The sector data can be explicitly invalidated by calling FS_STORAGE_FreeSectors().

Example

```
#include "FS.h"

void SampleStorageGetSectorUsage(void) {
  int SectorUsage;

  SectorUsage = FS_STORAGE_GetSectorUsage("", 7);
  switch (SectorUsage) {
  case FS_SECTOR_IN_USE:
    FS_X_Log("The sector is used to store data.\n");
    break;
  case FS_SECTOR_NOT_USED:
    FS_X_Log("The sector is not used to store data.\n");
    break;
  case FS_SECTOR_USAGE_UNKNOWN:
    FS_X_Log("The sector usage is unknown.\n");
    break;
  default:
    FS_X_Log("An error occurred during the operation.\n");
  }
}
```

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4.12.26 FS_STORAGE_GetSectorUsageEx()

Description

Returns information about the usage of a logical sector.

Prototype

```
int FS_STORAGE_GetSectorUsageEx(FS_VOLUME * pVolume,
                                U32         SectorIndex);
```

Parameters

Parameter	Description
pVolume	Instance of the volume that stores the logical sector.
SectorIndex	Index of the sector to be queried.

Return value

= FS_SECTOR_IN_USE	The sector contains valid data.
= FS_SECTOR_NOT_USED	The sector contains invalid data.
= FS_SECTOR_USAGE_UNKNOWN	The usage of the sector is unknown or the operation is not supported.
< 0	Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_GetSectorUsage() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.27 FS_STORAGE_GetVolumeStatusEx()

Description

Returns the presence status of a volume.

Prototype

```
int FS_STORAGE_GetVolumeStatusEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.

Return value

FS_MEDIA_NOT_PRESENT	Volume is not present.
FS_MEDIA_IS_PRESENT	Volume is present.
FS_MEDIA_STATE_UNKNOWN	Volume presence state is unknown.

Additional information

This function performs the same operation as FS_GetVolumeStatus() with the difference that the volume to be queried is identified by a volume instance instead a volume name. The application can get a volume instance from a volume name by calling FS_STORAGE_FindVolume().

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4.12.28 FS_STORAGE_Init()

Description

Initializes the storage layer.

Prototype

```
unsigned FS_STORAGE_Init(void);
```

Return value

Number of OS synchronization objects required to protect the file system against concurrent access from different tasks.

Additional information

This function initializes the drivers and if necessary the OS layer. It has to be called before any other function of the storage layer (`FS_STORAGE_...`) The storage layer allows an application to access the file system at logical sector level. The storage device is presented as an array of logical sectors that can be accessed via a 0-based index. This can be useful when using the file system as USB mass storage client driver.

`FS_STORAGE_Init()` is called internally at the initialization of the file system. The return value of this function is used by `FS_Init()` to calculate the number of internal buffers the file system has to allocate for the read and write operations. The application is not required to call `FS_STORAGE_Init()` if it already calls `FS_Init()`.

`FS_STORAGE_DeInit()` is the counterpart of `FS_STORAGE_Init()` that can be used to free the resources allocated by the drivers and if enabled of the OS layer.

Deprecated name

`FS_InitStorage`

Example

```
#include "FS.h"

void SampleStorageInit(void) {
  FS_STORAGE_Init();
  //
  // Access logical sectors...
  //
}
```

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4.12.29 FS_STORAGE_IsLLFormatted()

Description

Returns whether a volume is low-level formatted or not.

Prototype

```
int FS_STORAGE_IsLLFormatted(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked. It cannot be NULL.

Return value

= 1 Volume is low-level formatted.
= 0 Volume is not low-level formatted.
< 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_IsLLFormatted().

Example

```
#include "FS_Storage.h"

void SampleStorageIsLLFormatted(void) {
  FS_STORAGE_Init();
  //
  // Performs a low-level format of a NOR flash device if required.
  //
  if (FS_STORAGE_IsLLFormatted("nor:0:") == 0) {
    FS_STORAGE_FormatLow("nor:0:");
  }
}
```

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4.12.30 FS_STORAGE_IsLLFormattedEx()

Description

Checks if a storage device is low-level formatted.

Prototype

```
int FS_STORAGE_IsLLFormattedEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be queried.

Return value

= 1	Volume is low level formatted.
= 0	Volume is not low level formatted.
< 0	Low level format not supported by volume or an error occurred.

Additional information

This function performs the same operation as `FS_IsLLFormatted()` with the difference that the volume to be queried is identified by a volume instance instead a volume name. The application can get a volume instance from a volume name by calling `FS_STORAGE_FindVolume()`.

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4.12.31 FS_STORAGE_Mount()

Description

Initializes a volume in a specified access mode.

Prototype

```
int FS_STORAGE_Mount(const char * sVolumeName,
                     U8     MountType);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be mounted.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Read only access mode. • FS_MOUNT_RW Read and write access mode.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only mode.
= FS_MOUNT_RW	Volume is mounted read and write mode.
< 0	Error code indicating the failure reason.

Additional information

The application is not required to call this function before the first access to the storage device. The file system mounts by default the storage device at the first access after the file system initialization. This behavior can be configured via FS_SetAutoMount().

A mounted volume can be unmounted via FS_STORAGE_Unmount() or FS_STORAGE_Unmount-Forced().

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4.12.32 FS_STORAGE_MountEx()

Description

Initializes a volume in a specified access mode.

Prototype

```
int FS_STORAGE_MountEx(FS_VOLUME * pVolume,
                       U8          MountType);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be mounted.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Read only access mode. • FS_MOUNT_RW Read and write access mode.

Return value

= 0	Volume is not mounted.
= FS_MOUNT_RO	Volume is mounted read only mode.
= FS_MOUNT_RW	Volume is mounted read and write mode.
< 0	Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_Mount() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.33 FS_STORAGE_ReadSector()

Description

Reads the data of one logical sector.

Prototype

```
int FS_STORAGE_ReadSector(const char * sVolumeName,
                          void * pData,
                          U32    SectorIndex);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to read from. It cannot be NULL.
pData	out Buffer that receives the read sector data. It cannot be NULL.
SectorIndex	Index of the sector to read from.

Return value

= 0 OK, sector data read.
≠ 0 Error code indicating the failure reason.

Additional information

pData has to point to a memory region sufficiently large to store the contents of one logical sector.

The size of the logical sector depends on the type of storage device used. The application can query the size of the logical sector as well as the number of logical sectors of a storage device via FS_STORAGE_GetDeviceInfo(). Typically, the size of a logical sector is 512 bytes.

FS_STORAGE_ReadSector() reports an error and does not store any data to pData if SectorIndex is out of bounds.

The application can call FS_STORAGE_ReadSectors() instead of calling FS_STORAGE_ReadSector() multiple times if it has to read consecutive logical sectors at once.

Deprecated name

FS_ReadSector

Example

```
#include "FS.h"

void SampleStorageReadSector(void) {
  U32 aSectorData[512 / 4];

  //
  // Read the data of the logical sector with the index 10.
  //
  FS_STORAGE_ReadSector("", aSectorData, 10);
}
```

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4.12.34 FS_STORAGE_ReadSectorEx()

Description

Reads the contents of one logical sector from the storage device.

Prototype

```
int FS_STORAGE_ReadSectorEx(FS_VOLUME * pVolume,
                            void      * pData,
                            U32         SectorIndex);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to read from.
pData	out Contents of the logical sector.
SectorIndex	Index of the logical sector to be read.

Return value

= 0 OK, logical sector read successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as `FS_STORAGE_ReadSector()` with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling `FS_STORAGE_FindVolume()` or `FS_STORAGE_FindVolumeByIndex()`.

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4.12.35 FS_STORAGE_ReadSectors()

Description

Reads the data of one or more logical sectors.

Prototype

```
int FS_STORAGE_ReadSectors(const char * sVolumeName,
                           void * pData,
                           U32    SectorIndex,
                           U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to read from. It cannot be NULL.
pData	out Buffer that receives the read sector data. It cannot be NULL.
SectorIndex	Index of the first sector to read from.
NumSectors	Number of sectors to be read.

Return value

= 0 OK, sector data read.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to read the contents of multiple consecutive logical sectors. pData has to point to a memory region sufficiently large to store the contents of all logical sectors read.

The size of the logical sector depends on the type of storage device used. The application can query the size of the logical sector as well as the number of logical sectors of a storage device via FS_STORAGE_GetDeviceInfo(). Typically, the size of a logical sector is 512 bytes.

FS_STORAGE_ReadSectors() reports an error and does not perform any operation if the specified range of logical sectors exceeds the size of the storage device.

Example

```
#include "FS.h"

void SampleStorageReadSectors(void) {
  U32 aSectorData[512 * 2 / 4];

  //
  // Read the data of the logical sectors with the indexes 10 and 11.
  //
  FS_STORAGE_ReadSectors("", aSectorData, 10, 2);
}
```

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4.12.36 FS_STORAGE_ReadSectorsEx()

Description

Reads the contents of multiple logical sectors from a storage device.

Prototype

```
int FS_STORAGE_ReadSectorsEx(FS_VOLUME * pVolume,
                             void      * pData,
                             U32         SectorIndex,
                             U32         NumSectors);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to read from.
pData	out Contents of the logical sector.
SectorIndex	Index of the logical sector to be read.
NumSectors	Number of logical sectors to be read.

Return value

= 0 OK, logical sectors read successfully.
≠ 0 Error code indicating the failure reason

Additional information

This function performs the same operation as FS_STORAGE_ReadSectors() with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling FS_STORAGE_FindVolume() or FS_STORAGE_FindVolumeByIndex().

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4.12.37 FS_STORAGE_RefreshSectors()

Description

Reads the contents of a logical sector and writes it back.

Prototype

```
int FS_STORAGE_RefreshSectors(const char * sVolumeName,
                              U32    SectorIndex,
                              U32    NumSectors,
                              void * pBuffer,
                              U32    NumBytes);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which to perform the operation. It cannot be NULL.
SectorIndex	Index of the first sector to refresh (0-based).
NumSectors	Number of sectors to refresh starting with SectorIndex.
pBuffer	Temporary storage for the sector data. Must be at least one sector large. It cannot be NULL.
NumBytes	Number of bytes in pBuffer.

Return value

= 0 OK, sectors refreshed.
≠ 0 Error code indicating the failure reason

Additional information

This function reads the contents of each specified logical sector to pBuffer and then it writes the same data to it. FS_STORAGE_RefreshSectors() can read and write more than one logical sector at once if the size of pBuffer allows it. The larger pBuffer the faster runs the refresh operation.

FS_STORAGE_RefreshSectors() function can be used on volumes mounted on a NAND flash device to prevent the accumulation of bit errors due to excessive read operations (read disturb effect). The function can also be used to prevent data loses caused by the data reaching the retention limit. Reading and then writing back the contents of a logical sector causes the NAND driver to relocate the data on the NAND flash device that in turn eliminates bit errors. Typically, the refresh operation has to be performed periodically at large time intervals (weeks). The NAND flash may wear out too soon if the refresh operation is performed too often.

Example

```
#include "FS.h"

static U32 _aBuffer[2048 * 2 / 4];

void SampleStorageRefreshSectors(void) {

  //
  // Refresh the logical sectors with the indexes 10-99
  // stored on the NAND flash.
  //
  FS_STORAGE_RefreshSectors("nand:0:", 10, 100, _aBuffer, sizeof(_aBuffer));
}
```

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4.12.38 FS_STORAGE_RefreshSectorsEx()

Description

Reads the contents of a logical sector and writes it back.

Prototype

```
int FS_STORAGE_RefreshSectorsEx(FS_VOLUME * pVolume,
                                U32         SectorIndex,
                                U32         NumSectors,
                                void      * pBuffer,
                                U32         NumBytes);
```

Parameters

Parameter	Description
pVolume	Instance of the volume on which to perform the operation. It cannot be NULL.
SectorIndex	Index of the first sector to refresh (0-based).
NumSectors	Number of sectors to refresh starting with SectorIndex.
pBuffer	Temporary storage for the sector data. Must be at least one sector large. It cannot be NULL.
NumBytes	Number of bytes in pBuffer.

Return value

= 0 OK, sectors refreshed.
≠ 0 Error code indicating the failure reason

Additional information

This function performs the same operation as FS_STORAGE_RefreshSectors() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.39 FS_STORAGE_ResetCounters()

Description

Sets all statistical counters to 0.

Prototype

```
void FS_STORAGE_ResetCounters(void);
```

Additional information

This function can be used to set to 0 all the statistical counters maintained by the storage layer. This can be useful for example in finding out how many sector operations are performed during a specific file system operation. The application calls `FS_STORAGE_ResetCounters()` before the file system operation and then `FS_STORAGE_GetCounters()` at the end.

The statistical counters are available only on debug builds if the file system sources are compiled with `FS_DEBUG_LEVEL` greater than or equal to `FS_DEBUG_LEVEL_CHECK_PARA` or `FS_STORAGE_ENABLE_STAT_COUNTERS` set to 1.

Example

```
#include "FS.h"

void SampleStorageResetCounters(void) {
  FS_STORAGE_COUNTERS StatCnt;

  //
  // Set all statistical counters to 0.
  //
  FS_STORAGE_ResetCounters();

  //
  // Perform the file system operation...
  //

  //
  // Check the statistical counters.
  //
  FS_STORAGE_GetCounters(&StatCnt);
}
```

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4.12.40 FS_STORAGE_SetAutoMountType()

Description

Sets the automatic mount behavior.

Prototype

```
int FS_STORAGE_SetAutoMountType(const char * sVolumeName,
                                U8     MountType);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be configured.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Allows to automatically mount the volume in read only mode. • FS_MOUNT_RW Allows to automatically mount the volume in read and write mode. • 0 Disables the automatic mount operation for the volume.

Return value

≥ 0 OK, the previous mount type.
< 0 Error code indicating the failure reason.

Additional information

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.41 FS_STORAGE_SetAutoMountTypeEx()

Description

Sets the automatic mount behavior.

Prototype

```
int FS_STORAGE_SetAutoMountTypeEx(FS_VOLUME * pVolume,
                                  U8          MountType);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be configured.
MountType	Specifies how the volume has to be mounted. • FS_MOUNT_RO Allows to automatically mount the volume in read only mode. • FS_MOUNT_RW Allows to automatically mount the volume in read and write mode. • 0 Disables the automatic mount operation for the volume.

Return value

≥ 0 OK, the previous mount type.
< 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_SetAutoMount() with the difference that the volume is specified via a volume instance instead of a volume name.

This function is available only if the file system is built with FS_STORAGE_SUPPORT_MOUNT set to 1.

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4.12.42 FS_STORAGE_SetOnDeviceActivityCallback()

Description

Registers a function to be called on any logical sector read or write operation.

Prototype

```
void FS_STORAGE_SetOnDeviceActivityCallback
                       (const char                          * sVolumeName,
                              FS_ON_DEVICE_ACTIVITY_CALLBACK * pfOnDeviceActivity);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the callback function is registered. It cannot be NULL.
pfOnDeviceActivity	Function to be invoked.

Additional information

This function is optional. It is available only when the file system is built with FS_DEBUG_LEVEL set to a value grater than or equal to FS_DEBUG_LEVEL_CHECK_PARA or with FS_STORAGE_SUPPORT_DEVICE_ACTIVITY set to 1.

Example

Refer to the sample application FS_DeviceActivity.c located in the Sample/FS/Application folder of the emFile shipment.

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4.12.43 FS_STORAGE_SetWriteVerification()

Description

Enables or disables the verification of written sector data.

Prototype

```
void FS_STORAGE_SetWriteVerification(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Verification is disabled. • 1 Verification is enabled.

Additional information

With this feature enabled, the file system checks that the sector data was correctly written to storage by reading back the sector data and by comparing it with the sector data that was actually written. The verification is performed one logical sector at a time. A sector buffer is allocated from the memory pool for this operation.

Enabling the write verification can negatively affect the write performance of the file system.

This function is available only when the file system is built with `FS_STORAGE_VERIFY_WRITE` set to 1.

Deprecated function name: `FS_ConfigWriteVerification()`

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4.12.44 FS_STORAGE_Sync()

Description

Writes cached information to storage device.

Prototype

```
void FS_STORAGE_Sync(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be synchronized.

Additional information

This function updates all the information present only in sector cache (if enabled) to storage device. It is also requests the driver to perform a synchronization operation. The operations performed during the synchronization are driver-dependent.

Typically, `FS_STORAGE_Sync()` has to be called if a write-back sector cache is configured for the volume to reduce the chance of a data loss in case of an unexpected reset.

Deprecated name

`FS_CleanVolume`

Example

```
#include <string.h>
#include "FS.h"

void SampleStorageSync(void) {
  U32 aSectorData[512 / 4];

  memset(aSectorData, 'a', sizeof(aSectorData));
  //
  // Write some data to sector with the index 0.
  //
  FS_STORAGE_WriteSector("", aSectorData, 0);
  //
  // Make sure that the data is written to storage device.
  //
  FS_STORAGE_Sync("");
}
```

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4.12.45 FS_STORAGE_SyncEx()

Description

Writes cached information to storage device.

Prototype

```
int FS_STORAGE_SyncEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be synchronized.

Return value

= 0 OK, volume synchronized successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as `FS_STORAGE_Sync()` with the difference that the volume to be synchronized is identified by a volume instance instead of a volume name.

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4.12.46 FS_STORAGE_SyncSectors()

Description

Synchronizes the contents of one or more logical sectors.

Prototype

```
int FS_STORAGE_SyncSectors(const char * sVolumeName,
                           U32    SectorIndex,
                           U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume that stores the logical sectors.
SectorIndex	Index of the first sector to be synchronized (0-based).
NumSectors	Number of sectors to be synchronized starting with SectorIndex.

Return value

= 0 OK, sectors synchronized.
≠ 0 Error code indicating the failure reason.

Additional information

This operation is driver-dependent and is currently supported only by the RAID1 logical driver. The operation updates the contents of the specified logical sectors that are located on the secondary storage (mirrored) with the contents of the corresponding logical sectors from the primary storage (master). RAID1 logical driver updates the logical sectors only if the contents is different.

Example

```
#include "FS.h"

void SampleStorageSyncSectors(void) {
  //
  // Synchronizes the logical sectors with the indexes 7, 8 and 9.
  //
  FS_STORAGE_SyncSectors("", 7, 3);
}
```

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4.12.47 FS_STORAGE_SyncSectorsEx()

Description

Synchronizes the contents of one or more logical sectors.

Prototype

```
int FS_STORAGE_SyncSectorsEx(FS_VOLUME * pVolume,
                             U32         SectorIndex,
                             U32         NumSectors);
```

Parameters

Parameter	Description
pVolume	Instance of the volume that stores the logical sectors.
SectorIndex	Index of the first sector to be synchronized (0-based).
NumSectors	Number of sectors to be synchronized starting with SectorIndex.

Return value

= 0 OK, sectors synchronized.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_SyncSectors() with the difference that the volume is specified via a volume instance instead of a volume name.

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4.12.48 FS_STORAGE_Unmount()

Description

Synchronizes a volume and marks it as not initialized.

Prototype

```
void FS_STORAGE_Unmount(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be unmounted. It cannot be NULL.

Additional information

The function sends an unmount command to the driver and marks the volume as unmounted and uninitialized. If a write sector cache is enabled, FS_STORAGE_Unmount() also stores any modified data from sector cache to storage device. This function has to be called before the device is shutdown to prevent a data loss.

The file system mounts automatically the volume at the call to an API function of the storage layer.

Deprecated name

FS_UnmountLL

Example

```
#include "FS.h"

void SampleStorageUnmount(void) {
  //
  // Synchronize the sector cache and mark the volume as not initialized.
  //
  FS_STORAGE_Unmount("");
  //
  // The device can be shutdown here without loosing any data.
  //
}
```

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4.12.49 FS_STORAGE_UnmountEx()

Description

Synchronizes the volume and marks it as not initialized.

Prototype

```
void FS_STORAGE_UnmountEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be unmounted.

Additional information

This function performs the same operation as `FS_STORAGE_Unmount()` with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling `FS_STORAGE_FindVolume()` or `FS_STORAGE_FindVolumeByIndex()`.

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4.12.50 FS_STORAGE_UnmountForced()

Description

Marks a volume it as not initialized.

Prototype

```
void FS_STORAGE_UnmountForced(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be unmounted. It cannot be NULL.

Additional information

This function performs the same operations as FS_STORAGE_Unmount(). FS_STORAGE_Unmount-Forced() has to be called if a storage device has been removed before being regularly unmounted. When using FS_STORAGE_UnmountForced() there is no guarantee that the information cached by the file system is updated to storage.

The file system mounts automatically the volume at the call to an API function of the storage layer.

Example

```
#include "FS.h"

void SampleStorageUnmountForced(void) {
  if (FS_GetVolumeStatus("") == FS_MEDIA_IS_PRESENT) {
    //
    // Synchronize the sector cache and mark the volume as not initialized.
    //
    FS_STORAGE_Unmount("");
    //
    // The device can be shutdown here without loosing any data.
    //
  } else {
    //
    // Storage device has been removed. Mark the volume as not initialized.
    // Data loss is possible.
    //
    FS_STORAGE_UnmountForced("");
  }
}
```

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4.12.51 FS_STORAGE_UnmountForcedEx()

Description

Marks the volume as not initialized without synchronizing it.

Prototype

```
void FS_STORAGE_UnmountForcedEx(FS_VOLUME * pVolume);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to be unmounted.

Additional information

This function performs the same operation as `FS_STORAGE_UnmountForced()` with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling `FS_STORAGE_FindVolume()`.

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4.12.52 FS_STORAGE_WriteSector()

Description

Modifies the data of a logical sector.

Prototype

```
int FS_STORAGE_WriteSector(const char * sVolumeName,
                           const void * pData,
                                 U32    SectorIndex);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to write to. It cannot be NULL.
pData	in Buffer that contains the sector data to be written. It cannot be NULL.
SectorIndex	Index of the sector to write to.

Return value

= 0 OK, sector data modified.
≠ 0 Error code indicating the failure reason.

Additional information

pData has to point to a memory region that stores the contents of one logical sector.

The size of the logical sector depends on the type of storage device used. The application can query the size of the logical sector as well as the number of logical sectors of a storage device via FS_STORAGE_GetDeviceInfo(). Typically, the size of a logical sector is 512 bytes.

FS_STORAGE_WriteSector() reports an error and does modify the contents of the logical sector if SectorIndex is out of bounds.

The application can call FS_STORAGE_WriteSectors() instead of calling FS_STORAGE_WriteSector() multiple times if it has to write consecutive logical sectors at once.

Deprecated name

FS_WriteSector

Example

```
#include <string.h>
#include "FS_Storage.h"

void SampleStorageWriteSector(void) {
  U32 aSectorData[512 / 4];

  memset(aSectorData, 'a', sizeof(aSectorData));
  //
  // Write the data of the logical sector with the index 7.
  //
  FS_STORAGE_WriteSector("", aSectorData, 7);
}
```

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4.12.53 FS_STORAGE_WriteSectorEx()

Description

Writes a logical sector to the storage device.

Prototype

```
int FS_STORAGE_WriteSectorEx(      FS_VOLUME * pVolume,
                             const void      * pData,
                                   U32         SectorIndex);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to write to.
pData	in Contents of the logical sector.
SectorIndex	Index of the logical sector to be written.

Return value

= 0 OK, logical sector written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_WriteSector() with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance from a volume name by calling FS_STORAGE_FindVolume().

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4.12.54 FS_STORAGE_WriteSectors()

Description

Modifies the data of one or more logical sectors.

Prototype

```
int FS_STORAGE_WriteSectors(const char * sVolumeName,
                            const void * pData,
                                  U32    SectorIndex,
                                  U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to write to. It cannot be NULL.
pData	in Buffer that contains the sector data to be written. It cannot be NULL.
SectorIndex	Index of the first sector to be written.
NumSectors	Number of sectors to be written.

Return value

= 0 OK, sector data modified.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to modify the contents of multiple consecutive logical sectors. pData has to point to a memory area that stores the contents of all the logical sectors to be written.

The size of the logical sector depends on the type of storage device used. The application can query the size of the logical sector as well as the number of logical sectors of a storage device via FS_STORAGE_GetDeviceInfo(). Typically, the size of a logical sector is 512 bytes.

FS_STORAGE_WriteSectors() reports an error and does not perform any operation if the specified range of logical sectors exceeds the size of the storage device.

Example

```
#include "FS.h"

void SampleStorageWriteSectors(void) {
  U32 aSectorData[512 / 4 * 2];

  //
  // Write the data of the logical sectors with the indexes 7 and 8.
  //
  FS_STORAGE_WriteSectors("", aSectorData, 7, 2);
}
```

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4.12.55 FS_STORAGE_WriteSectorsEx()

Description

Writes multiple logical sectors to the storage device.

Prototype

```
int FS_STORAGE_WriteSectorsEx(      FS_VOLUME * pVolume,
                              const void      * pData,
                                    U32         SectorIndex,
                                    U32         NumSectors);
```

Parameters

Parameter	Description
pVolume	Instance of the volume to write to.
pData	in Contents of the logical sector.
SectorIndex	Index of the logical sector to be written.
NumSectors	Number of logical sectors to be written.

Return value

= 0 OK, logical sectors written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_STORAGE_WriteSectors() with the difference that the volume is specified via a volume instance instead a volume name. The application can get a volume instance form a volume name by calling FS_STORAGE_FindVolume().

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4.12.56 FS_DEV_INFO

Description

Information about the storage device.

Type definition

```
typedef struct {
  U16  NumHeads;
  U16  SectorsPerTrack;
  U32  NumSectors;
  U16  BytesPerSector;
} FS_DEV_INFO;
```

Structure members

Member	Description
NumHeads	Number of read / write heads.
SectorsPerTrack	Number of sectors stored on a track.
NumSectors	Total number of sectors on the storage device.
BytesPerSector	Size of a logical sector in bytes.

Additional information

NumHeads and SectorsPerTrack are relevant only for mechanical drives. The application can access the information about the storage device by calling FS_STORAGE_GetDeviceInfo().

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4.12.57 FS_ON_DEVICE_ACTIVITY_CALLBACK

Description

The type of the callback function invoked by the file system on a logical sector read or write operation.

Type definition

```
typedef void (FS_ON_DEVICE_ACTIVITY_CALLBACK)(FS_DEVICE * pDevice,
                                               unsigned    Operation,
                                               U32         StartSector,
                                               U32         NumSectors,
                                               int         SectorType);
```

Parameters

Parameter	Description
pDevice	Storage device that performed the operation.
Operation	Type of the operation performed.
StartSector	Index of the first logical sector transferred (0-based)
NumSectors	Number of logical sectors transferred in the current operation.
SectorType	Type of the data stored in the logical sector.

Additional information

This is the type of function that can be registered via FS_STORAGE_SetOnDeviceActivityCallback()

Operation can be set to one of the *Transfer direction* on page 374 values.

SectorType can be set to one of the *Sector data type* on page 373 values.

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4.12.58 FS_STORAGE_CONFIG

Description

Information about the storage layer configuration.

Type definition

```
typedef struct {
  U8  IsWriteVerificationEnabled;
} FS_STORAGE_CONFIG;
```

Structure members

Member	Description
IsWriteVerificationEnabled	Indicates if the sector write verification is enabled.

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4.12.59 FS_STORAGE_COUNTERS

Description

Statistical counters.

Type definition

```
typedef struct {
  U32  ReadOperationCnt;
  U32  ReadSectorCnt;
  U32  ReadSectorCachedCnt;
  U32  WriteOperationCnt;
  U32  WriteSectorCnt;
  U32  WriteSectorCntCleaned;
  U32  ReadSectorCntMan;
  U32  ReadSectorCntDir;
  U32  WriteSectorCntMan;
  U32  WriteSectorCntDir;
} FS_STORAGE_COUNTERS;
```

Structure members

Member	Description
ReadOperationCnt	Number of "Read sector operation" calls.
ReadSectorCnt	Number of sectors read (before cache).
ReadSectorCachedCnt	Number of sectors read from cache
WriteOperationCnt	Number of "Write sector operation" calls
WriteSectorCnt	Number of sectors written (before cache).
WriteSectorCntCleaned	Number of sectors written by the cache to storage in order to make room for other data.
ReadSectorCntMan	Number of management sectors read (before cache).
ReadSectorCntDir	Number of directory sectors (which store directory entries) read (before cache).
WriteSectorCntMan	Number of management sectors written (before cache).
WriteSectorCntDir	Number of directory sectors (which store directory entries) written (before cache).

Additional information

ReadSectorCnt can be (and typically is) higher than ReadOperationCnt, since one read operation can request multiple sectors (in a burst). The same applies to write operations: WriteSectorCnt can be (and typically is) higher than WriteOperationCnt, since one read operation can request multiple sectors (in a burst).

The statistical counters can be read via FS_STORAGE_GetCounters(). They are set to 0 when the file system is initialized. Additionally, the application can explicitly set them to 0 via FS_STORAGE_ResetCounters().

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4.12.60 Sector data type

Description

Type of data stored in a logical sector

Definition

```
#define FS_SECTOR_TYPE_DATA    0u
#define FS_SECTOR_TYPE_DIR     1u
#define FS_SECTOR_TYPE_MAN     2u
```

Symbols

Definition	Description
FS_SECTOR_TYPE_DATA	Sector that stores file data.
FS_SECTOR_TYPE_DIR	Sector that stores directory entries.
FS_SECTOR_TYPE_MAN	Sector that stores entries of the allocation table.

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4.12.61 Transfer direction

Description

Direction of the transferred data.

Definition

```
#define FS_OPERATION_READ     0
#define FS_OPERATION_WRITE    1
```

Symbols

Definition	Description
FS_OPERATION_READ	Data is transferred from storage device to MCU.
FS_OPERATION_WRITE	Data is transferred from MCU to storage device.

Additional information

One of these values is passed by the file system via Operation parameter to the callback function registered via FS_STORAGE_SetOnDeviceActivityCallback()

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4.13 FAT related functions

The functions described in this section can be used only on volumes formatted as FAT.

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4.13.1 FS_FAT_ConfigDirtyFlagUpdate()

Description

Enables / disables the update of the flag that indicates if the volume has been unmounted correctly.

Prototype

```
void FS_FAT_ConfigDirtyFlagUpdate(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

If enabled, the file system updates an internal dirty flag that is set to 1 each time data is written to storage device. The dirty flag is set to 0 when the application unmounts the file system. The value of the dirty flag is updated to storage device and can be used to check if the storage device has been properly unmounted before the system reset. `FS_GetVolumeInfo()` can be used to get the value of this dirty flag (IsDirty member of `FS_DISK_INFO`).

The update of the dirty flag is enabled by default if the compile-time option `FS_FAT_UPDATE_DIRTY_FLAG` is set to 1. `FS_FAT_ConfigDirtyFlagUpdate()` is available only if the compile-time option `FS_FAT_UPDATE_DIRTY_FLAG` is set to 1.

Example

```
#include "FS.h"

void SampleFATConfigDirtyFlagUpdate(void) {
  FS_FILE      * pFile;
  FS_DISK_INFO   VolumeInfo;

  FS_Init();
#if FS_FAT_UPDATE_DIRTY_FLAG
  FS_FAT_ConfigDirtyFlagUpdate(1);
#endif
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    FS_FClose(pFile);
  }
  FS_GetVolumeInfo("", &VolumeInfo);
  if (VolumeInfo.IsDirty) {
    FS_X_Log("Volume has been modified.\n");
  } else {
    FS_X_Log("Volume has not been modified.\n");
  }
}
```

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4.13.2 FS_FAT_ConfigFATCopyMaintenance()

Description

Enables / disables the update of the second allocation table.

Prototype

```
void FS_FAT_ConfigFATCopyMaintenance(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

The FAT file system has support for a second (redundant) allocation table. `FS_FAT_ConfigFATCopyMaintenance()` can be used to enable or disable the update of the second allocation table. The data in the second allocation table is not used by the file system but it may be required to be present by some PC file system checking utilities. Enabling this option can possible reduce the write performance of the file system.

The update of the second allocation table is enabled by default if the compile-time option `FS_MAINTAIN_FAT_COPY` is set to 1. `FS_FAT_ConfigFATCopyMaintenance()` is available only if the compile-time option `FS_MAINTAIN_FAT_COPY` is set to 1.

Example

```
#include "FS.h"

void SampleFATConfigFATCopyMaintenance(void) {
  FS_Init();
#if FS_MAINTAIN_FAT_COPY
  FS_FAT_ConfigFATCopyMaintenance(1);
#endif
  //
  // At each write access to the allocation table
  // the second allocation table is also updated.
  //
}
```

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4.13.3 FS_FAT_ConfigFSInfoSectorUse()

Description

Enables / disables the usage of information from the FSInfo sector.

Prototype

```
void FS_FAT_ConfigFSInfoSectorUse(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

FSInfo sector is a management sector present on FAT32-formatted volumes that stores information about the number of free clusters and the id of the first free cluster. This information, when available and valid, can be used to increase the performance of the operation that calculates the available free space on a volume such as `FS_GetVolumeFreeSpace()`, `FS_GetVolumeFreeSpaceKB()`, `FS_GetVolumeInfo()`, or `FS_GetVolumeInfoEx()`. If the information in the FSInfo sector is missing or invalid, the file system has to scan the entire allocation to calculate the available free space an operation that can take a long time to complete on storage devices with a large capacity.

The file system invalidates the information in the FSInfo sector on the first operation that allocates or frees a cluster. The FSInfo sector is updated when the volume is unmounted via `FS_Unmount()` or synchronized via `FS_Sync()`.

FSInfo sector is evaluated and updated by default if the compile-time option `FS_FAT_USE_FSINFO_SECTOR` is set to 1. `FS_FAT_ConfigFSInfoSectorUse()` is available only if the compile-time option `FS_FAT_USE_FSINFO_SECTOR` is set to 1.

Example

```
#include "FS.h"

void SampleFATConfigFSInfoSectorUse(void) {
  U32 NumBytes;

  FS_Init();
#if FS_FAT_USE_FSINFO_SECTOR
  FS_FAT_ConfigFSInfoSectorUse(1);
#endif
  NumBytes = FS_GetVolumeFreeSpace("");
}
```

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4.13.4 FS_FAT_ConfigROFileMovePermission()

Description

Enables / disables the permission to move (and rename) files and directories with the read-only file attribute set.

Prototype

```
void FS_FAT_ConfigROFileMovePermission(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

The application is per default allowed to move or rename via FS_Move() and FS_Rename() respectively files and directories that have the read-only file attribute (FS_ATTR_READ_ONLY) set. FS_FAT_ConfigROFileMovePermission() can be used to disable this option and thus to prevent an application to perform move or rename operations on files and directories marked as read-only.

FS_FAT_ConfigROFileMovePermission() is available only if the compile-time option FS_FAT_PERMIT_RO_FILE_MOVE is set to 1.

Example

```
#include "FS.h"

void SampleFATConfigROFileMovePermission(void) {
  FS_FILE * pFile;
  int       r;

#if FS_FAT_PERMIT_RO_FILE_MOVE
  FS_FAT_ConfigROFileMovePermission(0);
#endif
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile != NULL) {
    FS_FClose(pFile);
  }
  FS_SetFileAttributes("Test.txt", FS_ATTR_READ_ONLY);
  r = FS_Move("Test.txt", "TestOld.txt");
  if (r != 0) {
    //
    // A file marked as read-only cannot be moved to another location.
    //
  }
}
```

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4.13.5 FS_FAT_DisableLFN()

Description

Disables the support for long file names.

Prototype

```
void FS_FAT_DisableLFN(void);
```

Additional information

After calling this function the file system accepts only file and directory names in 8.3 format. Files and directories created with support for long file names enabled are still accessible since each long file name has an associated name in 8.3 format. The short name is automatically generated by the file system based on the first characters of the long name and a sequential index. The support for long file names can be activated via `FS_FAT_SupportLFN()`.

This function applies only to volumes formatted as FAT. EFS-formatted volumes have native support for long file names.

Example

```
#include "FS.h"

void SampleFATDisableLFN(void) {
  FS_FILE * pFile;

  FS_Init();
#if FS_SUPPORT_FAT
  FS_FAT_DisableLFN();
#endif
  pFile = FS_FOpen("FileName.txt", "w");
  if (pFile) {
    FS_FClose(pFile);
  }
}
```

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4.13.6 FS_FAT_FormatSD()

Description

Performs a high-level format as per SD Specification.

Prototype

```
int FS_FAT_FormatSD(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be formatted.

Return value

= 0 OK, format successful.
≠ 0 Error code indicating the failure reason.

Additional information

The SD Specification defines a layout for the information that is stored to an SD, SDHC or SDXC card that ensures the best read and write performance. The layout of the information is set during the format operation and takes advantage of the physical structure of the storage device being formatted in order to optimize the access to it. `FS_FAT_FormatSD()` formats the storage device using this layout.

SEGGER recommends formatting an SD card or an eMMC device using this function for improved file system performance. `FS_FAT_FormatSD()` can be used as well to format other types of storage devices.

Typically, `FS_FAT_FormatSD()` reserves more space for the file system management information in comparison to `FS_Format()`. For this reason, slightly less storage space will be available for the application when formatting using `FS_FAT_FormatSD()`.

`FS_FAT_FormatSD()` performs the following operations:

- Creates a Master Boot Record (MBR) if it does not exist.
- Stores information about the partition to the first entry of MBR.
- Formats the storage device as either FAT12, FAT16 or FAT32 depending on its capacity.

The type of FAT formatting used depends on the capacity of the storage device. The following table shows this relationship.

FAT type
FAT12
FAT16
FAT32

The function is available only if the file system is built with the `FS_SUPPORT_FAT` configuration define set to 1.

Deprecated name

`FS_FormatSD`

Example

```
#include "FS.h"

void SampleFATFormatSD(void) {
  FS_Init();
#if FS_SUPPORT_FAT
```

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```
  FS_FAT_FormatSD("");
#endif
}
```

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4.13.7 FS_FAT_GetConfig()

Description

Returns information about how the FAT component is configured to operate.

Prototype

```
int FS_FAT_GetConfig(FS_FAT_CONFIG * pConfig);
```

Parameters

Parameter	Description
pConfig	out Configuration information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

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4.13.8 FS_FAT_GetLFNConverter()

Description

Returns the type of configured file name converter.

Prototype

```
const FS_UNICODE_CONV *FS_FAT_GetLFNConverter(void);
```

Return value

Configured file name converter.

Additional information

This function is available only if `FS_SUPPORT_FILE_NAME_ENCODING` is set to 1 which is the default. Refer to `pUnicodeConv` parameter of `FS_FAT_SetLFNConverter()` for a list of possible return values.

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4.13.9 FS_FAT_GrowRootDir()

Description

Increases the size of the root directory.

Prototype

```
U32 FS_FAT_GrowRootDir(const char * sVolumeName,
                       U32    NumAddEntries);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which to increase the root directory.
NumAddEntries	Number of directory entries to be added.

Return value

> 0	Number of entries added.
= 0	Clusters after root directory are not free. The number of entries in the root directory has not been changed.
= 0xFFFFFFFF	An error occurred.

Additional information

The formatting function allocates per default one cluster for the root directory of a FAT32 formatted volume. The file system increases automatically the size of the root directory as more files are added to it. This operation has a certain overhead that depends on the size of the allocation table and on the available free space. This overhead can be eliminated by calling FS_FAT_GrowRootDir() to increase the size of the root directory to the number of files and directories the application is expected to store in it.

This function increases the size of the root directory on a FAT32 formatted volume by the number of entries specified in NumAddEntries. The file system allocates one directory entry for each file or directory if the support for long file names is not enabled. With the support for long file names enabled the number of directory entries allocated to a file or directory depends on the number of characters in the name of the created file or directory.

This function fails if one of the following conditions is true:

- the function is not called immediately after the format operation.
- the specified volume is formatted as FAT12 or FAT16.
- the required number of clusters cannot be allocated following the cluster already allocated to the root directory.

FS_FAT_GrowRootDir() is available only if the compile-time option FS_SUPPORT_FAT set to 1.

Example

```
#include "FS.h"

void SampleFATGrowRootDir(void) {
  FS_Format("", NULL);
#if FS_SUPPORT_FAT
  FS_FAT_GrowRootDir("", 64);
#endif
}
```

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4.13.10 FS_FAT_SetLFNConverter()

Description

Configures how long file names are to be encoded and decoded.

Prototype

```
void FS_FAT_SetLFNConverter(const FS_UNICODE_CONV * pUnicodeConv);
```

Parameters

Parameter	Description
pUnicodeConv	File name converter.

Additional information

This function is available only if FS_SUPPORT_FILE_NAME_ENCODING is set to 1 which is the default.

Permitted values for pUnicodeConv are:

Identifier
FS_UNICODE_CONV_CP437
FS_UNICODE_CONV_CP932
FS_UNICODE_CONV_CP936
FS_UNICODE_CONV_CP949
FS_UNICODE_CONV_CP950
FS_UNICODE_CONV_UTF8

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4.13.11 FS_FAT_SupportLFN()

Description

Enables the support for long file names.

Prototype

```
void FS_FAT_SupportLFN(void);
```

Additional information

The file system accepts per default only file and directory names in 8.3 format, that is maximum 8 characters in the base name of a file, an optional period character, and an optional extension of maximum 3 characters. The application can call `FS_FAT_SupportLFN()` to enable the file system to work with names for files and directories longer that in the 8.3 format.

This function applies only to volumes formatted as FAT. EFS-formatted volumes have native support for long file names.

Example

```
#include "FS.h"

void SampleFATSupportLFN(void) {
  FS_FILE * pFile;

  FS_Init();
#if FS_SUPPORT_FAT
  FS_FAT_SupportLFN();
#endif
  pFile = FS_FOpen("This is an unusually long file name", "w");
  if (pFile) {
    FS_FClose(pFile);
  }
}
```

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4.13.12 FS_FAT_CONFIG

Description

Information about the FAT configuration.

Type definition

```
typedef struct {
  U8  IsLFNSupported;
  U8  IsFSInfoSectorUsed;
  U8  IsATCopyMaintained;
  U8  IsROFileMovePermitted;
  U8  IsDirtyFlagUpdated;
  U8  IsFAT32Supported;
  U8  IsDeleteOptimized;
  U8  LinearAccessOptimizationLevel;
  U8  IsFreeClusterCacheSupported;
  U8  IsLowerCaseSFNSupported;
} FS_FAT_CONFIG;
```

Structure members

Member	Description
IsLFNSupported	Indicates if the support for long file names is enabled.
IsFSInfoSectorUsed	Indicates if the information about the free clusters is read from the FSInfo sector.
IsATCopyMaintained	Indicates if the copy of the allocation table is update.
IsROFileMovePermitted	Indicates if the file system is allowed to move file that have the read-only attribute set.
IsDirtyFlagUpdated	Indicates if the updates the dirty flag in the BPB sector.
IsFAT32Supported	Indicates if the support for FAT32 formatted volumes is enabled.
IsDeleteOptimized	Indicates if the optimization for the deletion of large files is enabled.
LinearAccessOptimizationLevel	Optimization level for the access to linearly allocated files.
IsFreeClusterCacheSupported	Indicates if the support for the cache of free clusters is enabled.
IsLowerCaseSFNSupported	Indicates if the optimization for storing of short file names in lower case is enabled.

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4.14 EFS related functions

The functions described in this section can be used only on volumes formatted as EFS.

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4.14.1 FS_EFS_ConfigCaseSensitivity()

Description

Configures how the file names are compared.

Prototype

```
void FS_EFS_ConfigCaseSensitivity(int OnOff);
```

Parameters

Parameter	Description
OnOff	Specifies if the case of a character is important or not. • 1 Character case is important. • 0 Character case is ignored.

Additional information

This function is optional and is active only when the file system is compiled with FS_EFS_CASE_SENSITIVE set to 1. By default the EFS file system layer ignores the case of a character in file names when it compares two file names. That is, “testfile.txt”, “TestFile.txt” and “TESTFILE.TXT” represent the same file name. The case of a file name is preserved when the file is created via FS_FOpen() or FS_FOpenEx() or in case of a directory when FS_MkDir() and FS_CreateDir() is called to create one.

If the case sensitivity is enabled by calling FS_EFS_ConfigCaseSensitivity() with the OnOff parameter set to 1 than “testfile.txt”, “TestFile.txt” and “TESTFILE.TXT” are three different file names.

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4.14.2 FS_EFS_ConfigStatusSectorSupport()

Description

Enables or disables the usage of information from the status sector.

Prototype

```
void FS_EFS_ConfigStatusSectorSupport(int OnOff);
```

Parameters

Parameter	Description
OnOff	Specifies if the status sector information has to be used or not. • 1 Status sector information is used. • 0 Status sector information is not used.

Additional information

This function is optional an is active only when the file system is compiled with FS_EFS_SUPPORT_STATUS_SECTOR set to 1. The status sector stores information about the free space available on the storage which helps the file system improve the performance of the operations that return the available free space such as FS_GetVolumeInfo().

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4.14.3 FS_EFS_GetConfig()

Description

Returns information about how the EFS component is configured to operate.

Prototype

```
int FS_EFS_GetConfig(FS_EFS_CONFIG * pConfig);
```

Parameters

Parameter	Description
pConfig	out Configuration information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

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4.14.4 FS_EFS_SetFileNameConverter()

Description

Configures how file names are to be encoded.

Prototype

```
void FS_EFS_SetFileNameConverter(const FS_UNICODE_CONV * pUnicodeConv);
```

Parameters

Parameter	Description
pUnicodeConv	File name converter.

Additional information

This function is available only if FS_SUPPORT_FILE_NAME_ENCODING is set to 1. By default, FS_SUPPORT_FILE_NAME_ENCODING is set to 0 in order to reduce the RAM and ROM usage.

Permitted values for pUnicodeConv are:

Identifier
FS_UNICODE_CONV_UTF8

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4.14.5 FS_EFS_CONFIG

Description

Information about the EFS configuration.

Type definition

```
typedef struct {
  U8  IsStatusSectorSupported;
  U8  IsCaseSensitiveName;
  U8  IsDirEntryBufferSupported;
  U8  NumDirEntryBuffers;
  U8  IsDeleteOptimized;
  U8  LinearAccessOptimizationLevel;
  U8  IsFreeClusterCacheSupported;
  U8  MaxDirEntrySize;
} FS_EFS_CONFIG;
```

Structure members

Member	Description
IsStatusSectorSupported	Indicates if the information of the status sector is updated.
IsCaseSensitiveName	Indicates if the comparison of file names is case sensitive.
IsDirEntryBufferSupported	Indicates if the support for directory entry buffers is enabled.
NumDirEntryBuffers	Number of configured directory entry buffers.
IsDeleteOptimized	Indicates if the optimization for the deletion of large files is enabled.
LinearAccessOptimizationLevel	Optimization level for the access to linearly allocated files.
IsFreeClusterCacheSupported	Indicates if the support for the cache of free clusters is enabled.
MaxDirEntrySize	Maximum number of bytes in a directory entry.

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4.15 exFAT-related functions

The functions described in this section can be used only on volumes formatted as exFAT.

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4.15.1 FS_EXFAT_ConfigDirtyFlagUpdate()

Description

Enables or disables the update of the flag that indicates if the volume has been unmounted correctly.

Prototype

```
void FS_EXFAT_ConfigDirtyFlagUpdate(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

If enabled, the file system updates an internal dirty flag that is set to 1 each time data is written to storage device. The dirty flag is set to 0 when the application unmounts the file system. The value of the dirty flag is updated to storage device and can be used to check if the storage device has been properly unmounted before the system reset. `FS_GetVolumeInfo()` can be used to get the value of this dirty flag (IsDirty member of `FS_DISK_INFO`).

The update of the dirty flag is enabled by default if the compile-time option `FS_EXFAT_UPDATE_DIRTY_FLAG` is set to 1. `FS_EXFAT_ConfigDirtyFlagUpdate()` is available only if the compile-time option `FS_EXFAT_UPDATE_DIRTY_FLAG` is set to 1.

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4.15.2 FS_EXFAT_ConfigROFileMovePermission()

Description

Enables / disables the permission to move (and rename) files and directories with the read-only file attribute set.

Prototype

```
void FS_EXFAT_ConfigROFileMovePermission(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

The application is per default allowed to move or rename via FS_Move() and FS_Rename() respectively files and directories that have the read-only file attribute (FS_ATTR_READ_ONLY) set. FS_EXFAT_ConfigROFileMovePermission() can be used to disable this option and thus to prevent an application to perform move or rename operations on files and directories marked as read-only.

FS_EXFAT_ConfigROFileMovePermission() is available only if the compile-time option FS_EXFAT_PERMIT_RO_FILE_MOVE is set to 1.

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4.15.3 FS_EXFAT_ConfigSpaceUsageUpdate()

Description

Enables or disables the update of the storage usage.

Prototype

```
void FS_EXFAT_ConfigSpaceUsageUpdate(int OnOff);
```

Parameters

Parameter	Description
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

If enabled, the file system updates the information about the amount of storage used by the file system in the boot sector of the volume.

The update of the usage information is enabled by default if the compile-time option FS_EXFAT_UPDATE_SPACE_USAGE is set to 1. FS_EXFAT_ConfigSpaceUsageUpdate() is available only if the compile-time option FS_EXFAT_UPDATE_SPACE_USAGE is set to 1.

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4.15.4 FS_EXFAT_FormatSD()

Description

Performs a high-level format as per SD Specification.

Prototype

```
int FS_EXFAT_FormatSD(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be formatted.

Return value

= 0 OK, format successful.
≠ 0 Error code indicating the failure reason.

Additional information

The SD Standard defines a layout for the information that is stored to an SD, SDHC or SDXC card that ensures the best read and write performance. The layout of the information is set during the format operation and takes advantage of the physical structure of the storage device being formatted in order to optimize the access to it. FS_EXFAT_FormatSD() formats the storage device using this layout.

SEGGER recommends formatting an SD card or an eMMC device using this function for improved file system performance. FS_EXFAT_FormatSD() can be used to format other types of storage devices as well.

Typically, FS_EXFAT_FormatSD() reserves more space for the file system management information in comparison to FS_Format(). For this reason, slightly less storage space will be available for the application when formatting using FS_EXFAT_FormatSD().

FS_EXFAT_FormatSD() performs the following operations:

- Creates a Master Boot Record (MBR) if it does not exist.
- Stores information about the partition to the first entry of MBR.
- Formats the partition as exFAT.

The function is available only if the file system is built with the FS_SUPPORT_EXFAT configuration define set to 1.

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4.15.5 FS_EXFAT_GetConfig()

Description

Returns information about how the exFAT component is configured to operate.

Prototype

```
int FS_EXFAT_GetConfig(FS_EXFAT_CONFIG * pConfig);
```

Parameters

Parameter	Description
pConfig	out Configuration information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

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4.15.6 FS_EXFAT_GetFileNameConverter()

Description

Returns the type of configured file name converter.

Prototype

```
const FS_UNICODE_CONV *FS_EXFAT_GetFileNameConverter(void);
```

Return value

Configured file name converter.

Additional information

This function is available only if `FS_SUPPORT_FILE_NAME_ENCODING` is set to 1 which is the default. Refer to `pUnicodeConv` parameter of `FS_EXFAT_SetFileNameConverter()` for a list of possible return values.

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4.15.7 FS_EXFAT_GrowRootDir()

Description

Increases the size of the root directory.

Prototype

```
U32 FS_EXFAT_GrowRootDir(const char * sVolumeName,
                         U32    NumAddEntries);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which to increase the root directory.
NumAddEntries	Number of directory entries to be added.

Return value

> 0	Number of entries added.
= 0	Clusters after root directory are not free. The number of entries in the root directory has not been changed.
= 0xFFFFFFFF	An error occurred.

Additional information

The formatting function allocates by default one cluster for the root directory of a formatted volume. The file system increases automatically the size of the root directory as more files are added to it. This operation has a certain overhead that depends on the size of the allocation table and on the available free space. This overhead can be eliminated by calling FS_EXFAT_GrowRootDir() to increase the size of the root directory to the number of files and directories the application is expected to store in it.

This function increases the size of the root directory on a formatted volume by the number of entries specified in NumAddEntries. The file system allocates one directory entry for each file or directory if the support for long file names is not enabled. With the support for long file names enabled the number of directory entries allocated to a file or directory depends on the number of characters in the name of the created file or directory.

This function fails if one of the following conditions is true:

- the function is not called immediately after the format operation.
- the required number of clusters cannot be allocated following the cluster already allocated to the root directory.

FS_EXFAT_GrowRootDir() is available only if the compile-time option FS_SUPPORT_EXFAT set to 1.

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4.15.8 FS_EXFAT_ReadOEMPara()

Description

Obtains information about one or more OEM parameters.

Prototype

```
int FS_EXFAT_ReadOEMPara(const char              * sVolumeName,
                         unsigned                  ParaIndex,
                         unsigned                  NumPara,
                         FS_EXFAT_OEM_PARA       * pPara);
```

Parameters

Parameter	Description
sVolumeName	in Name of the volume that stores the OEM parameters.
ParaIndex	Index of the first OEM parameter to be read.
NumPara	Number of OEM parameters to be read.
pPara	out Read OEM parameters.

Return value

= 0 OK, OEM parameters read successfully.
≠ 0 Error code indicating the failure reason.

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4.15.9 FS_EXFAT_SetFileNameConverter()

Description

Configures how long file names are to be encoded and decoded.

Prototype

```
void FS_EXFAT_SetFileNameConverter(const FS_UNICODE_CONV * pUnicodeConv);
```

Parameters

Parameter	Description
pUnicodeConv	File name converter.

Additional information

This function is available only if FS_SUPPORT_FILE_NAME_ENCODING is set to 1 which is the default.

Permitted values for pUnicodeConv are:

Identifier
FS_UNICODE_CONV_CP437
FS_UNICODE_CONV_CP932
FS_UNICODE_CONV_CP936
FS_UNICODE_CONV_CP949
FS_UNICODE_CONV_CP950
FS_UNICODE_CONV_UTF8

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4.15.10 FS_EXFAT_WriteOEMPara()

Description

Modifies the information of one or more OEM parameters.

Prototype

```
int FS_EXFAT_WriteOEMPara(const char              * sVolumeName,
                                unsigned            ParaIndex,
                                unsigned            NumPara,
                          const FS_EXFAT_OEM_PARA * pPara);
```

Parameters

Parameter	Description
sVolumeName	in Name of the volume that stores the OEM parameters.
ParaIndex	Index of the first OEM parameter to be written.
NumPara	Number of OEM parameters to be written.
pPara	in OEM parameters to be written.

Return value

= 0 OK, OEM parameters written successfully.
≠ 0 Error code indicating the failure reason.

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4.15.11 FS_EXFAT_CONFIG

Description

Information about the exFAT configuration.

Type definition

```
typedef struct {
  U8  IsSpaceUsageUpdated;
  U8  IsROFileMovePermitted;
  U8  IsDirtyFlagUpdated;
  U8  IsDeleteOptimized;
  U8  LinearAccessOptimizationLevel;
  U8  IsFreeClusterCacheSupported;
} FS_EXFAT_CONFIG;
```

Structure members

Member	Description
IsSpaceUsageUpdated	Indicates if the information about storage usage is updated in the boot sector.
IsROFileMovePermitted	Indicates if the file system is allowed to move file that have the read-only attribute set.
IsDirtyFlagUpdated	Indicates if the updates the dirty flag in the BPB sector.
IsDeleteOptimized	Indicates if the optimization for the deletion of large files is enabled.
LinearAccessOptimizationLevel	Optimization level for the access to linearly allocated files.
IsFreeClusterCacheSupported	Indicates if the support for the cache of free clusters is enabled.

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4.15.12 FS_EXFAT_OEM_PARA

Description

Information about an OEM parameter.

Type definition

```
typedef struct {
  U8  abGUID[];
  U8  abData[];
} FS_EXFAT_OEM_PARA;
```

Structure members

Member	Description
abGUID	Parameter identifier.
abData	Parameter value.

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4.16 Error-handling functions

An application can use the following functions to check and clear the error status of a file handle.

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4.16.1 FS_ClearErr()

Description

Clears error status of a file handle.

Prototype

```
void FS_ClearErr(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Additional information

The function sets the error status of a file handle to FS_ERRCODE_OK. FS_ClearErr() is the only function that clears the error status of a file handle. The other API functions modify the error status of a file handle only if it is cleared. The application has to call this function after it detects that an error occurred during a file system operation on an opened file handle and before it starts a new file system operation if it wants to get the correct error status in case of a failure.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleClearErr(void) {
  FS_FILE * pFile;
  U32       aBuffer[32 / 4];
  int       ErrCode;
  char      ac[100];
  U32       NumBytesRead;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    NumBytesRead = FS_Read(pFile, aBuffer, sizeof(aBuffer));
    ErrCode = FS_FError(pFile);
    if (ErrCode == FS_ERRCODE_OK) {
      SEGGER_snprintf(ac, sizeof(ac), "First read operation failed with: %d (%s)\n",
        ErrCode, FS_ErrorNo2Text(ErrCode));
      FS_X_Log(ac);
      FS_ClearErr(pFile);
    } else {
      SEGGER_snprintf(ac, sizeof(ac), "The first operation read %lu bytes from file.\n",
        NumBytesRead);
      FS_X_Log(ac);
    }
    NumBytesRead = FS_Read(pFile, aBuffer, sizeof(aBuffer));
    ErrCode = FS_FError(pFile);
    if (ErrCode != FS_ERRCODE_OK) {
      SEGGER_snprintf(ac, sizeof(ac), "Second read operation failed with: %d (%s)\n",
        ErrCode, FS_ErrorNo2Text(ErrCode));
      FS_X_Log(ac);
      FS_ClearErr(pFile);
    } else {
      SEGGER_snprintf(ac, sizeof(ac), "The second operation read %lu bytes from file.\n",
        NumBytesRead);
      FS_X_Log(ac);
    }
    FS_FClose(pFile);
  }
}
```

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4.16.2 FS_ErrorNo2Text()

Description

Returns a human-readable text description of an API error code.

Prototype

```
const char *FS_ErrorNo2Text(int ErrCode);
```

Parameters

Parameter	Description
ErrCode	Error code for which the text description has to be returned.

Return value

The text description as 0-terminated ASCII string.

Additional information

For a list of supported error codes refer to *Error codes* on page 413. If the error code is not known `FS_ErrorNo2Text()` returns the "Unknown error" string. The error status of an opened file handle can be queried via `FS_FError()`. Most of the API functions of the file system also return one of the defined codes in case of an error. This error code can be passed to `FS_ErrorNo2Text()` to get a human-readable text description.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleErrorNo2Text(void) {
  FS_FILE * pFile;
  int       r;
  char      ac[100];

  r = FS_FOpenEx("Test.txt", "r", &pFile);
  if (r) {
    SEGGER_snprintf(ac, sizeof(ac),
      "The file open operation failed with: %d (%s)\n", r, FS_ErrorNo2Text(r));
    FS_X_Log(ac);
  } else {
    //
    // Access the file contents...
    //
    FS_FClose(pFile);
  }
}
```

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4.16.3 FS_FEof()

Description

Returns if end of file has been reached.

Prototype

```
int FS_FEof(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

= 1 An attempt was made to read beyond the end of the file.
= 0 The end of file has not been reached.
< 0 An error occurred.

Additional information

The end-of-file flag of the file handle is set by the file system when the application tries to read more bytes than available in the file. This is not an error condition but just an indication that the file pointer is positioned beyond the last byte in the file and that by trying to read from this position no bytes are returned.

Example

```
#include "FS.h"

void SampleFEof(void) {
  FS_FILE * pFile;
  U32       aBuffer[32 / 4];
  int       r;
  int       ErrCode;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    while (1) {
      FS_Read(pFile, aBuffer, sizeof(aBuffer));
      if (FS_FEof(pFile)) {
        break;                  // End of file reached.
      }
      ErrCode = FS_FError(pFile);
      if (ErrCode) {
        break;                  // An error occurred while reading from file.
      }
    }
    FS_FClose(pFile);
  }
}
```

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4.16.4 FS_FError()

Description

Returns error status of a file handle.

Prototype

```
I16 FS_FError(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to opened file.

Return value

= FS_ERRCODE_OK	No error present.
≠ FS_ERRCODE_OK	An error has occurred.

Additional information

The application can use this function to check what kind of error caused an API function that does not return an error code such as FS_Read(), FS_FRead(), FS_Write() or FS_FWrite() to fail. The error status remains set until the application calls FS_ClearErr().

FS_ErrorNo2Text() can be used to return a human-readable description of the error as a 0-terminated string.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleFError(void) {
  FS_FILE * pFile;
  U32       aBuffer[32 / 4];
  int       ErrCode;
  char      ac[100];
  U32       NumBytesRead;

  pFile = FS_FOpen("Test.txt", "r");
  if (pFile) {
    NumBytesRead = FS_Read(pFile, aBuffer, sizeof(aBuffer));
    ErrCode = FS_FError(pFile);
    if (ErrCode != FS_ERRCODE_OK) {
      SEGGER_snprintf(ac, sizeof(ac), "The read operation failed with: %d (%s)\n",
        ErrCode, FS_ErrorNo2Text(ErrCode));
      FS_X_Log(ac);
      FS_ClearErr(pFile);
    } else {
      SEGGER_snprintf(ac, sizeof(ac), "The operation read %lu bytes from file.\n",
        NumBytesRead);
      FS_X_Log(ac);
    }
    FS_FClose(pFile);
  }
}
```

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4.16.5 Error codes

Description

Values returned by the API functions to indicate the reason of an error.

Definition

```
#define FS_ERRCODE_OK                          0
#define FS_ERRCODE_EOF                         (-1)
#define FS_ERRCODE_PATH_TOO_LONG               (-2)
#define FS_ERRCODE_INVALID_PARA                (-3)
#define FS_ERRCODE_WRITE_ONLY_FILE             (-5)
#define FS_ERRCODE_READ_ONLY_FILE              (-6)
#define FS_ERRCODE_READ_FAILURE                (-7)
#define FS_ERRCODE_WRITE_FAILURE               (-8)
#define FS_ERRCODE_FILE_IS_OPEN                (-9)
#define FS_ERRCODE_PATH_NOT_FOUND              (-10)
#define FS_ERRCODE_FILE_DIR_EXISTS             (-11)
#define FS_ERRCODE_NOT_A_FILE                  (-12)
#define FS_ERRCODE_TOO_MANY_FILES_OPEN         (-13)
#define FS_ERRCODE_INVALID_FILE_HANDLE         (-14)
#define FS_ERRCODE_VOLUME_NOT_FOUND            (-15)
#define FS_ERRCODE_READ_ONLY_VOLUME            (-16)
#define FS_ERRCODE_VOLUME_NOT_MOUNTED          (-17)
#define FS_ERRCODE_NOT_A_DIR                   (-18)
#define FS_ERRCODE_FILE_DIR_NOT_FOUND          (-19)
#define FS_ERRCODE_NOT_SUPPORTED               (-20)
#define FS_ERRCODE_CLUSTER_NOT_FREE            (-21)
#define FS_ERRCODE_INVALID_CLUSTER_CHAIN       (-22)
#define FS_ERRCODE_STORAGE_NOT_PRESENT         (-23)
#define FS_ERRCODE_BUFFER_NOT_AVAILABLE        (-24)
#define FS_ERRCODE_STORAGE_TOO_SMALL           (-25)
#define FS_ERRCODE_STORAGE_NOT_READY           (-26)
#define FS_ERRCODE_BUFFER_TOO_SMALL            (-27)
#define FS_ERRCODE_INVALID_FS_FORMAT           (-28)
#define FS_ERRCODE_INVALID_FS_TYPE             (-29)
#define FS_ERRCODE_FILENAME_TOO_LONG           (-30)
#define FS_ERRCODE_VERIFY_FAILURE              (-31)
#define FS_ERRCODE_VOLUME_FULL                 (-32)
#define FS_ERRCODE_DIR_NOT_EMPTY               (-33)
#define FS_ERRCODE_IOCTL_FAILURE               (-34)
#define FS_ERRCODE_INVALID_MBR                 (-35)
#define FS_ERRCODE_OUT_OF_MEMORY               (-36)
#define FS_ERRCODE_UNKNOWN_DEVICE              (-37)
#define FS_ERRCODE_ASSERT_FAILURE              (-38)
#define FS_ERRCODE_TOO_MANY_TRANSACTIONS_OPEN  (-39)
#define FS_ERRCODE_NO_OPEN_TRANSACTION         (-40)
#define FS_ERRCODE_INIT_FAILURE                (-41)
#define FS_ERRCODE_FILE_TOO_LARGE              (-42)
#define FS_ERRCODE_INVALID_CONFIG              (-43)
#define FS_ERRCODE_INVALID_USAGE               (-44)
#define FS_ERRCODE_TOO_MANY_INSTANCES          (-45)
#define FS_ERRCODE_TRANSACTION_ABORTED         (-46)
#define FS_ERRCODE_INVALID_CHAR                (-47)
#define FS_ERRCODE_INVALID_GPT                 (-48)
#define FS_ERRCODE_INVALID_CONTENT             (-49)
#define FS_ERRCODE_COMPRESS_FAILURE            (-50)
#define FS_ERRCODE_CRYPT_FAILURE               (-51)
#define FS_ERRCODE_INVALID_DIR                 (-52)
#define FS_ERRCODE_DEFECTIVE_STORAGE           (-53)
#define FS_ERRCODE_ERASE_FAILURE               (-54)
#define FS_ERRCODE_PERMANENT_FAILURE           (-55)
```

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Symbols

Definition	Description
FS_ERRCODE_OK	No error
FS_ERRCODE_EOF	End of file reached
FS_ERRCODE_PATH_TOO_LONG	Path to file or directory is too long
FS_ERRCODE_INVALID_PARA	Invalid parameter passed
FS_ERRCODE_WRITE_ONLY_FILE	File can only be written
FS_ERRCODE_READ_ONLY_FILE	File can not be written
FS_ERRCODE_READ_FAILURE	Error while reading from storage device
FS_ERRCODE_WRITE_FAILURE	Error while writing to storage device
FS_ERRCODE_FILE_IS_OPEN	Trying to delete a file which is open
FS_ERRCODE_PATH_NOT_FOUND	Path to file or directory not found
FS_ERRCODE_FILE_DIR_EXISTS	File or directory already exists
FS_ERRCODE_NOT_A_FILE	Trying to open a directory instead of a file
FS_ERRCODE_TOO_MANY_FILES_OPEN	Exceeded number of files opened at once
FS_ERRCODE_INVALID_FILE_HANDLE	The file handle has been invalidated
FS_ERRCODE_VOLUME_NOT_FOUND	The volume name specified in a path is does not exist
FS_ERRCODE_READ_ONLY_VOLUME	Trying to write to a volume mounted in read-only mode
FS_ERRCODE_VOLUME_NOT_MOUNTED	Trying access a volume which is not mounted
FS_ERRCODE_NOT_A_DIR	Trying to open a file instead of a directory
FS_ERRCODE_FILE_DIR_NOT_FOUND	File or directory not found
FS_ERRCODE_NOT_SUPPORTED	Functionality not supported
FS_ERRCODE_CLUSTER_NOT_FREE	Trying to allocate a cluster which is not free
FS_ERRCODE_INVALID_CLUSTER_CHAIN	Detected a shorter than expected cluster chain
FS_ERRCODE_STORAGE_NOT_PRESENT	Trying to access a removable storage which is not inserted
FS_ERRCODE_BUFFER_NOT_AVAILABLE	No more sector buffers available
FS_ERRCODE_STORAGE_TOO_SMALL	Not enough sectors on the storage device
FS_ERRCODE_STORAGE_NOT_READY	Storage device can not be accessed

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Definition	Description
FS_ERRCODE_BUFFER_TOO_SMALL	Sector buffer smaller than sector size of storage device
FS_ERRCODE_INVALID_FS_FORMAT	Storage device is not formatted or the format is not valid
FS_ERRCODE_INVALID_FS_TYPE	Type of file system is invalid or not configured
FS_ERRCODE_FILENAME_TOO_LONG	The name of the file is too long
FS_ERRCODE_VERIFY_FAILURE	Data verification failure
FS_ERRCODE_VOLUME_FULL	No more space on storage device
FS_ERRCODE_DIR_NOT_EMPTY	Trying to delete a directory which is not empty
FS_ERRCODE_IOCTL_FAILURE	Error while executing a driver control command
FS_ERRCODE_INVALID_MBR	Invalid information in the Master Boot Record
FS_ERRCODE_OUT_OF_MEMORY	Could not allocate memory
FS_ERRCODE_UNKNOWN_DEVICE	Storage device is not configured
FS_ERRCODE_ASSERT_FAILURE	FS_DEBUG_ASSERT() macro failed
FS_ERRCODE_TOO_MANY_TRANSACTIONS_OPEN	Maximum number of opened journal transactions exceeded
FS_ERRCODE_NO_OPEN_TRANSACTION	Trying to close a journal transaction which is not opened
FS_ERRCODE_INIT_FAILURE	Error while initializing the storage medium
FS_ERRCODE_FILE_TOO_LARGE	Trying to write to a file which is larger than 4 Gbytes
FS_ERRCODE_INVALID_CONFIG	The file system is not configured correctly
FS_ERRCODE_INVALID_USAGE	Trying to call a function in an invalid state
FS_ERRCODE_TOO_MANY_INSTANCES	Trying to create one instance more than maximum configured
FS_ERRCODE_TRANSACTION_ABORTED	A journal transaction has been stopped by the application
FS_ERRCODE_INVALID_CHAR	Invalid character in the name of a file
FS_ERRCODE_INVALID_GPT	Invalid information in the GUID partition
FS_ERRCODE_INVALID_CONTENT	The content of a file is invalid
FS_ERRCODE_COMPRESS_FAILURE	Error while compressing or decompressing the data
FS_ERRCODE_CRYPT_FAILURE	Error while encrypting or decrypting the data

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Definition	Description
FS_ERRCODE_INVALID_DIR	Invalid directory contents
FS_ERRCODE_DEFECTIVE_S-TORAGE	Storage device is not working properly
FS_ERRCODE_ER-ASE_FAILURE	Error while erasing a storage device block
FS_ERRCODE_PERMANEN-T_FAILURE	Processing disabled because of a critical error

Additional information

The last error code of a file handle can be checked using `FS_FError()`.

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4.17 Configuration checking functions

The functions described in this section are useful to check at runtime how the file system has been configured at compile time.

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4.17.1 FS_CONF_GetDebugLevel()

Description

Returns the level of debug information configured for the file system.

Prototype

```
int FS_CONF_GetDebugLevel(void);
```

Return value

Value of `FS_DEBUG_LEVEL` configuration define.

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4.17.2 FS_CONF_GetDirectoryDelimiter()

Description

Returns the character that is configured as delimiter between the directory names in a file path.

Prototype

```
char FS_CONF_GetDirectoryDelimiter(void);
```

Return value

Value of `FS_DIRECTORY_DELIMITER` configuration define.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleCONFGetDirectoryDelimiter(void) {
  char ac[100];
  char Delim;

  Delim = FS_CONF_GetDirectoryDelimiter();
  SEGGER_snprintf(ac, sizeof(ac),
    "The '%c' character is used to delimit directory names in a path\n", Delim);
  FS_X_Log(ac);
}
```

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4.17.3 FS_CONF_GetMaxPath()

Description

Returns the configured maximum number of characters in a path to a file or directory.

Prototype

```
int FS_CONF_GetMaxPath(void);
```

Return value

Value of FS_MAX_PATH configuration define.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleCONFGetMaxPath(void) {
  char ac[100];
  int  NumChars;

  NumChars = FS_CONF_GetMaxPath();
  SEGGER_snprintf(ac, sizeof(ac),
    "The maximum number of characters in the path is: %d\n", NumChars);
  FS_X_Log(ac);
}
```

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4.17.4 FS_CONF_GetNumVolumes()

Description

Returns the maximum number of volumes configured for the file system.

Prototype

```
int FS_CONF_GetNumVolumes(void);
```

Return value

Returns the value of FS_NUM_VOLUMES configuration define.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleCONFGetNumVolumes(void) {
  char ac[100];
  int  NumVolumes;

  NumVolumes = FS_CONF_GetNumVolumes();
  SEGGER_snprintf(ac, sizeof(ac),
    "The maximum number of supported by Journal: %d\n", NumVolumes);
  FS_X_Log(ac);
}
```

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4.17.5 FS_CONF_GetOSLocking()

Description

Returns the type of task locking configured for the file system.

Prototype

```
int FS_CONF_GetOSLocking(void);
```

Return value

Value of FS_OS_LOCKING configuration define.

Example

```
#include "FS.h"

void SampleCONFGetOSLocking(void) {
  int LockingType;

  LockingType = FS_CONF_GetOSLocking();
  switch (LockingType) {
  case FS_OS_LOCKING_NONE:
    FS_X_Log("The file system is not locked against concurrent access.\n");
    break;
  case FS_OS_LOCKING_API:
    FS_X_Log("The file system is locked at API function level.\n");
    break;
  case FS_OS_LOCKING_DRIVER:
    FS_X_Log("The file system is locked at device driver level.\n");
    break;
  default:
    FS_X_Log("The type of locking is unknown.\n");
    break;
  }
}
```

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4.17.6 FS_CONF_IsCacheSupported()

Description

Checks if the file system is configured to support the sector cache.

Prototype

```
int FS_CONF_IsCacheSupported(void);
```

Return value

Value of FS_SUPPORT_CACHE configuration define.

Additional information

This function does not check if the sector cache is actually active. It only indicates if the file system has been compiled with support for sector cache. The sector cache has to be activated via FS_AssignCache().

Example

```
#include "FS.h"

void SampleCONFIsCacheSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsCacheSupported();
  if (IsSupported) {
    FS_X_Log("The sector cache is supported.\n");
  } else {
    FS_X_Log("The sector cache is not supported.\n");
  }
}
```

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4.17.7 FS_CONF_IsDeInitSupported()

Description

Checks if the file system is configured to support deinitialization.

Prototype

```
int FS_CONF_IsDeInitSupported(void);
```

Return value

Value of `FS_SUPPORT_DEINIT` configuration define.

Example

```
#include "FS.h"

void SampleCONFIsDeInitSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsDeInitSupported();
  if (IsSupported) {
    FS_X_Log("File system deinitialization is supported.\n");
  } else {
    FS_X_Log("File system deinitialization is not supported.\n");
  }
}
```

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4.17.8 FS_CONF_IsEFSSupported()

Description

Checks if the file system is configured to support the EFS file system.

Prototype

```
int FS_CONF_IsEFSSupported(void);
```

Return value

Value of `FS_SUPPORT_EFS` configuration define.

Example

```
#include "FS.h"

void SampleCONFIsEFSSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsEFSSupported();
  if (IsSupported) {
    FS_X_Log("The file system supports EFS.\n");
  } else {
    FS_X_Log("The file system does not support EFS.\n");
  }
}
```

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4.17.9 FS_CONF_IsEncryptionSupported()

Description

Checks if the file system is configured to support encryption.

Prototype

```
int FS_CONF_IsEncryptionSupported(void);
```

Return value

Value of `FS_SUPPORT_ENCRYPTION` configuration define.

Example

```
#include "FS.h"

void SampleCONFIsEncryptionSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsEncryptionSupported();
  if (IsSupported) {
    FS_X_Log("The file system supports encryption.\n");
  } else {
    FS_X_Log("The file system does not support encryption.\n");
  }
}
```

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4.17.10 FS_CONF_IsFATSupported()

Description

Checks if the file system is configured to support the FAT file system.

Prototype

```
int FS_CONF_IsFATSupported(void);
```

Return value

Value of FS_SUPPORT_FAT configuration define.

Example

```
#include "FS.h"

void SampleCONFIsFATSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsFATSupported();
  if (IsSupported) {
    FS_X_Log("The file system supports FAT.\n");
  } else {
    FS_X_Log("The file system does not support FAT.\n");
  }
}
```

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4.17.11 FS_CONF_IsFreeSectorSupported()

Description

Checks if the file system is configured to support the “free sector” command.

Prototype

```
int FS_CONF_IsFreeSectorSupported(void);
```

Return value

Value of `FS_SUPPORT_FREE_SECTOR` configuration define.

Example

```
#include "FS.h"

void SampleCONFIsFreeSectorSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsFreeSectorSupported();
  if (IsSupported) {
    FS_X_Log("The file system supports \"free sector\" operation.\n");
  } else {
    FS_X_Log("The file system does not support \"free sector\" operation.\n");
  }
}
```

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4.17.12 FS_CONF_IsJournalSupported()

Description

Checks if the file system is configured to support journaling.

Prototype

```
int FS_CONF_IsJournalSupported(void);
```

Return value

Value of FS_SUPPORT_JOURNAL configuration define.

Example

```
#include "FS.h"

void SampleCONFIsJournalSupported(void) {
  int IsSupported;

  IsSupported = FS_CONF_IsJournalSupported();
  if (IsSupported) {
    FS_X_Log("The file system supports journaling.\n");
  } else {
    FS_X_Log("The file system does not support journaling.\n");
  }
}
```

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4.17.13 FS_CONF_IsTrialVersion()

Description

Checks if the file system has been configured as a trial (limited) version.

Prototype

```
int FS_CONF_IsTrialVersion(void);
```

Return value

= 0	Full version.
≠ 0	Trial version.

Example

```
#include "FS.h"

void SampleCONFIsTrialVersion(void) {
  int IsTrial;

  IsTrial = FS_CONF_IsTrialVersion();
  if (IsTrial) {
    FS_X_Log("This is a trial version of emFile.\n");
  } else {
    FS_X_Log("This is a full-featured version of emFile.\n");
  }
}
```

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4.17.14 FS_GetVersion()

Description

Returns the version number of the file system.

Prototype

```
U32 FS_GetVersion(void);
```

Return value

Version number.

Additional information

The version is formatted as follows: `Mmmrr`

where:

- `M` the major version number
- `mm` the minor version number
- `rr` the revision number

For example 40201 represents the version 4.02a (major version: 4, minor version: 2, revision: a)

Example

```
#include <stdio.h>
#include "FS.h"

void SampleGetVersion(void) {
  int  Version;
  int  MajorVersion;
  int  MinorVersion;
  char PatchVersion;
  char ac[100];

  Version = FS_GetVersion();
  MajorVersion = Version / 10000;
  MinorVersion = Version / 100 % 100;
  PatchVersion = Version % 100;
  SEGGER_snprintf(ac, sizeof(ac), "This is the version %d.%d.%d of emFile.\n",
    MajorVersion, MinorVersion, PatchVersion);
  FS_X_Log(ac);
}
```

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4.18 Path processing functions

This section describes functions that can be used to manipulate a path to a file or directory.

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4.18.1 FS_GetPathBaseName()

Description

Returns the name of the target file or directory with the extension removed.

Prototype

```
int FS_GetPathBaseName(const char     * sPath,
                       char     * pBaseName,
                       unsigned   SizeOfBaseName);
```

Parameters

Parameter	Description
sPath	in Path to the file or directory (0-terminated string). It cannot be set to NULL.
pBaseName	out The basename of the file or directory as 0-terminated string. It can be set to NULL.
SizeOfBaseName	Number of bytes in pBaseName. It can be set to 0.

Return value

> 0	Length of the basename in bytes.
< 0	An error occurred.

Additional information

The function returns the length of the basename excluding the 0-terminator irrespective of whether pBaseName is sufficiently large to store the basename or not. If pBaseName is not sufficiently large to store the basename including the 0-terminator, then the basename stored in pBaseName is truncated. The application can check for this condition by comparing the returned value with the value of SizeOfBaseName. If the returned value is greater than or equal to SizeOfBaseName, then the basename stored to pBaseName is truncated. In any of the above cases, the basename stored to pBaseName is 0-terminated.

The following tables show some usage examples.

Parameter
sPath
pBaseName
SizeOfBaseName
Result

Parameter
sPath
pBaseName
SizeOfBaseName
Result

Parameter
sPath
pBaseName
SizeOfBaseName
Result

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Parameter
sPath
pBaseName
SizeOfBaseName
Result

Parameter
sPath
pBaseName
SizeOfBaseName
Result

Parameter
sPath
pBaseName
SizeOfBaseName
Result

Parameter
sPath
pBaseName
SizeOfBaseName
Result

Example

```
#include "FS.h"

void SampleGetPathBaseName(void) {
  char acBaseName[32];

  FS_GetPathBaseName("nand:0:\\SubDir\\File.txt", acBaseName, sizeof(acBaseName));
}
```

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4.18.2 FS_GetPathDirName()

Description

Returns the path to a target file or directory with the volume name, base name, and extension removed.

Prototype

```
int FS_GetPathDirName(const char     * sPath,
                      char     * pDirName,
                      unsigned   SizeOfDirName);
```

Parameters

Parameter	Description
sPath	in Path to the file or directory (0-terminated string). It cannot be set to NULL.
pDirName	out The path to the file or directory as 0-terminated string. It can be set to NULL.
SizeOfDirName	Number of bytes in pDirName. It can be set to 0.

Return value

> 0	Length of the directory name in bytes.
< 0	An error occurred.

Additional information

The function returns the length of the directory name excluding the 0-terminator irrespective of whether pDirName is sufficiently large to store the directory name or not. If pDirName is not sufficiently large to store the directory name including the 0-terminator, then the directory name stored in pDirName is truncated. The application can check for this condition by comparing the returned value with the value of SizeOfDirName. If the returned value is greater than or equal to SizeOfDirName, then the directory name stored to pDirName is truncated. In any of the above cases, the directory name stored to pDirName is 0-terminated.

The following tables show some usage examples.

Parameter
sPath
pDirName
SizeOfDirName
Result

Parameter
sPath
pDirName
SizeOfDirName
Result

Parameter
sPath
pDirName
SizeOfDirName
Result

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Parameter
sPath
pDirName
SizeOfDirName
Result

Parameter
sPath
pDirName
SizeOfDirName
Result

Parameter
sPath
pDirName
SizeOfDirName
Result

Parameter
sPath
pDirName
SizeOfDirName
Result

Example

```
#include "FS.h"

void SampleGetPathDirName(void) {
  char acDirName[32];

  FS_GetPathDirName("ram:1:\\SubDir\\Test.txt", acDirName, sizeof(acDirName));
}
```

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4.18.3 FS_GetPathExtension()

Description

Returns the extension of a file or directory.

Prototype

```
int FS_GetPathExtension(const char     * sPath,
                        char     * pExtension,
                        unsigned   SizeOfExtension);
```

Parameters

Parameter	Description
sPath	in Path to the file or directory (0-terminated string). It cannot be set to NULL.
pExtension	out The extension of the file or directory as 0-terminated string. It can be set to NULL.
SizeOfExtension	Number of bytes in pExtension. It can be set to 0.

Return value

> 0	Length of the extension in bytes.
< 0	An error occurred.

Additional information

The function returns the length of the extension excluding the 0-terminator irrespective of whether pExtension is sufficiently large to store the extension or not. If pExtension is not sufficiently large to store the extension including the 0-terminator, then the extension stored in pExtension is truncated. The application can check for this condition by comparing the returned value with the value of SizeOfExtension. If the returned value is greater than or equal to SizeOfExtension, then the extension stored to pExtension is truncated. In any of the above cases, the extension stored to pExtension is 0-terminated and contains the leading point.

The following tables show some usage examples.

Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

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Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

Parameter
sPath
pExtension
SizeOfExtension
Result

Example

```
#include "FS.h"

void SampleGetPathExtension(void) {
  char acExtension[32];

  FS_GetPathExtension("SubDir\\File.txt", acExtension, sizeof(acExtension));
}
```

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4.18.4 FS_GetPathVolumeName()

Description

Returns the name of the volume from a path.

Prototype

```
int FS_GetPathVolumeName(const char     * sPath,
                         char     * pVolumeName,
                         unsigned   SizeOfVolumeName);
```

Parameters

Parameter	Description
sPath	in Path to the file or directory (0-terminated string). It cannot be set to NULL.
pVolumeName	out The name of the volume as 0-terminated string. It can be set to NULL.
SizeOfVolumeName	Number of bytes in pVolumeName. It can be set to 0.

Return value

> 0 Length of the volume name in bytes.
< 0 An error occurred.

Additional information

The function returns the length of the volume name excluding the 0-terminator irrespective of whether pVolumeName is sufficiently large to store the volume name or not. If pVolumeName is not sufficiently large to store the volume name including the 0-terminator, then the volume name stored in pVolumeName is truncated. The application can check for this condition by comparing the returned value with the value of SizeOfVolumeName. If the returned value is greater than or equal to SizeOfVolumeName, then the volume name stored to pVolumeName is truncated. In any of the above cases, the volume name stored to pVolumeName is 0-terminated.

The following tables show some usage examples.

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

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Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Parameter
sPath
pVolumeName
SizeOfVolumeName
Result

Example

```
#include "FS.h"

void SampleGetPathVolumeName(void) {
  char acVolumeName[32];

  FS_GetPathVolumeName("ram:1:\\Test.txt", acVolumeName, sizeof(acVolumeName));
}
```

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4.18.5 FS_MakePath()

Description

Creates a path to a file or directory from individual components.

Prototype

```
int FS_MakePath(      char     * pPath,
                      unsigned   SizeOfPath,
                const char     * sVolumeName,
                const char     * sDirName,
                const char     * sBaseName,
                const char     * sExtension);
```

Parameters

Parameter	Description
pPath	out Created path (0-terminated string). It can be set to NULL.
SizeOfPath	Number of bytes in pPath. It can be set to 0.
sVolumeName	in Volume name (0-terminated string) It can be set to NULL.
sDirName	in Directory name (0-terminated string) It can be set to NULL.
sBaseName	in Basename of file or directory (0-terminated string) It can be set to NULL.
sExtension	in Extension of file or directory (0-terminated string) It can be set to NULL.

Return value

> 0	Length of the path in bytes.
< 0	An error occurred.

Additional information

This function returns the length of the path excluding the 0-terminator irrespective of whether pPath is sufficiently large to store the path or not. If pPath is not sufficiently large to store the path including the 0-terminator, then the path stored in pPath is truncated. The application can check for this condition by comparing the returned value with the value of SizeOfPath. If the returned value is greater than or equal to SizeOfPath, then the path stored to pPath is truncated. In any of the above cases, the path stored to pPath is 0-terminated.

FS_MakePath() adds missing volume, directory and extension delimiters.

The following tables show some usage examples.

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

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Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

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Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Parameter
sVolumeName
sDirName
sBaseName
sExtension
pPath
SizeOfPath
Result

Example

```
#include "FS.h"

void SampleMakePath(void) {
  char acPath[FS_MAX_PATH];

  FS_MakePath(acPath, sizeof(acPath), "nor:0:", "\\SubDir\\",  "File", ".txt");
}
```

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4.19 Obsolete functions

This section describes API functions that should no longer be used in new applications. These functions will be removed in a future version of emFile.

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4.19.1 FS_AddOnExitHandler()

Description

Registers a deinitialization callback.

Prototype

```
void FS_AddOnExitHandler(FS_ON_EXIT_CB * pCB,
                         void            ( *pfOnExit)());
```

Parameters

Parameter	Description
pCB	in Structure holding the callback information.
pfOnExit	Pointer to the callback function to be invoked.

Additional information

The pCB memory location is used internally by the file system and it should remain valid from the time the handler is registered until the FS_DeInit() function is called. The FS_DeInit() function invokes all the registered callback functions in reversed order that is the last registered function is called first. In order to use this function the binary compile time switch FS_SUPPORT_DEINIT has to be set to 1.

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4.19.2 FS_CloseDir()

Description

Closes a directory.

Prototype

```
int FS_CloseDir(FS_DIR * pDir);
```

Parameters

Parameter	Description
pDir	Handle to an opened directory.

Return value

= 0 Directory has been closed.
≠ 0 An error occurred.

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4.19.3 FS_ConfigOnWriteDirUpdate()

Description

Configures if the directory entry has be updated after writing to file.

Prototype

```
void FS_ConfigOnWriteDirUpdate(char OnOff);
```

Parameters

Parameter	Description
OnOff	Specifies if the feature has to be enabled or disabled. • 1 Enable update directory after write. • 0 Do not update directory. FS_FClose() updates the directory entry.

Additional information

This function is deprecated. FS_SetFileWriteMode() has to be used instead.

Calling FS_ConfigOnWriteDirUpdate() with OnOff set to 1 is equivalent to calling FS_SetFileWriteMode() with WriteMode set to FS_WRITEMODE_SAFE.

Calling FS_ConfigOnWriteDirUpdate() with OnOff set to 0 is equivalent to calling FS_SetFileWriteMode() with WriteMode set to FS_WRITEMODE_MEDIUM.

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4.19.4 FS_DirEnt2Attr()

Description

Loads attributes of a directory entry.

Prototype

```
void FS_DirEnt2Attr(FS_DIRENT * pDirEnt,
                    U8        * pAttr);
```

Parameters

Parameter	Description
pDirEnt	in Data of directory entry.
pAttr	out Pointer to a memory location that receives the attributes.

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4.19.5 FS_DirEnt2Name()

Description

Loads the name of a directory entry.

Prototype

```
void FS_DirEnt2Name(FS_DIRENT * pDirEnt,
                    char      * pBuffer);
```

Parameters

Parameter	Description
pDirEnt	in Data of directory entry.
pBuffer	out Pointer to a memory location that receives the name.

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4.19.6 FS_DirEnt2Size()

Description

Loads the size of a directory entry.

Prototype

```
U32 FS_DirEnt2Size(FS_DIRENT * pDirEnt);
```

Parameters

Parameter	Description
pDirEnt	in Data of directory entry.

Return value

Size of the file or directory.

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4.19.7 FS_DirEnt2Time()

Description

Loads the time stamp of a directory entry.

Prototype

```
U32 FS_DirEnt2Time(FS_DIRENT * pDirEnt);
```

Parameters

Parameter	Description
pDirEnt	in Data of directory entry.

Return value

Time stamp of the file or directory.

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4.19.8 FS_GetNumFiles()

Description

Obtains the number of files in a directory.

Prototype

```
U32 FS_GetNumFiles(FS_DIR * pDir);
```

Parameters

Parameter	Description
pDir	Handle to the directory to be queried.

Return value

≠ 0xFFFFFFFF	Number of files in the specified directory.
= 0xFFFFFFFF	An error occurred.

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4.19.9 FS_OpenDir()

Description

API function. Open an existing directory for reading.

Prototype

```
FS_DIR *FS_OpenDir(const char * sDirName);
```

Parameters

Parameter	Description
sDirName	Fully qualified directory name.

Return value

= 0 Unable to open the directory.
≠ 0 Address of an FS_DIR data structure.

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4.19.10 FS_ReadDir()

Description

Reads next directory entry in directory.

Prototype

```
FS_DIRENT *FS_ReadDir(FS_DIR * pDir);
```

Parameters

Parameter	Description
pDir	Handle to an opened directory.

Return value

≠ 0 Pointer to a directory entry.
= 0 No more directory entries or error.

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4.19.11 FS_RewindDir()

Description

Sets pointer for reading the next directory entry to the first entry in the directory.

Prototype

```
void FS_RewindDir(FS_DIR * pDir);
```

Parameters

Parameter	Description
pDir	Handle to an opened directory.

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Chapter 5

Caching and buffering

This chapter gives an introduction to cache handling of emFile. Furthermore, it contains the function description and an example.

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5.1 Sector cache

The sector cache is a memory area where frequently used sector data can be stored for fast access. In many cases, this can reduce the average access time, thus increasing the performance. With applications that do not use a cache, data will always be read from the storage medium even if it has been used before. The sector cache stores accessed and processed sector data. If the sector data has to be processed again, it will be copied out of the cache instead of reading it from the storage device. This condition is called "hit". If the sector data is not present in the sector cache, it has to be read from the storage device. This condition is called "miss". The sector cache works efficiently when the number of hit conditions is greater than the number of miss conditions. The number of hit and miss conditions can be queried using the `FS_STORAGE_GetCounters()` function.

5.1.1 Write cache and journaling

The write-back caching has to be disabled if the journaling is employed to make the file system fail-safe. The journaling will not work properly if the write- back cache (and generally any form of write cache) is enabled. More detailed information can be found in the section *Journaling and write caching* on page 1458.

5.1.2 Types of caches

emFile supports the usage of different cache modules as listed in the following table:

Cache module	Description
`FS_CACHE_ALL`	A pure read cache.
`FS_CACHE_MAN`	A pure read cache that caches only the management sectors.
`FS_CACHE_RW`	A read / write cache module.
`FS_CACHE_RW_QUOTA`	A read / write cache module with configurable capacity per sector type.
`FS_CACHE_MULTI_WAY`	A read / write cache module with configurable associativity level.

5.1.2.1 FS_CACHE_ALL

This module is a pure read cache. All sectors that are read from a volume are cached. The caching is enabled right after calling `FS_AssignCache()`.

5.1.2.2 FS_CACHE_MAN

This module is also a pure read cache. In contrast to the `FS_CACHE_ALL`, this module only caches the management sectors of the file system (for example, the sectors of the allocation table). The caching is enabled right after calling `FS_AssignCache()`. This type of cache is useful if the application is creating and deleting a large number of files.

5.1.2.3 FS_CACHE_RW

This is a configurable cache module. It can be used either as a read cache, a write cache, or a read / write cache. Additionally, the type of sectors that has to be cached is configurable via `FS_CACHE_SetMode()`.

5.1.2.4 FS_CACHE_RW_QUOTA

This is a configurable cache module. It can be either used as read, write or as read / write cache. Additionally, the type of sectors and the maximum number of sectors of a given type that can be cached at the same time are configurable via `FS_CACHE_SetMode()` and `FS_CACHE_SetQuota()` respectively. It is mandatory to call `FS_CACHE_SetMode()` and `FS_CACHE_SetQuota()`; otherwise, the functionality of the cache module is disabled.

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5.1.2.5 FS_CACHE_MULTI_WAY

This is a configurable cache module that can be used as read, write or read / write cache. The type of sectors that should be cached and the number of places in the cache where the data of a sector can be mapped (associativity level) are configurable via `FS_CACHE_SetMode()` and `FS_CACHE_SetQuota()` respectively. By default, this cache works with an associativity level of two.

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5.1.3 Cache API functions

The following functions can be used to enable, configure and control the emFile sector cache modules.

Function	Description
FS_AssignCache()	Enables or disables a sector cache for a specific volume.
FS_CACHE_Clean()	Writes modified sector data to storage device.
FS_CACHE_GetNumSectors()	Obtains the size of the sector cache.
FS_CACHE_GetType()	Obtains the type of the configured sector cache.
FS_CACHE_Invalidate()	Removes all sector data from cache.
FS_CACHE_SetAssocLevel()	Modifies the associativity level of multi-way cache.
FS_CACHE_SetMode()	Sets the operating mode of sector cache.
FS_CACHE_SetQuota()	Sets the quotas of a specific sector cache.

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5.1.3.1 FS_AssignCache()

Description

Enables or disables a sector cache for a specific volume.

Prototype

```
U32 FS_AssignCache(const char          * sVolumeName,
                   void                * pData,
                   I32                   NumBytes,
                   FS_CACHE_TYPE         Type);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the sector cache should be enabled / disabled. Cannot be NULL.
pData	Pointer to a memory area that should be used as cache.
NumBytes	Number of bytes in the memory area pointed by pData.
Type	Specifies the type of the sector cache to be configured. It can take one of the following values: • FS_CACHE_ALL • FS_CACHE_MAN • FS_CACHE_RW • FS_CACHE_RW_QUOTA • FS_CACHE_MULTI_WAY.

Return value

> 0	OK, Number of sectors which fit in cache.
= 0	An error occurred. The memory area cannot be used as sector cache.

Additional information

The first configured volume is used if the empty string is specified as sVolumeName.

To disable the cache for a specific device, call FS_AssignCache() with NumBytes set to 0. In this case the function returns 0.

A range of the memory block assigned to the sector cache is used to store the management data. The following defines can help an application allocate a memory block sufficiently large to store a specified number of logical sectors: FS_SIZEOF_CACHE_ALL(), FS_SIZEOF_CACHE_MAN(), FS_SIZEOF_CACHE_RW(), FS_SIZEOF_CACHE_RW_QUOTA(), or FS_SIZEOF_CACHE_MULTI_WAY().

Example

The following example demonstrates how to enable and then disable a sector cache of type FS_CACHE_ALL.

```
#include "FS.h"

#define CACHE_SIZE FS_SIZEOF_CACHE_ALL(200, 512) // 200 sectors of 512 bytes.

static U32 _aCache[CACHE_SIZE / 4]; // Allocate RAM for the cache buffer.

void SampleCacheAssign(void) {
  //
  // Assign a read cache to the first configured storage device.
  //
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_ALL);

  //
```

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```
  // Access the file system with sector cache.
  //

  //
  // Disable the read cache.
  //
  FS_AssignCache("", 0, 0, 0);
}
```

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5.1.3.2 FS_CACHE_Clean()

Description

Writes modified sector data to storage device.

Prototype

```
int FS_CACHE_Clean(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.

Return value

= 0 OK, the sector cache was emptied successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used to make sure that modifications made to cached data are also committed to storage device.

Because only write or read / write caches need to be cleaned, this function can only be called for volumes where FS_CACHE_RW, FS_CACHE_RW_QUOTA, or FS_CACHE_MULTI_WAY module is assigned. The other cache modules ignore the cache clean operation.

The cleaning of the cache is also performed when the volume is unmounted via FS_Unmount() or when the cache is disabled or reassigned via FS_AssignCache().

Example

```
#include "FS.h"

void SampleCacheClean(void) {
  FS_CACHE_Clean("");
}
```

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5.1.3.3 FS_CACHE_GetNumSectors()

Description

Obtains the size of the sector cache.

Prototype

```
int FS_CACHE_GetNumSectors(const char * sVolumeName,
                           U32  * pNumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.
pNumSectors	out Number of sectors that can be stored in the cache at the same time. It cannot be NULL.

Return value

= 0 OK, number of sectors in the sector cache.
≠ 0 An error occurred.

Additional information

This function returns the number of sectors that can be stored in the cache at the same time.

Example

```
#include "FS.h"
#include <stdio.h>

void SampleCacheGetNumSectors(void) {
  U32  NumSectors;
  char ac[100];

  FS_CACHE_GetNumSectors("", &NumSectors);
  SEGGER_snprintf(ac, sizeof(ac), "Number of sectors in cache: %lu\n", NumSectors);
  FS_X_Log(ac);
}
```

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5.1.3.4 FS_CACHE_GetType()

Description

Obtains the type of the configured sector cache.

Prototype

```
int FS_CACHE_GetType(const char          * sVolumeName,
                     FS_CACHE_TYPE * pType);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.
pType	out Cache sector type. • FS_CACHE_NONE No sector cache configured. • FS_CACHE_ALL A pure read cache. • FS_CACHE_MAN A pure read cache that caches only the management sectors. • FS_CACHE_RW A read / write cache module. • FS_CACHE_RW_QUOTA A read / write cache module with configurable capacity per sector type. • FS_CACHE_MULTI_WAY A read / write cache module with configurable associativity level.

Return value

= 0 OK, type of sector cache returned.
≠ 0 Error code indicating the failure reason.

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5.1.3.5 FS_CACHE_Invalidate()

Description

Removes all sector data from cache.

Prototype

```
int FS_CACHE_Invalidate(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.

Return value

= 0 OK, the sector cache was emptied successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be called to remove all the sectors from the cache. `FS_CACHE_Invalidate()` does not write to storage modified sector data. After calling `FS_CACHE_Invalidate()` the contents of modified sector data is lost. `FS_CACHE_Clean()` has to be called first to prevent a data loss.

Example

```
#include "FS.h"

void SampleCacheInvalidate(void) {
  FS_CACHE_Invalidate("");
}
```

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5.1.3.6 FS_CACHE_SetAssocLevel()

Description

Modifies the associativity level of multi-way cache.

Prototype

```
int FS_CACHE_SetAssocLevel(const char * sVolumeName,
                           int    AssocLevel);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.
AssocLevel	Number of entries in the cache. It has to be a power of two value.

Return value

= 0 OK, associativity level set successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is supported only by the FS_CACHE_MULTI_WAY cache module. An error is returned if the function is used with any other cache module.

The associativity level specifies on how many different places in the cache the data of the same sector can be stored. The cache replacement policy uses this information to decide where to store the contents of a sector in the cache. Caches with higher associativity levels tend to have higher hit rates. The default associativity level is two.

Example

The following example shows how to configure the FS_CACHE_MULTI_WAY cache module to store the data of the same sector at 4 different places in the cache.

```
#include "FS.h"

void SampleCacheSetAssocLevel(void) {
  FS_CACHE_SetAssocLevel("", 4);
}
```

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5.1.3.7 FS_CACHE_SetMode()

Description

Sets the operating mode of sector cache.

Prototype

```
int FS_CACHE_SetMode(const char * sVolumeName,
                     int    TypeMask,
                     int    ModeMask);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.
TypeMask	Specifies the types of the sectors that have to be cached. This parameter can be an OR-combination of the Sector type masks (FS_SECTOR_TYPE_MASK_...)
ModeMask	Specifies the operating mode of the cache module. This parameter can be one of the values defined as Sector cache modes (FS_CACHE_MODE_...)

Return value

= 0 OK, mode set successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is supported by the following cache types: FS_CACHE_RW, FS_CACHE_RW_QUOTA, and FS_CACHE_MULTI_WAY. These cache modules have to be configured using this function otherwise, neither read nor write operations are cached.

When configured in FS_CACHE_MODE_WB mode the cache module writes the sector data automatically to storage device if free space is required for new sector data. The application can call the FS_CACHE_Clean() function at any time to write all the cache sector data to storage device.

Example

The following example shows how to configure the FS_CACHE_MULTI_WAY cache module to use a read cache for the data sectors and a write-back cache for the management and directory sectors.

```
#include "FS.h"

#define CACHE_SIZE FS_SIZEOF_CACHE_MULTI_WAY(200, 512)

static U32 _aCache[CACHE_SIZE / 4];  // Allocate RAM for the cache buffer.

void SampleCacheSetMode(void) {
  //
  // Assign a cache to the first available storage device.
  //
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_MULTI_WAY);
  //
  // Configure a read cache for the sectors that store file data.
  //
  FS_CACHE_SetMode("", FS_SECTOR_TYPE_MASK_DATA, FS_CACHE_MODE_R);
  //
  // Configure a write back cache for the sectors that store directory
  // and allocation table entries.
  //
  FS_CACHE_SetMode("",
```

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```
                    FS_SECTOR_TYPE_MASK_DIR | FS_SECTOR_TYPE_MASK_MAN,
                    FS_CACHE_MODE_WB);
  //
  // Access the file system with sector cache.
  //

  //
  // Disable the cache.
  //
  FS_AssignCache("", 0, 0, FS_CACHE_NONE);
}
```

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5.1.3.8 FS_CACHE_SetQuota()

Description

Sets the quotas of a specific sector cache.

Prototype

```
int FS_CACHE_SetQuota(const char * sVolumeName,
                      int    TypeMask,
                      U32    NumSectors);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume for which the cache should be cleaned. If not specified, the first volume will be used.
TypeMask	Specifies the types of the sectors that have to be cached. This parameter can be an OR-combination of the Sector type masks (FS_SECTOR_TYPE_MASK_...)
NumSectors	Specifies the maximum number of sectors to be stored for each sector type specified in TypeMask.

Return value

= 0 OK, maximum number of sectors set successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is currently only usable with the FS_CACHE_RW_QUOTA cache module. After the FS_CACHE_RW_QUOTA cache module has been assigned to a volume and the cache mode has been set, the quotas for the different sector types have to be configured using this function. Otherwise, neither read nor write operations are cached.

Example

The following example shows how to configure the FS_CACHE_RW_QUOTA cache module to limit the number of directory and data sector types to a maximum of 10 each.

```
#include "FS.h"

#define CACHE_SIZE   FS_SIZEOF_CACHE_RW_QUOTA(200, 512)

static U32 _acCache[CACHE_SIZE / 4];  // Allocate RAM for the cache buffer.

void SampleCacheSetQuota(void) {
  //
  // Assign a cache to the first available storage device.
  //
  FS_AssignCache("", _acCache, sizeof(_acCache), FS_CACHE_RW_QUOTA);
  //
  // Configure the cache module to cache all sectors. The sector data is cached
  // for read and write. Write operation to storage device are delayed.
  //
  FS_CACHE_SetMode("", FS_SECTOR_TYPE_MASK_ALL, FS_CACHE_MODE_WB);
  //
  // Set the maximum number of sectors to cache for directory
  // and data sector types 10 sectors each.
  //
  FS_CACHE_SetQuota("", FS_SECTOR_TYPE_MASK_DATA | FS_SECTOR_TYPE_MASK_DIR, 10);

  //
  // Access the file system with sector cache.
  //

  //
```

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```
  // Make sure that the data is written to storage device.
  //
  FS_CACHE_Clean("");

  //
  // Perform other accesses to file system with sector cache.
  //

  //
  // Disable the cache.
  //
  FS_AssignCache("", 0, 0, FS_CACHE_NONE);
}
```

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5.1.3.9 Sector cache types

Description

Types of sector caches.

Definition

```
#define FS_CACHE_NONE          NULL
#define FS_CACHE_ALL           FS_CacheAll_Init
#define FS_CACHE_MAN           FS_CacheMan_Init
#define FS_CACHE_RW            FS_CacheRW_Init
#define FS_CACHE_RW_QUOTA      FS_CacheRWQuota_Init
#define FS_CACHE_MULTI_WAY     FS_CacheMultiWay_Init
```

Symbols

Definition	Description
FS_CACHE_NONE	Pseudo-type that can be used to disable the sector cache.
FS_CACHE_ALL	A pure read cache.
FS_CACHE_MAN	A pure read cache that caches only the management sectors.
FS_CACHE_RW	A read / write cache module.
FS_CACHE_RW_QUOTA	A read / write cache module with configurable capacity per sector type.
FS_CACHE_MULTI_WAY	A read / write cache module with configurable associativity level.

Additional information

The type of a cache module can be configured via `FS_AssignCache()` function when the sector cache is enabled for a specified volume.

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5.1.3.10 Sector cache modes

Description

Operating modes of sector caches.

Definition

```
#define FS_CACHE_MODE_R      0x01u
#define FS_CACHE_MODE_WT     (FS_CACHE_MODE_R | FS_CACHE_MODE_W)
#define FS_CACHE_MODE_WB     (FS_CACHE_MODE_R | FS_CACHE_MODE_W | FS_CACHE_MODE_D)
```

Symbols

Definition	Description
FS_CACHE_MODE_R	Pure read cache.
FS_CACHE_MODE_WT	Write-through cache.
FS_CACHE_MODE_WB	Write-back cache.

Additional information

The operating mode of a cache module can be configured via the FS_CACHE_SetMode() function separately for each sector type.

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5.1.3.11 Sector cache size

Description

Calculates the cache size.

Definition

```
#define FS_SIZEOF_CACHE_ALL(NumSectors,          SectorSize)
  (FS_SIZEOF_CACHE_ALL_DATA +               \
   (FS_SIZEOF_CACHE_ALL_BLOCK_INFO +       \
   (SectorSize)) * (NumSectors))
#define FS_SIZEOF_CACHE_MAN(NumSectors,          SectorSize)
  (FS_SIZEOF_CACHE_MAN_DATA +               \
   (FS_SIZEOF_CACHE_MAN_BLOCK_INFO +       \
   (SectorSize)) * (NumSectors))
#define FS_SIZEOF_CACHE_RW(NumSectors,           SectorSize)
  (FS_SIZEOF_CACHE_RW_DATA +                \
   (FS_SIZEOF_CACHE_RW_BLOCK_INFO +        \
   (SectorSize)) * (NumSectors))
#define FS_SIZEOF_CACHE_RW_QUOTA(NumSectors,     SectorSize)
  (FS_SIZEOF_CACHE_RW_QUOTA_DATA +          \
   (FS_SIZEOF_CACHE_RW_QUOTA_BLOCK_INFO +  \
   (SectorSize)) * (NumSectors))
#define FS_SIZEOF_CACHE_MULTI_WAY(NumSectors,    SectorSize)
  (FS_SIZEOF_CACHE_MULTI_WAY_DATA +         \
   (FS_SIZEOF_CACHE_MULTI_WAY_BLOCK_INFO + \
   (SectorSize)) * (NumSectors))
#define FS_SIZEOF_CACHE_ANY(NumSectors,          SectorSize)
  FS_SIZEOF_CACHE_RW_QUOTA(NumSectors, SectorSize)
```

Symbols

Definition	Description
FS_SIZEOF_CACHE_ALL(NumSectors,	Calculates the cache size of a FS_CACHE_ALL cache module.
FS_SIZEOF_CACHE_MAN(NumSectors,	Calculates the cache size of a FS_CACHE_MAN cache module.
FS_SIZEOF_CACHE_RW(NumSectors,	Calculates the cache size of a FS_CACHE_RW cache module.
FS_SIZEOF_CACHE_RW_QUOTA(NumSectors,	Calculates the cache size of a FS_CACHE_RW_QUOTA cache module.
FS_SIZEOF_CACHE_MULTI_WAY(NumSectors,	Calculates the cache size of a FS_CACHE_MULTI_WAY cache module.
FS_SIZEOF_CACHE_ANY(NumSectors,	Calculates the size of cache that works with any cache module.

Additional information

These defines can be used to calculate the size of the memory area to be assigned to a cache module based on the size of a sector (SectorSize) and the number of sectors to be cached (NumSectors). The sector size of a specific volume can be queried via FS_GetVolumeInfo().

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5.1.3.12 Sector data flags

Description

Type of data stored in a logical sector.

Definition

```
#define FS_SECTOR_TYPE_MASK_DATA    (1u << FS_SECTOR_TYPE_DATA)
#define FS_SECTOR_TYPE_MASK_DIR     (1u << FS_SECTOR_TYPE_DIR)
#define FS_SECTOR_TYPE_MASK_MAN     (1u << FS_SECTOR_TYPE_MAN)
#define FS_SECTOR_TYPE_MASK_ALL     (FS_SECTOR_TYPE_MASK_DATA | \
   FS_SECTOR_TYPE_MASK_DIR  | \
   FS_SECTOR_TYPE_MASK_MAN)
#define FS_SECTOR_TYPE_COUNT        3u
```

Symbols

Definition	Description
FS_SECTOR_TYPE_MASK_DATA	Sector that stores file data.
FS_SECTOR_TYPE_MASK_DIR	Sector that stores directory entries.
FS_SECTOR_TYPE_MASK_MAN	Sector that stores entries of the allocation table.
FS_SECTOR_TYPE_MASK_ALL	All sector types.
FS_SECTOR_TYPE_COUNT	Number of sector types (for internal use only)

Additional information

These flags are typically used with the sector cache API functions to specify the type of sector data for which a specified parameter applies. The bit positions of the flags correspond to the values defined via *Sector data type* on page 373

5.1.4 Performance and resource usage

5.1.4.1 Performance

The listed performance values depend on the compiler options, the compiler version, the used CPU, the storage medium and the defined cache size. The performance values have been measured on a SEGGER emPower evaluation board https://www.segger.com/evaluate-our-software/segger/empower/ using an SD card as storage device. The test application has been compiled using SEGGER Embedded Studio IDE https://www.segger.com/products/development-tools/embedded-studio/, but any other IDE can be used as well. The test application is provided in source code and is located in the `Application` folder of the emFile shipment.

Description of the test

- Initialize the file system.
- Perform a high-level format if required.
- Create 50 files without a cache.
- Write the time which was required for creation in the terminal I/O window.
- Enable a read and write cache.
- Create 50 files with the enabled read and write cache.
- Write the time which was required for creation in the terminal I/O window.
- Flush the cache.
- Write the time which was required for flushing in the terminal I/O window.
- Disable the cache.
- Create 50 files again without a cache.
- Write the time which was required for creation in the terminal I/O window.

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Terminal output

```
Start
High-level formatting
Cache disabled
Creation of 50 files took: 16 ms
Cache enabled
Creation of 50 files took: 2 ms
Cache flush took: 0 ms
Cache disabled
Creation of 50 files took: 57 ms
Finished
```

Source code

```
/*********************************************************************
*                   (c) SEGGER Microcontroller GmbH                  *
*                        The Embedded Experts                        *
*                           www.segger.com                           *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_SectorCache.c
Purpose : Demonstrates how to configure and use the sector cache.

Additional information:
  Preparations:
    Works out-of-the-box with any storage device.

  Expected behavior:
    Measures the time it takes to create a number of files with
    and without the sector cache enabled. The results are output
    on the debug console.

  Sample output:
    Start
    Cache disabled
    Creation of 50 files took: 60 ms
    Cache enabled
    Creation of 50 files took: 18 ms
    Cache flush took: 0 ms
    Cache disabled
    Creation of 50 files took: 114 ms
    Finished
*/

/*********************************************************************
*
*       #include Section
*
**********************************************************************
*/
#include <string.h>
#include "FS.h"
#include "FS_OS.h"
#include "SEGGER.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define VOLUME_NAME   ""
#define NUM_FILES     32

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
```

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```
static U32  _aCache[0x400];
static char _aacFileName[NUM_FILES][13];
static char _ac[128];

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _CreateFiles
*/
static void _CreateFiles(void) {
  int       i;
  U32       Time;
  FS_FILE * apFile[NUM_FILES];

  Time = FS_X_OS_GetTime();
  for (i = 0; i < NUM_FILES; i++) {
    apFile[i] = FS_FOpen(&_aacFileName[i][0], "w");
#if ((FS_SUPPORT_FILE_BUFFER != 0) && (FS_SUPPORT_FILE_BUFFER_LIST != 0))
    //
    // A file buffer is not required for this test.
    //
    if (apFile[i] != NULL) {
      if (FS_IsFileBufferSet(apFile[i]) != 0) {
        (void)FS_UnsetFileBuffer(apFile[i]);
      }
    }
#endif // ((FS_SUPPORT_FILE_BUFFER != 0) && (FS_SUPPORT_FILE_BUFFER_LIST != 0))
  }
  Time = FS_X_OS_GetTime() - Time;
  SEGGER_snprintf(_ac, (int)sizeof(_ac), "Creation of %d files took: %d ms\n", NUM_FILES, Time);
  FS_X_Log(_ac);
  for (i = 0; i < NUM_FILES; i++) {
    (void)FS_FClose(apFile[i]);
  }
}

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       MainTask
*/
#ifdef __cplusplus
extern "C" {     /* Make sure we have C-declarations in C++ programs */
#endif
void MainTask(void);
#ifdef __cplusplus
}
#endif
void MainTask(void) {
  int i;
  U32 Time;

  FS_X_Log("Start\n");
  //
  // Initialize file system
  //
  FS_Init();
  //
  // Check if low-level format is required
  //
  (void)FS_FormatLLIfRequired(VOLUME_NAME);
  //
  // Check if volume needs to be high level formatted.
  //
```

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```
  if (FS_IsHLFormatted(VOLUME_NAME) == 0) {
    FS_X_Log("High-level formatting\n");
    (void)FS_FormatEx(VOLUME_NAME);
  }
  //
  // Prepare file names in advance.
  //
  for (i = 0; i < NUM_FILES; i++) {
    SEGGER_snprintf(_aacFileName[i], (int)sizeof(_aacFileName[0]), "file%.2d.txt", i);
  }
  //
  // Create and measure the time used to create the files with the cache enabled.
  //
  FS_X_Log("Cache disabled\n");
  _CreateFiles();
  //
  // Create and measure the time used to create the files.
  //
  (void)FS_AssignCache(VOLUME_NAME, _aCache, (int)sizeof(_aCache), FS_CACHE_RW);
  (void)FS_CACHE_SetMode(VOLUME_NAME, (int)FS_SECTOR_TYPE_MASK_ALL, (int)FS_CACHE_MODE_WB);
  FS_X_Log("Cache enabled\n");
  _CreateFiles();
  Time = FS_X_OS_GetTime();
  (void)FS_CACHE_Clean(VOLUME_NAME);
  Time = FS_X_OS_GetTime() - Time;
  SEGGER_snprintf(_ac, (int)sizeof(_ac), "Cache flush took: %d ms\n", Time);
  FS_X_Log(_ac);
  //
  // Create and measure the time used to create the files with the cache disabled.
  //
  FS_X_Log("Cache disabled\n");
  (void)FS_AssignCache(VOLUME_NAME, NULL, 0, FS_CACHE_NONE);
  _CreateFiles();
  FS_X_Log("Finished\n");
  for(;;) {
    ;
  }
}

/*************************** End of file ****************************/
```

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5.2 File buffer

emFile comes with support for file buffers. A file buffer is a small memory area assigned to an opened file where the file system can store frequently accessed file data. Using a file buffer can greatly increase performance, especially when the application has to access small amounts of data.

The file buffer can be configured in different access modes. In read mode, only the data that is read by the application from the file is stored in the file buffer, or in read/write mode, where the data read as well as the data written by the application is stored in the file buffer. The access modes can be changed at runtime, each time the file is opened, via `FS_SetFileBufferFlags()` or `FS_SetFileBuffer()`.

The size of the file buffer is configurable either globally for all opened files via `FS_ConfigFileBufferDefault()` or individually for each opened file via `FS_SetFileBuffer()`.

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Chapter 6

Device drivers

This chapter describes the file system components that provide access to a storage device.

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6.1 General information

emFile has been designed to operate with any kind of storage device. To use a specific type of storage device with emFile, a device driver for that specific storage device is required. A device driver is a file system component that provides block access to a storage device. The device driver consists of basic I/O functions for accessing the storage device and a global table that holds pointers to these functions.

The following table lists the device drivers available in emFile. The two-letter combination "RO" in the driver identifier indicates that the driver is not able to perform any write operations.

Driver name	Acronym	Identifier	Volume name
File Disk driver	FILEDISK	FS_FILEDISK_Driver	"file:"
File Disk driver	FILEDISK_RO	FS_FILEDISK_RO_Driver	"file:"
CompactFlash card and IDE driver	IDE	FS_IDE_Driver	"ide:"
SPI MMC/SD driver	MMC_SPI	FS_MMC_SPI_Driver	"mmc:"
Card Mode MMC/SD driver	MMC_CM	FS_MMC_CM_Driver	"mmc:"
Card Mode MMC/SD driver	MMC_CM_RO	FS_MMC_CM_RO_Driver	"mmc:"
SLC1 NAND driver	NAND	FS_NAND_Driver	"nand:"
Universal NAND driver	NAND_UNI	FS_NAND_UNI_Driver	"nand:"
Universal NAND driver	NAND_UNI_RO	FS_NAND_UNI_RO_Driver	"nand:"
Sector Map NOR driver	NOR	FS_NOR_Driver	"nor:"
Block Map NOR driver	NOR_BM	FS_NOR_BM_Driver	"nor:"
Block Map NOR driver	NOR_BM_RO	FS_NOR_BM_RO_Driver	"nor:"
System RAM Disk driver	RAMDISK	FS_RAMDISK_Driver	"ram:"
Universal RAM Disk driver	RAMDISK_UNI	FS_RAMDISK_UNI_Driver	"ram:"
Windows Drive driver	WINDRIVE	FS_WINDRIVE_Driver	"win:"
Windows Drive driver	WINDRIVE_RO	FS_WINDRIVE_RO_Driver	"win:"

By default, the file system is not configured to access any particular storage device. A device driver has to be added by the application by calling `FS_AddDevice()` in `FS_X_AddDevices()`. The file system calls `FS_X_AddDevices()` during the initialization to allow the application to configure the file system. `FS_AddDevice()` takes as parameter a pointer to the function table of the particular device driver as specified in the "Identifier" column in the table above. It is possible to add more than one device driver to the file system if more than one storage device is present in the system or if the system uses one storage device that is partitioned.

The file system assigns a volume to each device driver added by the application. A volume is an internal structure that contains information about the organization of the storage device and how to access it. The application uses the volume name as specified in the "Volume name" column in the table above to select a particular storage device. The names of the volumes are fixed and cannot be changed by the application.

If the same device driver is added to the file system more than once, a unit number is used to differentiate between them. The unit number is an optional part of the volume name, and it can be used by the application to access a specific storage device. Most device driver functions as well as most of the underlying hardware functions receive the unit number as the first parameter. If there are, for example, two NAND flash drivers which operate as two different NAND flash devices, the first one is identified as unit 0, the second one as unit 1. If there is just a single instance (as in most systems), the unit number parameter can be ignored by the underlying hardware functions.

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6.1.1 Hardware layer

Most of the device drivers require functions to access the hardware. This set of functions is called the hardware layer. The implementation of the hardware layer is the user's responsibility. emFile comes with template and sample hardware layers that can be used as a starting point in developing a new one.

The hardware layer can be implemented in two different ways:

- Polled mode
- Interrupt-driven mode

Polled mode

In the polled mode the software actively queries the completion of the I/O operation. No operating system is required to implement the device driver in this way. The following example demonstrates the fundamentals of a polled-driven hardware layer.

```
#include "FS.h"

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    FS hardware layer function. Writes a specified number of bytes
*    to storage device via DMA.
*/
static int _HW_Write(U8 Unit, const U8 * pData, int NumBytes) {
  int r;

  //
  // Start transmission using DMA.
  //
  _StartDMAWrite(Unit, pData, NumBytes);
  //
  // Wait for the DMA operation to complete.
  //
  while (1) {
    if (_IsDMAOperationCompleted()) {
      r = 0;          // OK, success.
      break;
    }
    if (_IsDMAError()) {
      r = 1;          // Error, could not write data via DMA.
      break;
    }
  }
  return r;
}
```

Interrupt-driven mode

In the interrupt-driven mode the completion of an I/O operation is signaled through an interrupt. This operating mode requires the support of an operating system. The following example demonstrates the fundamentals of an interrupt-driven hardware layer.

```
#include "FS.h"
#include "FS_OS.h"

/*********************************************************
*
*       _IRQ_Handler
*
*  Function description
*    Handles the hardware interrupt. Has to be registered
```

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```
*    as interrupt service routine.
*/
static void _IRQ_Handler(void) {
  //
  // Disable further interrupts.
  //
  _DisableInterrupts();
  //
  // Signal (wake) the waiting task.
  //
  FS_X_OS_Signal();
}
/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    FS hardware layer function. Writes a specified number of bytes
*    to storage device via DMA.
*/
static int _HW_Write(U8 Unit, const U8 * pData, int NumBytes) {
  //
  // Start transmission using DMA.
  //
  _StartDMAWrite(Unit, pData, NumBytes);
  //
  // Wait for the DMA operation to complete.
  //
  while (1) {
    if (_IsDMAOperationCompleted()) {
      r = 0;          // OK, success.
      break;
    }
    if (_IsDMAError()) {
      r = 1;          // Error, could not write data via DMA.
      break;
    }
    //
    // Wait for IRQ to signal the event and wake up the task.
    //
    r = FS_X_OS_Wait(TIMEOUT);
    if (r) {
      break;          // Error, timeout expired.
    }
  }
}
```

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6.2 RAM Disk driver

6.2.1 General information

The RAM Disk driver supports the use of any type of volatile and non-volatile RAM as storage. This includes the system memory as well as any RAM devices connected serially via an SPI or I2C bus using FRAM, MRAM or any other type of storage technology.

Two drivers for RAM storage are provided:

- System RAM Disk driver - Supports only system memory as storage.
- Universal RAM Disk driver - Supports system memory and serial RAM devices as storage.

A file system configuration that uses the system memory as storage is suitable for getting started using emFile because it does not require any hardware access functions to be implemented. The RAM Disk driver is also useful for testing the file system on a PC simulation.

6.2.1.1 Theory of operation

The RAM Disk driver stores the data of the logical sectors it receives from the file system without modification to the memory region configured by the application via `FS_RAMDISK_Configure()`. The byte offset at which the data is stored is calculated by multiplying the index of the logical sector by the size of a logical sector. For example, the data of the logical sector with the index 7 is stored at the byte offset 7 * 512 = 3584 assuming that the size of the logical sector is 512 bytes.

6.2.1.2 Fail-safe operation

Typically, all the file system data is lost in case of an unexpected power loss if a volatile RAM device or the system memory without battery backup is used as storage. For this reason, the fail-safety is relevant only for file system configurations that use a non-volatile RAM as storage.

Unexpected reset

In case of an unexpected reset, the data will be preserved. However, if the unexpected reset interrupts a write operation, the data of the sector may contain partially invalid data.

Power failure

A power failure causes an unexpected reset and has the same effects.

6.2.1.3 Wear leveling

Typically, a RAM storage does not wear out; therefore, the RAM Disk driver does not perform any wear leveling.

6.2.1.4 Formatting

The storage used by the RAM Disk driver has to be formatted after each startup of the system because its contents is typically lost. Exceptions to this are file system configurations that use as storage a system memory that is backed up via a battery or a non-volatile RAM device connected serially to the MCU.

The application has to format the storage via `FS_Format()` before it can store data on it. If the application adds only one RAM Disk driver to the file system, `FS_Format()` can be called with an empty string as volume name. For example, `FS_Format("", NULL)`. If more than one RAM Disk driver is added to the file system, the volume name has to be specified. For example, `FS_Format("ram:0:", NULL)` for the first storage device and `FS_Format("ram:1:", NULL)` for the second.

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6.2.2 System RAM Disk driver

This section describes the RAM Disk driver that can use the system memory as storage.

6.2.2.1 Supported hardware

The System RAM Disk driver can be used on any target hardware that has sufficient system memory to be used as storage.

6.2.2.2 Configuring the driver

The application has to add the System RAM Disk driver to the file system before using it. This is done by calling `FS_AddDevice()` in `FS_X_AddDevices()` with the parameter set to the function table of the System RAM Disk driver, `FS_RAMDISK_Driver`.

The maximum number of System RAM Disk driver instances that can be added to the file system can be configured at compile time using the `FS_RAMDISK_MAX_NUM_UNITS` configuration define. By default, a maximum number of four System RAM Disk driver instances can be added to the file system.

The application has to call `FS_RAMDISK_Configure()` for each driver instance to configure the range of the system memory to be used as storage. The specified memory range can be located on any system memory that is accessible to the CPU.

Example

```
#include <FS.h>

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define ALLOC_SIZE          0x1100    // Memory pool for the file system in bytes
#define NUM_SECTORS         16        // Number of sectors on the RAM storage
#define BYTES_PER_SECTOR    512       // Size of a sector in bytes

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
//
// Memory pool used for semi-dynamic allocation.
//
static U32 _aMemBlock[ALLOC_SIZE / 4];
//
// Memory to be used as storage.
//
static U32 _aRAMDisk[(NUM_SECTORS * BYTES_PER_SECTOR) / 4];

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*    It is supposed to add all devices, using primarily FS_AddDevice().
*
*  Note
*    (1) Other API functions may NOT be called, since this function is called
*        during initialization. The devices are not yet ready at this point.
```

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```
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_RAMDISK_Driver);
  FS_RAMDISK_Configure(0, _aRAMDisk, BYTES_PER_SECTOR, NUM_SECTORS);
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(BYTES_PER_SECTOR, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

6.2.2.2.1 Compile-time configuration

The compile-time configuration is realized via preprocessor defines that have to be added to the FS_Conf.h file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The System RAM Disk driver does not require any hardware access functions. The following table lists the configuration defines supported by the RAM Disk driver.

Define	Default value	Type	Description
FS_RAMDISK_NUM_UNITS	4	N	Maximum number of driver instances.

6.2.2.2.1.1 FS_RAMDISK_NUM_UNITS

This define specifies the maximum number of driver instances that can be created by the application. The memory for each driver instance is allocated dynamically.

6.2.2.2.2 Runtime configuration

This section describes the functions that can be used to configure an instance of the System RAM Disk driver.

Function	Description
FS_RAMDISK_Configure()	Configures an instance of a System RAM disk driver.

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6.2.2.2.2.1 FS_RAMDISK_Configure()

Description

Configures an instance of a System RAM disk driver.

Prototype

```
void FS_RAMDISK_Configure(U8     Unit,
                          void * pData,
                          U16    BytesPerSector,
                          U32    NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pData	Memory area to be used as storage. It cannot be NULL.
BytesPerSector	Number of bytes in a logical sector.
NumSectors	Number of logical sectors in the storage.

Additional information

The application has to call this function for each instance of the System RAM disk driver it adds to file system. Unit identifies the instance of the System RAM disk driver. The instance of the RAM disk driver added first to file system has the index 0, the second instance has the index 1, and so on.

pData has to point to a memory region that is at least BytesPerSector * NumSectors bytes large. The memory region can by located on any system memory that is accessible by CPU.

BytesPerSector has to be a power of 2 value.

Example

```
#include <FS.h>

#define NUM_SECTORS         16        // Number of sectors on the RAM storage
#define BYTES_PER_SECTOR    512       // Size of a sector in bytes

static U32 _aRAMDisk[(NUM_SECTORS * BYTES_PER_SECTOR) / 4]; // Memory to be used as storage.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Basic file system configuration...
  //

  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_RAMDISK_Driver);
  FS_RAMDISK_Configure(0, _aRAMDisk, BYTES_PER_SECTOR, NUM_SECTORS);

  //
  // Additional file system configuration...
  //
}
```

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6.2.2.3 Performance and resource usage

6.2.2.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The memory requirements of the System RAM Disk driver were measured as described in the section *Test procedure* on page 1439.

Usage: 500 bytes

6.2.2.3.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the System RAM Disk driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the `FS_RAMDisk.c`.

Usage: 40 bytes

6.2.2.3.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. Each instance of the System RAM Disk driver requires the following number of bytes:

Usage: 10 bytes

6.2.2.3.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests have been performed as described in the section *Performance* on page 1445. All values are given in Mbytes/sec.

CPU type	Write speed	Read speed
Atmel AT91SAM9261 (200 MHz)	**128**	**128**
LogicPD LH79520 (51 MHz)	**20**	**20**

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6.2.3 Universal RAM Disk driver

This section describes the RAM Disk driver that can use the system memory as well as a serial RAM device as storage.

6.2.3.1 Supported hardware

The Universal RAM Disk driver can be used on any target hardware that has sufficient system memory to be used as storage. In addition, the driver can be used with volatile and non-volatile RAM devices that are connected to the MCU via a serial bus such as SPI or I2C.

The following table shows the serial RAM devices that were tested by SEGGER or are known to be compatible with a tested device.

Device name	Storage capacity	Device type	Supported optional features
Fujitsu			
MB85RC64TA	64 Kibit	I2C	
MB85RS128TY	128 Kibit	SPI	
MB85RS1MT	1 Mibit	SPI	
MB85RS256TY	256 Kibit	SPI	
MB85RS512T	512 Kibit	SPI	
Infineon			
CY15B104QSN	4096 Mibit	SPI	extended SPI, DTR
FM24CL64B	64 Mibit	I2C	
FM24V01A	128 Mibit	I2C	
FM24V02A	256 Mibit	I2C	
FM25V02A	256 Mibit	SPI	
FM25V05	512 Mibit	SPI	
FM25V10	1 Mibit	SPI	

6.2.3.2 Configuring the driver

The application has to add the Universal RAM Disk driver to the file system before using it. This is done by calling `FS_AddDevice()` in `FS_X_AddDevices()` with the parameter set to the function table of the Universal RAM Disk driver `FS_RAMDISK_UNI_Driver`.

The maximum number of Universal RAM Disk driver instances that can be added to the file system can be configured at compile time using the `FS_RAMDISK_MAX_NUM_UNITS` configuration define. By default, a maximum number of four Universal RAM Disk driver instances can be added to the file system.

In addition, the application has to configure the RAMDISK physical layer to be used for accessing the storage and if required the RAMDISK hardware layer to be used for the data transfer with the RAM device.

Example

The following configuration example uses the system memory as storage.

```
#include <FS.h>

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define ALLOC_SIZE          0x1100    // Memory pool for the file system in bytes.
#define NUM_SECTORS         16        // Number of sectors on the RAM storage.
#define BYTES_PER_SECTOR    512       // Size of a sector in bytes.
```

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```
/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
//
// Memory pool used for semi-dynamic allocation.
//
static U32 _aMemBlock[ALLOC_SIZE / 4];
//
// Memory to be used as storage.
//
static U32 _aRAMDisk[(NUM_SECTORS * BYTES_PER_SECTOR) / 4];

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*    It is supposed to add all devices, using primarily FS_AddDevice().
*
*  Note
*    (1) Other API functions may NOT be called, since this function is called
*        during initialization. The devices are not yet ready at this point.
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_RAMDISK_UNI_Driver);
  FS_RAMDISK_UNI_SetPhyType(0, &FS_RAMDISK_PHY_System);
  FS_RAMDISK_UNI_SetSectorSize(0, BYTES_PER_SECTOR);
  FS_RAMDISK_SYS_SetMemBlock(0, _aRAMDisk, sizeof(_aRAMDisk));
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(BYTES_PER_SECTOR, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The following configuration example uses as storage a RAM device connected via I2C.

```
#include <FS.h>
#include "FS_RAMDISK_HW_I2C_GPIO_Template.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define ALLOC_SIZE          0x1100    // Memory pool for the file system in bytes.
#define NUM_SECTORS         16        // Number of sectors on the RAM storage.
#define BYTES_PER_SECTOR    512       // Size of a sector in bytes.
#define DEVICE_ADDRESS      0x50      // I2C address of the device.
#define DEVICE_SIZE         8192      // Capacity of the device in bytes.

/*********************************************************************
*
*       Static data
*
**********************************************************************
```

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```
*/
//
// Memory pool used for semi-dynamic allocation.
//
static U32 _aMemBlock[ALLOC_SIZE / 4];

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*    It is supposed to add all devices, using primarily FS_AddDevice().
*
*  Note
*    (1) Other API functions may NOT be called, since this function is called
*        during initialization. The devices are not yet ready at this point.
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_RAMDISK_UNI_Driver);
  FS_RAMDISK_UNI_SetPhyType(0, &FS_RAMDISK_PHY_I2C);
  FS_RAMDISK_UNI_SetSectorSize(0, BYTES_PER_SECTOR);
  FS_RAMDISK_I2C_SetDeviceAddress(0, DEVICE_ADDRESS);
  FS_RAMDISK_I2C_SetDeviceSize(0, DEVICE_SIZE);
  FS_RAMDISK_I2C_SetHWType(0, &FS_RAMDISK_HW_I2C_GPIO_Template);
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(BYTES_PER_SECTOR, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The following configuration example uses as storage a RAM device connected via SPI.

```
#include <FS.h>
#include "FS_RAMDISK_HW_SPI_Template.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define ALLOC_SIZE            0x1100    // Memory pool for the file system in bytes.
#define BYTES_PER_SECTOR      512       // Size of a sector in bytes.

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

/*********************************************************************
*
*       Public code
*
**********************************************************************
```

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```
*/

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*    It is supposed to add all devices, using primarily FS_AddDevice().
*
*  Note
*    (1) Other API functions may NOT be called, since this function is called
*        during initialization. The devices are not yet ready at this point.
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_RAMDISK_UNI_Driver);
  FS_RAMDISK_UNI_SetPhyType(0, &FS_RAMDISK_PHY_SPI);
  FS_RAMDISK_UNI_SetSectorSize(0, BYTES_PER_SECTOR);
  FS_RAMDISK_SPI_SetHWType(0, &FS_RAMDISK_HW_SPI_Template);
  FS_RAMDISK_SPI_SetDeviceList(0, &FS_RAMDISK_SPI_DeviceListAll);
  FS_RAMDISK_SPI_Allow2bitMode(0, 1);
  FS_RAMDISK_SPI_Allow4bitMode(0, 1);
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(BYTES_PER_SECTOR, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

6.2.3.2.1 Compile-time configuration

The compile-time configuration is realized via preprocessor defines that have to be added to the FS_Conf.h file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The RAM Disk driver does not require any hardware access functions. The following table lists the configuration defines supported by the RAM Disk driver.

Define	Default value	Type	Description
FS_RAMDISK_DATA_BUFFER_SIZE	32	N	Number of bytes to be reserved for the data buffers used for internal operations.
FS_RAMDISK_NUM_READ_RETRIES	10	N	Configures the number of retries in case of a read error.
FS_RAMDISK_NUM_UNITS	4	N	Maximum number of driver instances.
FS_RAMDISK_VERIFY_WRITE	0	B	Enables or disables the support for checking if the write operation was successful.

6.2.3.2.1.1 FS_RAMDISK_DATA_BUFFER_SIZE

This define can be used to specify the size of the buffers used by the Universal RAM Disk driver for internal operations such as verifying if the write operation was successful. All these buffers are allocated on the stack; therefore, increasing the value of FS_RAMDISK_DATA_BUFFER_SIZE increases the stack usage while providing better performance. FS_RAMDISK_DATA_BUFFER_SIZE has to be a non-zero value that is a multiple of 4.

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6.2.3.2.1.2 FS_RAMDISK_NUM_READ_RETRIES

`FS_RAMDISK_NUM_READ_RETRIES` can be used to specify the maximum number of times the Universal RAM Disk driver repeats a read operation in case of an error. A read retry is performed each time the read function of the RAMDISK physical layer reports an error.

6.2.3.2.1.3 FS_RAMDISK_NUM_UNITS

This define specifies the maximum number of driver instances that can be created by the application. The memory for each driver instance is allocated dynamically.

6.2.3.2.1.4 FS_RAMDISK_VERIFY_WRITE

This define can be used to activate the write verification of the Universal RAM Disk driver. The write verification is performed after each write operation by reading back the modified data from storage and by comparing it with the data requested to be written. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_RAMDISK_UNI_SetWriteVerification()`.

> **Note**
>
> Activating the write verification can negatively affect the write performance.

6.2.3.2.2 Runtime configuration

This section describes the functions that can be used to configure an instance of the RAM Disk driver.

Function	Description
`FS_RAMDISK_UNI_SetPhyType()`	Configures the physical layer type.
`FS_RAMDISK_UNI_SetByteRange()`	Configures the range of memory to be used as storage.
`FS_RAMDISK_UNI_SetSectorSize()`	Configures the size of the logical sector used by the driver.
`FS_RAMDISK_UNI_SetWriteVerification()`	Enables or disables the checking of the data write operation.

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6.2.3.2.2.1 FS_RAMDISK_UNI_SetPhyType()

Description

Configures the physical layer type.

Prototype

```
int FS_RAMDISK_UNI_SetPhyType(      U8                     Unit,
                              const FS_RAMDISK_PHY_TYPE * pPhyType);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pPhyType	Type of physical layer. It cannot be NULL.

Return value

= 0 OK, physical layer configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is mandatory and it has to be called once in FS_X_AddDevices() for each instance of the RAMDisk driver created by the application. Different instances of the RAMDisk driver are identified by the Unit parameter.

Permitted values for the pPhyType parameter are:

Identifier
FS_RAMDISK_PHY_System
FS_RAMDISK_PHY_I2C
FS_RAMDISK_PHY_SPI

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6.2.3.2.2.2 FS_RAMDISK_UNI_SetByteRange()

Description

Configures the range of memory to be used as storage.

Prototype

```
int FS_RAMDISK_UNI_SetByteRange(U8  Unit,
                                U32 StartOff,
                                U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
StartOff	Offset of the first byte to be used as storage (0-based).
NumBytes	Number of bytes to be used as storage.

Return value

= 0 OK, memory range configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

StartOff is rounded up to a multiple while NumBytes is rounded down to a multiple of logical sector size.

If NumBytes is set to 0 then the memory region used as storage starts at byte offset StartOff and extends to the end of the storage device.

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6.2.3.2.2.3 FS_RAMDISK_UNI_SetSectorSize()

Description

Configures the size of the logical sector used by the driver.

Prototype

```
int FS_RAMDISK_UNI_SetSectorSize(U8       Unit,
                                 unsigned BytesPerSector);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BytesPerSector	Logical sector size in bytes.

Return value

= 0 OK, memory range configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. If the size of the logical sector is not explicitly configured via FS_RAMDISK_UNI_SetSectorSize() then the file system uses the maximum logical sector size set via FS_SetMaxSectorSize(). FS_RAMDISK_UNI_SetSectorSize() can be called only in FS_X_AddDevices().

BytesPerSector has to be a power of 2 value.

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6.2.3.2.2.4 FS_RAMDISK_UNI_SetWriteVerification()

Description

Enables or disables the checking of the data write operation.

Prototype

```
int FS_RAMDISK_UNI_SetWriteVerification(U8 Unit,
                                        U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Universal RAM Disk driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The write operation is not checked. • ≠0 The write operation is checked.

Return value

= 0 OK, write verification configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. It can be used to enable the checking of the written data. This is done by reading back the contents of the written data and by comparing it with the data requested to be written. Enabling this feature can negatively impact the write performance of Universal RAM Disk driver.

The write verification feature is active only when the Universal RAM Disk driver is compiled with the `FS_RAMDISK_VERIFY_WRITE` configuration define is set to 1 (default is 0) or when the `FS_DEBUG_LEVEL` configuration define is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

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6.2.3.3 Additional driver functions

The functions documented in this section are optional. They can be used to get information about the status of the Universal RAM Disk driver or to directly access the data stored on a RAM device.

Function	Description
FS_RAMDISK_UNI_GetDiskInfo()	Gets information about the storage device.
FS_RAMDISK_UNI_ReadOff()	Reads a specified number of bytes from storage device.
FS_RAMDISK_UNI_WriteOff()	Writes a specified number of bytes to storage device.

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6.2.3.3.1 FS_RAMDISK_UNI_GetDiskInfo()

Description

Gets information about the storage device.

Prototype

```
int FS_RAMDISK_UNI_GetDiskInfo(U8                         Unit,
                               FS_RAMDISK_UNI_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDiskInfo	out Storage device information. It cannot be NULL.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

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6.2.3.3.2 FS_RAMDISK_UNI_ReadOff()

Description

Reads a specified number of bytes from storage device.

Prototype

```
int FS_RAMDISK_UNI_ReadOff(U8     Unit,
                           U32    Off,
                           void * pData,
                           U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Off	Byte offset to read from.
pData	out Data read from storage device. It cannot be NULL.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read successfully.
≠ 0 Error code indicating the failure reason.

Additional information

Off has to be specified in bytes and is relative to the beginning of the storage partition configured via FS_RAMDISK_UNI_SetByteRange().

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6.2.3.3.3 FS_RAMDISK_UNI_WriteOff()

Description

Writes a specified number of bytes to storage device.

Prototype

```
int FS_RAMDISK_UNI_WriteOff(      U8     Unit,
                                  U32    Off,
                            const void * pData,
                                  U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Off	Byte offset to write to.
pData	out Data to be written to the storage device. It cannot be NULL.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written successfully.
≠ 0 Error code indicating the failure reason.

Additional information

Off has to be specified in bytes and is relative to the beginning of the storage partition configured via FS_RAMDISK_UNI_SetByteRange().

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6.2.3.3.4 FS_RAMDISK_UNI_DISK_INFO

Description

Management information maintained by the Universal RAM Disk driver.

Type definition

```
typedef struct {
  U32  NumBytes;
  U16  BytesPerSector;
} FS_RAMDISK_UNI_DISK_INFO;
```

Structure members

Member	Description
NumBytes	Capacity of the storage device in bytes.
BytesPerSector	Size of the logical sector used by the driver in bytes.

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6.2.3.4 Performance and resource usage

6.2.3.4.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the Universal RAM Disk driver were measured as described in the section *Test procedure* on page 1439.

Usage: 600 bytes

6.2.3.4.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Universal RAM Disk driver internally for all the driver instances. The number of bytes can be seen in the compiler list file for `FS_RAMDISK_UNI_Drv.c`.

Usage: 16 bytes

6.2.3.4.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. Each instance of the Universal RAM Disk driver requires the following number of bytes:

Usage: 25 bytes

6.2.3.4.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests have been performed as described in the section *Performance* on page 1445. All values are given in Mbytes/sec.

CPU type	RAM device	Write speed	Read speed
ST STM32H743 (480 MHz)	Infineon CY15B104QSN (48 MHz, quad DTR)	**48**	**64**

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6.2.4 RAMDISK physical layer

6.2.4.1 General information

The table below lists the RAMDISK physical layers that ship with emFile. Refer to *Configuring the driver* on page 484 and *Configuring the driver* on page 488 for more information about how to add and configure a physical layer in an application.

Physical layer identifier	Hardware layer type
FS_RAMDISK_PHY_I2C	FS_RAMDISK_HW_TYPE_I2C
FS_RAMDISK_PHY_SPI	FS_RAMDISK_HW_TYPE_SPI
FS_RAMDISK_PHY_System	Not required.

The following sections provide information about the usage and the implementation of a RAMDISK physical layer.

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6.2.4.2 I2C physical layer

This physical layer supports any RAM device connected to the MCU via I2C.

The physical layer has to be configured at runtime. The following section describes how this can be done in the application.

6.2.4.2.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the I2C physical layer. The application can call these functions only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_RAMDISK_I2C_SetDeviceAddress()`	Configures the I2C address of the storage device.
`FS_RAMDISK_I2C_SetDeviceSize()`	Configures the capacity of the storage device.
`FS_RAMDISK_I2C_SetHWType()`	Configures the HW layer for the device access.

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6.2.4.2.1.1 FS_RAMDISK_I2C_SetDeviceAddress()

Description

Configures the I2C address of the storage device.

Prototype

```
int FS_RAMDISK_I2C_SetDeviceAddress(U8       Unit,
                                    unsigned Addr);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
Addr	I2C address to be configured.

Return value

= 0 OK, device address configured.
≠ 0 Error code indicating the failure reason.

Additional information

It is mandatory to call this function once for each configured I2C RAMDisk physical layer. The application must call it in FS_X_AddDevices().

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6.2.4.2.1.2 FS_RAMDISK_I2C_SetDeviceSize()

Description

Configures the capacity of the storage device.

Prototype

```
int FS_RAMDISK_I2C_SetDeviceSize(U8  Unit,
                                 U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
NumBytes	Device capacity to be configured.

Return value

= 0 OK, device capacity configured.
≠ 0 Error code indicating the failure reason.

Additional information

It is mandatory to call this function once for each configured I2C RAMDisk physical layer. The application must call it in FS_X_AddDevices().

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6.2.4.2.1.3 FS_RAMDISK_I2C_SetHWType()

Description

Configures the HW layer for the device access.

Prototype

```
int FS_RAMDISK_I2C_SetHWType(      U8                         Unit,
                             const FS_RAMDISK_HW_TYPE_I2C * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
pHWType	in HW layer to be used. It cannot be NULL.

Return value

= 0 OK, HW layer configured.
≠ 0 Error code indicating the failure reason.

Additional information

It is mandatory to call this function once for each configured I2C RAMDisk physical layer. The application must call it in FS_X_AddDevices().

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6.2.4.3 SPI physical layer

This physical layer supports any RAM device connected to the MCU via single, dual, quad, and octal SPI.

The physical layer has to be configured at runtime. The following section describes how this can be done in the application.

6.2.4.3.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the System physical layer. The application can call these functions only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_RAMDISK_SPI_Allow2bitMode()`	Specifies if the physical layer is permitted to exchange data via two data lines.
`FS_RAMDISK_SPI_Allow4bitMode()`	Specifies if the physical layer is permitted to exchange data via four data lines.
`FS_RAMDISK_SPI_AllowDTRMode()`	Specifies if the physical layer is permitted to exchange data on both clock edges.
`FS_RAMDISK_SPI_SetDeviceList()`	Configures the type of handled serial RAM devices.
`FS_RAMDISK_SPI_SetHWType()`	Configures the HW layer for the device access.
`FS_RAMDISK_SPI_SetMemAddr()`	Configures the address in the system memory where the device is mapped.

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6.2.4.3.1.1 FS_RAMDISK_SPI_Allow2bitMode()

Description

Specifies if the physical layer is permitted to exchange data via two data lines.

Prototype

```
int FS_RAMDISK_SPI_Allow2bitMode(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Return value

= 0 OK, 2 bit mode configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via two data lines is used only if this type of data transfer is supported by the serial RAM device. In dual mode two bits of data are transferred with each clock period which helps improve the performance. If the serial RAM device does not support the dual mode then the data is transferred in standard mode (one data bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.2.4.3.1.2 FS_RAMDISK_SPI_Allow4bitMode()

Description

Specifies if the physical layer is permitted to exchange data via four data lines.

Prototype

```
int FS_RAMDISK_SPI_Allow4bitMode(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Return value

= 0 OK, 4 bit mode configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via four data lines is used only if this type of data transfer is supported by the serial RAM device. In quad mode four bits of data are transferred on each clock period which helps improve the performance. If the serial RAM device does not support the quad mode then the data is transferred in dual mode if enabled and supported or in standard mode (one bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.2.4.3.1.3 FS_RAMDISK_SPI_AllowDTRMode()

Description

Specifies if the physical layer is permitted to exchange data on both clock edges.

Prototype

```
int FS_RAMDISK_SPI_AllowDTRMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Return value

= 0 OK, DTR mode configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. By default the data is exchanged only on one of the clock edges (SDR mode). In DTR mode the data is transferred on each edge of the clock which helps improve the performance. The SPI RAMDISK physical layer transfers the data in DTR mode only if the used serial RAM device supports it.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.2.4.3.1.4 FS_RAMDISK_SPI_SetDeviceList()

Description

Configures the type of handled serial RAM devices.

Prototype

```
int FS_RAMDISK_SPI_SetDeviceList(      U8                            Unit,
                                 const FS_RAMDISK_SPI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pDeviceList	List of serial RAM devices the physical layer can handle.

Return value

= 0 OK, device list successfully configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. By default the physical layer is configured to handle Infineon (Ramtron) serial FRAM devices. Handling of serial RAM devices from other manufacturers has to be explicitly enabled via this function.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NOR_SPI_DeviceListAll
FS_NOR_SPI_DeviceList-Default
FS_NOR_SPI_DeviceList-Fujitsu
FS_NOR_SPI_DeviceListInfineon

The application can save ROM space by setting FS_RAMDISK_DEVICE_LIST_DEFAULT to NULL at compile time and by calling at runtime FS_RAMDISK_SPI_SetDeviceList() with the actual list of serial RAM devices that have to be handled.

The application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

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6.2.4.3.1.5 FS_RAMDISK_SPI_SetHWType()

Description

Configures the HW layer for the device access.

Prototype

```
int FS_RAMDISK_SPI_SetHWType(      U8                         Unit,
                             const FS_RAMDISK_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
pHWType	in HW layer to be used. It cannot be NULL.

Return value

= 0 OK, HW layer configured.
≠ 0 Error code indicating the failure reason.

Additional information

It is mandatory to call this function once for each configured SPI RAMDisk physical layer. The application must call it in FS_X_AddDevices().

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6.2.4.3.1.6 FS_RAMDISK_SPI_SetMemAddr()

Description

Configures the address in the system memory where the device is mapped.

Prototype

```
int FS_RAMDISK_SPI_SetMemAddr(U8  Unit,
                              U32 Addr);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
Addr	Address in the system memory.

Return value

= 0 OK, address successfully configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called only in `FS_X_AddDevices()`.

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6.2.4.3.1.7 RAMDISK HW layer flags

Description

Additional options for data exchanged by the SPI RAMDISK hardware layer.

Definition

```
#define FS_RAMDISK_HW_FLAG_DTR_DATA      (1uL << 0)
#define FS_RAMDISK_HW_FLAG_DTR_ADDR      (1uL << 1)
#define FS_RAMDISK_HW_FLAG_DTR_CMD       (1uL << 2)
#define FS_RAMDISK_HW_FLAG_DQS_ACTIVE    (1uL << 3)
#define FS_RAMDISK_HW_FLAG_MODE_8BIT     (1uL << 4)
```

Symbols

Definition	Description
FS_RAMDISK_HW_FLAG_DTR_DATA	Exchange the data on each clock transition.
FS_RAMDISK_HW_FLAG_DTR_ADDR	Send the address on each clock transition.
FS_RAMDISK_HW_FLAG_DTR_CMD	Send the command on each clock transition.
FS_RAMDISK_HW_FLAG_DQS_ACTIVE	Enable the data strobe signal.
FS_RAMDISK_HW_FLAG_MODE_8BIT	Send eight mode bits after the data address.

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6.2.4.4 System physical layer

This physical layer supports any system memory.

The physical layer has to be configured at runtime. The following section describes how this can be done in the application.

6.2.4.4.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the System physical layer. The application can call these functions only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_RAMDISK_SYS_SetMemBlock()`	Configures the memory block to be used as storage.

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6.2.4.4.1.1 FS_RAMDISK_SYS_SetMemBlock()

Description

Configures the memory block to be used as storage.

Prototype

```
int FS_RAMDISK_SYS_SetMemBlock(U8     Unit,
                               void * pData,
                               U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based).
pData	Memory area to be used as storage. It cannot be NULL.
NumBytes	Number of bytes to be used as storage.

Return value

= 0 OK, memory block configured.
≠ 0 Error code indicating the failure reason.

Additional information

The application has to call this function for each instance of the RAM disk physical layer that is added to the file system. Unit identifies the instance of the RAM disk physical layer.

pData has to point to a memory region that is at least NumBytes bytes large. The memory region can by located on any system memory that is accessible by CPU.

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6.2.4.5 Physical layer API

The physical layers that come with emFile provide support for most of the popular RAM devices and target MCU types. Therefore, there is typically no need to modify any of the provided RAMDISK physical layers. In most cases, only the RAMDISK hardware layer has to be adapted to specific target hardware. However, when none of the provided RAMDISK physical layers are compatible with the target hardware, a new RAMDISK physical layer implementation is required. This section provides information about the API of the RAMDISK physical layer that helps to create a new physical layer from scratch or to modify an existing one.

The API of the physical layer is implemented as a structure of type `FS_RAMDISK_PHY_TYPE` that contains pointers to functions. The following sections describe these functions in detail, together with the data structure passed to these functions as parameters.

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6.2.4.5.1 FS_RAMDISK_PHY_TYPE

Description

RAMDISK physical layer API.

Type definition

```
typedef struct {
  FS_RAMDISK_PHY_TYPE_INIT_GET_DEVICE_INFO * pfInitGetDeviceInfo;
  FS_RAMDISK_PHY_TYPE_READ_OFF             * pfReadOff;
  FS_RAMDISK_PHY_TYPE_WRITE_OFF            * pfWriteOff;
  FS_RAMDISK_PHY_TYPE_DEINIT               * pfDeInit;
} FS_RAMDISK_PHY_TYPE;
```

Structure members

Member	Description
pfInitGetDeviceInfo	Initializes the instance of the RAM physical layer and returns the information about the RAM device.
pfReadOff	Reads data from the RAM device.
pfWriteOff	Writes data to the RAM device.
pfDeInit	Frees the resources allocated by the RAM physical layer instance.

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6.2.4.5.2 FS_RAMDISK_PHY_TYPE_INIT_GET_DEVICE_INFO

Description

Initializes the physical layer.

Type definition

```
typedef int FS_RAMDISK_PHY_TYPE_INIT_GET_DEVICE_INFO(
                                          U8                       Unit,
                                          FS_RAMDISK_DEVICE_INFO * pDeviceInfo);
```

Parameters

Parameter	Description
Unit	Index of the RAMDISK physical layer instance (0-based)
pDeviceInfo	out Information about the NAND flash device.

Return value

= 0 OK, physical layer successfully initialized.
≠ 0 An error occurred.

Additional information

This function is a member of the RAMDISK physical layer API. It has to be implemented by all the RAMDISK physical layers. This is the first function of the physical layer API that is called by the Universal RAM Disk driver when the RAM device is mounted.

This function has to perform the initialization of the hardware layer, and the identification of the RAM device. If the RAM device can be handled, then the function has to fill pDevInfo with information about the organization of the RAM device.

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6.2.4.5.3 FS_RAMDISK_PHY_TYPE_READ_OFF

Description

Reads data from a RAM device.

Type definition

```
typedef int FS_RAMDISK_PHY_TYPE_READ_OFF(U8     Unit,
                                         U32    Off,
                                         void * pData,
                                         U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the RAMDISK physical layer instance (0-based)
Off	Byte offset to read from.
pData	out Data read from RAM device.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the RAMDISK physical layer API. It has to be implemented by all the RAMDISK physical layers.

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6.2.4.5.4 FS_RAMDISK_PHY_TYPE_WRITE_OFF

Description

Writes data to a RAM device.

Type definition

```
typedef int FS_RAMDISK_PHY_TYPE_WRITE_OFF(      U8     Unit,
                                                U32    Off,
                                          const void * pData,
                                                U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the RAMDISK physical layer instance (0-based)
Off	Byte offset to write to.
pData	in Data to be written to the RAM device.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is a member of the RAMDISK physical layer API. It has to be implemented by all the RAMDISK physical layers.

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6.2.4.5.5 FS_RAMDISK_PHY_TYPE_DEINIT

Description

Releases the allocated resources.

Type definition

```
typedef void FS_RAMDISK_PHY_TYPE_DEINIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the RAMDISK physical layer instance (0-based)

Additional information

This function is a member of the RAMDISK physical layer API. It has to be implemented by the all the RAMDISK physical layers that allocate resources dynamically during the initialization such as memory for the physical layer instance.

The RAMDISK driver calls this function when the file system is unmounted.

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6.2.4.5.6 FS_RAMDISK_DEVICE_INFO

Description

Information about a RAM device.

Type definition

```
typedef struct {
  U32  NumBytes;
} FS_RAMDISK_DEVICE_INFO;
```

Structure members

Member	Description
NumBytes	Capacity of the storage device in bytes.

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6.2.4.6 Resource usage

This section describes the ROM and RAM usage of the RAMDISK physical layers.

6.2.4.6.1 ROM usage

The ROM usage depends on the compiler options, the compiler version, and the used CPU. The memory requirements of the RAMDISK physical layers were measured as described in the section *Test procedure* on page 1439.
The following table lists the ROM usage of all the available RAMDISK physical layers.

Name	ROM usage (Kbytes)
I2C	**0.5**
SPI	**1**
System	**0.1**

6.2.4.6.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for static variables inside the driver. The number of bytes can be seen in a compiler list file. The next table lists the static RAM usage of all the available RAMDISK physical layers.

Name	RAM usage (bytes)
I2C	**16**
SPI	**16**
System	**16**

6.2.4.6.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the physical layer at runtime. The amount of RAM required depends on the compile time and runtime configuration. The following table lists the dynamic RAM usage of the available RAMDISK physical layers.

Name	RAM usage (bytes)
I2C	**11**
SPI	**20**
System	**8**

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6.2.5 RAMDISK hardware layer

6.2.5.1 General information

The RAMDISK hardware layer provides functionality for accessing a RAM device via the target hardware such as GPIO, SPI, I2C, etc. The functions of the RAMDISK hardware layer are called by the RAMDISK physical layer to exchange commands and data with a RAM device. These functions are hardware dependent, and therefore they have to be implemented in the application. emFile comes with template hardware layers and sample implementations for popular evaluation boards that can be used as a starting point for implementing new hardware layers. The relevant files are located in the `/Sample/FS/Driver/RAM` folder of the emFile shipment.

The functions of the RAMDISK hardware layer are organized in a function table implemented as a C structure. Different hardware layer types are provided to support different ways of interfacing a RAM device. The type of hardware layer an application has to use depends on the type of RAMDISK physical layer configured. The following table shows what hardware layer is required by each physical layer.

RAMDISK hardware layer	RAMDISK physical layer
FS_RAMDISK_HW_TYPE_I2C	FS_RAMDISK_PHY_I2C
FS_RAMDISK_HW_TYPE_SPI	FS_RAMDISK_PHY_SPI

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6.2.5.2 Hardware layer API - FS_RAMDISK_HW_TYPE_I2C

This hardware layer supports serial RAM devices that are interfaced via I2C. The functions of this hardware layer are grouped in a structure of type `FS_RAMDISK_HW_TYPE_I2C`. The following sections describe these functions in detail.

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6.2.5.2.1 FS_RAMDISK_HW_TYPE_I2C

Description

HW layer for RAM devices connected via I2C.

Type definition

```
typedef struct {
  FS_RAMDISK_HW_TYPE_I2C_INIT  * pfInit;
  FS_RAMDISK_HW_TYPE_I2C_START * pfStart;
  FS_RAMDISK_HW_TYPE_I2C_STOP  * pfStop;
  FS_RAMDISK_HW_TYPE_I2C_READ  * pfRead;
  FS_RAMDISK_HW_TYPE_I2C_WRITE * pfWrite;
} FS_RAMDISK_HW_TYPE_I2C;
```

Structure members

Member	Description
pfInit	Initializes the I2C hardware.
pfStart	Generates a START condition on the I2C bus.
pfStop	Generates a STOP condition on the I2C bus.
pfRead	Transfers data from I2C device to MCU.
pfWrite	Transfers data from MCU to I2C device.

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6.2.5.2.2 FS_RAMDISK_HW_TYPE_I2C_INIT

Description

Initializes the HW layer.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_I2C_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

= 0 OK, HW layer successfully initialized.
≠ 0 An error occurred.

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6.2.5.2.3 FS_RAMDISK_HW_TYPE_I2C_START

Description

Start an I2C transaction.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_I2C_START(U8       Unit,
                                         unsigned Addr,
                                         int      IsRead);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Addr	Address of the device to be accessed.
IsRead	Type of operation to be executed. • 0 - Write operation. • 1 - Read operation.

Return value

= 0 OK, transaction successfully started.
≠ 0 An error occurred.

Additional information

This function is a member of the I2C RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

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6.2.5.2.4 FS_RAMDISK_HW_TYPE_I2C_STOP

Description

Ends an I2C transaction.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_I2C_STOP(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

= 0 OK, transaction successfully ended.
≠ 0 An error occurred.

Additional information

This function is a member of the I2C RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

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6.2.5.2.5 FS_RAMDISK_HW_TYPE_I2C_READ

Description

Transfers data from I2C device to MCU.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_I2C_READ(U8   Unit,
                                        U8 * pData,
                                        U32  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data read from I2C device.
NumBytes	Number of bytes to transfer.

Return value

= 0 OK, data successfully transferred.
≠ 0 An error occurred.

Additional information

This function is a member of the I2C RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

The function has to send a NAK after the last byte transferred.

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6.2.5.2.6 FS_RAMDISK_HW_TYPE_I2C_WRITE

Description

Transfers data from MCU to I2C device.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_I2C_WRITE(      U8   Unit,
                                         const U8 * pData,
                                               U32  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	in Data written to I2C device.
NumBytes	Number of bytes to transfer.

Return value

= 0 OK, data successfully transferred.
≠ 0 An error occurred.

Additional information

This function is a member of the I2C RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

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6.2.5.2.7 Sample implementation

The following sample implementation uses the GPIOs of an ST STM32H743 MCU to interface with an I2C RAM device. This RAMDISK hardware layer was tested on the SEGGER QSPI Flash Evaluator board (https://www.segger.com/evaluate-our-software/segger/qspi-flash-evaluator/)

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_RAMDISK_HW_I2C_GPIO_STM32H743_SEGGER_QSPI_Flash_Evaluator.c
Purpose : Hardware layer for SEGGER QSPI Flash Evaluator
          with RAM device connected via I2C.
Literature:
  [1] RM0433 Reference manual STM32H7x3 advanced ARM-based 32-bit MCUs
  [2] STM32H753xI Errata sheet STM32H753xI rev Y device limitations
Additional information:
  The value of RAM_NUM_DELAY_LOOPS was determined by testing with
  different I2C RAM devices. The resulting maximum SCL frequency
  for a stable data transfer is about 100 kHz which is relatively
  slow compared with the 1 MHz clock frequency supported by most
  of the I2C RAM devices.
  The reason for this limitation is that the HW layer is using
  the internal pull-up resistors of the GPIO ports for the SCL
  and SDA signals. According to the datasheet of STM32H7 device
  the value of the internal pull-up resistors is about 40 kOhm.
  The frequency of SCL signal can be greatly improved by using
  external pull-up resistors of about 4.7 kOhm.

  The device select address signals (A0-2) are set to logic low.
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#define RAM_NUM_DELAY_LOOPS       500   // Number of software cycles required
                                        // to generate a delay of at least
                                        // 4.7 us if the I2C device supports
                                        // standard-mode (400kHz) or of at least
                                        // 1.3 us if the I2C device support
                                        // fast-mode (1MHz).

/*********************************************************************
*
*       RAM_SET_SCL
*
*  Description
*    Sets the logic level of SCL signal to high.
*/
#define RAM_SET_SCL()             GPIOF_BSRR = 1uL << RAM_SCL_BIT

/*********************************************************************
*
*       RAM_CLR_SCL
*
*  Description
*    Sets the logic level of SCL signal to low.
*/
#define RAM_CLR_SCL()             GPIOF_BSRR = 1uL << (RAM_SCL_BIT + 16)
```

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```
/*********************************************************************
*
*       RAM_SET_SDA
*
*  Description
*    Sets the logic level of SDA signal to high.
*/
#define RAM_SET_SDA()             GPIOF_BSRR = 1uL << RAM_SDA_BIT

/*********************************************************************
*
*       RAM_CLR_SDA
*
*  Description
*    Sets the logic level of SDA signal to high.
*/
#define RAM_CLR_SDA()             GPIOF_BSRR = 1uL << (RAM_SDA_BIT + 16)

/*********************************************************************
*
*       RAM_SET_SDA_TO_INPUT
*
*  Description
*    Configures the direction of the SDA signal to input.
*/
#define RAM_SET_SDA_TO_INPUT()    GPIOF_MODER &= ~(MODER_MASK << (RAM_SDA_BIT << 1));

/*********************************************************************
*
*       RAM_SET_SDA_TO_OUTPUT
*
*  Description
*    Configures the direction of the SDA signal to output.
*/
#define RAM_SET_SDA_TO_OUTPUT()   GPIOF_MODER |= MODER_OUT << (RAM_SDA_BIT << 1)

/*********************************************************************
*
*       RAM_GET_SDA
*
*  Description
*    Returns the logic level of the SDA signal.
*/
#define RAM_GET_SDA()             (GPIOF_IDR & (1uL << RAM_SDA_BIT))

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*       RAM_DELAY
*
*  Description
*    Blocks the execution for a fixed period of time.
*/
#if RAM_NUM_DELAY_LOOPS
  #define RAM_DELAY()             _Delay()
#else
  #define RAM_DELAY()
#endif

/*********************************************************************
*
*       Port B registers
*/
#define GPIOB_BASE_ADDR           0x58020400uL
#define GPIOB_MODER               (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x00))
#define GPIOB_OTYPE               (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x04))
#define GPIOB_OSPEEDR             (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x08))
#define GPIOB_PUPDR               (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x0C))
#define GPIOB_IDR                 (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x10))
```

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```
#define GPIOB_ODR                 (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x14))
#define GPIOB_BSRR                (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x18))
#define GPIOB_AFRL                (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x20))

/*********************************************************************
*
*       Port F registers
*/
#define GPIOF_BASE_ADDR           0x58021400uL
#define GPIOF_MODER               (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x00))
#define GPIOF_OTYPE               (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x04))
#define GPIOF_OSPEEDR             (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x08))
#define GPIOF_PUPDR               (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x0C))
#define GPIOF_IDR                 (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x10))
#define GPIOF_ODR                 (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x14))
#define GPIOF_BSRR                (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x18))
#define GPIOF_AFRL                (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x20))
#define GPIOF_AFRH                (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x24))

/*********************************************************************
*
*       Reset and clock control
*/
#define RCC_BASE_ADDR             0x58024400uL
#define RCC_AHB3RSTR              (*(volatile U32*)(RCC_BASE_ADDR + 0x7C))
#define RCC_AHB3ENR               (*(volatile U32*)(RCC_BASE_ADDR + 0xD4))
#define RCC_AHB4ENR               (*(volatile U32*)(RCC_BASE_ADDR + 0xE0))

/*********************************************************************
*
*       GPIO bit positions of SPI signals
*/
#define RAM_SCL_BIT               10  // Port F
#define RAM_SDA_BIT               8   // Port F
#define RAM_A0_BIT                6   // Port B
#define RAM_A1_BIT                9   // Port F
#define RAM_A2_BIT                7   // Port F
#define RAM_WP_BIT                6   // Port F

/*********************************************************************
*
*       GPIO bits and masks
*/
#define OSPEEDR_HIGH              2uL
#define OSPEEDR_MASK              0x3uL
#define MODER_MASK                0x3uL
#define MODER_OUT                 1uL
#define MODER_ALT                 2uL
#define AFR_MASK                  0xFuL
#define PUPDR_MASK                0x3uL
#define PUPDR_PULLUP              0x1uL

/*********************************************************************
*
*       Masks for the peripheral enable bits
*/
#define AHB1ENR_GPIOBEN_BIT       1
#define AHB1ENR_GPIOFEN_BIT       5

/*********************************************************************
*
*        Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _Delay
*
*  Function description
*    Blocks the execution for a specified time.
*
*  Additional information
*    The delay time is specified via RAM_NUM_DELAY_LOOPS.
*/
```

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```
static void _Delay(void) {
  volatile int i;

  for (i = 0; i < RAM_NUM_DELAY_LOOPS; ++i) {
    ;
  }
}

/*********************************************************************
*
*       _WriteByte
*
*  Function description
*    Transfers 8 bits of data from MCU to I2C device.
*
*  Parameters
*    Data    8-bit value to be transferred.
*
*  Return value
*    ==0      Data accepted by the I2C device (ACK/NACK bit set to 0)
*    !=0      Data rejected by the I2C device (ACK/NACK bit set to 1)
*/
static int _WriteByte(U8 Data) {
  int r;
  int i;

  //
  // Send data bits with MSB first.
  //
  for (i = 0; i < 8; ++i) {
    if ((Data & (1 << 7)) != 0) {
      RAM_SET_SDA();
    } else {
      RAM_CLR_SDA();
    }
    Data <<= 1;
    RAM_DELAY();          // Wait tLOW
    RAM_SET_SCL();
    RAM_DELAY();          // Wait tHIGH
    RAM_CLR_SCL();
  }
  //
  // Receive ACK/NACK.
  //
  RAM_SET_SDA_TO_INPUT();
  RAM_DELAY();            // Wait tLOW
  RAM_SET_SCL();
  RAM_DELAY();            // Wait tHIGH
  r = RAM_GET_SDA();
  RAM_CLR_SCL();
  RAM_DELAY();            // Wait tLOW
  RAM_SET_SDA_TO_OUTPUT();
  return r;
}

/*********************************************************************
*
*       _ReadByte
*
*  Function description
*    Transfers 8 bits of data from I2C device to MCU.
*
*  Parameters
*    AckNack      Value of the ACK/NACK bit.
*                 * 0 - More data will be transferred (ACK/NACK is set to 0)
*                 * 1 - Last data to be transferred (ACK/NACK is set to 1)
*
*  Return value
*    Transferred 8-bit value.
*/
static U8 _ReadByte(int AckNack) {
  U8 Value;
  int i;

  //
  // Receive data bits with MSB first.
```

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```
  //
  RAM_SET_SDA_TO_INPUT();
  RAM_DELAY();            // Wait tLOW
  Value = 0;
  for (i = 0; i < 8; ++i) {
    RAM_SET_SCL();
    RAM_DELAY();          // Wait tHIGH
    Value <<= 1;
    if (RAM_GET_SDA() != 0) {
      Value |= 1u;
    }
    RAM_CLR_SCL();
    RAM_DELAY();          // Wait tLOW
  }
  //
  // Send ACK/NACK.
  //
  if (AckNack != 0) {
    RAM_CLR_SDA();
  } else {
    RAM_SET_SDA();
  }
  RAM_SET_SDA_TO_OUTPUT();
  RAM_SET_SCL();
  RAM_DELAY();            // Wait tHIGH
  RAM_CLR_SCL();
  return Value;
}

/*********************************************************************
*
*        Static code (public via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initializes the HW layer.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*
*  Return value
*    ==0      OK, HW layer successfully initialized.
*    !=0      An error occurred.
*/
static int _HW_Init(U8 Unit) {
  FS_USE_PARA(Unit);
  //
  // Enable the clocks of GPIO peripherals.
  //
  RCC_AHB4ENR  |= 0
               | (1uL << AHB1ENR_GPIOBEN_BIT)
               | (1uL << AHB1ENR_GPIOFEN_BIT)
               ;
  //
  // Clock signal (SCL).
  //
  GPIOF_MODER   &= ~(MODER_MASK   <<  (RAM_SCL_BIT << 1));
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_SCL_BIT - 8) << 2));
  GPIOF_PUPDR   &= ~(PUPDR_MASK   <<  (RAM_SCL_BIT << 1));
  GPIOF_PUPDR   |=   PUPDR_PULLUP <<  (RAM_SCL_BIT << 1);
  GPIOF_BSRR    =    1uL          <<   RAM_SCL_BIT;              // Set to high logic level.
  GPIOF_OTYPE   |=   1uL          <<   RAM_SCL_BIT;              // Set to open-drain.
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_SCL_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    <<  (RAM_SCL_BIT << 1);
  //
  // Data signal (SDA).
  //
  GPIOF_MODER   &= ~(MODER_MASK   <<  (RAM_SDA_BIT << 1));
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_SDA_BIT - 8) << 2));
  GPIOF_PUPDR   &= ~(PUPDR_MASK   <<  (RAM_SDA_BIT << 1));
```

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```
  GPIOF_PUPDR   |=   PUPDR_PULLUP <<  (RAM_SDA_BIT << 1);
  GPIOF_BSRR    =    1uL          <<   RAM_SDA_BIT;              // Set to high logic level.
  GPIOF_OTYPE   |=   1uL          <<   RAM_SDA_BIT;              // Set to open-drain.
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_SDA_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    <<  (RAM_SDA_BIT << 1);
  //
  // Address pin 0 (A0).
  //
  GPIOB_MODER   &= ~(MODER_MASK   <<  (RAM_A0_BIT << 1));
  GPIOB_AFRL    &= ~(AFR_MASK     <<  (RAM_A0_BIT << 2));
  GPIOB_BSRR    =    1uL          <<  (RAM_A0_BIT + 16);         // Set to low logic level.
  GPIOB_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_A0_BIT << 1));
  GPIOB_MODER   |=   MODER_OUT    <<  (RAM_A0_BIT << 1);
  //
  // Address pin 1 (A1).
  //
  GPIOF_MODER   &= ~(MODER_MASK   <<  (RAM_A1_BIT << 1));
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_A1_BIT - 8) << 2));
  GPIOF_BSRR    =    1uL          <<  (RAM_A1_BIT + 16);         // Set to low logic level.
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_A1_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    <<  (RAM_A1_BIT << 1);
  //
  // Address pin 2 (A2).
  //
  GPIOF_MODER   &= ~(MODER_MASK   <<  (RAM_A2_BIT << 1));
  GPIOF_AFRL    &= ~(AFR_MASK     <<  (RAM_A2_BIT << 2));
  GPIOF_BSRR    =    1uL          <<  (RAM_A2_BIT + 16);         // Set to low logic level.
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_A2_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    <<  (RAM_A2_BIT << 1);
  //
  // Write protect pin (WP).
  //
  GPIOF_MODER   &= ~(MODER_MASK   <<  (RAM_WP_BIT << 1));
  GPIOF_AFRL    &= ~(AFR_MASK     <<  (RAM_WP_BIT << 2));
  GPIOF_BSRR    =    1uL          <<  (RAM_WP_BIT + 16);
  // Set to low logic level to disable the write protection.
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK <<  (RAM_WP_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    <<  (RAM_WP_BIT << 1);
  return 0;
}

/*********************************************************************
*
*       _HW_Start
*
*  Function description
*    Start an I2C transaction.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    Addr           Address of the device to be accessed.
*    IsRead         Type of operation to be executed.
*                   * 0 - Write operation.
*                   * 1 - Read operation.
*
*  Return value
*    ==0      OK, transaction successfully started.
*    !=0      An error occurred.
*/
static int _HW_Start(U8 Unit, unsigned Addr, int IsRead) {
  int r;
  U8  AddrByte;

  FS_USE_PARA(Unit);
  AddrByte = (U8)(Addr << 1);
  if (IsRead != 0) {
    AddrByte |= 1u;
  }
  RAM_SET_SDA();
  RAM_SET_SCL();
  RAM_DELAY();            // Wait tBUF
  RAM_CLR_SDA();
  RAM_DELAY();            // Wait tHD;STA
  RAM_CLR_SCL();
  r = _WriteByte(AddrByte);
  if (r != 0) {
```

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```
    return 1;
  }
  return 0;
}

/*********************************************************************
*
*       _HW_Stop
*
*  Function description
*    Ends an I2C transaction.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*
*  Return value
*    ==0      OK, transaction successfully ended.
*    !=0      An error occurred.
*/
static int _HW_Stop(U8 Unit) {
  FS_USE_PARA(Unit);
  RAM_CLR_SDA();
  RAM_DELAY();             // Wait tLOW
  RAM_SET_SCL();
  RAM_DELAY();             // Wait tSU;STO
  RAM_SET_SDA();
  return 0;
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    Transfers data from I2C device to MCU.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pData          [OUT] Data read from I2C device.
*    NumBytes       Number of bytes to transfer.
*
*  Return value
*    ==0      OK, data successfully transferred.
*    !=0      An error occurred.
*/
static int _HW_Read(U8 Unit, U8 * pData, U32 NumBytes) {
  FS_USE_PARA(Unit);
  if (NumBytes != 0u) {
    --NumBytes;
    if (NumBytes != 0) {
      do {
        *pData++ = _ReadByte(1);
      } while (--NumBytes != 0u);
    }
    *pData = _ReadByte(0);
  }
  return 0;
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    Transfers data from MCU to I2C device.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pData          [IN] Data written to I2C device.
*    NumBytes       Number of bytes to transfer.
*
*  Return value
*    ==0      OK, data successfully transferred.
*    !=0      An error occurred.
*/
static int _HW_Write(U8 Unit, const U8 * pData, U32 NumBytes) {
```

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```
  int r;

  FS_USE_PARA(Unit);
  r = 0;                  // Set to indicate success.
  if (NumBytes != 0u) {
    do {
      r = _WriteByte(*pData++);
      if (r != 0) {
        break;
      }
    } while (--NumBytes != 0u);
  }
  return r;
}

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_RAMDISK_HW_I2C_GPIO_STM32H743_SEGGER_QSPI_Flash_Evaluator
*/
const FS_RAMDISK_HW_TYPE_I2C FS_RAMDISK_HW_I2C_GPIO_STM32H743_SEGGER_QSPI_Flash_Evaluator = {
  _HW_Init,
  _HW_Start,
  _HW_Stop,
  _HW_Read,
  _HW_Write
};

/************************** End of file ***************************/
```

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6.2.5.3 Hardware layer API - FS_RAMDISK_HW_TYPE_SPI

This hardware layer supports serial RAM devices that are interfaced via SPI. The functions of this hardware layer are grouped in a structure of type `FS_RAMDISK_HW_TYPE_SPI`. The following sections describe these functions in detail.

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6.2.5.3.1 FS_RAMDISK_HW_TYPE_SPI

Description

HW layer for RAM devices connected via SPI (single, dual, quad or octal).

Type definition

```
typedef struct {
  FS_RAMDISK_HW_TYPE_SPI_INIT    * pfInit;
  FS_RAMDISK_HW_TYPE_SPI_UNMAP   * pfUnmap;
  FS_RAMDISK_HW_TYPE_SPI_MAP     * pfMap;
  FS_RAMDISK_HW_TYPE_SPI_CONTROL * pfControl;
  FS_RAMDISK_HW_TYPE_SPI_READ    * pfRead;
  FS_RAMDISK_HW_TYPE_SPI_WRITE   * pfWrite;
  FS_RAMDISK_HW_TYPE_SPI_LOCK    * pfLock;
  FS_RAMDISK_HW_TYPE_SPI_UNLOCK  * pfUnlock;
} FS_RAMDISK_HW_TYPE_SPI;
```

Structure members

Member	Description
pfInit	Initializes the hardware.
pfUnmap	Configures the hardware for direct access to serial RAM device.
pfMap	Configures the hardware for access to serial RAM device via system memory.
pfControl	Sends a command to serial RAM device that does not transfer any data.
pfRead	Transfers data from serial RAM device to MCU.
pfWrite	Transfers data from MCU to serial RAM device.
pfLock	Requests exclusive access to SPI bus.
pfUnlock	Releases the exclusive access to SPI bus.

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6.2.5.3.2 FS_RAMDISK_HW_TYPE_SPI_INIT

Description

Initializes the SPI hardware.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

> 0 OK, frequency of the SPI clock in Hz.
= 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

This function is called by the SPI RAMDISK physical layer before any other function of the hardware layer each time the file system mounts the serial RAM deice. `FS_RAMDISK_HW_TYPE_SPI_INIT` has to perform the initialization of clock signals, GPIO ports, SPI controller, etc.

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6.2.5.3.3 FS_RAMDISK_HW_TYPE_SPI_UNMAP

Description

Configures the hardware for direct access to serial RAM device.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_UNMAP(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

= 0 OK, direct mode configured successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. It has to be implemented by all the hardware layers.

The physical layer calls this function before it starts sending commands directly to the serial RAM device. Typically, the SPI hardware can operate in two modes: command and memory. In command mode the physical layer can access the serial RAM device directly by sending commands to it. In the memory mode the SPI hardware translates read accesses to an assigned memory region to serial RAM device read commands. In this way, the contents of the contents of the serial RAM device is mapped into this memory region.

If the command and memory mode are mutually exclusive, `FS_NOR_HW_TYPE_SPIFI_UNMAP` has to disable the memory mode.

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6.2.5.3.4 FS_RAMDISK_HW_TYPE_SPI_MAP

Description

Configures the hardware for access to serial RAM device via system memory.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_MAP(      U8       Unit,
                                       const U8     * pCmd,
                                             unsigned NumBytesCmd,
                                       const U8     * pPara,
                                             unsigned NumBytesPara,
                                             unsigned NumBytesAddr,
                                             U16      BusWidth,
                                             unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be used for reading the data. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, memory mode configured successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. The implementation of this function is mandatory if the SPI hardware supports the access to RAM device via system memory. If FS_RAMDISK_HW_TYPE_SPI_MAP is not provided then the SPI RAMDISK physical layer accesses the RAM device in command mode.

Flags is a bitwise-or combination of *RAMDISK HW layer flags* on page 515.

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6.2.5.3.5 FS_RAMDISK_HW_TYPE_SPI_CONTROL

Description

Sends a command to serial RAM device that does not transfer any data.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_CONTROL(      U8       Unit,
                                           const U8     * pCmd,
                                                 unsigned NumBytesCmd,
                                                 U8       BusWidth,
                                                 unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
BusWidth	Number of data lines to be used for sending the command.
Flags	Options for the data exchange.

Return value

= 0 OK, command transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. The implementation of this function is mandatory.

Flags is a bitwise-or combination of *RAMDISK HW layer flags* on page 515.

The value of BusWidth is not encoded as is the case with the other functions of this physical layer. The value specified via BusWidth is the actual number of data lines that have to be used for the data transfer of the command code. Permitted values are 1, 2, 4 and 8.

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6.2.5.3.6 FS_RAMDISK_HW_TYPE_SPI_READ

Description

Transfers data from serial RAM device to MCU.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_READ(      U8       Unit,
                                        const U8     * pCmd,
                                              unsigned NumBytesCmd,
                                        const U8     * pPara,
                                              unsigned NumBytesPara,
                                              unsigned NumBytesAddr,
                                              U8     * pData,
                                              unsigned NumBytesData,
                                              U16      BusWidth,
                                              unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	out Data read from the serial RAM device. Can be NULL.
NumBytesData	Number of bytes to read from the serial RAM device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. The implementation of this function is mandatory.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara. If NumBytesAddr is equal to NumBytesPara then neither mode nor dummy bytes have to be sent. The number of dummy bytes to be generated can be calculated as NumBytesPara - NumBytesAddr. If the hardware generates dummy cycles instead of bytes then the number of dummy bytes has to converted to clock cycles by taking into account the number of data lines used for the data transfer of the address.

Flags is a bitwise-or combination of *RAMDISK HW layer flags* on page 515.

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6.2.5.3.7 FS_RAMDISK_HW_TYPE_SPI_WRITE

Description

Transfers data from MCU to serial RAM device.

Type definition

```
typedef int FS_RAMDISK_HW_TYPE_SPI_WRITE(      U8       Unit,
                                         const U8     * pCmd,
                                               unsigned NumBytesCmd,
                                         const U8     * pPara,
                                               unsigned NumBytesPara,
                                               unsigned NumBytesAddr,
                                         const U8     * pData,
                                               unsigned NumBytesData,
                                               U16      BusWidth,
                                               unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	in Data to be sent to the serial RAM device. Can be NULL.
NumBytesData	Number of bytes to be written the serial RAM device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI RAMDISK hardware layer API. The implementation of this function is mandatory.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara.

Flags is a bitwise-or combination of *RAMDISK HW layer flags* on page 515.

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6.2.5.3.8 FS_RAMDISK_HW_TYPE_SPI_LOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_RAMDISK_HW_TYPE_SPI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function to indicate that it needs exclusive to access the NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling this function first. It is also guaranteed that FS_RAMDISK_HW_TYPE_SPI_LOCK and FS_RAMDISK_HW_TYPE_SPI_UNLOCK are called in pairs. Typically, this function is used for synchronizing the access to SPI bus when the SPI bus is shared between the serial NOR flash and other SPI devices.

A possible implementation would make use of an OS semaphore that is acquired in FS_RAMDISK_HW_TYPE_SPI_LOCK and released in FS_RAMDISK_HW_TYPE_SPI_UNLOCK.

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6.2.5.3.9 FS_RAMDISK_HW_TYPE_SPI_UNLOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_RAMDISK_HW_TYPE_SPI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function when it no longer needs to access the serial NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling FS_RAMDISK_HW_TYPE_SPI_LOCK. It is also guaranteed that FS_RAMDISK_HW_TYPE_SPI_UNLOCK and FS_RAMDISK_HW_TYPE_SPI_LOCK are called in pairs.

FS_RAMDISK_HW_TYPE_SPI_UNLOCK and FS_RAMDISK_HW_TYPE_SPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the serial NOR flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired FS_RAMDISK_HW_TYPE_SPI_LOCK and released in FS_RAMDISK_HW_TYPE_SPI_UNLOCK.

