AN1045

Implementing File I/O Functions Using Microchip's Memory Disk Drive File System Library

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INTRODUCTION

This application note covers the usage of file I/O functions using Microchip's memory disk drive file system library. Microchip's memory disk drive file system is:

- Based on ISO/IEC 9293 specifications
- Known as the FAT16 file system, used on earlier DOS operating systems by Microsoft® Corporation
- Most popular file system with SD card, CF card and USB thumb drive

Most SD cards and MMCs, particularly those sized below 2 gigabytes (GB), use this standard. This application note presents a method to read and/or write to these storage devices through a microcontroller. This data can be read by a PC and data written by a PC can be read by a microcontroller. Most operating systems (i.e., Windows® XP) support this file system.

SD CARDS AND MMCs

SD cards and MMCs are proprietary, removable, Flash technology-based media, the use of which is licensed by the SD Card Association and the MultiMediaCard Association (see **"References"**), respectively.

Functionally, the two card formats are similar; however, the SD card has optional encryption security features that are not customarily found on the MMC. The specifications of these devices, and the terms and conditions for their use, vary, and should be examined for further application licensing information.

INTERFACE

The PICtail™ Daughter Board for SD and MMC cards, Microchip product number AC164122, provides an interface between SD or MMC cards and a PIC® microcontroller via the SPI bus. The PICtail Daughter Board is designed to operate with a multitude of demonstration boards, including all those having PICtail or PICtail Plus Daughter Board interfaces.

The SPI protocol uses four basic pins for communication: data in (SDI), data out (SDO), clock (SCK), and chip select ($\overline{CS}$). In addition, almost all SD card sockets have two electrically determined signals, card detect and write-protect, that allow the user to determine if the card is physically inserted and/or write-protected.

The MMC does not have a physical write-protect signal, but most card connectors will default to a non-write-protected state in this case.

More information about interfacing PIC® microcontrollers to SD cards or MMCs is included in *AN1003,* "*USB Mass Storage Device Using a PIC® MCU*" (DS01003), available from the Microchip web site.

CARD FILE SYSTEM

Important:	It is the user's responsibility to obtain a copy of, familiarize themselves fully with, and comply with the requirements and licensing obligations applicable to third party tools, systems and/or specifications including, but not limited to, Flash-based media and FAT file systems available from CompactFlash® Association, SD Card Association, MultiMediaCard Association and Microsoft® Corporation. Please refer to the license agreement for details.

An ISO/IEC 9293 system stores data in sectors. A sector size of 512 bytes is common. Since the number of available memory addresses is capped at FFFFh, sectors can be grouped into clusters that share an address to increase the size of the card.

The first sector on a card is the Master Boot Record (MBR). The MBR contains information about different logical subdivisions on a card, called partitions. Each of these partitions can be formatted with a unique file system. Typically, an SD card or MMC only has one active partition, which is comprised of the following parts:

- Boot sector
- FAT regions
- Root Directory region
- Data region

The boot sector is the first sector of the partition and contains basic information about the file system type.

The FAT region is actually a map of the card, indicating how the clusters are allocated in the data region. Generally, there are two copies of the FAT in the FAT region, to provide redundancy in case of data corruption.

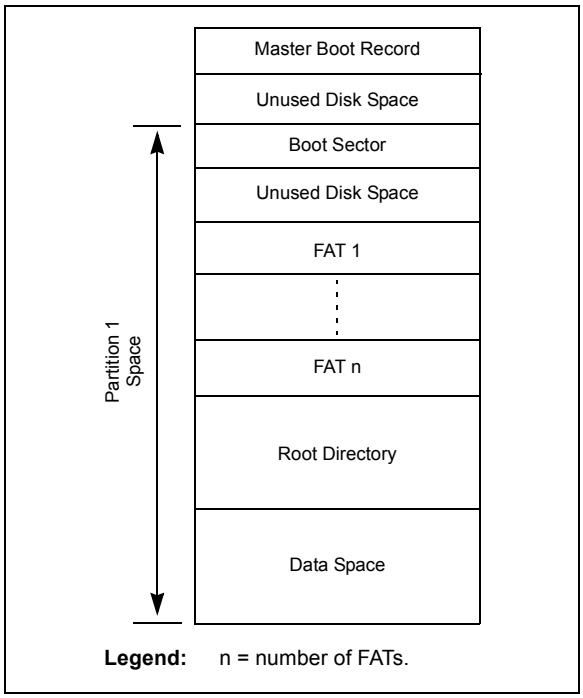
The root directory region follows the FAT region and is composed of a directory table that contains an entry for every directory and file on the card.

Collectively, the first three sections are the system area. The remaining space is the data region. Data stored in this region remains intact, even if it is deleted, until it is overwritten.

The FAT16 system uses 16-bit FAT entries, allowing approximately 65,536 (2^{16}) clusters to be represented. A signed byte in the boot sector defines the number of sectors per cluster for a disk. This byte has a range of -128 to 127. The only usable values in the FAT16 file system are positive, power-of-two values (1, 2, 4, 8, 16, 32, 64). This means that with the standard 512-byte sector size, the FAT16 file system can support a maximum of 2 GB of disk space.

The memory structure of an SD card or an MMC is illustrated in Figure 1.

FIGURE 1: DISK STRUCTURE



Master Boot Record

The MBR contains information that is used to boot the card, as well as information about the partitions on the card. The information in the master boot record is programmed when the card is manufactured, and any attempt to write to the MBR could render the disk unusable. The contents of the MBR are listed in Table 1.

TABLE 1: CONTENTS OF THE MBR

Offset	Description	Size
000h	Boot Code (machine code and data)	446 bytes
1BEh	Partition Entry 1	16 bytes
1CEh	Partition Entry 2	16 bytes
1DEh	Partition Entry 3	16 bytes
1EEh	Partition Entry 4	16 bytes
1FEh	Boot Signature Code (55h AAh)	2 bytes

Partition Entry in the MBR

Information about a partition on the disk is contained in a partition table entry of the master boot record. A file system descriptor is included in the entry to indicate which type of file system was specified when the partition was formatted. The following file descriptor values indicate FAT16 formatting: 04h (16-bit FAT, < 32M), 06h (16-bit FAT, ≥ 32M) and 0Eh (DOS CHS mapped). SD cards generally contain a single active partition. The contents of a partition table entry are listed in Table 2.