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6.2.5.3.10 Sample implementation

The following sample implementation uses the QUADSPI controller of an ST STM32H743 MCU to interface with an SPI RAM device. This RAMDISK hardware layer was tested on the SEGGER QSPI Flash Evaluator board (https://www.segger.com/evaluate-our-software/segger/qspi-flash-evaluator/)

```
/*********************************************************************
*                   (c) SEGGER Microcontroller GmbH                  *
*                        The Embedded Experts                        *
*                           www.segger.com                           *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_RAMDISK_HW_SPI_STM32H743_SEGGER_QSPI_Flash_Evaluator.c
Purpose : Hardware layer for SEGGER QSPI Flash Evaluator
          with RAM device connected via SPI.
Literature:
  [1] RM0433 Reference manual STM32H7x3 advanced ARM-based 32-bit MCUs
  [2] STM32H753xI Errata sheet STM32H753xI rev Y device limitations
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_RAMDISK_HW_PER_CLK_HZ
  #define FS_RAMDISK_HW_PER_CLK_HZ              240000000     // Clock of Quad-SPI unit.
#endif

#ifndef   FS_RAMDISK_HW_RAM_CLK_HZ
  #define FS_RAMDISK_HW_RAM_CLK_HZ              48000000
  // Frequency of the clock supplied to RAM device.
#endif

#ifndef   FS_RAMDISK_HW_QUADSPI_MEM_ADDR
  #define FS_RAMDISK_HW_QUADSPI_MEM_ADDR        0x90000000
  // This is the start address of the memory region used by the file system

  // to read the data from the serial RAM device. The hardware layer

  // uses this address to invalidate the data cache.
#endif

#ifndef   FS_RAMDISK_HW_USE_QUAD_MODE
  #define FS_RAMDISK_HW_USE_QUAD_MODE           1
  // Enables/disables the support for quad mode.
#endif

#ifndef   FS_RAMDISK_HW_USE_MEM_MAP_MODE
  #define FS_RAMDISK_HW_USE_MEM_MAP_MODE        1
  // Enables or disables the access to the RAM device data via system memory.
#endif

#ifndef   FS_RAMDISK_HW_RESET_TIME_MS
  #define FS_RAMDISK_HW_RESET_TIME_MS           10
  // Number milliseconds to keep the reset line low.
#endif

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
```

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```
*/

/*********************************************************************
*
*       QSPI registers
*/
#define QUADSPI_BASE_ADDR       0x52005000uL
#define QUADSPI_CR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x00))
#define QUADSPI_DCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x04))
#define QUADSPI_SR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x08))
#define QUADSPI_FCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x0C))
#define QUADSPI_DLR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x10))
#define QUADSPI_CCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x14))
#define QUADSPI_AR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x18))
#define QUADSPI_ABR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x1C))
#define QUADSPI_DR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x20))
#define QUADSPI_DR_BYTE         (*(volatile U8  *)(QUADSPI_BASE_ADDR + 0x20))
#define QUADSPI_PSMKR           (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x24))
#define QUADSPI_PSMAR           (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x28))
#define QUADSPI_PIR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x2C))
#define QUADSPI_LPTR            (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x30))

/*********************************************************************
*
*       Port B registers
*/
#define GPIOB_BASE_ADDR         0x58020400uL
#define GPIOB_MODER             (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x00))
#define GPIOB_OSPEEDR           (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x08))
#define GPIOB_PUPDR             (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x0C))
#define GPIOB_ODR               (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x14))
#define GPIOB_AFRL              (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x20))

/*********************************************************************
*
*       Port F registers
*/
#define GPIOF_BASE_ADDR         0x58021400uL
#define GPIOF_MODER             (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x00))
#define GPIOF_OSPEEDR           (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x08))
#define GPIOF_PUPDR             (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x0C))
#define GPIOF_ODR               (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x14))
#define GPIOF_BSRR              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x18))
#define GPIOF_AFRL              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x20))
#define GPIOF_AFRH              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x24))

/*********************************************************************
*
*       Reset and clock control
*/
#define RCC_BASE_ADDR           0x58024400uL
#define RCC_AHB3RSTR            (*(volatile U32*)(RCC_BASE_ADDR + 0x7C))
#define RCC_AHB3ENR             (*(volatile U32*)(RCC_BASE_ADDR + 0xD4))
#define RCC_AHB4ENR             (*(volatile U32*)(RCC_BASE_ADDR + 0xE0))

/*********************************************************************
*
*       System Control Block
*/
#define SCB_BASE_ADDR           0xE000E000uL
#define SCB_CCR                 (*(volatile U32 *)(SCB_BASE_ADDR + 0xD14))
  // Configuration Control Register

/*********************************************************************
*
*       Memory protection unit
*/
#define MPU_BASE_ADDR           0xE000ED90uL
#define MPU_TYPE                (*(volatile U32 *)(MPU_BASE_ADDR + 0x00))
#define MPU_CTRL                (*(volatile U32 *)(MPU_BASE_ADDR + 0x04))
#define MPU_RNR                 (*(volatile U32 *)(MPU_BASE_ADDR + 0x08))
#define MPU_RBAR                (*(volatile U32 *)(MPU_BASE_ADDR + 0x0C))
#define MPU_RASR                (*(volatile U32 *)(MPU_BASE_ADDR + 0x10))

/*********************************************************************
*
```

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```
*       Masks for the peripheral enable bits
*/
#define AHB1ENR_GPIOBEN         1
#define AHB1ENR_GPIOFEN         5
#define AHB3ENR_QSPIEN          14

/*********************************************************************
*
*       GPIO bit positions of SPI signals
*/
#define RAM_BK1_NCS_BIT         6   // Port B
#define RAM_CLK_BIT             10  // Port F
#define RAM_BK1_D0_BIT          8   // Port F
#define RAM_BK1_D1_BIT          9   // Port F
#define RAM_BK1_D2_BIT          7   // Port F
#define RAM_BK1_D3_BIT          6   // Port F
#define RAM_MP6_BIT             3   // Port F
#define RAM_RST_BIT             11  // Port F

/*********************************************************************
*
*       GPIO bits and masks
*/
#define OSPEEDR_HIGH            2uL
#define OSPEEDR_MASK            0x3uL
#define MODER_MASK              0x3uL
#define MODER_OUT               1uL
#define MODER_ALT               2uL
#define AFR_MASK                0xFuL

/*********************************************************************
*
*       Quad-SPI control register
*/
#define CR_EN_BIT               0
#define CR_ABORT_BIT            1
#define CR_SSHIFT_BIT           4
#define CR_SMIE_BIT             19
#define CR_APMS_BIT             22
#define CR_PRESCALER_BIT        24
#define CR_PRESCALER_MAX        255

/*********************************************************************
*
*       Quad-SPI device configuration register
*/
#define DCR_CKMODE_BIT          0
#define DCR_FSIZE_BIT           16
#define DCR_FSIZE_MAX           0x1FuL

/*********************************************************************
*
*       Quad-SPI status register
*/
#define SR_TEF_BIT              0
#define SR_TCF_BIT              1
#define SR_SMF_BIT              3
#define SR_TOF_BIT              4
#define SR_BUSY_BIT             5
#define SR_FLEVEL_BIT           8
#define SR_FLEVEL_MASK          0x3FuL

/*********************************************************************
*
*       Quad-SPI communication configuration register
*/
#define CCR_INTRUCTION_BIT      0
#define CCR_IMODE_BIT           8
#define CCR_MODE_NONE           0
#define CCR_MODE_SINGLE         1uL
#define CCR_MODE_DUAL           2uL
#define CCR_MODE_QUAD           3uL
#define CCR_ADMODE_BIT          10
#define CCR_ADSIZE_BIT          12
#define CCR_ADSIZE_MASK         0x03uL
#define CCR_ABMODE_BIT          14
```

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```
#define CCR_ABSIZE_BIT          16
#define CCR_ABSIZE_MASK         0x03uL
#define CCR_DCYC_BIT            18
#define CCR_DMODE_BIT           24
#define CCR_FMODE_BIT           26
#define CCR_FMODE_WRITE         0x0uL
#define CCR_FMODE_READ          0x1uL
#define CCR_FMODE_POLL          0x2uL
#define CCR_FMODE_MMAP          0x3uL
#define CCR_FMODE_MASK          0x3uL
#define CCR_DDRM_BIT            31

/*********************************************************************
*
*       MPU defines
*/
#define CTRL_ENABLE_BIT         0
#define CTRL_PRIVDEFENA_BIT     2
#define RNR_REGION_MASK         0xFF
#define RASR_ENABLE_BIT         0
#define RASR_SIZE_BIT           1
#define RASR_TEX_BIT            19
#define RASR_AP_BIT             24
#define RASR_XN_BIT             28
#define RASR_AP_FULL            0x3uL
#define TYPE_DREGION_BIT        8
#define TYPE_DREGION_MASK       0xFFuL
#define RBAR_REGION_BIT         0
#define RBAR_REGION_MASK        0x1FuL
#define RBAR_VALID_BIT          5

/*********************************************************************
*
*       Misc. defines
*/
#define NUM_BYTES_FIFO          32
#define CCR_DC_BIT              16
#define QUADSPI_MEM_SIZE_SHIFT  28              // Size of the memory region reserved for QUADSPI
 (256 MB)
#define QUADSPI_PRIO            15
#define CYCLES_PER_MS           150000          // Depends on the CPU clock frequency.
#define WAIT_TIMEOUT_MS         500
#define WAIT_TIMEOUT_CYCLES     (WAIT_TIMEOUT_MS * CYCLES_PER_MS)

/*********************************************************************
*
*      Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _CalcClockDivider
*
*  Function description
*    Calculates the divider for the clock supplied to RAM device.
*/
static U8 _CalcClockDivider(U32 * pFreq_Hz) {
  U8  Div;
  U32 Freq_Hz;
  U32 MaxFreq_Hz;

  Div        = 0;
  MaxFreq_Hz = *pFreq_Hz;
  for (;;) {
    Freq_Hz = FS_RAMDISK_HW_PER_CLK_HZ / (Div + 1);
    if (Freq_Hz <= MaxFreq_Hz) {
      break;
    }
    ++Div;
    if (Div == CR_PRESCALER_MAX) {
      break;
    }
  }
  *pFreq_Hz = Freq_Hz;
```

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```
  return Div;
}

/*********************************************************************
*
*       _GetMode
*
*  Function description
*    Returns the transfer mode for the QUADSPI peripheral.
*/
static U32 _GetMode(unsigned BusWidth, U32 NumBytes) {
  U32 Mode;

  Mode = CCR_MODE_NONE;
  if (NumBytes) {
    switch (BusWidth) {
    case 1:
      Mode = CCR_MODE_SINGLE;
      break;
    case 2:
      Mode = CCR_MODE_DUAL;
      break;
    case 4:
      Mode = CCR_MODE_QUAD;
      break;
    default:
      break;
    }
  }
  return Mode;
}

/*********************************************************************
*
*       _CalcNumCycles
*
*  Function description
*    Calculates the number of clock cycles required to transfer a specified number of bytes.
*/
static U32 _CalcNumCycles(unsigned BusWidth, U32 NumBytes, int IsDTRMode) {
  U32 NumCycles;

  NumCycles = 0;
  if (NumBytes != 0) {
    NumCycles = NumBytes << 3;        // Assume 8-bits per byte.
    switch (BusWidth) {
    case 2:
      NumCycles >>= 1;
      break;
    case 4:
      NumCycles >>= 2;
      break;
    default:
      break;
    }
    if (IsDTRMode != 0) {
      NumCycles >>= 1;                // The data is sent on both clock edges.
    }
  }
  return NumCycles;
}

/*********************************************************************
*
*       _ClearFlags
*
*  Function description
*    Clears the status flags of QUADSPI peripheral.
*/
static int _ClearFlags(void) {
  U32 TimeOut;
  int r;

  QUADSPI_FCR = 0
              | (1uL << SR_TEF_BIT)
              | (1uL << SR_TCF_BIT)
```

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```
              | (1uL << SR_SMF_BIT)
              | (1uL << SR_TOF_BIT)
              ;
  //
  // Wait for the flags to be cleared.
  //
  r       = 0;
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & ((1uL << SR_TEF_BIT) |
                       (1uL << SR_TCF_BIT) |
                       (1uL << SR_SMF_BIT) |
                       (1uL << SR_TOF_BIT))) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                    // Error, could not clear flags.
      break;
    }
  }
  return r;
}

/*********************************************************************
*
*       _Cancel
*
*  Function description
*    Interrupts an ongoing data transfer.
*/
static int _Cancel(void) {
  U32 TimeOut;
  int r;

  r       = 0;
  TimeOut = WAIT_TIMEOUT_CYCLES;
  QUADSPI_CR |= 1uL << CR_ABORT_BIT;
  for (;;) {
    if ((QUADSPI_CR & (1uL << CR_ABORT_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                    // Error, could not cancel data transfer.
      break;
    }
  }
  return r;
}

/*********************************************************************
*
*       _DisableDCache
*
*  Function description
*    Disables the data cache for the memory region where the RAM device is mapped.
*/
static void _DisableDCache(void) {
  U32 NumRegions;
  U32 iRegion;
  U32 Mask;

  if (SCB_CCR & (1uL << CCR_DC_BIT)) {      // Is data cache enabled?
    NumRegions = (MPU_TYPE >> TYPE_DREGION_BIT) & TYPE_DREGION_MASK;
    //
    // Find the next free region.
    //
    for (iRegion = 0; iRegion < NumRegions; ++iRegion) {
      MPU_RNR = iRegion;
      if ((MPU_RASR & (1uL << RASR_ENABLE_BIT)) == 0) {
        break;            // Found a free region.
      }
      //
      // Check if we already configured the MPU.
      //
      Mask = 0uL
           | (RBAR_REGION_MASK << RBAR_REGION_BIT)
```

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```
          | (1uL             << RBAR_VALID_BIT)
          ;
      if ((MPU_RBAR & ~Mask) == FS_RAMDISK_HW_QUADSPI_MEM_ADDR) {
        iRegion = NumRegions;
        break;            // Already configured.
      }
    }
    if (iRegion < NumRegions) {
      //
      // Use MPU to disable the data cache on the memory region assigned to QSPI.
      //
      MPU_CTRL &= ~(1uL << CTRL_ENABLE_BIT);      // Disable MPU first.
      MPU_RNR   = iRegion & RNR_REGION_MASK;
      MPU_RBAR  = FS_RAMDISK_HW_QUADSPI_MEM_ADDR;
      MPU_RASR  = 0
                | (1uL                          << RASR_XN_BIT)
                | (RASR_AP_FULL                 << RASR_AP_BIT)
                | (1uL                          << RASR_TEX_BIT)
                | ((QUADSPI_MEM_SIZE_SHIFT - 1) << RASR_SIZE_BIT)
                | (1uL                          << RASR_ENABLE_BIT)
                ;
      //
      // Enable MPU.
      //
      MPU_CTRL |= 0
               | (1uL << CTRL_PRIVDEFENA_BIT)
               | (1uL << CTRL_ENABLE_BIT)
               ;
    }
  }
}

/*********************************************************************
*
*      Static code (public via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initializes the SPI hardware.
*
*  Parameters
*    Unit       Index of the hardware layer (0-based).
*
*  Return value
*    > 0      OK, frequency of the SPI clock in Hz.
*    ==0      An error occurred.
*/
static int _HW_Init(U8 Unit) {
  U32 Div;
  U32 Freq_Hz;

  FS_USE_PARA(Unit);
  //
  // Enable the clocks of peripherals and reset them.
  //
  RCC_AHB4ENR  |= 0
               | (1uL << AHB1ENR_GPIOBEN)
               | (1uL << AHB1ENR_GPIOFEN)
               ;
  RCC_AHB3ENR  |=   1uL << AHB3ENR_QSPIEN;
  RCC_AHB3RSTR |=   1uL << AHB3ENR_QSPIEN;
  RCC_AHB3RSTR &= ~(1uL << AHB3ENR_QSPIEN);
  //
  // Wait for the unit to exit reset.
  //
  for (;;) {
    if ((RCC_AHB3RSTR & (1uL << AHB3ENR_QSPIEN)) == 0) {
      break;
    }
  }
```

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```
  //
  // Disable the cache on the memory region assigned to QSPI.
  //
  _DisableDCache();
  //
  // NCS of bank 1 is an output signal and is controlled by the QUADSPI unit.
  //
  GPIOB_MODER   &= ~(MODER_MASK   << (RAM_BK1_NCS_BIT << 1));
  GPIOB_MODER   |=   MODER_ALT    << (RAM_BK1_NCS_BIT << 1);
  GPIOB_AFRL    &= ~(AFR_MASK     << (RAM_BK1_NCS_BIT << 2));
  GPIOB_AFRL    |=   0xAuL        << (RAM_BK1_NCS_BIT << 2);
  GPIOB_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_NCS_BIT << 1));
  GPIOB_OSPEEDR |=   OSPEEDR_HIGH << (RAM_BK1_NCS_BIT << 1);
  //
  // CLK is an output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_CLK_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (RAM_CLK_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_CLK_BIT - 8) << 2));
  GPIOF_AFRH    |=   0x9uL        << ((RAM_CLK_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_CLK_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (RAM_CLK_BIT << 1);
  //
  // D0 of bank 1 is an input/output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D0_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (RAM_BK1_D0_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_BK1_D0_BIT - 8) << 2));
  GPIOF_AFRH    |=   0xAuL        << ((RAM_BK1_D0_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D0_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (RAM_BK1_D0_BIT << 1);
  //
  // D1 of bank 1 is an input/output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D1_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (RAM_BK1_D1_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_BK1_D1_BIT - 8) << 2));
  GPIOF_AFRH    |=   0xAuL        << ((RAM_BK1_D1_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D1_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (RAM_BK1_D1_BIT << 1);
#if FS_RAMDISK_HW_USE_QUAD_MODE
  //
  // D2 of bank 1 is an input/output signal and is controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D2_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (RAM_BK1_D2_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (RAM_BK1_D2_BIT << 2));
  GPIOF_AFRL    |=   0x9uL        << (RAM_BK1_D2_BIT << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D2_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (RAM_BK1_D2_BIT << 1);
  //
  // D3 of bank 1 is an output signal and is controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D3_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (RAM_BK1_D3_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (RAM_BK1_D3_BIT << 2));
  GPIOF_AFRL    |=   0x9uL        << (RAM_BK1_D3_BIT << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D3_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (RAM_BK1_D3_BIT << 1);
#else
  //
  // D2 and D3 are used as WP and HOLD signals when the quad mode
  // is disabled in the RAM device. We set these signals to
  // logic high here so that the data transfer works correctly
  // in single and dual mode.
  //
  GPIOF_BSRR    = 1uL << RAM_BK1_D2_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D2_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (RAM_BK1_D2_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (RAM_BK1_D2_BIT << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D2_BIT << 1));
  GPIOF_BSRR    = 1uL << RAM_BK1_D3_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_BK1_D3_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (RAM_BK1_D3_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (RAM_BK1_D3_BIT << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_BK1_D3_BIT << 1));
```

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```
#endif // FS_RAMDISK_HW_USE_QUAD_MODE
  //
  // The MP6 is the signal connected to the pin 6 of the RAM device
  // which is used by some dual stack devices as the chip select signal
  // for the second stack. We have to disable the second stack
  // by setting the MP6 signal to high in order to prevent that the
  // second stack is accidentally activated.
  //
  GPIOF_BSRR    = 1uL << RAM_MP6_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_MP6_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (RAM_MP6_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (RAM_MP6_BIT << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_MP6_BIT << 1));
  //
  // Set the RST signal to high to make sure that the RAM
  // device is not accidentally reset during the data transfer.
  //
  GPIOF_BSRR    = 1uL << RAM_RST_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (RAM_RST_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (RAM_RST_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((RAM_RST_BIT - 8) << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (RAM_RST_BIT << 1));
  //
  // Initialize the Quad-SPI controller.
  //
  Freq_Hz = FS_RAMDISK_HW_RAM_CLK_HZ;
  Div = (U32)_CalcClockDivider(&Freq_Hz);
  QUADSPI_CR  = 0
              | (1uL << CR_EN_BIT)                        // Enable the Quad-SPI unit.
              | (Div << CR_PRESCALER_BIT)
              ;
  QUADSPI_DCR = 0
              | (1uL           << DCR_CKMODE_BIT)
  // CLK signal stays HIGH when the RAM device is not selected.
              | (DCR_FSIZE_MAX << DCR_FSIZE_BIT)
  // We set the size of the RAM device to maximum because the actual capacity is not known at this stage.
              ;
#if FS_RAMDISK_HW_RESET_TIME_MS
  {
    volatile U32 NumCycles;

    GPIOF_BSRR = 1uL << (RAM_RST_BIT + 16);
  // Put the RAM device into reset state by setting the signal to low.
    NumCycles = FS_RAMDISK_HW_RESET_TIME_MS * CYCLES_PER_MS;
    do {
      ;
    } while (--NumCycles != 0u);
    GPIOF_BSRR = 1uL << RAM_RST_BIT;
  // Release the RAM device from the reset state by setting reset signal to high.
    NumCycles = FS_RAMDISK_HW_RESET_TIME_MS * CYCLES_PER_MS;
    do {
      ;
    } while (--NumCycles != 0u);
  }
#endif // FS_RAMDISK_HW_RESET_TIME_MS
  return (int)Freq_Hz;
}

/*********************************************************************
*
*       _HW_Unmap
*
*  Function description
*    Enables the direct access to RAM device.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*
*  Return value
*    ==0      OK, command mode configured successfully.
*    !=0      An error occurred.
*
*  Additional information
*    This function disables the memory-mapped mode.
*/
static int _HW_Unmap(U8 Unit) {
```

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```
  int r;

  FS_USE_PARA(Unit);            // This device has only one HW unit.
  r = 0;
  //
  // Restore the default sampling mode.
  //
  QUADSPI_CR &= ~(1uL << CR_SSHIFT_BIT);
  //
  // Cancel the memory mode so that the BUSY bit goes to 0
  // and we can write to QUADSPI_CCR register.
  //
  if ((QUADSPI_CCR & (CCR_FMODE_MASK << CCR_FMODE_BIT)) == (CCR_FMODE_MMAP << CCR_FMODE_BIT)) {
    r = _Cancel();
  }
  return r;
}

#if FS_RAMDISK_HW_USE_MEM_MAP_MODE

/*********************************************************************
*
*       _HW_Map
*
*  Function description
*    Configures the hardware for access to serial RAM device via system memory.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pCmd           [IN] Code of the command to be used for reading the data. Cannot be NULL.
*    NumBytesCmd    Number of bytes in the command code. Cannot be 0.
*    pPara          [IN] Command parameters (address and dummy bytes). Can be NULL.
*    NumBytesPara   Total number of address and dummy bytes to be sent. Can be 0.
*    NumBytesAddr   Number of address bytes to be send. Can be 0.
*    BusWidth       Number of data lines to be used for the data transfer.
*    Flags          Options for the data exchange.
*
*  Return value
*    ==0      OK, memory mode configured successfully.
*    !=0      An error occurred.
*/
static int _HW_Map(U8 Unit, const U8 * pCmd, unsigned NumBytesCmd, const U8 * pPara,
                   unsigned NumBytesPara, unsigned NumBytesAddr, U16 BusWidth, unsigned Flags) {
  U32 CfgReg;
  U32 CmdMode;
  U32 AddrMode;
  U32 DataMode;
  U32 NumDummyCycles;
  U32 AddrSize;
  U32 IsDTR;
  U32 AltMode;
  U32 AltSize;
  U32 NumBytesAlt;
  U32 NumBytes;
  U32 AltReg;
  int r;
  U32 TimeOut;

  FS_USE_PARA(Unit);
  // This MCU has only one QSPI controller.
  FS_USE_PARA(pPara);
  FS_DEBUG_ASSERT(FS_MTYPE_DRIVER, NumBytesCmd == 1u);
  // The QSPI controller is able to handle only 1-byte commands.
  //
  // Fill local variables.
  //
  r           = 0;
  AltReg      = 0;
  NumBytesAlt = NumBytesPara - NumBytesAddr;
  //
  // Calculate the transfer mode.
  //
  IsDTR = 0;
  if (   ((Flags & FS_RAMDISK_HW_FLAG_DTR_ADDR) != 0u)
      || ((Flags & FS_RAMDISK_HW_FLAG_DTR_DATA) != 0u)) {
    IsDTR = 1;
```

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```
  }
  //
  // Encode the mode and dummy bytes.
  //
  NumDummyCycles = 0;
  if (NumBytesAlt != 0) {
    NumBytes = NumBytesAlt;
    //
    // Check if a mode byte has to be sent and if yes encode its value.
    //
    if ((Flags & FS_RAMDISK_HW_FLAG_MODE_8BIT) != 0u) {
      NumBytes    = NumBytesAlt - 1u;
      NumBytesAlt = 1;
  // We never send more than one mode byte.
      if (pPara != NULL) {
        AltReg = (U32)*pPara;
      } else {
        AltReg = 0xFFuL;
      }
    } else {
      NumBytesAlt = 0;
    }
    if (NumBytes != 0u) {
      //
      // The remaining alternate bytes are not sent. Instead, we generate dummy cycles.
      //
      NumDummyCycles = _CalcNumCycles(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytes, IsDTR);
    }
  }
  //
  // It seems that QUADSPI is driving the data lines one half of the clock
  // cycle longer than required. This can cause that a wrong value is
  // sampled immediately after a data line is switched from output to input.
  // For this reason we configure QUADSPI to sample the data later than default.
  //
  if ((IsDTR == 0) && (NumBytesAlt != 0) && (NumDummyCycles == 0) ) {
    QUADSPI_CR |= 1uL << CR_SSHIFT_BIT;
  }
  //
  // Calculate the number of data lines to be used for the transfer.
  //
  CmdMode  = _GetMode(FS_BUSWIDTH_GET_CMD(BusWidth), NumBytesCmd);
  AddrMode = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAddr);
  AltMode  = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAlt);
  DataMode = _GetMode(FS_BUSWIDTH_GET_DATA(BusWidth), 1);
  // We always read at least one byte.
  //
  // Calculate the number of bytes in each command phase.
  //
  AddrSize = 0;
  if (NumBytesAddr) {
    AddrSize = (NumBytesAddr - 1) & CCR_ADSIZE_MASK;
  }
  AltSize = 0;
  if (NumBytesAlt) {
    AltSize = (NumBytesAlt - 1) & CCR_ABSIZE_MASK;
  }
  //
  // Configure the operation.
  //
  CfgReg = 0
         | (CCR_FMODE_MMAP << CCR_FMODE_BIT)
         | (DataMode       << CCR_DMODE_BIT)
         | (AddrSize       << CCR_ADSIZE_BIT)
         | (AddrMode       << CCR_ADMODE_BIT)
         | (AltSize        << CCR_ABSIZE_BIT)
         | (AltMode        << CCR_ABMODE_BIT)
         | (NumDummyCycles << CCR_DCYC_BIT)
         | (IsDTR          << CCR_DDRM_BIT)
         | (CmdMode        << CCR_IMODE_BIT)
         | (*pCmd          << CCR_INTRUCTION_BIT)
         ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
```

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```
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;
  // Error, QUADSPI is not ready.
      goto Done;
    }
  }
  r = _ClearFlags();
  if (r != 0) {
    goto Done;
  // Error, could not clear status flags.
  }
  QUADSPI_ABR = AltReg;
  QUADSPI_CCR = CfgReg;
Done:
  return r;
}

#endif // FS_RAMDISK_HW_USE_MEM_MAP_MODE

/*********************************************************************
*
*       _HW_Control
*
*  Function description
*    Sends a command to serial RAM device that does not transfer any data.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pCmd           [IN] Code of the command to be sent. Cannot be NULL.
*    NumBytesCmd    Number of bytes in the command code. Cannot be 0.
*    BusWidth       Number of data lines to be used for sending the command.
*    Flags          Options for the data exchange.
*
*  Return value
*    ==0      OK, command transferred successfully.
*    !=0      An error occurred.
*/
static int _HW_Control(U8 Unit, const U8 * pCmd, unsigned NumBytesCmd, U8 BusWidth, unsigned Flags) {
  U32 CfgReg;
  U32 CmdMode;
  U32 TimeOut;
  int r;

  FS_USE_PARA(Unit);
  // This MCU has only one QSPI controller.
  FS_USE_PARA(Flags);
  FS_DEBUG_ASSERT(FS_MTYPE_DRIVER, NumBytesCmd == 1u);
  // The QSPI controller is able to handle only 1-byte commands.
  //
  // Fill local variables.
  //
  r       = 0;
  CmdMode = _GetMode(BusWidth, NumBytesCmd);
  CfgReg  = 0
          | (CCR_FMODE_WRITE << CCR_FMODE_BIT)
          | (CmdMode         << CCR_IMODE_BIT)
          | (*pCmd           << CCR_INTRUCTION_BIT)
          ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                                  // Error, QUADSPI is not ready.
      goto Done;
    }
  }
  //
```

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```
  // Execute the command.
  //
  r = _ClearFlags();
  if (r != 0) {
    goto Done;                                          // Error, could not clear status flags.
  }
  QUADSPI_DLR = 0;
  QUADSPI_ABR = 0;
  QUADSPI_CCR = CfgReg;
  //
  // Wait until the command has been completed.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                            // Error, QUADSPI is not ready.
      break;
    }
  }
Done:
  return r;
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    Transfers data from serial RAM device to MCU.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pCmd           [IN] Code of the command to be sent. Cannot be NULL.
*    NumBytesCmd    Number of bytes in the command code. Cannot be 0.
*    pPara          [IN] Command parameters (address and dummy bytes). Can be NULL.
*    NumBytesPara   Total number of address and dummy bytes to be sent. Can be 0.
*    NumBytesAddr   Number of address bytes to be send. Can be 0.
*    pData          [OUT] Data read from the serial RAM device. Can be NULL.
*    NumBytesData   Number of bytes to read from the serial RAM device. Can be 0.
*    BusWidth       Number of data lines to be used for the data transfer.
*    Flags          Options for the data exchange.
*
*  Return value
*    ==0      OK, data transferred successfully.
*    !=0      An error occurred.
*/
static int _HW_Read(U8 Unit, const U8 * pCmd, unsigned NumBytesCmd, const U8 * pPara, unsigned NumBytesPara,

  unsigned NumBytesAddr, U8 * pData, unsigned NumBytesData, U16 BusWidth, unsigned Flags) {
  U32 AddrReg;
  U32 AltReg;
  U32 CfgReg;
  U32 DataMode;
  U32 AddrMode;
  U32 AltMode;
  U32 CmdMode;
  U32 DataReg;
  U32 AltSize;
  U32 AddrSize;
  U32 NumBytesAvail;
  U32 NumBytes;
  U32 NumBytesAlt;
  U32 IsDTR;
  U32 NumDummyCycles;
  U32 TimeOut;
  int r;

  FS_USE_PARA(Unit);
  // This MCU has only one QSPI controller.
  FS_DEBUG_ASSERT(FS_MTYPE_DRIVER, NumBytesCmd == 1u);
  // The QSPI controller is able to handle only 1-byte commands.
  //
  // Fill local variables.
```

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```
  //
  r           = 0;
  AddrReg     = 0;
  AltReg      = 0;
  NumBytesAlt = NumBytesPara - NumBytesAddr;
  //
  // Calculate the transfer mode.
  //
  IsDTR = 0;
  if (   ((Flags & FS_RAMDISK_HW_FLAG_DTR_ADDR) != 0u)
      || ((Flags & FS_RAMDISK_HW_FLAG_DTR_DATA) != 0u)) {
    IsDTR = 1;
  }
  //
  // Encode the address.
  //
  if (NumBytesAddr) {
    NumBytes = NumBytesAddr;
    do {
      AddrReg <<= 8;
      AddrReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
  //
  // Encode the mode and dummy bytes.
  //
  NumDummyCycles = 0;
  if (NumBytesAlt != 0) {
    NumBytes = NumBytesAlt;
    //
    // Check if a mode byte has to be sent and if yes encode its value.
    //
    if ((Flags & FS_RAMDISK_HW_FLAG_MODE_8BIT) != 0u) {
      NumBytes    = NumBytesAlt - 1u;
      NumBytesAlt = 1;
  // We never send more than one mode byte.
      if (pPara != NULL) {
        AltReg = (U32)*pPara;
      } else {
        AltReg = 0xFFuL;
      }
    } else {
      NumBytesAlt = 0;
    }
    if (NumBytes != 0u) {
      //
      // The remaining alternate bytes are not sent. Instead, we generate dummy cycles.
      //
      NumDummyCycles = _CalcNumCycles(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytes, IsDTR);
    }
  }
  //
  // Calculate the number of data lines to be used for the transfer.
  //
  CmdMode  = _GetMode(FS_BUSWIDTH_GET_CMD(BusWidth), NumBytesCmd);
  AddrMode = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAddr);
  AltMode  = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAlt);
  DataMode = _GetMode(FS_BUSWIDTH_GET_DATA(BusWidth), NumBytesData);
  //
  // Calculate the number of bytes in each command phase.
  //
  AddrSize = 0;
  if (NumBytesAddr) {
    AddrSize = (NumBytesAddr - 1) & CCR_ADSIZE_MASK;
  }
  AltSize = 0;
  if (NumBytesAlt) {
    AltSize = (NumBytesAlt - 1) & CCR_ABSIZE_MASK;
  }
  //
  // Configure the operation.
  //
  CfgReg = 0
         | (CCR_FMODE_READ << CCR_FMODE_BIT)
         | (DataMode       << CCR_DMODE_BIT)
         | (AltSize        << CCR_ABSIZE_BIT)
```

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```
        | (AltMode        << CCR_ABMODE_BIT)
        | (AddrSize       << CCR_ADSIZE_BIT)
        | (AddrMode       << CCR_ADMODE_BIT)
        | (NumDummyCycles << CCR_DCYC_BIT)
        | (IsDTR          << CCR_DDRM_BIT)
        | (CmdMode        << CCR_IMODE_BIT)
        | (*pCmd          << CCR_INTRUCTION_BIT)
        ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                            // Error, QUADSPI is not ready.
      goto Done;
    }
  }
  //
  // It seems that QUADSPI is driving the data lines one half of the clock
  // cycle longer than required. This can cause that a wrong value is
  // sampled immediately after a data line is switched from output to input.
  // For this reason we configure QUADSPI to sample the data later than default.
  //
  if ((IsDTR == 0) && (NumBytesAlt != 0) && (NumDummyCycles == 0) ) {
    QUADSPI_CR |= 1uL << CR_SSHIFT_BIT;
  }
  //
  // Execute the command.
  //
  r = _ClearFlags();
  if (r != 0) {
    goto Done;                          // Error, could not clear status flags.
  }
  if (NumBytesData != 0) {
    QUADSPI_DLR = NumBytesData - 1;     // 0 means "read 1 byte".
  }
  QUADSPI_ABR = AltReg;
  QUADSPI_CCR = CfgReg;
  if (NumBytesAddr != 0) {
    QUADSPI_AR = AddrReg;
  }
  //
  // Read data from RAM device.
  //
  if (NumBytesData != 0) {
    do {
      //
      // Wait for the data to be received.
      //
      TimeOut = WAIT_TIMEOUT_CYCLES;
      for (;;) {
        NumBytesAvail = (QUADSPI_SR >> SR_FLEVEL_BIT) & SR_FLEVEL_MASK;
        if ((NumBytesAvail >= 4) || (NumBytesAvail >= NumBytesData)) {
          break;
        }
        if (--TimeOut == 0u) {
          r = 1;                        // Error, no data received.
          goto Done;
        }
      }
      //
      // Read data and store it to destination buffer.
      //
      if (NumBytesData < 4) {
        //
        // Read single bytes.
        //
        do {
          *pData++ = QUADSPI_DR_BYTE;
        } while (--NumBytesData != 0);
      } else {
        //
```

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```
        // Read 4 bytes at a time.
        //
        DataReg = QUADSPI_DR;
        *pData++ = (U8)DataReg;
        *pData++ = (U8)(DataReg >> 8);
        *pData++ = (U8)(DataReg >> 16);
        *pData++ = (U8)(DataReg >> 24);
        NumBytesData -= 4;
      }
    } while (NumBytesData != 0);
  }
  //
  // Wait until the data transfer has been completed.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if (QUADSPI_SR & (1uL << SR_TCF_BIT)) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                // Error, transaction not completed.
      break;
    }
  }
Done:
  //
  // Restore the default sampling mode.
  //
  QUADSPI_CR &= ~(1uL << CR_SSHIFT_BIT);
  return r;
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    Transfers data from MCU to serial RAM device.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pCmd           [IN] Code of the command to be sent. Cannot be NULL.
*    NumBytesCmd    Number of bytes in the command code. Cannot be 0.
*    pPara          [IN] Command parameters (address and dummy bytes). Can be NULL.
*    NumBytesPara   Total number of address and dummy bytes to be sent. Can be 0.
*    NumBytesAddr   Number of address bytes to be send. Can be 0.
*    pData          [IN] Data to be sent to the serial RAM device. Can be NULL.
*    NumBytesData   Number of bytes to be written the serial RAM device. Can be 0.
*    BusWidth       Number of data lines to be used for the data transfer.
*    Flags          Options for the data exchange.
*
*  Return value
*    ==0      OK, data transferred successfully.
*    !=0      An error occurred.
*/
static int _HW_Write(U8 Unit, const U8 * pCmd, unsigned NumBytesCmd, const U8 * pPara, unsigned NumBytesPara,

  unsigned NumBytesAddr, const U8 * pData, unsigned NumBytesData, U16 BusWidth, unsigned Flags) {
  U32 AddrReg;
  U32 AltReg;
  U32 CfgReg;
  U32 DataMode;
  U32 AddrMode;
  U32 AltMode;
  U32 CmdMode;
  U32 DataReg;
  U32 AddrSize;
  U32 AltSize;
  U32 NumBytes;
  U32 NumBytesAlt;
  U32 NumBytesFree;
  U32 IsDTR;
  U32 TimeOut;
  int r;
```

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```
  FS_USE_PARA(Unit);
  // This MCU has only one QSPI controller.
  FS_DEBUG_ASSERT(FS_MTYPE_DRIVER, NumBytesCmd == 1u);
  // The QSPI controller is able to handle only 1-byte commands.
  //
  // Fill local variables.
  //
  r           = 0;
  AddrReg     = 0;
  AltReg      = 0;
  NumBytesAlt = NumBytesPara - NumBytesAddr;
  //
  // Calculate the transfer mode.
  //
  IsDTR = 0;
  if (   ((Flags & FS_RAMDISK_HW_FLAG_DTR_ADDR) != 0u)
      || ((Flags & FS_RAMDISK_HW_FLAG_DTR_DATA) != 0u)) {
    IsDTR = 1;
  }
  //
  // Encode the address.
  //
  if (NumBytesAddr) {
    NumBytes = NumBytesAddr;
    do {
      AddrReg <<= 8;
      AddrReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
  //
  // Encode additional information.
  //
  if (NumBytesPara > NumBytesAddr) {
    NumBytes = NumBytesAlt;
    do {
      AltReg <<= 8;
      AltReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
  //
  // Calculate the number of data lines to be used for the transfer.
  //
  CmdMode     = _GetMode(FS_BUSWIDTH_GET_CMD(BusWidth), NumBytesCmd);
  AddrMode    = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAddr);
  AltMode     = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAlt);
  DataMode    = _GetMode(FS_BUSWIDTH_GET_DATA(BusWidth), NumBytesData);
  //
  // Calculate the number of bytes in each command phase.
  //
  AddrSize = 0;
  if (NumBytesAddr) {
    AddrSize = NumBytesAddr - 1;
  }
  AltSize = 0;
  if (NumBytesAlt) {
    AltSize = NumBytesAlt - 1;
  }
  //
  // Configure the operation.
  //
  CfgReg = 0
         | (CCR_FMODE_WRITE << CCR_FMODE_BIT)
         | (DataMode        << CCR_DMODE_BIT)
         | (AltSize         << CCR_ABSIZE_BIT)
         | (AltMode         << CCR_ABMODE_BIT)
         | (AddrSize        << CCR_ADSIZE_BIT)
         | (AddrMode        << CCR_ADMODE_BIT)
         | (IsDTR           << CCR_DDRM_BIT)
         | (CmdMode         << CCR_IMODE_BIT)
         | (*pCmd           << CCR_INTRUCTION_BIT)
         ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
```

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```
  if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
    break;
  }
  if (--TimeOut == 0u) {
    r = 1;                                  // Error, QUADSPI is not ready.
    goto Done;
  }
}
//
// Execute the command.
//
r = _ClearFlags();
if (r != 0) {
  goto Done;                                // Error, could not clear status flags.
}
if (NumBytesData != 0) {
  QUADSPI_DLR = NumBytesData - 1;           // 0 means "read 1 byte".
}
QUADSPI_ABR = AltReg;
QUADSPI_CCR = CfgReg;
if (NumBytesAddr != 0) {
  QUADSPI_AR = AddrReg;
}
//
// Write data to RAM device.
//
if (NumBytesData != 0) {
  do {
    //
    // Wait for free space in FIFO.
    //
    TimeOut = WAIT_TIMEOUT_CYCLES;
    for (;;) {
      NumBytesFree = (QUADSPI_SR >> SR_FLEVEL_BIT) & SR_FLEVEL_MASK;
      NumBytesFree = NUM_BYTES_FIFO - NumBytesFree;
      if ((NumBytesFree >= 4) || (NumBytesFree >= NumBytesData)) {
        break;
      }
      if (--TimeOut == 0u) {
        r = 1;                              // Error, no free space in FIFO.
        goto Done;
      }
    }
    //
    // Get the data from source buffer and write it.
    //
    if (NumBytesData < 4) {
      //
      // Write single bytes.
      //
      do {
        QUADSPI_DR_BYTE = *pData++;
      } while (--NumBytesData != 0);
    } else {
      //
      // Write 4 bytes at a time if possible.
      //
      DataReg  = (U32)*pData++;
      DataReg |= (U32)*pData++ << 8;
      DataReg |= (U32)*pData++ << 16;
      DataReg |= (U32)*pData++ << 24;
      NumBytesData -= 4;
      QUADSPI_DR = DataReg;
    }
  } while (NumBytesData != 0);
}
//
// Wait until the data transfer has been completed.
//
TimeOut = WAIT_TIMEOUT_CYCLES;
for (;;) {
  if (QUADSPI_SR & (1uL << SR_TCF_BIT)) {
    break;
  }
  if (--TimeOut == 0u) {
    r = 1;                                  // Error, transfer not completed.
```

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```
      break;
    }
  }
Done:
  return r;
}

/*********************************************************************
*
*       Global data
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_RAMDISK_HW_SPI_STM32H743_SEGGER_QSPI_Flash_Evaluator
*/
const FS_RAMDISK_HW_TYPE_SPI FS_RAMDISK_HW_SPI_STM32H743_SEGGER_QSPI_Flash_Evaluator = {
  _HW_Init,
  _HW_Unmap,
#if FS_RAMDISK_HW_USE_MEM_MAP_MODE
  _HW_Map,
#else
  NULL,
#endif // FS_RAMDISK_HW_USE_MEM_MAP_MODE
  _HW_Control,
  _HW_Read,
  _HW_Write,
  NULL,
  NULL
};

/************************** End of file ****************************/
```

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6.3 NAND flash driver

6.3.1 General information

emFile supports the use of unmanaged NAND flash devices as data storage. Two drivers for NAND flash devices, also known as flash translation layers, are provided:

- *SLC1 NAND driver* - Supports SLC NAND flash devices that require 1-bit error correction. In addition, it supports the Microchip / Atmel and Adesto DataFlash devices.
- *Universal NAND driver* - Supports all modern SLC and MLC NAND flash devices. It can make use of the hardware ECC engine integrated into NAND flash devices to correct bit errors.

6.3.1.1 Selecting the correct NAND driver

The first factor to be considered is the type of storage device used. Microchip / Atmel and Adesto DataFlash devices are currently supported only by the SLC1 NAND driver while NAND flash devices are typically supported by both NAND drivers. The bit error correction requirement of the NAND flash device is the next factor. It indicates how many bit errors the error correcting code (ECC) has to be able to detect and correct. If the NAND flash device requires only 1-bit correction capability then the SLC1 NAND driver can be used. The SLC1 NAND driver performs the bit error detection and correction in the software. For a correction capability larger than 1 bit the Universal NAND driver has to be used instead. The Universal NAND driver is able to calculate the ECC either in the hardware using the ECC integrated into the NAND flash device or MCU or in the software using an ECC library such as SEGGER emLib-ECC (https://www.segger.com/products/security-iot/emlib/variations/ecc/).

You can always get in touch with us if you are not sure what type of NAND driver to choose.

6.3.1.2 Multiple driver configurations

Both NAND drivers store management information to the spare area of a page. The layout and the content of this information are different for each NAND driver, which means that data written using one NAND driver cannot be accessed with the other one and vice versa. For example, if an application uses the SLC1 NAND driver to store data to a NAND flash device then it cannot use the Universal NAND driver to access it. In this case, the Universal NAND driver reports that the NAND flash device is not properly formatted. For applications that have to support different types of NAND flash devices that require the usage of both NAND drivers, it is possible to select the correct NAND driver by checking the device ID of the connected NAND flash device. The description of the `FS_NAND_PHY_ReadDeviceId()` function provides an example showing how a NAND flash device can be identified during the configuration of the file system.

6.3.1.3 Software structure

The NAND driver is organized into different layers that contain from top to bottom:

- NAND driver layer
- *NAND physical layer*
- *NAND hardware layer*

It is possible to use the NAND driver with custom hardware. If port pins or a simple memory controller are used for accessing the flash memory, only the hardware layer needs to be ported; normally, no changes to the physical layer are required. If the NAND driver should be used with a special memory controller (for example special FPGA implementations), the physical layer needs to be adapted. In this case, the hardware layer is not required, because the memory controller manages the hardware access.

6.3.1.4 Bad block management

Bad block management is supported in the driver. Blocks marked as defective are skipped and are not used for data storage. The block is recognized as defective when the first byte

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in the spare area of the first or second page is different from `0xFF`. The driver marks blocks as defective in the following cases:

- when the NAND flash reports an error after a write operation.
- when the NAND flash reports an error after an erase operation.
- when an uncorrectable ECC error is detected on the data read from NAND flash.

6.3.1.5 Garbage collection

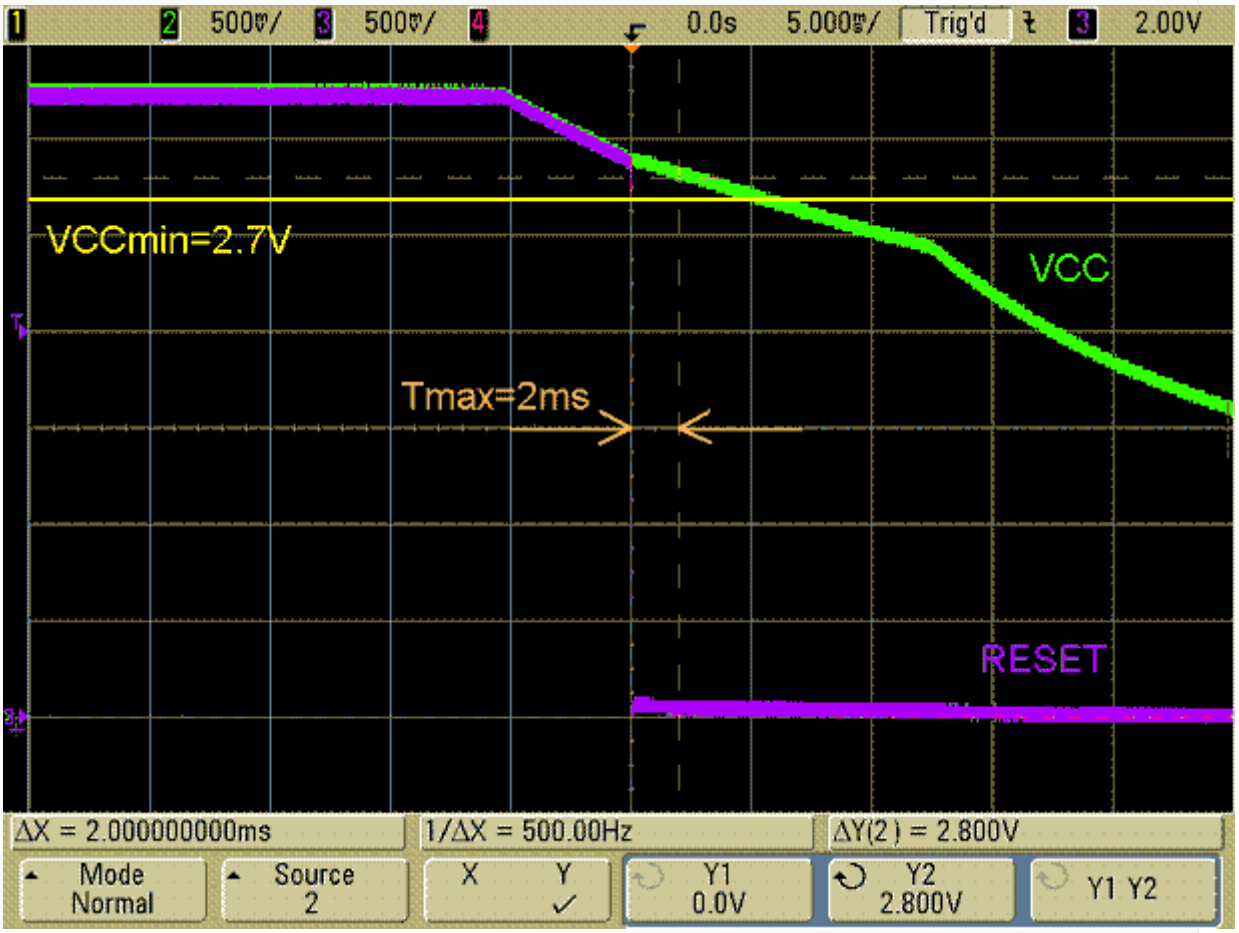
The driver performs the garbage collection automatically during the write operations. If no empty NAND blocks are available to store the data, new empty NAND blocks are created by erasing the data of the NAND blocks marked as invalid. This involves a NAND block erase operation which, depending on the characteristics of the NAND flash, can potentially take a long time to complete, and therefore reduces the write throughput. For applications that require maximum write throughput, the garbage collection can be done in the application. Typically, this operation can be performed when the file system is idle. Two API functions are provided: `FS_STORAGE_Clean()` and `FS_STORAGE_CleanOne()`. They can be called directly from the task that is performing the write or from a background task. The `FS_STORAGE_Clean()` function blocks until all the invalid NAND blocks are converted to free NAND blocks. A write operation following the call to this function runs at maximum speed. The other function, `FS_STORAGE_CleanOne()`, converts a single invalid NAND block. Depending on the number of invalid NAND blocks, several calls to this function are required to clean up the entire NAND flash.

6.3.1.6 Fail-safe operation

The NAND drivers are fail-safe, which means that the drivers make only atomic operations and guarantee that the file system data is always valid. If an unexpected power loss or reset interrupts a write operation, then the old data is kept while the new corrupted data is discarded. The fail-safe operation can only be guaranteed if the NAND flash device is able to fully complete the last command it received from the MCU. The picture below is an oscilloscope capture which shows how a power down sequence should look like in order to meet the requirements needed for a fail-safe operation of a NAND driver. The labels in the picture have the following meaning:

- VCC is the main power supply voltage.
- RESET is a signal driven high by a program running on the CPU. This signal goes low when the CPU stops running, indicating the point in time when the last command could have been sent to NAND flash.
- VCCmin is the minimum supply voltage required for the NAND flash to properly operate.
- Tmax is the time it takes for the longest NAND flash operation to complete, which is 2 ms for the NAND flash used in the test. As it can be seen in the picture, the supply voltage stays above VCCmin long enough to allow for any NAND flash command to finish.

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Power loss

6.3.1.7 Wear leveling

Wear leveling is supported by the NAND drivers. The procedure makes sure that the number of times a NAND block is erased remains approximately equal for all the NAND blocks. This is realized by maintaining an erase count for each NAND block. The maximum allowed erase count difference is configurable at compile time via `FS_NAND_MAX_ERASE_CNT_DIFF` as well as at runtime via `FS_NAND_SetMaxEraseCntDiff()` for the SLC1 NAND driver and `FS_NAND_UNI_SetMaxEraseCntDiff()` for the Universal NAND driver.

6.3.1.8 Read disturb errors

Read disturb errors are bit errors that occur when a large number of read operations (a few hundred thousand to one million) are performed on a NAND flash block without an erase operation taking place in between. These bit errors can be avoided by simply rewriting the sector data. This can be realized by calling the `FS_STORAGE_RefreshSectors()` storage layer API function in the application, which is able to refresh multiple sectors in a single call.

6.3.1.9 Low-level format

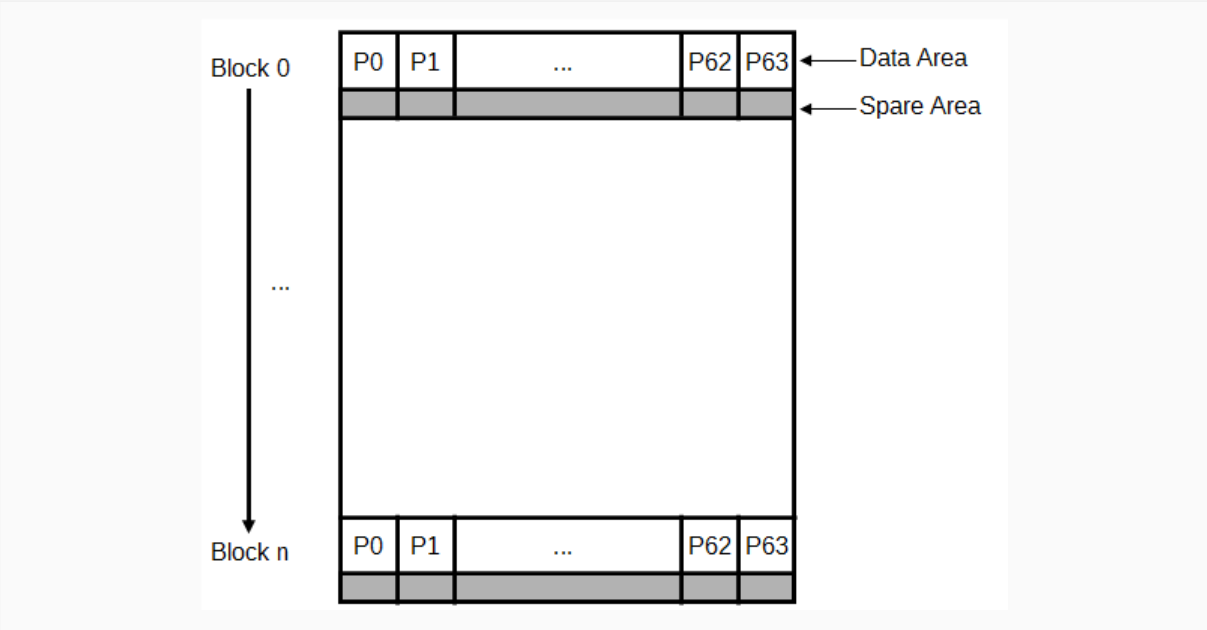
Before using a NAND flash device for the first time, the application has to initialize it by performing a low-level format operation on it. Refer to `FS_FormatLow()` and `FS_FormatLLIfRequired()` for detailed information about this.

6.3.1.10 NAND flash organization

A NAND flash device is a serial-type memory device that uses the I/O pins for both address and data transfer as well as for command inputs. A NAND flash device consists of a number

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of individual storage blocks. Every block contains a number of pages, typically 64. The pages can be written to individually, one at a time. When writing to a page, bits can only be changed from 1 to 0. Only entire blocks (all pages in the block) can be erased. Erasing means bringing all memory bits in all pages of the block to logical 1. The erase and program operations are executed automatically by the NAND flash device.



NAND organization

Small NAND flashes (up to 256 Mbytes) have a page size of 528 bytes, that is 512 bytes for storing file system data and 16 bytes, called the spare area, for storing management information (ECC, etc.).

Large NAND devices (256 Mbytes or more) have a page size of 2112 bytes with 2048 bytes used for storing file system data and with 64 bytes of spare area.

6.3.1.11 Pin description - parallel NAND flash device

This type of device uses 8 or 16 I/O signals to exchange the data with the MCU and an additional set of signals that are used to control the data transfer.

Signal name	Description
CE	Chip Enable - The CE signal enables the device. This signal is active low. If the signal is inactive, the device is in standby mode.
WE	Write Enable - The WE signal controls the transfer of data from MCU to NAND flash device. This signal is active low. Commands, address, and data are latched on the rising edge of the WE pulse.
RE	Read Enable - The RE signal controls the transfer of data from NAND flash device to MCU. This signal is active low. When active the NAND flash device outputs data.
CLE	Command Latch Enable - The CLE signal controls the activating path for commands sent to NAND flash device. This signal is active high. When active, command data sent via the I/O signals is latched by the NAND flash device into the internal command register on the rising edge of the WE signal.
ALE	Address Latch Enable - The ALE signal controls the activating path for address to the internal address registers. This signal is active high. Address data is latched on the rising edge of WE with ALE high.

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Signal name	Description
WP	Write Protect - The WP signal controls if data can be stored to NAND flash device. This signal is active low and is typically connected to VCC (recommended), but may also be connected to a port pin.
R/B	Ready/Busy - The R/B signal indicates the status of the NAND flash device operation to MCU. When low, it indicates that a program, erase or read operation is in process. The signal returns to high when the operation is completed. It is an open drain output that should be connected to a port pin with pull-up. If available, a port pin which can trigger an interrupt can be connected to this signal.
I/O0-I/O7	Data Input/Output - The data I/O signals are used to input command, address and data, and to output data during read operations.
I/O8-I/O15	Data Input/Output - Additional data I/O signals.

6.3.1.12 Pin description - DataFlash device

DataFlash devices are commonly used when low pin count and easy data transfer are required. DataFlash devices use the following pins:

Signal name	Description
CS	Chip Select - This signal selects the DataFlash device. The device is selected when the CS pin is driven low.
SCLK	Serial Clock - The SCLK signal is used to control the flow of data to and from the DataFlash. Data is always clocked into the device on the rising edge of SCLK and clocked out of the device on the falling edge of SCLK.
SI	Serial Data In - The SI signal is used to transfer data to the DataFlash device. It is used for all data input including opcodes and address sequences.
SO	Serial Data Out - The SO signal is used to transfer data serially out of the DataFlash device.

Additionally, the host system has to comply with the following requirements:

- The data transfer width is 8 bits.
- The Chip Select (CS) signal sets the device active at a low level and inactive at a high level.
- The clock signal has to be generated by the target system. The serial flash devices are always in slave mode.
- The bit order requires the most significant bit (MSB) to be sent out first.

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6.3.2 SLC1 NAND driver

The SLC1 NAND driver is an extremely efficient and low-footprint driver that can be used to access the data stored on a raw NAND flash device. The driver is designed to support one or more Single Level Cell (SLC) NAND flash devices that require 1-bit error correction capability. The SLC1 NAND flash driver can also be used to access the data stored on Microchip / Atmel and Adesto DataFlash devices. Different sector sizes are supported to help reduce the RAM usage of the file system.

6.3.2.1 Supported hardware

The SLC1 NAND driver supports almost all SLC NAND flash devices. This includes NAND flash devices with page sizes of 512 + 16 and 2048 + 64 bytes.

6.3.2.1.1 Tested and compatible NAND flash devices

The table below lists the NAND flash devices that have been tested or are compatible with a tested device. In addition, the NAND flash driver fully supports the Dialog Semiconductor / Adesto / Atmel DataFlash devices with capacities up to 128 MBit.

Device name	Page size	Number of blocks	Storage capacity	Bus width
ATO				
AFND1G08U3	2048+64 byte	1024	128 MB	8 bit
Dialog Semiconductor/Adesto/Atmel				
AT25PE16	512+16 byte	512	2 MB	1 bit
AT45BR3214B	512+16 byte	1024	4 MB	1 bit
AT45DB011B	256+8 byte	64	128 KB	1 bit
AT45DB021B	256+8 byte	128	256 KB	1 bit
AT45DB041B	256+8 byte	256	512 KB	1 bit
AT45DB081B	256+8 byte	512	1 MB	1 bit
AT45DB1282	1024+32 byte	2048	16 MB	1 bit
AT45DB161B	512+16 byte	512	2 MB	1 bit
AT45DB161E	512+16 byte	512	2 MB	1 bit
AT45DB321C	512+16 byte	1024	4 MB	1 bit
AT45DB321E	512+16 byte	1024	4 MB	1 bit
AT45DB641E	256+8 byte	4096	8 MB	1 bit
AT45DB642D	1024+32 byte	1024	8 MB	1 bit
AT45DCB002	512+16 byte	512	2 MB	1 bit
AT45DCB004	512+16 byte	1024	4 MB	1 bit
AT45DCB008	1024+32 byte	1024	8 MB	1 bit
Hynix				
HY27SA081G1M	512+16 byte	8192	512 MB	8 bit
HY27SS08121M	512+16 byte	4096	512 MB	8 bit
HY27SS08561M	512+16 byte	2048	256 MB	8 bit
HY27UA081G1M	512+16 byte	8192	512 MB	8 bit
HY27UF081G2A	2048+64 byte	1024	128 MB	8 bit
HY27UF081G2M	2048+64 byte	1024	128 MB	8 bit
HY27UF082G2M	2048+64 byte	2048	256 MB	8 bit
HY27UF084G2M	2048+64 byte	4096	512 MB	8 bit

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Device name	Page size	Number of blocks	Storage capacity	Bus width
HY27UG084G2M	2048+64 byte	4096	512 MB	8 bit
HY27UG084GDM	2048+64 byte	4096	512 MB	8 bit
HY27US08121M	512+16 byte	4096	512 MB	8 bit
HY27US08281A	512+16 byte	1024	128 MB	8 bit
HY27US08561M	512+16 byte	2048	256 MB	8 bit
ISSI				
IS34ML01G081	2048+64 byte	1024	128 MB	8 bit
IS34ML04G081	2048+64 byte	4096	512 MB	8 bit
IS35ML02G081	2048+64 byte	2048	256 MB	8 bit
Kioxia/Toshiba				
TC5816BFT	256+8 byte	512	2 MB	8 bit
TC582562A	512+8 byte	2048	32 MB	8 bit
TC58256AFT	512+8 byte	2048	32 MB	8 bit
TC58512FT	512+8 byte	4096	64 MB	8 bit
TC58V32AFT	512+8 byte	512	4 MB	8 bit
TC58V64BFT	512+8 byte	1024	8 MB	8 bit
TH58100FT	512+8 byte	8192	128 MB	8 bit
Micron				
MT29F2G08AAB	2048+64 byte	2048	256 MB	8 bit
MT29F2G08ABD	2048+64 byte	2048	256 MB	8 bit
MT29F2G16AAD	2048+64 byte	2048	256 MB	16 bit
MT29F4G08AAA	2048+64 byte	4096	512 MB	8 bit
MT29F4G08BAB	2048+64 byte	4096	512 MB	8 bit
STMicroelectronics				
NAND01GR3A	512+16 byte	8192	1 GB	8 bit
NAND01GR3B	2048+64 byte	1024	128 MB	8 bit
NAND01GW3A	512+16 byte	8192	1 GB	8 bit
NAND01GW3B	2048+64 byte	1024	128 MB	8 bit
NAND02GR3B	2048+64 byte	2048	256 MB	8 bit
NAND02GW3B	2048+64 byte	2048	256 MB	8 bit
NAND04GW3B	2048+64 byte	4096	512 MB	8 bit
NAND128R3A	512+16 byte	1024	128 MB	8 bit
NAND128W3A	512+16 byte	1024	128 MB	8 bit
NAND256R3A	512+16 byte	2048	256 MB	8 bit
NAND256W3A	512+16 byte	2048	256 MB	8 bit
NAND512R3A	512+16 byte	4096	512 MB	8 bit
NAND512W3A	512+16 byte	4096	512 MB	8 bit
Samsung				
K9F1208B0B	512+16 byte	4096	64 MB	8 bit
K9F1208R0B	512+16 byte	4096	64 MB	8 bit
K9F1208U0B	512+16 byte	4096	64 MB	8 bit
K9F1G08R0A	2048+64 byte	1024	128 MB	8 bit

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Device name	Page size	Number of blocks	Storage capacity	Bus width
K9F1G08U0A	2048+64 byte	1024	128 MB	8 bit
K9F1G08U0C	2048+64 byte	1024	128 MB	8 bit
K9F2808Q0B	512+16 byte	1024	16 MB	8 bit
K9F2808U0B	512+16 byte	1024	16 MB	8 bit
K9F2G08U0M	2048+64 byte	2048	256 MB	8 bit
K9F4G08U0A	2048+64 byte	4096	512 MB	8 bit
K9F4G08U0M	2048+64 byte	4096	512 MB	8 bit
K9F5608B0D	512+16 byte	2048	32 MB	8 bit
K9F5608R0D	512+16 byte	2048	32 MB	8 bit
K9F5608U0D	512+16 byte	2048	32 MB	8 bit
K9F6408Q0C	512+16 byte	1024	8 MB	8 bit
K9F6408U0C	512+16 byte	1024	8 MB	8 bit
K9F8G08U0M	4096+128 byte	4096	1 GB	8 bit
K9K1G08B0B	512+16 byte	8192	128 MB	8 bit
K9K1G08R0B	512+16 byte	8192	128 MB	8 bit
K9K1G08U0B	512+16 byte	8192	128 MB	8 bit
K9K1G08U0M	512+16 byte	8192	128 MB	8 bit
K9K2G08R0A	2048+64 byte	2048	256 MB	8 bit
K9K2G08U0M	2048+64 byte	2048	256 MB	8 bit
SkyHigh/Cypress				
S34ML01G100TFI000	2048+64 byte	1024	128 MB	8 bit
S34ML04G100TFI000	2048+64 byte	4096	512 MB	8 bit
S34MS02G100TFI000	2048+64 byte	2048	256 MB	8 bit
Winbond				
W29N08GVSIAA	2048+64 byte	8192	1 GB	8 bit

Support for devices not in this list

Most other NAND flash devices are compatible with one of the supported devices. Thus, the driver can be used with these devices or may only need a little modification, which can be easily done. Get in touch with us if you have questions about support for devices not in this list.

> **Note**
>
> DataFlash devices with a page size that is a power of 2 are not supported by the SLC1 NAND driver.

6.3.2.2 Theory of operation

NAND flash devices are divided into physical blocks and physical pages. One physical block is the smallest erasable unit; one physical page is the smallest writable unit. Small block NAND flashes contain multiple pages. One block typically contains 16 / 32 / 64 pages. Every page has a size of 528 bytes (512 data bytes + 16 spare bytes). Large block NAND flash devices contain blocks made up of 64 pages, each page containing 2112 bytes (2048 data bytes + 64 spare bytes). The driver uses the spare bytes for the following purposes:

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1. To check if the data status byte and block status are valid. If they are valid, the driver uses this sector. When the driver detects a bad sector, the whole block is marked as invalid and its content is copied to a non-defective block.
2. To store/read an ECC (Error Correcting Code) for data reliability. When reading a sector, the driver also reads the ECC stored in the spare area of the sector, calculates the ECC based on the read data, and compares the ECCs. If the ECCs are not identical, the driver tries to recover the data based on the read ECC. When writing to a page, the ECC is calculated based on the data the driver has to write to the page. The calculated ECC is then stored in the spare area.

6.3.2.3 Error correction using ECC

The SLC1 NAND driver is highly speed optimized and offers better error detection and correction than a standard memory controller ECC. The ECC is capable of single bit error correction and 2-bit random detection. When a block for which the ECC is calculated has 2 or more bit errors, the data cannot be corrected. Standard memory controllers calculate an ECC for the complete block size (512 / 2048 bytes). The ECC routines of the SLC1 NAND driver calculate the ECC for data chunks of 256 bytes (e.g., a page with 2048 bytes is divided into 8 parts of 256 bytes); therefore, the probability to detect and also correct data errors is much higher. This enhancement is realized with very good performance. The ECC computation of the SLC1 NAND driver is highly optimized, so that a performance of 18 Mbytes/second can be achieved with an ARM7-based MCU running at 48 MHz. We suggest the use of the SLC1 NAND driver without enabling the hardware ECC of the memory controller, because the performance of the driver is very high, and the error correction is much better.

6.3.2.4 Partial write operations

Most NAND devices allow a write operation to change an arbitrary number of bytes starting from any byte offset inside a page. A write operation that does not change all the bytes in a page is called partial write or partial programming. The driver makes extensive use of this feature to increase the write speed and to reduce the RAM usage. But there is a limitation of this method imposed by the NAND technology. The manufacturer does not guarantee the integrity of the data if a page is partially written more than a number of times without an intermediate erase operation. The maximum number of partial writes is usually four. Exceeding the maximum number of partial writes does not lead automatically to the corruption of data in that page, but it can increase the probability of bit errors. The driver is able to correct single bit errors using ECC. For some combinations of logical sector size and NAND page size, the driver might exceed the limit for the number of partial write operations. The table below summarizes the maximum number of partial writes performed by the SLC1 NAND driver for different logical sector sizes:

NAND page size (bytes)	Logical sector size (bytes)	Maximum number of partial write operations
512	512	4
2048	2048	4
2048	1024	5
2048	512	8

6.3.2.5 Configuring the driver

This section describes how to configure the file system to make use of the SLC1 NAND driver.

6.3.2.5.1 Compile time configuration

The SLC1 NAND driver can optionally be configured at compile time. Typically, this step can be omitted because the SLC1 NAND driver provides reasonable default values that work for most of the target applications. The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration

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define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the SLC1 NAND driver.

Define	Default value	Type	Description
FS_NAND_ENABLE_STATS	0 or 1	B	Enables or disables the support for statistical counters.
FS_NAND_NUM_READ_RETRIES	10	N	Configures the number of retries in case of a read error.
FS_NAND_NUM_WRITE_RETRIES	10	N	Configures the number of retries in case of a write error.
FS_NAND_NUM_UNITS	4	N	Configures the maximum number of driver instances.
FS_NAND_VERIFY_ERASE	0	B	Enables or disables the verification of the erase operation.
FS_NAND_VERIFY_WRITE	0	B	Enables or disables the verification of the write operation.

6.3.2.5.1.1 FS_NAND_ENABLE_STATS

This define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the SLC1 NAND driver that can be useful for debugging. The statistical counters can be queried via `FS_NAND_GetStatCounters()`. By default `FS_NAND_ENABLE_STATS` is set to 1 if `FS_DEBUG_LEVEL` is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

6.3.2.5.1.2 FS_NAND_NUM_READ_RETRIES

Number of times the SLC1 NAND driver retries the operation in case of a read error (device error or uncorrectable bit error). `NumReadRetries` of `FS_NAND_STAT_COUNTERS` is incremented by 1 on each retry.

6.3.2.5.1.3 FS_NAND_NUM_WRITE_RETRIES

Number of times the SLC1 NAND driver retries the operation in case of a write error. A write error occurs when the NAND flash device is not able to write the data to the memory array. This condition is typically reported via a flag in the status register of the NAND flash device that is queried by the NAND physical layer after each write operation. `NumWriteRetries` of `FS_NAND_STAT_COUNTERS` is incremented by 1 on each retry.

6.3.2.5.1.4 FS_NAND_NUM_UNITS

This define specifies the maximum number of driver instances of the SLC1 NAND driver the application is allowed to create. Four bytes of static RAM are reserved for each instance. If the maximum number of driver instances is smaller than the default, then `FS_NAND_NUM_UNITS` can be set to that value in order to reduce the RAM usage.

6.3.2.5.1.5 FS_NAND_VERIFY_ERASE

This define can be used to activate the erase verification of the SLC1 NAND driver. The erase verification is performed after each erase operation by reading back the entire data of the erase block and by comparing each byte in the block with `0xFF`. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NAND_SetEraseVerification()`.

> **Note**
>
> Activating the erase verification may negatively affect the write performance.

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6.3.2.5.1.6 FS_NAND_VERIFY_WRITE

This define can be used to activate the write verification of the SLC1 NAND driver. The write verification is performed after each write operation by reading back the modified data and by comparing it with the data requested to be written. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NAND_SetWriteVerification()`.

> **Note**
>
> Activating the write verification may negatively affect the write performance.

6.3.2.5.2 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of `FS_NAND_Driver`. This function call together with other function calls that configure the driver operation has to be added to `FS_X_AddDevices()` as demonstrated in the following example.

Example

```
#include <FS.h>
#include "FS_NAND_HW_Template.h"

#define ALLOC_SIZE      0x9000          // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add the driver to file system.
  //
  FS_AddDevice(&FS_NAND_Driver);
  //
  // Set the physical interface of the NAND flash.
  //
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_x8);
  //
  // Skip 2 blocks (256 Kbytes in case of 2K device)
  // The size of the configured area is 128 blocks.
  // For 2K devices, this means 2 Kbytes * 64 * 128 = 16 Mbytes
  //
  FS_NAND_SetBlockRange(0, 2, 128);
  //
  // Configure the HW access routines.
  //
  FS_NAND_x8_SetHWType(0, &FS_NAND_HW_Template);
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the SLC1 NAND driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
FS_NAND_SetBlockRange()	Specifies which NAND flash blocks can used as data storage.

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Function	Description
FS_NAND_SetCleanThreshold()	Specifies the minimum number sectors that the driver should keep available for fast write operations.
FS_NAND_SetEraseVerification()	Enables or disables the checking of the block erase operation.
FS_NAND_SetMaxEraseCntDiff()	Configures the threshold of the wear leveling procedure.
FS_NAND_SetNumWorkBlocks()	Sets number of work blocks the SLC1 NAND driver uses for write operations.
FS_NAND_SetOnFatalErrorCallback()	Registers a function to be called by the driver when a fatal error occurs.
FS_NAND_SetPhyType()	Configures NAND flash access functions.
FS_NAND_SetWriteVerification()	Enables or disables the checking of each page write operation.

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6.3.2.5.2.1 FS_NAND_SetBlockRange()

Description

Specifies which NAND flash blocks can used as data storage.

Prototype

```
void FS_NAND_SetBlockRange(U8  Unit,
                           U16 FirstBlock,
                           U16 MaxNumBlocks);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
FirstBlock	Index of the first NAND flash block to be used as storage (0-based).
MaxNumBlocks	Maximum number of NAND flash blocks to be used as storage.

Additional information

This function is optional. By default, the SLC1 NAND driver uses all blocks of the NAND flash as data storage. FS_NAND_SetBlockRange() is useful when a part of the NAND flash has to be used for another purpose, for example to store the application program used by a boot loader, and therefore it cannot be managed by the SLC1 NAND driver. Limiting the number of blocks used by the SLC1 NAND driver can also help reduce the RAM usage.

FirstBlock is the index of the first physical NAND block were 0 is the index of the first block of the NAND flash device. MaxNumBlocks can be larger that the actual number of available NAND blocks in which case the SCL1 NAND driver silently truncates the value to reflect the actual number of NAND blocks available.

The SLC1 NAND driver uses the first NAND block in the range to store management information at low-level format. If the first NAND block happens to be marked as defective, then the next usable NAND block is used.

The read optimization of the FS_NAND_PHY_2048x8 physical layer has to be disabled when this function is used to partition the NAND flash device in order to ensure data consistency. The read cache can be disabled at runtime using FS_NAND_2048x8_DisableReadCache().

If the FS_NAND_SetBlockRange() is used to subdivide the same physical NAND flash device into two or more partitions than the application has to make sure that they do not overlap.

Example

Sample configuration showing how to reserve the first 16 blocks of the NAND flash.

```
#include <FS.h>

void FS_X_AddDevices(void) {
  //
  // Basic file system configuration...
  //

  //
  // Add and configure the SLC1 NAND driver.
  // Only the NAND blocks with the physical
  // indexes 16-143 are used for storage.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_SetBlockRange(0, 16, 128);

  //
  // Additional file system configuration...
```

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```
  //
}
```

Sample configuration showing how to partition the same NAND flash device.

```
#include <FS.h>

void FS_X_AddDevices(void) {
  //
  // Basic file system configuration...
  //

  //
  // Add and configure the first SLC1 NAND driver.
  // The blocks 16 blocks are used for storage,
  // that is the NAND blocks with the physical
  // indexes 0-15.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_SetBlockRange(0, 0, 16);

  //
  // Add and configure the second SLC1 NAND driver.
  // The blocks 64 blocks are used for storage,
  // that is the NAND blocks with the physical
  // indexes 16-79.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_SetBlockRange(0, 16, 64);

  //
  // Additional file system configuration...
  //
}
```

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6.3.2.5.2.2 FS_NAND_SetCleanThreshold()

Description

Specifies the minimum number sectors that the driver should keep available for fast write operations.

Prototype

```
int FS_NAND_SetCleanThreshold(U8       Unit,
                              unsigned NumBlocksFree,
                              unsigned NumSectorsFree);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumBlocksFree	Number of blocks to be kept free.
NumSectorsFree	Number of sectors to be kept free on each block.

Return value

= 0 OK, threshold set.
≠ 0 An error occurred.

Additional information

Typically, used for allowing the NAND flash to write data fast to a file on a sudden reset. At the startup, the application reserves free space, by calling the function with NumBlocksFree and NumSectorsFree set to a value different than 0. The number of free sectors depends on the number of bytes written and on how the file system is configured. When the unexpected reset occurs, the application tells the driver that it can write to the free sectors, by calling the function with NumBlocksFree and NumSectorsFree set to 0. Then, the application writes the data to file and the NAND driver stores it to the free space. Since no erase or copy operation is required, the data is written as fastest as the NAND flash device permits it.

The NAND flash device will wear out faster than normal if sectors are reserved in a work block (NumSectors > 0).

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6.3.2.5.2.3 FS_NAND_SetEraseVerification()

Description

Enables or disables the checking of the block erase operation.

Prototype

```
void FS_NAND_SetEraseVerification(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The erase operation is not checked. • ≠0 The erase operation is checked.

Additional information

This function is optional. The result of a block erase operation is normally checked by evaluating the error bits maintained by the NAND flash device in an internal status register. `FS_NAND_SetEraseVerification()` can be used to enable additional verification of the block erase operation that is realized by reading back the contents of the entire erased physical block and by checking that all the bytes in it are set to `0xFF`. Enabling this feature can negatively impact the write performance of SLC1 NAND driver.

The block erase verification feature is active only when the SLC1 NAND driver is compiled with the `FS_NAND_VERIFY_ERASE` configuration define is set to 1 (default is 0) or when the `FS_DEBUG_LEVEL` configuration define is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

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6.3.2.5.2.4 FS_NAND_SetMaxEraseCntDiff()

Description

Configures the threshold of the wear leveling procedure.

Prototype

```
void FS_NAND_SetMaxEraseCntDiff(U8  Unit,
                                U32 EraseCntDiff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
EraseCntDiff	Maximum allowed difference between the erase counts of any two NAND blocks.

Additional information

This function is optional. It can be used to control how the SLC1 NAND driver performs the wear leveling. The wear leveling procedure makes sure that the NAND blocks are equally erased to meet the life expectancy of the storage device by keeping track of the number of times a NAND block has been erased (erase count). The SLC1 NAND driver executes this procedure when a new empty NAND block is required for data storage. The wear leveling procedure works by first choosing the next available NAND block. Then the difference between the erase count of the chosen block and the NAND block with lowest erase count is computed. If this value is greater than EraseCntDiff the NAND block with the lowest erase count is freed and made available for use.

The same threshold can also be configured at compile time via the FS_NAND_MAX_ERASE_CNT_DIFF configuration define.

Example

```
#include <FS.h>

void FS_X_AddDevices(void) {
  //
  // Basic file system configuration...
  //

  //
  // Add and configure the SLC1 NAND driver.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_SetMaxEraseCntDiff(0, 5000);

  //
  // Additional file system configuration...
  //
}
```

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6.3.2.5.2.5 FS_NAND_SetNumWorkBlocks()

Description

Sets number of work blocks the SLC1 NAND driver uses for write operations.

Prototype

```
void FS_NAND_SetNumWorkBlocks(U8  Unit,
                              U32 NumWorkBlocks);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumWorkBlocks	Number of work blocks.

Additional information

This function is optional. It can be used to change the default number of work blocks according to the requirements of the application. Work blocks are physical NAND blocks that the SLC1 NAND driver uses to temporarily store the data written to NAND flash device. The SLC1 NAND driver calculates at low-level format the number of work blocks based on the total number of blocks available on the NAND flash device.

By default, the NAND driver allocates 10% of the total number of NAND blocks used as storage, but no more than 10 NAND blocks. The minimum number of work blocks allocated by default depends on whether journaling is used or not. If the journal is active 4 work blocks are allocated, else SLC1 NAND driver allocates 3 work blocks. The currently allocated number of work blocks can be checked via `FS_NAND_GetDiskInfo()`. The value is returned in the `NumWorkBlocks` member of the `FS_NAND_DISK_INFO` structure.

Increasing the number of work blocks can help increase the write performance of the SLC1 NAND driver. At the same time the RAM usage of the SLC1 NAND driver increases since each configured work block requires a certain amount of RAM for the data management. This is a trade-off between write performance and RAM usage.

The new value take effect after the NAND flash device is low-level formatted via `FS_FormatLow()` or `FS_NAND_FormatLow()` API functions.

Example

```
#include <FS.h>

void FS_X_AddDevices(void) {
  //
  // Basic file system configuration...
  //

  //
  // Add and configure the SLC1 NAND driver.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_SetNumWorkBlocks(0, 5);

  //
  // Additional file system configuration...
  //
}
```

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6.3.2.5.2.6 FS_NAND_SetOnFatalErrorCallback()

Description

Registers a function to be called by the driver when a fatal error occurs.

Prototype

```
void FS_NAND_SetOnFatalErrorCallback
                                (FS_NAND_ON_FATAL_ERROR_CALLBACK * pfOnFatalError);
```

Parameters

Parameter	Description
pfOnFatalError	Pointer to callback function.

Additional information

This function is optional. If no callback function is registered the SLC1 NAND driver behaves as if the callback function returned 1. This means that the NAND flash remains writable after the occurrence of the fatal error. emFile versions previous to 4.04b behave differently and mark the NAND flash as read-only in this case. For additional information refer to FS_NAND_ON_FATAL_ERROR_CALLBACK.

Typically, the SLC1 NAND driver reports a fatal error when an uncorrectable bit error occurs, that is when the ECC is not able to correct the bit errors. A fatal error can also be reported on other events such the failure to erase a NAND block. The type of error is indicated to the callback function via the ErrorType member of the FS_NAND_FATAL_ERROR_INFO structure.

All instances of the SLC1 NAND driver share the same callback function. The Unit member of the FS_NAND_FATAL_ERROR_INFO structure passed as parameter to the pfOnFatalError callback function can be used to determine which driver instance triggered the fatal error.

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6.3.2.5.2.7 FS_NAND_SetPhyType()

Description

Configures NAND flash access functions.

Prototype

```
void FS_NAND_SetPhyType(      U8                  Unit,
                        const FS_NAND_PHY_TYPE * pPhyType);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pPhyType	in Physical layer to be used to access the NAND flash device.

Additional information

This function is mandatory and it has to be called in FS_X_AddDevices() once for each instance of the SLC1 NAND driver. The driver instance is identified by the Unit parameter. First SLC1 NAND driver instance added to the file system via a FS_AddDevice(&FS_NAND_Driver) call has the unit number 0, the SLC1 NAND driver added by a second call to FS_AddDevice() has the unit number 1 and so on.

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6.3.2.5.2.8 FS_NAND_SetWriteVerification()

Description

Enables or disables the checking of each page write operation.

Prototype

```
void FS_NAND_SetWriteVerification(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The write operation is not checked. • ≠0 The write operation is checked.

Additional information

This function is optional. The result of a page write operation is normally checked by evaluating the error bits maintained by the NAND flash device in an internal status register. FS_NAND_SetWriteVerification() can be used to enable additional verification of the page write operation that is realized by reading back the contents of the written page and by checking that all the bytes are matching the data requested to be written. Enabling this feature can negatively impact the write performance of SLC1 NAND driver.

The page write verification feature is active only when the SLC1 NAND driver is compiled with the FS_NAND_VERIFY_WRITE configuration define is set to 1 (default is 0) or when the FS_DEBUG_LEVEL configuration define is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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6.3.2.5.2.9 FS_NAND_ON_FATAL_ERROR_CALLBACK

Description

The type of the callback function invoked by the NAND driver when a fatal error occurs.

Type definition

```
typedef int FS_NAND_ON_FATAL_ERROR_CALLBACK(
                                      FS_NAND_FATAL_ERROR_INFO * pFatalErrorInfo);
```

Parameters

Parameter	Description
pFatalErrorInfo	Information about the fatal error.

Return value

= 0 The NAND driver has to mark the NAND flash device as read only.
≠ 0 The NAND flash device has to remain writable.

Additional information

If the callback function returns a 0 the NAND driver marks the NAND flash device as read-only and it remains in this state until the NAND flash device is low-level formatted. In this state all further write operations are rejected with an error by the NAND driver.

The application is responsible for handling the fatal error for example by checking the consistency of the file system via `FS_CheckDisk()`. The callback function is not allowed to invoke any other FS API functions therefore the handling of the error has to be done after the FS API function that triggered the error returns.

Depending on the type of NAND driver used, the fatal error handler can be registered either via `FS_NAND_SetOnFatalErrorCallback()` or `FS_NAND_UNI_SetOnFatalErrorCallback()`.

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6.3.2.5.2.10 FS_NAND_FATAL_ERROR_INFO

Description

Information passed to callback function when a fatal error occurs.

Type definition

```
typedef struct {
  U8   Unit;
  U8   ErrorType;
  U32  ErrorSectorIndex;
} FS_NAND_FATAL_ERROR_INFO;
```

Structure members

Member	Description
Unit	Instance of the NAND driver that generated the fatal error.
ErrorType	Type of fatal error.
ErrorSectorIndex	Index of the physical sector where the error occurred. Not applicable for all type of errors.

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6.3.2.6 Additional driver functions

The following functions are optional and can be used by the application to perform operations directly on the NAND flash device.

Function	Description
FS_NAND_Clean()	Makes sectors available for fast write operations.
FS_NAND_EraseBlock()	Sets all the bytes in a NAND block to 0xFF.
FS_NAND_EraseFlash()	Erases the entire NAND partition.
FS_NAND_FormatLow()	Performs a low-level format of the NAND flash device.
FS_NAND_GetBlockInfo()	Returns information about a specified NAND block.
FS_NAND_GetDiskInfo()	Returns information about the NAND partition.
FS_NAND_GetStatCounters()	Returns the actual values of statistical counters.
FS_NAND_IsBlockBad()	Checks if a NAND block is marked as defective.
FS_NAND_IsLLFormatted()	Checks if the NAND flash is low-level formatted.
FS_NAND_ReadPageRaw()	Reads data from a page without ECC.
FS_NAND_ReadPhySector()	This function reads a physical sector from NAND flash.
FS_NAND_ResetStatCounters()	Sets the values of statistical counters to 0.
FS_NAND_TestBlock()	Fills all the pages in a block (including the spare area) with the specified pattern and verifies if the data was written correctly.
FS_NAND_WritePage()	Stores data to a page of a NAND flash with ECC.
FS_NAND_WritePageRaw()	Stores data to a page of a NAND flash without ECC.

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6.3.2.6.1 FS_NAND_Clean()

Description

Makes sectors available for fast write operations.

Prototype

```
int FS_NAND_Clean(U8       Unit,
                  unsigned NumBlocksFree,
                  unsigned NumSectorsFree);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumBlocksFree	Number of blocks to be kept free.
NumSectorsFree	Number of sectors to be kept free on each block.

Return value

= 0 OK
≠ 0 An error occurred

Additional information

This function is optional. It can be used to free space on the NAND flash device for data that the application has to write as fast as possible. FS_NAND_UNI_Clean() performs two internal operations: (1) Converts all work blocks that have less free sectors than NumSectorsFree into data blocks. (2) If required, convert work blocks until at least NumBlocksFree are available.

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6.3.2.6.2 FS_NAND_EraseBlock()

Description

Sets all the bytes in a NAND block to `0xFF`.

Prototype

```
int FS_NAND_EraseBlock(U8       Unit,
                       unsigned BlockIndex);
```

Parameters

Parameter	Description
`Unit`	Index of the driver instance (0-based).
`BlockIndex`	Index of the NAND flash block to be erased.

Return value

= 0 OK, block erased.
≠ 0 An error occurred.

Additional information

This function is optional. `FS_NAND_EraseBlock()` function does not check if the block is marked as defective before erasing it.

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6.3.2.6.3 FS_NAND_EraseFlash()

Description

Erases the entire NAND partition.

Prototype

```
int FS_NAND_EraseFlash(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

≥ 0 Number of blocks which failed to erase.
< 0 An error occurred.

Additional information

This function is optional. After the call to `FS_NAND_EraseFlash()` all the bytes in the NAND partition are set to `0xFF`.

This function has to be used with care, since it also erases blocks marked as defective and therefore the information about the block status will be lost. `FS_NAND_EraseFlash()` can be used without this side effect on storage devices that are guaranteed to not have any bad blocks, such as DataFlash devices.

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6.3.2.6.4 FS_NAND_FormatLow()

Description

Performs a low-level format of the NAND flash device.

Prototype

```
int FS_NAND_FormatLow(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 OK, NAND flash device is low-level formatted.
≠ 0 An error occurred.

Additional information

This function is optional. It is recommended that application use `FS_FormatLow()` to initialize the NAND flash device instead of `FS_NAND_FormatLow()`.

After the low-level format operation all data that was stored on the NAND flash device is lost. A low-level format has to be performed only once before using the NAND flash device for the first time. The application can check if the NAND flash device is low-level formatted by calling `FS_IsLLFormated()` or alternatively `FS_NAND_IsLLFormated()`.

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6.3.2.6.5 FS_NAND_GetBlockInfo()

Description

Returns information about a specified NAND block.

Prototype

```
int FS_NAND_GetBlockInfo(U8                   Unit,
                         U32                  PhyBlockIndex,
                         FS_NAND_BLOCK_INFO * pBlockInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PhyBlockIndex	Index of the physical block to get information about.
pBlockInfo	out Information about the NAND block.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the SLC1 NAND driver and is typically not linked in production builds.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleNANDGetBlockInfo(void) {
  FS_NAND_BLOCK_INFO BlockInfo;
  char               ac[100];

  FS_X_Log("Get information about block 1 of the first SLC1 NAND driver instance\n");
  FS_NAND_GetBlockInfo(0, 1, &BlockInfo);
  SEGGER_snprintf(ac, sizeof(ac), "  sType:                   %s\n", BlockInfo.sType);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  EraseCnt:                0x%.8x\n", BlockInfo.EraseCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  LBI:                     %lu\n", BlockInfo.lbi);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsBlank:         %d\n", BlockInfo.NumSectorsBlank);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsECCCorrectable: %d
\n", BlockInfo.NumSectorsECCCorrectable);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsErrorInECC:    %d
\n", BlockInfo.NumSectorsErrorInECC);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsECCError:      %d\n", BlockInfo.NumSectorsECCError);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsInvalid:       %d\n", BlockInfo.NumSectorsInvalid);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsValid:         %d\n", BlockInfo.NumSectorsValid);
}
```

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6.3.2.6.6 FS_NAND_GetDiskInfo()

Description

Returns information about the NAND partition.

Prototype

```
int FS_NAND_GetDiskInfo(U8                   Unit,
                        FS_NAND_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDiskInfo	out Information about the NAND partition.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the SLC1 NAND driver and is typically not linked in production builds.

Example

```
#include <stdio.h>
#include "FS.h"

void SampleNANDGetDiskInfo(void) {
  FS_NAND_DISK_INFO DiskInfo;
  char              ac[100];

  memset(&DiskInfo, 0, sizeof(DiskInfo));
  FS_X_Log("Get information about the first SLC1 NAND driver instance:\n");
  FS_NAND_GetDiskInfo(0, &DiskInfo);
  SEGGER_snprintf(ac, sizeof(ac), "  NumPhyBlocks:       %lu\n", DiskInfo.NumPhyBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumLogBlocks:       %lu\n", DiskInfo.NumLogBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumPagesPerBlock:   %lu\n", DiskInfo.NumPagesPerBlock);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumSectorsPerBlock: %lu\n", DiskInfo.NumSectorsPerBlock);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  BytesPerPage:       %lu\n", DiskInfo.BytesPerPage);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  BytesPerSector:     %lu\n", DiskInfo.BytesPerSector);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumUsedPhyBlocks:   %lu\n", DiskInfo.NumUsedPhyBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  NumBadPhyBlocks:    %lu\n", DiskInfo.NumBadPhyBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  EraseCntMin:        %lu\n", DiskInfo.EraseCntMin);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  EraseCntMax:        %lu\n", DiskInfo.EraseCntMax);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  EraseCntAvg:        %lu\n", DiskInfo.EraseCntAvg);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  IsWriteProtected:   %d\n", DiskInfo.IsWriteProtected);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  HasFatalError:      %d\n", DiskInfo.HasFatalError);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  ErrorType:          %d\n", DiskInfo.ErrorType);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  ErrorSectorIndex:   %lu\n", DiskInfo.ErrorSectorIndex);
  FS_X_Log(ac);
```

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```
}
```

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6.3.2.6.7 FS_NAND_GetStatCounters()

Description

Returns the actual values of statistical counters.

Prototype

```
void FS_NAND_GetStatCounters(U8                      Unit,
                             FS_NAND_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pStat	out Values of statistical counters.

Additional information

This function is optional. It is active only when the file system is compiled with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or FS_NAND_ENABLE_STATS set to 1.

The statistical counters can be cleared via FS_NAND_ResetStatCounters().

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6.3.2.6.8 FS_NAND_IsBlockBad()

Description

Checks if a NAND block is marked as defective.

Prototype

```
int FS_NAND_IsBlockBad(U8       Unit,
                       unsigned BlockIndex);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the NAND flash block to be checked.

Return value

1 Block is defective
0 Block is not defective

Additional information

This function is optional.

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6.3.2.6.9 FS_NAND_IsLLFormatted()

Description

Checks if the NAND flash is low-level formatted.

Prototype

```
int FS_NAND_IsLLFormatted(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 1 NAND flash device is low-level formatted.
= 0 NAND flash device is not low-level formatted.
< 0 An error occurred.

Additional information

This function is optional.

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6.3.2.6.10 FS_NAND_ReadPageRaw()

Description

Reads data from a page without ECC.

Prototype

```
int FS_NAND_ReadPageRaw(U8         Unit,
                        U32        PageIndex,
                        void     * pData,
                        unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be read.
pData	out Data to be written.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is read beginning from byte offset 0 in the page. If more data is requested than the page + spare area size, typ. 2 Kbytes + 64 bytes, the function does not modify the remaining bytes in pData.

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6.3.2.6.11 FS_NAND_ReadPhySector()

Description

This function reads a physical sector from NAND flash.

Prototype

```
int FS_NAND_ReadPhySector(U8         Unit,
                          U32        PhySectorIndex,
                          void     * pData,
                          unsigned * pNumBytesData,
                          void     * pSpare,
                          unsigned * pNumBytesSpare);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PhySectorIndex	Physical sector index.
pData	Pointer to a buffer to store read data.
pNumBytesData	in Pointer to variable storing the size of the data buffer. out The number of bytes that were stored in the data buffer.
pSpare	Pointer to a buffer to store read spare data.
pNumBytesSpare	in Pointer to variable storing the size of the spare data buffer. out The number of bytes that were stored in the spare data buffer.

Return value

< 0	OK, all bytes are set to 0xFF in the physical sector.
= 0	OK, no bit errors.
= 1	OK, one bit error found and corrected.
= 2	OK, one bit error found in the ECC.
= 3	Error, more than 1 bit errors occurred.
= 4	Error, could not read form NAND flash device.
= 5	Error, internal operation.

Additional information

This function is optional.

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6.3.2.6.12 FS_NAND_ResetStatCounters()

Description

Sets the values of statistical counters to 0.

Prototype

```
void FS_NAND_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)

Additional information

This function is optional. It is active only when the file system is compiled with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or FS_NAND_ENABLE_STATS set to 1.

The statistical counters can be queried via FS_NAND_GetStatCounters().

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6.3.2.6.13 FS_NAND_TestBlock()

Description

Fills all the pages in a block (including the spare area) with the specified pattern and verifies if the data was written correctly.

Prototype

```
int FS_NAND_TestBlock(U8                  Unit,
                      unsigned            BlockIndex,
                      U32                 Pattern,
                      FS_NAND_TEST_INFO * pInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the NAND block to be tested.
Pattern	Data pattern to be written during the test.
pInfo	out Optional information about the test result.

Return value

FS_NAND_TEST_RETVAL_OK	OK, no bit errors.
FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR	OK, correctable bit errors found. The number of bit errors is returned in NumErrorsCorrectable of pResult.
FS_NAND_TEST_RETVAL_FATAL_ERROR	Fatal error, uncorrectable bit error found. The page index is returned in PageIndexFatalError of pResult.
FS_NAND_TEST_RETVAL_BAD_BLOCK	Bad block, skipped.
FS_NAND_TEST_RETVAL_ERASE_FAILURE	Erase operation failed. The block has been marked as defective.
FS_NAND_TEST_RETVAL_WRITE_FAILURE	Write operation failed. The block has been marked as defective.
FS_NAND_TEST_RETVAL_READ_FAILURE	Read operation failed.
FS_NAND_TEST_RETVAL_INTERNAL_ERROR	NAND flash access error.

Additional information

This function is optional. It can be used by the application to test the data reliability of a NAND block. BlockIndex is relative to the beginning of the NAND partition where the first block has the index 0.

Example

```
#include <stdio.h>
#include "FS.h"

void _SampleNANDTestBlock(void) {
  int               r;
  U32               NumPhyBlocks;
  U32               iBlock;
  FS_NAND_DISK_INFO DiskInfo;
  FS_NAND_TEST_INFO TestInfo;
  char              ac[100];

  memset(&DiskInfo, 0, sizeof(DiskInfo));
  memset(&TestInfo, 0, sizeof(TestInfo));
  FS_NAND_GetDiskInfo(0, &DiskInfo);
  NumPhyBlocks = DiskInfo.NumPhyBlocks;
  for (iBlock = 0; iBlock < NumPhyBlocks; ++iBlock) {
    r = FS_NAND_TestBlock(0, iBlock, 0xAA5500FFuL, &TestInfo);
```

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```
    switch (r) {
    case FS_NAND_TEST_RETVAL_OK:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: OK.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: %lu correctable error(s).\n",
        iBlock, TestInfo.BitErrorCnt);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_FATAL_ERROR:
      SEGGER_snprintf(ac, sizeof(ac),
        "Block %lu: %lu correctable error(s), fatal error on page %lu.\n",
        iBlock, TestInfo.BitErrorCnt, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_BAD_BLOCK:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Bad. Skipped.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_ERASE_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Erase failure. Marked as bad.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_WRITE_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Write failure on page %lu. Marked as bad.\n",
        iBlock, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_READ_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Read failure on page %lu.\n",
        iBlock, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    default:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Internal error.\n", iBlock);
      FS_X_Log(ac);
      break;
    }
  }
}
```

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6.3.2.6.14 FS_NAND_WritePage()

Description

Stores data to a page of a NAND flash with ECC.

Prototype

```
int FS_NAND_WritePage(      U8          Unit,
                            U32         PageIndex,
                      const void      * pData,
                            unsigned    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be written.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is written beginning with the byte offset 0 in the page. If more data is written than the size of the page, typically 2 KB + 64 bytes, the excess bytes are discarded. Data in the area reserved for ECC cannot be written using this function and it will be overwritten.

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6.3.2.6.15 FS_NAND_WritePageRaw()

Description

Stores data to a page of a NAND flash without ECC.

Prototype

```
int FS_NAND_WritePageRaw(      U8         Unit,
                               U32        PageIndex,
                         const void     * pData,
                               unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be written.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is written beginning at the byte offset 0 in the page. If more data is written than the size of the page + spare area, typically 2 Kbytes + 64 bytes, the excess bytes are ignored.

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6.3.2.6.16 FS_NAND_DISK_INFO

Description

Information about the NAND partition.

Type definition

```
typedef struct {
  U32  NumPhyBlocks;
  U32  NumLogBlocks;
  U32  NumUsedPhyBlocks;
  U32  NumBadPhyBlocks;
  U32  NumPagesPerBlock;
  U32  NumSectorsPerBlock;
  U32  BytesPerPage;
  U32  BytesPerSpareArea;
  U32  BytesPerSector;
  U32  EraseCntMin;
  U32  EraseCntMax;
  U32  EraseCntAvg;
  U8   BadBlockMarkingType;
  U8   IsWriteProtected;
  U8   HasFatalError;
  U8   ErrorType;
  U32  ErrorSectorIndex;
  U16  BlocksPerGroup;
  U32  NumWorkBlocks;
  U8   IsFormatted;
} FS_NAND_DISK_INFO;
```

Structure members

Member	Description
NumPhyBlocks	Total number of blocks in the NAND partition.
NumLogBlocks	Total number of NAND blocks that can be used to store data.
NumUsedPhyBlocks	Number of NAND blocks that store valid data.
NumBadPhyBlocks	Number of NAND blocks that are marked as defective.
NumPagesPerBlock	Number of pages in a NAND block.
NumSectorsPerBlock	Number of logical sectors stored in a NAND block.
BytesPerPage	Number of bytes in the main area of a NAND page.
BytesPerSpareArea	Number of bytes in the spare area of a NAND page.
BytesPerSector	Number of bytes is a logical sector.
EraseCntMin	Minimum value of the erase counts in the NAND partition.
EraseCntMax	Maximum value of the erase counts in the NAND partition.
EraseCntAvg	Average value of the erase counts of all the NAND blocks in the NAND partition.
BadBlockMarkingType	Type of the bad block marking.
IsWriteProtected	Set to 1 if the NAND flash device cannot be written.
HasFatalError	Set to 1 if the SLC1 NAND driver reported a fatal error.
ErrorType	Type of fatal error that has occurred.
ErrorSectorIndex	Sector index on which a fatal error occurred.
BlocksPerGroup	Number of NAND blocks in a group.
NumWorkBlocks	Number of work blocks used by the SLC1 NAND driver.
IsFormatted	Set to 1 if the NAND partition has been low-level formatted.

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Additional information

Refer to *Bad block marking types* on page 670 for a list of permitted values for BadBlock-MarkingType.

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6.3.2.6.17 FS_NAND_BLOCK_INFO

Description

Information about a NAND block.

Type definition

```
typedef struct {
  U32          EraseCnt;
  U32          lbi;
  U16          NumSectorsBlank;
  U16          NumSectorsValid;
  U16          NumSectorsInvalid;
  U16          NumSectorsECCError;
  U16          NumSectorsECCCorrectable;
  U16          NumSectorsErrorInECC;
  U8           IsDriverBadBlock;
  U8           BadBlockErrorType;
  U16          BadBlockErrorBRSI;
  U8           Type;
  const char * sType;
} FS_NAND_BLOCK_INFO;
```

Structure members

Member	Description
EraseCnt	Number of times the block has been erased
lbi	Logical block index assigned to queried physical block.
NumSectorsBlank	Sectors are not used yet.
NumSectorsValid	Sectors contain correct data.
NumSectorsInvalid	Sectors have been invalidated.
NumSectorsECCError	Sectors have incorrect ECC.
NumSectorsECCCorrectable	Sectors have correctable ECC error.
NumSectorsErrorInECC	Sectors have error in ECC.
IsDriverBadBlock	Set to 1 if the block has been marked as bad by the driver.
BadBlockErrorType	Type of the error that caused the block to be marked as defective.
BadBlockErrorBRSI	Block-relative sector index on which the fatal error occurred that caused the block to be marked as defective.
Type	Type of data stored in the block.
sType	Zero-terminated string holding the block type.

Additional information

Refer to *NAND block types* on page 677 for a list of permitted values for Type.

IsDriverBadBlock is valid only when Type is set to FS_NAND_BLOCK_TYPE_BAD.

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6.3.2.7 Performance and resource usage

This section provides information about the ROM and RAM usage as well as the performance of the SLC1 NAND driver. Each SLC1 NAND driver instance requires one instance of one NAND physical layer in order to operate. The resource usage of the used NAND physical layer has to be taken into account when calculating the total resource usage of the SLC1 NAND driver.

6.3.2.7.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the SLC1 NAND driver were measured as described in the section *Test procedure* on page 1439.

Usage: 4.5 Kbytes

6.3.2.7.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the SLC1 NAND driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the {FS_NAND_Drv.c} file.

Usage: 32 bytes

6.3.2.7.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the runtime configuration and on the characteristics of the used NAND flash device. The approximate RAM usage of the SLC1 NAND driver can be calculated as follows:

```
MemAllocated = 160 + 2 * NumberOfUsedBlocks + 4 * SectorsPerBlock
               + 1.04 * MaxSectorSize
```

Parameter	Description
MemAllocated	Number of bytes allocated for one instance of the NAND driver
NumberOfUsedBlocks	Number of NAND blocks used for data storage
SectorsPerBlock	Number of logical sectors that can be stored in a NAND block
MaxSectorSize	Size of a logical sector in bytes

Example 1

2 GBit NAND flash with 2K pages, 2048 blocks used, 512-byte sectors, one NAND block consists of 64 pages, each page holds 4 sectors of 512 bytes.

```
SectorsPerBlock    = 256
NumberOfUsedBlocks = 2048
MaxSectorSize      = 512
RAM usage          = (160 + 2 * 2048 + 4 * 256 + 1.04 * 512) bytes
RAM usage          = 5813 bytes
```

Example 2

2 GBit NAND flash with 2K pages, 2048 blocks used, 2048-byte sectors, one block consists of 64 pages, each page holds 1 sector of 2048 bytes.

```
SectorsPerBlock    = 64
NumberOfUsedBlocks = 2048
MaxSectorSize      = 2048
RAM usage          = (160 + 2 * 2048 + 4 * 64 + 1.04 * 2048) bytes
RAM usage          = 6642 bytes
```

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Example 3

512 MBit NAND flash with 512 pages, 4096 blocks used, 512-byte sectors, one block consists of 64 pages, each page holds 1 sector of 512 bytes.

```
SectorsPerBlock    = 32
NumberOfUsedBlocks = 8192
MaxSectorSize      = 512
RAM usage          = (160 + 2 * 4096 + 4 * 32 + 1.04 * 512) bytes
RAM usage          = 9013 bytes
```

6.3.2.7.4 Performance

The following performance measurements are in no way complete, but they give a good approximation of the time required for common operations on various target hardware. The tests were performed as described in the section *Performance* on page 1445. All values are given in Mbytes/sec.

CPU type	NAND flash device	Write speed	Read speed
Atmel AT91SAM7S (48 MHz)	NAND flash with 512 bytes per page using port mode.	**0.8**	**2.0**
Atmel AT91SAM7S (48 MHz)	NAND flash with 2048 bytes per page and a sector size of 512 bytes using port mode.	**0.7**	**2.0**
Atmel AT91SAM7S (48 MHz)	NAND flash with 2048 bytes per page and a sector size of 2048 bytes using the built-in NAND controller/external bus-interface.	**1.3**	**2.3**
Atmel AT91SAM7SE (48 MHz)	NAND flash with 2048 bytes per page and a sector size of 512 bytes using the built-in NAND controller/external bus-interface.	**1.6**	**3.1**
Atmel AT91SAM7SE (48 MHz)	NAND flash with 2048 bytes per page and a sector size of 2048 bytes using the built-in NAND controller/external bus-interface.	**3.8**	**5.9**
Atmel AT91SAM9261 (200 MHz)	NAND flash with 2048 bytes per page and a sector size of 512 bytes using the built-in NAND controller/external bus-interface.	**2.3**	**6.5**
Atmel AT91SAM9261 (200 MHz)	NAND flash with 2048 bytes per page and a sector size of 2048 bytes using the built-in NAND controller/external bus-interface.	**5.1**	**9.8**
Atmel AT91SAM9G45 (384 MHz)	NAND flash with 2048 bytes per page and a sector size of 2048 bytes using the built-in NAND controller/external bus-interface.	**4.7**	**12.4**
Atmel AT91SAM3U (96 MHz)	NAND flash with 2048 bytes per page and a sector size of 2048 bytes using the built-in NAND controller/external bus-interface.	**5.0**	**5.9**
Atmel AT91SAM3U (96 MHz)	NAND flash with 2048 bytes per page and a sector size of 512 bytes using the built-in NAND controller/external bus-interface.	**2.3**	**4.7**

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CPU type	NAND flash device	Write speed	Read speed
Atmel AT91SAM9261 (200 MHz)	AT45DB64 DataFlash with a sector size of 1024 bytes using the SPI interface.	**0.16**	**0.67**

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6.3.3 Universal NAND driver

The Universal NAND driver is a very efficient device driver that was designed to support NAND flash devices that are using Single-Level Cell (SLC) as well as Multi-Level Cell (MLC) technology. It requires a relatively small amount of RAM to operate, and it can correct multiple bit errors by using the internal ECC of a NAND flash device or by calling ECC calculation routines provided by the application. The ECC protects the sector data and the driver management data stored in the spare area of a page, which provides better data reliability. The Universal NAND driver uses a logical sector size that is equal to the page size of the used NAND flash device. The NAND flash device must have a page of at least 2048 bytes. Smaller logical sector sizes can be used with the help of an additional file system layer such as *Sector Size Adapter driver* on page 1313.

6.3.3.1 Supported hardware

In general, the Universal NAND driver supports almost all popular Single-Level Cell NAND flashes (SLC) with a page size larger than 2048+64 bytes. The table below shows the NAND flash devices that have been tested or are compatible with a tested device:

Device name	Page size	Number of blocks	Storage capacity	Bus width	HW ECC	Supported optional features
ATO						
AFND1G08U3	2048+64 byte	1024	128 MB	8 bit	No	
Alliance Memory						
AS5F31G04SND	2048+64 byte	1024	128 MB	1 bit	Yes	
AS5F32G04SND	2048+128 byte	2048	256 MB	1 bit	Yes	
AS5F32G04SNDA	2048+128 byte	2048	256 MB	1 bit	Yes	
AS5F32G04SNDB	2048+64 byte	2048	256 MB	1 bit	Yes	
AS5F34G04SND	2048+128 byte	4096	512 MB	1 bit	Yes	
AS5F34G04SNDA	2048+128 byte	4096	512 MB	1 bit	Yes	
AS5F34G04SNDB	2048+64 byte	4096	512 MB	1 bit	Yes	
AS5F38G04SND	4096+256 byte	4096	1 GB	1 bit	Yes	
AS9F31G08SA	2048+64 byte	1024	128 MB	8 bit	No	
AS9F32G08SA	2048+128 byte	2048	256 MB	8 bit	No	
AS9F34G08SA	2048+128 byte	4096	512 MB	8 bit	No	
AS9F38G08SA	2048+128 byte	8192	1 GB	8 bit	No	
Etron						
EM73C044VCF	2048+64 byte	1024	128 MB	1 bit	Yes	
EM73D044VCO	2048+128 byte	2048	256 MB	1 bit	Yes	
EM73E044VCE	2048+128 byte	4096	512 MB	1 bit	Yes	
EM73F044VCA	4096+256 byte	4096	1 GB	1 bit	Yes	
Foresee						
F35SQB004G	4096+256 byte	2048	512 MB	1 bit	Yes	
F35UQA512M	2048+64 byte	512	64 MB	1 bit	Yes	
F35UQB004G	4096+256 byte	2048	512 MB	1 bit	Yes	
GigaDevice						
GD5F1GQ4UFYIG	2048+64 byte	1024	128 MB	1 bit	Yes	
GD5F1GQ5UEYIG	1024+128 byte	1024	128 MB	1 bit	Yes	DTR
GD5F1GQ5UEYIH	1024+64 byte	1024	128 MB	1 bit	Yes	DTR

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Device name	Page size	Number of blocks	Storage capacity	Bus width	HW ECC	Supported optional features
GD5F2GM7REYIG	2048+128 byte	2048	256 MB	1 bit	Yes	DTR
GD5F2GQ5UEYIG	2048+128 byte	2048	256 MB	1 bit	Yes	DTR
GD5F8GM8UEYIG	4096+256 byte	4096	1 GB	1 bit	Yes	DTR
GD9FU1G8F2A	2048+128 byte	1024	128 MB	8 bit	No	
GD9FU4G8F2A	2048+128 byte	4096	512 MB	8 bit	Yes	
Hynix						
HY27UF081G2A	2048+64 byte	1024	128 MB	8 bit	No	
HY27UF081G2M	2048+64 byte	1024	128 MB	8 bit	No	
HY27UF082G2M	2048+64 byte	2048	256 MB	8 bit	No	
HY27UF084G2M	2048+64 byte	4096	512 MB	8 bit	No	
HY27UG084G2M	2048+64 byte	4096	512 MB	8 bit	No	
HY27UG084GDM	2048+64 byte	4096	512 MB	8 bit	No	
ISSI						
IS34ML01G081	2048+64 byte	1024	128 MB	8 bit	No	
IS34ML01G084	2048+64 byte	1024	128 MB	8 bit	No	
IS34ML02G084	2048+64 byte	2048	256 MB	8 bit	No	
IS34ML04G081	2048+64 byte	4096	512 MB	8 bit	No	
IS34ML04G084	2048+64 byte	4096	512 MB	8 bit	No	
IS34ML04G088	4096+256 byte	2048	512 MB	8 bit	No	
IS35ML02G081	2048+64 byte	2048	256 MB	8 bit	No	
IS37SML01G1	2048+64 byte	1024	128 MB	1 bit	Yes	
IS37SML01G8B	2048+128 byte	1024	128 MB	1 bit	Yes	
IS37SML02G8B	2048+128 byte	2048	256 MB	1 bit	Yes	
IS37SMW01G8B	2048+128 byte	1024	128 MB	1 bit	Yes	
IS37SMW02G8B	2048+128 byte	2048	256 MB	1 bit	Yes	
IS38SML01G1	2048+64 byte	1024	128 MB	1 bit	Yes	
IS38SML01G8B	2048+128 byte	1024	128 MB	1 bit	Yes	
Kioxia/Toshiba						
TC58BVG0S3HTAI0	2048+64 byte	1024	128 MB	8 bit	Yes	
TC58BVG1S3HTA00	2048+64 byte	2048	256 MB	8 bit	Yes	
TC58BYG0S3HBAI6	2048+64 byte	1024	128 MB	8 bit	Yes	
TC58CVG0S3HRAIJ	2048+64 byte	1024	128 MB	1 bit	Yes	
TC58CVG1S3HRAIF	2048+128 byte	2048	256 MB	1 bit	Yes	
TC58CVG1S3HRAIG	2048+64 byte	2048	256 MB	1 bit	Yes	
TC58CVG1S3HRAIJ	2048+64 byte	2048	256 MB	1 bit	Yes	
TC58CVG2S0HRAIJ	4096+128 byte	2048	512 MB	1 bit	Yes	
TC58CYG0S3HRAIJ	2048+64 byte	1024	128 MB	1 bit	Yes	
TC58CYG1S3HRAIJ	2048+64 byte	2048	256 MB	1 bit	Yes	
TC58CYG2S0HRAIG	4096+128 byte	2048	512 MB	1 bit	Yes	
TC58CYG2S0HRAIJ	4096+128 byte	2048	512 MB	1 bit	Yes	
TH58BYG3S0HBAI6	4096+128 byte	4096	1 GB	8 bit	Yes	
TH58CVG3S0HRAIJ	4096+128 byte	4096	1 GB	1 bit	Yes	

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Device name	Page size	Number of blocks	Storage capacity	Bus width	HW ECC	Supported optional features
TH58CYG3S0HRAIJ	4096+128 byte	4096	1 GB	1 bit	Yes	
Macronix						
MX30LF1G18AC	2048+64 byte	1024	128 MB	8 bit	No	
MX30LF1G28AD	2048+128 byte	1024	128 MB	8 bit	No	
MX30LF1GE8AB	2048+64 byte	1024	128 MB	8 bit	Yes	
MX30LF2G28AD	2048+128 byte	2048	256 MB	8 bit	No	
MX30LF2GE8AB	2048+64 byte	2048	256 MB	8 bit	Yes	
MX30LF4G28AD	4096+256 byte	2048	512 MB	8 bit	No	
MX30LF4GE8AB	2048+64 byte	4096	512 MB	8 bit	Yes	
MX35LF1G24AD-Z4I	2048+128 byte	1024	128 MB	1 bit	No	
MX35LF1GE4AB	2048+64 byte	1024	128 MB	1 bit	Yes	
MX35LF2G24AD-Z4I	2048+128 byte	2048	256 MB	1 bit	No	
MX35LF2GE4AD-Z4I	2048+64 byte	2048	256 MB	1 bit	Yes	
MX35LF4G24AD-Z4I	4096+256 byte	2048	512 MB	1 bit	No	
MX35LF4GE4AD-Z4I	4096+128 byte	2048	512 MB	1 bit	Yes	
MX35UF1GE4AC-Z4I	2048+64 byte	1024	128 MB	1 bit	Yes	
MX35UF4G24AD-Z4I	4096+256 byte	2048	512 MB	1 bit	No	
MX35UF4GE4AD-Z4I	4096+256 byte	2048	512 MB	1 bit	Yes	
MX60LF8G28AB	2048+112 byte	8192	1 GB	8 bit	No	
MX60LF8G28AD	4096+256 byte	4096	1 GB	8 bit	No	
Micron						
MT29F1G01AAADD	2048+64 byte	1024	128 MB	1 bit	Yes	
MT29F1G01ABAFD	2048+128 byte	1024	128 MB	1 bit	Yes	
MT29F1G01ABBFD	2048+128 byte	1024	128 MB	1 bit	Yes	
MT29F1G08ABADA	2048+64 byte	1024	128 MB	8 bit	Yes	
MT29F1G08ABAEA	2048+64 byte	1024	128 MB	8 bit	No	
MT29F1G08ABAFA	2048+128 byte	1024	128 MB	8 bit	Yes	
MT29F2G01AAAED	2048+64 byte	2048	256 MB	1 bit	Yes	
MT29F2G01ABAGD	2048+128 byte	2048	256 MB	1 bit	Yes	
MT29F2G01ABBGD	2048+128 byte	2048	256 MB	1 bit	Yes	
MT29F2G08AAB	2048+64 byte	2048	256 MB	8 bit	No	
MT29F2G08ABABA	2048+64 byte	2048	256 MB	8 bit	No	
MT29F2G08ABAEA	2048+64 byte	2048	256 MB	8 bit	Yes	
MT29F2G08ABAGA	2048+128 byte	2048	256 MB	8 bit	Yes	
MT29F2G08ABD	2048+64 byte	2048	256 MB	8 bit	No	
MT29F2G16AAD	2048+64 byte	2048	256 MB	16 bit	No	
MT29F2G16ABAEA	2048+64 byte	2048	256 MB	16 bit	Yes	
MT29F4G01AAADD	2048+64 byte	4096	512 MB	1 bit	Yes	
MT29F4G01ABAFD	4096+256 byte	4096	512 MB	1 bit	Yes	
MT29F4G01ABBFD	4096+256 byte	2048	512 MB	1 bit	Yes	
MT29F4G08AAA	2048+64 byte	4096	512 MB	8 bit	No	
MT29F4G08ABADA	2048+64 byte	4096	512 MB	8 bit	Yes	

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Device name	Page size	Number of blocks	Storage capacity	Bus width	HW ECC	Supported optional features
MT29F4G08ABAEA	4096+224 byte	4096	512 MB	8 bit	No	
MT29F4G08ABAFA	4096+256 byte	2048	512 MB	8 bit	Yes	
MT29F4G08ABBFA	4096+256 byte	2048	512 MB	8 bit	Yes	
MT29F4G08BAB	2048+64 byte	4096	512 MB	8 bit	No	
MT29F8G01ADAFD	4096+256 byte	4096	1 GB	1 bit	Yes	
MT29F8G01ADBFD	4096+256 byte	4096	1 GB	1 bit	Yes	
MT29F8G08ABABA	4096+224 byte	2048	1 GB	8 bit	No	
MT29F8G08ABACA	4096+224 byte	4096	1 GB	8 bit	No	
STMicroelectronics						
NAND01GR3B	2048+64 byte	1024	128 MB	8 bit	No	
NAND01GW3B	2048+64 byte	1024	128 MB	8 bit	No	
NAND02GR3B	2048+64 byte	2048	256 MB	8 bit	No	
NAND02GW3B	2048+64 byte	2048	256 MB	8 bit	No	
NAND04GW3B	2048+64 byte	4096	512 MB	8 bit	No	
Samsung						
K9F1G08R0A	2048+64 byte	1024	128 MB	8 bit	No	
K9F1G08U0A	2048+64 byte	1024	128 MB	8 bit	No	
K9F1G08U0C	2048+64 byte	1024	128 MB	8 bit	No	
K9F1G08U0F	2048+64 byte	1024	128 MB	8 bit	Yes	
K9F2G08U0M	2048+64 byte	2048	256 MB	8 bit	No	
K9F4G08U0A	2048+64 byte	4096	512 MB	8 bit	No	
K9F4G08U0M	2048+64 byte	4096	512 MB	8 bit	No	
K9F8G08U0M	4096+128 byte	4096	1 GB	8 bit	No	
K9K2G08R0A	2048+64 byte	2048	256 MB	8 bit	No	
K9K2G08U0M	2048+64 byte	2048	256 MB	8 bit	No	
SkyHigh/Cypress						
S34ML01G100TFI000	2048+64 byte	1024	128 MB	8 bit	No	
S34ML01G300TFI013	2048+64 byte	1024	128 MB	8 bit	Yes	
S34ML04G100TFI000	2048+64 byte	4096	512 MB	8 bit	No	
S34ML04G200TFI000	2048+128 byte	4096	512 MB	8 bit	No	
S34ML04G300TFI000	2048+128 byte	4096	512 MB	8 bit	Yes	
S34ML04G300TFI100	4096+256 byte	2048	512 MB	8 bit	Yes	
S34ML08G201TFI000	2048+128 byte	8192	1 GB	8 bit	No	
S34ML08G301TFI000	2048+128 byte	8192	1 GB	8 bit	Yes	
S34ML16G202TFI200	2048+128 byte	16384	2 GB	8 bit	No	
S34ML16G303TFI000	2048+128 byte	16384	2 GB	8 bit	Yes	
S34MS02G100TFI000	2048+64 byte	2048	256 MB	8 bit	No	
S35ML01G300WHI010	2048+64 byte	1024	128 MB	1 bit	Yes	
S35ML02G300WHI000	2048+128 byte	2048	256 MB	1 bit	Yes	
S35ML04G300WHI000	2048+128 byte	4096	512 MB	1 bit	Yes	
Winbond						
W25M02GVZEIT	2048+64 byte	2048	256 MB	1 bit	Yes	

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Device name	Page size	Number of blocks	Storage capacity	Bus width	HW ECC	Supported optional features
W25N01GVZEIG	2048+64 byte	1024	128 MB	1 bit	Yes	
W25N01JWSFIT	2048+64 byte	1024	128 MB	1 bit	Yes	DTR
W25N01KVZEIR	2048+96 byte	1024	128 MB	1 bit	Yes	
W25N02JWZEIF	2048+64 byte	2048	256 MB	1 bit	Yes	DTR
W25N02KVZEIU	2048+128 byte	2048	256 MB	1 bit	Yes	
W25N04KVZEIR	2048+128 byte	4096	512 MB	1 bit	Yes	
W25N04LWZEIG	4096+256 byte	2048	512 MB	1 bit	Yes	
W25N512GVEIG	2048+64 byte	512	64 MB	1 bit	Yes	
W29N02GZSIBF	2048+64 byte	2048	256 MB	8 bit	No	
W29N08GVSIAA	2048+64 byte	8192	1 GB	8 bit	No	
XTX						
XT27G02BTSIG	2048+64 byte	2048	256 MB	8 bit	Yes	

Support for devices not in the list

Most other NAND flash devices are compatible with one of the supported devices. Thus, the driver can be used with these devices or may only need a little modification, which can be easily done. Get in touch with us if you have questions about support for devices not in this list.

6.3.3.2 Theory of operation

NAND flash devices are divided into physical blocks and physical pages. One physical block is the smallest erasable unit while one physical page is the smallest writable unit. Large block NAND flash devices contain blocks made up of 64 pages, each page containing 2112 bytes (2048 data bytes + 64 spare bytes). The Universal NAND driver reserves the first page of a block for management data such as erase count. The Universal NAND driver uses the spare bytes for the following purposes:

1. To check if the block is valid.
   If a block is valid, then the driver uses it for data storage. When the driver detects an uncorrectable bit error in a page, the entire block containing that page is marked as invalid and its content is copied to a non-defective block.
2. To store/load management information.
   This includes the mapping of pages to logical sectors, the number of times a block has been erased and whether a page contains valid data or not.
3. To store and load an ECC (Error Correction Code) for data reliability.
   When reading a page, the driver also reads the ECC stored in the spare area of that page, calculates the ECC based on the read data and compares the ECCs. If the ECCs are not identical, the driver tries to recover the data based on the read ECC. When writing to a page, the ECC is calculated based on the data the driver has to write to the page. The calculated ECC is then stored in the spare area of that page.

6.3.3.3 Support for custom hardware

It is possible to use the Universal NAND driver with custom hardware. If port pins or a simple memory controller are used for accessing the flash memory, only the hardware layer needs to be ported and normally no changes to the physical layer are required. If the NAND driver has to be used with a special memory controller (for example, special FPGA implementations), the physical layer needs to be adapted. In this case, the hardware layer is not required, because the memory controller manages all the hardware accesses.

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6.3.3.4 Partial write operations

The Universal NAND driver writes only once to any page of the NAND flash between two erase operations of the NAND block that contains that page. Therefore, the number of partial write operations is one, which makes the driver compatible with any SLC and MLC NAND flash device.

6.3.3.5 High-reliability operation

This feature of the Universal NAND driver can be used to increase the reliability of the data stored in a NAND flash device. This works by checking the number of bit errors corrected by the ECC during each page read operation. If the number of bit errors is equal to or greater than a configured threshold, the Universal NAND driver copies the contents of the NAND block containing the read page to another location. This prevents the accumulation of bit errors that may cause ECC correction errors. An ECC correction error occurs when the number of bit errors is larger than the number of bit errors the ECC is able to correct. Typically, a correction error leads to data loss.

This feature requires support for the `FS_NAND_PHY_TYPE_GET_ECC_RESULT` function in the NAND physical layer. By default, the feature is disabled for performance reasons and has to be explicitly enabled at compile time by setting `FS_NAND_MAX_BIT_ERROR_CNT` to a value greater than 0. This value can be modified at runtime by calling `FS_NAND_UNI_SetMaxBitErrorCnt()`.

> **Note**
>
> Enabling the high-reliability operation may reduce the specified lifetime of the NAND flash due to the increased number of erase cycles.

6.3.3.6 Block grouping

The block grouping feature enables the Universal NAND driver to handle NAND flash devices with a relatively large capacity while keeping the RAM usage low. The RAM usage of the Universal NAND driver mainly depends on the number of storage blocks it has to handle, and typically the number of blocks increases with the capacity of the NAND flash device. By default, the Universal NAND driver treats each NAND block as an individual storage block. With the block grouping enabled, the Universal NAND driver is able to treat multiple adjacent NAND blocks as a single storage block. In this way, the number of storage blocks that have to be handled and the RAM usage are reduced.

For example, with the block grouping feature disabled, the Universal NAND driver requires about 8 KB of RAM for the handling of an 8 GB NAND flash device that typically contains 4096 blocks. Enabling the block grouping can help reduce the RAM usage to less than 2 KB, depending on the number of blocks in a group.

As an additional benefit, the time it takes the Universal NAND driver to low-level mount the NAND flash decreases with the block grouping enabled because of the reduced number of storage blocks.

The size of a block group can be configured at runtime via `FS_NAND_UNI_SetNumBlocksPerGroup()`. The block grouping feature is enabled by default at compile time with the number of blocks in the group set to one. If not required, the block grouping feature can be disabled by building the file system with `FS_NAND_SUPPORT_BLOCK_GROUPING` set to 0.

6.3.3.7 Configuring the driver

This section describes how to configure the file system to make use of the Universal NAND driver.

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6.3.3.7.1 Compile time configuration

The Universal NAND driver can optionally be configured at compile time. Typically, this step can be omitted because the Universal NAND driver provides reasonable default values that work for most of the target applications. The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the Universal NAND driver.

Define	Default value	Type	Description
FS_NAND_ECC_HOOK_DEFAULT	&FS_NAND_ECC_SW_1BIT	R	Configures the default ECC algorithm.
FS_NAND_ENABLE_ERROR_RECOVERY	0	B	Enables or disables the bit error recovery via RAID driver.
FS_NAND_ENABLE_STATS	0 or 1	B	Enables or disables the support for statistical counters.
FS_NAND_ENABLE_STATS_SECTOR_STATUS	1	B	Enables or disables the collection of statistical information about the number of valid logical sectors.
FS_NAND_FILL_READ_BUFFER	0 or 1	B	Enables or disables the filling of invalid sectors with predefined data.
FS_NAND_MAX_BIT_ERROR_CNT	0	N	Configures the number of bit errors that trigger a block relocation.
FS_NAND_MAX_PAGE_SIZE	0	N	Configures the size of the main area buffer.
FS_NAND_MAX_SPARE_AREA_SIZE	0	N	Configures the size of the spare area buffer.
FS_NAND_NUM_READ_RETRIES	10	N	Configures the number of retries in case of a read error.
FS_NAND_NUM_WRITE_RETRIES	10	N	Configures the number of retries in case of a write error.
FS_NAND_NUM_UNITS	4	N	Configures the maximum number of driver instances.
FS_NAND_OPTIMIZE_SPARE_AREA_READ	0	B	Enables or disables the optimization related to reading data from the spare area.
FS_NAND_READ_BUFFER_FILL_PATTERN	0xFF	N	Configures the value used to fill the contents of an invalid logical sector.
FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS	0	B	Configures how the blocks marked as defective are handled at low-level format.
FS_NAND_STAT_MAX_BIT_ERRORS	1	N	Configures the number of statistical counters for bit errors.
FS_NAND_SUPPORT_BLOCK_GROUPING	1	B	Enables or disables the block grouping feature.
FS_NAND_SUPPORT_FAIL_SAFE_ERASE	0	B	Enables or disables the fail-safe erase feature.
FS_NAND_VERIFY_ERASE	0	B	Enables or disables the verification of the erase operation.

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Define	Default value	Type	Description
FS_NAND_VERIFY_WRITE	0	B	Enables or disables the verification of the write operation.

6.3.3.7.1.1 FS_NAND_ECC_HOOK_DEFAULT

The FS_NAND_ECC_HOOK_DEFAULT can be used to specify default ECC calculation routines. For a file system configuration that has support for calculating the ECC in the hardware, FS_NAND_ECC_HOOK_DEFAULT can be set to NULL to reduce the ROM usage. In this case, it is mandatory that the application specifies a different ECC algorithm at runtime via FS_NAND_UNI_SetECCHook().

6.3.3.7.1.2 FS_NAND_ENABLE_ERROR_RECOVERY

This define can be used to enable the support for error recovery in the Universal NAND driver. The error recovery is performed by getting corrected data from a redundant partition via one of the RAID components of the file system. Refer to *RAID1 driver* on page 1320 and *RAID5 driver* on page 1330 for more information about this.

6.3.3.7.1.3 FS_NAND_ENABLE_STATS

This define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the Universal NAND driver. This information can be useful for analyzing the performance. The statistical counters can be queried via FS_NAND_UNI_GetStatCounters(). By default FS_NAND_ENABLE_STATS is set to 1 if FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

6.3.3.7.1.4 FS_NAND_ENABLE_STATS_SECTOR_STATUS

This define can be used to configure if the Universal NAND driver has to collect information about the number of valid logical sectors. Enabling this operation may negatively affect the performance of the low-level mount operation because the Universal NAND driver has to check the status of all logical sectors. FS_NAND_ENABLE_STATS_SECTOR_STATUS takes effect only if FS_NAND_ENABLE_STATS is set to 1.

6.3.3.7.1.5 FS_NAND_FILL_READ_BUFFER

FS_NAND_FILL_READ_BUFFER can be used to configure if the read buffer that receives the contents of an invalid logical sector has to be initialized with predefined data. The byte pattern that has to be used for filling the buffer contents can be specified via FS_NAND_READ_BUFFER_FILL_PATTERN. By default this feature is enabled only if no file system layer is used (both FS_SUPPORT_FAT and FS_SUPPORT_EFS set to 0), because the file system layer does not rely on this feature.

6.3.3.7.1.6 FS_NAND_MAX_BIT_ERROR_CNT

This define can be used to configure the monitoring of bit errors in the Universal NAND driver. The assigned value specifies the maximum number of correctable bit errors that are allowed to occur in a page before the block that contains that page is copied to another location. This is done in order to reduce the probability of a data loss as a result of an ECC correction error by keeping the number of bit errors below the bit error correction capability of the ECC algorithm. The value of FS_NAND_MAX_BIT_ERROR_CNT has to be smaller than or equal to the bit error correction capability that is required by the NAND flash device. The bit error monitoring is disabled if FS_NAND_MAX_BIT_ERROR_CNT is set to 0. The maximum number of bit errors can also be changed at runtime via FS_NAND_UNI_SetMaxBitErrorCnt(). Enabling this feature increases the data reliability, but it may negatively affect the performance.

6.3.3.7.1.7 FS_NAND_MAX_PAGE_SIZE

FS_NAND_MAX_PAGE_SIZE can be used to configure the size of the internal buffer that the Universal NAND driver uses for reading and writing the data of the main area of a page. If

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FS_NAND_MAX_PAGE_SIZE is set to 0 then the Universal NAND driver allocates a buffer with a size equal to the logical sector of the file system. In addition, the size of the buffer can be configured at runtime via FS_NAND_UNI_SetMaxPageSize().

6.3.3.7.1.8 FS_NAND_MAX_SPARE_AREA_SIZE

FS_NAND_MAX_SPARE_AREA_SIZE can be used to configure the size of the internal buffer that the Universal NAND driver uses for reading and writing the data of the spare area of a page. If FS_NAND_MAX_SPARE_AREA_SIZE is set to 0 then the Universal NAND driver allocates a buffer that is 1/32 of the internal buffer allocated for the main area of a page. For example, 64 bytes are allocated if the size of the buffer used for the main area of a page is 2048 bytes. If the ratio between the size of the main and spare area of the page is different from 1/32 then FS_NAND_MAX_SPARE_AREA_SIZE has to be set to the number of bytes in the spare area of the NAND flash device. In addition, the size of the buffer can be configured at runtime via FS_NAND_UNI_SetMaxSpareAreaSize().

6.3.3.7.1.9 FS_NAND_NUM_READ_RETRIES

FS_NAND_NUM_READ_RETRIES can be used to specify the number of times the Universal NAND driver retries the operation in case of a read error (device error or uncorrectable bit error). NumReadRetries of FS_NAND_STAT_COUNTERS is incremented by 1 on each retry.

6.3.3.7.1.10 FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS

FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS can be used to configure the behavior of the Universal NAND driver during the low-level format operation with regard to the NAND blocks marked as defective. If FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS is set to 1 then the NAND blocks marked as defective by the Universal NAND driver are erased during the low-level format operation. If FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS is set to 0 then the low-level format operation does not erase the NAND blocks marked as defective by the Universal NAND driver. This is the default behavior. Setting FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS to 1 is useful during the development of a NAND physical or hardware layer when NAND blocks may be marked as defective by mistake. These blocks can then be easily erased via a low-level format operation. The NAND blocks marked as defective by the manufacturer are never erased. In addition, these NAND blocks are never used for data storage.

6.3.3.7.1.11 FS_NAND_NUM_WRITE_RETRIES

FS_NAND_NUM_WRITE_RETRIES can be used to specify the number of times the Universal NAND driver retries the operation in case of a write error. A write error occurs when the NAND flash device is not able to write the data to the memory array. This condition is typically reported via a flag in the status register of the NAND flash device that is queried by the NAND physical layer after each write operation. NumWriteRetries of FS_NAND_STAT_COUNTERS is incremented by 1 on each retry.

6.3.3.7.1.12 FS_NAND_NUM_UNITS

This define specifies the maximum number of driver instances of the Universal NAND driver the application is allowed to create. Four bytes of static RAM are reserved for each instance. If the maximum number of driver instances is smaller than the default, then FS_NAND_NUM_UNITS can be set to that value in order to reduce the RAM usage.

6.3.3.7.1.13 FS_NAND_OPTIMIZE_SPARE_AREA_READ

This configuration define can be used to enable an optimization that reduces the amount of data transferred by the Universal NAND driver from the spare area of a page to the MCU. With FS_NAND_OPTIMIZE_SPARE_AREA_READ set to 0 the entire spare area of a page is transferred to the MCU each time the Universal NAND driver has to evaluate the management data of that page. If FS_NAND_OPTIMIZE_SPARE_AREA_READ is set to 1 then only the regions of the spare area that store the management data are transferred to the MCU. This may help improve the performance when the NAND flash device is connected to the MCU via a relatively slow interface such as SPI.

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6.3.3.7.1.14 FS_NAND_READ_BUFFER_FILL_PATTERN

The Universal NAND driver uses the byte value assigned to `FS_NAND_READ_BUFFER_FILL_PATTERN` to fill the read buffer that receives the contents of a logical sector that does not contain any valid data. The contents of a logical sector become valid when the file system layer writes any data to it. After a low-level format operation, the contents of all logical sectors are invalid. The contents of a logical sector can be explicitly invalidated via a sector free operation. `FS_NAND_READ_BUFFER_FILL_PATTERN` takes effect only if `FS_NAND_FILL_READ_BUFFER` is set to 1.

6.3.3.7.1.15 FS_NAND_STAT_MAX_BIT_ERRORS

`FS_NAND_STAT_MAX_BIT_ERRORS` defines how many bit error counters the Universal NAND driver has to maintain. Each counter keeps track of the number of times a certain number of bit errors occurred at the same time during one page read operation. The first counter keeps track of the number of 1-bit errors, the second counter keeps track of the number of 2-bit errors and so on. The bit error counters can be read via `FS_NAND_UNI_GetStatCounters()`. `FS_NAND_ENABLE_STATS_SECTOR_STATUS` takes effect only if `FS_NAND_ENABLE_STATS` is set to 1.

6.3.3.7.1.16 FS_NAND_SUPPORT_BLOCK_GROUPING

`FS_NAND_SUPPORT_BLOCK_GROUPING` can be used to specify if the Universal NAND driver is able to handle two or more adjacent NAND blocks as a single block. The number of blocks in the group has to be configured at runtime via `FS_NAND_UNI_SetNumBlocksPerGroup()`. The RAM usage of the Universal NAND driver depends on the number of NAND blocks it has to manage. Therefore, enabling the block grouping feature can help reduce the RAM usage because the number of blocks decreases. If the block grouping feature is not required by the application, then `FS_NAND_SUPPORT_BLOCK_GROUPING` can be set to 0 in order to reduce the RAM and ROM usage of the Universal NAND driver.

6.3.3.7.1.17 FS_NAND_SUPPORT_FAIL_SAFE_ERASE

`FS_NAND_SUPPORT_FAIL_SAFE_ERASE` can be used to enable or disable the detection of interrupted block erase operations. This feature works by invalidating the management data of the block before the erase operation and by writing a valid erase count to the block after a successful erase operation. In this way, the driver is able to identify and again erase these blocks during the low-level mount operation. With the support for the fail-safe erase operation enabled, the target hardware is no longer required to meet the timing requirements described in *Fail-safe operation* on page 572. Instead, the target hardware will have to make sure that a write page operation completes successfully. Typically, such an operation takes about 250 us to complete.

6.3.3.7.1.18 FS_NAND_VERIFY_ERASE

This define can be used to activate the erase verification of the Universal NAND driver. The erase verification is performed after each erase operation by reading back the entire data of the erased block and by comparing each byte in the block with `0xFF`. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NAND_UNI_SetEraseVerification()`.

> **Note**
>
> Activating the erase verification may negatively affect the write performance.

6.3.3.7.1.19 FS_NAND_VERIFY_WRITE

This define can be used to activate the write verification of the Universal NAND driver. The write verification is performed after each write operation by reading back the modified data and by comparing it with the data requested to be written. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NAND_UNI_SetWriteVerification()`.

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> **Note**
>
> Activating the write verification may negatively affect the write performance.

6.3.3.7.2 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of `FS_NAND_UNI_Driver`. This function call together with other function calls that configure the driver operation has to be added to `FS_X_AddDevices()` as demonstrated in the following example.

Example

```
#include "FS.h"
#include "FS_NAND_HW_Template.h"

#define ALLOC_SIZE      0x9000          // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add the NAND flash driver to file system. Volume name: "nand:0:".
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  //
  // Set the physical interface of the NAND flash.
  //
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  //
  // Configure the driver to use the internal ECC of NAND flash for error correction.
  //
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Configure the HW access routines.
  //
  FS_NAND_ONFI_SetHWType(0, &FS_NAND_HW_Template);
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the Universal NAND driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_UNI_AllowBlankUnusedSectors()`	Configures if the data of unused sectors has to be initialized.
`FS_NAND_UNI_AllowReadErrorBadBlocks()`	Configures if a block is marked as defective on read fatal error.
`FS_NAND_UNI_SetBlockRange()`	Specifies which NAND blocks the driver can use to store the data.
`FS_NAND_UNI_SetBlockReserve()`	Configures the number of NAND flash blocks to be reserved as replacement for the NAND flash blocks that become defective.
`FS_NAND_UNI_SetCleanThreshold()`	Specifies the minimum number sectors that the driver should

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Function	Description
	keep available for fast write operations.
FS_NAND_UNI_SetDriverBadBlockReclamation()	Configures if the bad blocks marked as defective by the driver have to be erased at low-level format or not.
FS_NAND_UNI_SetECCHook()	Configures the ECC algorithm to be used for the correction of bit errors.
FS_NAND_UNI_SetEraseVerification()	Enables or disables the checking of the block erase operation.
FS_NAND_UNI_SetMaxBitErrorCnt()	Configures the number of bit errors that trigger the relocation of the data stored in a NAND block.
FS_NAND_UNI_SetMaxEraseCntDiff()	Configures the threshold of the wear leveling procedure.
FS_NAND_UNI_SetMaxPageSize()	Configures the maximum handled page size.
FS_NAND_UNI_SetMaxSpareAreaSize()	Configures the maximum handled spare area size.
FS_NAND_UNI_SetNumBlocksPerGroup()	Specifies the number of physical NAND blocks in a virtual block.
FS_NAND_UNI_SetNumWorkBlocks()	Sets number of work blocks the Universal NAND driver uses for write operations.
FS_NAND_UNI_SetOnFatalErrorCallback()	Registers a function to be called by the driver when a fatal error occurs.
FS_NAND_UNI_SetPhyType()	Configures NAND flash access functions.
FS_NAND_UNI_SetWriteDisturbHandling()	Configures if the bit errors caused by write operations are handled or not.
FS_NAND_UNI_SetWriteVerification()	Enables or disables the checking of each page write operation.

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6.3.3.7.2.1 FS_NAND_UNI_AllowBlankUnusedSectors()

Description

Configures if the data of unused sectors has to be initialized.

Prototype

```
void FS_NAND_UNI_AllowBlankUnusedSectors(U8 Unit,
                                         U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 Sector data is filled with 0s. • ≠0 Sector data is not initialized (all bytes remain set to 0xFF).

Additional information

This function is optional. The default behavior of the Universal NAND driver is to fill the data of unused logical sectors with 0s. This done in order to reduce the chance of a bit error caused by an unwanted transition from 1 to 0 of the value stored to these memory cells.

Some NAND flash devices may wear out faster than expected if excessive number of bytes are set to 0. This limitation is typically documented in the data sheet of the corresponding NAND flash. For such devices it is recommended configure the Universal NAND driver to do not initialize the unused sectors with 0s. This can be done by calling `FS_NAND_UNI_AllowBlankUnusedSectors()` with the `OnOff` parameter set to 1 in `FS_X_AddDevices()`.

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6.3.3.7.2.2 FS_NAND_UNI_AllowReadErrorBadBlocks()

Description

Configures if a block is marked as defective on read fatal error.

Prototype

```
void FS_NAND_UNI_AllowReadErrorBadBlocks(U8 Unit,
                                         U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The block is not marked as defective. • ≠0 The block is marked as defective.

Additional information

This function is optional. The default behavior of the Universal NAND driver is to mark a block as defective if a read error or and uncorrectable bit error occurs while reading data from a page of that block.

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6.3.3.7.2.3 FS_NAND_UNI_SetBlockRange()

Description

Specifies which NAND blocks the driver can use to store the data.

Prototype

```
void FS_NAND_UNI_SetBlockRange(U8  Unit,
                               U16 FirstBlock,
                               U16 MaxNumBlocks);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
FirstBlock	Index of the first NAND flash block to be used as storage (0-based).
MaxNumBlocks	Maximum number of NAND flash blocks to be used as storage.

Additional information

This function is optional. By default, the Universal NAND driver uses all blocks of the NAND flash as data storage. FS_UNI_NAND_SetBlockRange() is useful when a part of the NAND flash has to be used for another purpose, for example to store the application program used by a boot loader, and therefore it cannot be managed by the Universal NAND driver. Limiting the number of blocks used by the Universal NAND driver can also help reduce the RAM usage.

FirstBlock is the index of the first physical NAND block were 0 is the index of the first block of the NAND flash device. MaxNumBlocks can be larger that the actual number of available NAND blocks in which case the Universal NAND driver silently truncates the value to reflect the actual number of NAND blocks available.

The Universal NAND driver uses the first NAND block in the range to store management information at low-level format. If the first NAND block happens to be marked as defective, then the next usable NAND block is used.

If the FS_UNI_NAND_SetBlockRange() is used to subdivide the same physical NAND flash device into two or more partitions than the application has to make sure that the created partitions do not overlap.

The read optimization of the FS_NAND_PHY_2048x8 physical layer has to be disabled when this function is used to partition the NAND flash device in order to ensure data consistency. The read cache can be disabled at runtime via FS_NAND_2048x8_DisableReadCache().

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6.3.3.7.2.4 FS_NAND_UNI_SetBlockReserve()

Description

Configures the number of NAND flash blocks to be reserved as replacement for the NAND flash blocks that become defective.

Prototype

```
void FS_NAND_UNI_SetBlockReserve(U8       Unit,
                                 unsigned pctOfBlocks);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pctOfBlocks	Number of NAND flash blocks to be reserved as percentage of the total number of NAND flash blocks.

Additional information

This function is optional. The Universal NAND driver reserves by default about 3% of the total number of NAND flash blocks which is sufficient for most applications. Reserving more NAND flash blocks can increase the lifetime of the NAND flash device. The NAND flash device has to be low-level formatted after changing the number of reserved blocks.

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6.3.3.7.2.5 FS_NAND_UNI_SetCleanThreshold()

Description

Specifies the minimum number sectors that the driver should keep available for fast write operations.

Prototype

```
int FS_NAND_UNI_SetCleanThreshold(U8       Unit,
                                  unsigned NumBlocksFree,
                                  unsigned NumSectorsFree);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumBlocksFree	Number of blocks to be kept free.
NumSectorsFree	Number of sectors to be kept free on each block.

Return value

= 0 OK, threshold has been set.
≠ 0 An error occurred.

Additional information

This function is optional. It can be used by the application to prepare the NAND flash device to write data as fast as possible once when an event occurs such an unexpected reset. At the startup, the application reserves free space, by calling the function with NumBlocksFree and NumSectorsFree set to a value different than 0. The number of free sectors depends on the number of bytes written and on how the file system is configured. When the unexpected reset occurs, the application tells the driver that it can write to the free sectors, by calling the function with NumBlocksFree and NumSectorsFree set to 0. Then, the application writes the data to file and the NAND driver stores it to the free space. Since no erase or copy operation is required, the data is written as fastest as the NAND flash device permits it.

The NAND flash device will wear out faster than normal if sectors are reserved in a work block (NumSectors > 0).

Example

The following sample code demonstrates how to determine the threshold parameters.

```
#include <stdio.h>
#include "FS.h"

void SampleNAND_UNISetCleanThreshold(void) {
  unsigned             NumPhyBlocks;
  unsigned             NumWorkBlocks;
  FS_FILE            * pFile;
  FS_NAND_DISK_INFO    DiskInfo;
  FS_NAND_BLOCK_INFO   BlockInfo;
  U32                  BlockIndex;
  unsigned             MaxNumSectors;
  unsigned             NumSectorsValid;
  char                 ac[100];

  //
  // Get information about the storage.
  //
  memset(&DiskInfo, 0, sizeof(DiskInfo));
  FS_NAND_UNI_GetDiskInfo(0, &DiskInfo);
  NumPhyBlocks  = DiskInfo.NumPhyBlocks;
  NumWorkBlocks = DiskInfo.NumWorkBlocks;
  //
  // Make sure that all work blocks are converted to data blocks.
```

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```
  //
  FS_NAND_UNI_Clean(0, NumWorkBlocks, 0);
  //
  // Create a test file, write to file the data
  // to be saved on sudden reset then close it.
  //
  pFile = FS_FOpen("Test.txt", "w");
  FS_Write(pFile, "Reset", 5);
  FS_FClose(pFile);
  //
  // Calculate how many work blocks were written
  // and the maximum number of sectors written in a work block.
  //
  NumWorkBlocks = 0;
  BlockIndex    = 0;
  MaxNumSectors = 0;
  do {
    memset(&BlockInfo, 0, sizeof(BlockInfo));
    FS_NAND_UNI_GetBlockInfo(0, BlockIndex++, &BlockInfo);
    if (BlockInfo.Type == FS_NAND_BLOCK_TYPE_WORK) {
      ++NumWorkBlocks;
      NumSectorsValid = BlockInfo.NumSectorsValid;
      if (MaxNumSectors < NumSectorsValid) {
        MaxNumSectors = NumSectorsValid;
      }
    }
  } while (--NumPhyBlocks);
  //
  // Clean up: remove the test file.
  //
  FS_Remove("Test.txt");
  //
  // Show the calculated values.
  // NumWorkBlocks and MaxNumSectors can be passed as 2nd and 3rd
  // argument in the call to FS_NAND_UNI_SetWorkBlockReserve().
  //
  SEGGER_snprintf(ac, sizeof(ac), "Number of work blocks used:  %u\n", NumWorkBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "Max. number of used sectors: %u\n", MaxNumSectors);
  FS_X_Log(ac);
}
```

Sample output

```
Number of work blocks used:  1
Max. number of used sectors: 5
```

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6.3.3.7.2.6 FS_NAND_UNI_SetDriverBadBlockReclamation()

Description

Configures if the bad blocks marked as defective by the driver have to be erased at low-level format or not.

Prototype

```
void FS_NAND_UNI_SetDriverBadBlockReclamation(U8 Unit,
                                              U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Configures if the feature has to be enable or disabled. • =1 Defective blocks marked as such by the driver are erased at low-level format. • =0 Defective blocks marked as such by the driver are not erased at low-level format.

Additional information

This function is active only when the option FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS is set to 1. The default behavior is to erase the blocks marked as defective by the driver.

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6.3.3.7.2.7 FS_NAND_UNI_SetECCHook()

Description

Configures the ECC algorithm to be used for the correction of bit errors.

Prototype

```
void FS_NAND_UNI_SetECCHook(      U8                  Unit,
                            const FS_NAND_ECC_HOOK * pECCHook);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pECCHook	in ECC algorithm.

Additional information

This function is optional. By default, the Universal NAND driver uses a software algorithm that is capable of correcting 1 bit errors and of detecting 2 bit errors. If the NAND flash device requires a better error correction, the application has to specify a different ECC algorithm via FS_NAND_UNI_SetECCHook().

The ECC algorithms can be either implemented in the software or the calculation routines can take advantage of any dedicated ECC HW available on the target system.

The following ECC algorithms are supported:

Type
FS_NAND_ECC_HW_NULL
FS_NAND_ECC_HW_4BIT
FS_NAND_ECC_HW_8BIT
FS_NAND_ECC_SW_1BIT

Additional software algorithms with error correction capabilities greater than 1 are supported via the SEGGER emLib ECC component (www.segger.com/products/security-iot/emlib/variations/ecc/).

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6.3.3.7.2.8 FS_NAND_UNI_SetEraseVerification()

Description

Enables or disables the checking of the block erase operation.

Prototype

```
void FS_NAND_UNI_SetEraseVerification(U8 Unit,
                                      U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The erase operation is not checked. • ≠0 The erase operation is checked.

Additional information

This function is optional. The result of a block erase operation is normally checked by evaluating the error bits maintained by the NAND flash device in an internal status register. `FS_NAND_UNI_SetEraseVerification()` can be used to enable additional verification of the block erase operation that is implemented by reading back the contents of the entire erased physical block and by checking that all the bytes in it are set to `0xFF`. Enabling this feature can negatively impact the write performance of Universal NAND driver.

The block erase verification feature is active only when the Universal NAND driver is compiled with the `FS_NAND_VERIFY_ERASE` configuration define is set to 1 (default is 0) or when the `FS_DEBUG_LEVEL` configuration define is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

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6.3.3.7.2.9 FS_NAND_UNI_SetMaxBitErrorCnt()

Description

Configures the number of bit errors that trigger the relocation of the data stored in a NAND block.

Prototype

```
void FS_NAND_UNI_SetMaxBitErrorCnt(U8       Unit,
                                   unsigned BitErrorCnt);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BitErrorCnt	Number of physical bit errors.

Additional information

This function is optional and is active only when the file system is compiled with FS_NAND_MAX_BIT_ERROR_CNT set to a value greater than 0.

FS_NAND_UNI_SetMaxBitErrorCnt() can be used to configure when the Universal NAND Driver has to copy the contents of a NAND block to another location in order to prevent the accumulation of bit errors. BitErrorCnt has to be smaller than or equal to the bit error correction requirement of the NAND flash device. The feature can be disabled by calling FS_NAND_UNI_SetMaxBitErrorCnt() with BitErrorCnt set to 0.

The lifetime of the NAND flash device can be negatively affected if this feature is enabled due to the increased number of block erase operations.

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6.3.3.7.2.10 FS_NAND_UNI_SetMaxEraseCntDiff()

Description

Configures the threshold of the wear leveling procedure.

Prototype

```
void FS_NAND_UNI_SetMaxEraseCntDiff(U8  Unit,
                                    U32 EraseCntDiff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
EraseCntDiff	Maximum allowed difference between the erase counts of any two NAND blocks.

Additional information

This function is optional. It can be used to control how the Universal NAND driver performs the wear leveling. The wear leveling procedure makes sure that the NAND blocks are equally erased to meet the life expectancy of the storage device by keeping track of the number of times a NAND block has been erased (erase count). The Universal NAND driver executes this procedure when a new empty NAND block is required for data storage. The wear leveling procedure works by first choosing the next available NAND block. Then the difference between the erase count of the chosen block and the NAND block with lowest erase count is computed. If this value is greater than EraseCntDiff the NAND block with the lowest erase count is freed and made available for use.

The same threshold can also be configured at compile time via the FS_NAND_MAX_ERASE_CNT_DIFF configuration define.

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6.3.3.7.2.11 FS_NAND_UNI_SetMaxPageSize()

Description

Configures the maximum handled page size.

Prototype

```
void FS_NAND_UNI_SetMaxPageSize(unsigned NumBytes);
```

Parameters

Parameter	Description
NumBytes	NAND page size in bytes.

Additional information

This function can be used at runtime to configure the size of the internal buffer used by the Universal NAND driver to read the data from a NAND page. This buffer is shared by all instances of the Universal NAND driver. If the application does not call FS_NAND_UNI_SetMaxPageSize() then the size of the internal page buffer is set to FS_NAND_MAX_PAGE_SIZE if FS_NAND_MAX_PAGE_SIZE is different than 0 or to the logical sector size of the file system if FS_NAND_MAX_PAGE_SIZE is set to 0.

FS_NAND_UNI_SetMaxPageSize() is for example useful when the application is using two NAND flash devices with different page sizes. In this case, the application has to call FS_NAND_UNI_SetMaxPageSize() with the NumBytes parameter set to the largest of the two page sizes.

FS_NAND_UNI_SetMaxPageSize() is available only if the file system is built with FS_NAND_MAX_PAGE_SIZE set to a value different than 0. The function has to be called in FS_X_AddDevices() before any instance of the Universal NAND driver is created.

NumBytes has to be a power of 2 value.

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6.3.3.7.2.12 FS_NAND_UNI_SetMaxSpareAreaSize()

Description

Configures the maximum handled spare area size.

Prototype

```
void FS_NAND_UNI_SetMaxSpareAreaSize(unsigned NumBytes);
```

Parameters

Parameter	Description
NumBytes	Spare area size of the NAND page in bytes.

Additional information

This function can be used at runtime to configure the size of the internal buffer used by the Universal NAND driver to read the data from a spare area of a NAND page. This buffer is shared by all instances of the Universal NAND driver. If the application does not call FS_NAND_UNI_SetMaxSpareAreaSize() then the size of the internal spare area buffer is set to FS_NAND_MAX_SPARE_AREA_SIZE if FS_NAND_MAX_SPARE_AREA_SIZE is different than 0 or to 1/32 of the logical sector size of the file system if FS_NAND_MAX_SPARE_AREA_SIZE is set to 0.

FS_NAND_UNI_SetMaxSpareAreaSize() is for example useful when NAND flash device has a spare area that is larger than 1/32 of the page size. In this case, the application has to call FS_NAND_UNI_SetMaxSpareAreaSize() with the NumBytes parameter set to the spare area size specified in the data sheet of the NAND flash device.

FS_NAND_UNI_SetMaxSpareAreaSize() is available only if the file system is built with FS_NAND_MAX_SPARE_AREA_SIZE set to a value different than 0. The function has to be called in FS_X_AddDevices() before any instance of the Universal NAND driver is created.

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6.3.3.7.2.13 FS_NAND_UNI_SetNumBlocksPerGroup()

Description

Specifies the number of physical NAND blocks in a virtual block.

Prototype

```
int FS_NAND_UNI_SetNumBlocksPerGroup(U8       Unit,
                                     unsigned BlocksPerGroup);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlocksPerGroup	Number of physical blocks in a virtual block. The value must be a power of 2.

Return value

= 0 OK, value configured.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. It can be used to specify how many physical NAND blocks are grouped together to form a virtual block. Grouping physical blocks helps reduce the RAM usage of the driver when the NAND flash device contains a large number of physical blocks. For example, the dynamic RAM usage of the Universal NAND driver using a NAND flash device with 8196 blocks and a page size of 2048 bytes is about 20 KB. The dynamic RAM usage is reduced to about 7 KB if 4 physical blocks are grouped together.

The FS_NAND_SUPPORT_BLOCK_GROUPING configuration define has to be set to 1 in order to enable this function. The FS_NAND_SUPPORT_BLOCK_GROUPING configuration define is set to 1 by default. When set to 0 the function returns an error if called in the application.

FS_NAND_UNI_SetNumBlocksPerGroup() is optional and may be called only from FS_X_AddDevices(). Changing the block grouping requires a low-level format of the NAND flash device.

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6.3.3.7.2.14 FS_NAND_UNI_SetNumWorkBlocks()

Description

Sets number of work blocks the Universal NAND driver uses for write operations.

Prototype

```
void FS_NAND_UNI_SetNumWorkBlocks(U8  Unit,
                                  U32 NumWorkBlocks);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumWorkBlocks	Number of work blocks.

Additional information

This function is optional. It can be used to change the default number of work blocks according to the requirements of the application. Work blocks are physical NAND blocks that the Universal NAND driver uses to temporarily store the data written to NAND flash device. The Universal NAND driver calculates at low-level format the number of work blocks based on the total number of blocks available on the NAND flash device.

By default, the NAND driver allocates 10% of the total number of NAND blocks used as storage, but no more than 10 NAND blocks. The minimum number of work blocks allocated by default depends on whether journaling is used or not. If the journal is active 4 work blocks are allocated, else Universal NAND driver allocates 3 work blocks. The currently allocated number of work blocks can be checked via `FS_NAND_UNI_GetDiskInfo()`. The value is returned in the `NumWorkBlocks` member of the `FS_NAND_DISK_INFO` structure.

Increasing the number of work blocks can help increase the write performance of the Universal NAND driver. At the same time the RAM usage of the Universal NAND driver increases since each configured work block requires a certain amount of RAM for the data management. This is a trade-off between write performance and RAM usage.

The new value take effect after the NAND flash device is low-level formatted via the `FS_FormatLow()` API function.

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6.3.3.7.2.15 FS_NAND_UNI_SetOnFatalErrorCallback()

Description

Registers a function to be called by the driver when a fatal error occurs.

Prototype

```
void FS_NAND_UNI_SetOnFatalErrorCallback
                                (FS_NAND_ON_FATAL_ERROR_CALLBACK * pfOnFatalError);
```

Parameters

Parameter	Description
pfOnFatalError	Function to be called when a fatal error occurs.

Additional information

This function is optional. The application can use this function to register a routine to be called by the file system when a fatal error occurs. Typically, a fatal error occurs when the ECC is not able to correct all the bit errors in a page and is an indication that some data was lost. A data loss leads in most of the cases to a damage of the file system structure.

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6.3.3.7.2.16 FS_NAND_UNI_SetPhyType()

Description

Configures NAND flash access functions.

Prototype

```
void FS_NAND_UNI_SetPhyType(      U8                 Unit,
                            const FS_NAND_PHY_TYPE * pPhyType);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pPhyType	in Physical layer to be used to access the NAND flash device.

Additional information

This function is mandatory and it has to be called in FS_X_AddDevices() once for each instance of the Universal NAND driver. The driver instance is identified by the Unit parameter. First Universal NAND driver instance added to the file system via a FS_AddDevice(&FS_NAND_UNI_Driver) call has the unit number 0, the Universal NAND driver added by a second call to FS_AddDevice() has the unit number 1 and so on.

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6.3.3.7.2.17 FS_NAND_UNI_SetWriteDisturbHandling()

Description

Configures if the bit errors caused by write operations are handled or not.

Prototype

```
void FS_NAND_UNI_SetWriteDisturbHandling(U8 Unit,
                                         U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Activation status of the feature. • =0 Write disturb errors are not handled (default). • ≠0 Write disturb errors are handled.

Additional information

This function is optional and is active only when the file system is compiled with FS_NAND_MAX_BIT_ERROR_CNT set to a value greater than 0.

A write operation can cause bit errors in the pages located on the same NAND block with the page being currently written. Normally, these bit errors are corrected later when the data of the NAND block is copied internally by the Universal NAND driver to another location on the NAND flash device during a wear leveling, a garbage collection or a write operation. This is the default behavior of the Universal NAND driver.

The Universal NAND driver is also able to check for and correct any bit errors right after the write operation in order to reduce the accumulation of bit errors that can lead to a data loss. This error handling mode can be enabled by calling FS_NAND_UNI_SetWriteDisturbHandling() with the OnOff parameter set to 1. In this error handling mode if the number of bit errors in any page in the checked NAND block is greater than or equal to the value configured via FS_NAND_UNI_SetMaxBitErrorCnt() then the NAND block is copied to another location on the NAND flash device in order to correct the bit errors.

The lifetime of the NAND flash device can be negatively affected if this feature is enabled due to the increased number of block erase operations. The write performance can be negatively affected as well.

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6.3.3.7.2.18 FS_NAND_UNI_SetWriteVerification()

Description

Enables or disables the checking of each page write operation.

Prototype

```
void FS_NAND_UNI_SetWriteVerification(U8 Unit,
                                      U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The write operation is not checked. • ≠0 The write operation is checked.

Additional information

This function is optional. The result of a page write operation is normally checked by evaluating the error bits maintained by the NAND flash device in an internal status register. FS_NAND_UNI_SetWriteVerification() can be used to enable additional verification of the page write operation that is implemented by reading back the contents of the written page and by checking that all the bytes are matching the data requested to be written. Enabling this feature can negatively impact the write performance of Universal NAND driver.

The page write verification feature is active only when the Universal NAND driver is compiled with the FS_NAND_VERIFY_WRITE configuration define is set to 1 (default is 0) or when the FS_DEBUG_LEVEL configuration define is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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6.3.3.7.2.19 FS_NAND_ECC_HOOK

Description

ECC calculation algorithm.

Type definition

```
typedef struct {
  FS_NAND_ECC_HOOK_CALC  * pfCalc;
  FS_NAND_ECC_HOOK_APPLY * pfApply;
  U8                       NumBitsCorrectable;
  U8                       ldBytesPerBlock;
  U8                       NumBitsCorrectableSpare;
} FS_NAND_ECC_HOOK;
```

Structure members

Member	Description
pfCalc	Calculates the ECC of specified data.
pfApply	Verifies and corrects bit errors using ECC.
NumBitsCorrectable	Number of bits the ECC algorithm is able to correct in the data block and 4 bytes of spare area.
ldBytesPerBlock	Number of bytes in the data block given as power of 2 exponent.
NumBitsCorrectableSpare	Number of bits the ECC algorithm is able to correct in the 4 bytes of the spare area.

Additional information

This structure contains pointers to API functions and attributes related to an ECC calculation algorithm.

ldBytesPerBlock is typically set to 9 which indicates a block size of 512 bytes. The size of the ECC block is imposed by the specifications of the NAND flash device. If the value is set to 0 the Universal NAND driver assumes that the ECC block is 512 bytes large.

NumBitsCorrectable is used by the Universal NAND driver to check if the ECC algorithm is capable of correcting the number of bit errors required by the used NAND flash device.

NumBitsCorrectableSpare is used by the Universal NAND driver to activate an optimization related to reading the data from the spare area. If NumBitsCorrectableSpare is set to a value different than 0 than the Universal NAND driver assumes that the 4 bytes of management data stored in the spare area of the NAND page are protected by a dedicated ECC. This enables the Universal NAND driver to read only the spare area instead of the entire NAND page when only the management data has to be evaluated which can help increase the performance of specific operations such as the mounting of NAND flash device.

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6.3.3.7.2.20 FS_NAND_ECC_HOOK_CALC

Description

Calculates the parity bits of the specified data using ECC.

Type definition

```
typedef void FS_NAND_ECC_HOOK_CALC(const U32 * pData,
                                   U8  * pSpare);
```

Parameters

Parameter	Description
pData	in Data to be written to the main area of the page.
pSpare	in Data to be written to the spare area of the page. out The calculated parity bits.

Additional information

FS_NAND_ECC_HOOK_CALC is called by the Universal NAND driver before it writes the data to the NAND flash device to calculate the parity check bits. The parity check bits are stored together with the data to NAND flash device. They are used by FS_NAND_ECC_HOOK_CALC to correct eventual bit errors.

This function has to calculate the parity bits of pData and of four bytes of pSpare. That is the calculated parity bits are used to protect the data stored in pData as well as pSpare. The number of bytes in pData to be protected by ECC is specified via ldBytesPerBlock in FS_NAND_ECC_HOOK. The data in pSpare to be protected by ECC is located at byte offset four. The calculated parity bits must be stored to pSpare at byte offset eight. The byte order of the stored parity bits is not relevant for the Universal NAND driver. pSpare is organized as follows:

Byte range
0-3
4-7
8-N

FS_NAND_ECC_HOOK_CALC is not allowed to store more than N - 8 + 1 parity check bytes at byte offset eight to pSpare. N depends on the size of the main and spare area of the NAND flash and on ldBytesPerBlock and can be calculate using this formula:

```
N = ((BytesPerSpareArea / (BytesPerPage >> ldBytesPerBlock)) - 8) - 1
```

Parameter
BytesPerSpareArea
BytesPerPage
ldBytesPerBlock

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6.3.3.7.2.21 FS_NAND_ECC_HOOK_APPLY

Description

Checks and corrects bit errors in the specified data using ECC.

Type definition

```
typedef int FS_NAND_ECC_HOOK_APPLY(U32 * pData,
                                   U8  * pSpare);
```

Parameters

Parameter	Description
pData	in Data read from the main area of the page. out Corrected main area data.
pSpare	in Data read from the spare area of the page. out Corrected spare area data.

Return value

< 0 Uncorrectable bit errors detected.
≥ 0 Number of bit errors detected and corrected.

Additional information

FS_NAND_ECC_HOOK_APPLY is called by the Universal NAND driver after it reads data with from the NAND flash device to verify that the data is not corrupted. If the function detects bit errors then it uses the parity check bits to correct them. The correction has to be performed in place that is directly in pData and pSpare. The parity check bits are located at byte offset eight in pSpare. They protect all the bytes in pData and four bytes of pSpare. Refer to FS_NAND_ECC_HOOK_CALC for a description of pSpare data layout. FS_NAND_ECC_HOOK_APPLY function has to also correct the bit errors that occurred in the parity check.

For backwards compatibility the return value is interpreted differently by the Universal NAND driver if ldBytesPerBlock is set to 0 as follows:

Value
0
1
2
3

The Universal NAND driver can possibly call this function with pData set to NULL when it needs to check only the data stored in the spare area of a NAND page if NumBitsCorrectableSpare in FS_NAND_ECC_HOOK is set to a value different than 0.

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6.3.3.8 Additional driver functions

The following functions are optional and can be used by the application to perform operations directly on the NAND flash device.

Function	Description
FS_NAND_UNI_Clean()	Makes storage space available for fast write operations.
FS_NAND_UNI_EraseBlock()	Sets all the bytes in a NAND block to 0xFF.
FS_NAND_UNI_EraseFlash()	Erases the entire NAND partition.
FS_NAND_UNI_GetBlockInfo()	Returns information about the specified NAND block.
FS_NAND_UNI_GetBlockInfoEx()	Returns information about the specified NAND block.
FS_NAND_UNI_GetDiskInfo()	Returns information about the NAND partition.
FS_NAND_UNI_GetStatCounters()	Returns the actual values of statistical counters.
FS_NAND_UNI_IsBlockBad()	Checks if a NAND block is marked as defective.
FS_NAND_UNI_Mount()	Mounts the NAND flash device.
FS_NAND_UNI_ReadLogSectorPartial()	Reads a specified number of bytes from a logical sector.
FS_NAND_UNI_ReadPageRaw()	Reads data from a page without ECC.
FS_NAND_UNI_ReadPhySector()	This function reads a physical sector from NAND flash.
FS_NAND_UNI_ResetStatCounters()	Sets the values of statistical counters to 0.
FS_NAND_UNI_TestBlock()	Fills all the pages in a block (including the spare area) with the specified pattern and verifies if the data was written correctly.
FS_NAND_UNI_WritePage()	Stores data to a page of a NAND flash with ECC.
FS_NAND_UNI_WritePageRaw()	Stores data to a page of a NAND flash without ECC.

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6.3.3.8.1 FS_NAND_UNI_Clean()

Description

Makes storage space available for fast write operations.

Prototype

```
int FS_NAND_UNI_Clean(U8       Unit,
                      unsigned NumBlocksFree,
                      unsigned NumSectorsFree);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumBlocksFree	Number of blocks to be kept free.
NumSectorsFree	Number of sectors to be kept free on each block.

Return value

= 0 OK, space has been made available.
≠ 0 An error occurred.

Additional information

This function is optional. It can be used to free space on the NAND flash device for data that the application has to write as fast as possible. FS_NAND_UNI_Clean() performs two internal operations: (1) Converts all work blocks that have less free sectors than NumSectorsFree into data blocks. (2) If required, convert work blocks until at least NumBlocksFree are available.

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6.3.3.8.2 FS_NAND_UNI_EraseBlock()

Description

Sets all the bytes in a NAND block to `0xFF`.

Prototype

```
int FS_NAND_UNI_EraseBlock(U8       Unit,
                           unsigned BlockIndex);
```

Parameters

Parameter	Description
`Unit`	Index of the driver instance (0-based).
`BlockIndex`	Index of the NAND flash block to be erased.

Return value

= 0 OK, block erased
≠ 0 An error occurred

Additional information

This function is optional. `FS_NAND_UNI_EraseBlock()` function does not check if the block is marked as defective before erasing it.

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6.3.3.8.3 FS_NAND_UNI_EraseFlash()

Description

Erases the entire NAND partition.

Prototype

```
int FS_NAND_UNI_EraseFlash(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

≥ 0 . Number of blocks which failed to erase.
< 0 An error occurred.

Additional information

This function is optional. After the call to this function all the bytes in the NAND partition are set to `0xFF`.

This function has to be used with care, since it also erases blocks marked as defective and therefore the information about the block status will be lost. `FS_NAND_EraseFlash()` can be used without this side effect on storage devices that are guaranteed to not have any bad blocks, such as DataFlash devices.

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6.3.3.8.4 FS_NAND_UNI_GetBlockInfo()

Description

Returns information about the specified NAND block.

Prototype

```
int FS_NAND_UNI_GetBlockInfo(U8                   Unit,
                             U32                  BlockIndex,
                             FS_NAND_BLOCK_INFO * pBlockInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the physical block to get information about.
pBlockInfo	out Information about the NAND block.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the driver and will typically not be linked in production builds.

FS_NAND_UNI_GetBlockInfo() has to read the contents of the entire NAND block in order to collect all the information which may take a relatively long time to complete. If the application does not require the information about the block status or about the status of the logical sectors stored in the NAND block it can call FS_NAND_UNI_GetBlockInfoEx() instead.

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6.3.3.8.5 FS_NAND_UNI_GetBlockInfoEx()

Description

Returns information about the specified NAND block.

Prototype

```
int FS_NAND_UNI_GetBlockInfoEx(U8                   Unit,
                               U32                  BlockIndex,
                               FS_NAND_BLOCK_INFO * pBlockInfo,
                               unsigned             Flags);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the physical block to get information about.
pBlockInfo	out Information about the NAND block.
Flags	Specifies the information to be returned.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the driver and will typically not be linked in production builds.

Flags is a bitwise-or combination of *Block info flags* on page 671.

The FS_NAND_BLOCK_INFO_FLAG_BAD_STATUS flag specifies if the information about the block status has to be returned via the members IsDriverBadBlock, BadBlockErrorType, BadBlockErrorBRSI of FS_NAND_BLOCK_INFO. If FS_NAND_UNI_GetBlockInfoEx() is called on a NAND block marked as defective with the FS_NAND_BLOCK_INFO_FLAG_BAD_STATUS flag cleared than the member Type of FS_NAND_BLOCK_INFO is set to NAND_BLOCK_TYPE_UNKNOWN.

The FS_NAND_BLOCK_INFO_FLAG_SECTOR_STATUS flag specifies if FS_NAND_UNI_GetBlockInfoEx() has to return information about the logical sectors stored in the NAND block. This information is returned via the members NumSectorsBlank, NumSectorsValid, NumSectorsInvalid, NumSectorsECCError, NumSectorsECCCorrectable, NumSectorsErrorInECC of FS_NAND_BLOCK_INFO

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6.3.3.8.6 FS_NAND_UNI_GetDiskInfo()

Description

Returns information about the NAND partition.

Prototype

```
int FS_NAND_UNI_GetDiskInfo(U8                  Unit,
                            FS_NAND_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDiskInfo	out Information about the NAND partition.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

FS_NAND_UNI_GetDiskInfo() can be used to get information about the NAND flash device and about the instance of the Universal NAND driver that is used to access it. If the NAND flash device is formatted then FS_NAND_UNI_GetDiskInfo() also returns statistical information about the usage of NAND blocks. If this information is not relevant to the application FS_NAND_UNI_Mount() can be called instead which typically requires less time to complete.

FS_NAND_UNI_GetDiskInfo() mounts the NAND flash device if required and leaves it in this state upon return.

This function is not required for the functionality of the Universal NAND driver and is typically not linked in production builds.

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6.3.3.8.7 FS_NAND_UNI_GetStatCounters()

Description

Returns the actual values of statistical counters.

Prototype

```
void FS_NAND_UNI_GetStatCounters(U8                      Unit,
                                 FS_NAND_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pStat	out Values of statistical counters.

Additional information

This function is optional. It is active only when the file system is compiled with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or FS_NAND_ENABLE_STATS set to 1.

The statistical counters can be cleared via FS_NAND_UNI_ResetStatCounters().

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6.3.3.8.8 FS_NAND_UNI_IsBlockBad()

Description

Checks if a NAND block is marked as defective.

Prototype

```
int FS_NAND_UNI_IsBlockBad(U8       Unit,
                           unsigned BlockIndex);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the NAND flash block to be checked.

Return value

1	Block is defective
0	Block is not defective

Additional information

This function is optional.

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6.3.3.8.9 FS_NAND_UNI_Mount()

Description

Mounts the NAND flash device.

Prototype

```
int FS_NAND_UNI_Mount(U8                   Unit,
                      FS_NAND_MOUNT_INFO * pMountInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pMountInfo	out Information about the mounted NAND flash device. Can be set to NULL.

Return value

= 0 OK, NAND flash device successfully mounted.
≠ 0 Error, could not mount NAND flash device.

Additional information

FS_NAND_UNI_Mount() can be used to explicitly mount the NAND flash device and to get information about it. This function returns a subset of the information returned by FS_NAND_UNI_GetDiskInfo() and therefore can be used instead of it if the application does not require statistical information about the usage of the NAND blocks. Typically, FS_NAND_UNI_Mount() requires less time to complete than FS_NAND_UNI_GetDiskInfo().

This function is not required for the functionality of the Universal NAND driver and is typically not linked in production builds.

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6.3.3.8.10 FS_NAND_UNI_ReadLogSectorPartial()

Description

Reads a specified number of bytes from a logical sector.

Prototype

```
int FS_NAND_UNI_ReadLogSectorPartial(U8         Unit,
                                     U32        LogSectorIndex,
                                     void     * pData,
                                     unsigned   Off,
                                     unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
LogSectorIndex	Index of the logical sector to read from.
pData	out Data read from NAND flash.
Off	Byte offset to read from (relative to beginning of the sector).
NumBytes	Number of bytes to be read.

Return value

≠ 0 Number of bytes read.
= 0 An error occurred.

Additional information

This function is optional.

For NAND flash devices with internal HW ECC only the specified number of bytes is transferred and not the entire sector. Typ. used by the applications that access the NAND flash directly (that is without a file system) to increase the read performance.

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6.3.3.8.11 FS_NAND_UNI_ReadPageRaw()

Description

Reads data from a page without ECC.

Prototype

```
int FS_NAND_UNI_ReadPageRaw(U8         Unit,
                            U32        PageIndex,
                            void     * pData,
                            unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be read.
pData	out Data to be written.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is read from byte offset 0 relative to the beginning of the page. If more data is requested than the page size (main + spare area, typically 2048 + 64 bytes) the function does not modify excess bytes in pData.

FS_NAND_UNI_ReadPageRaw() does not work correctly on NAND flash devices with HW ECC that cannot be disabled.

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6.3.3.8.12 FS_NAND_UNI_ReadPhySector()

Description

This function reads a physical sector from NAND flash.

Prototype

```
int FS_NAND_UNI_ReadPhySector(U8         Unit,
                              U32        PhySectorIndex,
                              void     * pData,
                              unsigned * pNumBytesData,
                              void     * pSpare,
                              unsigned * pNumBytesSpare);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PhySectorIndex	Physical sector index.
pData	Pointer to a buffer to store read data.
pNumBytesData	in Pointer to variable storing the size of the data buffer. out The number of bytes that were stored in the data buffer.
pSpare	Pointer to a buffer to store read spare data.
pNumBytesSpare	in Pointer to variable storing the size of the spare data buffer. out The number of bytes that were stored in the spare data buffer.

Return value

≥ 0 OK, sector data read.
< 0 An error occurred.

Additional information

This function is optional.

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6.3.3.8.13 FS_NAND_UNI_ResetStatCounters()

Description

Sets the values of statistical counters to 0.

Prototype

```
void FS_NAND_UNI_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)

Additional information

This function is optional. It is active only when the file system is compiled with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or FS_NAND_ENABLE_STATS set to 1.

The statistical counters can be queried via FS_NAND_UNI_GetStatCounters().

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6.3.3.8.14 FS_NAND_UNI_TestBlock()

Description

Fills all the pages in a block (including the spare area) with the specified pattern and verifies if the data was written correctly.

Prototype

```
int FS_NAND_UNI_TestBlock(U8                   Unit,
                          unsigned             BlockIndex,
                          U32                  Pattern,
                          FS_NAND_TEST_INFO * pInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
BlockIndex	Index of the NAND block to be tested.
Pattern	Data pattern to be written during the test.
pInfo	Additional parameters and information about the test.

Return value

FS_NAND_TEST_RETVAL_OK	OK, no bit errors.
FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR	OK, correctable bit errors found. The number of bit errors is returned in NumErrorsCorrectable of pResult.
FS_NAND_TEST_RETVAL_FATAL_ERROR	Fatal error, uncorrectable bit error found. The page index is returned in PageIndexFatalError of pResult.
FS_NAND_TEST_RETVAL_BAD_BLOCK	Bad block, skipped.
FS_NAND_TEST_RETVAL_ERASE_FAILURE	Erase operation failed. The block has been marked as defective.
FS_NAND_TEST_RETVAL_WRITE_FAILURE	Write operation failed. The block has been marked as defective.
FS_NAND_TEST_RETVAL_READ_FAILURE	Read operation failed.
FS_NAND_TEST_RETVAL_INTERNAL_ERROR	NAND flash access error.

Additional information

This function is optional. It can be used by the application to test the data reliability of a NAND block. BlockIndex is relative to the beginning of the NAND partition where the first block has the index 0.

Example

The following sample code demonstrates how FS_NAND_UNI_TestBlock() can be used to check all the blocks of a NAND flash device. The function does not work correctly on NAND flash devices with HW ECC that cannot be disabled.

```
#include <stdio.h>
#include "FS.h"

void SampleNAND_UNITestBlocks(void) {
  int               r;
  U32               NumPhyBlocks;
  U32               iBlock;
  FS_NAND_DISK_INFO DiskInfo;
  FS_NAND_TEST_INFO TestInfo;
  char              ac[100];

  memset(&DiskInfo, 0, sizeof(DiskInfo));
  memset(&TestInfo, 0, sizeof(TestInfo));
```

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```
  FS_NAND_UNI_GetDiskInfo(0, &DiskInfo);
  NumPhyBlocks = DiskInfo.NumPhyBlocks;
  TestInfo.NumBitsCorrectable = 1;
  TestInfo.BytesPerSpare      = (U16)DiskInfo.BytesPerSpareArea;
  for (iBlock = 0; iBlock < NumPhyBlocks; ++iBlock) {
    r = FS_NAND_UNI_TestBlock(0, iBlock, 0xAA5500FFuL, &TestInfo);
    switch (r) {
    case FS_NAND_TEST_RETVAL_OK:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: OK.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: %lu correctable error(s).\n",
        iBlock, TestInfo.BitErrorCnt);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_FATAL_ERROR:
      SEGGER_snprintf(ac, sizeof(ac),
        "Block %lu: %lu correctable error(s), fatal error on page %lu.\n",
        iBlock, TestInfo.BitErrorCnt, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_BAD_BLOCK:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Bad. Skipped.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_ERASE_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Erase failure. Marked as bad.\n", iBlock);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_WRITE_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac),
        "Block %lu: Write failure on page %lu. Marked as bad.\n",
        iBlock, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    case FS_NAND_TEST_RETVAL_READ_FAILURE:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Read failure on page %lu.\n",
        iBlock, TestInfo.PageIndex);
      FS_X_Log(ac);
      break;
    default:
      SEGGER_snprintf(ac, sizeof(ac), "Block %lu: Internal error.\n", iBlock);
      FS_X_Log(ac);
      break;
    }
  }
}
```

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6.3.3.8.15 FS_NAND_UNI_WritePage()

Description

Stores data to a page of a NAND flash with ECC.

Prototype

```
int FS_NAND_UNI_WritePage(      U8         Unit,
                                U32        PageIndex,
                          const void     * pData,
                                unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be written.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is written at byte offset 0 relative to the beginning of the page. If more data is written than the size of the page (main + spare area, typically 2048 + 64 bytes) then the excess bytes are discarded. The data in the area reserved for ECC cannot be modified using this function.

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6.3.3.8.16 FS_NAND_UNI_WritePageRaw()

Description

Stores data to a page of a NAND flash without ECC.

Prototype

```
int FS_NAND_UNI_WritePageRaw(      U8          Unit,
                                   U32         PageIndex,
                             const void      * pData,
                                   unsigned    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
PageIndex	Index of the page to be written.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is optional.

The data is written at the byte offset 0 relative to the beginning of the page. If more data is written than the size of the page (main + spare area, typically 2048 + 64 bytes) the excess bytes are discarded.

FS_NAND_UNI_WritePageRaw() does not work correctly on NAND flash devices with HW ECC that cannot be disabled.

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6.3.3.8.17 Bad block marking types

Description

Methods to mark a block as defective.

Definition

```
#define FS_NAND_BAD_BLOCK_MARKING_TYPE_FSPS     0
#define FS_NAND_BAD_BLOCK_MARKING_TYPE_FPS      1
#define FS_NAND_BAD_BLOCK_MARKING_TYPE_FLPS     2
#define FS_NAND_BAD_BLOCK_MARKING_TYPE_FSLPS    3
#define FS_NAND_BAD_BLOCK_MARKING_TYPE_FLPMS    4
```

Symbols

Definition	Description
FS_NAND_BAD_BLOCK_MARKING_TYPE_FSPS	The block is marked as defective in the spare area of the first and second page of the block.
FS_NAND_BAD_BLOCK_MARKING_TYPE_FPS	The block is marked as defective in the spare area of the first page of the block.
FS_NAND_BAD_BLOCK_MARKING_TYPE_FLPS	The block is marked as defective in the spare area of first and last page of the block.
FS_NAND_BAD_BLOCK_MARKING_TYPE_FSLPS	The block is marked as defective in the spare area of first, second and last page of the block.
FS_NAND_BAD_BLOCK_MARKING_TYPE_FLPMS	The block is marked as defective in the main and spare area of first and last page of the block.

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6.3.3.8.18 Block info flags

Description

Flags that control the information returned by `FS_NAND_UNI_GetBlockInfoEx()`.

Definition

```
#define FS_NAND_BLOCK_INFO_FLAG_BAD_STATUS       0x01u
#define FS_NAND_BLOCK_INFO_FLAG_SECTOR_STATUS    0x02u
```

Symbols

Definition	Description
FS_NAND_BLOCK_INFO_FLAG_BAD_STATUS	Return information about the status of the NAND block (defective or not)
FS_NAND_BLOCK_INFO_FLAG_SECTOR_STATUS	Return information about the status of all logical sectors in the NAND block.

Additional information

These flags can be passed as Flags parameter to `FS_NAND_UNI_GetBlockInfoEx()` in order to specify the type of information that has to be returned.

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6.3.3.8.19 ECC correction status

Description

Result of the bit error correction.

Definition

```
#define FS_NAND_CORR_NOT_APPLIED    0u
#define FS_NAND_CORR_APPLIED        1u
#define FS_NAND_CORR_FAILURE        2u
```

Symbols

Definition	Description
FS_NAND_CORR_NOT_APPLIED	No bit errors detected.
FS_NAND_CORR_APPLIED	Bit errors were detected and corrected.
FS_NAND_CORR_FAILURE	Bit errors were detected but not corrected.

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6.3.3.8.20 FS_NAND_MOUNT_INFO

Description

Information about the mounted NAND flash device.

Type definition

```
typedef struct {
  U32  NumPhyBlocks;
  U32  NumLogBlocks;
  U32  NumPagesPerBlock;
  U32  NumSectorsPerBlock;
  U32  BytesPerPage;
  U32  BytesPerSpareArea;
  U32  BytesPerSector;
  U8   BadBlockMarkingType;
  U8   IsWriteProtected;
  U8   HasFatalError;
  U8   ErrorType;
  U32  ErrorSectorIndex;
  U16  BlocksPerGroup;
  U32  NumWorkBlocks;
} FS_NAND_MOUNT_INFO;
```

Structure members

Member	Description
NumPhyBlocks	Total number of blocks in the NAND partition.
NumLogBlocks	Total number of NAND blocks that can be used to store data.
NumPagesPerBlock	Number of pages in a NAND block.
NumSectorsPerBlock	Number of logical sectors stored in a NAND block.
BytesPerPage	Number of bytes in the main area of a NAND page.
BytesPerSpareArea	Number of bytes in the spare area of a NAND page.
BytesPerSector	Number of bytes is a logical sector.
BadBlockMarkingType	Type of the bad block marking.
IsWriteProtected	Set to 1 if the NAND flash device cannot be written.
HasFatalError	Set to 1 if the SLC1 NAND driver reported a fatal error.
ErrorType	Type of fatal error that has occurred.
ErrorSectorIndex	Sector index on which a fatal error occurred.
BlocksPerGroup	Number of NAND blocks in a group.
NumWorkBlocks	Number of work blocks used by the SLC1 NAND driver.

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6.3.3.8.21 FS_NAND_STAT_COUNTERS

Description

Statistical counters of NAND flash driver.

Type definition

```
typedef struct {
  U32  NumFreeBlocks;
  U32  NumBadBlocks;
  U32  EraseCnt;
  U32  ReadDataCnt;
  U32  ReadSpareCnt;
  U32  ReadSectorCnt;
  U32  NumReadRetries;
  U32  WriteDataCnt;
  U32  WriteSpareCnt;
  U32  WriteSectorCnt;
  U32  NumWriteRetries;
  U32  ConvertViaCopyCnt;
  U32  ConvertInPlaceCnt;
  U32  NumValidSectors;
  U32  CopySectorCnt;
  U32  BlockRelocationCnt;
  U32  ReadByteCnt;
  U32  WriteByteCnt;
  U32  BitErrorCnt;
  U32  aBitErrorCnt[];
} FS_NAND_STAT_COUNTERS;
```

Structure members

Member	Description
NumFreeBlocks	Number of NAND blocks not used for data.
NumBadBlocks	Number of NAND blocks marked as defective.
EraseCnt	Number of block erase operation performed.
ReadDataCnt	Number of times the NAND driver read from the main area of a page.
ReadSpareCnt	Number of times the NAND driver read from the spare area of a page.
ReadSectorCnt	Number of logical sectors read from the NAND flash.
NumReadRetries	Number of times a read operation has been retried because of an error.
WriteDataCnt	Number of times the NAND driver wrote to the main area of a page.
WriteSpareCnt	Number of times the NAND driver wrote to the spare area of a page.
WriteSectorCnt	Number of logical sectors wrote to the NAND flash.
NumWriteRetries	Number of times a write operation has been retried because of an error.
ConvertViaCopyCnt	Number of block conversions via copy.
ConvertInPlaceCnt	Number of block conversions in place.
NumValidSectors	Number of logical sectors that contain valid data.
CopySectorCnt	Number of times the NAND driver copied a logical sector to another location.

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Member	Description
BlockRelocationCnt	Number of times the NAND driver relocated a NAND block due to errors.
ReadByteCnt	Number of bytes read from NAND flash.
WriteByteCnt	Number of bytes written to NAND flash.
BitErrorCnt	Number of bit errors detected and corrected.
aBitErrorCnt	Number of times a specific number of bit errors occurred.

Additional information

This structure can be used to get statistical information about the operation of the Universal as well as SLC1 NAND driver via the function FS_NAND_UNI_GetStatCounters() and FS_NAND_GetStatCounters() respectively.

aBitErrorCnt[0] stores the number of 1 bit error occurrences, aBitErrorCnt[1] stores the number of 2 bit error occurrences, and so on.

Example

Refer to FS_NAND_UNI_GetStatCounters() and FS_NAND_GetStatCounters() for a sample usage.

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6.3.3.8.22 FS_NAND_TEST_INFO

Description

Additional information passed to test routine.

Type definition

```
typedef struct {
  U8   NumBitsCorrectable;
  U8   OffSpareECCProt;
  U8   NumBytesSpareECCProt;
  U16  BytesPerSpare;
  U32  BitErrorCnt;
  U32  PageIndex;
} FS_NAND_TEST_INFO;
```

Structure members

Member	Description
NumBitsCorrectable	Number of bits the ECC can correct in the data and spare area (typically 4)
OffSpareECCProt	Offset in the spare area of the first byte protected by ECC (typically 4).
NumBytesSpareECCProt	Number of bytes in the spare area protected by ECC (typically 4 bytes)
BytesPerSpare	Total number of bytes in the spare area. When set to 0 the default value of 1/32 of page size is used.
BitErrorCnt	Number of bit errors detected and corrected.
PageIndex	Index of the physical page where the error happened.

Additional information

The test routine returns information about what went wrong during a test via FS_NAND_UNI_TestBlock() and FS_NAND_TestBlock().

Example

Refer to FS_NAND_UNI_TestBlock() and FS_NAND_TestBlock() for a sample usage.

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6.3.3.8.23 NAND block types

Description

Type of data stored to a NAND block.

Definition

```
#define FS_NAND_BLOCK_TYPE_UNKNOWN    0u
#define FS_NAND_BLOCK_TYPE_BAD        1u
#define FS_NAND_BLOCK_TYPE_EMPTY      2u
#define FS_NAND_BLOCK_TYPE_WORK       3u
#define FS_NAND_BLOCK_TYPE_DATA       4u
```

Symbols

Definition	Description
FS_NAND_BLOCK_TYPE_UNKNOWN	The type of the block cannot be determined.
FS_NAND_BLOCK_TYPE_BAD	The block marked as defective.
FS_NAND_BLOCK_TYPE_EMPTY	The block does not store any data.
FS_NAND_BLOCK_TYPE_WORK	The block that stores data temporarily.
FS_NAND_BLOCK_TYPE_DATA	The block that stores data permanently.

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6.3.3.8.24 NAND test return values

Description

Return values of the NAND block test functions.

Definition

```
#define FS_NAND_TEST_RETVAL_OK                  0
#define FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR   1
#define FS_NAND_TEST_RETVAL_FATAL_ERROR         2
#define FS_NAND_TEST_RETVAL_BAD_BLOCK           3
#define FS_NAND_TEST_RETVAL_ERASE_FAILURE       4
#define FS_NAND_TEST_RETVAL_WRITE_FAILURE       5
#define FS_NAND_TEST_RETVAL_READ_FAILURE        6
#define FS_NAND_TEST_RETVAL_INTERNAL_ERROR      (-1)
```

Symbols

Definition	Description
FS_NAND_TEST_RETVAL_OK	The test was successful.
FS_NAND_TEST_RETVAL_CORRECTABLE_ERROR	Bit errors occurred that were corrected via ECC.
FS_NAND_TEST_RETVAL_FATAL_ERROR	Bit errors occurred that the ECC was not able to correct.
FS_NAND_TEST_RETVAL_BAD_BLOCK	The tested block was marked as defective.
FS_NAND_TEST_RETVAL_ERASE_FAILURE	An error occurred during the block erase operation.
FS_NAND_TEST_RETVAL_WRITE_FAILURE	An error occurred while writing the data to the NAND block.
FS_NAND_TEST_RETVAL_READ_FAILURE	An error occurred while reading the data from the NAND block.
FS_NAND_TEST_RETVAL_INTERNAL_ERROR	An internal processing error occurred.

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6.3.3.9 Performance and resource usage

This section provides information about the ROM and RAM usage as well as the performance of the Universal NAND driver. Please note that a Universal NAND driver instance requires one instance of one NAND physical layer in order to operate. The resource usage of the used NAND physical layer has to be taken into account when calculating the total resource usage of the Universal NAND driver.

6.3.3.9.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the Universal NAND driver were measured as described in the section *Test procedure* on page 1439.

Usage: 7.9 Kbytes

6.3.3.9.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Universal NAND driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the {FS_NAND_UNI_Drv.c} file.

Usage: 32 bytes

6.3.3.9.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount required depends on the runtime configuration and the characteristics of the used NAND flash device. The approximate RAM usage of the Universal NAND driver can be calculated as follows:

```
MemAllocated = 148 + 2 * NumBlocks
             + ((PagesPerBlock - 1) + 18) * NumWorkBlocks
             + 1.04 * PageSize
```

Parameter	Description
MemAllocated	Number of bytes allocated for one instance of the NAND driver.
NumBlocks	Number of blocks in the NAND flash device.
NumWorkBlocks	Number of blocks the driver reserves as temporary storage for the written data. By default, 3 blocks are reserved. The number of work blocks can be specified at runtime via FS_NAND_UNI_SetNumWorkBlocks().
PageSize	Number of bytes in a page.

Example

This example uses a 2 GBit NAND flash device with 2Kbyte pages and 2048 blocks. One block consists of 64 pages and each page holds 1 sector of 2048 bytes.

```
PagesPerBlock = 64
NumBlocks     = 2048
NumWorkBlocks = 4
PageSize      = 2048
MemAllocated  = 148 + 2 * 2048 + (64 - 1 + 18) * 4 + 1.04 * 2048
              = 148 + 4096 + 324 + 2129
              = 6397 bytes
```

6.3.3.9.4 Performance

The following performance measurements are in no way complete, but they give a good approximation of the time required for common operations on various target hardware. The

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tests were performed as described in the section *Performance* on page 1445. All values are given in Mbytes/sec.

CPU type	NAND flash device	Write speed	Read speed
NXP LPC4322 (180 MHz)	Serial NAND flash with 2048 bytes per page connected to a quad SPI controller via 4 data lines transferring data at 60 MHz.	**4.1**	**12.2**
NXP LPC4322 (180 MHz)	Serial NAND flash with 2048 bytes per page connected to a standard SPI controller transferring data at 60 MHz.	**3.9**	**7.7**
ST STM32MP157 (650 MHz)	Parallel NAND flash with 4096 bytes per page connected to an external memory controller via an 8-bit data bus. The 8-bit ECC is calculated using SEGGER emFile-ECC.	**10.8**	**22.2**
Atmel AT91SAM3U (96 MHz)	Parallel NAND flash with 2048 bytes per page and a sector size of 2048 bytes with internal ECC enabled using the built-in NAND controller/external bus-interface.	**2.6**	**7.5**

6.3.3.9.5 How to reduce ROM usage

The ROM usage can be reduced by disabling optional features of the Universal NAND driver. This can be done by building the file system with `FS_OPTIMIZATION_TYPE` set to `FS_OPTIMIZATION_TYPE_MIN_SIZE` or by disabling the optional features individually. Refer to the section *Compile time configuration* on page 624 for more information about the available optional features.

If the application makes only read accesses to the NAND flash device, then the ROM usage can be reduced significantly by using the read-only variant of the Universal NAND driver. This can be done by specifying the `FS_NAND_UNI_RO_Driver` identifier in the call to `FS_AddDevice()`.

6.3.3.9.6 How to reduce RAM usage

The static RAM usage can be reduced by setting `FS_NAND_NUM_UNITS` to the maximum number of Universal NAND driver instances the application is expected to create at runtime.

The dynamic RAM usage depends on the number of NAND blocks the Universal NAND driver has to manage and on the number of configured work blocks. The number of NAND blocks can be reduced by activating the block grouping feature. Refer to the section *Block grouping* on page 623 for information about this feature. The number of work blocks can be configured via `FS_NAND_UNI_SetNumWorkBlocks()`.

> **Note**
>
> Reducing the number of work blocks may negatively affect the write performance of the Universal NAND driver.

6.3.3.9.7 How to improve performance

As a general rule, the best performance can be achieved when the application accesses the file data in blocks and at offsets that are a multiple of a NAND page size. The file system guarantees that the beginning of a file is aligned to a NAND page.

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In addition, the write performance can be improved by increasing the number of work blocks. The number of work blocks can be configured via FS_NAND_UNI_SetNumWorkBlocks().

The performance of the low-level mount operation can be improved by reducing the number of NAND blocks that the Universal NAND driver has to manage. This can be done by enabling the block grouping feature and by configuring a number of blocks per group greater than one. Refer to the section *Block grouping* on page 623 for information about this feature. If the rate of the data transfer between the MCU and the NAND flash device is relatively low, then building the file system with FS_NAND_OPTIMIZE_SPARE_AREA_READ set to 1 may help improve the performance of the low-level mount operation.

Building the file system with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL automatically enables the collection of statistical information in the Universal NAND driver. This may reduce the performance of the low-level mount operation because the Universal NAND driver will try to calculate the number of logical sectors stored on the NAND flash device that contain valid data. The application can disable the collection of statistical information by building the file system with FS_NAND_ENABLE_STATS set to 0 if it does not require such information. If the application requires statistical information about the operation of the Universal NAND driver but not about the number of valid logical sectors, then the performance of the low-level mount operation can be improved by disabling the collection of information about the number of valid logical sectors. This can be done by building the file system with FS_NAND_ENABLE_STATS_SECTOR_STATUS set to 0.

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6.3.4 NAND physical layer

6.3.4.1 General information

The NAND physical layer provides the basic functionality for accessing a NAND flash device such as device identification, block erase operation, page read and write operations, etc. Every instance of the Universal or SLC1 NAND driver requires an instance of a NAND physical layer in order to be able to operate. A NAND physical layer instance is automatically allocated either statically or dynamically at the first call to one of its API functions. Each instance is identified by a unit number that is identical to the unit number of the NAND driver that uses that instance of the NAND physical layer. The type of the NAND physical layer assigned to an instance of a Universal or SLC1 NAND driver is configured via `FS_NAND_UNI_SetPhyType()` and `FS_NAND_SetPhyType()` respectively.

The table below lists the NAND physical layers that ship with emFile. Refer to *Configuring the driver* on page 579 and *Configuring the driver* on page 623 for detailed information about how to add and configure a physical layer in an application.

Physical layer identifier	Works with Universal NAND driver?	Works with SLC1 NAND driver?	Hardware layer type
`FS_NAND_PHY_512x8`	no	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_2048x8`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_2048x8_TwoPlane`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_2048x8_Small`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_2048x16`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_4096x8`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_DataFlash`	no	yes	`FS_NAND_HW_TYPE_DF`
`FS_NAND_PHY_ONFI`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_ONFI_RO`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_ONFI_Small`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_QSPI`	yes	no	`FS_NAND_HW_TYPE_QSPI`
`FS_NAND_PHY_SPI`	yes	no	`FS_NAND_HW_TYPE_SPI`
`FS_NAND_PHY_x`	yes	yes	`FS_NAND_HW_TYPE`
`FS_NAND_PHY_x8`	yes	yes	`FS_NAND_HW_TYPE`

The following sections provide information about the usage and the implementation of a NAND physical layer.

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6.3.4.2 512x8 physical layer

This NAND physical layer supports any NAND flash device with a page size of 512 bytes and a spare area of 16 bytes that is connected to the MCU via an 8-bit data bus. It works only with the SLC1 NAND driver because the size of the spare area is not sufficiently large for the amount of management data required by the Universal NAND driver. The instances of this physical layer are allocated statically. The maximum number of instances can be configured at compile time via `FS_NAND_NUM_UNITS`.

6.3.4.2.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 512x8 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_512x8_SetHWType()`	Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_512x8`.

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6.3.4.2.1.1 FS_NAND_512x8_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_512x8.

Prototype

```
void FS_NAND_512x8_SetHWType(      U8                Unit,
                             const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_512x8.

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6.3.4.3 2048x8 physical layer

This NAND physical layer supports any NAND flash device with a page size of 2048 bytes and a spare area larger than or equal to 64 bytes that is connected to the MCU via an 8-bit data bus. The instances of this physical layer are allocated dynamically. The maximum number of instances can be configured at compile time via `FS_NAND_NUM_UNITS`.

6.3.4.3.1 Compile time configuration

The 2048x8 physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
`FS_NAND_2048X8_DEVICE_LIST_DEFAULT`	`&FS_NAND_2048X8_DeviceListDefault`	R	List of parallel NAND flash devices that can be handled by the physical layer.
`FS_NAND_SUPPORT_READ_CACHE`	0	B	Specifies if the internal page register of the NAND flash device should be used as read cache.

6.3.4.3.1.1 FS_NAND_2048X8_DEVICE_LIST_DEFAULT

`FS_NAND_2048X8_DEVICE_LIST_DEFAULT` specifies the list of parallel NAND flash devices that can be handled by the physical layer. It can be set to `NULL` in order to reduce the ROM usage if not all the devices included in `FS_NAND_2048X8_DeviceListDefault` have to be handled. In this case, it is mandatory that the application configures a list of devices via `FS_NAND_2048X8_SetDeviceList()`.

6.3.4.3.1.2 FS_NAND_SUPPORT_READ_CACHE

With `FS_NAND_SUPPORT_READ_CACHE` set to 1 the physical layer keeps track of the index of the last page read from the NAND flash device. If the same page is read again then the physical layer omits the operation that transfers the page data from the memory array to the internal page register of the NAND flash device. In this case, only a data transfer from the internal page register to the host is executed which helps improve the performance.

> **Note**
>
> This feature cannot be used if the NAND flash device is partitioned via either `FS_NAND_SetBlockRange()` or `FS_NAND_UNI_SetBlockRange()` and the created partitions are accessed via the file system.

6.3.4.3.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 2048x8 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_2048x8_DisableReadCache()`	Deactivates the page read optimization.
`FS_NAND_2048x8_EnableReadCache()`	Activates the page read optimization.
`FS_NAND_2048X8_SetDeviceList()`	Specifies the list of NAND flash devices that require special handling.

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Function	Description
FS_NAND_2048x8_SetHWType()	Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_2048x8.

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6.3.4.3.2.1 FS_NAND_2048x8_DisableReadCache()

Description

Deactivates the page read optimization.

Prototype

```
void FS_NAND_2048x8_DisableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. The optimization can be enabled at runtime via FS_NAND_2048x8_EnableReadCache().

Refer to FS_NAND_2048x8_EnableReadCache() for more information about how the page read optimization works

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6.3.4.3.2.2 FS_NAND_2048x8_EnableReadCache()

Description

Activates the page read optimization.

Prototype

```
void FS_NAND_2048x8_EnableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. Activating the read cache can increase the overall performance of the NAND driver especially when using the SLC1 NAND driver with a logical sector size smaller than the page of the used NAND flash device.

The optimization takes advantage of how the NAND flash device implements the read page operation. A NAND page read operation consists of two steps. In the first step, the page data is read from the memory array to internal page register of the NAND flash device. In the second step, the data is transferred from the internal page register of NAND flash device to MCU. With the optimization enabled the first step is skipped whenever possible.

The optimization is enabled by default and has to be disabled if two or more instances of the NAND driver are configured to access the same physical NAND flash device. At runtime, the optimization can be disabled via FS_NAND_2048x8_DisableReadCache().

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6.3.4.3.2.3 FS_NAND_2048X8_SetDeviceList()

Description

Specifies the list of NAND flash devices that require special handling.

Prototype

```
void FS_NAND_2048X8_SetDeviceList(      U8                            Unit,
                                  const FS_NAND_2048X8_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pDeviceList	in List of NAND flash devices.

Additional information

NAND flash devices that do not require special handling such as devices without HW ECC are always enabled. The special handling is required for example to determine if the HW ECC of the NAND flash device can be enabled and disabled at runtime.

By default, only special handling for NAND flash devices from Samsung and Toshiba is enabled (FS_NAND_ONFI_DeviceListDefault). The correct operation of NAND flash device from a manufacturer not included in the configured list of devices is not guaranteed if the NAND flash device requires special handling.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NAND_2048X8_DeviceListAll
FS_NAND_2048X8_DeviceListDefault
FS_NAND_2048X8_DeviceListStandard
FS_NAND_2048X8_DeviceListSamsung
FS_NAND_2048X8_DeviceListToshiba

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6.3.4.3.2.4 FS_NAND_2048x8_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_2048x8.

Prototype

```
void FS_NAND_2048x8_SetHWType(      U8                Unit,
                              const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_2048x8.

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6.3.4.4 Two-plane 2048x8 physical layer

This NAND physical layer supports any NAND flash device with a page size of 2048 bytes and a spare area larger than or equal to 64 bytes that is connected to the MCU via an 8-bit data bus. In addition, the NAND flash device has to be organized in two planes and provide support for executing an operation on both planes simultaneously. The instances of this physical layer are allocated dynamically. The maximum number of instances can be configured at build time via `FS_NAND_NUM_UNITS`.

`FS_NAND_PHY_2048x8_TwoPlane` uses the same runtime functions and compile time configuration defines as `FS_NAND_PHY_2048x8`.

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6.3.4.5 Small 2048x8 physical layer

This physical layer is a variant of FS_NAND_PHY_2048x8 with reduced ROM usage. FS_NAND_PHY_2048x8_Small supports the same NAND flash devices as FS_NAND_PHY_2048x8 but it does not provide support for the NAND internal page copy operation and for reading the ECC correction result. FS_NAND_PHY_2048x8_Small provides read as well as write access to a NAND flash device. The instances of this physical layer are allocated statically.

FS_NAND_PHY_2048x8_Small uses the same runtime functions and compile time configuration defines as FS_NAND_PHY_2048x8.

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6.3.4.6 2048x16 physical layer

This physical layer supports NAND flash devices with a page size of 2048 bytes and a spare area larger than or equal to 64 bytes that is connected to the MCU via a 16-bit data bus. The instances of this physical layer are allocated statically. The maximum number of instances can be configured at build time via `FS_NAND_NUM_UNITS`.

6.3.4.6.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 2048x16 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_2048x16_SetHWType()`	Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_2048x16`.

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6.3.4.6.1.1 FS_NAND_2048x16_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_2048x16.

Prototype

```
void FS_NAND_2048x16_SetHWType(      U8                Unit,
                               const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_2048x16.

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6.3.4.7 4096x8 physical layer

This NAND physical layer supports any NAND flash device with a page size of 4096 bytes and a spare area larger than or equal to 128 bytes that is connected to MCU via an 8-bit data bus. The instances of this physical layer are allocated statically. The maximum number of instances can be configured at build time via `FS_NAND_NUM_UNITS`.

6.3.4.7.1 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 4096x8 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_4096x8_SetHWType()`	Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_4096x8`.

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6.3.4.7.1.1 FS_NAND_4096x8_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_4096x8.

Prototype

```
void FS_NAND_4096x8_SetHWType(      U8                Unit,
                              const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_4096x8.

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6.3.4.8 DataFlash physical layer

This physical layer supports Dialog Semiconductor / Adesto / Atmel DataFlash storage devices. The devices are accessed via SPI using a hardware layer of type FS_NAND_HW_TYPE_DF. FS_NAND_PHY_DataFlash works only with the SLC1 NAND driver because the size of the spare area is not sufficiently large for the amount of management data required by the Universal NAND driver. The instances of this physical layer are allocated statically.

6.3.4.8.1 Compile time configuration

The DataFlash physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_BLOCK_TYPE	2	N	Specifies the size of the erase unit.
FS_NAND_SUPPORT_READ_CACHE	0	B	Specifies if the internal page register of the DataFlash device should be used as read cache.

6.3.4.8.1.1 FS_NAND_BLOCK_TYPE

FS_NAND_BLOCK_TYPE can be used to specify the size of the erase unit used by the DataFlash physical layer. The following erase unit sizes are supported: 1 block large (FS_NAND_BLOCK_TYPE = 0), 8 blocks large (FS_NAND_BLOCK_TYPE = 1) and 1 sector large (FS_NAND_BLOCK_TYPE = 2). By default FS_NAND_BLOCK_TYPE is set to 2 because it ensures maximum performance.

> **Note**
>
> The physical layer is not fail-safe when FS_NAND_BLOCK_TYPE is set to 1 because more than one erase operation has to be performed in order to erase the entire block.

6.3.4.8.1.2 FS_NAND_SUPPORT_READ_CACHE

With FS_NAND_SUPPORT_READ_CACHE set to 1, the physical layer keeps track of the index of the last page read from the DataFlash device. If the same page is read again, then the physical layer omits the operation that transfers the page data from the memory array to the internal page register of the DataFlash device. In this case, only a data transfer from the internal page register to the host is executed, which helps improve performance.

> **Note**
>
> This feature cannot be used if the DataFlash device is partitioned via FS_NAND_SetBlockRange() and the created partitions are accessed via the file system.

6.3.4.8.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the DataFlash physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NAND_DF_EraseChip()	Erases the entire device.

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Function	Description
FS_NAND_DF_SetMinPageSize()	Configures the required minimum page size.
FS_NAND_DF_SetHWType()	Configures the hardware access routines.

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6.3.4.8.2.1 FS_NAND_DF_EraseChip()

Description

Erases the entire device.

Prototype

```
void FS_NAND_DF_EraseChip(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)

Additional information

This function is optional. It sets all the bits of the DataFlash memory to 1. All the data stored on the DataFlash memory is lost.

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6.3.4.8.2.2 FS_NAND_DF_SetMinPageSize()

Description

Configures the required minimum page size.

Prototype

```
void FS_NAND_DF_SetMinPageSize(U8  Unit,
                               U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
NumBytes	Page size in bytes.

Additional information

This function is optional. The application can use it to request a minimum page size to work with. If the size of the physical page is smaller than the specified value then adjacent physical pages are grouped together into one virtual page that is presented as a single page to the SLC1 NAND driver. This is required when the size of a physical page is smaller than 512 bytes which is the minimum sector size the SLC1 NAND driver can work with. NumBytes has to be a power of 2 value.

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6.3.4.8.2.3 FS_NAND_DF_SetHWType()

Description

Configures the hardware access routines.

Prototype

```
void FS_NAND_DF_SetHWType(      U8                    Unit,
                          const FS_NAND_HW_TYPE_DF * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pHWType	Table of hardware routines.

Additional information

This function is mandatory and it has to be called once for each used instance of the physical layer.

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6.3.4.9 ONFI physical layer

This physical layer supports NAND flash devices that are compliant with the ONFI specification. The organization of the NAND flash device such as page size and number of blocks is determined automatically by evaluating the parameters stored in the NAND flash device according to the ONFI specification. The instances of this physical layer are allocated dynamically.

6.3.4.9.1 Compile time configuration

The ONFI physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_ONFI_DEVICE_LIST_DEFAULT	&FS_NAND_ONFI_DeviceListDefault	R	List of parallel NAND flash devices that can be handled by the physical layer.
FS_NAND_SUPPORT_EXT_ONFI_PARA	0	B	Specifies if the extended ONFI parameters have to be evaluated or not.

6.3.4.9.1.1 FS_NAND_ONFI_DEVICE_LIST_DEFAULT

FS_NAND_ONFI_DEVICE_LIST_DEFAULT specifies the list of parallel NAND flash devices that can be handled by the physical layer. It can be set to NULL in order to reduce the ROM usage if not all the devices included in FS_NAND_ONFI_DeviceListDefault have to be handled. In this case, it is mandatory that the application configures a list of devices via FS_NAND_ONFI_SetDeviceList().

6.3.4.9.1.2 FS_NAND_SUPPORT_EXT_ONFI_PARA

FS_NAND_SUPPORT_EXT_ONFI_PARA can be used to enable the evaluation of extended ONFI parameters. By default, the ONFI physical layer evaluates only the standard ONFI parameters. The extended ONFI parameters provide, for example, additional information about the bit error correction. Setting FS_NAND_SUPPORT_EXT_ONFI_PARA to 0 reduces the ROM usage.

6.3.4.9.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the ONFI physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NAND_ONFI_SetHWType()	Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_ONFI.
FS_NAND_ONFI_SetDeviceList()	Specifies the list of ONFI NAND flash devices that require special handling.

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6.3.4.9.2.1 FS_NAND_ONFI_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_ONFI`.

Prototype

```
void FS_NAND_ONFI_SetHWType(      U8                Unit,
                            const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
`Unit`	Index of the physical layer instance (0-based)
`pHWType`	Type of the hardware layer to use. Cannot be `NULL`.

Additional information

This function is mandatory and has to be called once in `FS_X_AddDevices()` for every instance of a NAND physical layer of type `FS_NAND_PHY_ONFI`.

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6.3.4.9.2.2 FS_NAND_ONFI_SetDeviceList()

Description

Specifies the list of ONFI NAND flash devices that require special handling.

Prototype

```
void FS_NAND_ONFI_SetDeviceList(      U8                          Unit,
                                const FS_NAND_ONFI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pDeviceList	in List of ONFI NAND flash devices.

Additional information

NAND flash devices that do not require special handling such as devices without HW ECC are always enabled. The special handling is required for example to determine if the HW ECC of the NAND flash device can be enabled and disabled at runtime.

By default, only special handling for NAND flash devices from Micron and Macronix is enabled (FS_NAND_ONFI_DeviceListDefault). The correct operation of NAND flash device from a manufacturer not included in the configured list of devices is not guaranteed if the NAND flash device requires special handling.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NAND_ONFI_DeviceListAll
FS_NAND_ONFI_DeviceListAllianceMemory
FS_NAND_ONFI_DeviceListDefault
FS_NAND_ONFI_DeviceListGigaDevice
FS_NAND_ONFI_DeviceListISSI
FS_NAND_ONFI_DeviceListMacronix
FS_NAND_ONFI_DeviceListMicron
FS_NAND_ONFI_DeviceListSkyHigh
FS_NAND_ONFI_DeviceListWinbond

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6.3.4.10 Read-only ONFI physical layer

This physical layer is a variant of FS_NAND_PHY_ONFI with read-only access. FS_NAND_PHY_ONFI_RO provides the same functionality as FS_NAND_PHY_ONFI except that it can only read data stored on the NAND flash device. The erase and write functions of FS_NAND_PHY_ONFI_RO do nothing and return an error to the NAND driver when called.

FS_NAND_PHY_ONFI_RO uses the same runtime configuration functions and compile time configuration defines as FS_NAND_PHY_ONFI.

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6.3.4.11 Small ONFI physical layer

This physical layer is a variant of FS_NAND_PHY_ONFI with reduced ROM usage. FS_NAND_PHY_ONFI_Small supports the same NAND flash devices as FS_NAND_PHY_ONFI but it does not provide support for the internal page copy operation and for reading the ECC correction result. FS_NAND_PHY_ONFI_Small provides read as well as write access to a NAND flash device.

FS_NAND_PHY_ONFI_Small uses the same runtime configuration functions and compile time configuration defines as FS_NAND_PHY_ONFI.

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6.3.4.12 Quad-SPI physical layer

This physical layer supports NAND flash devices interfaced via quad or dual SPI. The organization of the NAND flash device such as page size and number of blocks is determined automatically by evaluating the parameters stored in the NAND flash device. The instances of this physical layer are allocated dynamically.

6.3.4.12.1 Compile time configuration

The QSPI physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_DEVICE_OPERATION_TIMEOUT	500	N	Timeout for a NAND flash device operation in milliseconds.
FS_NAND_RESET_TIME	2	N	Time to wait for the device to become ready after reset in milliseconds.
FS_NAND_SPI_DEVICE_LIST_DEFAULT	&FS_NAND_SPI_DeviceListAll	R	List of serial NAND flash devices that can be handled by the physical layer.
FS_NAND_SUPPORT_COMPATIBILITY_MODE	0	N	Specifies the operating mode of the physical layer.
FS_NAND_SUPPORT_READ_CACHE	1	B	Specifies if the internal page register of the NAND flash should be used as read cache.

6.3.4.12.1.1 FS_NAND_DEVICE_OPERATION_TIMEOUT

FS_NAND_DEVICE_OPERATION_TIMEOUT specifies the maximum time in milliseconds the physical layer has to wait for a NAND flash operation to complete. This timeout is used for the read, write, and erase operations. This value has to be set according to the timings specified in the data sheet of the NAND flash device.

6.3.4.12.1.2 FS_NAND_RESET_TIME

FS_NAND_RESET_TIME specifies the time in milliseconds the physical layer waits for the NAND flash device to become ready after a reset command. This value has to be set according to the timings specified in the data sheet of the NAND flash device.

6.3.4.12.1.3 FS_NAND_SPI_DEVICE_LIST_DEFAULT

FS_NAND_SPI_DEVICE_LIST_DEFAULT specifies the list of serial NAND flash devices that can be handled by the physical layer. It can be set to NULL in order to reduce the ROM usage if not all the devices included in FS_NAND_SPI_DeviceListDefault have to be handled. In this case, it is mandatory that the application configures a list of devices via FS_NAND_QSPI_SetDeviceList().

6.3.4.12.1.4 FS_NAND_SUPPORT_COMPATIBILITY_MODE

emFile versions older than 4.06b wrongly stored the management data in a region of the spare area that was not protected by the HW ECC. This behavior affects only configurations that use the Micron MT29F1G01ABAFD NAND flash device. The correction of this behavior introduces a data compatibility issue that can be avoided by setting this define either to 1 or to 2. With FS_NAND_SUPPORT_COMPATIBILITY_MODE set to 1 the physical layer reads the management data from the old location if at the new location no management data is present. With FS_NAND_SUPPORT_COMPATIBILITY_MODE set to 2 the physical layer updates the

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management data to the old and new locations in addition to trying to read it from both of these locations.

6.3.4.12.1.5 FS_NAND_SUPPORT_READ_CACHE

With FS_NAND_SUPPORT_READ_CACHE set to 1 the physical layer keeps track of the index of the last page read from the serial NAND flash device. If the same page is read again then the physical layer omits the operation that transfers the page data from the memory array to the internal page register of the serial NAND flash device. In this case, only a data transfer from the internal page register to the host is executed, which helps improve the performance.

> **Note**
>
> This feature cannot be used if the NAND flash device is partitioned via FS_NAND_UNI_SetBlockRange() and the created partitions are accessed via the file system.

6.3.4.12.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the QSPI physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NAND_QSPI_Allow2bitMode()	Specifies if the physical layer can exchange data via 2 data lines.
FS_NAND_QSPI_Allow4bitMode()	Specifies if the physical layer can exchange data via 4 data lines.
FS_NAND_QSPI_AllowDTRMode()	Specifies if the physical layer is permitted to exchange data on both clock edges.
FS_NAND_QSPI_DisableReadCache()	Deactivates the page read optimization.
FS_NAND_QSPI_EnableReadCache()	Activates the page read optimization.
FS_NAND_QSPI_SetDeviceList()	Specifies the list of enabled serial NAND flash devices.
FS_NAND_QSPI_SetHWType()	Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_QSPI.

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6.3.4.12.2.1 FS_NAND_QSPI_Allow2bitMode()

Description

Specifies if the physical layer can exchange data via 2 data lines.

Prototype

```
void FS_NAND_QSPI_Allow2bitMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
OnOff	Activation status of the option. • 0 Data is exchanged via 1 data line. • 1 Data is exchanged via 2 data lines.

Additional information

This function is optional. By default the data is exchanged via 1 data line (standard SPI mode).

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6.3.4.12.2.2 FS_NAND_QSPI_Allow4bitMode()

Description

Specifies if the physical layer can exchange data via 4 data lines.

Prototype

```
void FS_NAND_QSPI_Allow4bitMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
OnOff	Activation status of the option. • 0 Data is exchanged via 1 data line or 2 data lines. • 1 Data is exchanged via 4 data lines.

Additional information

This function is optional. By default the data is exchanged via 1 data line (standard SPI mode).

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6.3.4.12.2.3 FS_NAND_QSPI_AllowDTRMode()

Description

Specifies if the physical layer is permitted to exchange data on both clock edges.

Prototype

```
void FS_NAND_QSPI_AllowDTRMode(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged only on one of the clock edges (SDR mode). In DTR mode the data is transferred on each edge of the clock which helps improve the performance.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

The DTR mode is enabled only if the configured hardware layer implements the optional function `FS_NAND_HW_TYPE_QSPI_READ_EX`.

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6.3.4.12.2.4 FS_NAND_QSPI_DisableReadCache()

Description

Deactivates the page read optimization

Prototype

```
void FS_NAND_QSPI_DisableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. The optimization can be enabled at runtime via FS_NAND_QSPI_EnableReadCache().

Refer to FS_NAND_QSPI_EnableReadCache() for more information about how the page read optimization works

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6.3.4.12.2.5 FS_NAND_QSPI_EnableReadCache()

Description

Activates the page read optimization

Prototype

```
void FS_NAND_QSPI_EnableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. Activating the read cache can increase the overall performance of the NAND driver.

The optimization takes advantage of how the NAND flash device implements the read page operation. A NAND page read operation consists of two steps. In the first step, the page data is read from the memory array to internal page register of the NAND flash device. In the second step, the data is transferred from the internal page register of NAND flash device to MCU. With the optimization enabled the first step is skipped whenever possible.

The optimization is enabled by default and has to be disabled if two or more instances of the NAND driver are configured to access the same physical NAND flash device. At runtime, the optimization can be disabled via FS_NAND_QSPI_DisableReadCache().

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6.3.4.12.2.6 FS_NAND_QSPI_SetDeviceList()

Description

Specifies the list of enabled serial NAND flash devices.

Prototype

```
void FS_NAND_QSPI_SetDeviceList(      U8                          Unit,
                                const FS_NAND_SPI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pDeviceList	in List of serial NAND flash devices.

Additional information

All supported serial NAND flash devices are enabled by default. Serial NAND flash devices that are not on the list are not recognized by the file system.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NAND_SPI_DeviceListAll
FS_NAND_SPI_DeviceListAllianceMemory
FS_NAND_SPI_DeviceList-Default
FS_NAND_SPI_DeviceListEtron
FS_NAND_SPI_DeviceList-Foresee
FS_NAND_SPI_DeviceList-GigaDevice
FS_NAND_SPI_DeviceListISSI
FS_NAND_SPI_DeviceList-Macronix
FS_NAND_SPI_DeviceList-Micron
FS_NAND_SPI_DeviceListSkyHigh
FS_NAND_SPI_DeviceList-Toshiba
FS_NAND_SPI_DeviceList-Winbond

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6.3.4.12.2.7 FS_NAND_QSPI_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_QSPI.

Prototype

```
void FS_NAND_QSPI_SetHWType(      U8                      Unit,
                            const FS_NAND_HW_TYPE_QSPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_QSPI.

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6.3.4.13 SPI physical layer

This physical layer supports NAND flash devices interfaced via standard SPI. The organization of the NAND flash device such as page size and number of blocks is determined automatically by evaluating the parameters stored in the NAND flash device. The instances of this physical layer are allocated dynamically.

6.3.4.13.1 Compile time configuration

The SPI physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_DEVICE_OPERATION_TIMEOUT	500	N	Timeout for a NAND flash device operation in milliseconds.
FS_NAND_RESET_TIME	2	N	Time to wait for the device to become ready after reset in milliseconds.
FS_NAND_SPI_DEVICE_LIST_DEFAULT	&FS_NAND_SPI_DeviceListAll	R	List of serial NAND flash devices that can be handled by the physical layer.
FS_NAND_SUPPORT_COMPATIBILITY_MODE	0	N	Specifies the operating mode of the physical layer.
FS_NAND_SUPPORT_READ_CACHE	1	B	Specifies if the internal page register of the NAND flash should be used as read cache.

6.3.4.13.1.1 FS_NAND_DEVICE_OPERATION_TIMEOUT

FS_NAND_DEVICE_OPERATION_TIMEOUT specifies the maximum time in milliseconds the physical layer has to wait for a NAND flash operation to complete. This value has to be set according to the timings specified in the data sheet of the NAND flash device.

6.3.4.13.1.2 FS_NAND_RESET_TIME

FS_NAND_RESET_TIME specifies the time in milliseconds the physical layer waits for the NAND flash device to become ready after a reset command. This value has to be set according to the timings specified in the data sheet of the NAND flash device.

6.3.4.13.1.3 FS_NAND_SPI_DEVICE_LIST_DEFAULT

FS_NAND_SPI_DEVICE_LIST_DEFAULT specifies the list of serial NAND flash devices that can be handled by the physical layer. It can be set to NULL in order to reduce the ROM usage if not all the devices included in FS_NAND_SPI_DeviceListDefault have to be handled. In this case it is mandatory that the application configures a list of devices via FS_NAND_SPI_SetDeviceList().

6.3.4.13.1.4 FS_NAND_SUPPORT_COMPATIBILITY_MODE

emFile versions older than 4.06b wrongly stored the management data to a region of the spare area that was not protected by the HW ECC. This behavior affects only configurations that use the Micron MT29F1G01ABAFD NAND flash device. The correction of this behavior introduces a data compatibility issue that can be avoided by setting this define either to 1 or to 2. With FS_NAND_SUPPORT_COMPATIBILITY_MODE set to 1 the physical layer reads the management data from the old location if at the new location no management data is present. With FS_NAND_SUPPORT_COMPATIBILITY_MODE set to 2 the physical layer updates the

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management data to the old and new locations in addition to trying to read it from both of these locations.

6.3.4.13.1.5 FS_NAND_SUPPORT_READ_CACHE

With `FS_NAND_SUPPORT_READ_CACHE` set to 1 the physical layer keeps track of the index of the last page read from the serial NAND flash device. If the same page is read again then the physical layer omits the operation that transfers the page data from the memory array to the internal page register of the serial NAND flash device. In this case only a data transfer from the internal page register to the host is executed which helps improve the performance.

> **Note**
>
> This feature cannot be used if the NAND flash device is partitioned via `FS_NAND_UNI_SetBlockRange()` and the created partitions are accessed via the file system.

6.3.4.13.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the SPI physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NAND_SPI_DisableReadCache()`	Deactivates the page read optimization.
`FS_NAND_SPI_EnableReadCache()`	Activates the page read optimization.
`FS_NAND_SPI_SetDeviceList()`	Specifies the list of enabled serial NAND flash devices.
`FS_NAND_SPI_SetHWType()`	Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_SPI`.

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6.3.4.13.2.1 FS_NAND_SPI_DisableReadCache()

Description

Deactivates the page read optimization

Prototype

```
void FS_NAND_SPI_DisableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. The optimization can be enabled at runtime via FS_NAND_SPI_EnableReadCache().

Refer to FS_NAND_SPI_EnableReadCache() for more information about how the page read optimization works

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6.3.4.13.2.2 FS_NAND_SPI_EnableReadCache()

Description

Activates the page read optimization

Prototype

```
void FS_NAND_SPI_EnableReadCache(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is optional and is available only when the file system is build with FS_NAND_SUPPORT_READ_CACHE set to 1 which is the default. Activating the read cache can increase the overall performance of the NAND driver.

The optimization takes advantage of how the NAND flash device implements the read page operation. A NAND page read operation consists of two steps. In the first step, the page data is read from the memory array to internal page register of the NAND flash device. In the second step, the data is transferred from the internal page register of NAND flash device to MCU. With the optimization enabled the first step is skipped whenever possible.

The optimization is enabled by default and has to be disabled if two or more instances of the NAND driver are configured to access the same physical NAND flash device. At runtime, the optimization can be disabled via FS_NAND_SPI_DisableReadCache().

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6.3.4.13.2.3 FS_NAND_SPI_SetDeviceList()

Description

Specifies the list of enabled serial NAND flash devices.

Prototype

```
void FS_NAND_SPI_SetDeviceList(      U8                          Unit,
                               const FS_NAND_SPI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pDeviceList	in List of serial NAND flash devices.

Additional information

All supported serial NAND flash devices are enabled by default. Serial NAND flash devices that are not on the list are not recognized by the file system.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NAND_SPI_DeviceListAll
FS_NAND_SPI_DeviceListAllianceMemory
FS_NAND_SPI_DeviceListDefault
FS_NAND_SPI_DeviceListGigaDevice
FS_NAND_SPI_DeviceListISSI
FS_NAND_SPI_DeviceListMacronix
FS_NAND_SPI_DeviceListMicron
FS_NAND_SPI_DeviceListToshiba
FS_NAND_SPI_DeviceListWinbond

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6.3.4.13.2.4 FS_NAND_SPI_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type `FS_NAND_PHY_SPI`.

Prototype

```
void FS_NAND_SPI_SetHWType(      U8                     Unit,
                           const FS_NAND_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
`Unit`	Index of the physical layer instance (0-based)
`pHWType`	Type of the hardware layer to use. Cannot be `NULL`.

Additional information

This function is mandatory and has to be called once in `FS_X_AddDevices()` for every instance of a NAND physical layer of type `FS_NAND_PHY_SPI`.

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6.3.4.14 8/16-bit data bus physical layer

This physical layer supports all the NAND flash devices supported by the following NAND physical layers:

- FS_NAND_PHY_512x8
- FS_NAND_PHY_2048x8
- FS_NAND_PHY_2048x16
- FS_NAND_PHY_4096x8
- FS_NAND_PHY_ONFI

6.3.4.14.1 Compile time configuration

The 16/8-bit data bus physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_SUPPORT_AUTO_DETECTION	1	B	Specifies if the parameters of the NAND flash device have to be automatically detected or not.

6.3.4.14.1.1 FS_NAND_SUPPORT_AUTO_DETECTION

By default, the 8-bit data bus physical layer tries to automatically detect the parameters of the NAND flash device such as the number of blocks and the number of pages per block by evaluating the value returned as a response to the READ ID (0x90) command. This behavior can be disabled by building the physical layer with FS_NAND_SUPPORT_AUTO_DETECTION set to 0. In this case, the application must call FS_NAND_x_Configure() in FS_X_AddDevices() to specify the parameters of the NAND flash device.

6.3.4.14.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 16/8-bit data bus physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NAND_x_Configure()	Configures the parameters of the NAND flash device for a NAND physical layer of type FS_NAND_PHY_x.
FS_NAND_x_SetHWType()	Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_x.

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6.3.4.14.2.1 FS_NAND_x_Configure()

Description

Configures the parameters of the NAND flash device for a NAND physical layer of type FS_NAND_PHY_x.

Prototype

```
void FS_NAND_x_Configure(U8       Unit,
                         unsigned NumBlocks,
                         unsigned PagesPerBlock,
                         unsigned BytesPerPage,
                         unsigned BytesPerSpareArea,
                         unsigned DataBusWidth);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
NumBlocks	Total number of blocks in the NAND flash device.
PagesPerBlock	Total number of pages in a NAND block.
BytesPerPage	Number of bytes in a page without the spare area.
BytesPerSpareArea	Number of bytes in the spare area of a NAND page.
DataBusWidth	Number of data lines used for data exchange.

Additional information

This function is mandatory only when the file system is built with FS_NAND_SUPPORT_AUTO_DETECTION set to 0 which is not the default. FS_NAND_x_Configure() has to be called once in FS_X_AddDevices() for each instance of the FS_NAND_PHY_x physical layer. FS_NAND_x_Configure() is not available if FS_NAND_SUPPORT_AUTO_DETECTION is set to 0.

By default, the FS_NAND_PHY_x physical layer identifies the parameters of the NAND flash device by evaluating the first and second byte of the reply returned by the NAND flash device to the READ ID (0x90) command. The identification operation is disabled if FS_NAND_SUPPORT_AUTO_DETECTION set to 0 and the application must specify the NAND flash parameters via this function.

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6.3.4.14.2.2 FS_NAND_x_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_x.

Prototype

```
void FS_NAND_x_SetHWType(      U8                Unit,
                         const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function is mandatory and has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_x.

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6.3.4.15 8-bit data bus physical layer

This physical layer supports all the NAND flash devices supported by the following NAND physical layers:

- FS_NAND_PHY_512x8
- FS_NAND_PHY_2048x8
- FS_NAND_PHY_4096x8
- FS_NAND_PHY_ONFI

6.3.4.15.1 Compile time configuration

The 8-bit data bus physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NAND_SUPPORT_AUTO_DETECTION	1	B	Specifies if the parameters of the NAND flash device have to be automatically detected or not.

6.3.4.15.1.1 FS_NAND_SUPPORT_AUTO_DETECTION

By default, the 8-bit data bus physical layer tries to automatically detect the parameters of the NAND flash device such as the number of blocks and the number of pages in a block by evaluating the value returned as a response to the READ ID (0x90) command. This behavior can be disabled by building the physical layer with FS_NAND_SUPPORT_AUTO_DETECTION set to 0. In this case, the application must call FS_NAND_x8_Configure() in FS_X_AddDevices() to specify the parameters of the NAND flash device.

6.3.4.15.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the 8-bit data bus physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NAND_x8_Configure()	Configures the parameters of the NAND flash device for a NAND physical layer of type FS_NAND_PHY_x8.
FS_NAND_x8_SetHWType()	Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_x8.

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6.3.4.15.2.1 FS_NAND_x8_Configure()

Description

Configures the parameters of the NAND flash device for a NAND physical layer of type FS_NAND_PHY_x8.

Prototype

```
void FS_NAND_x8_Configure(U8       Unit,
                          unsigned NumBlocks,
                          unsigned PagesPerBlock,
                          unsigned BytesPerPage,
                          unsigned BytesPerSpareArea);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
NumBlocks	Total number of blocks in the NAND flash device.
PagesPerBlock	Total number of pages in a NAND block.
BytesPerPage	Number of bytes in a page without the spare area.
BytesPerSpareArea	Number of bytes in the spare area of a NAND page.

Additional information

This function is mandatory only when the file system is built with FS_NAND_SUPPORT_AUTO_DETECTION set to 0 which is not the default. FS_NAND_x_Configure() has to be called once in FS_X_AddDevices() for each instance of the FS_NAND_PHY_x8 physical layer. FS_NAND_x_Configure() is not available if FS_NAND_SUPPORT_AUTO_DETECTION is set to 0.

By default, the FS_NAND_PHY_x8 physical layer identifies the parameters of the NAND flash device by evaluating the first and second byte of the reply returned by the NAND flash device to the READ ID (0x90) command. The identification operation is disabled if FS_NAND_SUPPORT_AUTO_DETECTION set to 0 and the application must specify the NAND flash parameters via this function.

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6.3.4.15.2.2 FS_NAND_x8_SetHWType()

Description

Configures the hardware access routines for a NAND physical layer of type FS_NAND_PHY_x8.

Prototype

```
void FS_NAND_x8_SetHWType(      U8                Unit,
                          const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. Cannot be NULL.

Additional information

This function has to be called once in FS_X_AddDevices() for every instance of a NAND physical layer of type FS_NAND_PHY_x8.

6.3.4.16 Physical layer API

The physical layers that come with emFile provide support for most of the popular NAND flash device and target MCU types. Therefore, there is no need to modify any of the provided NAND physical layers. Typically, only the NAND hardware layer has to be adapted to specific target hardware. However, when none of the provided NAND physical layers are compatible with the target hardware, a new NAND physical layer implementation is required. This section provides information about the API of the NAND physical layer that helps to create a new physical layer from scratch or to modify an existing one.

The API of the physical layer is implemented as a structure of type FS_NAND_PHY_TYPE that contains pointers to functions. The following sections describe these functions in detail together with the data structure passed to these functions as parameters.

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6.3.4.16.1 FS_NAND_PHY_TYPE

Description

NAND physical layer API.

Type definition

```
typedef struct {
  FS_NAND_PHY_TYPE_ERASE_BLOCK          * pfEraseBlock;
  FS_NAND_PHY_TYPE_INIT_GET_DEVICE_INFO * pfInitGetDeviceInfo;
  FS_NAND_PHY_TYPE_IS_WP                * pfIsWP;
  FS_NAND_PHY_TYPE_READ                 * pfRead;
  FS_NAND_PHY_TYPE_READ_EX              * pfReadEx;
  FS_NAND_PHY_TYPE_WRITE                * pfWrite;
  FS_NAND_PHY_TYPE_WRITE_EX             * pfWriteEx;
  FS_NAND_PHY_TYPE_ENABLE_ECC           * pfEnableECC;
  FS_NAND_PHY_TYPE_DISABLE_ECC          * pfDisableECC;
  FS_NAND_PHY_TYPE_CONFIGURE_ECC        * pfConfigureECC;
  FS_NAND_PHY_TYPE_COPY_PAGE            * pfCopyPage;
  FS_NAND_PHY_TYPE_GET_ECC_RESULT       * pfGetECCResult;
  FS_NAND_PHY_TYPE_DEINIT               * pfDeInit;
  FS_NAND_PHY_TYPE_SET_RAW_MODE         * pfSetRawMode;
} FS_NAND_PHY_TYPE;
```

Structure members

Member	Description
pfEraseBlock	Erases a NAND block.
pfInitGetDeviceInfo	Initializes the physical layer.
pfIsWP	Checks the write protection status of NAND flash device.
pfRead	Reads data from a NAND page.
pfReadEx	Reads data from a NAND page.
pfWrite	Writes data to a NAND page.
pfWriteEx	Writes data to a NAND page.
pfEnableECC	Enables the hardware ECC.
pfDisableECC	Disables the hardware ECC.
pfConfigureECC	Configures the hardware ECC.
pfCopyPage	Copies a NAND page.
pfGetECCResult	Returns the result of bit correction via ECC.
pfDeInit	Frees allocated resources.
pfSetRawMode	Enables or disables the raw operation mode.

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6.3.4.16.2 FS_NAND_PHY_TYPE_ERASE_BLOCK

Description

Erases a NAND block.

Type definition

```
typedef int FS_NAND_PHY_TYPE_ERASE_BLOCK(U8  Unit,
                                         U32 PageIndex);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndex	Index of the first page in the NAND block to be erased (0-based)

Return value

= 0 OK, the NAND block has been erased.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It is mandatory to be implemented by all the NAND physical layers. It is called by the NAND driver to set to 1 all the bits of a NAND block. A NAND block is the smallest erasable unit of a NAND flash device.

The index of the actual NAND block to be erased depends on the number of pages stored in a NAND block. For example if the NAND block contains 64 pages, then the PageIndex parameter passed by the NAND driver to the function has to be interpreted as follows:

- 0 - NAND block 0
- 64 - NAND block 1
- 128 - NAND block 2
- etc.

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6.3.4.16.3 FS_NAND_PHY_TYPE_INIT_GET_DEVICE_INFO

Description

Initializes the physical layer.

Type definition

```
typedef int FS_NAND_PHY_TYPE_INIT_GET_DEVICE_INFO(U8                   Unit,
                                                  FS_NAND_DEVICE_INFO * pDevInfo);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
pDevInfo	out Information about the NAND flash device.

Return value

= 0 OK, physical layer has been initialized.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It is mandatory to be implemented by all the NAND physical layers. It is the first function of the physical layer API that is called by the NAND driver when the NAND flash device is mounted.

This function initializes hardware layer, resets and tries to identify the NAND flash device. If the NAND flash device can be handled, the pDevInfo is filled with information about the organization and the ECC requirements of the NAND flash device.

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6.3.4.16.4 FS_NAND_PHY_TYPE_IS_WP

Description

Checks if the NAND flash device is write protected.

Type definition

```
typedef int FS_NAND_PHY_TYPE_IS_WP(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)

Return value

= 0 Data stored on the NAND flash device can be modified.
≠ 0 Data stored on the NAND flash device cannot be modified.

Additional information

This function is a member of the NAND physical layer API. It is mandatory to be implemented by all the NAND physical layers.

The write protection status is checked by evaluating the bit 7 of the NAND status register. Typical reason for write protection is that either the supply voltage is too low or the /WP-pin is connected to ground.

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6.3.4.16.5 FS_NAND_PHY_TYPE_READ

Description

Reads data from a NAND page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_READ(U8       Unit,
                                  U32      PageIndex,
                                  void   * pData,
                                  unsigned Off,
                                  unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndex	Index of the NAND page to read from (0-based).
pData	out Data read from NAND page.
Off	Byte offset to read from.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by all the NAND physical layers. The NAND driver uses FS_NAND_PHY_TYPE_READ to read data from the main as well as from the spare area of a page.

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6.3.4.16.6 FS_NAND_PHY_TYPE_READ_EX

Description

Reads data from two different locations of a NAND page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_READ_EX(U8       Unit,
                                     U32      PageIndex,
                                     void   * pData0,
                                     unsigned Off0,
                                     unsigned NumBytes0,
                                     void   * pData1,
                                     unsigned Off1,
                                     unsigned NumBytes1);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndex	Index of the NAND page to read from (0-based).
pData0	out Data read from Off0 of the NAND page.
Off0	Byte offset to read from for pData0.
NumBytes0	Number of bytes to be read.
pData1	out Data read from Off1 of a NAND page.
Off1	Byte offset to read from for pData1.
NumBytes1	Number of bytes to be read from Off1.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by all the NAND physical layers. FS_NAND_PHY_TYPE_READ_EX is typically used by the NAND driver to read the data from main and spare area of a page at the same time.

It is guaranteed that Off0 is always smaller than Off1 and that the region defined by Off0 and NumBytes0 does not overlap the region defined by Off1 and NumBytes1

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6.3.4.16.7 FS_NAND_PHY_TYPE_WRITE

Description

Writes data to a NAND page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_WRITE(      U8       Unit,
                                         U32      PageIndex,
                                   const void   * pData,
                                         unsigned Off,
                                         unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndex	Index of the NAND page to write to (0-based).
pData	in Data to be written to the NAND page.
Off	Byte offset to write to.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented only by a NAND physical layer that works with the SLC1 NAND driver. The Universal NAND driver does not call this function. FS_NAND_PHY_TYPE_WRITE is used by the SLC1 NAND driver to write data to the main as well as to the spare area of a page.

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6.3.4.16.8 FS_NAND_PHY_TYPE_WRITE_EX

Description

Writes data to two different locations of a NAND page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_WRITE_EX(      U8       Unit,
                                            U32      PageIndex,
                                      const void   * pData0,
                                            unsigned Off0,
                                            unsigned NumBytes0,
                                      const void   * pData1,
                                            unsigned Off1,
                                            unsigned NumBytes1);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndex	Index of the NAND page to write to (0-based).
pData0	in Data to be written to the NAND page at Off0.
Off0	Byte offset to write to for pData0.
NumBytes0	Number of bytes to be written at Off0.
pData1	in Data to be written to the NAND page at Off1.
Off1	Byte offset to write to for pData1.
NumBytes1	Number of bytes to be written at Off1.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by all the NAND physical layers. The NAND driver uses FS_NAND_PHY_TYPE_WRITE_EX to write data to the main and spare area of a page at the same time.

It is guaranteed that Off0 is always smaller than Off1 and that the region defined by Off0 and NumBytes0 does not overlap the region defined by Off1 and NumBytes1

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6.3.4.16.9 FS_NAND_PHY_TYPE_ENABLE_ECC

Description

Enables the hardware ECC.

Type definition

```
typedef int FS_NAND_PHY_TYPE_ENABLE_ECC(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)

Return value

= 0 OK, hardware ECC activated.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by the NAND physical layers that provide hardware support for bit error correction either on MCU via a dedicated NAND flash controller or via on-die ECC of the NAND flash device. FS_NAND_PHY_TYPE_ENABLE_ECC is called only by the Universal NAND driver.

After the call to this function the Universal NAND driver expects that FS_NAND_PHY_TYPE_READ and FS_NAND_PHY_TYPE_READ_EX return corrected data that is without bit errors. In addition, the Universal NAND driver expects that FS_NAND_PHY_TYPE_WRITE and FS_NAND_PHY_TYPE_WRITE_EX calculate and store the ECC to NAND flash device.

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6.3.4.16.10 FS_NAND_PHY_TYPE_DISABLE_ECC

Description

Deactivates the hardware ECC.

Type definition

```
typedef int FS_NAND_PHY_TYPE_DISABLE_ECC(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)

Return value

= 0 OK, hardware ECC deactivated.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by the NAND physical layers that provide hardware support for bit error correction. FS_NAND_PHY_TYPE_DISABLE_ECC is called only by the Universal NAND driver.

After the call to this function the Universal NAND driver expects that FS_NAND_PHY_TYPE_READ and FS_NAND_PHY_TYPE_READ_EX return data that might contain bit errors. In addition, the Universal NADN driver expects that FS_NAND_PHY_TYPE_WRITE and FS_NAND_PHY_TYPE_WRITE_EX store the data without calculating the ECC.

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6.3.4.16.11 FS_NAND_PHY_TYPE_CONFIGURE_ECC

Description

Configures the hardware ECC.

Type definition

```
typedef int FS_NAND_PHY_TYPE_CONFIGURE_ECC(U8  Unit,
                                           U8  NumBitsCorrectable,
                                           U16 BytesPerECCBlock);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
NumBitsCorrectable	Maximum number of bit errors the hardware ECC has to be able to correct.
BytesPerECCBlock	Number of consecutive data bytes protected by a single ECC.

Return value

= 0 OK, hardware ECC configured.
≠ 0 An error occurred.

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by the NAND physical layers that provide hardware support for bit error correction with configurable ECC strength. FS_NAND_PHY_TYPE_CONFIGURE_ECC is called only by the Universal NAND driver.

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6.3.4.16.12 FS_NAND_PHY_TYPE_COPY_PAGE

Description

Copies the contents of an entire page to another page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_COPY_PAGE(U8  Unit,
                                       U32 PageIndexSrc,
                                       U32 PageIndexDest);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
PageIndexSrc	Index of the page to copy from.
PageIndexDest	Index of the page to copy to.

Return value

= 0 OK, page copied.
≠ 0 An error occurred or operation not supported.

Additional information

This function is a member of the NAND physical layer API. It may be implemented by the NAND physical layers that can provide a faster method of copying the contents of a page than by first reading the source page contents to MCU and then by writing the contents to the destination page. One such method is the internal page copy operation supported by some NAND flash device. FS_NAND_PHY_TYPE_COPY_PAGE is called only by the Universal NAND driver.

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6.3.4.16.13 FS_NAND_PHY_TYPE_GET_ECC_RESULT

Description

Returns the error correction status of the last read page.

Type definition

```
typedef int FS_NAND_PHY_TYPE_GET_ECC_RESULT(U8                   Unit,
                                            FS_NAND_ECC_RESULT * pResult);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
pResult	out Information about the correction status.

Return value

= 0 OK, information returned.
≠ 0 An error occurred or operation not supported.

Additional information

This function is a member of the NAND physical layer API. It may be implemented by the NAND physical layers that can provide information about the status of the bit correction operation and about the number of bit errors corrected. FS_NAND_PHY_TYPE_GET_ECC_RESULT is called only by the Universal NAND driver.

The information returned by FS_NAND_PHY_TYPE_GET_ECC_RESULT is used by the Universal NAND driver to decide when a NAND block has to be relocated in order to prevent bit correction errors. A bit correction error occurs when the number of bit errors is greater than the number of bit errors the ECC is able to correct. Typically, a bit correction error causes a data loss.

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6.3.4.16.14 FS_NAND_PHY_TYPE_DEINIT

Description

Releases the allocated resources.

Type definition

```
typedef void FS_NAND_PHY_TYPE_DEINIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)

Additional information

This function is a member of the NAND physical layer API. It has to be implemented by the NAND physical layers that allocate resources dynamically during the initialization such as memory for the instance.

The NAND driver calls this function when the file system is unmounted.

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6.3.4.16.15 FS_NAND_PHY_TYPE_SET_RAW_MODE

Description

Enables or disables the data translation.

Type definition

```
typedef int FS_NAND_PHY_TYPE_SET_RAW_MODE(U8 Unit,
                                          U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the NAND physical layer instance (0-based)
OnOff	Activation status of the feature.

Return value

= 0 OK, status changed.
≠ 0 An error occurred or operation not supported.

Additional information

This function is a member of the NAND physical layer API. It may be implemented by the NAND physical layers that store the data to NAND flash device using a different layout than the NAND driver. FS_NAND_PHY_TYPE_SET_RAW_MODE is not called by the NAND driver during the normal operation. It is called only by specific functions of the Universal NAND driver such as FS_NAND_UNI_WritePageRaw() and FS_NAND_UNI_ReadPageRaw().

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6.3.4.16.16 FS_NAND_DEVICE_INFO

Description

Information about the NAND flash device.

Type definition

```
typedef struct {
  U8                BPP_Shift;
  U8                PPB_Shift;
  U16               NumBlocks;
  U16               BytesPerSpareArea;
  FS_NAND_ECC_INFO  ECC_Info;
  U8                DataBusWidth;
  U8                BadBlockMarkingType;
  U8                PPO_Shift;
} FS_NAND_DEVICE_INFO;
```

Structure members

Member	Description
BPP_Shift	Bytes per page as a power of two value.
PPB_Shift	Pages per block as a power of two value.
NumBlocks	Total number of blocks in the NAND flash device.
BytesPerSpareArea	Number of bytes in the spare area.
ECC_Info	Information about the ECC capability required by the NAND flash device.
DataBusWidth	Number of lines used for exchanging the data with the NAND flash device.
BadBlockMarkingType	Specifies how the blocks are marked as defective.
PPO_Shift	Number of operations performed in parallel by the NAND physical layer.

Additional information

The initialization function of the physical layer FS_NAND_PHY_TYPE_INIT_GET_DEVICE_INFO uses this structure to return information about the NAND flash device to the NAND driver.

Typical values for BPP_Shift are 9 and 11 for NAND flash devices with a page size (without the spare area) of 512 and 2048 bytes respectively.

BytesPerSpareArea is typically 1/32 of the page size (2^BPP_Shift) but some NAND flash devices have a spare area larger than this. For example Micron MT29F8G08ABABA has a spare area of 224 bytes for a page size of 4096 bytes.

DataBusWidth can take the following values:

- 0 - unknown
- 1 - SPI
- 8 - parallel 8-bit
- 16 - parallel 16-bit

Refer to *Bad block marking types* on page 670 for a list of permitted values for BadBlockMarkingType.

PPO_Shift (Planes Per Operation) has to be specified as a power of two value. Most of the NAND physical layers set this value to 0 to indicate that they do not support parallel operations. FS_NAND_PHY_2048x8_TwoPlane sets this value to 1 because it can read and write two NAND pages at once and it can erase two NAND blocks at once. This information is used by the Universal NAND driver to correctly identify and mark defective blocks.

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6.3.4.16.17 FS_NAND_ECC_INFO

Description

Information about the ECC used to protect data stored on the NAND flash.

Type definition

```
typedef struct {
  U8  NumBitsCorrectable;
  U8  ldBytesPerBlock;
  U8  HasHW_ECC;
  U8  IsHW_ECCEnabledPerm;
} FS_NAND_ECC_INFO;
```

Structure members

Member	Description
NumBitsCorrectable	Maximum number of bit errors the ECC should be able to correct.
ldBytesPerBlock	Number of bytes the ECC should protect as power of 2 exponent.
HasHW_ECC	Set to 1 if the NAND flash device has internal HW ECC.
IsHW_ECCEnabledPerm	Set to 1 if the internal HW ECC of the NAND flash device cannot be disabled.

Additional information

The value of IsHW_ECCEnabledPerm is valid only if the value of HasHW_ECC is different than 0.

ldBytesPerBlock is a power of 2 value. If HasHW_ECC is different than 0 ldBytesPerBlock represents the number of bytes in the main and spare area of a NAND page the internal HW ECC is able to protect against bit errors. More than one ECC is used to protect the data in a NAND page if the size of the NAND page is larger than ldBytesPerBlock. ldBytesPerBlock can never be larger than the size of a NAND page.

If HasHW_ECC is different than 0 than NumBitsCorrectable represents the maximum number of bit errors the internal HW ECC is able to correct.

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6.3.4.16.18 FS_NAND_ECC_RESULT

Description

Information about the ECC number of bits corrected in an ECC block.

Type definition

```
typedef struct {
  U8  CorrectionStatus;
  U8  MaxNumBitsCorrected;
} FS_NAND_ECC_RESULT;
```

Structure members

Member	Description
CorrectionStatus	Indicates if the correction succeeded or failed.
MaxNumBitsCorrected	Maximum number of bit errors detected and corrected in any ECC block of a page.

Additional information

This structure is filled by the FS_NAND_PHY_TYPE_GET_ECC_RESULT function of the NAND physical layer to return the result of the bit error correction operation.

Refer to *ECC correction status* on page 672 for a list of permitted values for CorrectionStatus.

An ECC block is the number of bytes protected by a single ECC. Typically, the ECC block is 512 bytes large, therefor the number of ECC blocks in a 2 KByte page is 4. Most of the NAND flash devices report the number of bits corrected in each of the ECC blocks. The value stored to MaxNumBitsCorrected must be the maximum of these values.

6.3.4.17 Additional physical layer functions

The following functions are optional. They can be called to get information about the NAND flash device and to control additional functionality of physical layers.

Function	Description
FS_NAND_PHY_ReadCASNPara()	Obtains CASN parameters from a NAND flash device.
FS_NAND_PHY_ReadDeviceId()	Obtains information about the type of NAND flash device.
FS_NAND_PHY_ReadONFIPara()	Obtains ONFI parameters from a NAND flash device.
FS_NAND_PHY_SetHWType()	Configures the hardware routines for the access to a parallel NAND flash device.
FS_NAND_PHY_SetHWTypeDataFlash()	Configures the hardware routines for the access to a DataFlash device.
FS_NAND_PHY_SetHWTypeQSPI()	Configures the hardware routines for the access to a QSPI NAND flash device.
FS_NAND_PHY_SetHWTypeSPI()	Configures the hardware routines for the access to a SPI NAND flash device.

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6.3.4.17.1 FS_NAND_PHY_ReadCASNPara()

Description

Obtains CASN parameters from a NAND flash device.

Prototype

```
int FS_NAND_PHY_ReadCASNPara(U8     Unit,
                             void * pData);
```

Parameters

Parameter	Description
Unit	Index of HW layer to be used for the access to NAND flash device.
pData	out Data of CASN parameter page read from NAND flash. This parameter can be set to NULL.

Return value

= 0 CASN parameters read.
≠ 0 CASN is not supported by the NAND flash.

Additional information

CASN stands for Common Attributes for SPI-NAND. CASN is designed to store parameters specific to serial NAND flash devices such as read and write command codes for specific bus access modes, layout of the ECC-protected data and so on. Refer to the data sheet of the NAND flash device for an exact description of the CASN parameters.

FS_NAND_PHY_ReadCASNPara() can be called before the file system is fully initialized such as from FS_X_AddDevices() because FS_NAND_PHY_ReadCASNPara() performs the operation by calling only functions of the configured NAND hardware layer. An instance of NAND driver is not required for the correct operation of FS_NAND_PHY_ReadCASNPara().

FS_NAND_PHY_ReadCASNPara() can be used to check if the NAND flash device supports CASN without reading the actual CASN parameters by calling the function with pData set to NULL.

The size of the buffer passed via pData must be at least 256 bytes large.

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6.3.4.17.2 FS_NAND_PHY_ReadDeviceId()

Description

Obtains information about the type of NAND flash device.

Prototype

```
int FS_NAND_PHY_ReadDeviceId(U8    Unit,
                             U8  * pData,
                             U32   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of HW layer to be used for the access to NAND flash device.
pData	out Identification data read from NAND flash device.
NumBytes	Number of bytes to read.

Return value

= 0 OK, id information read.
≠ 0 Error code that indicates the failure reason.

Additional information

FS_NAND_PHY_ReadDeviceId() executes the READ ID command to read the id information from the NAND flash device. NumBytes specifies the number of bytes to be read. Refer to the data sheet of the NAND flash device for additional information about the meaning of the data returned by the NAND flash device. Typically, the first byte stores the manufactured id while the second byte provides information about the organization of the NAND flash device.

FS_NAND_PHY_ReadDeviceId() can be called before the file system is fully initialized such as from FS_X_AddDevices() because it calls only functions of the NAND hardware layer to perform the operation. An instance of NAND driver is not required for invoking FS_NAND_PHY_ReadDeviceId().

The typical usage of FS_NAND_PHY_ReadDeviceId() is for determining at runtime the type of NAND driver for the used NAND flash device.

The type of HW layer to be used for the access to the NAND flash device can be configured via FS_NAND_PHY_SetHWType(), FS_NAND_PHY_SetHWTypeSPI() FS_NAND_PHY_SetHWTypeQSPI() or FS_NAND_PHY_SetHWTypeDataFlash().

Example

The following example shows how an application can select at runtime a different NAND driver based on the type of the NAND flash used.

```
#include "FS.h"

#define ALLOC_SIZE            0x4000    // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*/
void FS_X_AddDevices(void) {
  U8 Id;

  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Read the first byte of the identification array.
```

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```
  // This byte stores the manufacturer type.
  //
  FS_NAND_PHY_SetHWType(0, &FS_NAND_HW_Default);
  FS_NAND_PHY_ReadDeviceId(0, &Id, sizeof(Id));
  if (Id == 0xEC) {
    //
    // Found a Samsung NAND flash. Use the SLC1 NAND driver.
    // ECC is performed by the NAND driver
    //
    FS_AddDevice(&FS_NAND_Driver);
    FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
    FS_NAND_2048x8_SetHWType(0, &FS_NAND_HW_Default);
  } else if (Id == 0x2C) {
    //
    // Found a Micron NAND flash. Use the Universal NAND driver.
    // The ECC is performed by the NAND flash.
    //
    FS_AddDevice(&FS_NAND_UNI_Driver);
    FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
    FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
    FS_NAND_ONFI_SetHWType(0, &FS_NAND_HW_Default);
  } else {
    //
    // NAND flash from another manufacturer, use auto-identification.
    //
    FS_AddDevice(&FS_NAND_Driver);
    FS_NAND_SetPhyType(0, &FS_NAND_PHY_x8);
    FS_NAND_x8_SetHWType(0, &FS_NAND_HW_Default);
  }
}
```

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6.3.4.17.3 FS_NAND_PHY_ReadONFIPara()

Description

Obtains ONFI parameters from a NAND flash device.

Prototype

```
int FS_NAND_PHY_ReadONFIPara(U8     Unit,
                             void * pData);
```

Parameters

Parameter	Description
Unit	Index of HW layer to be used for the access to NAND flash device.
pData	out Data of ONFI parameter page read from NAND flash. This parameter can be set to NULL.

Return value

= 0 ONFI parameters read.
≠ 0 ONFI is not supported by the NAND flash.

Additional information

Refer to the data sheet of the NAND flash device for a description of the data layout of the returned ONFI parameters.

FS_NAND_PHY_ReadONFIPara() can be called before the file system is fully initialized such as from FS_X_AddDevices() because it calls only functions of the NAND hardware layer to perform the operation. An instance of NAND driver is not required for invoking FS_NAND_PHY_ReadONFIPara().

FS_NAND_PHY_ReadONFIPara() can be used to check if the NAND flash device is ONFI compliant without reading the actual ONFI parameters by calling the function with pData set to NULL.

The size of the buffer passed via pData must be at least 256 bytes large.

Example

This example demonstrates how an application can configure at runtime different NAND drivers based on the type of the NAND flash.

```
#include "FS.h"

#define ALLOC_SIZE            0x4000    // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*/
void FS_X_AddDevices(void) {
  int r;

  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Check whether the NAND flash supports ONFI.
  //
  FS_NAND_PHY_SetHWType(0, &FS_NAND_HW_Default);
  r = FS_NAND_PHY_ReadONFIPara(0, NULL);
  if (r != 0) {
    //
    // Found a NAND flash which does not support ONFI.
    //
```

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```
    FS_AddDevice(&FS_NAND_Driver);
    FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  } else {
    //
    // Found a NAND flash which supports ONFI.
    //
    FS_AddDevice(&FS_NAND_UNI_Driver);
    FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
    FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  }
}
```

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6.3.4.17.4 FS_NAND_PHY_SetHWType()

Description

Configures the hardware routines for the access to a parallel NAND flash device.

Prototype

```
int FS_NAND_PHY_SetHWType(      U8                Unit,
                          const FS_NAND_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. It cannot be set to NULL.

Return value

= 0 OK, HW layer configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called by the application if an access is made to a parallel NAND flash device via one of the following API functions:

- FS_NAND_PHY_ReadDeviceId()
- FS_NAND_PHY_ReadONFIPara()

FS_NAND_PHY_SetHWType() has to be called before calling any of the API functions listed above. The function has to be called once for each different unit number used.

FS_NAND_PHY_SetHWType() can be called from FS_X_AddDevices().

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6.3.4.17.5 FS_NAND_PHY_SetHWTypeDataFlash()

Description

Configures the hardware routines for the access to a DataFlash device.

Prototype

```
int FS_NAND_PHY_SetHWTypeDataFlash(      U8                    Unit,
                                   const FS_NAND_HW_TYPE_DF * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. It cannot be set to NULL.

Return value

= 0 OK, HW layer configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called by the application if an access is made to a DataFlash device via one of the following API functions:

- FS_NAND_PHY_ReadDeviceId()

FS_NAND_PHY_SetHWTypeDataFlash() has to be called before calling any of the API functions listed above. The function has to be called once for each different unit number used.

FS_NAND_PHY_SetHWTypeDataFlash() can be called from FS_X_AddDevices().

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6.3.4.17.6 FS_NAND_PHY_SetHWTypeQSPI()

Description

Configures the hardware routines for the access to a QSPI NAND flash device.

Prototype

```
int FS_NAND_PHY_SetHWTypeQSPI(      U8                      Unit,
                              const FS_NAND_HW_TYPE_QSPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. It cannot be set to NULL.

Return value

= 0 OK, HW layer configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called by the application if an access is made to a QSPI NAND flash device via one of the following API functions:

- FS_NAND_PHY_ReadCASNPara()
- FS_NAND_PHY_ReadDeviceId()
- FS_NAND_PHY_ReadONFIPara()

FS_NAND_PHY_SetHWTypeQSPI() has to be called before calling any of the API functions listed above. The function has to be called once for each different unit number used.

FS_NAND_PHY_SetHWTypeQSPI() can be called from FS_X_AddDevices().

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6.3.4.17.7 FS_NAND_PHY_SetHWTypeSPI()

Description

Configures the hardware routines for the access to a SPI NAND flash device.

Prototype

```
int FS_NAND_PHY_SetHWTypeSPI(      U8                    Unit,
                             const FS_NAND_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pHWType	Type of the hardware layer to use. It cannot be set to NULL.

Return value

= 0 OK, HW layer configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called by the application if an access is made to a SPI NAND flash device via one of the following API functions:

- FS_NAND_PHY_ReadCASNPara()
- FS_NAND_PHY_ReadDeviceId()
- FS_NAND_PHY_ReadONFIPara()

FS_NAND_PHY_SetHWTypeSPI() has to be called before calling any of the API functions listed above. The function has to be called once for each different unit number used.

FS_NAND_PHY_SetHWTypeSPI() can be called from FS_X_AddDevices().

6.3.4.18 Resource usage

This section describes the ROM and RAM usage of the NAND physical layers.

6.3.4.18.1 ROM usage

The ROM usage depends on the compiler options, the compiler version, and the CPU used. The memory requirements of the NAND physical layers were measured as described in the section *Test procedure* on page 1439.
The following table lists the ROM usage of all the available NAND physical layers.

Name	ROM usage (Kbytes)
512x8	**1.3**
2048x8	**1.6**
Two plane 2048x8	**1.4**
Small 2048x8	**1.4**
2048x16	**1.2**
4096x8	**1.1**
DataFlash	**1.7**
ONFI	**3.8**
Read-only ONFI	**3.5**
Small ONFI	**3.6**
QSPI	**5.2**

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Name	ROM usage (Kbytes)
SPI	**5.2**
8/16-bit data bus	**9.4**
8-bit data bus	**8.2**

6.3.4.18.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for static variables inside the driver. The number of bytes can be seen in a compiler list file. The next table lists the static RAM usage of all the available NAND physical layers.

Name	RAM usage (bytes)
512x8	**20**
2048x8	**16**
Two plane 2048x8	**16**
Small 2048x8	**16**
2048x16	**16**
4096x8	**16**
DataFlash	**64**
ONFI	**16**
Read-only ONFI	**16**
Small ONFI	**16**
QSPI	**16**
SPI	**16**
8/16-bit data bus	**16**
8-bit data bus	**16**

6.3.4.18.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the physical layer at runtime. The amount of RAM required depends on the compile time and runtime configuration. The following table lists the dynamic RAM usage of the available NAND physical layers.

Name	RAM usage (bytes)
512x8	**0**
2048x8	**24**
Two plane 2048x8	**24**
Small 2048x8	**24**
2048x16	**0**
4096x8	**0**
DataFlash	**0**
ONFI	**28**
Read-only ONFI	**28**
Small ONFI	**28**
QSPI	**44**
SPI	**44**
8/16-bit data bus	**8**
8-bit data bus	**8**

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6.3.5 NAND hardware layer

6.3.5.1 General information

The NAND hardware layer provides functionality for accessing a NAND flash device via the target hardware such as external memory controller, GPIO, SPI, etc. The functions of the NAND hardware layer are called by the NAND physical layer to exchange commands and data with a NAND flash device. Since these functions are hardware-dependent, they have to be implemented by the user. emFile comes with template hardware layers and sample implementations for popular evaluation boards that can be used as a starting point for implementing new hardware layers. The relevant files are located in the `/Sample/FS/Driver/NAND` folder of the emFile shipment.

6.3.5.2 Hardware layer types

The functions of the NAND hardware layer are organized in a function table implemented as a C structure. Different hardware layer types are provided to support different ways of interfacing a NAND flash device. The type of hardware layer an application has to use depends on the type of NAND physical layer configured. The following table shows what hardware layer is required by each physical layer.

NAND hardware layer	NAND physical layer
FS_NAND_HW_TYPE	FS_NAND_PHY_512x8 FS_NAND_PHY_2048x8 FS_NAND_PHY_2048x16 FS_NAND_PHY_4096x8 FS_NAND_PHY_x FS_NAND_PHY_x8 FS_NAND_PHY_ONFI
FS_NAND_HW_TYPE_DF	FS_NAND_PHY_DataFlash
FS_NAND_HW_TYPE_QSPI	FS_NAND_PHY_QSPI
FS_NAND_HW_TYPE_SPI	FS_NAND_PHY_SPI

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6.3.5.3 Hardware layer API - FS_NAND_HW_TYPE

This NAND hardware layer supports NAND flash devices that can be accessed via an 8- or 16-bit data bus. The functions of this hardware layer are grouped in a structure of type `FS_NAND_HW_TYPE`. The following sections describe these functions in detail.

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6.3.5.3.1 FS_NAND_HW_TYPE

Description

NAND hardware layer API for NAND flash devices connected via parallel I/O.

Type definition

```
typedef struct {
  FS_NAND_HW_TYPE_INIT_X8          * pfInit_x8;
  FS_NAND_HW_TYPE_INIT_X16         * pfInit_x16;
  FS_NAND_HW_TYPE_DISABLE_CE       * pfDisableCE;
  FS_NAND_HW_TYPE_ENABLE_CE        * pfEnableCE;
  FS_NAND_HW_TYPE_SET_ADDR_MODE    * pfSetAddrMode;
  FS_NAND_HW_TYPE_SET_CMD_MODE     * pfSetCmdMode;
  FS_NAND_HW_TYPE_SET_DATA_MODE    * pfSetDataMode;
  FS_NAND_HW_TYPE_WAIT_WHILE_BUSY * pfWaitWhileBusy;
  FS_NAND_HW_TYPE_READ_X8          * pfRead_x8;
  FS_NAND_HW_TYPE_WRITE_X8         * pfWrite_x8;
  FS_NAND_HW_TYPE_READ_X16         * pfRead_x16;
  FS_NAND_HW_TYPE_WRITE_X16        * pfWrite_x16;
} FS_NAND_HW_TYPE;
```

Structure members

Member	Description
pfInit_x8	Initializes a NAND flash device with an 8-bit data interface.
pfInit_x16	Initializes a NAND flash device with a 16-bit data interface.
pfDisableCE	Disables the NAND flash device.
pfEnableCE	Enables the NAND flash device.
pfSetAddrMode	Initiates the transfer of an address.
pfSetCmdMode	Initiates the transfer of a command.
pfSetDataMode	Initiates the transfer of data.
pfWaitWhileBusy	Waits for the NAND flash device to become ready.
pfRead_x8	Reads a specified number of bytes from NAND flash device via the 8-bit data interface.
pfWrite_x8	Writes a specified number of bytes to NAND flash device via the 8-bit data interface.
pfRead_x16	Reads a specified number of bytes from NAND flash device via the 16-bit data interface.
pfWrite_x16	Writes a specified number of bytes to NAND flash device via the 16-bit data interface.

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6.3.5.3.2 FS_NAND_HW_TYPE_INIT_X8

Description

Initializes the hardware for 8-bit mode access.

Type definition

```
typedef void FS_NAND_HW_TYPE_INIT_X8(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It has to be implemented by a NAND hardware layer that accesses a NAND flash device via an 8-bit data bus. FS_NAND_HW_TYPE_INIT_X8 is the first function of the hardware layer API that is called by a NAND physical layer during the mounting of the file system.

This function has to perform any initialization of the MCU hardware required to access the NAND flash device such as clocks, port pins, memory controllers, etc.

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6.3.5.3.3 FS_NAND_HW_TYPE_INIT_X16

Description

Initializes the hardware for 16-bit mode access.

Type definition

```
typedef void FS_NAND_HW_TYPE_INIT_X16(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. The implementation of this function is optional for systems that interface to the NAND flash device via an 8-bit data bus. FS_NAND_HW_TYPE_INIT_X16 must be implemented for systems that have the NAND flash device connected to MCU via a 16-bit data bus.

FS_NAND_HW_TYPE_INIT_X16 is the first function of the hardware layer API that is called by the NAND physical layer when the NAND flash device is mounted.

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6.3.5.3.4 FS_NAND_HW_TYPE_DISABLE_CE

Description

Disables the NAND flash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_DISABLE_CE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API and it is mandatory to be implemented. The implementation of this function can be left empty if the hardware is driving the Chip Enable (CE) signal. Typically, the NAND flash device is disabled by driving the CE signal to a logic low state level.

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6.3.5.3.5 FS_NAND_HW_TYPE_ENABLE_CE

Description

Enables the NAND flash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_ENABLE_CE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It is mandatory to be implemented by all NAND hardware layers. The implementation of this function can be left empty if the hardware is driving the Chip Enable (CE) signal. Typically, the NAND flash device is enabled by driving the CE signal to a logic-high level.

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6.3.5.3.6 FS_NAND_HW_TYPE_SET_ADDR_MODE

Description

Changes the data access to address mode.

Type definition

```
typedef void FS_NAND_HW_TYPE_SET_ADDR_MODE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It is mandatory to be implemented by all NAND hardware layers.

After the call to this function the NAND hardware layer has to make sure that any data sent to NAND flash device is interpreted as address information. This can be achieved by setting the Address Latch Enable signal (ALE) signal to logic-high and the Command Latch Enable (CLE) signal to logic low state.

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6.3.5.3.7 FS_NAND_HW_TYPE_SET_CMD_MODE

Description

Changes the data access to command mode.

Type definition

```
typedef void FS_NAND_HW_TYPE_SET_CMD_MODE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers.

After the call to this function the NAND hardware layer has to make sure that any data sent to NAND flash device is interpreted as command information. This can be achieved by setting the Command Latch Enable (CLE) signal to logic-high and the Address Latch Enable signal (ALE) signal to logic low state.

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6.3.5.3.8 FS_NAND_HW_TYPE_SET_DATA_MODE

Description

Changes the data access to data mode.

Type definition

```
typedef void FS_NAND_HW_TYPE_SET_DATA_MODE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers.

After the call to this function the NAND hardware layer has to make sure that any data sent to NAND flash device is interpreted as data information. This can be achieved by setting the Command Latch Enable (CLE) and Address Latch Enable signals to logic low state.

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6.3.5.3.9 FS_NAND_HW_TYPE_WAIT_WHILE_BUSY

Description

Waits for the NAND flash device to become ready.

Type definition

```
typedef int FS_NAND_HW_TYPE_WAIT_WHILE_BUSY(U8       Unit,
                                            unsigned us);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
us	Maximum time to wait in microseconds.

Return value

= 0 The NAND flash device is ready.
≠ 0 The NAND flash device is busy or the operation is not supported.

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers.

A NAND hardware layer calls this function every time it checks the status of the NAND flash device. A typical implementation uses the status of the Ready/Busy (R/B) signal that is set to logic low state by the NAND flash device as long as it is busy and it cannot accept and other commands from MCU.

FS_NAND_HW_TYPE_WAIT_WHILE_BUSY must return 1 if the status of the NAND flash device cannot be queried via R/B signal. In this case, the NAND hardware layer checks the status via a read status command.

Typically, a NAND flash device does not set R/B signal to logic low state immediately after it accepts a command from MCU but only after a time interval labeled as tWB in the data sheet of the NAND flash device. This means that FS_NAND_HW_TYPE_WAIT_WHILE_BUSY has to wait for tWB time interval to elapse before it samples the R/B signal for the first time in order to make sure that it returns correct status information to the NAND physical layer.

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6.3.5.3.10 FS_NAND_HW_TYPE_READ_X8

Description

Reads data from NAND flash device via 8-bit data bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_READ_X8(U8       Unit,
                                     void   * pData,
                                     unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	out Data read from NAND flash. It cannot be NULL.
NumBytes	Number of bytes to be read. It cannot be 0.

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It has to be implemented by a NAND hardware layer that exchanges the data with the NAND flash device via an 8-bit data bus.

FS_NAND_HW_TYPE_READ_X8 is called by a NAND physical layer in data mode to transfer data from NAND flash device to MCU. It is not called in address and command data access modes.

The transfer of the data is controlled by the MCU using the Read Enable (RE) signal. If the NAND hardware layer exchanges the data via GPIO it has to make sure that the timing of the RE signal meets the specifications of the NAND flash device.

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6.3.5.3.11 FS_NAND_HW_TYPE_WRITE_X8

Description

Writes data to NAND flash device via 8-bit data bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_WRITE_X8(      U8       Unit,
                                      const void   * pData,
                                            unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	in Data to be written to NAND flash. It cannot be NULL.
NumBytes	Number of bytes to be read. It cannot be 0.

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It has to be implemented by a NAND hardware layer that exchanges the data with the NAND flash device via an 8-bit data bus.

FS_NAND_HW_TYPE_WRITE_X8 is called by a NAND physical layer in all data access modes to transfer data from MCU to NAND flash device.

The transfer of the data is controlled by the MCU using the Write Enable (WE) signal. If the NAND hardware layer exchanges the data via GPIO it has to make sure that the timing of the WE signal meets the specifications of the NAND flash device.

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6.3.5.3.12 FS_NAND_HW_TYPE_READ_X16

Description

Reads data from NAND flash device via 16-bit data bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_READ_X16(U8       Unit,
                                      void   * pData,
                                      unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	out Data read from NAND flash. It cannot be NULL.
NumBytes	Number of bytes to be read. It cannot be 0.

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It has to be implemented by a NAND hardware layer that exchanges the data with the NAND flash device via a 16-bit data bus.

FS_NAND_HW_TYPE_READ_X16 is called by a NAND physical layer in data mode to transfer data from NAND flash device to MCU. It is not called in address and command data access modes.

The transfer of the data is controlled by the MCU using the Read Enable (RE) signal. If the NAND hardware layer exchanges the data via GPIO it has to make sure that the timing of the RE signal meets the specifications of the NAND flash device.

pData is aligned to a half-word (2-byte) boundary.

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6.3.5.3.13 FS_NAND_HW_TYPE_WRITE_X16

Description

Writes data to NAND flash device via 16-bit data bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_WRITE_X16(      U8       Unit,
                                       const void   * pdata,
                                             unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	in Data to be written to NAND flash. It cannot be NULL.
NumBytes	Number of bytes to be read. It cannot be 0.

Additional information

This function is a member of the FS_NAND_PHY_TYPE NAND hardware layer API. It has to be implemented by a NAND hardware layer that exchanges the data with the NAND flash device via a 16-bit data bus.

FS_NAND_HW_TYPE_WRITE_X16 is called by a NAND physical layer in all data access modes to transfer data from MCU to NAND flash device.

The transfer of the data is controlled by the MCU using the Write Enable (WE) signal. If the NAND hardware layer exchanges the data via GPIO it has to make sure that the timing of the WE signal meets the specifications of the NAND flash device.

pData is aligned to a half-word (2-byte) boundary.

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6.3.5.3.14 Sample implementation

The following sample implementation uses the GPIO ports of an NXP K66 MCU to interface with a NAND flash device. This NAND hardware layer was tested on the SEGGER emPower board (https://www.segger.com/evaluate-our-software/segger/empower/)

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_NAND_HW_K66_SEGGER_emPower.c
Purpose : NAND flash hardware layer header file for the SEGGER emPower
          V2 evaluation board.
Literature:
  [1] K66 Sub-Family Reference Manual
  [2] emPower Evaluation and prototyping platform for SEGGER software User Guide & Reference Manual
*/

/*********************************************************************
*
*       #include Section
*
**********************************************************************
*/
#include "FS.h"
#include "FS_NAND_HW_K66_SEGGER_emPower.h"
#include "MK66F18.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_NAND_HW_USE_OS
  #define FS_NAND_HW_USE_OS       0         // Enables / disables the
                                            // event-driven operation.
                                            //   0 - OS support disabled.
                                            //   1 - OS support enabled
                                            //       using the OS event of emFile.
                                            //   2 - OS support enabled using
                                            //       OS events of this HW layer.
#endif

/*********************************************************************
*
*       #include section, conditional
*
**********************************************************************
*/
#if FS_NAND_HW_USE_OS
  #include "RTOS.h"
  #include "FS_OS.h"
#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*        Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*        Port pins
*/
#define NAND_CS_PIN               0
#define NAND_WAIT_PIN             1
#define NAND_ALE_PIN              4
#define NAND_CLE_PIN              5
#define NAND_nOE_PIN              6
```

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```
#define NAND_nWE_PIN              7
#define NAND_DATA_MASK            0xff
#define NAND_D0_SHIFT             8
#define NAND_D0_PIN               8
#define NAND_D1_PIN               9
#define NAND_D2_PIN               10
#define NAND_D3_PIN               11
#define NAND_D4_PIN               12
#define NAND_D5_PIN               13
#define NAND_D6_PIN               14
#define NAND_D7_PIN               15

/*********************************************************************
*
*        Macros for pin configuration
*/
#define SET_DATA2INPUT()          GPIOD_PDDR &= ~(NAND_DATA_MASK << NAND_D0_SHIFT)
#define SET_DATA2OUTPUT()         GPIOD_PDDR |=  (NAND_DATA_MASK << NAND_D0_SHIFT)

/*********************************************************************
*
*        Macros for pin control
*/
#define NAND_GET_DATA(Data)       Data = *((volatile U8 *)&GPIOD_PDIR + 0x1);
#define NAND_SET_DATA(Data)       *((volatile U8 *)&GPIOD_PDOR + 0x1) = Data;
#define NAND_SET_ALE()            GPIOD_PSOR = (1 << NAND_ALE_PIN);
#define NAND_CLR_ALE()            GPIOD_PCOR = (1 << NAND_ALE_PIN);
#define NAND_SET_CLE()            GPIOD_PSOR = (1 << NAND_CLE_PIN);
#define NAND_CLR_CLE()            GPIOD_PCOR = (1 << NAND_CLE_PIN);
#define NAND_SET_CE()             GPIOD_PSOR = (1 << NAND_CS_PIN);
#define NAND_CLR_CE()             GPIOD_PCOR = (1 << NAND_CS_PIN);
#define NAND_SET_RE()             GPIOD_PSOR = (1 << NAND_nOE_PIN);
#define NAND_CLR_RE()             GPIOD_PCOR = (1 << NAND_nOE_PIN);
#define NAND_SET_WE()             GPIOD_PSOR = (1 << NAND_nWE_PIN);
#define NAND_CLR_WE()             GPIOD_PCOR = (1 << NAND_nWE_PIN);
#define NAND_GET_BUSY()           (GPIOD_PDIR & (1 << NAND_WAIT_PIN))
#define NAND_NOP()                __asm("nop")

/*********************************************************************
*
*        Misc. defines
*/
#define PORTD_IRQ_PRIO            15
#define WAIT_TIMEOUT_MS           1000      // Maximum time to wait for the NAND
                                            // flash device to become ready.
#define NUM_LOOPS_TWB             17        // Delay for tWB time.

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
#if (FS_NAND_HW_USE_OS == 2)
  static U8         _IsEventInited = 0;
  static OS_EVENT   _Event;
#endif // FS_NAND_HW_USE_OS == 2

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/
#if FS_NAND_HW_USE_OS

/*********************************************************************
*
*       _WaitForEvent
*
*  Function description
*    Waits for the interrupt to wake up the task.
*
*  Parameters
*    TimeOut      Maximum time to wait for the event in milliseconds.
*
```

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```
*  Return values
*    ==0      OK, event signaled.
*    !=0      An error occurred.
*/
static int _WaitForEvent(U32 TimeOut) {
  int r;

  PORTD_PCR1 |= PORT_PCR_IRQC(0xC);           // Generate an interrupt when the
                                              // the busy signal goes HIGH.
#if (FS_NAND_HW_USE_OS == 2)
  r = OS_EVENT_WaitTimed(&_Event, TimeOut);
#else
  r = FS_OS_Wait(TimeOut);
#endif
  if (r != 0) {
    PORTD_PCR1 &= ~PORT_PCR_IRQC_MASK;        // Disable the interrupt.
    PORTD_PCR1 |=  PORT_PCR_ISF_MASK;
  }
  return r;
}

#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       Static code (public via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_EnableCE
*
*  Function description
*    Enables the NAND flash device.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_EnableCE(U8 Unit) {
  FS_USE_PARA(Unit);
  NAND_CLR_CE();
}

/*********************************************************************
*
*       _HW_DisableCE
*
*  Function description
*    Disables the NAND flash device.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_DisableCE(U8 Unit) {
  FS_USE_PARA(Unit);
  NAND_SET_CE();
}

/*********************************************************************
*
*       _HW_SetDataMode
*
*  Function description
*    Changes the data access to data mode.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_SetDataMode(U8 Unit) {
  FS_USE_PARA(Unit);
  //
  // nCE low, CLE low, ALE low
  //
  NAND_CLR_CLE();
```

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```
  NAND_CLR_ALE();
}

/*********************************************************************
*
*       _HW_SetCmdMode
*
*  Function description
*    Changes the data access to command mode.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_SetCmdMode(U8 Unit) {
  FS_USE_PARA(Unit);
  //
  // nCE low, CLE high, ALE low
  //
  NAND_SET_CLE();
  NAND_CLR_ALE();
}

/*********************************************************************
*
*       _HW_SetAddr
*
*  Function description
*    Changes the data access to address mode.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_SetAddrMode(U8 Unit) {
  FS_USE_PARA(Unit);
  //
  // nCE low, CLE low, ALE high
  //
  NAND_CLR_CLE();
  NAND_SET_ALE();
}

/*********************************************************************
*
*       _HW_Read_x8
*
*  Function description
*    Reads data from NAND flash device via 8-bit data bus.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*    pData        [OUT] Data read from NAND flash. It cannot be NULL.
*    NumBytes     Number of bytes to be read. It cannot be 0.
*/
static void _HW_Read_x8(U8 Unit, void * p, unsigned NumBytes) {
  U8 * pData;

  FS_USE_PARA(Unit);
  pData = (U8 *)p;
  SET_DATA2INPUT();
  do {
    NAND_CLR_RE();        // Enable RE (active low)
    //
    // Wait for the data to be available (tREA time).
    // Two NOPs should actually be sufficient but
    // it seems that the MCU requires some time to
    // synchronize the contents of the PDIR register
    // of the GPIO port.
    //
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
    NAND_NOP();
```

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```
    NAND_GET_DATA(*pData++);
    NAND_SET_RE();        // Disable RE (active low)
  } while (--NumBytes);
}

/*********************************************************************
*
*       _HW_Write_x8
*
*  Function description
*    Writes data to NAND flash device via 8-bit data bus.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*    pData        [IN] Data to be written to NAND flash. It cannot be NULL.
*    NumBytes     Number of bytes to be read. It cannot be 0.
*/
static void _HW_Write_x8(U8 Unit, const void * p, unsigned NumBytes) {
  const U8 * pData;

  FS_USE_PARA(Unit);
  pData = (const U8 *)p;
  SET_DATA2OUTPUT();
  do {
    NAND_SET_DATA(*pData++);
    NAND_CLR_WE();        // Enable WE (active low)
    NAND_NOP();
    NAND_SET_WE();        // Disable WE (active low)
  } while (--NumBytes);
}

/*********************************************************************
*
*       _HW_Init_x8
*
*  Function description
*    Initializes the hardware for 8-bit mode access.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*/
static void _HW_Init_x8(U8 Unit) {
  FS_USE_PARA(Unit);
#if FS_NAND_HW_USE_OS
  //
  // Disable the interrupt.
  //
  NVIC_DisableIRQ(PORTD_IRQn);
  NVIC_SetPriority(PORTD_IRQn, PORTD_IRQ_PRIO);
#endif // FS_NAND_HW_USE_OS
  //
  // Add here the initialization of your NAND hardware
  //
  SIM_SCGC5   |= SIM_SCGC5_PORTD_MASK;               // Enable clock for Port D
  PORTD_PCR0   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR1   =  PORT_PCR_MUX(0x01)                 // Configure as GPIO
               |  PORT_PCR_PS_MASK                   // Enable the pull-up.
               |  PORT_PCR_PE_MASK
               ;
  PORTD_PCR4   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR5   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR6   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR7   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR8   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR9   =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR10  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR11  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR12  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR13  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR14  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  PORTD_PCR15  =  PORT_PCR_MUX(0x01);                // Configure as GPIO
  GPIOD_PDDR  |=  (1u << NAND_CS_PIN)
              |   (1u << NAND_ALE_PIN)
              |   (1u << NAND_CLE_PIN)
              |   (1u << NAND_nOE_PIN)
              |   (1u << NAND_nWE_PIN)
```

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```
              ;
  GPIOD_PDDR  &=  ~(1 << NAND_WAIT_PIN);
  NAND_SET_RE();                                        // Disable RE
  NAND_SET_WE();                                        // Disable WE
  NAND_SET_CLE();                                       // Disable CLE
  NAND_SET_ALE();                                       // Disable ALE
  NAND_SET_CE();                                        // Disable CE
#if FS_NAND_HW_USE_OS
  //
  // Create the OS event and enable the interrupt.
  //
#if (FS_NAND_HW_USE_OS == 2)
  if (_IsEventInited == 0) {
    OS_EVENT_Create(&_Event);
    _IsEventInited = 1;
  }
#endif // FS_NAND_HW_USE_OS == 2
  NVIC_EnableIRQ(PORTD_IRQn);
#endif
}

/*********************************************************************
*
*       _HW_WaitWhileBusy
*
*  Function description
*    Waits for the NAND flash device to become ready.
*
*  Parameters
*    Unit         Index of the NAND hardware layer instance (0-based)
*    us           Maximum time to wait in microseconds.
*
*  Return value
*    ==0    The NAND flash device is ready.
*    !=0    The NAND flash device is busy or the operation is not supported.
*/
static int _HW_WaitWhileBusy(U8 Unit, unsigned us) {
  volatile int NumLoops;

  FS_USE_PARA(Unit);
  FS_USE_PARA(us);
  //
  // Make sure that we do not sample the busy signal too early.
  // In order to do so we have to wait here at least the time
  // specified at tWB in the data sheet of the NAND flash device.
  // Typically this time is about 100 ns. Assuming that the CPU
  // is running at 168 MHz then we have to wait here 100 / 5.9 = 16.9
  // that is about 17 cycles.
  //
  NumLoops = NUM_LOOPS_TWB;
  do {
    NAND_NOP();
  } while (--NumLoops != 0);
  for (;;) {
    if (NAND_GET_BUSY() != 0) {
      break;
    }
#if FS_NAND_HW_USE_OS
    (void)_WaitForEvent(WAIT_TIMEOUT_MS);
#else
    NAND_NOP();
#endif // FS_NAND_HW_USE_OS
  }
  return 0;
}

/*********************************************************************
*
*      Public code
*
**********************************************************************
*/

#if FS_NAND_HW_USE_OS

/*********************************************************************
```

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```
*
*       PORTD_IRQHandler
*/
void PORTD_IRQHandler(void);
void PORTD_IRQHandler(void) {
  OS_EnterNestableInterrupt();
  PORTD_PCR1 &= ~PORT_PCR_IRQC_MASK;          // Disable the interrupt.
  PORTD_PCR1 |=  PORT_PCR_ISF_MASK;
#if (FS_NAND_HW_USE_OS == 2)
  OS_EVENT_Set(&_Event);
#else
  FS_OS_Signal();
#endif
  OS_LeaveNestableInterrupt();
}

#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_NAND_HW_K66_SEGGER_emPower
*/
const FS_NAND_HW_TYPE FS_NAND_HW_K66_SEGGER_emPower = {
  _HW_Init_x8,
  NULL,
  _HW_DisableCE,
  _HW_EnableCE,
  _HW_SetAddrMode,
  _HW_SetCmdMode,
  _HW_SetDataMode,
  _HW_WaitWhileBusy,
  _HW_Read_x8,
  _HW_Write_x8,
  NULL,
  NULL
};

/************************** End of file ***************************/
```

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6.3.5.4 Hardware layer API - FS_NAND_HW_TYPE_DF

This hardware layer supports Microchip / Atmel / Adesto DataFlash devices and is used by the `FS_NAND_PHY_DataFlash` physical layer to exchange data with a DataFlash device via a standard SPI interface. The functions of this hardware layer are grouped in the structure of type `FS_NAND_HW_TYPE_DF`. The following sections describe these functions in detail.

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6.3.5.4.1 FS_NAND_HW_TYPE_DF

Description

NAND hardware layer API for DataFlash devices.

Type definition

```
typedef struct {
  FS_NAND_HW_TYPE_DF_INIT       * pfInit;
  FS_NAND_HW_TYPE_DF_ENABLE_CS  * pfEnableCS;
  FS_NAND_HW_TYPE_DF_DISABLE_CS * pfDisableCS;
  FS_NAND_HW_TYPE_DF_READ       * pfRead;
  FS_NAND_HW_TYPE_DF_WRITE      * pfWrite;
} FS_NAND_HW_TYPE_DF;
```

Structure members

Member	Description
pfInit	Initializes the hardware.
pfEnableCS	Enables the DataFlash device.
pfDisableCS	Disables the DataFlash device.
pfRead	Transfers a specified number of bytes from DataFlash device to MCU.
pfWrite	Transfers a specified number of bytes from MCU to DataFlash device.

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6.3.5.4.2 FS_NAND_HW_TYPE_DF_INIT

Description

Initializes the hardware.

Type definition

```
typedef int FS_NAND_HW_TYPE_DF_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Return value

= 0 OK, initialization was successful.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_DF NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type. FS_NAND_HW_TYPE_DF_INIT is the first function of the hardware layer API that is called by a NAND physical layer during the mounting of the file system.

This function has to perform any initialization of the MCU hardware required to access the DataFlash device such as clocks, port pins, memory controllers, etc.

A DataFlash requires that the SPI communication protocol meets the following requirements:

- 8-bit data length.
- The most significant bit hast to be sent out first.
- Chip Select (CS) signal should be initially high to disable the DataFlash device.
- The SPI clock frequency does not have to exceed the maximum clock frequency that is specified by the DataFlash device (Usually: 20MHz).

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6.3.5.4.3 FS_NAND_HW_TYPE_DF_ENABLE_CS

Description

Enables the DataFlash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_DF_ENABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_DF NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The DataFlash device is enabled by driving the Chip Select (CS) signal to logic low state.

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6.3.5.4.4 FS_NAND_HW_TYPE_DF_DISABLE_CS

Description

Disables the DataFlash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_DF_DISABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_DF NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The DataFlash device is disabled by driving the Chip Select (CS) signal to logic-high.

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6.3.5.4.5 FS_NAND_HW_TYPE_DF_READ

Description

Transfers a specified number of bytes from DataFlash device to MCU.

Type definition

```
typedef void FS_NAND_HW_TYPE_DF_READ(U8   Unit,
                                     U8 * pData,
                                     int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	out Data read from DataFlash device.
NumBytes	Number of bytes to be read.

Additional information

This function is a member of the FS_NAND_HW_TYPE_DF NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

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6.3.5.4.6 FS_NAND_HW_TYPE_DF_WRITE

Description

Transfers a specified number of bytes from MCU to DataFlash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_DF_WRITE(      U8   Unit,
                                      const U8 * pData,
                                            int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	in Data to be written to DataFlash device.
NumBytes	Number of bytes to be written.

Additional information

This function is a member of the FS_NAND_HW_TYPE_DF NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

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6.3.5.4.7 Sample implementation

The following sample implementation uses the SPI controller of a NXP LPC4322 MCU to interface with a DataFlash device. This NAND hardware layer was tested on a SEGGER internal test board.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_NAND_HW_DF_LPC4322_SEGGER_QSPIFI_Test_Board.c
Purpose : DataFlash hardware layer for NXP LPC4322.
Literature:
  [1] UM10503 LPC43xx ARM Cortex-M4/M0 multi-core microcontroller
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*      Defines, configurable
*
**********************************************************************
*/
#define   PER_CLK_HZ            180000000uL     // Frequency of the clock supplied to SPI unit
#ifndef   SPI_CLK_HZ
  #define SPI_CLK_HZ            25000000uL
  // Frequency of the clock supplied to DataFlash device
#endif
#define   RESET_DELAY_LOOPS     100000
  // Number of software loops to wait for DataFlash to reset

/*********************************************************************
*
*       Defines, non-configurable
*
**********************************************************************
*/

/*********************************************************************
*
*       SPI unit
*/
#define SPI_BASE_ADDR         0x40100000
#define SPI_CR                (*(volatile U32*)(SPI_BASE_ADDR + 0x00))    // SPI Control Register
#define SPI_SR                (*(volatile U32*)(SPI_BASE_ADDR + 0x04))    // SPI Status Register
#define SPI_DR                (*(volatile U32*)(SPI_BASE_ADDR + 0x08))    // SPI Data Register
#define SPI_CCR               (*(volatile U32*)(SPI_BASE_ADDR + 0x0C))
  // SPI Clock Counter Register
#define SPI_TCR               (*(volatile U32*)(SPI_BASE_ADDR + 0x10))
  // SPI Test Control register
#define SPI_TSR               (*(volatile U32*)(SPI_BASE_ADDR + 0x14))
  // SPI Test Status register
#define SPI_INT               (*(volatile U32*)(SPI_BASE_ADDR + 0x1C))    // SPI Interrupt Flag

/*********************************************************************
*
*       Clock generation unit
*/
#define CGU_BASE_ADDR         0x40050000
#define BASE_SPI_CLK          (*(volatile U32*)(CGU_BASE_ADDR + 0x0074))

/*********************************************************************
*
*       Clock control unit 1
```

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```
*/
#define CCU1_BASE_ADDR        0x40051000
#define CLK_SPI_CFG           (*(volatile U32*)(CCU1_BASE_ADDR + 0x0A00))
#define CLK_SPI_STAT          (*(volatile U32*)(CCU1_BASE_ADDR + 0x0A04))

/*********************************************************************
*
*       System control unit
*/
#define SCU_BASE_ADDR         0x40086000
#define SFSP3_2               (*(volatile U32*)(SCU_BASE_ADDR + 0x188))
  // Pin configuration register for pin P3_2
#define SFSP3_3               (*(volatile U32*)(SCU_BASE_ADDR + 0x18C))
  // Pin configuration register for pin P3_3
#define SFSP3_6               (*(volatile U32*)(SCU_BASE_ADDR + 0x198))
  // Pin configuration register for pin P3_6
#define SFSP3_7               (*(volatile U32*)(SCU_BASE_ADDR + 0x19C))
  // Pin configuration register for pin P3_7
#define SFSP3_8               (*(volatile U32*)(SCU_BASE_ADDR + 0x1A0))
  // Pin configuration register for pin P3_8

/*********************************************************************
*
*       GPIO unit
*/
#define GPIO_BASE_ADDR        0x400F4000
#define GPIO_DIR5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2014))
  // Direction registers port 5
#define GPIO_SET5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2214))   // Set register for port
 5
#define GPIO_CLR5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2294))
  // Clear register for port 5

/*********************************************************************
*
*       Misc. defines
*/
#define CGU_IDIV_BIT           2
#define CGU_AUTOBLOCK_BIT      11
#define CGU_CLK_SEL_BIT        24
#define SFS_MODE_BIT           0
#define SFS_EPUN_BIT           4
#define SFS_EHS_BIT            5
#define SFS_EZI_BIT            6
#define SFS_ZIF_BIT            7
#define CLK_STAT_RUN_BIT       0
#define CLK_CFG_RUN_BIT        0
#define NOR_CS_BIT             11
#define CR_MSTR_BIT            5
#define SR_SPIF                7
#define CCR_COUNTER_MAX        0xFE        // The actual maximum value is
 0xFF but it has to be a multiple of 2
#define NOR_RESET_BIT          9

/*********************************************************************
*
*      Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _SetSpeed
*
*  Function description
*    Configures the speed of the clock supplied NOR flash device.
*
*  Return value
*    Frequency of the SPI clock in Hz.
*/
static U32 _SetSpeed(unsigned MaxFreq_Hz) {
  U32 Div;
  U32 Freq_Hz;

  //
```

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```
  // According to [1] the clock divisor has to be >= 8 and a multiple of 2.
  //
  Div = 8;
  while (1) {
    Freq_Hz = PER_CLK_HZ / Div;
    if (Freq_Hz <= MaxFreq_Hz) {
      break;
    }
    Div += 2;
    if (Div >= CCR_COUNTER_MAX) {
      Div = CCR_COUNTER_MAX;
      Freq_Hz = PER_CLK_HZ / Div;
      break;
    }
  }
  SPI_CCR = Div;
  return Freq_Hz;
}

/*********************************************************************
*
*       _TransferByte
*
*  Function description
*    Exchanges 8 bits of data with the NOR flash.
*
*  Parameters
*    Data       Data to be sent to NOR flash.
*
*  Return value
*    The data received from NOR flash
*/
static U8 _Transfer8Bits(U8 Data) {
  SPI_DR = Data;
  while (1) {
    if (SPI_SR & (1uL << SR_SPIF)) {
      break;
    }
  }
  Data = SPI_DR;
  return Data;
}

/*********************************************************************
*
*      Public code (via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initialize the hardware before accessing the device.
*
*  Parameters
*    Unit     Device index
*
*  Return Value
*    ==0      Hardware successfully initialized
*    !=0      An error occurred
*/
static int _HW_Init(U8 Unit) {
  unsigned NumLoops;

  FS_USE_PARA(Unit);    // This device has only one HW unit.
  BASE_SPI_CLK = 0
                 | 9uL  << CGU_CLK_SEL_BIT      // Use PLL1 as clock generator
                 | 1uL  << CGU_AUTOBLOCK_BIT
                 ;
  //
  // Enable the SPI clock if required.
  //
  if ((CLK_SPI_STAT & (1uL << CLK_STAT_RUN_BIT)) == 0) {
```

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```
    CLK_SPI_CFG |= (1uL << CLK_CFG_RUN_BIT);
    while (1) {
      if (CLK_SPI_STAT & (1uL << CLK_CFG_RUN_BIT)) {
        ;
      }
    }
  }
  //
  // Clock pin (SPI_CLK).
  //
  SFSP3_3 = 0
          | (1uL << SFS_MODE_BIT)       // Controlled by SPI unit.
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EHS_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  //
  // Master In Slave Out (SPI_MISO).
  //
  SFSP3_6 = 0
          | (1uL << SFS_MODE_BIT)       // Controlled by SPI unit.
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  //
  // Master Out Slave In (SPI_MOSI).
  //
  SFSP3_7 = 0
          | (1uL << SFS_MODE_BIT)       // Controlled by SPI unit.
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  //
  // Chip select pin (SPI_CS).
  //
  SFSP3_8 = 0
          | (4uL << SFS_MODE_BIT)       // GPIO controlled by the this hardware layer.
          | (1uL << SFS_EPUN_BIT)
          ;
  GPIO_DIR5 |= 1uL << NOR_CS_BIT;
  GPIO_SET5  = 1uL << NOR_CS_BIT;       // Set to idle state.
  //
  // Reset pin. Present only on 16-pin devices.
  //
  SFSP3_2 = 0
          | (4uL << SFS_MODE_BIT)                   // Controlled by this HW layer.
          | (1uL << SFS_EPUN_BIT)
          ;
  GPIO_DIR5 |= 1uL << NOR_RESET_BIT;
  //
  // Reset the NOR device.
  //
  GPIO_CLR5 = 1uL << NOR_RESET_BIT;                 // Assert reset signal (active low).
  NumLoops = RESET_DELAY_LOOPS;
  do {
    ;
  } while (--NumLoops);
  GPIO_SET5 = 1uL << NOR_RESET_BIT;                 // De-assert reset signal (active low).
  //
  // Configure the SPI unit.
  //
  SPI_CR = 0
         | (1uL << CR_MSTR_BIT)
         ;
  (void)_SetSpeed(SPI_CLK_HZ);
  return 0;
}

/*********************************************************************
*
*       _HW_EnableCS
*
*  Function description
*    Sets the device active using the chip select (CS) line.
*
*  Parameters
```

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```
*    Unit     Device index
*/
static void _HW_EnableCS(U8 Unit) {
  FS_USE_PARA(Unit);
  GPIO_CLR5 = 1uL << NOR_CS_BIT;      // The CS signal is active low.
}

/*********************************************************************
*
*       _HW_DisableCS
*
*  Function description
*    Sets the device inactive using the chip select (CS) line.
*
*  Parameters
*    Unit     Device index
*/
static void _HW_DisableCS(U8 Unit) {
  FS_USE_PARA(Unit);
  GPIO_SET5 = 1uL << NOR_CS_BIT;      // The CS signal is active low.
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    Reads a specified number of bytes from device.
*
*  Parameters
*    Unit       Device index
*    pData      Pointer to a data buffer
*    NumBytes   Number of bytes
*/
static void _HW_Read(U8 Unit, U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  do {
    *pData++ = _Transfer8Bits(0xFF);
  } while (--NumBytes);
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    Writes a specified number of bytes from data buffer to device.
*
*  Parameters
*    Unit         Device index
*    pData        Pointer to a data buffer
*    NumBytes     Number of bytes
*/
static void _HW_Write(U8 Unit, const U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  do {
    (void)_Transfer8Bits(*pData++);
  } while (--NumBytes);
}

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/
const FS_NAND_HW_TYPE_DF FS_NAND_HW_DF_LPC4322_SEGGER_QSPIFI_Test_Board = {
  _HW_Init,
  _HW_EnableCS,
  _HW_DisableCS,
  _HW_Read,
  _HW_Write
};

/************************** End of file ****************************/
```

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6.3.5.5 Hardware layer API - FS_NAND_HW_TYPE_QSPI

This hardware layer supports any serial NAND flash device with a standard, dual, or quad SPI interface. It is used by the `FS_NAND_PHY_QSPI` physical layer to exchange data with a NAND flash device that supports such an interface. Typically, the implementation of the `FS_NAND_HW_TYPE_QSPI` hardware layer makes use of an SPI controller that is able to exchange the data via two or four data lines. This kind of SPI controller is found on most of the popular MCUs, and they are typically used to execute code in-place from an external NAND flash device, but they can be equally well used to exchange data with a serial NAND flash device.

The functions of this hardware layer are grouped in the structure of type `FS_NAND_HW_TYPE_QSPI`. The following sections describe these functions in detail.

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6.3.5.5.1 FS_NAND_HW_TYPE_QSPI

Description

NAND hardware layer API for NAND flash devices connected via quad and dual SPI.

Type definition

```
typedef struct {
  FS_NAND_HW_TYPE_QSPI_INIT           * pfInit;
  FS_NAND_HW_TYPE_QSPI_CONTROL        * pfExecCmd;
  FS_NAND_HW_TYPE_QSPI_READ           * pfReadData;
  FS_NAND_HW_TYPE_QSPI_WRITE          * pfWriteData;
  FS_NAND_HW_TYPE_QSPI_POLL           * pfPoll;
  FS_NAND_HW_TYPE_QSPI_DELAY          * pfDelay;
  FS_NAND_HW_TYPE_QSPI_LOCK           * pfLock;
  FS_NAND_HW_TYPE_QSPI_UNLOCK         * pfUnlock;
  FS_NAND_HW_TYPE_QSPI_READ_EX        * pfReadEx;
  FS_NAND_HW_TYPE_QSPI_WRITE_MULTIPLE * pfWriteMultiple;
} FS_NAND_HW_TYPE_QSPI;
```

Structure members

Member	Description
pfInit	Initializes the hardware.
pfExecCmd	Executes a command without data transfer.
pfReadData	Transfers data from NAND flash device to MCU.
pfWriteData	Transfers data from MCU to NAND flash device.
pfPoll	Sends a command repeatedly and checks the response data for a specified condition.
pfDelay	Blocks the execution for the specified number of milliseconds.
pfLock	Requests exclusive access to SPI bus.
pfUnlock	Releases the exclusive access of SPI bus.
pfReadEx	Transfers data from NAND flash device to MCU.
pfWriteMultiple	Transfers data from MCU to NAND flash device.

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6.3.5.5.2 FS_NAND_HW_TYPE_QSPI_INIT

Description

Initializes the hardware.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Return value

Frequency of the QSPI clock in kHz.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is mandatory.

This function has to configure anything necessary for the data transfer via QSPI such as clocks, port pins, QSPI peripheral, DMA, etc.

The frequency value returned by the function has to be greater than or equal to the actual clock frequency used to transfer the data via QSPI. The FS_NAND_PHY_QSPI physical layer uses this value to calculate the number of software cycles it has to wait for NAND flash device to finish an operation before a timeout error is reported. FS_NAND_HW_TYPE_QSPI_INIT must return 0 if the clock frequency is unknown. In this case, the FS_NAND_PHY_QSPI physical layer waits indefinitely for the end of a NAND flash operation and it never reports a timeout error.

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6.3.5.5.3 FS_NAND_HW_TYPE_QSPI_CONTROL

Description

Executes a command without data transfer.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_CONTROL(U8 Unit,
                                         U8 Cmd,
                                         U8 BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
Cmd	Code of the command to be sent.
BusWidth	Number of data lines to be used for sending the command code.

Return value

= 0 OK, command sent.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is mandatory.

FS_NAND_HW_TYPE_QSPI_CONTROL must to send a 8 bits to NAND flash device containing the value specified via Cmd.

BusWidth specifies the number of data lines to be used when sending the command code. Permitted values are:

- 1 for standard SPI
- 2 for quad SPI (2 data lines)
- 4 for quad SPI (4 data lines)

Please note that this is not an encoded value such as the value passed via BusWidth in a call to FS_NAND_HW_TYPE_QSPI_READ, FS_NAND_HW_TYPE_QSPI_WRITE or FS_NAND_HW_TYPE_QSPI_POLL.

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6.3.5.5.4 FS_NAND_HW_TYPE_QSPI_READ

Description

Transfers data from NAND flash device to MCU.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_READ(      U8       Unit,
                                            U8       Cmd,
                                      const U8     * pPara,
                                            unsigned NumBytesPara,
                                            unsigned NumBytesAddr,
                                            U8     * pData,
                                            unsigned NumBytesData,
                                            U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
Cmd	Code of the command to be sent.
pPara	Additional command parameters (can be NULL).
NumBytesPara	Number of additional bytes to be sent after command. Can be 0 if pPara is NULL.
NumBytesAddr	Number of address bytes to be sent. Can be 0 if pPara is NULL.
pData	Data received from the NAND flash device.
NumBytesData	Number of bytes to be received from the NAND flash device.
BusWidth	Specifies the number of data lines to be used during the data transfer.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is mandatory.

The data has to be sent in this order: Cmd (1 byte) and pPara (NumBytesPara bytes). The first NumBytesAddr bytes in pPara represent the address bytes while the rest until NumBytesPara bytes are dummy bytes. These values are useful for QSPI hardware that can differentiate between address and dummy bytes. If NumBytesPara and NumBytesAddr are equal, no dummy bytes have to be sent. NumBytesPara is never be smaller than NumBytesAddr. The data received from NAND flash has to be stored to pData (NumBytesData bytes).

The number of data lines to be used during the data transfer is specified via BusWidth. The value is encoded with each nibble (4 bits) specifying the number of data lines for one part of the data transfer. The macros *SPI bus width decoding* on page 805 can be used to decode the number of data lines of each part of the request (command and address) and of the response (data). The dummy bytes have to be sent using the number of data lines returned by FS_BUSWIDTH_GET_ADDR().

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6.3.5.5.5 FS_NAND_HW_TYPE_QSPI_WRITE

Description

Transfers data from MCU to NAND flash device.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_WRITE(      U8       Unit,
                                             U8       Cmd,
                                       const U8     * pPara,
                                             unsigned NumBytesPara,
                                             unsigned NumBytesAddr,
                                       const U8     * pData,
                                             unsigned NumBytesData,
                                             U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
Cmd	Code of the command to be sent.
pPara	Additional command parameters (can be NULL).
NumBytesPara	Number of additional bytes to be sent after command. Can be 0 if pPara is NULL.
NumBytesAddr	Number of address bytes to be sent. Can be 0 if pPara is NULL.
pData	Data to be sent to NAND flash device.
NumBytesData	Number of data bytes to be sent to NAND flash device.
BusWidth	Specifies the number of data lines to be used during the data transfer.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is mandatory.

The data has to be sent in this order: Cmd (1 byte), pPara (NumBytesPara bytes), pData (NumBytesData bytes). The first NumBytesAddr bytes in pPara represent the address bytes while the rest until NumBytesPara bytes are dummy bytes. These values are useful for QSPI hardware that can differentiate between address and dummy bytes. If NumBytesPara and NumBytesAddr are equal, no dummy bytes have to be sent. NumBytesPara will never be smaller than NumBytesAddr.

The number of data lines to be used during the data transfer is specified via BusWidth. The value is encoded with each nibble specifying the number of data lines for one part of the data transfer. The macros *SPI bus width decoding* on page 805 can be used to decode the number of data lines of each part of the request (command, address and data). The dummy bytes have to be sent using the number of data lines returned by FS_BUSWIDTH_GET_ADDR().

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6.3.5.5.6 FS_NAND_HW_TYPE_QSPI_POLL

Description

Sends a command repeatedly and checks the response data for a specified condition.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_POLL(      U8       Unit,
                                            U8       Cmd,
                                      const U8     * pPara,
                                            unsigned NumBytesPara,
                                            U8       BitPos,
                                            U8       BitValue,
                                            U32      Delay,
                                            U32      TimeOut_ms,
                                            U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
Cmd	Code of the command to be sent.
pPara	Additional command parameters (can be NULL).
NumBytesPara	Number of additional bytes to be sent after command. Can be 0 if pPara is NULL.
BitPos	Position of the bit inside response data that has to be checked (0-based, with 0 being LSB)
BitValue	Bit value to wait for.
Delay_ms	Time between two command executions.
TimeOut_ms	Maximum time to wait for the bit at BitPos to be set to BitValue.
BusWidth	Specifies how many data lines have to be used for sending the command and parameters and for reading the data.

Return value

> 0	Error, timeout occurred.
= 0	OK, bit set to specified value.
< 0	Error, feature not supported.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is optional. FS_NAND_HW_TYPE_QSPI_POLL is called by the QSPI NAND physical layer when it has to wait for the NAND flash device to reach a certain status.

FS_NAND_HW_TYPE_QSPI_POLL has to read periodically a byte of data from the NAND flash device until the value of the bit at BitPos in the in the returned data byte is set to a value specified by BitValue. The data is read by sending a command with a code specified by Cmd followed by an optional number of additional bytes specified by pPara and NumBytesPara. Then 8 bits of data are transferred from NAND flash device to MCU and this the value stores the bit to be checked.

The number of data lines to be used during the data transfer is specified via BusWidth. The value is encoded with each nibble specifying the number of data lines for one part of the data transfer. The macros *SPI bus width decoding* on page 805 can be used to decode the number of data lines of each part of the request (command, parameters and data). The pPara data has to be sent using the number of data lines returned by FS_BUSWIDTH_GET_ADDR().

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The time FS_NAND_HW_TYPE_QSPI_POLL waits for the condition to be true shall not exceed the number of milliseconds specified by TimeOut_ms. Delay_ms specifies the number of milliseconds that can elapse between the execution of two consecutive commands.

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6.3.5.5.7 FS_NAND_HW_TYPE_QSPI_DELAY

Description

Blocks the execution for the specified number of milliseconds.

Type definition

```
typedef void FS_NAND_HW_TYPE_QSPI_DELAY(U8  Unit,
                                        int ms);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
ms	Number of milliseconds to wait.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is mandatory.

The time FS_NAND_HW_TYPE_QSPI_DELAY blocks does not have to be accurate. That is the function can block the execution longer that the number of specified milliseconds but no less than that.

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6.3.5.5.8 FS_NAND_HW_TYPE_QSPI_LOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_QSPI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is optional.

The FS_NAND_PHY_QSPI physical layer calls this function to indicate that it needs exclusive to access the NAND flash device via the SPI bus. It is guaranteed that the FS_NAND_PHY_QSPI physical layer does not attempt to communicate via the SPI bus before calling this function first. It is also guaranteed that FS_NAND_HW_TYPE_QSPI_LOCK and FS_NAND_HW_TYPE_QSPI_UNLOCK are called in pairs.

FS_NAND_HW_TYPE_QSPI_UNLOCK and FS_NAND_HW_TYPE_QSPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the NAND flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired in this function and released in FS_NAND_HW_TYPE_QSPI_UNLOCK.

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6.3.5.5.9 FS_NAND_HW_TYPE_QSPI_UNLOCK

Description

Releases the exclusive access of SPI bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_QSPI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The implementation of this function is optional.

The FS_NAND_PHY_QSPI physical layer calls this function when it no longer needs to access the NAND flash device via the SPI bus. It is guaranteed that the FS_NAND_PHY_QSPI physical layer does not attempt to communicate via the SPI bus before calling FS_NAND_HW_TYPE_QSPI_LOCK. It is also guaranteed that FS_NAND_HW_TYPE_QSPI_UNLOCK and FS_NAND_HW_TYPE_QSPI_LOCK are called in pairs.

FS_NAND_HW_TYPE_QSPI_UNLOCK and FS_NAND_HW_TYPE_QSPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the NAND flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired in this function and released in FS_NAND_HW_TYPE_QSPI_UNLOCK.

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6.3.5.5.10 FS_NAND_HW_TYPE_QSPI_READ_EX

Description

Transfers data from serial NAND flash device to MCU.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_READ_EX(      U8       Unit,
                                         const U8     * pCmd,
                                               unsigned NumBytesCmd,
                                         const U8     * pPara,
                                               unsigned NumBytesPara,
                                               unsigned NumBytesAddr,
                                               U8     * pData,
                                               unsigned NumBytesData,
                                               U16      BusWidth,
                                               unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	out Data read from the serial NAND flash device. Can be NULL.
NumBytesData	Number of bytes to read from the serial NAND flash device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the QSPI NAND hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data in DTR mode. If the hardware layer does not implement this function then FS_NAND_HW_TYPE_QSPI_READ is called instead.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara. If NumBytesAddr is equal to NumBytesPara then no dummy bytes have to be sent. The number of dummy bytes to be generated can be calculated as NumBytesPara - NumBytesAddr. If the hardware generates dummy cycles instead of bytes then the number of dummy bytes has to converted to clock cycles by taking into account the number of data lines used for the data transfer of the address.

This function performs the same operation as FS_NAND_HW_TYPE_QSPI_READ with the difference that it can handle multi-byte commands and additional data transfer options specified via Flags. Flags is a bitwise-or combination of *NAND HW layer flags* on page 804. In addition, this function is able to report an error via the return value.

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6.3.5.5.11 FS_NAND_HW_TYPE_QSPI_WRITE_MULTIPLE

Description

Transfers data from MCU to NAND flash device.

Type definition

```
typedef int FS_NAND_HW_TYPE_QSPI_WRITE_MULTIPLE(
                                                U8                    Unit,
                                                U8                    Cmd,
                                          const U8                  * pPara,
                                                unsigned              NumBytesPara,
                                                unsigned              NumBytesAddr,
                                          const FS_DATA_ITEM_CONST  * pDataItem,
                                                unsigned              NumDataItems,
                                                U16                   BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
Cmd	Code of the command to be sent.
pPara	Additional command parameters (can be NULL).
NumBytesPara	Number of additional bytes to be sent after command. Can be 0 if pPara is NULL.
NumBytesAddr	Number of address bytes to be sent. Can be 0 if pPara is NULL.
pDataItem	List of data blocks to be sent to NAND flash device.
NumDataItems	Number of data blocks to be sent to NAND flash device.
BusWidth	Specifies the number of data lines to be used during the data transfer.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_QSPI NAND hardware layer API. The function has to be implemented only by hardware layers that have to be exchange data with a serial NAND flash device that does not support Program Load Random Data commands. If the hardware layer does not implement this function, then FS_NAND_HW_TYPE_QSPI_WRITE is called instead.

The data has to be sent in this order: Cmd (1 byte), pPara (NumBytesPara bytes), pDataItem (NumDataItems bytes). The first NumBytesAddr bytes in pPara represent the address bytes while the rest until NumBytesPara bytes are dummy bytes. These values are useful for QSPI hardware that can differentiate between address and dummy bytes. If NumBytesPara and NumBytesAddr are equal, no dummy bytes have to be sent. NumBytesPara will never be smaller than NumBytesAddr.

The number of data lines to be used during the data transfer is specified via BusWidth. The value is encoded with each nibble specifying the number of data lines for one part of the data transfer. The macros *SPI bus width decoding* on page 805 can be used to decode the number of data lines of each part of the request (command, address and data). The dummy bytes have to be sent using the number of data lines returned by FS_BUSWIDTH_GET_ADDR().

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6.3.5.5.12 FS_DATA_ITEM_CONST

Description

Block of data.

Type definition

```
typedef struct {
  const U8 * pData;
  U32        NumBytes;
} FS_DATA_ITEM_CONST;
```

Structure members

Member	Description
pData	Block location in memory.
NumBytes	Size of the block in bytes.

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6.3.5.5.13 NAND HW layer flags

Description

Additional options for data exchanged via the QSPI NAND HW layer.

Definition

```
#define FS_NAND_HW_FLAG_DTR_DATA    (1uL << 0)
#define FS_NAND_HW_FLAG_DTR_ADDR    (1uL << 1)
```

Symbols

Definition	Description
FS_NAND_HW_FLAG_DTR_DATA	Exchange the data on each clock transition.
FS_NAND_HW_FLAG_DTR_ADDR	Send the address on each clock transition.

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6.3.5.5.14 SPI bus width decoding

Description

Macros for the handling of SPI bus width.

Definition

```
#define FS_BUSWIDTH_GET_CMD(BusWidth)     (((BusWidth) >> FS_BUSWIDTH_CMD_SHIFT)
  & FS_BUSWIDTH_MASK)
#define FS_BUSWIDTH_GET_ADDR(BusWidth)
  (((BusWidth) >> FS_BUSWIDTH_ADDR_SHIFT) & FS_BUSWIDTH_MASK)
#define FS_BUSWIDTH_GET_DATA(BusWidth)
  (((BusWidth) >> FS_BUSWIDTH_DATA_SHIFT) & FS_BUSWIDTH_MASK)
```

Symbols

Definition	Description
FS_BUSWIDTH_GET_CMD(BusWidth)	Returns the number of data lines to be used for sending the command code.
FS_BUSWIDTH_GET_ADDR(BusWidth)	Returns the number of data lines to be used for sending the data address.
FS_BUSWIDTH_GET_DATA(BusWidth)	Returns the number of data lines to be used for sending and receiving of the user data.

Additional information

The functions of the FS_NOR_HW_TYPE_SPIFI NOR hardware layer and of the FS_NAND_HW_TYPE_QSPI NAND hardware layer that exchange data with the storage device take a parameter that specifies how many data lines have to be used to send different parts of a request and to receive the answer. The value of this parameter is encoded as a 16-bit value and the macros in this section can help extract the bus width value for a specific part of the request and response.

The value is encoded as follows:

Bit range
0-3
4-7
8-11

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6.3.5.5.15 Sample implementation

The sample implementation listed below uses the QUADSPI controller of an ST STM32H743 MCU to interface with a serial NAND flash device. This NAND hardware layer was tested on a SEGGER internal test board.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_NAND_HW_QSPI_STM32H743_SEGGER_QSPI_Flash_Evaluator.c
Purpose : HW layer for quad and dual serial NAND flash for ST STM32H743.
Literature:
  [1] RM0433 Reference manual STM32H7x3 advanced ARM-based 32-bit MCUs
  [2] STM32H753xI Errata sheet STM32H753xI rev Y device limitations
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_NAND_HW_PER_CLK_HZ
  #define FS_NAND_HW_PER_CLK_HZ             240000000     // Clock of Quad-SPI unit
#endif

#ifndef   FS_NAND_HW_NAND_CLK_HZ
  #define FS_NAND_HW_NAND_CLK_HZ            48000000      // Frequency of the clock
                                                          // supplied to NAND flash device
#endif

#ifndef   FS_NAND_HW_CYCLES_PER_MS
  #define FS_NAND_HW_CYCLES_PER_MS          150000        // Number of software loops
                                                          // create a 1ms delay
#endif

#ifndef   FS_NAND_HW_USE_OS
  #define FS_NAND_HW_USE_OS                 0
  // Enables/disables the interrupt-driven operation.
                                                          // Permitted values:
                                                          //   0 - polling via CPU
                                                          //   1 - event-driven using embOS
                                                          //   2 - event-driven using other RTOS
#endif

#ifndef   FS_NAND_HW_USE_QUAD_MODE
  #define FS_NAND_HW_USE_QUAD_MODE          1
  // Enables/disables the support for quad mode.
#endif

/*********************************************************************
*
*       #include section, conditional
*
**********************************************************************
*/
#if FS_NAND_HW_USE_OS
  #include "stm32h7xx.h"
  #include "FS_OS.h"
#if (FS_NAND_HW_USE_OS == 1)
  #include "RTOS.h"
#endif // FS_NAND_HW_USE_OS == 1
```

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```
#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*       QSPI registers
*/
#define QUADSPI_BASE_ADDR       0x52005000uL
#define QUADSPI_CR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x00))
#define QUADSPI_DCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x04))
#define QUADSPI_SR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x08))
#define QUADSPI_FCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x0C))
#define QUADSPI_DLR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x10))
#define QUADSPI_CCR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x14))
#define QUADSPI_AR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x18))
#define QUADSPI_ABR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x1C))
#define QUADSPI_DR              (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x20))
#define QUADSPI_DR_BYTE         (*(volatile U8  *)(QUADSPI_BASE_ADDR + 0x20))
#define QUADSPI_PSMKR           (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x24))
#define QUADSPI_PSMAR           (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x28))
#define QUADSPI_PIR             (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x2C))
#define QUADSPI_LPTR            (*(volatile U32 *)(QUADSPI_BASE_ADDR + 0x30))

/*********************************************************************
*
*       Port B registers
*/
#define GPIOB_BASE_ADDR         0x58020400uL
#define GPIOB_MODER             (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x00))
#define GPIOB_OSPEEDR           (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x08))
#define GPIOB_PUPDR             (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x0C))
#define GPIOB_ODR               (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x14))
#define GPIOB_AFRL              (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x20))

/*********************************************************************
*
*       Port F registers
*/
#define GPIOF_BASE_ADDR         0x58021400uL
#define GPIOF_MODER             (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x00))
#define GPIOF_OSPEEDR           (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x08))
#define GPIOF_PUPDR             (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x0C))
#define GPIOF_ODR               (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x14))
#define GPIOF_BSRR              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x18))
#define GPIOF_AFRL              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x20))
#define GPIOF_AFRH              (*(volatile U32 *)(GPIOF_BASE_ADDR + 0x24))

/*********************************************************************
*
*       Reset and clock control
*/
#define RCC_BASE_ADDR           0x58024400uL
#define RCC_AHB3RSTR            (*(volatile U32*)(RCC_BASE_ADDR + 0x7C))
#define RCC_AHB3ENR             (*(volatile U32*)(RCC_BASE_ADDR + 0xD4))
#define RCC_AHB4ENR             (*(volatile U32*)(RCC_BASE_ADDR + 0xE0))

/*********************************************************************
*
*       Masks for the peripheral enable bits
*/
#define AHB4ENR_GPIOBEN         1
#define AHB4ENR_GPIOFEN         5
#define AHB3ENR_QSPIEN          14

/*********************************************************************
*
*       GPIO bit positions of SPI signals
*/
#define NAND_BK1_NCS_BIT        6   // Port B
#define NAND_CLK_BIT            10  // Port F
```

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```
#define NAND_BK1_D0_BIT         8   // Port F
#define NAND_BK1_D1_BIT         9   // Port F
#define NAND_BK1_D2_BIT         7   // Port F
#define NAND_BK1_D3_BIT         6   // Port F

/*********************************************************************
*
*       GPIO bits and masks
*/
#define OSPEEDR_HIGH            2uL
#define OSPEEDR_MASK            0x3uL
#define MODER_MASK              0x3uL
#define MODER_OUT               1uL
#define MODER_ALT               2uL
#define AFR_MASK                0xFuL

/*********************************************************************
*
*       Quad-SPI control register
*/
#define CR_EN_BIT               0
#define CR_ABORT_BIT            1
#define CR_SMIE_BIT             19
#define CR_APMS_BIT             22
#define CR_PRESCALER_BIT        24
#define CR_PRESCALER_MAX        255

/*********************************************************************
*
*       Quad-SPI device configuration register
*/
#define DCR_CKMODE_BIT          0
#define DCR_CSHT_BIT            8
#define DCR_FSIZE_BIT           16
#define DCR_FSIZE_MAX           0x1FuL

/*********************************************************************
*
*       Quad-SPI status register
*/
#define SR_TEF_BIT              0
#define SR_TCF_BIT              1
#define SR_SMF_BIT              3
#define SR_TOF_BIT              4
#define SR_BUSY_BIT             5
#define SR_FLEVEL_BIT           8
#define SR_FLEVEL_MASK          0x3FuL

/*********************************************************************
*
*       Quad-SPI communication configuration register
*/
#define CCR_INTRUCTION_BIT      0
#define CCR_IMODE_BIT           8
#define CCR_MODE_NONE           0
#define CCR_MODE_SINGLE         1uL
#define CCR_MODE_DUAL           2uL
#define CCR_MODE_QUAD           3uL
#define CCR_ADMODE_BIT          10
#define CCR_ADSIZE_BIT          12
#define CCR_ADSIZE_MASK         0x03uL
#define CCR_ABMODE_BIT          14
#define CCR_ABSIZE_BIT          16
#define CCR_ABSIZE_MASK         0x03uL
#define CCR_DCYC_BIT            18
#define CCR_DMODE_BIT           24
#define CCR_FMODE_BIT           26
#define CCR_FMODE_WRITE         0x0uL
#define CCR_FMODE_READ          0x1uL
#define CCR_FMODE_POLL          0x2uL
#define CCR_FMODE_MMAP          0x3uL
#define CCR_FMODE_MASK          0x3uL
#define CCR_DDRM_BIT            31

/*********************************************************************
*
```

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```
*       Misc. defines
*/
#define NUM_BYTES_FIFO          32
#define WAIT_TIMEOUT_MS         500
#define WAIT_TIMEOUT_CYCLES     (WAIT_TIMEOUT_MS * FS_NAND_HW_CYCLES_PER_MS)
#define QUADSPI_PRIO            15

/*********************************************************************
*
*       ASSERT_IS_LOCKED
*/
#if FS_SUPPORT_TEST
  #define ASSERT_IS_LOCKED()                  \
    if (_LockCnt != 1) {                      \
      FS_X_PANIC(FS_ERRCODE_INVALID_USAGE);   \
    }
#else
  #define ASSERT_IS_LOCKED()
#endif

/*********************************************************************
*
*       IF_TEST
*/
#if FS_SUPPORT_TEST
  #define IF_TEST(Expr)       Expr
#else
  #define IF_TEST(Expr)
#endif

/*********************************************************************
*
*      Static data
*
**********************************************************************
*/
#if FS_SUPPORT_TEST
  static U8 _LockCnt = 0;      // Just to test if the Lock()/Unlock
                               // function are called correctly.
#endif

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _CalcClockDivider
*/
static U8 _CalcClockDivider(U32 * pFreq_Hz) {
  U8  Div;
  U32 Freq_Hz;
  U32 MaxFreq_Hz;

  Div        = 0;
  MaxFreq_Hz = *pFreq_Hz;
  for (;;) {
    Freq_Hz = FS_NAND_HW_PER_CLK_HZ / (Div + 1);
    if (Freq_Hz <= MaxFreq_Hz) {
      break;
    }
    ++Div;
    if (Div == CR_PRESCALER_MAX) {
      break;
    }
  }
  *pFreq_Hz = Freq_Hz;
  return Div;
}

/*********************************************************************
*
*       _GetMode
```

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```
*/
static U32 _GetMode(unsigned BusWidth, U32 NumBytes) {
  U32 Mode;

  Mode = CCR_MODE_NONE;
  if (NumBytes) {
    switch (BusWidth) {
    case 1:
      Mode = CCR_MODE_SINGLE;
      break;
    case 2:
      Mode = CCR_MODE_DUAL;
      break;
    case 4:
      Mode = CCR_MODE_QUAD;
      break;
    default:
      break;
    }
  }
  return Mode;
}

/*********************************************************************
*
*       _CalcNumCycles
*
*  Function description
*    Calculates the number of clock cycles required to transfer a specified number of bytes.
*/
static U32 _CalcNumCycles(unsigned BusWidth, U32 NumBytes, int IsDTRMode) {
  U32 NumCycles;

  NumCycles = 0;
  if (NumBytes != 0) {
    NumCycles = NumBytes << 3;        // Assume 8-bits per byte.
    switch (BusWidth) {
    case 2:
      NumCycles >>= 1;
      break;
    case 4:
      NumCycles >>= 2;
      break;
    default:
      break;
    }
    if (IsDTRMode != 0) {
      NumCycles >>= 1;                // The data is sent on both clock edges.
    }
  }
  return NumCycles;
}

/*********************************************************************
*
*       _ClearFlags
*
*  Function description
*    Clears the status flags of QUADSPI peripheral.
*/
static int _ClearFlags(void) {
  U32 TimeOut;
  int r;

  QUADSPI_FCR = 0
              | (1uL << SR_TEF_BIT)
              | (1uL << SR_TCF_BIT)
              | (1uL << SR_SMF_BIT)
              | (1uL << SR_TOF_BIT)
              ;
  //
  // Wait for the flags to be cleared.
  //
  r       = 0;
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
```

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```
    if ((QUADSPI_SR & ((1uL << SR_TEF_BIT) |
                       (1uL << SR_TCF_BIT) |
                       (1uL << SR_SMF_BIT) |
                       (1uL << SR_TOF_BIT))) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                    // Error, could not clear flags.
      break;
    }
  }
  return r;
}

#if FS_NAND_HW_USE_OS

/*********************************************************************
*
*       _Cancel
*
*  Function description
*    Interrupts an ongoing data transfer.
*/
static int _Cancel(void) {
  U32 TimeOut;
  int r;

  r       = 0;
  TimeOut = WAIT_TIMEOUT_CYCLES;
  QUADSPI_CR |= 1uL << CR_ABORT_BIT;
  for (;;) {
    if ((QUADSPI_CR & (1uL << CR_ABORT_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                    // Error, could not cancel data transfer.
      break;
    }
  }
  return r;
}

#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       _Init
*
*  Function description
*    Initializes the QSPI hardware.
*/
static int _Init(void) {
  U32 Div;
  U32 Freq_Hz;

  //
  // Enable the clocks of peripherals and reset them.
  //
  RCC_AHB4ENR  |= 0
               | (1uL << AHB4ENR_GPIOBEN)
               | (1uL << AHB4ENR_GPIOFEN)
               ;
  RCC_AHB3ENR  |=   1uL << AHB3ENR_QSPIEN;
  RCC_AHB3RSTR |=   1uL << AHB3ENR_QSPIEN;
  RCC_AHB3RSTR &= ~(1uL << AHB3ENR_QSPIEN);
  //
  // Wait for the unit to exit reset.
  //
  for (;;) {
    if ((RCC_AHB3RSTR & (1uL << AHB3ENR_QSPIEN)) == 0) {
      break;
    }
  }
  //
  // NCS of bank 1 is an output signal and is controlled by the QUADSPI unit.
  //
```

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```
  GPIOB_MODER   &= ~(MODER_MASK   << (NAND_BK1_NCS_BIT << 1));
  GPIOB_MODER   |=   MODER_ALT    << (NAND_BK1_NCS_BIT << 1);
  GPIOB_AFRL    &= ~(AFR_MASK     << (NAND_BK1_NCS_BIT << 2));
  GPIOB_AFRL    |=   0xAuL        << (NAND_BK1_NCS_BIT << 2);
  GPIOB_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_NCS_BIT << 1));
  GPIOB_OSPEEDR |=   OSPEEDR_HIGH << (NAND_BK1_NCS_BIT << 1);
  //
  // CLK is an output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_CLK_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (NAND_CLK_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((NAND_CLK_BIT - 8) << 2));
  GPIOF_AFRH    |=   0x9uL        << ((NAND_CLK_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_CLK_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (NAND_CLK_BIT << 1);
  //
  // D0 of bank 1 is an input/output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D0_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (NAND_BK1_D0_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((NAND_BK1_D0_BIT - 8) << 2));
  GPIOF_AFRH    |=   0xAuL        << ((NAND_BK1_D0_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D0_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (NAND_BK1_D0_BIT << 1);
  //
  // D1 of bank 1 is an input/output signal controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D1_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (NAND_BK1_D1_BIT << 1);
  GPIOF_AFRH    &= ~(AFR_MASK     << ((NAND_BK1_D1_BIT - 8) << 2));
  GPIOF_AFRH    |=   0xAuL        << ((NAND_BK1_D1_BIT - 8) << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D1_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (NAND_BK1_D1_BIT << 1);
#if FS_NAND_HW_USE_QUAD_MODE
  //
  // D2 of bank 1 is an input/output signal and is controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D2_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (NAND_BK1_D2_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (NAND_BK1_D2_BIT << 2));
  GPIOF_AFRL    |=   0x9uL        << (NAND_BK1_D2_BIT << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D2_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (NAND_BK1_D2_BIT << 1);
  //
  // D3 of bank 1 is an output signal and is controlled by the QUADSPI unit.
  //
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D3_BIT << 1));
  GPIOF_MODER   |=   MODER_ALT    << (NAND_BK1_D3_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (NAND_BK1_D3_BIT << 2));
  GPIOF_AFRL    |=   0x9uL        << (NAND_BK1_D3_BIT << 2);
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D3_BIT << 1));
  GPIOF_OSPEEDR |=   OSPEEDR_HIGH << (NAND_BK1_D3_BIT << 1);
#else
  //
  // D2 and D3 are used as WP and HOLD signals when the quad mode
  // is disabled in the NAND flash device. We set these signals to
  // logic high here so that the data transfer works correctly
  // in single and dual mode.
  //
  GPIOF_BSRR    = 1uL << NAND_BK1_D2_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D2_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (NAND_BK1_D2_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (NAND_BK1_D2_BIT << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D2_BIT << 1));
  GPIOF_BSRR    = 1uL << NAND_BK1_D3_BIT;
  GPIOF_MODER   &= ~(MODER_MASK   << (NAND_BK1_D3_BIT << 1));
  GPIOF_MODER   |=   MODER_OUT    << (NAND_BK1_D3_BIT << 1);
  GPIOF_AFRL    &= ~(AFR_MASK     << (NAND_BK1_D3_BIT << 2));
  GPIOF_OSPEEDR &= ~(OSPEEDR_MASK << (NAND_BK1_D3_BIT << 1));
#endif // FS_NAND_HW_USE_QUAD_MODE
#if FS_NAND_HW_USE_OS
  //
  // Disable the interrupt and configure the priority.
  //
  NVIC_DisableIRQ(QUADSPI_IRQn);
  NVIC_SetPriority(QUADSPI_IRQn, QUADSPI_PRIO);
```

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```
#endif // FS_NAND_HW_USE_OS
  //
  // Initialize the Quad-SPI controller.
  //
  Freq_Hz = FS_NAND_HW_NAND_CLK_HZ;
  Div = (U32)_CalcClockDivider(&Freq_Hz);
  QUADSPI_CR  = 0
              | (1uL << CR_EN_BIT)                  // Enable the Quad-SPI unit.
              | (Div << CR_PRESCALER_BIT)
              ;
  QUADSPI_DCR = 0
              | (1uL           << DCR_CKMODE_BIT)   // CLK signal stays HIGH
                                                    // when the NAND flash is not selected.
              | (DCR_FSIZE_MAX << DCR_FSIZE_BIT)    // We set the NAND flash size to maximum
                                                    // since the actual value is not known
                                                    // at this stage.
              | (1uL           << DCR_CSHT_BIT)     // Wait at least 40ns at
 48MHz between two commands.
              ;
#if FS_NAND_HW_USE_OS
  //
  // Clear interrupt flags and enable the interrupt.
  //
  QUADSPI_CR  |= 0
              | (1uL << CR_SMIE_BIT)
              | (1uL << CR_APMS_BIT)
              ;
  QUADSPI_FCR  = 1uL << SR_SMF_BIT;
  NVIC_EnableIRQ(QUADSPI_IRQn);
#endif // FS_NAND_HW_USE_OS
  return (int)Freq_Hz / 1000;
}

/*********************************************************************
*
*       _Control
*
*  Function description
*    Executes a NAND flash command without data transfer.
*/
static int _Control(U8 Cmd, U8 BusWidth) {
  U32 CfgReg;
  U32 CmdMode;
  U32 TimeOut;
  int r;

  //
  // Initialize local variables.
  //
  r       = 0;
  CmdMode = _GetMode(BusWidth, sizeof(Cmd));
  CfgReg  = 0
          | (CCR_FMODE_WRITE << CCR_FMODE_BIT)
          | (CmdMode         << CCR_IMODE_BIT)
          | (Cmd             << CCR_INTRUCTION_BIT)
          ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                        // Error, QUADSPI is not ready.
      goto Done;
    }
  }
  //
  // Execute the command.
  //
  QUADSPI_DLR = 0;
  QUADSPI_ABR = 0;
  QUADSPI_CCR = CfgReg;
  //
```

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```
  // Wait until the command has been completed.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                                // Error, QUADSPI is not ready.
      break;
    }
  }
Done:
  return r;
}

/*********************************************************************
*
*       _Read
*
*  Function description
*    Transfers data from NAND flash device to MCU.
*/
static int _Read(const U8 * pCmd, unsigned NumBytesCmd, const U8 * pPara,
                 unsigned NumBytesPara, unsigned NumBytesAddr, U8 * pData,
                 unsigned NumBytesData, U16 BusWidth, unsigned Flags) {
  U32      AddrReg;
  U32      AltReg;
  U32      CfgReg;
  U32      DataMode;
  U32      AddrMode;
  U32      CmdMode;
  U32      DataReg;
  U32      NumCyclesDummy;
  U32      AddrSize;
  U32      NumBytesAvail;
  U32      NumBytes;
  U32      NumBytesDummy;
  U32      TimeOut;
  int      r;
  U32      IsDTR;
  U32      Cmd;
  unsigned BusWidthCmd;
  unsigned BusWidthAddr;
  unsigned BusWidthData;

  FS_DEBUG_ASSERT(FS_MTYPE_DRIVER, NumBytesCmd == 1u);
  // This QSPI controller is able to handle only 1-byte commands.
  //
  // Initialize local variables.
  //
  AddrReg        = 0;
  AltReg         = 0;
  NumBytesDummy  = NumBytesPara - NumBytesAddr;
  Cmd            = *pCmd;
  //
  // Calculate the transfer mode.
  //
  IsDTR = 0;
  if (   ((Flags & FS_NAND_HW_FLAG_DTR_ADDR) != 0u)
      || ((Flags & FS_NAND_HW_FLAG_DTR_DATA) != 0u)) {
    IsDTR = 1;
  }
  //
  // Calculate the number of data lines to be used for the transfer.
  //
  BusWidthCmd    = FS_BUSWIDTH_GET_CMD(BusWidth);
  BusWidthAddr   = FS_BUSWIDTH_GET_ADDR(BusWidth);
  BusWidthData   = FS_BUSWIDTH_GET_DATA(BusWidth);
  CmdMode        = _GetMode(BusWidthCmd, NumBytesCmd);
  AddrMode       = _GetMode(BusWidthAddr, NumBytesAddr);
  NumCyclesDummy = _CalcNumCycles(BusWidthAddr, NumBytesDummy, IsDTR);
  // The dummy bytes are sent using the address bus mode.
  DataMode       = _GetMode(BusWidthData, NumBytesData);
  //
  // Encode the address.
```

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```
//
if (NumBytesAddr) {
  NumBytes = NumBytesAddr;
  do {
    AddrReg <<= 8;
    AddrReg  |= (U32)(*pPara++);
  } while (--NumBytes);
}
AddrSize = 0;
if (NumBytesAddr) {
  AddrSize = (NumBytesAddr - 1) & CCR_ADSIZE_MASK;
}
CfgReg = 0
       | (CCR_FMODE_READ << CCR_FMODE_BIT)
       | (DataMode       << CCR_DMODE_BIT)
       | (NumCyclesDummy << CCR_DCYC_BIT)
       | (IsDTR          << CCR_DDRM_BIT)
       | (AddrSize       << CCR_ADSIZE_BIT)
       | (AddrMode       << CCR_ADMODE_BIT)
       | (CmdMode        << CCR_IMODE_BIT)
       | (Cmd            << CCR_INTRUCTION_BIT)
       ;
//
// Wait until the unit is ready for the new command.
//
TimeOut = WAIT_TIMEOUT_CYCLES;
for (;;) {
  if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
    break;
  }
  if (--TimeOut == 0u) {
    r = 1;                              // Error, QUADSPI is not ready.
    goto Done;
  }
}
//
// Execute the command.
//
r = _ClearFlags();
if (r != 0) {
  goto Done;
}
if (NumBytesData) {
  QUADSPI_DLR = NumBytesData - 1;       // 0 means "read 1 byte".
}
QUADSPI_ABR = AltReg;
QUADSPI_CCR = CfgReg;
if (NumBytesAddr) {
  QUADSPI_AR = AddrReg;
}
//
// Read data from NAND flash.
//
if (NumBytesData) {
  do {
    //
    // Wait for the data to be received.
    //
    TimeOut = WAIT_TIMEOUT_CYCLES;
    for (;;) {
      NumBytesAvail = (QUADSPI_SR >> SR_FLEVEL_BIT) & SR_FLEVEL_MASK;
      if ((NumBytesAvail >= 4) || (NumBytesAvail >= NumBytesData)) {
        break;
      }
      if (--TimeOut == 0u) {
        r = 1;                          // Error, no data received.
        goto Done;
      }
    }
    //
    // Read data and store it to destination buffer.
    //
    if (NumBytesData < 4) {
      //
      // Read single bytes.
      //
```

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```
        do {
          *pData++ = QUADSPI_DR_BYTE;
        } while (--NumBytesData);
      } else {
        //
        // Read 4 bytes at a time.
        //
        DataReg = QUADSPI_DR;
        *pData++ = (U8)DataReg;
        *pData++ = (U8)(DataReg >> 8);
        *pData++ = (U8)(DataReg >> 16);
        *pData++ = (U8)(DataReg >> 24);
        NumBytesData -= 4;
      }
    } while (NumBytesData);
  }
  //
  // Wait until the data transfer has been completed.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if (QUADSPI_SR & (1uL << SR_TCF_BIT)) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                // Error, transaction not completed.
      break;
    }
  }
Done:
  return r;
}

/*********************************************************************
*
*       _Write
*
*  Function description
*    Transfers data from MCU to NAND flash device.
*/
static int _Write(U8 Cmd, const U8 * pPara, unsigned NumBytesPara,
                  unsigned NumBytesAddr, const FS_DATA_ITEM_CONST * pDataItem,
                  unsigned NumDataItems, U16 BusWidth) {
  U32                       AddrReg;
  U32                       AltReg;
  U32                       CfgReg;
  U32                       DataMode;
  U32                       AddrMode;
  U32                       CmdMode;
  U32                       DataReg;
  U32                       AddrSize;
  U32                       NumCyclesDummy;
  U32                       NumBytes;
  U32                       NumBytesDummy;
  U32                       NumBytesFree;
  U32                       TimeOut;
  int                       r;
  unsigned                  BusWidthCmd;
  unsigned                  BusWidthAddr;
  unsigned                  BusWidthData;
  const U8                * pData;
  unsigned                  NumBytesData;
  unsigned                  NumBytesDataTotal;
  unsigned                  NumDataItemsToCheck;
  const FS_DATA_ITEM_CONST * pDataItemToCheck;

  //
  // Initialize local variables.
  //
  AddrReg             = 0;
  AltReg              = 0;
  NumBytesDummy       = NumBytesPara - NumBytesAddr;
  NumBytesDataTotal   = 0;
  pDataItemToCheck    = pDataItem;
  NumDataItemsToCheck = NumDataItems;
  if (pDataItemToCheck != NULL) {
```

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```
  if (NumDataItemsToCheck != 0) {
    do {
      if (pDataItemToCheck->pData != NULL) {
        NumBytesData       = pDataItemToCheck->NumBytes;
        NumBytesDataTotal += NumBytesData;
      }
      pDataItemToCheck++;
    } while (--NumDataItemsToCheck != 0);
  }
}
//
// Calculate the number of data lines to be used for the transfer.
//
BusWidthCmd    = FS_BUSWIDTH_GET_CMD(BusWidth);
BusWidthAddr   = FS_BUSWIDTH_GET_ADDR(BusWidth);
BusWidthData   = FS_BUSWIDTH_GET_DATA(BusWidth);
CmdMode        = _GetMode(BusWidthCmd, sizeof(Cmd));
AddrMode       = _GetMode(BusWidthAddr, NumBytesAddr);
NumCyclesDummy = _CalcNumCycles(BusWidthAddr, NumBytesDummy, 0);
// The dummy bytes are sent using the address bus mode.
DataMode       = _GetMode(BusWidthData, NumBytesDataTotal);
//
// Encode the address.
//
if (NumBytesAddr) {
  NumBytes = NumBytesAddr;
  do {
    AddrReg <<= 8;
    AddrReg  |= (U32)(*pPara++);
  } while (--NumBytes);
}
AddrSize = 0;
if (NumBytesAddr) {
  AddrSize = NumBytesAddr - 1;
}
CfgReg = 0
       | (CCR_FMODE_WRITE << CCR_FMODE_BIT)
       | (DataMode        << CCR_DMODE_BIT)
       | (NumCyclesDummy  << CCR_DCYC_BIT)
       | (AddrSize        << CCR_ADSIZE_BIT)
       | (AddrMode        << CCR_ADMODE_BIT)
       | (CmdMode         << CCR_IMODE_BIT)
       | (Cmd             << CCR_INTRUCTION_BIT)
       ;
//
// Wait until the unit is ready for the new command.
//
TimeOut = WAIT_TIMEOUT_CYCLES;
for (;;) {
  if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
    break;
  }
  if (--TimeOut == 0u) {
    r = 1;                                  // Error, QUADSPI is not ready.
    goto Done;
  }
}
//
// Execute the command.
//
r = _ClearFlags();
if (r != 0) {
  goto Done;
}
if (NumBytesDataTotal != 0u) {
  QUADSPI_DLR = NumBytesDataTotal - 1u;     // -1 because 0 means "read 1 byte".
}
QUADSPI_ABR = AltReg;
QUADSPI_CCR = CfgReg;
if (NumBytesAddr) {
  QUADSPI_AR = AddrReg;
}
//
// Write data to NAND flash.
//
if (NumBytesDataTotal != 0) {
```

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```
    do {
      pData        = pDataItem->pData;
      NumBytesData = pDataItem->NumBytes;
      if ((pData != NULL) && (NumBytesData != 0u)) {
        do {
          //
          // Wait for free space in FIFO.
          //
          TimeOut = WAIT_TIMEOUT_CYCLES;
          for (;;) {
            NumBytesFree = (QUADSPI_SR >> SR_FLEVEL_BIT) & SR_FLEVEL_MASK;
            NumBytesFree = NUM_BYTES_FIFO - NumBytesFree;
            if ((NumBytesFree >= 4) || (NumBytesFree >= NumBytesData)) {
              break;
            }
            if (--TimeOut == 0u) {
              r = 1;                            // Error, no free space in FIFO.
              goto Done;
            }
          }
          //
          // Get the data from source buffer and write it.
          //
          if (NumBytesData < 4) {
            //
            // Write single bytes.
            //
            do {
              QUADSPI_DR_BYTE = *pData++;
            } while (--NumBytesData);
          } else {
            //
            // Write 4 bytes at a time if possible.
            //
            DataReg  = (U32)*pData++;
            DataReg |= (U32)*pData++ << 8;
            DataReg |= (U32)*pData++ << 16;
            DataReg |= (U32)*pData++ << 24;
            NumBytesData -= 4;
            QUADSPI_DR = DataReg;
          }
        } while (NumBytesData != NULL);
      }
      pDataItem++;
    } while (--NumDataItems != 0);
  }
  //
  // Wait until the data transfer has been completed.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if (QUADSPI_SR & (1uL << SR_TCF_BIT)) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                    // Error, transfer not completed.
      break;
    }
  }
Done:
  return r;
}

/*********************************************************************
*
*       _Delay
*
*  Function description
*    Blocks the execution for the specified number of milliseconds.
*/
static void _Delay(int ms) {
#if FS_NAND_HW_USE_OS
  if (ms) {
    FS_OS_Delay(ms);
  }
#else
```

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```
  if (ms) {
    volatile U32 NumCycles;

    do {
      NumCycles = FS_NAND_HW_CYCLES_PER_MS;
      do {
        ;
      } while (--NumCycles);
    } while (--ms);
  }
#endif // FS_NAND_HW_USE_OS
}

#if FS_NAND_HW_USE_OS

/*********************************************************************
*
*       _Poll
*
*  Function description
*    Checks periodically the value of a status flag.
*
*  Parameters
*    Cmd            Code of the command to be sent. Cannot be NULL.
*    pPara          [IN] Command parameters (address and dummy bytes). Can be NULL.
*    NumBytesPara   Total number of address and dummy bytes to be sent. Can be 0.
*    NumBytesAddr   Number of address bytes to be send. Can be 0.
*    BitPos         Position of the bit to be checked.
*    BitValue       Value of the bit to wait for.
*    Delay          Number of clock cycles to wait between two queries.
*    TimeOut_ms     Maximum number of milliseconds to wait for the bit to be set.
*    BusWidth       Number of data lines to be used for the data transfer.
*
*  Return value
*    > 0    Timeout occurred.
*    ==0    OK, bit set to specified value.
*    < 0    Feature not supported.
*/
static int _Poll(U8 Cmd, const U8 * pPara, unsigned NumBytesPara, unsigned NumBytesAddr, U8 BitPos, U8 BitValue, U32 D
  U32 CfgReg;
  U32 DataMode;
  U32 CmdMode;
  U32 NumBytes;
  U32 NumBytesData;
  U32 DataMask;
  U32 DataMatch;
  U32 AddrReg;
  U32 AltReg;
  U32 NumBytesDummy;
  U32 AddrMode;
  U32 AddrSize;
  U32 NumCyclesDummy;
  U32 TimeOut;
  int r;

  //
  // Initialize local variables.
  //
  r              = 0;
  AddrReg        = 0;
  AltReg         = 0;
  DataMask       = 1uL           << BitPos;
  DataMatch      = (U32)BitValue << BitPos;
  Delay        <<= 4;           // 16 clock cycles are required to transfer 2 bytes.
  NumBytesData   = 1;           // The response consists of only one byte.
  NumBytesDummy  = NumBytesPara - NumBytesAddr;
  //
  // Encode the address.
  //
  if (NumBytesAddr) {
    NumBytes = NumBytesAddr;
    do {
      AddrReg <<= 8;
      AddrReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
```

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```
  //
  // Calculate the number of data lines to be used for the transfer.
  //
  CmdMode        = _GetMode(FS_BUSWIDTH_GET_CMD(BusWidth), sizeof(Cmd));
  AddrMode       = _GetMode(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesAddr);
  NumCyclesDummy = _CalcNumCycles(FS_BUSWIDTH_GET_ADDR(BusWidth), NumBytesDummy, 0);
  // The dummy bytes are sent using the address bus mode.
  DataMode       = _GetMode(FS_BUSWIDTH_GET_DATA(BusWidth), NumBytesData);
  //
  // Calculate the number of bytes in each command phase.
  //
  AddrSize = 0;
  if (NumBytesAddr) {
    AddrSize = (NumBytesAddr - 1) & CCR_ADSIZE_MASK;
  }
  //
  // Configure the operation.
  //
  CfgReg = 0
         | (CCR_FMODE_POLL << CCR_FMODE_BIT)
         | (AddrMode       << CCR_ADMODE_BIT)
         | (AddrSize       << CCR_ADSIZE_BIT)
         | (DataMode       << CCR_DMODE_BIT)
         | (NumCyclesDummy << CCR_DCYC_BIT)
         | (CmdMode        << CCR_IMODE_BIT)
         | (Cmd            << CCR_INTRUCTION_BIT)
         ;
  //
  // Wait until the unit is ready for the new command.
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    if ((QUADSPI_SR & (1uL << SR_BUSY_BIT)) == 0) {
      break;
    }
    if (--TimeOut == 0u) {
      r = 1;                                // Error, QUADSPI is not ready.
      goto Done;
    }
  }
  //
  // Start the poll operation. The end of operation is signaled by interrupt.
  //
  r = _ClearFlags();
  if (r != 0) {
    goto Done;                              // Error, could not clear status flags.
  }
  if (NumBytesData != 0) {
    QUADSPI_DLR = NumBytesData - 1;         // 0 means "read 1 byte".
  }
  QUADSPI_ABR   = AltReg;
  QUADSPI_PSMKR = DataMask;
  QUADSPI_PSMAR = DataMatch;
  QUADSPI_PIR   = Delay;
  QUADSPI_FCR   = 1uL << SR_SMF_BIT;
  QUADSPI_CCR   = CfgReg;
  if (NumBytesAddr != 0u) {
    QUADSPI_AR  = AddrReg;
  }
  r = FS_OS_Wait(TimeOut_ms);
  if (r != 0) {
    //
    // The timeout has expired. Cancel the poll operation.
    //
    (void)_Cancel();
    r = 1;                                  // A timeout occurred.
  }
Done:
  return r;
}

#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       Static code (public via callback)
```

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```
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initializes the QSPI hardware.
*
*  Parameters
*    Unit           Device index (0-based)
*
*  Return value
*    Frequency of the QSPI clock in kHz.
*/
static int _HW_Init(U8 Unit) {
  int r;

  FS_USE_PARA(Unit);
  r = _Init();
  return r;
}

/*********************************************************************
*
*       _HW_Control
*
*  Function description
*    Executes a NAND flash command without data transfer.
*
*  Parameters
*    Unit           Device index (0-based)
*    Cmd            Code of the command to be sent.
*    BusWidth       Number of data lines to be used for sending
*                   the command code.
*
*  Return value
*    ==0    OK, command sent.
*    !=0    An error occurred.
*/
static int _HW_Control(U8 Unit, U8 Cmd, U8 BusWidth) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
  r = _Control(Cmd, BusWidth);
  return r;
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    Transfers data from NAND flash device to MCU.
*
*  Parameters
*    Unit           Device index (0-based)
*    Cmd            Code of the command to be sent.
*    pPara          Additional command parameters (can be NULL).
*    NumBytesPara   Number of additional bytes to be sent after command.
*                   Can be 0 if pPara is NULL.
*    NumBytesAddr   Number of address bytes to be sent.
*                   Can be 0 if pPara is NULL.
*    pData          Data received from the NAND flash device.
*    NumBytesData   Number of bytes to be received from the NAND flash device.
*    BusWidth       Specifies the number of data lines to be used
*                   during the data transfer.
*
*  Return value
*    ==0    OK, data transferred.
*    !=0    An error occurred.
*/
static int _HW_Read(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara,
```

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```
                    unsigned NumBytesAddr, U8 * pData, unsigned NumBytesData,
                    U16 BusWidth) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
  r = _Read(&Cmd, sizeof(Cmd), pPara, NumBytesPara, NumBytesAddr, pData, NumBytesData, BusWidth, 0);
  return r;
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    Transfers data from MCU to NAND flash device.
*
*  Parameters
*    Unit           Device index (0-based)
*    Cmd            Code of the command to be sent.
*    pPara          Additional command parameters (can be NULL).
*    NumBytesPara   Number of additional bytes to be sent after command.
*                   Can be 0 if pPara is NULL.
*    NumBytesAddr   Number of address bytes to be sent.
*                   Can be 0 if pPara is NULL.
*    pData          Data to be sent to NAND flash device.
*    NumBytesData   Number of data bytes to be sent to NAND flash device.
*    BusWidth       Specifies the number of data lines to be used
*                   during the data transfer.
*
*  Return value
*    ==0    OK, data transferred.
*    !=0    An error occurred.
*/
static int _HW_Write(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara,
                     unsigned NumBytesAddr, const U8 * pData, unsigned NumBytesData,
                     U16 BusWidth) {
  int                r;
  FS_DATA_ITEM_CONST DataItem;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
  DataItem.pData    = pData;
  DataItem.NumBytes = NumBytesData;
  r = _Write(Cmd, pPara, NumBytesPara, NumBytesAddr, &DataItem, 1, BusWidth);
  return r;
}

/*********************************************************************
*
*       _HW_Delay
*
*  Function description
*    Blocks the execution for the specified number of milliseconds.
*
*  Parameters
*    Unit           Device index (0-based)
*    ms             Number of milliseconds to wait.
*
*  Additional information
*    This function is mandatory and it has to be implemented by any
*    hardware layer.
*/
static void _HW_Delay(U8 Unit, int ms) {
  FS_USE_PARA(Unit);
  _Delay(ms);
}

/*********************************************************************
*
*       _HW_Poll
*
*  Function description
*    Sends a command repeatedly and checks the response data
*    for a specified condition.
*
```

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```
*  Parameters
*    Unit           Device index (0-based)
*    Cmd            Code of the command to be sent.
*    pPara          Additional command parameters (can be NULL).
*    NumBytesPara   Number of additional bytes to be sent after command.
*                   Can be 0 if pPara is NULL.
*    BitPos         Position of the bit inside response data that has
*                   to be checked (0-based, with 0 being LSB)
*    BitValue       Bit value to wait for.
*    Delay_ms       Time between two command executions.
*    TimeOut_ms     Maximum time to wait for the bit at BitPos to be set to BitValue.
*    BusWidth       Specifies how many data lines have to be used for sending
*                   the command and parameters and for reading the data.
*
*  Return value
*    > 0    Error, timeout occurred.
*    ==0    OK, bit set to specified value.
*    < 0    Error, feature not supported.
*/
static int _HW_Poll(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara,
                    U8 BitPos, U8 BitValue, U32 Delay_ms, U32 TimeOut_ms, U16 BusWidth) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
#if FS_NAND_HW_USE_OS
  r = _Poll(Cmd, pPara, NumBytesPara, NumBytesPara, BitPos, BitValue, Delay_ms, TimeOut_ms, BusWidth);
#else
  FS_USE_PARA(Cmd);
  FS_USE_PARA(pPara);
  FS_USE_PARA(NumBytesPara);
  FS_USE_PARA(BitPos);
  FS_USE_PARA(BitValue);
  FS_USE_PARA(Delay_ms);
  FS_USE_PARA(TimeOut_ms);
  FS_USE_PARA(BusWidth);
  r = -1;                 // Set to indicate that the feature is not supported.
#endif // FS_NAND_HW_USE_OS
  return r;
}

/*********************************************************************
*
*       _HW_ReadEx
*
*  Function description
*    Transfers data from serial NAND flash device to MCU.
*
*  Parameters
*    Unit           Index of the hardware layer (0-based).
*    pCmd           [IN] Code of the command to be sent. Cannot be NULL.
*    NumBytesCmd    Number of bytes in the command code. Cannot be 0.
*    pPara          [IN] Command parameters (address and dummy bytes). Can be NULL.
*    NumBytesPara   Total number of address and dummy bytes to be sent. Can be 0.
*    NumBytesAddr   Number of address bytes to be send. Can be 0.
*    pData          [OUT] Data read from the serial NAND flash device. Can be NULL.
*    NumBytesData   Number of bytes to read from the serial NAND flash device. Can be 0.
*    BusWidth       Number of data lines to be used for the data transfer.
*    Flags          Options for the data exchange.
*
*  Return value
*    ==0      OK, data transferred successfully.
*    !=0      An error occurred.
*/
static int _HW_ReadEx(U8 Unit, const U8 * pCmd, unsigned NumBytesCmd, const U8 * pPara,
                      unsigned NumBytesPara, unsigned NumBytesAddr, U8 * pData,
                      unsigned NumBytesData, U16 BusWidth, unsigned Flags) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
  r = _Read(pCmd, NumBytesCmd, pPara, NumBytesPara, NumBytesAddr, pData, NumBytesData, BusWidth, Flags);
  return r;
}

/*********************************************************************
```

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```
*
*       _HW_WriteMultiple
*
*  Function description
*    Transfers data from MCU to NAND flash device.
*
*  Parameters
*    Unit           Index of the NAND hardware layer instance (0-based)
*    Cmd            Code of the command to be sent.
*    pPara          Additional command parameters (can be NULL).
*    NumBytesPara   Number of additional bytes to be sent after command.
*                   Can be 0 if pPara is NULL.
*    NumBytesAddr   Number of address bytes to be sent.
*                   Can be 0 if pPara is NULL.
*    pDataItem      List of data blocks to be sent to NAND flash device.
*    NumDataItems   Number of data blocks to be sent to NAND flash device.
*    BusWidth       Specifies the number of data lines to be used
*                   during the data transfer.
*
*  Return value
*    ==0    OK, data transferred.
*    !=0    An error occurred.
*/
static int _HW_WriteMultiple(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara,

  unsigned NumBytesAddr, const FS_DATA_ITEM_CONST * pDataItem, unsigned NumDataItems,
                           U16 BusWidth) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This MCU has only one HW unit.
  r = _Write(Cmd, pPara, NumBytesPara, NumBytesAddr, pDataItem, NumDataItems, BusWidth);
  return r;
}

/*********************************************************************
*
*       _HW_Lock
*
*  Function description
*    Requests exclusive access to SPI bus.
*
*  Parameters
*    Unit     Device index (0-based)
*
*  Additional information
*    This function is optional and it can be left unimplemented
*    or set to NULL in the structure of the hardware layer below.
*/
static void _HW_Lock(U8 Unit) {
  FS_USE_PARA(Unit);
  IF_TEST(_LockCnt++);
  ASSERT_IS_LOCKED();
}

/*********************************************************************
*
*       _HW_Unlock
*
*  Function description
*    Releases the exclusive access of SPI bus.
*
*  Parameters
*    Unit     Device index (0-based)
*
*  Additional information
*    This function is optional and it can be left unimplemented
*    or set to NULL in the structure of the hardware layer below.
*/
static void _HW_Unlock(U8 Unit) {
  FS_USE_PARA(Unit);
  ASSERT_IS_LOCKED();
  IF_TEST(_LockCnt--);
}

/*********************************************************************
```

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```
*
*       Public code
*
**********************************************************************
*/

#if FS_NAND_HW_USE_OS

/*********************************************************************
*
*       QUADSPI_IRQHandler
*/
void QUADSPI_IRQHandler(void);
void QUADSPI_IRQHandler(void) {
#if (FS_NAND_HW_USE_OS == 1)
  OS_EnterNestableInterrupt();
#endif // FS_NAND_HW_USE_OS == 1
  QUADSPI_FCR = 1uL << SR_SMF_BIT;    // Prevent other interrupts from occurring.
  FS_OS_Signal();
#if (FS_NAND_HW_USE_OS == 1)
  OS_LeaveNestableInterrupt();
#endif // FS_NAND_HW_USE_OS == 1
}

#endif // FS_NAND_HW_USE_OS

/*********************************************************************
*
*       Public const
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_NAND_HW_QSPI_STM32H743_SEGGER_QSPI_Flash_Evaluator
*/
const FS_NAND_HW_TYPE_QSPI FS_NAND_HW_QSPI_STM32H743_SEGGER_QSPI_Flash_Evaluator = {
  _HW_Init,
  _HW_Control,
  _HW_Read,
  _HW_Write,
  _HW_Poll,
  _HW_Delay,
  _HW_Lock,
  _HW_Unlock,
  _HW_ReadEx,
  _HW_WriteMultiple
};

/************************** End of file ****************************/
```

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6.3.5.6 Hardware layer API - FS_NAND_HW_TYPE_SPI

This hardware layer supports any serial NAND flash device with a standard SPI. It is used by the FS_NAND_PHY_SPI physical layer to exchange data with a NAND flash device that supports such an interface. Typically, the implementation of FS_NAND_HW_TYPE_SPI hardware layer makes use of an SPI controller. It is also possible to implement the data exchange via GPIO pins.

The functions of this hardware layer are grouped in the structure of type FS_NAND_HW_TYPE_SPI. The following sections describe these functions in detail.

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6.3.5.6.1 FS_NAND_HW_TYPE_SPI

Description

NAND hardware layer API for NAND flash devices connected via SPI.

Type definition

```
typedef struct {
  FS_NAND_HW_TYPE_SPI_INIT       * pfInit;
  FS_NAND_HW_TYPE_SPI_DISABLE_CS * pfDisableCS;
  FS_NAND_HW_TYPE_SPI_ENABLE_CS  * pfEnableCS;
  FS_NAND_HW_TYPE_SPI_DELAY      * pfDelay;
  FS_NAND_HW_TYPE_SPI_READ       * pfRead;
  FS_NAND_HW_TYPE_SPI_WRITE      * pfWrite;
  FS_NAND_HW_TYPE_SPI_LOCK       * pfLock;
  FS_NAND_HW_TYPE_SPI_UNLOCK     * pfUnlock;
} FS_NAND_HW_TYPE_SPI;
```

Structure members

Member	Description
pfInit	Initializes the hardware.
pfDisableCS	Disables the NAND flash device.
pfEnableCS	Enables the NAND flash device.
pfDelay	Block the execution for a specified number of milliseconds.
pfRead	Transfers a specified number of bytes from NAND flash device to MCU.
pfWrite	Transfers a specified number of bytes from MCU to NAND flash device.
pfLock	Request exclusive access to SPI bus.
pfUnlock	Releases the exclusive access to SPI bus.

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6.3.5.6.2 FS_NAND_HW_TYPE_SPI_INIT

Description

Initializes the hardware.

Type definition

```
typedef int FS_NAND_HW_TYPE_SPI_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Return value

≠ 0 OK, frequency of the SPI clock in kHz.
= 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type. FS_NAND_HW_TYPE_SPI_INIT is the first function of the hardware layer API that is called by a NAND physical layer during the mounting of the file system.

This function has to perform any initialization of the MCU hardware required to access the NAND flash device such as clocks, port pins, SPI controllers, etc.

A serial NAND flash requires that the SPI communication protocol meets the following requirements:

- 8-bit data length.
- The most significant bit hast to be sent out first.
- Chip Select (CS) signal should be initially high to disable the serial NAND flash device.
- The SPI clock frequency does not have to exceed the maximum clock frequency that is specified by the serial NAND flash device.

Typically, two SPI modes are supported:

- Mode 0 - CPOL = 0, CPHA = 0, SPI clock remains low in idle state.
- Mode 3 - CPOL = 1, CPHA = 1, SPI clock remains high in idle state.

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6.3.5.6.3 FS_NAND_HW_TYPE_SPI_DISABLE_CS

Description

Disables the NAND flash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_SPI_DISABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The NAND flash device is disabled by driving the Chip Select (CS) signal to logic-high. The NAND flash device ignores any command or data sent with the CS signal set to logic-high.

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6.3.5.6.4 FS_NAND_HW_TYPE_SPI_ENABLE_CS

Description

Enables the NAND flash device.

Type definition

```
typedef void FS_NAND_HW_TYPE_SPI_ENABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The NAND flash device is enabled by driving the Chip Select (CS) signal to logic low state. Typically, the NAND flash device is enabled at the beginning of command and data sequence and disabled at the end of it.

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6.3.5.6.5 FS_NAND_HW_TYPE_SPI_DELAY

Description

Blocks the execution for the specified number of milliseconds.

Type definition

```
typedef void FS_NAND_HW_TYPE_SPI_DELAY(U8  Unit,
                                       int ms);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
ms	Number of milliseconds to wait.

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The time FS_NAND_HW_TYPE_SPI_DELAY blocks does not have to be accurate. That is the function can block the execution longer that the number of specified milliseconds but no less than that.

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6.3.5.6.6 FS_NAND_HW_TYPE_SPI_READ

Description

Transfers a specified number of bytes from NAND flash device to MCU.

Type definition

```
typedef int FS_NAND_HW_TYPE_SPI_READ(U8       Unit,
                                     void   * pData,
                                     unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	Data read from NAND flash device.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The function has to sample the data on the falling edge of the SPI clock.

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6.3.5.6.7 FS_NAND_HW_TYPE_SPI_WRITE

Description

Transfers a specified number of bytes from MCU to NAND flash device.

Type definition

```
typedef int FS_NAND_HW_TYPE_SPI_WRITE(      U8       Unit,
                                      const void   * pData,
                                            unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)
pData	in Data to be written to NAND flash device.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. It is mandatory to be implemented by all the NAND hardware layers of this type.

The NAND flash device samples the data on the rising edge of the SPI clock.

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6.3.5.6.8 FS_NAND_HW_TYPE_SPI_LOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_SPI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. The implementation of this function is optional.

The FS_NAND_PHY_SPI physical layer calls this function to indicate that it needs exclusive to access the serial NAND flash device via the SPI bus. It is guaranteed that the FS_NAND_PHY_SPI physical layer does not attempt to exchange any data with the serial NAND flash device via the SPI bus before calling this function first. It is also guaranteed that FS_NAND_HW_TYPE_SPI_LOCK and FS_NAND_HW_TYPE_SPI_UNLOCK are called in pairs. Typically, this function is used for synchronizing the access to SPI bus when the SPI bus is shared between the serial NAND flash and other SPI devices.

A possible implementation would make use of an OS semaphore that is acquired in FS_NAND_HW_TYPE_SPI_LOCK and released in FS_NAND_HW_TYPE_SPI_UNLOCK.

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6.3.5.6.9 FS_NAND_HW_TYPE_SPI_UNLOCK

Description

Releases the exclusive access of SPI bus.

Type definition

```
typedef void FS_NAND_HW_TYPE_SPI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the NAND hardware layer instance (0-based)

Additional information

This function is a member of the FS_NAND_HW_TYPE_SPI NAND hardware layer API. The implementation of this function is optional.

The FS_NAND_PHY_SPI physical layer calls this function after it no longer needs to access the serial NAND flash device via the SPI bus. It is guaranteed that the FS_NAND_PHY_SPI physical layer does not attempt to exchange any data with the serial NAND flash device via the SPI bus before calling FS_NAND_HW_TYPE_SPI_LOCK. It is also guaranteed that FS_NAND_HW_TYPE_SPI_UNLOCK and FS_NAND_HW_TYPE_SPI_LOCK are called in pairs.

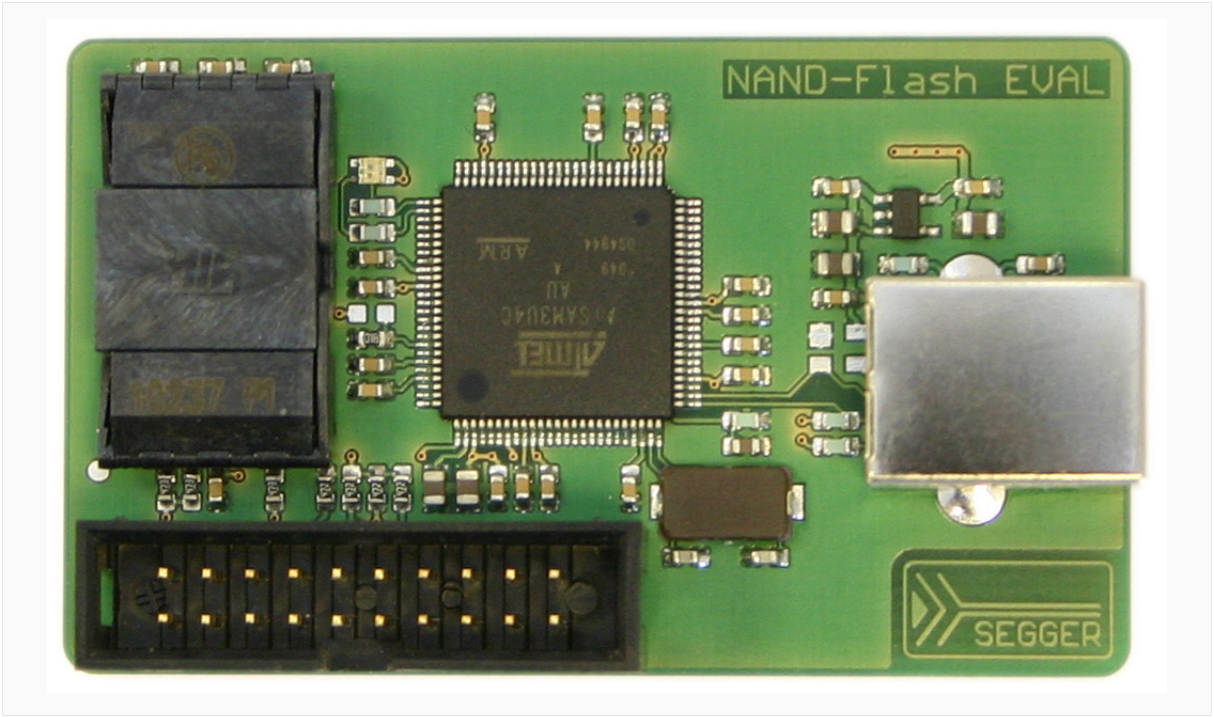
FS_NAND_HW_TYPE_SPI_UNLOCK and FS_NAND_HW_TYPE_SPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the serial NAND flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired FS_NAND_HW_TYPE_SPI_LOCK and released in FS_NAND_HW_TYPE_SPI_UNLOCK.

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6.3.6 Test hardware

The SEGGER NAND-Flash EVAL board is an easy-to-use and cost-effective testing tool designed to evaluate the features and the performance of the emFile NAND driver. The NAND driver can be used with emFile or emUSB-Device, in which case the board behaves like a mass storage device (USB drive). Common evaluation boards are usually used to perform these tests, but this approach brings several disadvantages. Software and hardware development tools are required to build and load the application into the target system. Moreover, the tests are restricted to the type of NAND flash which is soldered on the board. The NAND-Flash EVAL board was designed to overcome these limitations and provides the user with an affordable alternative. The main feature is that the NAND flash is not directly soldered on the board. A 48-pin TSOP socket is used instead which allows the user to experiment with different types of NAND flashes. This helps find the right NAND flash for an application and thus reduce costs. A further important feature is that the NAND-Flash EVAL board comes preloaded with a USB-MSD application. When connected to a PC over USB, the board shows up as a removable storage on the host operating system. Performance and functionality tests of NAND flash can thus be performed without the need for an expensive development environment. All current operating systems will recognize the board out of the box.

The NAND-Flash EVAL board comes with a ready-to-use USB-MSD application in binary form. emFile is provided in object code{c} form together with a start project which can be easily modified to create custom applications. For programming and debugging, a JTAG debug probe like J-Link is required. The package also contains the schematics of the board.



NAND-Flash EVAL

Feature list

- Atmel ATSAM3U4C ARM Cortex-M3 microcontroller
- NAND flash socket
- 2-color LED
- 20-pin JTAG header
- High speed USB interface

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6.3.7 FAQs

Q: Are Multi-Level Cell NAND flashes (MLCs) supported?
A: Yes, the Universal NAND driver supports MLCs.
Q: Are NAND flash devices with 4 KB pages supported?
A: Yes, they are supported via the `FS_NAND_PHY_4096x8` and `FS_NAND_PHY_ONFI` physical layers.
Q: What is the maximum supported storage capacity?
A: The maximum capacity of a NAND flash device supported by the NAND drivers depends on the number of physical blocks that are present on the storage device. The NAND drivers are designed to handle a maximum of 65535 physical blocks. The typical size of a physical block is 128 KB. This results in a maximum storage capacity of about 8 GB.

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6.4 NOR flash driver

6.4.1 General information

emFile supports the use of unmanaged NOR flash devices as data storage. Two drivers for NOR flash devices, also known as flash translation layers, are provided:

- Sector Map NOR driver - Supports almost any parallel or serial NOR flash device. This driver was optimized for increased write performance.
- Block Map NOR driver - Supports almost any parallel or serial NOR flash device. This driver was optimized for reduced RAM usage. The difference between the two NOR drivers consists in the way they manage the mapping of file system logical sectors to the NOR flash device. The Sector map driver was designed with the goal to access the data fast at a time when NOR flash devices had a relatively small capacity (a few Mbytes). To achieve this, the driver maintains a mapping table at logical sector granularity. This approach has proven to be very efficient, but for modern NOR flash devices with capacities larger than 8 Mbytes the RAM usage of the Sector Map NOR driver becomes increasingly high. This is the reason why the Block Map NOR driver was developed. The design goal of the Block Map NOR driver was to use as little RAM as possible. This is realized by mapping blocks of file system logical sectors to the NOR flash device.

6.4.1.1 Software structure

The NOR drivers are organized into different layers, arranged from top to bottom:

- NOR driver layer
- *NOR physical layer*
- *NOR hardware layer*

A hardware layer is required only for serial NOR flash devices. Typically, a CFI-compliant NOR flash device is mapped into the system memory of the MCU and can be accessed directly without a hardware layer. Normally, no changes to the physical layer are required. If the physical layer needs to be adapted, a template is provided.

6.4.1.2 Garbage collection

The driver performs the garbage collection automatically during the write operations. If no empty logical sectors are available to store the data, new empty logical sectors are created by erasing the data of the logical sectors marked as invalid. This involves a NOR physical sector erase operation which, depending on the characteristics of the NOR flash, can potentially take a long time to complete, and therefore reduces the write performance. For applications which require maximum write throughput, the garbage collection can be done in the application. Typically, this operation can be performed when the file system is idle. Two API functions are provided: `FS_STORAGE_Clean()` and `FS_STORAGE_CleanOne()`. They can be called directly from the task which is performing the write or from a background task. The `FS_STORAGE_Clean()` function blocks until all the invalid logical sectors are converted to free logical sectors. A write operation following the call to this function runs at maximum speed. The other function, `FS_STORAGE_CleanOne()`, converts the invalid sectors of a single physical sector. Depending on the number of invalid logical sectors, several calls to this function are required to clean up the entire storage device.

6.4.1.3 Fail-safe operation

The operation of emFile NOR driver is fail-safe. This means that the driver performs only atomic operations in order to make sure that the stored data is always valid after an unexpected power failure that interrupts a write operation. If the unexpected power failure interrupts the write operation, then the old version of the modified data is preserved.

The fail-safe operation is only guaranteed if the NOR flash device is able to fully complete the last write operation that it receives from the file system before the unexpected power failure. This means that the supply voltage of the NOR flash device has to remain valid for a sufficiently long time after the MCU enters reset (typically a few hundred microseconds)

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to allow the NOR flash device to complete that write operation. The exact timing can be taken from the data sheet of the NOR flash device.

The number of bytes written by the NOR driver in one write operation varies between the value configured via FS_NOR_LINE_SIZE and the page size of the NOR flash device. Not all the data the NOR driver writes to the storage is critical. Non-critical write operations can be interrupted by an unexpected power failure without negatively affecting the fail-safe operation. The critical data is always stored as a write operation containing FS_NOR_LINE_SIZE bytes. These types of write operations have to be completed by the NOR flash device and cannot be interrupted.

The erase operation of a NOR flash sector can be interrupted by an unexpected power failure because the NOR driver is able to determine at low-level mount which NOR flash sector was not completely erased. The incompletely erased NOR flash sectors will be erased again when required.

The above requirements for the write operation do not apply for configurations that use the Block Map NOR driver with the CRC verification enabled because in this configuration the file system is able to determine and discard incomplete write operations at low-level mount. However, the retention time of the data written during the interrupted operation can no longer be guaranteed.

6.4.1.4 Wear leveling

Wear leveling is supported by both NOR drivers. The wear leveling procedure makes sure that the number of erase cycles remains approximately equal for each physical sector. This works by keeping track of the index of the last erased physical sector. When a new erased physical sector is required to store data, then the first free physical sector with an index greater than the last one is selected. The index of the physical sector wraps around when the end of the NOR flash device is reached. In addition, the wear leveling procedure keeps a count of the number of times each physical sector has been erased, called the erase count, which is stored on the NOR flash device. The erase count is used to make sure that physical sectors that store data that is rarely modified are also equally erased. For this purpose, the wear leveling procedure calculates the difference between the erase counts of the selected physical sector and of the physical sector with the smallest erase count. If the calculated difference is greater than the value specified via FS_NOR_MAX_ERASE_CNT_DIFF or FS_NOR_BM_SetMaxEraseCntDiff(), then the physical sector with the smaller erase count is used instead.

6.4.1.5 Low-level format

Before using a NOR flash device for the first time, the application has to initialize it by performing a low-level format operation on it. Refer to FS_FormatLow() and FS_FormatLLIfRequired() for detailed information about this.

6.4.1.6 CRC verification

The integrity of the data stored on a NOR flash device using the Block Map NOR driver can be increased by enabling the CRC verification feature. With the CRC verification feature enabled, the Block Map NOR driver calculates a checksum of payload and management data that is written to the NOR flash device using a CRC (Cyclic Redundancy Check) algorithm. The calculated checksum is stored together with the payload and management data to the NOR flash device. Each time the Block Map NOR driver reads some data from the NOR flash device, it also calculates its checksum using the same algorithm. The calculated checksum is then compared with the checksum read from the NOR flash device and if a mismatch occurs an error is reported to the application via the return value of the called API function as well as via the callback registered using FS_NOR_BM_SetOnFatalErrorCallback(). Depending on what data was exactly damaged, error recovery may or may not be possible. The application may try to repair the damaged data by running a disk checking operation via FS_CheckDisk().
The CRC verification is disabled by default and has to be enabled at compile time as well as at runtime. FS_NOR_SUPPORT_CRC has to be set to 1 in order to enable the support for

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CRC verification at compile time. At runtime, FS_NOR_BM_EnableCRC() has to be called in FS_X_AddDevices() to activate the CRC verification feature. By default, the Block Map NOR driver uses the internal CRC calculation routines of the file system, but the application can register its own CRC calculation routines via FS_NOR_BM_SetCRCHook().

6.4.1.7 Bit error correction

The integrity of the data stored in a NOR flash device using the Block Map NOR driver can be increased by enabling the bit error correction. With the bit error correction feature enabled, the Block Map NOR driver calculates a parity check of payload and management data that is written to a NOR flash device using an error correction algorithm. The calculated parity check is stored together with the payload and management data to the NOR flash device. Each time the Block Map NOR driver reads some data from the NOR flash device, it uses the same error correction algorithm and the parity check read from the device to verify whether any bit errors occurred and, if so, to correct them. If the algorithm is not able to correct the bit errors, then an error is reported to the application via the return value of the called API function as well as via the callback registered using FS_NOR_BM_SetOnFatalErrorCallback(). Depending on what data was exactly damaged, error recovery may or may not be possible. The application may try to repair the damaged data by running a disk checking operation via FS_CheckDisk().
The bit error correction is disabled by default and has to be enabled at compile time as well as at runtime. FS_NOR_SUPPORT_ECC has to be set to 1 in order to enable the support for bit error correction at compile time. At runtime, FS_NOR_BM_EnableECC() has to be called in FS_X_AddDevices() to activate the bit error correction feature. By default, the Block Map NOR driver uses an error correction algorithm that is able to correct 1-bit errors and to detect 2-bit errors in the management and payload data of the file system, but the application can register its own bit error correction routines via FS_NOR_BM_SetECCHook().

6.4.1.8 Supported hardware

The NOR flash drivers can be used with almost any NOR flash device. This includes NOR flash devices with 8-bit and 16-bit parallel interfaces, as well as two 16-bit interfaces in parallel. Serial NOR flash devices are also supported. A NOR flash device has to meet the following requirements:

- The NOR flash device has to contain a minimum of two physical sectors. The physical sectors do not need to be of equal size, but at least two physical sectors of each size must exist. For example, a NOR flash device with 11 physical sectors organized as 8 * 8 Kbytes + 3 * 64 Kbytes is supported.
- All the physical sectors need to be at least 2048 bytes large.
- The erase operation must set all bits in a physical sector to one.

In order to provide the best write performance, the NOR drivers make use of a NOR flash device feature that permits the same location to be modified multiple times without an erase operation in between, as long as only bits set to 1 are changed to 0. For NOR flash devices that do not support this feature, the NOR drivers have to be compiled with the configuration define FS_NOR_CAN_REWRITE set to 0.

In general, the NOR drivers support almost all serial and parallel NOR flashes which meet the listed requirements. In addition, the NOR drivers can use the internal flash memory of an MCU as a storage device.

The following table shows the serial NOR flash devices that were tested by SEGGER or are known to be compatible with a tested device.

Device name	Storage capacity	Device type	Supported optional features
Cypress/Spansion			
S25FL032P	32 Mibit	SPI	extended SPI
S25FL064L	64 Mibit	SPI	extended SPI
S25FL064P	64 Mibit	SPI	extended SPI
S25FL127S	128 Mibit	SPI	extended SPI

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Device name	Storage capacity	Device type	Supported optional features
S25FL128L	128 Mibit	SPI	extended SPI
S25FL128S	128 Mibit	SPI	extended SPI
S25FL129P	128 Mibit	SPI	extended SPI
S25FL132K	32 Mibit	SPI	extended SPI
S25FL164K	64 Mibit	SPI	extended SPI
S25FL256L	256 Mibit	SPI	extended SPI
S25FL256S	256 Mibit	SPI	extended SPI
S25FL512S	512 Mibit	SPI	extended SPI
S25FS128S	128 Mibit	SPI	extended SPI
S25FS256S	256 Mibit	SPI	extended SPI
S25FS512S	512 Mibit	SPI	extended SPI
S26KL512S	512 Mibit	HyperBus	write buffer
S29GL064N	64 Mibit	CFI	write buffer
S70FL01GS	1 Gibit	SPI	extended SPI
S70FL256P	256 Mibit	CFI	extended SPI
Dialog Semiconductor/Adesto/Atmel			
AT25SF128A	128 Mibit	SPI	extended SPI
AT25SL321	32 Mibit	SPI	extended SPI
AT25XE041D	4 Mibit	SPI	extended SPI
AT25XE081D	8 Mibit	SPI	extended SPI
AT25XE161D	16 Mibit	SPI	extended SPI
AT25XE321D	32 Mibit	SPI	extended SPI
Eon			
EN25QH128A	128 Mibit	SPI	extended SPI
EN25QX64A	64 Mibit	SPI	extended SPI
GigaDevice			
GD25LQ128D	128 Mibit	SPI	extended SPI
GD25LQ128E	128 Mibit	SPI	extended SPI
GD25LQ16C	16 Mibit	SPI	extended SPI
GD25Q127C	128 Mibit	SPI	extended SPI
GD25Q16B	16 Mibit	SPI	extended SPI
GD25Q16C	16 Mibit	SPI	extended SPI
GD25Q256D	256 Mibit	SPI	extended SPI
GD25Q32C	32 Mibit	SPI	extended SPI
GD25Q32E	32 Mibit	SPI	extended SPI
GD25Q64C	64 Mibit	SPI	extended SPI
GD25Q64E	64 Mibit	SPI	extended SPI
ISSI			
IS25LE256E	256 Mibit	SPI	extended SPI
IS25LP01G	1 Gibit	SPI	extended SPI
IS25LP032D	32 Mibit	SPI	extended SPI
IS25LP064A	64 Mibit	SPI	extended SPI
IS25LP064D	64 Mibit	SPI	extended SPI, DTR

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Device name	Storage capacity	Device type	Supported optional features
IS25LP128	128 Mibit	SPI	extended SPI
IS25LP128F	128 Mibit	SPI	extended SPI
IS25LP256D	256 Mibit	SPI	extended SPI
IS25LP512M	512 Mibit	SPI	extended SPI
IS25LQ016B	16 Mibit	SPI	extended SPI
IS25LQ032B	32 Mibit	SPI	extended SPI
IS25LQ080	8 Mibit	SPI	extended SPI
IS25LQ080B	8 Mibit	SPI	extended SPI
IS25LX256	256 Mibit	SPI	extended SPI, OPI DTR
IS25WP01G	1 Gibit	SPI	extended SPI
IS25WP064A	64 Mibit	SPI	extended SPI
IS25WP256D	256 Mibit	SPI	extended SPI
IS25WP512MJ	512 Mibit	SPI	extended SPI, DTR
IS25WX256	256 Mibit	SPI	extended SPI, OPI DTR
Infineon			
S25HL512T	512 Mibit	SPI	extended SPI
S25HS01GT	1 Gibit	SPI	extended SPI
S28HL512T	512 Mibit	SPI	OPI STR, OPI DTR
Macronix			
MX25L12835F	128 Mibit	SPI	extended SPI
MX25L25635F	256 Mibit	SPI	extended SPI
MX25L25645G	256 Mibit	SPI	extended SPI
MX25L3233F	32 Mibit	SPI	extended SPI
MX25L3235E	32 Mibit	SPI	extended SPI
MX25L51245G	512 Mibit	SPI	extended SPI
MX25L6433F	64 Mibit	SPI	extended SPI
MX25L8035E	8 Mibit	SPI	extended SPI
MX25LM25645G	256 Mibit	SPI	OPI STR, OPI DTR
MX25LM51245G	512 Mibit	SPI	OPI STR, OPI DTR
MX25R3235F	32 Mibit	SPI	extended SPI
MX25R6435F	64 Mibit	SPI	extended SPI
MX25U256	256 Mibit	SPI	extended SPI
MX25UM51245G	512 Mibit	SPI	OPI STR, OPI DTR
MX25V1635F	16 Mibit	SPI	extended SPI
MX66L1G45G	1 Gibit	SPI	extended SPI
MX66L2G45G	2 Gibit	SPI	extended SPI
MX66L51235F	512 Mibit	SPI	extended SPI
MX66U2G45G	2 Gibit	SPI	extended SPI
Microchip			
SST25VF016B	16 Mibit	SPI	
SST26VF016B	16 Mibit	SPI	extended SPI
SST26VF032B	32 Mibit	SPI	extended SPI
SST26VF032BA	32 Mibit	SPI	extended SPI

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Device name	Storage capacity	Device type	Supported optional features
SST26VF064B	64 Mibit	SPI	extended SPI
Micron			
M25P128	128 Mibit	SPI	
M25P16	16 Mibit	SPI	
M25P32	32 Mibit	SPI	
M25P40	4 Mibit	SPI	
M25P64	64 Mibit	SPI	
M25P80	8 Mibit	SPI	
M25PX16	16 Mibit	SPI	
M28F256	256 Kibit	CFI	
M28W160	16 Mibit	CFI	
M28W320	32 Mibit	CFI	
M28W640	64 Mibit	CFI	
M29F080	8 Mibit	CFI	
M29W128GL	128 Mibit	CFI	
M29W160	16 Mibit	CFI	
M29W320	32 Mibit	CFI	
M29W640	64 Mibit	CFI	
M58LW064	64 Mibit	CFI	
MT25QL01GBB	1 Gibit	SPI	extended SPI
MT25QL02GC	2 Gibit	SPI	extended SPI
MT25QL128ABA	128 Mibit	SPI	extended SPI
MT25QL256ABA	256 Mibit	SPI	extended SPI
MT25QL512ABB	512 Mibit	SPI	extended SPI
MT25QU01GBB	1 Gibit	SPI	extended SPI
MT25QU02GAB	2 Gibit	SPI	extended SPI
MT25QU128ABA	128 Mibit	SPI	extended SPI
MT25TL01GHBB	1 Gibit	SPI	extended SPI
MT28F128	128 Mibit	CFI	
MT28F320	32 Mibit	CFI	
MT28F640	64 Mibit	CFI	
N25Q00AA	1 Gibit	SPI	extended SPI
N25Q032A	32 Mibit	SPI	extended SPI
N25Q064	64 Mibit	SPI	extended SPI
N25Q064A	64 Mibit	SPI	extended SPI
N25Q128A	128 Mibit	SPI	extended SPI
N25Q256	256 Mibit	SPI	extended SPI
N25Q256A	256 Mibit	SPI	extended SPI
N25Q512A	512 Mibit	SPI	extended SPI
TE28F128P30B85	128 Mibit	CFI	
TE28F128P33B85	128 Mibit	CFI	
TE28F256P30B95	256 Mibit	CFI	
TE28F256P33B95	256 Mibit	CFI	

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Device name	Storage capacity	Device type	Supported optional features
TE28F640P30B85	64 Mibit	CFI	
TE28F640P33B85	64 Mibit	CFI	
STMicroelectronics			
M95P08	8 Mibit	SPI	extended SPI
M95P16	16 Mibit	SPI	extended SPI
M95P32	32 Mibit	SPI	extended SPI
Winbond			
W25Q01JV	1 Gibit	SPI	extended SPI
W25Q02JV	2 Gibit	SPI	extended SPI, DTR
W25Q128FW	128 Mibit	SPI	extended SPI
W25Q128JV	128 Mibit	SPI	extended SPI
W25Q16DV	16 Mibit	SPI	extended SPI
W25Q16JV	16 Mibit	SPI	extended SPI
W25Q256JV	256 Mibit	SPI	extended SPI
W25Q256JW	256 Mibit	SPI	extended SPI
W25Q32JV	32 Mibit	SPI	extended SPI
W25Q32RV	32 Mibit	SPI	extended SPI
W25Q512JV	512 Mibit	SPI	extended SPI, DTR
W25Q64FV	64 Mibit	SPI	extended SPI
W25Q64FW	64 Mibit	SPI	extended SPI
W25Q64JV	64 Mibit	SPI	extended SPI
W25Q80DV	8 Mibit	SPI	extended SPI
W25Q80EW	8 Mibit	SPI	extended SPI

Support for devices not available in this list

Most other NOR flash devices are compatible with one of the supported devices. Thus, the driver can be used with these devices or may only need a little modification, which can easily be done. Get in touch with us if you have questions about support for devices not in this list.

6.4.1.8.1 Using the same NOR flash device for code and data

Most NOR flash devices cannot be read out during a program or erase operation. This means that the CPU cannot execute code from the NOR flash device while the NOR flash device is busy performing a program or erase operation. A program crash is almost certain if the CPU tries to execute code in this case.

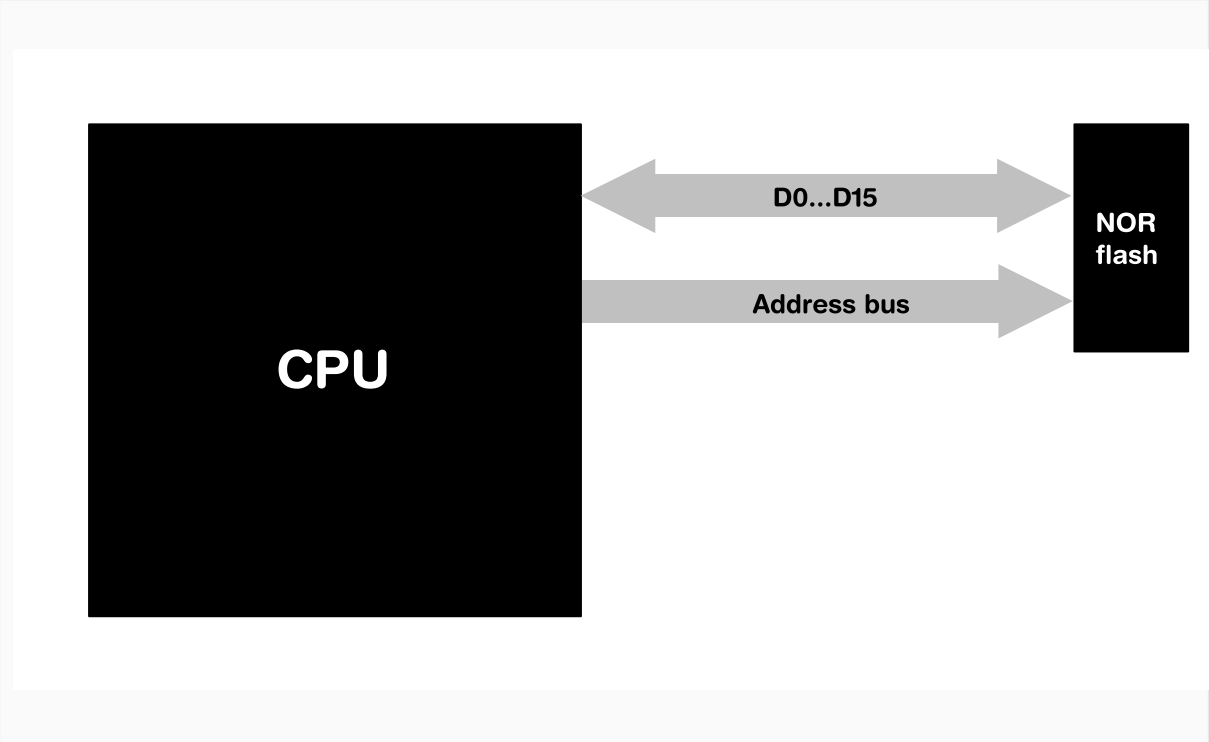
There are multiple options to solve this problem:

1. Multiple NOR flash devices can be used with code and data being stored on different devices.
2. A NOR flash device that supports multiple flash banks can be used. Typically, this type of NOR flash device allows code execution from one bank while performing an erase or program operation on a different one.
3. The hardware routines that program, erase or identify the NOR flash device are located in RAM and the interrupts are disabled.

6.4.1.9 Interfacing with a NOR flash device

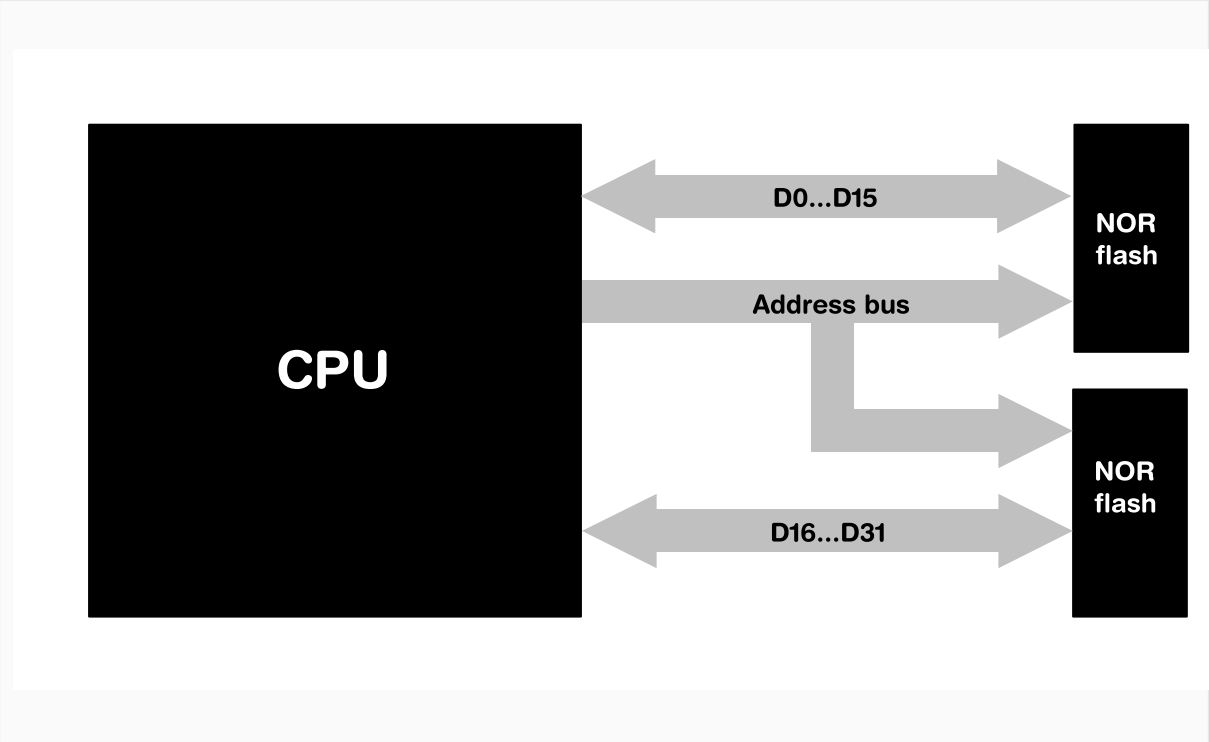
The most common setup is a CFI-compliant NOR flash device with a 16-bit interface. The picture below shows how this can be realized.

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NOR physical interface

In addition to this, emFile supports the use of two CFI-compliant NOR flash devices with a 16-bit interface which are connected to the same address bus as illustrated in the picture below.



Dual NOR physical interface

6.4.1.10 Common flash interface (CFI)

The NOR flash drivers can be used with any CFI-compliant 16-bit device. CFI is an open specification which may be implemented freely by flash memory vendors in their devices. It was developed jointly by Intel, AMD, Sharp, and Fujitsu. The idea behind CFI was the interchangeability of current and future flash memory devices offered by different vendors. If you use only CFI-compliant flash memory devices, you are able to use one driver for

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different flash products by reading identifying information out of the flash device itself. The identifying information for the device, such as memory size, byte/word configuration, block configuration, necessary voltages, and timing information, is stored directly on the device. For more technical details about CFI (Common Flash Interface) and SFDP (Serial Flash Discoverable Parameters), check the documents and specifications that are available free of charge at https://www.jedec.org.

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6.4.2 Sector Map NOR driver

This section describes the NOR driver that was optimized for increased write performance. The Sector Map NOR driver works by mapping single logical sectors to locations on the NOR flash device.

6.4.2.1 Theory of operation

Differentiating between logical sectors or blocks and physical sectors is essential to understand this section. A logical sector/block is the smallest readable and writable unit of any file system and its usual size is 512 bytes. A physical sector is an array of bytes on the NOR flash device that are erased together (typically between 2 Kbytes and 128 Kbytes). The Sector Map NOR driver is an abstraction layer between these two types of sectors.

Every time a logical sector is being updated, it is marked as invalid and the new content of this sector is written into another area of the flash. The physical address and the order of physical sectors can change with every write access. Hence, a direct relation between the sector number and its physical location cannot exist. The flash driver manages the logical sector numbers by writing them into special headers. To the upper layer, it does not matter where the logical sector is stored or how much flash memory is used as a buffer. All logical sectors (starting with sector 0) always exist and are always available for user access.

6.4.2.2 Configuring the driver

This section describes how to configure the file system to make use of the Sector Map NOR driver.

6.4.2.2.1 Compile time configuration

The Sector Map NOR driver can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the Sector Map NOR driver.

Define	Default value	Type	Description
`FS_NOR_CAN_REWRITE`	1	B	Indicates if modifying the same byte on the NOR flash device more than one time is permitted.
`FS_NOR_ENABLE_STATS`	0 or 1	B	Enables or disables the support for statistical counters.
`FS_NOR_LINE_SIZE`	1	N	Number of bytes in a write unit.
`FS_NOR_MAX_ERASE_CNT`	500000	N	Configures the maximum value of a valid erase count.
`FS_NOR_MAX_ERASE_CNT_DIFF`	5000	N	Configures the default maximum difference between erase counts.
`FS_NOR_MAX_NUM_SECTOR_SIZES`	11	N	Configures the maximum number of different sector sizes that the driver supports.
`FS_NOR_MIN_SEC-TOR_SIZE_SHIFT`	8	N	Configures the minimum size of a supported physical sector size.
`FS_NOR_NUM_FREE_SECTORCACHE`	100	N	Configures the default capacity of the list that stores the indexes of free sectors.
`FS_NOR_NUM_UNITS`	4	N	Maximum number of driver instances.

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Define	Default value	Type	Description
FS_NOR_OPTIMIZE_DIRTY_CHECK	1	B	Enables or disables the optimization for the blank checking of logical sectors.
FS_NOR_OPTIMIZE_HEADER_WRITE	0	B	Enables or disables the optimization for the writing of management data.
FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST	1	B	Enables or disables the optimization for the physical sector size management.
FS_NOR_READ_BUFFER_FILL_PATTERN	0xFF	N	Configures a bit pattern to be used for filling the contents of invalid logical sectors.
FS_NOR_SKIP_BLANK_SECTORS	1	B	Enables or disables the support for erasing blank physical sectors at low-level format.
FS_NOR_SUPPORT_CLEAN	1	B	Enables or disables the support for executing the garbage collection in the application.
FS_NOR_SUPPORT_VARIABLE_LINE_SIZE	0	B	Enables or disables the support for configuring at runtime the minimum number of bytes to be written at once.
FS_NOR_VERIFY_WRITE	0	B	Reads back and compares the sector data to check if the write operation was successful.
FS_NOR_VERIFY_ERASE	0	B	Reads back and compares the sector data to check if the erase operation was successful.

6.4.2.2.1.1 FS_NOR_CAN_REWRITE

For the majority of NOR flash devices, the same byte can be modified more than once without an erase operation in between while preserving the bits set to 0. That is, a byte can be written up to eight times with each write operation setting a different bit in that byte to 0. The Sector Map NOR driver leverages this feature to make efficient use of the storage space and to improve performance. FS_NOR_CAN_REWRITE has to be set to 0 for NOR flash devices that permit only one write operation to a byte or a range of bytes between two erase operations of that storage block.

6.4.2.2.1.2 FS_NOR_ENABLE_STATS

This define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the Sector Map NOR driver that can be useful for debugging. The statistical counters can be queried via FS_NOR_GetStatCounters(). By default FS_NOR_ENABLE_STATS is set to 1 if FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

6.4.2.2.1.3 FS_NOR_LINE_SIZE

FS_NOR_LINE_SIZE specifies the minimum number of bytes the Sector Map NOR driver writes at once. The amount of data written is always a multiple of this value. In addition, FS_NOR_LINE_SIZE specifies the alignment of the written data. That is, the offset at which the Sector Map NOR driver writes the data is always a multiple of this value. FS_NOR_LINE_SIZE has to be a power of two value.

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6.4.2.2.1.4 FS_NOR_MAX_ERASE_CNT

The Sector Map NOR driver uses the value of FS_NOR_MAX_ERASE_CNT to check the validity of an erase count stored in the header of a physical sector. If the value of the erase count is larger than FS_NOR_MAX_ERASE_CNT then the erase count is considered invalid and is set to the maximum value of all valid erase counts.

6.4.2.2.1.5 FS_NOR_MAX_ERASE_CNT_DIFF

The value of this define is used by the Sector Map NOR driver during the wear leveling procedure to decide which physical sector has to be used for storage. FS_NOR_SetMaxEraseCntDiff() can be used to modify this value at runtime. Refer to *Wear Leveling* on page 839 for more information about how this value is used.

6.4.2.2.1.6 FS_NOR_MAX_NUM_SECTOR_SIZES

FS_NOR_MAX_NUM_SECTOR_SIZES can be used to specify how many different physical sector sizes the Sector Map NOR driver is able to use as data storage. If FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST is set to 1, then the supported sector sizes depend on the value of FS_NOR_MIN_SECTOR_SIZE_SHIFT. More precisely, the Sector Map NOR driver is able to use as storage any physical sector with a size between $2^{FS_NOR_MIN_SECTOR_SIZE_SHIFT}$ and $2^{(FS_NOR_MIN_SECTOR_SIZE_SHIFT + FS_NOR_MAX_NUM_SECTOR_SIZES - 1)}$ that is a power of two value. With FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST set to 0, up to FS_NOR_MAX_NUM_SECTOR_SIZES physical sectors of arbitrary sizes are supported.

6.4.2.2.1.7 FS_NOR_MIN_SECTOR_SIZE_SHIFT

FS_NOR_MIN_SECTOR_SIZE_SHIFT can be used to specify the minimum size of a physical sector that is supported by the Sector Map NOR driver. The physical sector size is specified as a power of two exponent. This configuration define takes effect only when FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST is set to 1. For example, a value of 8 indicates that the minimum size of a physical sector is 2^8 = 256 bytes.

6.4.2.2.1.8 FS_NOR_NUM_FREE_SECTORCACHE

FS_NOR_NUM_FREE_SECTORCACHE can be used to specify the maximum number of physical sector indexes that an instance of the Sector Map NOR driver can remember as being ready to store data. Each entry of this list occupies 4 bytes. Increasing the capacity of the list can help increase the performance of the write operation at the cost of increased RAM usage.

6.4.2.2.1.9 FS_NOR_NUM_UNITS

This define specifies the maximum number of driver instances of the Sector Map NOR driver the application is allowed to create. Four bytes of static RAM are reserved for each instance. If the maximum number of driver instances is smaller than the default, then FS_NOR_NUM_UNITS can be set to that value in order to reduce the RAM usage.

6.4.2.2.1.10 FS_NOR_OPTIMIZE_DIRTY_CHECK

This define can be used to enable a speed optimization related to the check performed by the Sector Map NOR driver to determine if a logical sector is blank or not. With FS_NOR_OPTIMIZE_DIRTY_CHECK set to 1 the Sector Map NOR driver remembers which physical sectors were already checked so that the blank checking operation can be skipped. Activating this feature can help improve the write performance at the cost of increased RAM usage. The Sector Map NOR driver requires 1 bit of RAM for each physical sector used as storage.

6.4.2.2.1.11 FS_NOR_OPTIMIZE_HEADER_WRITE

FS_NOR_OPTIMIZE_HEADER_WRITE can be used to specify how the management data is written to storage. The management data is stored at the beginning of each physical and logical sector in an area called header. By default, the size of the physical sector header is 16 bytes and of the logical sector header is 8 bytes. The size of these headers is larger for NOR flash devices that specify a minimum number of bytes that have to be written at

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once and that are not able to perform incremental write operations. The default behavior of the Sector Map NOR driver, that is, when FS_NOR_OPTIMIZE_HEADER_WRITE is set to 0, is to write the entire header every time some of the information stored in it changes. With FS_NOR_OPTIMIZE_HEADER_WRITE set to 1 the Sector Map NOR driver tracks the changes made to a header and writes only the information that actually changed. Reducing the amount of data written to storage can help increase the write performance.
The internal flash memory of some MCUs does not allow a second write operation to the same byte with identical data without an erase operation in between. If this type of flash memory is used as storage, then it is mandatory to set FS_NOR_OPTIMIZE_HEADER_WRITE to 1.

6.4.2.2.1.12 FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST

The Sector Map NOR driver keeps track of the size of physical sectors it uses as storage. FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST can be used to configure how this list is managed. With FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST set to 1 the Sector Map NOR driver takes advantage of the fact that the size of a physical sector is typically a power of two value to keep the RAM usage to a minimum. If any of the physical sectors used as storage has a size that is not a power of two value then FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST will have to be set to 0. With FS_NOR_OPTIMIZE_SECTOR_SIZE_LIST set to 0 the RAM usage of the Sector Map NOR driver increases by FS_NOR_MAX_NUM_SECTOR_SIZES * 4 per driver instance.

6.4.2.2.1.13 FS_NOR_READ_BUFFER_FILL_PATTERN

The value of FS_NOR_READ_BUFFER_FILL_PATTERN is used by the Sector Map NOR driver to fill the contents of invalid logical sectors that is, logical sectors that were not written yet. The contents of all logical sectors are invalid after a low-level format operation. In addition, the contents of a logical sector can be invalidated via FS_STORAGE_FreeSectors().

6.4.2.2.1.14 FS_NOR_SKIP_BLANK_SECTORS

FS_NOR_SKIP_BLANK_SECTORS can be used to enable the support for the optimization that omits the erase of physical sectors that are already blank. This feature has to be explicitly enabled at runtime by calling FS_NOR_BM_SetBlankSectorSkip().

6.4.2.2.1.15 FS_NOR_SUPPORT_CLEAN

This define specifies if the application is allowed to perform a garbage collection operation. If FS_NOR_SUPPORT_CLEAN is set to 1 then the application can perform a garbage collection operation via FS_STORAGE_Clean() and FS_STORAGE_CleanOne(). For more information about the garbage collection, refer to *Garbage collection* on page 838. The automatic garbage collection operation performed by the Sector Map NOR driver is not disabled when FS_NOR_SUPPORT_CLEAN is set to 0. If the application does not call either FS_STORAGE_Clean() or FS_STORAGE_CleanOne(), then FS_NOR_SUPPORT_CLEAN can be safely set to 0 in order to save ROM space.

6.4.2.2.1.16 FS_NOR_SUPPORT_VARIABLE_LINE_SIZE

FS_NOR_SUPPORT_VARIABLE_LINE_SIZE can be used to enable the runtime configuration of the minimum number of bytes to be written by the Sector Map NOR driver at once. With FS_NOR_SUPPORT_VARIABLE_LINE_SIZE set to 1 the minimum number of bytes to be written at once can be configured via FS_NOR_SetDeviceLineSize() between 1 and FS_NOR_LINE_SIZE. In addition, the ability of the NOR flash device to perform incremental write operations can be configured via FS_NOR_SetDeviceRewriteSupport().
FS_NOR_SUPPORT_VARIABLE_LINE_SIZE is set to 1 when building the NOR Image Creator utility in order to give it the ability to create images for NOR flash devices with different characteristics. Typically, there is no need to modify the default value of FS_NOR_SUPPORT_VARIABLE_LINE_SIZE when building a target application.

6.4.2.2.1.17 FS_NOR_VERIFY_WRITE

This define can be used to activate the write verification of the Sector Map NOR driver. The write verification is performed after each write operation by reading back the modified

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data from storage and by comparing it with the data requested to be written. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NOR_SetWriteVerification()`.

> **Note**
>
> Activating the write verification can negatively affect the write performance.

6.4.2.2.1.18 FS_NOR_VERIFY_ERASE

This define can be used to activate the erase verification of the Sector Map NOR driver. The erase verification is performed after each erase operation by reading back the entire data of the erase physical sector from storage and by comparing it with `0xFF`. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NOR_SetEraseVerification()`.

> **Note**
>
> Activating the erase verification can negatively affect the erase performance.

6.4.2.2.2 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of `FS_NOR_Driver`. This function call together with other function calls that configure the driver operation have to be added to `FS_X_AddDevices()` as demonstrated in the following example. This example shows how to configure the file system to access a NOR flash device connected via SPI.

```
#include "FS.h"

#define ALLOC_SIZE        0x4000        // Size defined in bytes
#define BYTES_PER_SECTOR  2048

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the NOR flash driver. The first 65536 bytes of the
  // serial NOR flash device are not used by the file system as data storage
  // and can be used by the application for other purposes. The file system
  // uses a total of 1 Mbyte from the serial NOR flash device as storage.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_ST_M25);
  FS_NOR_Configure(0, 0x00000000, 0x00010000, 0x00100000);
  FS_NOR_SetSectorSize(0, BYTES_PER_SECTOR);
  //
  // Set a larger logical sector size as the default
  // in order to reduce the RAM usage of the NOR driver.
  //
  FS_SetMaxSectorSize(BYTES_PER_SECTOR);
}
```

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The API functions listed in the next table can be used by the application to configure the behavior of the Sector Map NOR driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NOR_Configure()`	Configures an instance of the sector map NOR driver.
`FS_NOR_ConfigureReserve()`	Configures the number of logical sectors to be reserved.
`FS_NOR_SetBlankSectorSkip()`	Configures if the physical sectors which are already blank should be erased during the low-level format operation.
`FS_NOR_SetDeviceLineSize()`	Configures the minimum number of bytes that can be written to NOR flash.
`FS_NOR_SetDeviceRewriteSupport()`	Specifies if the NOR flash device can rewrite the same data if 0s are preserved.
`FS_NOR_SetDirtyCheckOptimization()`	Enables or disables the blank checking of a logical sector before write.
`FS_NOR_SetEraseVerification()`	Enables or disables the checking of the sector erase operation.
`FS_NOR_SetPhyType()`	Configures the type of NOR physical layer.
`FS_NOR_SetSectorSize()`	Configures the number of bytes in a logical sector.
`FS_NOR_SetWriteVerification()`	Enables or disables the checking of the page write operation.

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6.4.2.2.2.1 FS_NOR_Configure()

Description

Configures an instance of the sector map NOR driver

Prototype

```
void FS_NOR_Configure(U8  Unit,
                      U32 BaseAddr,
                      U32 StartAddr,
                      U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
BaseAddr	Address of the first byte in NOR flash.
StartAddr	Address of the first byte the NOR driver is permitted to use as storage.
NumBytes	Number of bytes starting from StartAddr available to be used by the NOR driver as storage.

Additional information

This function is mandatory and it has to be called once in FS_X_AddDevices() for each instance of the sector map NOR driver created by the application. Different instances of the NOR driver are identified by the Unit parameter.

BaseAddr is used only for NOR flash devices that are memory mapped. For serial NOR flash devices that are not memory mapped BaseAddr has to be set to 0.

StartAddr has to be greater than or equal to BaseAddr and smaller than the total number of bytes in the NOR flash device. The sector map NOR driver rounds up StartAddr to the start address of the next physical sector in the NOR flash device.

NumBytes is rounded up to a physical sector boundary if the memory range defined by StartAddr and NumBytes is smaller than the capacity of the NOR flash device. If the memory range defined by StartAddr and NumBytes is larger than the capacity of the NOR flash device than NumBytes is rounded down so that the memory range fits into the NOR flash device.

The sector map NOR driver can work with physical sectors of different size. It is required that at least two physical sectors of each sector size are available.

Example

The following sample demonstrates how to configure the file system to work with a single CFI compliant NOR flash device connected via a 16-bit data bus.

```
#include "FS.h"

#define ALLOC_SIZE 0x2000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
```

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```
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add the NOR driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  //
  // Set the physical layer type for single CFI compliant
  // NOR flash device with 16-bit data bus interface.
  //
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  //
  // Configure the range of NOR flash device to be used as storage (2 Mbytes)
  //
  FS_NOR_Configure(0, 0x1000000, 0x1000000, 0x00200000);
}
```

The next sample demonstrates how to configure the file system to work with two CFI compliant NOR flash devices with each device being connected via a separate 16-bit data bus.

```
#include "FS.h"

#define ALLOC_SIZE 0x4000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add the NOR driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  //
  // Set the physical layer type for two CFI compliant
  // NOR flash devices with 16-bit data bus interface.
  //
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_2x16);
  //
  // Configure the range of NOR flash device to be used as storage (2 Mbytes each)
  //
  FS_NOR_Configure(0, 0x1000000, 0x1000000, 0x00400000);
}
```

The file system is able to handle two or more NOR flash devices that are not connected in parallel. The next sample shows how this can be realized.

```
#include "FS.h"

#define ALLOC_SIZE 0x4000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
```

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```
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the first NOR driver. The storage can be accessed
  // using the volume name "nor:0:". The physical layer is set to single
  // CFI compliant NOR flash device with 16-bit interface. The NOR flash
  // device is mapped at address 0x10000000 in the system memory and
  // 2 Mbytes of it are used by the file system as storage.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, 0x1000000, 0x1000000, 0x00200000);
  //
  // Add and configure the second NOR driver. The storage can be accessed
  // using the volume name "nor:1:". The physical layer is set to single
  // CFI compliant NOR flash device with 16-bit interface. The NOR flash
  // device is mapped at address 0x40000000 in the system memory and
  // 4 Mbytes of it are used by the file system as storage.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(1, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(1, 0x4000000, 0x4000000, 0x00400000);
}
```

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6.4.2.2.2.2 FS_NOR_ConfigureReserve()

Description

Configures the number of logical sectors to be reserved.

Prototype

```
void FS_NOR_ConfigureReserve(U8 Unit,
                             U8 pctToReserve);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
pctToReserve	Percent of the total number of logical sectors to reserve.

Additional information

This function is optional. By default, the sector map NOR driver reserves about 10% of the total number of logical sector for future improvements and extensions. `FS_NOR_ConfigureReserve()` can be used in an application to modify this value. If set to 0 the sector map NOR driver uses all the available logical sectors to store file system data.

The application has to reformat the NOR flash device in order for the modified value to take effect.

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6.4.2.2.2.3 FS_NOR_SetBlankSectorSkip()

Description

Configures if the physical sectors which are already blank should be erased during the low-level format operation.