TABLE 2: PARTITION TABLE ENTRY

Offset	Description	Size
00h	Boot Descriptor (80h if active partition, 00h if inactive)	1 byte
01h	First Partition Sector	3 bytes
04h	File System Descriptor	1 byte
05h	Last Partition Sector	3 bytes
08h	Number of sectors between the Master Boot Record and the first sector of the partition	4 bytes
0Ch	Number of sectors in the partition	4 bytes

Boot Sector

The boot sector is the first sector of a partition. It contains file system information, as well as pointers to important parts of the partition. The first entry in the boot sector is a command to jump past the boot information. The complete contents can be seen in Table 3.

TABLE 3: BOOT SECTOR ENTRY

Offset	Description	Size
00h	Jump Command	3 bytes
03h	OEM Name	8 bytes
0Bh	Bytes per Sector	2 bytes
0Dh	Sectors per Cluster	1 byte
0Eh	Total Number of Reserved Sectors	2 bytes
10h	Number of File Allocation Tables	1 byte
11h	Number of Root Directory Entries	2 bytes
13h	Total Number of Sectors (bits 0-15 out of 48)	2 bytes
15h	Media Descriptor	1 byte
16h	Number of Sectors per FAT	2 bytes
18h	Sectors per Track	2 bytes
1Ah	Number of Heads	2 bytes
1Ch	Number of Hidden Sectors	4 bytes
20h	Total Number of Sectors (bits 16-47 out of 48)	4 bytes
24h	Physical Drive Number	1 byte
25h	Current Head	1 byte
26h	Boot Signature	1 byte
27h	Volume ID	4 bytes
2Bh	Volume Label	11 bytes
36h	File System Type (not for determination)	8 bytes
1FEh	Signature (55h, AAh)	2 bytes

Root Directory

The root directory, located after the FAT region on the disk, is a table that stores file and directory information in 32-byte entries. An entry includes the file name, file size, the first cluster of the file and the time the file was created and/or modified.

Note: Generally, a file entry conforms to “eight dot three” short file name format. Only digits 0 to 9, letters A to Z, the space character and special characters, ! # $ % & ( ) - @ ^ _ ` { } ~ ', are used. Although it is customary to consider the period (.) and extension as elements of the file name, in this case, none of the characters after the initial name are used as part of the actual file name.
For example, a file named “FILE.TXT” would have the file name “FILE_ _ _ _” in the root directory, with the final 4 characters replaced by 4 instances of the space character “20h”.

The complete contents of a root directory entry are represented in Table 4.

TABLE 4: ROOT DIRECTORY ENTRY

Offset	Description	Size
00h	File Name(1)	8 bytes
08h	File Extension	3 bytes
0Bh	File Attributes	1 byte
0Ch	Reserved	1 byte
0Dh	File Creation Time (ms portion)	1 byte
0Eh	File Creation Time (hours, minutes and seconds)	2 bytes
10h	File Creation Date	2 bytes
12h	Last Access Date	2 bytes
14h	Extended Address-Index	2 bytes
16h	Last Update Time (hours, minutes and seconds)	2 bytes
18h	Last Update Date	2 bytes
1Ah	First Cluster of the File	2 bytes
1Ch	File Size	4 bytes

Note 1: The first character of the file name can take on special values (see Table 5).

TABLE 5: POSSIBLE VALUES FOR THE FIRST CHARACTER IN THE DIRECTORY FILE NAME

Value	Description
00h	This entry is available and no subsequent entry is in use.
E5h	The file in this entry was deleted and the entry is available.
05h	The first character in the file name is 'E5h'.
2Eh	This entry points to the current or previous directory.

File Allocation Table

The FAT has space for one 2-byte entry to correspond to every cluster in the data cluster section of the partition. For example, the third set of two bytes in the FAT will correspond to the first cluster in the data region. A value placed in each position can indicate many things. A list of values can be found in Table 6.