Prototype

```
void FS_NOR_SetBlankSectorSkip(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 All the physical sectors are erased. • ≠0 Physical sectors are not erased if they are blank (default).

Additional information

This function is optional. The blank checking feature is disabled by default and has to be explicitly enabled at compile time by setting FS_NOR_SKIP_BLANK_SECTORS to 1. The feature can then be enabled or disabled at runtime using FS_NOR_SetBlankSectorSkip().

Activating this feature can improve the speed of the low-level format operation when most of the physical sectors of the NOR flash device are already blank which is typically the case with NOR flash devices that ship from factory.

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6.4.2.2.2.4 FS_NOR_SetDeviceLineSize()

Description

Configures the minimum number of bytes that can be written to NOR flash.

Prototype

```
void FS_NOR_SetDeviceLineSize(U8 Unit,
                              U8 ldBytesPerLine);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
ldBytesPerLine	Line size in bytes as power of 2 exponent.

Additional information

This function is optional. Typically, the NOR flash have lines smaller than 4 bytes which is the fixed default value configured at compile time. The FS_NOR_SUPPORT_VARIABLE_LINE_SIZE configuration define has to be set to a value different than 0 in order to enable this function.

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6.4.2.2.2.5 FS_NOR_SetDeviceRewriteSupport()

Description

Specifies if the NOR flash device can rewrite the same data if 0s are preserved.

Prototype

```
void FS_NOR_SetDeviceRewriteSupport(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 Rewrite operations are not performed. • ≠0 Rewrite operations are performed (default).

Additional information

This function is optional. Typically, the NOR flash devices are able to rewrite the same data and by default this feature is disabled at compile time. The FS_NOR_SUPPORT_VARIABLE_LINE_SIZE configuration define has to be set to a value different than 0 in order to enable this function, otherwise the function does nothing.

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6.4.2.2.2.6 FS_NOR_SetDirtyCheckOptimization()

Description

Enables or disables the blank checking of a logical sector before write.

Prototype

```
void FS_NOR_SetDirtyCheckOptimization(U8 Unit,
                                      U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 Dirty check is disabled (default). • ≠0 Dirty check is enabled.

Additional information

This function is optional. Per default, the NOR driver checks if the data of the logical sector is blank (all bytes 0xFF) before it writes the data. This is necessary in order to make sure that the NOR driver does not write to partially written logical sectors. Writing to a partially written logical sector can cause a data loss since the write operation can change the value of a bit only from 1 to 0. A partially written logical sector occurs when the write operation is interrupted by an unexpected reset. In this case the status of the logical sector indicates that the logical sector is blank which is not correct. Therefore the logical sector cannot be used for storage and it is marked by the NOR driver as invalid.

Typically, the blank checking runs fast but on some targets it may reduce the write performance. In this cases, this option can be used to skip the blank checking which helps improve the performance. When the optimization is enabled, the blank checking is not longer performed on the logical sectors located on physical sectors that have been erased at least once since the last mount operation. The NOR driver can skip the blank checking for these physical sectors since it knows that they do not contain any partially written logical sectors. The application can remove any partially written logical sectors by performing a clean operation of the entire storage via the FS_STORAGE_Clean() or FS_STORAGE_CleanOne() API functions. The NOR driver requires one bit of RAM storage for each physical sector used as storage.

The FS_NOR_OPTIMIZE_DIRTY_CHECK configuration define has to be set to a value different than 0 in order to enable this function, otherwise the function does nothing.

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6.4.2.2.2.7 FS_NOR_SetEraseVerification()

Description

Enables or disables the checking of the sector erase operation.

Prototype

```
void FS_NOR_SetEraseVerification(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The erase operation is not checked. • ≠0 The erase operation is checked.

Additional information

This function is optional. The result of a sector erase operation is normally checked by evaluating the error bits maintained by the NOR flash device in an internal status register. `FS_NOR_SetEraseVerification()` can be used to enable additional verification of the sector erase operation that is realized by reading back the contents of the entire erased physical sector and by checking that all the bytes in it are set to `0xFF`. Enabling this feature can negatively impact the write performance of sector map NOR driver.

The sector erase verification feature is active only when the sector map NOR driver is compiled with the `FS_NOR_VERIFY_ERASE` configuration define is set to 1 (default is 0) or when the `FS_DEBUG_LEVEL` configuration define is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

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6.4.2.2.2.8 FS_NOR_SetPhyType()

Description

Configures the type of NOR physical layer.

Prototype

```
void FS_NOR_SetPhyType(      U8                Unit,
                       const FS_NOR_PHY_TYPE * pPhyType);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
pPhyType	in NOR physical layer.

Additional information

This function is mandatory and it has to be called once in FS_X_AddDevices() for each instance of the sector map NOR driver created by the application. Different instances of the sector map NOR driver are identified by the Unit parameter.

Permitted values for the pPhyType parameter are:

Identifier
FS_NOR_PHY_CFI_1x16
FS_NOR_PHY_CFI_2x16
FS_NOR_PHY_DSPI
FS_NOR_PHY_SFDP
FS_NOR_PHY_SPIFI
FS_NOR_PHY_ST_M25

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6.4.2.2.2.9 FS_NOR_SetSectorSize()

Description

Configures the number of bytes in a logical sector.

Prototype

```
void FS_NOR_SetSectorSize(U8  Unit,
                          U16 SectorSize);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
SectorSize	Number of bytes in a logical sector.

Additional information

This function is optional. It can be used to modify the size of the logical sector used by the sector map NOR driver. By default the sector map NOR driver uses the logical sector size configured a file system level that is set to 512 bytes at the file system initialization and can be later changed via FS_SetMaxSectorSize(). The NOR flash device has to be reformatted in order for the new logical sector size to take effect.

SectorSize has to be a power of 2 value.

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6.4.2.2.2.10 FS_NOR_SetWriteVerification()

Description

Enables or disables the checking of the page write operation.

Prototype

```
void FS_NOR_SetWriteVerification(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The write operation is not checked. • ≠0 The write operation is checked.

Additional information

This function is optional. The result of a page write operation is normally checked by evaluating the error bits maintained by the NOR flash device in an internal status register. FS_NOR_SetWriteVerification() can be used to enable additional verification of the page write operation that is realized by reading back the contents of the written page and by checking that all the bytes are matching the data requested to be written. Enabling this feature can negatively impact the write performance of sector map NOR driver.

The page write verification feature is active only when the sector map NOR driver is compiled with the FS_NOR_VERIFY_WRITE configuration define is set to 1 (default is 0) or when the FS_DEBUG_LEVEL configuration define is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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6.4.2.2.2.11 FS_NOR_STAT_COUNTERS

Description

Statistical counters maintained by the Sector Map NOR driver.

Type definition

```
typedef struct {
  U32  EraseCnt;
  U32  ReadSectorCnt;
  U32  WriteSectorCnt;
  U32  CopySectorCnt;
  U32  ReadCnt;
  U32  ReadByteCnt;
  U32  WriteCnt;
  U32  WriteByteCnt;
  U32  ReadPSHCnt;
  U32  WritePSHCnt;
} FS_NOR_STAT_COUNTERS;
```

Structure members

Member	Description
EraseCnt	Number of sector erase operations.
ReadSectorCnt	Number of logical sectors read by the file system.
WriteSectorCnt	Number of logical sectors written by the file system.
CopySectorCnt	Number of logical sectors copied internally by the driver.
ReadCnt	Number of times the driver read data from the NOR flash device.
ReadByteCnt	Number of bytes read by the driver from the NOR flash device.
WriteCnt	Number of times the driver wrote data to the NOR flash device.
WriteByteCnt	Number of bytes written by the driver to the NOR flash device.
ReadPSHCnt	Number of times the driver read from the header of a physical sector.
WritePSHCnt	Number of times the driver wrote to the header of a physical sector.

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6.4.2.2.3 Additional sample configurations

The sample configurations below show how to create multiple volumes, logical volumes, etc., on a NOR flash device. All configuration steps have to be performed inside the `FS_X_AddDevices()` function that is called during the initialization of the file system.

6.4.2.2.3.1 Multiple volumes on a single NOR flash device

The following example illustrates how to create multiple volumes on a single NOR flash device. The sample creates two volumes on one NOR flash device.

```
#include "FS.h"

#define ALLOC_SIZE 0x2000               // Size defined in bytes
//
// Config: 1 NOR flash, where NOR flash size -> 2 MB
//         2 volumes, , where volume 0 size -> 1MB, volume 1 -> 0.5MB
//
#define FLASH_BASE_ADDR             0x80000000
#define FLASH_VOLUME_0_START_ADDR   0x80000000
#define FLASH_VOLUME_0_SIZE         0x00100000  // 1 MByte
#define FLASH_VOLUME_1_START_ADDR   0x80100000
#define FLASH_VOLUME_1_SIZE         0x00080000  // 0.5 MByte

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Volume name: "nor:0:"
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, FLASH_BASE_ADDR, FLASH_VOLUME_0_START_ADDR, FLASH_VOLUME_0_SIZE);
  //
  // Volume name: "nor:1:"
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(1, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(1, FLASH_BASE_ADDR, FLASH_VOLUME_1_START_ADDR, FLASH_VOLUME_1_SIZE);
}
```

6.4.2.2.3.2 Multiple volumes on different NOR flash devices

The following example illustrates how to create multiple volumes on multiple NOR flash devices. This sample creates two volumes, each one located on a different NOR flash device.

```
#include "FS.h"

#define ALLOC_SIZE 0x2000               // Size defined in bytes
//
// Config:  2 NOR flash devices, where NOR flash 0 size -> 2 MB, NOR flash 1 -> 16MB
//          2 volumes, volume 0 size -> complete NOR 0, volume 1 -> complete NOR 1
//
#define FLASH0_BASE_ADDR            0x80000000
#define FLASH_VOLUME_0_START_ADDR   FLASH0_BASE_ADDR
#define FLASH_VOLUME_0_SIZE         0xFFFFFFFF  // Use the complete flash
#define FLASH1_BASE_ADDR            0x40000000
#define FLASH_VOLUME_1_START_ADDR   FLASH1_BASE_ADDR
#define FLASH_VOLUME_1_SIZE         0xFFFFFFFF  // Use the complete flash
```

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```
static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Volume name: "nor:0:"
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, FLASH0_BASE_ADDR, FLASH_VOLUME_0_START_ADDR, FLASH_VOLUME_0_SIZE);
  //
  // Volume name: "nor:1:"
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(1, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(1, FLASH1_BASE_ADDR, FLASH_VOLUME_1_START_ADDR, FLASH_VOLUME_1_SIZE);
}
```

6.4.2.2.3.3 Volume that stretches over multiple NOR flash devices

The following example illustrates how to create a volume that stretches over two NOR flash devices. This is realized by using the logical volume functionality.

```
#include "FS.h"

#define ALLOC_SIZE 0x2000               // Size defined in bytes
//
// Config:  2 NOR flash devices, where NOR flash 0 size -> 2 MB, NOR flash 1 -> 16MB
//          1 volume, where volume is NOR flash 0 + NOR flash 1
//
#define FLASH0_BASE_ADDR            0x80000000
#define FLASH_VOLUME_0_START_ADDR   FLASH0_BASE_ADDR
#define FLASH_VOLUME_0_SIZE         0xFFFFFFFF  // Use the complete flash
#define FLASH1_BASE_ADDR            0x40000000
#define FLASH_VOLUME_1_START_ADDR   FLASH1_BASE_ADDR
#define FLASH_VOLUME_1_SIZE         0xFFFFFFFF  // Use the complete flash

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Create physical device 0, this device will not be visible as a volume.
  //
  FS_AddPhysDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, FLASH0_BASE_ADDR, FLASH_VOLUME_0_START_ADDR, FLASH_VOLUME_0_SIZE);
  //
  // Create physical device 1, this device will not be visible as a volume
  //
  FS_AddPhysDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(1, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(1, FLASH1_BASE_ADDR, FLASH_VOLUME_1_START_ADDR, FLASH_VOLUME_1_SIZE);
```

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```
  //
  // Now create a logical volume, containing the physical devices. Volume name: "LogVol"
  //
  FS_LOGVOL_Create("LogVol");
  FS_LOGVOL_AddDevice("LogVol", &FS_NOR_Driver, 0, 0, 0);
  FS_LOGVOL_AddDevice("LogVol", &FS_NOR_Driver, 1, 0, 0);
}
```

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6.4.2.3 Additional driver functions

The functions documented in this section are optional. They can be used to get information about the status of the Sector Map NOR driver or to directly access the data stored on the NOR flash device.

Function	Description
FS_NOR_EraseDevice()	Erases all the physical sectors configured as storage.
FS_NOR_ErasePhySector()	Sets all the bits in a physical sector to 1.
FS_NOR_FormatLow()	Performs a low-level format of NOR flash device.
FS_NOR_GetDiskInfo()	Returns information about the organization and the management of the NOR flash device.
FS_NOR_GetSectorInfo()	Returns information about a specified physical sector.
FS_NOR_GetStatCounters()	Returns the values of the statistical counters.
FS_NOR_IsLLFormatted()	Checks it the NOR flash is low-level formatted.
FS_NOR_LogSector2PhySectorAddr()	Returns the address in memory of a specified logical sector.
FS_NOR_ReadOff()	Reads a range of bytes from the NOR flash device.
FS_NOR_ResetStatCounters()	Sets the value of the statistical counters to 0.
FS_NOR_WriteOff()	Writes data to NOR flash memory.

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6.4.2.3.1 FS_NOR_EraseDevice()

Description

Erases all the physical sectors configured as storage.

Prototype

```
int FS_NOR_EraseDevice(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).

Return value

= 0 Physical sectors erased.
≠ 0 An error occurred.

Additional information

This function is optional. After the call to this function all the bytes in area of the NOR flash device configured as storage are set to `0xFF`.

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6.4.2.3.2 FS_NOR_ErasePhySector()

Description

Sets all the bits in a physical sector to 1.

Prototype

```
int FS_NOR_ErasePhySector(U8  Unit,
                          U32 PhySectorIndex);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
PhySectorIndex	Index of the physical sector to be erased.

Return value

= 0 OK, physical sector erased successfully.
≠ 0 An error occurred.

Additional information

PhySectorIndex is 0-based and is relative to the beginning of the NOR flash area configured via FS_NOR_Configure(). The number of bytes actually erased depends on the size of the physical sector supported by the NOR flash device. Information about a physical sector can be obtained via FS_NOR_GetSectorInfo().

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6.4.2.3.3 FS_NOR_FormatLow()

Description

Performs a low-level format of NOR flash device.

Prototype

```
int FS_NOR_FormatLow(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).

Return value

= 0 OK, NOR flash device has been successfully low-level formatted.
≠ 0 An error occurred.

Additional information

This function is optional. FS_NOR_FormatLow() erases the first physical sector and stores the format information in it. The other physical sectors are either erased or invalidated. Per default the physical sectors are invalidated in order to reduce the time it takes for the operation to complete.

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6.4.2.3.4 FS_NOR_GetDiskInfo()

Description

Returns information about the organization and the management of the NOR flash device.

Prototype

```
int FS_NOR_GetDiskInfo(U8                 Unit,
                       FS_NOR_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
pDiskInfo	out Requested information.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the sector map NOR driver and will typically not be linked in production builds.

Example

```
#include "FS.h"

void SampleNORGetDiskInfo(void) {
  int              r;
  char             ac[128];
  FS_NOR_DISK_INFO DiskInfo;

  FS_X_Log("Get information about the first Sector Map NOR driver instance\n");
  r = FS_NOR_GetDiskInfo(0, &DiskInfo);
  if (r == 0) {
    SEGGER_snprintf(ac, sizeof(ac), "  Physical sectors: %lu\n", DiskInfo.NumPhysSectors);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Logical sectors : %lu\n", DiskInfo.NumLogSectors);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Used sectors:     %lu\n", DiskInfo.NumUsedSectors);
    FS_X_Log(ac);
  }
}
```

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6.4.2.3.5 FS_NOR_GetSectorInfo()

Description

Returns information about a specified physical sector.

Prototype

```
int FS_NOR_GetSectorInfo(U8                   Unit,
                         U32                  PhySectorIndex,
                         FS_NOR_SECTOR_INFO * pSectorInfo);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
PhySectorIndex	Index of the physical sector to be queried (0-based).
pSectorInfo	out Information related to the specified physical sector.

Return value

= 0 OK, information returned successfully.
≠ 0 An error occurred.

Additional information

This function is optional. The application can use it to get information about the usage of a particular physical sector.

PhySectorIndex is relative to the beginning of the region configured as storage via FS_NOR_Configure().

Example

```
#include "FS.h"

void SampleNORGetDiskInfo(void) {
  char               ac[128];
  FS_NOR_SECTOR_INFO SectorInfo;

  FS_X_Log("Get information about the physical sector 0 of the first Sector Map NOR driver instance
\n");
  FS_NOR_GetSectorInfo(0, 0, &SectorInfo);
  SEGGER_snprintf(ac, sizeof(ac), "  Offset:                  %lu\n", SectorInfo.Off);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Size:                    %lu bytes\n", SectorInfo.Size);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Erase count:             %lu\n", SectorInfo.EraseCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Used logical sectors:    %lu\n", SectorInfo.NumUsedSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Free logical sectors:    %lu\n", SectorInfo.NumFreeSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Erasable logical sectors: %lu
\n", SectorInfo.NumEraseableSectors);
  FS_X_Log(ac);
}
```

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6.4.2.3.6 FS_NOR_GetStatCounters()

Description

Returns the values of the statistical counters.

Prototype

```
void FS_NOR_GetStatCounters(U8                    Unit,
                            FS_NOR_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
pStat	out Statistical counter values.

Additional information

This function is optional. The application can use it to get the actual values of the statistical counters maintained by the sector map NOR driver. The statistical counters provide information about the number of internal operations performed by the sector map NOR driver such as sector read and write. All statistical counters are set to 0 when the NOR flash device is low-level mounted. The application can explicitly set them to 0 by using FS_NOR_ResetStatCounters(). A separate set of statistical counters is maintained for each instance of the sector map NOR driver.

The statistical counters are available only when the sector map NOR driver is compiled with the FS_DEBUG_LEVEL configuration define set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or with the FS_NOR_ENABLE_STATS configuration define set to 1.

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6.4.2.3.7 FS_NOR_IsLLFormatted()

Description

Checks it the NOR flash is low-level formatted.

Prototype

```
int FS_NOR_IsLLFormatted(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).

Return value

≠ 0 The NOR flash device is low-level formatted.
= 0 The NOR flash device is not low-level formatted or an error has occurred.

Additional information

This function is optional. An application should use `FS_IsLLFormatted()` instead.

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6.4.2.3.8 FS_NOR_LogSector2PhySectorAddr()

Description

Returns the address in memory of a specified logical sector.

Prototype

```
const void *FS_NOR_LogSector2PhySectorAddr(U8  Unit,
                                           U32 LogSectorIndex);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
LogSectorIndex	Index of the logical sector for which the address has to be calculated.

Return value

≠ NULL OK, address of the first byte in the logical sector.
= NULL An error occurred.

Additional information

This function is optional. It can be used only with NOR flash devices that are memory mapped. FS_NOR_LogSector2PhySectorAddr() returns the address in the system memory of the first byte in the specified logical sector.

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6.4.2.3.9 FS_NOR_ReadOff()

Description

Reads a range of bytes from the NOR flash device.

Prototype

```
int FS_NOR_ReadOff(U8     Unit,
                   U32    Off,
                   void * pData,
                   U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).
Off	Offset of the first byte to be read.
pData	out Read data.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the driver and will typically not be linked in production builds.

Off has to be specified in bytes and is relative to the beginning of the NOR flash area configured via FS_NOR_Configure().

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6.4.2.3.10 FS_NOR_ResetStatCounters()

Description

Sets the value of the statistical counters to 0.

Prototype

```
void FS_NOR_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the sector map NOR driver (0-based).

Additional information

This function is optional. The application can use it to set the statistical counters maintained by the sector map NOR driver to 0. The statistical counters can be read via `FS_NOR_GetStatCounters()`

`FS_NOR_ResetStatCounters()` is available only when the sector map NOR driver is compiled with the `FS_DEBUG_LEVEL` configuration define set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with the `FS_NOR_ENABLE_STATS` configuration define set to 1.

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6.4.2.3.11 FS_NOR_WriteOff()

Description

Writes data to NOR flash memory.

Prototype

```
int FS_NOR_WriteOff(      U8     Unit,
                          U32    Off,
                    const void * pData,
                          U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the Sector Map NOR driver (0-based).
Off	Location where to write the data.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written successfully.
≠ 0 An error occurred.

Additional information

Off has to be specified in bytes and is relative to the beginning of the NOR flash area configured via FS_NOR_Configure().

FS_NOR_WriteOff() is able to write across page and physical sector boundaries. This function can only change bit values from 1 to 0. The bits can be set to 1 block-wise via FS_NOR_EraseSector().

The function takes care of the alignment required when writing to NOR flash devices with line size larger than 1.

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6.4.2.3.12 FS_NOR_DISK_INFO

Description

Management information maintained by the Sector Map NOR driver.

Type definition

```
typedef struct {
  U32  NumPhysSectors;
  U32  NumLogSectors;
  U32  NumUsedSectors;
  U16  BytesPerSector;
} FS_NOR_DISK_INFO;
```

Structure members

Member	Description
NumPhysSectors	Number of physical sectors available for data storage.
NumLogSectors	Number of available logical sectors.
NumUsedSectors	Number of logical sectors that store valid data.
BytesPerSector	Size of the logical sector used by the driver in bytes.

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6.4.2.3.13 FS_NOR_SECTOR_INFO

Description

Information about a physical sector maintained by the Sector Map NOR driver.

Type definition

```
typedef struct {
  U32  Off;
  U32  Size;
  U32  EraseCnt;
  U16  NumUsedSectors;
  U16  NumFreeSectors;
  U16  NumEraseableSectors;
  U8   Type;
} FS_NOR_SECTOR_INFO;
```

Structure members

Member	Description
Off	Position of the physical sector relative to the first byte of NOR flash device
Size	Size of physical sector in bytes
EraseCnt	Number of times the physical sector has been erased
NumUsedSectors	Number of logical sectors that contain valid data
NumFreeSectors	Number of logical sectors that are empty (i.e. blank)
NumEraseableSectors	Number of logical sectors that contain old (i.e. invalid) data.
Type	Type of data stored in the physical sector (see FS_NOR_SECTOR_TYPE_...)

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6.4.2.4 Performance and resource usage

This section provides information about the ROM and RAM usage as well as the performance of the Sector Map NOR driver. Each driver instance requires one instance of one NOR physical layer in order to operate. The resource usage of the used NOR physical layer has to be taken into account when calculating the total resource usage of the Sector Map NOR driver. Refer to the section *Resource usage* on page 1013 for information about the resource usage of the available NOR physical layers.

6.4.2.4.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the Sector Map NOR driver were measured as described in the section *Test procedure* on page 1439.

Usage: 4.0 KBytes

6.4.2.4.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Sector Map NOR driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the `FS_NOR_Drv.c` file.

Usage: 20 bytes

6.4.2.4.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the runtime configuration and on the used NOR flash device. The approximate RAM usage of the Sector Map NOR driver can be calculated as follows:

```
MemAllocated = 500 + (BitsPerEntry * FlashSize / 8) / LogSectorSize
```

Parameter	Description
`MemAllocated`	Number of bytes allocated.
`BitsPerEntry`	Number of bits required to store the offset of the last byte on the storage.
`FlashSize`	Size in bytes of a NOR flash.
`LogSectorSize`	Size in bytes of a file system sector. Typically, 512 bytes or the value set in the call to `FS_SetMaxSectorSize()`.

The following table lists the approximate amount of RAM required for different combinations of NOR flash size and logical sector size:

Flash size (Mbytes)	512 byte sectors	1 Kbyte sectors	2 Kbyte sectors
1	4.6 KBytes	2.5 KBytes	1.5 KBytes
2	8.7 KBytes	4.6 KBytes	2.5 KBytes
4	16.8 KBytes	8.7 KBytes	4.6 KBytes
8	33.2 KBytes	16.8 KBytes	8.7 KBytes

> **Note**
>
> Please note that by increasing the logical sector size, the RAM usage of the file system also increases because more memory is required for the sector buffers.

6.4.2.4.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were

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performed as described in the section *Performance* on page 1445. All values are given in Kbytes/second.

CPU type	NOR flash device	Write speed	Read speed
ST STR912 (96 MHz)	Winbond W25Q32BV (SPI)	**75**	**2625**
NXP LPC2478 (57.6 MHz)	SST SST39VF201 CFI NOR flash device with 16-bit interface and without support for write buffer	**53.5**	**2560**
ST STM32F103 (72 MHz)	ST M29W128 CFI NOR flash device with 16-bit interface and with support for write buffer	**60.4**	**8000**
ST STM32F103 (72 MHz)	ST M25P64 SPI NOR flash device	**62.8**	**1125**
NXP LPC4357 (204 MHz)	Spansion S25FL032P serial NOR flash device interfaced via SPIFI.	**185**	**26947**

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6.4.2.5 FAQs

Q: How many physical sectors are reserved by the driver?
A: The driver reserves 2 physical sectors for its internal use.

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6.4.3 Block Map NOR driver

This section describes the NOR driver which is optimized for reduced RAM usage. It works by mapping blocks of logical sectors to physical sectors of the NOR flash device.

6.4.3.1 Theory of operation

Differentiating between logical sectors or blocks and physical sectors is essential to understand this section. A logical sector or block is the smallest readable and writable unit of any file system, and its usual size is 512 bytes. A physical sector is an array of bytes on the NOR flash device that are erased together (typically between 2 Kbytes - 128 Kbytes). The NOR flash driver is an abstraction layer between these two types of sectors.

The Block Map NOR driver maintains a table that maps ranges of logical sectors, called logical blocks, to physical sectors on the NOR flash device. The number of logical sectors in a logical block depends on how many logical sectors fit in a physical sector. Every time a logical sector is updated, its content is written to a special physical sector called a work block. A work block is a kind of temporary storage for the modified data of a logical sector that is later converted into a data block when a new empty work block needs to be allocated.

6.4.3.2 Configuring the driver

The Block Map NOR driver has to be configured at runtime and optionally at compile time. The following sections describe how this can be implemented in the application.

6.4.3.2.1 Compile time configuration

The Block Map NOR driver can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371 The following table lists the configuration defines supported by the Block Map NOR driver.

Define	Default value	Type	Description
FS_NOR_CAN_REWRITE	1	B	Specifies if modifying the same byte on the NOR flash device more than one time is permitted.
FS_NOR_CRC_HOOK_DEFAULT	&FS_NOR_CRC_SW	R	Specifies the default routines to be used for the CRC calculation.
FS_NOR_DATA_BUFFER_SIZE	32	N	Number of bytes to be reserved for the data buffers used for internal operations.
FS_NOR_ECC_HOOK_DATA_DEFAULT	&FS_NOR_ECC_SW_1bit_Data	R	Specifies the default routines to be used for the ECC calculation of the sector data.
FS_NOR_ECC_HOOK_MAN_DEFAULT	&FS_NOR_ECC_SW_1bit_Man	R	Specifies the default routines to be used for the ECC calculation of the management data.
FS_NOR_ENABLE_STATS	0 or 1	B	Enables or disables the support for statistical counters.
FS_NOR_LINE_SIZE	1	N	Configures the minimum number of bytes to write at once.
FS_NOR_LOG_SECTOR_RESERVE	4	N	Configures additional space to be reserved for the management data of a logical sector.

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Define	Default value	Type	Description
FS_NOR_MAX_ERASE_CNT	500000	N	Configures the maximum value of a valid erase count.
FS_NOR_MAX_ERASE_CNT_DIFF	5000	N	Configures the default maximum difference between erase counts.
FS_NOR_NUM_READ_RETRIES	10	N	Configures the number of retries in case of a read error.
FS_NOR_NUM_WRITE_RETRIES	10	N	Configures the number of retries in case of a write error.
FS_NOR_NUM_UNITS	4	N	Configures the maximum number of driver instances.
FS_NOR_OPTIMIZE_EMPTY_CHECK	0	B	Enables or disables the optimization for the checking of the physical sector empty status.
FS_NOR_OPTIMIZE_HEADER_WRITE	0	B	Enables or disables the optimization for the writing of management data.
FS_NOR_OPTIMIZE_DATA_WRITE	1	B	Enables or disables the optimization for the writing of logical sector data.
FS_NOR_PHY_SECTOR_RESERVE	8	N	Configures additional space to be reserved for the management data of a physical sector.
FS_NOR_READ_BUFFER_FILL_PATTERN	0xFF	N	Configures a bit pattern to be used for filling the contents of invalid logical sectors.
FS_NOR_SKIP_BLANK_SECTORS	1	B	Enables or disables the support for erasing blank physical sectors at low-level format.
FS_NOR_STRICT_FORMAT_CHECK	0	N	Enables or disables additional checks related to the low-level format.
FS_NOR_SUPPORT_CLEAN	1	B	Enables or disables the support for executing the garbage collection in the application.
FS_NOR_SUPPORT_CRC	0	B	Enables or disables the support for data integrity verification via CRC of payload and management data.
FS_NOR_SUPPORT_ECC	0	B	Enables or disables the support for data integrity verification via ECC of payload and management data.
FS_NOR_SUPPORT_FORMAT	1	B	Enables or disables the support for low-level formatting.
FS_NOR_SUPPORT_TRIM	1	B	Enables or disables the support for marking logical sectors as not being in use.
FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER	0	B	Enables or disables the support for configuring at runtime the byte order of management data.
FS_NOR_SUPPORT_VARIABLE_LINE_SIZE	0	B	Enables or disables the support for configuring at runtime the

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Define	Default value	Type	Description
			minimum number of bytes to be written at once.
FS_NOR_VERIFY_WRITE	0	B	Enables or disables the support for checking if the write operation was successful.
FS_NOR_VERIFY_ERASE	0	B	Enables or disables the support for checking if the erase operation was successful.

6.4.3.2.1.1 FS_NOR_CAN_REWRITE

For the majority of NOR flash devices the same byte can be modified more than once without an erase operation in between while preserving the bits set to 0. That is, a byte can be written up to eight times with each write operation setting a different bit in that byte to 0. The Block Map NOR driver makes use of this feature to make efficient use of the storage space and to improve the performance. FS_NOR_CAN_REWRITE has to be set to 0 for NOR flash devices that permit only one write operation to a byte or a range of bytes between two erase operations of that storage block.

6.4.3.2.1.2 FS_NOR_CRC_HOOK_DEFAULT

This define specifies the default routines for the CRC calculation. It can be set to NULL in order to save ROM space if the application registers its own routines via FS_NOR_BM_SetCRCHook()

6.4.3.2.1.3 FS_NOR_DATA_BUFFER_SIZE

This define can be used to specify the size of the buffers used by the Block Map NOR driver for internal operations such as copying the contents of a logical sector or verifying if a physical sector is blank. All these buffers are allocated on the stack; therefore, increasing the value of FS_NOR_DATA_BUFFER_SIZE increases the stack usage while providing better performance. FS_NOR_DATA_BUFFER_SIZE has to be a non-zero multiple of 4.
If the file system is built with FS_SUPPORT_EXT_MEM_MANAGER set to 0 then the Block Map NOR driver uses the available free memory as a buffer at the time the buffer is required, if the number of free bytes is larger than FS_NOR_DATA_BUFFER_SIZE. This means that it is possible to reduce the stack usage by setting FS_NOR_DATA_BUFFER_SIZE to a smaller value than the default and by increasing the size of the memory pool assigned to the file system via FS_AssignMemory() by the amount of memory required for the buffer.

6.4.3.2.1.4 FS_NOR_ECC_HOOK_DATA_DEFAULT

This define specifies the default routines for the ECC calculation of sector data. It can be set to NULL in order to save ROM space if the application registers its own routines via FS_NOR_BM_SetECCHook()

6.4.3.2.1.5 FS_NOR_ECC_HOOK_MAN_DEFAULT

This define specifies the default routines for the ECC calculation of the management data. It can be set to NULL in order to save ROM space if the application registers its own routines via FS_NOR_BM_SetECCHook()

6.4.3.2.1.6 FS_NOR_ENABLE_STATS

This define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the Block Map NOR driver that can be useful for debugging. The statistical counters can be queried via FS_NOR_BM_GetStatCounters(). By default FS_NOR_ENABLE_STATS is set to 1 if FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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6.4.3.2.1.7 FS_NOR_LINE_SIZE

FS_NOR_LINE_SIZE specifies the minimum number of bytes the Block Map NOR driver writes at once. The amount of data written is always a multiple of this value. In addition, FS_NOR_LINE_SIZE specifies the alignment of the written data. That is, the offset at which the Block Map NOR driver writes the data is always a multiple of this value. FS_NOR_LINE_SIZE has to be a power of two value.

6.4.3.2.1.8 FS_NOR_LOG_SECTOR_RESERVE

This define can be used to specify the number of additional bytes to be allocated for the management data of a logical sector. The NOR flash device has to be low-level formatted after FS_NOR_LOG_SECTOR_RESERVE is modified. FS_NOR_LOG_SECTOR_RESERVE exists for backward compatibility reasons with older emFile versions. Typically, the default value of FS_NOR_LOG_SECTOR_RESERVE does not have to be modified. FS_NOR_LOG_SECTOR_RESERVE must be a multiple of 4 bytes.

6.4.3.2.1.9 FS_NOR_MAX_ERASE_CNT

The Block Map NOR driver uses the value of FS_NOR_MAX_ERASE_CNT to check the validity of an erase count stored in the header of a physical sector. If the value of the erase count is larger than FS_NOR_MAX_ERASE_CNT, then the erase count is considered invalid and is set to the maximum value of all valid erase counts.

6.4.3.2.1.10 FS_NOR_MAX_ERASE_CNT_DIFF

The value of this define is used by the Block Map NOR driver during the wear leveling procedure to decide which physical sector has to be used for storage. FS_NOR_BM_SetMaxEraseCntDiff() can be used to modify this value at runtime. Refer to *Wear Leveling* on page 839 for more information about how this value is used.

6.4.3.2.1.11 FS_NOR_NUM_READ_RETRIES

FS_NOR_NUM_READ_RETRIES specifies the maximum number of times the Block Map NOR driver repeats a read operation in case of an error. A read retry is performed each time the read function of the NOR physical layer reports an error or if the CRC feature is activated when the CRC verification fails. NumReadRetries of FS_NOR_BM_STAT_COUNTERS is incremented by 1 on each retry.

6.4.3.2.1.12 FS_NOR_NUM_WRITE_RETRIES

FS_NOR_NUM_WRITE_RETRIES specifies the maximum number of times the Block Map NOR driver repeats a write operation in case of an error. A write retry is performed each time the write function of the NOR physical layer reports an error.

6.4.3.2.1.13 FS_NOR_NUM_UNITS

This define specifies the maximum number of driver instances of the Block Map NOR driver the application is allowed to create. Four bytes of static RAM are reserved for each instance. If the maximum number of driver instances is smaller than the default, then FS_NOR_NUM_UNITS can be set to that value in order to reduce the RAM usage.

6.4.3.2.1.14 FS_NOR_OPTIMIZE_EMPTY_CHECK

This configuration define can be used to enable an optimization that reduces the number of read operations performed by the Block Map NOR driver when it checks if a physical sector can be used to write data to it without being erased first. Setting FS_NOR_OPTIMIZE_EMPTY_CHECK to 1 has an effect only if either FS_NOR_SUPPORT_CLEAN or FS_NOR_SKIP_BLANK_SECTORS are set to 1 and the support for fail-safe erase operation is disabled.

6.4.3.2.1.15 FS_NOR_OPTIMIZE_HEADER_WRITE

FS_NOR_OPTIMIZE_HEADER_WRITE can be used to specify how the management data is written to storage. The management data is stored at the beginning of each physical and logical

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sector in an area called header. By default, the size of the physical sector header is 16 bytes and of the logical sector header is 8 bytes. The size of these headers is larger for NOR flash devices that specify a minimum number of bytes that have to be written at once and that are not able to perform incremental write operations. The default behavior of the Block Map NOR driver, that is when FS_NOR_OPTIMIZE_HEADER_WRITE is set to 0, is to write the entire header every time some of the information stored in it changes. With FS_NOR_OPTIMIZE_HEADER_WRITE set to 1 the Block Map NOR driver tracks the changes made to a header and writes only the information that actually changed. Reducing the amount of data written to storage can help increase the write performance.
The internal flash memory of some MCUs does not allow a second write operation to the same byte with identical data without an erase operation in between. If this type of flash memory is used as storage then it is mandatory to set FS_NOR_OPTIMIZE_HEADER_WRITE to 1.

6.4.3.2.1.16 FS_NOR_OPTIMIZE_DATA_WRITE

This configuration define can be used to enable an optimization that can help increase the performance of the write operation. With FS_NOR_OPTIMIZE_DATA_WRITE set to 1 the Block Map NOR driver tries to write the sector data directly to a data block instead of writing it first to a work block. In this way the total number of write operations is reduced, which as a side effect helps extend the lifetime of a NOR flash device. Enabling this optimization increases the RAM and ROM usage of the Block Map NOR driver.

6.4.3.2.1.17 FS_NOR_PHY_SECTOR_RESERVE

This define can be used to specify the number of additional bytes to be allocated for the management data of a physical sector. The NOR flash device has to be low-level formatted after FS_NOR_PHY_SECTOR_RESERVE is modified. FS_NOR_PHY_SECTOR_RESERVE exists for backward compatibility reasons with older emFile versions. Typically, the default value of FS_NOR_PHY_SECTOR_RESERVE does not have to be modified. FS_NOR_PHY_SECTOR_RESERVE must be a multiple of 4 bytes.

6.4.3.2.1.18 FS_NOR_READ_BUFFER_FILL_PATTERN

The value of FS_NOR_READ_BUFFER_FILL_PATTERN is used by the Block Map NOR driver to fill the contents of invalid logical sectors that is, logical sectors that were not written yet. The contents of all logical sectors are invalid after a low-level format operation. In addition, the contents of a logical sector can be invalidated via FS_STORAGE_FreeSectors().

6.4.3.2.1.19 FS_NOR_SKIP_BLANK_SECTORS

FS_NOR_SKIP_BLANK_SECTORS can be used to enable the support for the optimization that omits the erase of physical sectors that are already blank. This feature has to be explicitly enabled at runtime by calling FS_NOR_BM_SetBlankSectorSkip().

6.4.3.2.1.20 FS_NOR_STRICT_FORMAT_CHECK

FS_NOR_STRICT_FORMAT_CHECK can be used to enable additional checks related to the low-level formatting of the NOR flash device. If FS_NOR_STRICT_FORMAT_CHECK is set to 1 then the Block Map NOR driver checks at low-level mount if the number of logical blocks stored during the last low-level format operation matches the actual number of logical blocks available for storage. The low-level mount operation fails if the number of logical blocks is not equal, which for example triggers a low-level format operation if the application calls FS_FormatLLIfRequired()
This can be useful in a situation where an already low-level formatted NOR partition is enlarged. With FS_NOR_STRICT_FORMAT_CHECK set to 0 the low-level mount operation succeeds and the Block Map NOR driver will not use the additional space as storage. A low-level mount operation fails when an already formatted NOR partition is shrunk irrespective of the value of FS_NOR_STRICT_FORMAT_CHECK.

6.4.3.2.1.21 FS_NOR_SUPPORT_CLEAN

This define specifies if the application is allowed to perform a garbage collection operation. If FS_NOR_SUPPORT_CLEAN is set to 1 then the application can perform a garbage collection

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operation via FS_STORAGE_Clean() and FS_STORAGE_CleanOne(). For more information about the garbage collection refer to *Garbage collection* on page 838. The automatic garbage collection operation performed by the Block Map NOR driver is not disabled when FS_NOR_SUPPORT_CLEAN is set to 0. If the application does not call either FS_STORAGE_Clean() or FS_STORAGE_CleanOne() then FS_NOR_SUPPORT_CLEAN can be safely set to 0 in order to save ROM space.

6.4.3.2.1.22 FS_NOR_SUPPORT_CRC

FS_NOR_SUPPORT_CRC can be used to enable the support for the CRC verification. This feature has to be enabled at runtime via FS_NOR_BM_EnableCRC(). For more information about the CRC feature refer to *CRC verification* on page 839

6.4.3.2.1.23 FS_NOR_SUPPORT_ECC

FS_NOR_SUPPORT_ECC can be used to enable the support for the ECC verification. This feature has to be enabled at runtime via FS_NOR_BM_EnableECC(). For more information about the ECC feature refer to *Bit error correction* on page 840

6.4.3.2.1.24 FS_NOR_SUPPORT_FORMAT

FS_NOR_SUPPORT_FORMAT can be used to disable the support for the low-level format operation. The ability of the Block Map NOR driver to perform a low-level format operation is not required if the NOR flash device is already formatted, for example, by storing a file system image to it via an external utility. In such a case, FS_NOR_SUPPORT_FORMAT can be set to 0 to reduce the ROM usage.

6.4.3.2.1.25 FS_NOR_SUPPORT_TRIM

FS_NOR_SUPPORT_TRIM can be used to enable or disable the handling of file system operations that inform the Block Map NOR driver about logical sectors that are no longer in use. The Block Map NOR driver can use this information to optimize the internal operation that copies the data from one physical sector to another by not copying the contents of the logical sectors that are marked as being no longer in use. Enabling this feature increases the ROM usage of the Block Map NOR driver.

6.4.3.2.1.26 FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER

This define can be used to specify if the byte order of the management data can be configured at runtime or not. By default, multi-byte management data is stored in the native order of the MCU on which the target application is running. With FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER set to 1 the byte order can be configured at runtime via FS_NOR_BM_SetByteOrderLE() and FS_NOR_BM_SetByteOrderBE().
FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER is set to 1 when building the NOR Image Creator utility in order to give it the ability to create images for an MCU with a different byte ordering than that of the host PC. Typically, there is no need to modify the default value of FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER when building a target application.

6.4.3.2.1.27 FS_NOR_SUPPORT_VARIABLE_LINE_SIZE

FS_NOR_SUPPORT_VARIABLE_LINE_SIZE can be used to enable the runtime configuration of the minimum number of bytes to be written by the Block Map NOR driver at once. With FS_NOR_SUPPORT_VARIABLE_LINE_SIZE set to 1 the minimum number of bytes to be written at once can be configured via FS_NOR_BM_SetDeviceLineSize() between 1 and FS_NOR_LINE_SIZE. In addition, the ability of the NOR flash device to perform incremental write operations can be configured via FS_NOR_BM_SetDeviceRewriteSupport().
FS_NOR_SUPPORT_VARIABLE_LINE_SIZE is set to 1 when building the NOR Image Creator utility in order to give it the ability to create images for NOR flash devices with different characteristics. Typically, there is no need to modify the default value of FS_NOR_SUPPORT_VARIABLE_LINE_SIZE when building a target application.

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6.4.3.2.1.28 FS_NOR_VERIFY_WRITE

This define can be used to activate the write verification of the Block Map NOR driver. The write verification is performed after each write operation by reading back the modified data from storage and by comparing it with the data requested to be written. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NOR_BM_SetWriteVerification()`.

> **Note**
>
> Activating the write verification can negatively affect the write performance.

6.4.3.2.1.29 FS_NOR_VERIFY_ERASE

This define can be used to activate the erase verification of the Block Map NOR driver. The erase verification is performed after each erase operation by reading back the entire data of the erased physical sector from storage and by comparing it with `0xFF`. An error is reported if a difference is detected. This feature has to be enabled at runtime by calling `FS_NOR_BM_SetEraseVerification()`.

> **Note**
>
> Activating the erase verification can negatively affect the write performance.

6.4.3.2.2 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of `FS_NOR_BM_Driver`. This function call together with other function calls that configure the driver operation have to be added to `FS_X_AddDevices()` as demonstrated in the following example. This example shows how to configure the file system to access a NOR flash device connected via SPI.

```
#include "FS.h"

#define ALLOC_SIZE 0x4000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the NOR flash driver. The first 65536 bytes of the
  // serial NOR flash device are not used by the file system as data storage
  // and can be used by the application for other purposes. The file system
  // uses a total of 1 Mbyte from the serial NOR flash device as storage.
  //
  FS_AddDevice(&FS_NOR_BM_Driver);
  FS_NOR_BM_SetPhyType(0, &FS_NOR_PHY_ST_M25);
  FS_NOR_BM_Configure(0, 0x00000000, 0x00010000, 0x00100000);
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the Block Map NOR driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

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Function	Description
FS_NOR_BM_Configure()	Configures an instance of the Block Map NOR driver.
FS_NOR_BM_DisableCRC()	Disables the data integrity check.
FS_NOR_BM_DisableECC()	Disables the bit error correction via ECC.
FS_NOR_BM_EnableCRC()	Enables the data integrity check.
FS_NOR_BM_EnableECC()	Enables the bit error correction via ECC.
FS_NOR_BM_SetBlankSectorSkip()	Configures if the physical sectors which are already blank should be erased during the low-level format operation.
FS_NOR_BM_SetByteOrderBE()	Sets the byte order of multi byte management data to big-endian (default).
FS_NOR_BM_SetByteOrderLE()	Sets the byte order of multi-byte management data to little-endian format.
FS_NOR_BM_SetCRCHook()	Configures the calculation routines for CRC verification.
FS_NOR_BM_SetECCHook()	Configures the functions to be used for performing the bit error correction via ECC.
FS_NOR_BM_SetDeviceLineSize()	Configures the minimum number of bytes that can be written to NOR flash.
FS_NOR_BM_SetDeviceRewriteSupport()	Specifies if the NOR flash device can rewrite the same data if 0s are preserved.
FS_NOR_BM_SetEraseVerification()	Enables or disables the checking of the sector erase operation.
FS_NOR_BM_SetFailSafeErase()	Configures the fail-safe mode of the sector erase operation.
FS_NOR_BM_SetInvalidSectorError()	Configures if an error is reported when an invalid sector is read.
FS_NOR_BM_SetMaxEraseCntDiff()	Configure the threshold for the active wear leveling operation.
FS_NOR_BM_SetNumWorkBlocks()	Configures the number of work blocks.
FS_NOR_BM_SetOnFatalErrorCallback()	Registers a function to be called by the driver when a fatal error occurs.
FS_NOR_BM_SetPhyType()	Configures the type of NOR physical layer.
FS_NOR_BM_SetSectorSize()	Configures the number of bytes in a logical sector.
FS_NOR_BM_SetUsedSectorsErase()	Configures if the physical sectors have to be erased at low-level format.
FS_NOR_BM_SetWriteVerification()	Enables or disables the checking of the page write operation.

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6.4.3.2.2.1 FS_NOR_BM_Configure()

Description

Configures an instance of the Block Map NOR driver

Prototype

```
void FS_NOR_BM_Configure(U8  Unit,
                         U32 BaseAddr,
                         U32 StartAddr,
                         U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
BaseAddr	Address of the first byte in NOR flash.
StartAddr	Address of the first byte the NOR driver is permitted to use as storage.
NumBytes	Number of bytes starting from StartAddr available to be used by the NOR driver as storage.

Additional information

This function is mandatory and it has to be called once in FS_X_AddDevices() for each instance of the Block Map NOR driver created by the application. Different instances of the NOR driver are identified by the Unit parameter.

BaseAddr is used only for NOR flash devices that are memory mapped. For serial NOR flash devices that are not memory mapped BaseAddr has to be set to 0.

StartAddr has to be greater than or equal to BaseAddr and smaller than the total number of bytes in the NOR flash device. The Block Map NOR driver rounds up StartAddr to the start address of the next physical sector in the NOR flash device.

NumBytes is rounded up to a physical sector boundary if the memory range defined by StartAddr and NumBytes is smaller than the capacity of the NOR flash device. If the memory range defined by StartAddr and NumBytes is larger than the capacity of the NOR flash device than NumBytes is rounded down so that the memory range fits into the NOR flash device.

The Block Map NOR driver can work only with physical sectors of the same size. The longest continuous range of physical sectors with the same size is chosen that fits in the range defined by StartAddr and NumBytes parameters.

Example

```
#include "FS.h"
#include "FS_NOR_HW_SPIFI_Template.h"

#define ALLOC_SIZE 0x4000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give file system memory to work with.
  //
```

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```
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Configure the size of the logical sector and activate the file buffering.
  //
  FS_SetMaxSectorSize(512);
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
  //
  // Add and configure the NOR driver.
  //
  FS_AddDevice(&FS_NOR_BM_Driver);
  FS_NOR_BM_SetPhyType(0, &FS_NOR_PHY_SPIFI);
  FS_NOR_BM_Configure(0, 0x80000000, 0x80000000, 0x01000000);
  FS_NOR_BM_SetSectorSize(0, 512);
  //
  // Configure the NOR physical layer.
  //
  FS_NOR_SPIFI_Allow2bitMode(0, 1);
  FS_NOR_SPIFI_Allow4bitMode(0, 1);
  FS_NOR_SPIFI_SetHWType(0, &FS_NOR_HW_SPIFI_Template);
}
```

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6.4.3.2.2.2 FS_NOR_BM_DisableCRC()

Description

Disables the data integrity check.

Prototype

```
int FS_NOR_BM_DisableCRC(void);
```

Return value

= 0	Data integrity check deactivated.
≠ 0	An error occurred.

Additional information

The support for data integrity check is not available by default and it has to be included at compile time via the `FS_NOR_SUPPORT_CRC` define. This function disables the data integrity check for all instances of the NOR driver.

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6.4.3.2.2.3 FS_NOR_BM_DisableECC()

Description

Disables the bit error correction via ECC.

Prototype

```
int FS_NOR_BM_DisableECC(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 OK, ECC feature disabled.
≠ 0 An error occurred.

Additional information

This function is available only the file system sources are compiled with FS_NOR_SUPPORT_ECC set to 1.

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6.4.3.2.2.4 FS_NOR_BM_EnableCRC()

Description

Enables the data integrity check.

Prototype

```
int FS_NOR_BM_EnableCRC(void);
```

Return value

= 0	Data integrity check activated.
≠ 0	An error occurred.

Additional information

The support for data integrity check is not available by default and it has to be included at compile time via the `FS_NOR_SUPPORT_CRC` define. This function enables the data integrity check for all instances of the NOR driver.

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6.4.3.2.2.5 FS_NOR_BM_EnableECC()

Description

Enables the bit error correction via ECC.

Prototype

```
int FS_NOR_BM_EnableECC(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 OK, ECC feature enabled.
≠ 0 An error occurred.

Additional information

This function is available only the file system sources are compiled with FS_NOR_SUPPORT_ECC set to 1.

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6.4.3.2.2.6 FS_NOR_BM_SetBlankSectorSkip()

Description

Configures if the physical sectors which are already blank should be erased during the low-level format operation.

Prototype

```
void FS_NOR_BM_SetBlankSectorSkip(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 All the physical sectors are erased. • ≠0 Physical sectors are not erased if they are blank (default).

Additional information

This function is optional. The blank checking feature is disabled by default and has to be explicitly enabled at compile time by setting FS_NOR_SKIP_BLANK_SECTORS to 1. The feature can then be enabled or disabled at runtime using FS_NOR_BM_SetBlankSectorSkip().

Activating this feature can improve the speed of the low-level format operation when most of the physical sectors of the NOR flash device are already blank which is typically the case with NOR flash devices that ship from factory.

It is not recommended to enable this feature when performing a low-level format of a NOR flash device that was already used for data storage because the blank check operation is not able to determine if a physical sector was completely erased only by checking that all the bits are set to 1. An erase operation that is interrupted by an unexpected reset may leave the storage cells in an instable state even when the values of all storage cells in a physical sector read back as 1.

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6.4.3.2.2.7 FS_NOR_BM_SetByteOrderBE()

Description

Sets the byte order of multi byte management data to big-endian (default).

Prototype

```
int FS_NOR_BM_SetByteOrderBE(void);
```

Return value

= 0	Multi-byte management data is stored in big-endian format.
≠ 0	An error occurred.

Additional information

This function is optional. Multi-byte management data is stored in the byte order of the CPU. Typically, `FS_NOR_BM_SetByteOrderBE()` is used by the NOR Image Creator utility to create NOR images with a byte order of the target CPU when the byte order of the host CPU is different. The byte order can be set to little-endian using `FS_NOR_BM_SetByteOrderLE()`. By default the byte order is set to little-endian.

The support for configurable byte order is disabled by default and has to be enabled by compiling the Block Map NOR driver with the `FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER` configuration define set to 1 otherwise `FS_NOR_BM_SetByteOrderBE()` does nothing.

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6.4.3.2.2.8 FS_NOR_BM_SetByteOrderLE()

Description

Sets the byte order of multi-byte management data to little-endian format.

Prototype

```
int FS_NOR_BM_SetByteOrderLE(void);
```

Return value

= 0	Multi-byte management data is stored in little-endian format.
≠ 0	An error occurred.

Additional information

This function is optional. Multi-byte management data is stored in the byte order of the CPU. Typically, `FS_NOR_BM_SetByteOrderLE()` is used by the NOR Image Creator utility to create NOR images with a byte order of the target CPU when the byte order of the host CPU is different. The byte order can be set to big-endian using `FS_NOR_BM_SetByteOrderBE()`. By default the byte order is set to little-endian.

The support for configurable byte order is disabled by default and has to be enabled by compiling the Block Map NOR driver with the `FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER` configuration define set to 1 otherwise `FS_NOR_BM_SetByteOrderLE()` does nothing.

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6.4.3.2.2.9 FS_NOR_BM_SetCRCHook()

Description

Configures the calculation routines for CRC verification.

Prototype

```
int FS_NOR_BM_SetCRCHook(const FS_NOR_CRC_HOOK * pCRCHook);
```

Parameters

Parameter	Description
pCRCHook	CRC calculation routines.

Return value

= 0 OK, CRC calculation routines set.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The driver uses by default the internal software routines of the file system for the CRC calculation. `FS_NOR_BM_SetCRCHook()` can be used by the application to specify different CRC calculation functions. This function is available only when the `FS_NOR_SUPPORT_CRC` configuration define is set to 1. In order to save ROM space, the internal CRC software routines can be disabled a runtime by setting the `FS_NOR_CRC_HOOK_DEFAULT` configuration define to NULL.

Example

```
#include "FS.h"
#include "FS_NOR_HW_SPI_Template.h"

#define ALLOC_SIZE 0x4000               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

#if FS_NOR_SUPPORT_CRC

/*********************************************************************
*
*       _CalcCRC8
*
*  Function description
*    Calculates an 8-bit CRC using a bit-by-bit algorithm.
*/
static U8 _CalcCRC8(const U8 * pData, unsigned NumBytes, U8 crc) {
  FS_USE_PARA(pData);
  FS_USE_PARA(NumBytes);
  FS_USE_PARA(crc);
  return 0;     // TBD: Calculate the CRC.
}

/*********************************************************************
*
*       _CalcCRC16
*
*  Function description
*    Calculates an 16-bit CRC using a bit-by-bit algorithm.
*/
static U16 _CalcCRC16(const U8 * pData, unsigned NumBytes, U16 crc) {
  FS_USE_PARA(pData);
  FS_USE_PARA(NumBytes);
  FS_USE_PARA(crc);
  return 0;     // TBD: Calculate the CRC.
}
```

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```
/*********************************************************************
*
*       _CRCHook
*/
static const FS_NOR_CRC_HOOK _CRCHook = {
  _CalcCRC8,
  _CalcCRC16
};

#endif // FS_NOR_SUPPORT_CRC

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Configure the size of the logical sector and activate the file buffering.
  //
  FS_SetMaxSectorSize(512);
#if FS_SUPPORT_FILE_BUFFER
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif
  //
  // Add and configure the Block Map NOR driver.
  //
  FS_AddDevice(&FS_NOR_BM_Driver);
  FS_NOR_BM_SetPhyType(0, &FS_NOR_PHY_SFDP);
  FS_NOR_BM_Configure(0, 0, 0, 0x01000000);
  FS_NOR_BM_SetSectorSize(0, 512);
#if FS_NOR_SUPPORT_CRC
  FS_NOR_BM_EnableCRC();
  FS_NOR_BM_SetCRCHook(&_CRCHook);
#endif
  //
  // Configure the NOR physical layer.
  //
  FS_NOR_SFDP_SetHWType(0, &FS_NOR_HW_SPI_Template);
}
```

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6.4.3.2.2.10 FS_NOR_BM_SetECCHook()

Description

Configures the functions to be used for performing the bit error correction via ECC.

Prototype

```
int FS_NOR_BM_SetECCHook(      U8                Unit,
                         const FS_NOR_ECC_HOOK * pECCHookMan,
                         const FS_NOR_ECC_HOOK * pECCHookData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pECCHookMan	Functions for the bit error correction of the management data.
pECCHookData	Functions for the bit error correction of the sector data.

Return value

= 0 OK, ECC functions registered.
≠ 0 An error occurred.

Additional information

This function is optional. The driver uses by default the internal software routines of the file system for the parity check calculation. FS_NOR_BM_SetECCHook() can be used by the application to specify different parity check calculation functions. This function is available only when the FS_NOR_SUPPORT_ECC configuration define is set to 1. In order to save ROM space, the internal CRC software routines can be disabled a runtime by setting the FS_NOR_ECC_HOOK_MAN_DEFAULT and FS_NOR_ECC_HOOK_DATA_DEFAULT configuration define to NULL.

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6.4.3.2.2.11 FS_NOR_BM_SetDeviceLineSize()

Description

Configures the minimum number of bytes that can be written to NOR flash.

Prototype

```
int FS_NOR_BM_SetDeviceLineSize(U8 Unit,
                                U8 ldBytesPerLine);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
ldBytesPerLine	Line size in bytes as power of 2 exponent.

Return value

= 0 OK, line size changed.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. Typically, the NOR flash have lines smaller than 4 bytes which is the fixed default value configured at compile time. The FS_NOR_SUPPORT_VARIABLE_LINE_SIZE configuration define has to be set to a value different than 0 in order to enable this function.

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6.4.3.2.2.12 FS_NOR_BM_SetDeviceRewriteSupport()

Description

Specifies if the NOR flash device can rewrite the same data if 0s are preserved.

Prototype

```
int FS_NOR_BM_SetDeviceRewriteSupport(U8 Unit,
                                      U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Enables / disables the support for rewrite. • =0 Rewrite support is disabled. • ≠0 Rewrite support is enabled.

Return value

= 0 OK, support for rewrite changed.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. Typically, the NOR flash devices are able to rewrite the same data and by default this feature is disabled at compile time. The FS_NOR_SUPPORT_VARIABLE_LINE_SIZE configuration define has to be set to a value different than 0 in order to enable this function, otherwise the function does nothing.

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6.4.3.2.2.13 FS_NOR_BM_SetEraseVerification()

Description

Enables or disables the checking of the sector erase operation.

Prototype

```
void FS_NOR_BM_SetEraseVerification(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The erase operation is not checked. • ≠0 The erase operation is checked.

Additional information

This function is optional. The result of a sector erase operation is normally checked by evaluating the error bits maintained by the NOR flash device in an internal status register. `FS_NOR_BM_SetEraseVerification()` can be used to enable additional verification of the sector erase operation that is realized by reading back the contents of the entire erased physical sector and by checking that all the bytes in it are set to `0xFF`. Enabling this feature can negatively impact the write performance of Block Map NOR driver.

The sector erase verification feature is active only when the Block Map NOR driver is compiled with the `FS_NOR_VERIFY_ERASE` configuration define is set to 1 (default is 0) or when the `FS_DEBUG_LEVEL` configuration define is set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL`.

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6.4.3.2.2.14 FS_NOR_BM_SetFailSafeErase()

Description

Configures the fail-safe mode of the sector erase operation.

Prototype

```
int FS_NOR_BM_SetFailSafeErase(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 Sector erase operation is not fail-safe. • ≠0 Sector erase operation is fail-safe.

Return value

= 0 OK, fail	safe mode configured.
≠ 0	Error code indicating the failure reason.

Additional information

This function is optional. It can be used by the application to enable or disable the fail-safe sector erase feature of the Block Map NOR driver. The fail-safe sector erase feature helps the driver identify a sector erase operation that did not completed successfully due to an unexpected power failure. The Block Map NOR driver enables the fail-safe sector erase feature by default except when the NOR flash device does not support modifying the same data more than once (rewrite) or when the application activates the data integrity check feature via CRC. This is done for backward compatibility reasons. The application has to use `FS_NOR_BM_SetFailSafeErase()` to explicitly enable the fail-safe sector erase feature for configurations that require a fail-safe operation.

In addition, enabling the fail-safe sector erase feature has the potential of improving the performance of the clean operation executed via `FS_STORAGE_Clean()` and `FS_STORAGE_CleanOne()`.

The value configured via `FS_NOR_BM_SetFailSafeErase()` is evaluated only during the low-level format operation. That is, after changing the activation status of the fail-safe sector erase feature a low-level format operation has to be performed via `FS_FormatLow()` in order for the new configuration to be applied.

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6.4.3.2.2.15 FS_NOR_BM_SetInvalidSectorError()

Description

Configures if an error is reported when an invalid sector is read.

Prototype

```
void FS_NOR_BM_SetInvalidSectorError(U8 Unit,
                                     U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 No error is reported. • ≠0 An error is reported.

Additional information

This function is optional. An invalid sector is a logical sector that does not store any data. All logical sectors are invalid after a low-level format operation. A logical sector becomes valid as soon as the file system writes some data to it. The file system does not read invalid sectors with the exception of a high-level format operation.

By default the Block Map NOR driver does not report any error when the file system reads an invalid sector. The contents of an invalid sector is filled with the byte pattern specified via FS_NOR_READ_BUFFER_FILL_PATTERN.

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6.4.3.2.2.16 FS_NOR_BM_SetMaxEraseCntDiff()

Description

Configure the threshold for the active wear leveling operation.

Prototype

```
void FS_NOR_BM_SetMaxEraseCntDiff(U8  Unit,
                                  U32 EraseCntDiff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
EraseCntDiff	Difference between the erase counts.

Additional information

This function is optional. The application can use FS_NOR_BM_SetMaxEraseCntDiff() to modify the value of the threshold that is used to decide if a data block has to be relocated to make sure that is equally erased. The Block Map NOR driver compares the difference between the erase counts of two blocks with the configured value. If the calculated difference is larger than EraseCntDiff then the block with the smaller erase count is copied to the block with the larger erase count then the block with the smaller erase count is used to store new data to it.

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6.4.3.2.2.17 FS_NOR_BM_SetNumWorkBlocks()

Description

Configures the number of work blocks.

Prototype

```
void FS_NOR_BM_SetNumWorkBlocks(U8       Unit,
                                unsigned NumWorkBlocks);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
NumWorkBlocks	Number of work blocks to configure.

Additional information

This function is optional. Work blocks are physical sectors that are used by the Block Map NOR driver to temporarily store the data written to NOR flash device by the file system layer. An application can use this function to modify the number of work blocks used by the Block Map NOR driver according to its requirements. By default, the Block Map NOR driver allocates 1% from the total number of physical sectors configured for storage but no more than 10 work blocks. The minimum number of work blocks allocated by default depends on whether journaling is activated or not in the application. If the journal is active the 4 work blocks are allocated otherwise 3.

The write performance of the Block Map NOR driver can be improved by increasing the number work blocks which at the same time increases the RAM usage.

The NOR flash device has to be reformatted in order for the new number of work blocks to take effect.

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6.4.3.2.2.18 FS_NOR_BM_SetOnFatalErrorCallback()

Description

Registers a function to be called by the driver when a fatal error occurs.

Prototype

```
void FS_NOR_BM_SetOnFatalErrorCallback
                                (FS_NOR_ON_FATAL_ERROR_CALLBACK * pfOnFatalError);
```

Parameters

Parameter	Description
pfOnFatalError	Address to the callback function.

Additional information

Typically, the NOR driver reports a fatal error when data integrity check (CRC) fails.

All instances of the NOR driver share the same callback function. The Unit member of the FS_NOR_FATAL_ERROR_INFO structure passed as parameter to the pfOnFatalError callback function indicates what driver instance triggered the fatal error.

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6.4.3.2.2.19 FS_NOR_BM_SetPhyType()

Description

Configures the type of NOR physical layer.

Prototype

```
void FS_NOR_BM_SetPhyType(      U8                Unit,
                          const FS_NOR_PHY_TYPE * pPhyType);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
pPhyType	in NOR physical layer.

Additional information

This function is mandatory and it has to be called once in FS_X_AddDevices() for each instance of the Block Map NOR driver created by the application. Different instances of the Block Map NOR driver are identified by the Unit parameter.

Permitted values for the pPhyType parameter are:

Identifier
FS_NOR_PHY_CFI_1x16
FS_NOR_PHY_CFI_2x16
FS_NOR_PHY_DSPI
FS_NOR_PHY_SFDP
FS_NOR_PHY_SPIFI
FS_NOR_PHY_ST_M25

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6.4.3.2.2.20 FS_NOR_BM_SetSectorSize()

Description

Configures the number of bytes in a logical sector.

Prototype

```
void FS_NOR_BM_SetSectorSize(U8       Unit,
                             unsigned SectorSize);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
SectorSize	Number of bytes in a logical sector.

Additional information

This function is optional. It can be used to modify the size of the logical sector used by the Block Map NOR driver. By default the Block Map NOR driver uses the logical sector size configured a file system level that is set to 512 bytes at the file system initialization and can be later changed via FS_SetMaxSectorSize(). The NOR flash device has to be reformatted in order for the new logical sector size to take effect.

SectorSize has to be a power of 2 value.

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6.4.3.2.2.21 FS_NOR_BM_SetUsedSectorsErase()

Description

Configures if the physical sectors have to be erased at low-level format.

Prototype

```
void FS_NOR_BM_SetUsedSectorsErase(U8 Unit,
                                   U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 Physical sectors are invalidated (default). • ≠0 Physical sectors are erased.

Additional information

This function is optional. The default behavior of the Block Map NOR driver is to invalidate the physical sectors at low-level format which makes the format operation faster.

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6.4.3.2.2.22 FS_NOR_BM_SetWriteVerification()

Description

Enables or disables the checking of the page write operation.

Prototype

```
void FS_NOR_BM_SetWriteVerification(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
OnOff	Specifies if the feature has to be enabled or disabled • =0 The write operation is not checked. • ≠0 The write operation is checked.

Additional information

This function is optional. The result of a page write operation is normally checked by evaluating the error bits maintained by the NOR flash device in an internal status register. FS_NOR_BM_SetWriteVerification() can be used to enable additional verification of the page write operation. This is done by reading back the contents of the written page and by checking that all the bytes are matching the data requested to be written. Enabling this feature can negatively impact the write performance of Block Map NOR driver.

The page write verification feature is active only when the Block Map NOR driver is compiled with the FS_NOR_VERIFY_WRITE configuration define is set to 1 (default is 0) or when the FS_DEBUG_LEVEL configuration define is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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6.4.3.2.2.23 FS_NOR_CRC_HOOK

Description

Callback functions for the CRC calculation.

Type definition

```
typedef struct {
  FS_NOR_CRC_HOOK_CALC_CRC8  * pfCalcCRC8;
  FS_NOR_CRC_HOOK_CALC_CRC16 * pfCalcCRC16;
} FS_NOR_CRC_HOOK;
```

Structure members

Member	Description
pfCalcCRC8	Calculates an 8-bit CRC.
pfCalcCRC16	Calculates a 16-bit CRC.

Additional information

By default the Block Map NOR driver uses internal functions of the file system for the CRC calculation. This structure can be used to configure external CRC calculation callback functions that for example use hardware CRC calculation units for increased performance. The application can register the calculation callback functions via `FS_NOR_BM_SetCRCHook()`

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6.4.3.2.2.24 FS_NOR_CRC_HOOK_CALC_CRC8

Description

The type of the callback function invoked by the NOR driver to calculate an 8-bit CRC.

Type definition

```
typedef U8 FS_NOR_CRC_HOOK_CALC_CRC8(const U8     * pData,
                                     unsigned NumBytes,
                                     U8       crc);
```

Parameters

Parameter	Description
pData	in Data to be protected by CRC.
NumBytes	Number of bytes to be protected by CRC.
crc	Initial CRC value.

Return value

Calculated 8-bit CRC.

Additional information

This function calculates the CRC of the NumBytes of data pointed to by pData. The type of polynomial is not relevant.

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6.4.3.2.2.25 FS_NOR_CRC_HOOK_CALC_CRC16

Description

The type of the callback function invoked by the NOR driver to calculate a 16-bit CRC.

Type definition

```
typedef U16 FS_NOR_CRC_HOOK_CALC_CRC16(const U8     * pData,
                                       unsigned NumBytes,
                                       U16      crc);
```

Parameters

Parameter	Description
pData	in Data to be protected by CRC.
NumBytes	Number of bytes to be protected by CRC.
crc	Initial CRC value.

Return value

Calculated 16-bit CRC.

Additional information

This function calculates the CRC of the NumBytes of data pointed to by pData. The type of polynomial is not relevant. NumBytes is always an even number. pData is always aligned to a 16-bit boundary.

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6.4.3.2.2.26 FS_NOR_ECC_HOOK

Description

Callback functions for the ECC calculation.

Type definition

```
typedef struct {
  FS_NOR_ECC_HOOK_CALC  * pfCalc;
  FS_NOR_ECC_HOOK_APPLY * pfApply;
  U8                      NumBitsCorrectable;
  U8                      ldBytesPerBlock;
} FS_NOR_ECC_HOOK;
```

Structure members

Member	Description
pfCalc	Calculates the ECC of the specified data.
pfApply	Verifies and corrects bit errors using ECC.
NumBitsCorrectable	Number of bits the ECC algorithm is able to correct in the data block and 4 bytes of spare area.
ldBytesPerBlock	Number of bytes in the data block given as power of 2 value.

Additional information

By default the Block Map NOR driver uses internal functions of the file system for the ECC calculation. This structure can be used to configure external ECC calculation callback functions that for example use hardware ECC calculation units for increased performance. The application can register the calculation callback functions via FS_NOR_BM_SetECCHook()

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6.4.3.2.2.27 FS_NOR_ECC_HOOK_CALC

Description

Callback function that calculates the ECC of a data block.

Type definition

```
typedef void FS_NOR_ECC_HOOK_CALC(const U32 * pData,
                                  U8  * pECC);
```

Parameters

Parameter	Description
pData	in Data to be protected by ECC.
pECC	out Calculated parity check.

Additional information

The number of bytes in pData is specified by FS_NOR_ECC_HOOK::ldBytesPerBlock

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6.4.3.2.2.28 FS_NOR_ECC_HOOK_APPLY

Description

Callback function that corrects bit errors in a data block using ECC.

Type definition

```
typedef int FS_NOR_ECC_HOOK_APPLY(U32 * pData,
                                  U8  * pECC);
```

Parameters

Parameter	Description
pData	in Data to be checked for bit errors using ECC. out Data without bit errors.
pECC	in Parity check read from storage. out Parity check without bit errors.

Return value

≥ 0 OK, number of bit errors corrected.
< 0 Error, an uncorrectable bit error occurred.

Additional information

The number of bytes in pData is specified by FS_NOR_ECC_HOOK::ldBytesPerBlock

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6.4.3.2.2.29 FS_NOR_FATAL_ERROR_INFO

Description

Information passed to callback function when a fatal error occurs.

Type definition

```
typedef struct {
  U8   Unit;
  U8   ErrorType;
  U32  ErrorPSI;
} FS_NOR_FATAL_ERROR_INFO;
```

Structure members

Member	Description
Unit	Index of the driver that triggered the fatal error.
ErrorType	Type of the error that occurred.
ErrorPSI	Index of the physical sector in which the error occurred.

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6.4.3.2.2.30 FS_NOR_ON_FATAL_ERROR_CALLBACK

Description

The type of the callback function invoked by the NOR driver when a fatal error occurs.

Type definition

```
typedef int FS_NOR_ON_FATAL_ERROR_CALLBACK(
                                      FS_NOR_FATAL_ERROR_INFO * pFatalErrorInfo);
```

Parameters

Parameter	Description
pFatalErrorInfo	Information about the fatal error.

Return value

= 0 The NOR driver has to mark the NOR flash device as read only.
≠ 0 The NOR flash device has to remain writable.

Additional information

If the callback function returns a 0 the NOR driver marks the NOR flash device as read-only and it remains in this state until the NOR flash device is low-level formatted. In this state, all further write operations are rejected with an error by the NOR driver.

The application is responsible for handling the fatal error for example by checking the consistency of the file system via `FS_CheckDisk()`. The callback function is not allowed to invoke any other FS API functions therefore the handling of the error has to be done after the FS API function that triggered the error returns.

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6.4.3.3 Additional driver functions

The functions documented in this section are optional. They can be used to get information about the Block Map NOR driver or to directly access the data stored on the NOR flash device.

Function	Description
FS_NOR_BM_EraseDevice()	Erases all the physical sectors configured as storage.
FS_NOR_BM_ErasePhySector()	Sets all the bits in a physical sector to 1.
FS_NOR_BM_FormatLow()	Performs a low-level format of NOR flash device.
FS_NOR_BM_GetDiskInfo()	Returns information about the organization and the management of the NOR flash device.
FS_NOR_BM_GetSectorInfo()	Returns information about a specified physical sector.
FS_NOR_BM_GetStatCounters()	Returns the values of the statistical counters.
FS_NOR_BM_IsCRCEnabled()	Checks if the data integrity checking is enabled.
FS_NOR_BM_IsECCEnabled()	Checks if the bit error correction via ECC is enabled or not.
FS_NOR_BM_IsLLFormatted()	Checks it the NOR flash is low-level formatted.
FS_NOR_BM_Mount()	Mounts the NOR flash device.
FS_NOR_BM_ReadOff()	Reads a range of bytes from the NOR flash device.
FS_NOR_BM_ResetStatCounters()	Sets the value of the statistical counters to 0.
FS_NOR_BM_SuspendWearLeveling()	Disables temporarily the wear leveling process.
FS_NOR_BM_WriteOff()	Writes data to NOR flash memory.

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6.4.3.3.1 FS_NOR_BM_EraseDevice()

Description

Erases all the physical sectors configured as storage.

Prototype

```
int FS_NOR_BM_EraseDevice(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).

Return value

= 0 Physical sectors erased.
≠ 0 An error occurred.

Additional information

This function is optional. After the call to this function all the bytes in area of the NOR flash device configured as storage are set to `0xFF`.

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6.4.3.3.2 FS_NOR_BM_ErasePhySector()

Description

Sets all the bits in a physical sector to 1.

Prototype

```
int FS_NOR_BM_ErasePhySector(U8  Unit,
                             U32 PhySectorIndex);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
PhySectorIndex	Index of the physical sector to be erased.

Return value

= 0 OK, physical sector erased successfully.
≠ 0 An error occurred.

Additional information

PhySectorIndex is 0-based and is relative to the beginning of the NOR flash area configured via FS_NOR_BM_Configure(). The number of bytes actually erased depends on the size of the physical sector supported by the NOR flash device. Information about a physical sector can be obtained via FS_NOR_BM_GetSectorInfo().

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6.4.3.3.3 FS_NOR_BM_FormatLow()

Description

Performs a low-level format of NOR flash device.

Prototype

```
int FS_NOR_BM_FormatLow(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).

Return value

= 0 OK, NOR flash device has been successfully low-level formatted.
≠ 0 An error occurred.

Additional information

This function is optional. `FS_NOR_BM_FormatLow()` erases the first physical sector and stores the format information in it. The other physical sectors are either erased or invalidated. Per default the physical sectors are invalidated in order to reduce the time it takes for the operation to complete. The application can request the Block Map NOR driver to erase the physical sectors instead of invalidating them by calling `FS_NOR_BM_SetUsedSectorsErase()` with the Off parameter set to 1.

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6.4.3.3.4 FS_NOR_BM_GetDiskInfo()

Description

Returns information about the organization and the management of the NOR flash device.

Prototype

```
int FS_NOR_BM_GetDiskInfo(U8                    Unit,
                          FS_NOR_BM_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
pDiskInfo	out Requested information.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the Block Map NOR driver and will typically not be linked in production builds.

Example

```
#include "FS.h"

void SampleNOR_BMGetDiskInfo(void) {
  int                 r;
  char                ac[128];
  FS_NOR_BM_DISK_INFO DiskInfo;

  FS_X_Log("Get information about the first Block Map NOR driver instance\n");
  r = FS_NOR_BM_GetDiskInfo(0, &DiskInfo);
  if (r == 0) {
    SEGGER_snprintf(ac, sizeof(ac),
      "  Physical sectors:                    %lu\n", DiskInfo.NumPhySectors);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Logical blocks:                      %lu\n", DiskInfo.NumLogBlocks);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Used physical sectors:               %lu\n", DiskInfo.NumUsedPhySectors);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Valid physical sectors:              %lu\n", DiskInfo.NumPhySectorsValid);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Logical sectors in a physical sector: %lu\n", DiskInfo.LSectorsPerPSector);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Logical sector size:                 %lu bytes\n", DiskInfo.BytesPerSector);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Minimum erase count:                 %lu\n", DiskInfo.EraseCntMin);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Maximum erase count:                 %lu\n", DiskInfo.EraseCntMax);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Average erase count:                 %lu\n", DiskInfo.EraseCntAvg);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Erase counts for average:            %lu\n", DiskInfo.NumEraseCnt);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
```

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```
      "  Fatal error:                          %s\n", DiskInfo.HasFatalError ? "yes" : "no");
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Fatal error type:                     %d\n", DiskInfo.ErrorType);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Fatal error location (PSI):           %lu\n", DiskInfo.ErrorPSI);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Write protected:                      %s\n", DiskInfo.IsWriteProtected ? "yes": "no");
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Suspended wear leveling:              %s\n", DiskInfo.IsWLSuspended ? "yes" : "no");
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Maximum erase count difference:       %lu\n", DiskInfo.MaxEraseCntDiff);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac),
      "  Work blocks:                          %lu\n", DiskInfo.NumWorkBlocks);
    FS_X_Log(ac);
  }
}
```

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6.4.3.3.5 FS_NOR_BM_GetSectorInfo()

Description

Returns information about a specified physical sector.

Prototype

```
int FS_NOR_BM_GetSectorInfo(U8                       Unit,
                            U32                      PhySectorIndex,
                            FS_NOR_BM_SECTOR_INFO * pSectorInfo);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
PhySectorIndex	Index of the physical sector to be queried (0-based).
pSectorInfo	out Information related to the specified physical sector.

Return value

= 0 OK, information returned.
≠ 0 An error occurred.

Additional information

This function is optional. The application can use it to get information about the usage of a particular physical sector.

PhySectorIndex is relative to the beginning of the region configured as storage via FS_NOR_BM_Configure().

Example

```
#include <stdio.h>
#include "FS.h"

void SampleNOR_BMGetDiskInfo(void) {
  int                     r;
  char                    ac[128];
  const char            * sType;
  FS_NOR_BM_SECTOR_INFO   SectorInfo;

  FS_X_Log("Get information about the physical sector 0 of the first Block Map NOR driver instance
\n");
  r = FS_NOR_BM_GetSectorInfo(0, 0, &SectorInfo);
  if (r == 0) {
    switch (SectorInfo.Type) {
    case FS_NOR_BLOCK_TYPE_DATA:
      sType = "DATA";
      break;
    case FS_NOR_BLOCK_TYPE_WORK:
      sType = "WORK";
      break;
    case FS_NOR_BLOCK_TYPE_EMPTY_ERASED:
      sType = "EMPTY";
      break;
    case FS_NOR_BLOCK_TYPE_EMPTY_NOT_ERASED:
      sType = "INVALID";
      break;
    case FS_NOR_BLOCK_TYPE_UNKNOWN:
      // through
    default:
      sType = "UNKNOWN";
      break;
    }
    SEGGER_snprintf(ac, sizeof(ac), "  Offset:             %d\n", SectorInfo.Off);
    FS_X_Log(ac);
```

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```
    SEGGER_snprintf(ac, sizeof(ac), "  Size:                %d bytes\n", SectorInfo.Size);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Erase count:         %d\n", SectorInfo.EraseCnt);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Logical block index: %d\n", SectorInfo.lbi);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "  Block type:          %s\n", sType);
    FS_X_Log(ac);
  }
}
```

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6.4.3.3.6 FS_NOR_BM_GetStatCounters()

Description

Returns the values of the statistical counters.

Prototype

```
void FS_NOR_BM_GetStatCounters(U8                          Unit,
                               FS_NOR_BM_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
pStat	out Statistical counter values.

Additional information

This function is optional. The application can use it to get the actual values of the statistical counters maintained by the Block Map NOR driver. The statistical counters provide information about the number of internal operations performed by the Block Map NOR driver such as sector read and write. All statistical counters are set to 0 when the NOR flash device is low-level mounted. The application can explicitly set them to 0 by using `FS_NOR_BM_ResetStatCounters()`. A separate set of statistical counters is maintained for each instance of the Block Map NOR driver.

The statistical counters are available only when the file system is built with the `FS_DEBUG_LEVEL` configuration define set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with the `FS_NOR_ENABLE_STATS` configuration define set to 1.

Example

```
#include "FS.h"

void SampleNOR_BMGetStatCounters(void) {
#if FS_NOR_ENABLE_STATS
  char                    ac[128];
  int                     i;
  FS_NOR_BM_STAT_COUNTERS Stat;

  FS_X_Log("Get statistical counters of the first Block Map NOR driver instance\n");
  FS_NOR_BM_GetStatCounters(0, &Stat);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Free logical blocks:             %lu\n", Stat.NumFreeBlocks);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Physical sectors erased:         %lu\n", Stat.EraseCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Logical sectors read:            %lu\n", Stat.ReadSectorCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Logical sectors written:         %lu\n", Stat.WriteSectorCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Blocks converted via copy:       %lu\n", Stat.ConvertViaCopyCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Blocks converted in-place:       %lu\n", Stat.ConvertInPlaceCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Valid logical sectors:           %lu\n", Stat.NumValidSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Logical sectors copied:          %lu\n", Stat.CopySectorCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Read retries:                    %lu\n", Stat.NumReadRetries);
```

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```
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Physical sector headers read:    %lu\n", Stat.ReadPSHCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Physical sector headers written: %lu\n", Stat.WritePSHCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Logical sector headers read:     %lu\n", Stat.ReadLSHCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Logical sector headers written:  %lu\n", Stat.WriteLSHCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Read operations:                 %lu\n", Stat.ReadCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Bytes read:                      %lu\n", Stat.ReadByteCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Write operations:                %lu\n", Stat.WriteCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Bytes written:                   %lu\n", Stat.WriteByteCnt);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac),
    "  Total bit errors corrected:      %lu\n", Stat.BitErrorCnt);
  FS_X_Log(ac);
  for (i = 0; i < FS_NOR_STAT_MAX_BIT_ERRORS; ++i) {
    SEGGER_snprintf(ac, sizeof(ac),
      "  %d-bit errors corrected:         %lu\n", i + 1, Stat.aBitErrorCnt[i]);
  }
#endif
}
```

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6.4.3.3.7 FS_NOR_BM_IsCRCEnabled()

Description

Checks if the data integrity checking is enabled.

Prototype

```
int FS_NOR_BM_IsCRCEnabled(void);
```

Return value

= 0	Data integrity check is deactivated.
≠ 0	Data integrity check is activated.

Additional information

This function is available only the file system sources are compiled with `FS_NOR_SUPPORT_CRC` set to 1.

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6.4.3.3.8 FS_NOR_BM_IsECCEnabled()

Description

Checks if the bit error correction via ECC is enabled or not.

Prototype

```
int FS_NOR_BM_IsECCEnabled(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

≠ 0 The ECC feature is enabled.
= 0 The ECC feature is disabled.

Additional information

This function is available only the file system sources are compiled with FS_NOR_SUPPORT_ECC set to 1.

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6.4.3.3.9 FS_NOR_BM_IsLLFormatted()

Description

Checks it the NOR flash is low-level formatted.

Prototype

```
int FS_NOR_BM_IsLLFormatted(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).

Return value

≠ 0 The NOR flash device is low-level formatted.
= 0 The NOR flash device is not low-level formatted or an error has occurred.

Additional information

This function is optional. An application should use `FS_IsLLFormatted()` instead.

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6.4.3.3.10 FS_NOR_BM_Mount()

Description

Mounts the NOR flash device.

Prototype

```
int FS_NOR_BM_Mount(U8                      Unit,
                    FS_NOR_BM_MOUNT_INFO * pMountInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pMountInfo	out Information about the mounted NOR flash device. Can be set to NULL.

Return value

= 0 OK, NOR flash device successfully mounted.
≠ 0 Error, could not mount NOR flash device.

Additional information

FS_NOR_BM_Mount() can be used to explicitly mount the NOR flash device and to get information about it. This function returns a subset of the information returned by FS_NOR_BM_GetDiskInfo() and therefore can be used instead of it if the application does not require statistical information about the usage of the NOR sectors. Typically, FS_NOR_BM_Mount() requires less time to complete than FS_NOR_BM_GetDiskInfo().

This function is not required for the functionality of the Block Map driver and is typically not linked in production builds.

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6.4.3.3.11 FS_NOR_BM_ReadOff()

Description

Reads a range of bytes from the NOR flash device.

Prototype

```
int FS_NOR_BM_ReadOff(U8     Unit,
                      void * pData,
                      U32    Off,
                      U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
pData	out Read data.
Off	Offset of the first byte to be read.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is not required for the functionality of the driver and will typically not be linked in production builds.

Off has to be specified in bytes and is relative to the beginning of the NOR flash area configured via FS_NOR_BM_Configure().

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6.4.3.3.12 FS_NOR_BM_ResetStatCounters()

Description

Sets the value of the statistical counters to 0.

Prototype

```
void FS_NOR_BM_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).

Additional information

This function is optional. The application can use it to set to 0 the statistical counters maintained by the Block Map NOR driver. The statistical counters can be read via `FS_NOR_BM_GetStatCounters()`

`FS_NOR_BM_ResetStatCounters()` is available only when the file system is built with the `FS_DEBUG_LEVEL` configuration define set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with the `FS_NOR_ENABLE_STATS` configuration define set to 1.

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6.4.3.3.13 FS_NOR_BM_SuspendWearLeveling()

Description

Disables temporarily the wear leveling process.

Prototype

```
void FS_NOR_BM_SuspendWearLeveling(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).

Additional information

This function is optional. Disabling the wear leveling can help reduce the write latencies that occur when the Block Map NOR driver has to make space for the new data by erasing storage blocks that contain invalid data. With the wear leveling disabled the Block Map NOR driver searches for an already empty block (i.e. a storage block that does not have to be erased before use) when it needs more space. Empty blocks are created when the application performs a clean operation via `FS_STORAGE_Clean()` or `FS_STORAGE_CleanOne()`. The wear leveling is automatically re-enabled by the Block Map NOR driver when no more empty storage blocks are available and an erase operation is required to create one.

`FS_NOR_BM_SuspendWearLeveling()` disables only the wear leveling operation performed when the file system writes data to NOR flash device. The wear leveling is still performed during a clean operation.

The activation status of the wear leveling is returned via the IsWLSuspended member of the `FS_NOR_BM_DISK_INFO` structure that can be queried via `FS_NOR_BM_GetDiskInfo()`

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6.4.3.3.14 FS_NOR_BM_WriteOff()

Description

Writes data to NOR flash memory.

Prototype

```
int FS_NOR_BM_WriteOff(      U8     Unit,
                       const void * pData,
                             U32    Off,
                             U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the Block Map NOR driver (0-based).
pData	in Data to be written.
Off	Location where to write the data.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written successfully.
≠ 0 An error occurred.

Additional information

Off has to be specified in bytes and is relative to the beginning of the NOR flash area configured via FS_NOR_BM_Configure().

FS_NOR_BM_WriteOff() is able to write across page and physical sector boundaries. This function can only change bit values from 1 to 0. The bits can be set to 1 block-wise via FS_NOR_BM_ErasePhySector().

The function takes care of the alignment required when writing to NOR flash devices with line size larger than 1.

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6.4.3.3.15 FS_NOR_BM_DISK_INFO

Description

Management information maintained by the Block Map NOR driver.

Type definition

```
typedef struct {
  U16  NumPhySectors;
  U16  NumLogBlocks;
  U16  NumUsedPhySectors;
  U16  LSectorsPerPSector;
  U16  BytesPerSector;
  U32  EraseCntMax;
  U32  EraseCntMin;
  U32  EraseCntAvg;
  U8   HasFatalError;
  U8   ErrorType;
  U32  ErrorPSI;
  U8   IsWriteProtected;
  U8   IsWLSuspended;
  U32  MaxEraseCntDiff;
  U16  NumEraseCnt;
  U16  NumPhySectorsValid;
  U16  NumWorkBlocks;
} FS_NOR_BM_DISK_INFO;
```

Structure members

Member	Description
NumPhySectors	Number of physical sectors available for data storage.
NumLogBlocks	Number blocks available for the storage of file system data.
NumUsedPhySectors	Number of physical sectors that store valid data.
LSectorsPerPSector	Number of logical sectors that are mapped in a physical sector.
BytesPerSector	Size of the logical sector used by the driver in bytes.
EraseCntMax	Maximum value of an erase count.
EraseCntMin	Minimum value of an erase count.
EraseCntAvg	Average value of an erase count.
HasFatalError	Indicates if a fatal error has occurred during the operation (0 - no fatal error, 1 - a fatal error occurred)
ErrorType	Code indicating the type of fatal error that occurred.
ErrorPSI	Index of the physical sector where the fatal error occurred.
IsWriteProtected	Indicates if the NOR flash device has been switched permanently to read-only mode as a result of a fatal error (0 - NOR flash device is writable, 1 - NOR flash device is write protected)
IsWLSuspended	Indicates if the wear leveling process is temporarily suspended (0 - active, 1 - suspended)
MaxEraseCntDiff	Difference between the erase counts of two physical sectors that trigger an active wear leveling operation.
NumEraseCnt	Number of erase counts used for the calculation of the erase count average (EraseCntAvg)
NumPhySectorsValid	Number of physical sectors that have a valid header.
NumWorkBlocks	Number of work blocks used by the Block Map NOR driver.

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6.4.3.3.16 FS_NOR_BM_MOUNT_INFO

Description

Information about the mounted NOR flash device.

Type definition

```
typedef struct {
  U16  NumPhySectors;
  U16  NumLogBlocks;
  U16  LSectorsPerPSector;
  U16  BytesPerSector;
  U8   HasFatalError;
  U8   ErrorType;
  U32  ErrorPSI;
  U8   IsWriteProtected;
  U8   IsWLSuspended;
  U16  NumWorkBlocks;
} FS_NOR_BM_MOUNT_INFO;
```

Structure members

Member	Description
NumPhySectors	Number of physical sectors available for data storage.
NumLogBlocks	Number blocks available for the storage of file system data.
LSectorsPerPSector	Number of logical sectors that are mapped in a physical sector.
BytesPerSector	Size of the logical sector used by the driver in bytes.
HasFatalError	Indicates if a fatal error has occurred during the operation (0 - no fatal error, 1 - a fatal error occurred)
ErrorType	Code indicating the type of fatal error that occurred.
ErrorPSI	Index of the physical sector where the fatal error occurred.
IsWriteProtected	Indicates if the NOR flash device has been switched permanently to read-only mode as a result of a fatal error (0 - NOR flash device is writable, 1 - NOR flash device is write protected)
IsWLSuspended	Indicates if the wear leveling process is temporarily suspended (0 - active, 1 - suspended)
NumWorkBlocks	Number of work blocks used by the Block Map NOR driver.

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6.4.3.3.17 FS_NOR_BM_SECTOR_INFO

Description

Information about a physical sector maintained by the Block Map NOR driver.

Type definition

```
typedef struct {
  U32  Off;
  U32  Size;
  U32  EraseCnt;
  U16  lbi;
  U8   Type;
} FS_NOR_BM_SECTOR_INFO;
```

Structure members

Member	Description
Off	Position of the physical sector relative to the first byte of NOR flash device
Size	Size of physical sector in bytes
EraseCnt	Number of times the physical sector has been erased
lbi	Index of the logical block stored in the physical sector
Type	Type of data stored in the physical sector (see FS_NOR_BLOCK_TYPE_...)

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6.4.3.3.17.1 FS_NOR_BM_STAT_COUNTERS

Description

Statistical counters maintained by the Block Map NOR driver.

Type definition

```
typedef struct {
  U32  NumFreeBlocks;
  U32  EraseCnt;
  U32  ReadSectorCnt;
  U32  WriteSectorCnt;
  U32  ConvertViaCopyCnt;
  U32  ConvertInPlaceCnt;
  U32  NumValidSectors;
  U32  CopySectorCnt;
  U32  NumReadRetries;
  U32  ReadPSHCnt;
  U32  WritePSHCnt;
  U32  ReadLSHCnt;
  U32  WriteLSHCnt;
  U32  ReadCnt;
  U32  ReadByteCnt;
  U32  WriteCnt;
  U32  WriteByteCnt;
  U32  BitErrorCnt;
  U32  aBitErrorCnt[];
  U32  PreEraseCnt;
} FS_NOR_BM_STAT_COUNTERS;
```

Structure members

Member	Description
NumFreeBlocks	Number of blocks that are not used for data storage.
EraseCnt	Number of sector erase operations.
ReadSectorCnt	Number of logical sectors read by the file system.
WriteSectorCnt	Number of logical sectors written by the file system.
ConvertViaCopyCnt	Number of times a work block has been converted via a copy operation.
ConvertInPlaceCnt	Number of times a work block has been converted in-place (i.e. by changing the block type from work to data).
NumValidSectors	Number of valid logical sectors stored on the NOR flash device.
CopySectorCnt	Number of logical sectors copied internally by the driver.
NumReadRetries	Number of times the driver retried a read operation due to an error.
ReadPSHCnt	Number of times the driver read from the header of a physical sector.
WritePSHCnt	Number of times the driver wrote to the header of a physical sector.
ReadLSHCnt	Number of times the driver read from the header of a logical sector.
WriteLSHCnt	Number of times the driver wrote to the header of a logical sector.
ReadCnt	Number of times the driver read data from the NOR flash device.

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Member	Description
ReadByteCnt	Number of bytes read by the driver from the NOR flash device.
WriteCnt	Number of times the driver wrote data to the NOR flash device.
WriteByteCnt	Number of bytes written by the driver to the NOR flash device.
BitErrorCnt	Total number of bit errors corrected.
aBitErrorCnt	Number of times a specific number of bit errors occurred.
PreEraseCnt	Number of sector pre-erase operations.

Additional information

The statistical counters can be queried via `FS_NOR_BM_GetStatCounters()` and can be set to 0 via `FS_NOR_BM_ResetStatCounters()`.

`aBitErrorCnt`[0] stores the number of 1 bit error occurrences, `aBitErrorCnt`[1] stores the number of 2 bit error occurrences, and so on.

`PreEraseCnt` stores the number of times the Block Map NOR driver marked a physical sector as ready to be erased. The physical sectors are then erased before being used.

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6.4.3.4 Performance and resource usage

6.4.3.4.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The memory requirements of the Sector Map NOR driver were measured as described in the section *Test procedure* on page 1439.

Usage: 5.5 Kbytes

6.4.3.4.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Block Map NOR driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the `FS_NOR_BM_Drv.c` file.

Usage: 72 bytes

6.4.3.4.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the runtime configuration and on the used NOR flash device. The approximate RAM usage of the Block Map NOR driver can be calculated as follows:

```
MemAllocated = 84
             + (24 + PhySectorSize / LogSectorSize) * NumWorkBlocks
             + 1.5 * NumPhySectors
```

Parameter	Description
`MemAllocated`	Number of bytes allocated.
`PhySectorSize`	Size in bytes of a NOR flash physical sector.
`LogSectorSize`	Size in bytes of a file system sector. Typically, 512 bytes or the value set in the call to `FS_SetMaxSectorSize()` configuration function.
`NumWorkBlocks`	Number of physical sectors the driver reserves as temporary storage for the written data. Typically, 3 physical sectors or the number specified in the call to the `FS_NOR_BM_SetNumWorkBlocks()` configuration function.
`NumPhySectors`	Number of physical sectors managed by the driver.

6.4.3.4.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in Kbytes/second.

CPU type	NOR flash device	Write speed	Read speed
NXP LPC2478 (57.6 MHz)	SST SST39VF201 CFI NOR flash device with 16-bit interface and without support for write buffer	**45.5**	**2064**
ST STM32F103 (72 MHz)	ST M25P64 serial NOR flash device	**59.3**	**1110**
NXP LPC4357 (204 MHz)	Two Spansion S29GL064N CFI NOR flash devices with 16-bit interface and with support for write buffer.	**179**	**25924**

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6.4.3.4.5 How to reduce ROM usage

The ROM usage can be reduced by disabling optional features of the Block Map NOR driver. This can be done by building the file system with `FS_OPTIMIZATION_TYPE` set to `FS_OPTIMIZATION_TYPE_MIN_SIZE` or by disabling the optional features individually. Refer to the section *Compile time configuration* on page 886 for more information about the available optional features.

If the application makes only read accesses to the NOR flash device, then the ROM usage can be reduced significantly by using the read-only variant of the Block Map NOR driver. This can be done by specifying the `FS_NOR_BM_RO_Driver` identifier in the call to `FS_AddDevice()`.

6.4.3.4.6 How to reduce RAM usage

The static RAM usage can be reduced by setting `FS_NOR_NUM_UNITS` to the maximum number of Block Map NOR driver instances the application is expected to create at runtime.

The dynamic RAM usage depends on the number of NOR physical sectors the Block Map NOR driver has to manage and on the number of configured work blocks. The NOR physical layers are configured to use the largest physical sector size supported by the used NOR flash device in order to keep the number of managed NOR physical sectors to a minimum. The number of work blocks can be configured via `FS_NOR_BM_SetNumWorkBlocks()`.

> **Note**
>
> Reducing the number of work blocks may negatively affect the write performance of the Block Map NOR driver.

6.4.3.4.7 How to improve performance

As a general rule, the best performance can be achieved when the application accesses the file data in blocks and at offsets that are a multiple of a logical sector size. The file system guarantees that the beginning of a file is aligned to the beginning of a logical sector. Larger logical sector sizes provide better performance. The size of the logical sector can be configured via `FS_NOR_BM_SetSectorSize()`.

In addition, the write performance can be improved by increasing the number of work blocks. The number of work blocks can be configured via `FS_NOR_BM_SetNumWorkBlocks()`.

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6.4.4 NOR physical layer

6.4.4.1 General information

The NOR physical layer provides the basic functionality for accessing a NOR flash device such as device identification, block erase operation, read and write operations, etc. Every instance of the Sector map or Block Map NOR driver requires an instance of a NOR physical layer in order to be able to operate. A NOR physical layer instance is automatically allocated either statically or dynamically at the first call to one of its API functions. Each instance is identified by a unit number that is identical to the unit number of the NOR driver that uses that instance of the NOR physical layer. The type of the NOR physical layer assigned to an instance of a Sector map or Block Map NOR driver is configured via `FS_NOR_SetPhyType()` and `FS_NOR_BM_SetPhyType()` respectively.

The table below lists the NOR physical layers that ship with emFile. Refer to *Configuring the driver* on page 847 and *Configuring the driver* on page 886 for detailed information about how to add and configure a physical layer in an application.

Physical layer identifier	Hardware layer type
`FS_NOR_PHY_CFI_1x16`	Not required.
`FS_NOR_PHY_CFI_2x16`	Not required.
`FS_NOR_PHY_DSPI`	`FS_NOR_HW_TYPE_SPI`
`FS_NOR_PHY_SFDP`	`FS_NOR_HW_TYPE_SPI`
`FS_NOR_PHY_SPIFI`	`FS_NOR_HW_TYPE_SPIFI`
`FS_NOR_PHY_ST_M25`	`FS_NOR_HW_TYPE_SPI`

The following sections provide information about the usage and the implementation of a NOR physical layer.

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6.4.4.2 CFI 1x16 physical layer

This physical layer supports any CFI compliant NOR flash device connected via a 16-bit data bus.

The physical layer has to be configured at runtime and optionally at compile time. The following sections describe how this can be realized in the application.

6.4.4.2.1 Compile time configuration

The CFI 1x16 physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NOR_AMD_WRITE_BUFFER_SIZE	32	N	Size of the internal write buffer of AMD compatible NOR flash devices in bytes.
FS_NOR_AMD_STATUS_CHECK_TYPE	0	N	Configures how the status of a program and erase operation should be checked.
FS_NOR_DMB()	empty	F	Macro to synchronize the access to memory.
FS_NOR_DELAY()	empty	F	Macro to block the execution for a fixed time interval.
FS_NOR_DI()	empty	F	Macro to disable the interrupts globally.
FS_NOR_EI()	empty	F	Macro to enable the interrupts globally.
FS_NOR_FAR	empty	R	Memory type specifier. Used for 8/16-bit CPUs only.
FS_NOR_INTEL_WRITE_BUFFER_SIZE	32	N	Size of the internal write buffer of Intel compatible NOR flash devices in bytes.
FS_NOR_MAX_SECTOR_BLOCKS	6	N	Maximum number of different physical sector sizes that can be handled.
FS_NOR_REVERSE_ENDIANESS	0	B	

6.4.4.2.1.1 FS_NOR_AMD_WRITE_BUFFER_SIZE

FS_NOR_AMD_WRITE_BUFFER_SIZE specifies the maximum number of bytes the NOR flash device is able to buffer internally before the data is written to the memory array. This define is relevant only for NOR flash devices that comply with the AMD command set.

6.4.4.2.1.2 FS_NOR_AMD_STATUS_CHECK_TYPE

FS_NOR_AMD_STATUS_CHECK_TYPE specifies how the physical layer waits for a write or erase operation to complete. The following values are permitted:

Value	Description
0	The status is checked by polling the toggle bit. No error checking is possible because the devices do not provide this information. Typically, this polling mode is supported by legacy NOR flash devices. This is the default behavior for backward compatibility.

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Value	Description
1	The status is checked by polling the toggle bit. In addition, the status of the erase and write operation is checked for errors. This polling mode is supported by modern NOR flash devices such as those from Micron.
2	The status is checked by polling the status register. This polling mode is supported by Cypress HyperFlash devices.

6.4.4.2.1.3 FS_NOR_DMB()

`FS_NOR_DMB()` specifies a function that the file system can call to make sure that a code sequence is executed only after all the previous memory accesses are finished. On a Cortex-M architecture this macro has to expand to a DMB instruction.

6.4.4.2.1.4 FS_NOR_DELAY()

`FS_NOR_DELAY()` specifies a function that blocks the execution for a certain period of time. The function does not take any parameters and returns void. It is called each time the physical layer is checking for the completion status of a write or erase operation. For performance reasons, the amount of time the function blocks should be configured to be smaller than the time required by the NOR flash device to complete a write or erase operation. Using this feature can help reduce the CPU usage of the file system.

6.4.4.2.1.5 FS_NOR_DI()

`FS_NOR_DI()` specifies a function that disables the interrupts globally. The function does not take any parameters and returns void. The specified function is called after each access to the memory region where the NOR flash device is mapped in the system memory.

6.4.4.2.1.6 FS_NOR_EI()

`FS_NOR_EI()` specifies a function that enables the interrupts globally. The function does not take any parameters and returns void. The specified function is called before each access to the memory region where the NOR flash device is mapped in the system memory.

6.4.4.2.1.7 FS_NOR_FAR

`FS_NOR_FAR` is a memory type specifier that is used to cast the pointers used for the access to the memory region where the NOR flash device is mapped in the system memory. This configuration define is C compiler specific and is typically required only on 8- or 16-bit targets.

6.4.4.2.1.8 FS_NOR_INTEL_WRITE_BUFFER_SIZE

`FS_NOR_INTEL_WRITE_BUFFER_SIZE` specifies the maximum number of bytes the NOR flash device is able to buffer internally before the data is written to the memory array. This define is relevant only for NOR flash devices that comply with the Intel command set.

6.4.4.2.1.9 FS_NOR_MAX_SECTOR_BLOCKS

`FS_NOR_MAX_SECTOR_BLOCKS` specifies the number of different physical sector sizes that the physical layer can handle. This define can be set to 1 for NOR flash devices with physical sectors of the same size.

6.4.4.2.1.10 FS_NOR_REVERSE_ENDIANESS

`FS_NOR_REVERSE_ENDIANESS` specifies if the byte ordering of the CFI information has to be reversed because it is not presented in the byte ordering expected by the CPU.

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6.4.4.2.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the CFI 1x16 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NOR_CFI_SetAddrGap()`	Configures a memory access gap.
`FS_NOR_CFI_SetReadCFICallback()`	Registers a read function for the CFI parameters.

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6.4.4.2.2.1 FS_NOR_CFI_SetAddrGap()

Description

Configures a memory access gap.

Prototype

```
void FS_NOR_CFI_SetAddrGap(U8  Unit,
                           U32 StartAddr,
                           U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
StartAddr	Address of the first byte in the gap.
NumBytes	Number of bytes in the gap.

Additional information

This function is optional. The application can use FS_NOR_CFI_SetAddrGap() to specify a range in the memory region where the contents of the NOR flash device is mapped that is not assigned to the NOR flash device. Any access to an address equal to or greater than StartAddr is translated by NumBytes. StartAddr and NumBytes have to be aligned to a physical sector boundary of the used NOR flash device.

The application is permitted to call FS_NOR_CFI_SetAddrGap() only during the file system initialization in FS_X_AddDevices().

Example

```
#include "FS.h"

#define ALLOC_SIZE            0x4000
#define FLASH_BASE_ADDR       0x80000000
#define FLASH_START_ADDR      0x80000000
#define FLASH_SIZE            0x00400000
#define FLASH_GAP_START_ADDR  0x80200000
#define FLASH_GAP_SIZE        0x00200000

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver for a 4MB NOR flash.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_Configure(0, FLASH_BASE_ADDR, FLASH_START_ADDR, FLASH_SIZE);
  //
  // Configure a 2MB gap in the address space of NOR flash.
  //
  FS_NOR_CFI_SetAddrGap(0, FLASH_GAP_START_ADDR, FLASH_GAP_SIZE);
}
```

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6.4.4.2.2.2 FS_NOR_CFI_SetReadCFICallback()

Description

Registers a read function for the CFI parameters.

Prototype

```
void FS_NOR_CFI_SetReadCFICallback(U8                          Unit,
                                   FS_NOR_READ_CFI_CALLBACK * pfReadCFI);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based)
pfReadCFI	Function to be registered.

Additional information

This function is optional. It can be used to specify a different function for the reading of CFI parameters than the default function used by the physical layer. This is typically required when the CFI parameters do not fully comply with the CFI specification.

The application is permitted to call `FS_NOR_CFI_SetReadCFICallback()` only during the file system initialization in `FS_X_AddDevices()`.

Example

```
#include "FS.h"

#define ALLOC_SIZE                0x4000      // Size defined in bytes
#define BYTES_PER_SECTOR          2048

#define CFI_READCONFIG(BaseAddr)              // TBD
#define CFI_RESET(BaseAddr)                   // TBD
#define CFI_READCONFIG_NON_CONFORM(BaseAddr)  // TBD

static U32 _aMemBlock[ALLOC_SIZE / 4];        // Memory pool used for
                                              // semi-dynamic allocation.
static int _IsInited       = 0;
static int _IsCFICompliant = 0;

/*********************************************************************
*
*       _cbReadCFI
*/
static void _cbReadCFI(U8 Unit, U32 BaseAddr, U32 Off, U8 * pData, unsigned NumItems) {
  volatile U16 FS_NOR_FAR * pAddr;
  U8                        aData[3];

  FS_USE_PARA(Unit);
  //
  // We initially need to check whether the flash is fully CFI compliant.
  //
  if (_IsInited == 0) {
    FS_MEMSET(aData, 0, sizeof(aData));
    pAddr = (volatile U16 FS_NOR_FAR *)(BaseAddr + (0x10 << 1));
    CFI_READCONFIG(BaseAddr);
    aData[0] = (U8)*pAddr++;
    aData[1] = (U8)*pAddr++;
    aData[2] = (U8)*pAddr++;
    CFI_RESET(BaseAddr);
    if (   (aData[0] == 'Q')
        && (aData[1] == 'R')
        && (aData[2] == 'Y')) {
        _IsCFICompliant = 1;
    }
    _IsInited = 1;
  }
  pAddr = (volatile U16 FS_NOR_FAR *)(BaseAddr + (Off << 1));
```

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```
  //
  // Write the correct CFI-query sequence
  //
  if (_IsCFICompliant) {
    CFI_READCONFIG(BaseAddr);
  } else {
    CFI_READCONFIG_NON_CONFORM(BaseAddr);
  }
  //
  // Read the data
  //
  do {
    *pData++ = (U8)*pAddr++;  // Only the low byte of the CFI data is relevant
  } while(--NumItems);
  //
  // Perform a reset, which means, return from CFI mode to normal mode
  //
  CFI_RESET(BaseAddr);
}

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the NOR flash driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  //
  // Configure a different function for reading CFI information.
  //
  FS_NOR_CFI_SetReadCFICallback(0, _cbReadCFI);
  FS_NOR_Configure(0, 0x10000000, 0x10000000, 0xFFFFFFFF);
  FS_NOR_SetSectorSize(0, BYTES_PER_SECTOR);
  //
  // Set a larger logical sector size as the default
  // in order to reduce the RAM usage of the NOR driver.
  //
  FS_SetMaxSectorSize(BYTES_PER_SECTOR);
}
```

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6.4.4.2.2.3 FS_NOR_READ_CFI_CALLBACK

Description

Reads CFI information from a NOR flash device.

Type definition

```
typedef void (FS_NOR_READ_CFI_CALLBACK)(U8       Unit,
                                        U32      BaseAddr,
                                        U32      Off,
                                        U8     * pData,
                                        unsigned NumItems);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
BaseAddr	Address in system memory where the NOR flash device is mapped.
Off	Byte offset to read from.
pData	out CFI information read
NumItems	Number of 16-bit values to be read.

Additional information

This is the type of the callback function invoked by CFI NOR physical layers to read CFI information from NOR flash device. The CFI NOR physical layers already have an internal function for reading the CFI information. `FS_NOR_CFI_SetReadCFICallback()` can be used to register a callback function that replaces the functionality of this internal function.

Example

Refer to `FS_NOR_CFI_SetReadCFICallback()` for a sample usage.

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6.4.4.3 CFI 2x16 physical layer

This physical layer supports any setup with two CFI-compliant NOR flash devices each connected via a 16-bit data bus. It can be configured at compile time as well as at runtime in the same way as the CFI 1x16 physical layer.

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6.4.4.4 DSPI physical layer

This is a pseudo physical layer that uses the ST M25 and SFDP physical layers to access a serial NOR flash device. The data is exchanged via 1 SPI data line.

The DSPI physical layer has to be configured at runtime and optionally at compile time. The following sections describe how this can be realized in the application.

6.4.4.4.1 Compile time configuration

The DSPI physical layer uses the same configuration defines as the ST M25 and SFDP physical layers. Refer to *Compile time configuration* on page 989 and *Compile time configuration* on page 962 for more information.

6.4.4.4.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the DSPI physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NOR_DSPI_SetHWType()`	Configures the HW access routines.

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6.4.4.4.2.1 FS_NOR_DSPI_SetHWType()

Description

Configures the HW access routines.

Prototype

```
void FS_NOR_DSPI_SetHWType(      U8                    Unit,
                           const FS_NOR_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pHWType	Hardware access routines. Cannot be NULL.

Additional information

This function is mandatory and it has to be called once for each instance of the physical layer.

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6.4.4.5 SFDP physical layer

This physical layer supports any serial NOR flash device that complies with the JEDEC JESD216 specification. This specification standardizes the method of describing the capabilities of a serial NOR flash device. This information is stored internally by any compatible serial NOR flash device and is used by the SFDP physical layer to determine the capacity of the serial NOR flash device, the codes of single, dual, and quad read commands and so on.

6.4.4.5.1 Compile time configuration

The SFDP physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NOR_BYTES_PER_PAGE	256	N	Maximum number of bytes that can be stored at once in a NOR flash page.
FS_NOR_DELAY_SECTOR_ERASE	0	N	Delay in milliseconds between two status requests sent when waiting for the completion of the erase operation.
FS_NOR_DEVICE_LIST_DEFAULT	&FS_NOR_SPI_DeviceListDefault	R	Default list of NOR flash devices that can be handled.
FS_NOR_READ_ALIGNMENT	0	N	Specifies the alignment of the data read operation.
FS_NOR_SUPPORT_ACCESS_ALIGNMENT	1	B	Enables or disables the support for aligned read and write operations.
FS_NOR_TIMEOUT_PAGE_WRITE	5	N	Timeout in milliseconds for the page program operation.
FS_NOR_TIMEOUT_SECTOR_ERASE	3000	N	Timeout in milliseconds for the sector erase operation.

6.4.4.5.1.1 FS_NOR_BYTES_PER_PAGE

FS_NOR_BYTES_PER_PAGE specifies the maximum number of bytes that can be written at once by the serial NOR flash device. This value can be taken from the data sheet of the device. A write operation with a number of bytes larger than FS_NOR_BYTES_PER_PAGE is split by the physical layer into multiple write operations with a number of bytes smaller than or equal to FS_NOR_BYTES_PER_PAGE.

6.4.4.5.1.2 FS_NOR_DELAY_SECTOR_ERASE

FS_NOR_DELAY_SECTOR_ERASE specifies the number of milliseconds the physical layer has to wait between two device status requests. A device status request is performed by the physical layer when it waits for an erase operation to complete. Using this feature can help reduce the CPU usage of the file system.

6.4.4.5.1.3 FS_NOR_DEVICE_LIST_DEFAULT

FS_NOR_DEVICE_LIST_DEFAULT specifies the list of serial NOR flash devices that can be handled by the physical layer. FS_NOR_DEVICE_LIST_DEFAULT can be set to NULL in order to reduce the ROM usage if not all the devices included in FS_NOR_SPI_DeviceListDefault have to be handled. In this case, it is mandatory that the application configures a list of devices via FS_NOR_SFDP_SetDeviceList().

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6.4.4.5.1.4 FS_NOR_READ_ALIGNMENT

FS_NOR_READ_ALIGNMENT specifies how the data has to be read from the NOR flash device. If FS_NOR_READ_ALIGNMENT is set to 0, then the SFDP NOR physical layer reads the exact number of bytes from the exact address that are specified by the NOR driver. If FS_NOR_READ_ALIGNMENT is set to 1, 2 or 4, then the SFDP NOR physical layer checks the number of bytes and the address specified by the NOR driver and modifies them if required so that the read operation is using an address and a number of bytes that are a multiple of the specified alignment value. Any additional data that may be read during the process is discarded. FS_NOR_READ_ALIGNMENT has to be specified in number of bytes. This configuration define is effective only when FS_NOR_SUPPORT_ACCESS_ALIGNMENT is set to a value different from 0. The read alignment can be modified at runtime via FS_NOR_SFDP_SetReadAlignment().

6.4.4.5.1.5 FS_NOR_SUPPORT_ACCESS_ALIGNMENT

FS_NOR_SUPPORT_ACCESS_ALIGNMENT can be used to enable the support for aligned data read and write operations in the SFDP NOR physical layer. FS_NOR_SUPPORT_ACCESS_ALIGNMENT has to be set to 1 if the file system is using two NOR flash devices connected in parallel as storage, the data is transferred on both clock edges between the MCU and the NOR flash device (DTR mode) or a data read alignment is specified via FS_NOR_READ_ALIGNMENT.

6.4.4.5.1.6 FS_NOR_TIMEOUT_PAGE_WRITE

FS_NOR_TIMEOUT_PAGE_WRITE specifies the maximum number of milliseconds the physical layer has to wait for a write operation to complete. The completion of the write operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

6.4.4.5.1.7 FS_NOR_TIMEOUT_SECTOR_ERASE

FS_NOR_TIMEOUT_SECTOR_ERASE specifies the maximum number of milliseconds the physical layer has to wait for a physical sector erase operation to complete. The completion of the erase operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

6.4.4.5.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the SFDP physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NOR_SFDP_Allow2bitMode()	Specifies if the physical layer is permitted to exchange data via two data lines.
FS_NOR_SFDP_Allow4bitMode()	Specifies if the physical layer is permitted to exchange data via four data lines.
FS_NOR_SFDP_Configure()	Configures an instance of the physical layer.
FS_NOR_SFDP_SetDeviceList()	Configures the type of handled serial NOR flash devices.
FS_NOR_SFDP_SetDeviceParaList()	Configures parameters of serial NOR flash devices.
FS_NOR_SFDP_SetHWType()	Configures the HW access routines.
FS_NOR_SFDP_SetReadAlignment()	Specifies the alignment of the data read operation.
FS_NOR_SFDP_SetSectorSize()	Configures the size of the physical sector to be used by the driver.

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6.4.4.5.2.1 FS_NOR_SFDP_Allow2bitMode()

Description

Specifies if the physical layer is permitted to exchange data via two data lines.

Prototype

```
void FS_NOR_SFDP_Allow2bitMode(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via two data lines is used only if this type of data transfer is supported by the serial NOR flash device. In dual mode two bits of data are transferred with each clock period which helps improve the performance. If the serial NOR flash device does not support the dual mode then the data is transferred in standard mode (one data bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.5.2.2 FS_NOR_SFDP_Allow4bitMode()

Description

Specifies if the physical layer is permitted to exchange data via four data lines.

Prototype

```
void FS_NOR_SFDP_Allow4bitMode(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via four data lines is used only if this type of data transfer is supported by the serial NOR flash device. In quad mode four bits of data are transferred on each clock period which helps improve the performance. If the serial NOR flash device does not support the quad mode then the data is transferred in dual mode if enabled and supported or in standard mode (one bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.5.2.3 FS_NOR_SFDP_Configure()

Description

Configures an instance of the physical layer.

Prototype

```
void FS_NOR_SFDP_Configure(U8  Unit,
                           U32 StartAddr,
                           U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the SFDP physical layer (0-based).
StartAddr	Address of the first byte the SFDP physical layer is permitted to use as storage.
NumBytes	Number of bytes starting from StartAddr available to be used by the SFDP physical layer as storage.

Additional information

This function is optional. It can be called instead of the FS_NOR_BM_Configure() or FS_NOR_Configure(). Different instances of the SFDP physical layer are identified by the Unit parameter.

BaseAddr is used only for NOR flash devices that are memory mapped. For serial NOR flash devices that are not memory mapped BaseAddr has to be set to 0.

StartAddr has to be greater than or equal to BaseAddr and smaller than the total number of bytes in the NOR flash device. The SFDP physical layer rounds up StartAddr to the start address of the next physical sector in the NOR flash device.

NumBytes is rounded up to a physical sector boundary if the memory range defined by StartAddr and NumBytes is smaller than the capacity of the NOR flash device. If the memory range defined by StartAddr and NumBytes is larger than the capacity of the NOR flash device than NumBytes is rounded down so that the memory range fits into the NOR flash device.

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6.4.4.5.2.4 FS_NOR_SFDP_SetDeviceList()

Description

Configures the type of handled serial NOR flash devices.

Prototype

```
void FS_NOR_SFDP_SetDeviceList(      U8                        Unit,
                               const FS_NOR_SPI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pDeviceList	List of NOR flash devices the physical layer can handle.

Additional information

This function is optional. This function can be used to enable handling for vendor specific features of serial NOR flash device such as error handling and data protection. By default the physical layer is configured to handle only Micron serial NOR flash devices. Handling for serial NOR flash devices from other manufacturers has to be explicitly enabled via this function.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NOR_SPI_DeviceListAdesto
FS_NOR_SPI_DeviceListAll
FS_NOR_SPI_DeviceListCypress
FS_NOR_SPI_DeviceListDefault
FS_NOR_SPI_DeviceListEon
FS_NOR_SPI_DeviceListGigaDevice
FS_NOR_SPI_DeviceListInfineon
FS_NOR_SPI_DeviceListISSI
FS_NOR_SPI_DeviceListMacronix
FS_NOR_SPI_DeviceListMicron
FS_NOR_SPI_DeviceListMicron_x
FS_NOR_SPI_DeviceListMicron_x2
FS_NOR_SPI_DeviceListMicrochip

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Identifier
FS_NOR_SPI_DeviceListSpansion
FS_NOR_SPI_DeviceListSTM
FS_NOR_SPI_DeviceListWinbond

The application can save ROM space by setting FS_NOR_DEVICE_LIST_DEFAULT to NULL at compile time and by calling at runtime FS_NOR_SFDP_SetDeviceList() with the actual list of serial NOR flash devices that have to be handled.

The application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

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6.4.4.5.2.5 FS_NOR_SFDP_SetDeviceParaList()

Description

Configures parameters of serial NOR flash devices.

Prototype

```
void FS_NOR_SFDP_SetDeviceParaList
                              (      U8                              Unit,
                               const FS_NOR_SPI_DEVICE_PARA_LIST * pDeviceParaList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pDeviceParaList	List of device parameters.

Additional information

This function is optional. By default, the parameters of the used serial NOR flash device are determined by evaluating the SFDP tables stored in it. However, the information about the commands that can be used to write the data via two and four data lines is not stored to this parameters. `FS_NOR_SFDP_SetDeviceParaList()` can be used to specify this information. The parameters are matched by comparing the first byte (manufacturer id) and the third byte (device id) of the information returned by the READ ID (`0x9F`) function with the MfgId and Id members of the `FS_NOR_SPI_DEVICE_PARA` structure.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.5.2.6 FS_NOR_SFDP_SetHWType()

Description

Configures the HW access routines.

Prototype

```
void FS_NOR_SFDP_SetHWType(      U8                    Unit,
                           const FS_NOR_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pHWType	Hardware access routines. Cannot be NULL.

Additional information

It is mandatory to call this function during the file system initialization in FS_X_AddDevices() once for each instance of a physical layer.

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6.4.4.5.2.7 FS_NOR_SFDP_SetReadAlignment()

Description

Specifies the alignment of the data read operation.

Prototype

```
int FS_NOR_SFDP_SetReadAlignment(U8       Unit,
                                 unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
NumBytes	Alignment in bytes.

Return value

= 0 OK, read alignment set correctly.
≠ 0 Error code indicating the failure reason.

Additional information

Permitted values for NumBytes are 1, 2, and 4.

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6.4.4.5.2.8 FS_NOR_SFDP_SetSectorSize()

Description

Configures the size of the physical sector to be used by the driver.

Prototype

```
void FS_NOR_SFDP_SetSectorSize(U8  Unit,
                               U32 BytesPerSector);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
BytesPerSector	Sector size to be used.

Additional information

Typically, a serial NOR flash device supports erase commands that can be used to erase sectors of different sizes (4 KB, 32 KB, etc.) For performance reasons the physical layer chooses always the erase command corresponding to the largest physical sector. This function can be used to request the physical layer to use a different (smaller) physical sector size. The mount operation fails if the serial NOR flash device does not support the specified physical sector size.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.5.2.9 FS_NOR_SPI_DEVICE_PARA_LIST

Description

Defines a list of serial NOR flash device parameters.

Type definition

```
typedef struct {
  U8                              NumParas;
  const FS_NOR_SPI_DEVICE_PARA * pPara;
} FS_NOR_SPI_DEVICE_PARA_LIST;
```

Structure members

Member	Description
NumParas	Number of parameters
pPara	List of parameters.

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6.4.4.6 SPIFI physical layer

This physical layer supports serial NOR flash devices that are mapped to the system memory of the target system. The SPIFI physical layer is able to make use of the SFDP information stored in the interfaced NOR flash device in order to determine the storage geometry and the supported command set of that device.

6.4.4.6.1 Compile configuration

The SPIFI physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NOR_BYTES_PER_PAGE	256	N	Maximum number of bytes that can be stored at once to a NOR flash page.
FS_NOR_DELAY_SECTOR_ERASE	0	N	Delay in milliseconds between two status requests sent when waiting for the completion of the erase operation.
FS_NOR_DEVICE_LIST_DEFAULT	&FS_NOR_SPI_DeviceListDefault	R	Default list of NOR flash devices that can be handled.
FS_NOR_MAX_NUM_BYTES_DUMMY	5	N	Maximum number of dummy bytes required during a read operation the physical layer can handle.
FS_NOR_READ_ALIGNMENT	0	N	Specifies the alignment of the data read operation.
FS_NOR_SUPPORT_ACCESS_ALIGNMENT	1	B	Enables or disables the support for aligned read and write operations.
FS_NOR_TIMEOUT_PAGE_WRITE	5	N	Timeout in milliseconds for the page program operation.
FS_NOR_TIMEOUT_SECTOR_ERASE	3000	N	Timeout in milliseconds for the sector erase operation.

6.4.4.6.1.1 FS_NOR_BYTES_PER_PAGE

FS_NOR_BYTES_PER_PAGE specifies the maximum number of bytes that can be written at once by the serial NOR flash device. This value can be taken from the data sheet of the device. A write operation with a number of bytes larger than FS_NOR_BYTES_PER_PAGE is split by the physical layer into multiple write operations with a number of bytes smaller than or equal to FS_NOR_BYTES_PER_PAGE.

6.4.4.6.1.2 FS_NOR_DELAY_SECTOR_ERASE

FS_NOR_DELAY_SECTOR_ERASE specifies the number of milliseconds the physical layer has to wait between two device status requests. A device status request is performed by the physical layer when it waits for an erase operation to complete. Using this feature can help reduce the CPU usage of the file system.

6.4.4.6.1.3 FS_NOR_DEVICE_LIST_DEFAULT

FS_NOR_DEVICE_LIST_DEFAULT specifies the list of serial NOR flash devices that can be handled by the physical layer. FS_NOR_DEVICE_LIST_DEFAULT can be set to NULL in order to reduce

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the ROM usage if not all the devices included in FS_NOR_SPI_DeviceListDefault have to be handled. In this case, it is mandatory that the application configures a list of devices via FS_NOR_SFDP_SetDeviceList().

6.4.4.6.1.4 FS_NOR_MAX_NUM_BYTES_DUMMY

FS_NOR_MAX_NUM_BYTES_DUMMY specifies the maximum number of dummy bytes the physical layer can send when executing a read operation. The dummy bytes are necessary in order to give the serial NOR flash device time to prepare the data. The information about the actual number of dummy bytes required is read by the physical layer from the serial NOR flash device via SFDP.

6.4.4.6.1.5 FS_NOR_READ_ALIGNMENT

FS_NOR_READ_ALIGNMENT specifies how the data has to be read from the NOR flash device. If FS_NOR_READ_ALIGNMENT is set to 0, then the SPIFI NOR physical layer reads the exact number of bytes from the exact address that are specified by the NOR driver. If FS_NOR_READ_ALIGNMENT is set to 1, 2 or 4, then the SPIFI NOR physical layer checks the number of bytes and the address specified by the NOR driver and modifies them if required so that the read operation is using an address and a number of bytes that are a multiple of the specified alignment value. Any additional data that may be read during the process is discarded. FS_NOR_READ_ALIGNMENT has to be specified in number of bytes. This configuration define is effective only when FS_NOR_SUPPORT_ACCESS_ALIGNMENT is set to a value different from 0. The read alignment can be modified at runtime via FS_NOR_SPIFI_SetReadAlignment().

6.4.4.6.1.6 FS_NOR_SUPPORT_ACCESS_ALIGNMENT

FS_NOR_SUPPORT_ACCESS_ALIGNMENT can be used to enable the support for aligned data read and write operations in the SPIFI NOR physical layer. FS_NOR_SUPPORT_ACCESS_ALIGNMENT has to be set to 1 if the file system is using two NOR flash devices connected in parallel as storage, the data is transferred on both clock edges between the MCU and the NOR flash device (DTR mode) or a data read alignment is specified via FS_NOR_READ_ALIGNMENT.

6.4.4.6.1.7 FS_NOR_TIMEOUT_PAGE_WRITE

FS_NOR_TIMEOUT_PAGE_WRITE specifies the maximum number of milliseconds the physical layer has to wait for a write operation to complete. The completion of the write operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

6.4.4.6.1.8 FS_NOR_TIMEOUT_SECTOR_ERASE

FS_NOR_TIMEOUT_SECTOR_ERASE specifies the maximum number of milliseconds the physical layer has to wait for a physical sector erase operation to complete. The completion of the erase operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

6.4.4.6.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the SPIFI physical layer. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_NOR_SPIFI_Allow2bitMode()	Specifies if the physical layer is permitted to exchange data via two data lines.
FS_NOR_SPIFI_Allow4bitMode()	Specifies if the physical layer is permitted to exchange data via four data lines.
FS_NOR_SPIFI_Allow8bitMode()	Specifies if the physical layer is permitted to exchange data via eight data lines.

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Function	Description
FS_NOR_SPIFI_AllowDTRMode()	Specifies if the physical layer is permitted to exchange data on both clock edges.
FS_NOR_SPIFI_AllowOctalMode()	Specifies if the physical layer is permitted to exchange all the data via eight data lines (octal mode).
FS_NOR_SPIFI_SetDeviceList()	Configures the type of handled serial NOR flash devices.
FS_NOR_SPIFI_SetDeviceParaList()	Configures parameters of serial NOR flash devices.
FS_NOR_SPIFI_SetHWType()	Configures the HW access routines.
FS_NOR_SPIFI_SetReadAlignment()	Specifies the alignment of the data read operation.
FS_NOR_SPIFI_SetSectorSize()	Configures the size of the physical sector to be used by the driver.

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6.4.4.6.2.1 FS_NOR_SPIFI_Allow2bitMode()

Description

Specifies if the physical layer is permitted to exchange data via two data lines.

Prototype

```
void FS_NOR_SPIFI_Allow2bitMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via two data lines is used only if this type of data transfer is supported by the serial NOR flash device. In dual mode two bits of data are transferred with each clock period which helps improve the performance. If the serial NOR flash device does not support the dual mode then the data is transferred in standard mode (one data bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.6.2.2 FS_NOR_SPIFI_Allow4bitMode()

Description

Specifies if the physical layer is permitted to exchange data via four data lines.

Prototype

```
void FS_NOR_SPIFI_Allow4bitMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via four data lines is used only if this type of data transfer is supported by the serial NOR flash device. In quad mode four bits of data are transferred on each clock period which helps improve the performance. If the serial NOR flash device does not support the quad mode then the data is transferred in dual mode if enabled and supported or in standard mode (one bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.6.2.3 FS_NOR_SPIFI_Allow8bitMode()

Description

Specifies if the physical layer is permitted to exchange data via eight data lines.

Prototype

```
void FS_NOR_SPIFI_Allow8bitMode(U8 Unit,
                                U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via eight data lines is used only if this type of data transfer is supported by the serial NOR flash device.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.6.2.4 FS_NOR_SPIFI_AllowDTRMode()

Description

Specifies if the physical layer is permitted to exchange data on both clock edges.

Prototype

```
void FS_NOR_SPIFI_AllowDTRMode(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged only on one of the clock edges (SDR mode). In DTR mode the data is transferred on each edge of the clock which helps improve the performance. The SPIFI NOR physical layer transfers the data in DTR mode only if the used serial NOR flash device supports it.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

The DTR mode is enabled only if the configured hardware layer implements the following optional functions: `FS_NOR_HW_TYPE_SPIFI_CONTROL_EX`, `FS_NOR_HW_TYPE_SPIFI_READ_EX` and `FS_NOR_HW_TYPE_SPIFI_WRITE_EX`

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6.4.4.6.2.5 FS_NOR_SPIFI_AllowOctalMode()

Description

Specifies if the physical layer is permitted to exchange all the data via eight data lines (octal mode).

Prototype

```
void FS_NOR_SPIFI_AllowOctalMode(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
OnOff	Activation status of the option. • 0 Disable the option. • 1 Enable the option.

Additional information

This function is optional. By default the data is exchanged via one data line (standard SPI). The data transfer via eight data lines is used only if this type of data transfer is supported by the serial NOR flash device. In octal mode eight bits of data are transferred with each clock period which helps improve the performance. If the serial NOR flash device does not support the octal mode then the data is transferred in standard mode (one bit per clock period).

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

The octal mode is enabled only if the configured hardware layer implements the following optional functions: `FS_NOR_HW_TYPE_SPIFI_CONTROL_EX`, `FS_NOR_HW_TYPE_SPIFI_READ_EX` and `FS_NOR_HW_TYPE_SPIFI_WRITE_EX`

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6.4.4.6.2.6 FS_NOR_SPIFI_SetDeviceList()

Description

Configures the type of handled serial NOR flash devices.

Prototype

```
void FS_NOR_SPIFI_SetDeviceList(      U8                       Unit,
                                const FS_NOR_SPI_DEVICE_LIST * pDeviceList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pDeviceList	List of NOR flash devices the physical layer can handle.

Additional information

This function is optional. By default the physical layer is configured to handle Micron serial NOR flash devices. Handling of serial NOR flash devices from other manufacturers has to be explicitly enabled via this function.

Permitted values for the pDeviceList parameter are:

Identifier
FS_NOR_SPI_DeviceListAdesto
FS_NOR_SPI_DeviceListAll
FS_NOR_SPI_DeviceListCypress
FS_NOR_SPI_DeviceListDefault
FS_NOR_SPI_DeviceListEon
FS_NOR_SPI_DeviceListGigaDevice
FS_NOR_SPI_DeviceListInfineon
FS_NOR_SPI_DeviceListInfineonOctal
FS_NOR_SPI_DeviceListISSI
FS_NOR_SPI_DeviceListMacronix
FS_NOR_SPI_DeviceListMacronixOctal
FS_NOR_SPI_DeviceList_Micron
FS_NOR_SPI_DeviceList_Micron_x
FS_NOR_SPI_DeviceList_Micron_x2

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Identifier
FS_NOR_SPI_DeviceList-Microchip
FS_NOR_SPI_DeviceListS-pansion
FS_NOR_SPI_De-viceListSTM
FS_NOR_SPI_DeviceList-Winbond

The application can save ROM space by setting FS_NOR_DEVICE_LIST_DEFAULT to NULL at compile time and by calling at runtime FS_NOR_SPIFI_SetDeviceList() with the actual list of serial NOR flash devices that have to be handled.

The application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

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6.4.4.6.2.7 FS_NOR_SPIFI_SetDeviceParaList()

Description

Configures parameters of serial NOR flash devices.

Prototype

```
void FS_NOR_SPIFI_SetDeviceParaList
                              (      U8                              Unit,
                               const FS_NOR_SPI_DEVICE_PARA_LIST * pDeviceParaList);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pDeviceParaList	List of device parameters.

Additional information

This function is optional. This function can be used to enable handling for vendor specific features of serial NOR flash device such as error handling and data protection. By default, the parameters of the used serial NOR flash device are determined by evaluating the SFDP tables stored in it. However, the information about the commands that can be used to write the data via two and four data lines is not stored to this parameters. `FS_NOR_SFDP_SetDeviceParaList()` can be used to specify this information. The parameters are matched by comparing the first byte (manufacturer id) and the third byte (device id) of the information returned by the READ ID (`0x9F`) function with the MfgId and Id members of the `FS_NOR_SPI_DEVICE_PARA` structure.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.4.4.6.2.8 FS_NOR_SPIFI_SetHWType()

Description

Configures the HW access routines.

Prototype

```
void FS_NOR_SPIFI_SetHWType(      U8                      Unit,
                            const FS_NOR_HW_TYPE_SPIFI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer.
pHWType	Hardware layer to be used for data exchanged.

Additional information

It is mandatory to call this function during the file system initialization in `FS_X_AddDevices()` once for each instance of a physical layer.

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6.4.4.6.2.9 FS_NOR_SPIFI_SetReadAlignment()

Description

Specifies the alignment of the data read operation.

Prototype

```
int FS_NOR_SPIFI_SetReadAlignment(U8       Unit,
                                  unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
NumBytes	Alignment in bytes.

Return value

= 0 OK, read alignment set correctly.
≠ 0 Error code indicating the failure reason.

Additional information

Permitted values for NumBytes are 1, 2, and 4.

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6.4.4.6.2.10 FS_NOR_SPIFI_SetSectorSize()

Description

Configures the size of the physical sector to be used by the driver.

Prototype

```
void FS_NOR_SPIFI_SetSectorSize(U8  Unit,
                                U32 BytesPerSector);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
BytesPerSector	Sector size to be used.

Additional information

Typically, a serial NOR flash device supports erase commands that can be used to erase sectors of different sizes (4 KB, 32 KB, etc.) For performance reasons the physical layer chooses always the erase command corresponding to the largest physical sector. This function can be used to request the physical layer to use a different (smaller) physical sector size. The mount operation fails if the serial NOR flash device does not support the specified physical sector size.

The application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

6.4.4.6.3 Additional functions

The API functions listed in the following table can be used by the application to operate directly with the SPIFI physical layer. These functions can be called only after the file system configuration is completed.

Function	Description
FS_NOR_SPIFI_ExecCmd()	Sends command sequences to NOR flash device.

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6.4.4.6.3.1 FS_NOR_SPIFI_ExecCmd()

Description

Sends command sequences to NOR flash device.

Prototype

```
int FS_NOR_SPIFI_ExecCmd(      U8         Unit,
                         const U8       * pCmd,
                               unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pCmd	List of command codes. Must be different than NULL.
NumBytes	Number of command codes. Must be different than 0.

Return value

= 0 OK, command sequence sent successfully.
≠ 0 Error code that indicates the failure reason.

Additional information

This function is optional. It can be used to send one or more single byte commands to a NOR flash device. Each command code has to be specified as a single byte in pCmd. The specified commands are executed sequentially in separate SPI transactions beginning with pCmd[0]. All the commands are sent in single SPI mode.

Example

```
#include "FS.h"

void SampleNOR_SPIFIExeCmd(void) {
  U8 abCmd[2];

  //
  // Execute a software reset of the NOR flash device.
  //
  abCmd[0] = 0x66;
  abCmd[1] = 0x99;
  FS_NOR_SPIFI_ExecCmd(0, abCmd, sizeof(abCmd));
}
```

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6.4.4.7 ST M25 physical layer

This physical layer supports legacy serial NOR flash devices.

6.4.4.7.1 Compile time configuration

The ST M25 physical layer can optionally be configured at compile time. Typically, this step can be omitted because reasonable default values are provided that work with most of the applications. The following table provides a summary of the configuration defines supported by this physical layer.

Define	Default value	Type	Description
FS_NOR_MAX_NUM_DEVICES	0	N	Maximum number of device parameters that the user is allowed to define.
FS_NOR_TIMEOUT_PAGE_WRITE	5	N	Timeout in milliseconds for the page program operation.
FS_NOR_TIMEOUT_SECTOR_ERASE	3000	N	Timeout in milliseconds for the sector erase operation.

6.4.4.7.1.1 FS_NOR_MAX_NUM_DEVICES

FS_NOR_MAX_NUM_DEVICES specifies the maximum number of user-defined device parameters. This configuration define is used together with FS_NOR_SPI_AddDevice().

6.4.4.7.1.2 FS_NOR_TIMEOUT_PAGE_WRITE

FS_NOR_TIMEOUT_PAGE_WRITE specifies the maximum number of milliseconds the physical layer has to wait for a write operation to complete. The completion of the write operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

6.4.4.7.1.3 FS_NOR_TIMEOUT_SECTOR_ERASE

FS_NOR_TIMEOUT_SECTOR_ERASE specifies the maximum number of milliseconds the physical layer has to wait for a physical sector erase operation to complete. The completion of the erase operation is determined by evaluating the value returned by the serial NOR flash device to a status request.

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6.4.4.7.2 Runtime configuration

The API functions listed in the following table can be used by the application to configure the behavior of the ST M25 physical layer. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_NOR_SPI_AddDevice()`	Specifies parameters for a NOR flash device that has to be supported.
`FS_NOR_SPI_Configure()`	Configures the parameters of the NOR flash device.
`FS_NOR_SPI_SetHWType()`	Configures the HW access routines.
`FS_NOR_SPI_SetPageSize()`	Specifies the number of bytes in page.

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6.4.4.7.2.1 FS_NOR_SPI_AddDevice()

Description

Specifies parameters for a NOR flash device that has to be supported.

Prototype

```
void FS_NOR_SPI_AddDevice(const FS_NOR_SPI_DEVICE_PARA * pDevicePara);
```

Parameters

Parameter	Description
pDevicePara	Device parameters.

Additional information

This function is optional. It allows an application to define the parameters of a NOR flash device that is not yet supported by the physical layer. The maximum number of NOR flash devices that can be added to the list can be specified via FS_NOR_MAX_NUM_DEVICES define. By default this feature is disabled, that is FS_NOR_MAX_NUM_DEVICES is set to 0. The data pointed to by pDevicePara should remain valid until FS_DeInit() is called, because the function saves internally only the pointer value.

This function is available only when the file system is compiled with FS_NOR_MAX_NUM_DEVICES set to a value larger than 0.

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6.4.4.7.2.2 FS_NOR_SPI_Configure()

Description

Configures the parameters of the NOR flash device.

Prototype

```
void FS_NOR_SPI_Configure(U8  Unit,
                          U32 SectorSize,
                          U32 NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
SectorSize	The size of a physical sector in bytes.
NumSectors	The number of physical sectors available.

Additional information

This function is optional. By default the physical layer identifies the parameters of the NOR flash device automatically using the information returned by the READ ID (0x9F) command. This method does not work for some older ST M25 NOR flash devices. In this case the application can use FS_NOR_SPI_Configure() to specify the parameters of the NOR flash device. SPI NOR (M25 series) flash devices have uniform sectors, which means only one sector size is used for the entire device.

The capacity of the serial NOR flash device is determined as follows:

Value of 3rd byte
0x11
0x12
0x13
0x14
0x15
0x16
0x17
0x18

The application required to call FS_NOR_SPI_Configure(), only if the serial NOR flash device does not identify itself with one of the values specified in the table above.

SectorSize must be set to the size of the size of the storage area erased via the Block Erase (0xD8) command. NumSectors is the device capacity in bytes divided by SectorSize.

The application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

Example

```
#include "FS.h"

#define ALLOC_SIZE        0x4000        // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
```

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```
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add the NOR driver driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  //
  // Configure manually a 16 Mbit SPI NOR flash.
  //
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_ST_M25);
  FS_NOR_SPI_Configure(0, 0x10000, 32);
  FS_NOR_Configure(0, 0, 0, 0x10000 * 32);
}
```

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6.4.4.7.2.3 FS_NOR_SPI_SetHWType()

Description

Configures the HW access routines.

Prototype

```
void FS_NOR_SPI_SetHWType(      U8                    Unit,
                          const FS_NOR_HW_TYPE_SPI * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pHWType	Hardware access routines. Cannot be NULL.

Additional information

This function is mandatory and it has to be called once for each instance of the physical layer.

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6.4.4.7.2.4 FS_NOR_SPI_SetPageSize()

Description

Specifies the number of bytes in page.

Prototype

```
void FS_NOR_SPI_SetPageSize(U8  Unit,
                            U16 BytesPerPage);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
BytesPerPage	Number of bytes in a page.

Additional information

This function is optional. A page is the largest amount of bytes that can be written at once to a serial NOR flash device. By default the physical layer uses a page size of 256 bytes a value that is supported by the majority of serial NOR flash devices.

The size of a page cannot be automatically detected by the physical layer at runtime. Therefore, if the used serial NOR flash device has a page size different than 256 bytes, FS_NOR_SPI_SetPageSize() has to be used to configure the page size to the actual value. The write operation fails if the page size used by the physical layer is larger than the page size used by the serial NOR flash device. The write operation works if the application specifies a smaller page size than the actual page size of the serial NOR flash device but the write performance will be worst.

BytesPerPage has to be a power of 2 value.

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6.4.4.7.2.5 FS_NOR_SPI_DEVICE_PARA

Description

Defines the parameters of a serial NOR flash device.

Type definition

```
typedef struct {
  U8   Id;
  U8   ldBytesPerSector;
  U8   ldBytesPerPage;
  U8   NumBytesAddr;
  U32  NumSectors;
  U8   Flags;
  U8   MfgId;
  U8   CmdWrite112;
  U8   CmdWrite122;
  U8   CmdWrite114;
  U8   CmdWrite144;
  U8   CmdErase;
} FS_NOR_SPI_DEVICE_PARA;
```

Structure members

Member	Description
Id	Value to identify the serial NOR flash device.
ldBytesPerSector	Number of bytes in a physical sector as power of 2 exponent.
ldBytesPerPage	Number of bytes in a page as a power of 2 exponent.
NumBytesAddr	Number of address bytes.
NumSectors	Total number of physical sectors in the device.
Flags	Additional functionality supported by device that requires special processing.
MfgId	Id of device manufacturer.
CmdWrite112	Code of the command that has to be used for writing the data to NOR flash via 2 data lines.
CmdWrite122	Code of the command that has to be used for writing the data to NOR flash via 2 data lines.
CmdWrite114	Code of the command that has to be used for writing the data to NOR flash via 4 data lines.
CmdWrite144	Code of the command that has to be used for writing the data to NOR flash via 4 data lines.
CmdErase	Code of the command that has to be used for erasing a physical sector.

Additional information

Flags is a bitwise-or combination of *Device operation flags* on page 998.

Id is matched against the 3rd byte that is returned as response to READ ID (0x9F) command. MfgId is matched against the 1st byte that is returned as response to READ ID (0x9F) command.

Valid values for NumBytesAddr are 3 and 4. 4 has to be configured for NOR flash devices with a capacity larger than 128 Mbit (16 MB).

The commands configured via CmdWrite112 and CmdWrite114 have to send the command code and the address via one data line. The commands configured via CmdWrite122 and CmdWrite144 have to send only the command code via one data line.

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If `CmdErase` is set to 0 then the NOR physical layer uses the SECTOR ERASE (`0xD8`) command. The value specified via `ldBytesPerSector` has to correspond to the number of bytes erased by this command.

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6.4.4.7.2.6 Device operation flags

Description

Values to be used for the Flags member of `FS_NOR_SPI_DEVICE_PARA`

Definition

```
#define FS_NOR_SPI_DEVICE_FLAG_ERROR_STATUS     (1uL << 0)
#define FS_NOR_SPI_DEVICE_FLAG_WEL_ADDR_MODE    (1uL << 1)
```

Symbols

Definition	Description
FS_NOR_SPI_DEVICE_FLAG_ERROR_STATUS	The device reports errors via Flag Status Register.
FS_NOR_SPI_DEVICE_FLAG_WEL_ADDR_MODE	The write enable latch has to be set before changing the address mode.

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6.4.4.7.3 Additional functions

The API functions listed in the following table can be used by the application to operate directly with the ST M25 physical layer.

Function	Description
FS_NOR_SPI_ReadDeviceId()	Reads device identification information from NOR flash device.

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6.4.4.7.3.1 FS_NOR_SPI_ReadDeviceId()

Description

Reads device identification information from NOR flash device.

Prototype

```
void FS_NOR_SPI_ReadDeviceId(U8         Unit,
                             U8       * pId,
                             unsigned   NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer (0-based).
pId	out Information read from NOR flash.
NumBytes	Number of bytes to read from NOR flash.

Additional information

The data returned by this function is the response to the READ ID (0x9F) command.

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6.4.4.8 Physical layer API

The physical layers that come with emFile provide support for most of the popular NOR flash device and target MCU types. Therefore, there is typically no need to modify any of the provided NOR physical layers. Typically, only the NOR hardware layer has to be adapted to a specific target hardware. However, when none of the provided NOR physical layers are compatible with the target hardware, a new NOR physical layer implementation is required. This section provides information about the API of the NOR physical layer that helps to create a new physical layer from scratch or to modify an existing one.

The API of the physical layer is implemented as a structure of type `FS_NOR_PHY_TYPE` that contains pointers to functions. The following sections describe these functions in detail together with the data structure passed to these functions as parameters.

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6.4.4.8.1 FS_NOR_PHY_TYPE

Description

NOR physical layer API.

Type definition

```
typedef struct {
  FS_NOR_PHY_TYPE_WRITE_OFF       * pfWriteOff;
  FS_NOR_PHY_TYPE_READ_OFF        * pfReadOff;
  FS_NOR_PHY_TYPE_ERASE_SECTOR    * pfEraseSector;
  FS_NOR_PHY_TYPE_GET_SECTOR_INFO * pfGetSectorInfo;
  FS_NOR_PHY_TYPE_GET_NUM_SECTORS * pfGetNumSectors;
  FS_NOR_PHY_TYPE_CONFIGURE       * pfConfigure;
  FS_NOR_PHY_TYPE_ON_SELECT_PHY   * pfOnSelectPhy;
  FS_NOR_PHY_TYPE_DE_INIT         * pfDeInit;
  FS_NOR_PHY_TYPE_IS_SECTOR_BLANK * pfIsSectorBlank;
  FS_NOR_PHY_TYPE_INIT            * pfInit;
} FS_NOR_PHY_TYPE;
```

Structure members

Member	Description
pfWriteOff	Writes data to the NOR flash device.
pfReadOff	Reads data from the NOR flash device.
pfEraseSector	Erases a NOR physical sector.
pfGetSectorInfo	Returns information about a NOR physical sector.
pfGetNumSectors	Returns the number of NOR physical sectors.
pfConfigure	Configures an instance of the NOR physical layer.
pfOnSelectPhy	Prepares the access to the NOR flash device.
pfDeInit	Frees the resources allocated by the NOR physical layer instance.
pfIsSectorBlank	Verifies if a NOR physical sector is blank.
pfInit	Initializes the instance of the NOR physical layer.

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6.4.4.8.2 FS_NOR_PHY_TYPE_WRITE_OFF

Description

Writes data to the NOR flash device.

Type definition

```
typedef int FS_NOR_PHY_TYPE_WRITE_OFF(      U8     Unit,
                                            U32    Off,
                                      const void * pData,
                                            U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
Off	Byte offset to write to.
pData	in Data to be written to NOR flash device.
NumBytes	Number of bytes to be written.

Return value

= 0 OK, data written.
≠ 0 An error occurred.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. The NOR driver calls this function when it writes data to the NOR flash device. It is guaranteed that the NOR driver tries to modify memory regions of the NOR flash device that are erased. This means that the function does not have to check if the memory region it has to modify are already erased. FS_NOR_PHY_TYPE_WRITE_OFF has to be able to handle write requests that stretch over multiple physical sectors.

Off specifies a number of bytes relative to the StartAddr value specified in the call to FS_NOR_PHY_TYPE_CONFIGURE.

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6.4.4.8.3 FS_NOR_PHY_TYPE_READ_OFF

Description

Reads data from the NOR flash device.

Type definition

```
typedef int FS_NOR_PHY_TYPE_READ_OFF(U8     Unit,
                                     void * pData,
                                     U32    Off,
                                     U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
pData	out Data read from NOR flash device.
Off	Byte offset to read from.
NumBytes	Number of bytes to be read.

Return value

= 0 OK, data read.
≠ 0 An error occurred.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. The NOR driver calls this function when it reads data from the NOR flash device. FS_NOR_PHY_TYPE_READ_OFF has to be able to handle read request that stretch over multiple physical sectors.

Off specifies a number of bytes relative to the StartAddr value specified in the call to FS_NOR_PHY_TYPE_CONFIGURE.

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6.4.4.8.4 FS_NOR_PHY_TYPE_ERASE_SECTOR

Description

Erases a NOR physical sector.

Type definition

```
typedef int FS_NOR_PHY_TYPE_ERASE_SECTOR(U8           Unit,
                                         unsigned int SectorIndex);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
SectorIndex	Index of the NOR physical sector to be erased.

Return value

= 0 OK, physical sector is not blank.
≠ 0 An error occurred.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. The NOR driver calls this function when it erases a physical sector NOR flash device. The erase operation must set to 1 all the bits in the specified physical sector.

SectorIndex is relative to StartAddr value specified in the call to FS_NOR_PHY_TYPE_CONFIGURE. The physical sector located at StartAddr has the index 0.

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6.4.4.8.5 FS_NOR_PHY_TYPE_GET_SECTOR_INFO

Description

Returns information about a NOR physical sector.

Type definition

```
typedef void FS_NOR_PHY_TYPE_GET_SECTOR_INFO(U8           Unit,
                                             unsigned int SectorIndex,
                                             U32        * pOff,
                                             U32        * pNumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
SectorIndex	Index of the NOR physical sector to be queried.
pOff	out Byte offset of the NOR physical sector. Can be NULL.
pNumBytes	out Number of bytes in the NOR physical sector. Can be NULL.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. The NOR driver calls this function when it tries to determine the position and the size of a physical sector.

The value returned via pOff and SectorIndex are relative to StartAddr value specified in the call to FS_NOR_PHY_TYPE_CONFIGURE.

An error can be reported by setting *pNumBytes to 0 or by setting

- pOff to 0xFFFFFFFF.

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6.4.4.8.6 FS_NOR_PHY_TYPE_GET_NUM_SECTORS

Description

Returns the number of NOR physical sectors.

Type definition

```
typedef int FS_NOR_PHY_TYPE_GET_NUM_SECTORS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Return value

≠ 0 OK, the number of NOR physical sectors.
= 0 An error occurred.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. The value returned by this function is the number of physical sectors located in the memory region specified by StartAddr and NumBytes values specified in the call to `FS_NOR_PHY_TYPE_CONFIGURE`.

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6.4.4.8.7 FS_NOR_PHY_TYPE_CONFIGURE

Description

Configures an instance of the NOR physical layer.

Type definition

```
typedef void FS_NOR_PHY_TYPE_CONFIGURE(U8  Unit,
                                       U32 BaseAddr,
                                       U32 StartAddr,
                                       U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
BaseAddr	Address in system memory where the first byte of the NOR flash device is mapped.
StartAddr	Address of the first byte of the NOR flash device to be used for data storage.
NumBytes	Number of bytes to be used for data storage.

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layers. FS_NOR_PHY_TYPE_CONFIGURE is called by the NOR driver during the initialization of the file system.

For more information about the parameters refer to FS_NOR_Configure() and FS_NOR_BM_Configure().

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6.4.4.8.8 FS_NOR_PHY_TYPE_ON_SELECT_PHY

Description

Prepares the access to the NOR flash device.

Type definition

```
typedef void FS_NOR_PHY_TYPE_ON_SELECT_PHY(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented by all the NOR physical layer. The NOR driver calls this function during the file system initialization when a NOR physical layer is assigned to a driver instance. Typically, FS_NOR_PHY_TYPE_ON_SELECT_PHY allocates the memory requires for the instance of the NOR physical layer and set up everything requires for the access to NOR flash device.

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6.4.4.8.9 FS_NOR_PHY_TYPE_DE_INIT

Description

Frees the resources allocated by the NOR physical layer instance.

Type definition

```
typedef void FS_NOR_PHY_TYPE_DE_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Additional information

This function is a member of the NOR physical layer API. It is mandatory to be implemented only by the NOR physical layers that allocate dynamic memory. `FS_NOR_PHY_TYPE_DE_INIT` is called by the NOR driver at the file system deinitialization when the application calls `FS_DeInit()`. It has to free any dynamic memory allocated for the instance of specified the NOR physical layer.

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6.4.4.8.10 FS_NOR_PHY_TYPE_IS_SECTOR_BLANK

Description

Verifies if a NOR physical sector is blank.

Type definition

```
typedef int FS_NOR_PHY_TYPE_IS_SECTOR_BLANK(U8           Unit,
                                            unsigned int SectorIndex);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)
SectorIndex	Index of the NOR physical sector to be checked.

Return value

≠ 0 NOR physical sector is blank.
= 0 NOR physical sector is not blank.

Additional information

This function is a member of the NOR physical layer API. The implementation of this function is optional. By default the NOR driver checks if a physical sector is blank by reading the entire contents of the physical sector and by checking that all bits are set to 1. If the hardware provides a faster method to check if a physical sector is blank then this function can implemented to use this method for increasing the write performance. If the operation of the NOR driver has to be fail-safe then FS_NOR_PHY_TYPE_IS_SECTOR_BLANK must be able to detect an interrupted erase operation and in that case return that the physical sector is not blank even when all the bits in the physical sector read as 1.

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6.4.4.8.11 FS_NOR_PHY_TYPE_INIT

Description

Initializes the instance of the NOR physical layer.

Type definition

```
typedef int FS_NOR_PHY_TYPE_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the physical layer instance (0-based)

Return value

= 0 OK, physical layer initialized.
≠ 0 An error occurred.

Additional information

This function is a member of the NOR physical layer API. The implementation of this function is optional. If implemented, FS_NOR_PHY_TYPE_INIT is called by the NOR driver before the first access to the NOR flash device to identify the device, read the device parameters, etc.

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6.4.4.9 Resource usage

This section describes the ROM and RAM usage of the NOR physical layers.

6.4.4.9.1 ROM usage

The ROM usage depends on the compiler options, the compiler version, and the CPU used. The memory requirements of the NOR physical layers were measured as described in the section *Test procedure* on page 1439.
The following table lists the ROM usage of all the available NOR physical layers.

Name	ROM usage (Kbytes)
CFI 1x16	**3.0**
CFI 2x16	**3.1**
DSPI	**6.2**
SFDP	**4.0**
SPIFI	**3.8**
ST M25	**1.8**

6.4.4.9.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for static variables inside the driver. The number of bytes can be seen in a compiler list file. The next table lists the static RAM usage of all the available NOR physical layers.

Name	RAM usage (bytes)
CFI 1x16	**20**
CFI 2x16	**20**
DSPI	**20**
SFDP	**20**
SPIFI	**20**
ST M25	**20**

6.4.4.9.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the physical layer at runtime. The amount of RAM required depends on the compile time and runtime configuration. The following table lists the dynamic RAM usage of the available NOR physical layers.

Name	RAM usage (bytes)
CFI 1x16	**64**
CFI 2x16	**64**
DSPI	**0**
SFDP	**116**
SPIFI	**120**
ST M25	**38**

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6.4.5 NOR hardware layer

6.4.5.1 General information

The NOR hardware layer provides functionality for accessing a NOR flash device via the target hardware, such as an external memory controller, GPIO, SPI, etc. The functions of the NOR hardware layer are called by the NOR physical layer to exchange commands and data with a NOR flash device. These functions are hardware-dependent, and therefore they have to be implemented in the application. emFile comes with template hardware layers and sample implementations for popular evaluation boards that can be used as a starting point for implementing new hardware layers. The relevant files are located in the `/Sample/FS/Driver/NOR` folder of the emFile shipment.

The functions of the NOR hardware layer are organized in a function table implemented as a C structure. Different hardware layer types are provided to support different ways of interfacing a NOR flash device. The type of hardware layer an application has to use depends on the type of NOR physical layer configured. The following table shows what hardware layer is required by each physical layer.

NOR hardware layer	NOR physical layer

`FS_NOR_HW_TYPE_SPI`	`FS_NOR_PHY_DSPI`
	`FS_NOR_PHY_SFDP`
	`FS_NOR_PHY_ST_M25`

`FS_NOR_HW_TYPE_SPIFI`	`FS_NOR_PHY_SPIFI`

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6.4.5.2 Hardware layer API - FS_NOR_HW_TYPE_SPI

This hardware layer supports serial NOR flash devices that are interfaced via single or extended SPI. It is able to transfer the data via one, two or four data lines. The functions of this hardware layer are grouped in a structure of type `FS_NOR_HW_TYPE_SPI`. The following sections describe these functions in detail.

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6.4.5.2.1 FS_NOR_HW_TYPE_SPI

Description

Hardware layer for serial NOR flash devices.

Type definition

```
typedef struct {
  FS_NOR_HW_TYPE_SPI_INIT       * pfInit;
  FS_NOR_HW_TYPE_SPI_ENABLE_CS  * pfEnableCS;
  FS_NOR_HW_TYPE_SPI_DISABLE_CS * pfDisableCS;
  FS_NOR_HW_TYPE_SPI_READ       * pfRead;
  FS_NOR_HW_TYPE_SPI_WRITE      * pfWrite;
  FS_NOR_HW_TYPE_SPI_READ_X2    * pfRead_x2;
  FS_NOR_HW_TYPE_SPI_WRITE_X2   * pfWrite_x2;
  FS_NOR_HW_TYPE_SPI_READ_X4    * pfRead_x4;
  FS_NOR_HW_TYPE_SPI_WRITE_X4   * pfWrite_x4;
  FS_NOR_HW_TYPE_SPI_DELAY      * pfDelay;
  FS_NOR_HW_TYPE_SPI_LOCK       * pfLock;
  FS_NOR_HW_TYPE_SPI_UNLOCK     * pfUnlock;
  FS_NOR_HW_TYPE_SPI_READ_EX    * pfReadEx;
  FS_NOR_HW_TYPE_SPI_WRITE_EX   * pfWriteEx;
} FS_NOR_HW_TYPE_SPI;
```

Structure members

Member	Description
pfInit	Initializes the SPI hardware.
pfEnableCS	Enables the serial NOR flash device.
pfDisableCS	Disables the serial NOR flash device.
pfRead	Transfers data from serial NOR flash device to MCU via 1 data line.
pfWrite	Transfers data from MCU to serial NOR flash device via 1 data line.
pfRead_x2	Transfers data from serial NOR flash device to MCU via 2 data lines.
pfWrite_x2	Transfers data from MCU to serial NOR flash device via 2 data lines.
pfRead_x4	Transfers data from serial NOR flash device to MCU via 4 data lines.
pfWrite_x4	Transfers data from MCU to serial NOR flash device via 4 data lines.
pfDelay	Blocks the execution for the specified time.
pfLock	Requests exclusive access to SPI bus.
pfUnlock	Releases the exclusive access to SPI bus.
pfReadEx	Transfers data from serial NOR flash device to MCU.
pfWriteEx	Transfers data from MCU to serial NOR flash device.

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6.4.5.2.2 FS_NOR_HW_TYPE_SPI_INIT

Description

Initializes the SPI hardware.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPI_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

> 0 OK, frequency of the SPI clock in kHz.
= 0 An error occurred.

Additional information

This function is a member of the SPI NOR hardware layer API. It has to be implemented by all the hardware layers.

This function is called by the NOR physical layer once and before any other function of the hardware layer each time the file system mounts the serial NOR flash.

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6.4.5.2.3 FS_NOR_HW_TYPE_SPI_ENABLE_CS

Description

Enables the serial NOR flash device.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_ENABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPI NOR hardware layer API. It has to be implemented by all the hardware layers.

The Chip Select (CS) signal is used to address a specific serial NOR flash device connected via SPI. Enabling is equal to setting the CS signal to a logic low level.

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6.4.5.2.4 FS_NOR_HW_TYPE_SPI_DISABLE_CS

Description

Disables the serial NOR flash device.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_DISABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPI NOR hardware layer API. It has to be implemented by all the hardware layers.

The Chip Select (CS) signal is used to address a specific serial NOR flash device connected via SPI. Disabling is equal to setting the CS signal to a logic high level.

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6.4.5.2.5 FS_NOR_HW_TYPE_SPI_READ

Description

Transfers data from serial NOR flash device to MCU via 1 data line.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_READ(U8   Unit,
                                     U8 * pData,
                                     int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data transferred from the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. FS_NOR_HW_TYPE_SPI_READ does not have to be implemented if the hardware layer provides an implementation for FS_NOR_HW_TYPE_SPI_READ_EX.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.6 FS_NOR_HW_TYPE_SPI_WRITE

Description

Transfers data from MCU to serial NOR flash device via 1 data line.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_WRITE(      U8   Unit,
                                      const U8 * pData,
                                            int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	in Data transferred to the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. FS_NOR_HW_TYPE_SPI_WRITE does not have to be implemented if the hardware layer provides an implementation for FS_NOR_HW_TYPE_SPI_WRITE_EX.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.7 FS_NOR_HW_TYPE_SPI_READ_X2

Description

Transfers data from serial NOR flash device to MCU via 2 data lines.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_READ_X2(U8   Unit,
                                        U8 * pData,
                                        int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data transferred from the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

FS_NOR_HW_TYPE_SPI_READ_X2 transfers 2 bits of data on each clock period. Typically, the data is transferred via the DataOut (DO) and DataIn (DI) signals of the serial NOR flash where the even numbered bits of a byte are sent via the DI signal while the odd-numbered bits via the DO signal.

FS_NOR_HW_TYPE_SPI_READ_X2 is used only by the SFDP NOR physical layer.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.8 FS_NOR_HW_TYPE_SPI_WRITE_X2

Description

Transfers data from MCU to serial NOR flash device via 2 data lines.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_WRITE_X2(      U8   Unit,
                                         const U8 * pData,
                                               int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	in Data transferred to the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

FS_NOR_HW_TYPE_SPI_WRITE_X2 transfers 2 bits of data on each clock period. Typically, the data is transferred via the DataOut (DO) and DataIn (DI) signals of the serial NOR flash where the even numbered bits of a byte are sent via the DI signal while the odd-numbered bits via the DO signal.

FS_NOR_HW_TYPE_SPI_WRITE_X2 is used only by the SFDP NOR physical layer.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.9 FS_NOR_HW_TYPE_SPI_READ_X4

Description

Transfers data from serial NOR flash device to MCU via 4 data lines.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_READ_X4(U8   Unit,
                                        U8 * pData,
                                        int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data transferred from the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

FS_NOR_HW_TYPE_SPI_READ_X4 exchanges 4 bits of data on each clock period. Typically, the data is transferred via the DataOut (DO), DataIn (DO), Write Protect (WP), and Hold (H) signals of the serial NOR flash device. A byte is transferred as follows:

- bits 0 and 4 via the DI signal
- bits 1 and 5 via the DO signal
- bits 2 and 6 via the WP signal
- bits 3 and 7 via the H signal.

FS_NOR_HW_TYPE_SPI_READ_X4 is used only by the SFDP NOR physical layer.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.10 FS_NOR_HW_TYPE_SPI_WRITE_X4

Description

Transfers data from MCU to serial NOR flash device via 4 data lines.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_WRITE_X4(      U8   Unit,
                                         const U8 * pData,
                                               int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	in Data transferred to the serial NOR flash device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

FS_NOR_HW_TYPE_SPI_WRITE_X4 exchanges 4 bits of data on each clock period. Typically, the data is transferred via the DataOut (DO), DataIn (DO), Write Protect (WP), and Hold (H) signals of the serial NOR flash device. A byte is transferred as follows:

- bits 0 and 4 via the DI signal
- bits 1 and 5 via the DO signal
- bits 2 and 6 via the WP signal
- bits 3 and 7 via the H signal.

FS_NOR_HW_TYPE_SPI_WRITE_X4 is used only by the SFDP NOR physical layer.

The file system may potentially call this function with NumBytes set to 0. In this case the function does not have to perform any operation.

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6.4.5.2.11 FS_NOR_HW_TYPE_SPI_DELAY

Description

Blocks the execution for the specified time.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPI_DELAY(U8  Unit,
                                     U32 ms);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
ms	Number of milliseconds to block the execution.

Return value

= 0 OK, delay executed.
< 0 Functionality not supported.

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional. FS_NOR_HW_TYPE_SPI_DELAY can block the execution for longer than the number of milliseconds specified but not less than that. Typically, the function is implemented using a delay function of the used RTOS if any. If the hardware layer chooses not to implement FS_NOR_HW_TYPE_SPI_DELAY then the pfDelay member of FS_NOR_HW_TYPE_SPI can be set to NULL or to the address of a function that returns a negative value. If the function is not implemented by the hardware layer then the NOR physical layer blocks the execution by using a software loop. The number of software loops is calculated based in the SPI clock frequency returned by FS_NOR_HW_TYPE_SPI_INIT.

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6.4.5.2.12 FS_NOR_HW_TYPE_SPI_LOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function to indicate that it needs exclusive to access the NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling this function first. It is also guaranteed that FS_NOR_HW_TYPE_SPI_LOCK and FS_NOR_HW_TYPE_SPI_UNLOCK are called in pairs. Typically, this function is used for synchronizing the access to SPI bus when the SPI bus is shared between the serial NOR flash and other SPI devices.

A possible implementation would make use of an OS semaphore that is acquired in FS_NOR_HW_TYPE_SPI_LOCK and released in FS_NOR_HW_TYPE_SPI_UNLOCK.

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6.4.5.2.13 FS_NOR_HW_TYPE_SPI_UNLOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function after it no longer needs to access the serial NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling FS_NOR_HW_TYPE_SPI_LOCK. It is also guaranteed that FS_NOR_HW_TYPE_SPI_UNLOCK and FS_NOR_HW_TYPE_SPI_LOCK are called in pairs.

FS_NOR_HW_TYPE_SPI_UNLOCK and FS_NOR_HW_TYPE_SPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the serial NAND flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired FS_NOR_HW_TYPE_SPI_LOCK and released in FS_NOR_HW_TYPE_SPI_UNLOCK.

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6.4.5.2.14 FS_NOR_HW_TYPE_SPI_READ_EX

Description

Transfers data from serial NOR flash device to MCU.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPI_READ_EX(U8   Unit,
                                       U8 * pData,
                                       U32  NumBytes,
                                       U8   BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data transferred from the serial NOR flash device.
NumBytes	Number of bytes to be transferred.
BusWidth	Number of data lines to be used for the data transfer.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI NOR hardware layer API. FS_NOR_HW_TYPE_SPI_READ_EX does not have to be implemented if the hardware layer provides an implementation for FS_NOR_HW_TYPE_SPI_READ.

The difference between FS_NOR_HW_TYPE_SPI_READ_EX and FS_NOR_HW_TYPE_SPI_READ is that FS_NOR_HW_TYPE_SPI_READ_EX is able to transfer the data via a specified number of data lines and to report errors via the return value.

BusWidth permitted values are 1, 2 and 4.

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6.4.5.2.15 FS_NOR_HW_TYPE_SPI_WRITE_EX

Description

Transfers data from MCU to serial NOR flash device.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPI_WRITE_EX(      U8   Unit,
                                        const U8 * pData,
                                              U32  NumBytes,
                                              U8   BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	in Data transferred to the serial NOR flash device.
NumBytes	Number of bytes to be transferred.
BusWidth	Number of data lines to be used for the data transfer.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI NOR hardware layer API. FS_NOR_HW_TYPE_SPI_WRITE_EX does not have to be implemented if the hardware layer provides an implementation for FS_NOR_HW_TYPE_SPI_WRITE.

The difference between FS_NOR_HW_TYPE_SPI_WRITE_EX and FS_NOR_HW_TYPE_SPI_WRITE is that FS_NOR_HW_TYPE_SPI_WRITE_EX is able to transfer the data via a specified number of data lines and to report errors via the return value.

BusWidth permitted values are 1, 2 and 4.

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6.4.5.2.16 Sample implementation

The following sample implementation uses the SPI controller of an NXP K66 MCU to interface with a serial NOR flash device. This NOR hardware layer was tested on the SEGGER emPower board (https://www.segger.com/evaluate-our-software/segger/empower/)

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_NOR_HW_SPI_K66_SEGGER_emPower.c
Purpose : NOR SPI hardware layer for the SEGGER emPower board
Literature:
  [1] K66 Sub-Family Reference Manual
  [2] emPower Evaluation and prototyping platform for SEGGER software User Guide & Reference Manual
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_NOR_HW_SPI_BUS_CLK_HZ
  #define FS_NOR_HW_SPI_BUS_CLK_HZ          (168000000uL / 3)   // SPI module clock
#endif

#ifndef   FS_NOR_HW_SPI_NOR_CLK_HZ
  #define FS_NOR_HW_SPI_NOR_CLK_HZ          28000000uL          // Clock of NOR flash device
#endif

#ifndef   FS_NOR_HW_SPI_INIT_WAIT_LOOPS
  #define FS_NOR_HW_SPI_INIT_WAIT_LOOPS     20000               // Waits about
 1ms for the SPI module to start/stop
#endif

#ifndef   FS_NOR_HW_SPI_UNIT_NO
  #define FS_NOR_HW_SPI_UNIT_NO             0
  // Selects the number of SPI unit to be used for data transfer (Permitted values: 0 and 2)
#endif

#ifndef   FS_NOR_HW_SPI_USE_OS
  #define FS_NOR_HW_SPI_USE_OS              0
  // Enables / disables the event-driven operation.
                                                                  //   0 - OS support disabled.
                                                                  //   1
 - OS support enabled using OS event of emFile.
                                                                  //   2
 - OS support enabled using OS events of this HW layer.
#endif

/*********************************************************************
*
*       #include section, conditional
*
**********************************************************************
*/
#if FS_NOR_HW_SPI_USE_OS
  #include "FS_OS.h"
  #include "RTOS.h"
  #include "MK66F18.h"
#endif // FS_NOR_HW_SPI_USE_OS
```

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```
/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*       SPI module
*/
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
  #define SPI_BASE_ADDR     0x400AC000uL
#else
  #define SPI_BASE_ADDR     0x4002C000uL
#endif
#define SPI_MCR             (*(volatile U32 *)(SPI_BASE_ADDR + 0x00))
  // Module Configuration Register
#define SPI_TCR             (*(volatile U32 *)(SPI_BASE_ADDR + 0x08))     // Transfer Count Register
#define SPI_CTAR0           (*(volatile U32 *)(SPI_BASE_ADDR + 0x0C))
  // Clock and Transfer Attributes Register (In Master Mode)
#define SPI_CTAR1           (*(volatile U32 *)(SPI_BASE_ADDR + 0x10))
  // Clock and Transfer Attributes Register (In Master Mode)
#define SPI_SR              (*(volatile U32 *)(SPI_BASE_ADDR + 0x2C))     // Status Register
#define SPI_RSER            (*(volatile U32 *)(SPI_BASE_ADDR + 0x30))
  // DMA/Interrupt Request Select and Enable Register
#define SPI_PUSHR           (*(volatile U32 *)(SPI_BASE_ADDR + 0x34))
  // PUSH TX FIFO Register In Master Mode
#define SPI_POPR            (*(volatile U32 *)(SPI_BASE_ADDR + 0x38))     // POP RX FIFO Register
#define SPI_TXFR0           (*(volatile U32 *)(SPI_BASE_ADDR + 0x3C))     // Transmit FIFO Registers
#define SPI_TXFR1           (*(volatile U32 *)(SPI_BASE_ADDR + 0x40))     // Transmit FIFO Registers
#define SPI_TXFR2           (*(volatile U32 *)(SPI_BASE_ADDR + 0x44))     // Transmit FIFO Registers
#define SPI_TXFR3           (*(volatile U32 *)(SPI_BASE_ADDR + 0x48))     // Transmit FIFO Registers
#define SPI_RXFR0           (*(volatile U32 *)(SPI_BASE_ADDR + 0x7C))     // Receive FIFO Registers
#define SPI_RXFR1           (*(volatile U32 *)(SPI_BASE_ADDR + 0x80))     // Receive FIFO Registers
#define SPI_RXFR2           (*(volatile U32 *)(SPI_BASE_ADDR + 0x84))     // Receive FIFO Registers
#define SPI_RXFR3           (*(volatile U32 *)(SPI_BASE_ADDR + 0x88))     // Receive FIFO Registers

#if (FS_NOR_HW_SPI_USE_OS == 0)

/*********************************************************************
*
*       System integration module
*/
#define SIM_BASE_ADDR       0x40047000uL
#define SIM_SCGC3           (*(volatile U32 *)(SIM_BASE_ADDR + 0x1030))
  // System Clock Gating Control Register 3
#define SIM_SCGC5           (*(volatile U32 *)(SIM_BASE_ADDR + 0x1038))
  // System Clock Gating Control Register 5
#define SIM_SCGC6           (*(volatile U32 *)(SIM_BASE_ADDR + 0x103C))
  // System Clock Gating Control Register 6

/*********************************************************************
*
*       Port B
*/
#define PORTB_BASE_ADDR     0x4004A000uL
#define PORTB_PCR20         (*(volatile U32 *)(PORTB_BASE_ADDR + 0x50))   // Port Control Register
#define PORTB_PCR21         (*(volatile U32 *)(PORTB_BASE_ADDR + 0x54))   // Port Control Register
#define PORTB_PCR22         (*(volatile U32 *)(PORTB_BASE_ADDR + 0x58))   // Port Control Register
#define PORTB_PCR23         (*(volatile U32 *)(PORTB_BASE_ADDR + 0x5C))   // Port Control Register
#define PORTB_DFER          (*(volatile U32 *)(PORTB_BASE_ADDR + 0xC0))
  // Digital filter enable register

/*********************************************************************
*
*       Port C
*/
#define PORTC_BASE_ADDR     0x4004B000uL
#define PORTC_PCR4          (*(volatile U32 *)(PORTC_BASE_ADDR + 0x10))   // Port Control Register
#define PORTC_PCR5          (*(volatile U32 *)(PORTC_BASE_ADDR + 0x14))   // Port Control Register
#define PORTC_PCR6          (*(volatile U32 *)(PORTC_BASE_ADDR + 0x18))   // Port Control Register
#define PORTC_PCR7          (*(volatile U32 *)(PORTC_BASE_ADDR + 0x1C))   // Port Control Register
#define PORTC_DFER          (*(volatile U32* )(PORTC_BASE_ADDR + 0xC0))
  // Digital filter enable register
```

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```
/*********************************************************************
*
*       GPIO B
*/
#define GPIOB_BASE_ADDR     0x400FF040uL
#define GPIOB_PDOR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x00))
  // Port Data Output Register
#define GPIOB_PSOR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x04))
  // Port Set Output Register
#define GPIOB_PCOR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x08))
  // Port Clear Output Register
#define GPIOB_PTOR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x0C))
  // Port Toggle Output Register
#define GPIOB_PDIR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x10))
  // Port Data Input Register
#define GPIOB_PDDR          (*(volatile U32 *)(GPIOB_BASE_ADDR + 0x14))
  // Port Data Direction Register

/*********************************************************************
*
*       GPIO C
*/
#define GPIOC_BASE_ADDR     0x400FF080uL
#define GPIOC_PDOR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x00))
  // Port Data Output Register
#define GPIOC_PSOR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x04))
  // Port Set Output Register
#define GPIOC_PCOR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x08))
  // Port Clear Output Register
#define GPIOC_PTOR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x0C))
  // Port Toggle Output Register
#define GPIOC_PDIR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x10))
  // Port Data Input Register
#define GPIOC_PDDR          (*(volatile U32 *)(GPIOC_BASE_ADDR + 0x14))
  // Port Data Direction Register

#else

/*********************************************************************
*
*       Port C
*/
#define PORTC_BASE_ADDR     0x4004B000uL
#define PORTC_DFER          (*(volatile U32* )(PORTC_BASE_ADDR + 0xC0))
  // Digital filter enable register

#endif // FS_NOR_HW_SPI_USE_OS

/*********************************************************************
*
*       Port Control Register
*/
#define PCR_MUX_BIT         8     // Alternate port setting
#define PCR_MUX_GPIO        1uL   // Controlled directly by the HW layer
#define PCR_MUX_SPI0        2uL   // Controlled by SPI module
#define PCR_MUX_SPI2        2uL   // Controlled by SPI module
#define PCR_MUX_MASK        0x7uL
#define PCR_DSE_BIT         6     // Driver strength enable
#define PCR_PE_BIT          1     // Pull enable
#define PCR_PS_BIT          0     // Pull-up enable

/*********************************************************************
*
*       Clock enable bits
*/
#define SCGC3_SPI2_BIT      12  // SPI2
#define SCGC5_PORTB_BIT     10  // GPIO B
#define SCGC5_PORTC_BIT     11  // GPIO C
#define SCGC6_SPI0_BIT      12  // SPI0

/*********************************************************************
*
*       SPI Module Configuration Register
*/
#define MCR_MSTR_BIT        31
#define MCR_FRZ_BIT         27
```

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```
#define MCR_CLR_TXF_BIT     11
#define MCR_CLR_RXF_BIT     10
#define MCR_HALT_BIT        0

/*********************************************************************
*
*       SPI Status Register
*/
#define SR_TCF_BIT          31
#define SR_TXRXS_BIT        30
#define SR_EOQF_BIT         28
#define SR_TFUF_BIT         27
#define SR_TFFF_BIT         25
#define SR_RFOF_BIT         19
#define SR_RFDF_BIT         17
#define SR_RXCTR_BIT        4
#define SR_RXCTR_MASK       0xFuL

/*********************************************************************
*
*       SPI Clock and Transfer Attributes Register
*/
#define CTAR_DBR_BIT        31
#define CTAR_FMSZ_BIT       27
#define CTAR_CPOL_BIT       26
#define CTAR_CPHA_BIT       25
#define CTAR_BR_BIT         0
#define CTAR_BR_MAX         0xFuL

/*********************************************************************
*
*       SPI misc. defines
*/
#define PUSHR_CTAS_BIT      28
#define RSER_RFDF_RE_BIT    17
#define SPI_IRQ_PRIO        15
#define WAIT_TIMEOUT_MS     1000

/*********************************************************************
*
*       NOR flash pin assignments
*/
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
  #define NOR_CS_PIN        20  // Port B
  #define NOR_CLK_PIN       21  // Port B
  #define NOR_MOSI_PIN      22  // Port B
  #define NOR_MISO_PIN      23  // Port B
#else
  #define NOR_CS_PIN        4   // Port C
  #define NOR_CLK_PIN       5   // Port C
  #define NOR_MOSI_PIN      6   // Port C
  #define NOR_MISO_PIN      7   // Port C
#endif

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
#if (FS_NOR_HW_SPI_USE_OS == 2)
  static U8         _IsEventInited = 0;
  static OS_EVENT   _Event;
#endif // FS_NOR_HW_SPI_USE_OS == 2

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

#if FS_NOR_HW_SPI_USE_OS

/*********************************************************************
*
```

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```
*       _WaitForEvent
*
*  Function description
*    Waits for the interrupt to wake up the task.
*
*  Parameters
*    TimeOut      Maximum time to wait for the event in milliseconds.
*
*  Return values
*    ==0      OK, event signaled.
*    !=0      An error occurred.
*/
static int _WaitForEvent(U32 TimeOut) {
  int r;

  SPI_RSER |= 1uL << RSER_RFDF_RE_BIT;        // Enable the interrupt.
#if (FS_NOR_HW_SPI_USE_OS == 2)
  r = OS_EVENT_WaitTimed(&_Event, TimeOut);
#else
  r = FS_OS_Wait(TimeOut);
#endif
  if (r != 0) {
    SPI_RSER &= ~(1uL << RSER_RFDF_RE_BIT);   // Disable the interrupt.
  }
  return r;
}

#endif // FS_NOR_HW_SPI_USE_OS

/*********************************************************************
*
*       _StoreU16BE
*
*  Function description
*    Stores a 16 bit value in big endian format into a byte array.
*/
static void _StoreU16BE(U8 *pBuffer, unsigned Data) {
  *pBuffer++ = (U8)(Data >> 8);
  *pBuffer   = (U8) Data;
}

/*********************************************************************
*
*       _LoadU16BE
*
*  Function description
*    Reads a 16 bit value stored in big endian format from a byte array.
*/
static U16 _LoadU16BE(const U8 * pBuffer) {
  U16 r;

  r = *pBuffer++;
  r = (U16)((r << 8) | *pBuffer);
  return r;
}

/*********************************************************************
*
*       _Transfer8Bit
*/
static U8 _Transfer8Bit(U8 Data) {
  U32 NumBytes;

  SPI_PUSHR = Data;
  //
  // Wait to receive 1 byte.
  //
  while (1) {
    NumBytes = (SPI_SR >> SR_RXCTR_BIT) & SR_RXCTR_MASK;
    if (NumBytes == 1) {
      break;
    }
#if FS_NOR_HW_SPI_USE_OS
    {
      int r;
```

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```
      r = _WaitForEvent(WAIT_TIMEOUT_MS);
      if (r != 0) {
        break;
      }
    }
#endif // FS_NOR_HW_SPI_USE_OS
  }
  Data = (U8)SPI_POPR;
  return Data;
}

#if (FS_NOR_HW_SPI_UNIT_NO == 0)

/*********************************************************************
*
*       _Read64Bits
*
*  Function description
*    Transfers 64 bits of data from NOR device to MCU.
*/
static void _Read64Bits(U8 * pData) {
  U16 Data16;
  U32 NumItems;
  U32 Dummy;

  //
  // Send dummy data.
  //
  Dummy = 0
        | 0xFFFFuL
        | (1uL << PUSHR_CTAS_BIT)
  // Use the second set of parameters which is configured for 16-bit transfers.
        ;
  SPI_PUSHR = Dummy;
  SPI_PUSHR = Dummy;
  SPI_PUSHR = Dummy;
  SPI_PUSHR = Dummy;
  //
  // Wait to receive 4 half-words (4 is the FIFO size)
  //
  while (1) {
    NumItems = (SPI_SR >> SR_RXCTR_BIT) & SR_RXCTR_MASK;
    if (NumItems == 4) {
      break;
    }
#if FS_NOR_HW_SPI_USE_OS
    {
      int r;

      r = _WaitForEvent(WAIT_TIMEOUT_MS);
      if (r != 0) {
        break;
      }
    }
#endif // FS_NOR_HW_SPI_USE_OS
  }
  //
  // Read data from FIFO.
  //
  Data16 = (U16)SPI_POPR;
  _StoreU16BE(pData, Data16);
  Data16 = (U16)SPI_POPR;
  _StoreU16BE(pData + 2, Data16);
  Data16 = (U16)SPI_POPR;
  _StoreU16BE(pData + 4, Data16);
  Data16 = (U16)SPI_POPR;
  _StoreU16BE(pData + 6, Data16);
}

/*********************************************************************
*
*       _Write64Bits
*
*  Function description
*    Transfers 64 bits of data from MCU to NOR device.
*/
```

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```
static void _Write64Bits(const U8 * pData) {
  U16 Data16;
  U32 NumItems;

  //
  // Write data to NOR device. Use the second set of parameters which is configured for
 16-bit transfers.
  //
  Data16 = _LoadU16BE(pData);
  SPI_PUSHR = (U32)Data16 | (1uL << PUSHR_CTAS_BIT);
  Data16 = _LoadU16BE(pData + 2);
  SPI_PUSHR = (U32)Data16 | (1uL << PUSHR_CTAS_BIT);
  Data16 = _LoadU16BE(pData + 4);
  SPI_PUSHR = (U32)Data16 | (1uL << PUSHR_CTAS_BIT);
  Data16 = _LoadU16BE(pData + 6);
  SPI_PUSHR = (U32)Data16 | (1uL << PUSHR_CTAS_BIT);
  //
  // Wait to receive 4 half-words (4 is the FIFO size)
  //
  while (1) {
    NumItems = (SPI_SR >> SR_RXCTR_BIT) & SR_RXCTR_MASK;
    if (NumItems == 4) {
      break;
    }
#if FS_NOR_HW_SPI_USE_OS
    {
      int r;

      r = _WaitForEvent(WAIT_TIMEOUT_MS);
      if (r != 0) {
        break;
      }
    }
#endif // FS_NOR_HW_SPI_USE_OS
  }
  //
  // Discard the received data.
  //
  SPI_MCR |= 1uL << MCR_CLR_RXF_BIT;
}

#endif // FS_NOR_HW_SPI_UNIT_NO == 0

/*********************************************************************
*
*       Static code (public via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initialize the SPI for use with the NOR flash.
*
*  Parameters
*    Unit   Device index
*
*  Return value
*    SPI frequency that is set - given in kHz, 0 in case of an error.
*/
static int _HW_Init(U8 Unit) {
  int      Freq_Hz;
  unsigned NumLoops;
  unsigned Scaler;
  unsigned Div;

  FS_USE_PARA(Unit);
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
  //
  // Enable the clock of GPIOs and SPI0.
  //
  SIM_SCGC3 |= 1uL << SCGC3_SPI2_BIT;
  SIM_SCGC5 |= 1uL << SCGC5_PORTB_BIT;
```

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```
  //
  // Clock line (controlled by the SPI module)
  //
  PORTB_PCR21 = 0
              | (PCR_MUX_SPI2 << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // MOSI line (controlled by the SPI module)
  //
  PORTB_PCR22 = 0
              | (PCR_MUX_SPI2 << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // MISO line (controlled by the SPI module)
  //
  PORTB_PCR23 = 0
              | (PCR_MUX_SPI2 << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Chip select (controlled by the HW layer)
  //
  PORTB_PCR20 = 0
              | (PCR_MUX_GPIO << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              ;
  GPIOB_PSOR  = 1uL << NOR_CS_PIN;         // Active low
  GPIOB_PDDR |= 1uL << NOR_CS_PIN;
  //
  // Disable the digital filtering on all port pins controlled by the SPI module.
  //
  PORTB_DFER &= ~((1uL << NOR_CLK_PIN)  |
                  (1uL << NOR_MISO_PIN) |
                  (1uL << NOR_MOSI_PIN));
#else
  //
  // Enable the clock of GPIOs and SPI0.
  //
  SIM_SCGC5 |= 1uL << SCGC5_PORTC_BIT;
  SIM_SCGC6 |= 1uL << SCGC6_SPI0_BIT;
  //
  // Clock line (controlled by the SPI module)
  //
  PORTC_PCR5 = 0
             | (PCR_MUX_SPI0 << PCR_MUX_BIT)
             | (1uL          << PCR_PE_BIT)
             | (1uL          << PCR_PS_BIT)
             | (1uL          << PCR_DSE_BIT)
             ;
  //
  // MOSI line (controlled by the SPI module)
  //
  PORTC_PCR6 = 0
             | (PCR_MUX_SPI0 << PCR_MUX_BIT)
             | (1uL          << PCR_PE_BIT)
             | (1uL          << PCR_PS_BIT)
             | (1uL          << PCR_DSE_BIT)
             ;
  //
  // MISO line (controlled by the SPI module)
  //
  PORTC_PCR7 = 0
             | (PCR_MUX_SPI0 << PCR_MUX_BIT)
             | (1uL          << PCR_PE_BIT)
             | (1uL          << PCR_PS_BIT)
             | (1uL          << PCR_DSE_BIT)
             ;
```

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```
  //
  // Chip select (controlled by the HW layer)
  //
  PORTC_PCR4 = 0
             | (PCR_MUX_GPIO << PCR_MUX_BIT)
             | (1uL          << PCR_PE_BIT)
             | (1uL          << PCR_PS_BIT)
             ;
  GPIOC_PSOR  = 1uL << NOR_CS_PIN;         // Active low
  GPIOC_PDDR |= 1uL << NOR_CS_PIN;
  //
  // Disable the digital filtering on all port pins controlled by the SPI module.
  //
  PORTC_DFER &= ~((1uL << NOR_CLK_PIN)  |
                  (1uL << NOR_MISO_PIN) |
                  (1uL << NOR_MOSI_PIN));
#endif // FS_NOR_HW_SPI_UNIT_NO == 2
#if FS_NOR_HW_SPI_USE_OS
  //
  // Disable the interrupt and configure the priority.
  //
  NVIC_DisableIRQ(SPI0_IRQn);
  NVIC_SetPriority(SPI0_IRQn, SPI_IRQ_PRIO);
#endif // FS_NOR_HW_SPI_USE_OS
  //
  // Calculate the clock scaler based on the configured clock frequency.
  //
  Scaler  = 0;
  Div     = 2;
  Freq_Hz = FS_NOR_HW_SPI_BUS_CLK_HZ;
  for (;;) {
    if (((unsigned)Freq_Hz / Div) <= FS_NOR_HW_SPI_NOR_CLK_HZ) {
      break;
    }
    //
    // We do this here since the 3rd divisor is not power of 2.
    //
    if (Div == 2) {
      Div = 4;
    } else if (Div == 4) {
      Div = 6;
    } else if (Div == 6) {
      Div = 8;
    } else {
      Div <<= 1;
    }
    ++Scaler;
    if (Scaler == CTAR_BR_MAX) {
      break;
    }
  }
  //
  // Stop the SPI module.
  //
  SPI_MCR |= 1uL << MCR_HALT_BIT;
  NumLoops = FS_NOR_HW_SPI_INIT_WAIT_LOOPS;
  do {
    if ((SPI_SR & (1uL << SR_TXRXS_BIT)) == 0) {
      break;
    }
  } while (--NumLoops);
  //
  // Configure the SPI module.
  //
  SPI_MCR   = 0
            | (1uL << MCR_MSTR_BIT)
            | (1uL << MCR_CLR_TXF_BIT)
            | (1uL << MCR_CLR_RXF_BIT)
            | (1uL << MCR_HALT_BIT)
            ;
  SPI_TCR   = 0;
  SPI_CTAR0 = 0
            | (1uL    << CTAR_DBR_BIT)
            | (7uL    << CTAR_FMSZ_BIT)     // 8 bits
            | (1uL    << CTAR_CPOL_BIT)
            | (1uL    << CTAR_CPHA_BIT)
```

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```
            | (Scaler << CTAR_BR_BIT)
            ;
  SPI_CTAR1 = 0
            | (1uL    << CTAR_DBR_BIT)
            | (15uL   << CTAR_FMSZ_BIT)     // 16 bits
            | (1uL    << CTAR_CPOL_BIT)
            | (1uL    << CTAR_CPHA_BIT)
            | (Scaler << CTAR_BR_BIT)
            ;
  SPI_SR    = 0
            | (1uL << SR_TCF_BIT)
            | (1uL << SR_EOQF_BIT)
            | (1uL << SR_TFUF_BIT)
            | (1uL << SR_TFFF_BIT)
            | (1uL << SR_RFOF_BIT)
            | (1uL << SR_RFDF_BIT)
            ;
  //
  // Start the SPI module.
  //
  SPI_MCR &= ~(1uL << MCR_HALT_BIT);
  NumLoops = FS_NOR_HW_SPI_INIT_WAIT_LOOPS;
  do {
    if (SPI_SR & (1uL << SR_TXRXS_BIT)) {
      break;
    }
  } while (--NumLoops);
#if FS_NOR_HW_SPI_USE_OS
  //
  // Create the OS event and enable the interrupt.
  //
#if (FS_NOR_HW_SPI_USE_OS == 2)
  if (_IsEventInited == 0) {
    OS_EVENT_Create(&_Event);
    _IsEventInited = 1;
  }
#endif // FS_NOR_HW_SPI_USE_OS == 2
  NVIC_EnableIRQ(SPI0_IRQn);
#endif // FS_NOR_HW_SPI_USE_OS
  //
  // Make a dummy transfer so that the polarity of the clock signal is set correctly.
  // Without this, the first byte transfer will send/receive the wrong value.
  //
  _Transfer8Bit(0xFF);
#if (FS_NOR_HW_SPI_USE_OS == 0)
  SPI_RSER  = 0;
#endif
  return Freq_Hz;
}

/*********************************************************************
*
*       _HW_EnableCS
*
*  Function description
*    Activates chip select signal (CS) of the NOR flash chip.
*
*  Parameters
*    Unit   Device index
*/
static void _HW_EnableCS(U8 Unit) {
  FS_USE_PARA(Unit);
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
  GPIOB_PCOR = 1uL << NOR_CS_PIN;         // Active low
#else
  GPIOC_PCOR = 1uL << NOR_CS_PIN;         // Active low
#endif
}

/*********************************************************************
*
*       _HW_DisableCS
*
*  Function description
*    Deactivates chip select signal (CS) of the NOR flash chip.
*
```

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```
*  Parameters
*    Unit   Device index
*/
static void _HW_DisableCS(U8 Unit) {
  FS_USE_PARA(Unit);
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
  GPIOB_PSOR = 1uL << NOR_CS_PIN;         // Active low
#else
  GPIOC_PSOR = 1uL << NOR_CS_PIN;         // Active low
#endif
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    Reads a specified number of bytes from NOR flash to buffer.
*
*  Parameters
*    Unit       Device index
*    pData      Pointer to a data buffer
*    NumBytes   Number of bytes to be read
*/
static void _HW_Read(U8 Unit, U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  if (NumBytes) {
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
    do {
      *pData++ = _Transfer8Bit(0xFF);
    } while (--NumBytes);
#else
    //
    // Read 64 bits at a time if possible.
    //
    if (((unsigned)NumBytes & 7) == 0) {      // Multiple of 8 bytes?
      unsigned NumLoops;

      NumLoops = (unsigned)NumBytes >> 3;
      do {
        _Read64Bits(pData);
        pData += 8;
      } while (--NumLoops);
    } else {
      do {
        *pData++ = _Transfer8Bit(0xFF);
      } while (--NumBytes);
    }
#endif
  }
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    Writes a specified number of bytes from data buffer to NOR flash.
*
*  Parameters
*    Unit       Device index
*    pData      Pointer to a data buffer
*    NumBytes   Number of bytes to be written
*/
static void _HW_Write(U8 Unit, const U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  if (NumBytes) {
#if (FS_NOR_HW_SPI_UNIT_NO == 2)
    do {
      (void)_Transfer8Bit(*pData++);
    } while (--NumBytes);
#else
    //
    // Write 64 bits at a time if possible.
    //
    if (((unsigned)NumBytes & 7) == 0) {      // Multiple of 8 bytes?
```

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```
      unsigned NumLoops;

      NumLoops = (unsigned)NumBytes >> 3;
      do {
        _Write64Bits(pData);
        pData += 8;
      } while (--NumLoops);
    } else {
      do {
        (void)_Transfer8Bit(*pData++);
      } while (--NumBytes);
    }
#endif
  }
}

/*********************************************************************
*
*      Public code
*
**********************************************************************
*/

#if FS_NOR_HW_SPI_USE_OS

/*********************************************************************
*
*       SPI0_IRQHandler
*/
void SPI0_IRQHandler(void);
void SPI0_IRQHandler(void) {
  OS_EnterInterrupt();
  SPI_RSER &= ~(1uL << RSER_RFDF_RE_BIT);       // Disable the interrupt.
#if (FS_NOR_HW_SPI_USE_OS == 2)
  OS_EVENT_Set(&_Event);
#else
  FS_OS_Signal();
#endif // FS_NOR_HW_SPI_USE_OS == 2
  OS_LeaveInterrupt();
}

#endif // FS_NOR_HW_SPI_USE_OS

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/
const FS_NOR_HW_TYPE_SPI FS_NOR_HW_SPI_K66_SEGGER_emPower = {
  _HW_Init,
  _HW_EnableCS,
  _HW_DisableCS,
  _HW_Read,
  _HW_Write,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL
};

/************************** End of file ****************************/
```

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6.4.5.3 Hardware layer API - FS_NOR_HW_TYPE_SPIFI

This hardware layer supports serial NOR flash devices that are interfaced via SPI with their data content being mapped to the system memory of the MCU. This type of interface translates read accesses to the system memory region where the serial NOR flash device is mapped to read operations via the SPI bus. Therefore, the hardware layer can read the data from the serial NOR flash device by simply reading data from the system memory. Any other operations with the serial NOR flash device are performed by sending the commands directly via the SPI bus.

That is, this hardware layer is able to transfer the data via one, two, or four data lines. The functions of this hardware layer are grouped in a structure of type `FS_NOR_HW_TYPE_SPIFI`. The following sections describe these functions in detail.

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6.4.5.3.1 FS_NOR_HW_TYPE_SPIFI

Description

Hardware layer for serial NOR flash devices that are memory-mapped.

Type definition

```
typedef struct {
  FS_NOR_HW_TYPE_SPIFI_INIT       * pfInit;
  FS_NOR_HW_TYPE_SPIFI_UNMAP      * pfSetCmdMode;
  FS_NOR_HW_TYPE_SPIFI_MAP        * pfSetMemMode;
  FS_NOR_HW_TYPE_SPIFI_CONTROL    * pfExecCmd;
  FS_NOR_HW_TYPE_SPIFI_READ       * pfReadData;
  FS_NOR_HW_TYPE_SPIFI_WRITE      * pfWriteData;
  FS_NOR_HW_TYPE_SPIFI_POLL       * pfPoll;
  FS_NOR_HW_TYPE_SPIFI_DELAY      * pfDelay;
  FS_NOR_HW_TYPE_SPIFI_LOCK       * pfLock;
  FS_NOR_HW_TYPE_SPIFI_UNLOCK     * pfUnlock;
  FS_NOR_HW_TYPE_SPIFI_MAP_EX     * pfMapEx;
  FS_NOR_HW_TYPE_SPIFI_CONTROL_EX * pfControlEx;
  FS_NOR_HW_TYPE_SPIFI_READ_EX    * pfReadEx;
  FS_NOR_HW_TYPE_SPIFI_WRITE_EX   * pfWriteEx;
  FS_NOR_HW_TYPE_SPIFI_POLL_EX    * pfPollEx;
  FS_NOR_HW_TYPE_SPIFI_NOTIFY     * pfNotify;
  FS_NOR_HW_TYPE_SPIFI_LOAD       * pfLoad;
} FS_NOR_HW_TYPE_SPIFI;
```

Structure members

Member	Description
pfInit	Initializes the hardware.
pfSetCmdMode	Configures the hardware for direct access to serial NOR flash.
pfSetMemMode	Configures the hardware for access to serial NOR flash via system memory.
pfExecCmd	Sends a command to serial NOR flash that does not transfer any data.
pfReadData	Transfers data from serial NOR flash to MCU.
pfWriteData	Transfers data from MCU to serial NOR flash.
pfPoll	Checks periodically the value of a status flag.
pfDelay	Blocks the execution for the specified time.
pfLock	Requests exclusive access to SPI bus.
pfUnlock	Releases the exclusive access to SPI bus.
pfMapEx	Configures the hardware for access to serial NOR flash via system memory.
pfControlEx	Sends a command to serial NOR flash that does not transfer any data.
pfReadEx	Transfers data from serial NOR flash to MCU.
pfWriteEx	Transfers data from MCU to serial NOR flash.
pfPollEx	Checks periodically the value of a status flag.
pfNotify	Informs about changes of the stored data.
pfLoad	Reads data from the system memory where the NOR flash device is mapped.

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6.4.5.3.2 FS_NOR_HW_TYPE_SPIFI_INIT

Description

Initializes the SPI hardware.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Return value

> 0 OK, frequency of the SPI clock in Hz.
= 0 An error occurred.

Additional information

This function is a member of the SPIFI NOR hardware layer API. It has to be implemented by all the hardware layers.

This function is called by the NOR physical layer before any other function of the hardware layer each time the file system mounts the serial NOR flash. `FS_NOR_HW_TYPE_SPIFI_INIT` has to perform the initialization of clock signals, GPIO ports, SPI controller, etc.

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6.4.5.3.3 FS_NOR_HW_TYPE_SPIFI_UNMAP

Description

Configures the hardware for direct access to serial NOR flash.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_UNMAP(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPIFI NOR hardware layer API. It has to be implemented by all the hardware layers.

The physical layer calls this function before it starts sending commands directly to the serial NOR flash. Typically, the SPI hardware can operate in two modes: command and memory. In command mode the physical layer can access the serial NOR flash directly by sending commands to it. In the memory mode the SPI hardware translates read accesses to an assigned memory region to serial NOR flash read commands. In this way, the contents of the contents of the serial NOR flash is mapped into this memory region.

If the command and memory mode are mutually exclusive, `FS_NOR_HW_TYPE_SPIFI_UNMAP` has to disable the memory mode.

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6.4.5.3.4 FS_NOR_HW_TYPE_SPIFI_MAP

Description

Configures the hardware for access to serial NOR flash via system memory.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_MAP(U8       Unit,
                                       U8       ReadCmd,
                                       unsigned NumBytesAddr,
                                       unsigned NumBytesDummy,
                                       U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
ReadCmd	Code of the command to be used for reading the data.
NumBytesAddr	Number of address bytes to be used for the read command.
NumBytesDummy	Number of dummy bytes to be sent after the read command.
BusWidth	Number of data lines to be used for the data transfer.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is not required if the hardware layer implements FS_NOR_HW_TYPE_SPIFI_MAP_EX.

This function is called by the physical layer when it no longer wants to send commands directly to the serial NOR flash device. After the call to this function the physical layer expects that the contents of the serial NOR flash device is available in the system memory region assigned to SPI hardware and that the data can be accessed by simple memory read operations.

If the command and memory mode are mutually exclusive, then FS_NOR_HW_TYPE_SPIFI_MAP has to disable the command mode.

If the specified read command requires the generation of a number of dummy cycles that is not a multiple of eight then the hardware layer will have to implement the FS_NOR_HW_TYPE_SPIFI_MAP_EX function.

BusWidth encodes the number of data lines to be used when transferring the command, address and data. The value can be decoded using FS_BUSWIDTH_GET_CMD(), FS_BUSWIDTH_GET_ADDR() and FS_BUSWIDTH_GET_DATA(). The dummy bytes are sent using the same number of data lines as the address. For additional information refer to *SPI bus width decoding* on page 805

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6.4.5.3.5 FS_NOR_HW_TYPE_SPIFI_CONTROL

Description

Sends a command to serial NOR flash that does not transfer any data.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_CONTROL(U8 Unit,
                                          U8 Cmd,
                                          U8 BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Cmd	Code of the command to be sent.
BusWidth	Number of data lines to be used for sending the command.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is not required if the hardware layer implements FS_NOR_HW_TYPE_SPIFI_CONTROL_EX.

Typically, the physical layer calls FS_NOR_HW_TYPE_SPIFI_CONTROL to enable or disable the write mode in the serial NOR flash, to set the number of address bytes, etc. FS_NOR_HW_TYPE_SPIFI_CONTROL is called by the physical layer only with the SPI hardware configured in command mode. FS_NOR_HW_TYPE_SPIFI_CONTROL has to wait for the command to complete before it returns.

The value of BusWidth is not encoded as is the case with the other functions of this physical layer. The value specified via BusWidth is the actual number of data lines that have to be used for the data transfer of the command code. Permitted values are 1, 2, and 4.

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6.4.5.3.6 FS_NOR_HW_TYPE_SPIFI_READ

Description

Transfers data from serial NOR flash to MCU.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_READ(      U8       Unit,
                                             U8       Cmd,
                                       const U8     * pPara,
                                             unsigned NumBytesPara,
                                             unsigned NumBytesAddr,
                                             U8     * pData,
                                             unsigned NumBytesData,
                                             U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Cmd	Code of the command to be sent.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	out Data read from the serial NOR flash device. Can be NULL.
NumBytesData	Number of bytes to read from the serial NOR flash device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is not required if the hardware layer implements FS_NOR_HW_TYPE_SPIFI_READ_EX.

This function is called with the SPI hardware in command mode. Typically, the physical layer calls this function when it wants to read parameters or status information from the serial NOR flash device. FS_NOR_HW_TYPE_SPIFI_READ has to wait for the data transfer to complete before it returns.

If FS_NOR_HW_TYPE_SPIFI_MAP is provided then the physical layer reads the contents of the serial NOR flash device via reads accesses to the system memory. FS_NOR_HW_TYPE_SPIFI_READ is used by the physical layer to read the contents of the serial NOR flash device if FS_NOR_HW_TYPE_SPIFI_MAP is not provided.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara. If NumBytesAddr is equal to NumBytesPara then no dummy bytes have to be generated. The number of dummy bytes to be generated can be calculated as NumBytesPara - NumBytesAddr. If the hardware is generating dummy cycles instead of bytes then the number of dummy bytes have to converted to clock cycles by taking into account the number of data lines used for the data transfer of the address. If the specified read command requires the generation of a number of dummy cycles that is not a multiple of eight then the hardware layer will have to implement the FS_NOR_HW_TYPE_SPIFI_READ_EX function.

BusWidth encodes the number of data lines to be used when transferring the command, address and data. The value can be decoded using FS_BUSWIDTH_GET_CMD(), FS_BUSWIDTH_GET_ADDR() and FS_BUSWIDTH_GET_DATA(). The dummy bytes are sent using the

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same number of data lines as the address. For additional information refer to *SPI bus width decoding* on page 805

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6.4.5.3.7 FS_NOR_HW_TYPE_SPIFI_WRITE

Description

Transfers data from MCU to serial NOR flash.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_WRITE(      U8       Unit,
                                              U8       Cmd,
                                        const U8     * pPara,
                                              unsigned NumBytesPara,
                                              unsigned NumBytesAddr,
                                        const U8     * pData,
                                              unsigned NumBytesData,
                                              U16      BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Cmd	Code of the command to be sent.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	in Data to be sent to the serial NOR flash device. Can be NULL.
NumBytesData	Number of bytes to be written the serial NOR flash device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is not required if the hardware layer implements FS_NOR_HW_TYPE_SPIFI_WRITE_EX.

This function is called with the SPI hardware in command mode. Typically, the physical layer calls this function when it wants to modify the data in a page of the serial NOR flash device or to erase a NOR physical sector. FS_NOR_HW_TYPE_SPIFI_WRITE has to wait for the data transfer to complete before it returns.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara. If NumBytesAddr is equal to NumBytesPara then no additional data have to be sent. The number of additional bytes to be sent can be calculated as NumBytesPara - NumBytesAddr. This data has to be sent via the same number of data lines as the address.

BusWidth encodes the number of data lines to be used when transferring the command, address and data. The value can be decoded using FS_BUSWIDTH_GET_CMD(), FS_BUSWIDTH_GET_ADDR() and FS_BUSWIDTH_GET_DATA(). The dummy bytes are sent using the same number of data lines as the address. For additional information refer to *SPI bus width decoding* on page 805

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6.4.5.3.8 FS_NOR_HW_TYPE_SPIFI_POLL

Description

Checks periodically the value of a status flag.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_POLL(U8  Unit,
                                      U8  Cmd,
                                      U8  BitPos,
                                      U8  BitValue,
                                      U32 Delay,
                                      U32 TimeOut_ms,
                                      U16 BusWidth);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Cmd	Code of the command to be sent.
BitPos	Position of the bit to be checked.
BitValue	Value of the bit to wait for.
Delay	Number of clock cycles to wait between two queries.
TimeOut_ms	Maximum number of milliseconds to wait for the bit to be set.
BusWidth	Number of data lines to be used for the data transfer.

Return value

> 0	Timeout occurred.
= 0	OK, bit set to specified value.
< 0	Feature not supported.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

This function is called with the SPI hardware in command mode. FS_NOR_HW_TYPE_SPIFI_POLL has to wait for the NOR flash device to set a flag to a specified value. This has to be realized by periodically reading one byte from the serial NOR flash device via the specified command and by checking that the bit at BitPos in the read byte is set to the value specified by BitValue. A BitPos of 0 specifies the position of the least significant bit in the response.

BusWidth encodes the number of data lines to be used when transferring the command and data. The value can be decoded using FS_BUSWIDTH_GET_CMD(), and FS_BUSWIDTH_GET_DATA(). For additional information refer to *SPI bus width decoding* on page 805

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6.4.5.3.9 FS_NOR_HW_TYPE_SPIFI_DELAY

Description

Blocks the execution for the specified time.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_DELAY(U8  Unit,
                                       U32 ms);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
ms	Number of milliseconds to block the execution.

Return value

= 0 OK, delay executed.
< 0 Functionality not supported.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. FS_NOR_HW_TYPE_SPIFI_DELAY can block the execution for longer than the number of milliseconds specified but not less than that. Typically, the function is implemented using a delay function of the used RTOS if any. If the hardware layer chooses not to implement FS_NOR_HW_TYPE_SPIFI_DELAY then the pfDelay member of FS_NOR_HW_TYPE_SPIFI can be set to NULL or to the address of a function that returns a negative value. If the function is not implemented by the hardware layer then the NOR physical layer blocks the execution by using a software loop. The number of software loops is calculated based in the SPI clock frequency returned by FS_NOR_HW_TYPE_SPIFI_INIT.

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6.4.5.3.10 FS_NOR_HW_TYPE_SPIFI_LOCK

Description

Releases the exclusive access to SPI bus.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function to indicate that it needs exclusive to access the NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling this function first. It is also guaranteed that FS_NOR_HW_TYPE_SPIFI_LOCK and FS_NOR_HW_TYPE_SPIFI_UNLOCK are called in pairs. Typically, this function is used for synchronizing the access to SPI bus when the SPI bus is shared between the serial NOR flash and other SPI devices.

A possible implementation would make use of an OS semaphore that is acquired in FS_NOR_HW_TYPE_SPIFI_LOCK and released in FS_NOR_HW_TYPE_SPIFI_UNLOCK.

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6.4.5.3.11 FS_NOR_HW_TYPE_SPIFI_UNLOCK

Description

Requests exclusive access to SPI bus.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The NOR physical layer calls this function when it no longer needs to access the serial NOR flash device via the SPI bus. It is guaranteed that the NOR physical layer does not attempt to exchange any data with the serial NOR flash device via the SPI bus before calling FS_NOR_HW_TYPE_SPIFI_LOCK. It is also guaranteed that FS_NOR_HW_TYPE_SPIFI_UNLOCK and FS_NOR_HW_TYPE_SPIFI_LOCK are called in pairs.

FS_NOR_HW_TYPE_SPIFI_UNLOCK and FS_NOR_HW_TYPE_SPIFI_LOCK can be used to synchronize the access to the SPI bus when other devices than the serial NOR flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired FS_NOR_HW_TYPE_SPIFI_LOCK and released in FS_NOR_HW_TYPE_SPIFI_UNLOCK.

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6.4.5.3.12 FS_NOR_HW_TYPE_SPIFI_MAP_EX

Description

Configures the hardware for access to serial NOR flash via system memory.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_MAP_EX(      U8       Unit,
                                        const U8     * pCmd,
                                              unsigned NumBytesCmd,
                                        const U8     * pPara,
                                              unsigned NumBytesPara,
                                              unsigned NumBytesAddr,
                                              U16      BusWidth,
                                              unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be used for reading the data. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, memory mode configured successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data via eight data lines or in DTR mode. If the hardware layer does not implement this function then FS_NOR_HW_TYPE_SPIFI_MAP is called instead.

This function performs the same operation as FS_NOR_HW_TYPE_SPIFI_MAP with the difference that it can handle multi-byte commands and additional data transfer options received via Flags. Flags is a bitwise-or combination of *NOR HW layer flags* on page 1064. In addition, this function is able to report an error via the return value.

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6.4.5.3.13 FS_NOR_HW_TYPE_SPIFI_CONTROL_EX

Description

Sends a command to serial NOR flash that does not transfer any data.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_CONTROL_EX(      U8       Unit,
                                            const U8     * pCmd,
                                                  unsigned NumBytesCmd,
                                                  U8       BusWidth,
                                                  unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
BusWidth	Number of data lines to be used for sending the command.
Flags	Options for the data exchange.

Return value

= 0 OK, command transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data via eight data lines or in DTR mode. If the hardware layer does not implement this function then FS_NOR_HW_TYPE_SPIFI_CONTROL is called instead.

This function performs the same operation as FS_NOR_HW_TYPE_SPIFI_CONTROL with the difference that it can handle multi-byte commands and additional data transfer options specified via Flags. Flags is a bitwise-or combination of *NOR HW layer flags* on page 1064. In addition, this function is able to report an error via the return value.

The value of BusWidth is not encoded as is the case with the other functions of this physical layer. The value specified via BusWidth is the actual number of data lines that have to be used for the data transfer of the command code. Permitted values are 1, 2, 4 and 8.

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6.4.5.3.14 FS_NOR_HW_TYPE_SPIFI_READ_EX

Description

Transfers data from serial NOR flash to MCU.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_READ_EX(      U8       Unit,
                                         const U8     * pCmd,
                                               unsigned NumBytesCmd,
                                         const U8     * pPara,
                                               unsigned NumBytesPara,
                                               unsigned NumBytesAddr,
                                               U8     * pData,
                                               unsigned NumBytesData,
                                               U16      BusWidth,
                                               unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	out Data read from the serial NOR flash device. Can be NULL.
NumBytesData	Number of bytes to read from the serial NOR flash device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data via eight data lines or in DTR mode. If the hardware layer does not implement this function then FS_NOR_HW_TYPE_SPIFI_READ is called instead.

The first address byte is stored at *pPara. NumBytesAddr is always smaller than or equal to NumBytesPara. If NumBytesAddr is equal to NumBytesPara then neither mode nor dummy bytes have to be sent. The number of mode bytes is always one and is indicated by FS_NOR_HW_FLAG_MODE_8BIT being set in Flags. The value of the mode byte is located at *(pPara + NumBytesAddr). The number of dummy bytes to be generated can be calculated as NumBytesPara - NumBytesAddr. If FS_NOR_HW_FLAG_MODE_8BIT is set in Flags then one has to be subtracted from the calculate value. One additional dummy nibble (half-byte) has to be generated if FS_NOR_HW_FLAG_DUMMY_4BIT is set in Flags. If the hardware generates dummy cycles instead of bytes then the number of dummy bytes has to converted to clock cycles by taking into account the number of data lines used for the data transfer of the address.

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This function performs the same operation as `FS_NOR_HW_TYPE_SPIFI_READ` with the difference that it can handle multi-byte commands and additional data transfer options specified via `Flags`. `Flags` is a bitwise-or combination of *NOR HW layer flags* on page 1064. In addition, this function is able to report an error via the return value.

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6.4.5.3.15 FS_NOR_HW_TYPE_SPIFI_WRITE_EX

Description

Transfers data from MCU to serial NOR flash.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_WRITE_EX(      U8       Unit,
                                          const U8     * pCmd,
                                                unsigned NumBytesCmd,
                                          const U8     * pPara,
                                                unsigned NumBytesPara,
                                                unsigned NumBytesAddr,
                                          const U8     * pData,
                                                unsigned NumBytesData,
                                                U16      BusWidth,
                                                unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
pData	in Data to be sent to the serial NOR flash device. Can be NULL.
NumBytesData	Number of bytes to be written the serial NOR flash device. Can be 0.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

= 0 OK, data transferred successfully.
≠ 0 An error occurred.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data via eight data lines or in DTR mode. If the hardware layer does not implement this function then FS_NOR_HW_TYPE_SPIFI_WRITE is called instead.

This function performs the same operation as FS_NOR_HW_TYPE_SPIFI_WRITE with the difference that it can handle multi-byte commands and additional data transfer options specified via Flags. Flags is a bitwise-or combination of *NOR HW layer flags* on page 1064. In addition, this function is able to report an error via the return value.

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6.4.5.3.16 FS_NOR_HW_TYPE_SPIFI_POLL_EX

Description

Checks periodically the value of a status flag.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_POLL_EX(      U8       Unit,
                                         const U8     * pCmd,
                                               unsigned NumBytesCmd,
                                         const U8     * pPara,
                                               unsigned NumBytesPara,
                                               unsigned NumBytesAddr,
                                               U8       BitPos,
                                               U8       BitValue,
                                               U32      Delay,
                                               U32      TimeOut_ms,
                                               U16      BusWidth,
                                               unsigned Flags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pCmd	in Code of the command to be sent. Cannot be NULL.
NumBytesCmd	Number of bytes in the command code. Cannot be 0.
pPara	in Command parameters (address and dummy bytes). Can be NULL.
NumBytesPara	Total number of address and dummy bytes to be sent. Can be 0.
NumBytesAddr	Number of address bytes to be send. Can be 0.
BitPos	Position of the bit to be checked.
BitValue	Value of the bit to wait for.
Delay	Number of clock cycles to wait between two queries.
TimeOut_ms	Maximum number of milliseconds to wait for the bit to be set.
BusWidth	Number of data lines to be used for the data transfer.
Flags	Options for the data exchange.

Return value

> 0	Timeout occurred.
= 0	OK, bit set to specified value.
< 0	Feature not supported.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional. The function has to be implemented only by hardware layers that have to be able to transfer the data of the polling command via eight data lines or in DTR mode. If the hardware layer does not implement this function then FS_NOR_HW_TYPE_SPIFI_POLL is called instead.

This function performs the same operation as FS_NOR_HW_TYPE_SPIFI_POLL with the difference that it can handle multi-byte commands and additional data transfer options specified via Flags. Flags is a bitwise-or combination of *NOR HW layer flags* on page 1064. In addition, this function is able to report an error via the return value.

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6.4.5.3.17 FS_NOR_HW_TYPE_SPIFI_NOTIFY

Description

Informs about changes of the stored data.

Type definition

```
typedef void FS_NOR_HW_TYPE_SPIFI_NOTIFY(U8  Unit,
                                         U32 Addr,
                                         U32 NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
Addr	Address of the first byte that changed.
NumBytes	Number of bytes that changed.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The SPIFI NOR physical layer calls this function at the end of a write or erase operation to inform the SPIFI HW layer about the range of bytes modified by the operation. This information can be used for example to invalidate a data cache.