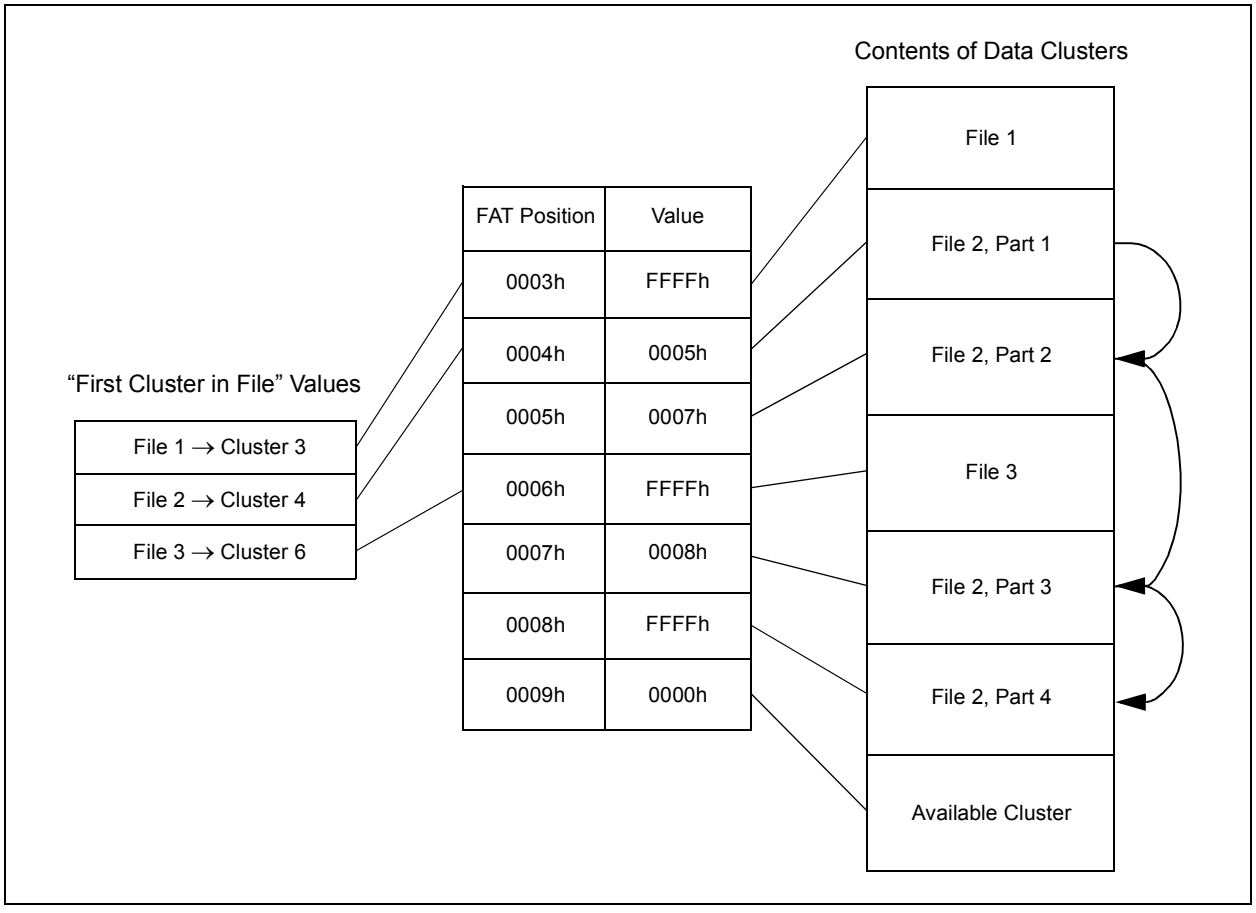
TABLE 6: FAT VALUES

Value	Description
0000h	Cluster is available for use.
0001h	Cluster is reserved.
0002-FFEFh	Points to next cluster in the file.
FFF0-FFF6h	Cluster is reserved.
FFF7h	Cluster is bad.
FFF8h-FFFFh	Last cluster of a file.

Every file has at least one cluster assigned to it. If that file size is smaller than the size of a cluster, the FAT entry for that cluster will contain the last cluster value, indicating that there are no more clusters assigned to that file. Otherwise, it will contain the value of the next cluster of the file. By linking clusters in this way, the FAT can create a chain of clusters to contain larger files, and can allocate non-sequential clusters to a file.

An example of this is shown in Figure 2. It is important to note that the values that would point towards Clusters 0 and 1 are reserved to indicate special conditions. Because of this, the first cluster in the data region is labeled as Cluster 2. The FAT entries corresponding to Clusters 0 and 1 contain the media descriptor, followed by bytes containing the value, FFh.

FIGURE 2: FAT CLUSTER CHAIN



The “First Cluster in File” values in three root directory entries indicate the start of three files. The FAT demonstrates the links between the files. File 1 and File 3 are smaller than the size of a cluster, so they are only assigned one cluster. The cluster entries in the FAT that correspond to these files contain only the End-Of-File value. File 2 is larger than three clusters, but smaller than four, so it is assigned four clusters. Since there were not three consecutive clusters available when File 2 was created, it was assigned nonconsecutive clusters. This is called “fragmentation”. The values of the cluster entries in the FAT for File 2 point to the next cluster in the file. The last cluster entry in the FAT for File 2 contains the End-Of-File value.

Directories

Directories in this file system, with the exception of the root directory, are written in the same way that files are written. Each directory occupies one or more clusters in the data section of the partition, and each has its own directory entry and chain of FAT entries. Bit four of the attribute field in the directory entry of a directory is set, indicating that the entry belongs to a directory. Directory names in this library follow short file name format (8.3 format). Directories differ from files in that they have no extension, though.

Each directory contains 32-byte directory entries. Two directory entries, the dot entry and the dotdot entry, are present in every directory except the root directory. The dot entry is the first entry in any subdirectory. The name value in this entry is a single dot (2Eh) followed by ten space characters (20h). The first-cluster-in-file value of this entry will point to the cluster that the entry is in. The dotdot entry is similar, except the name contains two dots followed by nine spaces, and the first-cluster-in-file value points to the directory that contains entry for the directory the dotdot entry is in (the previous directory).

When directories are enabled in this library, all file modification will be done in the Current Working Directory (CWD). When the user initializes the card by calling `FSInit`, the current working directory is automatically set to the root directory. After this, the current working directory can be changed with the `FSchdir` function.

When specifying path names in the directory manipulation functions, there are several conventions that should be followed. Directory names in a path string are delimited by the backslash character (\). Note that when denoting a backslash character in a string, an additional backslash must be added as part of an escape sequence, as the backslash itself is used by C to begin escape sequences. If the first character of a path string is a backslash, the path will be assumed to be specified relative to the root directory. If a path string begins with a directory name, the path will be assumed to be specified relative to the current working directory. If a dot (.) or dotdot (..) is included in the path as a directory name, the code will operate using those directory entries. For example, if the user changes the CWD to `".\\TEST\..\\TEST\\..\\.\\."`, they will end in the same directory that they started in, assuming the directory “TEST” exists in the original directory. More examples of path strings can be seen in Table 7.

TABLE 7: EXAMPLE DIRECTORY PATH STRINGS

Path	Meaning
`"\\"`	The root directory
`"."`	Current directory
`".."`	Previous directory
`"ONE"`	Directory ONE in the current directory
`".\\ONE"`	Directory ONE in the current directory
`"\\ONE"`	Directory ONE in the root directory
`"..\\ONE"`	Directory ONE in the previous directory
`"ONE\\TWO"`	Directory TWO in directory ONE in the current directory
`"\\ONE\\TWO"`	Directory TWO in directory ONE in the root directory
`"ONE\\..\\TWO"`	Directories ONE and TWO in the current directory (this path could be used to create non-existent directories in the same place using the `FATmkdir` function)

FUNCTIONS

User Functions

There are thirteen functions users can call that manage file and disk manipulation. Table 8 provides a brief overview of each.

TABLE 8: FILE AND DISK MANIPULATION FUNCTIONS

Function Name	Description
FSInit	This function initializes the card, loads the master boot record (partition information), loads the boot sector and updates the parameters passed into it with information from each of these.
FSfclose	This function updates the file information, writes the rest of the entry in and frees the RAM from the heap that was used to hold the information about that file. This function will also update time-stamp information for the file.
FSfeof	This function detects if the end of the file has been reached.
FSfopen	This function allocates space in the heap for file information. If the file being opened already exists, FSfopen can open it so data will be appended on the end of the file, erase it and create a new file with the same name to be written to, or simply open it for reading. If the file does not exist, FSfopen can create it. This function then returns a pointer to the structure in the heap that contains information for this file.
FSfopenpgm	This function opens a file on the SD card and associates an FSFILE structure (stream) with it using arguments specified in ROM. This function is only necessary on the PIC18 architecture.
FSfread	This function will read information from an open file to a buffer. The number of bytes written can be specified by its parameters. If FSfread is called consecutively on the same open file, the read will continue from the place it stopped after the previous read. This function will return the number of data objects read.
FSfseek	This function changes the position in a file. When a user calls FSfseek, they specify the base address to set, which can either be at the beginning or end of the file, or at the current position in the file. The user also specifies an offset to add to the base (note that if the base address is at the end of the file, the offset will be subtracted). So, if fseek is called FSfseek with the base set to the beginning of the file, and a specified offset of '0', the position would be changed to the first byte of the file.
FSftell	This function returns the current position in the file. The first position in the file is the first byte in the first sector of the first cluster which has the value '0'. So, if a file was created and 2000 bytes were written to it, FSftell would return the number 1999 if it was called.
FSfwrite	This function writes information from a buffer to an open file. The algorithm it uses reads a sector from the data region of the disk to SRAM, modifies the relevant bytes and then writes the sector back to the disk. Because each FSfwrite call reads the data first, the ability to open multiple files at a time is supported. This also means that writing data in larger blocks will take less time than writing the same amount of data in smaller blocks, since fewer sector reads and writes will be needed.
FSremove	This function searches for a file based on a file name parameter passed into it. If the file is found, its root directory entry is marked as deleted and its FAT entry is erased.
FSremovepgm	This function deletes the file identified by a given file name. If the file is opened with FSfopen, it must be closed before calling FSremovepgm. The file name must be specified in ROM. This function is only necessary on the PIC18 architecture.
FSrewind	This function resets the position of the file to the beginning of the file.
SetClockVars	This function is used in user-defined Clock mode to manually set the current date and time. This date and time will be applied to files as they are created or modified.
FSmkdir	This directory manipulation function will create a new subdirectory in the current working directory.
FSchdir	This directory manipulation function will change the current working directory to one specified by the user.

TABLE 8: FILE AND DISK MANIPULATION FUNCTIONS (CONTINUED)

Function Name	Description
FSrmdir	This directory manipulation function will delete the directory specified by the user. The user may also choose to specify whether subdirectories and files contained within the deleted directory are removed. If the user does not allow the function to delete subdirectories, it will fail if the user attempts to delete a non-empty directory.
FSgetcwd	This directory manipulation function will return the name of the current working directory to the user.
FindFirst	This function will locate files in the current working directory that meet the name and attribute criteria passed in by the user. The user will also pass in a SearchRec Structure Pointer. Once a file is located, the file name, file size, create time and date stamp, and attributes fields in the SearchRec structure will be updated with the correct file information.
FindFirstpgm	This function operates in the same manner as the FindFirst function, except the name criteria for the file to be found will be passed into the function in ROM. This function is only necessary on the PIC18 architecture.
FindNext	This function will locate the next file in the current working directory that matches the criteria specified in the last call of FindFirst or FindFirstpgm. It will then update the SearchRec structure provided by the user with the file information.
FSformat	This function will erase the root directory and file allocation table of a card. The user may also call the function in a mode that will cause it to create a new boot sector based on the information in the master boot record.
FSfprintf	This function will write a formatted string to a file. This function will automatically replace any format specifiers in the string passed in by the user with dynamic values from variables passed into the function.

Library Setup

There are several customizations that can be used with this library. The following should be done before compiling a project:

1. Add the appropriate physical layer file to the project. Interfaces for the SD card in SPI mode (SD-SPI.c, SD-SPI.h) and the Compact-Flash card using the PMP module (CF-PMP.c, CF-PMP.h) or manual bit toggling (CF-Bit transaction.c, CF-Bit transaction.h) are provided. Set the appropriate include file name in FSconfig.h.
2. Define system clock frequency in FSconfig.h.
3. If using static memory for file objects, specify the maximum number of files that are going to be open at any one time in FSconfig.h.
4. If using the SD SPI interface, specify the appropriate register names in SD-SPI.h. For example, if you're using SPI module 1 on the PIC24, change the definition of SPI1CON to SPI1CON1. If using module 2, change the definition to SPI1CON2.
5. If using a PIC18, modify the linker file to include a 512-byte section of RAM that will act as a buffer for file reads/writes. This buffer is defined at the top of the physical interface files. Also create a section in the linker mapped to this RAM called "dataBuffer". Repeat this process to create a buffer for FAT reads and writes. This buffer will need a section mapped to the RAM you allocate called "FATBuffer".
6. If planning to use dynamic memory to allocate file objects, set the corresponding preprocessor directive in the FSconfig.h file to "#if 1". Also, if using PIC18, a section must be created in the linker file called "_SRAM_ALLOC_HEAP" that contains enough memory to contain all of the opened file objects. Each file object is 46 bytes. Due to the variation in the memory allocation algorithm, the allocated amount required will be larger. This is also true when using a PIC24. Testing will be necessary to determine if enough memory was allocated to the heap. Include the salloc.c and salloc.h files in the project when using PIC18. If planning on using dynamic memory allocation with the PIC24, you will need to create a heap in the MPLINK30 tab of the Build Options menu.
7. Set the library path and include path (and linker path, if PIC18) in the General tab of the Build Options menu.
8. Set the required input and output pins in your physical layer header file (SD-SPI.h, CF-PMP.h, ...).
9. Make sure that all pins used are configured as digital I/Os, including PORTB pins set in the Configuration registers and any pins that could be analog channels for the A/D converter.
10. Select the appropriate device and language toolset. The code that will be compiled will be appropriate to the processor type (PIC18, PIC24F, PIC24H, dsPIC30 or dsPIC33).
11. There are several definitions in FSconfig.h that can be used to disable library functionality to save code space if the user does not require those functions. To use any write functions, uncomment the ALLOW_WRITES definition; to use directory functionality, uncomment ALLOW_DIRS; to use the format function, uncomment ALLOW_FORMATS; to use the file search functions, uncomment ALLOW_FILESEARCH. If you wish to use the functions that accept parameters passed through ROM (pgm functions) on PIC18, you may uncomment ALLOW_PGMFUNCTIONS. The pgm functions will not work with other architectures. However, arguments in ROM can be passed into standard functions (e.g., FSfopen instead of FSfopenpgm) directly in PIC24, dsPIC30 and dsPIC33 architectures. ALLOW_FSFPRINTF will enable the FSfprintf function when uncommented.
12. Uncomment a define to select a Clock mode for determining file create/modify/access times. The INCREMENTTIMESTAMP mode will set the times to a static value and will not provide accurate timing values. This mode is useful when file times are unimportant, as it reduces complexity. The USERDEFINEDCLOCK mode will allow the user to manually set the timing values using the SetClockVars function. The USEREALTIMECLOCK mode will set the timing values automatically, based on the values in the Real-Time Clock and Calendar module. This mode will require the user to enable and configure the RTCC module, and it is not available in architectures that don't support RTCC.

FAT16 Initialization and File Creation

The following example C18 code illustrates a basic sequence of function calls to open a file for reading. This example initializes the card with the `FSInit` function and then calls `FSfopen` to create a new file. Then, the code calls `FSfopenpgm`, a function which performs the same function as `FSfopen`, but accepts ROM parameters. This call opens an existing file in the read mode. The code reads one ten byte object and five one byte objects from the existing file. The example then shows how it writes these objects to the newly created files and then closes both files. Finally, the code deletes the old file. It is important to close a currently open file before deleting it.