Addr is the address in the system memory.

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6.4.5.3.18 FS_NOR_HW_TYPE_SPIFI_LOAD

Description

Reads data from system memory.

Type definition

```
typedef int FS_NOR_HW_TYPE_SPIFI_LOAD(U8   Unit,
                                       U8 * pData,
                                       U32  Addr,
                                       U32  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer (0-based).
pData	out Data read from system memory.
Addr	Address in the system memory to read from.
NumBytes	Number of bytes be read.

Additional information

This function is a member of the SPIFI NOR hardware layer API. The implementation of this function is optional.

The SPIFI NOR physical layer calls this function when it has to read data from the NOR flash device via the system memory. If this function is not implemented, then the SPIFI NOR physical layer reads the data directly from the system memory.

Addr is the address in the system memory.

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6.4.5.3.19 NOR HW layer flags

Description

Additional options for data exchanged via the SPI NOR HW layers.

Definition

```
#define FS_NOR_HW_FLAG_DTR_DATA        (1uL << 0)
#define FS_NOR_HW_FLAG_DTR_ADDR        (1uL << 1)
#define FS_NOR_HW_FLAG_DTR_CMD         (1uL << 2)
#define FS_NOR_HW_FLAG_DQS_ACTIVE      (1uL << 3)
#define FS_NOR_HW_FLAG_DQS_INVERTED    (1uL << 4)
#define FS_NOR_HW_FLAG_DTR_D1_D0       (1uL << 5)
#define FS_NOR_HW_FLAG_ADDR_3BYTE      (1uL << 6)
#define FS_NOR_HW_FLAG_DUMMY_4BIT      (1uL << 7)
#define FS_NOR_HW_FLAG_DUMMY_2BIT      (1uL << 8)
#define FS_NOR_HW_FLAG_DUMMY_1BIT      (1uL << 9)
#define FS_NOR_HW_FLAG_MODE_8BIT       (1uL << 10)
#define FS_NOR_HW_FLAG_MODE_4BIT       (1uL << 11)
#define FS_NOR_HW_FLAG_MODE_2BIT       (1uL << 12)
#define FS_NOR_HW_FLAG_MODE_1BIT       (1uL << 13)
#define FS_NOR_HW_FLAG_DUMMY_HALF      (1uL << 14)
```

Symbols

Definition	Description
FS_NOR_HW_FLAG_DTR_DATA	Exchange the data on each clock transition.
FS_NOR_HW_FLAG_DTR_ADDR	Send the address on each clock transition.
FS_NOR_HW_FLAG_DTR_CMD	Send the command on each clock transition.
FS_NOR_HW_FLAG_DQS_ACTIVE	Enable the data strobe signal.
FS_NOR_HW_FLAG_DQS_INVERTED	Data strobe signal is inverted in reference to clock signal.
FS_NOR_HW_FLAG_DTR_D1_D0	Send odd-numbered bytes on the rising edge of the clock signal.
FS_NOR_HW_FLAG_ADDR_3BYTE	Send a 3-byte address to NOR flash device.
FS_NOR_HW_FLAG_DUMMY_4BIT	Generate additional dummy cycles equivalent to four bits of data.
FS_NOR_HW_FLAG_DUMMY_2BIT	Generate additional dummy cycles equivalent to two bits of data.
FS_NOR_HW_FLAG_DUMMY_1BIT	Generate additional dummy cycles equivalent to one bit of data.
FS_NOR_HW_FLAG_MODE_8BIT	Send eight mode bits after the data address.
FS_NOR_HW_FLAG_MODE_4BIT	Send four mode bits after the data address.
FS_NOR_HW_FLAG_MODE_2BIT	Send two mode bits after the data address.
FS_NOR_HW_FLAG_MODE_1BIT	Send one mode bit after the data address.
FS_NOR_HW_FLAG_DUMMY_HALF	Generate an additional dummy cycle that is half of the clock signal period.

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6.4.5.3.20 Sample implementation

The following sample implementation uses the SPIFI controller of an NXP LPC4322 MCU to interface with a serial NOR flash device. This NOR hardware layer has been tested on a SEGGER internal test board.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : NOR_PHY_SPIFI_NXP_LPC4322_SEGGER_QSPIFI_Test_Board.c
Purpose : Low-level flash driver for NXP SPIFI interface.
Literature:
  [1] UM10503 LPC43xx ARM Cortex-M4/M0 multi-core microcontroller
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*      Defines, configurable
*
**********************************************************************
*/
#define SPIFI_CLK_HZ          60000000uL    // Frequency of the clock supplied to SPIFI unit.
#define SPIFI_DATA_ADDR       0x80000000
  // This is the start address of the memory region used by the file system

  // to read the data from the serial NOR flash device. The hardware layer

  // performs a dummy read from this address when switching to memory mode

  // in order to clean the caches. It should be set to the value passed

  // as second parameter to FS_NOR_Configure()/FS_NOR_BM_Configure() in FS_X_AddDevices().
#define RESET_DELAY_LOOPS     100000
  // Number of software loops to wait for NOR device to reset
#define USE_OS                0             // Enables / disables the interrupt driver operation

/*********************************************************************
*
*       #include section, conditional
*
**********************************************************************
*/
#if USE_OS
  #include "RTOS.h"
  #include "lpc43xx.h"
#endif

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*       SPIFI unit
*/
#define SPIFI_BASE_ADDR       0x40003000
#define SPIFI_CTRL            (*(volatile U32*)(SPIFI_BASE_ADDR + 0x00))
  // SPIFI control register
```

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```
#define SPIFI_CMD             (*(volatile U32*)(SPIFI_BASE_ADDR + 0x04))
  // SPIFI command register
#define SPIFI_ADDR            (*(volatile U32*)(SPIFI_BASE_ADDR + 0x08))
  // SPIFI address register
#define SPIFI_IDATA           (*(volatile U32*)(SPIFI_BASE_ADDR + 0x0C))
  // SPIFI intermediate data register
#define SPIFI_CLIMIT          (*(volatile U32*)(SPIFI_BASE_ADDR + 0x10))
  // SPIFI cache limit register
#define SPIFI_DATA32          (*(volatile U32*)(SPIFI_BASE_ADDR + 0x14))    // SPIFI data register
 (32-bit access, 4 bytes at once)
#define SPIFI_DATA16          (*(volatile U16*)(SPIFI_BASE_ADDR + 0x14))    // SPIFI data register
 (16-bit access, 2 bytes at once)
#define SPIFI_DATA8           (*(volatile U8*) (SPIFI_BASE_ADDR + 0x14))    // SPIFI data register
 (8-bit access, 1 byte at once)
#define SPIFI_MCMD            (*(volatile U32*)(SPIFI_BASE_ADDR + 0x18))
  // SPIFI memory command register
#define SPIFI_STAT            (*(volatile U32*)(SPIFI_BASE_ADDR + 0x1C))    // SPIFI status register

/*********************************************************************
*
*       Clock generation unit
*/
#define CGU_BASE_ADDR         0x40050000
#define IDIVA_CTRL            (*(volatile U32*)(CGU_BASE_ADDR + 0x0048))
#define IDIVB_CTRL            (*(volatile U32*)(CGU_BASE_ADDR + 0x004C))
#define BASE_SPIFI_CLK        (*(volatile U32*)(CGU_BASE_ADDR + 0x0070))

/*********************************************************************
*
*       Clock control unit 1
*/
#define CCU1_BASE_ADDR        0x40051000
#define CLK_SPIFI_CFG         (*(volatile U32*)(CCU1_BASE_ADDR + 0x0300))
#define CLK_SPIFI_STAT        (*(volatile U32*)(CCU1_BASE_ADDR + 0x0304))

/*********************************************************************
*
*       System control unit
*/
#define SCU_BASE_ADDR         0x40086000
#define SFSP3_2               (*(volatile U32*)(SCU_BASE_ADDR + 0x188))
  // Pin configuration register for pin P3_2
#define SFSP3_3               (*(volatile U32*)(SCU_BASE_ADDR + 0x18C))
  // Pin configuration register for pin P3_3
#define SFSP3_4               (*(volatile U32*)(SCU_BASE_ADDR + 0x190))
  // Pin configuration register for pin P3_4
#define SFSP3_5               (*(volatile U32*)(SCU_BASE_ADDR + 0x194))
  // Pin configuration register for pin P3_5
#define SFSP3_6               (*(volatile U32*)(SCU_BASE_ADDR + 0x198))
  // Pin configuration register for pin P3_6
#define SFSP3_7               (*(volatile U32*)(SCU_BASE_ADDR + 0x19C))
  // Pin configuration register for pin P3_7
#define SFSP3_8               (*(volatile U32*)(SCU_BASE_ADDR + 0x1A0))
  // Pin configuration register for pin P3_8

/*********************************************************************
*
*       GPIO unit
*/
#define GPIO_BASE_ADDR        0x400F4000
#define GPIO_DIR5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2014))
  // Direction registers port 5
#define GPIO_SET5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2214))   // Set register for port
 5
#define GPIO_CLR5             (*(volatile U32*)(GPIO_BASE_ADDR + 0x2294))
  // Clear register for port 5

/*********************************************************************
*
*       SPIFI command register
*/
#define CMD_BITPOS_BIT                0
#define CMD_BITPOS_MASK               0x7uL
#define CMD_BITVAL_BIT                3
#define CMD_BITVAL_MASK               0x1uL
#define CMD_DATALEN_BIT               0
```

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```
#define CMD_DATALEN_MASK               0x3FFFuL
#define CMD_POLL_BIT                   14
#define CMD_DOUT_BIT                   15
#define CMD_INTLEN_BIT                 16
#define CMD_INTLEN_MASK                0x7uL
#define CMD_FIELDFORM_BIT              19
#define CMD_FIELDFORM_ALL_SERIAL       0x0uL
#define CMD_FIELDFORM_QUAD_DUAL_DATA   0x1uL
#define CMD_FIELDFORM_SERIAL_OPCODE    0x2uL
#define CMD_FIELDFORM_ALL_QUAD_DUAL    0x3uL
#define CMD_FRAMEFORM_BIT              21
#define CMD_FRAMEFORM_OPCODE           0x1uL
#define CMD_FRAMEFORM_OPCODE_1BYTE     0x2uL
#define CMD_FRAMEFORM_OPCODE_2BYTES    0x3uL
#define CMD_FRAMEFORM_OPCODE_3BYTES    0x4uL
#define CMD_FRAMEFORM_OPCODE_4BYTES    0x5uL
#define CMD_OPCODE_BIT                 24
#define CMD_OPCODE_MASK                0xFFuL

/*********************************************************************
*
*       SPIFI control register
*/
#define CTRL_TIMEOUT_BIT               0
#define CTRL_CSHIGH_BIT                16
#define CTRL_D_PRFTCH_DIS_BIT          21
#define CTRL_MODE3_BIT                 23
#define CTRL_INTEN_BIT                 22
#define CTRL_PRFTCH_DIS_BIT            27
#define CTRL_DUAL_BIT                  28
#define CTRL_FBCLK_BIT                 30

/*********************************************************************
*
*       SPIFI status register
*/
#define STAT_MCINIT_BIT                0
#define STAT_CMD_BIT                   1
#define STAT_RESET_BIT                 4
#define STAT_INTRQ_BIT                 5

/*********************************************************************
*
*       Misc. defines
*/
#define CGU_IDIV_BIT                   2
#define CGU_AUTOBLOCK_BIT              11
#define CGU_CLK_SEL_BIT                24
#define SFS_MODE_BIT                   0
#define SFS_EPUN_BIT                   4
#define SFS_EHS_BIT                    5
#define SFS_EZI_BIT                    6
#define SFS_ZIF_BIT                    7
#define CLK_STAT_RUN_BIT               0
#define CLK_CFG_RUN_BIT                0
#define NOR_RESET_BIT                  9
#define SPIFI_PRIO                     15

/*********************************************************************
*
*       ASSERT_IS_LOCKED
*/
#if FS_SUPPORT_TEST
  #define ASSERT_IS_LOCKED()                  \
    if (_LockCnt != 1) {                      \
      FS_X_PANIC(FS_ERRCODE_INVALID_USAGE);   \
    }
#else
  #define ASSERT_IS_LOCKED()
#endif

/*********************************************************************
*
*       IF_TEST
*/
#if FS_SUPPORT_TEST
```

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```
  #define IF_TEST(Expr)       Expr
#else
  #define IF_TEST(Expr)
#endif

/*********************************************************************
*
*      Static data
*
**********************************************************************
*/
#if FS_SUPPORT_TEST
  static U8 _LockCnt = 0;      // Just to test if the Lock()/Unlock function are called correctly.
#endif

/*********************************************************************
*
*      Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _GetFieldForm
*
*  Function description
*    Determines the value to be stored in the FIELDFORM field
*    of the SPIFI_CMD and SPIFI_MCMD registers. It also returns
*    the value of the SPIFI_CTRL.DUAL field.
*/
static U32 _GetFieldForm(U16 BusWidth, int * pIsDual) {
  U32 FieldForm;
  int IsDual;

  IsDual = 0;
  if (BusWidth == 0x112u) {
    FieldForm = CMD_FIELDFORM_QUAD_DUAL_DATA;   // Data field is dual other fields are serial.
    IsDual    = 1;
  } else if (BusWidth == 0x114u) {
    FieldForm = CMD_FIELDFORM_QUAD_DUAL_DATA;   // Data field is quad other fields are serial.
  } else if (BusWidth == 0x122u) {
    FieldForm = CMD_FIELDFORM_SERIAL_OPCODE;    // Opcode field is serial. Other fields are dual.
    IsDual    = 1;
  } else if (BusWidth == 0x144u) {
    FieldForm = CMD_FIELDFORM_SERIAL_OPCODE;    // Opcode field is serial. Other fields are quad.
  } else if (BusWidth == 0x444u) {
    FieldForm = CMD_FIELDFORM_ALL_QUAD_DUAL;    // Opcode field is serial. Other fields are quad.
  } else {
    FieldForm = CMD_FIELDFORM_ALL_SERIAL;       // All fields of the command are serial.
  }
  if (pIsDual) {
    *pIsDual = IsDual;
  }
  return FieldForm;
}

/*********************************************************************
*
*       _GetFieldFormEx
*
*  Function description
*    Same functionality as _GetFieldForm() with BusWidth not encoded.
*/
static U32 _GetFieldFormEx(U8 BusWidth, int * pIsDual) {
  U32 FieldForm;
  int IsDual;

  IsDual = 0;
  if (BusWidth == 1) {
    FieldForm = CMD_FIELDFORM_ALL_SERIAL;       // All fields of the command are serial.
  } else if (BusWidth == 2) {
    FieldForm = CMD_FIELDFORM_ALL_QUAD_DUAL;    // All fields are dual.
    IsDual = 1;
  } else if (BusWidth == 4) {
    FieldForm = CMD_FIELDFORM_ALL_QUAD_DUAL;    // All fields are quad.
```

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```
  } else {
    FieldForm = CMD_FIELDFORM_ALL_SERIAL;       // All fields of the command are serial.
  }
  if (pIsDual) {
    *pIsDual = IsDual;
  }
  return FieldForm;
}

/*********************************************************************
*
*       _GetFrameForm
*
*  Function description
*    Determines the value to be stored in the FAMEFORM field
*    of the SPIFI_CMD and SPIFI_MCMD registers.
*/
static U32 _GetFrameForm(unsigned NumBytesAddr) {
  U32 FrameForm;

  if (NumBytesAddr == 1) {
    FrameForm = CMD_FRAMEFORM_OPCODE_1BYTE;     // Opcode + 1 address byte.
  } else if (NumBytesAddr == 2) {
    FrameForm = CMD_FRAMEFORM_OPCODE_2BYTES;    // Opcode + 2 address bytes.
  } else if (NumBytesAddr == 3) {
    FrameForm = CMD_FRAMEFORM_OPCODE_3BYTES;    // Opcode + 3 address bytes.
  } else if (NumBytesAddr == 4) {
    FrameForm = CMD_FRAMEFORM_OPCODE_4BYTES;    // Opcode + 4 address bytes.
  } else {
    FrameForm = CMD_FRAMEFORM_OPCODE;           // Opcode, no address bytes.
  }
  return FrameForm;
}

/*********************************************************************
*
*       _Reset
*/
static void _Reset(void) {
  SPIFI_STAT = (1uL << STAT_RESET_BIT);
  // Reset the SPIFI controller. The controller is put into SPI mode.
  while (1) {
    if ((SPIFI_STAT & ((1uL << STAT_CMD_BIT)   |
                       (1uL << STAT_RESET_BIT) |
                       (1uL << STAT_MCINIT_BIT))) == 0) {
      break;
  // Wait until the SPIFI controller is ready again.
    }
  }
}

/*********************************************************************
*
*      Public code
*
**********************************************************************
*/

#if USE_OS

/*********************************************************************
*
*       SPIFI_IRQHandler
*/
void SPIFI_IRQHandler(void);
void SPIFI_IRQHandler(void) {
  OS_EnterInterrupt();
  SPIFI_STAT |= 1uL << STAT_INTRQ_BIT;          // Prevent other interrupts from occurring.
  FS_X_OS_Signal();
  OS_LeaveInterrupt();
}

#endif

/*********************************************************************
*
```

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```
*      Public code (via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    HW layer function. It is called before any other function of the physical layer.
*    It should configure the HW so that the other functions can access the NOR flash.
*
*  Return value
*    Frequency of the SPI clock in Hz.
*/
static int _HW_Init(U8 Unit) {
  unsigned NumLoops;

  FS_USE_PARA(Unit);    // This device has only one HW unit.
  //
  // Use IDIVA as clock for SPIFI. The input of IDIVA is PLL1.
  //
  IDIVA_CTRL     = 0
                 | (9uL << CGU_CLK_SEL_BIT)     // Use PLL1 as input
                 | (2uL << CGU_IDIV_BIT)        // Divide PLL1 by 3
                 | (1uL << CGU_AUTOBLOCK_BIT)
                 ;
  BASE_SPIFI_CLK = 0
                 | 12uL << CGU_CLK_SEL_BIT    // Use IDIVA as clock generator
                 | 1uL  << CGU_AUTOBLOCK_BIT
                 ;
  //
  // Enable the SPIFI clock if required.
  //
  if ((CLK_SPIFI_STAT & (1uL << CLK_STAT_RUN_BIT)) == 0) {
    CLK_SPIFI_CFG |= (1uL << CLK_CFG_RUN_BIT);
    while (1) {
      if (CLK_SPIFI_STAT & (1uL << CLK_CFG_RUN_BIT)) {
        ;
      }
    }
  }
  //
  // Clock pin.
  //
  SFSP3_3 = 0
          | (3uL << SFS_MODE_BIT)
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EHS_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  //
  // Data pins.
  //
  SFSP3_4 = 0
          | (3uL << SFS_MODE_BIT)
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  SFSP3_5 = 0
          | (3uL << SFS_MODE_BIT)
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  SFSP3_6 = 0
          | (3uL << SFS_MODE_BIT)
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  SFSP3_7 = 0
          | (3uL << SFS_MODE_BIT)
          | (1uL << SFS_EPUN_BIT)
          | (1uL << SFS_EZI_BIT)
          ;
  //
```

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```
  // Chip select pin.
  //
  SFSP3_8 = 0
          | (3uL << SFS_MODE_BIT)                   // Controlled by this HW layer.
          | (1uL << SFS_EPUN_BIT)
          ;
  //
  // Reset pin. Present only on 16-pin devices.
  //
  SFSP3_2 = 0
          | (4uL << SFS_MODE_BIT)                   // Controlled by this HW layer.
          | (1uL << SFS_EPUN_BIT)
          ;
  GPIO_DIR5 |= 1uL << NOR_RESET_BIT;
  //
  // Reset the NOR device.
  //
  GPIO_CLR5 = 1uL << NOR_RESET_BIT;                 // Assert reset signal (active low).
  NumLoops = RESET_DELAY_LOOPS;
  do {
    ;
  } while (--NumLoops);
  GPIO_SET5 = 1uL << NOR_RESET_BIT;                 // De-assert reset signal (active low).
#if USE_OS
  //
  // Disable the interrupt and configure the priority.
  //
  NVIC_DisableIRQ(SPIFI_IRQn);
  NVIC_SetPriority(SPIFI_IRQn, SPIFI_PRIO);
#endif
  //
  // Configure the SPIFI unit.
  //
  SPIFI_CTRL = 0
             | (0xFFFFuL << CTRL_TIMEOUT_BIT)       // Use the maximum timeout.
             | (0xFuL    << CTRL_CSHIGH_BIT)        // Set minimum CS high time to maximum value.
             | (0x1uL    << CTRL_D_PRFTCH_DIS_BIT)  // Disable memory prefetches.
             | (0x1uL    << CTRL_MODE3_BIT)         // CLK idle mode is high.
             | (0x1uL    << CTRL_PRFTCH_DIS_BIT)    // Disables prefetching of cache lines.
             | (0x1uL    << CTRL_FBCLK_BIT)
  // Read data is sampled using a feedback clock from the SCK pin.
             ;
#if USE_OS
  //
  // Clear interrupt flag.
  //
  SPIFI_STAT = 1uL << STAT_INTRQ_BIT;
  NVIC_EnableIRQ(SPIFI_IRQn);
#endif
  return SPIFI_CLK_HZ;
}

/*********************************************************************
*
*       _HW_SetCmdMode
*
*  Function description
*    HW layer function. It enables the direct access to NOR flash via SPI.
*    This function disables the memory-mapped mode.
*/
static void _HW_SetCmdMode(U8 Unit) {
  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);            // This device has only one HW unit.
  _Reset();
}

/*********************************************************************
*
*       _HW_SetMemMode
*
*  Function description
*    HW layer function. It enables the memory-mapped mode. In this mode
*    the data can be accessed by doing read operations from memory.
*    The HW is responsible to transfer the data via SPI.
*    This function disables the direct access to NOR flash via SPI.
*/
```

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```
static void _HW_SetMemMode(U8 Unit, U8 ReadCmd, unsigned NumBytesAddr, unsigned NumBytesDummy, U16 BusWidth) {
  U32 FieldForm;
  U32 FrameForm;
  U32 OpCode;
  U32 IntLen;
  int IsDual;
  U32 MCmdReg;
  U32 v;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This device has only one HW unit.
  //
  // Determine how the data transferred is sent (serial, dual or quad)
  // and how many address bytes to send.
  //
  IsDual    = 0;
  FieldForm = _GetFieldForm(BusWidth, &IsDual);
  FrameForm = _GetFrameForm(NumBytesAddr);
  IntLen    = NumBytesDummy & CMD_INTLEN_MASK;
  OpCode    = ReadCmd & CMD_OPCODE_MASK;
  MCmdReg   = 0
            | (IntLen    << CMD_INTLEN_BIT)
            | (FieldForm << CMD_FIELDFORM_BIT)
            | (FrameForm << CMD_FRAMEFORM_BIT)
            | (OpCode    << CMD_OPCODE_BIT)
            ;
  //
  // Configure the SPIFI controller to work in memory-mapped mode.
  //
  v = SPIFI_CTRL;
  if (IsDual) {
    v |=   1uL << CTRL_DUAL_BIT;
  } else {
    v &= ~(1uL << CTRL_DUAL_BIT);
  }
  SPIFI_CTRL = v;
  SPIFI_MCMD = MCmdReg;
  //
  // Wait until MCMD is written
  //
  while (1) {
    if (SPIFI_STAT & (1uL << STAT_MCINIT_BIT)) {
      break;
    }
  }
  //
  // Perform dummy read to bring controller into sync and invalidate all caches etc.
  // It seems to be necessary but not documented in the datasheet.
  //
  *(volatile U32*)SPIFI_DATA_ADDR;
}

/*********************************************************************
*
*       _HW_ExecCmd
*
*  Function description
*    HW layer function. It requests the NOR flash to execute a simple command.
*    The HW has to be in SPI mode.
*/
static void _HW_ExecCmd(U8 Unit, U8 Cmd, U8 BusWidth) {
  U32 FieldForm;
  int IsDual;
  U32 FrameForm;
  U32 CmdReg;
  U32 v;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This device has only one HW unit.
  IsDual    = 0;
  FieldForm = _GetFieldFormEx(BusWidth, &IsDual);
  FrameForm = _GetFrameForm(0);                 // 0 - No address bytes are sent.
  CmdReg    = 0
            | (FieldForm << CMD_FIELDFORM_BIT)  // Configure the transfer mode.
            | (FrameForm << CMD_FRAMEFORM_BIT)  // Send only the command byte.
            | ((U32)Cmd  << CMD_OPCODE_BIT)     // Command code.
```

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```
            ;
  v = SPIFI_CTRL;
  if (IsDual) {
    v |=   1uL << CTRL_DUAL_BIT;
  } else {
    v &= ~(1uL << CTRL_DUAL_BIT);
  }
  SPIFI_CTRL = v;
  SPIFI_CMD  = CmdReg;
  //
  // Wait until nCS is set high, indicating that the command has been completed.
  //
  while (1) {
    if ((SPIFI_STAT & (1uL << STAT_CMD_BIT)) == 0) {
      break;
    }
  }
}

/*********************************************************************
*
*       _HW_ReadData
*
*  Function description
*    HW layer function. It transfers data from NOR flash to MCU.
*    The HW has to be in SPI mode.
*/
static void _HW_ReadData(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara, unsigned NumBytesAddr, U8 * pData,
  U32      DataLen;
  U32      AddrReg;
  U32      IDataReg;
  U32      CmdReg;
  U32      FieldForm;
  int      IsDual;
  U32      FrameForm;
  U32      IntLen;
  unsigned NumBytes;
  U32      v;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This device has only one HW unit.
  //
  // Fill local variables.
  //
  IsDual    = 0;
  FieldForm = _GetFieldForm(BusWidth, &IsDual);
  FrameForm = _GetFrameForm(NumBytesAddr);
  IntLen    = 0;
  DataLen   = NumBytesData & CMD_DATALEN_MASK;
  AddrReg   = 0;
  IDataReg  = 0;
  //
  // Encode the address.
  //
  if (NumBytesAddr) {
    NumBytes = NumBytesAddr;
    do {
      AddrReg <<= 8;
      AddrReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
  //
  // Encode the dummy and mode bytes.
  //
  if (NumBytesPara > NumBytesAddr) {
    NumBytes = NumBytesPara - NumBytesAddr;
    IntLen   = NumBytes;
    do {
      IDataReg <<= 8;
      IDataReg  |= (U32)(*pPara++);
    } while (--NumBytes);
  }
  CmdReg = 0
         | (DataLen   << CMD_DATALEN_BIT)
         | (IntLen    << CMD_INTLEN_BIT)
         | (FieldForm << CMD_FIELDFORM_BIT)
```

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```
          | (FrameForm << CMD_FRAMEFORM_BIT)
          | ((U32)Cmd  << CMD_OPCODE_BIT)
          ;
  //
  // Set dual/quad mode.
  //
  v = SPIFI_CTRL;
  if (IsDual) {
    v |=   1uL << CTRL_DUAL_BIT;
  } else {
    v &= ~(1uL << CTRL_DUAL_BIT);
  }
  SPIFI_CTRL = v;
  //
  // Execute the command.
  //
  SPIFI_ADDR  = AddrReg;
  SPIFI_IDATA = IDataReg;
  SPIFI_CMD   = CmdReg;
  //
  // Read data from NOR flash.
  //
  if (NumBytesData) {
    do {
      *pData++ = SPIFI_DATA8;
    } while (--NumBytesData);
  }
  //
  // Wait until nCS is set high, indicating that the command has been completed.
  //
  while (1) {
    if ((SPIFI_STAT & (1uL << STAT_CMD_BIT)) == 0) {
      break;
    }
  }
}

/*********************************************************************
*
*       _HW_WriteData
*
*  Function description
*    HW layer function. It transfers data from MCU to NOR flash.
*    The HW has to be in SPI mode.
*/
static void _HW_WriteData(U8 Unit, U8 Cmd, const U8 * pPara, unsigned NumBytesPara, unsigned NumBytesAddr, const U8 *
  U32      DataLen;
  U32      AddrReg;
  U32      IDataReg;
  U32      FieldForm;
  int      IsDual;
  U32      FrameForm;
  U32      IntLen;
  unsigned NumBytesAtOnce;
  unsigned NumBytes;
  U32      v;
  U32      CmdReg;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);    // This device has only one HW unit.
  //
  // Fill local variables.
  //
  IsDual    = 0;
  FieldForm = _GetFieldForm(BusWidth, &IsDual);
  FrameForm = _GetFrameForm(NumBytesAddr);
  IntLen    = 0;
  DataLen   = NumBytesData & CMD_DATALEN_MASK;
  AddrReg   = 0;
  IDataReg  = 0;
  //
  // Encode the address.
  //
  if (NumBytesAddr) {
    NumBytes = NumBytesAddr;
    do {
```

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```
    AddrReg <<= 8;
    AddrReg  |= (U32)(*pPara++);
  } while (--NumBytes);
}
//
// Encode the dummy and mode bytes.
//
if (NumBytesPara > NumBytesAddr) {
  NumBytes = NumBytesPara - NumBytesAddr;
  IntLen   = NumBytes;
  do {
    IDataReg <<= 8;
    IDataReg  |= (U32)(*pPara++);
  } while (--NumBytes);
}
CmdReg = 0
       | (DataLen   << CMD_DATALEN_BIT)
       | (1uL       << CMD_DOUT_BIT)     // Transfer data to NOR flash
       | (IntLen    << CMD_INTLEN_BIT)
       | (FieldForm << CMD_FIELDFORM_BIT)
       | (FrameForm << CMD_FRAMEFORM_BIT)
       | ((U32)Cmd  << CMD_OPCODE_BIT)
       ;
//
// Set dual/quad mode.
//
v = SPIFI_CTRL;
if (IsDual) {
  v |=   1uL << CTRL_DUAL_BIT;
} else {
  v &= ~(1uL << CTRL_DUAL_BIT);
}
SPIFI_CTRL = v;
//
// Execute the command.
//
SPIFI_ADDR  = AddrReg;
SPIFI_IDATA = IDataReg;
SPIFI_CMD   = CmdReg;
//
// Wait for the command to start execution.
//
if (NumBytesData) {
  while (1) {
    if (SPIFI_STAT & (1uL << STAT_CMD_BIT)) {
      break;
    }
  }
}
//
// Write data to NOR flash.
//
if (NumBytesData) {
  do {
    NumBytesAtOnce = NumBytesData >= 4 ? 4 : 1;
    if (NumBytesAtOnce == 4) {
      v = 0
        | (U32)*pData
        | ((U32)(*(pData + 1)) << 8)
        | ((U32)(*(pData + 2)) << 16)
        | ((U32)(*(pData + 3)) << 24)
        ;
      SPIFI_DATA32 = v;
    } else {
      SPIFI_DATA8 = *pData;
    }
    NumBytesData -= NumBytesAtOnce;
    pData        += NumBytesAtOnce;
  } while (NumBytesData);
}
//
// Wait until nCS is set high, indicating that the command has been completed.
//
while (1) {
  if ((SPIFI_STAT & (1uL << STAT_CMD_BIT)) == 0) {
    break;
```

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```
    }
  }
}

/*********************************************************************
*
*       _HW_Poll
*
*  Function description
*    HW layer function. Sends a command repeatedly and checks the
*    response for a specified condition.
*
*  Return value
*    > 0    Timeout occurred.
*    ==0    OK, bit set to specified value.
*    < 0    Feature not supported.
*
*  Additional information
*    The function executes periodically a command and waits
*    until specified bit in the response returned by the NOR flash
*    is set to a value specified by BitValue. The position of the bit
*    that has to be checked is specified by BitPos where 0 is the
*    position of the least significant bit in the byte.
*/
static int _HW_Poll(U8 Unit, U8 Cmd, U8 BitPos, U8 BitValue, U32 Delay, U32 TimeOut_ms, U16 BusWidth) {
  int r;

  ASSERT_IS_LOCKED();
  FS_USE_PARA(Unit);
  FS_USE_PARA(Delay);
  r = -1;                 // Set to indicate that the feature is not supported.
#if USE_OS
  {
    U32 AddrReg;
    U32 IDataReg;
    U32 CmdReg;
    U32 FieldForm;
    int IsDual;
    U32 FrameForm;
    U32 v;

    //
    // Fill local variables.
    //
    IsDual    = 0;
    FieldForm = _GetFieldForm(BusWidth, &IsDual);
    FrameForm = _GetFrameForm(0);                 // The command does not require any address bytes.
    AddrReg   = 0;
    IDataReg  = 0;
    CmdReg = 0
           | ((BitValue & CMD_BITVAL_MASK) << CMD_BITVAL_BIT)
           | ((BitPos & CMD_BITPOS_MASK)   << CMD_BITPOS_BIT)
           | (1uL                          << CMD_POLL_BIT)
           | (FieldForm                    << CMD_FIELDFORM_BIT)
           | (FrameForm                    << CMD_FRAMEFORM_BIT)
           | (Cmd                          << CMD_OPCODE_BIT)
           ;
    //
    // Set dual/quad mode.
    //
    v = SPIFI_CTRL;
    if (IsDual) {
      v |=   1uL << CTRL_DUAL_BIT;
    } else {
      v &= ~(1uL << CTRL_DUAL_BIT);
    }
    SPIFI_CTRL = v;
    //
    // Execute the command.
    //
    SPIFI_STAT  = 1uL << STAT_INTRQ_BIT;    // Clear the interrupt flag.
    SPIFI_CTRL |= 1uL << CTRL_INTEN_BIT;    // Enable interrupt.
    SPIFI_ADDR  = AddrReg;
    SPIFI_IDATA = IDataReg;
    SPIFI_CMD   = CmdReg;
    r = FS_X_OS_Wait(TimeOut_ms);
```

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```
    SPIFI_CTRL &= ~(1uL << CTRL_INTEN_BIT); // Disable interrupt.
    if (r) {
      r = 1;                                // A timeout occurred.
    } else {
      r = 0;                                // Bit set to the requested value.
    }
    _Reset();                               // Cancel the polling operation.
    //
    // Wait until nCS is set high, indicating that the command has been completed.
    //
    while (1) {
      if ((SPIFI_STAT & (1uL << STAT_CMD_BIT)) == 0) {
        break;
      }
    }
  }
#else
  FS_USE_PARA(Cmd);
  FS_USE_PARA(BitPos);
  FS_USE_PARA(BitValue);
  FS_USE_PARA(Delay);
  FS_USE_PARA(TimeOut_ms);
  FS_USE_PARA(BusWidth);
#endif
  return r;
}

/*********************************************************************
*
*       _HW_Delay
*
*  Function description
*    HW layer function. Blocks the execution for the specified number
*    of milliseconds.
*/
static int _HW_Delay(U8 Unit, U32 ms) {
  int r;

  FS_USE_PARA(Unit);
  r = -1;                 // Set to indicate that the feature is not supported.
#if USE_OS
  if (ms) {
    FS_X_OS_Delay(ms);
    r = 0;
  }
#else
  FS_USE_PARA(ms);
#endif
  return r;
}

/*********************************************************************
*
*       _HW_Lock
*
*  Function description
*    HW layer function. Requests exclusive access to SPI bus.
*/
static void _HW_Lock(U8 Unit) {
  FS_USE_PARA(Unit);
  IF_TEST(_LockCnt++);
  ASSERT_IS_LOCKED();
}

/*********************************************************************
*
*       _HW_Unlock
*
*  Function description
*    HW layer function. Releases the exclusive access of SPI bus.
*/
static void _HW_Unlock(U8 Unit) {
  FS_USE_PARA(Unit);
  ASSERT_IS_LOCKED();
  IF_TEST(_LockCnt--);
}
```

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```
/*********************************************************************
*
*       Global data
*
**********************************************************************
*/
const FS_NOR_HW_TYPE_SPIFI FS_NOR_HW_SPIFI_LPC4322_SEGGER_QSPIFI_Test_Board = {
  _HW_Init,
  _HW_SetCmdMode,
  _HW_SetMemMode,
  _HW_ExecCmd,
  _HW_ReadData,
  _HW_WriteData,
  _HW_Poll,
  _HW_Delay,
  _HW_Lock,
  _HW_Unlock,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL
};

/************************** End of file ****************************/
```

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6.4.6 FAQs

Q: What is the maximum supported storage capacity?

A: The maximum capacity of a NOR flash device supported by the NOR drivers depends on the number of physical sectors (also known as erase blocks) that are present on the storage device. The NOR drivers are designed to handle a maximum of 65535 physical sectors. The typical size of a physical block is 64 KB. This results in a maximum storage capacity of about 4 GB.

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6.5 MMC/SD card driver

6.5.1 General information

emFile supports the use of MultiMediaCard (MMC) and Secure Digital (SD) cards as well as of eMMC (Embedded MMC) as storage devices.

MMC/SD cards are mechanically small, removable mass storage devices. The main design goal of these devices is to provide a very low-cost mass storage product, implemented as a card with a simple controlling unit, and a compact, easy-to-implement interface. These requirements lead to a reduction of the functionality of each card to an absolute minimum. eMMC devices operate in the same way as an MMC card with the difference that they are not removable devices. Instead, they can be soldered on a circuit board.

In order to meet the requirements of any system, the MMC/SD cards are designed to operate in two different I/O modes:

- SPI mode
- Card mode

Two device drivers are provided that support these different operating modes:

- *SPI MMC/SD driver* - Supports legacy MMC and SD cards, and it transfers the data via standard SPI.
- *Card Mode MMC/SD driver* - Supports legacy eMMC and SD cards, and it can transfer the data via one, four or eight data lines. The drivers require very little RAM and provide an extremely efficient data transfer. The selection of the driver depends on the access mode supported by the target hardware.

For more technical details about MMC and SD cards, check the documents and specifications available on https://www.jedec.org and https://www.sdcard.org

6.5.1.1 Fail-safe operation

The data will be preserved in case of an unexpected reset. However, a power failure can be critical because data may be lost if the SD card does not have sufficient time to complete the in-progress write operation. As a countermeasure, the hardware has to make sure that the power supply to the SD card drops slowly enough to allow the SD card to complete the write operation. The SD specification requires that a write operation has to finish within 250 ms. However, an SD card is allowed to buffer the data written by the host and that can potentially increase the time it takes the SD card to complete the write operation. This type of write buffering can be disabled via `FS_MMC_CM_AllowBufferedWrite()`. Typically, industrial-grade SD cards are able to handle power failures internally so that no special hardware and software considerations are required.

eMMC devices have the same requirements with regard to the fail-safe operation as SD cards. In addition, eMMC devices have the ability to write the data in a fail-safe way that reduces the chance of data loss in case of a power failure. This type of write operation is called Reliable Write and can be enabled via `FS_MMC_CM_AllowReliableWrite()`. Enabling this write mode is recommended for a correct fail-safe operation of the file system.

6.5.1.2 Wear leveling

MMC/SD cards are controlled by an internal controller; this controller also handles wear leveling. Therefore, the driver does not need to handle wear leveling.

6.5.1.3 CRC verification

CRC (Cyclic Redundancy Check) is a method to produce a checksum. The checksum is a small, fixed number of bits calculated based on the contents of a block of data. The checksum is used to detect errors in a data block after transmission or storage. A CRC is computed and appended before transmission or storage, and verified afterward by the recipient to confirm that no changes occurred. CRC is a good solution for error detection, but reduces the transmission speed, because a CRC checksum has to be computed for every

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data block that is transmitted or stored. `FS_MMC_ActivateCRC()` and `FS_MMC_DeactivateCRC()` can be used to control the CRC calculation of the SPI MMC/SD driver. The Card Mode MMC/SD driver calculates the CRC in the hardware with the help of the SD host controller. In this case, the CRC calculation and verification is always enabled, and it cannot be deactivated.

6.5.1.4 Power control

Power control should be considered when creating designs using the MMC and/or SD cards. The ability to have software power control of the cards makes the design more flexible and robust. The host will be able to turn power to the card on or off independent of whether the card is inserted or removed. This can improve card initialization when there is a contact bounce during card insertion. The host waits a specified time after the card is inserted before powering up the card and starting the initialization process. Also, if the card goes into an unknown state, the host can cycle the power and start the initialization process again. When card access is unnecessary, allowing the host to power down the bus can reduce the overall power consumption.

6.5.1.5 Supported hardware

Generally emFile supports any SD card that complies with any version of the SD Specification up to and including 3.0. In addition, MMC devices are supported that comply with any version of the MMC Specification up to and including 5.0.

The following memory card and device types are supported:

- MMC - eMMC, MMC card, RS-MMC, RS-MMC DV, MMCplus, MMCmobile, MMCmicro
- SD - SDSC (SD Standard Capacity), SDHC (SD High Capacity), SDXC (SD eXtended Capacity) in any form factor.

> **Note**
>
> The MMC cards conforming with the version 4.x or newer of the MMC specification (MMCplus, MMCmobile, MMCmicro, eMMC, etc.) work only with the Card Mode MMC/SD driver because these devices do not support the SPI mode.

The difference between MMC and SD cards is that SD cards can operate with a higher clock frequency. In normal mode the range of the clock frequency supplied to an SD card can be between 0 and 25 MHz, whereas MMC cards can only operate up to 20 MHz. The newer MMC cards that comply to the version 4.x or higher of the MMC specification can also operate at higher frequencies up to 26 MHz.

An SD card can also operate in high speed mode with a clock frequency up to 50 MHz. The MMC cards conforming to the version 3.x or lower of the MMC specification do not support the high speed mode. The version 4.x of the MMC specification improves this and allows the MMC cards to operate with a clock frequency of up to 52 MHz in high speed mode.

The version 3.0 of the SD Specification and the version 4.5 of the MMC Specification introduce new access modes that allow the devices to exchange the data with a host at a clock frequency of up to around 200 MHz in single and dual data rate modes. These ultra-high-speed access modes use a voltage level of 1.8 V for SD cards and either 1.8 or 1.2 V for MMC devices for the I/O signals. The following table lists the access modes currently supported by emFile:

Device Type	Access Mode	Data Rate	I/O Voltage [V]	Bus Width [Data Lines]	Max. Clock Frequency [MHz]
SD	Default Speed	Single	3.3	1, 4	25
SD	High Speed	Single	3.3	1, 4	50
SD	SDR12	Single	1.8	1, 4	25
SD	SDR25	Single	1.8	1, 4	50
SD	DDR50	Dual	1.8	4	50

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Device Type	Access Mode	Data Rate	I/O Voltage [V]	Bus Width [Data Lines]	Max. Clock Frequency [MHz]
SD	SDR50	Single	1.8	4	100
SD	SDR104	Single	1.8	4	208
MMC	Default Speed	Single	3.3, 1.8	1, 4, 8	26
MMC	High Speed	Single	3.3, 1.8	1, 4, 8	52
MMC	High Speed	Dual	3.3, 1.8	4, 8	52
MMC	HS200	Single	1.8	4, 8	200
MMC	HS400	Dual	1.8	8	200

The HS400 Enhanced Strobe mode and 1.2 V I/O voltage are currently not supported for eMMC. The ultra-high-speed access modes are supported only by the Card Mode MMC/SD driver.

MMC and SD cards also differ in the number of interface signals with MMC cards typically requiring more signals than the SD cards. The number of signals used depends on the operating mode.

Card mode

In this mode, the MMC cards compliant with version 3.x or smaller of the MMC specification require 6 signals: 1 command, 1 clock, 1 data and 3 power lines. The MMC cards compliant with version 4.x or higher of the MMC specification require up to 13 signals: 1 command, 1 clock, up to 8 data and 3 power lines. In contrast to the MMC cards, SD cards require up to 9 signals: 1 command, 1 clock, up to 4 data and 3 power lines.

SPI mode

Both card systems use the same interface signals: 1 chip select, 1 data input, 1 data output, 1 clock and 3 power lines.

6.5.1.6 Pin description - MMC/SD card in card mode

The table below describes the pin assignment of the electrical interface of SD and MMC cards working in card mode.

Pin No.	Name	Type	Description
1	CD/DAT3	Input/Output using push-pull drivers	Card Detect / Data line [Bit 3]. After power up, this line is an input with a 50-kOhm pull-up resistor. This can be used for card detection; relevant only for SD cards. The pull-up resistor is disabled after the initialization procedure for using this line as DAT3, Data line [Bit 3], for data transfer.
2	CMD	Push-pull	Command/Response. CMD is a bidirectional command channel used for card initialization and data transfer commands. The CMD signal has two operation modes: open-drain for initialization mode and push-pull for fast command transfer. Commands are sent from the MMC bus master (card host controller) to the card and responses are sent from the cards to the host.
3	VSS	Power supply	Supply voltage ground.
4	VDD	Power supply	Supply voltage.
5	CLK	Input	Clock signal. With each cycle of this signal, a one-bit transfer on the command and data

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Pin No.	Name	Type	Description
			lines is done. The frequency may vary between zero and the maximum clock frequency.
6	VSS2	Power supply	Supply voltage ground.
7	DAT0	Input/Output using push-pull drivers	Data line [Bit 0]. DAT is a bidirectional data channel. The DAT signal operates in push-pull mode. Only one card or the host is driving this signal at a time. Relevant only for SD cards: For data transfers, this line is the Data line [Bit 0].
8	DAT1	Input/Output using push-pull drivers	Data line [Bit 1]. For data transfer, this line is the Data line [Bit 1]. Connect an external pull-up resistor to this data line even if only DAT0 is to be used. Otherwise, unexpected high current consumption may occur due to the floating inputs of DAT1.
9	DAT2	Input/Output using push-pull drivers	Data line [Bit 2]. For data transfer, this line is the Data line [Bit 2]. Connect an external pull-up resistor to this data line even if only DAT0 is to be used. Otherwise, unexpected high current consumption may occur due to the floating inputs of DAT2.
10	DAT4	Input/Output using push-pull drivers	Data line [Bit 4]. Relevant only for MMC storage devices. On SD cards this line does not exist. Not used for data transfers via four data lines. For data transfer via eight data lines, this line carries the bit 4.
11	DAT5	Input/Output using push-pull drivers	Data line [Bit 5]. Relevant only for MMC storage devices. On SD cards this line does not exist. Not used for data transfers via four data lines. For data transfer via eight data lines, this line carries the bit 5.
12	DAT6	Input/Output using push-pull drivers	Data line [Bit 6]. Relevant only for MMC storage devices. On SD cards this line does not exist. Not used for data transfers via four data lines. For data transfer via eight data lines, this line carries the bit 6.
13	DAT7	Input/Output using push-pull drivers	Data line [Bit 7]. Relevant only for MMC storage devices. On SD cards this line does not exist. Not used for data transfers via four data lines. For data transfer via eight data lines, this line carries the bit 7.

The table below describes the pin assignment of the electrical interface of a micro SD card working in card mode.

Pin no.	Name	Type	Description
1	DAT2	Input/Output using push-pull drivers	Data line [Bit 2]. On MMC cards this line does not exist. Relevant only for SD cards: For data transfer, this line is the Data line [Bit 2]. Connect an external pull-up resistor to this data line even if only DAT0 is to be used. Otherwise, unexpected high current consumption may occur due to the floating inputs of DAT2.
2	CD/DAT3	Input/Output using push-pull drivers	Card Detect / Data line [Bit 3]. After power up, this line is an input with a 50-kOhm pull-up resistor. This can be used for card detection; rel-

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Pin no.	Name	Type	Description
			evant only for SD cards. The pull-up resistor is disabled after the initialization procedure for using this line as DAT3, Data line [Bit 3], for data transfer.
3	CMD	Push-pull	Command/Response. CMD is a bidirectional command channel used for card initialization and data transfer commands. The CMD signal has two operation modes: open-drain for initialization mode and push-pull for fast command transfer. Commands are sent from the MMC bus master (card host controller) to the card and responses are sent from the cards to the host.
4	VDD	Power supply	Supply voltage.
5	CLK	Input	Clock signal. With each cycle of this signal, a one-bit transfer on the command and data lines is done. The frequency may vary between zero and the maximum clock frequency.
6	VSS	Power supply	Supply ground.
7	DAT0	Input/Output using push-pull drivers	Data line [Bit 0]. DAT is a bidirectional data channel. The DAT signal operates in push-pull mode. Only one card or the host is driving this signal at a time. Relevant only for SD cards: For data transfers, this line is the Data line [Bit 0].
8	DAT1	Input/Output using push-pull drivers	Data line [Bit 1]. On MMC cards this line does not exist. Relevant only for SD cards: For data transfer, this line is the Data line [Bit 1]. Connect an external pull-up resistor to this data line even if only DAT0 is to be used. Otherwise, unexpected high current consumption may occur due to the floating inputs of DAT1.

Additional information

External pull-up resistors must be connected to all data lines even if they are not used. Otherwise, unexpected high current consumption may occur due to the floating of these signals.

6.5.1.7 Pin description - MMC/SD card in SPI mode

The table below describes the pin assignment of the electrical interface of SD and MMC cards working in SPI mode

Pin no.	Name	Type	Description
1	CS	Input	Chip Select. It sets the card active at low level and inactive at high level.
2	DataIn (MOSI)	Input	Data Input (Master Out Slave In.) Transmits data to the card.
3	VSS	Supply ground	Power supply ground. Supply voltage ground.
4	VDD	Supply voltage	Supply voltage.
5	SCLK	Input	Clock signal. It must be generated by the target system. The card is always in slave mode.
6	VSS2	Supply ground	Supply ground.

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Pin no.	Name	Type	Description
7	DataOut (MISO)	Output	Data Output (Master In Slave Out.) Line to transfer data to the host.
8	Reserved	Not used	The reserved pin is a floating input. Therefore, connect an external pull-up resistor to it. Otherwise, non-expected high current consumption may occur due to the floating input.
9	Reserved	Not used	The reserved pin is a floating input. Therefore, connect an external pull-up resistor to it. Otherwise, non-expected high current consumption may occur due to the floating input.

The table below describes the pin assignment of the electrical interface of a micro SD card working in SPI mode:

Pin no.	Name	Type	Description
1	Reserved	Not used	The reserved pin is a floating input. Therefore, connect an external pull-up resistor to it. Otherwise, non-expected high current consumption may occur due to the floating input.
2	CS	Input	Chip Select. It sets the card active at low level and inactive at high level.
3	DataIn (MOSI)	Input	Data Input (Master Out Slave In.) Transmits data to the card.
4	VDD	Supply voltage	Supply voltage.
5	SCLK	Input	Clock signal. It must be generated by the target system. The card is always in slave mode.
6	VSS	Supply ground	Supply ground.
7	DataOut (MISO)	Output	Data Output (Master In Slave Out.) Line to transfer data to the host.
8	Reserved	Not used	The reserved pin is a floating input. Therefore, connect an external pull-up resistor to it. Otherwise, non-expected high current consumption may occur due to the floating input.

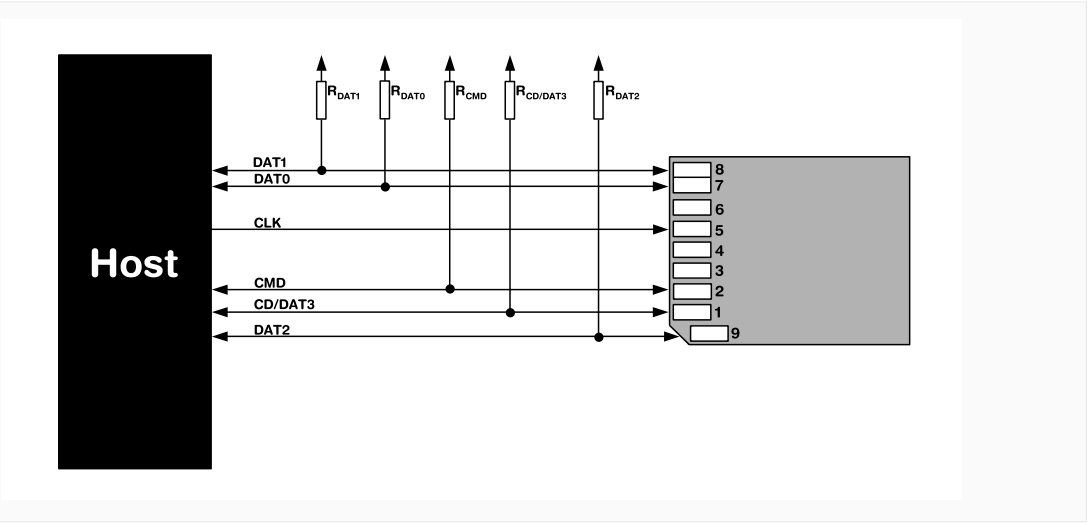
Additional information

- The data transfer width is 8 bits.
- Data should be output on the falling edge and must remain valid until the next period. Rising edge means data is sampled (i.e., read).
- The bit order requires the most significant bit (MSB) to be sent out first.
- Data polarity is normal, which means a logical “1” is represented with a high level on the data line and a logical “0” is represented with a low level.
- MMC/SD cards support different voltage ranges. Initial voltage should be 3.3V.

6.5.1.8 Interfacing with an MMC/SD card

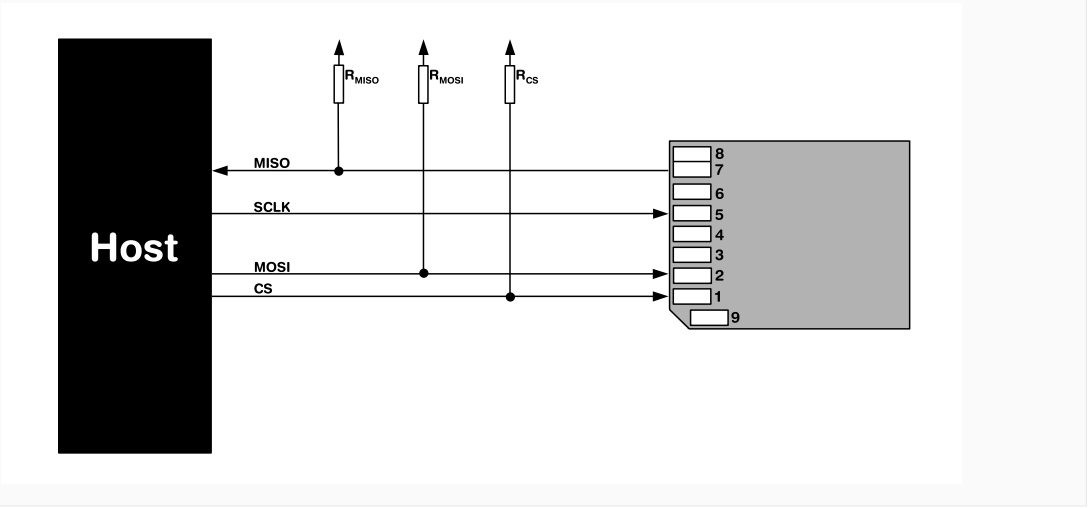
The following picture shows how an MMC/SD card working in card mode can be interfaced to a system.

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SD card schematic - card mode

The following picture shows how an MMC/SD card working in SPI mode can be interfaced to a system.



SD card schematic - SPI mode

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6.5.2 SPI MMC/SD driver

6.5.2.1 Theory of operation

The Serial Peripheral Interface (SPI) bus is a very loose de facto standard for controlling almost any digital electronics that accepts a clocked serial stream of bits. SPI operates in full duplex (sending and receiving at the same time).

6.5.2.2 Configuring the driver

This section describes how to configure the file system to make use of the SPI MMC/SD driver.

6.5.2.2.1 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of the `FS_MMC_SPI_Driver` structure. This function call together with other function calls that configure the driver operation have to be added to `FS_X_AddDevices()` as demonstrated in the following example. This example shows how to configure the file system to access an MMC/SD card connected via SPI.

```
#include "FS.h"
#include "FS_MMC_HW_SPI_Template.h"

#define ALLOC_SIZE 0x1300               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the SPI MMC/SD driver.
  //
  FS_AddDevice(&FS_MMC_SPI_Driver);
  FS_MMC_SetHWType(0, &FS_MMC_HW_SPI_Template);
  // FS_MMC_ActivateCRC();   // Uncommenting this line activates
                             // the CRC calculation of the SPI MMC/SD driver.
  //
  // Configure the file system for fast write operations.
  //
#if FS_SUPPORT_FILE_BUFFER
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif
  FS_SetFileWriteMode(FS_WRITEMODE_FAST);
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the SPI MMC/SD driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
FS_MMC_ActivateCRC()	Enables the data verification.
FS_MMC_DeactivateCRC()	Disables the data verification.
FS_MMC_SetHWType()	Configures the hardware access routines.

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6.5.2.2.1.1 FS_MMC_ActivateCRC()

Description

Enables the data verification.

Prototype

```
void FS_MMC_ActivateCRC(void);
```

Additional information

This function is optional. The data verification uses a 16-bit CRC to detect any corruption of the data being exchanged with the storage device. By default, the data verification is disabled to improve performance. `FS_MMC_ActivateCRC()` can be used at runtime to enable the data verification for all driver instances. The data verification can be disabled via `FS_MMC_DeactivateCRC()`.

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6.5.2.2.1.2 FS_MMC_DeactivateCRC()

Description

Disables the data verification.

Prototype

```
void FS_MMC_DeactivateCRC(void);
```

Additional information

This function is optional. It can be used by an application to disable the data verification previously enabled via `FS_MMC_ActivateCRC()`.

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6.5.2.2.1.3 FS_MMC_SetHWType()

Description

Configures the hardware access routines.

Prototype

```
void FS_MMC_SetHWType(      U8                    Unit,
                      const FS_MMC_HW_TYPE_SPI * pHWType);
```

Additional information

This function is mandatory and it has to be called once for each instance of the driver.

6.5.2.3 Additional driver functions

These functions are optional. They can be used to get information about the operation of the Card Mode MMC/SD driver and to perform additional operations on the used SD card or MMC device.

Function	Description
FS_MMC_GetCardId()	This function retrieves the card Id of SD/ MMC card.
FS_MMC_GetCardInfo()	This function returns information about the SD/MMC device.
FS_MMC_GetStatCounters()	Returns the value of statistical counters.
FS_MMC_ResetStatCounters()	Sets the values of all statistical counters to 0.

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6.5.2.3.1 FS_MMC_GetCardId()

Description

This function retrieves the card Id of SD/MMC card.

Prototype

```
int FS_MMC_GetCardId(U8               Unit,
                     FS_MMC_CARD_ID * pCardId);
```

Parameters

Parameter	Description
Unit	Device index number.
pCardId	out Card identification data.

Return value

= 0 CardId has been read.
≠ 0 An error has occurred.

Additional information

This function is optional. The application can call this function to get the information stored in the CID register of an MMC or SD card. The CID register stores information which can be used to uniquely identify the card such as serial number, product name, manufacturer id, etc. For more information about the information stored in this register refer to SD or MMC specification.

Example

The following example shows how to read and decode the contents of the CID register stored in an SD card.

```
#include <stdio.h>
#include "FS.h"

void SampleMMCGetCardId(void) {
  U8            ManId;
  char          acOEMId[2 + 1];
  char          acProductName[5 + 1];
  U8            ProductRevMajor;
  U8            ProductRevMinor;
  U32           ProductSN;
  U8            MfgMonth;
  U16           MfgYear;
  U16           MfgDate;
  U8          * p;
  MMC_CARD_ID   CardId;
  char          ac[100];

  FS_MEMSET(&CardId, 0, sizeof(CardId));
  FS_MMC_GetCardId(0, &CardId);
  p = CardId.aData;
  ManId = *p++;
  strncpy(acOEMId, (char *)p, 2);
  acOEMId[2] = '\0';
  p += 2;
  strncpy(acProductName, (char *)p, 5);
  acProductName[5] = '\0';
  p += 5;
  ProductRevMajor  = *p >> 4;
  ProductRevMinor  = *p++ & 0xF;
  ProductSN        = (U32)*p++ << 24;
  ProductSN       |= (U32)*p++ << 16;
  ProductSN       |= (U32)*p++ << 8;
  ProductSN       |= (U32)*p++;
  MfgDate          = (U16)*p++;
```

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```
  MfgDate         |= (U16)*p++;
  MfgMonth         = (U8)(MfgDate & 0xF);
  MfgYear          = MfgDate >> 4;
  FS_X_Log("SD card identification:\n");
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturer Id:       0x%02x\n", ManId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  OEM/Application Id:    %s\n", acOEMId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product name:          %s\n", acProductName);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product revision:      %lu.%lu
\n", (U32)ProductRevMajor, (U32)ProductRevMinor);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product serial number: 0x%08lx\n", ProductSN);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturing date:    %lu-%lu
\n", (U32)MfgMonth, (U32)MfgYear);
  FS_X_Log(ac);
}
```

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6.5.2.3.2 FS_MMC_GetCardInfo()

Description

This function returns information about the SD/MMC device.

Prototype

```
int FS_MMC_GetCardInfo(U8                 Unit,
                       FS_MMC_CARD_INFO * pCardInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pCardInfo	out Information about the device.

Return value

= 0 Card information returned.
≠ 0 An error has occurred.

Additional information

This function is optional. It can be used to get information about the type of the storage card used, about the type of the data transfer, etc.

Example

The following example shows how to get information about the storage device.

```
#include <stdio.h>
#include "FS.h"

void SampleMMCGetCardInfo(void) {
  FS_MMC_CARD_INFO   CardInfo;
  const char       * sCardType;
  char               ac[100];
  const char       * sAccessMode;

  FS_MEMSET(&CardInfo, 0, sizeof(CardInfo));
  FS_MMC_GetCardInfo(0, &CardInfo);
  switch (CardInfo.CardType) {
  case FS_MMC_CARD_TYPE_MMC:
    sCardType = "MMC";
    break;
  case FS_MMC_CARD_TYPE_SD:
    sCardType = "SD";
    break;
  case FS_MMC_CARD_TYPE_UNKNOWN:
    // through
  default:
    sCardType = "UNKNOWN";
    break;
  }
  switch (CardInfo.AccessMode) {
  case FS_MMC_ACCESS_MODE_DS:
    sCardType = "DS";
    break;
  case FS_MMC_ACCESS_MODE_HS:
    sCardType = "HS";
    break;
  case FS_MMC_ACCESS_MODE_UNKNOWN:
    // through
  default:
    sCardType = "UNKNOWN";
    break;
  }
  FS_X_Log("Card information:");
  SEGGER_snprintf(ac, sizeof(ac), "  Card type:         %s\n", sCardType);
```

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```
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Bus width:         %d line\n", CardInfo.BusWidth);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Write protected:   %s\n",
    CardInfo.IsWriteProtected ? "yes" : "no");
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  High speed mode:   %s\n",
    CardInfo.IsHighSpeedMode ? "yes" : "no");
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Bytes per sector:  %d\n",
    (int)CardInfo.BytesPerSector);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Number of sectors: %lu\n", CardInfo.NumSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Clock frequency:   %lu Hz\n", CardInfo.ClockFreq);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Voltage level:     %d.%d V\n",
    (int)CardInfo.VoltageLevel / 1000, (int)CardInfo.VoltageLevel % 1000 / 100);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Access mode:       %s\n", sAccessMode);
  FS_X_Log(ac);
}
```

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6.5.2.3.3 FS_MMC_GetStatCounters()

Description

Returns the value of statistical counters.

Prototype

```
void FS_MMC_GetStatCounters(U8                    Unit,
                            FS_MMC_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the driver (0-based)
pStat	out The values of statistical counters.

Additional information

This function is optional. The SPI SD/MMC driver collects statistics about the number of internal operations such as the number of logical sectors read or written by the file system layer. The application can use FS_MMC_GetStatCounters() to get the current value of these counters. The statistical counters are automatically set to 0 when the storage device is mounted or when the application calls FS_MMC_ResetStatCounters().

The statistical counters are available only when the file system is compiled with FS_DEBUG_LEVEL greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or with FS_MMC_ENABLE_STATS set to 1.

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6.5.2.3.4 FS_MMC_ResetStatCounters()

Description

Sets the values of all statistical counters to 0.

Prototype

```
void FS_MMC_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Additional information

This function is optional. The statistical counters are automatically set to 0 when the storage device is mounted. The application can use `FS_MMC_ResetStatCounters()` at any time during the file system operation. The statistical counters can be queried via `FS_MMC_GetStatCounters()`.

The statistical counters are available only when the file system is compiled with `FS_DEBUG_LEVEL` greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with `FS_MMC_ENABLE_STATS` set to 1.

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6.5.2.4 Performance and resource usage

6.5.2.4.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the Card Mode MMC/SD driver were measured as described in the section *Test procedure* on page 1439.

Usage: 2.8 Kbytes

6.5.2.4.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Card Mode MMC/SD driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the `FS_MMC_CM_Drv.c` file.

Usage: 12 bytes

6.5.2.4.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the compile time and runtime configuration.

Usage: 22 bytes

6.5.2.4.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in Mbytes/second.

CPU type	MMC/SD device	Write speed	Read speed
Atmel AT91SAM7S (48 MHz)	Ultron 256MB SD card	**2.3**	**2.3**
Atmel AT91SAM9261 (178 MHz)	Ultron 256MB SD card	**2.3**	**2.5**
TI TM4C129	SanDisk 16GB Ultra PLUS SD card	**2.0**	**2.2**
NXP LPC1768	SanDisk Extreme PRO 32GB	**1.6**	**1.6**
ST STM32H753	SanDisk Extreme PRO 32GB	**1.4**	**1.5**

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6.5.3 Card Mode MMC/SD driver

6.5.3.1 Configuring the driver

This section describes how to configure the file system to make use of the Card Mode MMC/SD driver.

6.5.3.1.1 Compile time configuration

The Card Mode MMC/SD driver can optionally be configured at compile time. Typically, this step can be omitted because the Card Mode MMC/SD driver provides reasonable default values that work for most of the target applications. The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371 The following table lists the configuration defines supported by the Card Mode MMC/SD driver.

Define	Default value	Type	Description
FS_MMC_DISABLE_DAT3_PULLUP	0	B	Configures if the internal pull-up mounted on the DAT3 signal has to be disabled.
FS_MMC_ENABLE_STATS	0 or 1	B	Enables or disables the support for statistical counters.
FS_MMC_NOTIFY_EVENT	0	B	Enables or disables the support for event notification.
FS_MMC_NUM_RETRIES	5	N	Configures the number of retries in case of a read or write error.
FS_MMC_NUM_UNITS	2	N	Maximum number of driver instances.
FS_MMC_READ_DATA_TIMEOUT	0	N	Maximum number of milliseconds to wait for the data to be received from the storage device.
FS_MMC_READ_SINGLE_LAST_SECTOR	0	B	Configures how the last sector of the storage device has to be read.
FS_MMC_SELECT_CARD_TIMEOUT	512	N	Maximum number of times a failed card select operation has to be repeated.
FS_MMC_SUPPORT_ERROR_RECOVERY	0	B	Enables or disables the support for advanced error recovery.
FS_MMC_SUPPORT_MMC	1	B	Enables or disables the handling of MMC devices.
FS_MMC_SUPPORT_POWER_SAVE	0	B	Enables or disables the support for putting an MMC device into sleep mode.
FS_MMC_SUPPORT_SD	1	B	Enables or disables the handling of SD cards.
FS_MMC_SUPPORT_TRIM	0	B	Enables or disables the support for marking a logical sector as not in use.
FS_MMC_SUPPORT_UHS	0	B	Enables or disables the data access with clock frequencies up to 200 MHz.

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Define	Default value	Type	Description
FS_MMC_TEST_BUS_WIDTH	0	B	Enables or disables the detection of the number of connected data signals.
FS_MMC_WAIT_READY_TIMEOUT	0x00FFFFFF	N	Maximum number of times to check for the ready status of the storage device.

6.5.3.1.1.1 FS_MMC_DISABLE_DAT3_PULLUP

An SD card has an internal pull-up mounted on the DAT3 signal that can be used for card detection. Typically, this way of detecting the presence of an SD card is not used. Instead, the SD card slot has a mechanical switch that is used for this purpose. The internal pull-up is no longer necessary after the initialization of the SD card. Therefore, the SD Specification recommends disabling the pull-up during data transfers that use the DAT3 signal that is when the data is transferred via four data lines. If FS_MMC_DISABLE_DAT3_PULLUP is set to 1 then the Card Mode MMC/SD driver will disable the pull-up before the SD card is configured to transfer the data via the four data lines.

6.5.3.1.1.2 FS_MMC_ENABLE_STATS

This define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the Card Mode MMC/SD driver that can be useful for debugging. The statistical counters can be queried via FS_MMC_CM_GetStatCounters() and set to 0 via FS_MMC_CM_ResetStatCounters(). By default FS_MMC_ENABLE_STATS is set to 1 if FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

6.5.3.1.1.3 FS_MMC_NOTIFY_EVENT

FS_MMC_NOTIFY_EVENT can be used to configure the Card Mode MMC/SD driver to report internal events such as a device initialization via a registered callback function.

6.5.3.1.1.4 FS_MMC_NUM_RETRIES

This define can be used to specify the number of times the Card Mode MMC/SD driver retries the operation in case of a read or write error.

6.5.3.1.1.5 FS_MMC_NUM_UNITS

This define specifies the maximum number of driver instances of the Card Mode MMC/SD driver the application is allowed to create. Four bytes of static RAM are reserved for each instance. If the maximum number of driver instances is smaller than the default value, then FS_MMC_NUM_UNITS can be set to that value in order to reduce the RAM usage.

6.5.3.1.1.6 FS_MMC_READ_DATA_TIMEOUT

FS_MMC_READ_DATA_TIMEOUT specifies the maximum number of milliseconds the Card Mode MMC/SD driver has to wait for the data to be received from the storage device. A value of 0 is interpreted as 0xFFFFFFFF milliseconds for backward compatibility. Typically, a storage device requires a maximum of 200 milliseconds to complete a read operation.

6.5.3.1.1.7 FS_MMC_READ_SINGLE_LAST_SECTOR

FS_MMC_READ_SINGLE_LAST_SECTOR can be used to specify how the last logical sector located on the storage device has to be read. If FS_MMC_READ_SINGLE_LAST_SECTOR is set to 0 then the last logical sector can be read either via a command that reads one logical sector (CMD_READ_SINGLE_BLOCK) or via a command that reads multiple logical sectors (CMD_READ_MULTIPLE_BLOCKS). If FS_MMC_READ_SINGLE_LAST_SECTOR is set to 1 then the last logical sector is always read via a CMD_READ_SINGLE_BLOCK command. This feature has to be

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activated for a storage device that is not able to handle correctly CMD_READ_MULTIPLE_BLOCKS commands that read the last sector.

6.5.3.1.1.8 FS_MMC_SELECT_CARD_TIMEOUT

FS_MMC_SELECT_CARD_TIMEOUT specifies the maximum number of times the Card Mode MMC/SD driver has to repeat a failed card select operation before it reports an error to the Storage layer. The Card Mode MMC/SD driver selects a storage device before each data exchange operation. At the end of the operation, the storage device is deselected.

6.5.3.1.1.9 FS_MMC_SUPPORT_ERROR_RECOVERY

FS_MMC_SUPPORT_ERROR_RECOVERY can be used to enable advanced error recovery procedures of the Card Mode MMC/SD driver such as storage device reinitialization.

6.5.3.1.1.10 FS_MMC_SUPPORT_MMC

FS_MMC_SUPPORT_MMC can be used to disable the handling of MMC devices in the Card Mode MMC/SD driver. If the target application is expected to work only with SD cards then this configuration define can be safely set to 0 in order to save ROM space. The handling of MMC devices does not have to be explicitly enabled at runtime if FS_MMC_SUPPORT_MMC is set to 1.

6.5.3.1.1.11 FS_MMC_SUPPORT_POWER_SAVE

FS_MMC_SUPPORT_POWER_SAVE can be used to enable the support for putting an MMC device into sleep mode. This feature has to be enabled at runtime by calling FS_MMC_CM_AllowPowerSaveMode() with the second argument set to 1. With this feature enabled, the Card Mode MMC/SD driver puts the MMC device into sleep mode after each operation to preserve power. In addition, the application can explicitly put the MMC device into sleep mode by calling FS_MMC_CM_EnterPowerSaveMode().

6.5.3.1.1.12 FS_MMC_SUPPORT_SD

FS_MMC_SUPPORT_SD can be used to disable the handling of SD cards in the Card Mode MMC/SD driver. If the target application is expected to work only with MMC devices such as eMMC then this configuration define can be safely set to 0 in order to save ROM space. The handling of SD cards does not have to be explicitly enabled at runtime if FS_MMC_SUPPORT_SD is set to 1.

6.5.3.1.1.13 FS_MMC_SUPPORT_TRIM

FS_MMC_SUPPORT_TRIM can be used to specify if the information about unused logical sectors is forwarded to the storage device. If FS_MMC_SUPPORT_TRIM is set to 1 then the storage device is informed about logical sectors that do not contain valid data anymore, such as when a file is deleted. Currently, only MMC devices support this operation.

6.5.3.1.1.14 FS_MMC_SUPPORT_UHS

FS_MMC_SUPPORT_UHS can be used to enable the support for access modes with a clock frequency of up to about 200 MHz. Refer to *Supported hardware* on page 1081 for a list of supported access modes. All ultra-high-speed access modes are disabled by default and have to be explicitly enabled at runtime by the application in FS_X_AddDevices() by calling one of the functions listed in the following table with the OnOff parameter set to 1.

Device type	UHS Access mode	Function name
SD	DDR50	FS_MMC_CM_AllowAccessModeDDR50()
SD	SDR50	FS_MMC_CM_AllowAccessModeSDR50()
SD	SDR104	FS_MMC_CM_AllowAccessModeSDR104()
MMC	High Speed DDR	FS_MMC_CM_AllowAccessModeHS_DDR()
MMC	HS200	FS_MMC_CM_AllowAccessModeHS200()

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Device type	UHS Access mode	Function name
MMC	HS400	FS_MMC_CM_AllowAccessModeHS400()

In addition, the voltage level of the I/O lines has to be set to 1.8 V by calling the FS_MMC_CM_AllowVoltageLevel1V8() with the OnOff parameter set to 1.

6.5.3.1.1.15 FS_MMC_TEST_BUS_WIDTH

This configuration define can be used to enable the runtime detection of the number of data signals connected to an eMMC device. If FS_MMC_TEST_BUS_WIDTH is set to 1, then the Card Mode MMC/SD driver requests the eMMC device to send a predefined data pattern that can be used to determine how many data signals are physically connected. This information is used by the Card Mode MMC/SD driver to configure the eMMC device for a data transfer via the maximum number of data signals available.

6.5.3.1.1.16 FS_MMC_WAIT_READY_TIMEOUT

FS_MMC_WAIT_READY_TIMEOUT specifies the maximum number of times the Card Mode MMC/SD driver has to check for the ready status of the storage device before it reports an error to the Storage layer.

6.5.3.1.2 Runtime configuration

The driver must be added to the file system by calling FS_AddDevice() with the driver identifier set to the address of the FS_MMC_CM_Driver structure. This function call together with other function calls that configure the driver operation have to be added to FS_X_AddDevices() as demonstrated in the following example. This example shows how to configure the file system to access an MMC/SD card in card mode.

```
#include "FS.h"
#include "FS_MMC_HW_CM_Template.h"

#define ALLOC_SIZE 0x1300               // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the Card mode MMC/SD driver.
  //
  FS_AddDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(0, 1);
  FS_MMC_CM_SetHWType(0, &FS_MMC_HW_CM_Template);
  //
  // Configure the file system for fast write operations.
  //
#if FS_SUPPORT_FILE_BUFFER
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif
  FS_SetFileWriteMode(FS_WRITEMODE_FAST);
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the Card Mode MMC/SD driver. The application can call them only at the file system initialization in FS_X_AddDevices().

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Function	Description
FS_MMC_CM_Allow4bitMode()	Allows the driver to exchange the data via 4 lines.
FS_MMC_CM_Allow8bitMode()	Allows the driver to exchange the data via 8 data lines.
FS_MMC_CM_AllowCacheActivation()	Allows the driver to activate the data cache of an eMMC device.
FS_MMC_CM_AllowAccessModeDDR50()	Allows the driver to exchange the data with an SD card using DDR50 access mode.
FS_MMC_CM_AllowAccessModeHS200()	Allows the driver to exchange the data with an MMC device using the HS200 access mode.
FS_MMC_CM_AllowAccessModeHS400()	Allows the driver to exchange the data with an eMMC device using the HS400 access mode.
FS_MMC_CM_AllowAccessModeHS_DDR()	Allows the driver to exchange the data with an MMC device using the High Speed DDR access mode.
FS_MMC_CM_AllowAccessModeSDR104()	Allows the driver to exchange the data with an SD card using SDR104 access mode.
FS_MMC_CM_AllowAccessModeSDR50()	Allows the driver to exchange the data with an SD card using SDR50 access mode.
FS_MMC_CM_AllowBufferedWrite()	Enables / disables the write buffering.
FS_MMC_CM_AllowHighSpeedMode()	Allows the driver to exchange the data in high speed mode.
FS_MMC_CM_AllowPowerSaveMode()	Configures if the driver has to request the eMMC to save power.
FS_MMC_CM_AllowReliableWrite()	Allows the driver to use reliable write operations for MMC devices.
FS_MMC_CM_AllowVoltageLevel1V8()	Allows the driver to user 1.8 V signaling on the I/O lines.
FS_MMC_CM_SetDriverStrength()	Configures the output driving strength of the MMC/SD device.
FS_MMC_CM_SetSectorRange()	Configures an area for data storage.
FS_MMC_CM_SetHS200Tuning()	Enables or disables the tuning for the HS200 access mode.
FS_MMC_CM_SetHWType()	Configures the HW access routines.
FS_MMC_CM_SetOnDeviceInitCallback()	Registers a callback function for the device initialization event.
FS_MMC_CM_SetSDR104Tuning()	Enables or disables the tuning for the SDR104 access mode.
FS_MMC_CM_SetSDR50Tuning()	Enables or disables the tuning for the SDR50 access mode.

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6.5.3.1.2.1 FS_MMC_CM_Allow4bitMode()

Description

Allows the driver to exchange the data via 4 lines.

Prototype

```
void FS_MMC_CM_Allow4bitMode(U8 Unit,
                             U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Data is exchanged via 1 line. • 1 Data is exchanged via 4 lines.

Additional information

This function is optional. By default, the 4-bit mode is disabled which means that the Card Mode MMC/SD driver exchanges data via only one data line. Using 4-bit mode can help increase the performance of the data transfer. The 4-bit mode is used for the data transfer only if the connected MMC/SD card supports it which is typically the case with all modern cards. If not then the Card Mode MMC/SD driver falls back to 1-bit mode.

The application can query the actual number of data lines used by the Card Mode MMC/SD driver for the data transfer by evaluating the value of BusWidth member of the FS_MMC_CARD_INFO structure returned by FS_MMC_CM_GetCardInfo().

An application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

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6.5.3.1.2.2 FS_MMC_CM_Allow8bitMode()

Description

Allows the driver to exchange the data via 8 data lines.

Prototype

```
void FS_MMC_CM_Allow8bitMode(U8 Unit,
                             U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Data is exchanged via 1 or 4 lines. • 1 Data is exchanged via 8 lines.

Additional information

This function is optional. By default, the 8-bit mode is disabled which means that the Card Mode MMC/SD driver exchanges data via only one data line. Using 8-bit mode can help increase the performance of the data transfer. The 8-bit mode is used for the data transfer only if the connected MMC/SD card supports it. If not then the Card mode MMC/SD driver falls back to either 4- or 1-bit mode. Only MMC devices support the 8-bit mode. The SD cards are not able to transfer the data via 8-bit lines.

The application can query the actual number of data lines used by the Card Mode MMC/SD driver for the data transfer by evaluating the value of BusWidth member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.5.3.1.2.3 FS_MMC_CM_AllowCacheActivation()

Description

Allows the driver to activate the data cache of an eMMC device.

Prototype

```
void FS_MMC_CM_AllowCacheActivation(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Cache activation is not allowed. • 1 Cache activation is allowed.

Additional information

This function is optional. It can be used to configure if the Card Mode MMC/SD driver is allowed to enable the data cache of an eMMC device. The data cache is activated only if supported by the eMMC device. By default, the Card Mode MMC/SD driver activates the data cache for improved read and write performance. With the data cache enabled, the fail-safety of the file system can no longer be guaranteed.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowCacheActivation()` is available only when the file system is built with `FS_MMC_SUPPORT_MMC` set to 1.

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6.5.3.1.2.4 FS_MMC_CM_AllowAccessModeDDR50()

Description

Allows the driver to exchange the data with an SD card using DDR50 access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeDDR50(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use DDR50 access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an SD card on both clock edges and at a clock frequency of maximum 50 MHz. The voltage level of the I/O lines used by this access mode is 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The DDR50 access mode is used only if the connected SD card supports it.

The application can check if the Card Mode MMC/SD driver is actually using the DDR50 access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The DDR50 access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeDDR50()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_SD` set to 1.

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6.5.3.1.2.5 FS_MMC_CM_AllowAccessModeHS200()

Description

Allows the driver to exchange the data with an MMC device using the HS200 access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeHS200(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use HS200 access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an MMC device on a single clock edge and at a clock frequency of maximum 200 MHz. The voltage level of the I/O lines used by this access mode can be either 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The HS200 access mode is used only if the connected MMC device supports it. In this access mode the data is transferred either via 4 or 8 lines. The data transfer via 4 and 8 data lines can be enabled via `FS_MMC_CM_Allow4bitMode()` and `FS_MMC_CM_Allow8bitMode()` respectively.

The application can check if the Card Mode MMC/SD driver is actually using the HS200 access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The HS200 access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeHS200()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_MMC` set to 1.

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6.5.3.1.2.6 FS_MMC_CM_AllowAccessModeHS400()

Description

Allows the driver to exchange the data with an eMMC device using the HS400 access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeHS400(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use HS400 access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an MMC device on both clock edges and at a clock frequency of maximum 200 MHz. The voltage level of the I/O lines used by this access mode can be either 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The HS400 access mode is used only if the connected MMC device supports it. In this access mode the data is always transferred via 8 lines. The data transfer via 8 data lines can be enabled via `FS_MMC_CM_Allow8bitMode()`.

The application can check if the Card Mode MMC/SD driver is actually using the HS400 access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The HS400 access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeHS400()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_MMC` set to 1.

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6.5.3.1.2.7 FS_MMC_CM_AllowAccessModeHS_DDR()

Description

Allows the driver to exchange the data with an MMC device using the High Speed DDR access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeHS_DDR(U8 Unit,
                                     U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use High Speed DRR access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an MMC device on both clock edges and at a clock frequency of maximum 52 MHz. The voltage level of the I/O lines used by this access mode can be either 3.3 V or 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The 3.3 V voltage level is enabled by default. The High Speed DDR access mode is used only if the connected MMC device supports it.

The application can check if the Card Mode MMC/SD driver is actually using the high speed DDR access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The High Speed DDR access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeHS_DDR()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_MMC` set to 1.

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6.5.3.1.2.8 FS_MMC_CM_AllowAccessModeSDR104()

Description

Allows the driver to exchange the data with an SD card using SDR104 access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeSDR104(U8 Unit,
                                     U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use SDR104 access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an SD card on a single clock edge and at a clock frequency of maximum 208 MHz. The voltage level of the I/O lines used by this access mode is 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The SDR104 access mode is used only if the connected SD card supports it.

The application can check if the Card Mode MMC/SD driver is actually using the SDR104 access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The SDR104 access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeSDR104()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_SD` set to 1.

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6.5.3.1.2.9 FS_MMC_CM_AllowAccessModeSDR50()

Description

Allows the driver to exchange the data with an SD card using SDR50 access mode.

Prototype

```
void FS_MMC_CM_AllowAccessModeSDR50(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use another access mode. • 1 Use SDR50 access mode.

Additional information

This function is optional. The application can use it to request the Card Mode MMC/SD driver to exchange data with an SD card on a single clock edge and at a clock frequency of maximum 100 MHz. The voltage level of the I/O lines used by this access mode is 1.8 V. The support for the 1.8 V voltage level can be enabled via `FS_MMC_CM_AllowVoltageLevel1V8()`. The SDR50 access mode is used only if the connected SD card supports it.

The application can check if the Card Mode MMC/SD driver is actually using the SDR50 access mode for the data transfer by evaluating the AccessMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The SDR50 access mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_AllowAccessModeSDR50()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_SD` set to 1.

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6.5.3.1.2.10 FS_MMC_CM_AllowBufferedWrite()

Description

Enables / disables the write buffering.

Prototype

```
void FS_MMC_CM_AllowBufferedWrite(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the buffered write operation should be enabled or not. • 0 Buffered write operation is disabled. • 1 Buffered write operation is enabled.

Additional information

SD and MMC storage devices can perform write operations in parallel to receiving data from the host by queuing write requests. This feature is used by the driver in order to achieve the highest write performance possible. In case of a power fail the hardware has to prevent that the write operation is interrupted by powering the storage device until the write queue is emptied. The time it takes the storage device to empty the queue is not predictable and it can take from a few hundreds o milliseconds to a few seconds to complete. This function allows the application to disable the buffered write and thus reduce the time required to supply the storage device at power fail. With the write buffering disabled the driver writes only one sector at time and it waits for the previous write sector operation to complete.

Disabling the write buffering can considerably reduce the write performance. Most of the industrial grade SD and MMC storage devices are fail safe so that disabling the write buffering is not required. For more information consult the data sheet of your storage device.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.5.3.1.2.11 FS_MMC_CM_AllowHighSpeedMode()

Description

Allows the driver to exchange the data in high speed mode.

Prototype

```
void FS_MMC_CM_AllowHighSpeedMode(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Use standard speed mode. • 1 Use high speed mode.

Additional information

This function is optional. The application can use this function to request the Card Mode MMC/SD driver to use the highest clock frequency supported by the used MMC/SD card. The standard clock frequency supported by an SD card is 25 MHz and 26 MHz by an MMC device. This is the clock frequency used by the Card Mode MMC/SD driver after the initialization of the MMC/SD card. However, most of the modern SD cards and MMC devices are able to exchange the data at higher clock frequencies up to 50 MHz for SD cards and 52 MHz for MMC devices. This high speed mode has to be explicitly enabled in the SD card or MMC device after initialization. The Card mode SD/MMC driver automatically enables the high speed mode in the SD card or MMC device if `FS_MMC_CM_AllowHighSpeedMode()` is called with `OnOff` set to 1 and the used SD card or MMC device actually supported.

The application can check if the Card Mode MMC/SD driver is actually using the high speed mode for the data transfer by evaluating the IsHighSpeedMode member of the `FS_MMC_CARD_INFO` structure returned by `FS_MMC_CM_GetCardInfo()`.

The high speed mode can be used only if the SD/MMC host controller supports it. The availability of this functionality is not checked by the Card Mode MMC/SD driver.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.5.3.1.2.12 FS_MMC_CM_AllowPowerSaveMode()

Description

Configures if the driver has to request the eMMC to save power.

Prototype

```
int FS_MMC_CM_AllowPowerSaveMode(U8 Unit,
                                 U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies if the MMC device has to be put to sleep between data transfers • 0 The MMC device remains active. • 1 The MMC device is put to sleep.

Return value

= 0 OK, feature configured.
≠ 0 An error occurred.

Additional information

This function is optional and active only if the sources are compiled with the FS_MMC_SUPPORT_POWER_SAVE set to 1.

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6.5.3.1.2.13 FS_MMC_CM_AllowReliableWrite()

Description

Allows the driver to use reliable write operations for MMC devices.

Prototype

```
void FS_MMC_CM_AllowReliableWrite(U8 Unit,
                                  U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 Reliable write operation is disabled (default). • 1 Reliable write operation is enabled.

Additional information

This function is optional. A reliable write operation makes sure that the sector data is not corrupted in case of an unexpected reset. MMC devices compliant with the version 4.3 or newer of the MMC specification support a fail-safe write feature which makes sure that the old data remains unchanged until the new data is successfully programmed. Using this type of write operation the data remains valid in case of an unexpected reset which improves the data reliability. The support for this feature is optional and the Card Mode MMC/SD driver activates it only if the used MMC device actually supports it and only if `FS_MMC_CM_AllowReliableWrite()` has been called with `OnOff` set to 1.

Enabling the reliable write feature can possibly reduce the write performance.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

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6.5.3.1.2.14 FS_MMC_CM_AllowVoltageLevel1V8()

Description

Allows the driver to user 1.8 V signaling on the I/O lines.

Prototype

```
void FS_MMC_CM_AllowVoltageLevel1V8(U8 Unit,
                                    U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the permission status. • 0 1.8 V signaling is not allowed. • 1 1.8 V signaling is allowed.

Additional information

This function is optional. It gives the application the ability to configure if the Card Mode MMC/SD driver can exchange the data with an SD card or MMC device using 1.8 V voltage level on the I/O lines. This voltage level is required for the ultra high speed access modes.

An application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

FS_MMC_CM_AllowVoltageLevel1V8() is available only when the file system is built with FS_MMC_SUPPORT_UHS set to 1.

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6.5.3.1.2.15 FS_MMC_CM_SetDriverStrength()

Description

Configures the output driving strength of the MMC/SD device.

Prototype

```
void FS_MMC_CM_SetDriverStrength(U8       Unit,
                                 unsigned DriverStrength);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
DriverStrength	Specifies the output driving strength.

Additional information

This function is optional. It gives the application the ability to configure if the output driving strength of the MMC/SD device. Refer to *Driver strength types* on page 1124 for permitted values for DriverStrength. The specified driver strength is used only if the MMC/SD device actually supports it. If the MMC/SD device does not support the specified driver strength then the default driver strength is used.

The actual driver strength can be queried via FS_MMC_CM_GetCardInfo(). The value is stored in the FS_MMC_CARD_INFO::DriverStrength member of the returned data structure.

An application is permitted to call this function only at the file system initialization in FS_X_AddDevices().

FS_MMC_CM_SetDriverStrength() is available only when the file system is built with FS_MMC_SUPPORT_UHS set to 1.

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6.5.3.1.2.16 FS_MMC_CM_SetSectorRange()

Description

Configures an area for data storage.

Prototype

```
void FS_MMC_CM_SetSectorRange(U8  Unit,
                              U32 StartSector,
                              U32 MaxNumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
StartSector	Index of the first sector to be used as storage.
MaxNumSectors	Maximum number of sectors to be used as storage.

Additional information

This function is optional. It allows an application to use only a specific area of an SD/MMC storage device as storage. By default the Card Mode MMC/SD driver uses the entire available space as storage.

StartSector is relative to the beginning of the SD/MMC storage device. For example, if StartSector is set to 3 than the sectors with the indexes 0, 1, and 2 are not used for storage. The initialization of SD/MMC storage device fails if StartSector is out of range.

If MaxNumSectors is set to 0 the Card mode SD/MMC driver uses for storage the remaining sectors starting from StartSector. If MaxNumSectors is larger than the available number or sectors the actual number of sectors used for storage is limited to the number of sectors available.

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6.5.3.1.2.17 FS_MMC_CM_SetHS200Tuning()

Description

Enables or disables the tuning for the HS200 access mode.

Prototype

```
void FS_MMC_CM_SetHS200Tuning(U8 Unit,
                              U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the tuning activation status. • 0 Tuning is not performed. • 1 Tuning is performed.

Additional information

This function is optional. It gives the application the ability to select if a tuning procedure is performed at the initialization of an MMC device that is exchanging the data in HS200 access mode. The tuning procedure is required in order to determine the correct sampling point of the data that is received from the SD card. By default, the tuning procedure is enabled for the HS200 access mode.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_SetHS200Tuning()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_MMC` set to 1.

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6.5.3.1.2.18 FS_MMC_CM_SetHWType()

Description

Configures the HW access routines.

Prototype

```
void FS_MMC_CM_SetHWType(      U8                   Unit,
                         const FS_MMC_HW_TYPE_CM * pHWType);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pHWType	in Specifies the type of the hardware layer to be used to communicate with the storage device.

Additional information

This function is mandatory. It has to be called in `FS_X_AddDevices()` once for each instance of the card mode SD/MMC driver. The driver instance is identified by the `Unit` parameter.

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6.5.3.1.2.19 FS_MMC_CM_SetOnDeviceInitCallback()

Description

Registers a callback function for the device initialization event.

Prototype

```
void FS_MMC_CM_SetOnDeviceInitCallback
                                (FS_MMC_ON_DEVICE_INIT_CALLBACK * pfOnDeviceInit);
```

Parameters

Parameter	Description
pfOnDeviceInit	Function to be invoked when the device is initialized.

Additional information

This function is available only when the file system is built with FS_MMC_NOTIFY_EVENT set to 1.

The Card Mode MMC/SD driver calls the registered function at the end of a successful storage device initialization.

The registered callback is not allowed to call any API function of the file system with the exception of these Card Mode MMC/SD driver API functions:

- FS_MMC_CM_WriteExtCSD()
- FS_MMC_CM_ReadExtCSD()

The Unit parameter passed to these API functions has to match the value of the Unit parameter passed to the callback function.

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6.5.3.1.2.20 FS_MMC_CM_SetSDR104Tuning()

Description

Enables or disables the tuning for the SDR104 access mode.

Prototype

```
void FS_MMC_CM_SetSDR104Tuning(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the tuning activation status. • 0 Tuning is not performed. • 1 Tuning is performed.

Additional information

This function is optional. It gives the application the ability to select if a tuning procedure is performed at the initialization of the SD card that is exchanging the data in SDR104 access mode. The tuning procedure is required in order to determine the correct sampling point of the data that is received from the SD card. By default, the tuning procedure is enabled for the SDR104 access mode as required by the SD Specification.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_SetSDR104Tuning()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_SD` set to 1.

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6.5.3.1.2.21 FS_MMC_CM_SetSDR50Tuning()

Description

Enables or disables the tuning for the SDR50 access mode.

Prototype

```
void FS_MMC_CM_SetSDR50Tuning(U8 Unit,
                              U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
OnOff	Specifies the tuning activation status. • 0 Tuning is not performed. • 1 Tuning is performed.

Additional information

This function is optional. It gives the application the ability to select if a tuning procedure is performed at the initialization of the SD card that is exchanging the data in SDR50 access mode. The tuning procedure is required in order to determine the correct sampling point of the data that is received from the SD card. By default, the tuning procedure is disabled for the SDR50 access mode.

An application is permitted to call this function only at the file system initialization in `FS_X_AddDevices()`.

`FS_MMC_CM_SetSDR50Tuning()` is available only when the file system is built with `FS_MMC_SUPPORT_UHS` and `FS_MMC_SUPPORT_SD` set to 1.

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6.5.3.1.2.22 Driver strength types

Description

Types of output driver strengths of an MMC/SD storage device.

Definition

```
#define FS_MMC_DRIVER_STRENGTH_TYPE_B    0u
#define FS_MMC_DRIVER_STRENGTH_TYPE_A    1u
#define FS_MMC_DRIVER_STRENGTH_TYPE_C    2u
#define FS_MMC_DRIVER_STRENGTH_TYPE_D    3u
#define FS_MMC_DRIVER_STRENGTH_TYPE_E    4u
```

Symbols

Definition	Description
FS_MMC_DRIVER_STRENGTH_TYPE_B	50 Ohm impedance and x1 driving capability. This is the default value.
FS_MMC_DRIVER_STRENGTH_TYPE_A	33 Ohm impedance and x1.5 driving capability.
FS_MMC_DRIVER_STRENGTH_TYPE_C	66 Ohm impedance and x0.75 driving capability.
FS_MMC_DRIVER_STRENGTH_TYPE_D	100 Ohm impedance and x0.5 driving capability.
FS_MMC_DRIVER_STRENGTH_TYPE_E	40 Ohm impedance and x1.2 driving capability. For eMMC devices only.

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6.5.3.1.2.23 FS_MMC_ON_DEVICE_INIT_CALLBACK

Description

Type of function called by the Card Mode MMC/SD driver to report that the storage device was initialized.

Type definition

```
typedef int (FS_MMC_ON_DEVICE_INIT_CALLBACK)(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)

Return value

= 0 OK, operation executed successfully.
≠ 0 An error occurred.

Additional information

`FS_MMC_CM_SetOnDeviceInitCallback()` can be used to register a function of this type as a callback for the device initialization event. The Card Mode MMC/SD driver will report an initialization failure to the application if the registered callback function returns a value different than 0.

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6.5.3.2 Additional driver functions

These functions are optional. They can be used to get information about the operation of the Card Mode MMC/SD driver and to perform additional operations on the used SD card or MMC device.

Function	Description
FS_MMC_CM_EnterPowerSaveMode()	Puts the MMC to sleep in order to save power.
FS_MMC_CM_Erase()	Erases the contents of one or more logical sectors.
FS_MMC_CM_GetCardId()	Returns the identification data of the SD/MMC device.
FS_MMC_CM_GetCardInfo()	This function returns information about the SD/MMC device.
FS_MMC_CM_GetStatCounters()	Returns the value of statistical counters.
FS_MMC_CM_ReadCSD()	Reads the contents of the CSD register of a storage device.
FS_MMC_CM_ReadExtCSD()	Reads the contents of the Extended CSD register of an MMC device.
FS_MMC_CM_ReadGeneral()	Reads a block of data via General Command (CMD56).
FS_MMC_CM_ReadSCR()	Reads the contents of the SD Configuration register of an SD card.
FS_MMC_CM_ReadSectors()	Reads blocks of data from the active partition of the storage card.
FS_MMC_CM_ReadSSR()	Reads the contents of the SD Status register of an SD card.
FS_MMC_CM_ResetStatCounters()	Sets to 0 all statistical counters.
FS_MMC_CM_UnlockCardForced()	Unlocks an SD card.
FS_MMC_CM_WriteExtCSD()	Writes to the Extended CSD register of a MMC device.
FS_MMC_CM_WriteGeneral()	Writes a block of data via General Command (CMD56).
FS_MMC_CM_WriteSectors()	Writes blocks of data to the selected partition of the storage card.

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6.5.3.2.1 FS_MMC_CM_EnterPowerSaveMode()

Description

Puts the MMC to sleep in order to save power.

Prototype

```
int FS_MMC_CM_EnterPowerSaveMode(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 The eMMC device is in Sleep state.
≠ 0 An error occurred.

Additional information

This function is optional. It can be used to explicitly put the eMMC device into Sleep state in order to reduce power consumption.

This function is active only if the sources are compiled with the define `FS_MMC_SUPPORT_POWER_SAVE` set to 1.

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6.5.3.2.2 FS_MMC_CM_Erase()

Description

Erases the contents of one or more logical sectors.

Prototype

```
int FS_MMC_CM_Erase(U8  Unit,
                    U32 StartSector,
                    U32 NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
StartSector	Index of the first sector to be erased.
NumSectors	Number of sector to be erased.

Return value

= 0 Sectors erased.
≠ 0 An error has occurred.

Additional information

This function is optional. The application can use it to set the contents of the specified logical sectors to a predefined value. The erase operation sets all the bits in the specified logical sectors either to 1 or to 0. The actual value is implementation defined in the EXT_CSD register.

The erase operation is supported only for MMC devices.

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6.5.3.2.3 FS_MMC_CM_GetCardId()

Description

Returns the identification data of the SD/MMC device.

Prototype

```
int FS_MMC_CM_GetCardId(U8               Unit,
                        FS_MMC_CARD_ID * pCardId);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pCardId	out Card identification data.

Return value

= 0 CardId has been read.
≠ 0 An error has occurred.

Additional information

This function is optional. The application can call this function to get the information stored in the CID register of an MMC or SD card. The CID register stores information which can be used to uniquely identify the card such as serial number, product name, manufacturer id, etc. For more information about the information stored in this register refer to SD or MMC specification. The data of the CID register starts at byte offset 1 in pCardId->aData.

Example

The following example shows how to read and decode the contents of the CID register stored in an SD card.

```
#include <stdio.h>
#include "FS.h"

void SampleMMC_CMGetCardId_SDCard(void) {
  U8            ManId;
  char          acOEMId[2 + 1];
  char          acProductName[5 + 1];
  U8            ProductRevMajor;
  U8            ProductRevMinor;
  U32           ProductSN;
  U8            MfgMonth;
  U16           MfgYear;
  U16           MfgDate;
  U8          * p;
  MMC_CARD_ID   CardId;
  char          ac[100];

  memset(&CardId, 0, sizeof(CardId));
  FS_MMC_CM_GetCardId(0, &CardId);
  p = CardId.aData;
  ++p;      // Skip the start of message.
  ManId = *p++;
  strncpy(acOEMId, (char *)p, 2);
  acOEMId[2] = '\0';
  p += 2;
  strncpy(acProductName, (char *)p, 5);
  acProductName[5] = '\0';
  p += 5;
  ProductRevMajor  = *p >> 4;
  ProductRevMinor  = *p++ & 0xF;
  ProductSN        = (U32)*p++ << 24;
  ProductSN       |= (U32)*p++ << 16;
  ProductSN       |= (U32)*p++ << 8;
  ProductSN       |= (U32)*p++;
```

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```
  MfgDate          = (U16)*p++ << 8;
  MfgDate         |= (U16)*p++;
  MfgMonth         = (U8)(MfgDate & 0xF);
  MfgYear          = MfgDate >> 4;
  FS_X_Log("SD card identification:\n");
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturer Id:       0x%02x\n", ManId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  OEM/Application Id:    %s\n", acOEMId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product name:          %s\n", acProductName);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product revision:      %lu.%lu
\n", (U32)ProductRevMajor, (U32)ProductRevMinor);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product serial number: 0x%08lx\n", ProductSN);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturing date:    %lu-%lu
\n", (U32)MfgMonth, (U32)MfgYear);
  FS_X_Log(ac);
}
```

The following example shows how to read and decode the contents of the CID register stored in an eMMC device.

```
#include <stdio.h>
#include "FS.h"

void SampleMMC_CMGetCardId_eMMC(void) {
  U8            ManId;
  char          acProductName[6 + 1];
  U8            ProductRev;
  U8            DeviceType;
  const char  * sDeviceType;
  U8            OEMId;
  U8            CSDRev;
  U32           ProductSN;
  U8            MfgMonth;
  U16           MfgYear;
  U16           MfgDate;
  U8          * p;
  MMC_CARD_ID   CardId;
  char          ac[100];
  U32           aBuffer[512 / 4];

  //
  // The year of the manufacturing date field has to be interpreted differently
  // based on the eMMC version. The eMMC version is stored in the Extended CSD register.
  //
  FS_MMC_CM_ReadExtCSD(0, aBuffer);
  p = (U8 *)aBuffer;
  CSDRev = (int)*(p + 192);
  memset(&CardId, 0, sizeof(CardId));
  FS_MMC_CM_GetCardId(0, &CardId);
  p = CardId.aData;
  ++p;      // Skip the start of message.
  ManId      = *p++;
  DeviceType = *p++ & 0x3;
  switch (DeviceType) {
  case 0:
    sDeviceType = "Device";
    break;
  case 1:
    sDeviceType = "BGA";
    break;
  case 2:
    sDeviceType = "POP";
    break;
  default:
    sDeviceType = "Unknown";
    break;
  }
  OEMId       = *p++;
  strncpy(acProductName, (char *)p, 6);
  acProductName[6] = '\0';
  p += 6;
```

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```
  ProductRev  = *p++;
  ProductSN   = (U32)*p++ << 24;
  ProductSN  |= (U32)*p++ << 16;
  ProductSN  |= (U32)*p++ << 8;
  ProductSN  |= (U32)*p++;
  MfgDate     = *p++;
  MfgMonth    = MfgDate >> 4;
  MfgYear     = (MfgDate & 0xF);
  if (MfgYear >= 13) {
    MfgYear += 1997;
  } else {
    if (CSDRev > 4) {
      MfgYear += 2013;
    } else {
      MfgYear += 1997;
    }
  }
  FS_X_Log("eMMC identification:\n");
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturer Id:       0x%02x\n", ManId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Device/BGA:            %s\n", sDeviceType);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  OEM/Application Id:    %lu\n", (U32)OEMId);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product name:          %s\n", acProductName);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product revision:      %lu\n", (U32)ProductRev);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Product serial number: 0x%08lx\n", ProductSN);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Manufacturing date:    %lu-%lu
\n", (U32)MfgMonth, (U32)MfgYear);
  FS_X_Log(ac);
}
```

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6.5.3.2.4 FS_MMC_CM_GetCardInfo()

Description

This function returns information about the SD/MMC device.

Prototype

```
int FS_MMC_CM_GetCardInfo(U8                 Unit,
                          FS_MMC_CARD_INFO * pCardInfo);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pCardInfo	out Information about the device.

Return value

= 0 Card information returned.
≠ 0 An error has occurred.

Additional information

This function is optional. It can be used to get information about the type of the storage card used, about how many data lines are used for the data transfer, etc.

Example

The following example shows how to get information about the storage device.

```
#include <stdio.h>
#include "FS.h"

void SampleMMC_CMGetCardInfo(void) {
  FS_MMC_CARD_INFO   CardInfo;
  const char       * sCardType;
  char               ac[100];
  const char       * sAccessMode;

  FS_MEMSET(&CardInfo, 0, sizeof(CardInfo));
  FS_MMC_CM_GetCardInfo(0, &CardInfo);
  switch (CardInfo.CardType) {
  case FS_MMC_CARD_TYPE_MMC:
    sCardType = "MMC";
    break;
  case FS_MMC_CARD_TYPE_SD:
    sCardType = "SD";
    break;
  case FS_MMC_CARD_TYPE_UNKNOWN:
    // through
  default:
    sCardType = "UNKNOWN";
    break;
  }
  switch (CardInfo.AccessMode) {
  case FS_MMC_ACCESS_MODE_DS:
    sAccessMode = "DS";
    break;
  case FS_MMC_ACCESS_MODE_HS:
    sAccessMode = "HS";
    break;
  case FS_MMC_ACCESS_MODE_SDR50:
    sAccessMode = "SDR50";
    break;
  case FS_MMC_ACCESS_MODE_DDR50:
    sAccessMode = "DDR50";
    break;
  case FS_MMC_ACCESS_MODE_SDR104:
    sAccessMode = "SDR104";
```

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```
    break;
  case FS_MMC_ACCESS_MODE_HS_DDR:
    sAccessMode = "HS DDR";
    break;
  case FS_MMC_ACCESS_MODE_HS200:
    sAccessMode = "HS200";
    break;
  case FS_MMC_ACCESS_MODE_HS400:
    sAccessMode = "HS400";
    break;
  case FS_MMC_ACCESS_MODE_UNKNOWN:
    // through
  default:
    sAccessMode = "UNKNOWN";
    break;
  }
  FS_X_Log("Card information:\n");
  SEGGER_snprintf(ac, sizeof(ac), "  Card type:         %s\n", sCardType);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Bus width:         %d line(s)\n", CardInfo.BusWidth);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Write protected:   %s\n",
    CardInfo.IsWriteProtected ? "yes" : "no");
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  High speed mode:   %s\n",
    CardInfo.IsHighSpeedMode ? "yes" : "no");
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Bytes per sector:  %d\n",
    (int)CardInfo.BytesPerSector);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Number of sectors: %lu\n", CardInfo.NumSectors);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Clock frequency:   %lu Hz\n", CardInfo.ClockFreq);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Voltage level:     %d.%d V\n",
    (int)CardInfo.VoltageLevel / 1000, (int)CardInfo.VoltageLevel % 1000 / 100);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Access mode:       %s\n", sAccessMode);
  FS_X_Log(ac);
  SEGGER_snprintf(ac, sizeof(ac), "  Driver strength:   %d\n",
    (int)CardInfo.DriverStrength);
  FS_X_Log(ac);
}
```

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6.5.3.2.5 FS_MMC_CM_GetStatCounters()

Description

Returns the value of statistical counters.

Prototype

```
void FS_MMC_CM_GetStatCounters(U8                    Unit,
                               FS_MMC_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pStat	out Current value of statistical counters.

Additional information

This function is optional. The Card mode SD/MMC driver collects statistics about the number of internal operations such as the number of logical sectors read or written by the file system layer. The application can use `FS_MMC_CM_GetStatCounters()` to get the current value of these counters. The statistical counters are automatically set to 0 when the storage device is mounted or when the application calls `FS_MMC_CM_ResetStatCounters()`.

The statistical counters are available only when the file system is compiled with `FS_DEBUG_LEVEL` greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with `FS_MMC_ENABLE_STATS` set to 1.

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6.5.3.2.6 FS_MMC_CM_ReadCSD()

Description

Reads the contents of the CSD register of a storage device.

Prototype

```
int FS_MMC_CM_ReadCSD(U8   Unit,
                      U8 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pData	out Contents of the CSD register.

Return value

= 0 Register contents returned.
≠ 0 An error has occurred.

Additional information

This function is optional. It can be used to read the information stored in the Card-Specific Register that is found in any SD card or MMC device. For more information about the contents of the CSD register refer to the SD specification.

pData has to be at least 16 bytes large.

Bit 127 of CSD is returned in bit 7 of pData[0] byte. Bit 0 of CSD is returned in bit 0 of pData[15] byte. Typically, an SD host controller sets to 0 the CRC bits (CSD bits 1-7) and the CSD bit 0.

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6.5.3.2.7 FS_MMC_CM_ReadExtCSD()

Description

Reads the contents of the Extended CSD register of an MMC device.

Prototype

```
int FS_MMC_CM_ReadExtCSD(U8    Unit,
                         U32 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pData	out Contents of the Extended CSD register.

Return value

= 0 Register contents returned.
≠ 0 An error has occurred.

Additional information

This function is optional. For more information about the contents of the Extended CSD register refer to the MMC specification. The contents of the Extended CSD register can be modified via FS_MMC_CM_WriteExtCSD().

pData has to be at least 512 bytes large.

Example

The following example shows how to read data from the Extended CSD register of an MMC device.

```
#include "FS.h"

void SampleMMC_CMReadExtCSD(void) {
  U32   aExtCSD[512 / 4];
  U8  * pData8;
  int   r;
  char  ac[100];

  FS_MEMSET(aExtCSD, 0, sizeof(aExtCSD));
  r = FS_MMC_CM_ReadExtCSD(0, aExtCSD);
  if (r == 0) {
    pData8 = (U8 *)aExtCSD;
    SEGGER_snprintf(ac, sizeof(ac), "POWER_CLASS: %d\n", (int)pData8[187]);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "BUS_WIDTH:   %d\n", (int)pData8[183]);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "HS_TIMING:   %d\n", (int)pData8[185]);
    FS_X_Log(ac);
  }
}
```

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6.5.3.2.8 FS_MMC_CM_ReadGeneral()

Description

Reads a block of data via General Command (CMD56).

Prototype

```
int FS_MMC_CM_ReadGeneral(U8    Unit,
                          U32   Arg,
                          U32 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Arg	Command argument to be sent.
pData	out Read data.

Return value

= 0 OK, data successfully read.
≠ 0 An error has occurred.

Additional information

This function is optional. It can be used to read vendor-specific data from the storage device such as a health report. Additional information about the usage of CMD56 can be found in the data sheet of the storage device.

Not all the storage devices support CMD56. `FS_MMC_CM_ReadGeneral()` does not check if the command is actually supported by the storage device. Typically, the storage device reports an error if it does not support CMD56.

The value passed via `Arg` is vendor-specific and is sent as is to the storage device. The only exception is the bit 0 of `Arg` that indicates the direction of the data transfer and that is automatically set to 1 by this function.

`pData` has to be at least 512 bytes large.

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6.5.3.2.9 FS_MMC_CM_ReadSCR()

Description

Reads the contents of the SD Configuration register of an SD card.

Prototype

```
int FS_MMC_CM_ReadSCR(U8    Unit,
                      U32 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pData	out Contents of the SD Configuration register.

Return value

= 0 OK, register contents returned successfully.
≠ 0 An error occurred.

Additional information

pData has to be at least 8 bytes large.

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6.5.3.2.10 FS_MMC_CM_ReadSectors()

Description

Reads blocks of data from the active partition of the storage card.

Prototype

```
int FS_MMC_CM_ReadSectors(U8    Unit,
                          U32   SectorIndex,
                          U32 * pData,
                          U32   NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
SectorIndex	Index of the first data block to be read.
pData	out Read data.
NumSectors	Number of data blocks to be read.

Return value

= 0 OK, data read successfully.
≠ 0 An error occurred.

Additional information

The size of a single data block is 512 bytes.

In addition to reading data from the default partition of an eMMC device (User Data Area), this function can be used to read data from the Boot Area 1 and 2 partitions. The application is responsible for selecting the corresponding partition via the Extended CSD register as described in the eMMC specification. The Extended CSD register can be modified via FS_MMC_CM_WriteExtCSD().

An SD card has only one data partition.

Example

The following example reads the contents of the data blocks with the indexes 7 and 8 from the selected partition of the storage device.

```
#include "FS.h"

void SampleMMC_CMReadSectors(void) {
  U32 aData[1024 / 4];

  FS_MEMSET(aData, 0, sizeof(aData));
  FS_MMC_CM_ReadSectors(0, 7, aData, 2);
}
```

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6.5.3.2.11 FS_MMC_CM_ReadSSR()

Description

Reads the contents of the SD Status register of an SD card.

Prototype

```
int FS_MMC_CM_ReadSSR(U8    Unit,
                      U32 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pData	out Contents of the SD Status register.

Return value

= 0 OK, register contents returned successfully.
≠ 0 An error occurred.

Additional information

pData has to be at least 64 bytes large.

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6.5.3.2.12 FS_MMC_CM_ResetStatCounters()

Description

Sets to 0 all statistical counters.

Prototype

```
void FS_MMC_CM_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Additional information

This function is optional. The statistical counters are automatically set to 0 when the storage device is mounted. The application can use `FS_MMC_CM_ResetStatCounters()` at any time during the file system operation. The statistical counters can be queried via `FS_MMC_CM_GetStatCounters()`.

The statistical counters are available only when the file system is compiled with `FS_DEBUG_LEVEL` greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with `FS_MMC_ENABLE_STATS` set to 1.

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6.5.3.2.13 FS_MMC_CM_UnlockCardForced()

Description

Unlocks an SD card.

Prototype

```
int FS_MMC_CM_UnlockCardForced(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 OK, the SD card has been erased.
≠ 0 An error has occurred.

Additional information

This function is optional. SD cards can be locked with a password in order to prevent inadvertent access to sensitive data. It is not possible to access the data on a locked SD card without knowing the locking password. The application can use `FS_MMC_CM_UnlockCardForced()` to make locked SD card accessible again. The unlocking operation erases all the data stored on the SD card including the lock password.

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6.5.3.2.14 FS_MMC_CM_WriteExtCSD()

Description

Writes to the Extended CSD register of a MMC device.

Prototype

```
int FS_MMC_CM_WriteExtCSD(      U8          Unit,
                                unsigned    Off,
                          const U8        * pData,
                                unsigned    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Off	Byte offset in the Extended CSD register.
pData	in Register contents.
NumBytes	Number of bytes in pData buffer.

Return value

= 0 Register contents returned
≠ 0 An error has occurred

Additional information

This function is optional. Only the byte range 0-191 of the Extended CSD register is modifiable. For more information about the contents of the Extended CSD register refer to the MMC specification. The contents of the Extended CSD register can be read via FS_MMC_CM_ReadExtCSD().

Example

The following example shows how to select the Boot Area 1 of the connected eMMC device as the active partition.

```
#include "FS.h"

void SampleMMC_CMWriteExtCSD(void) {
  U8 Data;

  Data = 0x01;
  FS_MMC_CM_WriteExtCSD(0, 179, &Data, sizeof(Data));
}
```

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6.5.3.2.15 FS_MMC_CM_WriteGeneral()

Description

Writes a block of data via General Command (CMD56).

Prototype

```
int FS_MMC_CM_WriteGeneral(      U8    Unit,
                                 U32   Arg,
                           const U32 * pData);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Arg	Command argument to be sent.
pData	in Data to be written.

Return value

= 0 OK, data successfully written.
≠ 0 An error has occurred.

Additional information

This function is optional. It can be used to write vendor-specific data to a storage device such as the programming of a product string. Additional information about the usage of CMD56 can be found in the data sheet of the storage device.

Not all the storage devices support CMD56. `FS_MMC_CM_WriteGeneral()` does not check if the command is actually supported by the storage device. Typically, the storage device reports an error if it does not support CMD56.

The value passed via `Arg` is vendor-specific and is sent as is to the storage device. The only exception is the bit 0 of `Arg` that indicates the direction of the data transfer and that is automatically set to 0 by this function.

`pData` has to be at least 512 bytes large.

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6.5.3.2.16 FS_MMC_CM_WriteSectors()

Description

Writes blocks of data to the selected partition of the storage card.

Prototype

```
int FS_MMC_CM_WriteSectors(      U8    Unit,
                                 U32   SectorIndex,
                           const U32 * pData,
                                 U32   NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
SectorIndex	Index of the first data block to be written.
pData	in Data to be written.
NumSectors	Number of data blocks to be written.

Return value

= 0 OK, data written successfully.
≠ 0 An error occurred.

Additional information

The size of a single data block is 512 bytes.

In addition to writing data to the default partition of an eMMC device (User Data Area), this function can be used to write data to the Boot Area 1 and 2 partitions. The application is responsible for selecting the corresponding partition via the Extended CSD register as described in the eMMC specification. The Extended CSD register can be modified via FS_MMC_CM_WriteExtCSD().

An SD card has only one data partition.

Example

The following example writes the contents of the data blocks with the indexes 5 and 6 to the selected partition of the storage device.

```
#include "FS.h"

void SampleMMC_CMWriteSectors(void) {
  U32 aData[1024 / 4];

  FS_MEMSET(aData, 0x55, sizeof(aData));
  FS_MMC_CM_WriteSectors(0, 5, aData, 2);
}
```

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6.5.3.2.17 FS_MMC_CARD_ID

Description

Information about the storage card.

Type definition

```
typedef struct {
  U8  aData[];
} FS_MMC_CARD_ID;
```

Structure members

Member	Description
aData	Identification information as returned by the SD card or MMC device as response to CMD10 command.

Additional information

The card identification can be read via `FS_MMC_GetCardId()` or `FS_MMC_CM_GetCardId()`

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6.5.3.2.18 FS_MMC_CARD_INFO

Description

Information about the storage device.

Type definition

```
typedef struct {
  U8   CardType;
  U8   BusWidth;
  U8   IsWriteProtected;
  U8   IsHighSpeedMode;
  U16  BytesPerSector;
  U32  NumSectors;
  U32  ClockFreq;
  U16  VoltageLevel;
  U8   AccessMode;
  U8   DriverStrength;
} FS_MMC_CARD_INFO;
```

Structure members

Member	Description
CardType	Type of the storage card.
BusWidth	Number of data lines used for the data transfer.
IsWriteProtected	Set to 1 if the card is write protected.
IsHighSpeedMode	Set to 1 if the card operates in the high-speed mode.
BytesPerSector	Number of bytes in a sector.
NumSectors	Total number of sectors on the card.
ClockFreq	Frequency of the clock supplied to storage device in Hz.
VoltageLevel	Voltage level of I/O lines.
AccessMode	Type of data transfer.
DriverStrength	Actual output driving strength of the MMC/SD device.

Additional information

For a list of permitted values for CardType refer to *Storage card types* on page 1150. BusWidth can take one of these values: 1, 4 or 8. BytesPerSector is typically 512 bytes. For a list of permitted values for AccessMode refer to *Data transfer types* on page 1149. IsHighSpeedMode is deprecated and AccessMode can be used instead. IsHighSpeedMode set to 1 is equivalent to AccessMode set to FS_MMC_ACCESS_MODE_HS.

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6.5.3.2.19 FS_MMC_STAT_COUNTERS

Description

Statistical counters maintained by the MMC/SD driver

Type definition

```
typedef struct {
  U32  WriteSectorCnt;
  U32  WriteErrorCnt;
  U32  ReadSectorCnt;
  U32  ReadErrorCnt;
  U32  CmdExecCnt;
  U32  ReinitCnt;
} FS_MMC_STAT_COUNTERS;
```

Structure members

Member	Description
WriteSectorCnt	Number of logical sectors read.
WriteErrorCnt	Number of write errors.
ReadSectorCnt	Number of logical sectors written.
ReadErrorCnt	Number of read errors.
CmdExecCnt	Number of commands executed.
ReinitCnt	Number of times the storage device was reinitialized.

Additional information

ReinitCnt is valid only if FS_MMC_SUPPORT_ERROR_RECOVERY is different than 0.

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6.5.3.2.20 Data transfer types

Description

Types of exchanging data with an MMC/SD storage device.

Definition

```
#define FS_MMC_ACCESS_MODE_UNKNOWN    0u
#define FS_MMC_ACCESS_MODE_DS         1u
#define FS_MMC_ACCESS_MODE_HS         2u
#define FS_MMC_ACCESS_MODE_SDR50      3u
#define FS_MMC_ACCESS_MODE_DDR50      4u
#define FS_MMC_ACCESS_MODE_SDR104     5u
#define FS_MMC_ACCESS_MODE_HS_DDR     6u
#define FS_MMC_ACCESS_MODE_HS200      7u
#define FS_MMC_ACCESS_MODE_HS400      8u
```

Symbols

Definition	Description
FS_MMC_ACCESS_MODE_UNKNOWN	Invalid access mode
FS_MMC_ACCESS_MODE_DS	Clock frequency up to 25 MHz for SD cards and 26 MHz for MMC devices (Default speed).
FS_MMC_ACCESS_MODE_HS	Clock frequency up to 50 MHz for SD cards and 52 MHz for MMC devices (High speed).
FS_MMC_ACCESS_MODE_SDR50	Clock frequency up to 100 MHz with 1.8 V signaling. For SD cards only.
FS_MMC_ACCESS_MODE_DDR50	Clock frequency up to 50 MHz with 1.8 V signaling and data exchanged on both clock edges. For SD cards only.
FS_MMC_ACCESS_MODE_SDR104	Clock frequency up to 208 MHz with 1.8 V signaling. For SD cards only.
FS_MMC_ACCESS_MODE_HS_DDR	Clock frequency up to 52 MHz with 1.8 V and 3.3V signaling and data exchanged on both clock edges. For MMC devices only.
FS_MMC_ACCESS_MODE_HS200	Clock frequency up to 200 MHz with 1.8 V signaling. For MMC devices only.
FS_MMC_ACCESS_MODE_HS400	Clock frequency up to 200 MHz with 1.8 V signaling and data exchanged on both clock edges. For MMC devices only.

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6.5.3.2.21 Storage card types

Description

Type of storage devices supported by the MMC/SD driver.

Definition

```
#define FS_MMC_CARD_TYPE_UNKNOWN    0
#define FS_MMC_CARD_TYPE_MMC        1
#define FS_MMC_CARD_TYPE_SD         2
```

Symbols

Definition	Description
FS_MMC_CARD_TYPE_UNKNOWN	The driver was not able to identify the device.
FS_MMC_CARD_TYPE_MMC	The storage device conforms to MMC specification.
FS_MMC_CARD_TYPE_SD	The storage device conforms to SD specification.

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6.5.3.3 Performance and resource usage

6.5.3.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the Card Mode MMC/SD driver were measured as described in the section *Test procedure* on page 1439.

Usage: 3.9 Kbytes

6.5.3.3.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the Card Mode MMC/SD driver internally for all the driver instances. The number of bytes can be seen in the compiler list file of the `FS_MMC_CM_Drv.c` file.

Usage: 12 bytes

6.5.3.3.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the compile time and runtime configuration.

Usage: 42 bytes

6.5.3.3.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in Mbytes/second.

CPU type	MMC/SD device	Write speed	Read speed
Atmel AT91SAM9263 (200 MHz)	Ultron 256MB SD card	**10.0**	**9.3**
NXP LPC2478 (57 MHz)	Ultron 256MB SD card	**2.4**	**3.1**
NXP LPC3250 (208 MHz)	Ultron 256MB SD card	**3.9**	**8.4**
NXP K66 (168 MHz)	SanDisk 16GB Ultra PLUS SD card	**3.6**	**11.1**
Microchip SAME70 (300 MHz)	SanDisk 16GB Ultra PLUS SD card	**11.1**	**20.4**
NXP iMX6U5	SanDisk 16GB Ultra PLUS SD card	**15.1**	**18.4**
NXP iMXRT1052	SanDisk 16GB Ultra PLUS SD card	**16.9**	**19.5**
NXP LPC54608	SanDisk 16GB Ultra PLUS SD card	**11.6**	**18.4**
Renesas RZGE1	Silicon Motion SM661G8 eMMC	**5.5**	**16.5**
ST STM32H743	SanDisk 16GB Ultra PLUS SD card	**10.0**	**14.4**
ST STM32F746	Transcend 16GB Class 10 SD card	**12.2**	**18.9**
ST STM32F469	SanDisk 16GB Ultra PLUS SD card	**16.1**	**17.8**
ST STM32H753 (400 MHz)	SanDisk 32GB Ultra SD card	**13.7**	**49.8**
NXP iMXRT595	SanDisk SDINBDA6-16 eMMC device	**102.4**	**136.5**

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6.5.4 MMC/SD hardware layer

The hardware layer provides the functions required by the MMC/SD driver to access the target hardware via SPI controller, SD host controller, GPIO, etc. The functions of the MMC/SD hardware layer are called by the MMC/SD driver to exchange commands and data with an MMC or SD card. Since these functions are hardware dependent, they have to be implemented by the user. emFile comes with template hardware layers and sample implementations for popular evaluation boards that can be used as a starting point for the implementation of new hardware layers. The relevant files are located in the `/Sample/FS/Driver/MMC_SPI` and `/Sample/FS/Driver/MMC_CM` folders of the emFile shipment.

6.5.4.1 Hardware layer types

The functions of the MMC/SD hardware layer are organized in a function table implemented as a C structure. Different hardware layer types are provided to support different ways of interfacing an MMC or SD card. The type of hardware layer an application has to use depends on the MMC/SD driver used. The following table lists what hardware layer is required by each MMC/SD driver.

MMC/SD hardware layer	MMC/SD driver
`FS_MMC_HW_TYPE_SPI`	*SPI MMC/SD driver*
`FS_MMC_HW_TYPE_CM`	*Card Mode MMC/SD driver*

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6.5.4.2 Hardware layer API - FS_MMC_HW_TYPE_SPI

This hardware layer supports MMC cards that comply with the version 3.x or older of the MMC specification and SD cards of all types that are interfaced to the target MCU via SPI. The functions of this hardware layer are grouped in a structure of type `FS_MMC_HW_TYPE_SPI`. The following sections describe these functions in detail.

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6.5.4.2.1 FS_MMC_HW_TYPE_SPI

Description

Hardware layer for the SPI MMC/SD driver.

Type definition

```
typedef struct {
  FS_MMC_HW_TYPE_SPI_ENABLE_CS           * pfEnableCS;
  FS_MMC_HW_TYPE_SPI_DISABLE_CS          * pfDisableCS;
  FS_MMC_HW_TYPE_SPI_IS_PRESENT          * pfIsPresent;
  FS_MMC_HW_TYPE_SPI_IS_WRITE_PROTECTED * pfIsWriteProtected;
  FS_MMC_HW_TYPE_SPI_SET_MAX_SPEED       * pfSetMaxSpeed;
  FS_MMC_HW_TYPE_SPI_SET_VOLTAGE         * pfSetVoltage;
  FS_MMC_HW_TYPE_SPI_READ                * pfRead;
  FS_MMC_HW_TYPE_SPI_WRITE               * pfWrite;
  FS_MMC_HW_TYPE_SPI_READ_EX             * pfReadEx;
  FS_MMC_HW_TYPE_SPI_WRITE_EX            * pfWriteEx;
  FS_MMC_HW_TYPE_SPI_LOCK                * pfLock;
  FS_MMC_HW_TYPE_SPI_UNLOCK              * pfUnlock;
} FS_MMC_HW_TYPE_SPI;
```

Structure members

Member	Description
pfEnableCS	Enables the card.
pfDisableCS	Disables the card.
pfIsPresent	Checks if the card is inserted.
pfIsWriteProtected	Checks if the card is write protected.
pfSetMaxSpeed	Configures the clock frequency supplied to the card.
pfSetVoltage	Configures the voltage level of the card power supply.
pfRead	Transfers data from card to MCU.
pfWrite	Transfers data from MCU to card.
pfReadEx	Transfers data from card to MCU.
pfWriteEx	Transfers data from MCU to card.
pfLock	Requires exclusive access to SPI bus.
pfUnlock	Releases exclusive access to SPI bus.

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6.5.4.2.2 FS_MMC_HW_TYPE_SPI_ENABLE_CS

Description

Enables the storage card.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_ENABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The Chip Select (CS) signal is used to address a specific MMC or SD card connected via SPI. Enabling the card is equal to setting the CS signal to a logic low level.

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6.5.4.2.3 FS_MMC_HW_TYPE_SPI_DISABLE_CS

Description

Disables the storage card.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_DISABLE_CS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The Chip Select (CS) signal is used to address a specific MMC or SD card connected via SPI. Disabling the card is equal to setting the CS signal to a logic high level.

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6.5.4.2.4 FS_MMC_HW_TYPE_SPI_IS_PRESENT

Description

Checks if the storage card is present.

Type definition

```
typedef int FS_MMC_HW_TYPE_SPI_IS_PRESENT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

FS_MEDIA_STATE_UNKNOWN	The presence state of the card is unknown.
FS_MEDIA_NOT_PRESENT	The card is present.
FS_MEDIA_IS_PRESENT	The card is not present.

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

Typically, the card presence detection is implemented via a dedicated Card Detect (CD) signal. This signal is connected to a switch inside the card slot that changes its state each time the card is removed or inserted. If the hardware does not provide such signal the function has to return FS_MEDIA_STATE_UNKNOWN.

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6.5.4.2.5 FS_MMC_HW_TYPE_SPI_IS_WRITE_PROTECTED

Description

Checks if the storage card is write protected.

Type definition

```
typedef int FS_MMC_HW_TYPE_SPI_IS_WRITE_PROTECTED(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

= 0 The card data can be modified.
≠ 0 The card data cannot be modified.

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

Typically, the card protection status is implemented via a dedicated Write Protected (WP) signal. This signal is connected to a switch inside the card slot that reflects the status of the write protect switch found on SD cards. If the hardware does not provide such signal the function has to return 0.

MMC and micro SD cards do not have a write protection switch. Please note that the write protect switch does not really protect the data on an SD card form being modified. It is merely an indication that the data has to be protected. It is the responsibility of the host MCU to respect the status of this switch.

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6.5.4.2.6 FS_MMC_HW_TYPE_SPI_SET_MAX_SPEED

Description

Configures the clock frequency supplied to the storage card.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_SPI_SET_MAX_SPEED(U8  Unit,
                                             U16 MaxFreq);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
MaxFreq	Maximum allowed frequency of the SPI clock in kHz.

Return value

≠ 0 The actual clock frequency in kHz.
= 0 An error occurred.

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The hardware layer is allowed to set a clock frequency smaller than the value specified via MaxFreq but never greater than that. The SPI MMC/SD driver calls this function at least two times during the initialization of the MMC or SD card:

- Before the initialization starts to set the clock frequency to 400 kHz.
- After the card identification to set the standard clock frequency which is 25 MHz for SD cards or 20 MHz for MMC cards.

The function has to return the actual configured clock frequency. If the precise frequency is unknown such as for implementation using I/O port “bit-banging”, the return value has to be less than the specified frequency. This may lead to longer timeout values but is in general does not cause any problems. The SPI MMC/SD driver uses the returned value to calculate timeout values.

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6.5.4.2.7 FS_MMC_HW_TYPE_SPI_SET_VOLTAGE

Description

Configures the voltage level of the storage card power supply.

Type definition

```
typedef int FS_MMC_HW_TYPE_SPI_SET_VOLTAGE(U8  Unit,
                                           U16 VMin,
                                           U16 VMax);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
VMin	Minimum supply voltage level in mV.
VMax	Maximum supply voltage level in mV.

Return value

≠ 0 Card slot supports the voltage range.
= 0 Card slot does not support the voltage range.

Additional information

This function is a member of the SPI MMC/SD hardware layer. It has to be implemented by all the hardware layers.

By default, all cards work with the initial voltage of 3.3V. If hardware layer has to save power, then the supply voltage can be adjusted within the specified range.

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6.5.4.2.8 FS_MMC_HW_TYPE_SPI_READ

Description

Transfers data from storage card to MCU.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_READ(U8   Unit,
                                     U8 * pData,
                                     int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	out Data transferred from card.
NumBytes	Number of bytes to be transferred.

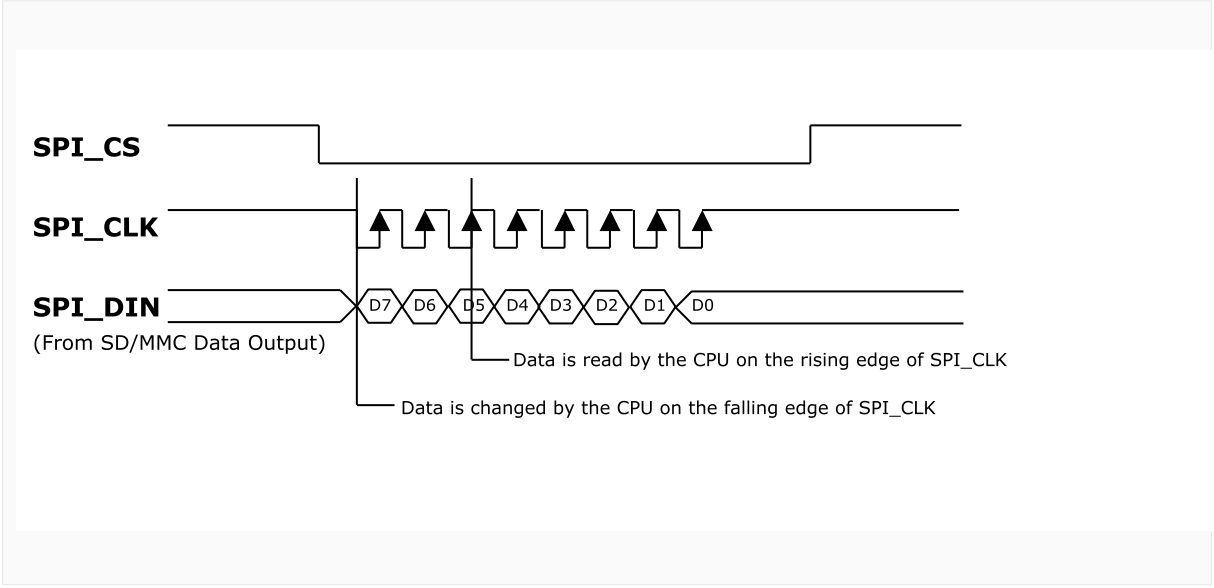
Additional information

This function is a member of the SPI MMC/SD hardware layer. FS_MMC_HW_TYPE_SPI_READ does not have to be implemented if the hardware layer provides an implementation for FS_MMC_HW_TYPE_SPI_READ_EX.

The data is received via the DIN (MISO) signal of the SPI interface with the data being sampled on the rising edge of the clock signal. According to the SD specification the DOUT (MOSI) signal must be driven to logic high during the data transfer, otherwise the SD card will not work properly.

The SPI MMC/SD driver calls this function only when the card is enabled that is with the CS signal at logic low level.

The following picture shows the waveforms of the SPI signals during the transfer of 8 bits from card to MCU.



Read access

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6.5.4.2.9 FS_MMC_HW_TYPE_SPI_WRITE

Description

Transfers data from MCU to card.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_WRITE(      U8   Unit,
                                      const U8 * pData,
                                            int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	in Data to be transferred to card.
NumBytes	Number of bytes to be transferred to card.

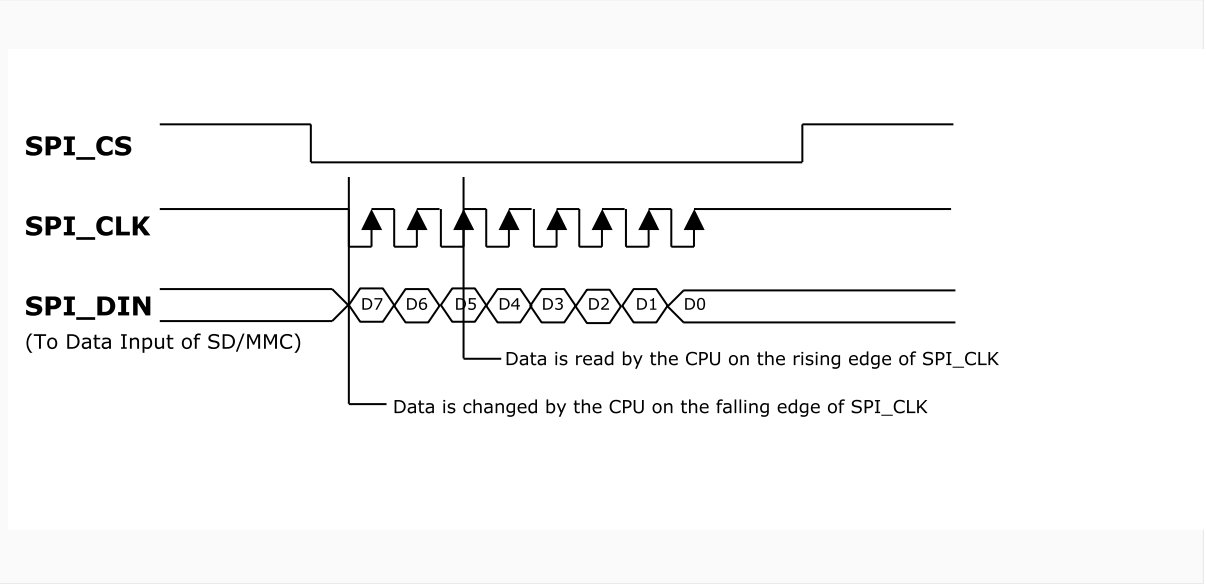
Additional information

This function is a member of the SPI MMC/SD hardware layer. FS_MMC_HW_TYPE_SPI_WRITE does not have to be implemented if the hardware layer provides an implementation for FS_MMC_HW_TYPE_SPI_WRITE_EX.

The data is sent via the DOUT (MOSI) signal of the SPI interface with the data being changed on the falling edge of the clock signal.

The SPI MMC/SD driver also calls this function when the card is not enabled that is with the CS signal at logic low in order to generate empty cycles.

The following picture shows the waveforms of the SPI signals during the transfer of 8 bits from MCU to card.



Write access

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6.5.4.2.10 FS_MMC_HW_TYPE_SPI_READ_EX

Description

Transfers data from card to MCU.

Type definition

```
typedef int FS_MMC_HW_TYPE_SPI_READ_EX(U8   Unit,
                                       U8 * pData,
                                       int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	out Data transferred from card.
NumBytes	Number of bytes to be transferred.

Return value

= 0 OK, data transferred.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI MMC/SD hardware layer. FS_MMC_HW_TYPE_SPI_READ_EX does not have to be implemented if the hardware layer provides an implementation for FS_MMC_HW_TYPE_SPI_READ. It provides the same functionality as FS_MMC_HW_TYPE_SPI_READ with the difference that it can report the result of the operation to the SPI MMC/SD driver.

The SPI MMC/SD driver calls this function only when the card is enabled that is with the CS signal at logic low level.

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6.5.4.2.11 FS_MMC_HW_TYPE_SPI_WRITE_EX

Description

Transfers data from MCU to storage card.

Type definition

```
typedef int FS_MMC_HW_TYPE_SPI_WRITE_EX(      U8   Unit,
                                        const U8 * pData,
                                              int  NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	in Data to be transferred to card.
NumBytes	Number of bytes to be transferred to card.

Return value

= 0 OK, data transferred.
≠ 0 An error occurred.

Additional information

This function is a member of the SPI MMC/SD hardware layer. FS_MMC_HW_TYPE_SPI_WRITE_EX does not have to be implemented if the hardware layer provides an implementation for FS_MMC_HW_TYPE_SPI_WRITE. It provides the same functionality as FS_MMC_HW_TYPE_SPI_WRITE with the difference that it can report the result of the operation to the SPI MMC/SD driver.

The SPI MMC/SD driver also calls this function when the card is not enabled that is with the CS signal at logic low in order to generate empty cycles.

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6.5.4.2.12 FS_MMC_HW_TYPE_SPI_LOCK

Description

Requires exclusive access to SPI bus.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_LOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the SPI MMC/SD hardware layer. The implementation of this function is optional.

The SPI MMC/SD driver calls this function to indicate that it needs exclusive to access the card via the SPI bus. It is guaranteed that the SPI MMC/SD driver does not attempt to exchange any data with the card via the SPI bus before calling this function first. It is also guaranteed that FS_MMC_HW_TYPE_SPI_LOCK and FS_MMC_HW_TYPE_SPI_UNLOCK are called in pairs. Typically, this function is used for synchronizing the access to SPI bus when the SPI bus is shared between the card and other SPI devices.

A possible implementation would make use of an OS semaphore that is acquired in FS_MMC_HW_TYPE_SPI_LOCK and released in FS_MMC_HW_TYPE_SPI_UNLOCK.

FS_MMC_HW_TYPE_SPI_LOCK is called only when the SPI MMC/SD driver is compiled with FS_MMC_SUPPORT_LOCKINGset to 1.

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6.5.4.2.13 FS_MMC_HW_TYPE_SPI_UNLOCK

Description

Releases the exclusive access to SPI bus.

Type definition

```
typedef void FS_MMC_HW_TYPE_SPI_UNLOCK(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the SPI MMC/SD hardware layer. The implementation of this function is optional.

The SPI MMC/SD driver calls this function when it no longer needs to access the card via the SPI bus. It is guaranteed that the SPI MMC/SD driver does not attempt to exchange any data with the card via the SPI bus before calling FS_MMC_HW_TYPE_SPI_LOCK. It is also guaranteed that FS_MMC_HW_TYPE_SPI_UNLOCK and FS_MMC_HW_TYPE_SPI_LOCK are called in pairs.

FS_MMC_HW_TYPE_SPI_UNLOCK and FS_MMC_HW_TYPE_SPI_LOCK can be used to synchronize the access to the SPI bus when other devices than the serial NAND flash are connected to it. A possible implementation would make use of an OS semaphore that is acquired FS_MMC_HW_TYPE_SPI_LOCK and released in FS_MMC_HW_TYPE_SPI_UNLOCK.

FS_MMC_HW_TYPE_SPI_LOCK is called only when the SPI MMC/SD driver is compiled with FS_MMC_SUPPORT_LOCKING set to 1.

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6.5.4.2.14 Sample implementation

The following sample implementation uses the SPI controller of a TI TM4C129 MCU to interface with an SD card. This hardware layer was tested on the TI TIVAC129 evaluation board.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File        : FS_MMC_HW_SPI_TM4C129_TI_TIVAC129.c
Purpose     : Generic HW layer for the MMC / SD driver working in SPI mode.
Literature  :
  [1] Tiva TM4C129XNCZAD Microcontroller DATA SHEET
  [2] Tiva TM4C129X Development Board User's Guide

Additional information
  The SD card and NOR flash device share the same CS signal. In order to
  be able to work with the SD card, the jumper J7 has to be configured
  according to "2.1.10 EEPROM and SD Card" in [2].
*/

/*********************************************************************
*
*       #include Section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_MMC_HW_SPI_PERIPH_CLOCK_KHZ
  #define FS_MMC_HW_SPI_PERIPH_CLOCK_KHZ            120000uL    // Clock of SSI peripheral in kHz
#endif

#ifndef   FS_MMC_HW_SPI_MAX_SPI_CLOCK_KHZ
  #define FS_MMC_HW_SPI_MAX_SPI_CLOCK_KHZ           24000uL
  // Maximum clock frequency supplied to SD card
#endif

#ifndef   FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES
  #define FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES         100000uL
  // Time to wait for an operation to finish (software loops)
#endif

#ifndef   FS_MMC_HW_SPI_USE_DMA
  #define FS_MMC_HW_SPI_USE_DMA                     1
  // Enables/disables the data transfer via DMA
#endif

#ifndef   FS_MMC_HW_SPI_DEFAULT_SUPPLY_VOLTAGE
  #define FS_MMC_HW_SPI_DEFAULT_SUPPLY_VOLTAGE      3300        // in mV, example means 3.3V
#endif

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

/*********************************************************************
*
*       SSI registers
*/
#define SSI_BASE_ADDR             0x4000B000uL
```

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```
#define SSICR0                  (*(volatile U32 *)(SSI_BASE_ADDR + 0x000))      // SSI Control 0
#define SSICR1                  (*(volatile U32 *)(SSI_BASE_ADDR + 0x004))      // SSI Control 1
#define SSIDR                   (*(volatile U32 *)(SSI_BASE_ADDR + 0x008))      // SSI Data
#define SSISR                   (*(volatile U32 *)(SSI_BASE_ADDR + 0x00C))      // SSI Status
#define SSICPSR                 (*(volatile U32 *)(SSI_BASE_ADDR + 0x010))
  // SSI Clock Prescale
#define SSIIM                   (*(volatile U32 *)(SSI_BASE_ADDR + 0x014))
  // SSI Interrupt Mask
#define SSIRIS                  (*(volatile U32 *)(SSI_BASE_ADDR + 0x018))
  // SSI Raw Interrupt Status
#define SSIMIS                  (*(volatile U32 *)(SSI_BASE_ADDR + 0x01C))
  // SSI Masked Interrupt Status
#define SSIICR                  (*(volatile U32 *)(SSI_BASE_ADDR + 0x020))
  // SSI Interrupt Clear
#define SSIDMACTL               (*(volatile U32 *)(SSI_BASE_ADDR + 0x024))      // SSI DMA Control
#define SSICC                   (*(volatile U32 *)(SSI_BASE_ADDR + 0xFC8))
  // SSI Clock Configuration

/*********************************************************************
*
*       System control registers
*/
#define SYS_BASE_ADDR           0x400FE000uL
#define RCGCGPIO                (*(volatile U32 *)(SYS_BASE_ADDR + 0x608))
  // GPIO Run Mode Clock Gating Control
#define RCGCDMA                 (*(volatile U32 *)(SYS_BASE_ADDR + 0x60C))
  // DMA Run Mode Clock Gating Control
#define RCGCSSI                 (*(volatile U32 *)(SYS_BASE_ADDR + 0x61C))
  // SSI Run Mode Clock Gating Control
#define PRGPIO                  (*(volatile U32 *)(SYS_BASE_ADDR + 0xA08))
  // GPIO Run Mode Peripheral Ready
#define PRDMA                   (*(volatile U32 *)(SYS_BASE_ADDR + 0xA0C))
  // DMA Run Mode Peripheral Ready
#define PRSSI                   (*(volatile U32 *)(SYS_BASE_ADDR + 0xA1C))
  // SSI Run Mode Peripheral Ready

/*********************************************************************
*
*       GPIO Port F
*/
#define PF_BASE_ADDR            0x4005D000uL
#define PF_GPIOAFSEL            (*(volatile U32 *)(PF_BASE_ADDR + 0x420))
  // GPIO Alternate Function Select
#define PF_GPIODR2R             (*(volatile U32 *)(PF_BASE_ADDR + 0x500))       // GPIO
 2-mA Drive Select
#define PF_GPIODR4R             (*(volatile U32 *)(PF_BASE_ADDR + 0x504))       // GPIO
 4-mA Drive Select
#define PF_GPIODR8R             (*(volatile U32 *)(PF_BASE_ADDR + 0x508))       // GPIO
 8-mA Drive Select
#define PF_GPIOODR              (*(volatile U32 *)(PF_BASE_ADDR + 0x50C))
  // GPIO Open Drain Select
#define PF_GPIOPUR              (*(volatile U32 *)(PF_BASE_ADDR + 0x510))
  // GPIO Pull-Up Select
#define PF_GPIOPDR              (*(volatile U32 *)(PF_BASE_ADDR + 0x514))
  // GPIO Pull-Down Select
#define PF_GPIODEN              (*(volatile U32 *)(PF_BASE_ADDR + 0x51C))
  // GPIO Digital Enable
#define PF_GPIOPCTL             (*(volatile U32 *)(PF_BASE_ADDR + 0x52C))
  // GPIO Port Control
#define PF_GPIOPC               (*(volatile U32 *)(PF_BASE_ADDR + 0xFC4))
  // GPIO Peripheral Configuration

/*********************************************************************
*
*       GPIO Port H
*/
#define PH_BASE_ADDR            0x4005F000uL
#define PH_GPIODATA             (*(volatile U32 *)(PH_BASE_ADDR + 0x000))       // GPIO Data
#define PH_GPIODIR              (*(volatile U32 *)(PH_BASE_ADDR + 0x400))       // GPIO Direction
#define PH_GPIOAFSEL            (*(volatile U32 *)(PH_BASE_ADDR + 0x420))
  // GPIO Alternate Function Select
#define PH_GPIODR2R             (*(volatile U32 *)(PH_BASE_ADDR + 0x500))       // GPIO
 2-mA Drive Select
#define PH_GPIODR4R             (*(volatile U32 *)(PH_BASE_ADDR + 0x504))       // GPIO
 4-mA Drive Select
```

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```
#define PH_GPIODR8R               (*(volatile U32 *)(PH_BASE_ADDR + 0x508))       // GPIO
 8-mA Drive Select
#define PH_GPIOODR                (*(volatile U32 *)(PH_BASE_ADDR + 0x50C))
  // GPIO Open Drain Select
#define PH_GPIOPUR                (*(volatile U32 *)(PH_BASE_ADDR + 0x510))
  // GPIO Pull-Up Select
#define PH_GPIOPDR                (*(volatile U32 *)(PH_BASE_ADDR + 0x514))
  // GPIO Pull-Down Select
#define PH_GPIODEN                (*(volatile U32 *)(PH_BASE_ADDR + 0x51C))
  // GPIO Digital Enable
#define PH_GPIOPCTL               (*(volatile U32 *)(PH_BASE_ADDR + 0x52C))
  // GPIO Port Control
#define PH_GPIOPC                 (*(volatile U32 *)(PH_BASE_ADDR + 0xFC4))
  // GPIO Peripheral Configuration

/*********************************************************************
*
*       GPIO Port Q
*/
#define PQ_BASE_ADDR              0x40066000uL
#define PQ_GPIODATA               (*(volatile U32 *)(PQ_BASE_ADDR + 0x000))       // GPIO Data
#define PQ_GPIODIR                (*(volatile U32 *)(PQ_BASE_ADDR + 0x400))       // GPIO Direction
#define PQ_GPIOAFSEL              (*(volatile U32 *)(PQ_BASE_ADDR + 0x420))
  // GPIO Alternate Function Select
#define PQ_GPIODR2R               (*(volatile U32 *)(PQ_BASE_ADDR + 0x500))       // GPIO
 2-mA Drive Select
#define PQ_GPIODR4R               (*(volatile U32 *)(PQ_BASE_ADDR + 0x504))       // GPIO
 4-mA Drive Select
#define PQ_GPIODR8R               (*(volatile U32 *)(PQ_BASE_ADDR + 0x508))       // GPIO
 8-mA Drive Select
#define PQ_GPIOODR                (*(volatile U32 *)(PQ_BASE_ADDR + 0x50C))
  // GPIO Open Drain Select
#define PQ_GPIOPUR                (*(volatile U32 *)(PQ_BASE_ADDR + 0x510))
  // GPIO Pull-Up Select
#define PQ_GPIOPDR                (*(volatile U32 *)(PQ_BASE_ADDR + 0x514))
  // GPIO Pull-Down Select
#define PQ_GPIODEN                (*(volatile U32 *)(PQ_BASE_ADDR + 0x51C))
  // GPIO Digital Enable
#define PQ_GPIOPCTL               (*(volatile U32 *)(PQ_BASE_ADDR + 0x52C))
  // GPIO Port Control
#define PQ_GPIOPC                 (*(volatile U32 *)(PQ_BASE_ADDR + 0xFC4))
  // GPIO Peripheral Configuration

/*********************************************************************
*
*       DMA controller
*/
#define DMA_BASE_ADDR             0x400FF000uL
#define DMACFG                    (*(volatile U32 *)(DMA_BASE_ADDR + 0x004))
  // DMA configuration
#define DMACTLBASE                (*(volatile U32 *)(DMA_BASE_ADDR + 0x008))
  // DMA Channel Control Base Pointer
#define DMAUSEBURSTCLR            (*(volatile U32 *)(DMA_BASE_ADDR + 0x01C))
  // DMA Channel Useburst Clear
#define DMAREQMASKCLR             (*(volatile U32 *)(DMA_BASE_ADDR + 0x024))
  // DMA Channel Request Mask Clear
#define DMAENASET                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x028))
  // DMA Channel Enable Set
#define DMAENACLR                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x02C))
  // DMA Channel Enable Clear
#define DMAALTCLR                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x034))
  // DMA Channel Primary Alternate Clear
#define DMAPRIOCLR                (*(volatile U32 *)(DMA_BASE_ADDR + 0x03C))
  // DMA Channel Priority Clear
#define DMACHMAP0                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x510))
  // DMA Channel Map Select 0
#define DMACHMAP1                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x514))
  // DMA Channel Map Select 1
#define DMACHMAP2                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x518))
  // DMA Channel Map Select 2
#define DMACHMAP3                 (*(volatile U32 *)(DMA_BASE_ADDR + 0x51C))
  // DMA Channel Map Select 3

/*********************************************************************
*
*       Flash controller
```

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```
*/
#define FLASH_BASE_ADDR           0x400FD000uL
#define FLASHPP                   (*(volatile U32 *)(FLASH_BASE_ADDR + 0xFC0))
  // Flash Peripheral Properties
#define FLASHDMASZ                (*(volatile U32 *)(FLASH_BASE_ADDR + 0xFD0))
  // Flash DMA Address Size
#define FLASHDMAST                (*(volatile U32 *)(FLASH_BASE_ADDR + 0xFD4))
  // Flash DMA Starting Address

/*********************************************************************
*
*       Pin assignment
*/
#define CS_PIN                    4     // Port H
#define CLK_PIN                   0     // Port Q
#define DAT0_PIN                  2     // Port Q
#define DAT1_PIN                  0     // Port F

/*********************************************************************
*
*       Flags in system registers
*/
#define RCGCSSI_SSI3              3
#define RCGCGPIO_GPIOF            5
#define RCGCGPIO_GPIOH            7
#define RCGCGPIO_GPIOQ            14

/*********************************************************************
*
*       SSI related defines
*/
#define CR0_DSS                   0
#define CR0_DSS_8BIT              7uL
#define CR0_SPO                   6
#define CR0_SCR                   8
#define CR0_SPH                   7
#define CR0_SCR_MASK              0xFFuL
#define CR1_SSE                   1
#define CR1_MODE                  6
#define CR1_MODE_BI               1uL
#define CR1_MODE_QUAD             2uL
#define CR1_MODE_ADV              3uL
#define CR1_MODE_MASK             3uL
#define CR1_DIR                   8
#define SR_TNF                    1
#define SR_RNE                    2
#define SR_BSY                    4

/*********************************************************************
*
*       DMA related defines
*/
#define DMA_MAX_TRANSFER_SIZE     1024    // in items
#define DMA_CHANNEL_READ          14
#define DMA_CHANNEL_WRITE         15
#define CHMAP1_SSI3_RX            2uL
#define CHMAP1_SSI3_TX            2uL
#define CHMAP_CHSEL_MASK          0xFuL
#define CHCTL_XFERMODE            0
#define CHCTL_XFERMODE_BASIC      1uL
#define CHCTL_XFERSIZE            4
#define CHCTL_XFERSIZE_MASK       0x3FFuL
#define CHCTL_ARBSIZE             14
#define CHCTL_ARBSIZE_4           2uL
#define CHCTL_SRCINC              26
#define CHCTL_SRCINC_NOINC        3uL
#define CHCTL_DSTINC              30
#define CHCTL_DSTINC_NOINC        3uL
#define DMACTL_RXDMAE             0
#define DMACTL_TXDMAE             1
#define CFG_MASTEREN              0
#define PP_DFA                    28

/*********************************************************************
*
*       Misc. defines
```

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```
*/
#define DEFAULT_SPI_CLOCK_KHZ     400uL
#if (DMA_CHANNEL_READ < DMA_CHANNEL_WRITE)
  #define NUM_DMA_DESC            (DMA_CHANNEL_WRITE + 1)
#else
  #define NUM_DMA_DESC            (DMA_CHANNEL_READ + 1)
#endif

/*********************************************************************
*
*       Local data types
*
**********************************************************************
*/

/*********************************************************************
*
*       DMA_DESC
*/
typedef struct DMA_DESC {
  volatile U32 SRCENDP;
  volatile U32 DESTENDP;
  volatile U32 CHCTL;
  volatile U32 Reserved;
} DMA_DESC;

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static U8            _IsInited;
#if FS_MMC_HW_SPI_USE_DMA
  //
  // The DMA descriptors have to aligned on a 1KB boundary.
  //
#ifdef __ICCARM__
  #pragma data_alignment=1024
  static DMA_DESC    _aDMADesc[NUM_DMA_DESC];
#endif
#ifdef __SES_ARM
  static DMA_DESC    _aDMADesc[NUM_DMA_DESC] __attribute__ ((aligned (1024)));
#endif
  static volatile U8 _Dummy;
#endif

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _EnableClocks
*/
static void _EnableClocks(void) {
  U32 TimeOut;

  //
  // Provide a clock to SSI module and wait for it to become ready.
  //
  RCGCSSI |= 1uL << RCGCSSI_SSI3;
  TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
  while (1) {
    if (PRSSI & (1uL << RCGCSSI_SSI3)) {
      break;
    }
    if (--TimeOut == 0) {
      break;
    }
  }
  //
  // Provide a clock to GPIO ports and wait for them to become ready.
```

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```
  //
  RCGCGPIO |= 0
           | (1uL << RCGCGPIO_GPIOF)
           | (1uL << RCGCGPIO_GPIOH)
           | (1uL << RCGCGPIO_GPIOQ)
           ;
  TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
  while (1) {
    if (PRGPIO & ((1uL << RCGCGPIO_GPIOF) | (1uL << RCGCGPIO_GPIOQ) | (1uL << RCGCGPIO_GPIOH))) {
      break;
    }
    if (--TimeOut == 0) {
      break;
    }
  }
#if FS_MMC_HW_SPI_USE_DMA
  //
  // Provide a clock to DMA controller and wait for it to become ready.
  //
  RCGCDMA |= 1uL << 0;
  TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
  while (1) {
    if (PRDMA & ((1uL << 0))) {
      break;
    }
    if (--TimeOut == 0) {
      break;
    }
  }
#endif
}

/*********************************************************************
*
*       _InitPins
*/
static void _InitPins(void) {
  //
  // Give the control of CLK, DAT0-3 signals to SSI module.
  //
  PQ_GPIOAFSEL |= 0
               |  (1uL << CLK_PIN)
               |  (1uL << DAT0_PIN)
               ;
  PF_GPIOAFSEL |= 0
               |  (1uL << DAT1_PIN)
               ;
  PQ_GPIOPCTL  &= ~((0xFuL << (CLK_PIN  << 2)) |
                    (0xFuL << (DAT0_PIN << 2)));
  PQ_GPIOPCTL  |= 0
               |  (0xEuL << (CLK_PIN  << 2))
               |  (0xEuL << (DAT0_PIN << 2))
               ;
  PF_GPIOPCTL  &= ~((0xFuL << (DAT1_PIN << 2)));
  PF_GPIOPCTL  |= 0
               |  (0xEuL << (DAT1_PIN << 2))
               ;
  //
  // Set the output drive strength to 2mA as done in the TI sample code.
  //
  PQ_GPIOPC    &= ~((0x3uL << (CLK_PIN  << 1)) |
                    (0x3uL << (DAT0_PIN << 1)));
  PF_GPIOPC    &= ~((0x3uL << (DAT1_PIN << 1)));
  PQ_GPIODR2R  |= 0
               |  (1uL << CLK_PIN)
               |  (1uL << DAT0_PIN)
               ;
  PQ_GPIODR4R  &= ~((0x1uL << CLK_PIN) |
                    (0x1uL << DAT0_PIN));
  PQ_GPIODR8R  &= ~((0x1uL << CLK_PIN) |
                    (0x1uL << DAT0_PIN));
  PF_GPIODR2R  |= 0
               |  (1uL << DAT1_PIN)
               ;
  PF_GPIODR4R  &= ~((0x1uL << DAT1_PIN));
  PF_GPIODR8R  &= ~((0x1uL << DAT1_PIN));
```

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```
  //
  // Enable pull-ups on all signal lines.
  //
  PQ_GPIOPUR   |= 0
                |  (1uL << CLK_PIN)
                |  (1uL << DAT0_PIN)
                ;
  PF_GPIOPUR   |= 0
                |  (1uL << DAT1_PIN)
                ;
  PQ_GPIOODR   &= ~((0x1uL << CLK_PIN) |
                    (0x1uL << DAT0_PIN));
  PF_GPIOODR   &= ~((0x1uL << DAT1_PIN));
  PQ_GPIOPDR   &= ~((0x1uL << CLK_PIN) |
                    (0x1uL << DAT0_PIN));
  PF_GPIOPDR   &= ~((0x1uL << DAT1_PIN));
  //
  // Enable the pins.
  //
  PQ_GPIODEN   |= 0
                |  (1uL << CLK_PIN)
                |  (1uL << DAT0_PIN)
                ;
  PF_GPIODEN   |= 0
                |  (1uL << DAT1_PIN)
                ;
  //
  // The CS signal is controlled by the driver.
  //
  PH_GPIODIR   |=   1uL << CS_PIN;
  PH_GPIOAFSEL &= ~(1uL << CS_PIN);
  PH_GPIOPUR   &= ~(1uL << CS_PIN);
  PH_GPIOPDR   &= ~(1uL << CS_PIN);
  PH_GPIOODR   &= ~(1uL << CS_PIN);
  PH_GPIODEN   |=   1uL << CS_PIN;
}

#if FS_MMC_HW_SPI_USE_DMA

/*********************************************************************
*
*       _InitDMA
*/
static void _InitDMA(void) {
  DMACFG         |= 1uL << CFG_MASTEREN;        // Enable the DMA controller.
  DMACTLBASE      = (U32)_aDMADesc;             // The descriptor table must be 1024 aligned.
  DMAPRIOCLR      = 0                           // Set the priority to default.
                  | (1uL << DMA_CHANNEL_READ)
                  | (1uL << DMA_CHANNEL_WRITE)
                  ;
  DMAALTCLR       = 0
  // Use the primary control structure in the DMA descriptor table.
                  | (1uL << DMA_CHANNEL_READ)
                  | (1uL << DMA_CHANNEL_WRITE)
                  ;
  DMAUSEBURSTCLR  = 0                           // Respond to single and burst requests.
                  | (1uL << DMA_CHANNEL_READ)
                  | (1uL << DMA_CHANNEL_WRITE)
                  ;
  DMAREQMASKCLR   = 0                           // Allow the recongition of requests.
                  | (1uL << DMA_CHANNEL_READ)
                  | (1uL << DMA_CHANNEL_WRITE)
                  ;
  //
  // Receive requests from SSI.
  //
  DMACHMAP1      &= ~((CHMAP_CHSEL_MASK << ((DMA_CHANNEL_READ - 8) << 2)) |
                      (CHMAP_CHSEL_MASK << ((DMA_CHANNEL_WRITE - 8) << 2)));
  DMACHMAP1      |= (CHMAP1_SSI3_RX << ((DMA_CHANNEL_READ  - 8) << 2))
                  |  (CHMAP1_SSI3_TX << ((DMA_CHANNEL_WRITE - 8) << 2))
                  ;
  //
  // Give DMA access to internal flash memory.
  //
  FLASHPP     |= 1uL << PP_DFA;
  FLASHDMASZ   = 0x3FFFFuL;
```

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```
  FLASHDMAST  = 0;              // Internal flash memory starts at address 0.
}

/*********************************************************************
*
*       _StartDMAWrite
*/
static void _StartDMAWrite(const U8 * pData, U32 NumBytes) {
  U32        TimeOut;
  U32        CHCTLReg;
  DMA_DESC * pDMADesc;

  //
  // Stop the DMA channels if required.
  //
  if (DMAENASET & ((1uL << DMA_CHANNEL_WRITE) | (1uL << DMA_CHANNEL_READ))) {
    DMAENACLR = 0
              | (1uL << DMA_CHANNEL_WRITE)
              | (1uL << DMA_CHANNEL_READ)
              ;
    TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
    while (1) {
      if ((DMAENASET & ((1uL << DMA_CHANNEL_WRITE) | (1uL << DMA_CHANNEL_READ))) == 0) {
        break;
      }
      if (--TimeOut == 0) {
        break;
      }
    }
  }
  //
  // Configure the write data transfer.
  //
  NumBytes = (NumBytes - 1) & CHCTL_XFERSIZE_MASK;
  CHCTLReg = 0
           | (CHCTL_DSTINC_NOINC   << CHCTL_DSTINC)
           | (CHCTL_ARBSIZE_4      << CHCTL_ARBSIZE)
           | (NumBytes             << CHCTL_XFERSIZE)
           | (CHCTL_XFERMODE_BASIC << CHCTL_XFERMODE)
           ;
  //
  // Fill in the DMA descriptor.
  //
  pDMADesc = &_aDMADesc[DMA_CHANNEL_WRITE];
  pDMADesc->SRCENDP  = (U32)(pData + NumBytes);
  pDMADesc->DESTENDP = (U32)&SSIDR;
  pDMADesc->CHCTL    = CHCTLReg;
  //
  // Configure the read data transfer.
  //
  CHCTLReg = 0
           | (CHCTL_DSTINC_NOINC   << CHCTL_DSTINC)
           | (CHCTL_SRCINC_NOINC   << CHCTL_SRCINC)
           | (CHCTL_ARBSIZE_4      << CHCTL_ARBSIZE)
           | (NumBytes             << CHCTL_XFERSIZE)
           | (CHCTL_XFERMODE_BASIC << CHCTL_XFERMODE)
           ;
  //
  // Fill in the DMA descriptor.
  //
  pDMADesc = &_aDMADesc[DMA_CHANNEL_READ];
  pDMADesc->SRCENDP  = (U32)&SSIDR;
  pDMADesc->DESTENDP = (U32)&_Dummy;
  pDMADesc->CHCTL    = CHCTLReg;
  //
  // Start the DMA transfer.
  //
  SSIDMACTL  = 0
             | (1uL << DMACTL_RXDMAE)
             | (1uL << DMACTL_TXDMAE)
             ;
  DMAENASET |= 0
            | (1uL << DMA_CHANNEL_READ)
            | (1uL << DMA_CHANNEL_WRITE)
            ;
}
```

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```
/*********************************************************************
*
*       _StartDMARead
*/
static void _StartDMARead(U8 * pData, U32 NumBytes) {
  U32 TimeOut;
  U32 CHCTLReg;
  DMA_DESC * pDMADesc;

  _Dummy = 0xFF;
  FS_USE_PARA(_Dummy);
  //
  // Stop the DMA channels if required.
  //
  if (DMAENASET & ((1uL << DMA_CHANNEL_WRITE) | (1uL << DMA_CHANNEL_READ))) {
    DMAENACLR = 0
              | (1uL << DMA_CHANNEL_WRITE)
              | (1uL << DMA_CHANNEL_READ)
              ;
    TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
    while (1) {
      if ((DMAENASET & ((1uL << DMA_CHANNEL_WRITE) | (1uL << DMA_CHANNEL_READ))) == 0) {
        break;
      }
      if (--TimeOut == 0) {
        break;
      }
    }
  }
  //
  // Configure the write data transfer.
  //
  NumBytes = (NumBytes - 1) & CHCTL_XFERSIZE_MASK;
  CHCTLReg = 0
           | (CHCTL_DSTINC_NOINC   << CHCTL_DSTINC)
           | (CHCTL_SRCINC_NOINC   << CHCTL_SRCINC)
           | (CHCTL_ARBSIZE_4      << CHCTL_ARBSIZE)
           | (NumBytes             << CHCTL_XFERSIZE)
           | (CHCTL_XFERMODE_BASIC << CHCTL_XFERMODE)
           ;
  //
  // Fill in the DMA descriptor.
  //
  pDMADesc = &_aDMADesc[DMA_CHANNEL_WRITE];
  pDMADesc->SRCENDP  = (U32)&_Dummy;
  pDMADesc->DESTENDP = (U32)&SSIDR;
  pDMADesc->CHCTL    = CHCTLReg;
  //
  // Configure the read data transfer.
  //
  CHCTLReg = 0
           | (CHCTL_SRCINC_NOINC   << CHCTL_SRCINC)
           | (CHCTL_ARBSIZE_4      << CHCTL_ARBSIZE)
           | (NumBytes             << CHCTL_XFERSIZE)
           | (CHCTL_XFERMODE_BASIC << CHCTL_XFERMODE)
           ;
  //
  // Fill in the DMA descriptor.
  //
  pDMADesc = &_aDMADesc[DMA_CHANNEL_READ];
  pDMADesc->SRCENDP  = (U32)&SSIDR;
  pDMADesc->DESTENDP = (U32)(pData + NumBytes);
  pDMADesc->CHCTL    = CHCTLReg;
  //
  // Start the DMA transfer.
  //
  SSIDMACTL  = 0
             | (1uL << DMACTL_RXDMAE)
             | (1uL << DMACTL_TXDMAE)
             ;
  DMAENASET |= 0
            | (1uL << DMA_CHANNEL_READ)
            | (1uL << DMA_CHANNEL_WRITE)
            ;
}
```

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```
/*********************************************************************
*
*       _WaitForEndOfDMAOperation
*/
static void _WaitForEndOfDMAOperation(void) {
  U32 TimeOut;

  TimeOut = FS_MMC_HW_SPI_WAIT_TIMEOUT_CYCLES;
  while (1) {
    if ((DMAENASET & (1uL << DMA_CHANNEL_READ)) == 0) {
      break;
    }
    if (--TimeOut == 0) {
      break;
    }
  }
}

#endif

/*********************************************************************
*
*       _SetMaxSpeed
*/
static U16 _SetMaxSpeed(U16 MaxFreq_kHz) {
  U32 SCRValue;
  U32 CPSValue;
  U32 Factor;

  if (MaxFreq_kHz > FS_MMC_HW_SPI_MAX_SPI_CLOCK_KHZ) {
    MaxFreq_kHz = FS_MMC_HW_SPI_MAX_SPI_CLOCK_KHZ;
  }
  CPSValue = 0;
  Factor = (FS_MMC_HW_SPI_PERIPH_CLOCK_KHZ + (MaxFreq_kHz - 1)) / MaxFreq_kHz;
  do {
    CPSValue += 2;
    SCRValue = ((Factor + (CPSValue - 1)) / CPSValue) - 1;
  } while (SCRValue > 255);
  SSICPSR  = CPSValue;
  SSICR0  &= ~(CR0_SCR_MASK << CR0_SCR);
  SSICR0  |=   SCRValue     << CR0_SCR;
  MaxFreq_kHz = (U16)(FS_MMC_HW_SPI_PERIPH_CLOCK_KHZ / (CPSValue * (1 + SCRValue)));
  return MaxFreq_kHz;
}

/*********************************************************************
*
*       _Write
*/
static void _Write(const U8 * pData, int NumBytes) {
#if FS_MMC_HW_SPI_USE_DMA
  int NumBytesAtOnce;

  do {
    NumBytesAtOnce = SEGGER_MIN(NumBytes, DMA_MAX_TRANSFER_SIZE);
    _StartDMAWrite(pData, (U32)NumBytesAtOnce);
    _WaitForEndOfDMAOperation();
    NumBytes -= (int)NumBytesAtOnce;
    pData    += NumBytesAtOnce;
  } while (NumBytes);
#else
  do {
    volatile U8 Dummy;
    //
    // Wait for room in FIFO.
    //
    while ((SSISR & (1uL << SR_TNF)) == 0) {
      ;
    }
    SSIDR = *pData++;
    //
    // Discard received data.
    //
    while ((SSISR & (1ul << SR_RNE)) == 0) {
      ;
```

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```
    }
    Dummy = SSIDR;
    FS_USE_PARA(Dummy);
  } while (--NumBytes);
#endif
  //
  // Wait for the data transfer to finish.
  //
  while (SSISR & (1uL << SR_BSY)) {
    ;
  }
}

/*********************************************************************
*
*       _Read
*/
static void _Read(U8 * pData, int NumBytes) {
#if FS_MMC_HW_SPI_USE_DMA
  int NumBytesAtOnce;

  do {
    NumBytesAtOnce = SEGGER_MIN(NumBytes, DMA_MAX_TRANSFER_SIZE);
    _StartDMARead(pData, (U32)NumBytesAtOnce);
    _WaitForEndOfDMAOperation();
    NumBytes -= NumBytesAtOnce;
    pData    += NumBytesAtOnce;
  } while (NumBytes);
#else
  do {
    //
    // Wait for room in FIFO.
    //
    while ((SSISR & (1uL << SR_TNF)) == 0) {
      ;
    }
    SSIDR = 0xFF;
    //
    // Wait for some data to be received.
    //
    while ((SSISR & (1ul << SR_RNE)) == 0) {
      ;
    }
    *pData++ = (U8)SSIDR;
  } while (--NumBytes);
#endif
}

/*********************************************************************
*
*       _Init
*/
static void _Init(void) {
  _EnableClocks();
  _InitPins();
  SSICR1 = 0;
  SSICR0 = 0
         | (CR0_DSS_8BIT << CR0_DSS)
         | (1uL          << CR0_SPO)
         | (1uL          << CR0_SPH)
         ;
  SSICC  = 0;
  SSIICR = ~0uL;
  SSIIM  = 0;
  SSIDMACTL = 0;
  (void)_SetMaxSpeed(DEFAULT_SPI_CLOCK_KHZ);
  SSICR1 |= 1uL << CR1_SSE;
  //
  // Empty the receive queue.
  //
  while (1) {
    if ((SSISR & (1uL << SR_RNE)) == 0) {
      break;
    }
    (void)SSIDR;
  }
```

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```
#if FS_MMC_HW_SPI_USE_DMA
  _InitDMA();
#endif
  _IsInited = 1;
}

/*********************************************************************
*
*       Public code (through callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_EnableCS
*
*  Function description
*    FS low level function. Sets the card slot active using the
*    chip select (CS) line.
*
*  Parameters
*    Unit     Device index
*/
static void _HW_EnableCS(U8 Unit) {
  volatile U32 * pReg;

  FS_USE_PARA(Unit);
  pReg  = (volatile U32 *)((U8 *)&PH_GPIODATA + ((1uL << CS_PIN) << 2));
  *pReg = ~(1uL << CS_PIN);         // Active low
}

/*********************************************************************
*
*       _HW_DisableCS
*
*  Function description
*    FS low level function. Clears the card slot inactive using the
*    chip select (CS) line.
*
*  Parameters
*    Unit     Device index
*/
static void _HW_DisableCS(U8 Unit) {
  volatile U32 * pReg;

  FS_USE_PARA(Unit);
  pReg  = (volatile U32 *)((U8 *)&PH_GPIODATA + ((1uL << CS_PIN) << 2));
  *pReg = 1uL << CS_PIN;            // Active low
}

/*********************************************************************
*
*       _HW_IsWriteProtected
*
*  Function description
*    FS low level function. Returns the state of the physical write
*    protection of the SD cards.
*
*  Parameters
*    Unit     Device index
*
*  Return value
*    ==1      The card is write protected
*    ==0      The card is not write protected
*/
static int _HW_IsWriteProtected(U8 Unit) {
  FS_USE_PARA(Unit);
  return 0;
}

/*********************************************************************
*
*       _HW_SetMaxSpeed
*
*  Function description
```

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```
*    FS low level function. Sets the SPI interface to a maximum frequency.
*    Make sure that you set the frequency lower or equal but never higher
*    than the given value. Recommended startup frequency is 100kHz - 400kHz.
*
*  Parameters
*    Unit       Device index
*    MaxFreq    SPI clock frequency in kHz
*
*  Return value
*    max. frequency     The maximum frequency set in kHz
*    ==0                The frequency could not be set
*/
static U16 _HW_SetMaxSpeed(U8 Unit, U16 MaxFreq) {
  FS_USE_PARA(Unit);
  MaxFreq = _SetMaxSpeed(MaxFreq);
  return MaxFreq;         // We are not faster than this.
}

/*********************************************************************
*
*       _HW_SetVoltage
*
*  Function description
*    FS low level function. Be sure that your card slot si within the given
*    voltage range. Return 1 if your slot can support the required voltage,
*    and if not, return 0;
*
*  Parameters
*    Unit       Device index
*    Vmin       Minimum supply voltage supported by host
*    Vmax       Maximum supply voltage supported by host
*
*  Return value
*    ==1        The card slot supports the voltage range
*    ==0        The card slot does not support the voltage range
*/
static int _HW_SetVoltage(U8 Unit, U16 Vmin, U16 Vmax) {
  FS_USE_PARA(Unit);
  if ((FS_MMC_HW_SPI_DEFAULT_SUPPLY_VOLTAGE >= Vmin) && (FS_MMC_HW_SPI_DEFAULT_SUPPLY_VOLTAGE <= Vmax)) {
    return 1;         // Supply voltage supported.
  }
  return 0;           // Supply voltage not supported.
}

/*********************************************************************
*
*       _HW_IsPresent
*
*  Function description
*    Returns the state of the media. If you do not know the state, return
*    FS_MEDIA_STATE_UNKNOWN and the higher layer will try to figure out if
*    a media is present.
*
*  Parameters
*    Unit     Device index
*
*  Return value
*    FS_MEDIA_STATE_UNKNOWN     Media state is unknown
*    FS_MEDIA_NOT_PRESENT       Media is not present
*    FS_MEDIA_IS_PRESENT        Media is present
*/
static int _HW_IsPresent(U8 Unit) {
  FS_USE_PARA(Unit);
  if (_IsInited == 0) {
    _Init();
  }
  return FS_MEDIA_IS_PRESENT;
}

/*********************************************************************
*
*       _HW_Read
*
*  Function description
*    FS low level function. Reads a specified number of bytes from MMC
*    card to buffer.
```

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```
*
*  Parameters
*    Unit       Device index
*    pData      Pointer to a data buffer
*    NumBytes   Number of bytes
*/
static void _HW_Read(U8 Unit, U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  _Read(pData, NumBytes);
}

/*********************************************************************
*
*       _HW_Write
*
*  Function description
*    FS low level function. Writes a specified number of bytes from
*    data buffer to the MMC/SD card.
*
*  Parameters
*    Unit       Device index
*    pData      Pointer to a data buffer
*    NumBytes   Number of bytes
*/
static void _HW_Write(U8 Unit, const U8 * pData, int NumBytes) {
  FS_USE_PARA(Unit);
  _Write(pData, NumBytes);
}

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/
const FS_MMC_HW_TYPE_SPI FS_MMC_HW_SPI_TM4C129_TI_TIVAC129 = {
  _HW_EnableCS,
  _HW_DisableCS,
  _HW_IsPresent,
  _HW_IsWriteProtected,
  _HW_SetMaxSpeed,
  _HW_SetVoltage,
  _HW_Read,
  _HW_Write,
  NULL,
  NULL,
  NULL,
  NULL
};

/************************** End of file ****************************/
```

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6.5.4.3 Hardware layer API - FS_MMC_HW_TYPE_CM

This hardware layer supports MMC cards and eMMC devices that comply with the version 4.x or newer of the MMC specification and SD cards of all types that are interfaced to the target MCU via a host controller that works in card mode. The functions of this hardware layer are grouped in a structure of type `FS_MMC_HW_TYPE_CM`. The following sections describe these functions in detail.

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6.5.4.3.1 FS_MMC_HW_TYPE_CM

Description

Hardware layer API for Card Mode MMC/SD driver

Type definition

```
typedef struct {
  FS_MMC_HW_TYPE_CM_INIT                      * pfInitHW;
  FS_MMC_HW_TYPE_CM_DELAY                     * pfDelay;
  FS_MMC_HW_TYPE_CM_IS_PRESENT                * pfIsPresent;
  FS_MMC_HW_TYPE_CM_IS_WRITE_PROTECTED        * pfIsWriteProtected;
  FS_MMC_HW_TYPE_CM_SET_MAX_SPEED             * pfSetMaxSpeed;
  FS_MMC_HW_TYPE_CM_SET_RESPONSE_TIMEOUT      * pfSetResponseTimeOut;
  FS_MMC_HW_TYPE_CM_SET_READ_DATA_TIMEOUT     * pfSetReadDataTimeOut;
  FS_MMC_HW_TYPE_CM_SEND_CMD                  * pfSendCmd;
  FS_MMC_HW_TYPE_CM_GET_RESPONSE              * pfGetResponse;
  FS_MMC_HW_TYPE_CM_READ_DATA                 * pfReadData;
  FS_MMC_HW_TYPE_CM_WRITE_DATA                * pfWriteData;
  FS_MMC_HW_TYPE_CM_SET_DATA_POINTER          * pfSetDataPointer;
  FS_MMC_HW_TYPE_CM_SET_BLOCK_LEN             * pfSetHWBlockLen;
  FS_MMC_HW_TYPE_CM_SET_NUM_BLOCKS            * pfSetHWNumBlocks;
  FS_MMC_HW_TYPE_CM_GET_MAX_READ_BURST        * pfGetMaxReadBurst;
  FS_MMC_HW_TYPE_CM_GET_MAX_WRITE_BURST       * pfGetMaxWriteBurst;
  FS_MMC_HW_TYPE_CM_GET_MAX_REPEAT_WRITE_BURST * pfGetMaxWriteBurstRepeat;
  FS_MMC_HW_TYPE_CM_GET_MAX_FILL_WRITE_BURST  * pfGetMaxWriteBurstFill;
  FS_MMC_HW_TYPE_CM_SET_VOLTAGE               * pfSetVoltage;
  FS_MMC_HW_TYPE_CM_GET_VOLTAGE               * pfGetVoltage;
  FS_MMC_HW_TYPE_CM_SET_MAX_CLOCK             * pfSetMaxClock;
  FS_MMC_HW_TYPE_CM_ENABLE_TUNING             * pfEnableTuning;
  FS_MMC_HW_TYPE_CM_DISABLE_TUNING            * pfDisableTuning;
  FS_MMC_HW_TYPE_CM_START_TUNING              * pfStartTuning;
  FS_MMC_HW_TYPE_CM_GET_MAX_TUNINGS           * pfGetMaxTunings;
} FS_MMC_HW_TYPE_CM;
```

Structure members

Member	Description
pfInitHW	Initializes the hardware layer.
pfDelay	Blocks the execution for the specified time.
pfIsPresent	Checks if the card is inserted.
pfIsWriteProtected	Checks if the card is write protected.
pfSetMaxSpeed	Configures the clock frequency supplied to the card.
pfSetResponseTimeOut	Configures the maximum time to wait for a response from card.
pfSetReadDataTimeOut	Configures the maximum time to wait for data from card.
pfSendCmd	Sends a command to card.
pfGetResponse	Receives a response from card.
pfReadData	Transfers data from card to MCU.
pfWriteData	Transfers data from MCU to card.
pfSetDataPointer	Configures the pointer to the data to be exchanged.
pfSetHWBlockLen	Configures the size of the data block to be exchanged.
pfSetHWNumBlocks	Configures the number of data blocks to be exchanged.
pfGetMaxReadBurst	Returns the maximum number of data blocks that can be transferred at once from card to MCU.
pfGetMaxWriteBurst	Returns the maximum number of data blocks that can be transferred at once from MCU to card.

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Member	Description
pfGetMaxWriteBurstRepeat	Returns the maximum number of blocks with identical data that can be transferred at once from MCU to card.
pfGetMaxWriteBurstFill	Returns the maximum number of blocks with identical data that can be transferred at once from MCU to card.
pfSetVoltage	Sets the voltage level of I/O lines.
pfGetVoltage	Returns the voltage level of I/O lines.
pfSetMaxClock	Configures the clock frequency supplied to the card.
pfEnableTuning	Enables the tuning procedure.
pfDisableTuning	Disables the tuning procedure.
pfStartTuning	Indicates the beginning of a tuning sequence.
pfGetMaxTunings	Returns the maximum number of tuning sequences.

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6.5.4.3.2 FS_MMC_HW_TYPE_CM_INIT

Description

Initializes the hardware layer.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_INIT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The Card Mode MMC/SD driver calls `FS_MMC_HW_TYPE_CM_INIT` before any other function of the hardware layer. `FS_MMC_HW_TYPE_CM_INIT` must perform any steps required to initialize the target hardware such as enabling the clocks, setting up special function registers, etc.

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6.5.4.3.3 FS_MMC_HW_TYPE_CM_DELAY

Description

Blocks the execution for the specified time.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_DELAY(int ms);
```

Parameters

Parameter	Description
ms	Number of milliseconds to block the execution.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The specified time is a minimum delay. The actual delay is permitted to be longer. This can be helpful when using an RTOS. Every RTOS has a delay API function, but the accuracy is typically 1 tick, which is 1 ms in most cases. Therefore, a delay of 1 tick is typically between 0 and 1 ms. To compensate for this, the equivalent of 1 tick should be added to the delay parameter before passing it to an RTOS delay function.

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6.5.4.3.4 FS_MMC_HW_TYPE_CM_IS_PRESENT

Description

Checks if the card is present.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_IS_PRESENT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

FS_MEDIA_STATE_UNKNOWN	The presence state of the card is unknown.
FS_MEDIA_NOT_PRESENT	The card is present.
FS_MEDIA_IS_PRESENT	The card is not present.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

Typically, the card presence detection is implemented via a dedicated Card Detect (CD) signal. This signal is connected to a switch inside the card slot that changes its state each time the card is removed or inserted. If the hardware does not provide such signal the function has to return FS_MEDIA_STATE_UNKNOWN.

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6.5.4.3.5 FS_MMC_HW_TYPE_CM_IS_WRITE_PROTECTED

Description

Checks if the card is write protected.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_IS_WRITE_PROTECTED(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

= 0 The card data can be modified.
≠ 0 The card data cannot be modified.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

Typically, the card protection status is implemented via a dedicated Write Protected (WP) signal. This signal is connected to a switch inside the card slot that reflects the status of the write protect switch found on SD cards. If the hardware does not provide such signal the function has to return 0.

eMMC devices and micro SD cards do not have a write protection switch. Please note that the write protect switch does not really protect the data on an SD card form being modified. It is merely an indication that the data has to be protected. It is the responsibility of the host MCU to respect the status of this switch.

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6.5.4.3.6 FS_MMC_HW_TYPE_CM_SET_MAX_SPEED

Description

Configures the clock frequency supplied to the card.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_SET_MAX_SPEED(U8  Unit,
                                            U16 MaxFreq);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
MaxFreq	Maximum allowed frequency of the bus clock in kHz.

Return value

≠ 0 The actual clock frequency in kHz.
= 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The hardware layer is allowed to set a clock frequency smaller than the value specified via MaxFreq but never greater than that. The Card Mode MMC/SD driver calls this function at least two times during the initialization of the MMC or SD card:

- Before the initialization starts to set the clock frequency to 400 kHz.
- After the card identification to set the standard clock frequency which is 25 MHz for SD cards or 26 MHz for MMC cards and eMMC devices.

FS_MMC_HW_TYPE_CM_SPI_SET_MAX_SPEED is called a third time by the Card Mode MMC/SD driver during the initialization if the high speed mode is enabled in the driver via FS_MMC_CM_AllowHighSpeedMode() and the card supports this mode. In this case the clock frequency is set to 50 MHz for SD cards and to 52 MHz for MMC cards and eMMC devices.