EXAMPLE 1: INITIALIZATION AND FILE CREATION EXAMPLE FOR PIC18

```
#include "FSIO.h"

#define bfrsize 5

    void main(void)
    {
        FSFILE *pOldFile, pNewFile;
        char myData[20];
        char bfr [6];
        int bytesRead, bytesWritten;
        char newFile[] = "newfile.txt";
        char writeArg = "w";

        // Must initialize the FAT16 library. It also initializes SPI and other related pins.
        if( !FSInit() )
            // Failed to initialize FAT16 - do something…
            return 1; // Card not present or wrong format

        // Create a new file

        pNewFile = FSfopen (newFile, writeArg);

        // Open an existing file to read
        pOldFile = FSfopenpgm ("myfile.txt", "r");
        if ( pOldFile == NULL )
            // Either file is not present or card is not present
            return 1;

        // Read 10 bytes of data from the file.
        bytesRead = FSfread((void*)myData, 10, 1, pOldFile);
        // read bfrSize (5) items (of size 1 byte). returns items count
        bytesRead = FSfread( (void *)bfr, 1, bfrSize, pOldFile );


        // Write those fifteen bytes to the new file
        bytesWritten = FSfwrite ((void *) myData, 10, 1, pNewFile);
        bytesWritten = FSfwrite ((void *) bfr, 1, bfrSize, pNewFile);

        // After processing, close the file.
        FSfclose( pOldFile );
        FSfclose (pNewFile);

        //Delete the old file
        FSremovepgm ("myfile.txt");

}
```

Memory Usage

Unoptimized memory usage for the file interface library using the SD-SPI physical layer is given in Table 9. 512 bytes of data memory are used for the data buffer, and an additional 512 are used for the file allocation table buffer. Additional data memory will be needed based on the number of files opened by the user at once. The default values provided are for two files opened in static allocation mode. The C18 data memory value includes a 200h byte stack. The first row of the table indicates the smallest amount of memory that the library will use (for read-only mode), and each subsequent row indicates the increase in memory caused by enabling other functionality.

TABLE 9: FILE I/O LIBRARY MEMORY USAGE(1)

Functions Included	Program Memory (C30)	Data Memory (C30)	Program Memory (C18)	Data Memory (C18)
All extra functions disabled (Read-Only mode)	11364 bytes	1220 bytes	19655 bytes	1771 bytes
File search enabled	+1608 bytes	+0 bytes	+3628 bytes	+0 bytes
Write enabled	+6150 bytes	+0 bytes	+11972 bytes	+0 bytes
Format enabled (write must be enabled)	+2520 bytes	+0 bytes	+4888 bytes	+0 bytes
Directories enabled (write must be enabled)	+6870 bytes	+70 bytes	+13796 bytes	+79 bytes
Directories and search are both enabled	+42 bytes	+0 bytes	+142 bytes	+0 bytes
`pgm` functions enabled	N/A	N/A	+1788 bytes	+0 bytes
`FSfprintf` enabled	+4794 bytes	+0 bytes	+5515 bytes	+0 bytes

Note 1: This is a resource requirement for V1.0. Please refer to the ReadMe file for version-specific resource requirement.

Comments

- During sector reads and writes, the card should not be removed.
- The size of the PIC18 stack may need to be increased. Otherwise, a stack overflow could occur when functions are called and the data are pushed to the stack. If the stack size is increased in this way, the memory model in the **Project > Build Options > C18** tab must be set to "Multi-Bank Model." To change the size of the stack, the linker script must be modified. An example of this is given in **Appendix A: "The PIC18 Linker Script"**.

Explanation of Data Types and Structures

- `DISK` – The `DISK` structure contains information about the physical disk. The user should never have to directly use the information stored in this structure.
- `FILE` – The `FILE` structure contains information about a file on the disk. The user should never have to directly use the information stored in this structure.
- Types defined in `generic.h`
  - `BYTE` – An unsigned char (8 bits)
  - `WORD` – A short int (16 bits)
  - `SWORD` – An unsigned short long (24 bits)
  - `DWORD` – An unsigned long (32 bits)
- `SearchRec` – The `SearchRec` structure contains the name, create time and date stamps, size and attributes of a file found using the `FindFirst`, `FindFirstpgm` or `FindNext` function. The complete contents of the `SearchRec` structure can be seen in Table 10.

TABLE 10: CONTENTS OF THE `SearchRec` STRUCTURE

Element	Function
char file name	The name of the file (null-terminated)
unsigned char attributes	The file attributes
unsigned long file size	The size of the file in bytes
unsigned long time-stamp	The create time and date of the file

Bits	Value
31:25	Year (0 = 1980, 1 = 1981, …)
24:21	Month (1 = Jan, 12 = Dec)
20:16	Day (1-31)
15:11	Hours (0-23)
10:5	Minutes (0-59)
4:0	(Seconds/2) (0-29)

UNSUPPORTED FEATURES

The following features are not supported:

- Long file names
- FAT32

REFERENCES

- SD Card Association – http://www.sdcard.org
- CompactFlash® Association – http://www.compactflash.org
- The following documents are referenced by this application note.
  - SD Memory Card Specifications, Part 1 "*Physical Layer Specification*", Version 1.01, September 2000
  - SD Memory Card Specifications, Part 2 "*File System Specification*", Version 1.0, February 2000
- MultiMediaCard Association – http://www.mmca.org
- PCGuide: FAT File System Disk Volume Structures – http://www.pcguide.com/ref/hdd/file/fat.htm
- ISO/IEC 9293 – http://www.iso.ch/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER = 21273
- FAT32 File System Specification – http://www.microsoft.com/whdc/system/platform/firmware/fatgen.mspx
- From Wikipedia – http://en.wikipedia.org/wiki/Fat16

CONCLUSION

File creation and storage is undoubtedly useful for applications that need to store large amounts of data or small amounts of data over long periods of time. By using this application note and the C18/C30 code provided with it, the user can minimize his or her development time.

APPENDIX A: THE PIC18 LINKER SCRIPT

This sample linker script reserves three blocks of memory: one specified by section `_SRAM_ALLOC_HEAP`, one specified by section `dataBuffer` and one specified by section `FATBuffer`. The heap section does not need to be reserved if dynamic memory is not being used to store file objects.

This script also contains a 0x200 byte stack. If a stack spans multiple memory banks, like this one does, the “Multi-Bank” model should be selected in the Project Build Options menu.