The function has to return the actual configured clock frequency. If the precise frequency is unknown such as for implementation using I/O port “bit-banging”, the return value has to be less than the specified frequency. This may lead to longer timeout values but is in general does not cause any problems. The Card Mode MMC/SD driver uses the returned value to calculate timeout values.

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6.5.4.3.7 FS_MMC_HW_TYPE_CM_SET_RESPONSE_TIMEOUT

Description

Configures the maximum time to wait for a response from card.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SET_RESPONSE_TIMEOUT(U8  Unit,
                                                    U32 Value);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
Value	Number of clock cycles to wait.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The specified value is the maximum number of clock cycles the hardware layer has to wait for a response from the card. If the card does not respond within the specified timeout then FS_MMC_HW_TYPE_CM_GET_RESPONSE has to return an error to the Card Mode MMC/SD driver.

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6.5.4.3.8 FS_MMC_HW_TYPE_CM_SET_READ_DATA_TIMEOUT

Description

Configures the maximum time to wait for data from card.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SET_READ_DATA_TIMEOUT(U8  Unit,
                                                     U32 Value);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
Value	Number of clock cycles to wait.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The specified value is the maximum number of clock cycles the hardware layer has to wait for data to be received from the card. If the card does not start sending the data within the specified timeout then FS_MMC_HW_TYPE_CM_READ_DATA has to return an error to the Card Mode MMC/SD driver. The timeout value specified via FS_MMC_HW_TYPE_CM_SET_READ_DATA_TIMEOUT has to be used as timeout for a write data operation if the MMC/SD host controller supports this feature.

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6.5.4.3.9 FS_MMC_HW_TYPE_CM_SEND_CMD

Description

Sends a command to card.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SEND_CMD(U8       Unit,
                                        unsigned Cmd,
                                        unsigned CmdFlags,
                                        unsigned ResponseType,
                                        U32      Arg);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
Cmd	Command code.
CmdFlags	Command options.
ResponseType	Type of response expected.
Arg	Command arguments.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

Cmd is a command code defined in the SD or MMC specification.

CmdFlags specifies additional information about the command execution such as the direction of the data transfer if any, the number of data lines to be used for the data exchange, etc. CmdFlags is a bitwise-or combination of *Card mode command flags* on page 1210

ResponseType specifies the format of the response expected for the sent command. It can be set to one of *Card mode response formats* on page 1213values. If the command requests a response from the card then the Card Mode MMC/SD driver calls FS_MMC_HW_TYPE_CM_GET_RESPONSE to get it.

Arg is the value that is stored at the bit positions 8:39 in a command codeword.

A command codeword is always sent via the CMD signal. The same signal is used by a card to send a response back to MCU.

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6.5.4.3.10 FS_MMC_HW_TYPE_CM_GET_RESPONSE

Description

Receives a response from card.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_GET_RESPONSE(U8     Unit,
                                           void * pData,
                                           U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	out Received response.
NumBytes	Number of bytes to be received.

Return value

= 0 OK, response received.
≠ 0 Error code indicating the failure reason.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The response is sent by the card via the CMD signal. A response codeword can be either 48- or 136-bit large.

Refer to *Card mode error codes* on page 1212 for possible return values.

The MMC and SD specifications describe the structure of a response in terms of bit units with bit 0 being the first transmitted via the CMD signal. The following table shows at which byte offsets the response has to be stored to pData.

48-bit response:

Byte offset pData
0
1
2
3
4
5

136-bit response:

Byte offset pData
0
1
2
3
4
5
6

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Byte offset pData
7
8
9
10
11
12
13
14
15
16

The first and last byte of a response codeword store control and check information that is not used by the Card Mode MMC/SD driver. If this information is not provided by the SD and MMC host controller then the hardware layer does not have to store any data to these locations of pData. That is the response data must be stored at byte offset 1 in pData.

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6.5.4.3.11 FS_MMC_HW_TYPE_CM_READ_DATA

Description

Transfers data from card to MCU.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_READ_DATA(U8       Unit,
                                        void   * pData,
                                        unsigned BlockSize,
                                        unsigned NumBlocks);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	out Data read from the card.
BlockSize	Number of bytes in a block to be transferred.
NumBlocks	Number of blocks be transferred.

Return value

= 0 OK, data read.
≠ 0 Error code indicating the failure reason.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The Card Mode MMC/SD driver initiates a data transfer by sending a read command via FS_MMC_HW_TYPE_CM_SEND_CMD. After it checks the response via FS_MMC_HW_TYPE_CM_GET_RESPONSE the Card Mode MMC/SD driver calls FS_MMC_HW_TYPE_CM_READ_DATA to transfer the data from card.

Typically, an MMC or SD host controller transfers the data one block at a time. BlockSize specifies the size of one block in bytes with the number of blocks being specified via NumBlocks. BlockSize and NumBlocks can never be 0. Typically the size of block is 512 bytes but during the initialization of the card the Card Mode MMC/SD driver can request blocks of different (smaller) sizes. The total number of bytes to be transferred by FS_MMC_HW_TYPE_CM_READ_DATA is BlockSize * NumBlocks.

The number of data signals to be used for the data transfer is specified by the Card Mode MMC/SD driver via the command flags when the command that initiates the read operation is sent. FS_MMC_CMD_FLAG_USE_SD4MODE is set in the command flags when the data has to be exchanged via 4 data signals. This flag can be set for SD cards as well as MMC devices. FS_MMC_CMD_FLAG_USE_MMC8MODE is set only for MMC devices to transfer the data via 8 data signals.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.12 FS_MMC_HW_TYPE_CM_WRITE_DATA

Description

Transfers data from MCU to card.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_WRITE_DATA(      U8       Unit,
                                         const void   * pData,
                                               unsigned BlockSize,
                                               unsigned NumBlocks);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	in Data to be written to card.
BlockSize	Number of bytes in a block to be transferred.
NumBlocks	Number of blocks be transferred.

Return value

= 0 OK, data written.
≠ 0 Error code indicating the failure reason.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

The Card Mode MMC/SD driver initiates a data transfer by sending a write command via FS_MMC_HW_TYPE_CM_SEND_CMD. After it checks the response via FS_MMC_HW_TYPE_CM_GET_RESPONSE the Card Mode MMC/SD driver calls FS_MMC_HW_TYPE_CM_WRITE_DATA to transfer the data to card.

Typically, an MMC or SD host controller transfers the data one block at a time. BlockSize specifies the size of one block in bytes with the number of blocks being specified via NumBlocks. BlockSize and NumBlocks can never be 0. Typically the size of block is 512 bytes but during the initialization of the card the Card Mode MMC/SD driver can request blocks of different (smaller) sizes. The total number of bytes to be transferred by FS_MMC_HW_TYPE_CM_WRITE_DATA is BlockSize * NumBlocks.

The number of data signals to be used for the data transfer is specified by the Card Mode MMC/SD driver via the command flags when the command that initiates the write operation is sent. FS_MMC_CMD_FLAG_USE_SD4MODE is set in the command flags when the data has to be exchanged via 4 data signals. This flag can be set for SD cards as well as MMC devices. FS_MMC_CMD_FLAG_USE_MMC8MODE is set only for MMC devices to transfer the data via 8 data signals.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.13 FS_MMC_HW_TYPE_CM_SET_DATA_POINTER

Description

Configures the pointer to the data to be exchanged.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SET_DATA_POINTER(      U8     Unit,
                                                const void * pData);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	Data exchanged with the card.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer It has to be implemented only by a hardware layer that has to prepare the data transfer such as via DMA before the read or write command that initiates that data transfer is sent to card.

FS_MMC_HW_TYPE_CM_SET_DATA_POINTER is called by the Card Mode MMC/SD driver before each command that exchanges the data with the card. pData points to the same memory region as pData passed to FS_MMC_HW_TYPE_CM_READ_DATA and FS_MMC_HW_TYPE_CM_WRITE_DATA.

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6.5.4.3.14 FS_MMC_HW_TYPE_CM_SET_BLOCK_LEN

Description

Configures the size of the data block to be exchanged.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SET_BLOCK_LEN(U8  Unit,
                                             U16 BlockSize);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
BlockSize	Number of bytes in the block.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer It has to be implemented only by a hardware layer that has to prepare the data transfer such as via DMA before the read or write command that initiates that data transfer is sent to card.

FS_MMC_HW_TYPE_CM_SET_BLOCK_LEN is called by the Card Mode MMC/SD driver before each command that exchanges the data with the card. The same value is passed via BlockSize as the value passed via BlockSize to FS_MMC_HW_TYPE_CM_READ_DATA and FS_MMC_HW_TYPE_CM_WRITE_DATA.

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6.5.4.3.15 FS_MMC_HW_TYPE_CM_SET_NUM_BLOCKS

Description

Configures the number of data blocks to be exchanged.

Type definition

```
typedef void FS_MMC_HW_TYPE_CM_SET_NUM_BLOCKS(U8  Unit,
                                               U16 NumBlocks);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
NumBlocks	Number of bytes to be exchanged.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer It has to be implemented only by a hardware layer that has to prepare the data transfer such as via DMA before the read or write command that initiates that data transfer is sent to card.

FS_MMC_HW_TYPE_CM_SET_NUM_BLOCKS is called by the Card Mode MMC/SD driver before each command that exchanges the data with the card. The same value is passed via NumBlocks as the value passed via NumBlocks to FS_MMC_HW_TYPE_CM_READ_DATA and FS_MMC_HW_TYPE_CM_WRITE_DATA.

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6.5.4.3.16 FS_MMC_HW_TYPE_CM_GET_MAX_READ_BURST

Description

Returns the maximum number of data blocks that can be transferred at once from card to MCU.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_MAX_READ_BURST(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

Number of blocks that can be transferred at once. It cannot be 0.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

FS_MMC_HW_TYPE_CM_GET_MAX_READ_BURST is called by the Card Mode MMC/SD driver during initialization. It has to return the maximum number of 512 byte blocks the hardware layer is able to transfer from the card via a single read command. The larger the number of blocks the hardware layer can exchange at once the better is the read performance.

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6.5.4.3.17 FS_MMC_HW_TYPE_CM_GET_MAX_WRITE_BURST

Description

Returns the maximum number of data blocks that can be transferred at once from MCU to card.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_MAX_WRITE_BURST(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

Number of blocks that can be transferred at once. It cannot be 0.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. It has to be implemented by all the hardware layers.

FS_MMC_HW_TYPE_CM_GET_MAX_WRITE_BURST is called by the Card Mode MMC/SD driver during initialization. It has to return the maximum number of 512 byte blocks the hardware layer is able to transfer to the card via a single write command. The larger the number of blocks the hardware layer can exchange at once the better is the write performance.

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6.5.4.3.18 FS_MMC_HW_TYPE_CM_GET_MAX_REPEAT_WRITE_BURST

Description

Returns the maximum number of blocks of identical data that can be transferred from MCU to card.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_MAX_REPEAT_WRITE_BURST(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

Number of blocks that can be transferred at once.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer is not required to implement this function.

FS_MMC_HW_TYPE_CM_GET_MAX_REPEAT_WRITE_BURST is called by the Card Mode MMC/SD driver during initialization. It has to return the maximum number of 512 byte blocks the hardware layer is able to repeatedly transfer to the card via a single write command. The command that starts a repeated write operation has FS_MMC_CMD_FLAG_WRITE_BURST_REPEAT set in the command flags passed to FS_MMC_HW_TYPE_CM_SEND_CMD. The Card Mode MMC/SD driver transfers the data by calling FS_MMC_HW_TYPE_CM_WRITE_DATA with pData always pointing to a single block of BlockSize regardless of the NumBlock value. That FS_MMC_HW_TYPE_CM_WRITE_DATA does not have to increment pData by BlockSize after each block transfer. The larger the number of blocks the hardware layer can exchange at once the better is the write performance.

A return value of 0 indicates that the feature is not supported.

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6.5.4.3.19 FS_MMC_HW_TYPE_CM_GET_MAX_FILL_WRITE_BURST

Description

Returns the maximum number of blocks of identical data that can be transferred from MCU to card.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_MAX_FILL_WRITE_BURST(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

Number of blocks that can be transferred at once.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer is not required to implement this function.

FS_MMC_HW_TYPE_CM_GET_MAX_FILL_WRITE_BURST is called by the Card Mode MMC/SD driver during initialization. It has to return the maximum number of 512 byte blocks the hardware layer is able to repeatedly transfer to the card via a single write command. The command that starts a repeated write operation has FS_MMC_CMD_FLAG_WRITE_BURST_FILL set in the command flags passed to FS_MMC_HW_TYPE_CM_SEND_CMD. The Card Mode MMC/SD driver transfers the data by calling FS_MMC_HW_TYPE_CM_WRITE_DATA with pData always pointing to a single block of BlockSize regardless of the NumBlocks value. FS_MMC_HW_TYPE_CM_GET_MAX_FILL_WRITE_BURST has to take the first four bytes from pData and send them repeatedly to card until BlockSize * NumBlocks are sent. Typically this operation is realized by using DMA configured to transfer four bytes at once and without incrementing the destination address. The larger the number of blocks the hardware layer can exchange at once the better is the write performance.

A return value of 0 indicates that the feature is not supported.

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6.5.4.3.20 FS_MMC_HW_TYPE_CM_SET_VOLTAGE

Description

Changes the voltage level of the I/O lines.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_SET_VOLTAGE(U8  Unit,
                                          U16 VMin,
                                          U16 VMax,
                                          int IsSwitchSequence);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
VMin	Minimum voltage of I/O lines to be set.
VMax	Maximum voltage of I/O lines to be set.
IsSwitchSequence	Specifies if a voltage switch sequence has to be performed according to SD specification. • 1 Voltage switch sequence has to be performed. • 0 No voltage switch sequence is required.

Return value

= 0 OK, voltage switched successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables any ultra high speed mode in the Card Mode MMC/SD driver.

The values of VMin and VMax are specified in mV with VMin always smaller than or equal to VMax.

IsSwitchSequence is set to 1 only if an SD card is connected. For MMC cards or eMMC devices IsSwitchSequence is always set to 0. If IsSwitchSequence is set to 1 then the function has to wait for the SD card to change the voltage level of the I/O lines as follows:

- Wait for the SD card to drive either the CMD or one of the DAT lines to low.
- Stop providing clock to SD card.
- Wait for the SD card to start the switch sequence by checking if either the CMD or one of the DAT lines to low.
- Wait at least 5 ms.
- Start providing the clock to SD card using a 1.8 V voltage level.
- Wait at least 1 ms.
- Check if the SD card drives one of the DAT lines to high. This function has to wait for the power to stabilize before it returns.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.21 FS_MMC_HW_TYPE_CM_GET_VOLTAGE

Description

Returns the current voltage level of the I/O lines.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_VOLTAGE(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

≠ 0 OK, voltage level of I/O lines in mV.
= 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables any ultra high speed mode in the Card Mode MMC/SD driver.

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6.5.4.3.22 FS_MMC_HW_TYPE_CM_SET_MAX_CLOCK

Description

Configures the clock frequency supplied to the card.

Type definition

```
typedef U32 FS_MMC_HW_TYPE_CM_SET_MAX_CLOCK(U8       Unit,
                                            U32      MaxFreq,
                                            unsigned ClkFlags);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
MaxFreq	Maximum allowed frequency of the bus clock in kHz.
ClkFlags	Additional clock generation options.

Return value

≠ 0 The actual clock frequency in kHz.
= 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables any ultra high speed mode in the Card Mode MMC/SD driver.

The hardware layer is allowed to set a clock frequency smaller than the value specified via MaxFreq but never greater than that.

FS_MMC_HW_TYPE_CM_SPI_SET_MAX_SPEED_EX is similar to FS_MMC_HW_TYPE_CM_SPI_SET_MAX_SPEED with the exception that it allows the configuration of a clock frequency greater than 65535 kHz which is required by some of the ultra high speed modes. In addition, FS_MMC_HW_TYPE_CM_SPI_SET_MAX_SPEED_EX has the ability to configure if the data received from the card has to be sampled on one clock edge or on both clock edges.

ClkFlags is a bitwise-or combination of *Card mode clock flags* on page 1211 values. These flags specify, for example, how the data has to be sampled.

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6.5.4.3.23 FS_MMC_HW_TYPE_CM_ENABLE_TUNING

Description

Stops the normal operation and enters the tuning procedure.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_ENABLE_TUNING(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

= 0 OK, tuning procedure activated.
≠ 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables an ultra high speed mode that requires the tuning of the data sampling point.

FS_MMC_HW_TYPE_CM_ENABLE_TUNING is called by the Card Mode MMC/SD driver one time at the beginning of the tuning procedure. The call to this function is followed by one or more calls to FS_MMC_HW_TYPE_CM_START_TUNING. FS_MMC_HW_TYPE_CM_DISABLE_TUNING is called at the end of the tuning procedure.

Typically, this function can be used to enabled the delay line loop that is used for generating the sampling clock.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.24 FS_MMC_HW_TYPE_CM_DISABLE_TUNING

Description

Restores the normal operation after the tuning procedure.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_DISABLE_TUNING(U8  Unit,
                                             int Result);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
Result	Specifies if the tuning procedure was successful or not. • 0 - The tuning procedure was successful. • 1 - The tuning procedure failed.

Return value

= 0 OK, tuning procedure deactivated.
≠ 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables an ultra high speed mode that requires the tuning of the data sampling point.

FS_MMC_HW_TYPE_CM_DISABLE_TUNING is called by the Card Mode MMC/SD driver one time at the end of the tuning procedure.

Typically, this function can be used to disable the delay line loop that is used for generating the sampling clock when the tuning procedure fails.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.25 FS_MMC_HW_TYPE_CM_START_TUNING

Description

Indicates the beginning of a tuning sequence.

Type definition

```
typedef int FS_MMC_HW_TYPE_CM_START_TUNING(U8       Unit,
                                           unsigned TuningIndex);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
TuningIndex	Index of the current tuning sequence (0-based)

Return value

= 0 OK, tuning sequence failed.
≠ 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables an ultra high speed mode that requires the tuning of the data sampling point.

FS_MMC_HW_TYPE_CM_START_TUNING is called by the Card Mode MMC/SD driver one time at the beginning of each tuning sequence. On the first call TuningIndex is set to 0, on the second to 1 and so on. The maximum value of TuningIndex is the value returned by FS_MMC_HW_TYPE_CM_GET_MAX_TUNINGS minus 1. TuningIndex can be used for example to select a different delay line unit.

Refer to *Card mode error codes* on page 1212 for possible return values.

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6.5.4.3.26 FS_MMC_HW_TYPE_CM_GET_MAX_TUNINGS

Description

Queries the maximum number of tuning sequences.

Type definition

```
typedef U16 FS_MMC_HW_TYPE_CM_GET_MAX_TUNINGS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

≠ 0 OK, maximum number of tuning sequences.
= 0 An error occurred.

Additional information

This function is a member of the Card Mode MMC/SD hardware layer. A hardware layer has to implement this function if the hardware supports 1.8 V signaling and the application enables an ultra high speed mode that requires the tuning of the data sampling point.

FS_MMC_HW_TYPE_CM_GET_MAX_TUNINGS is called by the Card Mode MMC/SD driver one time at the beginning of the tuning procedure after the call to FS_MMC_HW_TYPE_CM_ENABLE_TUNING.

The return value can be for example the number of delay line units available.

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6.5.4.3.27 Card mode command flags

Description

Additional options for the executed command.

Definition

```
#define FS_MMC_CMD_FLAG_DATATRANSFER          (1uL << 0)
#define FS_MMC_CMD_FLAG_WRITETRANSFER         (1uL << 1)
#define FS_MMC_CMD_FLAG_SETBUSY               (1uL << 2)
#define FS_MMC_CMD_FLAG_INITIALIZE            (1uL << 3)
#define FS_MMC_CMD_FLAG_USE_SD4MODE           (1uL << 4)
#define FS_MMC_CMD_FLAG_STOP_TRANS            (1uL << 5)
#define FS_MMC_CMD_FLAG_WRITE_BURST_REPEAT    (1uL << 6)
#define FS_MMC_CMD_FLAG_USE_MMC8MODE          (1uL << 7)
#define FS_MMC_CMD_FLAG_NO_CRC_CHECK          (1uL << 8)
#define FS_MMC_CMD_FLAG_WRITE_BURST_FILL      (1uL << 9)
#define FS_MMC_CMD_FLAG_SWITCH_VOLTAGE        (1uL << 10)
```

Symbols

Definition	Description
FS_MMC_CMD_FLAG_DATATRANSFER	Command that exchanges data with the card.
FS_MMC_CMD_FLAG_WRITETRANSFER	Command that sends data to card. Implies FS_MMC_CMD_FLAG_DATATRANSFER.
FS_MMC_CMD_FLAG_SETBUSY	Command that expects an R1b command.
FS_MMC_CMD_FLAG_INITIALIZE	Specifies that the initialization delay has to be performed. According to SD specification this is the maximum of 1 millisecond, 74 clock cycles and supply ramp up time.
FS_MMC_CMD_FLAG_USE_SD4MODE	Command that transfers the data via 4 data lines.
FS_MMC_CMD_FLAG_STOP_TRANS	Command that stops a data transfer (typically CMD12)
FS_MMC_CMD_FLAG_WRITE_BURST_REPEAT	Specifies that the same sector data is written to consecutive sector indexes.
FS_MMC_CMD_FLAG_USE_MMC8MODE	Command that transfers the data via 8 data lines (MMC only).
FS_MMC_CMD_FLAG_NO_CRC_CHECK	CRC verification has to be disabled for the command. Typically used with the MMC bus test commands.
FS_MMC_CMD_FLAG_WRITE_BURST_FILL	Specifies that the 32-bit value is used to fill the contents of consecutive sector indexes.
FS_MMC_CMD_FLAG_SWITCH_VOLTAGE	Specifies that the signaling of the I/O lines has to be changed to 1.8 V

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6.5.4.3.28 Card mode clock flags

Description

Additional options for the clock generation.

Definition

```
#define FS_MMC_CLK_FLAG_DDR_MODE           (1uL << 0)
#define FS_MMC_CLK_FLAG_STROBE_MODE        (1uL << 1)
#define FS_MMC_CLK_FLAG_ENHANCED_STROBE    (1uL << 2)
```

Symbols

Definition	Description
FS_MMC_CLK_FLAG_DDR_MODE	Specifies that the data is exchanged on both clock edges.
FS_MMC_CLK_FLAG_STROBE_MODE	Specifies that the received data is sampled using a strobe signal generated by the storage device.
FS_MMC_CLK_FLAG_ENHANCED_STROBE	Specifies that the received response and data are sampled using a strobe signal generated by the storage device.

Additional information

The FS_MMC_CLK_FLAG_STROBE_MODE and FS_MMC_CLK_FLAG_ENHANCED_STROBE flags are used to specify how to sample the data coming from an eMMC device in HS400 access mode. If FS_MMC_CLK_FLAG_STROBE_MODE is set and FS_MMC_CLK_FLAG_ENHANCED_STROBE and cleared then the received data is sampled using the strobe signal while the command response using the clock supplied to eMMC device. If FS_MMC_CLK_FLAG_STROBE_MODE and FS_MMC_CLK_FLAG_ENHANCED_STROBE are both set then the received data as well as the command response are sampled using the strobe signal.

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6.5.4.3.29 Card mode error codes

Description

Values that indicate the result of an operation.

Definition

```
#define FS_MMC_CARD_NO_ERROR                 0
#define FS_MMC_CARD_RESPONSE_TIMEOUT         1
#define FS_MMC_CARD_RESPONSE_CRC_ERROR       2
#define FS_MMC_CARD_READ_TIMEOUT             3
#define FS_MMC_CARD_READ_CRC_ERROR           4
#define FS_MMC_CARD_WRITE_CRC_ERROR          5
#define FS_MMC_CARD_RESPONSE_GENERIC_ERROR   6
#define FS_MMC_CARD_READ_GENERIC_ERROR       7
#define FS_MMC_CARD_WRITE_GENERIC_ERROR      8
#define FS_MMC_CARD_TUNING_ERROR             9
#define FS_MMC_CARD_VOLTAGE_SWITCH_ERROR     10
```

Symbols

Definition	Description
FS_MMC_CARD_NO_ERROR	Success.
FS_MMC_CARD_RESPONSE_TIMEOUT	No response received.
FS_MMC_CARD_RESPONSE_CRC_ERROR	CRC error in response detected.
FS_MMC_CARD_READ_TIMEOUT	No data received.
FS_MMC_CARD_READ_CRC_ERROR	CRC error in received data detected.
FS_MMC_CARD_WRITE_CRC_ERROR	Card detected an CRC error in the received data.
FS_MMC_CARD_RESPONSE_GENERIC_ERROR	Start bit, end bit or command index error.
FS_MMC_CARD_READ_GENERIC_ERROR	An error occurred during while receiving data from card.
FS_MMC_CARD_WRITE_GENERIC_ERROR	An error occurred during while sending data to card.
FS_MMC_CARD_TUNING_ERROR	An error occurred during the tuning procedure.
FS_MMC_CARD_VOLTAGE_SWITCH_ERROR	An error occurred during the voltage switch procedure.

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6.5.4.3.30 Card mode response formats

Description

Response types returned by different commands.

Definition

```
#define FS_MMC_RESPONSE_FORMAT_NONE     0
#define FS_MMC_RESPONSE_FORMAT_R1       1
#define FS_MMC_RESPONSE_FORMAT_R2       2
#define FS_MMC_RESPONSE_FORMAT_R3       3
#define FS_MMC_RESPONSE_FORMAT_R6       FS_MMC_RESPONSE_FORMAT_R1
#define FS_MMC_RESPONSE_FORMAT_R7       FS_MMC_RESPONSE_FORMAT_R1
```

Symbols

Definition	Description
FS_MMC_RESPONSE_FORMAT_NONE	No response expected.
FS_MMC_RESPONSE_FORMAT_R1	Card status (48-bit large)
FS_MMC_RESPONSE_FORMAT_R2	CID or CSD register (128-bit large)
FS_MMC_RESPONSE_FORMAT_R3	OCR register (48-bit large)
FS_MMC_RESPONSE_FORMAT_R6	Published RCA response (48-bit large)
FS_MMC_RESPONSE_FORMAT_R7	Card interface condition (48-bit large)

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6.5.4.3.31 Sample implementation

The following sample implementation uses the SD host controller of an NXP K66 MCU to interface with an SD card. This MMC hardware layer was tested on the SEGGER emPower board (https://www.segger.com/evaluate-our-software/segger/empower/)

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_MMC_HW_CM_K66_SEGGER_emPower.c
Purpose : SD/MMC (card mode) hardware layer for Freescale Kinetis K66
Literature:
  [1] UM06001 emPower Evaluation and prototyping platform for SEGGER software User Guide & Reference
 Manual
  [2] K66P144M180SF5RMV2 K66 Sub-Family Reference Manual
  [3] SD Specifications Part 1 Physical Layer Simplified Specification Version 2.00
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_MMC_HW_CM_USE_DMA
  #define FS_MMC_HW_CM_USE_DMA              1           // Turns the DMA support on and off
#endif

#ifndef   FS_MMC_HW_CM_PERIPH_CLOCK
  #define FS_MMC_HW_CM_PERIPH_CLOCK         168000000uL // Peripheral clock speed in Hz
#endif

#ifndef   FS_MMC_HW_CM_MAX_SPEED
  #define FS_MMC_HW_CM_MAX_SPEED            50000
  // Limits the maximum communication speed to this value (kHz)
#endif

#ifndef   FS_MMC_HW_CM_NUM_DMA_DESC
  #define FS_MMC_HW_CM_NUM_DMA_DESC         32          // Number of DMA descriptors to allocate
#endif

#ifndef   FS_MMC_HW_CM_POWER_GOOD_DELAY
  #define FS_MMC_HW_CM_POWER_GOOD_DELAY     1000
  // Number of milliseconds to wait for the power to stabilize.
#endif

#ifndef   FS_MMC_HW_CM_USE_OS
  #define FS_MMC_HW_CM_USE_OS               0
  // Enables / disables the event-driven operation.
                                                        //   0 - OS support disabled.
                                                        //   1
 - OS support enabled using OS event of emFile.
                                                        //   2
 - OS support enabled using OS events of this HW layer.
#endif

/*********************************************************************
*
*       #include section, conditional
*
**********************************************************************
*/
```

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```
#if FS_MMC_HW_CM_USE_OS
  #include "FS_OS.h"
  #include "RTOS.h"
  #include "MK66F18.h"
#endif // FS_MMC_HW_CM_USE_OS

/*********************************************************************
*
*       Defines, fixed
*
**********************************************************************
*/

#if (FS_MMC_HW_CM_USE_OS == 0)

/*********************************************************************
*
*       System integration module
*/
#define SIM_BASE_ADDR             0x40047000
#define SIM_SCGC3                 (*(volatile U32*)(SIM_BASE_ADDR + 0x1030))
  // System Clock Gating Control Register 3
#define SIM_SCGC5                 (*(volatile U32*)(SIM_BASE_ADDR + 0x1038))
  // System Clock Gating Control Register 5

/*********************************************************************
*
*       PORT E
*/
#define PORTE_BASE_ADDR           0x4004D000
#define PORTE_PCR0                (*(volatile U32*)(PORTE_BASE_ADDR + 0x00))
  // Pin control register 0
#define PORTE_PCR1                (*(volatile U32*)(PORTE_BASE_ADDR + 0x04))
  // Pin control register 1
#define PORTE_PCR2                (*(volatile U32*)(PORTE_BASE_ADDR + 0x08))
  // Pin control register 2
#define PORTE_PCR3                (*(volatile U32*)(PORTE_BASE_ADDR + 0x0C))
  // Pin control register 3
#define PORTE_PCR4                (*(volatile U32*)(PORTE_BASE_ADDR + 0x10))
  // Pin control register 4
#define PORTE_PCR5                (*(volatile U32*)(PORTE_BASE_ADDR + 0x14))
  // Pin control register 5
#define PORTE_PCR6                (*(volatile U32*)(PORTE_BASE_ADDR + 0x18))
  // Pin control register 5
#define PORTE_PCR27               (*(volatile U32*)(PORTE_BASE_ADDR + 0x6C))
  // Pin control register 27
#define PORTE_DFER                (*(volatile U32*)(PORTE_BASE_ADDR + 0xC0))
  // Digital filter enable register

/*********************************************************************
*
*       GPIO E
*/
#define GPIOE_BASE                0x400FF000
#define GPIOE_PDOR                (*(volatile U32*)(GPIOE_BASE + 0x100))
  // Port Data Output Register
#define GPIOE_PDIR                (*(volatile U32*)(GPIOE_BASE + 0x110))
  // Port Data Input Register
#define GPIOE_PDDR                (*(volatile U32*)(GPIOE_BASE + 0x114))
  // Port Data Direction Register

/*********************************************************************
*
*       SDHC
*/
#define SDHC_BASE                 0x400B1000
#define SDHC_BLKATTR              (*(volatile U32*)(SDHC_BASE + 0x04))
  // Block Attributes Register
#define SDHC_CMDARG               (*(volatile U32*)(SDHC_BASE + 0x08))
  // Command Argument Register
#define SDHC_XFERTYP              (*(volatile U32*)(SDHC_BASE + 0x0C))   // Transfer Type Register
#define SDHC_CMDRSP0              (*(volatile U32*)(SDHC_BASE + 0x10))   // Command Response 0
#define SDHC_DATPORT              (*(volatile U32*)(SDHC_BASE + 0x20))
  // Buffer Data Port Register
#define SDHC_PRSSTAT              (*(volatile U32*)(SDHC_BASE + 0x24))   // Present State Register
```

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```
#define SDHC_PROCTL               (*(volatile U32*)(SDHC_BASE + 0x28))
  // Protocol Control Register
#define SDHC_SYSCTL               (*(volatile U32*)(SDHC_BASE + 0x2C))   // System Control Register
#define SDHC_IRQSTAT              (*(volatile U32*)(SDHC_BASE + 0x30))
  // Interrupt Status Register
#define SDHC_IRQSTATEN            (*(volatile U32*)(SDHC_BASE + 0x34))
  // Interrupt Status Enable Register
#define SDHC_IRQSIGEN             (*(volatile U32*)(SDHC_BASE + 0x38))
  // Interrupt Signal Enable Register
#define SDHC_WML                  (*(volatile U32*)(SDHC_BASE + 0x44))   // Watermark Level Register
#define SDHC_ADSADDR              (*(volatile U32*)(SDHC_BASE + 0x58))
  // ADMA System Address Register
#define SDHC_VENDOR               (*(volatile U32*)(SDHC_BASE + 0xC0))   // Vendor Specific Register

/*********************************************************************
*
*       MPU
*/
#define MPU_BASE                  0x4000D000
#define MPU_RGDAAC0               (*(volatile U32*)(MPU_BASE + 0x800))
  // Region Descriptor Alternate Access Control 0

#else

/*********************************************************************
*
*       Port E
*/
#define PORTE_BASE_ADDR           0x4004D000uL
#define PORTE_DFER                (*(volatile U32 *)(PORTE_BASE_ADDR + 0xC0))
  // Digital filter enable register

#endif // (FS_MMC_HW_CM_USE_OS == 0)

/*********************************************************************
*
*       Pin assignments of signals
*/
#define SD_CMD_BIT                3   // Command         (GPIO E)
#define SD_CLK_BIT                2   // Clock           (GPIO E)
#define SD_D0_BIT                 1   // Data 0          (GPIO E)
#define SD_D1_BIT                 0   // Data 1          (GPIO E)
#define SD_D2_BIT                 5   // Data 2          (GPIO E)
#define SD_D3_BIT                 4   // Data 3          (GPIO E)
#define SD_CD_BIT                 6   // Card detect     (GPIO E)

/*********************************************************************
*
*       Port control register bits
*/
#define PCR_MUX_BIT               8   // Alternate port setting
#define PCR_MUX_GPIO              1   // Controlled directly by the HW layer
#define PCR_MUX_SDHC              4   // Controlled by SDHC
#define PCR_DSE_BIT               6   // Driver strength enable
#define PCR_PE_BIT                1   // Pull enable
#define PCR_PS_BIT                0   // Pull-up enable

/*********************************************************************
*
*       Clock enable bits
*/
#define SCGC3_SDHC_BIT            17    // SDHC
#define SCGC5_PORTE_BIT           13    // GPIO E

/*********************************************************************
*
*       SDHC interrupt request bits
*/
#define IRQSTAT_CC_BIT            0   // Command complete
#define IRQSTAT_TC_BIT            1   // Transfer complete
#define IRQSTAT_DINT_BIT          3   // DMA interrupt
#define IRQSTAT_BWR_BIT           4   // Buffer write ready
#define IRQSTAT_BRR_BIT           5   // Buffer read ready
#define IRQSTAT_CTOE_BIT          16  // Command timeout error
#define IRQSTAT_CCE_BIT           17  // Command CRC error
#define IRQSTAT_CEBE_BIT          18  // Command end bit error
```

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```
#define IRQSTAT_CIE_BIT           19  // Command index error
#define IRQSTAT_DTOE_BIT          20  // Data timeout error
#define IRQSTAT_DCE_BIT           21  // Data CRC error
#define IRQSTAT_DEBE_BIT          22  // Data end bit error
#define IRQSTAT_DMAE_BIT          28  // DMA error

/*********************************************************************
*
*       SDHC present status bits
*/
#define PRSSTAT_CIHB_BIT          0   // Command inhibit (CMD)
#define PRSSTAT_CDIHB_BIT         1   // Command inhibit (DAT)
#define PRSSTAT_SDSTB_BIT         3   // Set to 1 if the clock is stable
#define PRSSTAT_SDOFF_BIT         7
#define PRSSTAT_BWEN_BIT          10
#define PRSSTAT_DLSL_DAT0_BIT     24

/*********************************************************************
*
*       SDHC system control bits
*/
#define SYSCTL_IPGEN_BIT          0
#define SYSCTL_HCKEN_BIT          1
#define SYSCTL_PEREN_BIT          2
#define SYSCTL_SDCLKEN_BIT        3
#define SYSCTL_DVS_BIT            4
#define SYSCTL_DVS_MASK           0xFuL
#define SYSCTL_DVS_MAX            (SYSCTL_DVS_MASK + 1)
#define SYSCTL_SDCLKFS_BIT        8
#define SYSCTL_SDCLKFS_MASK       0xFFuL
#define SYSCTL_DTOCV_BIT          16
#define SYSCTL_DTOCV_MASK         0xFuL
#define SYSCTL_DTOCV_MAX          (SYSCTL_DTOCV_MASK - 1)
#define SYSCTL_RSTA_BIT           24
#define SYSCTL_RSTC_BIT           25
#define SYSCTL_RSTD_BIT           26
#define SYSCTL_INITA_BIT          27

/*********************************************************************
*
*       SDHC transfer type bits
*/
#define XFERTYP_DMAEN_BIT         0     // DMA enable
#define XFERTYP_BCEN_BIT          1
#define XFERTYP_DTDSEL_BIT        4
#define XFERTYP_MSBSEL_BIT        5
#define XFERTYP_RSPTYP_BIT        16
#define XFERTYP_RSPTYP_NONE       0uL
#define XFERTYP_RSPTYP_136BIT     1uL
#define XFERTYP_RSPTYP_48BIT      2uL
#define XFERTYP_RSPTYP_48BIT_BUSY 3uL
#define XFERTYP_CCCEN_BIT         19
#define XFERTYP_CICEN_BIT         20
#define XFERTYP_DPSEL_BIT         21
#define XFERTYP_CMDIDX_BIT        24
#define XFERTYP_CMDIDX_MASK       0x3FuL

/*********************************************************************
*
*       SDHC protocol control bits
*/
#define PROCTL_DTW_BIT            1
#define PROCTL_DTW_MASK           0x3uL
#define PROCTL_DTW_4BIT           0x1uL
#define PROCTL_EMODE_BIT          4
#define PROCTL_EMODE_LE           2uL
#define PROCTL_DMAS_BIT           8
#define PROCTL_DMAS_MASK          0x3uL
#define PROCTL_DMAS_DMA2          2uL

/*********************************************************************
*
*       SDHC block attributes bits
*/
#define BLKATTR_BLKCNT_BIT        16
```

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```
/*********************************************************************
*
*       SDHC Watermark level
*/
#define WML_RDWML_BIT             0
#define WML_RDWML_MASK            0xFFuL
#define WML_WRWML_BIT             16
#define WML_WRWML_MASK            0xFFuL

/*********************************************************************
*
*       DMA attributes
*/
#define DMA_ATTR_VALID_BIT        0
#define DMA_ATTR_END_BIT          1
#define DMA_ATTR_INT_BIT          2
#define DMA_ATTR_ACT_BIT          4
#define DMA_ATTR_ACT_TRAN         2uL

/*********************************************************************
*
*       MPU region descriptor bits
*/
#define RGD_M5RE_BIT              27
#define RGD_M5WE_BIT              26

/*********************************************************************
*
*       Number of sectors to transfer at once
*/
#define MAX_BLOCK_SIZE            512
#define MAX_DMA_LEN               65532

#if FS_MMC_HW_CM_USE_DMA
  #define NUM_BLOCKS_AT_ONCE      ((FS_MMC_HW_CM_NUM_DMA_DESC * MAX_DMA_LEN) / MAX_BLOCK_SIZE)
#else
  #define NUM_BLOCKS_AT_ONCE      65535
#endif // FS_MMC_HW_CM_USE_DMA

#if FS_MMC_HW_CM_USE_DMA
  #define NUM_BLOCKS_AT_ONCE_REPEAT_SAME      FS_MMC_HW_CM_NUM_DMA_DESC
#else
  #define NUM_BLOCKS_AT_ONCE_REPEAT_SAME      65535
#endif

/*********************************************************************
*
*       Timeouts and delays
*/
#define CYCLES_PER_MS             2100
#define WAIT_TIMEOUT_MS           1000
#define WAIT_TIMEOUT_CYCLES       (WAIT_TIMEOUT_MS * CYCLES_PER_MS)
#define SDHC_IRQ_PRIO             15
#if FS_MMC_HW_CM_USE_DMA
  #define STAT_MASK               ((1uL << IRQSTAT_CC_BIT)   | \
                                   (1uL << IRQSTAT_TC_BIT)   | \
                                   (1uL << IRQSTAT_CTOE_BIT) | \
                                   (1uL << IRQSTAT_CCE_BIT)  | \
                                   (1uL << IRQSTAT_CEBE_BIT) | \
                                   (1uL << IRQSTAT_CIE_BIT)  | \
                                   (1uL << IRQSTAT_DTOE_BIT) | \
                                   (1uL << IRQSTAT_DCE_BIT)  | \
                                   (1uL << IRQSTAT_DEBE_BIT) | \
                                   (1uL << IRQSTAT_DINT_BIT))
#else
  #define STAT_MASK               ((1uL << IRQSTAT_CC_BIT)   | \
                                   (1uL << IRQSTAT_TC_BIT)   | \
                                   (1uL << IRQSTAT_BWR_BIT)  | \
                                   (1uL << IRQSTAT_BRR_BIT)  | \
                                   (1uL << IRQSTAT_CTOE_BIT) | \
                                   (1uL << IRQSTAT_CCE_BIT)  | \
                                   (1uL << IRQSTAT_CEBE_BIT) | \
                                   (1uL << IRQSTAT_CIE_BIT)  | \
                                   (1uL << IRQSTAT_DTOE_BIT) | \
                                   (1uL << IRQSTAT_DCE_BIT)  | \
                                   (1uL << IRQSTAT_DEBE_BIT))
```

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```
#endif

/*********************************************************************
*
*       Local data types
*
**********************************************************************
*/

#if FS_MMC_HW_CM_USE_DMA

/*********************************************************************
*
*       DMA_DESC
*
*  Description
*    Memory layout of a ADMA2 descriptor
*/
typedef struct {
  U16 Attr;       // Descriptor attributes
  U16 NumBytes;   // Number of bytes to transfer
  U32 Addr;       // Destination/source memory address (32-bit aligned)
} DMA_DESC;

#endif

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static U16          _BlockSize;   // Size of the block to transfer as set by the upper layer
static U16          _NumBlocks;   // Number of blocks to transfer as set by the upper layer
static U8           _RepeatSame;  // Set to
 1 if the same data has to be written to consecutive block indexes.
#if FS_MMC_HW_CM_USE_DMA
  static DMA_DESC   _aDMADesc[FS_MMC_HW_CM_NUM_DMA_DESC];    // List of DMA descriptors
  static void     * _pData;                     // Destination/source buffer for the DMA transfers
#endif // FS_MMC_HW_CM_USE_DMA
#if (FS_MMC_HW_CM_USE_OS == 2)
  static U8         _IsEventInited = 0;
  static OS_EVENT   _Event;
#endif // FS_MMC_HW_CM_USE_OS == 2

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

#if FS_MMC_HW_CM_USE_OS

/*********************************************************************
*
*       _WaitForEvent
*
*  Function description
*    Waits for the interrupt to wake up the task.
*
*  Parameters
*    TimeOut      Maximum time to wait for the event in milliseconds.
*
*  Return values
*    ==0      OK, event signaled.
*    !=0      An error occurred.
*/
static int _WaitForEvent(U32 TimeOut) {
  int r;

  SDHC_IRQSIGEN |= STAT_MASK;             // Enable interrupts.
#if (FS_MMC_HW_CM_USE_OS == 2)
  r = OS_EVENT_WaitTimed(&_Event, TimeOut);
#else
  r = FS_OS_Wait(TimeOut);
```

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```
#endif
  if (r != 0) {
    SDHC_IRQSIGEN &= ~STAT_MASK;          // Disable interrupts.
  }
  return r;
}

#endif // FS_MMC_HW_CM_USE_OS

/*********************************************************************
*
*       _WaitForResponse
*
*  Function description
*    Waits for a command response to arrive.
*
*  Return values
*    FS_MMC_CARD_NO_ERROR                Success
*    FS_MMC_CARD_RESPONSE_CRC_ERROR      CRC error in response
*    FS_MMC_CARD_RESPONSE_TIMEOUT        No response received
*    FS_MMC_CARD_RESPONSE_GENERIC_ERROR  Any other error
*/
static int _WaitForResponse(void) {
  U32 Status;
  U32 TimeOut;
  int r;

  //
  // Wait for command to finish
  //
  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_IRQSTAT;
    if ((Status & (1uL << IRQSTAT_CTOE_BIT)) != 0u) {
      r = FS_MMC_CARD_RESPONSE_TIMEOUT;           // Error, no response received.
      break;
    }
    if ((Status & (1uL << IRQSTAT_CCE_BIT)) != 0u) {
      r = FS_MMC_CARD_RESPONSE_CRC_ERROR;         // Error, CRC error detected in response.
      break;
    }
    if ((Status & (1uL << IRQSTAT_CEBE_BIT)) != 0u) {
      r = FS_MMC_CARD_RESPONSE_GENERIC_ERROR;     // Error, end bit of response is 0.
      break;
    }
    if ((Status & (1uL << IRQSTAT_CIE_BIT)) != 0u) {
      r = FS_MMC_CARD_RESPONSE_GENERIC_ERROR;     // Error, command index do not match.
      break;
    }
#if FS_MMC_HW_CM_USE_DMA
    if ((Status & (1uL << IRQSTAT_DMAE_BIT)) != 0u) {
      r = FS_MMC_CARD_RESPONSE_GENERIC_ERROR;     // Error, DMA failure.
      break;
    }
#endif // FS_MMC_HW_CM_USE_DMA
    if ((Status & (1uL << IRQSTAT_CC_BIT)) != 0u) {
      r = FS_MMC_CARD_NO_ERROR;                   // OK, valid response received.
      break;
    }
#if FS_MMC_HW_CM_USE_OS
    r = _WaitForEvent(WAIT_TIMEOUT_MS);
    if (r != 0) {
      r = FS_MMC_CARD_RESPONSE_TIMEOUT;           // Error, no response received.
      break;
    }
#endif // FS_MMC_HW_CM_USE_OS
    if (TimeOut-- == 0u) {
      r = FS_MMC_CARD_RESPONSE_TIMEOUT;           // Error, no response received.
      break;
    }
  }
  return r;
}

#if (FS_MMC_HW_CM_USE_DMA == 0)
```

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```
/*********************************************************************
*
*       _WaitForRxReady
*
*  Function description
*    Waits until new data is received. The function returns in case of a receiving error.
*
*  Return values
*    FS_MMC_CARD_NO_ERROR               Success
*    FS_MMC_CARD_READ_CRC_ERROR         CRC error in received data
*    FS_MMC_CARD_READ_TIMEOUT           No data received
*    FS_MMC_CARD_READ_GENERIC_ERROR     Any other error
*
*  Additional information
*/
static int _WaitForRxReady(void) {
  U32 Status;
  U32 TimeOut;
  int r;

  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_IRQSTAT;
    if ((Status & (1uL << IRQSTAT_DEBE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_GENERIC_ERROR;         // Error, 0 detected on the end bit.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DCE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_CRC_ERROR;             // Error, CRC check failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DTOE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_TIMEOUT;               // Error, data timeout.
      break;
    }
    if ((Status & (1uL << IRQSTAT_BRR_BIT)) != 0u) {
      r = FS_MMC_CARD_NO_ERROR;                   // OK, data can be read from queue.
      break;
    }
#if FS_MMC_HW_CM_USE_OS
    r = _WaitForEvent(WAIT_TIMEOUT_MS);
    if (r != 0) {
      r = FS_MMC_CARD_RESPONSE_TIMEOUT;           // Error, no response received.
      break;
    }
#endif // FS_MMC_HW_CM_USE_OS
    if (TimeOut-- == 0u) {
      r = FS_MMC_CARD_READ_TIMEOUT;               // Error, data timeout.
      break;
    }
  }
  return r;
}

/*********************************************************************
*
*       _WaitForTxReady
*
*   Function description
*     Waits until the transmitter is ready to send new data.
*     The function returns in case of an underrun condition.
*     This can happen when we are not able to deliver the data fast enough.
*
*   Return values
*     FS_MMC_CARD_NO_ERROR              Success
*     FS_MMC_CARD_WRITE_GENERIC_ERROR   Any other error
*/
static int _WaitForTxReady(void) {
  U32 Status;
  U32 TimeOut;
  int r;

  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_IRQSTAT;
    if ((Status & (1uL << IRQSTAT_DTOE_BIT)) != 0u) {
```

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```
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, data timeout.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DCE_BIT)) != 0u) {
      r = FS_MMC_CARD_WRITE_CRC_ERROR;            // Error, CRC check failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_BWR_BIT)) != 0u) {
      r = FS_MMC_CARD_NO_ERROR;                   // OK, data can be written to queue.
      break;
    }
#if FS_MMC_HW_CM_USE_OS
    r = _WaitForEvent(WAIT_TIMEOUT_MS);
    if (r != 0) {
      r = FS_MMC_CARD_RESPONSE_TIMEOUT;           // Error, no response received.
      break;
    }
#endif // FS_MMC_HW_CM_USE_OS
    if (TimeOut-- == 0u) {
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, data timeout.
      break;
    }
  }
  return r;
}
#endif // FS_MMC_HW_CM_USE_DMA == 0

/*********************************************************************
*
*       _WaitForCmdReady
*
*  Function description
*    Waits for the last command to finish.
*/
static void _WaitForCmdReady(void) {
  U32 Status;
  U32 TimeOut;

  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_PRSSTAT;
    if ((Status & (1uL << PRSSTAT_CIHB_BIT)) == 0u) {
      if ((Status & (1uL << PRSSTAT_CDIHB_BIT)) == 0u) {
        if ((Status & (1uL << PRSSTAT_DLSL_DAT0_BIT)) != 0u) {
          break;
        }
      }
    }
    if (TimeOut-- == 0u) {
      break;
    }
  }
}

/*********************************************************************
*
*       _Delay1ms
*
*  Function description
*    Busy loops for about 1 millisecond.
*/
static void _Delay1ms(void) {
  volatile int i;

  for (i = 0; i < CYCLES_PER_MS; ++i) {
    ;
  }
}

/*********************************************************************
*
*       _Reset
*
*   Function description
*     Resets the command and data state machines. Typ. called in case of an error.
*/
```

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```
static void _Reset(void) {
  //
  // Reset command path.
  //
  SDHC_SYSCTL |=   1uL << SYSCTL_RSTC_BIT;
  SDHC_SYSCTL &= ~(1uL << SYSCTL_RSTC_BIT);
  //
  // Reset data path.
  //
  SDHC_SYSCTL |=   1uL << SYSCTL_RSTD_BIT;
  SDHC_SYSCTL &= ~(1uL << SYSCTL_RSTD_BIT);
}

/*********************************************************************
*
*       _SetWMLRead
*
*   Function description
*     Sets the watermark level for read operations.
*/
static void _SetWMLRead(U32 NumBytes) {
  U32 NumWords;

  NumWords  = NumBytes >> 2;
  NumWords /= 3;
  if (NumWords == 0) {
    NumWords = 1;
  }
  if (NumWords > WML_RDWML_MASK) {
    NumWords = WML_RDWML_MASK;
  }
  SDHC_WML &= ~(WML_RDWML_MASK << WML_RDWML_BIT);
  SDHC_WML |= NumWords << WML_RDWML_BIT;
}

/*********************************************************************
*
*       _SetWMLlWrite
*
*   Function description
*     Sets the watermark level for write operations.
*/
static void _SetWMLWrite(U32 NumBytes) {
  U32 NumWords;

  NumWords  = NumBytes >> 2;
  NumWords  = (NumWords << 1) / 3;
  if (NumWords == 0) {
    NumWords = 1;
  }
  if (NumWords > WML_WRWML_MASK) {
    NumWords = WML_WRWML_MASK;
  }
  SDHC_WML &= ~(WML_WRWML_MASK << WML_WRWML_BIT);
  SDHC_WML |= NumWords << WML_WRWML_BIT;
}

#if (FS_MMC_HW_CM_USE_DMA == 0)

/*********************************************************************
*
*       _GetWMLRead
*/
static U32 _GetWMLRead(void) {
  U32 NumWords;

  NumWords = (SDHC_WML >> WML_RDWML_BIT) & WML_RDWML_MASK;
  return NumWords;
}

/*********************************************************************
*
*       _GetWMLWrite
*/
static U32 _GetWMLWrite(void) {
  U32 NumWords;
```

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```
  NumWords = (SDHC_WML >> WML_WRWML_BIT) & WML_WRWML_MASK;
  return NumWords;
}

#endif // FS_MMC_HW_CM_USE_DMA == 0

#if FS_MMC_HW_CM_USE_DMA

/*********************************************************************
*
*       _StartDMATransfer
*
*  Function description
*    Starts a DMA data transfer.
*/
static void _StartDMATransfer(void) {
  U32        NumBytes;
  DMA_DESC * pDesc;
  int        i;
  U8       * pAddr;
  U32        NumBytesAtOnce;

  pDesc    = _aDMADesc;
  pAddr    = (U8 *)_pData;
  NumBytes = _NumBlocks * _BlockSize;
  for (i = 0; i < FS_MMC_HW_CM_NUM_DMA_DESC; ++i) {
    if (_RepeatSame == 0) {
      NumBytesAtOnce = SEGGER_MIN(NumBytes, MAX_DMA_LEN);
    } else {
      NumBytesAtOnce = SEGGER_MIN(NumBytes, MAX_BLOCK_SIZE);
    }
    pDesc->Addr      = (U32)pAddr;
    pDesc->NumBytes  = NumBytesAtOnce;
    pDesc->Attr      = (DMA_ATTR_ACT_TRAN << DMA_ATTR_ACT_BIT)
                     | (1uL               << DMA_ATTR_VALID_BIT)
                     ;
    if (_RepeatSame == 0) {
      pAddr         += NumBytesAtOnce;
    }
    NumBytes        -= NumBytesAtOnce;
    if (NumBytes == 0) {
      pDesc->Attr   |= (1uL << DMA_ATTR_INT_BIT)
  // Set the DMA interrupt flag at the end of transfer.
                     |  (1uL << DMA_ATTR_END_BIT)
                     ;
      break;
    }
    ++pDesc;
  }
  SDHC_ADSADDR  = (U32)_aDMADesc;
  SDHC_PROCTL  &= ~(PROCTL_DMAS_MASK << PROCTL_DMAS_BIT);
  SDHC_PROCTL  |=  (PROCTL_DMAS_DMA2 << PROCTL_DMAS_BIT);
}

/*********************************************************************
*
*       _WaitForEndOfDMARead
*
*  Function description
*    Waits for the end of a DMA read transfer.
*
*  Return value
*    ==0    OK, data transferred successfully.
*    !=0    An error occurred.
*/
static int _WaitForEndOfDMARead(void) {
  U32 Status;
  U32 TimeOut;
  int r;

  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_IRQSTAT;
    if ((Status & (1uL << IRQSTAT_DTOE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_TIMEOUT;               // Error, data timeout.
```

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```
      break;
    }
    if ((Status & (1uL << IRQSTAT_DCE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_CRC_ERROR;             // Error, CRC check failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DMAE_BIT)) != 0u) {
      r = FS_MMC_CARD_READ_GENERIC_ERROR;         // Error, DMA transfer failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DINT_BIT)) != 0u) {
      r = FS_MMC_CARD_NO_ERROR;                   // OK, DMA transfer complete.
      break;
    }
#if FS_MMC_HW_CM_USE_OS
    r = _WaitForEvent(WAIT_TIMEOUT_MS);
    if (r != 0) {
      r = FS_MMC_CARD_READ_TIMEOUT;               // Error, no response received.
      break;
    }
#endif // FS_MMC_HW_CM_USE_OS
    if (TimeOut-- == 0u) {
      r = FS_MMC_CARD_READ_TIMEOUT;               // Error, data timeout.
      break;
    }
  }
  return r;
}

/*********************************************************************
*
*       _WaitForEndOfDMAWrite
*
*  Function description
*    Waits for the end of a DMA write transfer.
*
*  Return value
*    ==0    OK, data transferred successfully.
*    !=0    An error occurred.
*/
static int _WaitForEndOfDMAWrite(void) {
  U32 Status;
  U32 TimeOut;
  int r;

  TimeOut = WAIT_TIMEOUT_CYCLES;
  for (;;) {
    Status = SDHC_IRQSTAT;
    if ((Status & (1uL << IRQSTAT_DTOE_BIT)) != 0u) {
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, data timeout.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DCE_BIT)) != 0u) {
      r = FS_MMC_CARD_WRITE_CRC_ERROR;            // Error, CRC check failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DMAE_BIT)) != 0u) {
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, DMA transfer failed.
      break;
    }
    if ((Status & (1uL << IRQSTAT_DINT_BIT)) != 0u) {
      r = FS_MMC_CARD_NO_ERROR;                   // OK, DMA transfer complete.
      break;
    }
#if FS_MMC_HW_CM_USE_OS
    r = _WaitForEvent(WAIT_TIMEOUT_MS);
    if (r != 0) {
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, no response received.
      break;
    }
#endif // FS_MMC_HW_CM_USE_OS
    if (TimeOut-- == 0u) {
      r = FS_MMC_CARD_WRITE_GENERIC_ERROR;        // Error, data timeout.
      break;
    }
  }
```

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```
  return r;
}

#endif // FS_MMC_HW_CM_USE_DMA

/*********************************************************************
*
*       Public code (via callback)
*
**********************************************************************
*/

/*********************************************************************
*
*       _HW_Init
*
*  Function description
*    Initialize the SD / MMC host controller.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*/
static void _HW_Init(U8 Unit) {
  int i;

  FS_USE_PARA(Unit);
  //
  // Enable the clock of GPIOs and of SDHC
  //
  SIM_SCGC3 |= 1uL << SCGC3_SDHC_BIT;
  SIM_SCGC5 |= 1uL << SCGC5_PORTE_BIT;
  //
  // Clock line
  //
  PORTE_PCR2  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Command line
  //
  PORTE_PCR3  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Data 0 line
  //
  PORTE_PCR1  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Data 1 line
  //
  PORTE_PCR0  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Data 2 line
  //
  PORTE_PCR5  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Data 3 line
  //
  PORTE_PCR4  = (PCR_MUX_SDHC << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
```

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```
              | (1uL          << PCR_PS_BIT)
              | (1uL          << PCR_DSE_BIT)
              ;
  //
  // Write protect is controlled by the HW layer.
  //
  PORTE_PCR27 = (PCR_MUX_GPIO << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              ;
  //
  // Card detect is controlled by the HW layer
  //
  PORTE_PCR6  = (PCR_MUX_GPIO << PCR_MUX_BIT)
              | (1uL          << PCR_PE_BIT)
              | (1uL          << PCR_PS_BIT)
              ;
  //
  // Disable the digital filtering on all port pins assigned to SDHC.
  //
  PORTE_DFER &= ~((1uL << SD_CD_BIT)  |
                  (1uL << SD_CLK_BIT) |
                  (1uL << SD_CMD_BIT) |
                  (1uL << SD_D0_BIT)  |
                  (1uL << SD_D1_BIT)  |
                  (1uL << SD_D2_BIT)  |
                  (1uL << SD_D3_BIT));
#if FS_MMC_HW_CM_USE_DMA
  //
  // Give DMA access to system memory.
  //
  MPU_RGDAAC0 |= (1uL << RGD_M5RE_BIT)
              |  (1uL << RGD_M5WE_BIT)
              ;
#endif
#if FS_MMC_HW_CM_USE_OS
  //
  // Disable the interrupt and configure the priority.
  //
  NVIC_DisableIRQ(SDHC_IRQn);
  NVIC_SetPriority(SDHC_IRQn, SDHC_IRQ_PRIO);
#endif // FS_MMC_HW_CM_USE_OS
  //
  // Configure SDHC.
  //
  SDHC_SYSCTL   = 1uL << SYSCTL_RSTA_BIT;              // Reset peripheral.
  SDHC_SYSCTL   = 0;                                   // Start peripheral.
  SDHC_PROCTL   = PROCTL_EMODE_LE << PROCTL_EMODE_BIT; // Muti-byte data is little endian.
  SDHC_VENDOR   = 0;                                   // No external DMA requests.
  SDHC_IRQSIGEN = 0;                                   // Disable all the interrupts.
  //
  // Wait for the power to stabilize before the first access to SD card
  //
  for (i = 0; i < FS_MMC_HW_CM_POWER_GOOD_DELAY; ++i) {
    _Delay1ms();
  }
#if FS_MMC_HW_CM_USE_OS
  //
  // Create the OS event and enable the interrupt.
  //
#if (FS_MMC_HW_CM_USE_OS == 2)
  if (_IsEventInited == 0) {
    OS_EVENT_Create(&_Event);
    _IsEventInited = 1;
  }
#endif // FS_MMC_HW_CM_USE_OS == 2
  NVIC_EnableIRQ(SDHC_IRQn);
#endif // FS_MMC_HW_CM_USE_OS
}

/*********************************************************************
*
*       _HW_Delay
*
*  Function description
*    Blocks the execution for the specified time.
```

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```
*
*  Parameters
*    ms   Number of milliseconds to delay.
*/
static void _HW_Delay(int ms) {
  int i;

  for (i = 0; i < ms; ++i) {
    _Delay1ms();
  }
}

/*********************************************************************
*
*       _HW_IsPresent
*
*  Function description
*    Returns the state of the media. If you do not know the state, return
*    FS_MEDIA_STATE_UNKNOWN and the higher layer will try to figure out if
*    a media is present.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Return value
*    FS_MEDIA_STATE_UNKNOWN     The state of the media is unknown
*    FS_MEDIA_NOT_PRESENT       No card is present
*    FS_MEDIA_IS_PRESENT        A card is present
*/
static int _HW_IsPresent(U8 Unit) {
  int r;

  FS_USE_PARA(Unit);
  r = (GPIOE_PDIR & (1uL << SD_CD_BIT)) ? FS_MEDIA_IS_PRESENT : FS_MEDIA_NOT_PRESENT;
  return r;
}

/*********************************************************************
*
*       _HW_IsWriteProtected
*
*  Function description
*    Returns whether card is write protected or not.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Notes
*    (1) The emPower V2 board does not have an WP detect pin.
*/
static int _HW_IsWriteProtected(U8 Unit) {
  FS_USE_PARA(Unit);
  return 0;           // Note 1
}

/*********************************************************************
*
*       _HW_SetMaxSpeed
*
*  Function description
*    Sets the frequency of the MMC/SD card controller.
*    The frequency is given in kHz.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Additional information
*    This function is called two times:
*    1. During card initialization
*       Initialize the frequency to not more than 400kHz.
*
*    2. After card initialization
*       The CSD register of card is read and the max frequency
*       the card can operate is determined.
*       [In most cases: MMC cards 20MHz, SD cards 25MHz]
*/
```

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```
static U16 _HW_SetMaxSpeed(U8 Unit, U16 Freq) {
  U32 Prescaler;
  U32 Divisor;
  U32 Factor;
  U32 SDClock;

  FS_USE_PARA(Unit);
  //
  // Limit the communication speed.
  //
  if (Freq > FS_MMC_HW_CM_MAX_SPEED) {
    Freq = FS_MMC_HW_CM_MAX_SPEED;
  }
  SDClock = Freq * 1000;              // Convert to Hz
  Factor  = (FS_MMC_HW_CM_PERIPH_CLOCK + SDClock - 1) / SDClock;
  //
  // Determine the prescaler and the divisor values.
  //
  if (Factor == 0) {
    Factor = 1;
  }
  if (Factor <= SYSCTL_DVS_MAX) {
    Prescaler  = 0;
    Divisor    = Factor - 1;
  } else {
    Prescaler = 1;
    while (1) {
      //
      // Compensate for integer division errors. We must generate a clock frequency <= Freq.
      //
      if (Factor & 1) {
        ++Factor;
      }
      Factor >>= 1;
      if (Factor <= SYSCTL_DVS_MAX) {
        Divisor = Factor - 1;
        break;
      }
      Prescaler <<= 1;
    }
  }
  //
  // Stop the clock to be able to change its frequency.
  //
  SDHC_SYSCTL &= ~(1uL << SYSCTL_SDCLKEN_BIT);
  //
  // Set the prescaler and the divisor.
  //
  SDHC_SYSCTL &= ~((SYSCTL_SDCLKFS_MASK << SYSCTL_SDCLKFS_BIT) |
                   (SYSCTL_DVS_MASK     << SYSCTL_DVS_BIT));
  SDHC_SYSCTL |= ((Prescaler & SYSCTL_SDCLKFS_MASK) << SYSCTL_SDCLKFS_BIT)
              |  ((Divisor & SYSCTL_DVS_MASK)       << SYSCTL_DVS_BIT)
              ;
  //
  // Enable the clock to SD card.
  //
  SDHC_SYSCTL |= (1uL << SYSCTL_SDCLKEN_BIT)
              |  (1uL << SYSCTL_PEREN_BIT)
              |  (1uL << SYSCTL_HCKEN_BIT)
              |  (1uL << SYSCTL_IPGEN_BIT)
              ;
  //
  // Wait for the clock to stabilize.
  //
  while ((SDHC_PRSSTAT & (1uL << PRSSTAT_SDSTB_BIT)) == 0) {
    ;
  }
  //
  // Return the actual clock frequency.
  //
  Factor = 1;
  if (Prescaler) {
    Factor *= Prescaler << 1;
  }
  Factor *= Divisor + 1;
  Freq = FS_MMC_HW_CM_PERIPH_CLOCK / 1000 / Factor;
```

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```
  return Freq;
}

/*********************************************************************
*
*       _HW_SetResponseTimeOut
*
*  Function description
*    Sets the response time out value given in MMC/SD card cycles.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Notes
*    (1) The SD host controller has only a short and a long timeout.
*        We always set the long timeout before we send a command.
*/
static void _HW_SetResponseTimeOut(U8 Unit, U32 Value) {
  FS_USE_PARA(Unit);
  FS_USE_PARA(Value);
  //
  // Note 1
  //
}

/*********************************************************************
*
*       _HW_SetReadDataTimeOut
*
*  Function description
*    Sets the read data time out value given in MMC/SD card cycles.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*/
static void _HW_SetReadDataTimeOut(U8 Unit, U32 Value) {
  FS_USE_PARA(Unit);

  if (Value > SYSCTL_DTOCV_MAX) {
    Value = SYSCTL_DTOCV_MAX;
  }
  SDHC_SYSCTL &= ~(SYSCTL_DTOCV_MASK << SYSCTL_DTOCV_BIT);
  SDHC_SYSCTL |= Value << SYSCTL_DTOCV_BIT;
}

/*********************************************************************
*
*       _HW_SendCmd
*
*  Function description
*    Sends a command to the card.
*
*  Parameters
*    Unit           Index of the SD / MMC host controller (0-based).
*    Cmd            Command number according to [4]
*    CmdFlags       Additional information about the command to execute
*    ResponseType   Type of response as defined in [4]
*    Arg            Command parameter
*/
static void _HW_SendCmd(U8 Unit, unsigned Cmd, unsigned CmdFlags, unsigned ResponseType, U32 Arg) {
  U32 RegValue;

  FS_USE_PARA(Unit);
  _WaitForCmdReady();
  _Reset();
  _RepeatSame = 0;
  if (CmdFlags & FS_MMC_CMD_FLAG_WRITE_BURST_REPEAT) {
    _RepeatSame = 1;
  }
  RegValue = (Cmd & XFERTYP_CMDIDX_MASK) << XFERTYP_CMDIDX_BIT;   // Set the command index.
  switch (ResponseType) {
  //
  // No response is expected
  //
  case FS_MMC_RESPONSE_FORMAT_NONE:
  default:
```

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```
    RegValue |= XFERTYP_RSPTYP_NONE << XFERTYP_RSPTYP_BIT;
    break;
  //
  // Short response is expected (48bit)
  //
  case FS_MMC_RESPONSE_FORMAT_R3:
    RegValue |= XFERTYP_RSPTYP_48BIT << XFERTYP_RSPTYP_BIT;
    break;

  case FS_MMC_RESPONSE_FORMAT_R1:
    if (CmdFlags & FS_MMC_CMD_FLAG_SETBUSY) {
      RegValue |= XFERTYP_RSPTYP_48BIT_BUSY << XFERTYP_RSPTYP_BIT;
    } else {
      RegValue |= XFERTYP_RSPTYP_48BIT      << XFERTYP_RSPTYP_BIT;
    }
    RegValue |= 0
             |  (1uL << XFERTYP_CICEN_BIT)      // Check the received command index.
             |  (1uL << XFERTYP_CCCEN_BIT)      // Check the CRC of response.
             ;
    break;
  //
  // Long response is expected (136bit)
  //
  case FS_MMC_RESPONSE_FORMAT_R2:
    RegValue |= (XFERTYP_RSPTYP_136BIT << XFERTYP_RSPTYP_BIT)
             |  (1uL                   << XFERTYP_CCCEN_BIT)    // Check the CRC of response.
             ;
    break;
  }
  //
  // If required, Setup the transfer over data lines.
  //
  if (CmdFlags & FS_MMC_CMD_FLAG_DATATRANSFER) {
    RegValue |= (1uL << XFERTYP_DPSEL_BIT)
             ;
    if (_NumBlocks > 1) {
      RegValue |= (1uL << XFERTYP_MSBSEL_BIT)
               |  (1uL << XFERTYP_BCEN_BIT)
               ;
    }
    if (CmdFlags & FS_MMC_CMD_FLAG_WRITETRANSFER) {
      _SetWMLWrite(_BlockSize);
    } else {
      _SetWMLRead(_BlockSize);
      RegValue |= (1uL << XFERTYP_DTDSEL_BIT);  // Read data from SD card.
    }
    //
    // Configure the size and the number of blocks to transfer
    //
    SDHC_BLKATTR = (_NumBlocks << BLKATTR_BLKCNT_BIT) | _BlockSize;
    //
    // Configure the number of data lines to use for the transfer.
    //
    SDHC_PROCTL &= ~(PROCTL_DTW_MASK << PROCTL_DTW_BIT);
    if (CmdFlags & FS_MMC_CMD_FLAG_USE_SD4MODE) {
      SDHC_PROCTL |= (PROCTL_DTW_4BIT << PROCTL_DTW_BIT);
    }
#if FS_MMC_HW_CM_USE_DMA
    RegValue |= (1uL << XFERTYP_DMAEN_BIT);
    _StartDMATransfer();
#endif // FS_MMC_HW_CM_USE_DMA
  }
  //
  // Enable all the status flags we handle.
  //
  SDHC_IRQSTATEN = STAT_MASK;
  //
  // This is the initialization delay defined by the SD card specification as:
  // maximum of 1 msec, 74 clock cycles and supply ramp up time.
  // The sequence below sends 80 clock cycles which is enough for
  // the power supply of SD card to raise to Vdd min.
  //
  if (CmdFlags & FS_MMC_CMD_FLAG_INITIALIZE) {
    SDHC_SYSCTL |= 1uL << SYSCTL_INITA_BIT;
    while (SDHC_SYSCTL & (1uL << SYSCTL_INITA_BIT)) {
      ;
```

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```
    }
  }
  SDHC_IRQSTAT = ~0uL;                      // Reset all status flags.
  SDHC_CMDARG  = Arg;
  SDHC_XFERTYP = RegValue;                  // Send the command.
}

/*********************************************************************
*
*       _HW_GetResponse
*
*  Function description
*    Receives the responses that was sent by the card after
*    a command was sent to the card.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*    pBuffer  User allocated buffer where the response is stored.
*    Size     Size of the buffer in bytes
*
*  Return values
*     FS_MMC_CARD_NO_ERROR               Success
*     FS_MMC_CARD_RESPONSE_CRC_ERROR     CRC error in response
*     FS_MMC_CARD_RESPONSE_TIMEOUT       No response received
*     FS_MMC_CARD_RESPONSE_GENERIC_ERROR  Any other error
*
*  Notes
*     (1) The response data has to  be stored at byte offset 1 since
*         the controller does not provide the first byte of response.
*/
static int _HW_GetResponse(U8 Unit, void * pBuffer, U32 Size) {
  U8           * pData;
  volatile U32 * pReg;
  U32            NumWords;
  U32            Value;
  U32            i;
  int            r;

  FS_USE_PARA(Unit);
  r = _WaitForResponse();
  if (r != FS_MMC_CARD_NO_ERROR) {
    _Reset();
    return r;                     // Error
  }
  //
  // The size we get from the upper driver is total response size in bytes.
  // We compute here the number of read accesses to the 32-bit register which
  // holds the response. Take into account that the first byte of the response
  // is not delivered by the hardware
  //
  NumWords = (Size - 1) / 4;
  pData    = (U8 *)pBuffer;
  pReg     = (volatile U32 *)&SDHC_CMDRSP0 + (NumWords - 1);
  //
  // In case of a 136 bit response SDHC does not deliver the checksum byte.
  // By not incrementing the data pointer the bytes are saved at expected positions.
  //
  if (NumWords != 4) {
    ++pData;                      // See note (1)
  }
  for (i = 0; i < NumWords; ++i) {
    Value = *pReg;
    *pData++ = (U8)(Value >> 24);
    *pData++ = (U8)(Value >> 16);
    *pData++ = (U8)(Value >> 8);
    *pData++ = (U8)Value;
    --pReg;
  }
  return FS_MMC_CARD_NO_ERROR;  // OK, valid command received.
}

/*********************************************************************
*
*       _HW_ReadData
*
*  Function description
```

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```
*    Reads data from the card using the SD / MMC host controller.
*
*  Return values
*    FS_MMC_CARD_NO_ERROR             Success
*    FS_MMC_CARD_READ_CRC_ERROR       CRC error in received data
*    FS_MMC_CARD_READ_TIMEOUT         No data received
*    FS_MMC_CARD_READ_GENERIC_ERROR   Any other error
*/
static int _HW_ReadData(U8 Unit, void * pBuffer, unsigned NumBytes, unsigned NumBlocks) {
#if FS_MMC_HW_CM_USE_DMA
  int r;

  FS_USE_PARA(Unit);
  FS_USE_PARA(pBuffer);
  FS_USE_PARA(NumBytes);
  FS_USE_PARA(NumBlocks);
  r = _WaitForEndOfDMARead();
  return r;
#else
  U32   NumWords;
  U32 * pData32;
  U32   NumWordsAtOnce;
  U32   WordsPerBlock;
  U32   WMLRead;
  int   r;

  FS_USE_PARA(Unit);
  pData32       = (U32 *)pBuffer;
  WordsPerBlock = NumBytes / 4;
  WMLRead       = _GetWMLRead();
  do {
    NumWords = WordsPerBlock;
    do {
      r = _WaitForRxReady();
      if (r != FS_MMC_CARD_NO_ERROR) {
        _Reset();
        return r;                               // Error
      }
      NumWordsAtOnce  = SEGGER_MIN(NumWords, WMLRead);
      NumWords       -= NumWordsAtOnce;
      do {
        *pData32++ = SDHC_DATPORT;
      } while (--NumWordsAtOnce);
      SDHC_IRQSTAT = 1uL << IRQSTAT_BRR_BIT;
  // This flag is only set by SDHC. We have to clear it here to get the next notification.
    } while (NumWords);
  } while (--NumBlocks);
  return FS_MMC_CARD_NO_ERROR;                  // OK, data received.
#endif
}

/*********************************************************************
*
*       _HW_WriteData
*
*  Function description
*    Writes the data to SD / MMC card using the SD / MMC host controller.
*
*  Return values
*    FS_MMC_CARD_NO_ERROR      Success
*    FS_MMC_CARD_READ_TIMEOUT  No data received
*/
static int _HW_WriteData(U8 Unit, const void * pBuffer, unsigned NumBytes, unsigned NumBlocks) {
#if FS_MMC_HW_CM_USE_DMA
  int r;

  FS_USE_PARA(Unit);
  FS_USE_PARA(pBuffer);
  FS_USE_PARA(NumBytes);
  FS_USE_PARA(NumBlocks);
  r = _WaitForEndOfDMAWrite();
  return r;
#else
  U32         NumWords;
  const U32 * pData32;
  int         r;
```

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```
  U32         NumWordsAtOnce;
  U32         WordsPerBlock;
  U32         WMLWrite;

  FS_USE_PARA(Unit);
  pData32       = (U32 *)pBuffer;
  WordsPerBlock = NumBytes / 4;
  WMLWrite      = _GetWMLWrite();
  do {
    NumWords = WordsPerBlock;
    if (_RepeatSame) {
      pData32 = (U32 *)pBuffer;
    }
    do {
      r = _WaitForTxReady();
      if (r != FS_MMC_CARD_NO_ERROR) {
        _Reset();
        return r;                               // Error
      }
      NumWordsAtOnce  = SEGGER_MIN(NumWords, WMLWrite);
      NumWords       -= NumWordsAtOnce;
      do {
        SDHC_DATPORT = *pData32++;
      } while (--NumWordsAtOnce);
      SDHC_IRQSTAT = 1uL << IRQSTAT_BWR_BIT;
  // This flag is only set by SDHC. We have to clear it here to get the next notification.
    } while (NumWords);
  } while (--NumBlocks);
  return FS_MMC_CARD_NO_ERROR;                  // OK, data sent.
#endif
}

/*********************************************************************
*
*       _HW_SetDataPointer
*
*  Function description
*    Tells the hardware layer where to read data from  or write data to.
*    Some SD host controllers require the address of the data buffer
*    before sending the command to the card, eg. programming the DMA.
*    In most cases this function can be left empty.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*    p        Data buffer.
*/
static void _HW_SetDataPointer(U8 Unit, const void * p) {
  FS_USE_PARA(Unit);
#if FS_MMC_HW_CM_USE_DMA
  _pData = (void *)p;     // Cast const away. The same buffer is used also for read operations.
#else
  FS_USE_PARA(p);
#endif
}

/*********************************************************************
*
*       _HW_SetBlockLen
*
*  Function description
*    Sets the block size (sector size) that has to be transferred.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*/
static void _HW_SetBlockLen(U8 Unit, U16 BlockSize) {
  FS_USE_PARA(Unit);
  _BlockSize = BlockSize;
}

/*********************************************************************
*
*       _HW_SetNumBlocks
*
*  Function description
*    Sets the number of blocks (sectors) to be transferred.
```

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```
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*/
static void _HW_SetNumBlocks(U8 Unit, U16 NumBlocks) {
  FS_USE_PARA(Unit);
  _NumBlocks = NumBlocks;
}

/*********************************************************************
*
*       _HW_GetMaxReadBurst
*
*  Function description
*    Returns the number of block (sectors) that can be read at once
*    with a single READ_MULTIPLE_SECTOR command.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Return value
*    Number of sectors that can be read at once.
*/
static U16 _HW_GetMaxReadBurst(U8 Unit) {
  FS_USE_PARA(Unit);
  return NUM_BLOCKS_AT_ONCE;
}

/*********************************************************************
*
*       _HW_GetMaxWriteBurst
*
*  Function description
*    Returns the number of block (sectors) that can be written at once
*    with a single WRITE_MULTIPLE_SECTOR command.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Return value
*    Number of sectors that can be written at once.
*/
static U16 _HW_GetMaxWriteBurst(U8 Unit) {
  FS_USE_PARA(Unit);
  return NUM_BLOCKS_AT_ONCE;
}

/*********************************************************************
*
*       _HW_GetMaxWriteBurstRepeat
*
*  Function description
*    Returns the number of block (sectors) that can be written at once
*    with a single WRITE_MULTIPLE_SECTOR command and that contain the
*    same data.
*
*  Parameters
*    Unit     Index of the SD / MMC host controller (0-based).
*
*  Return value
*    Number of sectors that can be written at once. The function has
*    to return 0 if the feature is not supported.
*/
static U16 _HW_GetMaxWriteBurstRepeat(U8 Unit) {
  FS_USE_PARA(Unit);
  return NUM_BLOCKS_AT_ONCE_REPEAT_SAME;
}

/*********************************************************************
*
*      Public code
*
**********************************************************************
*/

#if FS_MMC_HW_CM_USE_OS
```

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```
/*********************************************************************
*
*       SDHC_IRQHandler
*/
void SDHC_IRQHandler(void);
void SDHC_IRQHandler(void) {
  OS_EnterInterrupt();
  SDHC_IRQSIGEN &= ~STAT_MASK;              // Disable interrupts.
#if (FS_MMC_HW_CM_USE_OS == 2)
  OS_EVENT_Set(&_Event);
#else
  FS_OS_Signal();
#endif // FS_MMC_HW_CM_USE_OS == 2
  OS_LeaveInterrupt();
}

#endif // FS_MMC_HW_CM_USE_OS

/*********************************************************************
*
*       FS_MMC_HW_CM_K66_SEGGER_emPower
*/
const FS_MMC_HW_TYPE_CM FS_MMC_HW_CM_K66_SEGGER_emPower = {
  _HW_Init,
  _HW_Delay,
  _HW_IsPresent,
  _HW_IsWriteProtected,
  _HW_SetMaxSpeed,
  _HW_SetResponseTimeOut,
  _HW_SetReadDataTimeOut,
  _HW_SendCmd,
  _HW_GetResponse,
  _HW_ReadData,
  _HW_WriteData,
  _HW_SetDataPointer,
  _HW_SetBlockLen,
  _HW_SetNumBlocks,
  _HW_GetMaxReadBurst,
  _HW_GetMaxWriteBurst,
  _HW_GetMaxWriteBurstRepeat,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL,
  NULL
};

/************************** End of file ****************************/
```

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6.5.5 Troubleshooting

If the driver test fails or if the card cannot be accessed at all, please follow the troubleshooting guidelines below.

6.5.5.1 SPI mode troubleshooting guide

First, verify the SPI configuration. The SPI data transfer has to be configured as follows:

- 8 bits per transfer.
- Most significant bit first.
- Data changes on falling edge.
- Data is sampled on rising edge.

Then verify the waveform of the SPI signals using an oscilloscope. The following reference images were taken with an oscilloscope that was set up to trigger a single time on the falling edge of the Chip Select (CS) signal. The color coding of the signals in these pictures is as follows:

Color	Description
RED	MOSI - Master Out Slave In (Pin 2)
PURPLE	MISO - Master In Slave Out (Pin 7)
GREEN	CLK - Clock (Pin 5)
YELLOW	CS - Chip Select (Pin 1)

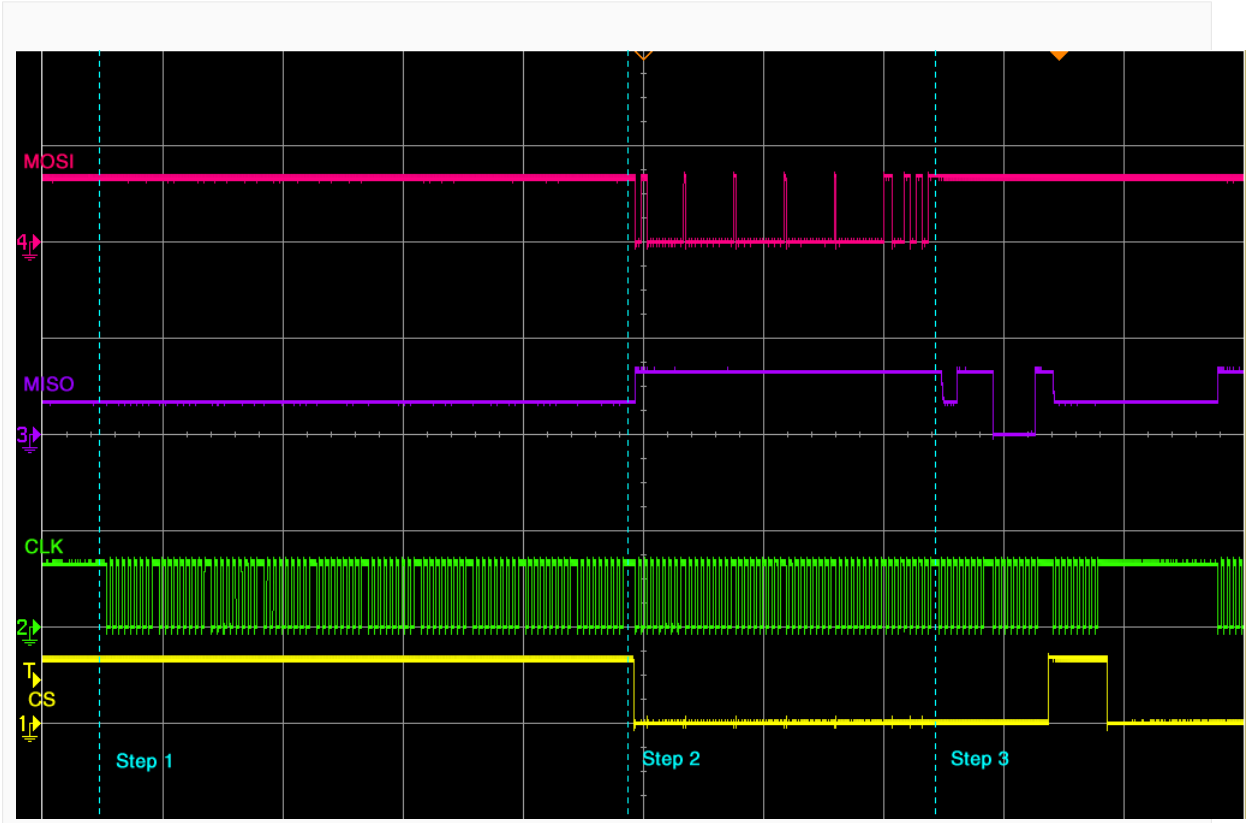
To check if your implementation of the hardware layer works correctly, compare your output of the relevant lines (SCLK, CS, MISO, MOSI) with the correct output which is shown in the following pictures. The output of your card should be similar. In the example, MISO has a pull-up and a pull-down of equal value. This means that the MISO signal level is at 50% (1.65V) when the output of the card is inactive. On other target hardware, the inactive level can be low (in case a pull-down is used) or high (if a pull-up is used).

The initial communication sequence consists of the following three parts:

1. Outputs 10 dummy bytes with CS disabled, MOSI = 1.
2. Sets CS low and sends a 6-byte command (`GO_IDLE_STATE` command).
3. Receives two bytes, sets CS high and outputs 1 dummy byte with CS disabled, MOSI = 1.

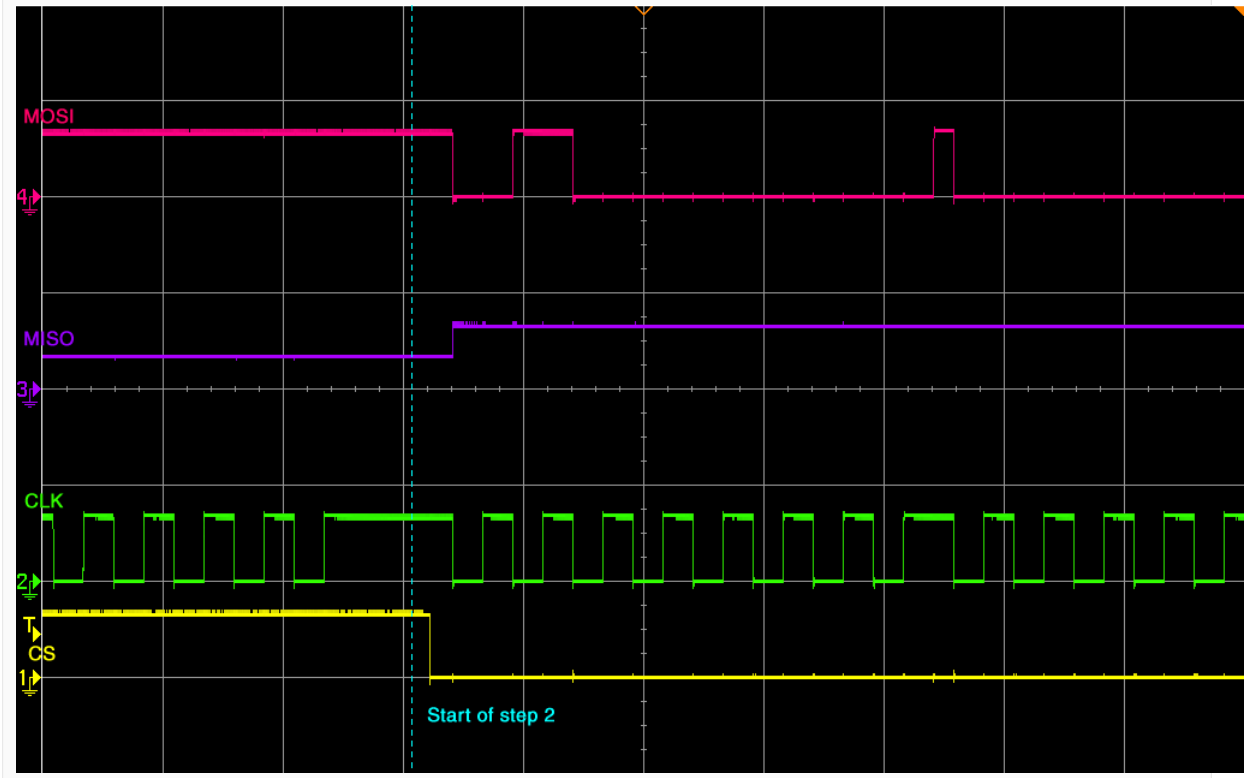
The following picture shows the data flow of a correct initialization of an SD card.

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Card initialization

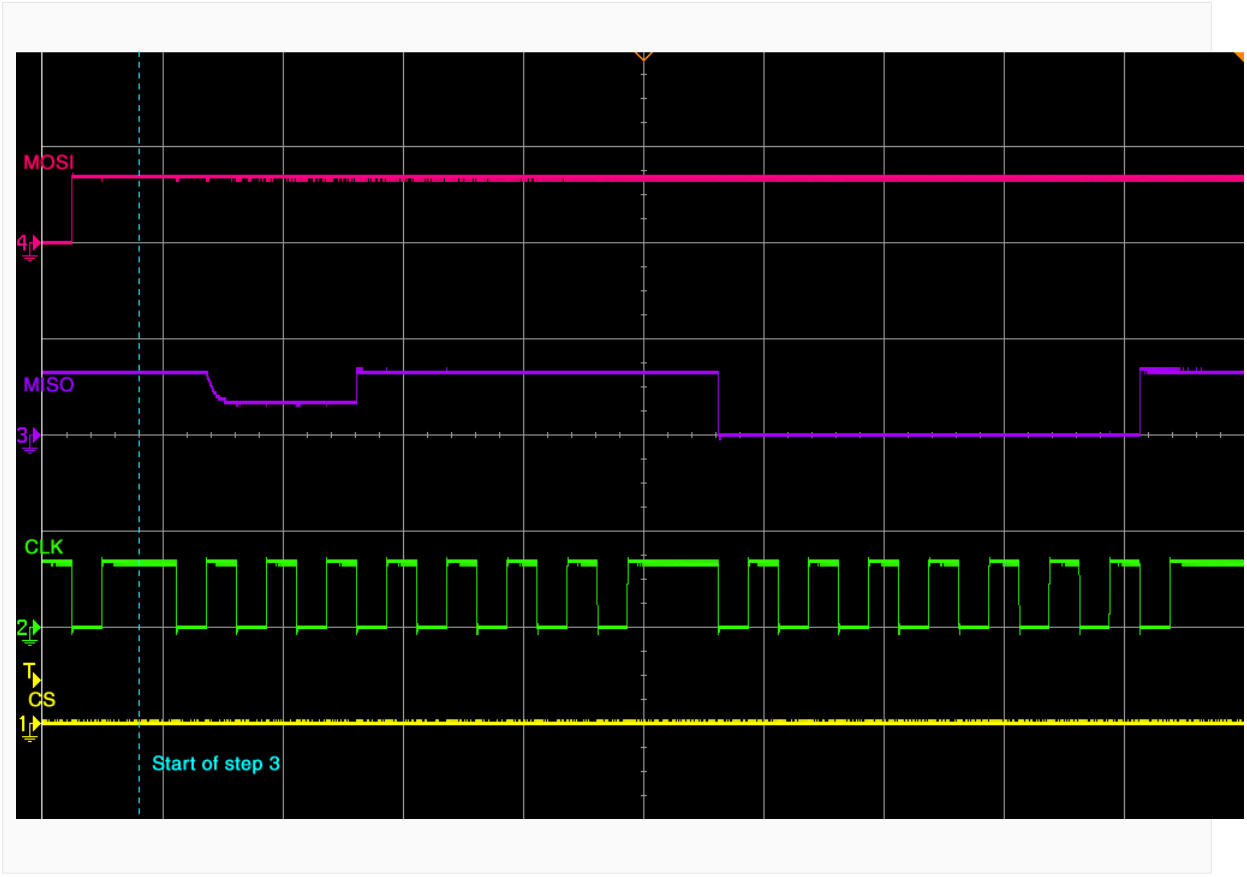
After sending 8 dummy bytes to the card, CS is activated and the `GO_IDLE_STATE` command is sent to the card. The first byte is `0x40` or b01000000. You can see (and should verify) that MOSI changes on the falling edge of CLK. The `GO_IDLE_STATE` command is the reset command. It sets the card into idle state regardless of the current card state.



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Reset command

The card responds to a command with two bytes. The SD Card Association defines that the first byte of the response should always be ignored. The second byte is the answer from the card. The answer to the `GO_IDLE_STATE` command should be `0x01`. This means that the card is in idle state.



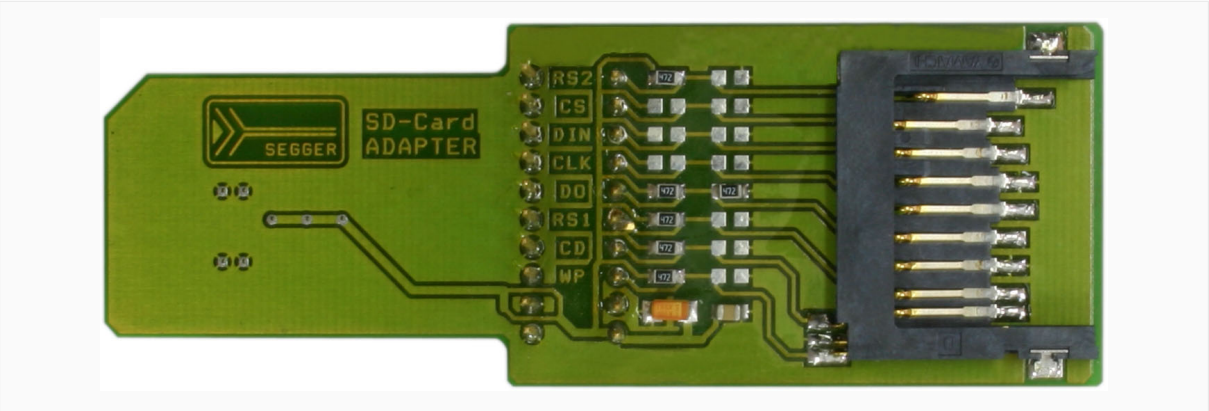
Reset response

If the card does not return `0x01`, then check the initialization sequence of your hardware. At the end of the command sequence, the CS signal has to be deselected; that is, the signal has to be set to logic high.

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6.5.6 Test hardware

The SEGGER SD Card Adapter is an easy-to-use measurement board that can be used to troubleshoot problems related to interfacing emFile with MMC and SD cards in SPI as well as card mode.

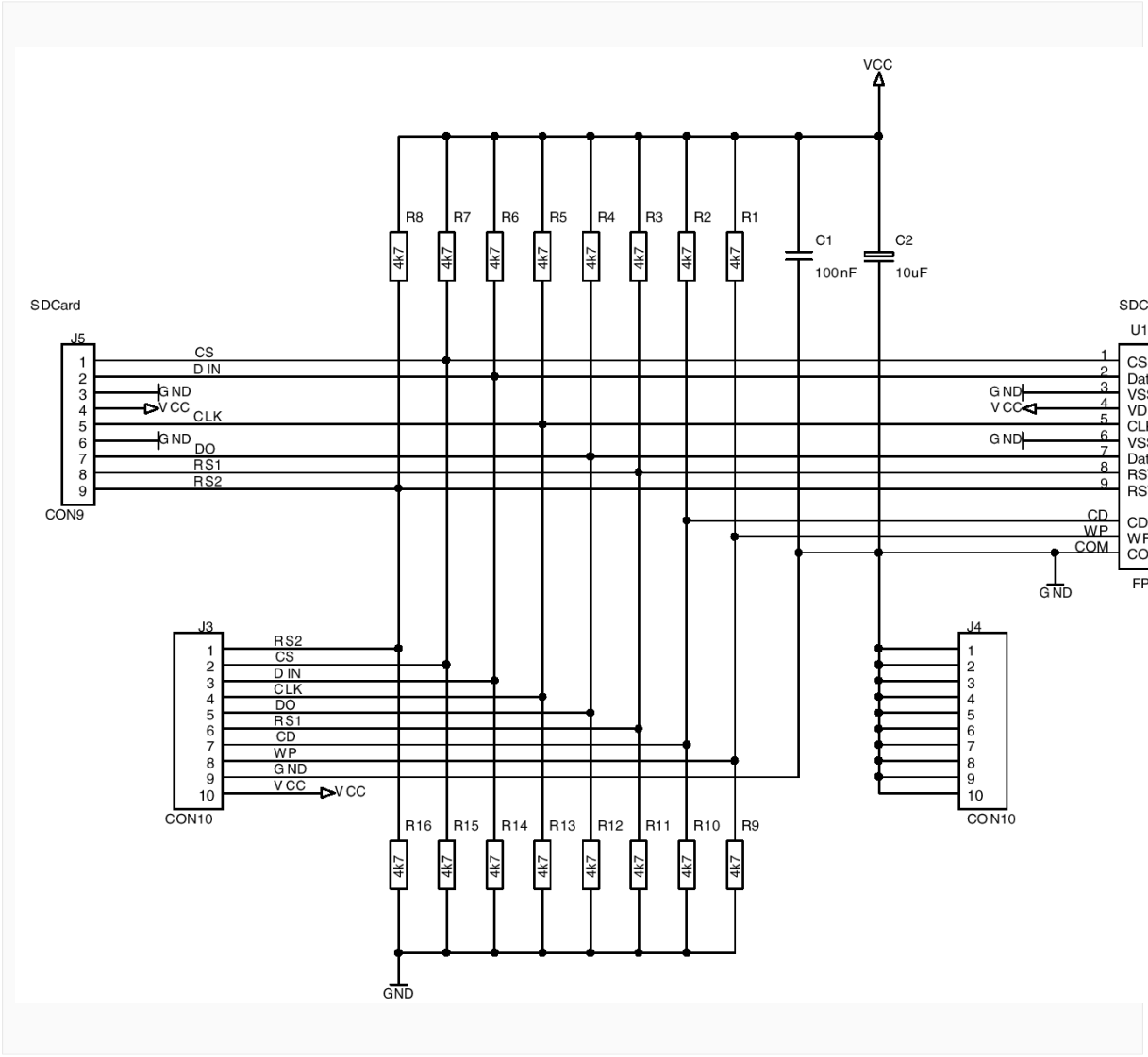


SD card adapter

The adapter board is shaped in the form of an SD card on one side so that it can be directly inserted into any SD card slot. The pads on the same side of the board provide mechanical contact with the signals of the SD card slot of the target hardware. The signals are routed on the adapter board to an SD card socket mounted on it where the SD card can be inserted. All the signals are connected to a header where they can be easily captured using an oscilloscope probe. Another header is provided for GND signals.

The picture below shows the schematic of the adapter board.

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Schematic of SD card adapter

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6.5.7 FAQs

Q: What is the maximum supported storage capacity?
A: The MMC/SD drivers are designed to support SD cards and eMMC devices with a maximum capacity of about 2 TB.

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6.6 CompactFlash card and IDE driver

6.6.1 General information

emFile supports the use of CompactFlash (CF) cards and IDE devices as storage devices. Both types of storage devices share a common interface and are supported by the CF/IDE driver that is able to operate in different modes specified by this interface. The access to the hardware is realized via a set of I/O routines called the CF/IDE hardware layer.

For details on CompactFlash cards check the specification which is available at: http://www.compactflash.org/

Information about the AT Attachment interface can be found at the Technical Committee T13 that is responsible for the ATA standard: http://www.t13.org/

6.6.1.1 Fail-safe operation

The data will be preserved in case of an unexpected reset, but a power failure can be critical. If the card does not have sufficient time to complete a write operation, data may be lost. As a countermeasure, the hardware has to make sure that the power supply to the device drops slowly.

6.6.1.2 Wear-leveling

CF cards and IDE devices have an internal controller that is responsible for performing the wear-leveling. Therefore, the CF/IDE driver does not need to handle wear-leveling.

6.6.1.3 Supported hardware

The CF/IDE driver can be used to access most ATA HD drives and CF cards using the True IDE or Memory card mode.

6.6.1.3.1 Pin description - True IDE mode

The following table describes the signals used in True IDE mode.

Signal name	Dir	Pin	Description
A2-A0	I	18, 19, 20	Only A[2:0] are used to select one of eight registers in the Task File, the remaining address lines should be grounded by the host.
PDIAG	I/O	46	This input/output is the Pass Diagnostic signal in the Master/Slave handshake protocol.
DASP	I/O	45	This input/output is the Disk Active/Slave Present signal in the Master/Slave handshake protocol.
CD1, CD2	O	26, 25	These Card Detect pins are connected to ground on the CompactFlash Storage Card or CF+ Card. They are used by the host to determine that the CompactFlash Storage Card or CF+ Card is fully inserted into its socket.
CS0, CS1	I	7, 32	CS0 is the chip select for the Task File registers while CS1 is used to select the Alternate Status Register and the Device Control Register.
CSEL	I	39	This internally pulled-up signal is used to configure this device as a Master or a Slave when configured in True IDE Mode. When this pin is grounded, the device is configured as a Master. When the pin is open, the device is configured as a Slave.

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Signal name	Dir	Pin	Description
D15 - D00	I/O	27 - 31 47 - 49 2 - 6 21 - 23	All Task File operations occur in byte mode on the low order bus D00-D07 while all data transfers are 16 bit using D00-D15.
GND	--	1, 5	Ground.
IORD	I	34	This is an I/O Read strobe generated by the host. This signal gates I/O data onto the bus from the CompactFlash Storage Card or CF+ Card when the card is configured to use the I/O interface.
IOWR	I	35	The I/O Write strobe pulse is used to clock I/O data on the Card Data bus into the CompactFlash Storage Card or CF+ Card controller registers when the CompactFlash Storage Card or CF+ Card is configured to use the I/O interface. The clocking will occur on the negative to positive edge of the signal (trailing edge).
OE (ATA SEL)	I	9	To enable True IDE Mode, this input should be grounded by the host.
INTRQ	O	37	This signal is the active high interrupt request to the host.
REG	I	44	This input signal is not used and should be connected to VCC by the host.
RESET	I	41	This input pin is the active low hardware reset from the host.
VCC	--	13, 38	+5V, +3.3V power.
VS1, VS2	O	33, 4	Voltage Sense Signals. -VS1 is grounded so that the CompactFlash Storage Card or CF+ Card CIS can be read at 3.3 volts and -VS2 is reserved by PCMCIA for a secondary voltage.
IORDY	O	42	This output signal may be used as IORDY.
WE	I	36	This input signal is not used and should be connected to VCC by the host.
IOIS16	O	24	This output signal is asserted low when the device is expecting a word data transfer cycle.

6.6.1.3.2 Pin description - Memory card mode

The following table describes the signals used in Memory card mode.

Signal name	Dir	Pin	Description
A10 - A0	I	8, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20	These address lines along with the -REG signal are used to select the following: the I/O port address registers within the CompactFlash Storage Card or CF+ Card, the memory mapped port address registers within the CompactFlash Storage Card or CF+ Card, a byte in the card's information structure and its configuration control and status registers.
BVD1	I/O	46	This signal is asserted high, as BVD1 is not supported.
BVD2	I/O	45	This signal is asserted high, as BVD2 is not supported.
CD1, CD2	O	26, 25	These Card Detect pins are connected to ground on the CompactFlash Storage Card or CF+ Card. They are used by

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Signal name	Dir	Pin	Description
			the host to determine that the CompactFlash Storage Card or CF+ Card is fully inserted into its socket.
CE1, CE2	I	7, 32	These input signals are used both to select the card and to indicate to the card whether a byte or a word operation is being performed. -CE2 always accesses the odd byte of the word. We recommend connecting these pins together.
CSEL	I	39	This signal is not used for this mode, but should be grounded by the host.
D15 - D00	I/O	27 - 31 47 - 49 2 - 6 21 - 23	These lines carry the Data, Commands, and Status information between the host and the controller. D00 is the LSB of the Even Byte of the Word. D08 is the LSB of the Odd Byte of the Word.
GND	--	1, 5	Ground.
INPACK	O	43	This signal is not used in this mode.
IORD	I	34	This signal is not used in this mode.
IOWR	I	35	This signal is not used in this mode.
OE (ATA SEL)	I	9	This is an Output Enable strobe generated by the host interface. It is used to read data from the CompactFlash Storage Card or CF+ Card in Memory Mode and to read the CIS and configuration registers.
READY	O	37	In Memory Mode, this signal is set high when the CompactFlash Storage Card or CF+ Card is ready to accept a new data transfer operation and is held low when the card is busy. At power up and at Reset, the READY signal is held low (busy) until the CompactFlash Storage Card or CF+ Card has completed its power up or reset function. No access of any type should be made to the CompactFlash Storage Card or CF+ Card during this time. Note, however, that when a card is powered up and used with +RESET continuously disconnected or asserted, the reset function of this pin is disabled and consequently the continuous assertion of +RESET will not cause the READY signal to remain continuously in the busy state.
REG	I	44	This signal is used during Memory Cycles to distinguish between Common Memory and Register (Attribute) Memory accesses. High for Common Memory, Low for Attribute Memory. To use it with emFile, this signal should be high.
RESET	I	41	When the pin is high, this signal Resets the CompactFlash Storage Card or CF+ Card. The CompactFlash Storage Card or CF+ Card is reset only at power up if this pin is left high or open from power up.
VCC	--	13, 38	+5 V, +3.3 V power.
VS1, VS2	O	33, 4	Voltage Sense Signals. -VS1 is grounded so that the CompactFlash Storage Card or CF+ Card CIS can be read at 3.3 volts and -VS2 is reserved by PCMCIA for a secondary voltage.
WAIT	O	42	The -WAIT signal is driven low by the CompactFlash Storage Card or CF+ Card to signal the host to delay completion of a memory or I/O cycle that is in progress.

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Signal name	Dir	Pin	Description
WE	I	36	This is a signal driven by the host and used for strobing memory write data to the registers of the CompactFlash Storage Card or CF+ Card when the card is configured in the memory interface mode.
WP	O	24	The CompactFlash Storage Card or CF+ Card does not have a write protect switch. This signal is held low after the completion of the reset initialization sequence.

6.6.1.4 Theory of operation

6.6.1.4.1 CompactFlash card

A CF card is a mechanically small, removable mass storage device. It contains a single chip controller and one or more flash memory modules in a matchbox-sized package with a 50-pin connector consisting of two rows of 25 female contacts each on 50 mil (1.27 mm) centers. The controller interfaces with a host system allowing data to be written to and read from the flash memory modules.

There are two different Compact Flash Types, namely CF Type I and CF Type II. The only difference between CF Type I and CF Type II cards is the card thickness. CF Type I cards are 3.3 mm thick and CF Type II cards are 5 mm thick. A CF Type I card will operate in a CF Type I or CF Type II slot. A CF Type II card will only fit in a CF Type II slot. The electrical interfaces are identical. CompactFlash is available in both CF Type I and CF Type II cards, though predominantly in CF Type I cards. The Microdrive is a CF Type II card. Most CF I/O cards are CF Type I, but there are some CF Type II I/O cards.

CF cards are designed with flash technology, a nonvolatile storage solution that does not require a battery to retain data indefinitely. The CF card specification version 2.0 supports data rates up to 16 MB/sec and capacities up to 137 GB. CF cards consume only five percent of the power required by small disk drives.

CompactFlash cards support both 3.3V and 5V operation and can be interchanged between 3.3V and 5V systems. This means that any CF card can operate at either voltage. Other small form factor flash cards may be available to operate at 3.3V or 5V, but any single card can operate at only one of the voltages. CF+ data storage cards are also available using magnetic disk (IBM Microdrive).

CF cards can operate in three modes:

- Memory card mode
- I/O Card mode
- True IDE mode

Currently, only the True IDE and Memory card modes are supported by the CF/IDE driver.

6.6.1.5 IDE (ATA) drives

Just like Compact Flash cards, ATA drives have a built-in controller to drive and control the mechanical hardware. There are two types of ATA drive connectors. 5.25- and 3.5-inch drives use a 40-pin male interface to connect to an IDE controller. 2.5- and 1.8-inch drives, mostly used in notebooks and embedded systems, have a 50-pin male interface.

IDE ATA drives can operate in three different modes:

- PIO (Programmed I/O)
- Multiword DMA
- Ultra DMA

Currently, the CF/IDE driver supports only PIO mode via True IDE.

6.6.1.6 Configuring the driver

This section describes how to configure the file system to make use of the CF/IDE driver.

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6.6.1.7 Runtime configuration

The driver must be added to the file system by calling `FS_AddDevice()` with the driver identifier set to the address of the `FS_IDE_Driver` structure. This function call together with other function calls that configure the driver operation have to be added to `FS_X_AddDevices()` as demonstrated in the following example.

```
#include "FS.h"
#include "FS_IDE_HW_TrueIDE_Template.h"

#define ALLOC_SIZE 0x800                // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the CF/IDE driver in master mode.
  //
  FS_AddDevice(&FS_IDE_Driver);
  FS_IDE_Configure(0, 0);
  FS_IDE_SetHWType(0, &FS_IDE_HW_TrueIDE_Template);
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the CF/IDE driver. The application can call them only during file system initialization in `FS_X_AddDevices()`.

Function	Description
FS_IDE_Configure()	Configures a driver instance.
FS_IDE_SetHWType()	Configures the hardware access routines.

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6.6.1.7.1 FS_IDE_Configure()

Description

Configures a driver instance.

Prototype

```
void FS_IDE_Configure(U8 Unit,
                      U8 IsSlave);
```

Parameters

Parameter	Description
Unit	Driver index (0-based)
IsSlave	Working mode. • 1 Slave mode. • 0 Master mode.

Additional information

This function is optional. The application has to call this function only when the device does not use the default IDE master/slave configuration. By default, all even-numbered units (0, 2, 4…) work in master mode, while all odd-numbered units work in slave mode.

`FS_IDE_Configure` function has to be called from `FS_X_AddDevices()` and it can be called before or after adding the device driver to the file system.

Example

The following example demonstrates how to configure two different CF cards or IDE devices:

```
#include "FS.h"
#include "FS_IDE_HW_TrueIDE_Template.h"

#define ALLOC_SIZE 0x800                // Size defined in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                        // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the first driver.
  // The device works as master on the IDE bus. Volume name: "ide:0:"
  //
  FS_AddDevice(&FS_IDE_Driver);
  FS_IDE_Configure(0, 0);
  FS_IDE_SetHWType(0, &FS_IDE_HW_TrueIDE_Template);
  //
  // Add and configure the second driver.
  // The device works also as master on the IDE bus. Volume name: "ide:1:"
  //
  FS_AddDevice(&FS_IDE_Driver);
  FS_IDE_Configure(1, 0);
  FS_IDE_SetHWType(1, &FS_IDE_HW_TrueIDE_Template);
}
```

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6.6.1.7.2 FS_IDE_SetHWType()

Description

Configures the hardware access routines.

Prototype

```
void FS_IDE_SetHWType(      U8                Unit,
                      const FS_IDE_HW_TYPE * pHWType);
```

Parameters

Parameter	Description
Unit	Driver index (0-based)
pHWType	in Hardware access routines (hardware layer).

Additional information

This function is mandatory. The FS_IDE_HW_Default hardware layer is provided to help the porting to the new hardware layer API. This hardware layer contains pointers to the public functions used by the device driver to access the hardware in the version 3.x of emFile. Configure FS_IDE_HW_Default as hardware layer if you do not want to port your existing hardware layer to the new hardware layer API.

Example

For an example of usage, refer to FS_IDE_Configure().

6.6.2 CF/IDE hardware layer

The CF/IDE hardware layer provides the functions to access the target hardware (IDE controller, GPIO, etc.). They have to be implemented by the user since they are hardware-dependent. emFile comes with template hardware layers and some sample implementations for popular evaluation boards. These files can be found in the Sample/FS/Driver/IDE folder of the emFile shipment. The functions are organized in a function table which is a structure of type FS_IDE_HW_TYPE.

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6.6.2.1 Hardware layer API - FS_IDE_HW_TYPE

This hardware layer supports all CF cards and IDE devices. The following sections describe the functions of this hardware layer in detail.

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6.6.2.1.1 FS_IDE_HW_TYPE

Description

Hardware layer API

Type definition

```
typedef struct {
  FS_IDE_HW_TYPE_RESET       * pfReset;
  FS_IDE_HW_TYPE_IS_PRESENT  * pfIsPresent;
  FS_IDE_HW_TYPE_DELAY_400NS * pfDelay400ns;
  FS_IDE_HW_TYPE_READ_REG    * pfReadReg;
  FS_IDE_HW_TYPE_WRITE_REG   * pfWriteReg;
  FS_IDE_HW_TYPE_READ_DATA   * pfReadData;
  FS_IDE_HW_TYPE_WRITE_DATA  * pfWriteData;
} FS_IDE_HW_TYPE;
```

Structure members

Member	Description
pfReset	Resets the bus interface.
pfIsPresent	Checks if the device is connected.
pfDelay400ns	Blocks the execution for 400ns.
pfReadReg	Reads the value of a register.
pfWriteReg	Writes the value of a register.
pfReadData	Transfers data from device to MCU.
pfWriteData	Transfers data from MCU do device.

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6.6.2.1.2 FS_IDE_HW_TYPE_RESET

Description

Resets the bus interface.

Type definition

```
typedef void FS_IDE_HW_TYPE_RESET(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

This function is called when the driver detects a new storage device. For ATA HD drives, there is no action required and this function can be left empty.

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6.6.2.1.3 FS_IDE_HW_TYPE_IS_PRESENT

Description

Checks presence status of the storage device.

Type definition

```
typedef int FS_IDE_HW_TYPE_IS_PRESENT(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Return value

≠ 0 Device is present.
= 0 Device is not present.

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

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6.6.2.1.4 FS_IDE_HW_TYPE_DELAY_400NS

Description

Blocks the execution for 400ns.

Type definition

```
typedef void FS_IDE_HW_TYPE_DELAY_400NS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

The function is always called when a command is sent or parameters are set in the CF card or IDE device to give the integrated logic time to finish a command. When using slow CF cards or IDE devices with fast processors this function should guarantee that a delay of 400ns is respected. However, this function may be left empty if you fast devices are used (modern CF-Cards and IDE drives are faster than 400ns when executing commands.)

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6.6.2.1.5 FS_IDE_HW_TYPE_READ_REG

Description

Reads the value of a device register.

Type definition

```
typedef U16 FS_IDE_HW_TYPE_READ_REG(U8       Unit,
                                    unsigned RegOff);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
RegOff	Offset of the register that has to be read.

Return value

Value read from the device register.

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

RegOff is always a multiple of two value because the IDE driver always reads two 8-bit registers at a time. The value of the register at the offset RegOff must be stored in the low-order byte of the return value while the value of the register at RegOff + 1 in the high-order byte.

Possible values for RegOff:

Value
0x06
0x0C
0x0E

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6.6.2.1.6 FS_IDE_HW_TYPE_WRITE_REG

Description

Writes the value of a device register.

Type definition

```
typedef void FS_IDE_HW_TYPE_WRITE_REG(U8       Unit,
                                      unsigned RegOff,
                                      U16      Data);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
RegOff	Offset of the register that has to be written.
Data	Value to be written to the specified register.

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

RegOff is always a multiple of two value because the IDE driver always writes two 8-bit registers at a time. The value of the register at the offset RegOff is stored in the low-order byte of Data while the value of the register at the offset RegOff + 1 in the high-order byte of Data.

Possible values for RegOff:

Value
0x02
0x04
0x06
0x0C
0x0E

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6.6.2.1.7 FS_IDE_HW_TYPE_READ_DATA

Description

Transfers data from device memory to MCU.

Type definition

```
typedef void FS_IDE_HW_TYPE_READ_DATA(U8       Unit,
                                      U8     * pData,
                                      unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	out Data transferred from device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

pData is always 16-bit aligned in order to enable the reading of two bytes at a time. For the same reason, NumBytes is always a multiple of two value.

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6.6.2.1.8 FS_IDE_HW_TYPE_WRITE_DATA

Description

Transfers data from MCU to device memory.

Type definition

```
typedef void FS_IDE_HW_TYPE_WRITE_DATA(      U8       Unit,
                                       const U8     * pData,
                                             unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the hardware layer instance (0-based)
pData	in Data to be transferred to device.
NumBytes	Number of bytes to be transferred.

Additional information

This function is a member of the CF/IDE hardware layer. All hardware layers are required to implement this function.

pData is always 16-bit aligned in order to enable the writing of two bytes at a time. For the same reason, NumBytes is always a multiple of two value.

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6.6.3 Performance and resource usage

6.6.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version, and the used CPU. The memory requirements of the IDE/CF driver were measured as described in the section *Test procedure* on page 1439.

Usage: 1.6 Kbytes

6.6.3.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 24 bytes

6.6.3.2.1 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the runtime configuration.

Usage: 18 bytes

6.6.3.3 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in Mbytes/sec.

CPU type	Storage device	Write speed	Read speed
LogicPD H79520 (51 MHz)	IDE memory-mapped	**1.4**	**1.7**
Cogent EP7312 (74 MHz)	CompacFlash card, True IDE mode	**1.9**	**2.5**
Cogent EP7312 (74 MHz)	HDD, True IDE mode	**1.7**	**2.4**

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6.7 Windows Drive driver

This driver can be used to access the data stored on any drive of a Windows operating system via the emFile API functions. Typical usage includes testing and evaluation of emFile before deployment on target hardware. The Windows Drive driver is also able to use a regular file stored on the file system of the Windows PC as storage.

6.7.1 Supported hardware

The Windows Drive driver is compatible with any Windows operating system version newer than Windows 98. Older Windows versions are not supported, because they do not provide access to a Windows drive via the API functions. Windows drives formatted as NTFS are not supported.

6.7.2 Theory of operation

The driver works by reading and writing entire logical sectors. The size of a logical sector can be specified at compile time via `FS_WINDRIVE_SECTOR_SIZE` or at runtime via `FS_WINDRIVE_SetGeometry()`. The size of the logical sector has to match the size of the logical sector used by the Windows drive. Any logical sector size can be used if the Windows Drive driver is configured to use a regular file as storage. On some Windows systems, administrator privileges are required to access a Windows drive. The Windows Drive driver reports an error if the user does not have the required privileges.

> **Note**
>
> Do not use this driver on partitions containing important data. The Windows Drive driver is primarily meant to be used for evaluation purposes. Problems may occur if the program using emFile is debugged or terminated unexpectedly using the Windows Task Manager.

6.7.3 Fail-safe operation

The driver is not designed to be used on target hardware; therefore, the fail-safe operation is not relevant. However, the fail-safe operation is generally guaranteed because it is handled by the underlying operating system and hardware.

6.7.4 Wear-leveling

The driver does not perform any wear leveling. The wear leveling is handled by the storage device.

6.7.5 Configuring the Windows Drive driver

6.7.5.1 Compile time configuration

The configuration at compile time is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371

The Windows Drive driver does not require any hardware access functions.

The following table lists the configuration defines supported by the Windows Drive driver.

Define	Default value	Type	Description
`FS_WINDRIVE_SECTOR_SIZE`	512	N	Default size of a logical sector in bytes.

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Define	Default value	Type	Description
FS_WINDRIVE_NUM_UNITS	4	N	Maximum number of driver instances.

6.7.5.1.1 FS_WINDRIVE_SECTOR_SIZE

This define specifies the default size of the logical sector when the driver is configured to use a regular file as storage. This value can be modified at runtime via FS_WINDRIVE_SetGeometry().

6.7.5.1.2 FS_WINDRIVE_NUM_UNITS

This define specifies the maximum number of driver instances that can be created by the application. The memory for each driver instance is allocated dynamically from the memory pool assigned to the file system.

6.7.5.2 Runtime configuration

The driver can be added to the file system by calling FS_AddDevice() with the driver label FS_WINDRIVE_Driver. This function call together with other function calls that configure the driver operation has to be added to FS_X_AddDevices() as demonstrated in the following example.

Example

```
#include "FS.h"

#define FS_ALLOC_SIZE       0x1000          // Memory pool for the file system in bytes

static U32 _aMemBlock[FS_ALLOC_SIZE / 4];   // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
#ifdef _WIN32
  //
  // Add and configure the driver to access the Windows drive with the letter 'E'.
  //
  FS_AddDevice(&FS_WINDRIVE_Driver);
  FS_WINDRIVE_Configure(0, "\\\\.\\E:");
#endif // _WIN32
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading and writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the Windows Drive driver. The application can call them only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_WINDRIVE_AllowImageFile()	Configures if a regular file can be used as storage.
FS_WINDRIVE_Configure()	Configures a driver instance.
FS_WINDRIVE_ConfigureEx()	Configures a driver instance.
FS_WINDRIVE_SetGeometry()	Configures the storage capacity of an image file.

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6.7.5.2.1 FS_WINDRIVE_AllowImageFile()

Description

Configures if a regular file can be used as storage.

Prototype

```
int FS_WINDRIVE_AllowImageFile(U8 Unit,
                               U8 OnOff);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
OnOff	Specifies the permission status. • 1 Using a regular file is permitted. • 0 Using a regular file is not permitted.

Return value

= 0 OK, file storage configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This is an optional function can be used to specify if the driver instance is allowed to use a regular file as data storage. By default, a driver instance is allowed to use a Windows drive as well as a regular file as storage.

If the function is called with OnOff set to 0 then the driver instance is permitted to access the data stored to regular files.

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6.7.5.2.2 FS_WINDRIVE_Configure()

Description

Configures a driver instance.

Prototype

```
void FS_WINDRIVE_Configure(      U8     Unit,
                           const char * sName);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
sName	in Name of the Windows drive or of the image file to be used as storage. Can be NULL.

Additional information

Either FS_WINDRIVE_Configure() or FS_WINDRIVE_ConfigureEx() has to be called once for each instance of the WINDRIVE driver. sName is a 0-terminated wide char string that stores the path to the Windows drive or to the image file to be used as storage.

If sName is set to NULL the driver shows a dialog box that allows the user to select a specific drive from a list a list of available Windows drives. If sName is a path to a regular file that file has to exists before FS_WINDRIVE_ConfigureEx() is called. Selecting a Windows drive as storage requires administrator privileges. The file system reports an error to the application if this is not the case and the application will not be able to access the to use the Windows drive as storage.

The size of the logical sector used by the WinDrive driver can be configured at compile time via FS_WINDRIVE_SECTOR_SIZE or at runtime via FS_WINDRIVE_SetGeometry().

Example

Refer to *Runtime configuration* on page 485 for a sample usage.

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6.7.5.2.3 FS_WINDRIVE_ConfigureEx()

Description

Configures a driver instance.

Prototype

```
void FS_WINDRIVE_ConfigureEx(U8      Unit,
                             LPCWSTR sName);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
sName	in Name of the Windows drive or of the image file to be used as storage. Can be NULL.

Additional information

This function performs the same operation as FS_WINDRIVE_Configure() with the difference that sName is a pointer to a 0-terminated string containing wide characters. FS_WINDRIVE_ConfigureEx() has to be used when the path to the Windows drive or image file can contain non-ASCII characters.

sName has to point to 0-terminated string containing wide characters. A string literal can be declared in C by prefixing it with the 'L' character. For example the path to the drive with the letter 'E' can be specified as L"\\\\.\\E:"

If sName is set to NULL the driver shows a dialog box that allows the user to select a specific drive from a list a list of available Windows drives. If sName is a path to a regular file that file has to exists before FS_WINDRIVE_ConfigureEx() is called. Selecting a Windows drive as storage requires administrator privileges. The file system reports an error to the application if this is not the case and the application will not be able to access the to use the Windows drive as storage.

The size of the logical sector used by the WINDRIVE driver can be configured at compile time via FS_WINDRIVE_SECTOR_SIZE or at runtime via FS_WINDRIVE_SetGeometry().

Example

```
#include "FS.h"

#define FS_ALLOC_SIZE       0x1000          // Memory pool for the file system in bytes

static U32 _aMemBlock[FS_ALLOC_SIZE / 4];   // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
#ifdef _WIN32
  //
  // Add and configure the driver to access the Windows drive with
  // the letter 'E' assigned to it.
  //
  FS_AddDevice(&FS_WINDRIVE_Driver);
  FS_WINDRIVE_ConfigureEx(0, L"\\\\.\\E:");
#endif // _WIN32
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

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6.7.5.2.4 FS_WINDRIVE_SetGeometry()

Description

Configures the storage capacity of an image file.

Prototype

```
int FS_WINDRIVE_SetGeometry(U8  Unit,
                            U32 BytesPerSector,
                            U32 NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
BytesPerSector	Number of bytes in a logical sector. Has to be a power of 2 value.
NumSectors	Number of logical sectors that can be stored to the image file.

Return value

= 0 OK, parameters set.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. When not called the driver uses the sector size configured via FS_WINDRIVE_SECTOR_SIZE. The number of sectors is calculated by dividing the size of the image file to FS_WINDRIVE_SECTOR_SIZE. This implies that by default the driver fails to initialize if the image file is missing.

Calling FS_WINDRIVE_SetGeometry() changes the behavior of the driver during initialization in that the driver will try to create the image file if missing. In addition, if an image file is present the driver checks verifies if the size of the image file matches the size configured via FS_WINDRIVE_SetGeometry() and if not it recreates the image file.

The size of the image file in bytes is NumSectors * BytesPerSector. Image files larger than or equal to 4 Gbytes are not supported.

Example

```
#include "FS.h"

#define FS_ALLOC_SIZE       0x1000          // Memory pool for the file system in bytes
#define BYTES_PER_SECTOR    512             // Logical sector size in bytes
#define NUM_SECTORS         1024            // Number of logical sectors

static U32 _aMemBlock[FS_ALLOC_SIZE / 4];   // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
#ifdef _WIN32
  //
  // Add and configure the driver to use a regular file as storage.
  //
  FS_AddDevice(&FS_WINDRIVE_Driver);
  FS_WINDRIVE_Configure(0, "C:\\Temp\\WinDrive.bin");
  FS_WINDRIVE_SetGeometry(0, BYTES_PER_SECTOR, NUM_SECTORS);
#endif // _WIN32
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
```

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```
}
```

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6.8 File Disk driver

This driver uses as storage a regular file located on the host file system. Typical usage includes testing and evaluation of emFile before deployment on target hardware.

6.8.1 Supported hardware

The File Disk driver is compatible with any Windows or Linux operating system.

6.8.2 Theory of operation

The driver works by reading and writing entire logical sectors. The size of a logical sector as well as the number of logical sectors can be specified at runtime via `FS_FILEDISK_Configure()`. Any logical sector size is supported.

The file used as storage is automatically created if it does not exist. If the file already exists, then the file is truncated to the size configured via `FS_FILEDISK_Configure()`.

6.8.3 Fail-safe operation

The File Disk driver is not designed to be used on target hardware; therefore, the fail-safe operation is not relevant. However, the fail-safe operation is generally guaranteed because it is handled by the underlying operating system and hardware.

6.8.4 Wear-leveling

The File Disk driver does not perform any wear leveling. The wear leveling is handled by the underlying operating system and hardware.

6.8.5 Configuring the File Disk driver

6.8.5.1 Compile time configuration

The configuration at compile time is done via preprocessor defines that have to be added to the `FS_Conf.h` file that is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371

The File Disk driver does not require any hardware access functions.

The following table lists the configuration defines supported by the File Disk driver.

Type	Define	Default value	Description
N	`FS_FILEDISK_NUM_UNITS`	1	Maximum number of driver instances.
B	`FS_FILEDISK_SUPPORT_TRIM`	0	Enables or disables the support for marking logical sectors as not being in use.
N	`FS_FILEDISK_WORK_BUFFER_SIZE`	512	Size of the working buffer used for the access to the storage device.

6.8.5.1.1 FS_FILEDISK_NUM_UNITS

This define specifies the maximum number of driver instances that can be created by the application. The memory for each driver instance is allocated dynamically from the memory pool assigned to the file system.

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6.8.5.1.2 FS_FILEDISK_SUPPORT_TRIM

FS_FILEDISK_SUPPORT_TRIM can be used to enable or disable the handling of file system operations that inform the File Disk driver about logical sectors that are no longer in use. This functionality is optional and not required for the correct operation of the File Disk driver. The *Storage Image Creator* utility uses this functionality for implementation of the *exportimage* command. The information about the usage of the logical sectors is stored to a separate status file located in the same directory as the data file used for the storage of the file system data. The name of the status file is created by appending the ".sta" file extension to the name of the data file.

6.8.5.1.3 FS_FILEDISK_WORK_BUFFER_SIZE

FS_FILEDISK_WORK_BUFFER_SIZE is the size of all the working buffers that the File Disk driver uses for operations that access the storage device such as changing the usage status of logical sectors. These buffers are allocated on the stack. Increasing the buffer size can help improve the performance of the driver.

6.8.5.2 Runtime configuration

The driver can be added to the file system by calling FS_AddDevice() with the driver label FS_FILEDISK_Driver. This function call together with other function calls that configure the driver operation has to be added to FS_X_AddDevices() as demonstrated in the following example.

Example

```
#include "FS.h"

#define FS_ALLOC_SIZE       0x1000          // Memory pool for the file system in bytes.

static U32 _aMemBlock[FS_ALLOC_SIZE / 4];   // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
#ifdef _WIN32
  //
  // Add and configure the driver to use the "FileDisk.bin" as storage.
  // The total capacity of the storage device is 512 * 1024 = 512 KB
  //
  FS_AddDevice(&FS_FILEDISK_Driver);
  FS_FILEDISK_Configure(0, "FileDisk.bin", 512, 1024);
#endif // _WIN32
#if FS_SUPPORT_FILE_BUFFER
  //
  // Enable the file buffer to increase the performance
  // when reading and writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
#endif // FS_SUPPORT_FILE_BUFFER
}
```

The API functions listed in the next table can be used by the application to configure the behavior of the File Disk driver. The application can call these functions only at the file system initialization in FS_X_AddDevices().

Function	Description
FS_FILEDISK_Configure()	Configures a driver instance.

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6.8.5.2.1 FS_FILEDISK_Configure()

Description

Configures a driver instance.

Prototype

```
int FS_FILEDISK_Configure(      U8          Unit,
                          const char      * sFileName,
                                unsigned    BytesPerSector,
                                U32         NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
sFileName	in Path to the file to be used as storage.
BytesPerSector	Number of bytes in a logical sector.
NumSectors	Number of logical sectors to be used as storage.

Return value

= 0 OK, instance configured successfully.
≠ 0 Error code indicating the failure reason.

Additional information

FS_FILEDISK_Configure() has to be called once for each instance of the File Disk driver. The application is allowed to call this function only at file system initialization in FS_X_AddDevices().

sFileName is a 0-terminated character string that stores the path to the file to be used as storage. A copy of this path is stored to the driver instance.

If BytesPerSector is set to 0 then the File Disk driver uses the maximum logical sector size configured for the file system. By default, the maximum logical sector size is set to 512 bytes. This value can be modified via FS_SetMaxSectorSize().

If the file used as storage does not exist then the file is created when the driver is initialized. The size of the created file is calculated as BytesPerSector * NumSectors. If the file used as storage exists and NumSectors is different than 0 then the size of the file is set to BytesPerSector * NumSectors. If the file used as storage exists and NumSectors is set to 0 then the actual number of sectors is calculated based on the size of the file used as storage.

Example

Refer to *Runtime configuration* on page 485 for a sample usage.

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6.8.5.3 Additional driver functions

The functions documented in this section are optional. They can be used to get information about the status of the File Disk driver.

Function	Description
FS_FILEDISK_GetDiskInfo()	Returns information about the storage device.

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6.8.5.3.1 FS_FILEDISK_GetDiskInfo()

Description

Returns information about the storage device.

Prototype

```
int FS_FILEDISK_GetDiskInfo(U8                       Unit,
                            FS_FILEDISK_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of the instance to configure (0-based)
pDiskInfo	out Storage device information. It cannot be NULL.

Return value

= 0 OK, information returned successfully.
≠ 0 Error code indicating the failure reason.

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6.8.5.3.2 FS_FILEDISK_DISK_INFO

Description

Management information maintained by the File Disk driver.

Type definition

```
typedef struct {
  U64          NumBytes;
  U16          BytesPerSector;
  const char * sFileName;
} FS_FILEDISK_DISK_INFO;
```

Structure members

Member	Description
NumBytes	Capacity of the storage device in bytes.
BytesPerSector	Size of the logical sector used by the driver in bytes.
sFileName	Name of the file that is used as storage.

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Chapter 7

Logical drivers

This chapter describes the file system components that provide block processing.

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7.1 General information

A logical driver is a file system component that provides block processing of the data exchanged between the Storage layer and the storage device such as partitioning and encryption. It implements the same interface as a device driver but in contrast to a device driver it does not access any storage device. Instead, the requests received from the Storage layer are processed internally and then forwarded to either another logical driver or to a device driver to perform the data access.

The following table lists the available logical drivers.

Driver name	Acronym	Identifier	Volume name
Disk Partition driver	DISKPART	`FS_DISKPART_Driver`	`“diskpart:”`
Encryption driver	CRYPT	`FS_CRYPT_Driver`	`“crypt:”`
Authenticated Encryption driver	CRYPT_AE	`FS_CRYPT_AE_Driver`	`“crypt:”`
Sector Read-Ahead driver	READAHEAD	`FS_READAHEAD_Driver`	`“rah:”`
Sector Size Adapter driver	SECSIZE	`FS_SECSIZE_Driver`	`“secsize:”`
Sector Write Buffer driver	WRBUF	`FS_WRBUF_Driver`	`“wrbuf:”`
RAID1 driver	RAID1	`FS_RAID1_Driver`	`“raid:”`
RAID5 driver	RAID5	`FS_RAID5_Driver`	`“raid:”`
Logical Volume driver	LOGVOL	`FS_LOGVOL_Driver`	`“lvol:”`

A logical driver has to be added to the file system in the same way as a device driver. To add a logical driver to emFile, `FS_AddDevice()` has to be called with the address of the corresponding driver identifier as parameter. For more information about the usage of the names listed in the “Volume name” column, refer to *General information* on page 480

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7.2 Disk Partition driver

This logical driver can be used to access storage device partitions as defined by Master Boot Record (MBR) or GUID Partition Table (GPT). Typically, the partitioning information is stored in the first logical sectors of a storage device.

7.2.1 Master Boot Record

An MBR contains information about how the storage device is divided and an optional machine code for bootstrapping PC-compatible computers. This information is always stored on the first logical sector of the storage device. The partitioning information is organized in a table that contains four entries of 16 bytes. Each entry stores the following information about the partition:

Offset (bytes)	Size (byte)	Description
0	1	Partition status: • `0x80` - bootable • `0x00` - non-bootable Any other value is invalid.
1	3	First sector in the partition as cylinder/head/sector address.
4	1	Partition type.
5	3	Last sector in the partition as cylinder/head/sector address.
8	4	First sector in the partition as logical block address.
12	4	Number of sectors in the partition.

The driver uses only the information stored in a valid partition table entry. Invalid partition table entries are ignored. The position and the size of the partition are taken from the last two fields in the entry. The cylinder, head, and sector information as well as the partition type are also ignored.

A separate volume is assigned to each driver instance. The volumes can be accessed using the following names: "diskpart:0:", "diskpart:1:", "diskpart:2:" and "diskpart:3:".

> **Note**
>
> This logical driver is not required if an application has to access only the first storage device partition, as emFile uses this partition by default.

7.2.2 Configuring the driver

7.2.2.1 Runtime configuration

To add the driver, use `FS_AddDevice()` with the driver identifier set to `FS_DISKPART_Driver`. This function has to be called from within `FS_X_AddDevices()`. Refer to `FS_X_AddDevices()` for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
`FS_DISKPART_Configure()`	Configures the parameters of a driver instance.

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7.2.2.1.1 FS_DISKPART_Configure()

Description

Configures the parameters of a driver instance.

Prototype

```
void FS_DISKPART_Configure(      U8                Unit,
                           const FS_DEVICE_TYPE * pDeviceType,
                                 U8                DeviceUnit,
                                 U8                PartIndex);
```

Parameters

Parameter	Description
Unit	Index of the DISKPART instance to configure.
pDeviceType	Type of device driver that is used to access the storage device.
DeviceUnit	Index of the device driver instance that is used to access the storage device (0-based).
PartIndex	Index of the partition in the partition table stored in MBR.

Additional information

This function has to be called once for each instance of the driver. The application can use FS_DISKPART_Configure() to set the parameters that allows the driver to access the partition table stored in Master Boot Record (MBR). The size and the position of the partition are read from MBR on the first access to storage device.

Example

This example demonstrates how to configure the file system to access the first two MBR partitions of an SD card.

```
#include "FS.h"

#define ALLOC_SIZE  2048    // Size of emFile memory pool

static U32 _aMemBlock[ALLOC_SIZE / 4];

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  U8 DeviceUnit;
  U8 PartIndex;
  U8 Unit;
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add SD/MMC card device driver.
  //
  DeviceUnit = 0;
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  //
  // Configure logical driver to access the first MBR partition.
  // Partition will be mounted as volume "diskpart:0:".
  //
  PartIndex = 0;
  Unit      = 0;
  FS_AddDevice(&FS_DISKPART_Driver);
  FS_DISKPART_Configure(Unit, &FS_MMC_CM_Driver, DeviceUnit, PartIndex);
  //
  // Configure logical driver to access the second MBR partition.
```

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```
  // Partition will be mounted as volume "diskpart:1:".
  //
  PartIndex = 1;
  Unit      = 1;
  FS_AddDevice(&FS_DISKPART_Driver);
  FS_DISKPART_Configure(Unit, &FS_MMC_CM_Driver, DeviceUnit, PartIndex);
}
```

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7.2.3 Performance and resource usage

7.2.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.5 Kbytes

7.2.3.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in the compiler list file.

Usage: 20 bytes

7.2.3.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Usage: 18 bytes

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7.3 Encryption driver

The Encryption driver is a logical driver that can be used to protect the file system data against an unauthorized access. This is done by encrypting the data before writing it to the storage device using an encryption algorithm and a key specified by the application. emFile comes with a very efficient implementation of the Data Encryption Standard (DES) and of the Advanced Encryption Standard (AES) algorithms. The AES algorithm supports 128-bit and 256-bit key lengths.

The logical driver can be used with both the FAT and EFS file systems and with any storage device.

A separate volume is assigned to each driver instance. The volumes can be accessed using the following names: “crypt:0:”, “crypt:1:”, etc.

7.3.1 Theory of operation

The sector data is transformed to make it unreadable for anyone who tries to read it directly. The operation which makes the data unreadable is called encryption and is performed when the file system writes the sector data. When the contents of a sector is read, the reverse operation is applied, which makes the data readable again. This is the operation called decryption. Both operations use a cryptographic algorithm and a key for data transformation. The same key is used for encryption and decryption. Without the knowledge of the key, it is not possible to decrypt the data.

7.3.2 Configuring the driver

7.3.2.1 Compile time configuration

The next table lists the available configuration defines followed by a detailed description of them. The configuration defines have to be added to the FS_Conf.h file that is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371

Define	Default value	Type	Description
FS_CRYPT_NUM_UNITS	4	N	Maximum number of driver instances.

7.3.2.1.1 FS_CRYPT_NUM_UNITS

This define specifies the maximum number of driver instances an application is allowed to create. Four bytes of static RAM are reserved for each driver instance. If the maximum number of driver instances is smaller than the default, then FS_CRYPT_NUM_UNITS can be set to that value in order to reduce the RAM usage.

7.3.2.2 Runtime configuration

To add the driver, call FS_AddDevice() with the driver identifier set to FS_CRYPT_Driver. This function has to be called from within FS_X_AddDevices(). Refer to FS_X_AddDevices() for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
FS_CRYPT_Configure()	Sets the working parameters of a driver instance.
FS_CRYPT_SetSectorBufferSize()	Sets the size of the internal buffer used for cryptographic operations.

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7.3.2.2.1 FS_CRYPT_Configure()

Description

Sets the working parameters of a driver instance.

Prototype

```
void FS_CRYPT_Configure(      U8                    Unit,
                        const FS_DEVICE_TYPE      * pDeviceType,
                              U8                    DeviceUnit,
                        const FS_CRYPT_ALGO_TYPE  * pAlgoType,
                              void                * pContext,
                        const U8                  * pKey);
```

Parameters

Parameter	Description
Unit	Index of driver to be configured (0-based).
pDeviceType	in Device to access the storage medium.
DeviceUnit	Number of device to access the storage medium (0-based).
pAlgoType	in The type of encryption algorithm.
pContext	in Data specific to cryptographic algorithm.
pKey	in Password for data encryption/decryption.

Additional information

This function has to be called once for each driver instance. pAlgoType is a pointer to one of the following structures:

Algorithm type
FS_CRYPT_ALGO_DES
FS_CRYPT_ALGO_AES128
FS_CRYPT_ALGO_AES256

pContext is passed as parameter to the encryption and decryption routines via pContext. The memory region pContext points to has to remain valid from the moment the driver is configured until the FS_DeInit() function is called.

The number of bytes in pKey array has to match the size of the key required by the used cryptographic algorithm as follows:

Algorithm type
FS_CRYPT_ALGO_DES
FS_CRYPT_ALGO_AES128
FS_CRYPT_ALGO_AES256

Example

```
#include "FS.h"

#define ALLOC_SIZE  2048    // Size of emFile memory pool

static U32            _aMemBlock[ALLOC_SIZE / 4];
static FS_AES_CONTEXT _Context;

/*********************************************************************
*
*       FS_X_AddDevices
*
```

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```
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  U8 DeviceUnit;
  U8 Unit;
  U8 aPass[16] = {'s', 'e', 'c', 'r', 'e', 't'};

  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add SD/MMC card device driver.
  //
  DeviceUnit = 0;
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(DeviceUnit, 1);
  //
  // Add the encryption driver. The storage can be accessed as volume "crypt:0:".
  //
  Unit = 0;
  FS_AddDevice(&FS_CRYPT_Driver);
  FS_CRYPT_Configure(Unit,
                     &FS_MMC_CM_Driver,
                     DeviceUnit,
                     &FS_CRYPT_ALGO_AES128,
                     &_Context,
                     aPass);
}
```

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7.3.2.2.2 FS_CRYPT_SetSectorBufferSize()

Description

Sets the size of the internal buffer used for cryptographic operations.

Prototype

```
void FS_CRYPT_SetSectorBufferSize(unsigned NumBytes);
```

Parameters

Parameter	Description
NumBytes	Buffer size in bytes.

Additional information

The CRYPT logical driver uses an internal sector buffer that is shared by all the driver instances. By default, the size of this buffer is equal to the maximum sector size set for the file system via `FS_SetMaxSectorSize()`.

This function can be used to modify the size of the internal sector buffer for example for reducing the RAM usage if the storage device uses a sector size that is smaller than the maximum sector size of the file system.

In addition, setting the buffer size to a multiple of a sector size can help increase the write performance for storage device such as SD cards and eMMC devices.

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7.3.3 Performance and resource usage

7.3.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU in use. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.3 Kbytes

In addition, one of the following cryptographic algorithms is required:

Physical layer	Description	ROM [Kbytes]
FS_CRYPT_ALGO_DES	DES encryption algorithm.	**3.2**
FS_CRYPT_ALGO_AES128	AES encryption algorithm using a 128-bit key.	**12.0**
FS_CRYPT_ALGO_AES256	AES encryption algorithm using a 256-bit key.	**12.0**

7.3.3.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 24 bytes

7.3.3.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount required depends on the runtime configuration and on the selected encryption algorithm.

Every driver instance requires **16 bytes** of RAM. In addition, the context of the AES encryption algorithm requires **480 bytes** and that of the DES encryption algorithm **128 bytes** of RAM.

7.3.3.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in KB/second.

CPU type	Storage device	Encryption algorithm	Write speed	Read speed
ST STM32F207 (96 MHz)	SD card in 4-bit mode	AES with a 128-bit key (SW)	**639**	**661**
NXP Kinetis K60 (120 MHz)	NAND flash device interfaced via 8-bit bus	AES with a 128-bit key (SW)	**508**	**550**

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7.4 Authenticated Encryption driver

7.4.1 General information

The Authentication Encryption driver is a logical driver that can be used to protect the file system data against unauthorized access. This is done by encrypting the data before writing it to the storage device using an encryption algorithm and a key specified by the application. In addition, this logical driver is able to check if the encrypted data was maliciously manipulated by using a message authentication code.

emFile comes with sample encryption algorithms that use the encryption routines included in the SEGGER emCrypt product (https://www.segger.com/products/security-iot/emcrypt/) In addition, sample encryption algorithms are provided that use the cryptographic hardware acceleration units of individual MCUs. The Authentication Encryption driver is also able to use encryption algorithms that are provided by the application. More information about the encryption algorithm can be found in the section *Encryption algorithm* on page 1512.

The logical driver can be used with both the FAT and EFS file systems and with any storage device.

A separate volume is assigned to each driver instance. The volumes can be accessed using the following names: “`crypt:0:`”, “`crypt:1:`”, etc.

7.4.2 Theory of operation

The sector data is transformed to make it unreadable for anyone who tries to read it directly. The operation which makes the data unreadable is called encryption and is performed when the file system writes the sector data. When the contents of a sector is read, the reverse operation is applied, which makes the data readable again. This is the operation called decryption. Both operations use a cryptographic algorithm and a key for data transformation. The same key is used for encryption and decryption. Without the knowledge of the key, it is not possible to decrypt the data.

7.4.2.1 Low-level format

The driver uses some of the available storage space to store management information. This management information has to be initialized once before any data access to the storage via a low-level format operation. The application is responsible for performing this operation either via `FS_FormatLow()` or `FS_FormatLLIfRequired()`.

7.4.2.2 Fail-safe operation

The operation of the driver is fail-safe. This means that the driver makes sure that after an unexpected power failure that interrupts a sector write operation either the old or the new sector data is present but not some combination of both.

An unexpected power failure may affect the consistency of the stored data. More precisely, the message authentication code of the sectors being written during the power failure may be left invalid. These data inconsistencies are automatically corrected by the driver during the low-level mount operation before any access to the sector data.

7.4.3 Configuring the driver

7.4.3.1 Compile time configuration

The next table lists the available configuration defines followed by a detailed description of them. The configuration defines have to be added to the `FS_Conf.h` file that is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371

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Define	Default value	Type	Description
FS_CRYPT_ENABLE_STATS	0 or 1	B	Enables or disables the support for statistical counters.
FS_CRYPT_NUM_UNITS	4	N	Maximum number of driver instances.
FS_CRYPT_MAX_AUTH_TAG_SIZE	16	N	Configures the maximum size of an authentication tag.
FS_CRYPT_READ_BUFFER_FILL_PATTERN	0xFF	N	Value that is used to fill the data of an invalid sector.
FS_CRYPT_SUPPORT_TRIM	1	B	Enables or disables the support for marking logical sectors that are not being in use.

7.4.3.1.1 FS_CRYPT_ENABLE_STATS

This configuration define can be used to enable the support for statistical counters. The statistical counters provide information about the number of operations performed internally by the Authenticated Encryption driver that can be used, for example, for analyzing driver performance. The statistical counters can be queried via FS_CRYPT_AE_GetStatCounters(). By default FS_CRYPT_ENABLE_STATS is set to 1 if FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

7.4.3.1.2 FS_CRYPT_NUM_UNITS

This define specifies the maximum number of driver instances an application is allowed to create. Four bytes of static RAM are reserved for each driver instance. If the maximum number of driver instances is smaller than the default, then FS_CRYPT_NUM_UNITS can be set to that value in order to reduce the RAM usage.

7.4.3.1.3 FS_CRYPT_MAX_AUTH_TAG_SIZE

This define specifies the maximum number of bytes in an authentication tag that is supported by any instance of the CRYPT logical driver. If set to 0, then the support for authenticated encryption is disabled.

7.4.3.1.4 FS_CRYPT_READ_BUFFER_FILL_PATTERN

This define can be used to specify the value that has to be stored in the data of an invalid logical sector that is read by the file system.

7.4.3.1.5 FS_CRYPT_SUPPORT_TRIM

FS_CRYPT_SUPPORT_TRIM can be used to enable or disable the handling of file system operations that inform a driver about logical sectors that are no longer in use. The Authenticated Encryption driver can use this information to optimize some of the internal operations such as the data consistency check. Enabling this feature increases the ROM usage of the Authenticated Encryption driver.

7.4.3.2 Runtime configuration

To add the driver, call FS_AddDevice() with the driver identifier set to FS_CRYPT_AE_Driver. This function has to be called from within FS_X_AddDevices(). Refer to FS_X_AddDevices() for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
FS_CRYPT_AE_Configure()	Sets the working parameters of a driver instance.

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Function	Description
FS_CRYPT_AE_SetAuthTagBufferSize()	Sets the size of the internal buffer used for storing authentication tags.
FS_CRYPT_AE_SetMaxAuthTagSize()	Sets maximum number of bytes in an authentication tag.
FS_CRYPT_AE_SetOnFatalErrorCallback()	Registers a function to be called by the driver when a fatal error occurs.
FS_CRYPT_AE_SetSectorBufferSize()	Sets the size of the internal buffer used for storing sector data.

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7.4.3.2.1 FS_CRYPT_AE_Configure()

Description

Sets the working parameters of a driver instance.

Prototype

```
int FS_CRYPT_AE_Configure(      U8                   Unit,
                          const FS_DEVICE_TYPE     * pDeviceType,
                                U8                   DeviceUnit,
                          const FS_CRYPT_ALGO_TYPE * pAlgoType,
                                void               * pContext,
                          const U8                 * pKey);
```

Parameters

Parameter	Description
Unit	Index of driver to be configured (0-based).
pDeviceType	in Device to access the storage medium.
DeviceUnit	Number of device to access the storage medium (0-based).
pAlgoType	in The type of encryption algorithm.
pContext	in Data specific to cryptographic algorithm.
pKey	in Password for data encryption/decryption.

Return value

= 0 OK, driver instance configured successfully.
≠ 0 An error occurred.

Additional information

This function has to be called once for each driver instance.

pContext is passed as parameter to the encryption and decryption routines via pContext. The memory region pContext points to has to remain valid from the moment the driver is configured until the FS_DeInit() function is called.

The number of bytes in pKey array has to match the size of the key required by the used cryptographic algorithm.

Example

```
#include "FS.h"
#include "FS_CRYPT_ALGO_AES_CCM_emCrypt.h"

#define ALLOC_SIZE  2048    // Size of emFile memory pool

static U32            _aMemBlock[ALLOC_SIZE / 4];
static FS_AES_CONTEXT _Context;

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  U8 DeviceUnit;
  U8 Unit;
  U8 aPass[16] = {'s', 'e', 'c', 'r', 'e', 't'};

  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add SD/MMC card device driver.
```

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```
  //
  DeviceUnit = 0;
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(DeviceUnit, 1);
  //
  // Add the Authenticated Encryption driver.
  // The storage can be accessed as volume "crypt:0:".
  //
  Unit = 0;
  FS_AddDevice(&FS_CRYPT_AE_Driver);
  FS_CRYPT_AE_Configure(Unit,
                        &FS_MMC_CM_Driver,
                        DeviceUnit,
                        &FS_CRYPT_ALGO_AES128_CCM_emCrypt,
                        &_Context,
                        aPass);
}
```

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7.4.3.2.2 FS_CRYPT_AE_SetAuthTagBufferSize()

Description

Sets the size of the internal buffer used for storing authentication tags.

Prototype

```
void FS_CRYPT_AE_SetAuthTagBufferSize(unsigned NumBytes);
```

Parameters

Parameter	Description
NumBytes	Buffer size in bytes.

Additional information

The CRYPT logical driver uses an internal buffer for authentication tags that is shared by all the driver instances. By default, the size of this buffer is equal to `FS_CRYPT_MAX_AUTH_TAG_SIZE`.

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7.4.3.2.3 FS_CRYPT_AE_SetMaxAuthTagSize()

Description

Sets maximum number of bytes in an authentication tag.

Prototype

```
int FS_CRYPT_AE_SetMaxAuthTagSize(U8       Unit,
                                  unsigned NumBytes);
```

Parameters

Parameter	Description
Unit	Index of driver to be configured (0-based).
NumBytes	Maximum size of authentication tag in bytes.

Return value

= 0 OK, maximum size of authentication tag set successfully.
≠ 0 An error occurred.

Additional information

NumBytes has to be smaller than or equal to FS_CRYPT_MAX_AUTH_TAG_SIZE. This function fails if NumBytes is greater than FS_CRYPT_MAX_AUTH_TAG_SIZE.

The value set via this function is used only during the low-level format operation.

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7.4.3.2.4 FS_CRYPT_AE_SetOnFatalErrorCallback()

Description

Registers a function to be called by the driver when a fatal error occurs.

Prototype

```
void FS_CRYPT_AE_SetOnFatalErrorCallback
                                (FS_CRYPT_ON_FATAL_ERROR_CALLBACK * pfOnFatalError);
```

Parameters

Parameter	Description
pfOnFatalError	Address to the callback function.

Additional information

Typically, the Authenticated Encryption driver reports a fatal error when the data authentication fails.

All instances of the Authenticated Encryption driver share the same callback function. The Unit member of the FS_CRYPT_AE_FATAL_ERROR_INFO structure passed as parameter to the pfOnFatalError callback function indicates what driver instance triggered the fatal error.

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7.4.3.2.5 FS_CRYPT_AE_SetSectorBufferSize()

Description

Sets the size of the internal buffer used for storing sector data.

Prototype

```
void FS_CRYPT_AE_SetSectorBufferSize(unsigned NumBytes);
```

Parameters

Parameter	Description
NumBytes	Buffer size in bytes.

Additional information

The CRYPT logical driver uses an internal sector buffer that is shared by all the driver instances. By default, the size of this buffer is equal to the maximum sector size set for the file system via `FS_SetMaxSectorSize()`. This function can be used to modify the size of the internal sector buffer for example for reducing the RAM usage if the storage device uses a sector size that is smaller than the maximum sector size of the file system.

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7.4.3.2.6 FS_CRYPT_ON_FATAL_ERROR_CALLBACK

Description

The type of the callback function invoked by the Authenticated Encryption driver when a fatal error occurs.

Type definition

```
typedef int FS_CRYPT_ON_FATAL_ERROR_CALLBACK(
                                    FS_CRYPT_FATAL_ERROR_INFO * pFatalErrorInfo);
```

Parameters

Parameter	Description
pFatalErrorInfo	Information about the fatal error.

Return value

≠ 0 OK, fatal error handled.

Additional information

The application is responsible for handling the fatal error by for example checking the consistency of the file system via `FS_CheckDisk()`. The callback function is not allowed to invoke any other FS API functions therefore the handling of the error has to be done after the FS API function that triggered the error returns.

The fatal error handler can be registered via `FS_CRYPT_AE_SetOnFatalErrorCallback()`.

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7.4.3.2.7 FS_CRYPT_FATAL_ERROR_INFO

Description

Information passed to callback function when a fatal error occurs.

Type definition

```
typedef struct {
  U8   Unit;
  U32  ErrorSectorIndex;
} FS_CRYPT_FATAL_ERROR_INFO;
```

Structure members

Member	Description
Unit	Index of the driver that triggered the fatal error.
ErrorSectorIndex	Index of the logical sector that has an authentication error.

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7.4.4 Additional driver functions

The following table lists the API functions that can be called by the application at runtime to perform operations on the driver.

Function	Description
FS_CRYPT_AE_FormatLow()	Performs a low-level format of the storage device.
FS_CRYPT_AE_GetDiskInfo()	Obtains information about storage.
FS_CRYPT_AE_GetSectorInfo()	Obtains information about a logical sector.
FS_CRYPT_AE_GetStatCounters()	Returns the values of the statistical counters.
FS_CRYPT_AE_IsLLFormatted()	Checks if the storage device is low-level formatted.
FS_CRYPT_AE_ResetStatCounters()	Sets the value of the statistical counters to 0.

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7.4.4.1 FS_CRYPT_AE_FormatLow()

Description

Performs a low-level format of the storage device.

Prototype

```
int FS_CRYPT_AE_FormatLow(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Authenticated Encryption driver (0-based).

Return value

= 0 OK, storage device successfully formatted.
≠ 0 An error occurred.

Additional information

This function is optional. Alternatively, the storage device can be low-level formatted via `FS_FormatLow()` .

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7.4.4.2 FS_CRYPT_AE_GetDiskInfo()

Description

Obtains information about storage.

Prototype

```
int FS_CRYPT_AE_GetDiskInfo(U8                      Unit,
                            FS_CRYPT_AE_DISK_INFO * pDiskInfo);
```

Parameters

Parameter	Description
Unit	Index of driver to be queried (0-based).
pDiskInfo	out Information about storage.

Return value

= 0 OK, information returned successfully.
≠ 0 An error occurred.

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7.4.4.3 FS_CRYPT_AE_GetSectorInfo()

Description

Obtains information about a logical sector.

Prototype

```
int FS_CRYPT_AE_GetSectorInfo(U8                       Unit,
                              U32                      SectorIndex,
                              FS_CRYPT_AE_SECTOR_INFO * pSectorInfo);
```

Parameters

Parameter	Description
Unit	Index of driver to be queried (0-based).
SectorIndex	Index of the logical sector to be queried.
pSectorInfo	out Information about a logical sector.

Return value

= 0 OK, information returned successfully.
≠ 0 An error occurred.

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7.4.4.4 FS_CRYPT_AE_GetStatCounters()

Description

Returns the values of the statistical counters.

Prototype

```
void FS_CRYPT_AE_GetStatCounters(U8                          Unit,
                                 FS_CRYPT_AE_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Index of the Authenticated Encryption driver (0-based).
pStat	out Statistical counter values.

Additional information

This function is optional. The application can use it to get the actual values of the statistical counters maintained by the Authenticated Encryption driver. The statistical counters provide information about the number of internal operations performed by the Authenticated Encryption driver such as sector read and write from the information and data area. All statistical counters are set to 0 when the storage device is low-level mounted. The application can explicitly set the statistical counters to 0 by using `FS_CRYPT_AE_ResetStatCounters()`. A separate set of statistical counters is maintained for each instance of the Authenticated Encryption driver.

The statistical counters are available only when the file system is built with the `FS_DEBUG_LEVEL` configuration define set to a value greater than or equal to `FS_DEBUG_LEVEL_CHECK_ALL` or with the `FS_NOR_ENABLE_STATS` configuration define set to 1.

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7.4.4.5 FS_CRYPT_AE_IsLLFormatted()

Description

Checks if the storage device is low-level formatted.

Prototype

```
int FS_CRYPT_AE_IsLLFormatted(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Authenticated Encryption driver (0-based).

Return value

≠ 0 The storage device is low-level formatted.
= 0 The storage device is not low-level formatted or an error has occurred.

Additional information

This function is optional. Alternatively, the formatting status of the storage device can be obtained via `FS_IsLLFormatted()`.

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7.4.4.6 FS_CRYPT_AE_ResetStatCounters()

Description

Sets the value of the statistical counters to 0.

Prototype

```
void FS_CRYPT_AE_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the Authenticated Encryption driver (0-based).

Additional information

This function is optional. The application can use it to set to 0 the statistical counters maintained by the Authenticated Encryption driver. The statistical counters can be read via FS_CRYPT_AE_GetStatCounters()

FS_CRYPT_AE_ResetStatCounters() is available only when the file system is built with the FS_DEBUG_LEVEL configuration define set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL or with the FS_CRYPT_ENABLE_STATS configuration define set to 1.

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7.4.4.7 FS_CRYPT_AE_DISK_INFO

Description

Management information maintained by the Authenticated Encryption driver.

Type definition

```
typedef struct {
  U32  NumSectors;
  U32  ErrorSectorIndex;
  U16  BytesPerSector;
  U16  SIEntriesPerSector;
  U8   SIEntrySize;
  U8   AuthTagSize;
  U8   HasFatalError;
} FS_CRYPT_AE_DISK_INFO;
```

Structure members

Member	Description
NumSectors	Capacity of the storage device in sectors.
ErrorSectorIndex	Index of the logical sector where the fatal error occurred.
BytesPerSector	Size of a sector in bytes.
SIEntriesPerSector	Number of sector information entries that are stored in a sector.
SIEntrySize	Size of a sector information entry in bytes.
AuthTagSize	Size of an authentication tag in bytes.
HasFatalError	Indicates if a fatal error occurred during the operation (0 - no fatal error, 1 - a fatal error occurred)

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7.4.4.8 FS_CRYPT_AE_SECTOR_INFO

Type definition

```
typedef struct {
  U8   IsValid;
  U8   State;
  U32  aAuthTag[];
} FS_CRYPT_AE_SECTOR_INFO;
```

Structure members

Member	Description
IsValid	Set to 1 if the logical sector contains valid data.
State	Toggles with each sector data change.
aAuthTag	Value of the authentication tag.

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7.4.4.9 FS_CRYPT_AE_STAT_COUNTERS

Description

Statistical counters maintained by the Authentication Encryption driver.

Type definition

```
typedef struct {
  U32  ReadSectorCntStatus;
  U32  WriteSectorCntStatus;
  U32  ReadSectorCntInfo;
  U32  WriteSectorCntInfo;
  U32  ReadSectorCntData;
  U32  WriteSectorCntData;
  U32  RepairSectorCnt;
} FS_CRYPT_AE_STAT_COUNTERS;
```

Structure members

Member	Description
ReadSectorCntStatus	Number of times the logical sector that stores the status information was read.
WriteSectorCntStatus	Number of times the logical sector that stores the status information was written.
ReadSectorCntInfo	Number of logical sectors read by the file system from the sector information area.
WriteSectorCntInfo	Number of logical sectors written by the file system to the sector information area.
ReadSectorCntData	Number of logical sectors read by the file system from the sector data area.
WriteSectorCntData	Number of logical sectors written by the file system to the sector data area.
RepairSectorCnt	Number of logical sectors that were repaired.

Additional information

The statistical counters can be queried via `FS_CRYPT_AE_GetStatCounters()` and can be set to 0 via `FS_CRYPT_AE_ResetStatCounters()`.

`RepairSectorCnt` indicates for how many logical sectors the check operation of the Authenticated Encryption driver had to recalculate the authentication tag.

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7.4.5 Performance and resource usage

7.4.5.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 4 KB

7.4.5.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 42 bytes

7.4.5.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime. The amount of RAM required depends on the runtime configuration and on the selected encryption algorithm.

Every driver instance requires **61 bytes** of RAM. In addition, two work buffers are allocated that are shared among all driver instances. The first buffer is used for storing sector data. By default, the size of this buffer is equal to the maximum logical sector size that is supported by the file system. The second buffer is used for storing authentication tags. By default, the size of this buffer is `FS_CRYPT_MAX_AUTH_TAG_SIZE` bytes.

7.4.5.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445. All values are given in KB/second.

CPU type	Storage device	Encryption algorithm	Write speed	Read speed
ST STM32H573 (240 MHz)	SD card in 4-bit mode	AES with a 128-bit key (HW)	**1302**	**3324**
ST STM32H573 (240 MHz)	NOR flash device interfaced via 8-bit bus	AES with a 128-bit key (HW)	**62**	**5725**

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7.5 Sector Read-Ahead driver

The driver reads in advance more sectors than requested and caches them to the provided buffer. The maximum number of sectors which fit in the buffer are read at once. If the requested sectors are present in the buffer, the driver returns the cached sector contents and the storage medium is not accessed. The driver should be used on SD/MMC/eMMC storage devices where reading single sectors is less efficient than reading all the sectors at once. By default, the driver is not active. The file system activates the driver when the allocation table is searched for free clusters. This will improve performance in the case where the whole allocation table needs to be scanned. To activate the support for read-ahead in the file system, the `FS_SUPPORT_READ_AHEAD` define must be set to 1 in `FS_Conf.h`. The logical driver works with the FAT as well as with the EFS file system.

7.5.1 Configuring the driver

7.5.1.1 Runtime configuration

To add the driver, call `FS_AddDevice()` with the driver identifier set to `FS_READAHEAD_Driver`. This function has to be called from within `FS_X_AddDevices()`. Refer to `FS_X_AddDevices()` for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
`FS_READAHEAD_Configure()`	Sets the parameters which allows the driver instance to access the storage medium.

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7.5.1.1.1 FS_READAHEAD_Configure()

Description

Sets the parameters which allows the driver instance to access the storage medium.

Prototype

```
void FS_READAHEAD_Configure(      U8               Unit,
                            const FS_DEVICE_TYPE * pDeviceType,
                                  U8               DeviceUnit,
                                  U32            * pData,
                                  U32              NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based)
pDeviceType	in Device driver used to access the storage device.
DeviceUnit	Index of the storage device (0-based)
pData	in Buffer to store the sector data read from storage device.
NumBytes	Number of bytes in the read buffer.

Additional information

This function is mandatory and it has to be called once for each instance of the driver. The read buffer has to be sufficiently large to store at least one logical sector.

Example

This example demonstrates how to configure the driver in order to access the data stored on an SD card.

```
#include "FS.h"

#define ALLOC_SIZE  2048    // Size of emFile memory pool
#define BUFFER_SIZE 4096

static U32 _aMemBlock[ALLOC_SIZE / 4];
static U32 _aReadBuffer[BUFFER_SIZE / 4];

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add SD/MMC card device driver.
  //
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  //
  // Add and configure the read-ahead driver. Volume name: "rah:0:"
  //
  FS_AddDevice(&FS_READAHEAD_Driver);
  FS_READAHEAD_Configure(0, &FS_MMC_CM_Driver, 0,
                         _aReadBuffer, sizeof(_aReadBuffer));
}
```

7.5.2 Additional driver functions

The following table lists the API functions that can be called by the application at runtime to perform operations on the driver.

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Function	Description
FS_READAHEAD_GetStatCounters()	Returns the values of the statistical counters.
FS_READAHEAD_ResetStatCounters()	Sets to 0 the values of all statistical counters.

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7.5.2.1 FS_READAHEAD_GetStatCounters()

Description

Returns the values of the statistical counters.

Prototype

```
void FS_READAHEAD_GetStatCounters(U8                          Unit,
                                  FS_READAHEAD_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
Unit	Driver index (0-based)
pStat	out Values of statistical counters.

Additional information

This function is optional. The statistical counters are updated only when the file system is compiled with FS_READAHEAD_ENABLE_STATS set to 1 or with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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7.5.2.2 FS_READAHEAD_ResetStatCounters()

Description

Sets to 0 the values of all statistical counters.

Prototype

```
void FS_READAHEAD_ResetStatCounters(U8 Unit);
```

Parameters

Parameter	Description
Unit	Driver index (0-based)

Additional information

This function is optional. It is available only when the file system is compiled with FS_READAHEAD_ENABLE_STATS set to 1 or with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_ALL.

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7.5.2.3 FS_READAHEAD_STAT_COUNTERS

Type definition

```
typedef struct {
  U32  ReadSectorCnt;
  U32  ReadSectorCachedCnt;
} FS_READAHEAD_STAT_COUNTERS;
```

Structure members

Member	Description
ReadSectorCnt	Internal use.
ReadSectorCachedCnt	Internal use.

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7.5.3 Performance and resource usage

7.5.3.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.4 Kbytes

7.5.3.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in the compiler list file.

Usage: 20 bytes

7.5.3.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Usage: 30 bytes

7.5.3.4 Performance

The detection of free space is 2 times faster when a 4 KB read-ahead buffer is used (measured on a 4 GB SD card formatted with 4 KB clusters).

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7.6 Sector Size Adapter driver

The logical driver supports access to a storage device using a sector size different from that of the underlying layer (typically a storage driver). The sector size of the logical driver is configurable and can be larger or smaller than the sector size of the lower layer.

Typically, the logical driver is placed between the file system and a storage driver, and it is configured with a sector size smaller than that of the storage layer to help reduce the RAM usage of the internal sector buffers of the file system.

7.6.1 Configuring the driver

To add the driver, call `FS_AddDevice()` with the driver identifier set to `FS_SECSIZE_Driver`. This function has to be called from within `FS_X_AddDevices()`. Refer to `FS_X_AddDevices()` for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
`FS_SECSIZE_Configure()`	Sets the parameters of a driver instance.

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7.6.1.1 FS_SECSIZE_Configure()

Description

Sets the parameters of a driver instance.

Prototype

```
void FS_SECSIZE_Configure(      U8                Unit,
                          const FS_DEVICE_TYPE * pDeviceType,
                                U8                DeviceUnit,
                                U16               BytesPerSector);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDeviceType	in Storage device.
DeviceUnit	Unit number of storage device.
BytesPerSector	Sector size in bytes presented to upper layer.

Additional information

This function is mandatory and it has to be called once for each instance of the driver. BytesPerSector has to be a power of 2 value.

Example

This example demonstrates how to configure the logical driver to access a NAND flash via the Universal NAND driver.

```
#include "FS.h"

#define ALLOC_SIZE  0x8000    // Size of emFile memory pool

static U32 _aMemBlock[ALLOC_SIZE / 4];

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add NAND flash device driver.
  //
  FS_AddPhysDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Add sector conversion logical driver.
  //
  FS_AddDevice(&FS_SECSIZE_Driver);
  FS_SECSIZE_Configure(0, &FS_NAND_UNI_Driver, 0, 512);
}
```

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7.6.2 Performance and resource usage

7.6.2.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.1 Kbytes

7.6.2.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in the compiler list file.

Usage: 20 bytes

7.6.2.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Each driver instance requires **30 bytes** of RAM. In addition, a driver instance requires a working buffer of the size of one storage driver logical sector if the sector size of the storage driver is larger than the sector size configured for the logical driver configured via `FS_SECSIZE_Configure()`.

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7.7 Sector Write Buffer driver

This driver was designed to help improve the write performance of the file system. It operates by temporarily storing the sector data in RAM, which takes significantly less time than writing directly to a storage device. The sector data is written later to storage at the request of the application or when the internal buffer is full. The sectors are written to storage in the same order in which they were written by the file system.

The advantages of using this driver are:

- a file system write operation blocks for a very short period of time.
- the number of write operations is reduced when the same sector is written in succession.
- the driver can be used with the Journaling activated since the write order is preserved. The internal buffer can be flushed by the application by calling the `FS_STORAGE_Sync()` API function. The function blocks until all sectors stored in the internal buffer are written to storage. Typically, this function should be called from a low-priority task when the application does not access the file system.

7.7.1 Configuring the driver

7.7.1.1 Runtime configuration

To add the driver, call `FS_AddDevice()` with the driver identifier set to `FS_WRBUF_Driver`. This function has to be called from within `FS_X_AddDevices()`. Refer to `FS_X_AddDevices()` for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
`FS_WRBUF_Configure()`	Sets the parameters of a driver instance.

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7.7.1.1.1 FS_WRBUF_Configure()

Description

Sets the parameters of a driver instance.

Prototype

```
void FS_WRBUF_Configure(      U8               Unit,
                        const FS_DEVICE_TYPE * pDeviceType,
                              U8               DeviceUnit,
                              void           * pBuffer,
                              U32              NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDeviceType	in Storage device.
DeviceUnit	Unit number of storage device.
pBuffer	in Storage for sector data.
NumBytes	Number of bytes in pBuffer.

Additional information

This function is mandatory and it has to be called once for each instance of the driver. FS_SIZEOF_WRBUF() can be used to calculate the number of bytes required to be allocated in order to store a specified number of logical sectors.

Example

This example demonstrates how to configure the logical driver to access an SD card via the SD/MMC card mode driver.

```
#include "FS.h"

#define ALLOC_SIZE  0x1000    // Size of emFile memory pool

static U32 _aMemBlock[ALLOC_SIZE / 4];
static U32 _aWriteBuffer[FS_SIZEOF_WRBUF(8, 512) / 4];

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add and configure the NOR flash driver.
  //
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(0, 1);
  FS_MMC_CM_SetHWType(0, &FS_MMC_HW_CM_Default);
  //
  // Add and configure the write buffer driver.
  //
  FS_AddDevice(&FS_WRBUF_Driver);
  FS_WRBUF_Configure(0, &FS_MMC_CM_Driver, 0,
                     _aWriteBuffer, sizeof(_aWriteBuffer));
}
```

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7.7.1.1.2 Write buffer size

Description

Calculates the write buffer size.

Definition

```
#define FS_SIZEOF_WRBUF(NumSectors,    BytesPerSector)
  ((FS_SIZEOF_WRBUF_SECTOR_INFO + (BytesPerSector)) * (NumSectors))
```

Additional information

This define can be used in an application to calculate the number of bytes that have to be allocated in order to store the specified number of logical sectors. `NumSectors` specifies the number of logical sectors while `BytesPerSector` the size of a logical sector in bytes.

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7.7.2 Performance and resource usage

7.7.2.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.2 Kbytes

7.7.2.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 20 bytes

7.7.2.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Usage: 32 bytes

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7.8 RAID1 driver

RAID1 is a logical file system driver that can be used to increase the integrity and reliability of the data saved on a storage device. This is realized by keeping a copy of all sector data on a separate partition, also known as mirroring. When a read error occurs, the data is recovered by reading it from the mirror partition.

7.8.1 Theory of operation

The logical driver uses a master and a mirror partition. On a file system write request, the sector data is written to both master and mirror partitions. On a file system read request, the logical driver tries to read the sector data from the master partition first. If a read error occurs, then the sector data is read from the mirror partition. This way the data is recovered, and no error is reported to the file system.

The logical driver can be configured to store the sector data either on the same or on two separate storage devices, according to user requirements. If a single storage device is used, the first half is used as master partition. When using two different storage devices the size of the volumes does not have to be equal. The number of sectors available to the file system will be that of the smallest storage device. However, it is required that the sector size of both storage devices is equal. If necessary, the sector size can be adapted using the SECSIZE logical driver. For more information refer to *Sector Size Adapter driver* on page 1313.

7.8.2 NAND flash error recovery

The Universal NAND driver can make use of the RAID driver to avoid data loss when an uncorrectable ECC error happens during a read operation. This feature is by default disabled, and it can be enabled at compile time by setting the `FS_NAND_ENABLE_ERROR_RECOVERY` switch to 1 in `FS_Conf.h`.

7.8.3 Sector data synchronization

An unexpected reset that interrupts a write operation may lead to a data inconsistency. It is possible that the data of the last written sector is stored only on the master partition, but not on the mirror partition. After a restart, the file system will continue to operate correctly, but in case of a read error affecting this sector, old data is read from the mirror partition, which may cause data corruption. This situation can be prevented by synchronizing all the sectors on the RAID volume. The application can perform the synchronization by calling the `FS_STORAGE_SyncSectors()` API function. For example, a low-priority task can call the function in parallel with other file system activities. For an example, refer to `FS_RAID1_SetSyncBuffer()`.

7.8.4 Configuring the driver

7.8.4.1 Runtime configuration

The API functions listed in the next table can be used by the application to configure the behavior of the RAID1 driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_RAID1_Configure()`	Configures the parameters of a driver instance.
`FS_RAID1_SetSectorRanges()`	Configures the position and the size of the RAID partitions.
`FS_RAID1_SetSyncBuffer()`	Sets a buffer for the synchronization operation.

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Function	Description
FS_RAID1_SetSyncSource()	Specifies the source storage device for the synchronization operation.

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7.8.4.1.1 FS_RAID1_Configure()

Description

Configures the parameters of a driver instance.

Prototype

```
void FS_RAID1_Configure(      U8               Unit,
                        const FS_DEVICE_TYPE * pDeviceType0,
                              U8               DeviceUnit0,
                        const FS_DEVICE_TYPE * pDeviceType1,
                              U8               DeviceUnit1);
```

Parameters

Parameter	Description
Unit	Index of the driver instance.
pDeviceType0	in Type of the primary (master) storage device.
DeviceUnit0	Index of the primary (master) storage device (0-based).
pDeviceType1	in Type of the secondary (mirror) storage device.
DeviceUnit1	Index of the secondary (mirror) storage device.

Additional information

This function has to be called once for each driver instance. The same storage device can used both as primary and as secondary device in which case the first half is used as primary device the other half is used as secondary device.

Example

The following example shows how to configure RAID1 on a single volume.

```
#include "FS.h"

#define ALLOC_SIZE      0x8000            // Size of the memory pool in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];    // Memory pool used for
                                          // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Set the file system sector size.
  //
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the first NAND driver.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Add and configure the RAID driver.
  //
  FS_AddDevice(&FS_RAID1_Driver);
  FS_RAID1_Configure(0, &FS_NAND_UNI_Driver, 0, &FS_NAND_UNI_Driver, 0);
```

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```
}
```

The next example demonstrates how to configure RAID1 on two separate volumes.

```
#include "FS.h"

#define ALLOC_SIZE      0x8000              // Size of the memory pool in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];      // Memory pool used for
                                            // semi-dynamic allocation.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Set the file system sector size.
  //
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the NAND driver for the primary storage.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Add and configure the NAND driver for the secondary storage.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(1, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(1, &FS_NAND_ECC_HW_NULL);
  //
  // Add and configure the RAID driver.
  //
  FS_AddDevice(&FS_RAID1_Driver);
  FS_RAID1_Configure(0, &FS_NAND_UNI_Driver, 0, &FS_NAND_UNI_Driver, 1);
}
```

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7.8.4.1.2 FS_RAID1_SetSectorRanges()

Description

Configures the position and the size of the RAID partitions.

Prototype

```
void FS_RAID1_SetSectorRanges(U8  Unit,
                              U32 NumSectors,
                              U32 StartSector0,
                              U32 StartSector1);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumSectors	Number of sectors in the partition.
StartSector0	Start sector of first partition (0-based).
StartSector1	Start sector of second partition (0-based).

Additional information

This function is optional. Per default, the RAID1 driver uses the entire available space of a storage device. The application can use `FS_RAID1_SetSectorRanges()` to specify areas of the primary and secondary storage devices the RAID1 driver has to use as storage.

Example

This example configures a RAID volume of 10000 sectors. The primary storage starts at sector index 0 and the secondary storage at sector index 10000.

```
#include "FS.h"

#define ALLOC_SIZE      0x8000            // Size of the memory pool in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];    // Memory pool used for
                                          // semi-dynamic allocation.
/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Set the file system sector size.
  //
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the first NAND driver.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Add and configure the RAID driver.
  //
  FS_AddDevice(&FS_RAID1_Driver);
  FS_RAID1_Configure(0, &FS_NAND_UNI_Driver, 0, &FS_NAND_UNI_Driver, 0);
  FS_RAID1_SetSectorRanges(0, 10000, 0, 10000);
}
```

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7.8.4.1.3 FS_RAID1_SetSyncBuffer()

Description

Sets a buffer for the synchronization operation.

Prototype

```
void FS_RAID1_SetSyncBuffer(U8     Unit,
                            void * pBuffer,
                            U32    NumBytes);
```

Parameters

Parameter	Description
Unit	Index of the driver instance.
pBuffer	Pointer to a memory location to be used as buffer.
NumBytes	Number of bytes in the buffer.

Additional information

This function is optional. The configured buffer is used for when the sector data is synchronized between the primary and the secondary storage device via FS_STORAGE_SyncSectors(). The size of the buffer has to be sufficiently large to store at least two logical sectors otherwise the synchronization operation will fail. A larger buffer allows the driver to read and write multiple logical sectors at once which help increase the performance of the synchronization operation.

Example

The following example shows how to configure a synchronization buffer of 16 KB and how to synchronize the RAID volume after an unexpected reset.

```
#include "FS.h"

#define ALLOC_SIZE      0x8000              // Size of the memory pool in bytes
#define BUFFER_SIZE     0x8000              // Size of the sync buffer in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];      // Memory pool used for
                                            // semi-dynamic allocation.
static U32 _aSyncBuffer[BUFFER_SIZE / 4];   // Buffer for the RAID synchronization.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Set the file system sector size.
  //
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the first NAND driver.
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  //
  // Add and configure the RAID driver.
  //
  FS_AddDevice(&FS_RAID1_Driver);
```

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```
  FS_RAID1_Configure(0, &FS_NAND_UNI_Driver, 0, &FS_NAND_UNI_Driver, 0);
  FS_RAID1_SetSyncBuffer(0, _aSyncBuffer, sizeof(_aSyncBuffer));
}

/*********************************************************************
*
*       _SampleSyncRAID1
*
*  Function description
*    Performs synchronization of the RAID1 partitions. This function may
*    be called from a low-priority task in order to minimize the effect
*    on the normal file system activity.
*/
static void _SampleSyncRAID1(void) {
  U32         iSector;
  FS_DEV_INFO DevInfo;
  //
  // Get the number of sectors on the storage.
  //
  FS_STORAGE_GetDeviceInfo("", &DevInfo);
  //
  // Synchronize one sector at a time to avoid
  // blocking the application for too long time.
  //
  for (iSector = 0; iSector < DevInfo.NumSectors; ++iSector) {
    FS_STORAGE_SyncSectors("", iSector, 1);
  }
}
```

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7.8.4.1.4 FS_RAID1_SetSyncSource()

Description

Specifies the source storage device for the synchronization operation.

Prototype

```
void FS_RAID1_SetSyncSource(U8       Unit,
                            unsigned StorageIndex);
```

Parameters

Parameter	Description
Unit	Index of the driver instance.
StorageIndex	Index of the storage device to be used as source. • 0 - primary storage device. • 1 - secondary storage device.

Additional information

This function is optional. It can be used by an application to specify the storage device that has to be used as source when synchronizing the RAID1 partitions via `FS_STORAGE_SyncSectors()`. Per default the primary storage device is used as source.

Example

The following example shows how to use the secondary device as source for the synchronization operation.

```
#include "FS.h"

#define ALLOC_SIZE        0x8000           // Size of the memory pool in bytes
#define BUFFER_SIZE       0x8000           // Size of the sync buffer in bytes
#define NUM_SECTORS       2048             // Number of sectors on the RAM disk
#define BYTES_PER_SECTOR  512              // Size of a RAM disk sector
#define BASE_ADDR         0x80000000       // Address in memory of the first byte
                                           // in the NOR flash

static U32 _aMemBlock[ALLOC_SIZE / 4];     // Memory pool used for
                                           // semi-dynamic allocation.
static U32 _aRAMDisk[(NUM_SECTORS * BYTES_PER_SECTOR) / 4];  // Storage for RAM disk.
static U32 _aSyncBuffer[BUFFER_SIZE / 4];  // Buffer for the synchronization.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*    It is supposed to add all devices, using primarily FS_AddDevice().
*
*  Note
*    (1) Other API functions
*        Other API functions may NOT be called, since this function is called
*        during initialization. The devices are not yet ready at this point.
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the RAM disk first for maximum read performance.
  //
  FS_AddDevice(&FS_RAMDISK_Driver);
  FS_RAMDISK_Configure(0, _aRAMDisk, BYTES_PER_SECTOR, NUM_SECTORS);
  //
  // Add and configure the driver for NOR flash.
  //
```

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```
  FS_AddDevice(&FS_NOR_BM_Driver);
  FS_NOR_BM_SetPhyType(0, &FS_NOR_PHY_CFI_1x16);
  FS_NOR_BM_Configure(0, BASE_ADDR, BASE_ADDR, BYTES_PER_SECTOR * NUM_SECTORS);
  //
  // Add and configure the RAID driver.
  //
  FS_AddDevice(&FS_RAID1_Driver);
  FS_RAID1_Configure(0, &FS_RAMDISK_Driver, 0, &FS_NOR_BM_Driver, 0);
  FS_RAID1_SetSyncBuffer(0, _aSyncBuffer, sizeof(_aSyncBuffer));
  //
  // Copy data from NOR flash to RAM disk when synchronizing at restart.
  //
  FS_RAID1_SetSyncSource(0, 1);
}
```

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7.8.5 Performance and resource usage

7.8.5.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.5 Kbytes

7.8.5.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 20 bytes

7.8.5.3 Runtime RAM usage

Runtime RAM usage is the amount of RAM allocated by the driver at runtime.

Usage: 48 bytes

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7.9 RAID5 driver

RAID5 is a logical file system driver that can be used to increase the integrity and reliability of the data saved on a storage device. This is realized by keeping a parity check of the sector data of two or more consecutive sectors. In case of a read error, the sector data is recovered using the parity check information.

7.9.1 Theory of operation

RAID5 requires at least three storage partitions. Storage space equivalent to the size of one partition is used for parity check information, making it unavailable for data storage. Parity checking means adding an extra piece of information (a formula result) that can be used to replicate data in the case of a hardware defect or failure. The storage capacity required for the parity checking information can be reduced by increasing the number of partitions, thus increasing overall available capacity. The RAID5 add-on calculates the parity checking information using the "eXclusive Or" function (XOR). The result of an XOR function performed on any number of inputs is such that if one input is lost (i.e., one partition fails) the missing piece of information can be calculated (i.e., recovered or replicated) using the XOR result and the other known inputs.

7.9.2 NAND flash error recovery

The Universal NAND driver can make use of the RAID5 driver to avoid data loss when an uncorrectable ECC error happens during a read operation. This feature is by default disabled, and it can be enabled at compile time by setting the `FS_NAND_ENABLE_ERROR_RECOVERY` configuration define to 1 in `FS_Conf.h`.

7.9.3 Configuring the driver

7.9.3.1 Runtime configuration

The API functions listed in the next table can be used by the application to configure the behavior of the RAID5 driver. The application can call them only at the file system initialization in `FS_X_AddDevices()`.

Function	Description
`FS_RAID5_AddDevice()`	Configures a storage device for data storage.
`FS_RAID5_SetNumSectors()`	Specifies the number of logical sectors in a single RAID partition.
`FS_RAID5_GetOperatingMode()`	Returns the operating mode of the specified RAID5 partition.

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7.9.3.1.1 FS_RAID5_AddDevice()

Description

Configures a storage device for data storage.

Prototype

```
void FS_RAID5_AddDevice(      U8               Unit,
                        const FS_DEVICE_TYPE * pDeviceType,
                              U8               DeviceUnit,
                              U32              StartSector);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDeviceType	in Type of storage device.
DeviceUnit	Index of the first storage device (0-based).
StartSector	Index of the first sector to be used for data storage (0-based).

Additional information

This function has to be called at least three times in FS_X_AddDevices() because the RAID5 logical driver requires at least three partitions for correct operation. One partition stores the parity check data while the other partitions store the payload. The partitions do not have to be located on different physical storage devices.

The number of logical sectors covered by a single parity check sector is one less than the total number of partitions added to the RAID5 logical driver. A configuration with one or two partitions is invalid and is reported as an error during the initialization of the RAID5 logical driver instance.

It is mandatory that all the configured partitions have the same logical sector size. If the configured partitions have different logical sector sizes, than the SECSIZE logical driver can be used to adapt them.

The RAID5 logical driver uses as storage the same number of logical sectors from each partition because the data is distributed equally between these partitions. Typically, the RAID5 logical driver uses the entire partition for data storage. This is the case when all configured partitions contain the same number of sectors. When the configured partitions have different number of sectors, then the RAID5 logical driver uses the number of logical sectors of the partition with smallest capacity. The number of logical sectors used by the RAID logical driver from each partition can be also explicitly configured via FS_RAID5_SetNumSectors().

StartSector can be used to locate the RAID partition at other logical sector offset on the storage device than 0, when the first number of logical sectors on the partition are reserved for other purposes.

Example

The following code snippet shows how to configure the RAID 5 add-on that uses three partitions located on the same NAND flash device.

```
#include "FS.h"
#include "FS_NAND_HW_Template.h"

#define ALLOC_SIZE      0x8000              // Size of the memory pool in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];      // Memory pool used for
                                            // semi-dynamic allocation.
/*********************************************************************
*
*       FS_X_AddDevices
```

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```
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system some memory to work with.
  //
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the RAID5 volume. Volume name: "raid5:0:"
  //
  FS_AddDevice(&FS_RAID5_Driver);
  FS_RAID5_AddDevice(0, &FS_NAND_UNI_Driver, 0, 0);
  FS_RAID5_AddDevice(0, &FS_NAND_UNI_Driver, 0, 1000);
  FS_RAID5_AddDevice(0, &FS_NAND_UNI_Driver, 0, 2000);
  FS_RAID5_SetNumSectors(0, 1000);
  //
  // Add and configure the driver NAND driver. Volume name: "nand:0:"
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  FS_NAND_ONFI_SetHWType(0, &FS_NAND_HW_Template);
}
```

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7.9.3.1.2 FS_RAID5_SetNumSectors()

Description

Specifies the number of logical sectors in a single RAID partition.

Prototype

```
void FS_RAID5_SetNumSectors(U8  Unit,
                            U32 NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
NumSectors	Number of sectors in the RAID partition.

Additional information

This function is optional and can be called only from FS_X_AddDevices(). By default, the RAID5 logical driver uses all the logical sectors of a partition to store the data. FS_RAID5_SetNumSectors() can be used to configure a different value for the number of logical sectors when for example the end of a partition is reserved and cannot be used for data storage.

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7.9.3.1.3 FS_RAID5_GetOperatingMode()

Description

Returns the operating mode of the specified RAID5 partition.

Prototype

```
int FS_RAID5_GetOperatingMode(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

≥ 0 Operating mode.
< 0 An error occurred.

Additional information

This function is optional and can be called from an application to get the operating mode of the RAID5 logical driver. The RAID5 logical driver can operate in one of the following modes:

- FS_RAID_OPERATING_MODE_NORMAL All storage devices are present and are operating normally.
- FS_RAID_OPERATING_MODE_DEGRADED One storage device is not operating properly.
- FS_RAID_OPERATING_MODE_FAILURE Two or more storage devices are not operating properly.

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7.9.3.1.4 RAID operating modes

Description

Operating modes of a RAID logical driver.

Definition

```
#define FS_RAID_OPERATING_MODE_NORMAL      0
#define FS_RAID_OPERATING_MODE_DEGRADED    1
#define FS_RAID_OPERATING_MODE_FAILURE     2
```

Symbols

Definition	Description
FS_RAID_OPERATING_MODE_NORMAL	All storage devices present and operating normally.
FS_RAID_OPERATING_MODE_DEGRADED	One storage device is not operating properly.
FS_RAID_OPERATING_MODE_FAILURE	Two or more storage devices are not operating properly.

Additional information

The operating mode of RAID5 logical driver can be queried via the `FS_RAID5_GetOperatingMode()` API function.

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7.9.4 Performance and resource usage

7.9.4.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 2.2 Kbytes

7.9.4.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be taken from the compiler list file.

Usage: 30 bytes

7.9.4.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Each driver instance requires **23 bytes** of RAM. In addition, **11 bytes** of RAM are required for each different storage device used by the RAID5 driver instance and **12 bytes** for each configured partition.

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7.10 Logical Volume driver

This driver can be used by an application to create a volume that extends over two or more existing volumes. In addition, the Logical Volume driver can also be configured to create a volume using as storage only a specified sector range of an already existing volume. The volumes created via the Logical Volume driver can be accessed by the application in the same way as any other volume attached to a device or logical driver. The type of the storage device attached to the volumes combined via the Logical Volume driver is not relevant as long as they have the same logical sector size. The combined volumes can be attached to device as well as to logical drivers.

The Logical Volume driver is included in the LOGVOL component that also provides the implementation of the `FS_LOGVOL_Create()` and `FS_LOGVOL_AddDevice()` API functions. These functions were the only way for creating logical volumes in emFile versions older than 5.x. The functionality provided by the Logical Volume driver is similar to the functionality of the API functions `FS_LOGVOL_Create()` and `FS_LOGVOL_AddDevice()`. The difference is that the volume created using the latter method is not attached to a driver and as a consequence the volume cannot be used with any of the logical drivers, for example, to encrypt its contents via the *Encryption driver* on page 1279. Therefore SEGGER recommends the Logical Volume driver as the preferred method of creating logical volumes.

The volume attached to a Logical Volume driver has a fixed name as described in the section *General information* on page 1274. If the application wishes to access the volume under a different name, then it can do so by configuring an alias for the volume name via `FS_SetVolumeAlias()`.

7.10.1 Configuring the driver

The Logical Volume driver has to be configured at compile time and at runtime. This section describes how this can be realized.

7.10.1.1 Compile time configuration

The next table lists the available configuration defines followed by a detailed description of them. The configuration defines must be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371

Define	Default value	Type	Description
`FS_LOGVOL_NUM_UNITS`	4	N	Maximum number of driver instances.
`FS_LOGVOL_SUPPORT_CLEAN`	1	B	Enables or disables the support for executing the garbage collection in the application.
`FS_LOGVOL_SUPPORT_DRIVER_MODE`	0	B	Configures the working mode of the driver.
`FS_LOGVOL_SUPPORT_TRIM`	1	B	Enables or disables the support for marking logical sectors as not being in use.

7.10.1.1.1 FS_LOGVOL_NUM_UNITS

This define specifies the maximum number of driver instances an application is allowed to create. Four bytes of static RAM are reserved for each driver instance. If the maximum number of driver instances is smaller than the default then `FS_LOGVOL_NUM_UNITS` can be set to that value in order to reduce the RAM usage.

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7.10.1.1.2 FS_LOGVOL_SUPPORT_CLEAN

This define specifies if the application is allowed to perform a garbage collection operation via the LOGVOL driver. If FS_LOGVOL_SUPPORT_CLEAN is set to 1 then the application can perform a garbage collection operation via FS_STORAGE_Clean() and FS_STORAGE_CleanOne() on the device configured as data storage. If the used storage device does not support garbage collection then FS_LOGVOL_SUPPORT_CLEAN can be safely set to 0 in order to reduce the ROM usage.

7.10.1.1.3 FS_LOGVOL_SUPPORT_DRIVER_MODE

FS_LOGVOL_SUPPORT_DRIVER_MODE can be used to configure if the LOGVOL component works in legacy or driver mode. By default, the component works in legacy mode, which means that the application has to use the functions FS_LOGVOL_Create() and FS_LOGVOL_AddDevice() to configure a volume. If FS_LOGVOL_SUPPORT_DRIVER_MODE is set to 1 then the LOGVOL component works in driver mode. In this mode the LOGVOL component behaves like any other logical driver in that an instance of the driver can be added to the file system via FS_AddDevice(). Each instance of the Logical Volume driver must be configured at runtime by calling FS_LOGVOL_AddDeviceEx() in FS_X_AddDevice().

7.10.1.1.4 FS_LOGVOL_SUPPORT_TRIM

FS_LOGVOL_SUPPORT_TRIM can be used to enable or disable the handling of file system operations that inform a device driver about logical sectors that are no longer in use. A device driver can use this information to optimize the internal operation that copies the data from one physical location to another by not copying the contents of the logical sectors that are marked as being no longer in use. Enabling this feature increases the ROM usage of the LOGVOL driver.

7.10.1.2 Runtime configuration

The Logical Volume driver has to be added to the file system by calling FS_AddDevice() in FS_X_AddDevices() with the driver identifier set to FS_LOGVOL_Driver. Refer to FS_X_AddDevices() for more information. The following table lists the API functions that can be called by the application to configure the driver.

Function	Description
FS_LOGVOL_AddDeviceEx()	Adds a storage device to a logical volume.

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7.10.1.2.1 FS_LOGVOL_AddDeviceEx()

Description

Adds a storage device to a logical volume.

Prototype

```
int FS_LOGVOL_AddDeviceEx(      U8               Unit,
                          const FS_DEVICE_TYPE * pDeviceType,
                                U8               DeviceUnit,
                                U32              StartSector,
                                U32              NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
pDeviceType	Type of the storage device that has to be added.
DeviceUnit	Index of the storage device that has to be added (0-based).
StartSector	Index of the first sector that has to be used as storage (0-based).
NumSectors	Number of sectors that have to be used as storage.

Return value

= 0 OK, storage device added.
≠ 0 An error occurred.

Additional information

This function has to be called at least once for each instance of a LOGVOL driver. Each call to FS_LOGVOL_AddDeviceEx() defines a range of sectors to be used a storage from a volume attached to a device or logical driver. The volume to be used as storage is identified by pDeviceType and DeviceUnit. If the defined logical volume extends over two or more existing sectors then all of these volumes need to have the same logical sector size.

If NumSectors is set to 0 then all the sectors of the specified volume are used as storage.

FS_LOGVOL_AddDeviceEx does nothing if FS_LOGVOL_SUPPORT_DRIVER_MODE is set to 0.

Example

The following example demonstrates how to configure the logical driver to use as storage only a sector range of an SD card via the SD/MMC card mode driver. The application can access the volume under the name “sdcard”.

```
#include "FS.h"
#include "FS_MMC_HW_CM_Template.h"

#define ALLOC_SIZE          0x2000        // Size of emFile memory pool
#define START_SECTOR        0             // Index of the first sector to be used.
#define NUM_SECTORS         10000         // Number of sectors in the LOGVOL volume.

static U32 _aMemBlock[ALLOC_SIZE / 4];    // emFile memory pool.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give file system memory to work with.
```

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```
  //
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Add SD/MMC card device driver but do not attach any volume to it.
  //
  FS_AddPhysDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(0, 1);
  FS_MMC_CM_AllowHighSpeedMode(0, 1);
  FS_MMC_CM_SetHWType(0, &FS_MMC_HW_CM_Template);
  //
  // Add and configure the logical volume. Volume name: "sdcard".
  //
#if FS_LOGVOL_SUPPORT_DRIVER_MODE
  FS_AddDevice(&FS_LOGVOL_Driver);
  FS_LOGVOL_AddDeviceEx(0, &FS_MMC_CM_Driver, 0, START_SECTOR, NUM_SECTORS);
#endif // FS_LOGVOL_SUPPORT_DRIVER_MODE
#if (FS_MAX_LEN_VOLUME_ALIAS > 0)
  FS_SetVolumeAlias("lvol:0:", "sdcard");
#endif // FS_MAX_LEN_VOLUME_ALIAS > 0
}
```

This next example demonstrates how to configure the logical driver to use as storage volumes attached to a NAND and NOR flash device.

```
#include "FS.h"
#include "FS_NAND_HW_Template.h"
#include "FS_NOR_HW_SPIFI_Template.h"

#define ALLOC_SIZE          0x4000        // Size of emFile memory pool
#define BYTES_PER_SECTOR    2048          // Number of bytes in a logical sector.

static U32 _aMemBlock[ALLOC_SIZE / 4];    // emFile memory pool.

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give file system memory to work with.
  //
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
  //
  // Configure the size of the logical sector and activate the file buffering.
  //
  FS_SetMaxSectorSize(BYTES_PER_SECTOR);
  //
  // Add and configure the Universal NAND driver.
  //
  FS_AddPhysDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  FS_NAND_ONFI_SetHWType(0, &FS_NAND_HW_Template);
  //
  // Add and configure the NOR driver.
  //
  FS_AddPhysDevice(&FS_NOR_BM_Driver);
  FS_NOR_BM_SetPhyType(0, &FS_NOR_PHY_SPIFI);
  FS_NOR_BM_Configure(0, 0x80000000, 0x80000000, 0x01000000);
  FS_NOR_BM_SetSectorSize(0, BYTES_PER_SECTOR);
  FS_NOR_SPIFI_Allow2bitMode(0, 1);
  FS_NOR_SPIFI_Allow4bitMode(0, 1);
  FS_NOR_SPIFI_SetHWType(0, &FS_NOR_HW_SPIFI_Template);
#if FS_LOGVOL_SUPPORT_DRIVER_MODE
  //
  // Add and configure the logical volume.
  // The entire storage space of the NAND and NOR device is used.
  // Volume name: "lvol:0:".
  //
  FS_AddDevice(&FS_LOGVOL_Driver);
  FS_LOGVOL_AddDeviceEx(0, &FS_NAND_UNI_Driver, 0, 0, 0);
  FS_LOGVOL_AddDeviceEx(0, &FS_NOR_BM_Driver, 0, 0, 0);
```

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```
#endif // FS_LOGVOL_SUPPORT_DRIVER_MODE
}
```

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7.10.2 Performance and resource usage

7.10.2.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the driver presented in the tables below were measured as described in the section *Test procedure* on page 1439.

Usage: 1.0 Kbytes

7.10.2.2 Static RAM usage

Static RAM usage is the amount of RAM required by the driver for variables inside the driver. The number of bytes can be seen in a compiler list file.

Usage: 24 bytes

7.10.2.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the driver at runtime.

Usage: 6 bytes for each driver instance + **21 bytes** for each sector range defined via `FS_LOGVOL_AddDeviceEx()`.

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Chapter 8

Custom drivers

This chapter describes how to implement a custom device or logical driver.

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8.1 General information

emFile comes with device drivers that support all of the popular storage devices such as NAND flash, NOR flash and SD card. However, using a storage device that is not supported by emFile may require the implementation of a custom device driver. In addition, the functionality of the file system may be extended by implementing a custom logical driver. The following sections describe which functions are required to be implemented and how the custom device or logical driver can be used with emFile.

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8.2 Driver layer API

This section describes the functions of a device or logical driver. The API of the driver layer is implemented as a structure of type `FS_DEVICE_TYPE` that contains pointers to functions.

> **Note**
>
> The actual names of these functions are not relevant because the file system accesses them via the function table.

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8.2.1 FS_DEVICE_TYPE

Type definition

```
typedef struct {
  FS_DEVICE_TYPE_GET_NAME      * pfGetName;
  FS_DEVICE_TYPE_ADD_DEVICE    * pfAddDevice;
  FS_DEVICE_TYPE_READ          * pfRead;
  FS_DEVICE_TYPE_WRITE         * pfWrite;
  FS_DEVICE_TYPE_IOCTL         * pfIoCtl;
  FS_DEVICE_TYPE_INIT_MEDIUM   * pfInitMedium;
  FS_DEVICE_TYPE_GET_STATUS    * pfGetStatus;
  FS_DEVICE_TYPE_GET_NUM_UNITS * pfGetNumUnits;
} FS_DEVICE_TYPE;
```

Structure members

Member	Description
pfGetName	Returns the name of the driver.
pfAddDevice	Creates a new driver instance.
pfRead	Reads sector data.
pfWrite	Writes sector data.
pfIoCtl	Executes command.
pfInitMedium	Initializes the storage device.
pfGetStatus	Returns presence status of the storage device.
pfGetNumUnits	Returns the number of driver instances.

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8.2.2 FS_DEVICE_TYPE_GET_NAME

Description

Returns the driver name.

Type definition

```
typedef const char * FS_DEVICE_TYPE_GET_NAME(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

Name of the driver as 0-terminated string.

Additional information

The returned name is used by the file system to create the volume name. The name must be unique between all device and logical drivers configured by the application.

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8.2.3 FS_DEVICE_TYPE_ADD_DEVICE

Description

Creates a new driver instance.

Type definition

```
typedef int FS_DEVICE_TYPE_ADD_DEVICE(void);
```

Return value

≥ 0	OK, index of the created driver instance.
< 0	Error code indicating the failure reason.

Additional information

This is the first function called by the file system. Typically, it is called from `FS_AddDevice()` or `FS_AddPhysDevice()` at the file system initialization.

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8.2.4 FS_DEVICE_TYPE_READ

Description

Reads one or more logical sectors from storage device.

Type definition

```
typedef int FS_DEVICE_TYPE_READ(U8     Unit,
                                 U32    SectorIndex,
                                 void * pData,
                                 U32    NumSectors);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
SectorIndex	First logical sector to be read from the device.
pData	Pointer to buffer that receives the sector data.
NumSectors	Number of logical sectors to be read.