EXAMPLE A-1: PIC18 LINKER SCRIPT

```
// $Id: 18f8722i.lkr,v 1.4 2005/12/19 16:40:18 nairnj Exp $
// File: 18f8722i.lkr
// Sample ICD2 linker script for the PIC18F8722 processor

LIBPATH .

FILES c018i.o
FILES clib.lib
FILES p18f8722.lib

CODEPAGE   NAME=vectors    START=0x0            END=0x29           PROTECTED
CODEPAGE   NAME=page       START=0x2A           END=0x1FD7F
CODEPAGE   NAME=debug      START=0x1FD80        END=0x1FFFF        PROTECTED
CODEPAGE   NAME=idlocs     START=0x200000       END=0x200007       PROTECTED
CODEPAGE   NAME=config     START=0x300000       END=0x30000D       PROTECTED
CODEPAGE   NAME=devid      START=0x3FFFFE       END=0x3FFFFF       PROTECTED
CODEPAGE   NAME=eedata     START=0xF00000       END=0xF003FF       PROTECTED

ACCESSBANK NAME=accessram  START=0x0            END=0x5F
DATABANK   NAME=gpr1       START=0x60           END=0xFF
DATABANK   NAME=gpr2       START=0x100          END=0x1FF
DATABANK   NAME=gpr3       START=0x200          END=0x2FF
DATABANK   NAME=gpr4       START=0x300          END=0x3FF
DATABANK   NAME=gpr5       START=0x400          END=0x4FF
DATABANK   NAME=gpr6       START=0x500          END=0x5FF
DATABANK   NAME=gpr7       START=0x600          END=0x6FF
// Allocate 0x200 bytes for the data buffer
DATABANK   NAME=buffer1    START=0x700          END=0x8FF          PROTECTED
// Allocate 0x200 bytes for the FAT buffer
DATABANK   NAME=buffer2    START=0x900          END=0xAFF          PROTECTED
// Allocate 0x200 bytes for the heap
DATABANK   NAME=gpr8       START=0xB00          END=0xBFF
DATABANK   NAME=gpr9       START=0xC00          END=0xDFF
DATABANK   NAME=gpr10      START=0xE00          END=0xEF3
DATABANK   NAME=dbgspr     START=0xEF4          END=0xEFF          PROTECTED
DATABANK   NAME=gpr11      START=0xF00          END=0xF5F
ACCESSBANK NAME=accesssfr  START=0xF60          END=0xFFF          PROTECTED


SECTION    NAME=CONFIG            ROM=config
// Create a heap section
SECTION    NAME=_SRAM_ALLOC_HEAP  RAM=gpr8
// Create the data buffer section
SECTION    NAME=dataBuffer        RAM=buffer1
// Create the FAT buffer section
SECTION    NAME=FATBuffer         RAM=buffer2

STACK SIZE=0x200 RAM=gpr9
```

APPENDIX B: API DETAILS

FSInit

Initializes the hardware and mounts the card in the library. If the card is not detected, returns FALSE. Must be called before calling any other API function. If card is removed and inserted, the application must call `FSInit` to remount the card. You can detect if the card is present by calling the `MediaIsPresent()` low level function.

Syntax

```
int FSInit(void)
```

Parameters

None

Return Values

True if card is present and the format is FAT16 or FAT12

False otherwise

Precondition

None

Side Effects

None

Example

```
// Initialize library and detect card.
if ( FSInit() != TRUE )
// Failed to initialize FAT16.
```

FSfclose

Closes an opened file

Syntax

```
int FSfclose( FSFILE *stream )
```

Parameters

`stream` – A pointer to a `FILE` structure obtained from a previous call of `FSfopen`

Return Values

Returns `0` on success

Returns EOF (-1) on failure

Precondition

`FSfopen` was called and the `stream` contains the pointer returned by `FSfopen`

Side Effects

None

Example

```
if( FSfclose( stream ) == EOF )
{
// Failed to close the file.
...
}
...
```

FSfeof

Detects if End-Of-File position is reached.

Syntax

```
int FSfeof( FSFILE *stream )
```

Parameters

`stream` – pointer to opened file

Return Values

Returns non-zero if the End-Of-File indicator (EOF) is reached

Return 0 otherwise

Precondition

File is opened successfully

Side Effects

None

Example

```
if (FSfeof (pFile) == 0)
{
    // Error
    ...
}
```

FSfopen

Opens a file on the card and associates a FILE structure (stream) with it.

Syntax

```
FSFILE * FSfopen ( const char * fileName, const char *mode )
```

Parameters

filename – A null terminated char string specifying the file name. This string must be stored in RAM. The file name must be fewer than 8 characters, followed by a radix (.) followed by an extension containing three of fewer characters. The file Name cannot contain any directory or drive letter information.

mode – A null terminated string specifying the file operation. This string must also be specified in RAM.

The valid strings are:

r	Read Only	
w	Write	If a file with the same name exists, it will be overwritten No reads allowed
a	Append	If the file exists, the current location will be set to the end of the file. Otherwise, the file will be created. No reads allowed

Return Values

A pointer to an FSFILE structure to identify the file in subsequent operations
NULL if the specified file could not be opened

Precondition

FSInit is called

Side Effects

None

Example

```
// Create argument strings in RAM and use them to call the function
FSFILE * fPtr;
char [9] name = "myFile.txt";
char [2] modeArg = "w";
fPtr = FSfopen( name, modeArg );
```

FSfopenpgm

Opens a file on the SD card and associates a FSFILE structure (stream) with it using arguments specified in ROM.

Syntax

```
FSFILE * FSfopenpgm (const rom char * fileName, const rom char *mode)
```

Parameters

filename – A null terminated char string specifying the file name. This string must be stored in ROM. The file name must be fewer than 8 characters, followed by a radix (.) followed by an extension containing three of fewer characters. The fileName cannot contain any directory or drive letter information.

mode – A null terminated string specifying the file operation. This string must also be specified in ROM. The valid strings are:

r	Read Only	
w	Write	If a file with the same name exists, it will be overwritten No reads allowed
a	Append	The file must exist for this operation No reads allowed

Return Values

A pointer to FILE structure to identify the file in subsequent operations

NULL if the specified file could not be opened

Precondition

FSInit is called

Side Effects

None

Example

```
// Create a file called MYFILE.TXT
FSFILE * fPtr;
fPtr = FSfopen( "myfile.txt", "w");
```

FSfread

Reads data from the previously opened file. `FSfread` reads n items of data, each of length `size` bytes from the given file `stream`. The data is copied to the buffer pointed by `ptr`. The total number of bytes transferred is `n * size` .

Syntax

```
size_t FSfread( void *ptr, size_t size, size_t n, FSFILE *stream )
```

Parameters

`ptr` – pointer to buffer to hold the data read

`size` – length of item in bytes

`n` – number of items to read

`stream` – `stream` pointer to file opened with read (`r`) mode

Return Values

On success `FSfread` returns the number of items (not bytes) actually read

On End-Of-File or error it returns `0`

Precondition

File is opened is read mode

Side Effects

None

Example

```
...
//Read 100 packets of size 10 bytes each
nItems = FSfread( bfr, 10, 100, pFile );

if( nItems == 0 )
{
    // No packet was read
    ...
}
else if( nItems < 100 )
{
    // did not read all 100 packets. Possible EOF
    ....
}
else
{
    //read all 100 packets
    ...
}
```

FSfseek

The FSfseek function moves the file pointer position associated with the stream. The new position is offset bytes from the file location given by whence.

Syntax

```
int FSfseek( FSFILE *stream, long offset, int whence )
```

Parameters

whence – file location defining the starting point for offset. Must be 0, 1, or 2 as follows:

SEEK_SET	0	File beginning
SEEK_CUR	1	Current file pointer position
SEEK_END	2	End-Of-File

offset – number of bytes away from the starting point defined by whence

stream – pointer to opened file

Return Values

Return 0 if success

Returns -1 on error

Precondition

File is opened successfully

Side Effects

None

Example

```
// move 100 bytes forward from the current position.
If( FSfseek( pFile, 100, SEEK_CUR ) !=  0 )
{
    ...  //handle error condition
}
```

FSftell

Returns the current position of the file pointer

Syntax

```
long FSftell( FSFILE *stream )
```

Parameters

`stream` – pointer to opened file

Return Values

Returns the current file pointer position on success

Returns -1L on error

Precondition

File is opened successfully

Side Effects

None

Example

```
// get current file position
long pos = FSftell( pFile );
If (pos == -1)
{
   ...  //handle error condition
}
```

FSfwrite

Writes data to the previously opened file. `FSfwrite` writes n items of data, each of length `size` bytes to the given file `stream`. The data is copied from the buffer pointed to by `ptr`. The total number of bytes transferred is `n * size` .

Syntax

```
size_t FSfwrite( const void *ptr, size_t size, size_t n, FSFILE *stream )
```

Parameters

`ptr` – pointer to buffer holding data to write

`size` – length of item in bytes

`n` – number of items to write

`stream` – `stream` pointer to file opened with write (`w`) or append (`a`) mode

Return Values

On successful completion `FSfwrite` returns the number of items (not bytes) actually written
On error it returns a short count or 0

Precondition

File is opened in write (`w`) or append (`a`) mode

Side Effects

None

Example

```
If( FSfwrite( ptr, 100, 20, pFile ) != 20 )
{
   // not all items were written
   ...  //handle error condition
}
```

FSremove

The FSremove function deletes the file identified by filename. If the file is opened with FSfopen, it must be closed before calling FSremove. The file name must be specified in RAM.

Syntax

```
int FSremove (const char * filename)
```

Parameters

filename – A pointer to a null terminated string in RAM

Return Values

Returns 0 on success

Returns EOF (-1) on failure

Precondition

FSInit is called successfully

Side Effects

None

Example

```
// Create a string for the file name in RAM and then deletes the file with that
// name
char name[] = "myfile.txt";
if( FSremove(name) == EOF )
{
// error handling
...
}
...
```

FSremovepgm

The FSremovepgm function deletes the file identified by filename. If the file has been opened with FSfopen, it must be closed before calling FSremovepgm. The file name must be specified in ROM.

Syntax

```
int FSremove (const rom char * filename)
```

Parameters

filename – A pointer to a null terminated string in ROM

Return Values

Returns 0 on success

Returns EOF (-1) on failure

Precondition

FSInit is called successfully.

Side Effects

None

Example

```
// Deletes MYFILE.TXT
if( FSremovepgm ("myfile.txt") == EOF )
{
// error handling
...
}
...
```

FSrewind

The FSrewind function resets the file position to the beginning of the file.

Syntax

```
void FSrewind (FSFILE *stream)
```

Parameters

stream – A pointer to FILE structure obtained from a previous call of FSfopen

Return Values

None

Precondition

File is already opened be a previous call of FSfopen

Side Effects

None

SetClockVars

The SetClockVars function sets the timing variables used to set file create/modify/access times. This function is only used when the user-defined Clock mode is selected.

Syntax

```
int SetClockVars (unsigned int year, unsigned char month, unsigned char day, unsigned char hour, unsigned char minute, unsigned char second);
```

Parameters

year – The year, from 1980 to 2107

month – The month, from 1-12

day – The day, from 1-31

hour – The hour of the day, from 0 (midnight) to 23

minute – The current minute, from 0 to 59

second – The current second, from 0 to 59

Return Values

Returns 0 on success

Returns -1 if an invalid parameter is passed in

Precondition

USERDEFINEDCLOCK is defined in FSconfig.h

Side Effects

Modified global timing variables

Example

```
// Set the date and time to
// 2:35:20 PM, January 12, 2007
if (SetClockVars (2007, 1, 12, 14, 35, 20))
{
       // Invalid values passed in
       ...
}
```

FSformat

The `FSformat` function will erase the root directory and file allocation table of a card. It can also create a new boot sector, based on the mode the user calls the function in.

Syntax

```
int FSformat (char mode, long int serialNumber, char * volumeID);
```

Parameters

`Mode`	–	0	Just erase FAT and root
		1	Create a new boot sector. Will fail if MBR is not present.
`serialNumber`	–		The serial number to program into the new boot sector
`volumeID`	–		The name of the card. Must be 8 or fewer chars.

Return Values

Returns 0 on success

Returns -1L otherwise

Preconditions

None

Side Effects

None

Example

```
char volID[] = "MyCard";
// Erase FAT and root, create new boot sector
// Set card serial number to 0x12345678, set
// card name to "MyCard"
If (FSformat (1, 0x12345678, volID))
{
       // Format failed
       …
}
```

FSmkdir

The FSmkdir function will create a directory based on the path string passed in by the user. Every directory in the path string that does not exist will be created. Directory names in the path string must be no more than 8 ASCII characters. Directory names are delimited by the backslash character. A dot (.) as a directory name will access the current directory. Two dots (..) will access the previous directory. Beginning the path string with a backslash will create the directories specified in the root directory. Beginning the path string with a directory name will create the directories specified in the current working directory.