Return value

= 0 OK, data successfully read.
≠ 0 Error code indicating the failure reason.

Additional information

The sector data has to be stored at the following bytes offsets in pData:

Byte offset
0
BytesPerSector
BytesPerSector * 2
BytesPerSector * 3
...
BytesPerSector * (NumSectors - 1)

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8.2.5 FS_DEVICE_TYPE_WRITE

Description

Writes one or more logical sectors to storage device.

Type definition

```
typedef int FS_DEVICE_TYPE_WRITE(      U8     Unit,
                                       U32    SectorIndex,
                                 const void * pData,
                                       U32    NumSectors,
                                       U8     RepeatSame);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
SectorIndex	First sector to be written to the device.
pData	Pointer to buffer containing the sector data to be written.
NumSectors	Number of logical sectors to write.
RepeatSame	Specifies how the sector data has to be written • 0 - Different data is stored to each sector. • 1 - Same data is stored to all sectors.

Return value

= 0 OK, data successfully written.
≠ 0 Error code indicating the failure reason.

Additional information

The sector data is stored at the following bytes offsets in pData if RepeatSame is set to 0:

Byte offset
0
BytesPerSector
BytesPerSector * 2
BytesPerSector * 3
...
BytesPerSector * (NumSectors - 1)

If RepeatSame is set to 1 then pData points to a memory region that is BytePerSector bytes large. This block of data has to be stored repeatedly to the logical sector indexes SectorIndex to SectorIndex + (NumSectors - 1)

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8.2.6 FS_DEVICE_TYPE_IOCTL

Description

Executes a driver command.

Type definition

```
typedef int FS_DEVICE_TYPE_IOCTL(U8     Unit,
                                  I32    Cmd,
                                  I32    Aux,
                                  void * pBuffer);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).
Cmd	Command to be executed.
Aux	Command parameter.
pBuffer	in Command parameter. out Command response.

Return value

≥ 0 OK, command executed successfully.
< 0 Error code indicating the failure reason.

Additional information

Cmd can be set to one of the *I/O command codes* on page 1357 values.

Aux and pBuffer are optional parameters to the command.

pBuffer is used by some of the commands to return a value to the caller.

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8.2.7 FS_DEVICE_TYPE_INIT_MEDIUM

Description

Initializes the specified driver instance.

Type definition

```
typedef int FS_DEVICE_TYPE_INIT_MEDIUM(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

= 0 OK, driver instance initialized.
≠ 0 Error code indicating the failure reason.

Additional information

This function is typically called when formatting or mounting a storage device.

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8.2.8 FS_DEVICE_TYPE_GET_STATUS

Description

Returns the presence status of the storage device.

Type definition

```
typedef int FS_DEVICE_TYPE_GET_STATUS(U8 Unit);
```

Parameters

Parameter	Description
Unit	Index of the driver instance (0-based).

Return value

FS_MEDIA_STATE_UNKNOWN	Presence status of storage device is unknown.
FS_MEDIA_NOT_PRESENT	Storage device is not present.
FS_MEDIA_IS_PRESENT	Storage device is present.

Additional information

This function is relevant only for drivers that access a removable storage device such as an SD card. For other storage devices or for a logical driver this function can simply return FS_MEDIA_IS_PRESENT.

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8.2.9 FS_DEVICE_TYPE_GET_NUM_UNITS

Description

Returns the number of driver instances.

Type definition

```
typedef int FS_DEVICE_TYPE_GET_NUM_UNITS(void);
```

Return value

≥ 0	Number of driver instances.
< 0	Error code indicating the failure reason.

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8.2.10 FS_ON_READ_ERROR_CALLBACK

Description

The function is called when a driver encounters an error while reading sector data.

Type definition

```
typedef int FS_ON_READ_ERROR_CALLBACK(const FS_DEVICE_TYPE * pDeviceType,
                                      U32                    DeviceUnit,
                                      U32                    SectorIndex,
                                      void                 * pBuffer,
                                      U32                    NumSectors);
```

Parameters

Parameter	Description
pDeviceType	Type of storage device which encountered the read error.
DeviceUnit	Unit number of the storage device where the read error occurred.
SectorIndex	Index of the sector where the read error occurred.
pBuffer	out Corrected sector data.
NumSectors	Number of sectors on which the read error occurred.

Return value

= 0 OK, sector data returned.
≠ 0 An error occurred.

Additional information

Typically, called by the NAND driver to get corrected sector data when a bit error occurs.

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8.2.11 FS_READ_ERROR_DATA

Description

Data passed as parameter to the FS_CMD_SET_READ_ERROR_CALLBACK command.

Type definition

```
typedef struct {
  FS_ON_READ_ERROR_CALLBACK * pfCallback;
} FS_READ_ERROR_DATA;
```

Structure members

Member	Description
pfCallback	Function to be called on a read error.

Additional information

This structure is passed via pBuffer to FS_DEVICE_TYPE_IOCTL.

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8.2.12 I/O command codes

Description

Command codes sent by the file system to device and logical drivers.

Definition

```
#define FS_CMD_REQUIRES_FORMAT            1003L
#define FS_CMD_GET_DEVINFO                1004L
#define FS_CMD_FORMAT_LOW_LEVEL           1005L
#define FS_CMD_FREE_SECTORS               1006L
#define FS_CMD_SET_DELAY                  1007L
#define FS_CMD_UNMOUNT                    1008L
#define FS_CMD_UNMOUNT_FORCED             1009L
#define FS_CMD_SYNC                       1010L
#define FS_CMD_DEINIT                     1011L
#define FS_CMD_CLEAN_ONE                  1012L
#define FS_CMD_CLEAN                      1013L
#define FS_CMD_GET_SECTOR_USAGE           1014L
#define FS_CMD_ENABLE_READ_AHEAD          1015L
#define FS_CMD_DISABLE_READ_AHEAD         1016L
#define FS_CMD_GET_CLEAN_CNT              1017L
#define FS_CMD_SET_READ_ERROR_CALLBACK    1018L
#define FS_CMD_SYNC_SECTORS               1019L
```

Symbols

Definition	Description
FS_CMD_REQUIRES_FORMAT	Checks if the storage device is low-level formatted.
FS_CMD_GET_DEVINFO	Returns information about the storage device.
FS_CMD_FORMAT_LOW_LEVEL	Performs a low-level format operation.
FS_CMD_FREE_SECTORS	Informs the driver about unused logical sectors.
FS_CMD_SET_DELAY	Configures an access delay.
FS_CMD_UNMOUNT	Invalidates all information about the storage device.
FS_CMD_UNMOUNT_FORCED	Invalidates all information about the storage device.
FS_CMD_SYNC	Request the driver to write any cached information to the storage device.
FS_CMD_DEINIT	Frees all resources allocated by all the driver instances.
FS_CMD_CLEAN_ONE	Requests the driver to perform one clean operation.
FS_CMD_CLEAN	Requests the driver to completely clean the storage device.
FS_CMD_GET_SECTOR_USAGE	Queries the driver about the usage of a logical sector.
FS_CMD_ENABLE_READ_AHEAD	Requests the driver to start reading sectors in advance.
FS_CMD_DISABLE_READ_AHEAD	Requests the driver to stop reading sectors in advance.
FS_CMD_GET_CLEAN_CNT	Returns the number of operations required to completely clean the storage device.
FS_CMD_SET_READ_ERROR_CALLBACK	Registers a handler for sector read errors.
FS_CMD_SYNC_SECTORS	Informs the driver about the sectors that must be synchronized.

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Additional information

FS_CMD_GET_DEVINFO is mandatory to be implemented. In addition, the driver implementation has to return 0 in response to FS_CMD_FREE_SECTORS if it does not implement this command. The other commands are optional and the driver is permitted to return -1 if it does not implement them.

FS_CMD_REQUIRES_FORMAT and FS_CMD_FORMAT_LOW_LEVEL must be implemented by any device driver that uses a storage device which has to be initialize once before use. FS_CMD_FORMAT_LOW_LEVEL is used by FS_FormatLow().

FS_CMD_SET_DELAY is used only by the FS simulation to test the RAM Disk driver.

The handling of FS_CMD_UNMOUNT and FS_CMD_UNMOUNT_FORCED has to invalidate any cached information related to the storage device.

The handling of FS_CMD_SYNC must write any dirty cached sector data to the storage device.

FS_CMD_DEINIT has to be handled only if the driver allocates dynamic memory and only when the file system is built with FS_SUPPORT_DEINIT set to 1.

The following tables details the usage of the Aux and pBuffer parameters specified in the call to FS_DEVICE_TYPE_IOCTL for each command code as well as the meaning of the return value. The commands that are not specified in a table do not make use of that parameter.

Cmd
FS_CMD_FREE_SECTORS
FS_CMD_SET_DELAY
FS_CMD_GET_SECTOR_USAGE
FS_CMD_SYNC_SECTORS

Cmd
FS_CMD_FREE_SECTORS
FS_CMD_SET_DELAY
FS_CMD_SET_READ_ERROR_CALLBACK
FS_CMD_SYNC_SECTORS

Cmd
FS_CMD_GET_DEVINFO
FS_CMD_CLEAN_ONE
FS_CMD_GET_SECTOR_USAGE
FS_CMD_GET_CLEAN_CNT

Cmd
FS_CMD_REQUIRES_FORMAT
FS_CMD_GET_DEVINFO
FS_CMD_FORMAT_LOW_LEVEL
FS_CMD_FREE_SECTORS
FS_CMD_SET_DELAY
FS_CMD_CLEAN_ONE
FS_CMD_CLEAN
FS_CMD_GET_SECTOR_USAGE
FS_CMD_GET_CLEAN_CNT

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Cmd
FS_CMD_SYNC_SECTORS

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8.3 Template implementation

The following template implementation can be used as a starting point for the implementation of a new device or logical driver. The implementation is included in the emFile shipment in the `Sample/FS/Driver/Template` folder.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_TEMPLATE_Driver.c
Purpose : Template for a FS driver.
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FS_TMPL_NUM_UNITS
  #define FS_TMPL_NUM_UNITS     4     // Maximum number of driver instances.
#endif

/*********************************************************************
*
*       Local data types
*
**********************************************************************
*/
typedef struct {
  U32 NumSectors;
  U16 NumHeads;
  U16 SectorsPerTrack;
  U8  ldBytesPerSector;
  U8  IsInited;
  U8  Unit;
} TMPL_INST;

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static TMPL_INST * _apInst[FS_TMPL_NUM_UNITS];
static int         _NumUnits = 0;

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _AllocInstIfRequired
*
*  Function description
*    Allocates memory for a driver instance.
*
```

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```
*  Parameters
*    Unit       Index of the driver instance.
*
*  Return value
*    !=NULL     OK, driver instance.
*    ==NULL     An error occurred.
*
*  Additional information
*    This function does not perform any operation if the driver instance
*    is already allocated.
*/
static TMPL_INST * _AllocInstIfRequired(unsigned Unit) {
  TMPL_INST * pInst;

  pInst = NULL;                         // Set to indicate error.
  if (Unit < (unsigned)FS_TMPL_NUM_UNITS) {
    pInst = _apInst[Unit];
    if (pInst == NULL) {
      FS_ALLOC_ZEROED_PTR(SEGGER_PTR2PTR(void *, &pInst), (I32)sizeof(TMPL_INST), "TMPL_INST");
      if (pInst != NULL) {
        _apInst[Unit] = pInst;
        pInst->Unit   = (U8)Unit;
      }
    }
  }
  return pInst;
}

/*********************************************************************
*
*       _GetInst
*
*  Function description
*    Returns a driver instance by driver index.
*
*  Parameters
*    Unit       Index of the driver instance.
*
*  Return value
*    !=NULL     OK, driver instance.
*    ==NULL     An error occurred.
*/
static TMPL_INST * _GetInst(unsigned Unit) {
  TMPL_INST * pInst;

  pInst = NULL;
  if (Unit < (unsigned)FS_TMPL_NUM_UNITS) {
    pInst = _apInst[Unit];
  }
  return pInst;
}

/*********************************************************************
*
*       _Init
*
*  Function description
*    Initializes the driver instance.
*
*  Parameters
*    pInst    Driver instance.
*
*  Return value
*    ==0      OK, driver instance initialize successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _Init(TMPL_INST * pInst) {
  //
  // TBD: Add code that initializes the storage device.
  //
  FS_USE_PARA(pInst);
  return FS_ERRCODE_INIT_FAILURE;
}

/*********************************************************************
*
```

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```
*       _InitIfRequired
*
*  Function description
*    Initializes the driver instance.
*
*  Parameters
*    pInst    Driver instance.
*
*  Return value
*    ==0      OK, driver instance initialize successfully.
*    !=0      Error code indicating the failure reason.
*
*  Additional information
*    This function does not perform any operation if the driver instance
*    is already initialized.
*/
static int _InitIfRequired(TMPL_INST * pInst) {
  int r;

  r = 0;
  if (pInst->NumSectors == 0u) {
    r = _Init(pInst);
  }
  return r;
}

/*********************************************************************
*
*       _GetStatus
*
*  Function description
*    Obtains the presence status of the storage device.
*
*  Parameters
*    pInst    Driver instance.
*
*  Return value
*    == FS_MEDIA_STATE_UNKNOWN    Presence status of storage device is unknown.
*    == FS_MEDIA_NOT_PRESENT      Storage device is not present.
*    == FS_MEDIA_IS_PRESENT       Storage device is present.
*/
static int _GetStatus(TMPL_INST * pInst) {
  //
  // TBD: Add code that queries the presence status.
  //
  FS_USE_PARA(pInst);
  return FS_MEDIA_STATE_UNKNOWN;
}

/*********************************************************************
*
*       _ReadSectors
*
*  Function description
*    Reads one or more logical sectors from storage device.
*
*  Parameters
*    pInst          Driver instance.
*    SectorIndex    First logical sector to be read from the device.
*    pData          Pointer to buffer that receives the sector data.
*    NumSectors     Number of logical sectors to be read.
*
*  Return value
*    ==0    OK, data successfully read.
*    !=0    Error code indicating the failure reason.
*/
static int _ReadSectors(TMPL_INST * pInst, U32 SectorIndex, void * pData, U32 NumSectors) {
  U32 NumSectorsTotal;

  if ((pData == NULL) || (NumSectors == 0u)) {
    return 0;                                          // OK, nothing to do.
  }
  NumSectorsTotal = pInst->NumSectors;
  if ((SectorIndex >= NumSectorsTotal) || ((SectorIndex + NumSectors) > NumSectorsTotal)) {
    FS_DEBUG_ERROROUT((FS_MTYPE_DRIVER, "TMPL: _ReadSectors: Invalid sector range ([%d, %d] not in
 [0, %d]).", (int)SectorIndex, (int)SectorIndex + (int)NumSectors - 1, (int)NumSectorsTotal - 1));
```

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```
    return FS_ERRCODE_INVALID_PARA;                  // Error, invalid sector range.
  }
  //
  // TBD: Add code that performs the read operation.
  //
  return FS_ERRCODE_READ_FAILURE;
}

/*********************************************************************
*
*       _WriteSectors
*
*  Function description
*    Writes one or more logical sectors to storage device.
*
*  Parameters
*    pInst        Driver instance.
*    SectorIndex  First sector to be written to the device.
*    pData        Pointer to buffer containing the sector data to be written.
*    NumSectors   Number of logical sectors to write.
*    RepeatSame   Specifies how the sector data has to be written
*                 *  0 - Different data is stored to each sector.
*                 *  1 - Same data is stored to all sectors.
*
*  Return value
*    ==0    OK, data successfully written.
*    !=0    Error code indicating the failure reason.
*/
static int _WriteSectors(TMPL_INST * pInst, U32 SectorIndex, const void * pData, U32 NumSectors, int RepeatSame) {
  U32 NumSectorsTotal;

  if ((pData == NULL) || (NumSectors == 0u)) {
    return 0;                                        // OK, nothing to do.
  }
  NumSectorsTotal = pInst->NumSectors;
  if ((SectorIndex >= NumSectorsTotal) || ((SectorIndex + NumSectors) > NumSectorsTotal)) {
    FS_DEBUG_ERROROUT((FS_MTYPE_DRIVER, "TMPL: _WriteSectors: Invalid sector range ([%d, %d] not in
 [0, %d]).", (int)SectorIndex, (int)SectorIndex + (int)NumSectors - 1, (int)NumSectorsTotal - 1));
    return FS_ERRCODE_INVALID_PARA;                  // Error, invalid sector range.
  }
  //
  // TBD: Add code that performs the write operation.
  //
  (void)RepeatSame;
  return FS_ERRCODE_WRITE_FAILURE;
}

/*********************************************************************
*
*       _FreeSectors
*
*  Function description
*    Informs the storage device about unused sectors.
*
*  Parameters
*    pInst          Driver instance.
*    SectorIndex    Index of the first sector in the range.
*    NumSectors     Number of sectors in the range
*
*  Return value
*    ==0      OK, successfully marked sectors as free.
*    !=0      Error code indicating the failure reason.
*
*  Additional information
*    This function has to return success if it does not perform any operation.
*    The reason for this to prevent the file system from running into errors.
*/
static int _FreeSectors(TMPL_INST * pInst, U32 SectorIndex, U32 NumSectors) {
  U32 NumSectorsTotal;

  if (NumSectors == 0u) {
    return 0;                                        // OK, nothing to do.
  }
  NumSectorsTotal = pInst->NumSectors;
  if ((SectorIndex >= NumSectorsTotal) || ((SectorIndex + NumSectors) > NumSectorsTotal)) {
```

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```
    FS_DEBUG_ERROROUT((FS_MTYPE_DRIVER, "TMPL: _FreeSectors: Invalid sector range ([%d, %d] not in
 [0, %d]).", (int)SectorIndex, (int)SectorIndex + (int)NumSectors - 1, (int)NumSectorsTotal - 1));
    return FS_ERRCODE_INVALID_PARA;                   // Error, invalid sector range.
  }
  //
  // TBD: Add code that frees sectors.
  //
  (void)pInst;
  (void)SectorIndex;
  (void)NumSectors;
  return 0;
}

/*********************************************************************
*
*       _ExecCmdGetDevInfo
*
*  Function description
*    Executes the FS_CMD_GET_DEVINFO command.
*
*  Parameters
*    pInst        Driver instance.
*    pBuffer      [OUT] Command result.
*
*  Return value
*    ==0      OK, command executed successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _ExecCmdGetDevInfo(TMPL_INST * pInst, void * pBuffer) {
  int           r;
  FS_DEV_INFO * pDeviceInfo;

  r = FS_ERRCODE_INVALID_PARA;
  if (pBuffer != NULL) {
    r = _InitIfRequired(pInst);
    if (r == 0) {
      pDeviceInfo = SEGGER_PTR2PTR(FS_DEV_INFO, pBuffer);
      pDeviceInfo->NumSectors      = pInst->NumSectors;
      pDeviceInfo->BytesPerSector  = (U16)(1uL << pInst->ldBytesPerSector);
      pDeviceInfo->NumHeads        = pInst->NumHeads;
      pDeviceInfo->SectorsPerTrack = pInst->SectorsPerTrack;
    }
  }
  return r;
}

/*********************************************************************
*
*       _ExecCmdFreeSectors
*
*  Function description
*    Executes the FS_CMD_FREE_SECTORS command.
*
*  Parameters
*    pInst      Driver instance.
*    Aux        Command parameter.
*    pBuffer    [IN] Command parameter.
*
*  Return value
*    ==0      OK, command executed successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _ExecCmdFreeSectors(TMPL_INST * pInst, I32 Aux, const void * pBuffer) {
  int r;
  U32 SectorIndex;
  U32 NumSectors;

  r = FS_ERRCODE_INVALID_PARA;
  if (pBuffer != NULL) {
    SectorIndex = (U32)Aux;
    NumSectors  = *SEGGER_CONSTPTR2PTR(const U32, pBuffer);
    r = _FreeSectors(pInst, SectorIndex, NumSectors);
  }
  return r;
}
```

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```
/*********************************************************************
*
*       _ExecCmdUnmount
*
*  Function description
*    Executes the FS_CMD_UNMOUNT command.
*
*  Parameters
*    pInst      Driver instance.
*
*  Return value
*    ==0      OK, command executed successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _ExecCmdUnmount(TMPL_INST * pInst) {
  pInst->IsInited         = 0;
  pInst->NumSectors       = 0;
  pInst->ldBytesPerSector = 0;
  return 0;
}

/*********************************************************************
*
*       _ExecCmdUnmountForced
*
*  Function description
*    Executes the FS_CMD_UNMOUNT_FORCED command.
*
*  Parameters
*    pInst      Driver instance.
*
*  Return value
*    ==0      OK, command executed successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _ExecCmdUnmountForced(TMPL_INST * pInst) {
  pInst->IsInited         = 0;
  pInst->NumSectors       = 0;
  pInst->ldBytesPerSector = 0;
  return 0;
}

#if FS_SUPPORT_DEINIT

/*********************************************************************
*
*       _ExecCmdDeInit
*
*  Function description
*    Frees the resources allocated for a driver instance.
*
*  Parameters
*    pInst      Driver instance.
*
*  Return value
*    ==0      OK, command executed successfully.
*    !=0      Error code indicating the failure reason.
*/
static int _ExecCmdDeInit(TMPL_INST * pInst) {
  unsigned Unit;

  Unit = pInst->Unit;
  FS_FREE(pInst);
  _apInst[Unit] = NULL;
  _NumUnits--;
  return 0;
}

#endif // FS_SUPPORT_DEINIT

/*********************************************************************
*
*       Public code (indirectly via callback)
*
**********************************************************************
*/
```

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```
/*********************************************************************
*
*       _TMPL_GetDriverName
*
*  Function description
*    Returns the driver name.
*
*  Parameters
*    Unit   Index of the driver instance (0-based).
*
*  Return value
*    Name of the driver as 0-terminated string.
*
*  Additional information
*    The returned name is used by the file system to create the volume name.
*    The name must be unique between all device and logical drivers configured
*    by the application.
*/
static const char * _TMPL_GetDriverName(U8 Unit) {
  FS_USE_PARA(Unit);
  return "tmpl";
}

/*********************************************************************
*
*       _TMPL_AddDevice
*
*  Function description
*    Creates a new driver instance.
*
*  Return value
*    >=0    OK, index of the created driver instance.
*    < 0    Error code indicating the failure reason.
*
*  Additional information
*    This is the first function called by the file system. Typically,
*    it is called from FS_AddDevice() or FS_AddPhysDevice()
*    at the file system initialization.
*/
static int _TMPL_AddDevice(void) {
  TMPL_INST * pInst;
  int         r;

  r = FS_ERRCODE_INVALID_PARA;
  pInst = _AllocInstIfRequired(_NumUnits);
  if (pInst != NULL) {
    r = (int)_NumUnits++;
  }
  return r;
}

/*********************************************************************
*
*       _TMPL_Read
*
*  Function description
*    Reads one or more logical sectors from storage device.
*
*  Parameters
*    Unit           Index of the driver instance (0-based).
*    SectorIndex    First logical sector to be read from the device.
*    pData          Pointer to buffer that receives the sector data.
*    NumSectors     Number of logical sectors to be read.
*
*  Return value
*    ==0    OK, data successfully read.
*    !=0    Error code indicating the failure reason.
*
*  Additional information
*    The sector data has to be stored at the following bytes offsets in pData:
*    +-----------------------------------+---------------------------------+
*    | Byte offset                       | Logical sector index            |
*    +-----------------------------------+---------------------------------+
*    | 0                                 | SectorIndex                     |
*    +-----------------------------------+---------------------------------+
```

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```
*    | BytesPerSector                    | SectorIndex + 1               |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * 2                | SectorIndex + 2               |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * 3                | SectorIndex + 3               |
*    +-----------------------------------+-------------------------------+
*    | ...                               | ...                           |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * (NumSectors - 1) | SectorIndex + (NumSectors - 1) |
*    +-----------------------------------+-------------------------------+
*/
static int _TMPL_Read(U8 Unit, U32 SectorIndex, void * pData, U32 NumSectors) {
  int         r;
  TMPL_INST * pInst;

  pInst = _GetInst(Unit);
  if (pInst == NULL) {
    return FS_ERRCODE_INVALID_PARA;                  // Error, instance not found.
  }
  r = _ReadSectors(pInst, SectorIndex, pData, NumSectors);
  return r;
}

/*********************************************************************
*
*       _TMPL_Write
*
*  Function description
*    Writes one or more logical sectors to storage device.
*
*  Parameters
*    Unit         Index of the driver instance (0-based).
*    SectorIndex  First sector to be written to the device.
*    pData        Pointer to buffer containing the sector data to be written.
*    NumSectors   Number of logical sectors to write.
*    RepeatSame   Specifies how the sector data has to be written
*                 *  0 - Different data is stored to each sector.
*                 *  1 - Same data is stored to all sectors.
*
*  Return value
*    ==0    OK, data successfully written.
*    !=0    Error code indicating the failure reason.
*
*  Additional information
*    The sector data is stored at the following bytes offsets in pData
*    if RepeatSame is set to 0:
*    +-----------------------------------+-------------------------------+
*    | Byte offset                       | Logical sector index          |
*    +-----------------------------------+-------------------------------+
*    | 0                                 | SectorIndex                   |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector                    | SectorIndex + 1               |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * 2                | SectorIndex + 2               |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * 3                | SectorIndex + 3               |
*    +-----------------------------------+-------------------------------+
*    | ...                               | ...                           |
*    +-----------------------------------+-------------------------------+
*    | BytesPerSector * (NumSectors - 1) | SectorIndex + (NumSectors - 1) |
*    +-----------------------------------+-------------------------------+
*
*    If RepeatSame is set to 1 then pData points to a memory region that
*    is BytePerSector bytes large. This block of data has to be stored
*    repeatedly to the logical sector indexes SectorIndex to
*    SectorIndex + (NumSectors - 1)
*/
static int _TMPL_Write(U8 Unit, U32 SectorIndex, const void * pData, U32 NumSectors, U8 RepeatSame) {
  int         r;
  TMPL_INST * pInst;

  pInst = _GetInst(Unit);
  if (pInst == NULL) {
    return FS_ERRCODE_INVALID_PARA;                  // Error, instance not found.
  }
  r = _WriteSectors(pInst, SectorIndex, pData, NumSectors, (int)RepeatSame);
```

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```
  return r;
}

/*********************************************************************
*
*       _TMPL_IoCtl
*
*  Function description
*    Executes a driver command.
*
*  Parameters
*    Unit      Index of the driver instance (0-based).
*    Cmd       Command to be executed.
*    Aux       Command parameter.
*    pBuffer   [IN] Command parameter.
*              [OUT] Command response.
*
*  Return value
*    >=0      OK, command executed successfully.
*    < 0      Error code indicating the failure reason.
*
*  Additional information
*    Cmd can be one of the codes listed in \ref{I/O command codes}.
*    Aux and pBuffer are optional parameters to the command.
*    pBuffer is used by some of the commands to return a value
*    to the caller.
*/
static int _TMPL_IoCtl(U8 Unit, I32 Cmd, I32 Aux, void * pBuffer) {
  int         r;
  TMPL_INST * pInst;

  pInst = _GetInst(Unit);
  if (pInst == NULL) {
    return FS_ERRCODE_INVALID_PARA;
  }
  switch (Cmd) {
  case FS_CMD_GET_DEVINFO:
    r = _ExecCmdGetDevInfo(pInst, pBuffer);
    break;
  case FS_CMD_FREE_SECTORS:
    r = _ExecCmdFreeSectors(pInst, Aux, pBuffer);
    break;
  case FS_CMD_UNMOUNT:
    r = _ExecCmdUnmount(pInst);
    break;
  case FS_CMD_UNMOUNT_FORCED:
    r = _ExecCmdUnmountForced(pInst);
    break;
#if FS_SUPPORT_DEINIT
  case FS_CMD_DEINIT:
    r = _ExecCmdDeInit(pInst);
    break;
#endif // FS_SUPPORT_DEINIT
  default:
    r = FS_ERRCODE_NOT_SUPPORTED;                 // Error, command not supported.
    break;
  }
  return r;
}

/*********************************************************************
*
*       _TMPL_InitMedium
*
*  Function description
*    Initializes the specified driver instance.
*
*  Parameters
*    Unit   Index of the driver instance (0-based).
*
*  Return value
*    ==0    OK, driver instance initialized.
*    !=0    Error code indicating the failure reason.
*
*  Additional information
*    This function is typically called when formatting or mounting
```

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```
*    a storage device.
*/
static int _TMPL_InitMedium(U8 Unit) {
  int         r;
  TMPL_INST * pInst;

  r     = FS_ERRCODE_INVALID_PARA;
  pInst = _GetInst(Unit);
  if (pInst != NULL) {
    r = _InitIfRequired(pInst);
  }
  return r;
}

/*********************************************************************
*
*       _TMPL_GetStatus
*
*  Function description
*    Returns the presence status of the storage device.
*
*  Parameters
*    Unit     Index of the driver instance (0-based).
*
*  Return value
*    == FS_MEDIA_STATE_UNKNOWN    Presence status of storage device is unknown.
*    == FS_MEDIA_NOT_PRESENT      Storage device is not present.
*    == FS_MEDIA_IS_PRESENT       Storage device is present.
*
*  Additional information
*    This function is relevant only for drivers that access a removable
*    storage device such as an SD card. For other storage devices or
*    for a logical driver this function can simply return FS_MEDIA_IS_PRESENT.
*/
static int _TMPL_GetStatus(U8 Unit) {
  int         Status;
  TMPL_INST * pInst;

  Status = FS_MEDIA_STATE_UNKNOWN;
  pInst = _GetInst(Unit);
  if (pInst != NULL) {
    Status = _GetStatus(pInst);
  }
  return Status;
}

/*********************************************************************
*
*       _GetNumUnits
*
*  Function description
*    Returns the number of driver instances.
*
*  Return value
*    >=0    Number of driver instances.
*    < 0    Error code indicating the failure reason.
*/
static int _TMPL_GetNumUnits(void) {
  return _NumUnits;
}

/*********************************************************************
*
*       Public data
*
**********************************************************************
*/
const FS_DEVICE_TYPE FS_TMPL_Driver = {
  _TMPL_GetDriverName,
  _TMPL_AddDevice,
  _TMPL_Read,
  _TMPL_Write,
  _TMPL_IoCtl,
  _TMPL_InitMedium,
  _TMPL_GetStatus,
  _TMPL_GetNumUnits
```

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```
};

/************************** End of file ***************************/
```

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Chapter 9

Configuration of emFile

This chapter describes how to configure emFile at compile time as well as at runtime.

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9.1 General information

emFile was designed to be highly configurable in order to meet the different requirements of target applications. Typically, the configuration is performed by the application runtime and optionally by the user at compile time.

emFile can be used without the need for changing any of the configuration defines at compile time. All configuration defines are preconfigured with valid values that meet the requirements of most applications. Device and logical drivers do not have to be configured at compile time. The application can add them at runtime as required.

The default configuration of emFile can be changed at compile time by specifying different values for the configuration defines in `FS_Conf.h` that is dedicated to this purpose. This is the main configuration file for the file system. It is not recommended to modify any file system files in order to change the default values of the configuration defines.

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9.2 Compile time configuration

This section describes the configuration defines of the File system and Storage layer that can be used to customize the behavior of emFile. The configuration defines of other file system components are described in their respective sections of the emFile manual.

The following types of configuration defines exist:

- Binary switches (B) - Switches can have a value of either 0 or 1, for deactivated and activated, respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration defines.
- Numerical values (N) - Numerical values are used somewhere in the code in place of a numerical constant. A typical example is the configuration of the sector size of a storage device.
- Character values (C) - This is a configuration define that takes a single character as value. A typical example is the character used to separate directory names in a path to a file or directory.
- Character strings (S) - A configuration define of this type can take as value a 0-terminated array of characters. A typical usage is a configuration define that specifies a file name.
- Text replacement (R) - This type of configuration define contains text to be replaced by the preprocessor. It is typically used for functions and variable specifiers that enable compiler-specific optimizations.
- Function replacement (F) - Configuration defines of this type are function replacement macros that can also take parameters. They are typically used to substitute the default implementation of functions used by the file system at compile time.

9.2.1 General file system configuration

The following table lists the configuration defines that apply to the entire file system.

Define	Type	Default value	Description
FS_BUFFER_SIZE_FILE_COPY	N	512	Size of the work buffer used by FS_CopyFile().
FS_BUFFER_SIZE_FILE_PRINT	N	128	Size of the work buffer used by FS_FPrintf().
FS_BUFFER_SIZE_FILE_WIPE	N	512	Size of the work buffer used by FS_WipeFile().
FS_BUFFER_SIZE_TRUNCATE	N	512	Size of the work buffer used by FS_Truncate().
FS_BUFFER_SIZE_VERIFY	N	128	Size of the work buffer used by FS_Verify().
FS_DIRECTORY_DELIMITER	C	'\\'	Character used to delimit directories in a path.
FS_DRIVER_ALIGNMENT	N	4	Defines the minimum data alignment for 0-copy operation.
FS_FILL_PATTERN_UNUSED_DATA	N	0xFF	Value to be used to fill unused bytes in a logical sector.
FS_MAX_LEN_FULL_FILE_NAME	N	256	Maximum number of characters in a fully qualified file name.
FS_MAX_LEN_VOLUME_ALIAS	N	0	Maximum number of characters in a volume alias.
FS_MAX_PATH	N	260	Maximum number of characters in a path.

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Define	Type	Default value	Description
FS_MEMORY_ALIGNMENT	N	4	Alignment of internally allocated memory.
FS_MULTI_HANDLE_SAFE	B	0	Enables or disables simultaneous read/write access to a file.
FS_NUM_DIR_HANDLES	N	1	Maximum number of file system directory handles.
FS_NUM_VOLUMES	N	4	Maximum number of file system volumes.
FS_OPTIMIZATION_TYPE	N	FS_OPTIMIZATION_TYPE_BALANCED	Optimization goal of the file system.
FS_OPTIMIZE	R		Function specifier for optimized functions.
FS_SUPPORT_BUSY_LED	B	1	Enables or disables support for the busy LED.
FS_SUPPORT_CACHE	B	1	Enables or disables support for the sector cache.
FS_SUPPORT_CHECK_MEMORY	B	0	Enables or disables the check for 0-copy operations.
FS_SUPPORT_DEINIT	B	0	Enables or disables support for deinitialization.
FS_SUPPORT_EFS	B	0	Enables or disables support for the EFS file system.
FS_SUPPORT_EXFAT	B	0	Enables or disables support for the exFAT file system.
FS_SUPPORT_EXT_ASCII	B	0 or 1	Enables or disables support for extended ASCII characters in file names.
FS_SUPPORT_EXT_MEM_MANAGER	B	0	Enables or disables support for an external memory manager.
FS_SUPPORT_FAT	B	1	Enables or disables support for the FAT file system.
FS_SUPPORT_FILE_BUFFER	B	1	Enables or disables support for the file buffer.
FS_SUPPORT_FILE_BUFFER_LIST	B	0	Enables or disables support for a dedicated file buffer list.
FS_SUPPORT_FILE_BUFFER_RELOCATABLE	B	0	Enables or disables support for a configurable file buffer location.
FS_SUPPORT_FILE_NAME_ENCODING	B	0	Enables or disables support for encoded file names.
FS_SUPPORT_FREE_SECTOR	B	1	Enables or disables support for unused sector notification.
FS_SUPPORT_GPT	B	1	Enables or disables support for GUID partition tables.
FS_SUPPORT_LARGE_FILES	B	0 or 1	Enables or disables support for files with a size larger than or equal to 4GB.

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Define	Type	Default value	Description
FS_SUPPORT_MBCS	B	0	Enables or disables support for multi-byte character sets in file names.
FS_SUPPORT_POSIX	B	0	Enables or disables support for POSIX compatibility.
FS_SUPPORT_SECTOR_BUFFER_BURST	B	0	Enables or disables support for accessing multiple logical sectors via the internal sector buffers.
FS_SUPPORT_SECTOR_BUFFER_CACHE	B	0	Enables or disables support for caching of internal sector buffers.
FS_SUPPORT_TIME_DATE_ENHANCED	B	0 or 1	Enables or disables support for extended timestamps.
FS_SUPPORT_VOLUME_ALIAS	B	1	Enables or disables support for setting an alternative volume name.
FS_SUPPRESS_EOF_ERROR	B	0	Enables or disables end of file error reporting.

9.2.1.1 FS_BUFFER_SIZE_FILE_COPY

FS_CopyFile() uses a work buffer located on the stack for reading the data from the file to be copied. FS_BUFFER_SIZE_FILE_COPY can be used to specify the size of this work buffer. A larger buffer provides better performance at the expense of increased stack usage.

9.2.1.2 FS_BUFFER_SIZE_FILE_PRINT

FS_FPrintf() uses a work buffer located on the stack for formatting the data before it is written to the file. FS_BUFFER_SIZE_FILE_PRINT can be used to specify the size of this work buffer. A larger buffer provides better performance at the expense of increased stack usage.

9.2.1.3 FS_BUFFER_SIZE_FILE_WIPE

FS_WipeFile() uses a work buffer located on the stack for the random data that is written to the file. FS_BUFFER_SIZE_FILE_WIPE can be used to specify the size of this work buffer. A larger buffer provides a better performance at the expense of increased stack usage.

9.2.1.4 FS_BUFFER_SIZE_TRUNCATE

FS_Truncate() uses a work buffer located on the stack for the initialization of the extended file contents when the support for POSIX operation is enabled. FS_BUFFER_SIZE_TRUNCATE can be used to specify the size of this work buffer. A larger buffer provides better performance at the expense of increased stack usage.

9.2.1.5 FS_BUFFER_SIZE_VERIFY

FS_Verify() uses a work buffer located on the stack for reading the data from the file to be verified. FS_BUFFER_SIZE_VERIFY can be used to specify the size of this work buffer. A larger buffer provides a better performance at the expense of increased stack usage.

9.2.1.6 FS_DIRECTORY_DELIMITER

FS_DIRECTORY_DELIMITER defines the character that is used to separate the names of the directories in a path to a file or directory. Typically, the value of this define is set either to '\' or to '/'.

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9.2.1.7 FS_DRIVER_ALIGNMENT

The value of this define is used by the file system to check if a 0-copy operation can be executed. A 0-copy operation is performed only when the address of the data is aligned to FS_DRIVER_ALIGNMENT and the number of data bytes in the block is a multiple of the logical sector size. If the data to be read or written is not aligned to FS_DRIVER_ALIGNMENT, then the file system uses the internal sector buffers for the data transfers, which is typically slower in comparison with a 0-copy operation.

9.2.1.8 FS_FILL_PATTERN_UNUSED_DATA

The value of this define is used by the file system to initialize all the unused bytes of the logical sector that stores the data located at the end of a file that has a size which is not a multiple of a logical sector size.

9.2.1.9 FS_MAX_LEN_FULL_FILE_NAME

This configuration define is used when FS_MULTI_HANDLE_SAFE is set to 1 to reserve space for the fully qualified file name in the file object assigned to an opened file. The value specified via this configuration define is also used by the BigFAT component to reserve space in the file handle for the name of the opened file.

9.2.1.10 FS_MAX_LEN_VOLUME_ALIAS

This configuration define specifies the maximum number of characters allowed in a volume alias including the 0-terminator. If set to 0 then only a reference to the volume alias is stored. A volume alias can be set via FS_SetVolumeAlias(). The RAM usage of the file system increases if this configuration define is set to a value different from 0. The volume alias feature can be enabled via FS_SUPPORT_VOLUME_ALIAS.

9.2.1.11 FS_MAX_PATH

FS_MAX_PATH specifies the maximum number of characters in a path to a file or directory including the 0-terminator. It is used for example by FS_CreateDir() for allocating a work buffer for path processing.

9.2.1.12 FS_MEMORY_ALIGNMENT

FS_MEMORY_ALIGNMENT can be used to specify the alignment of the memory allocated by the file system from the internal memory pool that is configured via FS_AssignMemory(). Permitted values for this define are 4 and 8. The value represents the alignment in number of bytes. The configured alignment can be obtained at runtime using FS_GetMemInfo(). This function returns the alignment via the NumBytesAlignment member of the FS_MEM_INFO structure.

FS_MEMORY_ALIGNMENT is not used if the file system is built with FS_SUPPORT_EXT_MEM_MANAGER set to 1.

9.2.1.13 FS_MULTI_HANDLE_SAFE

This configuration define has to be set to 1 if the application is expected to write and read from a file at the same time. Activating this feature increases the RAM usage of the file system. For more information refer to *Resource usage* on page 1439.

9.2.1.14 FS_NUM_DIR_HANDLES

The value of this configuration define specifies the maximum number of directory handles that can be opened at the same time via FS_OpenDir(). Please note that FS_OpenDir() is deprecated. It is recommended that applications use FS_FindFirstFile() and FS_FindNextFile() instead for listing the contents of a directory.

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9.2.1.15 FS_NUM_VOLUMES

FS_NUM_VOLUMES specifies the maximum number of volumes the file system can handle. This value is currently used only by the Journaling component, and it represents the maximum number of volumes on which the journal can be enabled.

9.2.1.16 FS_OPTIMIZATION_TYPE

This configuration define can be used to modify multiple configuration defines at once in order to configure the file system operation for a specified goal such as reduced memory usage or increased speed. If FS_OPTIMIZATION_TYPE is set to FS_OPTIMIZATION_TYPE_BALANCED then the configuration defines are set as documented in the "Default value" column of the summary table that documents that define.

With FS_OPTIMIZATION_TYPE set to FS_OPTIMIZATION_TYPE_MIN_SIZE the configuration defines are set as in the following table.

Define	Value
FS_SUPPORT_FREE_SECTOR	0
FS_SUPPORT_CACHE	0
FS_MAX_LEN_FULL_FILE_NAME	64
FS_SUPPORT_BUSY_LED	0
FS_SUPPORT_FILE_BUFFER	0
FS_SUPPORT_VOLUME_ALIAS	0
FS_NUM_VOLUMES	1
FS_BUFFER_SIZE_VERIFY	32
FS_BUFFER_SIZE_FILE_COPY	32
FS_BUFFER_SIZE_FILE_WIPE	32
FS_BUFFER_SIZE_TRUNCATE	32
FS_BUFFER_SIZE_PRINT	32
FS_DEBUG_LEVEL	0
FS_JOURNAL_SUPPORT_FREE_SECTOR	0
FS_JOURNAL_SUPPORT_FAST_SECTOR_SEARCH	0
FS_FAT_SUPPORT_FAT32	0
FS_FAT_USE_FSINFO_SECTOR	0
FS_FAT_OPTIMIZE_DELETE	0
FS_FAT_OPTIMIZE_LINEAR_ACCESS	0
FS_FAT_SUPPORT_FREE_CLUSTER_CACHE	0
FS_FAT_LFN_BIT_ARRAY_SIZE	32
FS_FAT_LFN_LOWER_CASE_SHORT_NAMES	0
FS_EFS_OPTIMIZE_DELETE	0
FS_EFS_SUPPORT_STATUS_SECTOR	0
FS_EFS_SUPPORT_DIRENTRY_BUFFERS	1
FS_EFS_OPTIMIZE_LINEAR_ACCESS	0
FS_NO_CLIB	1
FS_NAND_NUM_UNITS	1
FS_NAND_SUPPORT_CLEAN	0
FS_NAND_ECC_HOOK_DEFAULT	NULL
FS_NAND_SUPPORT_BLOCK_GROUPING	0

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Define	Value
FS_NAND_SUPPORT_FAST_WRITE	0
FS_NAND_SPI_DEVICE_LIST_DEFAULT	NULL
FS_NAND_SUPPORT_EXT_ONFI_PARA	0
FS_NAND_ONFI_DEVICE_LIST_DEFAULT	NULL
FS_NAND_2048X8_DEVICE_LIST_DEFAULT	NULL
FS_NOR_NUM_UNITS	1
FS_NOR_SUPPORT_CLEAN	0
FS_NOR_SKIP_BLANK_SECTORS	0
FS_NOR_NUM_FREE_SECTORCACHE	32
FS_NOR_SUPPORT_FORMAT	0
FS_NOR_MAX_SECTOR_BLOCKS	1
FS_NOR_DEVICE_LIST_DEFAULT	NULL
FS_NOR_OPTIMIZE_DATA_WRITE	0
FS_NOR_SUPPORT_ACCESS_ALIGNMENT	0
FS_MMC_NUM_UNITS	1
FS_IDE_NUM_UNITS	1
FS_RAMDISK_NUM_UNITS	1
FS_WINDRIVE_NUM_UNITS	1
FS_CRYPT_NUM_UNITS	1
FS_CRYPT_AES_OPTIMIZE_MIX_SUBST	0
FS_LOGVOL_NUM_UNITS	1
FS_READAHEAD_NUM_UNITS	1
FS_DISKPART_NUM_UNITS	1
FS_RAID_NUM_UNITS	1
FS_SECSIZE_NUM_UNITS	1
FS_WRBUF_NUM_UNITS	1

With FS_OPTIMIZATION_TYPE set to FS_OPTIMIZATION_TYPE_MAX_SPEED the configuration defines are set as in the following table.

Define	Value
FS_SUPPORT_SECTOR_BUFFER_BURST	1
FS_SUPPORT_SECTOR_BUFFER_CACHE	1
FS_EFS_SUPPORT_FREE_CLUSTER_CACHE	1
FS_CRYPT_AES_OPTIMIZE_MIX_COLUMNS	2
FS_NOR_OPTIMIZE_EMPTY_CHECK	1

The configuration defines that are not listed in the above tables are left to their default values.

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9.2.1.16.1 Optimization types

Description

Types of build optimization.

Definition

```
#define FS_OPTIMIZATION_TYPE_BALANCED     0
#define FS_OPTIMIZATION_TYPE_MIN_SIZE     1
#define FS_OPTIMIZATION_TYPE_MAX_SPEED    2
```

Symbols

Definition	Description
FS_OPTIMIZATION_TYPE_BALANCED	No special optimization.
FS_OPTIMIZATION_TYPE_MIN_SIZE	Optimized for reduced ROM and RAM usage.
FS_OPTIMIZATION_TYPE_MAX_SPEED	Optimized for maximum speed.

Additional information

These values can be assigned at compile-time to the FS_OPTIMIZATION_TYPE configuration define.

9.2.1.17 FS_OPTIMIZE

The declaration of some of the computing-intensive file system functions is prefixed with this configuration define. The application can set it to a compiler-specific specifier that makes the function run faster such as executing the function from RAM.

9.2.1.18 FS_SUPPORT_BUSY_LED

FS_SUPPORT_BUSY_LED can be used to enable or disable the support for a callback function that is invoked by the file system at the beginning and at the end of a sector read or write operation. As the name of this configuration define suggests, the registered callback function can be used to indicate that the file system is busy accessing the storage device by turning an LED on and off. The callback function must be registered at runtime via FS_SetBusyLEDCallback().

9.2.1.19 FS_SUPPORT_CACHE

This configuration define can be used to enable or disable the support for sector cache. The sector cache must be enabled at runtime by the application. Refer to *Sector cache* on page 457 for more information about this.

9.2.1.20 FS_SUPPORT_CHECK_MEMORY

FS_SUPPORT_CHECK_MEMORY can be used to enable or disable additional checks on the data subject to 0-copy operations. The check is performed by a callback function registered by the application via FS_SetMemAccessCallback(). If FS_SUPPORT_CHECK_MEMORY is set to 1 then the callback is invoked on each read and write operation to check if a 0-copy operation can be performed.

9.2.1.21 FS_SUPPORT_DEINIT

By default, the file system does not free any resources it allocates at runtime such as dynamic memory. By setting FS_SUPPORT_DEINIT to 1, support is enabled in the file system for freeing the allocated resources. This can be useful when the application no longer uses

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the file system and the resources are required for other purposes. The application can free the resources at runtime by calling FS_DeInit(). If the application wishes to use the file system again, it has to call FS_Init() before doing this in order to reallocate the resources.

9.2.1.22 FS_SUPPORT_EFS

This configuration define can be used to enable or disable the support for the EFS file system. The support for the EFS file system is disabled by default.

9.2.1.23 FS_SUPPORT_EXFAT

This configuration define can be used to enable or disable the support for the exFAT file system. The support for the exFAT file system is disabled by default.

9.2.1.24 FS_SUPPORT_EXT_ASCII

FS_SUPPORT_EXT_ASCII can be used to enable or disable the support for extended ASCII characters in the file names. Extended ASCII characters are characters with a value between 128 and 255. Typically, this is the range where the language-specific characters are stored. The file system requires this information for the case-insensitive comparison of the file names. If the application uses file names that contain only ASCII characters, that is, with a value between 0 and 127, then FS_SUPPORT_EXT_ASCII can be set to 0, which is the default. Setting FS_SUPPORT_EXT_ASCII to 1 increases the ROM usage of the file system.

The support for extended ASCII characters is automatically enabled if the support for the exFAT file system is enabled via FS_SUPPORT_EXFAT.

9.2.1.25 FS_SUPPORT_EXT_MEM_MANAGER

This configuration define can be used to enable or disable the support for external memory allocation. By default, the file system uses a very simple internal memory allocator that is suitable for any embedded application. If FS_SUPPORT_EXT_MEM_MANAGER is set to 1, then the application can configure at runtime a pair of callback functions for the management of the memory allocation. This can be realized via FS_SetMemHandler().

9.2.1.26 FS_SUPPORT_FAT

This configuration define can be used to enable or disable the support for the FAT file system. The support for the FAT file system is enabled by default.

9.2.1.27 FS_SUPPORT_FILE_BUFFER

This configuration define controls the activation of the file buffer functionality. File buffers make the access to a file faster when the application is reading or writing small amounts of data. Enabling this functionality increases the ROM and RAM usage of the file system. The file buffer functionality has to be explicitly enabled at runtime. For more information refer to *File buffer* on page 478.

9.2.1.28 FS_SUPPORT_FILE_BUFFER_LIST

This configuration define controls how the file system manages the file buffers it allocates for each opened file handle.

By default, a file buffer is allocated when a file handle is created for the first time and remains attached to this file handle until the file system is deinitialized. This is the case when FS_SUPPORT_FILE_BUFFER_LIST is set to 0, which is the default.

By building the file system with FS_SUPPORT_FILE_BUFFER_LIST set to 1, the file buffers are managed via a dedicated list. This allows an application to detach a file buffer from an opened file handle via FS_UnsetFileBuffer() if a file buffer is not required for the access to the file data. In this way, the file buffer is made available to another file handle that may make use of it.

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The RAM usage of the file system increases by six bytes per file buffer with FS_SUPPORT_FILE_BUFFER_LIST set to 1.

9.2.1.29 FS_SUPPORT_FILE_BUFFER_RELOCATABLE

Configures if a file buffer is permitted to operate at different locations in the file system. This changes the way a structured file, such as a file that protects the data via authenticated encryption, is accessed. For the access to a regular file, the value of FS_SUPPORT_FILE_BUFFER_RELOCATABLE is not relevant.

By default, the file buffer operates immediately above the file system layer. If FS_SUPPORT_FILE_BUFFER_RELOCATABLE is set to 1 then the file buffer operates immediately below the file system API. In this case, any access to a structured file enters first through the file buffer if a file buffer is configured for that file.

9.2.1.30 FS_SUPPORT_FILE_NAME_ENCODING

FS_SUPPORT_FILE_NAME_ENCODING can be used to enable the support for encoded file names such as UTF-8 and Shift JIS. The encoding type of the file and directory names has to be configured at runtime via FS_FAT_SetLFNConverter() or FS_EFS_SetFileNameConverter()

9.2.1.31 FS_SUPPORT_FREE_SECTOR

If FS_SUPPORT_FREE_SECTOR is set to 1, then the file system informs the device and logical drivers about the unused sectors. For example, when a file is deleted, the file system sends a notification to the driver indicating that the range or ranges of sectors that were used to store the file contents are no longer in use. The driver can use this information to optimize the management of data. Not all drivers make use of this information. This functionality is similar to the TRIM command of the ATA command set.

9.2.1.32 FS_SUPPORT_GPT

This configuration define can be used to enable the support for GUID partition tables. With FS_SUPPORT_GPT set to 0 the file system is able to handle only MBR partition tables.

9.2.1.33 FS_SUPPORT_LARGE_FILES

This configuration define can be used to enable the support for files with a size larger than or equal to 4GB. By default, the support for large files is disabled because the maximum file size supported by the FAT and the EFS file systems is smaller than 4GB.

The support for large files is automatically enabled if the support for the exFAT file system is enabled via FS_SUPPORT_EXFAT.

It is not required to enable the support for large files when using the BigFAT component.

9.2.1.34 FS_SUPPORT_MBCS

This configuration define can be used to enable the support for file and directory names that use multibyte character sets. Enabling this feature increases the ROM usage of the file system. The type of character set used by the file system can be configured at runtime via FS_SetCharSetType().

9.2.1.35 FS_SUPPORT_POSIX

This configuration define can be used to change the behavior of the API functions so that they work in the same way as their equivalent POSIX function. The POSIX behavior is enabled by setting FS_SUPPORT_POSIX to 1. The behavior can also be changed at runtime using FS_ConfigPOSIXSupport().

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9.2.1.36 FS_SUPPORT_SECTOR_BUFFER_BURST

This configuration define can be used to enable the internal sector buffers to access more than one logical sector at once. Currently, this feature is used only for accelerating the calculation of the free space via `FS_GetVolumeInfoEx()` when the application specifies a work buffer.

9.2.1.37 FS_SUPPORT_SECTOR_BUFFER_CACHE

The `FS_SUPPORT_SECTOR_BUFFER_CACHE` configuration define can be used to activate a cache that stores information about the data present in the internal sector buffers of the file system. Enabling this feature can help accelerate file system operations that access the same logical sector, such as the creation or removal of files located in the same directory.

9.2.1.38 FS_SUPPORT_TIME_DATE_ENHANCED

This configuration define can be used to enable the support for timestamps with timezone information and millisecond accuracy. This type of timestamp is used by the exFAT file system. `FS_SUPPORT_TIME_DATE_ENHANCED` is set by default to 1 if the support for the exFAT file system is enabled. Otherwise, this configuration define is set to 0 to reduce the RAM usage.

9.2.1.39 FS_SUPPORT_VOLUME_ALIAS

This configuration define can be used to enable the setting of an alternative name for a volume name. The configured volume alias can then be used as a replacement for the volume name in a path to a file or directory or to identify a volume in a call to an API function that requires a volume name. A volume alias can be set via `FS_SetVolumeAlias()`. The configured volume alias can be obtained either via `FS_GetVolumeInfo()` or `FS_GetVolumeAlias()`.

9.2.1.40 FS_SUPPRESS_EOF_ERROR

`FS_SUPPRESS_EOF_ERROR` can be used to configure the file system to not generate an error in case of an end-of-file condition. An end-of-file condition occurs when the application is trying to read past the end of the file. If `FS_SUPPRESS_EOF_ERROR` is set to 1, then no `FS_ERRCODE_EOF` error is reported via `FS_FError()`. The handling of an end-of-file condition can be changed at runtime via `FS_ConfigEOFErrorSuppression()`.

9.2.2 FAT configuration

This section describes the configuration defines specific to the FAT file system.

Define	Type	Default value	Description
FS_FAT_CHECK_UNUSED_DIR_ENTRIES	B	0	Enables/disables the checking of unused directory entries.
FS_FAT_LFN_LOWER_CASE_SHORT_NAMES	B	1	Enables/disables optimization for short file names.
FS_FAT_LFN_BIT_ARRAY_SIZE	N	256	Maximum number of short file name indexes to handle at a time.
FS_FAT_LFN_MAX_SHORT_NAME	N	1000	Maximum index of a short file name.
FS_FAT_LFN_UNICODE_CONV_DEFAULT	R	&FS_UNICODE_CONV_CP437	Configures the default Unicode file name converter.
FS_FAT_OPTIMIZE_LINEAR_ACCESS	B	1	Configures the linear file access optimization.

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Define	Type	Default value	Description
FS_FAT_OPTIMIZE_DELETE	B	1	Enables/disables optimization for large file removal.
FS_FAT_PERMIT_RO_FILE_MOVE	B	0	Allows/denies removal of read-only file names.
FS_FAT_SUPPORT_FAT32	B	1	Enables/disables support for FAT32.
FS_FAT_SUPPORT_FREE_CLUSTER_CACHE	B	1	Enables/disables support for free cluster cache.
FS_FAT_UPDATE_DIRTY_FLAG	B	0	Enables/disables support for boot sector dirty flag.
FS_FAT_USE_FSINFO_SECTOR	B	1	Enables/disables support for FSInfo sector.
FS_MAINTAIN_FAT_COPY	B	0	Enables/disables update of the second allocation table.
FS_UNICODE_UPPERCASE_EXT	R	{0x0000, 0x0000}	Additional entries in the Unicode letter case conversion table.

9.2.2.1 FS_FAT_CHECK_UNUSED_DIR_ENTRIES

This configuration define can be used to enable additional verification steps for the contents of a directory. By default, the disk checking operation stops the processing of a directory as soon as it reaches the first unused directory entry. If FS_FAT_CHECK_UNUSED_DIR_ENTRIES is set to 1 then the disk checking operation verifies that all the directory entries located after the first unused directory entry are also marked as not in use. Enabling this feature can potentially increase the time required for the disk checking operation to complete.

9.2.2.2 FS_FAT_LFN_LOWER_CASE_SHORT_NAMES

This configuration define specifies how the file system handles the creation of files or directories with names consisting only of lowercase letters and punctuation that fit in the 8.3 format. If FS_FAT_LFN_LOWER_CASE_SHORT_NAMES is set to 1 then the file system creates only a short directory entry for the file or directory name if it consists only of lowercase letters and punctuation characters. This is done in order to save storage space. The information about the case of the letters in the name is preserved. If FS_FAT_LFN_LOWER_CASE_SHORT_NAMES is set to 0 then in addition to the short entry a long file name entry is generated. The described handling is available only when the support for long file names is enabled via FS_FAT_SupportLFN().

9.2.2.3 FS_FAT_LFN_BIT_ARRAY_SIZE

FS_FAT_LFN_BIT_ARRAY_SIZE can be used to specify the size of the work buffer of the functionality that generates short file names from long file names. The value represents the size in bits of the array used to remember the indexes of the short file names found. The work buffer is allocated on the stack.

9.2.2.4 FS_FAT_LFN_MAX_SHORT_NAME

The short names generated automatically by the file system for each long file name have a prefix that consists of the first characters of the long file name followed by a generated index. FS_FAT_LFN_MAX_SHORT_NAME can be used to specify the maximum value of that index. The maximum index value of a short file name is FS_FAT_LFN_MAX_SHORT_NAME + FS_FAT_LFN_BIT_ARRAY_SIZE - 1.

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9.2.2.5 FS_FAT_LFN_UNICODE_CONV_DEFAULT

FS_FAT_LFN_UNICODE_CONV_DEFAULT specifies the set of routines to be used for the conversion of file name characters to Unicode. It can be set to NULL in order to save ROM space if the file names are encoded using another code page. In this case, the application must specify a Unicode converter at runtime via FS_FAT_SetLFNConverter().

9.2.2.6 FS_FAT_OPTIMIZE_LINEAR_ACCESS

FS_FAT_OPTIMIZE_LINEAR_ACCESS can be used to enable or disable an optimization that caches the IDs of clusters allocated linearly for a file. Enabling this optimization can improve read and write performance of the file system by reducing the number of accesses to the allocation table. FS_FAT_OPTIMIZE_LINEAR_ACCESS can take the values 0 and 1. The optimization is disabled if FS_FAT_OPTIMIZE_LINEAR_ACCESS is set to 0. With FS_FAT_OPTIMIZE_LINEAR_ACCESS set to 1, which is the default value, the file system caches only the IDs of the linearly allocated clusters that are located after the current file position.

9.2.2.7 FS_FAT_OPTIMIZE_DELETE

FS_FAT_OPTIMIZE_DELETE can be used to enable or disable an optimization related to the deletion of large files. If FS_FAT_OPTIMIZE_DELETE is set to 1 the delete operation is accelerated by updating the allocation table at once, if possible. FS_FAT_OPTIMIZE_DELETE can be set to 0 for applications that do not deal with large files in order to reduce the ROM usage.

9.2.2.8 FS_FAT_PERMIT_RO_FILE_MOVE

By default, the files and directories with the read-only file attribute set cannot be moved or renamed via the API functions FS_Move() and FS_Rename() respectively. If FS_FAT_PERMIT_RO_FILE_MOVE is set to 1 then the read-only file attribute is ignored and the files and directories with this attribute set can be moved and renamed. This behavior can also be modified at runtime via FS_FAT_ConfigROFileMovePermission()

9.2.2.9 FS_FAT_SUPPORT_FAT32

FS_FAT_SUPPORT_FAT32 can be used to enable or disable the handling of FAT32 formatted volumes. If FS_FAT_SUPPORT_FAT32 is set to 0 then the file system will not be able to recognize volumes formatted as FAT32. In this case the file system will also not be able to format a volume as FAT32.

9.2.2.10 FS_FAT_SUPPORT_FREE_CLUSTER_CACHE

This configuration define can be used to enable or disable an optimization related to the handling of the allocation table. If FS_FAT_SUPPORT_FREE_CLUSTER_CACHE is set to 1 then the file system caches the information about which clusters are free in order to reduce the number of accesses to the allocation table. This functionality is used only in the FAST write mode. In the SAFE or MEDIUM write modes the functionality is not used even when enabled at compile time. FS_FAT_SUPPORT_FREE_CLUSTER_CACHE can be set to 0 in order to reduce the ROM usage.

9.2.2.11 FS_FAT_UPDATE_DIRTY_FLAG

If FS_FAT_UPDATE_DIRTY_FLAG is set to 1 then the file system sets a dirty flag in the Boot Parameter Block (BPB) of the FAT volume on the first write operation to indicate that the volume has been modified and that the file system may not have updated all the information to the storage device. The dirty flag is cleared later when FS_Unmount(), FS_UnmountForced(), FS_Sync(), or FS_DeInit() is called. The application can query the volume dirty flag using FS_GetVolumeInfo(). A dirty flag set to 1 at file system mount indicates that the file system was not properly unmounted before reset. In this case, it is recommended to call FS_CheckDisk() to check the integrity of the file system structure. The feature can also be enabled or disabled at runtime via FS_FAT_ConfigDirtyFlagUpdate(). FS_FAT_UPDATE_DIRTY_FLAG can be set to 0 to reduce the ROM usage.

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9.2.2.12 FS_FAT_USE_FSINFO_SECTOR

FS_FAT_USE_FSINFO_SECTOR can be used to enable or disable the handling of the information stored in the FSInfo sector of a volume formatted as FAT32. The FSInfo sector stores information about the number of free clusters and the index of the first free cluster. This information can be used to accelerate the calculation of available free space. If the information stored in the FSInfo sector is not valid then the file system falls back to calculating the free space by evaluating the entire contents of the allocation table that may take a relatively long time to complete on large-capacity volumes.

The handling of the FSInfo sector can be enabled or disabled at runtime via FS_FAT_ConfigFSInfoSectorUse().

FS_FAT_USE_FSINFO_SECTOR can be safely set to 0 to reduce ROM usage without affecting the correct operation of the file system.

9.2.2.13 FS_MAINTAIN_FAT_COPY

This configuration define can be used to enable or disable the update of the backup allocation table of a FAT file system. If FS_MAINTAIN_FAT_COPY is set to 1 then the file system updates the main as well as the backup allocation table. The backup allocation table is not evaluated by the emFile but some other file systems may fail to mount a volume if the backup allocation is not present and up to date. This feature can also be enabled or disabled at runtime via FS_FAT_ConfigFATCopyMaintenance(). Setting FS_MAINTAIN_FAT_COPY to 0 increases the write performance and reduces the ROM usage.

9.2.2.14 FS_UNICODE_UPPERCASE_EXT

The long file name component of the file system uses a table allocated in ROM for the case conversion of Unicode letters. In order to save ROM space, this table does not contain entries for every possible letter supported by Unicode. FS_UNICODE_UPPERCASE_EXT can be used to extend this table with new entries. Each entry is an initializer for a C structure containing two 16-bit values. The first value is the code point of the small letter and the second value is the code point of the corresponding capital letter. The entries are separated by comma characters. The last entry must always be {0x0000, 0x0000} which is the end of table indicator.

9.2.3 EFS configuration

This section describes the configuration defines specific to the EFS file system.

Define	Type	Default value	Description
FS_EFS_CASE_SENSITIVE	B	0	Enables/disables file name case sensitivity.
FS_EFS_MAX_DIR_ENTRY_SIZE	N	255	Maximum directory entry size.
FS_EFS_NUM_DIRENTRY_BUFFERS	N	2	Maximum number of directory entry buffers.
FS_EFS_OPTIMIZE_DELETE	B	0	Enables/disables optimization for large file removal.
FS_EFS_OPTIMIZE_LINEAR_ACCESS	B	1	Configures the linear file access optimization.
FS_EFS_SUPPORT_DIRENTRY_BUFFERS	B	1	Enables/disables support for directory entry buffers.
FS_EFS_SUPPORT_FREE_CLUSTER_CACHE	B	0	Enables/disables support for free cluster cache.
FS_EFS_SUPPORT_STATUS_SECTOR	B	1	Enables/disables support for status sector.

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9.2.3.1 FS_EFS_CASE_SENSITIVE

FS_EFS_CASE_SENSITIVE specifies if the comparison of file or directory names should consider the case of the letters or not. If FS_EFS_CASE_SENSITIVE is set to 0, then the case of the letters in a file or directory name is not relevant. That is TEST.TXT and test.txt represent the same file. If FS_EFS_CASE_SENSITIVE is set to 1, the TEST.TXT, test.txt and TEST.txt represent different file names. This feature can also be enabled or disabled at runtime via FS_EFS_ConfigCaseSensitivity().

9.2.3.2 FS_EFS_MAX_DIR_ENTRY_SIZE

FS_EFS_MAX_DIR_ENTRY_SIZE can be used to specify the maximum directory entry size. The minimum size of a directory entry is 21 bytes while the maximum is 255 bytes. The first 20 bytes in the directory store the size of the file, attributes, time stamps, etc. The remaining bytes are used to store the file name.

9.2.3.3 FS_EFS_NUM_DIRENTRY_BUFFERS

FS_EFS_NUM_DIRENTRY_BUFFERS specifies the number of work buffers the file system has to allocate for the handling of directory entries. The value of this configuration define is evaluated only when FS_EFS_SUPPORT_DIRENTRY_BUFFERS is set to 1.

9.2.3.4 FS_EFS_OPTIMIZE_DELETE

FS_EFS_OPTIMIZE_DELETE can be used to enable or disable an optimization related to the deletion of large files. If FS_EFS_OPTIMIZE_DELETE is set to 1 the delete operation is accelerated by updating the allocation table at once if possible. FS_EFS_OPTIMIZE_DELETE can be set to 0 for applications that do not deal with large files in order to reduce the ROM usage.

9.2.3.5 FS_EFS_OPTIMIZE_LINEAR_ACCESS

FS_EFS_OPTIMIZE_LINEAR_ACCESS can be used to enable or disable an optimization that caches the IDs of clusters allocated linearly for a file. Enabling this optimization can improve read and write performance of the file system by reducing the number of accesses to the allocation table. FS_EFS_OPTIMIZE_LINEAR_ACCESS can take the values 0 and 1. The optimization is disabled if FS_EFS_OPTIMIZE_LINEAR_ACCESS is set to 0. With FS_EFS_OPTIMIZE_LINEAR_ACCESS set to 1, which is the default value, the file system caches only the IDs of the linearly allocated clusters that are located after the current file position.

9.2.3.6 FS_EFS_SUPPORT_STATUS_SECTOR

This configuration define can be used to enable or disable the handling of the Status sector of an EFS formatted volume. The Status sector is the equivalent of the FSInfo sector for FAT32 formatted volumes. It stores information about the number of free clusters. This information is used by the file system to accelerate the operation that calculates the available free space. The handling of the Status sector can also be enabled or disabled at runtime via FS_EFS_ConfigStatusSectorSupport().

9.2.3.7 FS_EFS_SUPPORT_DIRENTRY_BUFFERS

FS_EFS_SUPPORT_DIRENTRY_BUFFERS can be used to specify where the work buffers for the handling of directory entries are allocated. If FS_EFS_SUPPORT_DIRENTRY_BUFFERS is set to 1, the work buffers are allocated from the memory pool of the file system. Each work buffer is FS_EFS_MAX_DIR_ENTRY_SIZE + 1 bytes large. If FS_EFS_SUPPORT_DIRENTRY_BUFFERS is set to 0, then the work buffers are allocated on the stack, which is the default.

9.2.3.8 FS_EFS_SUPPORT_FREE_CLUSTER_CACHE

This configuration define can be used to enable or disable an optimization related to the handling of the allocation table. If FS_EFS_SUPPORT_FREE_CLUSTER_CACHE is set to 1 then the file system caches the information about which clusters are free in order to reduce the

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number of accesses to the allocation table. This functionality is used only in the FAST write mode. In the SAFE or MEDIUM write modes the functionality is not used even when enabled at compile time. FS_EFS_SUPPORT_FREE_CLUSTER_CACHE can be set to 0 in order to reduce the ROM usage.

9.2.4 exFAT configuration

This section describes the configuration defines specific to the exFAT file system.

Define	Type	Default value	Description
FS_EXFAT_FILE_NAME_CONV_DEFAULT	R	&FS_UNICODE_CONV_CP437	Configures the default Unicode file name converter.
FS_EXFAT_MAX_NUM_OEM_PARA	N	1	Configures the number of handled OEM parameters.
FS_EXFAT_OPTIMIZE_LINEAR_ACCESS	B	1	Configures the linear file access optimization.
FS_EXFAT_PERMIT_RO_FILE_MOVE	B	0	Allows/denies removal of read-only file names.
FS_EXFAT_SUPPORT_FREE_CLUSTER_CACHE	B	1	Enables/disables support for free cluster cache.
FS_EXFAT_UPDATE_DIRTY_FLAG	B	0	Enables/disables support for boot sector dirty flag.
FS_EXFAT_UPDATE_SPACE_USAGE	B	1	Enables/disables support for space usage maintenance.

9.2.4.1 FS_EXFAT_FILE_NAME_CONV_DEFAULT

FS_EXFAT_FILE_NAME_CONV_DEFAULT specifies the set of routines to be used for the conversion of file name characters to Unicode. It can be set to NULL in order to save ROM space if the file names are encoded using another code page. In this case, the application must specify a Unicode converter at runtime via FS_EXFAT_SetFileNameConverter().

9.2.4.2 FS_EXFAT_MAX_NUM_OEM_PARA

This configuration define can be used to specify the maximum number of OEM parameters that can be handled by the file system. The OEM parameters are stored in the boot region of the exFAT file system. A maximum of 10 OEM parameters is supported.

The OEM parameters can be accessed via FS_EXFAT_ReadOEMPara() and FS_EXFAT_WriteOEMPara().

The OEM parameters are not preserved between high-level format operations if FS_EXFAT_MAX_NUM_OEM_PARA is set to 0.

9.2.4.3 FS_EXFAT_OPTIMIZE_LINEAR_ACCESS

FS_EXFAT_OPTIMIZE_LINEAR_ACCESS can be used to enable or disable an optimization that caches the IDs of clusters allocated linearly for a file. Enabling this optimization can improve read and write performance of the file system by reducing the number of accesses to the allocation table. FS_EXFAT_OPTIMIZE_LINEAR_ACCESS can take the values 0 and 1. The optimization is disabled if FS_EXFAT_OPTIMIZE_LINEAR_ACCESS is set to 0. With FS_EXFAT_OPTIMIZE_LINEAR_ACCESS set to 1, which is the default value, the file system caches only the IDs of the linearly allocated clusters that are located after the current file position.

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9.2.4.4 FS_EXFAT_PERMIT_RO_FILE_MOVE

By default, the files and directories with the read-only file attribute set cannot be moved or renamed via the API functions FS_Move() and FS_Rename() respectively. If FS_EXFAT_PERMIT_RO_FILE_MOVE is set to 1, then the read-only file attribute is ignored and the files and directories with this attribute set can be moved and renamed. This behavior can also be modified at runtime via FS_EXFAT_ConfigROFileMovePermission().

9.2.4.5 FS_EXFAT_SUPPORT_FREE_CLUSTER_CACHE

This configuration define can be used to enable or disable an optimization related to the handling of the allocation table. If FS_EXFAT_SUPPORT_FREE_CLUSTER_CACHE is set to 1 then the file system caches the information about which clusters are free in order to reduce the number of accesses to the allocation table. This functionality is used only in the FAST write mode. In the SAFE or MEDIUM write modes, the functionality is not used even when enabled at compile time. FS_EXFAT_SUPPORT_FREE_CLUSTER_CACHE can be set to 0 in order to reduce the ROM usage.

9.2.4.6 FS_EXFAT_UPDATE_DIRTY_FLAG

If FS_EXFAT_UPDATE_DIRTY_FLAG is set to 1, then the file system sets a dirty flag in the boot sector of the exFAT volume on the first write operation to indicate that the volume has been modified and that the file system may not have updated all the information to the storage device. The dirty flag is cleared later when FS_Unmount(), FS_UnmountForced(), FS_Sync(), or FS_DeInit() is called. The application can query the volume dirty flag using FS_GetVolumeInfo(). A dirty flag set to 1 at file system mount indicates that the file system was not properly unmounted before a reset. In this case, it is recommended to call FS_CheckDisk() to check the integrity of the file system structure.

The feature can also be enabled or disabled at runtime via FS_EXFAT_ConfigDirtyFlagUpdate(). FS_EXFAT_UPDATE_DIRTY_FLAG can be set to 0 to reduce the ROM usage.

9.2.4.7 FS_EXFAT_UPDATE_SPACE_USAGE

FS_EXFAT_UPDATE_SPACE_USAGE can be used to enable or disable the maintenance of the information about the used storage space. This information is stored in the boot sector of the volume, and it can be used by the file system to accelerate the calculation of available free space. If the information stored in the boot sector is not valid, then the file system falls back to calculating the free space by evaluating the entire contents of the Allocation Bitmap. The Allocation Bitmap stores information about the allocation status of the file system clusters. Scanning the Allocation Bitmap may take a relatively long time to complete on large capacity volumes.

The updating of the used storage space can be enabled or disabled at runtime via FS_EXFAT_ConfigSpaceUsageUpdate().

FS_EXFAT_UPDATE_SPACE_USAGE can be safely set to 0 to reduce ROM usage without affecting the correct operation of the file system.

9.2.5 Storage layer configuration

This section describes the configuration defines specific to the Storage layer.

Define	Type	Default value	Description
FS_STORAGE_ENABLE_STAT_COUNTERS	B	0	Enables/disables support for statistical counters.
FS_STORAGE_SUPPORT_DEVICE_ACTIVITY	B	0	Enables/disables the support for device activity callback.
FS_STORAGE_SUPPORT_MOUNT	B	0	Enables/disables the support for mounting the storage device.

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Define	Type	Default value	Description
FS_STORAGE_VERIFY_WRITE	B	0	Enables or disables the verification of written sector data.

9.2.5.1 FS_STORAGE_ENABLE_STAT_COUNTERS

This configuration define can be used to enable the statistical counters of the Storage layer. The statistical counters are enabled by default when the file system is configured at compile time with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_PARA. The statistical counters can be queried using FS_STORAGE_GetCounters() and cleared using FS_STORAGE_ResetCounters().

9.2.5.2 FS_STORAGE_SUPPORT_DEVICE_ACTIVITY

FS_STORAGE_SUPPORT_DEVICE_ACTIVITY enables or disables the support for a callback that is invoked by the file system at each sector read or write operation. The callback function can be registered by the application at runtime via FS_STORAGE_SetOnDeviceActivityCallback(). The support for the device activity callback is enabled by default at compile time when the file system is configured with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_PARA.

9.2.5.3 FS_STORAGE_SUPPORT_MOUNT

This configuration define enables or disables the support for the mount operation. The mount operation enables the application to control how the storage device is accessed, such as in read-only or read and write mode. With the support for the mount operation disabled, the storage device is always mounted automatically in read and write mode at the first access to it. Setting FS_STORAGE_SUPPORT_MOUNT to one enables the following API functions: FS_STORAGE_Mount(), FS_STORAGE_MountEx(), FS_STORAGE_SetAutoMountType(), FS_STORAGE_SetAutoMountTypeEx(), FS_STORAGE_GetAutoMountType(), FS_STORAGE_GetAutoMountTypeEx(), FS_STORAGE_GetMountType(), FS_STORAGE_GetMountTypeEx(). In addition, the RAM usage of the file system increases by two bytes per volume instance.

9.2.5.4 FS_STORAGE_VERIFY_WRITE

FS_STORAGE_VERIFY_WRITE can be used for testing purposes to verify if the sector data was correctly written to storage. If the configuration define is set to 1, the file system reads back and compares the contents of each written logical sector to the sector data actually written. Enabling this functionality can potentially have a negative impact on the write performance of the file system. For this reason, SEGGER recommends enabling this feature only when investigating issues related to the operation of the file system. In addition, the write verification can be enabled and disabled at runtime via FS_STORAGE_SetWriteVerification().

The write verification feature requires a work buffer with a size equal to the maximum logical sector size supported by the file system. This buffer is allocated dynamically at runtime from the memory pool assigned to the file system.

FS_STORAGE_VERIFY_WRITE is a replacement for the obsolete FS_VERIFY_WRITE configuration define.

9.2.6 Standard C function replacement

This section describes the configuration defines that can be used to replace the standard C functions called by emFile by other functions.

Define	Type	Default value	Description
FS_MEMCMP(s1, s2, n)	F	memcmp(s1, s2, n)	Replaces memcmp() standard C function.

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Define	Type	Default value	Description
FS_MEMCPY(s1, s2, n)	F	memcpy(s1, s2, n)	Replaces memcpy() standard C function.
FS_MEMMOVE(s1, s2, n)	F	memmove(d, s, n)	Replaces memmove() standard C function.
FS_MEMSET(s, c, n)	F	memset(s, c, n)	Replaces memset() standard C function.
FS_MEMXOR(pd, ps, n)	F	SEGGER_memxor(pd, ps, n)	Performs XOR operation on a memory range.
FS_NO_CLIB	B	0	Enables/disables standard C function replacements.
FS_STRCHR(s, c)	F	strchr(s, c)	Replaces strchr() standard C function.
FS_STRCMP(s1, s2)	F	strcmp(s1, s2)	Replaces strcmp() standard C function.
FS_STRCPY(s1, s2)	F	strcpy(s1, s2)	Replaces strcpy() standard C function.
FS_STRLEN(s)	F	strlen(s)	Replaces strlen() standard C function.
FS_STRNCAT(s1, s2, n)	F	strncat(s1, s2, n)	Replaces strncat() standard C function.
FS_STRNCMP(s1, s2, n)	F	strncmp(s1, s2, n)	Replaces strncmp() standard C function.
FS_STRNCPY(s1, s2, n)	F	strncpy(s1, s2, n)	Replaces strncpy() standard C function.
FS_TOLOWER(c)	F	tolower(c)	Replaces tolower() standard C function.
FS_TOUPPER(c)	F	toupper(c)	Replaces toupper() standard C function.
FS_ISLOWER(c)	F	islower(c)	Replaces islower() standard C function.
FS_ISUPPER(c)	F	isupper(c)	Replaces isupper() standard C function.
FS_VSNPRINTF(s, n, f, a)	F	SEGGER_vsnprintf(s, n, f, a)	Replaces vsnprintf() standard C function.

9.2.6.1 FS_NO_CLIB

emFile uses functions of the standard C library to perform specific operations. If FS_NO_CLIB is set to 1, then the file system calls internal functions to perform these operations instead of the equivalent standard C library functions.

By default, emFile includes the following header files of the standard C library:

- stdlib.h
- string.h
- ctype.h
- stdarg.h

An application can prevent these header files from being included by adding the following definitions to FS_Conf.h:

- Set FS_MEMCPY() to a function provided by the application.
- Set FS_MEMMOVE() to a function provided by the application.
- Set FS_NO_CLIB to 1.
- Set FS_BUFFER_SIZE_FILE_PRINT to 0.

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9.2.7 CRC function replacement

This section describes the configuration defines that can be used to replace the internal CRC calculation functions used by emFile.

Define	Type	Default value	Description
`FS_CRC32_CALC(pData, NumBytes, crc)`	F	`FS_CRC32_Calc(pData, NumBytes, crc)`	32-bit CRC that uses the polynomial `0x04C11DB7` (CRC-32)
`FS_CRC16_CCITT_CALC(pData, NumBytes, crc)`	F	`FS_CRC16_CCITT_Calc(pData, NumBytes, crc)`	16-bit CRC that uses the polynomial `0x1021` (CRC-16-CCITT)
`FS_CRC16_ANSI_CALC(pData, NumBytes, crc)`	F	`FS_CRC16_ANSI_Calc(pData, NumBytes, crc)`	16-bit CRC that uses the polynomial `0x8005` (CRC-16-ANSI)
`FS_CRC8_CCITT_CALC(pData, NumBytes, crc)`	F	`FS_CRC8_CCITT_Calc(pData, NumBytes, crc)`	8-bit CRC that uses the polynomial `0x07` (CRC-8-CCITT)

9.2.8 Sample configuration

A sample configuration file `FS_Conf.h` can be found in the `Config` folder of the emFile shipment. If you want to change the default configuration, insert the corresponding configuration defines in this file.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                      The Embedded Experts                          *
*                         www.segger.com                             *
**********************************************************************

-------------------------- END-OF-HEADER -----------------------------

File    : FS_Conf.h
Purpose : emFile compile time configuration.
*/
#ifndef FS_CONF_H
#define FS_CONF_H               // Avoid multiple inclusion

//
// Enable the EFS file system.
//
#define FS_SUPPORT_FAT      0
#define FS_SUPPORT_EFS      1

#endif                          // Avoid multiple inclusion

/************************** End of file ******************************/
```

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9.3 Runtime configuration

The runtime configuration of the file system is realized via a set of functions that have to be implemented by the application according to its requirements. This section describes these functions in detail.

emFile comes with sample implementations that can be used as a starting point for creating a custom file system configuration. Every folder of the emFile shipment that contains sample hardware layer implementations also contains a suitable configuration file (e.g., `Sample/FS/RAM/FS_ConfigRamDisk.c`) with implementations of runtime configuration functions explained in this chapter. The configuration files can be used without modification to run emFile "out of the box".

The following table lists the names of the functions that have to be provided by the application followed by a detailed description of these functions. Additional functions are required to be implemented by the application if the emFile is configured to generate debug messages. For additional information, refer to *Debug messages* on page 1413

Function	Description
`FS_X_AddDevices()`	Configures the file system.
`FS_X_GetTimeDate()`	Returns the current time and date.

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9.3.1 FS_X_AddDevices()

Description

Configures the file system.

Prototype

```
void FS_X_AddDevices(void);
```

Additional information

This function is responsible for configuring the file system at runtime and it has to be implemented by any application that uses emFile.

`FS_X_AddDevices()` is called during the file system initialization from either `FS_Init()` or `FS_STORAGE_Init()`. At the minimum, this function has to provide memory for the file system to work with either via `FS_AssignMemory()` or `FS_SetMemHandler()`. In addition, `FS_X_AddDevices()` has to add at least one device driver to the file system via `FS_AddDevice()` and to configure the device driver.

API functions that access a storage device may not be called in `FS_X_AddDevices()` because the device drivers may not be ready at this point to perform any data transfers.

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9.3.2 FS_X_GetTimeDate()

Description

Returns the current time and date.

Prototype

```
U32 FS_X_GetTimeDate(void);
```

Return value

Current time and date in a format suitable for the file system.

Additional information

This function is called by the file system in order to generate the time stamps for the accessed files and directories. `FS_X_GetTimeDate()` is not required when the application accesses the storage device only via the Storage layer and not via the File system layer.

Alternatively, the application can register a runtime a callback function via `FS_SetTimeDate-Callback()` that returns the date and time.

The return value is formatted as follows:

Bit range
0-4
5-10
11-15
16-20
21-24
25-31

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Chapter 10

OS integration

This chapter provides information about how to configure emFile to work in a multitasking application.

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10.1 General information

emFile does not require an operating system to work. However, when an application uses two or more tasks to concurrently access the file system then these accesses have to be synchronized in order to prevent a corruption of the file system structure. The access to the file system is synchronized via a set of API functions called the OS layer. The implementation of the OS layer is specific to the OS used by the application. emFile comes with ready-to-use OS layers for SEGGER embOS and Micrium uC/OS. The implementation of these OS layers can be found in the `Sample/FS/OS` folder of the emFile shipment. Support for other operating systems is available on request.

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10.2 Compile time configuration

By default, the support for OS is disabled in emFile because the majority of the applications either use only one task or, if they use multiple tasks, only one task accesses the file system at a time. Therefore, the OS support has to be explicitly enabled at compile time. The following table lists the configuration defines that can be used for this.

Macro	Default	Type	Description
FS_OS_LOCKING	FS_OS_LOCKING_NONE	N	Configures the OS support

10.2.1 FS_OS_LOCKING

Setting FS_OS_LOCKING to FS_OS_LOCKING_NONE disables the OS support. This is the default value. The OS layer is not required in this case. If FS_OS_LOCKING is set to FS_OS_LOCKING_API or FS_OS_LOCKING_DRIVER then the support for OS is enabled and an OS layer is required.

With FS_OS_LOCKING set to FS_OS_LOCKING_API (coarse lock granularity), the file system requires only one OS synchronization object. The task synchronization takes place in the API layer. The file system is locked at the beginning of an API function and unlocked upon return. This means that only one task can execute a file system operation at a time. The API functions of the device and logical driver do not lock the file system. These are the functions that are described in the *Device drivers* on page 479 and *Logical drivers* on page 1273 sections. It is the responsibility of the application to lock the file system by using either FS_Lock()/FS_Unlock() or FS_LockVolume()/FS_UnlockVolume() when calling one of the driver API functions.

With FS_OS_LOCKING set to FS_OS_LOCKING_DRIVER (fine lock granularity), an OS synchronization object is required for each device or logical driver type configured by the application. In addition, an OS synchronization object is required for the protection of the internal file system resources that are shared between the tasks. In this locking mode, the task synchronization takes place at the driver level and every time a task accesses an internal shared resource such as a sector buffer or a file handle. It is recommended to use this type of locking only when the file system is configured to use different storage device types such as NOR and NAND flash, SD card and NAND flash, etc. This type of locking cannot be used when the same storage device is accessed via two different logical drivers. For example, when a NAND flash device is partitioned into two and the first partition is accessed via the *Encryption driver* on page 1279 and the second via the *RAID1 driver* on page 1320.

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10.2.1.1 OS locking

Description

Types of locking for multitasking access.

Definition

```
#define FS_OS_LOCKING_NONE      0
#define FS_OS_LOCKING_API       1
#define FS_OS_LOCKING_DRIVER    2
```

Symbols

Definition	Description
FS_OS_LOCKING_NONE	No locking against concurrent access.
FS_OS_LOCKING_API	Locking is performed at API function level (coarse locking).
FS_OS_LOCKING_DRIVER	Locking is performed at device driver level (fine locking).

Additional information

These values can be assigned at compile-time to the FS_OS_LOCKING configuration define.

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10.3 Runtime configuration

emFile requires an OS layer specific to the OS used by the application if FS_OS_LOCKING is set to a value different from 0 at compile time. The OS layer is responsible for providing the OS specific synchronization routines the file system can use to make sure that only one task executes a critical section of the file system.

The following table lists the functions of the OS layer followed by a detailed description of each function.

Function	Description
FS_X_OS_Init()	Allocates the OS layer resources.
FS_X_OS_DeInit()	Releases the OS layer resources.
FS_X_OS_Delay()	Blocks the execution for the specified time.
FS_X_OS_Lock()	Acquires the specified OS synchronization object.
FS_X_OS_Unlock()	Releases the specified OS synchronization object.
FS_X_OS_Wait()	Waits for an OS synchronization object to be signaled.
FS_X_OS_Signal()	Signals an OS synchronization object.
FS_X_OS_GetTime()	Number of milliseconds elapsed since the start of the application.

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10.3.1 FS_X_OS_Init()

Description

Allocates the OS layer resources.

Prototype

```
void FS_X_OS_Init(unsigned NumLocks);
```

Parameters

Parameter	Description
NumLocks	Number of OS synchronization objects required.

Additional information

This function has to be implemented by any OS layer. FS_X_OS_Init() is called during the file system initialization. It has to create the number of specified OS synchronization objects. The type of the OS synchronization object is not relevant as long as it can be used to protect a critical section. The file system calls FS_X_OS_Lock() before it enters a critical section and FS_X_OS_Unlock() when the critical sector is leaved.

In addition, FS_X_OS_Init() has to create the OS synchronization object used by the optional functions FS_X_OS_Signal() and FS_X_OS_Wait().

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10.3.2 FS_X_OS_DeInit()

Description

Releases the OS layer resources.

Prototype

```
void FS_X_OS_DeInit(void);
```

Additional information

This function has to be implemented only for file system configurations that set `FS_SUPPORT_DEINIT` to 1. `FS_X_OS_DeInit()` has to release all the OS synchronization objects that were allocated in `FS_X_OS_Init()`.

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10.3.3 FS_X_OS_Delay()

Description

Blocks the execution for the specified time.

Prototype

```
void FS_X_OS_Delay(int ms);
```

Parameters

Parameter	Description
ms	Number of milliseconds to block the execution.

Additional information

The implementation of this function is optional. `FS_X_OS_Delay()` is called by implementations of the hardware layers to block efficiently the execution of a task.

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10.3.4 FS_X_OS_Lock()

Description

Acquires the specified OS synchronization object.

Prototype

```
void FS_X_OS_Lock(unsigned LockIndex);
```

Parameters

Parameter	Description
LockIndex	Index of the OS synchronization object (0-based).

Additional information

This function has to be implemented by any OS layer. The file system calls FS_X_OS_Lock() when it tries to enter a critical section that is protected by the OS synchronization object specified via LockIndex. FS_X_OS_Lock() has to block the execution of the calling task until the OS synchronization object can be acquired. The OS synchronization object is later released via a call to FS_X_OS_Unlock(). All OS synchronization objects are created in FS_X_OS_Init().

It is guaranteed that the file system does not perform a recursive locking of the OS synchronization object. That is FS_X_OS_Lock() is not called two times in a row from the same task on the same OS synchronization object without a call to FS_X_OS_Unlock() in between.

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10.3.5 FS_X_OS_Unlock()

Description

Releases the specified OS synchronization object.

Prototype

```
void FS_X_OS_Unlock(unsigned LockIndex);
```

Parameters

Parameter	Description
LockIndex	Index of the OS synchronization object (0-based).

Additional information

This function has to be implemented by any OS layer. The OS synchronization object to be released was acquired via a call to `FS_X_OS_Lock()`. All OS synchronization objects are created in `FS_X_OS_Init()`.

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10.3.6 FS_X_OS_Wait()

Description

Waits for an OS synchronization object to be signaled.

Prototype

```
int FS_X_OS_Wait(int TimeOut);
```

Parameters

Parameter	Description
TimeOut	Maximum time in milliseconds to wait for the OS synchronization object to be signaled.

Return value

= 0 OK, the OS synchronization object was signaled within the timeout.
≠ 0 An error or a timeout occurred.

Additional information

The implementation of this function is optional. `FS_X_OS_Wait()` is called by some hardware layer implementations that work in event-driven mode. That is a condition is not check periodically by the CPU until is met but the hardware layer calls `FS_X_OS_Wait()` to block the execution while waiting for the condition to be met. The blocking is realized via an OS synchronization object that is signaled via `FS_X_OS_Signal()` in an interrupt that is triggered when the condition is met.

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10.3.7 FS_X_OS_Signal()

Description

Signals an OS synchronization object.

Prototype

```
void FS_X_OS_Signal(void);
```

Additional information

The implementation of this function is optional. `FS_X_OS_Signal()` is called by some hardware layer implementations that work in event-driven mode. Refer to `FS_X_OS_Wait()` for more details about how this works.

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10.3.8 FS_X_OS_GetTime()

Description

Number of milliseconds elapsed since the start of the application.

Prototype

```
U32 FS_X_OS_GetTime(void);
```

Return value

Number of milliseconds elapsed.

Additional information

The implementation of this function is optional. `FS_X_OS_GetTime()` is not called by the file system. It is typically used by some test applications as time base for performance measurements.

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10.3.9 Sample implementation

The following example shows the implementation of an OS layer for SEGGER embOS. The implementation file is located in the `Sample/FS/OS` folder of the emFile shipment.

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_OS_embOS.c
Purpose : embOS OS Layer for the file system.
*/

/*********************************************************************
*
*       #include Section
*
**********************************************************************
*/
#include "FS.h"
#include "FS_OS.h"
#include "RTOS.h"

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
static OS_RSEMA   * _paSema;
static OS_EVENT     _Event;
#if FS_SUPPORT_DEINIT
  static unsigned   _NumLocks;
#endif

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       FS_X_OS_Lock
*
*  Function description
*    Acquires the specified OS resource.
*
*  Parameters
*    LockIndex    Identifies the OS resource (0-based).
*
*  Additional information
*    This function has to block until it can acquire the OS resource.
*    The OS resource is later released via a call to FS_X_OS_Unlock().
*/
void FS_X_OS_Lock(unsigned LockIndex) {
  OS_RSEMA * pSema;

  pSema = _paSema + LockIndex;
  (void)OS_Use(pSema);
  FS_DEBUG_LOG((FS_MTYPE_OS, "OS: LOCK Index: %d\n", LockIndex));
}

/*********************************************************************
*
*       FS_X_OS_Unlock
*
*  Function description
*    Releases the specified OS resource.
*
```

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```
*  Parameters
*    LockIndex    Identifies the OS resource (0-based).
*
*  Additional information
*    The OS resource to be released was acquired via a call to FS_X_OS_Lock()
*/
void FS_X_OS_Unlock(unsigned LockIndex) {
  OS_RSEMA * pSema;

  pSema = _paSema + LockIndex;
  FS_DEBUG_LOG((FS_MTYPE_OS, "OS: UNLOCK Index: %d\n", LockIndex));
  OS_Unuse(pSema);
}

/*********************************************************************
*
*       FS_X_OS_Init
*
*  Function description
*    Initializes the OS resources.
*
*  Parameters
*    NumLocks   Number of locks that should be created.
*
*  Additional information
*    This function is called by FS_Init(). It has to create all resources
*    required by the OS to support multi tasking of the file system.
*/
void FS_X_OS_Init(unsigned NumLocks) {
  unsigned   i;
  OS_RSEMA * pSema;
  unsigned   NumBytes;

  NumBytes = NumLocks * sizeof(OS_RSEMA);
  _paSema = SEGGER_PTR2PTR(OS_RSEMA, FS_ALLOC_ZEROED((I32)NumBytes, "OS_RSEMA"));
  pSema =_paSema;
  for (i = 0; i < NumLocks; i++) {
    OS_CREATERSEMA(pSema++);
  }
  OS_EVENT_Create(&_Event);
#if FS_SUPPORT_DEINIT
  _NumLocks = NumLocks;
#endif
}

#if FS_SUPPORT_DEINIT

/*********************************************************************
*
*       FS_X_OS_DeInit
*
*  Function description
*    This function has to release all the resources that have been
*    allocated by FS_X_OS_Init().
*/
void FS_X_OS_DeInit(void) {
  unsigned   i;
  OS_RSEMA * pSema;
  unsigned   NumLocks;

  NumLocks = _NumLocks;
  pSema    = &_paSema[0];
  for (i = 0; i < NumLocks; i++) {
    OS_DeleteRSema(pSema);
    pSema++;
  }
  OS_EVENT_Delete(&_Event);
  FS_Free(_paSema);
  _paSema  = NULL;
  _NumLocks = 0;
}

#endif // FS_SUPPORT_DEINIT

/*********************************************************************
*
```

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```
*       FS_X_OS_GetTime
*/
U32 FS_X_OS_GetTime(void) {
  return (U32)OS_GetTime32();
}

/*********************************************************************
*
*       FS_X_OS_Wait
*
*  Function description
*    Waits for an event to be signaled.
*
*  Parameters
*    Timeout  Time to be wait for the event object.
*
*  Return value
*    ==0      Event object was signaled within the timeout value
*    !=0      An error or a timeout occurred.
*/
int FS_X_OS_Wait(int TimeOut) {
  int r;

  r = -1;
  if ((U8)OS_EVENT_WaitTimed(&_Event, TimeOut) == 0u) {
    r = 0;
  }
  return r;
}

/*********************************************************************
*
*       FS_X_OS_Signal
*
*  Function description
*    Signals an event.
*/
void FS_X_OS_Signal(void) {
  OS_EVENT_Set(&_Event);
}

/*********************************************************************
*
*       FS_X_OS_Delay
*
*  Function description
*    Blocks the execution for the specified number of milliseconds.
*/
void FS_X_OS_Delay(int ms) {
  OS_Delay(ms + 1);
}

/************************** End of file ****************************/
```

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Chapter 11

Debugging

This chapter provides information about how to troubleshoot emFile in case it is not working as expected.

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11.1 General information

emFile comes with an optional debug functionality that helps investigate potential issues related to the file system operation. The debug functionality can be used by an application to enable additional parameter and consistency checks and to enable the reporting of debug messages. The type of checks to be performed as well as the type of debug messages to be generated can be configured at compile time by assigning a different value (debug level) to *FS_DEBUG_LEVEL* on page 1418 configuration define.

> **Note**
>
> Enabling the debug functionality can have a negative effect on the read and write performance, and it can also increase the ROM and RAM usage of the file system.

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11.2 Debug messages

Debug messages are human-readable text messages generated by the file system on error or warning conditions or when specific internal operations are performed. The file system provides the debug messages as 0-terminated strings to the application via calls to dedicated API functions. These functions have to be implemented in the application and the application is free to choose how to handle the debug messages. For example, the debug messages can be forwarded to a host system via the SEGGER Real Time Transfer (https://www.segger.com/products/debug-probes/j-link/technology/about-real-time-transfer/).

The debug messages are organized in three classes: error, warning and trace. Each debug message class is passed to the application via a separate API function. In addition, the reporting of a specific class of debug messages can be enabled or disabled via different debug levels. The table below lists the supported debug message classes together with the API function that is used to pass them to the application.

Class	Handling function	Debug level	Description
error	`FS_X_ErrorOut()`	≥ `FS_DEBUG_LEVEL_LOG_ERRORS`	Fault condition the file system cannot recover from.
warning	`FS_X_Warn()`	≥ `FS_DEBUG_LEVEL_LOG_WARNINGS`	Fault condition the file system can recover from.
trace	`FS_X_Log()`	≥ `FS_DEBUG_LEVEL_LOG_ALL`	Information about internal processing.

The debug messages also have a type assigned to them that is used to identify the component of the file system that reported that message. Refer to section *Debug message types* on page 1430 for a description of the supported message types. It is possible to configure at compile time as well as at runtime what type of debug messages are reported by the file system. The sections *FS_LOG_MASK_DEFAULT* on page 1419 and *Runtime configuration* on page 485 provide more information about how this is realized.

11.2.1 Debug output and error functions

This section describes the API functions an application has to provide in order to be able to handle the debug messages and assertion errors generated by the file system. emFile comes with a sample implementation for these functions that demonstrates how to send the debug messages to a host system. The implementation of the sample functions can be found in the `Config/FS_ConfigIO.c` file of the emFile shipment. These functions can be adapted according to the requirements of the target application. The typical release build does not use debugging and therefore these functions may be removed from the source code to save some ROM space if the linker is not able to eliminate unreferenced functions automatically.

The table below and the next sections provide more detailed information about these API functions.

Function	Description
`FS_X_ErrorOut()`	Outputs an error debug message.
`FS_X_Log()`	Outputs a trace debug message.
`FS_X_Panic()`	Handles an assertion error.
`FS_X_Warn()`	Outputs a warning debug message.

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11.2.2 FS_X_ErrorOut()

Description

Outputs an error debug message.

Prototype

```
void FS_X_ErrorOut(const char * sText);
```

Parameters

Parameter	Description
sText	Debug message to be output (0-terminated).

Additional information

The file system calls this function to output an error debug message.

`FS_X_ErrorOut()` is optional and has to be present only when the file system is built with `FS_DEBUG_LEVEL` set to a value greater than or equal to `FS_DEBUG_LEVEL_LOG_ERRORS`.

`sText` is not terminated by a newline character. The file system make sure that `sText` is never set to NULL.

`FS_X_ErrorOut()` is not permitted to call any API function of the file system.

Example

```
#include <stdio.h>

void FS_X_ErrorOut(const char * s) {
  printf("FS error: %s\n", s);
}
```

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11.2.3 FS_X_Log()

Description

Outputs a trace debug message.

Prototype

```
void FS_X_Log(const char * sText);
```

Parameters

Parameter	Description
sText	Debug message to be output (0-terminated).

Additional information

The file system calls this function to output a trace debug message.

FS_X_Log() is optional and has to be present only when the file system is built with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_LOG_ALL.

sText is always terminated by a newline character. The file system makes sure that sText is never set to NULL.

FS_X_Log() is not permitted to call any API function of the file system.

Example

```
#include <stdio.h>

void FS_X_Log(const char * s) {
  puts(s);
}
```

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11.2.4 FS_X_Panic()

Description

Handles an assertion error.

Prototype

```
void FS_X_Panic(int ErrorCode);
```

Parameters

Parameter	Description
ErrorCode	Identifies the type of error.

Additional information

This function is called by the file system only when FS_DEBUG_LEVEL is set to a value greater than or equal to FS_DEBUG_LEVEL_CHECK_PARA. Typically, FS_X_Panic() is called on a critical error condition such as insufficient memory or invalid parameter.

Refer to *Error codes* on page 413 for permitted values for ErrorCode.

FS_X_Panic() is not permitted to call any API function of the file system.

Example

```
#include <stdio.h>

void FS_X_Panic(int ErrorCode) {
  printf("FS panic: %d\n", ErrorCode);
  while (1) {
    ;
  }
}
```

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11.2.5 FS_X_Warn()

Description

Outputs a warning debug message.

Prototype

```
void FS_X_Warn(const char * sText);
```

Parameters

Parameter	Description
sText	Debug message to be output (0-terminated).

Additional information

The file system calls this function to output a warning debug message.

FS_X_Warn() is optional and has to be present only when the file system is built with FS_DEBUG_LEVEL set to a value greater than or equal to FS_DEBUG_LEVEL_LOG_WARNINGS.

sText is not terminated by a newline character. The file system makes sure that sText is never set to NULL.

FS_X_Warn() is not permitted to call any API function of the file system.

Example

```
#include <stdio.h>

void FS_X_Warn(const char * s) {
  printf("FS warning: %s\n", s);
}
```

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11.3 Configuration

The debug functionality has to be configured at compile time and can be optionally configured at runtime.

11.3.1 Compile time configuration

The compile time configuration is realized via preprocessor defines that have to be added to the `FS_Conf.h` file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the debug functionality.

Define	Type	Default value	Description
`FS_DEBUG_LEVEL`	N	`FS_DEBUG_LEVEL_CHECK_PARA`	Default behavior of the debug functionality.
`FS_DEBUG_MAX_LEN_MESSAGE`	N	100	Size of the format buffer in bytes.
`FS_DEBUG_STATIC_MESSAGE_BUFFER`	B	0	Configures where the buffer for the formatting of debug messages is allocated.
`FS_LOG_MASK_DEFAULT`	N	`FS_MTYPE_INIT`	Default debug message types to be traced.
`FS_X_PANIC()`	F	`FS_X_Panic()`	Handles an assertion error.

11.3.1.1 FS_DEBUG_LEVEL

This define can be used to configure the behavior of the debug functionality. The application can choose between six debug levels that enable different features of the debug functionality. The debug levels are structured hierarchically so that higher debug levels also enable the features assigned to lower debug levels.

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11.3.1.1.1 Debug levels

Description

Amount of debug information.

Definition

```
#define FS_DEBUG_LEVEL_NOCHECK          0
#define FS_DEBUG_LEVEL_CHECK_PARA       1
#define FS_DEBUG_LEVEL_CHECK_ALL        2
#define FS_DEBUG_LEVEL_LOG_ERRORS       3
#define FS_DEBUG_LEVEL_LOG_WARNINGS     4
#define FS_DEBUG_LEVEL_LOG_ALL          5
```

Symbols

Definition	Description
FS_DEBUG_LEVEL_NOCHECK	No run time checks are performed.
FS_DEBUG_LEVEL_CHECK_PARA	Parameter checks are performed.
FS_DEBUG_LEVEL_CHECK_ALL	Parameter checks and consistency checks are performed.
FS_DEBUG_LEVEL_LOG_ERRORS	Error conditions are reported.
FS_DEBUG_LEVEL_LOG_WARNINGS	Error and warning conditions are reported.
FS_DEBUG_LEVEL_LOG_ALL	Error and warning conditions as well as trace messages are reported.

Additional information

These values can be assigned at compile-time to the FS_DEBUG_LEVEL configuration define.

The debug levels are hierarchical so that higher debug levels also enable the features assigned to lower debug levels.

11.3.1.2 FS_DEBUG_MAX_LEN_MESSAGE

This define specifies the size of the buffer to be used for the formatting of debug messages. This buffer is allocated on the stack. It can be set to a smaller value than the default to save stack space. The debug messages will be truncated if they do not fit in the formatting buffer.

11.3.1.3 FS_DEBUG_STATIC_MESSAGE_BUFFER

FS_DEBUG_STATIC_MESSAGE_BUFFER can be used to specify where the buffer used for the formatting of debug messages is allocated (statically or on the stack). By default, the buffer for the formatting of debug messages is allocated on the stack. The size of the buffer is specified by FS_DEBUG_MAX_LEN_MESSAGE. The stack load can be reduced by setting FS_DEBUG_STATIC_MESSAGE_BUFFER to 1 in which case the buffer is allocated statically. It is not recommended to set FS_DEBUG_STATIC_MESSAGE_BUFFER to 1 with FS_OS_LOCKING set to FS_OS_LOCKING_DRIVER because the debug messages may get corrupted when two or more tasks access different storage devices of different types at the same time.

11.3.1.4 FS_LOG_MASK_DEFAULT

This configuration define specifies the type of debug messages to be generated from the class of log messages. The value is a bitwise-OR combination of the message types described in the section *Debug message types* on page 1430. The type of log debug messages to be generated can be modified at runtime via FS_SetLogFilter() and FS_AddLogFilter().

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11.3.1.5 FS_X_PANIC()

This configuration define can be used to replace the default handler for assertion errors. It takes the error code as a parameter. Refer to `FS_X_Panic()` for more information.

11.3.2 Runtime configuration

The type of debug messages that are generated by the file system during the operation can be managed using the API functions listed in the following table.

Function	Description
`FS_AddErrorFilter()`	Enables error debug messages.
`FS_AddLogFilter()`	Enables trace debug messages.
`FS_AddWarnFilter()`	Enables warning debug messages.
`FS_GetErrorFilter()`	Queries activation status of error debug messages.
`FS_GetLogFilter()`	Queries activation status of trace debug messages.
`FS_GetWarnFilter()`	Queries activation status of warning debug messages.
`FS_SetErrorFilter()`	Enables and disables error debug messages.
`FS_SetLogFilter()`	Enables and disables trace debug messages.
`FS_SetWarnFilter()`	Enables and disables warning debug messages.

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11.3.2.1 FS_AddErrorFilter()

Description

Enables error debug messages.

Prototype

```
void FS_AddErrorFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types to be enabled.

Additional information

FS_AddErrorFilter() can be used to enable a specified set of debug message types of the error class.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_ERRORS.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.2 FS_AddLogFilter()

Description

Enables trace debug messages.

Prototype

```
void FS_AddLogFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types to be enabled.

Additional information

FS_AddLogFilter() can be used to enable a specified set of debug message types of the trace class.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_ALL.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.3 FS_AddWarnFilter()

Description

Enables warning debug messages.

Prototype

```
void FS_AddWarnFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types to be enabled.

Additional information

FS_AddWarnFilter() can be used to enable a specified set of debug message types of the warning class.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_WARNINGS.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.4 FS_GetErrorFilter()

Description

Queries activation status of error debug messages.

Prototype

```
U32 FS_GetErrorFilter(void);
```

Return value

Value indicating the activation status for all debug message types of the error class.

Additional information

This function is optional and is available only when the file system is built with `FS_DEBUG_LEVEL` set to a value equal or greater than `FS_DEBUG_LEVEL_LOG_ERRORS`.

The return value is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.5 FS_GetLogFilter()

Description

Queries activation status of trace debug messages.

Prototype

```
U32 FS_GetLogFilter(void);
```

Return value

Value indicating the activation status for all debug message types of the trace class.

Additional information

This function is optional and is available only when the file system is built with `FS_DEBUG_LEVEL` set to a value equal or greater than `FS_DEBUG_LEVEL_LOG_ALL`.

The return value is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.6 FS_GetWarnFilter()

Description

Queries activation status of warning debug messages.

Prototype

```
U32 FS_GetWarnFilter(void);
```

Return value

Value indicating the activation status for all debug message types of the warning class.

Additional information

This function is optional and is available only when the file system is built with `FS_DEBUG_LEVEL` set to a value equal or greater than `FS_DEBUG_LEVEL_LOG_WARNINGS`.

The return value is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.7 FS_SetErrorFilter()

Description

Enables and disables error debug messages.

Prototype

```
void FS_SetErrorFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types.

Additional information

FS_AddErrorFilter() can be used to enable and disable a specified set of debug message types of the error class. The debug message types that have the bit set to 1 in FilterMask are enabled while the other debug message types are disabled.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_ERRORS.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.8 FS_SetLogFilter()

Description

Enables and disables trace debug messages.

Prototype

```
void FS_SetLogFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types.

Additional information

FS_SetLogFilter() can be used to enable and disable a specified set of debug message types of the trace class. The debug message types that have the bit set to 1 in FilterMask are enabled while the other debug message types are disabled.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_ALL.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.9 FS_SetWarnFilter()

Description

Enables and disables warning debug messages.

Prototype

```
void FS_SetWarnFilter(U32 FilterMask);
```

Parameters

Parameter	Description
FilterMask	Specifies the message types.

Additional information

FS_SetWarnFilter() can be used to enable and disable a specified set of debug message types of the warning class. The debug message types that have the bit set to 1 in FilterMask are enabled while the other debug message types are disabled.

This function is optional and is available only when the file system is built with FS_DEBUG_LEVEL set to a value equal or greater than FS_DEBUG_LEVEL_LOG_WARNINGS.

FilterMask is specified by or-ing one or more message types described at *Debug message types* on page 1430.

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11.3.2.10 Debug message types

Description

Flags that control the output of debug messages.

Definition

```
#define FS_MTYPE_INIT       (1uL << 0)
#define FS_MTYPE_API        (1uL << 1)
#define FS_MTYPE_FS         (1uL << 2)
#define FS_MTYPE_STORAGE    (1uL << 3)
#define FS_MTYPE_JOURNAL    (1uL << 4)
#define FS_MTYPE_CACHE      (1uL << 5)
#define FS_MTYPE_DRIVER     (1uL << 6)
#define FS_MTYPE_OS         (1uL << 7)
#define FS_MTYPE_MEM        (1uL << 8)
#define FS_MTYPE_BIGFAT     (1uL << 9)
#define FS_MTYPE_ADAPT      (1uL << 10)
```

Symbols

Definition	Description
FS_MTYPE_INIT	Debug messages output during the initialization.
FS_MTYPE_API	Debug messages from the API functions.
FS_MTYPE_FS	Debug messages from the file system layer.
FS_MTYPE_STORAGE	Debug messages from the storage layer.
FS_MTYPE_JOURNAL	Debug messages from the Journaling component.
FS_MTYPE_CACHE	Debug messages from the sector cache.
FS_MTYPE_DRIVER	Debug messages from the device and logical drivers.
FS_MTYPE_OS	Debug messages from the OS layer.
FS_MTYPE_MEM	Debug messages from the internal memory allocator.
FS_MTYPE_BIGFAT	Debug messages from the BigFAT component.
FS_MTYPE_ADAPT	Debug messages from emFile adaptation layers.

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11.4 Troubleshooting

This section provides some ideas about how to analyze why the file system is not working as expected.

emFile comes with an API function called FS_FOpen() that is the equivalent of the fopen() function that is part of any standard C library. This function takes as parameters a file name and an access mode. If the specified file access type is allowed and no error occurs, the function returns a pointer to a file handle that can be used to perform operations on that file.

```
#include "FS.h"

int SampleFileOpen(const char * s) {
  FS_FILE * pFile;

  pFile = FS_FOpen("test.txt", "r");
  if (pFile == NULL) {
    return -1;  // report error
  } else {
    return 0;   // file system is up and running!
  }
}
```

If this pointer is zero after calling FS_FOpen(), there was a problem opening the file. There are basically three main reasons why this could happen:

- The file or path does not exist.
- The drive could not be read or written.
- The drive contains an invalid BIOS parameter block or partition table. These faults can be caused by corrupted media. To verify the validity of your medium, either check if the medium is physically okay or check the medium with another operating system (for example Windows).

There are also faults that are relatively seldom but also possible:

- A compiler/linker error has occurred.
- Stack overflow.
- Memory failure.
- Electromagnetic influence (EMC, EMV, ESD.) To find out what the real reason for the error is, you may just try reading and writing a raw sector. Here is an example function that tries writing a single sector to your device. After reading back and verifying the sector data, you know if sectored access to the device is possible and if your device is working.

```
#include "FS.h"

#define BYTES_PER_SECTOR    512

int SampleWriteSector(void) {
  U8  acBufferOut[BYTES_PER_SECTOR];
  U8  acBufferIn[BYTES_PER_SECTOR];
  U32 SectorIndex;
  int r;
  int i;
  //
  // Do not write on the first sectors. They contain
  // information about partitioning and media geometry.
  //
  SectorIndex = 80;
  //
  // Fill the buffer with data.
  //
  for (i = 0; i < BYTES_PER_SECTOR; i++) {
    acBufferOut[i] = i % 256;
  }
  //
  // Write one sector.
  //
  r = FS_STORAGE_WriteSector("", acBufferOut, SectorIndex);
  if (r) {
```

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```
    FS_X_Log("Cannot write to sector.\n");
    return -1;
  }
  //
  // Read back the sector contents.
  //
  r = FS_STORAGE_ReadSector("", acBufferIn, SectorIndex);
  if (r) {
    FS_X_Log("Cannot read from sector.\n");
    return -1;
  }
  //
  // Compare the sector contents.
  //
  for (i = 0; i < BYTES_PER_SECTOR; i++) {
    if (acBufferIn[i] != acBufferOut[i]) {
      FS_X_Log("Sector not correctly written.\n");
      return -1;
    }
  }
  return 0;
}
```

If you still receive no valid pointer to a file handle although the sectors of the device are accessible and other operating systems report the device to be valid, you may have to take a look into the running system by stepping through the function `FS_FOpen()`.

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Chapter 12

Profiling with SystemView

This chapter describes the profiling instrumentation of emFile.

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12.1 General information

emFile is instrumented to generate profiling information of API functions and driver-level functions. This profiling information exposes the run-time behavior of emFile in an application, recording which API functions have been called, how long the execution took, and revealing which driver-level functions have been called by API functions or events like interrupts.

The profiling information is recorded using SystemView. SystemView is a real-time recording and visualization tool for profiling data. It exposes the true run-time behavior of a system, going far deeper than the insight provided by debuggers. This is particularly effective when developing and working with complex systems comprising an OS with multiple threads and interrupts, and one or more middleware components.

SystemView can ensure a system performs as designed, track down inefficiencies, and show unintended interactions and resource conflicts. The recording of profiling information with SystemView is minimally intrusive to the system and can be done on virtually any system. With SEGGER's Real Time Technology (RTT) and a J-Link, SystemView can record data in real-time and analyze the data live, while the system is running.

The emFile profiling instrumentation can be easily configured and set up.

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12.2 Configuring profiling

Profiling can be included or excluded at compile-time and enabled at run-time. When profiling is excluded, no additional overhead in performance or memory usage is generated. Even when profiling is enabled, the overhead is minimal, due to the efficient implementation of SystemView.

The SystemView module needs to be added to the application to enable profiling. If not already part of the project, download the sources from https://www.segger.com/systemview.html and add them to the project.

Also make sure that the `FS_SYSVIEW.c` file from the `FS` directory of the emFile shipment is included in the project.

12.2.1 Compile-time configuration

The configuration of emFile can be changed via compile-time flags which can be added to `FS_Conf.h`. `FS_Conf.h` is the main configuration file of the file system.

To include profiling, the configuration define `FS_SUPPORT_PROFILE` must be set to 1 in the emFile configuration (`FS_Conf.h`) or via the project preprocessor defines.

The following table lists the configuration defines related to profiling.

Define	Type	Default value	Description
`FS_SUPPORT_PROFILE`	B	0	Enables/disables profiling support.
`FS_SUPPORT_PROFILE_END_CALL`	B	0	Enables/disables the profiling of return values.

Refer to *Configuration of emFile* on page 1371 for a description of configuration define types.

12.2.1.1 FS_SUPPORT_PROFILE

This configuration define can be used to enable the support for profiling instrumentation in emFile. By default, the support is disabled to save ROM space.

12.2.1.2 FS_SUPPORT_PROFILE_END_CALL

This configuration define specifies if the return values of the profiled functions have to be recorded. This feature is disabled by default to save ROM space. `FS_SUPPORT_PROFILE_END_CALL` has effect only when `FS_SUPPORT_PROFILE` is set to 1.

For detailed information about the configuration of emFile and the types of the configuration defines, refer to *Configuration of emFile* on page 1371.

12.2.2 Runtime configuration

To enable profiling at run-time, `FS_SYSVIEW_Init()` needs to be called. Profiling can be enabled at any time, but it is recommended to do this in `FS_X_AddDevices()` as demonstrated in the sample below:

```
#include "FS.h"

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
#if FS_SUPPORT_PROFILE
  FS_SYSVIEW_Init();
#endif
```

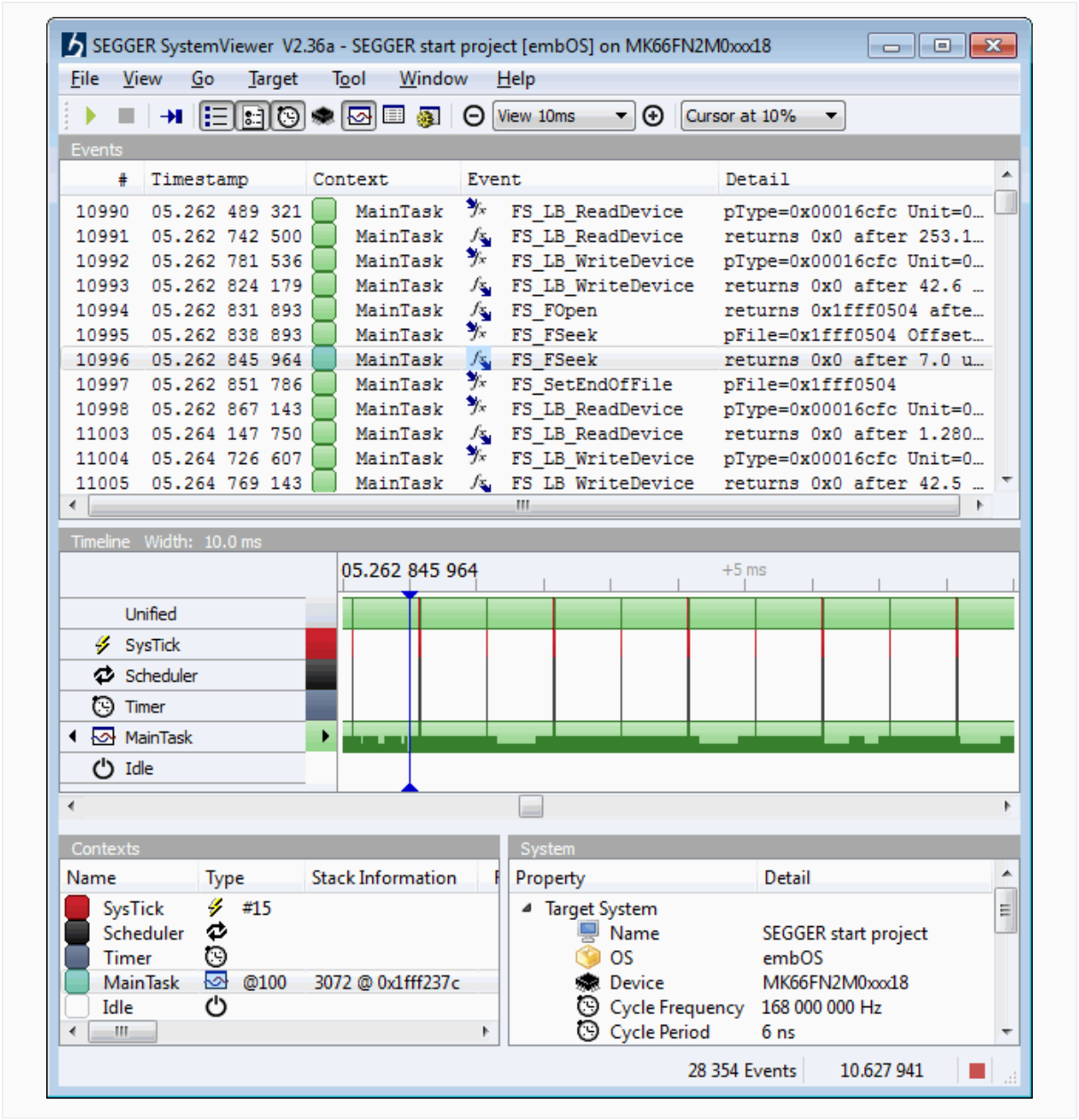
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```
  //
  // Add device driver initialization here.
  //
}
```

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12.3 Recording and analyzing profiling information

When profiling is included and enabled emFile generates profiling events. On a system which supports RTT (i.e., ARM Cortex-M and Renesas RX), the data can be read and analyzed with SystemView and a J-Link. Connect the J-Link to the target system using the default debug interface and start the SystemView host application. If the system does not support RTT, SystemView can be configured for single-shot or postmortem mode. Please refer to the SystemView User Manual for more information.



Main window of SystemView

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Chapter 13

Performance and resource usage

This chapter contains information about the RAM and ROM requirements and how to measure and improve performance of emFile.

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13.1 Resource usage

emFile has been designed to meet the requirements of any embedded system. This means the file system can be configured to include only the features required by a specific system in order to keep the RAM and ROM usage at a minimum while providing efficient access to the storage device.

The actual RAM and ROM memory requirements of emFile depend on the features used. The following section provides information about how to calculate the memory requirements and some values for typical applications. Note that the values are valid for the given configuration. Features can affect the size of others. For example, if FAT32 is deactivated, the format function gets smaller because the 32-bit-specific part of format is not added into the final executable.

13.1.1 ROM usage

13.1.1.1 Test procedure

The ROM usage was measured by compiling the file system sources with SEGGER Embedded Studio for ARM V7.10 for a Cortex-M CPU with the size optimization enabled.
The file system was configured to use the lowest debug level and the OS support was disabled:

```
#define FS_OS_LOCKING                0 // Disable OS support
#define FS_DEBUG_LEVEL               0 // Set debug level
```

No driver has been added to the file system. For information about the memory usage of a specific emFile driver refer to the “Performance and resource usage” section of the respective driver in the *Device drivers* on page 479 section.

The sample application listed below has been used to calculate the memory resources of commonly used functions. You can easily reproduce the measurement results by compiling this sample application. Build the application listed below and generate a linker listing to get the memory requirements of an application which only includes startup code and the empty main() function. Afterward, set the value of the macro STEP to 1 to get the memory requirement of the minimum file system. Subtract the ROM requirements of STEP=0 from the ROM requirements of STEP=1 to get the exact ROM requirements of a minimal file system. Increment the value of the macro STEP to include more file system functions and repeat your calculation.

FS_TEST_ROMUsage.c

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                      The Embedded Experts                          *
*                         www.segger.com                             *
**********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_TEST_ROMUsage.c
Purpose : Application to calculate the ROM usage of the file system.
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include "FS.h"
#include "FS_Int.h"

#if FS_DEBUG_LEVEL > 0
  #error FS_DEBUG_LEVEL has to be to 0.
#endif
```

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```
/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   STEP
  #define STEP      0    // Change this line to adjust which portions of code are linked
#endif

#ifndef   SUBSTEP
  #define SUBSTEP   0
#endif

/*********************************************************************
*
*       Static data
*
**********************************************************************
*/
#if STEP >= 9
  static U32 _aCache[FS_SIZEOF_CACHE_ANY(2, 512) / 4];
#endif // STEP >= 9
#if (STEP >= 10)
  static U32 _aBuffer[16];
  static U8  _NumErrors;
#endif // STEP >= 10

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

#if (STEP >= 10)

/*********************************************************************
*
*       _OnError
*/
static int _cbOnError(int ErrCode, ...) {
  (void)ErrCode;
  _NumErrors++;
  return FS_CHECKDISK_ACTION_DO_NOT_REPAIR;
}

#endif // STEP >= 10

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       MainTask
*/
void MainTask(void);
void MainTask(void) {
#if STEP >= 1            // Step 1: Minimum file system
  FS_FILE * pFile;

  FS_Init();
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Create("", 100uL * 1024uL);
#endif
  pFile = FS_FOpen("File.txt", "w");
#endif
#if STEP >= 2           // Step 2: Write a file
  FS_Write(pFile, "Test", 4);
#endif
#if STEP >= 3           // Step 3: Remove a file
```

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```
  FS_Remove("File.txt");
#endif
#if STEP >= 4           // Step 4: Open a directory
  {
    FS_FIND_DATA fd;
    char         acFileName[16];

    FS_FindFirstFile(&fd, "", acFileName, sizeof(acFileName));
    FS_FindClose(&fd);
   }
#endif
#if STEP >= 5          // Step 5: Create a directory
  FS_MkDir("TestDir");
#endif
#if STEP >= 6          // Step 6: Add long file name support
#if (FS_SUPPORT_FAT != 0)
  FS_FAT_SupportLFN();
#endif
#endif
#if STEP >= 7          // Step 7: Low-level format a storage device
  FS_FormatLow("");
#endif
#if STEP >= 8          // Step 8: High-level format a storage device
  FS_Format("", NULL);
#endif
#if STEP >= 9          // Step 9: Assign cache
#if (SUBSTEP == 0)
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_ALL);
#endif
#if (SUBSTEP == 1)
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_MAN);
#endif
#if (SUBSTEP == 2)
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_RW);
#endif
#if (SUBSTEP == 3)
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_RW_QUOTA);
#endif
#if (SUBSTEP == 4)
  FS_AssignCache("", _aCache, sizeof(_aCache), FS_CACHE_MULTI_WAY);
#endif

#endif
#if STEP >= 10         // Step 10: Disk checking
  _NumErrors = 0;
  FS_CheckDisk("", _aBuffer, sizeof(_aBuffer), 1, _cbOnError);
#endif
#if STEP >= 11         // Step 11: Get information about storage device
  {
    FS_DISK_INFO DiskInfo;

    FS_GetVolumeInfo("", &DiskInfo);
  }
#endif
#if STEP >= 12         // Step 12: Get the size of a file
  FS_GetFileSize(pFile);
#endif
#if STEP >= 1          // Step 1: Minimum file system
  FS_FClose(pFile);
#endif
}

/*********************************************************************
*
*       FS_X_AddDevices
*/
void FS_X_AddDevices(void) {
  ;
}

/*********************************************************************
*
*       FS_X_GetTimeDate
*
*  Description:
*    Current time and date in a format suitable for the file system.
```

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```
*
*    Bit 0-4:   2-second count (0-29)
*    Bit 5-10:  Minutes (0-59)
*    Bit 11-15: Hours (0-23)
*    Bit 16-20: Day of month (1-31)
*    Bit 21-24: Month of year (1-12)
*    Bit 25-31: Count of years from 1980 (0-127)
*
*/
U32 FS_X_GetTimeDate(void) {
  U32 r;
  U16 Sec, Min, Hour;
  U16 Day, Month, Year;

  Sec   = 0;        // 0 based.  Valid range: 0..59
  Min   = 0;        // 0 based.  Valid range: 0..59
  Hour  = 0;        // 0 based.  Valid range: 0..23
  Day   = 1;        // 1 based.    Means that 1 is 1. Valid range is 1..31 (depending on month)
  Month = 1;        // 1 based.    Means that January is 1. Valid range is 1..12.
  Year  = 0;        // 1980 based. Means that 2007 would be 27.
  r   = Sec / 2 + (Min << 5) + (Hour  << 11);
  r  |= (U32)(Day + (Month << 5) + (Year  << 9)) << 16;
  return r;
}

/*************************** End of file ****************************/
```

13.1.1.2 Test results

The following table shows the ROM usage of different API functions for the FAT file system.

Step	Substep	Description	ROM [Kbytes]
1		File system core (without driver)	9.5
2		Write file	1.1
3		Remove file	0.03
4		Open directory	0.5
5		Create directory	0.5
6		Long file name support	3.5
7		Low-level format storage device	0.3
8		High-level format storage device	1.7
9	0	Assign a cache (FS_CACHE_ALL)	0.4
9	1	Assign a cache (FS_CACHE_MAN)	0.4
9	2	Assign a cache (FS_CACHE_RW)	0.7
9	3	Assign a cache (FS_CACHE_RW_QUOTA)	1.0
9	4	Assign a cache (FS_CACHE_MULTI_WAY)	1.1
10		Disk checking	3.5
11		Get information about storage device	0.4
12		Get the size of a file	0.05

Additional information

Typically, a simple file system uses about 10 Kbytes of ROM. To calculate the overall ROM usage, the ROM usage of the used driver(s) needs to be added.

13.1.2 Static RAM usage

Static RAM usage refers to the amount of RAM required by the file system internally for all the storage devices. **Usage: 150 bytes**

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13.1.3 Dynamic RAM usage

Dynamic RAM is the amount of memory allocated by the file system at runtime. Most of the dynamic RAM is allocated during the initialization of the file system. The amount of memory allocated depends on the number of added devices, the number of simultaneously opened files and the type of OS locking as follows:

Data structure	Size (Bytes)	Count
File handle	24 + 4 (if FS_SUPPORT_FILE_BUFFER = 1)	Maximum number of simultaneously open files. Depends on application, minimum is 1.
File object	46 + 2 (if FS_FAT_OPTIMIZE_LINEAR_ACCESS = 1 or FS_EFS_OPTIMIZE_LINEAR_ACCESS = 1) + 6 (if FS_FAT_OPTIMIZE_LINEAR_ACCESS = 2 or FS_EFS_OPTIMIZE_LINEAR_ACCESS = 2) + FS_MAX_LEN_FULL_FILE_NAME (if FS_MULTI_HANDLE_SAFE = 1) + 8 (if FS_SUPPORT_ENCRYPTION = 1)	Maximum number of simultaneously open files. Depends on application, minimum is 1.
Volume instance	120 + 4 (if FS_SUPPORT_VOLUME_ALIAS ≠ 0 and FS_MAX_LEN_VOLUME_ALIAS = 0) + FS_MAX_LEN_VOLUME_ALIAS (if FS_SUPPORT_VOLUME_ALIAS ≠ 0 and FS_MAX_LEN_VOLUME_ALIAS > 0)	Number of FS_AddDevice() calls
FS_OS_LOCKING = 0 (no OS is used)		
Sector buffer	8 + sector size (512 bytes by default)	2 + 1 (if FS_SUPPORT_ENCRYPTION = 1) + 1 (if FS_SUPPORT_JOURNAL = 1)
FS_OS_LOCKING = 1 (OS locking at API level)		
Sector buffer	8 + sector size (512 bytes by default)	2 + 1 (if FS_SUPPORT_ENCRYPTION = 1) + 1 (if FS_SUPPORT_JOURNAL = 1)
OS synchronization object	Depends on the OS used	1
FS_OS_LOCKING = 2 (OS locking at driver level)		
Sector buffer	8 + sector size (512 bytes by default)	2 + 1 (if FS_SUPPORT_ENCRYPTION = 1) + 1 (if FS_SUPPORT_JOURNAL = 1) x number of FS_AddDevice() calls
OS synchronization object	Depends on the OS used	1 + number of FS_AddDevice() calls
OS locking instance	16	number of FS_AddDevice() calls

Note

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The RAM usage of a volume instance does not include the RAM required by the device or logical driver attached to that volume. The amount of RAM required by a driver instance is documented in the “Performance and resource usage” of that driver.

Note

File handles and file objects can also be allocated after the file system initialization depending on how many files the application opens at the same time.

RAM usage example

A small file system application with the following configuration

- only one file is opened at a time
- no operating system support
- using the SD card driver

requires approximately **1300 bytes**.

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13.2 Performance

A benchmark is used to measure the speed of the software on available targets. This benchmark is in no way complete, but it gives an approximation of the length of time required for common operations on various targets. You can find the measurement results in the chapter describing the individual drivers.

13.2.1 Test procedure

The performance tests are executed using the `FS_PerformanceSimple.c` application that can be found in the `{Sample/FS/Application}` folder of the emFile shipment.

The test application performs the following steps:

1. Format the drive.
2. Create and open a file for writing.
3. Start measuring of write performance.
4. Write a multiple of 8 Kbytes.
5. Stop measuring of write performance.
6. Close the file.
7. Reopen the file for reading.
8. Start measuring of read performance.
9. Read a multiple of 8 Kbytes.
10. Stop measuring of read performance.
11. Close the file.
12. Show the performance results.

FS_PerformanceSimple.c

```
/*********************************************************************
*                  (c) SEGGER Microcontroller GmbH                   *
*                       The Embedded Experts                         *
*                          www.segger.com                            *
*********************************************************************

------------------------- END-OF-HEADER -----------------------------

File    : FS_PerformanceSimple.c
Purpose : Sample program that can be used to measure the performance
          of the file system.

Additional information:
  Preparations:
    Works out-of-the-box with any storage device.

  Expected behavior:
    Measures the speed at witch the file system can write and read blocks
    of data to and from a file. The size of the file as well as the number
    of bytes that have to be written at once are configurable.

    The application always formats the storage device to make sure that
    the measurements are not influenced by the data already stored on the
    file system.

  Sample output:
    Start
    High-level format
    Writing 4 chunks of 2048 KB.......OK
    Reading 4 chunks of 2048 KB.......OK

    W Speed: 9183 KB/s
    R Speed: 18123 KB/s
    Finished

  Notes:
    The sample application may report a write or read speed of 0
    if a very fast storage device is used for the test such as a RAM disk.
    This is normal behavior and the reason for this is that the accuracy
    of the time base used for the measurements is limited to 1 ms.
    This limitation can be removed by increasing the size of the work buffer
```

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```
    via the BLOCK_SIZE configuration define.
*/

/*********************************************************************
*
*       #include section
*
**********************************************************************
*/
#include <string.h>
#include "FS.h"
#include "FS_OS.h"
#include "SEGGER.h"

/*********************************************************************
*
*       Defines, configurable
*
**********************************************************************
*/
#ifndef   FILE_SIZE
  #define FILE_SIZE             (8192L * 1024L)
  // Size of the file in bytes to be used for testing.
#endif

#ifndef   BLOCK_SIZE
  #define BLOCK_SIZE            (8 * 1024L)
  // Block size for individual read / write operation in bytes.
#endif

#ifndef   NUM_BLOCKS_MEASURE
  #define NUM_BLOCKS_MEASURE    (64)                  // Number of blocks for individual measurement
#endif

#ifndef   VOLUME_NAME
  #define VOLUME_NAME           ""                    // Name of the volume to be used for testing.
#endif

#ifndef   FILE_NAME
  #define FILE_NAME             "SEGGER.txt"          // Name of the file to be used for testing.
#endif

#ifndef   USE_PREALLOCATION
  #define USE_PREALLOCATION     1
  // Configures if the file preallocation has to be used.
#endif

#if FS_SUPPORT_JOURNAL
  #ifndef   JOURNAL_SIZE
    #define JOURNAL_SIZE        0                     // Size of the Journaling file in bytes.
  #endif
#endif

/*********************************************************************
*
*       Local data types
*
**********************************************************************
*/

/*********************************************************************
*
*       RESULT
*/
typedef struct {
  const char * sName;
  I32          Min;
  I32          Max;
  I32          Total;
  I32          Av;
  I32          Sum;
  I32          NumSamples;
  U32          NumBytes;
} RESULT;

/*********************************************************************
```

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```
*
*       Static data
*
**********************************************************************
*/
static U32    _aBuffer[BLOCK_SIZE / 4];
static RESULT _aResult[2];
static int    _TestNo;
static char   _ac[512];

/*********************************************************************
*
*       Static code
*
**********************************************************************
*/

/*********************************************************************
*
*       _WriteFile
*
*  Function description
*    Measures the write time.
*/
static I32 _WriteFile(FS_FILE * pFile, const void * pData, U32 NumBytes, U32 NumBlocksMeasure) {
  I32 t;
  U32 i;

  t = (I32)FS_X_OS_GetTime();
  for (i = 0; i < NumBlocksMeasure; i++) {
    (void)FS_Write(pFile, pData, NumBytes);
  }
  return (I32)FS_X_OS_GetTime() - t;
}


/*********************************************************************
*
*       _ReadFile
*
*  Function description
*    Measures the read performance.
*/
static I32 _ReadFile(FS_FILE * pFile, void * pData, U32 NumBytes, U32 NumBlocksMeasure) {
  I32 t;
  U32 i;

  t = (I32)FS_X_OS_GetTime();
  for (i = 0; i < NumBlocksMeasure; i++) {
    (void)FS_Read(pFile, pData, NumBytes);
  }
  return (I32)FS_X_OS_GetTime() - t;
}
/*********************************************************************
*
*       _StartTest
*/
static void _StartTest(const char * sName, U32 NumBytes) {
  RESULT * pResult;

  if ((_TestNo + 1) < (int)SEGGER_COUNTOF(_aResult)) {
    pResult = &_aResult[++_TestNo];
    pResult->sName      = sName;
    pResult->Min        =  0x7fffffff;
    pResult->Max        = -0x7fffffff;
    pResult->Total      = 0;
    pResult->NumSamples = 0;
    pResult->Sum        = 0;
    pResult->NumBytes   = NumBytes;
  }
}

/*********************************************************************
*
*       _StoreResult
*/
```

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```
static void _StoreResult(I32 t) {
  RESULT * pResult;

  pResult = &_aResult[_TestNo];
  if (t > pResult->Max) {
    pResult->Max = t;
  }
  if (t < pResult->Min) {
    pResult->Min = t;
  }
  pResult->Total += t;
  pResult->NumSamples++;
  pResult->Sum += (I32)t;
  pResult->Av   = pResult->Sum / pResult->NumSamples;
}

/*********************************************************************
*
*       _GetAverage
*/
static double _GetAverage(int Index) {
  RESULT   * pResult;
  double     v;
  unsigned   NumKBytes;

  pResult = &_aResult[Index];
  v = (double)pResult->Av;
  if ((U32)v == 0u) {
    v = 1.0;
  // Make sure that we display the maximum speed if the timer resolution is too low.
  }
  v = (double)1000.0 / v;
  NumKBytes = pResult->NumBytes >> 10;
  v = v * (double)NumKBytes;
  return v;
}

/*********************************************************************
*
*       Public code
*
**********************************************************************
*/

/*********************************************************************
*
*       MainTask
*/
#ifdef __cplusplus
extern "C" {     /* Make sure we have C-declarations in C++ programs */
#endif
void MainTask(void);
#ifdef __cplusplus
}
#endif
void MainTask(void) {
  int       i;
  U32       Space;
  unsigned  NumLoops;
  U32       NumBytes;
  U32       NumBytesAtOnce;
  FS_FILE * pFile;
  I32       t;
  int       r;
  U32       NumBlocksMeasure;
  char      acFileName[128];

  FS_X_Log("Start\n");
  FS_Init();
  _TestNo = -1;
  //
  // Check if we need to low-level format the volume
  //
  if (FS_IsLLFormatted(VOLUME_NAME) == 0) {
    FS_X_Log("Low-level format\n");
    (void)FS_FormatLow(VOLUME_NAME);
```

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```
  }
  //
  // Volume is always high level formatted
  // before doing any performance tests.
  //
  FS_X_Log("High-level format\n");
#if FS_SUPPORT_FAT
  r = FS_FAT_FormatSD(VOLUME_NAME);
#elif FS_SUPPORT_EXFAT
#if FS_EXFAT_UPDATE_SPACE_USAGE
  FS_EXFAT_ConfigSpaceUsageUpdate(0);
  // Make sure that we get exact information about the free space.
#endif // FS_EXFAT_UPDATE_SPACE_USAGE
  r = FS_EXFAT_FormatSD(VOLUME_NAME);
#else
  r = FS_FormatEx(VOLUME_NAME);
#endif // FS_SUPPORT_FAT
  if (r == 0) {
#if FS_SUPPORT_JOURNAL
    FS_SetFileWriteMode(FS_WRITEMODE_SAFE);
#if JOURNAL_SIZE
    //
    // Enable Journaling.
    //
    FS_JOURNAL_CreateEx(VOLUME_NAME, JOURNAL_SIZE, 1);
#endif // JOURNAL_SIZE
#else
    //
    // Configure the file system so that the
    // directory entry and the allocation table
    // are updated when the file is closed.
    //
    FS_SetFileWriteMode(FS_WRITEMODE_FAST);
#endif // FS_SUPPORT_JOURNAL
    //
    // Fill the buffer with data.
    //
    memset(_aBuffer, (int)'a', sizeof(_aBuffer));
    //
    // Get some general info.
    //
    Space            = FS_GetVolumeFreeSpace(VOLUME_NAME);
    Space            = SEGGER_MIN(Space, (U32)FILE_SIZE);
    NumBytesAtOnce   = BLOCK_SIZE;
    NumBlocksMeasure = NUM_BLOCKS_MEASURE;
    for (;;) {
      NumBytes = NumBytesAtOnce * NumBlocksMeasure;
      if (NumBytes <= Space) {
        break;
      }
      NumBytesAtOnce   >>= 1;
      NumBlocksMeasure >>= 1;
    }
    NumLoops = Space / NumBytes;
    if (NumLoops != 0u) {
      //
      // Create file of full size.
      //
      _StartTest("W", NumBytes);
      SEGGER_snprintf(acFileName, (int)sizeof(acFileName), "%s%c
%s", VOLUME_NAME, FS_DIRECTORY_DELIMITER, FILE_NAME);
      pFile = FS_FOpen(acFileName, "w");
#if USE_PREALLOCATION
      //
      // Preallocate the file, setting the file pointer to the highest position
      // and declare it as the end of the file.
      //
      (void)FS_FSeek(pFile, (I32)Space, FS_SEEK_SET);
      (void)FS_SetEndOfFile(pFile);
      //
      // Set file position to the beginning.
      //
      (void)FS_FSeek(pFile, 0, FS_SEEK_SET);
#endif // USE_PREALLOCATION
      //
      // Check write performance with clusters/file size preallocated.
```

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```
      //
      SEGGER_snprintf(_ac, (int)sizeof(_ac), "Writing %d chunks of %lu
 KB...", NumLoops, NumBytes >> 10);
      FS_X_Log(_ac);
      for (i = 0; i < (int)NumLoops ; i++) {
        t = _WriteFile(pFile, _aBuffer, NumBytesAtOnce, NumBlocksMeasure);
        _StoreResult(t);
        FS_X_Log(".");
      }
      FS_X_Log("OK\n");
      (void)FS_FClose(pFile);
      //
      // Check read performance.
      //
      _StartTest("R", NumBytes);
      SEGGER_snprintf(_ac, (int)sizeof(_ac), "Reading %d chunks of %lu
 KB..." , NumLoops, NumBytes >> 10);
      FS_X_Log(_ac);
      pFile = FS_FOpen(acFileName, "r");
      for (i = 0; i < (int)NumLoops; i++) {
        t = _ReadFile(pFile, _aBuffer, NumBytesAtOnce, NumBlocksMeasure);
        _StoreResult(t);
        FS_X_Log(".");
      }
      FS_X_Log("OK\n\n");
      (void)FS_FClose(pFile);
      (void)FS_Remove(acFileName);
      //
      // Show results for performance list.
      //
      for (i = 0; i <= _TestNo; i++) {
        SEGGER_snprintf(_ac, (int)sizeof(_ac), "%s Speed: %d KB/s (%d
 ms)\n", _aResult[i].sName, (int)_GetAverage(i), _aResult[i].Total);
        FS_X_Log(_ac);
      }
    } else {
      FS_X_Log("ERROR: Not enough free space available on the storage.\n");
    }
    FS_Unmount(VOLUME_NAME);
  } else {
    FS_X_Log("ERROR: Volume could not be formatted!\n");
  }
  FS_X_Log("Finished\n");
  for (;;) {
    ;
  }
}

/************************** End of file ***************************/
```

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13.2.2 How to improve performance

If you find that the performance of emFile on your hardware is not what you expect, there are several ways you can improve it.

Use a different write mode

The default behavior of the file system is to update the allocation table and the directory entry after each write operation. If several write operations are performed between the opening and the closing of the file, it is recommended to set the write mode to `FS_WRITEMODE_MEDIUM` or `FS_WRITEMODE_FAST` to increase the performance. In these modes, the allocation table and the directory entry are updated only when the file is closed. Refer to `FS_SetFileWriteMode()` to learn how the write mode can be configured. Please note that these write modes cannot be used when journaling is enabled.

Pre-allocate the files

The pre-allocation of a file helps reduce the number of accesses to the storage device and therefore improves the read and write performance. When a file is pre-allocated, the file system reserves storage space for that file in the allocation table before the file is actually filled with data. As such, a write access to the allocation table is no longer necessary when the data is actually stored to the file. A file can be pre-allocated by calling either `FS_SetEndOfFile()` or `FS_SetFileSize()` in the application after the file is opened.

Write multiples of a logical sector size

The file system implements a 0-copy mechanism in which data written to a file using the `FS_FWrite()` and `FS_Write()` functions is passed directly to the device driver if the data is written at a sector boundary and the number of bytes written is a multiple of the sector size. In any other case the file system uses a read-modify-write operation which increases the number of I/O operations and reduces the performance. The file system makes sure that the content of a file always begins at a sector boundary.

Use a file buffer

It is recommended to activate the file buffering when the application reads and writes amounts of data smaller than the sector size. Refer to `FS_ConfigFileBufferDefault()` to see how this can be done. The file buffer is a small cache which helps reduce the number of times the storage medium is accessed and thus increase the performance.

Use a sector cache

The sector cache can be enabled to increase the overall performance of the file system. For more information refer to *Caching and buffering* on page 456.

Configure a read-ahead driver

The read-ahead driver is useful when a storage medium is used which is more efficient when several sectors are read or written at once. This includes storage media such as CompactFlash cards, SD and MMC cards and USB sticks. Normally, the file system reads the allocation table one sector at a time. If configured, the file system activates the read-ahead driver at runtime when the allocation table is accessed. This reduces, for example, the time it takes to determine the amount of free space. For more information refer to *Sector Read-Ahead driver* on page 1306.

Optimize the hardware layer

Ensure that the routines of the hardware layer are fast. It depends on your compiler how to do that. Some compilers have the option to define a function as running from RAM which is faster compared to running it from flash.

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Use the FS_OPTIMIZE macro

The definitions of time-critical functions in emFile are prefixed with the macro `FS_OPTIMIZE`. By default, it expands to nothing. You can use this macro to enable the compiler optimization only for these functions. It depends on your compiler how to define this macro.

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Chapter 14

Journaling

This chapter documents and explains emFile's Journaling component. The Journaling component is an extension to the file system that makes the file operations fail-safe.

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14.1 General information

emFile Journaling is an additional component that can be used to protect the integrity of the file system structure against an unexpected reset. The FAT and EFS file systems are by design not fail-safe; therefore, the use of the Journaling component is recommended for any system that may suddenly lose power while writing data to a storage device. The Journaling component is located between the file system and the storage layer and works by temporarily storing all the data changes performed by the file system layer in a journal file. The changes are then copied at once from the journal file to the actual destination on the storage device.

14.1.1 Driver fail-safety

Data can be lost in case of an unexpected reset in either the file system layer (FAT or EFS) or in the driver layer. The entire system is fail-safe only if both layers are fail-safe. The Journaling component ensures that the file system layer is fail-safe. For fail-safety of the driver layer, refer to *Device drivers* on page 479.

14.1.2 Features

- Non-fail-safe file systems will be fail-safe.
- Fully compatible with standard file system implementations (e.g., FAT).
- Every type of storage device is supported. No reformat required.
- Multiple write accesses to the storage medium can be combined in the user application.

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14.2 Theory of operation

emFile is typically used with non-fail-safe file systems like FAT. Loss of data can occur in either the driver layer or the file system layer. The driver layer is typically fail-safe. Therefore, the only place where a typical data loss can occur is the file system layer. The file system can be corrupted when a write operation is interrupted, for example, in the event of a power failure or system crash. This is due to the design of the FAT file system and is true for all implementations from any vendor. The emFile Journaling component adds fail-safety to the file system layer.

The goal of this additional component is to guarantee a file system that is always in a consistent state. Operations at the file system layer are mostly not atomic. For example, a single call to `FS_FWrite()` that writes data into a new file causes the execution of the following three storage layer operations:

1. Allocate cluster and update FAT.
2. Write user data.
3. Update directory entry.

An unexpected interrupt (such as a power failure) in this process can corrupt the file system. To prevent such corruptions, the Journaling component stores every write access to achieve an always consistent state of the file system. All changes to the file system are stored in a journal file. The data stored in the journal file is copied to the actual destination on the storage device only if the file system layer operation has been finished without interruption. This procedure guarantees an always consistent state of the file system, because an interruption of the copy process does not lead to data loss. The interrupted copy process is restarted after a restart of the target hardware.

The following table lists the possible error scenarios:

	Moment of error	State	Data
1.	Journal empty	Consistent	—
2.	While writing into journal	Consistent	Lost
3.	While finalizing the journal	Consistent	Lost
4.	After finalization	Consistent	Preserved
5.	While copying from journal into file system	Consistent	Preserved
6.	After copy process, before invalidation of the journal	Consistent	Preserved
7.	While invalidating the journal	Consistent	Preserved

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14.3 Write optimization

The Journaling component has been optimized for write performance. When data is written at the end of a file, which is the case in most applications, only the management information (allocation table and directory entry) is actually stored to the journal file. The file contents is written directly to the actual destination on the storage device that helps improve the write performance. The fail-safety of the file system layer is not affected as the file contents overwrite storage blocks that are not allocated to any file or directory. The optimization is disabled as soon as a file or directory is deleted during a journal transaction. This is done in order to make sure that the data of the deleted file or directory is preserved in case of an unexpected reset.

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14.4 How to use the Journaling component

Using the Journaling component is very simple from the application's perspective. Only two changes have to be made to an existing application in order to enable the Journaling component:

1. The Journaling component has to be enabled in the file system configuration via the FS_SUPPORT_JOURNAL configuration define. Optionally, the name of the journal file can be configured via the FS_JOURNAL_FILE_NAME configuration define. For more information about additional compile-time options, refer to the section *Configuration* on page 1418.
2. The application has to call either FS_JOURNAL_Create() or FS_JOURNAL_CreateEx() after formatting the volume to create the file required for the journal operation. Refer to FS_JOURNAL_Create() and FS_JOURNAL_CreateEx() for detailed information.

Everything else is done by the Journaling component.

14.4.1 Combining multiple write operations

The Journaling component can be used in the application to create a journal transaction that consists of multiple write operations. This can be useful when, for example, the changes made to two different files have to be performed in an atomic way. That is, after an unexpected reset that interrupts the write operation, the files have to contain either the old or the new data but never a combination of both. A journal transaction can be opened via FS_JOURNAL_Begin() and has to be closed using FS_JOURNAL_End() as shown in the sample below.

```
#include "FS.h"

void SampleJournalMultipleWrite(void) {
  FS_FILE * pFile;

  //
  // Begin an operations which have to be be fail-safe.
  // All following steps will be stored into journal.
  //
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Begin("");
#endif // FS_SUPPORT_JOURNAL
  pFile = FS_FOpen("File1.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 1", 6);
    FS_FClose(pFile);
  }
  pFile = FS_FOpen("File2.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 2", 6);
    FS_FClose(pFile);
  }
  //
  // End an operation which has to be be fail-safe.
  // Data is copied from journal into file system.
  //
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_End("");
#endif // FS_SUPPORT_JOURNAL
}
```

14.4.2 Preserving the consistency of a file

The Journaling component can be used in the application to protect the contents of the file against unexpected resets. This means that after an unexpected reset that interrupted the file write operation, the file will contain either the old data or the new data but not a combination of both. The same applies to the particular case where the application writes to an empty file. The first method uses FS_JOURNAL_Begin() and FS_JOURNAL_End() to create a journal transaction as shown in the next example code. The advantage of this method is that a relatively small writing buffer can be used.

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```
#include "FS.h"

void SampleJournalFileConsistency1(void) {
  U8        aBuffer[128];
  FS_FILE * pFile;

  pFile = FS_FOpen("File.txt", "w");
  if (pFile) {
#if FS_SUPPORT_JOURNAL
    FS_JOURNAL_Begin("");
#endif // FS_SUPPORT_JOURNAL
    memset(aBuffer, 'a', sizeof(aBuffer));
    FS_Write(pFile, aBuffer, sizeof(aBuffer));
    memset(aBuffer, 'b', sizeof(aBuffer));
    FS_Write(pFile, aBuffer, sizeof(aBuffer));
    //
    // Changes are committed in a single journaling transaction
    // assuming the journal file is sufficiently large to store
    // all the changes performed by the file system.
    //
#if FS_SUPPORT_JOURNAL
    FS_JOURNAL_End("");
#endif // FS_SUPPORT_JOURNAL
    FS_FClose(pFile);
  }
}
```

The second method uses a buffer sufficiently large to store the contents of the entire file that is then passed to `FS_FWrite()` or `FS_Write()` in a single function call. This method is demonstrated in the following example code.

```
#include "FS.h"

void SampleJournalFileConsistency2(void) {
  U8        aBuffer[256];
  FS_FILE * pFile;

  pFile = FS_FOpen("File.txt", "w");
  if (pFile) {
    memset(aBuffer, 'a', 128);
    memset(&aBuffer[128], 'b', 128);
    //
    // The changes are committed in a single journal transaction
    // assuming that the journal file is sufficiently large to
    // store all the changes.
    //
    FS_Write(pFile, aBuffer, sizeof(aBuffer));
    FS_FClose(pFile);
  }
}
```

Both methods require that the journal file is sufficiently large to store all the changes made to the storage device by the file system during the write operation. When writing to a file that is not empty the management data and the file contents are stored in the journal file. If the file the application is writing to is initially empty then only the management data has to be stored to the journal file. In this case the contents of the file are written directly to the actual destination on the storage device which means that a smaller journal file can be used.

14.4.3 Journaling and write caching

In order to guarantee the correct operation of the Journaling component, most of the write caching performed by the file system has to be disabled. That is, the file system has to be configured to write the data immediately to the storage device instead of keeping the data in its internal RAM buffers. If not configured in this way, the journaling is no longer able to ensure the fail-safety of the file system on an unexpected reset because the data stored in the internal RAM buffers will be lost.

The correct operation of the Journaling component is guaranteed when:

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- **The sector cache in write-back mode is disabled**. emFile comes with support for caching at logical sector level. The sector cache is disabled by default, and it has to be explicitly enabled in the application via `FS_AssignCache()`. Five types of sector caches are provided, with three of them also supporting a write mode. The `FS_CACHE_ALL` and `FS_CACHE_MAN` cache types are pure read caches and can always be used together with the Journaling component. The other three types of caches, `FS_CACHE_RW`, `FS_CACHE_RW_QUOTA`, and `FS_CACHE_MULTI_WAY`, can work in read as well as in write-back and write-through mode. The application has to make sure that the write-back mode is disabled for this type of sector caches. The write-through mode can be used together with the Journaling component without negatively affecting the fail-safety of the file system. For detailed information about the configuration of sector caches, refer to *Caching and buffering* on page 456.
- **The delayed update of directory entries is disabled**. The file system can be configured to update the directory entries only when the file is closed. This is done in order to increase the write performance. This feature is enabled via `FS_ConfigOnWriteDirUpdate()` with the OnOff parameter set to 0. The application has to make sure that this API function is not called at all or that it is called with the OnOff parameter set to 1.
- **The file system write mode is set to `FS_WRITEMODE_SAFE`**. emFile can be configured to use different methods when it writes data to a file. The application has to make sure that the write mode is set to `FS_WRITEMODE_SAFE`. This write mode guarantees that the data is written immediately to the storage device. By default, the file system uses the `FS_WRITEMODE_SAFE` write mode. The write mode can be changed at runtime via `FS_SetFileWriteMode()`. If this function is called in the application, then the WriteMode parameter has to be set to `FS_WRITEMODE_SAFE`. Alternatively, the call to `FS_SetFileWriteMode()` can be removed.

> **Note**
>
> Beginning with the version 4.04g of emFile, an application is allowed to use a file buffer in write mode with the Journaling component enabled without the risk of damaging the structure of a file system in case of an unexpected reset. This was not possible with versions older than 4.04g because of the way the file buffer was implemented.

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14.5 Configuration

The Journaling component has to be configured at compile time as well as at runtime to enable its operation.

14.5.1 Compile time configuration

The configuration at compile time is realized via preprocessor defines that have to be added to the FS_Conf.h file which is the main configuration file of emFile. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the Journaling component.

Define	Type	Default value	Description
FS_SUPPORT_JOURNAL	B	0	Enables or disables the Journaling component.
FS_JOURNAL_FILE_NAME	S	"Journal.dat"	Configures the default name of the journal file.
FS_MAX_LEN_JOURNAL_FILE_NAME	N	0	Configures the space reserved for the journal file name.
FS_JOURNAL_ENABLE_STATS	B	0	Enables or disables the support for statistical counters.
FS_JOURNAL_SUPPORT_FREE_SECTOR	B	1	Enables or disables the support for informing the device driver about unused logical sectors.
FS_JOURNAL_SUPPORT_FAST_SECTOR_SEARCH	B	1	Specifies which method to use when searching for a logical sector in the journal file.
FS_JOURNAL_OPTIMIZE_SPACE_USAGE	B	0	Enables or disables the efficient handling of consecutive logical sector operations.

14.5.1.1 FS_SUPPORT_JOURNAL

This define has to be set to 1 in order to enable the support for the Journaling component in the file system. The journal must be initialized in the application at runtime by calling either FS_JOURNAL_Create() or FS_JOURNAL_CreateEx().

14.5.1.2 FS_JOURNAL_FILE_NAME

This define specifies the default name of the journal file. The name of the journal file can be changed at runtime by calling FS_JOURNAL_SetFileName().

14.5.1.3 FS_MAX_LEN_JOURNAL_FILE_NAME

FS_MAX_LEN_JOURNAL_FILE_NAME is the maximum number of characters (including the 0-terminator) in the name of the journal file. A value of 0 disables the feature, which is the default. The RAM usage of a volume instance increases by the number of bytes specified via this configuration define. The actual file name can be set at runtime using FS_JOURNAL_SetFileName()

14.5.1.4 FS_JOURNAL_ENABLE_STATS

The support for statistical counters can be enabled or disabled by using this define. The statistical counters provide information about the operation of the Journaling component. The values of the statistical counters can be queried via FS_JOURNAL_GetStatCounters() and cleared via FS_JOURNAL_ResetStatCounters().

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14.5.1.5 FS_JOURNAL_SUPPORT_FREE_SECTOR

With this feature enabled, the Journaling component forwards information about unused logical sectors to the device driver. A device driver such as a NAND or NOR driver can use this information to optimize the handling of the data. The operation has to be enabled at runtime via the IsFreeSectorSupported parameter of `FS_JOURNAL_CreateEx()`.

14.5.1.6 FS_JOURNAL_SUPPORT_FAST_SECTOR_SEARCH

If this define is set to 1 then each entry in the logical to physical mapping table of the Journaling component is 32 bits in size, which improves the read and write performance. At the same time, setting `FS_JOURNAL_SUPPORT_FAST_SECTOR_SEARCH` to 1 increases the RAM usage of the Journaling component.

14.5.1.7 FS_JOURNAL_OPTIMIZE_SPACE_USAGE

Setting this configuration define to 1 enables the Journaling component to group consecutive sector operations so that the space available in the journal file is used more efficiently. In particular, this option helps prevent the occurrence of journal overflow events when the application deletes large files with the support for the free sector operation enabled. Enabling this option increases the RAM usage of the Journaling component.

14.5.2 Runtime configuration

The Journaling component requires a file to temporarily store the changes performed by the file system. This file has to be created at runtime after the storage device is formatted by calling either `FS_JOURNAL_Create()` or `FS_JOURNAL_CreateEx()`.

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14.6 API functions

The table below lists the available API functions.

Function	Description
FS_JOURNAL_Begin()	Opens a journal transaction.
FS_JOURNAL_Create()	Creates the journal file.
FS_JOURNAL_CreateEx()	Creates the journal file.
FS_JOURNAL_Disable()	Deactivates the journal.
FS_JOURNAL_Enable()	Activates the journal.
FS_JOURNAL_End()	Closes a journal transaction.
FS_JOURNAL_GetInfo()	Returns information about the journal.
FS_JOURNAL_GetOpenCnt()	Returns the number times the current journal transaction has been opened.
FS_JOURNAL_GetStatCounters()	Returns statistical information about the operation.
FS_JOURNAL_Invalidate()	Cancels the pending journal transaction.
FS_JOURNAL_IsEnabled()	Checks the journal operational status.
FS_JOURNAL_IsPresent()	Checks the presence of journal file.
FS_JOURNAL_ResetStatCounters()	Sets to 0 all statistical counters.
FS_JOURNAL_SetFileName()	Configures the name of the journal file.
FS_JOURNAL_SetOnOverflowExCallback()	Registers a callback function for the journal full event.
FS_JOURNAL_SetOnOverflowCallback()	Registers a callback function for the journal full event.

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14.6.1 FS_JOURNAL_Begin()

Description

Opens a journal transaction.

Prototype

```
int FS_JOURNAL_Begin(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 0 OK, journal transaction opened.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The file system opens and closes journal transactions automatically as required. The application can use this function together with `FS_JOURNAL_End()` to create journal transactions that extend over multiple file system operations. A journal transaction can be opened more than once using `FS_JOURNAL_Begin()` and it has to be closed by calling `FS_JOURNAL_End()` by the same number of times.

Following the call to `FS_JOURNAL_Begin()` all the data written by the application is stored to the journal file until either the application calls `FS_JOURNAL_End()` or the journal becomes full. An application can get informed about a journal full event by registering a callback function via `FS_JOURNAL_SetOnOverflowCallback()` or `FS_JOURNAL_SetOnOverflowExCallback()`

It is mandatory that `FS_JOURNAL_Begin()` and `FS_JOURNAL_End()` are called in pairs. The calls to these functions can be nested. The current nesting level can be queried via `FS_JOURNAL_GetOpenCnt()`.

Example

```
#include "FS.h"

void SampleJournalBegin(void) {
  FS_FILE * pFile;

#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Begin("");               // Open the journal transaction.
#endif // FS_SUPPORT_JOURNAL
  pFile = FS_FOpen("File1.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 1", 6);
    FS_FClose(pFile);
  }
  pFile = FS_FOpen("File2.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 2...", 6);
    FS_FClose(pFile);
  }
  pFile = FS_FOpen("File3.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 3...", 6);
    FS_FClose(pFile);
  }
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_End("");                 // Close the journal transaction.
#endif // FS_SUPPORT_JOURNAL
}
```

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14.6.2 FS_JOURNAL_Create()

Description

Creates the journal file.

Prototype

```
int FS_JOURNAL_Create(const char * sVolumeName,
                      U32    NumBytes);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).
NumBytes	Size of journal file in bytes.

Return value

= 1 OK, journal already exists.
= 0 OK, journal successfully created.
< 0 Error code indicating the failure reason.

Additional information

This function is mandatory. It has to be called after the file system initialization to create the journal file. FS_JOURNAL_Create() does nothing if the journal file already exists. The name of the journal file can be configured at compile time via FS_JOURNAL_FILE_NAME or at runtime via FS_JOURNAL_SetFileName().

The size of the journal file can be calculated by using the following formula:

JournalSize = 3 * BytesPerSector + (16 + BytesPerSector) * NumSectors

Parameter
JournalSize
BytesPerSector
NumSectors

The number of sectors the journal file is able to store on a transaction depends on the file system operations performed by the application. The table below can be used to calculate the approximate number of sectors that are stored during a specific file system operation.

API function
FS_CreateDir()
FS_DeleteDir()
FS_FClose()
FS_FOpen()
FS_FWrite()
FS_MkDir()
FS_ModifyFileAttributes()
FS_Move()
FS_Remove()
FS_Rename()
FS_RmDir()

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API function
FS_SetEndOfFile()
FS_SetFileAttributes()
FS_SetFileSize()
FS_SetFileTime()
FS_SetFileTimeEx()
FS_SetVolumeLabel()
FS_SyncFile()
FS_SetVolumeLabel()
FS_Write()

The values in the table above are for orientation only. The recommended procedure for determining the size of the journal file is as follows:

Step
1
2
3
4

An overflow event is reported by the Journaling component by invoking the callback function registered via either FS_JOURNAL_SetOnOverflowExCallback() or FS_JOURNAL_SetOnOverflowCallback(). In addition, the size of the journal file can be fine tuned by evaluating the value of the MaxWriteSectorCnt member of the FS_JOURNAL_STAT_COUNTERS returned via FS_JOURNAL_GetStatCounters().

If a journal is created using FS_JOURNAL_Create() the information about unused logical sectors is not forwarded to the device driver. FS_JOURNAL_CreateEx() can be used instead to specify how this information has to be handled.

The journal operation remains disabled after the journal creation if the application previously disable it via FS_JOURNAL_Disable(). In this case the journal operation has to be explicitly enabled by the application after the journal creation via FS_JOURNAL_Enable().

Example

```
#include "FS.h"

void SampleJournalCreate(void) {
#if FS_SUPPORT_JOURNAL
  //
  // Create journal of 200 Kbytes on the first volume of the file system.
  //
  FS_JOURNAL_Create("", 200 * 1024);
#endif // FS_SUPPORT_JOURNAL
}
```

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14.6.3 FS_JOURNAL_CreateEx()

Description

Creates the journal file.

Prototype

```
int FS_JOURNAL_CreateEx(const char * sVolumeName,
                        U32    NumBytes,
                        U8     IsFreeSectorSupported);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).
NumBytes	Size of journal file in bytes.
IsFreeSectorSupported	Handling of the information about unused sectors. • 1 Forwarded to the device driver • 0 Not forwarded to device driver.

Return value

= 1 OK, journal already exists.
= 0 OK, journal successfully created.
< 0 Error code indicating the failure reason.

Additional information

This function is mandatory. It performs the same operations as `FS_JOURNAL_Create()`. In addition, `IsFreeSectorSupported` can be used to specify if the information about the logical sectors that are no longer in use has to be passed to the device driver. The NOR and NAND drivers as well as the SD/MMC driver with eMMC as storage device can use this information to improve the write performance.

Example

```
#include "FS.h"

void SampleJournalCreateEx(void) {
#if FS_SUPPORT_JOURNAL
  //
  // Create a journal file of 100 Kbytes on the first volume of the file system.
  // The journal component is configured to inform the device driver about
  // logical sectors that are no longer used by the file system.
  //
  FS_JOURNAL_CreateEx("", 100 * 1024, 1);
#endif // FS_SUPPORT_JOURNAL
}
```

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14.6.4 FS_JOURNAL_Disable()

Description

Deactivates the journal.

Prototype

```
int FS_JOURNAL_Disable(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 0 OK, the journal operation is disabled.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. `FS_JOURNAL_Disable()` can be used to disable the journal if the next file system operations do not have to be protected against unexpected resets. After the call to this function the integrity of the file system is no more guaranteed. The journal operation can be re-enabled by calling `FS_JOURNAL_Enable()`.

The operational status of the journal can be queried using `FS_JOURNAL_IsEnabled()`.

Example

```
#include "FS.h"

void SampleJournalDisableEnable(void) {
  FS_FILE * pFile;

#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Disable("");
#endif // FS_SUPPORT_JOURNAL
  //
  // The following file system operations are not fail safe.
  //
  pFile = FS_FOpen("File1.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 1", 6);
    FS_FClose(pFile);
  }
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Enable("");
#endif // FS_SUPPORT_JOURNAL
  //
  // The following file system operations are fail safe.
  //
  pFile = FS_FOpen("File2.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 2...", 6);
    FS_FClose(pFile);
  }
}
```

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14.6.5 FS_JOURNAL_Enable()

Description

Activates the journal.

Prototype

```
int FS_JOURNAL_Enable(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 0 OK, the journal operation is enabled.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The journal is enabled automatically when the file system is mounted if a valid journal file is found. `FS_JOURNAL_Enable()` can be used to re-enable the journal after the application disabled it via `FS_JOURNAL_Disable()`.

After the call to `FS_JOURNAL_Enable()` all file system operations are protected against unexpected resets.

The operational status of the journal can be queried using `FS_JOURNAL_IsEnabled()`.

Example

```
#include "FS.h"

void SampleJournalDisableEnable(void) {
  FS_FILE * pFile;

#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Disable("");
#endif // FS_SUPPORT_JOURNAL
  //
  // The following file system operations are not fail safe.
  //
  pFile = FS_FOpen("File1.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 1", 6);
    FS_FClose(pFile);
  }
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Enable("");
#endif // FS_SUPPORT_JOURNAL
  //
  // The following file system operations are fail safe.
  //
  pFile = FS_FOpen("File2.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 2...", 6);
    FS_FClose(pFile);
  }
}
```

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14.6.6 FS_JOURNAL_End()

Description

Closes a journal transaction.

Prototype

```
int FS_JOURNAL_End(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 0 OK, journal transaction closed.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The file system opens and closes journal transactions automatically as required. The application can use this function together with FS_JOURNAL_Begin() to create journal transactions that extend over multiple file system operations.

Following the outermost call to FS_JOURNAL_End() the sector data stored to journal file is copied to actual destination on the storage device. The other nested calls to FS_JOURNAL_End() simply close the transaction at that nesting level but do not copy any data.

It is mandatory that FS_JOURNAL_Begin() and FS_JOURNAL_End() are called in pair. The calls to these functions can be nested. The current nesting level can be queried via FS_JOURNAL_GetOpenCnt().

Example

```
#include "FS.h"

void SampleJournalBegin(void) {
  FS_FILE * pFile;

#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Begin("");               // Open the journal transaction.
#endif // FS_SUPPORT_JOURNAL
  pFile = FS_FOpen("File1.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 1", 6);
    FS_FClose(pFile);
  }
  pFile = FS_FOpen("File2.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 2...", 6);
    FS_FClose(pFile);
  }
  pFile = FS_FOpen("File3.txt", "w");
  if (pFile) {
    FS_Write(pFile, "Test 3...", 6);
    FS_FClose(pFile);
  }
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_End("");                 // Close the journal transaction.
#endif // FS_SUPPORT_JOURNAL
}
```

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14.6.7 FS_JOURNAL_GetInfo()

Description

Returns information about the journal.

Prototype

```
int FS_JOURNAL_GetInfo(const char            * sVolumeName,
                       FS_JOURNAL_INFO * pInfo);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).
pInfo	out Journal information.

Return value

= 0 OK, information returned.
< 0 Error code indicating the failure reason.

Additional information

This function is optional. The application can call it to get information about the journal such as if the journal is enabled, the number of free sectors in the journal and so on.

FS_JOURNAL_GetInfo() mounts the specified volume if the auto mount feature is enabled for that volume and the volume is not mounted at the time of the call.

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14.6.8 FS_JOURNAL_GetOpenCnt()

Description

Returns the number times the current journal transaction has been opened.

Prototype

```
int FS_JOURNAL_GetOpenCnt(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

≥ 0 OK, number of nested calls.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The application can use `FS_JOURNAL_GetOpenCnt()` to check how many times `FS_JOURNAL_Begin()` has been called in a row without a call to `FS_JOURNAL_End()` in between.

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14.6.9 FS_JOURNAL_GetStatCounters()

Description

Returns statistical information about the operation.

Prototype

```
int FS_JOURNAL_GetStatCounters(const char                    * sVolumeName,
                               FS_JOURNAL_STAT_COUNTERS * pStat);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).
pStat	out Statistical information.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. It can be used to get information about the number of operations performed by the journal since the last file system mount operation or since the last call to FS_JOURNAL_ResetStatCounters().

FS_JOURNAL_GetStatCounters() is available only when the file system is compiled with either FS_JOURNAL_ENABLE_STATS set to 1 or with FS_DEBUG_LEVEL set to a value equal to or larger than FS_DEBUG_LEVEL_CHECK_ALL.

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14.6.10 FS_JOURNAL_Invalidate()

Description

Cancels the pending journal transaction.

Prototype

```
int FS_JOURNAL_Invalidate(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

≥ 0 OK, journal data has been discarded.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. It can be used to discard all the modifications stored in the journal during a journal transaction opened via `FS_JOURNAL_Begin()`. After the call to `FS_JOURNAL_Invalidate()` the current journal transaction is closed. In case of a journal transaction opened multiple times it is not necessary to call `FS_JOURNAL_Invalidate()` for the number of times the journal transaction has been opened.

A read sector cache has to be invalidated after canceling a journal transaction via `FS_JOURNAL_Invalidate()`. The application can configure a read sector cache via `FS_AssignCache()`.

Example

```
#include "FS.h"

static int _GetData(U8 * pData) {
  int NumBytes;

  NumBytes = -1;
  //
  // ...
  //
  return NumBytes;
}

void SampleJournalInvalidate(void) {
  int       IsError;
  FS_FILE * pFile;
  U8        abBuffer[16];
  int       NumBytes;
  IsError = 0;
  //
  // Begin the journal transaction.
  //
#if FS_SUPPORT_JOURNAL
  FS_JOURNAL_Begin("");
#endif // FS_SUPPORT_JOURNAL
  //
  // Create the file and write to it.
  //
  pFile = FS_FOpen("Test.txt", "w");
  if (pFile) {
    while (1) {
      //
      // Get the data from an external source.
      //
      NumBytes = _GetData(abBuffer);
      if (NumBytes == 0) {
```

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```
        FS_FClose(pFile);
        break;                        // No more data available.
      }
      if (NumBytes < 0) {
        IsError = 1;
        break;                        // Error, could not get data.
      }
      //
      // Write the data to file.
      //
      FS_Write(pFile, abBuffer, (U32)NumBytes);
    }
  }
  //
  // Close the transaction.
  //
#if FS_SUPPORT_JOURNAL
  if (IsError) {
    FS_JOURNAL_Invalidate("");
  } else {
    FS_JOURNAL_End("");
  }
#endif // FS_SUPPORT_JOURNAL
}
```

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14.6.11 FS_JOURNAL_IsEnabled()

Description

Checks the journal operational status.

Prototype

```
int FS_JOURNAL_IsEnabled(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 1 The journal is active. All the file system operations are fail safe.
= 0 The journal is not active. The file system operations are not fail safe.
< 0 Error code indicating the failure reason.

Additional information

This function is optional. The journal is automatically activated at file system mount if a valid journal file is present. The journal file can be created using `FS_JOURNAL_Create()` or `FS_JOURNAL_CreateEx()`. The journal can be enabled and disabled at runtime using `FS_JOURNAL_Enable()` and `FS_JOURNAL_Disable()` respectively.

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14.6.12 FS_JOURNAL_IsPresent()

Description

Checks the presence of journal file.

Prototype

```
int FS_JOURNAL_IsPresent(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 1 OK, journal file is present and valid.
= 0 OK, journal file is not present.
< 0 Error code indicating the failure reason.

Additional information

This function is optional. The application can call it to check if a journal file is present on the specified volume and that the file is also valid.

`FS_JOURNAL_IsPresent()` mounts the specified volume if the auto mount feature is enabled for that volume and the volume is not mounted at the time of the call.

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14.6.13 FS_JOURNAL_ResetStatCounters()

Description

Sets to 0 all statistical counters.

Prototype

```
int FS_JOURNAL_ResetStatCounters(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).

Return value

= 0 OK, statistical counters cleared.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. The statistical counters are cleared each time the volume is mounted. An application can use FS_JOURNAL_ResetStatCounters() to explicitly clear the statistical counters at runtime for example for testing purposes. The statistical counters can be queried via FS_JOURNAL_GetStatCounters()

FS_JOURNAL_ResetStatCounters() is available only when the file system is compiled with either FS_JOURNAL_ENABLE_STATS set to 1 or with FS_DEBUG_LEVEL set to a value equal to or larger than FS_DEBUG_LEVEL_CHECK_ALL.

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14.6.14 FS_JOURNAL_SetFileName()

Description

Configures the name of the journal file.

Prototype

```
int FS_JOURNAL_SetFileName(const char * sVolumeName,
                           const char * sFileName);
```

Parameters

Parameter	Description
sVolumeName	Journal instance identified by volume name (0-terminated string).
sFileName	Name of the journal file (0-terminated string)

Return value

= 0 OK, file name set.
≠ 0 Error code indicating the failure reason.

Additional information

This function is optional. It can be used by an application to specify at runtime a name for the journal file. FS_JOURNAL_SetFileName() has to be called before the creation of the journal file via FS_JOURNAL_Create() or FS_JOURNAL_CreateEx().

FS_JOURNAL_SetFileName() is available only when the file system is compiled with the FS_MAX_LEN_JOURNAL_FILE_NAME configuration define set to a value greater than 0.

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14.6.15 FS_JOURNAL_SetOnOverflowExCallback()

Description

Registers a callback function for the journal full event.

Prototype

```
void FS_JOURNAL_SetOnOverflowExCallback
                              (FS_JOURNAL_ON_OVERFLOW_EX_CALLBACK * pfOnOverflow);
```

Parameters

Parameter	Description
pfOnOverflow	Function to be invoked when the journal full event occurs.

Additional information

This function is optional. A journal full event occurs when there is no more free space in the journal file to store the modifications requested by the file system layer. When this event occurs, the data currently stored in the journal is copied to the actual destination on the storage device to make free space for the new data. This behavior can be changed via the return value of the callback function. Refer to FS_JOURNAL_ON_OVERFLOW_EX_CALLBACK for more information.

The file system is no longer fail safe in the time interval from the occurrence of the journal full event to the end of current journal transaction.

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14.6.16 FS_JOURNAL_SetOnOverflowCallback()

Description

Registers a callback function for the journal full event.

Prototype

```
void FS_JOURNAL_SetOnOverflowCallback
                                  (FS_JOURNAL_ON_OVERFLOW_CALLBACK * pfOnOverflow);
```

Parameters

Parameter	Description
pfOnOverflow	Function to be invoked when the journal full event occurs.

Additional information

This function is optional. A journal full event occurs when there is no more free space in the journal file to store the modifications requested by the file system layer. When this event occurs, the data currently stored in the journal is copied to the actual destination on the storage device to make free space for the new data.

The file system is no longer fail safe in the time interval from the occurrence of the journal full event to the end of current journal transaction.

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14.6.17 FS_JOURNAL_INFO

Description

Information about the journal.

Type definition

```
typedef struct {
  U8   IsEnabled;
  U8   IsFreeSectorSupported;
  U16  OpenCnt;
  U32  NumSectors;
  U32  NumSectorsFree;
} FS_JOURNAL_INFO;
```

Structure members

Member	Description
IsEnabled	Set to 1 if the journal is used to protect the integrity of the file system structure.
IsFreeSectorSupported	Set to 1 if the journal has been configured to forward “free sector” requests to device driver.
OpenCnt	Number of times the current transaction has been opened.
NumSectors	Number of logical sectors that can be stored in the journal.
NumSectorsFree	Number of logical sectors that do not store any file system data.

Additional information

The information about the journal can be queried via FS_JOURNAL_GetInfo()

NumSectorsFree is always smaller than or equal to NumSectors. The difference between NumSectors and NumSectorsFree represents the number of logical sectors that can still be stored to journal without causing a journal overflow.

IsEnabled and OpenCnt values are identical to the values returned by FS_JOURNAL_IsEnabled() and FS_JOURNAL_GetOpenCnt() respectively.

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14.6.18 FS_JOURNAL_ON_OVERFLOW_EX_CALLBACK

Description

Prototype of the function that is called on a journal overflow event.

Type definition

```
typedef int (FS_JOURNAL_ON_OVERFLOW_EX_CALLBACK)
                                  (const FS_JOURNAL_OVERFLOW_INFO * pOverflowInfo);
```

Parameters

Parameter	Description
pOvrflowInfo	Information related to the overflow event.

Return value

0	The journal transaction has to continue to completion.
1	The journal transaction has to be aborted with an error.

Additional information

This type of callback function can be registered using `FS_JOURNAL_SetOnOverflowExCallback()`.

The return value indicates the journal module how to proceed when an overflow event occurs.

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14.6.19 FS_JOURNAL_ON_OVERFLOW_CALLBACK

Description

Prototype of the function that is called on a journal overflow event.

Type definition

```
typedef void (FS_JOURNAL_ON_OVERFLOW_CALLBACK)(const char * sVolumeName);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume on which the overflow event occurred.

Additional information

This type of callback function can be registered using `FS_JOURNAL_SetOnOverflowCallback()`.

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14.6.20 FS_JOURNAL_OVERFLOW_INFO

Description

Information about a journal overflow event.

Type definition

```
typedef struct {
  U8  VolumeIndex;
} FS_JOURNAL_OVERFLOW_INFO;
```

Structure members

Member	Description
VolumeIndex	Index of the volume on which the journal overflow occurred.

Additional information

This type of information is returned via a callback of type FS_JOURNAL_ON_OVERFLOW_EX_CALLBACK when a journal overflow event occurs.

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14.6.21 FS_JOURNAL_STAT_COUNTERS

Description

Journal statistical counters.

Type definition

```
typedef struct {
  U32  WriteSectorCnt;
  U32  NumTransactions;
  U32  FreeSectorCnt;
  U32  OverflowCnt;
  U32  WriteSectorCntStorage;
  U32  ReadSectorCntStorage;
  U32  MaxWriteSectorCnt;
  U32  FreeSectorCntStorage;
  U32  FreeOperationCntStorage;
} FS_JOURNAL_STAT_COUNTERS;
```

Structure members

Member	Description
WriteSectorCnt	Number of sectors written by the file system to journal.
NumTransactions	Number of journal transactions performed.
FreeSectorCnt	Number of sectors freed by the file system and recorded to journal.
OverflowCnt	Number of times the journal was cleaned before the end of a transaction.
WriteSectorCntStorage	Number of sectors written by the journal to the storage device.
ReadSectorCntStorage	Number of sectors read by the journal from the storage device.
MaxWriteSectorCnt	Maximum number of sectors written by the file system to journal file in any journal transaction.
FreeSectorCntStorage	Number of sectors freed by journal on the storage device.
FreeOperationCntStorage	Number of free sector operations performed by the journal on the storage device.

Additional information

The statistical counters can be queried via FS_JOURNAL_GetStatCounters(). The application can use FS_JOURNAL_ResetStatCounters() to set all the statistical counters to 0.

MaxWriteSectorCnt can be used to fine tune the size of the journal file by comparing its value with the number of sectors that can be stored in the journal file. The number of sectors that can be stored in the journal file can be read via FS_JOURNAL_GetInfo().

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14.7 Performance and resource usage

This section describes the memory requirements (RAM and ROM) of the Journaling component as well as the read and write performance.

14.7.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The following values were measured as described in the section *Test procedure* on page 1439.

Usage: 3.3 Kbytes

14.7.2 Static RAM usage

The static RAM usage represents the amount of RAM required by the Journaling component to store static variables. The number of bytes can be seen in the list file of the compiled Journaling component.

Usage: 16 bytes

14.7.3 Dynamic RAM usage

The dynamic RAM usage is the amount of RAM allocated by the Journaling component at runtime. The number of bytes allocated depends on the journal size and on the number of volumes on which the Journaling component is enabled. The approximate runtime RAM usage of the Journaling component can be calculated as follows:

```
MemAllocated = (JournalSize / (BytesPerSector + 16) * 4 + 56) * NumVolumes
```

Parameter	Description
`MemAllocated`	Number of bytes allocated
`JournalSize`	Size of the journal file in bytes. This is the second parameter specified in the call to `FS_JOURNAL_Create()` `FS_JOURNAL_CreateEx()`
`NumVolumes`	Number of volumes on which the journaling is active

14.7.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance and resource usage* on page 474.

All speed values are in Kbytes/second.

CPU type	Storage device	Write speed	Read speed
NXP LPC2478 (57.6 MHz)	SST SST39VF201 (1x16 bit, no “write burst”)	**5.6**	**2534**
ST STM32F103 (72 MHz)	ST M29W128 (1x16, with “write burst”, 64 bytes)	**18.5**	**7877**

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14.8 FAQs

Q: Can a journal be created when other files are already present on the disk?
A: Yes. The Journaling component saves the data in a regular file called by default "Journal.dat". If there is sufficient space left on the storage device, there is no problem creating the journal even if other files are present.
Q: Can the journal file be recreated?
A: Yes. Follow this procedure to recreate the journal:

- Remove the journal file via FS_Remove()
- Unmount the file system via FS_Unmount() or FS_UnmountForced()
- Mount the file system via FS_Mount() or FS_MountEx()
- Re-create the journal file via FS_JOURNAL_Create() or FS_JOURNAL_CreateEx()
- Re-initialize the file system via FS_DeInit() and FS_Init() if the size of the journal file is increased.

Q: Can a journal be deleted?
A: Yes, by deleting the journal file.
Q: What if the journal isn't sufficiently large?
A: If the journal is not sufficiently large, the data already present in the journal file is copied to the actual destination on the storage device in order to make room for the new data.
Q: Can multiple tasks use a journal at the same time?
A: Yes, the journal is multitasking safe.
Q: Can FS_JOURNAL_Begin() and FS_JOURNAL_End() be nested?
A: Yes. The Journaling component maintains an open counter that is incremented each time FS_JOURNAL_Begin() is called and is decremented with each call to FS_JOURNAL_End(). When the open counter reaches zero, the data is copied from the journal file to the actual destination on the storage device and the journal transaction is terminated.

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Chapter 15

Encryption

This chapter documents the emFile Encryption component. The component can be used to store the data securely.

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15.1 General information

emFile Encryption is an additional component which can be used to secure the data of the entire volume or of individual files. Without encryption support, all data is stored in a readable form. Using the Encryption component, the data can be made unreadable by using a secret key that is stored on the storage device. Without the knowledge of the secret key, it is not possible to make the data readable again.

The main features of the Encryption component are:

- Can be used with both FAT and EFS file systems.
- All storage types such as NAND, NOR, SD/MMC/CompactFlash cards are supported.
- Only minor changes to the application are required.
- DES and AES with 128-bit and 256-bit key lengths are supported.
- Encryption of the entire storage device or of individual files.
- Support for authenticated encryption.
- Support for storing extra data in plaintext format.
- A utility is provided for file decryption and encryption on a PC.
- Two packages are available: Encryption (DES) and Extra Strong Encryption (DES and AES [1])

[1] The AES encryption algorithm is subject to export regulations

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15.2 How to use encryption

Using file encryption is very simple from the application's perspective. The following changes have to be made to an existing application in order to enable the encryption of individual files:

1. Enable file encryption in the emFile configuration. Refer to Compile time configuration for detailed information.
2. Call `FS_CRYPT_Prepare()` to initialize an encryption object. This operation has to be performed only once. Refer to `FS_CRYPT_Prepare()` for detailed information.
3. Open a file and call `FS_SetEncryptionObject()` to assign the encryption object to the file handle. Refer to `FS_SetEncryptionObject()` for detailed information.

The actual encryption and decryption is performed by the Encryption component when the application accesses the file contents via the file read and write API functions.

The authenticated encryption can be enabled by calling `FS_SetEncryptionObjectEx()` instead of `FS_SetEncryptionObject()` with the IsEnhanced parameter set to 1.

> **Note**
>
> The application has to make sure that the size of an encrypted file is always a multiple of the cryptographic algorithm block size (16 bytes for DES and AES) so that the last bytes in the file are encrypted with that cryptographic algorithm. Otherwise, the data of the last incomplete block is only scrambled by using a different algorithm. This limitation does not apply to authenticated encryption.

Example usage

This sample function opens a file and writes a text message to it. The file contents are encrypted using the DES encryption algorithm. The changes required to an application to support encryption are marked with the comment: `// Required for encryption`.

```
#include "FS.h"

void SampleEncryptionFile(void) {
  FS_FILE               * pFile;
#if FS_SUPPORT_ENCRYPTION
  const U8                aKey[8] = {1, 2, 3, 4};     // Required for encryption
  FS_CRYPT_OBJ            CryptObj;                   // Required for encryption
  static FS_DES_CONTEXT   _Context;                   // Required for encryption
  static int              _IsInited;                  // Required for encryption
#endif // FS_SUPPORT_ENCRYPTION

#if FS_SUPPORT_ENCRYPTION
  //
  // Create the encryption object. It contains all the necessary information
  // for the encryption/decryption of data. This step must be performed only once.
  //
  if (_IsInited == 0) {                               // Required for encryption
    FS_CRYPT_Prepare(&CryptObj, &FS_CRYPT_ALGO_DES,   // Required for encryption
                     &_Context, 512, aKey);           // Required for encryption
    _IsInited = 1;                                    // Required for encryption
  }
#endif // FS_SUPPORT_ENCRYPTION
  pFile = FS_FOpen("cipher.bin", "w");
  if (pFile) {
#if FS_SUPPORT_ENCRYPTION
    //
    // Assign the created encryption object to file handle.
    //
    FS_SetEncryptionObject(pFile, &CryptObj);         // Required for encryption
#endif // FS_SUPPORT_ENCRYPTION
    //
    // Write data to file using encryption. The message
    // is padded with '\n' characters to a multiple of
    // DES block size (16 bytes).
    //
```

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```
    FS_Write(pFile, "This message has been encrypted using "
                    "SEGGER emFile.\n\n\n\n\n\n\n\n\n\n\n\n", 64);
    FS_FClose(pFile);
  }
}
```

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15.3 Additional information

The Encryption component also supports the encryption of entire volumes. For more information refer to *Encryption driver* on page 1279.

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15.4 Compile time configuration

The configuration of emFile can be changed via compile time flags that can be added to FS_Conf.h which is the main configuration file of the file system. For detailed information about the configuration of emFile and of the configuration define types, refer to *Configuration of emFile* on page 1371. The following table lists the configuration defines supported by the Encryption component.

Define	Default value	Type	Description
FS_CRYPT_AES_OPTIMIZE_MIX_SUBST	1	N	Enables or disables speed optimization of the AES algorithm.
FS_CRYPT_AES_OPTIMIZE_MIX_COLUMNS	0	N	Configures the speed optimization level of the AES algorithm.
FS_CRYPT_AES_SUPPORT_INPLACE_CALC	0	B	Enables or disables the support for in-place calculation of the AES algorithm.
FS_CRYPT_AUTH_TAG_BUFFER_SIZE	16	N	Configures the size of the authentication tag buffer.
FS_CRYPT_DES_SUPPORT_INPLACE_CALC	0	B	Enables or disables the support for in-place calculation of the DES algorithm.
FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE	0	N	Specifies the size of the area for storing extra data.
FS_CRYPT_SUPPORT_ENHANCED_MODE	0	B	Enables or disables the support for enhanced file encryption.
FS_CRYPT_SUPPORT_STANDARD_MODE	1	B	Enables or disables the support for standard file encryption.
FS_SUPPORT_ENCRYPTION	0	B	Enables or disables the support for the file encryption.

15.4.1 FS_CRYPT_AES_OPTIMIZE_MIX_SUBST

This configuration define can be used to enable a speed optimization of the AES software algorithm that makes use of precalculated values stored in ROM. Setting this define to 1 increases the ROM usage of the file system.

15.4.2 FS_CRYPT_AES_OPTIMIZE_MIX_COLUMNS

This define can be used to control the level of optimization enabled via FS_CRYPT_AES_OPTIMIZE_MIX_SUBST. Permitted values are 0, 1, and 2 with 2 being the highest optimization level.

15.4.3 FS_CRYPT_AES_SUPPORT_INPLACE_CALC

Enables or disables the use of the same data buffer as input and output for the AES encryption algorithm.

15.4.4 FS_CRYPT_AUTH_TAG_BUFFER_SIZE

This define can be used to specify the size of the work buffer used by the file system to temporarily store the values of processed authentication tags during the access to a file.

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The set value has to be greater than or equal to the size of the largest authentication tag used by the encryption algorithm. The work buffer is allocated on the stack.

15.4.5 FS_CRYPT_DES_SUPPORT_INPLACE_CALC

Enables or disables the use of the same data buffer as input and output for the DES encryption algorithm.

15.4.6 FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE

This define can be used to specify the size of the area reserved for storing extra data to a file encrypted using the enhanced mode. The extra data is stored in plaintext format.

The value of this define has to be specified in bytes, and it has to be a multiple of 16. Permitted values are: 0, 16, 32, 48 and 64.

The logic related to the extra data feature is disabled if the file system is built with `FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE` set to 0.

The size of the extra data area can be modified at runtime for each file individually via `FS_CRYPT_SetFileExtraDataSize()`.

15.4.7 FS_CRYPT_SUPPORT_ENHANCED_MODE

Enables or disables the support for authenticated file encryption. The authenticated file encryption has to be enabled at runtime by calling `FS_SetEncryptionObjectEx()` for the accessed file. The IsEnhanced parameter has to be set to 1.

15.4.8 FS_CRYPT_SUPPORT_STANDARD_MODE

Enables or disables the support for file encryption without authentication. The file encryption has to be enabled at runtime by calling either `FS_SetEncryptionObject()` or `FS_SetEncryptionObjectEx()` for the accessed file. `FS_SetEncryptionObjectEx()` has to be called with the IsEnhanced parameter set to 0. This configuration define can be set to 0 to save ROM space if the application that accesses the encrypted file is using only authenticated file encryption.

15.4.9 FS_SUPPORT_ENCRYPTION

Enables or disables the support for file encryption in the file system. The encrypted access to a file has to be enabled at runtime by calling either `FS_SetEncryptionObject()` or `FS_SetEncryptionObjectEx()`.

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15.5 API functions

The following table lists the available API functions.

Function	Description
FS_CRYPT_DecodeFileHeader()	Loads information from a file header.
FS_CRYPT_DecodeFileHeaderEx()	Loads information from a file header.
FS_CRYPT_Decrypt()	Decrypts the specified number of bytes.
FS_CRYPT_DecryptEx()	Decrypts the specified number of bytes and verifies the authentication tags.
FS_CRYPT_EncodeFileHeader()	Stores information to a file header.
FS_CRYPT_EncodeFileHeaderEx()	Stores information to a file header.
FS_CRYPT_Encrypt()	Encrypts the specified number of bytes.
FS_CRYPT_EncryptEx()	Encrypts the specified number of bytes and calculates the authentication tags.
FS_CRYPT_GetFileExtraDataSize()	Obtains the size of the area reserved for extra data.
FS_CRYPT_Prepare()	Initializes the object required for the encryption/decryption of file contents.
FS_CRYPT_ReadFileExtraData()	Reads from the area reserved for extra data.
FS_CRYPT_SetFileExtraDataSize()	Modifies the size of the area reserved for extra data.
FS_CRYPT_WriteFileExtraData()	Writes to the area reserved for extra data.
FS_SetEncryptionObject()	Assigns an encryption object to a file handle.
FS_SetEncryptionObjectEx()	Assigns an encryption object to a file handle.

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15.5.1 FS_CRYPT_DecodeFileHeader()

Description

Loads information from a file header.

Prototype

```
int FS_CRYPT_DecodeFileHeader(const FS_CRYPT_OBJ * pCryptObj,
                                    U32          * pFileSize,
                              const U32          * pData,
                                    unsigned       NumBytes);
```

Parameters

Parameter	Description
pCryptObj	in Instance of the encryption object.
pFileSize	out Number of user bytes stored in the file. It can be set to NULL.
pData	in Encoded file header information.
NumBytes	Number of bytes to decode.

Return value

> 0	OK, number of file header bytes successfully decoded.
< 0	Error code indicating the failure reason.

Additional information

This function can be used on a host PC to load the data stored in the header of a file that was encrypted with authentication. The header is stored at byte offset 0 in the file. The header has a size of at least 32 bytes.

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15.5.2 FS_CRYPT_DecodeFileHeaderEx()

Description

Loads information from a file header.

Prototype

```
int FS_CRYPT_DecodeFileHeaderEx(const FS_CRYPT_OBJ       * pCryptObj,
                                      FS_CRYPT_FILE_INFO * pInfo,
                                const U32                * pData,
                                      unsigned             NumBytes);
```

Parameters

Parameter	Description
pCryptObj	in Instance of the encryption object.
pInfo	out Information loaded from the file header. It can be set to NULL.
pData	in Encoded file header information.
NumBytes	Number of bytes to decode.

Return value

> 0 OK, number of file header bytes successfully decoded.
< 0 Error code indicating the failure reason.

Additional information

This function can be used on a host PC to load the data stored in the header of a file that was encrypted with authentication. The header is stored at byte offset 0 in the file. The header has a size of at least 32 bytes.

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15.5.3 FS_CRYPT_Decrypt()

Description

Decrypts the specified number of bytes.

Prototype

```
int FS_CRYPT_Decrypt(const FS_CRYPT_OBJ * pCryptObj,
                           U8           * pDataOut,
                     const U8           * pDataIn,
                           U32            NumBytes,
                           U32          * pBlockIndex);
```

Parameters

Parameter	Description
pCryptObj	in The instance of the encryption object.
pDataOut	out Decrypted data (plain text).
pDataIn	in Data to be decrypted (cipher text).
NumBytes	Number of bytes to decrypt.
pBlockIndex	in Index of the decrypted data block. out Index of the next block to be decrypted.

Return value

= 0 OK, data decrypted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used on a host computer to decrypt a file encrypted on a target system by using the Encryption component. On a target system the data is decrypted automatically by the file system. pBlockIndex can be used to start the decryption at an arbitrary block index inside the file. The size of the block is the value passed to BytesPerBlock in the call to FS_CRYPT_Prepare() that was used to initialize the encryption object.

Example

For an example usage, refer to the source code of the FSFileEncrypter.exe utility located in the Windows\FS\FSFileEncrypter\Application\FSFileEncrypter.c file of the emFile shipment.

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15.5.4 FS_CRYPT_DecryptEx()

Description

Decrypts the specified number of bytes and verifies the authentication tags.

Prototype

```
int FS_CRYPT_DecryptEx(const FS_CRYPT_OBJ * pCryptObj,
                             U32          * pDataOut,
                       const U32          * pDataIn,
                             U32            NumBytes,
                             U32          * pBlockIndex,
                       const U32          * pAuthTagList,
                             U32            SizeOfAuthTagList);
```

Parameters

Parameter	Description
pCryptObj	in The instance of the encryption object.
pDataOut	out Decrypted data (plaintext).
pDataIn	in Data to be decrypted (ciphertext).
NumBytes	Number of bytes to decrypt.
pBlockIndex	in Index of the decrypted data block. out Index of the next block to be decrypted.
pAuthTagList	in List of authentication tags to be checked. It can be set to NULL.
SizeOfAuthTagList	Number of bytes in pAuthTagList. It can be set to 0.

Return value

= 0 OK, data decrypted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used on a host PC to decrypt a file encrypted on a target system by using the Encryption component. On a target system the data is decrypted automatically by the file system. pBlockIndex can be used to start the decryption at an arbitrary block index inside the file. The size of the block is the value passed to BytesPerBlock in the call to FS_CRYPT_Prepare() that was used to initialize the encryption object.

The authentication tags have to be aligned to a four byte boundary in pAuthTagList. If pAuthTagList is set to NULL and SizeOfAuthTagList is set to 0 then the authentication tags are not verified.

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15.5.5 FS_CRYPT_EncodeFileHeader()

Description

Stores information to a file header.

Prototype

```
int FS_CRYPT_EncodeFileHeader(const FS_CRYPT_OBJ * pCryptObj,
                              U32                  FileSize,
                              U32                * pData,
                              unsigned             SizeOfData);
```

Parameters

Parameter	Description
pCryptObj	in Instance of the encryption object.
FileSize	Number of user bytes stored in the file.
pData	out Encoded file header information.
SizeOfData	Maximum number of bytes to encode.

Return value

> 0	OK, number of file header bytes successfully encoded.
< 0	Error code indicating the failure reason.

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15.5.6 FS_CRYPT_EncodeFileHeaderEx()

Description

Stores information to a file header.

Prototype

```
int FS_CRYPT_EncodeFileHeaderEx(const FS_CRYPT_OBJ       * pCryptObj,
                                const FS_CRYPT_FILE_INFO * pInfo,
                                      U32                * pData,
                                      unsigned             SizeOfData);
```

Parameters

Parameter	Description
pCryptObj	in Instance of the encryption object.
pInfo	in Information to be stored to header. It can be set to NULL.
pData	out Encoded file header information.
SizeOfData	Maximum number of bytes to encode.

Return value

> 0 OK, number of file header bytes successfully encoded.
< 0 Error code indicating the failure reason.

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15.5.7 FS_CRYPT_Encrypt()

Description

Encrypts the specified number of bytes.

Prototype

```
int FS_CRYPT_Encrypt(const FS_CRYPT_OBJ * pCryptObj,
                           U8           * pDataOut,
                     const U8           * pDataIn,
                           U32            NumBytes,
                           U32          * pBlockIndex);
```

Parameters

Parameter	Description
pCryptObj	in The instance of the encryption object.
pDataOut	out Encrypted data (ciphertext).
pDataIn	in Data to be encrypted (plaintext).
NumBytes	Number of bytes to encrypt.
pBlockIndex	in Index of the encrypted data block. out Index of the next block to be encrypted.

Return value

= 0 OK, data encrypted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used on a host computer to encrypt a file that can be later decrypted on a target system by using the Encryption component. On a target system the data is decrypted automatically by the file system when the application reads the data from file. pBlockIndex can be used to start the encryption at an arbitrary block index inside the file. The size of the block is the value passed to BytesPerBlock in a call to FS_CRYPT_Prepare() that was used to initialize the encryption object.

Example

For an example usage refer to the source code of the FSFileEncrypter.exe utility located in the Windows\FS\FS_FileEncrypter\Src folder of the emFile shipment.

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15.5.8 FS_CRYPT_EncryptEx()

Description

Encrypts the specified number of bytes and calculates the authentication tags.

Prototype

```
int FS_CRYPT_EncryptEx(const FS_CRYPT_OBJ * pCryptObj,
                             U32          * pDataOut,
                       const U32          * pDataIn,
                             U32            NumBytes,
                             U32          * pBlockIndex,
                             U32          * pAuthTagList,
                             U32            SizeOfAuthTagList);
```

Parameters

Parameter	Description
pCryptObj	in The instance of the encryption object.
pDataOut	out Encrypted data (ciphertext).
pDataIn	in Data to be encrypted (plaintext).
NumBytes	Number of bytes to encrypt.
pBlockIndex	in Index of the encrypted data block. out Index of the next block to be encrypted.
pAuthTagList	out List of calculated authentication tags. It can be set to NULL.
SizeOfAuthTagList	Number of bytes in pAuthTag. It can be set to 0.

Return value

= 0 OK, data encrypted successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function can be used on a host PC to encrypt a file that can be later decrypted on a target system by using the Encryption component. On a target system the data is decrypted automatically by the file system when the application reads the data from file. pBlockIndex can be used to start the encryption at an arbitrary block index inside the file. The size of the block is the value passed to BytesPerBlock in a call to FS_CRYPT_Prepare() that was used to initialize the encryption object.

The authentication tags are stored aligned to a four byte boundary in pAuthTagList. If pAuthTagList is set to NULL and SizeOfAuthTagList is set to 0 then the function does not calculate and store any authentication tags.

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15.5.9 FS_CRYPT_GetFileExtraDataSize()

Description

Obtains the size of the area reserved for extra data.

Prototype

```
int FS_CRYPT_GetFileExtraDataSize(FS_FILE * pFile);
```

Parameters

Parameter	Description
pFile	Handle to the file to be queried.

Return value

≥ 0 OK, size of the extra data in bytes.
< 0 Error code indicating the failure reason.

Additional information

This function is available only when the file system is built with FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE set to a value different than 0.

FS_CRYPT_GetFileExtraDataSize() fails with an error if the file was not already initialized via a call to one of the following API functions: FS_CRYPT_SetFileExtraDataSize(), FS_CRYPT_WriteFileExtraData() or FS_SetEncryptionObjectEx().

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15.5.10 FS_CRYPT_Prepare()

Description

Initializes the object required for the encryption/decryption of file contents.

Prototype

```
int FS_CRYPT_Prepare(      FS_CRYPT_OBJ        * pCryptObj,
                     const FS_CRYPT_ALGO_TYPE * pAlgoType,
                           void               * pContext,
                           U32                  BytesPerBlock,
                     const U8                 * pKey);
```

Parameters

Parameter	Description
pCryptObj	Instance of the object to be initialized.
pAlgoType	in Encryption algorithm to be used.
pContext	in Data for the encryption algorithm.
BytesPerBlock	Size of the block to encrypt/decrypt at once.
pKey	in Password for data encryption.

Return value

= 0 OK, object initialized successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called once for each encryption object. pAlgoType is a pointer to one of the following structures:

Algorithm type
FS_CRYPT_ALGO_DES
FS_CRYPT_ALGO_AES128
FS_CRYPT_ALGO_AES256

The pContext parameter points to a structure of type FS_DES_CONTEXT when the FS_CRYPT_ALGO_DES algorithm is specified or to FS_AES_CONTEXT structure when the FS_CRYPT_ALGO_AES128 or the FS_CRYPT_ALGO_AES256 are specified. The context pointer is saved to object structure and must point to a valid memory location as long as the encryption object is in use.

BytesPerBlock is a power of two value that has to be smaller than or equal to the logical sector size of the volume that stores the file to be encrypted or decrypted.

The number of bytes in pKey depends on the algorithm type as follows:

Algorithm type
FS_CRYPT_ALGO_DES
FS_CRYPT_ALGO_AES128
FS_CRYPT_ALGO_AES256

The encryption object can be shared between different files.

Example

Refer to *How to use encryption* on page 1490.

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15.5.11 FS_CRYPT_ReadFileExtraData()

Description

Reads from the area reserved for extra data.

Prototype

```
int FS_CRYPT_ReadFileExtraData(FS_FILE   * pFile,
                               unsigned    Off,
                               void      * pData,
                               unsigned    NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to the file to read from.
Off	Offset of the first byte to be read.
pData	out Read data.
NumBytes	Number of bytes to be read.

Return value

≥ 0 OK, number of bytes successfully read.
< 0 Error code indicating the failure reason.

Additional information

This function is available only when the file system is built with FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE set to a value different than 0.

The function fails with an error if Off is set to a value that is greater than or equal to the size of the extra data area.

If the application attempts to read more data than available in the extra data area, then FS_CRYPT_ReadFileExtraData() reads only the available data and returns the number of bytes actually stored to pData.

FS_CRYPT_ReadFileExtraData() fails with an error if the file was not already initialized via a call to one of the following API functions: FS_CRYPT_SetFileExtraDataSize(), FS_CRYPT_WriteFileExtraData() or FS_SetEncryptionObjectEx().

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15.5.12 FS_CRYPT_SetFileExtraDataSize()

Description

Modifies the size of the area reserved for extra data.

Prototype

```
int FS_CRYPT_SetFileExtraDataSize(FS_FILE   * pFile,
                                  unsigned    NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to the file to be modified.
NumBytes	Size of the extra data in bytes.

Return value

= 0 OK, operation completed successfully.
≠ 0 Error code indicating the failure reason.

Additional information

This function is available only when the file system is built with FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE set to a value different than 0.

NumBytes has to be smaller than or equal to FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE.

FS_CRYPT_SetFileExtraDataSize() can be called only on a file of 0 size and before the call to FS_SetEncryptionObjectEx().

FS_CRYPT_SetFileExtraDataSize() fails with an error if the file is not empty or if the function is called for a second time for the same file handle.

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15.5.13 FS_CRYPT_WriteFileExtraData()

Description

Writes to the area reserved for extra data.

Prototype

```
int FS_CRYPT_WriteFileExtraData(      FS_FILE  * pFile,
                                      unsigned   Off,
                                const void     * pData,
                                      unsigned   NumBytes);
```

Parameters

Parameter	Description
pFile	Handle to the file to write to.
Off	Offset of the first byte to be written.
pData	in Data to be written.
NumBytes	Number of bytes to be written.

Return value

≥ 0 OK, number of bytes successfully written.
< 0 Error code indicating the failure reason.

Additional information

This function is available only when the file system is built with FS_CRYPT_MAX_FILE_EXTRA_DATA_SIZE set to a value different than 0.

The function fails with an error if Off is set to a value that is greater than or equal to the size of the extra data area.

If the application attempts to write more data than the space available in the extra data area, then FS_CRYPT_WriteFileExtraData() writes only the amount of data that fits into the extra data area and returns the number of bytes actually written.

FS_CRYPT_WriteFileExtraData() can be called before as well as after configuring the encryption object for the file via FS_SetEncryptionObjectEx()

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15.5.14 FS_SetEncryptionObject()

Description

Assigns an encryption object to a file handle.

Prototype

```
int FS_SetEncryptionObject(FS_FILE      * pFile,
                           FS_CRYPT_OBJ * pCryptObj);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pCryptObj	Instance of the object to be initialized.

Return value

= 0 OK, configured the object to be used for file encryption.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called once immediately after the file has been opened and before any other operation on that file. The pointer to encryption object is saved internally by the file system to the file handle. This means that the memory it points to has to remain valid until the file is closed or until the FS_SetEncryptionObject() is called for the same file handle with pCryptObj set to NULL.

The encryption object can be initialized using FS_CRYPT_Prepare().

FS_SetEncryptionObject() always configures the standard encryption mode.

Example

Refer to *How to use encryption* on page 1490.

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15.5.15 FS_SetEncryptionObjectEx()

Description

Assigns an encryption object to a file handle.

Prototype

```
int FS_SetEncryptionObjectEx(FS_FILE      * pFile,
                             FS_CRYPT_OBJ * pCryptObj,
                             int            IsEnhanced);
```

Parameters

Parameter	Description
pFile	Handle to opened file.
pCryptObj	Instance of the object to be initialized.
IsEnhanced	Specifies the file encryption mode. • 0 Standard encryption. • 1 Enhanced encryption.

Return value

= 0 OK, configured the object to be used for file encryption.
≠ 0 Error code indicating the failure reason.

Additional information

This function has to be called once immediately after the file has been opened and before any other operation on that file. The pointer to encryption object is saved internally by the file system to the file handle. This means that the memory it points to has to remain valid until the file is closed or until the FS_SetEncryptionObjectEx() is called for the same file handle with pCryptObj set to NULL.

The encryption object can be initialized using FS_CRYPT_Prepare().

This function is available only when the file system is built with FS_SUPPORT_ENCRYPTION set to 1.

FS_SetEncryptionObjectEx() performs the same operation as FS_SetEncryptionObject() with the difference that is permits the application to select the encryption mode via the IsEnhanced parameter. FS_SetEncryptionObjectEx() reports an error if IsEnhanced is set to 1 and the file system built with FS_CRYPT_SUPPORT_ENHANCED_MODE set to 0 or if IsEnhanced is set to 0 and the file system built with FS_CRYPT_SUPPORT_STANDARD_MODE set to 0.

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15.5.16 FS_CRYPT_FILE_INFO

Description

File header data accessible to the application.

Type definition

```
typedef struct {
  U32  FileSize;
  U8   ExtraDataSize;
  U8   abExtraData[];
} FS_CRYPT_FILE_INFO;
```

Structure members

Member	Description
FileSize	Amount of ciphertext data, in bytes.
ExtraDataSize	Amount of extra data, in bytes.
abExtraData	Buffer for the extra data.

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15.5.17 Encryption algorithm

The encryption algorithm is a set of functions that the file system calls to perform the actual data encryption and decryption. The following sections describe these functions in detail.

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15.5.17.1 FS_CRYPT_ALGO_TYPE

Description

Encryption algorithm API.

Type definition

```
typedef struct {
  FS_CRYPT_ALGO_TYPE_PREPARE    * pfPrepare;
  FS_CRYPT_ALGO_TYPE_ENCRYPT    * pfEncrypt;
  FS_CRYPT_ALGO_TYPE_DECRYPT    * pfDecrypt;
  U16                             BitsPerBlock;
  U16                             BitsPerAuthTag;
  FS_CRYPT_ALGO_TYPE_ENCRYPT_EX * pfEncryptEx;
  FS_CRYPT_ALGO_TYPE_DECRYPT_EX * pfDecryptEx;
} FS_CRYPT_ALGO_TYPE;
```

Structure members

Member	Description
pfPrepare	Initializes the operation of the algorithm.
pfEncrypt	Encrypts a block of data.
pfDecrypt	Decrypts a block of data.
BitsPerBlock	Number of bits processed at once by the algorithm.
BitsPerAuthTag	Number of bits in the authentication tag.
pfEncryptEx	Encrypts a block of data and calculates the authentication tag.
pfDecryptEx	Decrypts a block of data and verifies the authentication tag.

Additional information

BitsPerBlock is set for example to 128 for the AES algorithm and to 64 for the DES algorithm.

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15.5.17.2 FS_CRYPT_ALGO_TYPE_PREPARE

Description

Initializes the operation of the algorithm.

Type definition

```
typedef void FS_CRYPT_ALGO_TYPE_PREPARE(      void * pContext,
                                        const U8   * pKey);
```

Parameters

Parameter	Description
pContext	Algorithm-specific data.
pKey	Encryption key.

Additional information

This function is a member of the FS_CRYPT_ALGO_TYPE cryptographic algorithm. It initializes the operation of the cryptographic algorithm such as key expansion. FS_CRYPT_ALGO_TYPE_PREPARE is called from FS_CRYPT_Prepare().

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15.5.17.3 FS_CRYPT_ALGO_TYPE_ENCRYPT

Description

Encrypts a data block.

Type definition

```
typedef void FS_CRYPT_ALGO_TYPE_ENCRYPT(      void * pContext,
                                              U8   * pDataOut,
                                        const U8   * pDataIn,
                                              U32    NumBytes,
                                              U32    BlockIndex);
```

Parameters

Parameter	Description
pContext	Algorithm-specific data.
pDataOut	out Encrypted data (ciphertext).
pDataIn	in Data to be encrypted (plaintext).
NumBytes	Number of bytes to be encrypted.
BlockIndex	Index of the data block to be encrypted.

Additional information

This function is a member of the FS_CRYPT_ALGO_TYPE cryptographic algorithm. It encrypts the specified data block using the key specified in the call to FS_CRYPT_Prepare().

NumBytes is always a multiple of the encryption block size specified via BitsPerBlock of FS_CRYPT_ALGO_TYPE.

BlockIndex is set to the index of the logical sector that stores the data being encrypted. It can be used for example as initialization vector for AES and DES cryptographic algorithms.

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15.5.17.4 FS_CRYPT_ALGO_TYPE_DECRYPT

Description

Decrypts a data block.

Type definition

```
typedef void FS_CRYPT_ALGO_TYPE_DECRYPT(      void * pContext,
                                              U8   * pDataOut,
                                        const U8   * pDataIn,
                                              U32    NumBytes,
                                              U32    BlockIndex);
```

Parameters

Parameter	Description
pContext	Algorithm-specific data.
pDataOut	out Decrypted data (plaintext).
pDataIn	in Data to be decrypted (ciphertext).
NumBytes	Number of bytes to be decrypted.
BlockIndex	Index of the data block to be decrypted.

Additional information

This function is a member of the FS_CRYPT_ALGO_TYPE cryptographic algorithm. It decrypts the specified data block using the key specified in the call to FS_CRYPT_Prepare().

NumBytes is always a multiple of the encryption block size specified via BitsPerBlock of FS_CRYPT_ALGO_TYPE.

BlockIndex is set to the index of the logical sector that stores the data being encrypted. It can be used for example as initialization vector for AES and DES cryptographic algorithms. BlockIndex is set to the same value passed to FS_CRYPT_ALGO_TYPE_ENCRYPT when encrypting the same data block.

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15.5.17.5 FS_CRYPT_ALGO_TYPE_ENCRYPT_EX

Description

Encrypts a data block and calculates the authentication tag.

Type definition

```
typedef int FS_CRYPT_ALGO_TYPE_ENCRYPT_EX(      void * pContext,
                                                U32  * pDataOut,
                                          const U32  * pDataIn,
                                                U32    NumBytes,
                                                U32    BlockIndex,
                                                U32  * pAuthTag);
```

Parameters

Parameter	Description
pContext	Algorithm-specific data.
pDataOut	out Encrypted data (ciphertext). It can be set to NULL.
pDataIn	in Data to be encrypted (plaintext).
NumBytes	Number of bytes to be encrypted.
BlockIndex	Index of the data block to be encrypted.
pAuthTag	out Calculated authentication tag.

Return value

= 0 OK, data encrypted correctly.
≠ 0 An error occurred.

Additional information

This function is a member of the FS_CRYPT_ALGO_TYPE cryptographic algorithm. It encrypts the specified data block using the key specified in the call to FS_CRYPT_Prepare().

NumBytes is always a multiple of the encryption block size specified via BitsPerBlock of FS_CRYPT_ALGO_TYPE.

BlockIndex is set to the index of the logical sector that stores the data being encrypted. It can be used for example as initialization vector for AES and DES cryptographic algorithms.

pAuthTag is a buffer sufficiently large to store the authentication tag. The size of the authentication tag is specified via BitsPerAuthTag of FS_CRYPT_ALGO_TYPE.

pDataOut and pDataIn can point to the same memory area.

If pDataOut is set to NULL, then the function has to calculate the authentication tag of the data pointed to by pDataIn without encrypting it.

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15.5.17.6 FS_CRYPT_ALGO_TYPE_DECRYPT_EX

Description

Decrypts a data block and verifies the authentication tag.

Type definition

```
typedef int FS_CRYPT_ALGO_TYPE_DECRYPT_EX(      void * pContext,
                                                U32  * pDataOut,
                                          const U32  * pDataIn,
                                                U32    NumBytes,
                                                U32    BlockIndex,
                                          const U32  * pAuthTag);
```

Parameters

Parameter	Description
pContext	Algorithm-specific data.
pDataOut	out Decrypted data (plaintext). It can be set to NULL.
pDataIn	in Data to be decrypted (ciphertext).
NumBytes	Number of bytes to be decrypted.
BlockIndex	Index of the data block to be decrypted.
pAuthTag	in Authentication tag to be verified.

Return value

= 0 OK, data decrypted correctly.
≠ 0 An error occurred such as authentication tag mismatch.

Additional information

This function is a member of the FS_CRYPT_ALGO_TYPE cryptographic algorithm. It decrypts the specified data block using the key specified in the call to FS_CRYPT_Prepare().

NumBytes is always a multiple of the encryption block size specified via BitsPerBlock of FS_CRYPT_ALGO_TYPE.

BlockIndex is set to the index of the logical sector that stores the data being encrypted. It can be used for example as initialization vector for AES and DES cryptographic algorithms. BlockIndex is set to the same value passed to FS_CRYPT_ALGO_TYPE_ENCRYPT when encrypting the same data block.

pAuthTag is the authentication tag calculated at encryption. The size of the authentication tag is specified via BitsPerAuthTag of FS_CRYPT_ALGO_TYPE.

pDataOut and pDataIn can point to the same memory area.

If pDataOut is set to NULL, then the function has to verify the authentication tag of the data pointed to by pDataIn without decrypting it.

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15.6 Encryption utility

emFile comes with command line utilities that allow the encryption and decryption of files on a host PC. Two separate executables are provided that support cryptographic algorithms with different strengths. The reason for this is export regulations that apply to encryption software.

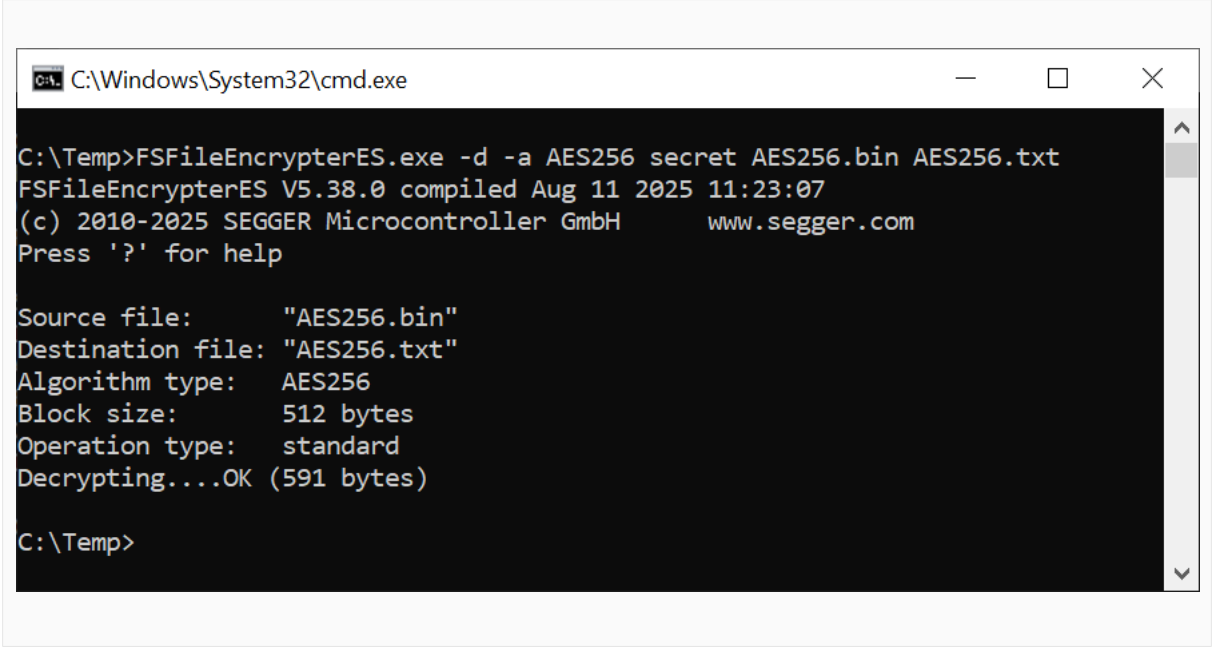
The `FSFileEncrypter.exe` utility supports only encryption algorithms with a key length smaller than or equal to 56 bits. These encryption algorithms are not subject to any export regulations. Currently, this utility supports only the DES cryptographic algorithm.

The `FSFileEncrypterES.exe` utility supports encryption algorithms with any key length. This utility supports DES as well as AES cryptographic algorithms with and without authentication.

15.6.1 Using the file encryption utility

The utilities can be invoked directly from the command line or via a batch file. In order to use the utility directly, a terminal window must be opened first. First, the name of the executable either `FSFileEncrypter.exe` or `FSFileEncrypterES.exe` has to be input on the command line followed by optional and required arguments. By pressing the Enter key, the utility starts the encryption or decryption operation as specified.

Below is a screenshot of the `FSFileEncrypterES.exe` utility that is invoked to decrypt the contents of the `AES256.bin` file. The decrypted plaintext is stored to the `AES256.txt` file. In this example, the ciphertext is decrypted by using the AES cryptographic algorithm with a 256-bit key. The type of the cryptographic algorithm is specified via the `-a` option. Information about the decrypting process is displayed on the terminal window. In case of an error, a message is displayed indicating the failure reason. In this case, the utility returns with a status of 1 and does not create any destination file.



AES decryption

15.6.2 Command line options

The following table lists the parameters which can be omitted when invoking the utilities.

Option	Description
-a	Selects the encryption algorithm.
-b	Sets the size of the encryption block.
-d	Performs decryption.

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Option	Description
-e	Specifies file for extra data.
-h	Shows the usage message and exits.
-q	Suppresses log information.

15.6.2.1 -a

Description

Selects the encryption algorithm. The default encryption algorithm is DES.

Syntax

-a <AlgoType>

Additional information

The following table lists all valid values of `AlgoType`:

Type	Supported by `FSFileEncrypter`?	Supported by `FSFileEncrypterES`?	Description
DES	Yes	Yes	Data Encryption Standard, 56-bit key length
AES128	No	Yes	Advanced Encryption Standard, 128-bit key length
AES256	No	Yes	Advanced Encryption Standard, 256-bit key length
XTSAES128	No	Yes	Advanced Encryption Standard with XEX-based tweaked-codebook mode with ciphertext stealing, 128-bit key length
XTSAES256	No	Yes	Advanced Encryption Standard with XEX-based tweaked-codebook mode with ciphertext stealing, 256-bit key length
AESCCM128	No	Yes	Advanced Encryption Standard with counter with cipher block chaining message authentication code, 128-bit key length
AESCCM256	No	Yes	Advanced Encryption Standard with counter with cipher block chaining message authentication code, 256-bit key length
AESGCM128	No	Yes	Advanced Encryption Standard with Galois/Counter Mode, 128-bit key length

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Type	Supported by FSFileEncrypter?	Supported by FSFileEncrypterES?	Description
AESGCM256	No	Yes	Advanced Encryption Standard with Galois/Counter Mode, 256-bit key length

Example

Shows how to encrypt the contents of the file `plain.txt` to the file `cipher.bin` using the DES cryptographic algorithm. The encryption key is the string `secret`.

```
C:>FSFileEncrypter -a DES secret plain.txt cipher.bin
```

15.6.2.2 -b

Description

Sets the size of the encryption block. Default block size is 512 bytes.

Syntax

-b <BlockSize>

Additional information

The parameter has to be a power-of-two value and represents the number of bytes in the block. The block size has to be equal to the value passed to BytesPerBlock in the call to the `FS_CRYPT_Prepare()` function that was used to initialize the encryption object on the target application.

Example

Shows how to encrypt the contents of the file `plain.txt` to the `cipher.bin` file using the DES cryptographic algorithm. The encryption key is the string `secret` and the size of the encryption block is 2048 bytes.

```
C:>FSFileEncrypter -b 2048 secret plain.txt cipher.bin
```

15.6.2.3 -d

Description

Performs decryption. Default is encryption.

Syntax

-d

Example

Shows how to decrypt the contents of the file `cipher.bin` to the `plain.txt` file using the DES cryptographic algorithm. The encryption key is the string `secret`.

```
FSFileEncrypter -d secret cipher.bin plain.txt
```

15.6.2.4 -e

Description

Specifies the file that stores the extra data.

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Syntax

-e <ExtraFile>

Additional information

This command is supported only by the `FSFileEncrypterES.exe` utility.

The specified file is accessed in read mode when performing encryption. The size of the file has to be a multiple of 16 bytes that is smaller than 64.

When performing decryption, the file is accessed in write mode. If the file exists, its contents will be overwritten.

Example

Shows how to encrypt the contents of the file `plain.txt` to the `cipher.bin` file using the AES GCM cryptographic algorithm. The encryption key is the string `secret`. The data is present in the `extra.bin` is stored to the header of the encrypted file.

```
C:>FSFileEncrypterES -a AESGCM256 -e extra.bin secret plain.txt cipher.bin
```

15.6.2.5 -h

Description

Shows the usage message and exits.

Syntax

-h

Example

```
FSFileEncrypterES V5.44.0 compiled Oct  1 2026 11:59:19
(c) 2010-2026 SEGGER Microcontroller GmbH      www.segger.com
Press '?' for help

DESCRIPTION
  File encryption/decryption utility for SEGGER emFile.
USAGE
  FSFileEncrypterES [-a <AlgoType>] [-b <BlockSize>]
    [-d] [-h] [-q] <Key> <SrcFile> <DestFile>
OPTIONS
  -a <AlgoType>   Type of the encryption algorithm. AlgoType can be one of:
                  DES       Data Encryption Standard, 56-bit key length
                  AES128    Advanced Encryption Standard, 128-bit key length
                  AES256    Advanced Encryption Standard, 256-bit key length
                  XTSAES128 AES with tweak and ciphertext stealing,
                            two keys of 128-bit length
                  XTSAES256 AES with tweak and ciphertext stealing,
                            two keys of 256-bit length
                  AESCCM128 AES with counter mode and authentication,
                            128-bit key length
                  AESCCM256 AES with counter mode and authentication,
                            256-bit key length
                  AESGCM128 AES with Galois/counter mode and authentication,
                            128-bit key length
                  AESGCM256 AES with Galois/counter mode and authentication,
                            256-bit key length
                  Default is DES.
  -b <BlockSize>  Number of bytes to be encrypted/decrypted at once.
                  BlockSize must be a power of 2 value. When encrypting a file
                  BlockSize has to be smaller than or equal to the sector size
                  of the target file system. When decrypting a file, BlockSize
                  has to be equal to the value used to encrypt the file.
```

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```
                  Default is 512 bytes. Permitted values are 512, 1024, 2048,
                  and 4096.
  -d              Perform decryption. Default is encryption.
  -e <ExtraFile>  Path to extra data file.
  -h              Show this help information.
  -q              Do not show log messages.
ARGUMENTS
  <Key>           Encryption/decryption key as ASCII string. Non-printable
                  characters can be specified as 2 hexadecimal characters
                  prefixed by the sequence '\x'.
                  Ex: the key value 1234 can be specified as \x04\xD2.
                  Missing bytes are set to 0.
  <SrcFile>       Path to file to be encrypted/decrypted.
  <DestFile>      Path to encrypted/decrypted file.
```

15.6.2.6 -q

Description

Suppresses log information. Default is to log messages to the console.

Syntax

`-q`

15.6.3 Command line arguments

The following table lists the mandatory parameters. These parameters must be specified on the command line in the order that they are described in this table.

Parameter	Description
<Key>	A string which specifies the encryption key.
<SrcFile>	Path to the file to read from.
<DestFile>	Path to the file to write to.

15.6.3.1 <Key>

Description

A string which specifies the encryption key. Non-printable characters can be input in hexadecimal form by prefixing them with the string `\x`. The key is case-sensitive.

Example

The file `plain.txt` is encrypted using the DES cryptographic algorithm and the result is stored to the `cipher.bin` file. The password looks like this in binary form: `0x70 0x61 0x73 0x73 0x01 0x02 0x03 0x04`.

```
C:>FSFileEncrypterES pass\x01\x02\x03\x04 plain.txt cipher.bin
```

15.6.3.2 <SrcFile>

Description

Path to the file to read from.

Additional information

It specifies the plain text file in case encryption is performed. When decrypting, this parameter specifies the encrypted file. The parameters `SrcFile` and `DestFile` must specify two different files.

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Example

Shows how to encrypt the contents of the file `plain.txt` to the file `cipher.bin` using the AES cryptographic algorithm. `plain.txt` is the source file.

```
C:>FSFileEncrypterES -a AES128 pass plain.txt cipher.bin
```

15.6.3.3 <DestFile>

Description

Path to the file to write to.

Additional information

It specifies the cipher text file in case encryption is performed. When decrypting this parameter specifies the plain text file. The parameters `SrcFile` and `DestFile` must specify two different files.

Example

Shows how to decrypt the contents of the file `cipher.bin` to the file `plain.txt` using the AES cryptographic algorithm. `plain.txt` is the destination file.

```
C:>FSFileEncrypterES -d -a AES256 pass cipher.bin plain.txt
```

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15.7 Performance and resource usage

This section describes the memory requirements (RAM and ROM) of the encryption component as well as the read and write performance. This section lists only the values for the encryption at the file level. Refer to *Performance and resource usage* on page 1283 for the performance and resource usage of volume encryption.

15.7.1 ROM usage

The ROM usage depends on the compiler options, the compiler version and the CPU used. The following values were measured as described in the section *Test procedure* on page 1439.

Usage: 0.4 Kbytes

In addition, one of the following cryptographic algorithms is required:

Algorithm type	ROM usage
FS_CRYPT_ALGO_DES	**3.2 Kbytes**
FS_CRYPT_ALGO_AES128	**12 Kbytes**
FS_CRYPT_ALGO_AES256	**12 Kbytes**

15.7.2 Static RAM usage

Static RAM usage is the amount of RAM required by the encryption component for static variables. The encryption component does not allocate any static variables.

15.7.3 Dynamic RAM usage

Dynamic RAM usage is the amount of RAM allocated by the encryption component at runtime. The encryption component requires one sector buffer for the encryption and decryption of data. The size of a sector buffer is by default 512 bytes. This value can be changed in the application via `FS_SetMaxSectorSize()`.

15.7.4 Performance

These performance measurements are in no way complete, but they give an approximation of the length of time required for common operations on various targets. The tests were performed as described in the section *Performance* on page 1445.

All values are in Kbytes/second.

CPU type	Storage device	Write speed	Read speed
NXP Kinetis K60 (120 MHz)	NAND flash interfaced via 8-bit bus using AES with a 128-bit key.	**522**	**553**
ST STM32F4 (96 MHz)	SD card as storage medium using AES with a 128-bit key.	**500**	**530**

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Chapter 16

BigFAT

This chapter describes the component for files larger than 4GB.

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16.1 General information

The FAT and EFS file systems are not able to handle files larger than 4 GB because the size of the file is stored as a 32-bit value. The BigFAT component can be used in a target application to remove this limitation. Using the BigFAT component, a target application can create, read, write and otherwise perform typical operations on files larger than 4 GB. This is done by distributing the data across fragment files smaller than 4 GB. The created fragment files are compatible with the file system on which they are stored.

The main features of the BigFAT component are:

- Can be used with both FAT and EFS file systems.
- Supports all storage types such as NAND, NOR, SD cards, and USB drives.
- Utility available to merge or split files on a PC.

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16.2 Theory of operation

BigFAT is built on top of the FAT and EFS file systems. It splits the data of a file that grows larger than 4 GB into smaller files. Consequently, they can be stored to the file system as regular files. The file system operations are redirected to the appropriate file, depending on the file position that is accessed by the embedded application.

Files with a size smaller than 4 GB - 128 KB are treated like regular files. In this case, the file access works as in a standard file system implementation. As soon as the file grows above the limit, the file gets extended. An extended file consists of one base file and one or more continuation files. The continuation files are stored in the same directory as the base file, with the name derived from the name of the base file plus an additional file extension. The name of the base file remains unchanged. The file extension of a continuation file has the format `.<Index>.BigFAT`, where the Index is a three-digit decimal number. The index of the first continuation file is set to one, and it increases by one with each additional continuation file. BigFAT requires support for long file names on the underlying file system layer in order to be able to apply the additional file extension of continuation files.

When the base file grows larger than 4 GB - 128 KB, the first continuation file is created. This procedure is required in order to guarantee that the first byte in the continuation file is aligned to a logical sector boundary. This helps increase the performance of the file system accessing the file data. The same procedure is applied when the first continuation file exceeds the 4 GB - 128 KB limit, with the second continuation file being created and so on.

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16.3 Configuration

The BigFAT component can optionally be configured at compile time and does not have to be configured at runtime. However, the application has to make sure that the support for long file names is enabled via `FS_FAT_SupportLFN()` if the BigFAT files are located on a FAT-formatted volume. This is not necessary for EFS-formatted volumes because EFS comes with native support for long file names.

16.3.1 Compile-time configuration

The handle to an opened BigFAT file stores the fully qualified name of the file. The maximum number of characters in the file name including the 0-terminator is configured via the `FS_MAX_LEN_FULL_FILE_NAME` configuration define. By default, `FS_MAX_LEN_FULL_FILE_NAME` is set to a value that works with most applications. `FS_MAX_LEN_FULL_FILE_NAME` can be set to a smaller value to save RAM space if the paths to the BigFAT files accessed by the application are not longer than that value.

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16.4 API functions

The table below lists the available API functions.

Function	Description
FS_BIGFAT_CheckDisk()	Checks the consistency of the file system structure.
FS_BIGFAT_Close()	Closes a big file.
FS_BIGFAT_Copy()	Duplicates a big file.
FS_BIGFAT_FindClose()	Ends a directory scanning operation.
FS_BIGFAT_FindFirst()	Initiates a directory scanning operation and returns information about the first file or directory.
FS_BIGFAT_FindNext()	Returns information about the next file or directory in a directory scanning operation.
FS_BIGFAT_GetInfo()	Returns information about a big file.
FS_BIGFAT_GetPos()	Returns the read and write position in the big file.
FS_BIGFAT_GetSize()	Returns the size of the big file.
FS_BIGFAT_GetTime()	Gets the timestamp of a big file.
FS_BIGFAT_ModifyAttr()	Modifies file attributes.
FS_BIGFAT_Move()	Changes the location and the name of a big file.
FS_BIGFAT_Open()	Opens a big file.
FS_BIGFAT_Read()	Reads data from the big file.
FS_BIGFAT_Remove()	Deletes a big file.
FS_BIGFAT_SetPos()	Changes the access position in the big file.
FS_BIGFAT_SetSize()	Increases or reduces the size of a big file.
FS_BIGFAT_SetTime()	Sets the timestamp of a big file.
FS_BIGFAT_Sync()	Saves cached information to storage device.
FS_BIGFAT_Write()	Writes data to the big file.

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16.4.1 FS_BIGFAT_CheckDisk()

Description

Checks the consistency of the file system structure.

Prototype

```
int FS_BIGFAT_CheckDisk(const char                          * sVolumeName,
                        void                                * pBuffer,
                        U32                                   BufferSize,
                        int                                   MaxRecursionLevel,
                        FS_CHECKDISK_ON_ERROR_CALLBACK      * pfOnError);
```

Parameters

Parameter	Description
sVolumeName	Name of the volume to be checked.
pBuffer	Work buffer to be used for checking the allocation table.
BufferSize	Size of the work buffer in bytes. It cannot be NULL.
MaxRecursionLevel	The maximum directory depth the function is allowed to check.
pfOnError	Function that has to be called when an error is found. It cannot be NULL.

Return value

= FS_CHECKDISK_RETVAL_OK	No errors found or the callback returned FS_CHECKDISK_ACTION_DO_NOT_REPAIR.
= FS_CHECKDISK_RETVAL_RETRY	An error has been found. The error has been corrected since the callback function returned FS_CHECKDISK_ACTION_SAVE_CLUSTERS or FS_CHECKDISK_ACTION_DELETE_CLUSTERS. FS_CheckDisk() has to be called again to check for the next error.
= FS_CHECKDISK_RETVAL_ABORT	The application requested the abort of disk checking operation through the callback returning FS_CHECKDISK_ACTION_ABORT.
= FS_CHECKDISK_RETVAL_MAX_RECURSE	Maximum recursion level reached. The disk checking operation has been aborted.
< 0	Error code indicating the failure reason.

Additional information

This function performs the same operation as FS_CheckDisk() with the difference that it checks big files for defects. In addition to FS_CheckDisk(), FS_BIGFAT_CheckDisk() is able to detect the following errors:

- missing fragment file.
- fragment file without a corresponding base file.
- fragment file with invalid size.

These checks are performed after the call to FS_CheckDisk().

Refer to FS_CheckDisk() for more information about the usage of this function.

Example

```
#include <stdio.h>
```

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```
#include <stdarg.h>
#include <string.h>
#include "FS.h"

static U32 _aBuffer[1024 / 4];
static int _NumErrors;

/*********************************************************************
*
*       _OnError
*/
int _OnError(int ErrCode, ...) {
  va_list      ParamList;
  const char * sFormat;
  char         c;
  char         ac[256];

  (void)memset(&ParamList, 0, sizeof(ParamList));
  sFormat = FS_CheckDisk_ErrCode2Text(ErrCode);
  if (sFormat) {
    va_start(ParamList, ErrCode);
    vsprintf(ac, sFormat, ParamList);
    FS_X_Log(ac);
    FS_X_Log("\n");
  }
  if (ErrCode != FS_CHECKDISK_ERRCODE_CLUSTER_UNUSED) {
    FS_X_Log("  Do you want to repair this? (y/n/a)");
  } else {
    FS_X_Log("  * Convert lost cluster chain into file (y)\n"
             "  * Delete cluster chain                 (d)\n"
             "  * Do not repair                        (n)\n"
             "  * Abort                                (a) ");
    FS_X_Log("\n");
  }
  _NumErrors++;
  c = getchar();
  FS_X_Log("\n");
  if ((c == 'y') || (c == 'Y')) {
    return FS_CHECKDISK_ACTION_SAVE_CLUSTERS;
  } else if ((c == 'a') || (c == 'A')) {
    return FS_CHECKDISK_ACTION_ABORT;
  } else if ((c == 'd') || (c == 'D')) {
    return FS_CHECKDISK_ACTION_DELETE_CLUSTERS;
  }
  return FS_CHECKDISK_ACTION_DO_NOT_REPAIR;     // Do not repair anything.
}

/*********************************************************************
*
*       SampleBigFATCheckDisk
*/
void SampleBigFATCheckDisk(void) {
  int r;

  while (1) {
    r = FS_BIGFAT_CheckDisk("", _aBuffer, sizeof(_aBuffer), 5, _OnError);
    if (r != FS_CHECKDISK_RETVAL_RETRY) {
      break;
    }
  }
  if (_NumErrors == 0) {
    FS_X_Log("No errors were found.\n");
  } else {
    FS_X_Log("Errors were found.\n");
  }
}
```

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16.4.2 FS_BIGFAT_Close()

Description

Closes a big file.

Prototype

```
int FS_BIGFAT_Close(FS_BIGFAT_FILE * pBigFile);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.

Return value

= 0 OK, file closed.
≠ 0 Error code indicating the failure reason.

Additional information

The application has to call FS_BIGFAT_Close() after it no longer needs to access the big file. FS_BIGFAT_Close() frees all the file system resources allocated to the opened file.

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open(). After the call to FS_BIGFAT_Close() the file handle pBigFile is no longer valid and the memory allocated for it can be released by the application. The application can also use pBigFile as parameter to FS_BIGFAT_Open() to open a file again.

Example

```
#include "FS.h"

void SampleBigFATClose(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for reading and then closes it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt", FS_BIGFAT_OPEN_FLAG_READ);
  if (r == 0) {

    //
    // Perform read accesses to file
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.3 FS_BIGFAT_Copy()

Description

Duplicates a big file.

Prototype

```
int FS_BIGFAT_Copy(const char * sFileNameSrc,
                   const char * sFileNameDest,
                         void * pBuffer,
                         U32    NumBytes);
```

Parameters

Parameter	Description
sFileNameSrc	in Path to the file to be copied (0-terminated).
sFileNameDest	in Path to the copied file (0-terminated).
pBuffer	in Buffer for the copy operation (optional). Can be set to NULL.
NumBytes	Size of the copy buffer.

Return value

= 0 OK, file duplicated.
≠ 0 Error code indicating the failure reason.

Additional information

The source and destination files can be located on different volumes.

If no working buffer is specified the function uses a buffer of 512 bytes that is allocated on the stack.

Example

```
#include "FS.h"

void SampleBigFATCopy(void) {
  //
  // Copies the contents of "Test.txt" to file "TestCopy.txt" in the folder "SubDir".
  //
  FS_BIGFAT_Copy("Test.txt", "SubDir\\TestCopy.txt", NULL, 0);
}
```

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16.4.4 FS_BIGFAT_FindClose()

Description

Ends a directory scanning operation.

Prototype

```
int FS_BIGFAT_FindClose(FS_BIGFAT_FIND_DATA * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

= 0 OK, scan context closed.
< 0 Error code indicating the failure reason.

Additional information

pFD has to point to a structure that was successfully initialized via a call to `FS_BIGFAT_FindFirst()`.

Example

Refer to the sample usage of `FS_BIGFAT_FindFirst()`.

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16.4.5 FS_BIGFAT_FindFirst()

Description

Initiates a directory scanning operation and returns information about the first file or directory.

Prototype

```
int FS_BIGFAT_FindFirst(      FS_BIGFAT_FIND_DATA * pFD,
                        const char                * sDirName,
                              char                * sFileName,
                              int                   SizeOfFileName);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.
sDirName	Name of the directory to search in.
sFileName	Buffer that receives the name of the file found.
SizeOfFileName	Size in bytes of the sFileName buffer.

Return value

= 1 OK, no files or directories available in directory.
= 0 OK, information about the file or directory returned.
< 0 Error code indicating the failure reason.

Additional information

The name of a visited file is truncated if it does not fit into sFileName buffer.

The file system is able to handle a sFileName buffer with a maximum size of 32767 bytes.

Example

```
#include <stdio.h>
#include <string.h>
#include "FS.h"

void SampleBigFATFind(void) {
  FS_BIGFAT_FIND_DATA FindData;
  int                 r;
  char                acFileName[32];
  char                ac[100];

  //
  // Lists the names of all files and directories located in the root directory
  // of the default volume.
  //
  memset(acFileName, 0, sizeof(acFileName));
  r = FS_BIGFAT_FindFirst(&FindData, "", acFileName, sizeof(acFileName));
  if (r < 0) {
    SEGGER_snprintf(ac, sizeof(ac), "Cannot list directory (%s)\n", FS_ErrorNo2Text(r));
    FS_X_Log(ac);
  } else {
    if (r == 1) {
      FS_X_Log("Empty directory\n");
    } else {
      for (;;) {
        SEGGER_snprintf(ac, sizeof(ac), "%s\n", acFileName);
        FS_X_Log(ac);
        r = FS_BIGFAT_FindNext(&FindData);
        if (r < 0) {
          SEGGER_snprintf(ac, sizeof(ac), "Cannot list directory (%s)\n", FS_ErrorNo2Text(r));
          FS_X_Log(ac);
          break;
```

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```
        } else {
          if (r == 1) {
            break;              // No more files or directories available.
          }
        }
      }
    }
  }
  FS_BIGFAT_FindClose(&FindData);
}
```

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16.4.6 FS_BIGFAT_FindNext()

Description

Returns information about the next file or directory in a directory scanning operation.

Prototype

```
int FS_BIGFAT_FindNext(FS_BIGFAT_FIND_DATA * pFD);
```

Parameters

Parameter	Description
pFD	Context of the directory scanning operation.

Return value

= 1 OK, no files or directories available in directory.
= 0 OK, information about the file or directory returned.
< 0 Error code indicating the failure reason.

Additional information

pFD has to point to a structure that was successfully initialized via a call to FS_BIGFAT_FindFirst().

Example

Refer to the sample usage of FS_BIGFAT_FindFirst().

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16.4.7 FS_BIGFAT_GetInfo()

Description

Returns information about a big file.

Prototype

```
int FS_BIGFAT_GetInfo(const char           * sFileName,
                      FS_BIGFAT_INFO * pInfo);
```

Parameters

Parameter	Description
sFileName	in Path to the file (0-terminated)
pInfo	out Information about the big file.

Return value

= 0 OK, information returned.
≠ 0 Error code indicating the failure reason.

Additional information

FS_BIGFAT_GetTime() can be called instead of FS_BIGFAT_GetInfo() to get the timestamp of a big file.

Example

```
#include <stdio.h>
#include <string.h>
#include "FS.h"

void SampleBigFATGetInfo(void) {
  FS_BIGFAT_INFO FileInfo;
  int            r;
  FS_FILETIME    FileTime;
  char           ac[100];

  //
  // Gets information about a file and shows them.
  //
  memset(&FileInfo, 0, sizeof(FileInfo));
  r = FS_BIGFAT_GetInfo("Test.txt", &FileInfo);
  if (r == 0) {
    SEGGER_snprintf(ac, sizeof(ac), "Size:          %llu bytes\n", FileInfo.FileSize);
    FS_X_Log(ac);
    SEGGER_snprintf(ac, sizeof(ac), "Attributes:    0x%02X\n", FileInfo.Attributes);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.CreationTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Creation time: %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastAccessTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Access time:   %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
    FS_TimeStampToFileTime(FileInfo.LastWriteTime, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Write time:    %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
}
```

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16.4.8 FS_BIGFAT_GetPos()

Description

Returns the read and write position in the big file.

Prototype

```
int FS_BIGFAT_GetPos(FS_BIGFAT_FILE * pBigFile,
                     U64            * pPos);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.
pPos	out Position in the file as byte offset (0-based).

Return value

= 0 OK, file position returned.
≠ 0 Error code indicating the failure reason.

Additional information

The current file position can be modified by using FS_BIGFAT_SetPos() and is increased after each read or write operation by the number of bytes accessed.

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include <stdio.h>
#include "FS.h"

void SampleBigFATGetPos(void) {
  FS_BIGFAT_FILE BigFile;
  U64            FilePos;
  int            r;
  char           ac[100];

  //
  // Opens a file for writing, writes some data to it and queries the file position.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {
    FS_BIGFAT_GetPos(&BigFile, &FilePos);
    SEGGER_snprintf(ac, sizeof(ac), "File position before write: %llu\n", FilePos);
    FS_X_Log(ac);
    FS_BIGFAT_Write(&BigFile, "Test", 4, NULL);
    FS_BIGFAT_GetPos(&BigFile, &FilePos);
    SEGGER_snprintf(ac, sizeof(ac), "File position after write: %llu\n", FilePos);
    FS_X_Log(ac);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.9 FS_BIGFAT_GetSize()

Description

Returns the size of the big file.

Prototype

```
int FS_BIGFAT_GetSize(FS_BIGFAT_FILE * pBigFile,
                      U64            * pSize);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.
pSize	out Size of the file in bytes.

Return value

= 0 OK, file size returned.
≠ 0 Error code indicating the failure reason.

Additional information

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include <stdio.h>
#include "FS.h"

void SampleBigFATGetSize(void) {
  FS_BIGFAT_FILE BigFile;
  U64            FileSize;
  int            r;
  char           ac[100];

  //
  // Opens a file for writing, writes some data to it and queries the file size.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {
    FS_BIGFAT_Write(&BigFile, "Test", 4, NULL);
    FS_BIGFAT_GetSize(&BigFile, &FileSize);
    SEGGER_snprintf(ac, sizeof(ac), "File size: %llu\n", FileSize);
    FS_X_Log(ac);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.10 FS_BIGFAT_GetTime()

Description

Gets the timestamp of a big file.

Prototype

```
int FS_BIGFAT_GetTime(const char * sFileName,
                      U32  * pTimeStamp,
                      int    TimeType);
```

Parameters

Parameter	Description
sFileName	in Partially-qualified path to the file to be queried (0-terminated)
pTimeStamp	out Read timestamp value.
TimeType	Type of timestamp to return. It can take one of the following values: • FS_FILETIME_CREATE • FS_FILETIME_ACCESS • FS_FILETIME_MODIFY

Return value

= 0 OK, timestamp returned.
≠ 0 Error code indicating the failure reason.

Additional information

Refer to FS_GetFileTime() for a description of the timestamp format. FS_TimeStampToFileTime() can be used to convert the timestamp to a FS_FILETIME structure that can be used to easily process the time information.

Example

```
#include "FS.h"

void SampleBigFATGetTime(void) {
  U32         TimeStamp;
  FS_FILETIME FileTime;
  char        ac[100];
  int         r;

  //
  // Gets the last modification time of a big file.
  //
  r = FS_BIGFAT_GetTime("Test.txt", &TimeStamp, FS_FILETIME_MODIFY);
  if (r == 0) {
    FS_TimeStampToFileTime(TimeStamp, &FileTime);
    SEGGER_snprintf(ac, sizeof(ac), "Access time: %d-%.2d-%.2d %.2d:%.2d:%.2d",
      FileTime.Year, FileTime.Month,  FileTime.Day,
      FileTime.Hour, FileTime.Minute, FileTime.Second);
    FS_X_Log(ac);
  }
}
```

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16.4.11 FS_BIGFAT_ModifyAttr()

Description

Modifies file attributes.

Prototype

```
int FS_BIGFAT_ModifyAttr(const char     * sFileName,
                         unsigned   SetMask,
                         unsigned   ClrMask);
```

Parameters

Parameter	Description
sFileName	in Path to the file (0-terminated)
SetMask	Attributes that have to be set.
ClrMask	Attributes that have to be cleared.

Return value

= 0 OK, attributes modified.
≠ 0 Error code indicating the failure reason.

Additional information

The value passed to SetMask and ClrMask is a bitwise-or combination of *File attributes* on page 165. The FS_ATTR_DIRECTORY attribute cannot be set or cleared. The function does not report any error if the application attempts to do this.

Example

```
#include "FS.h"

void SampleBigFATModifyAttr(void) {
  //
  // Clears the ARCHIVE attribute and sets the SYSTEM and HIDDEN attributes
  // of the file "Test.txt".
  //
  FS_BIGFAT_ModifyAttr("Test.txt", FS_ATTR_SYSTEM | FS_ATTR_HIDDEN, FS_ATTR_ARCHIVE);
}
```

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16.4.12 FS_BIGFAT_Move()

Description

Changes the location and the name of a big file.

Prototype

```
int FS_BIGFAT_Move(const char * sFileNameSrc,
                   const char * sFileNameDest);
```

Parameters

Parameter	Description
sFileNameSrc	in Path to the actual file (0-terminated)
sFileNameDest	in Path to the new file (0-terminated)

Return value

= 0 OK, file moved.
≠ 0 Error code indicating the failure reason.

Additional information

The source and destination paths can be located on different volumes.

A file can be renamed by calling FS_BIGFAT_Move() with sFileNameDest set to the same parent directory as sFileNameSrc with the new file name added to it.

Example

```
#include "FS.h"

void SampleBigFATMove(void) {
  //
  // Moves the contents of "Test.txt" to file "TestCopy.txt" in the folder "SubDir".
  //
  FS_BIGFAT_Move("Test.txt", "SubDir\\TestCopy.txt");
}
```

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16.4.13 FS_BIGFAT_Open()

Description

Opens a big file.

Prototype

```
int FS_BIGFAT_Open(      FS_BIGFAT_FILE * pBigFile,
                   const char           * sFileName,
                         unsigned         Flags);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.
sFileName	in Path to the file to be opened (0-terminated character string).
Flags	Specifies how the file has to be accessed.

Return value

= 0 OK, file opened.
≠ 0 Error code indicating the failure reason.

Additional information

The application has to call this function once for each file it wants to access. FS_BIGFAT_Open() creates or opens the base file according to Flags and initializes pBigFile. The application has to allocate pBigFile and to make sure that it stays valid until FS_BIGFAT_Close() is called. pBigFile identifies the opened file within the application and is passed as parameter to all the other API functions that access the file.

FS_BIGFAT_Open() makes a copy of sFileName that is then stored in pBigFile. Therefore, the application can release the memory allocated to sFileName after FS_BIGFAT_Open() returns.

Flags is a bitwise-or combination of *File open flags* on page 1557. Permitted combinations are:

Flag combination
FS_BIGFAT_OPEN_FLAG_READ
FS_BIGFAT_OPEN_FLAG_WRITE FS_BIGFAT_OPEN_FLAG_CREATE
FS_BIGFAT_OPEN_FLAG_WRITE FS_BIGFAT_OPEN_FLAG_APPEND FS_BIGFAT_OPEN_FLAG_CREATE
FS_BIGFAT_OPEN_FLAG_READ FS_BIGFAT_OPEN_FLAG_WRITE
FS_BIGFAT_OPEN_FLAG_READ FS_BIGFAT_OPEN_FLAG_WRITE

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Flag combination
FS_BIG- FAT_OPEN_FLAG_CREATE
FS_BIG- FAT_OPEN_FLAG_READ FS_BIG- FAT_OPEN_FLAG_WRITE FS_BIGFAT_OPEN_FLAG_AP- PEND FS_BIG- FAT_OPEN_FLAG_CREATE

Example

The next example demonstrates how to open a file for reading.

```
#include "FS.h"

void SampleBigFATOpenRead(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for reading on the root directory of the default volume.
  // The file has to exist before opening it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt", FS_BIGFAT_OPEN_FLAG_READ);
  if (r == 0) {

    //
    // Perform read accesses to file
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

This example demonstrates how to open a file for writing.

```
#include "FS.h"

void SampleBigFATOpenWrite(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing on the root directory of the default volume.
  // The file has to exist before opening it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt", FS_BIGFAT_OPEN_FLAG_WRITE);
  if (r == 0) {

    //
    // Perform write accesses to file.
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

This example demonstrates how to open a file for reading and writing.

```
#include "FS.h"

void SampleBigFATOpenReadWrite(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for reading and writing on the root directory of the "nand:0:" volume.
```

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```
  // The file has to exist before opening it.
  //
  r = FS_BIGFAT_Open(&BigFile, "nand:0:\\Test.txt",
                     FS_BIGFAT_OPEN_FLAG_READ | FS_BIGFAT_OPEN_FLAG_WRITE);
  if (r == 0) {

    //
    // Perform read and write accesses to file
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

This example demonstrates how to create a file.

```
#include <stdio.h>
#include "FS.h"

void SampleBigFATOpenWriteCreate(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing on the folder "SubDir" of the default volume.
  // The directory delimiter is the '\' character. If the file does
  // not exist it is created. If the file exists it is truncated to 0.
  //
  r = FS_BIGFAT_Open(&BigFile, "\\SubDir\\Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {

    //
    // Perform write accesses to file.
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

The next example demonstrates how to open a file for writing at the end of it.

```
#include "FS.h"

void SampleBigFATOpenAppend(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing at the end on the root directory of the default volume.
  // The file has to exist before opening it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_APPEND);
  if (r == 0) {

    //
    // Perform write accesses to file.
    //

    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.14 FS_BIGFAT_Read()

Description

Reads data from the big file.

Prototype

```
int FS_BIGFAT_Read(FS_BIGFAT_FILE * pBigFile,
                   void           * pData,
                   U32              NumBytesToRead,
                   U32            * pNumBytesRead);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened big file. It cannot be set to NULL.
pData	out Data read from big file.
NumBytesToRead	Number of bytes requested to be read from the big file.
pNumBytesRead	out Number of bytes actually read from the big file. It can be set to NULL.

Return value

= 0 OK, data read from file.
≠ 0 Error code indicating the failure reason.

Additional information

The data is read from the current position in the file that is stored in the file handle. The current file position is set to the first byte in the file (that is 0) when the file is opened. The file position is advanced by the number of bytes actually read from the file.

If either pData is set to NULL or NumBytesToRead is set to 0 success is returned but no data is read. *pNumBytesRead is set to 0 in this case.

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include "FS.h"

void SampleBigFATRead(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;
  U8             abData[4];

  //
  // Opens a file for reading on the root directory of the default volume.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt", FS_BIGFAT_OPEN_FLAG_READ);
  if (r == 0) {
    //
    // Read some data from the beginning of the opened file
    //
    FS_BIGFAT_Read(&BigFile, abData, sizeof(abData), NULL);
    //
    // Close the file.
    //
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.15 FS_BIGFAT_Remove()

Description

Deletes a big file.

Prototype

```
int FS_BIGFAT_Remove(const char * sFileName);
```

Parameters

Parameter	Description
sFileName	in Path to the file to be removed (0-terminated)

Return value

= 0 OK, file removed.
≠ 0 Error code indicating the failure reason.

Additional information

The contents of the big file is lost after calling this function.

Example

```
#include "FS.h"

void SampleBigFATRemove(void) {
  //
  // Deletes the file "Test.txt" located in the folder "SubDir".
  //
  FS_BIGFAT_Remove("SubDir\\Test.txt");
}
```

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16.4.16 FS_BIGFAT_SetPos()

Description

Changes the access position in the big file.

Prototype

```
int FS_BIGFAT_SetPos(FS_BIGFAT_FILE * pBigFile,
                     U64              Pos);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.
Pos	Position in the file as byte offset (0-based).

Return value

= 0 OK, file position changed.
≠ 0 Error code indicating the failure reason.

Additional information

The current file position can be queried using `FS_BIGFAT_GetPos()`.

`pBigFile` has to point to a structure that was successfully initialized via a call to `FS_BIGFAT_Open()`.

Example

```
#include "FS.h"

void SampleBigFATSetPos(void) {
  FS_BIGFAT_FILE BigFile;
  U64            FilePos;
  int            r;

  //
  // Opens a file for writing, writes some data to it and then overwrites it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {
    FS_BIGFAT_Write(&BigFile, "Test", 4, NULL);
    FS_BIGFAT_SetPos(&BigFile, 0);
    FS_BIGFAT_Write(&BigFile, "Done", 4, NULL);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.17 FS_BIGFAT_SetSize()

Description

Increases or reduces the size of a big file.

Prototype

```
int FS_BIGFAT_SetSize(FS_BIGFAT_FILE * pBigFile,
                      U64              Size);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.
Size	New file size.

Return value

= 0 OK, file size changed.
≠ 0 Error code indicating the failure reason.

Additional information

If the file is extended then the additional bytes contain uninitialized data. In addition, the position in the file is not modified.

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include "FS.h"

void SampleBigFATSetSize(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing and sets it size to 100 Kbytes.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {
    FS_BIGFAT_SetSize(&BigFile, 100 * 1024);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.18 FS_BIGFAT_SetTime()

Description

Sets the timestamp of a big file.

Prototype

```
int FS_BIGFAT_SetTime(const char * sFileName,
                      U32    TimeStamp,
                      int    TimeType);
```

Parameters

Parameter	Description
sFileName	in Partially-qualified path to the file to be queried (0-terminated)
TimeStamp	The value of the timestamp to be set.
TimeType	Type of timestamp to be modified. It can take one of the following values: • FS_FILETIME_CREATE • FS_FILETIME_ACCESS • FS_FILETIME_MODIFY

Return value

= 0 OK, timestamp modified.
≠ 0 Error code indicating the failure reason.

Additional information

Refer to FS_GetFileTime() for a description of the timestamp format. FS_FileTimeToTimeStamp() can be used to convert a FS_FILETIME structure to a timestamp that can be used in a call to FS_SetFileTimeEx().

This function is optional because the file system automatically updates the timestamps of a big file as required.

Example

```
#include "FS.h"

void SampleBigFATSetTime(void) {
  U32         TimeStamp;
  FS_FILETIME FileTime;

  //
  // Modifies the creation time of a big file.
  //
  FileTime.Year   = 2022;
  FileTime.Month  = 12;
  FileTime.Day    = 22;
  FileTime.Hour   = 8;
  FileTime.Minute = 2;
  FileTime.Second = 48;
  FS_FileTimeToTimeStamp(&FileTime, &TimeStamp);
  FS_BIGFAT_SetTime("Test.txt", TimeStamp, FS_FILETIME_CREATE);
}
```

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16.4.19 FS_BIGFAT_Sync()

Description

Saves cached information to storage device.

Prototype

```
int FS_BIGFAT_Sync(FS_BIGFAT_FILE * pBigFile);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened file.

Return value

= 0 OK, file synchronized.
≠ 0 Error code indicating the failure reason.

Additional information

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include <stdio.h>
#include "FS.h"

void SampleBigFATSync(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing, writes some data to it while making sure that
  // the data is written to storage.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt",
                     FS_BIGFAT_OPEN_FLAG_WRITE | FS_BIGFAT_OPEN_FLAG_CREATE);
  if (r == 0) {
    FS_BIGFAT_Write(&BigFile, "Test1", 5, NULL);
    FS_BIGFAT_Sync(&BigFile);
    FS_BIGFAT_Write(&BigFile, "Test2", 5, NULL);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.20 FS_BIGFAT_Write()

Description

Writes data to the big file.

Prototype

```
int FS_BIGFAT_Write(      FS_BIGFAT_FILE * pBigFile,
                    const void           * pData,
                          U32              NumBytesToWrite,
                          U32            * pNumBytesWritten);
```

Parameters

Parameter	Description
pBigFile	File handle that identifies the opened big file.
pData	in Data to be written to the big file.
NumBytesToWrite	Number of bytes requested to be written to the big file.
pNumBytesWritten	out Number of bytes actually written to the big file. Can be NULL.

Return value

= 0 OK, data written to file.
≠ 0 Error code indicating the failure reason.

Additional information

The data is written at the current position in the file that is stored in the file handle. The current file position is set to the first byte in the file (that is 0) when the file is opened. The file position is advanced by the number of bytes actually written to the file.

pBigFile has to point to a structure that was successfully initialized via a call to FS_BIGFAT_Open().

Example

```
#include "FS.h"

void SampleBigFATWrite(void) {
  FS_BIGFAT_FILE BigFile;
  int            r;

  //
  // Opens a file for writing on the root directory of the default volume.
  // The file has to exist before opening it.
  //
  r = FS_BIGFAT_Open(&BigFile, "Test.txt", FS_BIGFAT_OPEN_FLAG_WRITE);
  if (r == 0) {
    //
    // Write some data to file.
    //
    FS_BIGFAT_Write(&BigFile, "Test", 4, NULL);
    FS_BIGFAT_Close(&BigFile);
  }
}
```

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16.4.21 FS_BIGFAT_INFO

Description

Information about a big file.

Type definition

```
typedef struct {
  U8   Attributes;
  U32  CreationTime;
  U32  LastAccessTime;
  U32  LastWriteTime;
  U64  FileSize;
} FS_BIGFAT_INFO;
```

Structure members

Member	Description
Attributes	File or directory attributes.
CreationTime	Date and time when the file was created.
LastAccessTime	Date and time when the file was accessed last.
LastWriteTime	Date and time when the file was written to last.
FileSize	Size of the file in bytes.

Additional information

The Attributes member is a bitwise-or combination of the following flags: FS_ATTR_READ_ONLY, FS_ATTR_HIDDEN, FS_ATTR_SYSTEM, FS_ATTR_ARCHIVE, or FS_ATTR_DIRECTORY.

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16.4.22 FS_BIGFAT_FIND_DATA

Description

Information about a file or directory.

Type definition

```
typedef struct {
  U8              Attributes;
  U32             CreationTime;
  U32             LastAccessTime;
  U32             LastWriteTime;
  U64             FileSize;
  char          * sFileName;
  U16             SizeOfFileName;
  FS_FIND_DATA    FindData;
  FS_BIGFAT_FILE  BigFile;
} FS_BIGFAT_FIND_DATA;
```

Structure members

Member	Description
Attributes	Attributes of the file or directory.
CreationTime	Date and time when the file or directory was created.
LastAccessTime	Date and time when the file or directory was accessed last.
LastWriteTime	Date and time when the file or directory was modified last.
FileSize	Size of the file in bytes.
sFileName	Name of the file or directory as 0-terminated string. It points to the buffer passed as argument to FS_BIGFAT_FindFirst().
SizeOfFileName	Internal. Not to be used by the application.
FindData	Internal. Not to be used by the application.
BigFile	Internal. Not to be used by the application.

Additional information

This structure contains also the context for the file listing operation. These members are considered internal and should not be used by the application. FS_BIGFAT_FIND_DATA is used as context by the FS_BIGFAT_FindFirst() and FS_BIGFAT_FindNext() pair of functions.

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16.4.23 File open flags

Description

Options for opening a file.

Definition

```
#define FS_BIGFAT_OPEN_FLAG_READ      0x01u
#define FS_BIGFAT_OPEN_FLAG_WRITE     0x02u
#define FS_BIGFAT_OPEN_FLAG_CREATE    0x04u
#define FS_BIGFAT_OPEN_FLAG_APPEND    0x08u
```

Symbols

Definition	Description
FS_BIGFAT_OPEN_FLAG_READ	The application can read from the opened file.
FS_BIGFAT_OPEN_FLAG_WRITE	The application can write to the opened file.
FS_BIGFAT_OPEN_FLAG_CREATE	The file is created if it does not exists or it is truncated to 0 if it exists.
FS_BIGFAT_OPEN_FLAG_APPEND	The application can write only at the end of the file.

Additional information

These flags can be used as values for the Flags parameter of `FS_BIGFAT_Open()`. The flags are bitmasks that can be combined by a bitwise-or operator.

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16.5 BigFAT converter utility

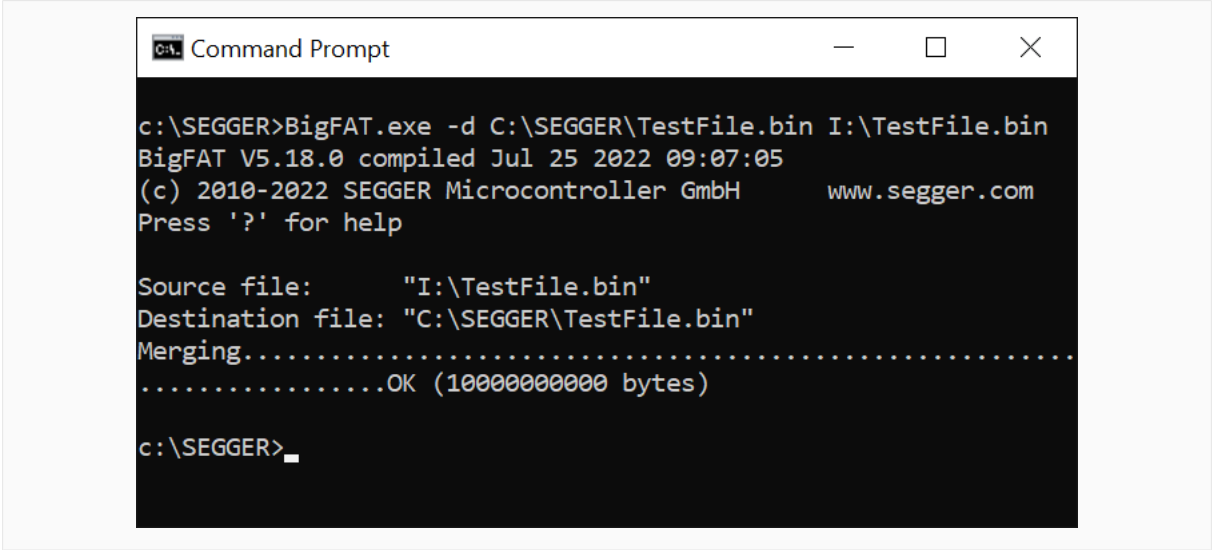
emFile comes with a convenient command line utility for PC that helps to convert between a regular host file and one or more fragment files that can be managed by a target application using the BigFAT component. The command line utility is able to merge the fragment files generated on a target device into a single file larger than 4 Gbytes. In addition, the command line utility is able to split a file larger than 4 Gbytes into fragment files that can later be copied to a target device in order to be accessed by a target application.

16.5.1 Using the utility

The utility can be invoked directly from the command line or via a batch file. A terminal window must be opened first in order to use the utility interactively. First, the name of the executable (`BigFAT.exe`) has to be input on the command line followed by optional and required arguments. By pressing the Enter key, the utility starts the merge or split operation as specified.

Below is a screenshot of the `BigFAT.exe` utility that is invoked to merge the contents of the file `TestFile1.bin` created on the target device.

The merged data replaces the contents of the original file. In case of an error, a message is displayed indicating the failure reason, and the utility returns with a status of 1. The original target file is left unmodified in this case.



Merging operation

Assuming the original `TestFile1.bin` file is 6 Gbytes large, then at the end of execution it is truncated to 4 Gbytes - 128 Kbytes. The remaining number of bytes is stored to a file named `TestFile1.bin.001.BigFAT`.

16.5.2 Command line options

The following table lists the parameters which can be omitted when invoking the utility.

Option	Description
-d	Specifies a destination file.
-h	Shows the usage message and exits.
-q	Suppresses log information.
-s	Performs a split operation.
-v	Shows version information and exits.

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16.5.2.1 -d

Description

Specifies the name of a destination file. By default, the source file is overwritten.

Syntax

-d <DestFile>

Example

The following example shows how to merge the contents of the file `TestFileTarget.bin` into the file `TestFileHost.bin`.

```
C:>BigFAT.exe -d TestFileHost.bin TestFileTarget.bin
```

The following example shows how to split the contents of the file `TestFileHost.bin` into the file `TestFileTarget.bin`.

```
C:>BigFAT.exe -s -d TestFileTarget.bin TestFileHost.bin
```

16.5.2.2 -h

Description

Shows the usage message and exits.

Syntax

-h

Example

```
C:>BigFAT.exe -h
BigFAT V5.18.0 compiled Jul 22 2022 15:32:43
(c) 2010-2020 SEGGER Microcontroller GmbH      www.segger.com
Press '?' for help

DESCRIPTION
  BigFAT merge/split utility for SEGGER emFile.
USAGE
  BigFAT [-d <DestFile>] [-h] [-q] [-s] [-v] <SrcFile>
OPTIONS
  -d <DestFile>   Path to merged/split file to be created.
                  Default is the name of the source file.
  -h              Show this help information.
  -q              Do not show log messages.
  -s              Split a big file. Default is merging.
  -v              Show version information.
ARGUMENTS
  <SrcFile>       Path to file to be merged/split.
```

16.5.2.3 -q

Description

Suppresses log information. By default, all the log messages are shown in the terminal window.

Syntax

-q

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16.5.2.4 -s

Description

Performs a split operation. By default, a merge operation is performed.

Syntax

`-s`

Example

The following example demonstrates how to split the contents of the file `TestFile1.bin`. The original file is overwritten. The created fragment files can be copied to the target device.

```
C:>BigFAT.exe -s TestFile1.bin
```

16.5.2.5 -v

Description

Shows version information and exits.

Syntax

`-v`

Example

```
C:>BigFAT.exe -v
BigFAT V5.18.0 compiled Jul 22 2022 15:32:43
(c) 2010-2020 SEGGER Microcontroller GmbH      www.segger.com
Press '?' for help
```

16.5.3 Command line arguments

The following table lists the mandatory parameters.

Parameter	Description
SrcFile	Path to the file to be converted.

16.5.3.1 SrcFile

Description

Path to the file to be converted.

Additional information

In case of a merge operation, `SrcFile` specifies the name of the first fragment file of a file created via the BigFAT component on a target storage device. If a split operation is executed, then `SrcFile` specifies the name of the host file to be converted.

Example

The following example demonstrates how to merge the contents of the file `TestFile1.bin` generated on a target device via the BigFAT component.

```
C:>BigFAT.exe TestFile3.bin
```

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Chapter 17

NAND Image Creator

This chapter provides information about the emFile utility that can be used to create file system images for NAND flash devices.

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17.1 General information

The NAND Image Creator is a command line utility that can be used to create a file containing a one-to-one representation of the contents of a NAND flash device (image file) with preselected files and directories found on the host PC.

The NAND Image Creator provides commands for performing standard file system operations such as formatting the storage device at both the low and high levels, copying files and directories from the host PC to the image file or checking the consistency of the file system structure.

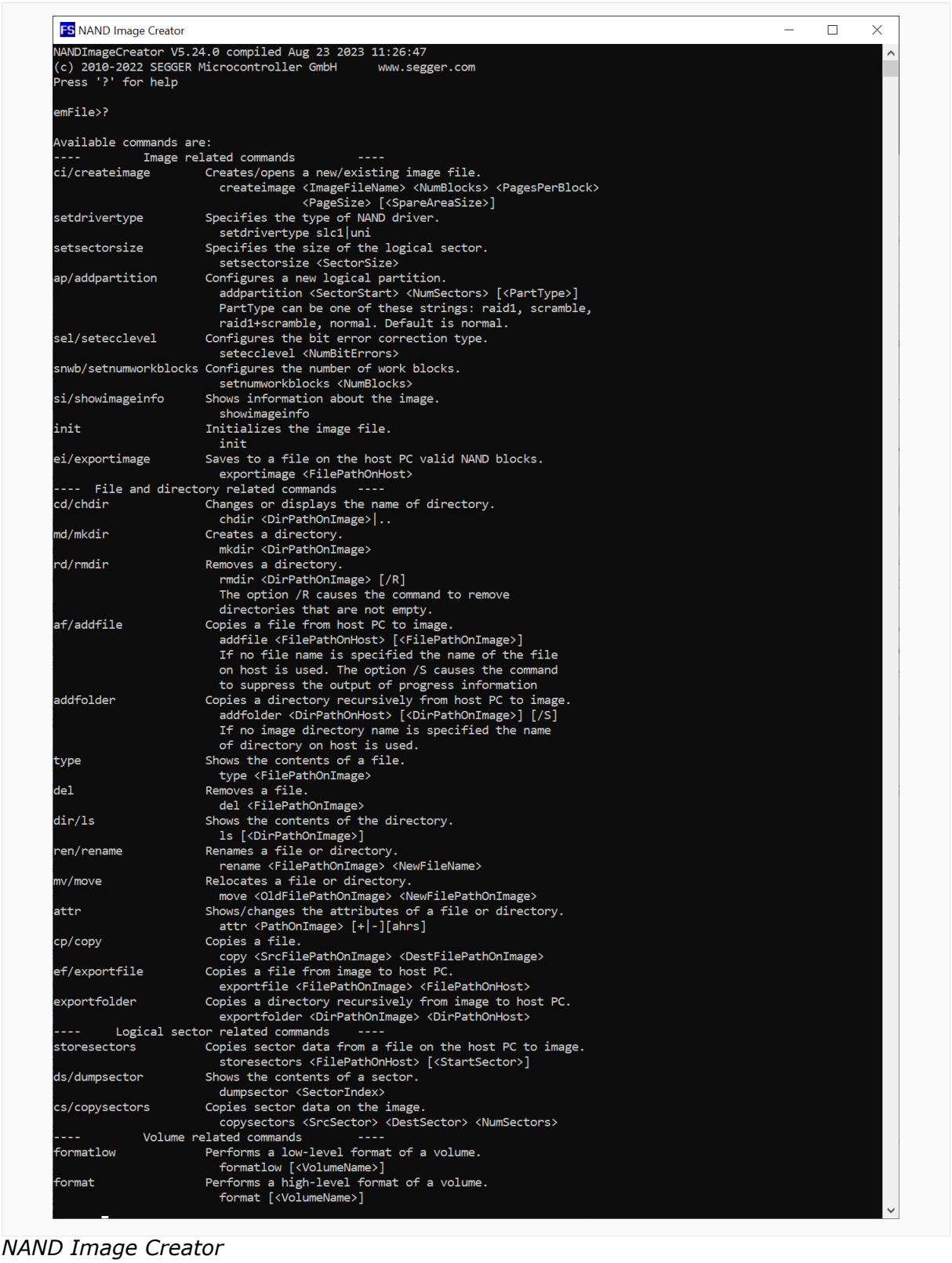
The generated image file is a regular binary file that can be programmed directly into the NAND flash device of the target system via a SEGGER production programmer (https://www.segger.com/products/flash-in-circuit-programmers/) or via any other third-party utility.

The NAND Image Creator ships with executables for Windows, Linux and macOS systems that can be used to create images for the FAT and EFS file systems.

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17.2 Using the NAND Image Creator

The NAND Image Creator utility can be used like any other command line based program. For the ease of usage, many commands are kept similar to their DOS counterparts. By entering "?" or just pressing the Enter key, an overview of the commands is printed on the screen, and it should look like the picture below.



NAND Image Creator

The NAND Image Creator utility can work in two modes: interactive and script. The interactive mode is entered when the utility is started with no command line arguments. In this mode the user is prompted to type in the commands to be executed. The script mode is

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entered when the utility is started with a command line argument that specifies the name of a file containing the commands to be executed, one command per line.

17.2.1 Sample script file

The following sample shows a simple script file that does the following:

- Creates a 128 Mbyte NAND flash image file `C:\flash.bin`
- Sets the type of NAND driver that will be used on the target to access the NAND flash device to the Universal NAND driver. This command is optional since the default driver type is the Universal NAND driver.
- Creates the image file.
- Low-level formats the volume on the image file.
- High-level formats the volume on the image file.
- Copies the `Test.txt` file from drive `C:` of the host Windows PC to the root directory of the volume stored on the image file.
- Copies recursively the contents of the `Data` directory from the host PC to the `Data` directory of the volume stored on the image file.

```
createimage C:\flash.bin 1024 64 2048
setdrivertype uni
init
formatlow
format
addfile C:\Test.txt
addfolder C:\Data\
q
```

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17.3 Supported commands

The image file can be processed by using built-in commands of the NAND Image Creator utility. The table below lists all the available commands followed by a detailed description. The optional command parameters are enclosed in square brackets in the syntax description of a command.

Command	Description
Image related commands	
createimage	Creates/opens a new/existing image file.
setdrivertype	Configures the NAND driver type.
setsectorsize	Configures the logical sector size.
addpartition	Configures a logical partition.
seteccclevel	Configures the error correction type.
setnumworkblocks	Configures the number of work blocks.
showimageinfo	Shows information about the image file.
init	Initializes the image file.
exportimage	Saves to a file the NAND blocks that contain valid data.
File and directory related commands	
cd	Changes the current working directory.
md	Creates a directory.
rd	Removes a directory.
addfile	Copies a file from the host PC to the image file.
addfolder	Copies a folder including its subfolders and files from the host PC to the image file.
type	Shows the contents of a file.
del	Deletes a file.
dir	Lists the contents of the directory.
ren	Renames a file or directory.
move	Moves a file or directory to another location.
attr	Shows/changes the file/directory attributes.
copy	Copies a file to another location.
exportfile	Copies a file from the image file to the host PC.
exportfolder	Copies a directory recursively from the image to the host PC.
Logical sector related commands	
storesectors	Copies logical sector data from a file on the PC host to the image file.
dumpsector	Shows the contents of a logical sector.
copysectors	Copies logical sector data to another location.
Volume related commands	
formatlow	Low-level formats a volume.
format	High-level formats a volume.
df	Shows the available free space on a volume.
diskinfo	Shows information about a volume.
getdevinfo	Shows information about a storage device.
checkdisk	Checks a volume for errors.
creatembr	Writes the partition table to the master boot record (MBR).

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Command	Description
listvolumes	Shows the names of all available volumes.

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17.3.1 Image-related commands

The following sections describe the commands required to create an image file.

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17.3.1.1 createimage

Description

Creates/opens a new/existing image file.

Syntax

```
createimage <ImageFileName> <NumBlocks> <PagesPerBlock> <PageSize>
            [<SpareAreaSize>]
ci          <ImageFileName> <NumBlocks> <PagesPerBlock> <PageSize>
            [<SpareAreaSize>]
```

Parameters

Parameter	Description
ImageFileName	Name of the image file to be created/opened.
NumBlocks	Number of NAND blocks.
PagesPerBlock	Number of pages in a NAND block.
PageSize	Number of bytes in a NAND page excluding the spare area.
SpareAreaSize	Number of bytes in the spare area of a NAND page.

Additional information

This command is mandatory, and it must be the first command to be executed.

The size of the image file is NumBlocks * PagesPerBlock * (PageSize + SpareAreaSize) bytes large. The image file is silently overwritten if the image file already exists, but the calculated size of the file does not match. If SpareAreaSize is not specified, then the utility calculates it as 1/32 of PageSize.

PageSize has to be a power of 2 value. The values for PagesPerBlock and PageSize have to match the values of the NAND flash device the file image will be stored to, otherwise the application will not be able to access the data via emFile.

SpareAreaSize has to match the value returned via the BytesPerSpareArea member of FS_NAND_DISK_INFO by FS_NAND_GetDiskInfo() or FS_NAND_UNI_GetDiskInfo(). This value may be smaller than the size of the spare area specified in the data sheet of the NAND flash device.

NumBlocks has to match either the maximum number of blocks in the NAND flash device or the number of blocks specified as the second parameter in the call to FS_NAND_SetBlock-Range() or FS_NAND_UNI_SetBlockRange().

Example

The example shows how to create a 128 Mbytes image file.

```
createimage C:\nand.bin 1024 64 2048
```

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17.3.1.2 setdrivertype

Description

Configures the NAND driver type.

Syntax

```
setdrivertype <DriverType>
```

Parameters

Parameter	Description
DriverType	The type of NAND driver used to access the files on the target. • slc1 - SLC1 NAND driver • uni - Universal NAND driver

Additional information

This command is optional. If not executed, an image file is created that can be accessed on the target using the Universal NAND driver.

Example

The example shows how to specify that the SLC1 NAND driver is used on the target to access the NAND flash.

```
setdrivertype slc1
```

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17.3.1.3 setsectorsize

Description

Configures the logical sector size.

Syntax

```
setsectorsize <SectorSize>
```

Parameters

Parameter	Description
SectorSize	The size of the logical sector in bytes.

Additional information

This command is optional. It can be used to set the size of the logical sector when the SLC1 NAND driver type is selected. Any power of 2 value between 512 bytes and the number of bytes in a NAND page can be used. When this command is not executed, the size of the logical sector is set automatically to the configured page size of the NAND flash device. The size of the logical sector has to be smaller than or equal to the size of the logical sector configured on the target application via `FS_SetMaxSectorSize()`.

Example

This example shows how to set the logical sector size to 512 bytes.

```
setsectorsize 512
```

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17.3.1.4 addpartition

Description

Configures a logical partition.

Syntax

```
addpartition <StartSector> <NumSectors> [<PartType>]
ap           <StartSector> <NumSectors> [<PartType>]
```

Parameters

Parameter	Description
StartSector	Index of the first sector in the partition.
NumSectors	Number of sectors in the partition.
PartType	Type of the partition to create. Permitted values are: • normal - The entire partition space is used by the file system as storage (default). • raid1 - The file system can use only half of the partition space as storage. The other half is used as a mirror partition.

Additional information

This command is optional. It allows the creation of logical partitions on the image file. The command fails if the defined sector range overlaps the range of an already defined logical partition. A maximum of four logical partitions can be created. The partition list has to be stored to the image after initialization of the image using the creatembr command. The data on the created logical partitions can be accessed using the Disk Partition driver. The logical partitions can be formatted using the format command. The value of StartSector is relative to the beginning of the storage device.

Example

This example shows how to configure 2 logical partitions. Sector 0 is reserved for the Master Boot Record, where the partition list is stored.

```
addpartition 1 10000
addpartition 10001 20000
```

A possible emFile configuration that allows the application to access the logical partitions looks like this:

```
#include <FS.h>
#include "FS_NAND_HW_Template.h"

#define ALLOC_SIZE      0x9000          // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the NAND partition. Volume name: "nand:0:"
  //
  FS_AddDevice(&FS_NAND_UNI_Driver);
  FS_NAND_UNI_SetPhyType(0, &FS_NAND_PHY_ONFI);
  FS_NAND_UNI_SetECCHook(0, &FS_NAND_ECC_HW_NULL);
  FS_NAND_ONFI_SetHWType(0, &FS_NAND_HW_Template);
  //
  // Add and configure the first logical volume. Volume name: "diskpart:0"
  //
  FS_AddDevice(&FS_DISKPART_Driver);
```

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```
  FS_DISKPART_Configure(0, &FS_NAND_UNI_Driver, 0, 0);
  //
  // Add and configure the second logical volume. Volume name: "diskpart:1"
  //
  FS_AddDevice(&FS_DISKPART_Driver);
  FS_DISKPART_Configure(1, &FS_NAND_UNI_Driver, 0, 1);
}
```

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17.3.1.5 setecclevel

Description

Configures the error correction type.

Syntax

```
setecclevel <NumBitErrors>
sel         <NumBitErrors>
```

Parameters

Parameter	Description
NumBitErrors	Number of bit errors the ECC stored to spare area must be able to correct. Permitted values are: • 0 - hardware ECC. • 1 - 1-bit software ECC.

Additional information

This command is optional. If not executed, a 1-bit software-calculated ECC is stored to the spare area. If NumBitErrors is set to 0, then the bytes in the spare area reserved for the ECC are set to 0xFF.

Example

This example shows how to set the correction level to hardware ECC.

```
setecclevel 0
```

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17.3.1.6 setnumworkblocks

Description

Configures the number of work blocks.

Syntax

```
setnumworkblocks <NumBlocks>
snwb             <NumBlocks>
```

Parameters

Parameter	Description
NumBlocks	Number of NAND blocks reserved for work blocks.

Additional information

This command is optional. If this command is not executed, the number of work blocks is set to 3. The number of work blocks specified via this command has to match the number of work blocks configured by the target application via `FS_NAND_SetNumWorkBlocks()` or `FS_NAND_UNI_SetNumWorkBlocks()`.

Example

This example shows how to set the number of work blocks to 8.

```
setnumworkblocks 8
```

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17.3.1.7 showimageinfo

Description

Shows information about the image file.

Syntax

```
showimageinfo
si
```

Example

```
showimageinfo
  Name:             nand.bin
  Driver type:      Universal
  Num blocks:       1024
  Pages per block:  64
  Page size:        2048 bytes
  Spare area size:  64 bytes
  Bytes per sector: 2048 bytes
```

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17.3.1.8 init

Description

Initializes the image file.

Syntax

```
init
```

Additional information

This command must be executed before any other command which operates on files and directories.

Example

```
init
```

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17.3.1.9 exportimage

Description

Saves to a file the NAND blocks that contain valid data.

Syntax

```
exportimage <FilePathOnHost>
ei          <FilePathOnHost>
```

Parameters

Parameter	Description
`FilePathOnHost`	Path to destination file on host PC.

Additional information

This command is optional. It can be used to create an image file that contains only NAND blocks with valid data. The NAND blocks that contain invalid data or are empty are discarded. The created file can be used to program the NAND flash device. The programming utility has to make sure that the NAND blocks that are not programmed are blank, that is, all the bytes in these blocks are set to `0xFF`. Typically, the created file is smaller than the original image file, which helps reduce the programming time.

Example

```
exportimage C:\NAND.bin
```

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17.3.2 File and directory related commands

The following sections describe the commands that can be used to operate on the files and directories stored on the image file. The commands described in this section can be executed only after the execution of the `init` command.

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17.3.2.1 cd

Description

Changes the current working directory.

Syntax

```
chdir <DirPathOnImage>
cd    <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to new directory to change to.

Additional information

If DirPathOnImage is set to .., the command changes to the parent directory. After initialization, the current directory is set to the root directory.

Example

In the following sample the working directory is changed to Test and then back to the original directory.

```
cd Test
cd ..
```

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17.3.2.2 md

Description

Creates a directory.

Syntax

```
mkdir <DirPathOnImage>
md    <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be created.

Additional information

This command is able to create any missing directories in the path.

Example

```
md Test\Dir\
```

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17.3.2.3 rd

Description

Removes a directory.

Syntax

```
rmdir <DirPathOnImage> [/R]
rd    <DirPathOnImage> [/R]
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be deleted.
/R	Option that causes the command to delete non-empty directories.

Additional information

If the /R option is not specified, then the directory to be deleted must be empty.

Example

```
rd Test
```

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17.3.2.4 addfile

Description

Copies a file from the host PC to the image file.

Syntax

```
addfile <FilePathOnHost> [<FilePathOnImage>]
af      <FilePathOnHost> [<FilePathOnImage>]
```

Parameters

Parameter	Description
FilePathOnHost	Path to the source file on the host PC.
FilePathOnImage	Path to the destination file on the image.

Additional information

If FilePathOnImage is not specified then the name of the source file is used.

Example

The following command copies the contents of the Test.txt file from the host PC to the Dest.txt file on the image.

```
addfile C:\Test.txt Dest.txt
```

The following command copies the contents of the Test.txt file to a file with the same name on the image.

```
addfile C:\Test.txt
```

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17.3.2.5 addfolder

Description

Copies a folder including its subfolders and files from the host PC to the image file.

Syntax

```
addfolder <DirPathOnHost> [<DirPathOnImage>] [/S]
```

Parameters

Parameter	Description
DirPathOnHost	Path to source directory on the host PC.
DirPathOnImage	Path to destination directory on the image.
/S	Option that causes the command to suppress the output of progress information.

Additional information

If DirPathOnImage is not specified, then the name of the source directory is used.

Example

The following command copies the contents of the Data directory on the PC to the Dest directory on the image.

```
addfolder C:\Data Dest
```

The following command copies the contents of the Data directory on the PC to a directory with the same name on the image.

```
addfolder C:\Data
```

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17.3.2.6 type

Description

Shows the contents of a file.

Syntax

```
type <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be shown.

Example

The following command line shows the contents of the file `Test.txt` located in the root directory of the image.

```
type Test.txt
```

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17.3.2.7 del

Description

Deletes a file.

Syntax

```
del <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be deleted.

Example

The following command line deletes the file `Test.txt` located on the root directory of the image.

```
del Test.txt
```

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17.3.2.8 dir

Description

Lists the contents of the directory.

Syntax

```
ls  [<DirPathOnImage>]
dir [<DirPathOnImage>]
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory on image to be listed.

Additional information

If DirPathOnImage is not specified then the command lists the contents of the current working directory.

Example

The following command line shows the contents of the directory TestDir.

```
dir nand:0:\TestDir
.                   (Dir) Attributes: ----
..                  (Dir) Attributes: ----
SubDir              (Dir) Attributes: ----
Test1.txt                 Attributes: A--- Size: 30
Test2.txt                 Attributes: A--- Size: 31
```

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17.3.2.9 ren

Description

Renames a file or directory.

Syntax

```
rename <FilePathOnImage> <NewFileName>
ren    <FilePathOnImage> <NewFileName>
```

Parameters

Parameter	Description
FilePathOnImage	Path to file or directory that has to be renamed.
NewFileName	New name of the file or directory.

Additional information

If DirPathOnImage is not specified then the command lists the contents of the current working directory.

Example

The following command line changes the name of the Test.txt file located in the Test directory to Test2.txt.

```
ren Test\Test.txt Test2.txt
```

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17.3.2.10 move

Description

Moves a file or directory to another location.

Syntax

```
move <SrcFilePathOnImage> <DestFilePathOnImage>
mv   <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to file or directory to be moved.
DestFilePathOnImage	Path to destination file or directory on the image.

Example

The following command line moves the `Test.txt` file located in the `Test` directory to the root directory. The file is renamed to `New.txt`.

```
move Test\Test.txt New.txt
```

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17.3.2.11 attr

Description

Shows/changes the file/directory attributes.

Syntax

```
attr <PathOnImage> [<Operation> <Attributes>]
```

Parameters

Parameter	Description
PathOnImage	Path to file or directory.
Operation	Operation to be executed on attributes. Permitted values are: • + sets the attributes. • - clears the attributes.
Attributes	The list of attributes to be changed. The following attributes are supported: • a - archive. • h - hidden. • r - read-only. • s - system.

Example

The following example clears the archive and read-only attributes of the Test.txt file.

```
attr Test.txt -ar
```

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17.3.2.12 copy

Description

Copies a file to another location.

Syntax

```
copy <SrcFilePathOnImage> <DestFilePathOnImage>
cp   <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to the file to be copied.
DestFilePathOnImage	Path to the destination file.

Example

The following example copies the contents of the `Test.txt` to the `Test2.txt` file.

```
copy Test.txt Test2.txt
```

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17.3.2.13 exportfile

Description

Copies a file from the image file to the host PC.

Syntax

```
exportfile <FilePathOnImage> <FilePathOnHost>
ef         <FilePathOnImage> <FilePathOnHost>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the source file on the image.
FilePathOnHost	Path to the destination file on the PC.

Example

The following command copies the contents of the `Test.txt` file from the image to the `Dest.txt` file on the host PC.

```
exportfile Test.txt C:\Dest.txt
```

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17.3.2.14 exportfolder

Description

Copies a directory recursively from image to host PC.

Syntax

```
exportfolder <DirPathOnImage> <DirPathOnHost>
```

Parameters

Parameter	Description
DirPathOnImage	Path to the source directory on the image.
DirPathOnHost	Path to the destination directory on the PC.

Example

The following command copies the contents of the entire current volume from the image to the `Exported\RootDir` directory on the host PC.

```
exportfolder \ Exported\RootDir
```

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17.3.3 Logical sector related commands

The following sections describe commands that can be used to operate on logical sectors.

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17.3.3.1 storesectors

Description

Copies logical sector data from a file on the PC host to the image file.

Syntax

```
storesectors <FilePathOnImage> [<StartSector>]
```

Parameters

Parameter	Description
`FilePathOnImage`	Path to the file on host that contains sector data.
`StartSector`	Index of the first logical sector to be written.

Additional information

This command is optional. The sector data must be stored sequentially in the file. For example, if the sector size is 2048 bytes and the data is stored starting from sector index 100, then the byte at offset 0 in the file stores the first byte of sector 100, the byte at offset 2048 in the file stores the first byte of sector 101, and so on. The size of the file has to be a multiple of the sector size. The size of the sector is the size specified as the argument to the `setsectorsize` command.

Example

This example reads sector data from the file `SectorData.bin` and writes it starting from sector index 100.

```
storesectors SectorData.bin 100
```

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17.3.3.2 dumpsector

Description

Shows the contents of a logical sector.

Syntax

```
dumpsector <SectorIndex>
ds         <SectorIndex>
```

Parameters

Parameter	Description
SectorIndex	Index of the logical sector to be displayed.

Example

The following command shows the contents of the logical sector 0.

```
dumpsector 0
00000000 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000010 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000020 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000030 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 34 33 ..43214321432143
00000040 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000050 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000060 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 21..432143214321
00000070 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000080 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000090 34 33 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 4321..4321432143
000000A0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000000B0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000000C0 32 31 34 33 32 31 0D 0A 34 33 32 31 34 33 32 31 214321..43214321
000000D0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000000E0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000000F0 34 33 32 31 34 33 32 31 0D 0A 34 33 32 31 34 33 43214321..432143
00000100 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000110 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000120 32 31 34 33 32 31 34 33 32 31 0D 0A 34 33 32 31 2143214321..4321
00000130 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000140 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000150 34 33 32 31 34 33 32 31 34 33 32 31 0D 0A 34 33 432143214321..43
00000160 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000170 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000180 32 31 34 33 32 31 34 33 32 31 34 33 32 31 0D 0A 21432143214321..
00000190 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001A0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001B0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001C0 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 34 33 ..43214321432143
000001D0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000001E0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000001F0 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 21..432143214321
```

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17.3.3.3 copysectors

Description

Copies logical sector data to another location.

Syntax

```
copysectors <SrcSector> <DestSector> <NumSectors>
cs          <SrcSector> <DestSector> <NumSectors>
```

Parameters

Parameter	Description
SrcSector	Index of the first source sector.
DestSector	Index of the first destination sector.
NumSectors	Number of sectors to copy.

Additional information

This command operates only on the `nand:0:` volume. The command reports an error if the source and destination sector ranges overlap.

Example

This example copies 10000 logical sectors from sector index 0 to sector index 20000.

```
copysectors 0 20000 10000
```

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17.3.4 Volume-specific commands

The following sections describe commands that operate on the file system volumes located on the image file.

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17.3.4.1 formatlow

Description

Low-level formats a volume.

Syntax

```
formatlow [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.

Additional information

If VolumeName is not specified then the command formats the current volume. The current volume can be selected via the cd command.

Every NAND volume has to be low-level formatted once when the image file is newly created.

Example

This example demonstrates how to format the volume nand:1:.

```
formatlow nand:1:
Low-level format...OK
```

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17.3.4.2 format

Description

High-level formats a volume.

Syntax

```
format [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.

Additional information

If VolumeName is not specified then the command formats the current first volume. The current volume can be selected via the cd command.

Every NAND volume has to be high-level formatted once when the image file is newly created.

Example

This example demonstrates how to format the volume nand:0:.

```
format
High-level format...OK
```

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17.3.4.3 df

Description

Shows the available free space on a volume.

Syntax

```
diskfree [<VolumeName>]
df       [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command calculates the free space of the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get the free space on the first volume.

```
df
Available free space is 127647744 bytes
```

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17.3.4.4 diskinfo

Description

Shows information about a storage device.

Syntax

```
diskinfo [<VolumeName>]
di       [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command returns information about the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the volume nand:1:.

```
diskinfo nand:1:
    127647744 bytes total disk space
     17719296 bytes available free space
         8192 bytes per cluster
        15582 cluster available on volume
         2163 free cluster available on volume
```

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17.3.4.5 getdevinfo

Description

Shows information about a volume.

Syntax

```
getdevinfo [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified, then the command returns information about the first volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the storage device used by the first volume.

```
getdevinfo
        62370 available sectors
         2048 bytes per sector
```

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17.3.4.6 checkdisk

Description

Checks a volume for errors.

Syntax

```
checkdisk [<VolumeName>]
chkdsk    [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be checked.

Additional information

If VolumeName is not specified then the command checks the current volume for errors. The current volume can be selected via the cd command.

Example

This example demonstrates how to check the file system structure of the first volume.

```
checkdisk
```

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17.3.4.7 creatembr

Description

Writes the partition table to the master boot record (MBR).

Syntax

```
creatembr [<VolumeName>]
cm        [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be written.

Additional information

If VolumeName is not specified then the command writes the MBR to the current volume. The current volume can be selected via the cd command.

This command stores the partition table configured via the addpartition command to the MBR of the specified volume. The command has to be executed after the low-level format and before any high-level format operation. Typically, the partition table is located on the nand:0: volume.

Example

This example writes the MBR to sector 0 of the nand:0: volume.

```
creatembr nand:0:
```

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17.3.4.8 listvolumes

Description

Shows the names of all available volumes.

Syntax

```
listvolumes
lv
```

Example

Shows the names of the volumes in a configuration using five volumes.

```
listvolumes
Available volumes:
  nand:0:
  diskpart:0:
  diskpart:1:
  diskpart:2:
  diskpart:3:
```

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Chapter 18

NOR Image Creator

This chapter provides information about the emFile utility that can be used to create file system images for NOR flash devices.

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18.1 General information

The NOR Image Creator is a command-line utility that can be used to create a file containing a one-to-one representation of the contents of a NOR flash device (image file) with preselected files and directories found on the host PC.

The NOR Image Creator provides commands for performing standard file system operations such as formatting the storage device low-level as well as high-level, copying files and directories from the host PC to the image file or checking the consistency of the file system structure.

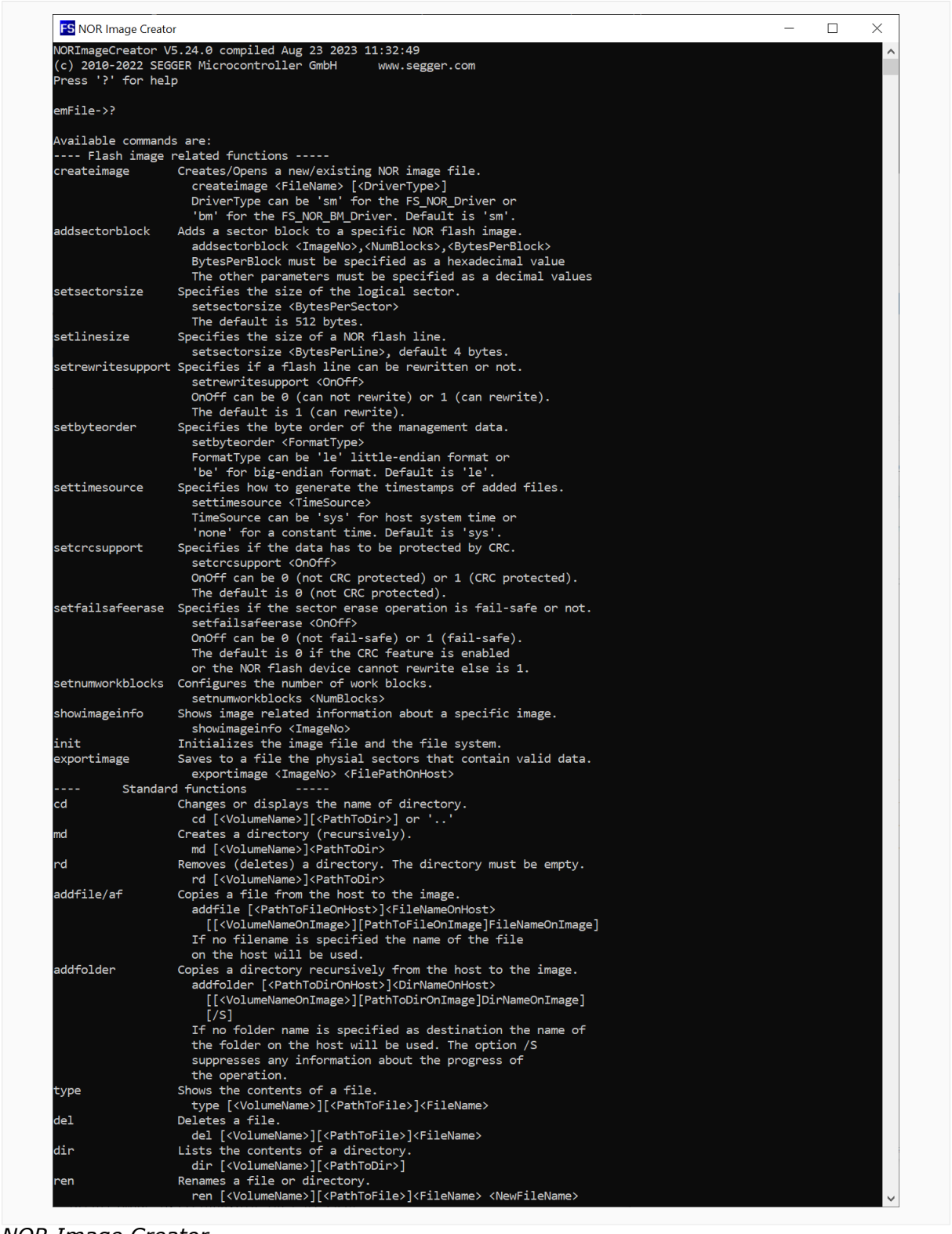
The generated image file is a regular binary file that can be programmed directly into the NOR flash device of the target system via a SEGGER production programmer (https://www.segger.com/products/flash-in-circuit-programmers/) or any other third-party utility.

The NOR Image Creator ships with executables for Windows, Linux, and macOS systems that can be used to create images for the FAT and EFS file systems.

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18.2 Using the NOR Image Creator utility

The NOR Image Creator utility can be used like any other command-line-based program. For the ease of usage, many commands are kept similar to their DOS counterparts. By entering "?" or just pressing the Enter key, an overview of the commands is printed on the screen, and it should look like the picture below.



NOR Image Creator

The NOR Image Creator utility can work in two modes: interactive and script. The interactive mode is entered when the utility is started with no command-line arguments. In this mode, the user is prompted to type in the commands to be executed. The script mode is entered

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when the utility is started with a command-line argument that specifies the name of a file containing the commands to be executed, one command per line.

18.2.1 Sample script file

The following sample shows a simple script file which does the following:

- Creates a NOR flash image file `C:\flash.bin`
- Adds a sector block of 4 Mbytes (64 x 64 kByte) to the image file.
- Creates the image file.
- Low-level formats the volume on the image file.
- High-level formats the volume on the image file.
- Copies the `Test.txt` file from drive `C:` of the host Windows PC to the root directory of the volume stored on the image file.
- Recursively copies the contents of the `Data` directory from the host PC to the `Data` directory of the volume stored on the image file.
- Closes the NOR Image Creator utility.

```
createimage C:\flash.bin
addsectorblock 0, 64, 10000
init
formatlow
format
addfile C:\Test.txt
addfolder C:\Data\
q
```

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18.3 Supported commands

The image file can be processed by using the built-in commands of the NOR Image Creator utility. The table below lists all the available commands followed by a detailed description. The optional command parameters are enclosed in square brackets in the syntax description of a command. If not otherwise stated all the numeric parameters have to be specified in decimal format.

Command	Description
Image related commands	
createimage	Creates/opens a new/existing image file.
addsectorblock	Configures a block of NOR physical sectors.
setsectorsize	Configures the logical sector size.
setlinesize	Specifies the minimum number of bytes that can be programmed at once
setrewritesupport	Configures if the NOR driver is allowed to perform rewrite operations.
setbyteorder	Specifies the byte order of the management data.
settimesource	Specifies how the timestamps of added files are generated.
setcrcsupport	Specifies if the data has to be protected by CRC.
setnumworkblocks	Configures the number of work blocks.
seteccsupport	Specifies if the data has to be protected by ECC.
showimageinfo	Shows information about the image file.
init	Initializes the image file.
exportimage	Saves to a file the NOR physical sectors that contain valid data.
File and directory related commands	
cd	Changes the current working directory.
md	Creates a directory.
rd	Removes a directory.
addfile	Copies a file from the host PC to the image file.
addfolder	Copies a folder including its subfolders and files from the host PC to the image file.
type	Shows the contents of a file.
del	Deletes a file.
dir	Lists the contents of the directory.
ren	Renames a file or directory.
move	Moves a file or directory to another location.
attrib	Shows/changes the file/directory attributes.
copy	Copies a file to another location.
exportfile	Copies a file from the image file to the host PC.
exportfolder	Copies a folder including its subfolders and files from the image file to the host PC.
Volume specific commands	
formatlow	Low-level formats a volume.
format	High-level formats a volume.
df	Shows the available free space on a volume.
diskinfo	Shows information about a volume.

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Command	Description
getdevinfo	Shows information about a storage device.
checkdisk	Checks a volume for errors.
listvol	Shows the names of all available volumes.
clean	Runs a clean operation on a volume.
createjournal	Creates the journal file on a volume.

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18.3.1 Image related commands

The following sections describe the commands required to create an image file.

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18.3.1.1 createimage

Description

Creates/opens a new/existing image file.

Syntax

```
createimage <ImageFileName>[,<DriverType>]
```

Parameters

Parameter	Description
`ImageFileName`	Name of the image file to be created/opened.
`DriverType`	The type of NOR driver used to access the files on the target. • `sm` - Sector Map NOR driver (default). • `bm` - Block Map NOR driver.

Additional information

This command is mandatory and it must be the first command to be executed.

If `DriverType` is not specified, then the Sector Map NOR driver is assumed.

Example

The example shows how to create an image file for the Block Map NOR driver.

```
createimage C:\flash.bin bm
```

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18.3.1.2 addsectorblock

Description

Configures a block of NOR physical sectors.

Syntax

```
addsectorblock <ImageNo>,<NumSectors>,<SectorSize>
```

Parameters

Parameter	Description
ImageNo	Index of the image file.
NumSectors	Number of NOR physical sectors in the block.
SectorSize	Size of one NOR physical sector.

Additional information

This command is mandatory and has to be executed at least once. addsectorblock can be used to describe the geometry of the physical NOR flash device used on the target. It specifies the characteristics of a continuous block of NOR physical sectors. The command can be executed more than once with different parameters. SectorSize has to be specified in bytes as a hexadecimal number without any prefix or suffix. For example, a NOR physical sector of 64 Kbytes can be specified as 10000.

ImageNo specifies the index of the image file. The first image file created via createimage has the index 0, the second image the index 1, and so on.

Example

The following example shows how to configure the image for a NOR flash device that has 32 physical sectors of 64 Kbytes and 8 physical sectors of 4 Kbytes.

```
addsectorblock 0,32,10000
addsectorblock 0,8,1000
```

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18.3.1.3 setsectorsize

Description

Configures the logical sector size.

Syntax

```
setsectorsize <SectorSize>
```

Parameters

Parameter	Description
SectorSize	The size of the logical sector in bytes.

Additional information

This command is optional. It can be used to set the size of the logical sector used by the file system. By default, the file system uses a logical sector size of 512 bytes. The size of the logical sector has to be smaller than or equal to the size of the logical sector configured on the target application via `FS_SetMaxSectorSize()`.

`SectorSize` has to be a power of 2 value.

Example

This example shows how to set the logical sector size to 512 bytes.

```
setsectorsize 2038
```

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18.3.1.4 setlinesize

Description

Specifies the minimum number of bytes that can be programmed at once.

Syntax

```
setlinesize <LineSize>
```

Parameters

Parameter	Description
LineSize	Minimum number of bytes that can be programmed at once.

Additional information

This command is optional. By default, the minimum number of bytes that the NOR driver programs is 4. LineSize has to be a power of 2 value.

Example

This example shows how to set the line size to 16 bytes.

```
setlinesize 16
```

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18.3.1.5 setrewritesupport

Description

Configures if the NOR driver is allowed to perform rewrite operations.

Syntax

```
setrewritesupport <OnOff>
```

Parameters

Parameter	Description
`OnOff`	Indicates if the feature is activated or not. • `1` - NOR driver is permitted to rewrite data (default). • `0` - NOR driver is not permitted to rewrite data.

Additional information

This command is optional. By default, the NOR driver is permitted to modify the same byte of the NOR flash device memory as long as bits are changed from 0 to 1 without an erase operation in between. The majority of NOR flash devices support this feature, but some do not. For this type of NOR flash device, this command has to be called with `OnOff` set to 0.

Example

This example shows how to specify that the NOR flash can rewrite data.

```
setrewritesupport 1
```

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18.3.1.6 setbyteorder

Description

Specifies the byte order of the management data.

Syntax

```
setbyteorder <FormatType>
```

Parameters

Parameter	Description
FormatType	Specifies the byte ordering. • le - little endian format. • be - big endian format.

Additional information

This command is optional. By default, the NOR driver stores multi-byte management data in the byte order of the host CPU, which is typically little-endian. The byte order of the management data has to match the byte order of the target CPU. `setbyteorder` can be used to explicitly configure the byte order.

Example

This example shows how to configure the byte order to big-endian.

```
setbyteorder be
```

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18.3.1.7 settimesource

Description

Specifies how the timestamps of added files are generated.

Syntax

```
settimesource <TimeSource>
```

Parameters

Parameter	Description
TimeSource	Specifies the time source to be used. • sys - time of host PC (default). • none - constant value.

Additional information

This command is optional. By default, the NOR Image Creator utility uses the current time and date of the host PC to generate the timestamps of the files and directories. In some cases it is desirable to have the same constant timestamp for all the files and directories stored on the image file so that for example the generated image file can be compared for correctness against a reference image file.

Example

This example shows how to configure the NOR Image Creator utility to use a constant time stamp for all the files and directories it creates on the image file.

```
settimesource none
```

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18.3.1.8 setcrcsupport

Description

Specifies if the data has to be protected by CRC.

Syntax

```
setcrcsupport <OnOff>
```

Parameters

Parameter	Description
OnOff	Indicates if the feature is activated or not. • 1 - Data is protected by CRC. • 0 - Data is not protected by CRC (default).

Additional information

This command is optional. By default, the management and user data stored by the NOR driver is not protected by CRC.

Example

This example shows how to configure the NOR Image Creator utility to protect the data via CRC.

```
setcrcsupport 1
```

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18.3.1.9 setnumworkblocks

Description

Configures the number of work blocks.

Syntax

```
setnumworkblocks <NumWorkBlocks>
```

Parameters

Parameter	Description
NumWorkBlocks	Number of work blocks.

Additional information

This command is optional and applies only to the Block Map NOR driver. By default, the Block Map NOR driver calculates the number of work blocks automatically based on the number of physical sectors available as storage. The setnumworkblocks command can be used to overwrite the calculated value. NumWorkBlocks has to be set to a value greater than 0.

Example

This example shows how to set the number of work blocks to 8.

```
setnumworkblocks 8
```

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18.3.1.10 seteccsupport

Description

Specifies if the data has to be protected by ECC.

Syntax

```
seteccsupport <OnOff>
```

Parameters

Parameter	Description
OnOff	Indicates if the feature is activated or not. • 1 - Data is protected by ECC. • 0 - Data is not protected by ECC (default).

Additional information

This command is optional. By default, the management and user data stored by the NOR driver is not protected by ECC.

Example

This example shows how to configure the NOR Image Creator utility to protect the data via ECC.

```
seteccsupport 1
```

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18.3.1.11 showimageinfo

Description

Shows information about the image file.

Syntax

```
showimageinfo <ImageNo>
```

Parameters

Parameter	Description
ImageNo	Index of the image file.

Example

```
showimageinfo
Information about image 0:
  Name:             NORImageCreator_NOR.img
  ImageSize:        8388608 bytes
  NumSectorBlocks:  1
    Block 0: 128 sectors of 0x00010000 bytes
```

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18.3.1.12 init

Description

Initializes the image file.

Syntax

```
init
```

Additional information

This command must be executed before any other command which operates on files and directories.

Example

```
init
```

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18.3.1.13 exportimage

Description

Saves to a file the NOR physical sectors that contain valid data.

Syntax

```
exportimage <FilePathOnHost>
ei          <FilePathOnHost>
```

Parameters

Parameter	Description
FilePathOnHost	Path to destination file on host PC.

Additional information

This command is optional. It can be used to create an image file that contains only NOR physical sectors with valid data. The NOR physical sectors that contain invalid data or are empty are discarded. The created file can be used to program the NOR flash device. The programming utility has to make sure that the NOR physical sectors that are not programmed are blank, that is, all the bytes in these physical sectors are set to `0xFF`. Typically, the created file is smaller than the original image file, which helps reduce the programming time.

Example

```
exportimage C:\NOR.bin
```

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18.3.2 File and directory related commands

The following sections describe the commands that can be used to operate on the files and directories stored on the image file. The commands described in this section can be executed only after the execution of the `init` command.

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18.3.2.1 cd

Description

Changes the current working directory.

Syntax

```
cd <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to new directory to change to.

Additional information

If DirPathOnImage is set to .., the command changes to the parent directory. After initialization, the current directory is set to the root directory.

Example

In the following sample the working directory is changed to Test and then back to the original directory.

```
cd Test
cd ..
```

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18.3.2.2 md

Description

Creates a directory.

Syntax

```
md <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be created.

Additional information

This command is able to create any missing directories in the path.

Example

```
md Test\Dir\
```

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18.3.2.3 rd

Description

Removes a directory.

Syntax

```
rd <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be deleted.

Additional information

The directory to be deleted must be empty.

Example

```
rd Test
```

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18.3.2.4 addfile

Description

Copies a file from the host PC to the image file.

Syntax

```
addfile <FilePathOnHost> [<FilePathOnImage>]
```

Parameters

Parameter	Description
FilePathOnHost	Path to the source file on the host PC.
FilePathOnImage	Path to destination file on the image.

Additional information

If FilePathOnImage is not specified then the name of the source file is used.

Example

The following command copies the contents of the Test.txt file from the host PC to the Dest.txt file on the image.

```
addfile C:\Test.txt Dest.txt
```

The following command copies the contents of the Test.txt file to a file with the same name on the image.

```
addfile C:\Test.txt
```

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18.3.2.5 addfolder

Description

Copies a folder including its subfolders and files from the host PC to the image file.

Syntax

```
addfolder <DirPathOnHost> [<DirPathOnImage>]
```

Parameters

Parameter	Description
DirPathOnHost	Path to source directory on the host PC.
DirPathOnImage	Path to destination directory on the image.

Additional information

If DirPathOnImage is not specified then the name of the source directory is used.

Example

The following command copies the contents of the Data directory on the host PC to the Dest directory on the image.

```
addfolder C:\Data Dest
```

The following command copies the contents of the Data directory on the host PC to a directory with the same name on the image.

```
addfolder C:\Data
```

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18.3.2.6 type

Description

Shows the contents of a file.

Syntax

```
type <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be shown.

Example

The following command line shows the contents of the file `Test.txt` located on the root directory of the image.

```
type Test.txt
```

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18.3.2.7 del

Description

Deletes a file.

Syntax

```
del <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be deleted.

Example

The following command line deletes the file `Test.txt` located in the root directory of the image.

```
del Test.txt
```

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18.3.2.8 dir

Description

Lists the contents of the directory.

Syntax

```
dir [<DirPathOnImage>]
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory on image to be listed.

Additional information

If DirPathOnImage is not specified then the command lists the contents of the current working directory.

Example

The following command line shows the contents of the current directory.

```
dir
TestDir             (Dir) Attributes: ----
.                   (Dir) Attributes: ----
..                  (Dir) Attributes: ----
SubDir              (Dir) Attributes: ----
Test1.txt                 Attributes: A--- Size: 30
Test2.txt                 Attributes: A--- Size: 31
```

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18.3.2.9 ren

Description

Renames a file or directory.

Syntax

```
ren <FilePathOnImage> <NewFileName>
```

Parameters

Parameter	Description
FilePathOnImage	Path to file or directory that has to be renamed.
NewFileName	New name of the file or directory.

Additional information

If DirPathOnImage is not specified, then the command lists the contents of the current working directory.

Example

The following command line changes the name of the Test.txt file located in the Test directory to Test2.txt.

```
ren Test\Test.txt Test2.txt
```

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18.3.2.10 move

Description

Moves a file or directory to another location.

Syntax

```
move <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to file or directory to be moved.
DestFilePathOnImage	Path to destination file or directory on the image.

Example

The following command line moves the `Test.txt` file located in the `Test` directory to the root directory. The file is renamed to `New.txt`.

```
move Test\Test.txt New.txt
```

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18.3.2.11 attrib

Description

Shows/changes the file/directory attributes.

Syntax

```
attrib <PathOnImage> [<Operation> <Attributes>]
```

Parameters

Parameter	Description
PathOnImage	Path to file or directory.
Operation	Operation to be executed on attributes. Permitted values are: • + sets the attributes. • - clears the attributes.
Attributes	The list of attributes to be changed. The following attributes are supported: • a archive. • h hidden. • r read-only. • s system.

Example

The following example clears the archive and read-only attributes of the Test.txt file.

```
attr Test.txt -ar
```

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18.3.2.12 copy

Description

Copies a file to another location.

Syntax

```
copy <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to the file to be copied.
DestFilePathOnImage	Path to the destination file.

Example

The following example copies the contents of the `Test.txt` to the `Test2.txt` file.

```
copy Test.txt Test2.txt
```

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18.3.2.13 exportfile

Description

Copies a file from the image file to the host PC.

Syntax

```
exportfile <FilePathOnImage> <FilePathOnHost>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the source file on the image.
FilePathOnHost	Path to the destination file on the PC.

Example

The following command copies the contents of the `Test.txt` file from the image file to the `Dest.txt` file on the host PC.

```
exportfile Test.txt C:\Dest.txt
```

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18.3.2.14 exportfolder

Description

Copies a folder including its subfolders and files from the image file to the host PC.

Syntax

```
exportfolder <DirPathOnImage> <DirPathOnHost>
```

Parameters

Parameter	Description
DirPathOnImage	Path to the source directory on the image.
DirPathOnHost	Path to the destination directory on the PC.

Additional information

The command copies the contents of a folder including all folders and files that are stored in it. An identical copy of the specified directory on the image file is created in the specified folder on the host PC.

Example

The following command copies the contents of the `Data` directory on the image file to `C:\Dest` directory on the host PC.

```
addfolder Data C:\Dest
```

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18.3.3 Volume-specific commands

The following sections describe commands that operate on the file system volumes located on the image file.

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18.3.3.1 formatlow

Description

Low-level formats a volume.

Syntax

```
formatlow [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.

Additional information

If VolumeName is not specified then the command formats the current volume. The current volume can be selected via the cd command.

Every NOR volume has to be low-level formatted once when the image file is newly created.

Example

This example demonstrates how to format the volume nor:1:

```
formatlow nor:1:
Low-level format...OK
```

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18.3.3.2 format

Description

High-level formats a volume.

Syntax

```
format [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.

Additional information

If VolumeName is not specified then the command formats the current first volume. The current volume can be selected via the cd command.

Every NOR volume has to be high-level formatted once when the image file is newly created.

Example

This example demonstrates how to format the volume nor:0:

```
format
High-level format...OK
```

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18.3.3.3 df

Description

Shows the available free space on a volume.

Syntax

```
df [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command calculates the free space of the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get the free space on the first volume.

```
df
Available free space is 127647744 bytes
```

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18.3.3.4 diskinfo

Description

Shows information about a storage device.

Syntax

```
diskinfo [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command returns information about the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the volume nor:1:.

```
diskinfo nor:1:
      7333888 bytes total disk space
      7333888 bytes available free space

         1024 bytes per cluster
         7162 cluster available on volume
         7162 free cluster available on volume
```

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18.3.3.5 getdevinfo

Description

Shows information about a volume.

Syntax

```
getdevinfo [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified, then the command returns information about the first volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the storage device used by the first volume.

```
getdevinfo
        14399 Available sectors
          512 bytes per sector

            0 sectors per track
            0 number of heads
```

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18.3.3.6 checkdisk

Description

Checks a volume for errors.

Syntax

```
checkdisk [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be checked.

Additional information

If VolumeName is not specified then the command checks the current volume for errors. The current volume can be selected via the cd command.

Example

This example demonstrates how to check the file system structure of the first volume.

```
checkdisk
```

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18.3.3.7 listvol

Description

Shows the names of all available volumes.

Syntax

```
listvol
```

Example

Shows the names of the volumes in a configuration using five volumes.

```
listvol
Available volumes:
  nor:0:
```

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18.3.3.8 clean

Description

Runs a clean operation on a volume.

Syntax

```
clean [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be cleaned.

Additional information

If VolumeName is not specified then the command cleans the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to clean the volume nor:1:.

```
clean nor:1:
```

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18.3.3.9 createjournal

Description

Creates the journal file on a volume.

Syntax

```
createjournal [<VolumeName>][<PathToFile>]<FileName>
               <JournalSize> [<SupportFreeSector>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that stores the journal file.
PathToFile	Path to the journal file.
FileName	Name of the journal file.
JournalSize	Size of the journal file.
SupportFreeSector	Size of the journal file.

Additional information

If VolumeName is not specified then the command creates the journal on the current volume. The current volume can be selected via the cd command. If PathToFile is not specified then the journal file is created on the root directory of the specified volume. JournalSize has to be specified in bytes. The value of SupportFreeSector is passed as third argument to FS_JOURNAL_CreateEx(). If not specified, SupportFreeSector is set to 0.

The parameters passed to the createjournal command have to match the parameters passed to FS_JOURNAL_CreateEx() on the target application.

Example

This example demonstrates how to create a journal file of 128 Kbytes on the current volume.

```
createjournal Journal.dat 131072 1
Create journal file 'Journal.dat'...OK
```

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Chapter 19

Storage Image Creator

This chapter provides information about the emFile utilities that can be used to create a file system image for an SD card, an eMMC device or a USB drive.

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19.1 General information

The Storage Image Creator is a command-line utility that can be used to create a file containing a one-to-one representation of the contents of a managed storage device such as an SD card, an eMMC device, or a USB drive, with preselected files and directories found on the host PC.

The Storage Image Creator provides commands for performing standard file system operations such as formatting the storage device, copying files and directories from the host PC to the image file or checking the consistency of the file system structure.

The generated image file is a regular binary file that stores the contents of all the logical sectors of the storage device. This file has to be stored via an image writer utility to the target storage device.

The Storage Image Creator ships with executables for Windows, Linux, and macOS systems that can be used to create images for the FAT and EFS file systems. The utilities use the same syntax regardless of the file system and operating system. A separate set of executables is provided for each file system.

The Storage Image Creator for FAT utility has the ability to create file system images that are formatted as exFAT.

The Storage Image Creator for FAT utility ships with the following executables:

OS	Executable	Location in shipment
Windows	`StorageImageCreator.exe`	`Windows/FS`
Linux	`StorageImageCreator`	`Linux/FS`
macOS	`StorageImageCreator`	`macOS/FS`

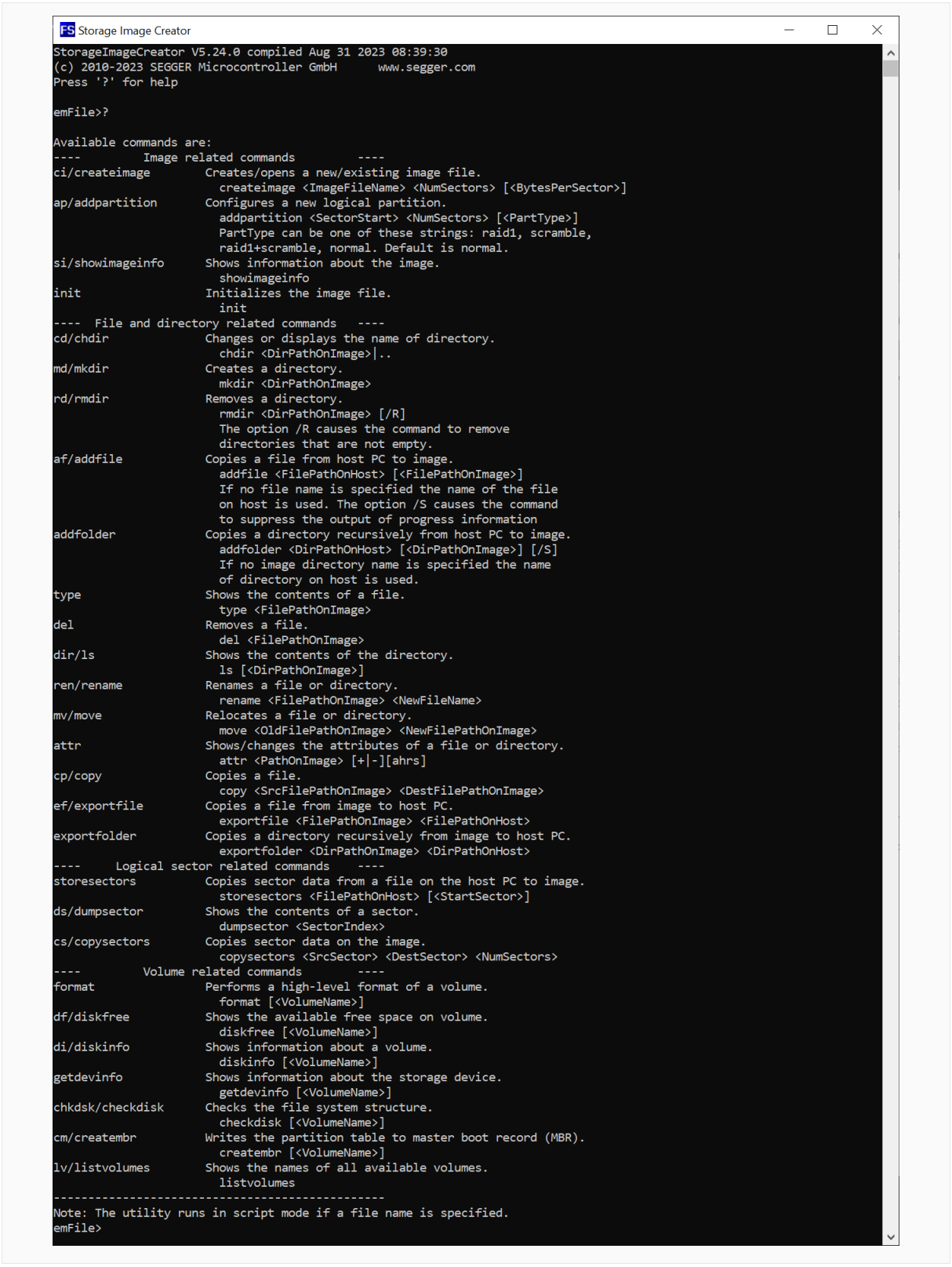
The Storage Image Creator for EFS utility ships with the following executables:

OS	Executable	Location in shipment
Windows	`StorageImageCreatorEFS.exe`	`Windows/FS`
Linux	`StorageImageCreatorEFS`	`Linux/FS`
macOS	`StorageImageCreatorEFS`	`macOS/FS`

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19.2 Using the Storage Image Creator

The Storage Image Creator utility can be used like any other command-line-based program. For ease of use, many commands are kept similar to their MS DOS counterparts. By entering "?" or just pressing the Enter key, an overview of the commands is printed on the screen, and it should look like the picture below.



Storage Image Creator

The Storage Image Creator utility can work in two modes: interactive and script. The interactive mode is entered when the utility is started with no command line arguments. In this

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mode, the user is prompted to type in the commands to be executed. The script mode is entered when the utility is started with a command line argument that specifies the name of a file containing the commands to be executed, one command per line. The command options can be prefixed either with a forward slash or with a minus character.

19.2.1 Example script file

This is an example script file that performs the following operations:

- Creates a 2 GB image file located at `C:\Temp\SDCard.bin`.
- Initializes the image file.
- Formats the volume on the image file.
- Copies the `Test.txt` file from the `C:\Temp` folder of the host Windows PC to the root directory of the volume contained in the image file.
- Recursively copies the contents of the `C:\Temp\Data` directory from the host PC to the `Data` directory located in the root directory of the volume contained in the image file.

```
createimage C:\Temp\SDCard.bin 4194304
init
format
addfile C:\Temp\Test.txt
addfolder C:\Temp\Data
q
```

19.2.2 Example usage

A step-by-step example usage that demonstrates how to create an image for an eMMC device can be found by following this link: https://wiki.segger.com/Creating_an_eMMC_image_using_Storage_Image_Creator

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19.3 Supported commands

The image file can be processed by using the commands of the Storage Image Creator utility. The table below lists all the available commands followed by a detailed description. The optional command parameters are enclosed in square brackets in the syntax description of a command.

Command	Description
Image related commands	
createimage	Creates/opens a new/existing image file.
addpartition	Configures a logical partition.
showimageinfo	Shows information about the image file.
init	Initializes the image file.
exportimage	Saves valid logical sectors to a specified file.
importimage	Loads logical sectors from a specified file.
File and directory related commands	
cd	Changes the current working directory.
md	Creates a directory.
rd	Removes a directory.
addfile	Copies a file from the host PC to the image file.
addfolder	Copies a folder including its subfolders and files from the host PC to the image file.
type	Shows the contents of a file.
del	Deletes a file.
dir	Lists the contents of the directory.
ren	Renames a file or directory.
move	Moves a file or directory to another location.
attr	Shows/changes the file/directory attributes.
copy	Copies a file to another location.
exportfile	Copies a file from the image file to the host PC.
exportfolder	Copies a directory recursively from the image to the host PC.
Logical sector related commands	
storesectors	Copies logical sector data from a file on the host PC to the image file.
dumpsector	Shows the contents of a logical sector.
copysectors	Copies logical sector data to another location.
Volume related commands	
format	Performs a format of a volume.
formatexfat	Performs a format of a volume as exFAT.
df	Shows the available free space on a volume.
diskinfo	Shows information about a volume.
getdevinfo	Shows information about a storage device.
checkdisk	Checks a volume for errors.
creatembr	Writes the partition table to the master boot record (MBR).
listvolumes	Shows the names of all available volumes.
createjournal	Creates the journal file on a volume.
freesectors	Updates usage information of logical sectors.

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19.3.1 Image-related commands

The following sections describe the commands required to create an image file.

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19.3.1.1 createimage

Description

Creates/opens a new/existing image file.

Syntax

```
createimage <ImageFileName> <NumSectors> [<SectorSize>]
ci          <ImageFileName> <NumSectors> [<SectorSize>]
```

Parameters

Parameter	Description
ImageFileName	Name of the image file to be created/opened.
NumSectors	Number of logical sectors in the image.
SectorSize	Number of bytes in a logical sector.

Additional information

This command is mandatory, and it must be the first command to be executed.

The size of the created image file is NumSectors * SectorSize bytes. The image file is silently overwritten if the image file already exists, but the calculated size of the file does not match. If SectorSize is not specified, then the utility uses logical sectors of 512 bytes.

SectorSize has to be a power-of-2 value.

Example

The example shows how to create a 1 GB image file.

```
createimage C:\Temp\SDcard.bin 2097152
```

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19.3.1.2 addpartition

Description

Configures a logical partition.

Syntax

```
addpartition <StartSector> <NumSectors>
ap           <StartSector> <NumSectors>
```

Parameters

Parameter	Description
StartSector	Index of the first sector in the partition.
NumSectors	Number of sectors in the partition.

Additional information

This command is optional. It allows the creation of logical partitions on the image file. The command fails if the defined sector range overlaps the range of an already defined logical partition. A maximum of four logical partitions can be created. The partition list has to be stored to the image after initialization of the image using the `creatembr` command. The data on the created logical partitions can be accessed using the Disk Partition driver. The logical partitions can be formatted using the `format` command. The value of StartSector is relative to the beginning of the storage device.

Example

This example shows how to configure 2 logical partitions. Sector 0 is reserved for the Master Boot Record, where the partition list is stored.

```
addpartition 1 10000
addpartition 10001 20000
```

A possible emFile configuration that allows the application to access the logical partitions looks like this:

```
#include <FS.h>
#include "FS_MMC_HW_CM_Template.h"

#define ALLOC_SIZE      0x9000          // Memory pool for the file system in bytes

static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for semi-dynamic allocation.

void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  FS_SetMaxSectorSize(2048);
  //
  // Add and configure the SD card partition. Volume name: "mmc:0:"
  //
  FS_AddDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_SetHWType(0, &FS_MMC_HW_CM_Template);
  //
  // Add and configure the first logical volume. Volume name: "diskpart:0"
  //
  FS_AddDevice(&FS_DISKPART_Driver);
  FS_DISKPART_Configure(0, &FS_MMC_CM_Driver, 0, 0);
  //
  // Add and configure the second logical volume. Volume name: "diskpart:1"
  //
  FS_AddDevice(&FS_DISKPART_Driver);
  FS_DISKPART_Configure(1, &FS_MMC_CM_Driver, 0, 1);
}
```

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19.3.1.3 showimageinfo

Description

Shows information about the image file.

Syntax

```
showimageinfo
si
```

Example

```
showimageinfo
  File name:         SDCard.bin
  File size:         1073741824 bytes
  Number of sectors: 2097152
  Sector size:       512 bytes
```

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19.3.1.4 init

Description

Initializes the image file.

Syntax

```
init
```

Additional information

This command must be executed before any other command which operates on files and directories.

Example

```
init
```

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19.3.1.5 exportimage

Description

Saves valid logical sectors to a specified file.

Syntax

```
exportimage <FilePathOnHost> [FileType]
ei          <FilePathOnHost> [FileType]
```

Parameters

Parameter	Description
FilePathOnHost	Path to destination file on host PC.
FileType	Format of the created file. Permitted values are: • `trim` - Binary file that stores the data of all the logical sectors up to and including the last that contains valid data (default). • `srec` - Motorola S-record file that stores only the logical sectors that contain valid data. • `sblk` - Binary file that stores the data of all valid logical sectors.

Additional information

This command can be used to extract the contents of all the logical sectors that contain valid data from the image file to a specified export file. The information stored in the export file can be used to program a storage device in a more efficient way than programming the actual image file because the export file contains only the information that has to actually be programmed, which can help reduce the programming time.

The exportimage command is able to export the data in three file formats. The format of the export file is specified via the second command parameter.

A `trim` file stores the contents of all the logical sectors up to and including the last one that contains valid data. The index of the first logical sector stored in the file is always 0 because the file system stores here either format or partitioning information. The logical sectors are stored in consecutive order and without gaps. Typically, the exported file is smaller than the image file because the file system starts allocating storage space from the beginning of the storage device. The exported file may contain invalid logical sectors. The data of these logical sectors is filled with 0s.

A `srec` file stores the contents of all logical sectors that contain valid data in Motorola S-record format. The address stored in the S-record is the byte offset of the data relative to the beginning of the storage device.

A `sblk` file is organized in sector blocks that contain the data of one or more consecutive sectors. Each sector block starts with a 16-byte header and is followed by the sector data. The sector block header stores information about the sector data such as the index of the first sector stored in the sector block and the size of the sector block in bytes. Inside a sector block, the logical sectors are stored in consecutive order and without gaps.

The following table describes the structure of the sector block header. All values are stored in big endian format.

Byte range	Byte count	Description
0-3	4	Index of the first logical sector in the sector block.
4-7	4	Number of bytes in the sector data that follows the sector block header.
8-16	8	Reserved.

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Example

```
exportimage C:\Temp\SDCard.bin
```

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19.3.1.6 importimage

Description

Loads logical sectors from a specified file.

Syntax

```
importimage <FilePathOnHost> [FileType] [/O]
ii          <FilePathOnHost> [FileType] [/O]
```

Parameters

Parameter	Description
FilePathOnHost	Path to source file on host PC.
FileType	Format of the source file. Permitted values are: • `trim` - Binary file that stores the data of all the logical sectors up to and including the last that contains valid data (default). • `srec` - Motorola S-record file that stores only the logical sectors that contain valid data. • `sblk` - Binary file that stores the data of all valid logical sectors.
/O	Option that causes the command to load only logical sectors that contain valid data from a file in `trim` format.

Additional information

This command can be used to copy logical sector data from a specified import file to the image file. The information about the location of the logical sectors is taken from the import file.

The `importimage` command is able to import the data in three file formats. The format of the import file is specified via the second command parameter. For more information about the format of the import file refer to the `exportimage` command.

The /O option can be used with an import file in `trim` format to optimize the import operation by loading only the logical sectors that contain valid data. This requires that the import file is a valid file system image.

Example

```
importimage C:\Temp\SDCard.bin trim
```

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19.3.2 File and directory related commands

The following sections describe the commands that can be used to operate on the files and directories stored on the image file. The commands described in this section can be executed only after the execution of the `init` command.

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19.3.2.1 cd

Description

Changes the current working directory.

Syntax

```
chdir <DirPathOnImage>
cd    <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to new directory to change to.

Additional information

If DirPathOnImage is set to .., the command changes to the parent directory. After initialization, the current directory is set to the root directory.

Example

In the following sample the working directory is changed to Test and then back to the original directory.

```
cd Test
cd ..
```

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19.3.2.2 md

Description

Creates a directory.

Syntax

```
mkdir <DirPathOnImage>
md    <DirPathOnImage>
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be created.

Additional information

This command is able to create any missing directories in the path.

Example

```
md Test\Dir\
```

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19.3.2.3 rd

Description

Removes a directory.

Syntax

```
rmdir <DirPathOnImage> [/R]
rd    <DirPathOnImage> [/R]
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory to be deleted.
/R	Option that causes the command to delete non-empty directories.

Additional information

If the /R option is not specified, then the directory to be deleted must be empty.

Example

```
rd Test
```

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19.3.2.4 addfile

Description

Copies a file from the host PC to the image file.

Syntax

```
addfile <FilePathOnHost> [<FilePathOnImage>]
af      <FilePathOnHost> [<FilePathOnImage>]
```

Parameters

Parameter	Description
`FilePathOnHost`	Path to the source file on the host PC.
`FilePathOnImage`	Path to the destination file on the image.

Additional information

If `FilePathOnImage` is not specified, then the name of the source file is used.

Example

The following command copies the contents of the `Test.txt` file from the host PC to the `Dest.txt` file on the image.

```
addfile C:\Test.txt Dest.txt
```

The following command copies the contents of the `Test.txt` file to a file with the same name on the image.

```
addfile C:\Test.txt
```

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19.3.2.5 addfolder

Description

Copies a folder including its subfolders and files from the host PC to the image file.

Syntax

```
addfolder <DirPathOnHost> [<DirPathOnImage>] [/S]
```

Parameters

Parameter	Description
DirPathOnHost	Path to source directory on the host PC.
DirPathOnImage	Path to destination directory on the image.
/S	Option that causes the command to suppress the output of progress information.

Additional information

If DirPathOnImage is not specified, then the name of the source directory is used.

Example

The following command copies the contents of the Data directory on the PC to the Dest directory on the image.

```
addfolder C:\Data Dest
```

The following command copies the contents of the Data directory on the PC to a directory with the same name on the image.

```
addfolder C:\Data
```

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19.3.2.6 type

Description

Shows the contents of a file.

Syntax

```
type <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be shown.

Example

The following command line shows the contents of the file `Test.txt` located on the root directory of the image.

```
type Test.txt
```

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19.3.2.7 del

Description

Deletes a file.

Syntax

```
del <FilePathOnImage>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the file on the image to be deleted.

Example

The following command line deletes the file `Test.txt` located in the root directory of the image.

```
del Test.txt
```

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19.3.2.8 dir

Description

Lists the contents of the directory.

Syntax

```
ls  [<DirPathOnImage>]
dir [<DirPathOnImage>]
```

Parameters

Parameter	Description
DirPathOnImage	Path to directory on image to be listed.

Additional information

If DirPathOnImage is not specified, then the command lists the contents of the current working directory.

Example

The following command line shows the contents of the directory TestDir.

```
dir file:0:\TestDir
.                   (Dir) Attributes: ----
..                  (Dir) Attributes: ----
SubDir              (Dir) Attributes: ----
Test1.txt                 Attributes: A--- Size: 30
Test2.txt                 Attributes: A--- Size: 31
```

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19.3.2.9 ren

Description

Renames a file or directory.

Syntax

```
rename <FilePathOnImage> <NewFileName>
ren    <FilePathOnImage> <NewFileName>
```

Parameters

Parameter	Description
FilePathOnImage	Path to file or directory that has to be renamed.
NewFileName	New name of the file or directory.

Additional information

If DirPathOnImage is not specified then the command lists the contents of the current working directory.

Example

The following command line changes the name of the Test.txt file located in the Test directory to Test2.txt.

```
ren Test\Test.txt Test2.txt
```

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19.3.2.10 move

Description

Moves a file or directory to another location.

Syntax

```
move <SrcFilePathOnImage> <DestFilePathOnImage>
mv   <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to file or directory to be moved.
DestFilePathOnImage	Path to destination file or directory on the image.

Example

The following command line moves the `Test.txt` file located in the `Test` directory to the root directory. The file is renamed to `New.txt`.

```
move Test\Test.txt New.txt
```

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19.3.2.11 attr

Description

Shows/changes the file/directory attributes.

Syntax

```
attr <PathOnImage> [<Operation> <Attributes>]
```

Parameters

Parameter	Description
PathOnImage	Path to file or directory.
Operation	Operation to be executed on attributes. Permitted values are: • + sets the attributes. • - clears the attributes.
Attributes	The list of attributes to be changed. The following attributes are supported: • a - archive. • h - hidden. • r - read-only. • s - system.

Example

The following example clears the archive and read-only attributes of the Test.txt file.

```
attr Test.txt -ar
```

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19.3.2.12 copy

Description

Copies a file to another location.

Syntax

```
copy <SrcFilePathOnImage> <DestFilePathOnImage>
cp   <SrcFilePathOnImage> <DestFilePathOnImage>
```

Parameters

Parameter	Description
SrcFilePathOnImage	Path to the file to be copied.
DestFilePathOnImage	Path to the destination file.

Example

The following example copies the contents of the `Test.txt` to the `Test2.txt` file.

```
copy Test.txt Test2.txt
```

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19.3.2.13 exportfile

Description

Copies a file from the image file to the host PC.

Syntax

```
exportfile <FilePathOnImage> <FilePathOnHost>
ef         <FilePathOnImage> <FilePathOnHost>
```

Parameters

Parameter	Description
FilePathOnImage	Path to the source file on the image.
FilePathOnHost	Path to the destination file on the PC.

Example

The following command copies the contents of the `Test.txt` file from the image to the `Dest.txt` file on the host PC.

```
exportfile Test.txt C:\Dest.txt
```

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19.3.2.14 exportfolder

Description

Copies a directory recursively from the image to the host PC.

Syntax

```
exportfolder <DirPathOnImage> <DirPathOnHost>
```

Parameters

Parameter	Description
DirPathOnImage	Path to the source directory on the image.
DirPathOnHost	Path to the destination directory on the PC.

Example

The following command copies the contents of the entire current volume from the image to the `Exported\RootDir` directory on the host PC.

```
exportfolder \ Exported\RootDir
```

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19.3.3 Logical sector related commands

The following sections describe commands that can be used to operate on logical sectors.

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19.3.3.1 storesectors

Description

Copies logical sector data from a file on the PC host to the image file.

Syntax

```
storesectors <FilePathOnImage> [<StartSector>]
```

Parameters

Parameter	Description
`FilePathOnImage`	Path to the file on host that contains sector data.
`StartSector`	Index of the first logical sector to be written.

Additional information

This command is optional. The sector data must be stored sequentially in the file. For example, if the sector size is 2048 bytes and the data is stored starting from sector index 100, then the byte at offset 0 in the file stores the first byte of sector 100, the byte at offset 2048 in the file stores the first byte of sector 101, and so on. The size of the file has to be a multiple of the sector size. The size of the sector is the size specified as the second argument to the `createimage` command.

Example

This example reads sector data from the file `SectorData.bin` and writes it starting from sector index 100.

```
storesectors SectorData.bin 100
```

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19.3.3.2 dumpsector

Description

Shows the contents of a logical sector.

Syntax

```
dumpsector <SectorIndex>
ds         <SectorIndex>
```

Parameters

Parameter	Description
SectorIndex	Index of the logical sector to be displayed.

Example

The following command shows the contents of the logical sector 0.

```
dumpsector 0
00000000 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000010 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000020 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000030 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 34 33 ..43214321432143
00000040 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000050 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000060 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 21..432143214321
00000070 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000080 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000090 34 33 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 4321..4321432143
000000A0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000000B0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000000C0 32 31 34 33 32 31 0D 0A 34 33 32 31 34 33 32 31 214321..43214321
000000D0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000000E0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000000F0 34 33 32 31 34 33 32 31 0D 0A 34 33 32 31 34 33 43214321..432143
00000100 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000110 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000120 32 31 34 33 32 31 34 33 32 31 0D 0A 34 33 32 31 2143214321..4321
00000130 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000140 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
00000150 34 33 32 31 34 33 32 31 34 33 32 31 0D 0A 34 33 432143214321..43
00000160 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000170 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
00000180 32 31 34 33 32 31 34 33 32 31 34 33 32 31 0D 0A 21432143214321..
00000190 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001A0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001B0 34 33 32 31 34 33 32 31 34 33 32 31 34 33 32 31 4321432143214321
000001C0 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 34 33 ..43214321432143
000001D0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000001E0 32 31 34 33 32 31 34 33 32 31 34 33 32 31 34 33 2143214321432143
000001F0 32 31 0D 0A 34 33 32 31 34 33 32 31 34 33 32 31 21..432143214321
```

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19.3.3.3 copysectors

Description

Copies logical sector data to another location.

Syntax

```
copysectors <SrcSector> <DestSector> <NumSectors>
cs          <SrcSector> <DestSector> <NumSectors>
```

Parameters

Parameter	Description
SrcSector	Index of the first source sector.
DestSector	Index of the first destination sector.
NumSectors	Number of sectors to copy.

Additional information

This command operates only on the `file:0:` volume. The command reports an error if the source and destination sector ranges overlap.

Example

This example copies 10000 logical sectors from sector index 0 to sector index 20000.

```
copysectors 0 20000 10000
```

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19.3.4 Volume-related commands

The following sections describe commands that operate on the file system volumes located on the image file.

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19.3.4.1 format

Description

Performs a format of a volume.

Syntax

```
format [<VolumeName>] [<SectorsPerCluster>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.
SectorsPerCluster	Number of logical sectors in a cluster.

Additional information

If VolumeName is not specified then the command formats the current volume. The current volume can be selected via the cd command.

Every volume has to be formatted once when the image file is newly created.

If SectorsPerCluster is not specified then the file system chooses an appropriate value that is based on the capacity of the storage device. SectorsPerCluster has to be a power-of-two value within the following limits: 1--128 for FAT and 1--32768 for EFS.

Example

This example demonstrates how to format the volume file:0:.

```
format
Formatting "file:0:" as FAT...OK
```

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19.3.4.2 formatexfat

Description

Performs a format of a volume as exFAT.

Syntax

```
formatexfat [<VolumeName>] [<SectorsPerCluster>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that has to be formatted.
SectorsPerCluster	Number of logical sectors in a cluster.

Additional information

This command is supported only by the Storage Image Creator for FAT utility.

If VolumeName is not specified then the command formats the current volume. The current volume can be selected via the cd command.

Every volume has to be formatted once when the image file is newly created.

If SectorsPerCluster is not specified then the file system chooses an appropriate value that is based on the capacity of the storage device. SectorsPerCluster has to be a power-of-two value within the following limits: 0--65536.

Example

This example demonstrates how to format the volume file:0:.

```
formatexfat
Formatting "file:0:" as exFAT...OK
```

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19.3.4.3 df

Description

Shows the available free space on a volume.

Syntax

```
diskfree [<VolumeName>]
df       [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command calculates the free space of the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get the free space on the first volume.

```
df
Available free space is 127647744 bytes
```

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19.3.4.4 diskinfo

Description

Shows information about a storage device.

Syntax

```
diskinfo [<VolumeName>]
di       [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command returns information about the current volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the volume file:1:.

```
diskinfo file:1:
    127647744 bytes total disk space
     17719296 bytes available free space
         8192 bytes per cluster
        15582 cluster available on volume
         2163 free cluster available on volume
```

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19.3.4.5 getdevinfo

Description

Shows information about a volume.

Syntax

```
getdevinfo [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be queried.

Additional information

If VolumeName is not specified then the command returns information about the first volume. The current volume can be selected via the cd command.

Example

This example demonstrates how to get information about the storage device used by the first volume.

```
getdevinfo
        62370 available sectors
         2048 bytes per sector
```

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19.3.4.6 checkdisk

Description

Checks a volume for errors.

Syntax

```
checkdisk [<VolumeName>]
chkdsk    [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be checked.

Additional information

If VolumeName is not specified then the command checks the current volume for errors. The current volume can be selected via the cd command.

Example

This example demonstrates how to check the file system structure of the first volume.

```
checkdisk
```

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19.3.4.7 creatembr

Description

Writes the partition table to the master boot record (MBR).

Syntax

```
creatembr [<VolumeName>]
cm        [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be written.

Additional information

If VolumeName is not specified then the command writes the MBR to the current volume. The current volume can be selected via the cd command.

This command writes the partition table configured via the addpartition command to the MBR of the specified volume. The command has to be executed before any format operation. Typically, the partition table is located on the file:0: volume.

Example

This example writes the MBR to sector 0 of the file:0: volume.

```
creatembr file:0:
```

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19.3.4.8 listvolumes

Description

Shows the names of all available volumes.

Syntax

```
listvolumes
lv
```

Example

Shows the names of the volumes in a configuration using five volumes.

```
listvolumes
Available volumes:
  file:0:
  diskpart:0:
  diskpart:1:
  diskpart:2:
  diskpart:3:
```

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19.3.4.9 createjournal

Description

Creates the journal file on a volume.

Syntax

```
createjournal [<VolumeName>][<PathToFile>]<FileName>
               <JournalSize> [<SupportFreeSector>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume that stores the journal file.
PathToFile	Path to the journal file.
FileName	Name of the journal file.
JournalSize	Size of the journal file.
SupportFreeSector	Size of the journal file.

Additional information

If VolumeName is not specified then the command creates the journal on the current volume. The current volume can be selected via the cd command. If PathToFile is not specified then the journal file is created on the root directory of the specified volume. JournalSize has to be specified in bytes. The value of SupportFreeSector is passed as the third argument to FS_JOURNAL_CreateEx(). If not specified, SupportFreeSector is set to 0.

The parameters passed to the createjournal command have to match the parameters passed to FS_JOURNAL_CreateEx() on the target application.

Example

This example demonstrates how to create a journal file of 128 Kbytes on the current volume.

```
createjournal Journal.dat 131072 1
Create journal file 'Journal.dat'...OK
```

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19.3.4.10 freesectors

Description

Updates the usage information of logical sectors.

Syntax

```
freesectors [<VolumeName>]
fs          [<VolumeName>]
```

Parameters

Parameter	Description
VolumeName	Name of the volume to be processed.

Additional information

This is an optional command that can be used for updating the information about the usage of all logical sectors of a volume. This is done by analyzing the file system structure and by informing the device driver about the logical sectors that do not store any valid data. The sector usage information helps the Storage Image Creator utility to reduce the size of an exported image to a minimum.

Typically, the `freesectors` command has to be performed on a file system image that was not created using the Storage Image Creator utility, for example, by copying the data directly from a physical storage device.

If the file system image contains more than one partition, then the `freesectors` command has to be executed on each partition.

If `VolumeName` is not specified, then the command processes the current volume. The current volume can be selected via the `cd` command.

Example

This example demonstrates how to update the sector usage information of the current volume.

```
freesectors
Freeing sectors of 'file:0:'...OK
```

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Chapter 20

Porting emFile 2.x to 3.x

This chapter describes the differences between the versions 2.x and 3.x of emFile and the changes required to port an existing application.

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20.1 Differences between version 2.x and 3.x

Most of the differences between emFile version 2.x and version 3.x are internal. The API of emFile version 2.x is a subset of the API of version 3.x. Only a few functions were completely removed. Refer to section *API differences* on page 1697 for a complete overview of the removed and obsolete functions.

emFile version 3.x has new driver handling. You can include device drivers and allocate the required memory for it without the need to recompile the entire file system. Refer to *Configuration of emFile* on page 1371 for detailed information about the integration of a driver into emFile. For detailed information about the emFile device drivers, refer to the chapter *Device drivers* on page 479.

Because of these differences, we recommend starting with a new file system project and including your application code, if the start project runs without any problem. Refer to the chapter *Running emFile on target hardware* on page 56 for detailed information about the best way to start working with emFile version 3.x. The following sections give an overview of the changes introduced in version 3.x of emFile.

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20.2 API differences

Function	Description
Changed functions	
`FS_GetFreeSpace()`	Number of parameters reduced. Parameter `DevIndex` removed.
`FS_GetTotalSpace()`	Number of parameters reduced. Parameter `DevIndex` removed.
Removed functions	
`FS_CloseDir()`	No direct replacement. See the note below the table.
`FS_DirEnt2Attr()`	No direct replacement. See the note below the table.
`FS_DirEnt2Name()`	No direct replacement. See the note below the table.
`FS_DirEnt2Size()`	No direct replacement. See the note below the table.
`FS_DirEnt2Time()`	No direct replacement. See the note below the table.
`FS_GetNumFiles()`	No direct replacement. See the note below the table.
`FS_OpenDir()`	No direct replacement. See the note below the table.
`FS_ReadDir()`	No direct replacement. See the note below the table.
`FS_RewindDir()`	No direct replacement. See the note below the table.
Obsolete file system extended functions	
`FS_IoCtl()`	This function should not be used in emFile version 3.x. Alternatively, `FS_IsLLFormatted()` has to be used instead to check if a low-level format is required and `FS_GetDeviceInfo()` to get information about the storage device.

Note

The handling of the directories was changed in version 3.x of emFile. Refer to `FS_FindClose()` for an example of the new way of directory handling.

In emFile version 3.x, the header file `FS_Api.h` is renamed to FS.h. Therefore, change the name of the file system header file in your application.

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20.3 Configuration differences

The configuration of emFile version 3.x has been simplified compared to emFile version 2.x. emFile version 3.x can be used "out of the box". You can use it without the need for changing any of the compile-time flags. All compile-time configuration flags are preconfigured with valid values, which match the requirements of most applications. A lot of the compile-time flags of emFile version 2.x were removed and replaced with runtime configuration functions.

Removed/replaced configuration macros

Macros removed in version 3.x	Macros used in version 3.x
File system configuration	
FS_MAXOPEN	--
FS_POSIX_DIR_SUPPORT	--
FS_DIR_MAXOPEN	FS_NUM_DIR_HANDLES
FS_DIRNAME_MAX	--
FS_SUPPORT_BURST	--
FS_DRIVER_ALIGNMENT	--
FAT configuration macros	
FS_FAT_SUPPORT_LFN	Replaced by FS_FAT_SupportLFN(). Refer to FS_FAT_SupportLFN() for more information.

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Chapter 21

Porting emFile 3.x to 4.x

This chapter describes the differences between the versions 3.x and 4.x of emFile and the changes required to port an application to the new version.

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21.1 Differences between version 3.x and 4.x

Most of the differences between emFile version 3.x and version 4.x are internal. The API of emFile version 3.x is a subset of the version 4.x API. There are two differences that require the porting of an application using emFile:

- The API of the hardware layer has been improved.
- The SD/MMC device driver for Atmel MCUs has been removed.

emFile version 4.x has a new hardware layer API. The names of the functions are no longer hard-coded in the source. Instead, the drivers call the functions indirectly via a function table. The hardware layer is specified as an instance of a structure that contains pointers to functions. This gives the application greater flexibility, allowing it to configure different hardware layers at runtime depending on the target hardware it runs on. The emFile configurations that do not require a hardware layer are not affected by this change.

The SD/MMC device driver for Atmel MCUs (`FS_MMC_CM_Driver4Atmel`) has been removed from the version 4.x of emFile. The reason for this change is to eliminate duplicated functionality. The SD/MMC card mode device driver (`FS_MMC_CM_Driver`) supports all the functionality of the SD/MMC device driver for Atmel MCUs and can be used as a replacement.

The following sections give detailed information about the changes introduced in the version 4.x of emFile that require changes in the application.

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21.2 Hardware layer API differences

The function prototypes of the new hardware layer API of version 4.x are identical to the hardware layer functions used in the version 3.x of emFile. No functions have been added to or removed from the new hardware layer API and no changes are required to the implementation of the existing hardware layer functions. Typically, the following changes are required for porting an application to version 4.x:

- A function table containing pointers to the hardware layer functions has to be declared as a global variable in the file that implements the old hardware layer. The type of the function table depends on the hardware layer used.
- A header file has to be created that declares the function table as external.
- The header file has to be included in the file that defines the `FS_X_AddDevices()` function.
- A call to one of the functions that configure the type of the hardware layer has to be added to `FS_X_AddDevices()`. These functions take as second argument a pointer to the function table.

Alternatively, the steps 1 to 3 can be skipped, and a default hardware layer can be used instead. The function tables of these hardware layers contain pointers to functions used in the version 3.x of emFile. More information can be found in the following sections that describe the differences for each hardware layer type.

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21.2.1 NAND device driver differences

Sample hardware layers using the new API and the corresponding file system configuration files can be found in the Sample/FS/Driver/NAND folder of the emFile shipment and are located in the following files:

Hardware layer for parallel NAND flash via memory controller

- FS_NAND_HW_Template.h
- FS_NAND_HW_Template.c
- FS_ConfigNAND_Template.c

Hardware layer for parallel NAND flash via I/O port

- FS_NAND_HW_TemplatePort.h
- FS_NAND_HW_TemplatePort.c
- FS_ConfigNAND_TemplatePort.c

Hardware layer for DataFlash via SPI

- FS_NAND_HW_DF_Template.h
- FS_NAND_HW_DF_Template.c
- FS_ConfigNAND_DF_Template.c

Hardware layer for serial NAND flash via SPI

- FS_NAND_HW_SPI_Template.h
- FS_NAND_HW_SPI_Template.c
- FS_ConfigNAND_UNI_SPI_Template.c

21.2.1.1 Porting without hardware layer modification

The porting of the application to the new hardware layer API can be done without modifying the existing hardware layer. emFile comes with default hardware layers that contain pointers to the hardware layer functions used in the version 3.x of emFile. A call to the function that configures the hardware layer type has to be added to the file system configuration and the file that defines the default hardware layer has to be added to the project. The following table shows in which file each default hardware layer is defined. All the files are located in the Sample/FS/Driver/NAND folder of the emFile shipment.

Default hardware layer	File name
FS_NAND_HW_Default	FS_NAND_HW_Default.c
FS_NAND_HW_DF_Default	FS_NAND_HW_DF_Default.c
FS_NAND_HW_SPI_Default	FS_NAND_HW_SPI_Default.c

The table below lists the default hardware layer required by each physical layer:

Physical layer	Default hardware layer
FS_NAND_PHY_x	FS_NAND_HW_Default
FS_NAND_PHY_x8	FS_NAND_HW_Default
FS_NAND_PHY_512x8	FS_NAND_HW_Default
FS_NAND_PHY_2048x8	FS_NAND_HW_Default
FS_NAND_PHY_2048x16	FS_NAND_HW_Default
FS_NAND_PHY_4096x8	FS_NAND_HW_Default
FS_NAND_PHY_ONFI	FS_NAND_HW_Default
FS_NAND_PHY_DataFlash	FS_NAND_HW_DF_Default
FS_NAND_PHY_SPI	FS_NAND_HW_SPI_Default

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For more information about the functions of the physical layers, refer to *NAND physical layer* on page 682.

Example

The following example shows how to port an existing configuration using the SLC1 NAND device driver. Two changes are required:

- The function call marked with the comment "Add this line" in the code snippet below has to be added to the existing emFile configuration.
- The file `Sample/FS/Driver/NAND/FS_NAND_HW_Default.c` that defines the `FS_NAND_HW_Default` hardware layer has to be added to the project.

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // The next line is optional.
  //
  // FS_SetMaxSectorSize(2048);
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_NAND_Driver);
  FS_NAND_SetPhyType(0, &FS_NAND_PHY_2048x8);
  FS_NAND_2048x8_SetHWType(0, &FS_NAND_HW_Default);   // Add this line.
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
}
```

21.2.1.2 Replacement functions

The following table lists the replacement functions of the hardware layer for parallel NAND flash.

Old function	Member of FS_NAND_HW_TYPE structure
FS_NAND_HW_X_Init_x8()	(*pfInit_x8)()
FS_NAND_HW_X_Init_x16()	(*pfInit_x16)()
FS_NAND_HW_X_DisableCE()	(*pfDisableCE)()
FS_NAND_HW_X_EnableCE()	(*pfEnableCE)()
FS_NAND_HW_X_SetAddrMode()	(*pfSetAddrMode)()
FS_NAND_HW_X_SetCmdMode()	(*pfSetCmdMode)()
FS_NAND_HW_X_SetDataMode()	(*pfSetDataMode)()
FS_NAND_HW_X_WaitWhileBusy()	(*pfWaitWhileBusy)()
FS_NAND_HW_X_Read_x8()	(*pfRead_x8)()
FS_NAND_HW_X_Write_x8()	(*pfWrite_x8)()
FS_NAND_HW_X_Read_x16()	(*pfRead_x16)()
FS_NAND_HW_X_Write_x16()	(*pfWrite_x16)()

The following table lists the replacement functions of the hardware layer for DataFlash.

Old function	Member of FS_NAND_HW_TYPE_DF structure
FS_DF_HW_X_Init()	(*pfInit)()
FS_DF_HW_X_EnableCS()	(*pfEnableCS)()
FS_DF_HW_X_DisableCS()	(*pfDisableCS)()

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Old function	Member of FS_NAND_HW_TYPE_DF structure
FS_DF_HW_X_Read()	(*pfRead)()
FS_DF_HW_X_Write()	(*pfWrite)()

The following table lists the replacement functions of the hardware layer for serial NAND flash.

Old function	Member of FS_NAND_HW_TYPE_SPI structure
FS_NAND_HW_SPI_X_Init()	(*pfInit)()
FS_NAND_HW_SPI_X_DisableCS()	(*pfDisableCS)()
FS_NAND_HW_SPI_X_EnableCS()	(*pfEnableCS)()
FS_NAND_HW_SPI_X_Delay()	(*pfDelay)()
FS_NAND_HW_SPI_X_Read()	(*pfRead)()
FS_NAND_HW_SPI_X_Write()	(*pfWrite)()

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21.2.2 NOR device driver differences

Sample hardware layers using the new API and the corresponding file system configurations can be found in the Sample/FS/Driver/NOR folder of the emFile shipment and are located in the following files:

Hardware layer for serial NOR flash

- FS_NOR_HW_SPI_Template.h
- FS_NOR_HW_SPI_Template.c
- FS_ConfigNOR_SPI_Template.c

Hardware layer for QSPI NOR flash

- FS_NOR_HW_SPIFI_Template.h
- FS_NOR_HW_SPIFI_Template.c
- FS_ConfigNOR_BM_SPIFI_Template.c

21.2.2.1 Porting without hardware layer modification

The porting of the application to the new hardware layer API can be done without modifying the existing hardware layer. emFile comes with default hardware layers that contain pointers to the hardware layer functions used in the version 3.x of emFile. A call to the function that sets the hardware layer type has to be added to the file system configuration and the file that defines the default hardware layer has to be added to the project. The table below shows in which file each default hardware layer is defined. The files are located in the Sample/FS/Driver/NOR folder of the emFile shipment:

Default hardware layer	File name
FS_NOR_HW_ST_M25_Default	FS_NOR_HW_ST_M25_Default.c
FS_NOR_HW_SFDP_Default	FS_NOR_HW_SFDP_Default.c

The table below lists the default hardware layer required by each physical layer:

Physical layer	Default hardware layer
FS_NOR_PHY_ST_M25	FS_NOR_HW_ST_M25_Default
FS_NOR_PHY_SFDP	FS_NOR_HW_SFDP_Default

For more information about the functions of the physical layers refer to *NOR physical layer* on page 951.

Example

This example shows how to port an existing configuration for a serial NOR flash. The function call marked with the comment "Add this line" has to be added to the existing configuration. No other changes of file system configuration are required. Additionally, the file Sample/FS/Driver/NOR/FS_NOR_HW_ST_M25_Default.c that defines the FS_NOR_HW_ST_M25_Default hardware layer has to be added to the project.

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_NOR_Driver);
  FS_NOR_SetPhyType(0, &FS_NOR_PHY_ST_M25);
  FS_NOR_SPI_SetHWType(0, &FS_NOR_HW_ST_M25_Default);  // Add this line.
  FS_NOR_Configure(0, FLASH0_BASE_ADDR, FLASH0_START_ADDR, FLASH0_SIZE);
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
```

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```
}
```

21.2.2.2 Replacement functions

The following table lists the replacement functions of the SPI hardware layer.

Old function	Member of the FS_NOR_HW_TYPE_SPI structure
FS_NOR_SPI_HW_X_Init()	(*pfInit)()
FS_NOR_SPI_HW_X_EnableCS()	(*pfEnableCS)()
FS_NOR_SPI_HW_X_DisableCS()	(*pfDisableCS)()
FS_NOR_SPI_HW_X_Read()	(*pfRead)()
FS_NOR_SPI_HW_X_Write()	(*pfWrite)()
FS_NOR_SPI_HW_X_Read_x2()	(*pfRead_x2)()
FS_NOR_SPI_HW_X_Write_x2()	(*pfWrite_x2)()
FS_NOR_SPI_HW_X_Read_x4()	(*pfRead_x4)()
FS_NOR_SPI_HW_X_Write_x4()	(*pfWrite_x4)()

Note

The ..._x2 and ..._x4 functions have to be defined only when the FS_NOR_PHY_SFDP physical layer is configured and the hardware supports dual and quad SPI data transfer modes.

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21.2.3 MMC/SD SPI device driver differences

Sample hardware layers using the new API and the corresponding file system configurations can be found in the Sample/FS/Driver/MMC_SPI folder of the emFile shipment and are located in the following files:

Hardware layer for SD card via SPI

- FS_MMC_HW_SPI_Template.h
- FS_MMC_HW_SPI_Template.c
- FS_ConfigMMC_SPI_Template.c

Hardware layer for SD card via I/O port

- FS_MMC_HW_SPI_TemplatePort.h
- FS_MMC_HW_SPI_TemplatePort.c
- FS_ConfigMMC_SPI_TemplatePort.c

21.2.3.1 Porting without hardware layer modification

It is possible to port an existing application to the new hardware layer API without modifying the existing hardware layer. emFile comes with a default hardware layer that contains pointers to the hardware layer functions used in the version 3.x of emFile. A call to the function FS_MMC_SetHWType() has to be added to file system configuration and the file that defines the default hardware layer (FS_MMC_HW_SPI_Default.c) has to be added to the project. The file is located in the Sample/FS/Driver/MMC_SPI folder of the emFile shipment.

Example

This example shows how to modify an existing emFile configuration to work with the new hardware layer API. The function call marked with the comment "Add this line." has to be added to the existing configuration. No other changes to file system configuration are required. In addition, the file Sample/FS/Driver/MMC_SPI/FS_MMC_HW_SPI_Default.c that defines the FS_MMC_HW_SPI_Default hardware layer has to be added to the project.

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_MMC_SPI_Driver);
  FS_MMC_SetHWType(0, &FS_MMC_HW_SPI_Default);    // Add this line.
//  FS_MMC_ActivateCRC();    // Uncommenting this line will activate
                             // the CRC calculation of the MMC/SD SPI driver.
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
}
```

21.2.3.2 Replacement functions

The following table lists the replacement functions of the SPI hardware layer.

Old function	Member of FS_MMC_HW_TYPE_SPI structure
FS_MMC_HW_X_EnableCS()	(*pfEnableCS)()
FS_MMC_HW_X_DisableCS()	(*pfDisableCS)()
FS_MMC_HW_X_IsPresent()	(*pfIsPresent)()
FS_MMC_HW_X_IsWriteProtected()	(*pfIsWriteProtected)()
FS_MMC_HW_X_SetMaxSpeed()	(*pfSetMaxSpeed)()

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Old function	Member of FS_MMC_HW_TYPE_SPI structure
FS_MMC_HW_X_SetVoltage()	(*pfSetVoltage)()
FS_MMC_HW_X_Read()	(*pfRead)()
FS_MMC_HW_X_Write()	(*pfWrite)()
FS_MMC_HW_X_Read()	(*pfReadEx)()
FS_MMC_HW_X_Write()	(*pfWriteEx)()
FS_MMC_HW_X_Lock()	(*pfLock)()
FS_MMC_HW_X_Unlock()	(*pfUnlock)()

Note

The locking functions have to be implemented only when the MMC / SD SPI device driver is compiled with the FS_MMC_SUPPORT_LOCKING define set to 1.

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21.2.4 MMC/SD card mode device driver differences

Sample hardware layers using the new API and the corresponding file system configurations are available in the Sample/FS/Driver/MMC_CM folder of the emFile shipment and are located in the following files:

- FS_MMC_HW_CM_Template.h
- FS_MMC_HW_CM_Template.c
- FS_ConfigMMC_CardModeTemplate.c

21.2.4.1 Porting without hardware layer modification

It is possible to port the application to the new hardware layer API without modifying the existing hardware layer. emFile comes with a default hardware layer that contains pointers to the hardware layer functions used in the version 3.x of emFile. A call to the function FS_MMC_CM_SetHWType() has to be added to file system configuration and the file that defines the default hardware layer (FS_MMC_HW_CM_Default.c) has to be added to the project. The file is located in the Sample/FS/Driver/MMC_CM folder of the emFile shipment.

Example

This example shows the modifications that have to be done to an existing application. The function call marked with the comment "Add this line." has to be added to the existing configuration. No other changes of file system configuration are required. Additionally, the file Sample/FS/Driver/MMC_CM/FS_MMC_HW_CM_Default.c that defines the FS_MMC_HW_CM_Default hardware layer has to be added to the project.

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  //
  // Add and configure the driver.
  //
  FS_AddDevice(&FS_MMC_CM_Driver);
  FS_MMC_CM_Allow4bitMode(0, 1);
  FS_MMC_CM_SetHWType(0, &FS_MMC_HW_CM_Default);      // Add this line.
  //
  // Configure the file system for fast write operations.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
  FS_SetFileWriteMode(FS_WRITEMODE_FAST);
}
```

21.2.4.2 Replacement functions

The following table lists the replacement functions of the SD / MMC card mode hardware layer.

Old function	Member of FS_MMC_HW_TYPE_CM structure
FS_MMC_HW_X_InitHW()	(*pfInitHW)()
FS_MMC_HW_X_Delay()	(*pfDelay)()
FS_MMC_HW_X_IsPresent()	(*pfIsWriteProtected)()
FS_MMC_HW_X_IsWriteProtected()	(*pfIsPresent)()
FS_MMC_HW_X_SetMaxSpeed()	(*pfSetMaxSpeed)()
FS_MMC_HW_X_SetResponseTime-Out()	(*pfSetResponseTimeOut)()
FS_MMC_HW_X_SetReadDataTime-Out()	(*pfSetReadDataTimeOut)()
FS_MMC_HW_X_SendCmd()	(*pfSendCmd)()
FS_MMC_HW_X_GetResponse()	(*pfGetResponse)()

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Old function	Member of FS_MMC_HW_TYPE_CM structure
FS_MMC_HW_X_ReadData()	(*pfReadData)()
FS_MMC_HW_X_WriteData()	(*pfWriteData)()
FS_MMC_HW_X_SetDataPointer()	(*pfSetDataPointer)()
FS_MMC_HW_X_SetHWBlockLen()	(*pfSetHWBlockLen)()
FS_MMC_HW_X_SetHWNumBlocks()	(*pfSetHWNumBlocks)()
FS_MMC_HW_X_GetMaxReadBurst()	(*pfGetMaxReadBurst)()
FS_MMC_HW_X_GetMaxWriteBurst()	(*pfGetMaxWriteBurst)()

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21.2.5 CompactFlash / IDE device driver differences

Sample hardware layers using the new API and the corresponding file system configurations can be found in the Sample/FS/Driver/IDE folder of the emFile shipment in the following files:

Hardware layer for memory map mode

- FS_IDE_HW_TemplateMemMapped16bit.h
- FS_IDE_HW_TemplateMemMapped16Bit.c
- FS_ConfigIDE_TemplateMemMapped16Bit.c

Hardware layer for true IDE mode

- FS_IDE_HW_TemplateTrueIDE.h
- FS_IDE_HW_TemplateTrueIDE.c
- FS_ConfigIDE_TemplateTrueIDE.c

21.2.5.1 Porting without hardware layer modification

It is possible to port the application to the new hardware layer API without modifying the existing hardware layer. emFile comes with a default hardware layer that contains pointers to the hardware layer functions used in the version 3.x of emFile. A call to the function FS_IDE_SetHWType() has to be added to file system configuration and the file that defines the default hardware layer (FS_IDE_HW_Default.c) has to be added to the project. The file is located in the Sample/FS/Driver/IDE folder of the emFile shipment.

Example

This example shows the modifications that have to be done to an existing application. The function call marked with the comment "Add this line." has to be added to the existing configuration. No other changes of file system configuration are required. In addition, the file Sample/FS/Driver/IDE/FS_IDE_HW_Default.c which defines the FS_IDE_HW_Default hardware layer has to be added to the project.

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  FS_AddDevice(&FS_IDE_Driver);
  FS_IDE_SetHWType(0, &FS_IDE_HW_Default);    // Add this line.
  //
  // Enable the file buffer to increase the performance
  // when reading/writing a small number of bytes.
  //
  FS_ConfigFileBufferDefault(512, FS_FILE_BUFFER_WRITE);
}
```

21.2.5.2 Replacement functions

The following table lists the replacement functions of the hardware layer.

Old function	Member of FS_IDE_HW_TYPE structure
FS_IDE_HW_Reset()	(*pfReset)()
FS_IDE_HW_IsPresent()	(*pfIsPresent)()
FS_IDE_HW_Delay400ns()	(*pfDelay400ns)()
FS_IDE_HW_ReadReg()	(*pfReadReg)()
FS_IDE_HW_WriteReg()	(*pfWriteReg)()
FS_IDE_HW_ReadData()	(*pfReadData)()
FS_IDE_HW_WriteData()	(*pfWriteData)()

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21.2.6 MMC / SD device driver for ATMEL MCUs

The MMC / SD device driver for ATMEL microcontrollers (`FS_MMC_CM_Driver4Atmel`) is no longer available in the version 4.x of emFile. The MMC/SD card mode device driver (`FS_MMC_CM_Driver`) provides the same functionality and can be used as a replacement. Changes are required both to emFile configuration and to the hardware layer in order to port an existing application to the version 4.x of emFile.

21.2.6.1 Configuration changes

The MMC / SD device driver for ATMEL MCUs has to be replaced in the `FS_X_AddDevices()` function by the MMC/SD card mode device driver. In addition, the hardware layer has to be explicitly configured.

Example

This example shows what changes have to be done to emFile configuration. The function calls that are marked with the comment "Remove this line." have to be removed from the file system configuration. The function calls that have to be added are marked with the comment "Add this line."

```
void FS_X_AddDevices(void) {
  FS_AssignMemory(&_aMemBlock[0], sizeof(_aMemBlock));
  FS_AddDevice(&FS_MMC_CM_Driver4Atmel);            // Remove this line.
  FS_AddDevice(&FS_MMC_CM_Driver);                  // Add this line.
  FS_MMC_CM_Allow4bitMode(0, 1);                    // Add this line.
  FS_MMC_CM_SetHWType(0, &FS_MMC_CM_HW_Default);    // Add this line.
}
```

21.2.6.2 Hardware layer changes

The hardware layer APIs of the MMC / SD device driver for ATMEL MCUs and those of the MMC / SD card mode device driver are different. A new hardware layer has to be implemented for the MMC/SD card mode device driver to port an existing application. For more information about the functions of the hardware layer for the MMC / SD card mode device driver, refer to *Hardware layer* on page 43. Sample implementations for ATMEL AT91SAM9x MCU can be found in the `Sample/FS/Driver/MMC_CM` folder of the emFile shipment.

The table below lists the functions of the hardware layer for the MMC / SD device driver for ATMEL MCUs together with their possible replacement functions.

Old function	Possible replacement
`FS_MCI_HW_EnableClock()`	The clock to the MCI host should be enabled in the `(*pfInitHW)()` function.
`FS_MCI_HW_EnableISR()`	The interrupt of the MCI host should be enabled in the `(*pfInitHW)()` function.
`FS_MCI_HW_GetMClk()`	The information returned by this function is not required anymore.
`FS_MCI_HW_GetMCIInfo()`	The information returned by this function is not required anymore.
`FS_MCI_HW_Init()`	`(*pfInitHW)()`
`FS_MCI_HW_IsCardPresent()`	`(*pfIsPresent)()`
`FS_MCI_HW_IsCardWriteProtected()`	`(*pfIsWriteProtected)()`
`FS_MCI_HW_GetTransferMem()`	Non-cached memory should be allocated via a dedicated BSP function.

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Chapter 22

Porting emFile 4.x to 5.x

This chapter describes the differences between the versions 4.x and 5.x of emFile and the changes required to port an existing application.

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22.1 Differences between version 4.x and 5.x

Most of the differences between emFile version 4.x and version 5.x are internal. The API of emFile version 4.x is a subset of the API of version 5.x. There are two differences that require the porting of an application using emFile:

- The prototypes of the optional API functions are conditionally compiled.
- Some header and source files were removed or renamed.

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22.2 Function prototype differences

emFile uses configuration defines to enable or disable different optional features of the file system at compile time. Typically, the optional features come with API functions that can be called by an application to make use of that optional feature. In older emFile versions these API functions performed no operation or unnecessarily allocated resources when the feature was disabled. The version 5.x changes this in that it defines the body and the prototype of these API functions only when the feature is enabled.

As a result of these changes, it is possible that errors are reported when building an application that calls an API function of an optional feature that is not enabled at compile time. The solution to this problem is to enclose the calls to these API functions with #if/#endif processor commands that make sure the function is called only when the optional feature is enabled.

For example, if the same application is expected to be compiled to make use of the memory allocator provided by emFile as well as of the memory allocation functions of the C library, then the emFile configuration functions have to be called as in the following example:

```
#include <FS.h>
#include <stdlib.h>

#define ALLOC_SIZE        0x4000        // Size defined in bytes

#if (FS_SUPPORT_EXT_MEM_MANAGER == 0)
  static U32 _aMemBlock[ALLOC_SIZE / 4];  // Memory pool used for
                                          // semi-dynamic allocation.
#endif

/*********************************************************************
*
*       FS_X_AddDevices
*
*  Function description
*    This function is called by the FS during FS_Init().
*/
void FS_X_AddDevices(void) {
  //
  // Give the file system memory to work with.
  //
#if (FS_SUPPORT_EXT_MEM_MANAGER == 0)
  FS_AssignMemory(_aMemBlock, sizeof(_aMemBlock));
#else
  FS_SetMemHandler((FS_MEM_ALLOC_CALLBACK *)malloc, free);
#endif // FS_SUPPORT_EXT_MEM_MANAGER == 0

  //
  // Additional file system configuration...
  //
}
```

The following table lists all the prototypes of all optional API functions together with the name and the value of the configuration define that enables the optional feature. Note that the table contains all the function prototypes that are conditionally compiled, including the function prototypes that were conditionally compiled in older emFile versions.

Function	Condition
FS_ConfigEOFErrorSuppression()	FS_SUPPRESS_EOF_ERROR ≠ 0
FS_SetVolumeAlias()	FS_MAX_LEN_VOLUME_ALIAS > 0
FS_DeInit()	FS_SUPPORT_DEINIT ≠ 0
FS_AddOnExitHandler()	FS_SUPPORT_DEINIT ≠ 0
FS_AssignMemory()	FS_SUPPORT_EXT_MEM_MANAGER = 0
FS_SetMemHandler()	FS_SUPPORT_EXT_MEM_MANAGER ≠ 0
FS_ConfigPOSIXSupport()	FS_SUPPORT_POSIX ≠ 0

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Function	Condition
FS_ConfigWriteVerification()	FS_VERIFY_WRITE ≠ 0
FS_JOURNAL_Begin()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_Create()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_CreateEx()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_Disable()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_Enable()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_End()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_GetInfo()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_GetOpenCnt()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_GetStatCounters()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_Invalidate()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_IsEnabled()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_IsPresent()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_ResetStatCounters()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_SetFileName()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_SetOnOverflowExCallback()	FS_SUPPORT_JOURNAL ≠ 0
FS_JOURNAL_SetOnOverflowCallback()	FS_SUPPORT_JOURNAL ≠ 0
FS_FAT_FormatSD()	FS_SUPPORT_FAT ≠ 0
FS_FAT_GrowRootDir()	FS_SUPPORT_FAT ≠ 0
FS_FAT_SupportLFN()	FS_SUPPORT_FAT ≠ 0
FS_FAT_DisableLFN()	FS_SUPPORT_FAT ≠ 0
FS_FAT_SetLFNConverter()	FS_SUPPORT_FAT ≠ 0 && FS_SUPPORT_FILE_NAME_ENCODING ≠ 0
FS_FAT_ConfigFSInfoSectorUse()	FS_SUPPORT_FAT ≠ 0 && FS_FAT_USE_FSINFO_SECTOR ≠ 0
FS_FAT_ConfigFATCopyMaintenance()	FS_SUPPORT_FAT ≠ 0 && FS_MAINTAIN_FAT_COPY ≠ 0
FS_FAT_ConfigROFileMovePermission()	FS_SUPPORT_FAT ≠ 0 && FS_FAT_PERMIT_RO_FILE_MOVE ≠ 0
FS_FAT_ConfigDirtyFlagUpdate()	FS_SUPPORT_FAT ≠ 0 && FS_FAT_UPDATE_DIRTY_FLAG ≠ 0
FS_EFS_ConfigStatusSectorSupport()	FS_SUPPORT_EFS ≠ 0 && FS_EFS_SUPPORT_STATUS_SECTOR ≠ 0
FS_EFS_ConfigCaseSensitivity()	FS_SUPPORT_EFS ≠ 0 && FS_EFS_CASE_SENSITIVE ≠ 0
FS_EFS_SetFileNameConverter()	FS_SUPPORT_EFS ≠ 0 && FS_SUPPORT_FILE_NAME_ENCODING ≠ 0
FS_ConfigFileBufferDefault()	FS_SUPPORT_FILE_BUFFER ≠ 0
FS_SetFileBufferFlags()	FS_SUPPORT_FILE_BUFFER ≠ 0
FS_SetFileBufferFlagsEx()	FS_SUPPORT_FILE_BUFFER ≠ 0
FS_SetFileBuffer()	FS_SUPPORT_FILE_BUFFER ≠ 0
FS_SetBusyLEDCallback()	FS_SUPPORT_BUSY_LED ≠ 0
FS_SetMemCheckCallback()	FS_SUPPORT_CHECK_MEMORY ≠ 0
FS_STORAGE_DeInit()	FS_SUPPORT_DEINIT ≠ 0

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Function	Condition
FS_STORAGE_GetCounters()	FS_STORAGE_ENABLE_STAT_COUNTERS ≠ 0
FS_STORAGE_ResetCounters()	FS_STORAGE_ENABLE_STAT_COUNTERS ≠ 0
FS_STORAGE_SetOnDeviceActivityCallback()	FS_STORAGE_SUPPORT_DEVICE_ACTIVITY ≠ 0
FS_AssignCache()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_Clean()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_Command()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_SetMode()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_SetQuota()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_SetAssocLevel()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_GetNumSectors()	FS_SUPPORT_CACHE ≠ 0
FS_CACHE_Invalidate()	FS_SUPPORT_CACHE ≠ 0
FS_SetFSType()	FS_SUPPORT_MULTIPLE_FS ≠ 0
FS_GetFSType()	FS_SUPPORT_MULTIPLE_FS ≠ 0
FS_Free()	FS_SUPPORT_DEINIT ≠ 0
FS_Lock()	FS_OS_LOCKING = FS_OS_LOCKING_API
FS_Unlock()	FS_OS_LOCKING = FS_OS_LOCKING_API
FS_LockVolume()	FS_OS_LOCKING = FS_OS_LOCKING_DRIVER
FS_UnlockVolume()	FS_OS_LOCKING = FS_OS_LOCKING_DRIVER
FS_SYSVIEW_Init()	FS_SUPPORT_PROFILE ≠ 0
FS_AddErrorFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ERRORS
FS_SetErrorFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ERRORS
FS_GetErrorFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ERRORS
FS_AddWarnFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_WARNINGS
FS_SetWarnFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_WARNINGS
FS_GetWarnFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_WARNINGS
FS_AddLogFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ALL
FS_SetLogFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ALL
FS_GetLogFilter()	FS_DEBUG_LEVEL ≥ FS_DEBUG_LEVEL_LOG_ALL
FS_NOR_GetStatCounters()	FS_NOR_ENABLE_STATS ≠ 0
FS_NOR_ResetStatCounters()	FS_NOR_ENABLE_STATS ≠ 0
FS_NOR_SetBlankSectorSkip()	FS_NOR_SKIP_BLANK_SECTORS ≠ 0
FS_NOR_SetDeviceLineSize()	FS_NOR_SUPPORT_VARIABLE_LINE_SIZE ≠ 0
FS_NOR_SetDeviceRewriteSupport()	FS_NOR_SUPPORT_VARIABLE_LINE_SIZE ≠ 0
FS_NOR_SetDirtyCheckOptimization()	FS_NOR_OPTIMIZE_DIRTY_CHECK ≠ 0
FS_NOR_SetEraseVerification()	FS_NOR_VERIFY_ERASE ≠ 0
FS_NOR_SetWriteVerification()	FS_NOR_VERIFY_WRITE ≠ 0
FS_NOR_BM_DisableCRC()	FS_NOR_SUPPORT_CRC ≠ 0

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Function	Condition
FS_NOR_BM_EnableCRC()	FS_NOR_SUPPORT_CRC ≠ 0
FS_NOR_BM_GetStatCounters()	FS_NOR_ENABLE_STATS ≠ 0
FS_NOR_BM_IsCRCEnabled()	FS_NOR_SUPPORT_CRC ≠ 0
FS_NOR_BM_ResetStatCounters()	FS_NOR_ENABLE_STATS ≠ 0
FS_NOR_BM_SetBlankSectorSkip()	FS_NOR_SKIP_BLANK_SECTORS ≠ 0
FS_NOR_BM_SetByteOrderBE()	FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER ≠ 0
FS_NOR_BM_SetByteOrderLE()	FS_NOR_SUPPORT_VARIABLE_BYTE_ORDER ≠ 0
FS_NOR_BM_SetCRCHook()	FS_NOR_SUPPORT_CRC ≠ 0
FS_NOR_BM_SetDeviceLineSize()	FS_NOR_SUPPORT_VARIABLE_LINE_SIZE ≠ 0
FS_NOR_BM_SetDeviceRewriteSupport()	FS_NOR_SUPPORT_VARIABLE_LINE_SIZE ≠ 0
FS_NOR_BM_SetEraseVerification()	FS_NOR_VERIFY_ERASE ≠ 0
FS_NOR_BM_SetFailSafeErase()	FS_NOR_SUPPORT_FAIL_SAFE_ERASE ≠ 0
FS_NOR_BM_SetWriteVerification()	FS_NOR_VERIFY_WRITE ≠ 0
FS_NOR_SPI_AddDevice()	FS_NOR_MAX_NUM_DEVICES ≠ 0
FS_MMC_GetStatCounters()	FS_MMC_ENABLE_STATS ≠ 0
FS_MMC_ResetStatCounters()	FS_MMC_ENABLE_STATS ≠ 0
FS_MMC_CM_AllowPowerSaveMode()	FS_MMC_SUPPORT_POWER_SAVE ≠ 0
FS_MMC_CM_EnterPowerSaveMode()	FS_MMC_SUPPORT_POWER_SAVE ≠ 0
FS_MMC_CM_GetStatCounters()	FS_MMC_ENABLE_STATS ≠ 0
FS_MMC_CM_ResetStatCounters()	FS_MMC_ENABLE_STATS ≠ 0
FS_NAND_GetStatCounters()	FS_NAND_ENABLE_STATS ≠ 0
FS_NAND_ResetStatCounters()	FS_NAND_ENABLE_STATS ≠ 0
FS_NAND_SetEraseVerification()	FS_NAND_VERIFY_ERASE ≠ 0
FS_NAND_SetWriteVerification()	FS_NAND_VERIFY_WRITE ≠ 0
FS_NAND_UNI_GetStatCounters()	FS_NAND_ENABLE_STATS ≠ 0
FS_NAND_UNI_ResetStatCounters()	FS_NAND_ENABLE_STATS ≠ 0
FS_NAND_UNI_SetDriverBadBlockReclamation()	FS_NAND_RECLAIM_DRIVER_BAD_BLOCKS ≠ 0
FS_NAND_UNI_SetEraseVerification()	FS_NAND_VERIFY_ERASE ≠ 0
FS_NAND_UNI_SetNumBlocksPerGroup()	FS_NAND_SUPPORT_BLOCK_GROUPING ≠ 0
FS_NAND_UNI_SetWriteVerification()	FS_NAND_VERIFY_WRITE ≠ 0
FS_NAND_2048x8_EnableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_NAND_2048x8_DisableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_NAND_x8_Configure()	FS_NAND_SUPPORT_AUTO_DETECTION ≠ 0
FS_NAND_x_Configure()	FS_NAND_SUPPORT_AUTO_DETECTION = 0
FS_NAND_SPI_EnableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_NAND_SPI_DisableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_NAND_QSPI_EnableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_NAND_QSPI_DisableReadCache()	FS_NAND_SUPPORT_READ_CACHE ≠ 0
FS_WINDRIVE_Configure()	_WIN32
FS_WINDRIVE_ConfigureEx()	_WIN32
FS_WINDRIVE_SetGeometry()	_WIN32

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Function	Condition
FS_SetEncryptionObject()	FS_SUPPORT_ENCRYPTION ≠ 0
FS_READAHEAD_GetStatCounters()	FS_READAHEAD_ENABLE_STATS ≠ 0
FS_READAHEAD_ResetStatCounters()	FS_READAHEAD_ENABLE_STATS ≠ 0

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22.3 File naming differences

The names of some of the emFile header and source files were renamed in order to improve consistency. This change makes sure that the names of all the header and source files that ship with emFile begin with the prefix "FS_". In addition, the contents of some of the header and source files were moved to other files in order to keep the number of files to a minimum. The removal of some of the header files can possibly cause compiler errors. The errors can be corrected by including the name of the header file specified in the following table instead of the missing header file.

The next table lists the names of the header and source files that were renamed, moved or deleted in the version 5.x of emFile. The first column stores the original file name while the second column holds either the new file name or the file name that stores its contents. If the file has been deleted, the name of the file is set to "-" in the second column. The third column stores a code indicating the operation that was performed on that file:

- M - contents of the file have been moved
- R - file has been renamed
- D - file has been deleted

Old file name	New file name	Operation
CRYPT_ALGO_AES.c	FS_CRYPT_ALGO_AES.c	R
CRYPT_ALGO_DES.c	FS_CRYPT_ALGO_DES.c	R
CRYPT_Drv.c	FS_CRYPT_Drv.c	R
CRYPT_File.c	FS_CRYPT_File.c	R
EFS.h	FS_EFS.h	R
EFS_API.c	FS_EFS_API.c	R
EFS_CheckDisk.c	FS_EFS_CheckDisk.c	R
EFS_Dir.c	FS_EFS_Dir.c	R
EFS_DirEntry.c	FS_EFS_DirEntry.c	R
EFS_Format.c	FS_EFS_Format.c	R
EFS_Intern.h	FS_EFS_Int.h	R
EFS_Misc.c	FS_EFS_Misc.c	R
EFS_Move.c	FS_EFS_Move.c	R
EFS_Open.c	FS_EFS_Open.c	R
EFS_Read.c	FS_EFS_Read.c	R
EFS_Rename.c	FS_EFS_Rename.c	R
EFS_SetEndOfFile.c	FS_EFS_SetEndOfFile.c	R
EFS_Write.c	FS_EFS_Write.c	R
FAT.h	FS_FAT.h	R
FAT_API.c	FS_FAT_API.c	R
FAT_CheckDisk.c	FS_FAT_CheckDisk.c	R
FAT_Dir.c	FS_FAT_Dir.c	R
FAT_DirEntry.c	FS_FAT_DirEntry.c	R
FAT_DiskInfo.c	FS_FAT_DiskInfo.c	R
FAT_Format.c	FS_FAT_Format.c	R
FAT_FormatSD.c	FS_FAT_FormatSD.c	R
FAT_Intern.h	FS_FAT_Int.h	R
FAT_Ioct.c	-	D
FAT_LFN.c	FS_FAT_LFN.c	R

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Old file name	New file name	Operation
FAT_Misc.c	FS_FAT_Misc.c	R
FAT_Move.c	FS_FAT_Move.c	R
FAT_Open.c	FS_FAT_Open.c	R
FAT_Read.c	FS_FAT_Read.c	R
FAT_Rename.c	FS_FAT_Rename.c	R
FAT_SetEndOfFile.c	FS_FAT_SetEndOfFile.c	R
FAT_VolumeLabel.c	FS_FAT_VolumeLabel.c	R
FAT_Write.c	FS_FAT_Write.c	R
FS_AddSpaceHex.c	FS_Debug.c	M
FS_API.h	-	D
FS_AssignCache.c	FS_CACHE_Core.c	R
FS_CacheAll.c	FS_CACHE_All.c	R
FS_CacheMan.c	FS_CACHE_Man.c	R
FS_CacheMultiWay.c	FS_CACHE_MultiWay.c	R
FS_CacheRW.c	FS_CACHE_RW.c	R
FS_CacheRWQuota.c	FS_CACHE_RWQuota.c	R
FS_CLib.h	-	D
FS_Dev.h	-	D
FS_DF_X_HW.h	FS.h	M
FS_ErrorOut.c	FS_Debug.c	M
FS_FRead.c	FS_Read.c	M
FS_FWrite.c	FS_Write.c	M
FS_GetFilePos.c	-	D
FS_GetNumOpenFiles.c	FS_Misc.c	M
FS_Lbl.h	-	D
FS_Log.c	FS_Debug.c	M
FS_SetFilePos.c	-	D
FS_Warn.c	FS_Debug.c	M
FS__ECC256.c	FS_ECC256.c	R
IDE_Drv.c	FS_IDE_Drv.c	R
IDE_X_HW.h	FS.h	M
MMC_Drv.c	FS_MMC_Drv.c	R
MMC_SD_CardMode_Drv.c	FS_MMC_CM_Drv.c	R
MMC_SD_CardMode_X_HW.h	FS.h	M
MMC_X_HW.h	FS.h	M
NAND_Drv.c	FS_NAND_Drv.c	R
NAND_ECC_HW.c	FS_NAND_ECC_HW.c	R
NAND_ECC_SW_1Bit.c	FS_NAND_ECC_SW_1Bit.c	R
NAND_HW_SPI_X.h	FS.h	M
NAND_Misc.c	FS_NAND_Misc.c	R
NAND_PHY_2048x16.c	FS_NAND_PHY_2048x16.c	R
NAND_PHY_2048x8.c	FS_NAND_PHY_2048x8.c	R

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Old file name	New file name	Operation
NAND_PHY_4096x8.c	FS_NAND_PHY_4096x8.c	R
NAND_PHY_512x8.c	FS_NAND_PHY_512x8.c	R
NAND_PHY_DataFlash.c	FS_NAND_PHY_DataFlash.c	R
NAND_PHY_ONFI.c	FS_NAND_PHY_ONFI.c	R
NAND_PHY_SPI.c	FS_NAND_PHY_SPI.c	R
NAND_PHY_x8.c	FS_NAND_PHY_x8.c	R
NAND_Private.h	FS_NAND_Int.h	R
NAND_UNI_Drv.c	FS_NAND_UNI_Drv.c	R
NAND_X_HW.h	FS.h	M
NOR_BM_Drv.c	FS_NOR_BM_Drv.c	R
NOR_Drv.c	FS_NOR_Drv.c	R
NOR_HW_CFI_1x16.c	FS_NOR_HW_CFI_1x16.c	R
NOR_HW_CFI_2x16.c	FS_NOR_HW_CFI_2x16.c	R
NOR_HW_SPI_X.h	FS.h	M
NOR_PHY_CFI.c	FS_NOR_PHY_CFI.c	R
NOR_PHY_DSPI.c	FS_NOR_PHY_DSPI.c	R
NOR_PHY_SFDP.c	FS_NOR_PHY_SFDP.c	R
NOR_PHY_SPIFI.c	FS_NOR_PHY_SPIFI.c	R
NOR_PHY_ST_M25.c	FS_NOR_PHY_ST_M25.c	R
NOR_Private.h	FS_NOR_Int.h	R
NOR_SPI_Dev.c	FS_NOR_SPI_Dev.c	R
NOR_SPI_Dev.h	FS.h	M
RAMDISK.c	FS_RAMDisk.c	R
WinDrive.c	FS_WinDrive.c	R
FS_X_embOS.c	FS_OS_embOS.c	R
FS_X_FreeRTOS.c	FS_OS_FreeRTOS.c	R
FS_X_None.c	FS_OS_None.c	R
FS_X_ucOS_II.c	FS_OS_ucOS_II.c	R
FS_X_Win32.c	FS_OS_Win32.c	R

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Chapter 23

Support

This chapter describes how to contact the SEGGER support.

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23.1 Contacting support

There are different ways to contact the emFile support if you are a registered user:

1. You can send an email to support_emfile@segger.com*
2. You can create a support ticket at segger.com/ticket.

Please include the following information in the email or ticket:

- Used emFile version.
- Used emFile license number.
- If you are unsure about the above information, you can also send the name of the emFile shipment file.
- A detailed description of the problem.
- Optionally, a test project that can be used to reproduce the problem.

*By sending us an email your (personal) data will automatically be processed. For further information please refer to our privacy policy which is available at https://www.segger.com/legal/privacy-policy/.

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23.2 Where can I find the license number?

The license number is part of the shipped .zip file name. For example, the license number shipped in the file `emFile_PRO_Src_V5.26.0_FS-01234_t17ynMvA_240129.zip` is FS-01234.

The license number is also stored in the header of all the *.c and *.h files that are included in the emFile shipment. For example, if you open FS.h you should find the license number as in the example below:

```
---------------------------------------------------------------------
Licensing information
Licensor:                 SEGGER Microcontroller GmbH
Licensed to:              MyCompany
Licensed SEGGER software: emFile
License number:           FS-01234
License model:            SSL
Licensed product:         Any
Licensed platform:        ARM Cortex M
Licensed number of seats: -
---------------------------------------------------------------------
Support and Update Agreement (SUA)
SUA period:               2024-02-12 - 2024-08-12
Contact to extend SUA:    sales@segger.com
---------------------------------------------------------------------
File        : FS.h
Purpose     : Define global functions and types to be used by an
              application using the file system.

              This file needs to be included by any module using the
              file system.
--------------------------- END-OF-HEADER -----------------------------
```

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Chapter 24

FAQs

This chapter contains a collection of frequently asked questions (FAQs) together with their respective answers.

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24.1 Questions and answers

Q: Is my data safe when an unexpected reset occurs?

A: In general, the data which is already on the storage device is safe. If a read operation is interrupted, this is completely harmless. If a write operation is interrupted, then the data written during this operation may or may not be stored on the storage device. This depends on when the unexpected reset occurred. In any case, the data which was on the storage device prior to the write operation is not affected. This is true if the storage device is not affected by the reset, meaning that the storage device is able to complete a pending write operation. All this is true for the device drivers that come with emFile. However, the structure of the FAT or EFS file systems can be corrupted by an unexpected reset. This can be prevented by using the Journaling component.

Q: I use FAT and I can only create a limited number of root directory entries. Why?

A: With FAT12 and FAT16 the root directory is special because it has a fixed size. The size of the root directory can be specified at format, but once formatted this value is constant and determines the number of entries the root directory can hold. FAT32 does not have this limitation and the size of the root directory can be variable. Microsoft's "FAT32 File System Specification" says on page 22: "For FAT12 and FAT16 media, the root directory is located in a fixed location on the disk immediately following the last FAT and is of a fixed size in sectors computed from the `BPB_RootEntCnt` value […] For FAT32, the root directory can be of variable size and is a cluster chain, just like any other directory is." Here `BPB_RootEntCnt` specifies the count of 32-byte directory entries in the root directory and as the citation says, the number of sectors is computed from this value. In addition, which file system is used depends on the size of the storage medium, that is, the number of clusters and the cluster size, where each cluster contains one or more sectors. Using small cluster sizes (for example, a cluster size equal to 512 bytes), one can use FAT32 on a storage medium with more than 32 MB. (FAT16 can address at least 216 clusters with a 512-byte cluster size. That is 65536 * 512 = 33554432 bytes = 32768 KB = 32 MB). If the storage medium is smaller than or equal to 32 MB or the cluster size is greater than 512 bytes, FAT32 cannot be used. The second parameter of the `FS_Format()` API function can be used to set a custom root directory size for a FAT12 / FAT16 volume. This parameter is a pointer to an `FS_FORMAT_INFO` structure that contains a member named NumRootDirEntries which can be used to specify the number of entries in the root directory.

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Chapter 25

Glossary

List of some of the terms used in this manual together with a short explanation.

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25.1 List of terms

Allocation table
A reserved storage area where the file system stores information about what clusters are allocated.

BPB
BIOS Parameter Block. Logical sector (typically the first in a partition) that stores information about how the storage device is formatted. This information is updated during the high-level format operation.

BSP
Board Support Package.

CHS address
Address on a mechanical storage device specified as Cylinder, Head, and Sector.

Cluster
Smallest storage allocation unit of the file system. It consists of one or more logical sectors.

Cluster chain
File system data structure that stores information about what clusters are allocated to the same file or directory.

Directory entry
File system data structure that stores information about a file or directory such as name, size, time stamps, etc.

EFS
Embedded File System. SEGGER's proprietary file system specifically designed for embedded systems.

eMMC
embedded Multi-Media Card. An MMC compatible storage device that is packaged in an integrated circuit.

FAT
File Allocation Table. Widely used file system designed by Microsoft.

LFN
Long File Name. Extension for FAT file system that provides support for file and directory names longer than 8 characters in the base name and 3 characters in the extension.

Logical sector
Smallest storage allocation unit that a device or logical driver can handle.

MBR
Master Boot Record. File system data structure that stores information about how the storage device is partitioned.

MCU
Microcontroller Unit. A small computer that embeds a CPU, memory, and peripherals on the same integrated circuit.

MMC
Multi-Media Card. Type of removable non-volatile storage device that conforms with MMC specification.

Flash memory
A type of non-volatile storage device that can be electrically erased and programmed.

OS layer
emFile interface to task synchronization services provided by an operating system.

SD card
Secure Digital card. Type of removable non-volatile storage device that conforms with SD specification.

Storage device
A device that can store and preserve data between power cycles such as NAND flash, NOR flash, SD card, eMMC, or USB drive.

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