Syntax

```
int FSmkdir (char * path);
```

Parameters

path – The path of directories to create

Return Values

Returns 0 on success

Returns -1 otherwise

Precondition

FSInit is called successfully

Side Effects

None

Example

```
char path[] = "\ONE\TWO\THREE\FOUR";
// The path starts with a '\' so dir ONE will be
// created in the root directory if it doesn't exist
// Dir TWO will be created in dir ONE if it doesn't
// exist.  THREE will be created in TWO.  FOUR will be
// created in THREE
if (FSmkdir (path))
{
       // Error
       ...
}
```

FSchdir

The `FSchdir` function will change the current working directory based on the path string passed in by the user. Directory names are delimited by the backslash character. A dot (.) as a directory name will access the current directory. Two dots (..) will access the previous directory. Beginning the path string with a backslash will change to the directory specified starting from the root directory. Beginning the path string with a directory name will change to the directory specified starting from the current working directory.

Syntax

```
int FSchdir (char * path);
```

Parameters

path – The path of directory to change to

Return Values

Returns 0 on success

Returns -1 otherwise

Precondition

`FSInit` is called successfully

Side Effects

The current working directory will be changed

Example

```
char path[] = "\ONE\TWO\THREE";
char path2[] = "..\..\..";
// Change to directory THREE
if (FSchdir (path))
{
       // Error
       ...
}
// Change back to the root
// The first .. will change from THREE to TWO.
// The second .. will change from TWO to ONE.
// The third .. will change from ONE to the root
// Calling this function with a path of "\" would
// also change to the root
if (FSchdir (path2))
{
       // Error
...
}
```

FSrmdir

The FSrmdir function will delete a directory based on the path string passed in by the user. Directory names in the path string must be no more than 8 ASCII characters. Directory names are delimited by the backslash character. A dot (.) as a directory name will access the current directory. Two dots (..) will access the previous directory. The user can specify whether subdirectories and files in the directory should be deleted.

Syntax

```
int FSrmdir (char * path, unsigned char rmsubdirs);
```

Parameters

path	–	The path of the directory to delete	
rmsubdirs	–	TRUE	All subdirectories and files will be deleted
		FALSE	The dir will only be deleted if it is empty

Return Values

Returns 0 on success

Returns -1 otherwise

Precondition

FSInit is called successfully

Side Effects

None

Example

```
char path[] = "\ONE\TWO\THREE\FOUR";
// Delete directory FOUR if it exists
if (FSrmdir (path, FALSE))
{
       // Error
       // Maybe there's something in FOUR
       // Try to delete all contents
       if (FSrmdir (path, TRUE))
       {
              // Error
              // Maybe FOUR just doesn't exist
              ...
       }
       ...
}
```

FSgetcwd

The FSgetcwd function will return the path of the current working directory, copied into a char array passed in by the user. If the user passes in a NULL Array Pointer, a default array of size 10 bytes will be used. If the current working directory name is too large for the array, the number of characters that fit in the array will be copied into it, starting at the beginning of the path.

Syntax

```
char * FSgetcwd (char * path, int numchars);
```

Parameters

path	–	The path to copy the current working dir name to
numchars	–	The number of characters that can be copied into the path

Return Values

Returns a pointer to the current working directory name string

Precondition

FSInit is called successfully

Side Effects

The default name string will be overwritten if the function is called with a NULL Path Pointer.

Example

```
char dir[] = "\ONE\TWO\THREE\FOUR";
char buffer[40];
char * pointer;
char * pointer2;

FSmkdir (dir);
FSchdir (dir);
// Our current working directory is now
// \ONE\TWO\THREE\FOUR
// Copy the first 40 characters of the path name into
// buffer
pointer = FSgetcwd (path, 40);
// Get a pointer to a string with the first 10 chars of // the path name
pointer2 = FSgetcwd (NULL, NULL);
```

FindFirst

The FindFirst function will locate the first file in the current working directory that matches the naming and attribute criteria passed in by the user and copy its parameters into a structure passed in by the user.

Syntax

```
int FindFirst (const char * fileName, unsigned int attr, SearchRec * rec);
```

Parameters

fileName – The name the file must correspond to

TABLE B-1: FILE NAME FORMATS

Format	Function
.	Find any file or directory
FILENAME.EXT	Find a file named FILENAME.EXT
FILENAME.*	Find a file with name FILENAME and any extension
*.EXT	File a file with any name and the extension EXT
*	Find any directory
ADIRNAME	Find a directory named ADIRNAME
FI*.E*	Find any file with name starting with FI- and extension starting with E-

attr – The attributes that the file may have

TABLE B-2: ATTRIBUTE VALUES

Attribute	Value	Function
ATTR_READ_ONLY	01h	File may have read-only attribute
ATTR_HIDDEN	02h	File may have hidden attribute
ATTR_SYSTEM	04h	File may be a system file
ATTR_VOLUME	08h	File may be a volume label
ATTR_DIRECTORY	10h	File may be a directory
ATTR_ARCHIVE	20h	File may have archive attribute
ATTR_MASK	3Fh	File may have any attributes

rec – Pointer to the structure that will contain file information if a file is found.

Return Values

Returns 0 on success

Returns -1L otherwise

Precondition

FSInit is called successfully

Side Effects

The search criteria in the `SearchRec` structure from the last call of `FindFirst` or `FindFirstpgm` will be lost.

Example

```
SearchRec file;
unsigned char attributes = ATTR_HIDDEN | ATTR_SYSTEM | ATTR_READ_ONLY | ATTR_VOLUME
| ATTR_ARCHIVE;

char name[] = "FILE*.*";

// Find any non-directory file that has a name starting
// with the letters FILE-
if (FindFirst (name, attributes, &file))
{
       // Error
       ...
}
// Delete the file we found if its empty
if( file.size == 0)
       FSremove (file.filename);
```

FindFirstpgm

The FindFirstpgm function performs the same function as the FindFirst function, but accepts a file name string passed into the function in ROM. This function will only be needed on the PIC18 architecture.

Syntax

```
int FindFirstpgm (const rom char * fileName, unsigned int attr, SearchRec * rec);
```

Parameters

fileName	–	The name the file must correspond to
attr	–	The attributes that the file may have
rec	–	Pointer to the structure that will contain file information if a file is found

Return Values

Returns 0 on success

Returns -1L otherwise

Precondition

FSInit is called successfully

Side Effects

The search criteria from the last call of FindFirst or FindFirstpgm will be lost.

Example

```
SearchRec file;
unsigned char attributes = ATTR_MASK;

// Find any file that has a name starting with the
// letters FILE-
if (FindFirstpgm ("FILE*.*", attributes, &file))
{
       // Error
       ...
}
// Delete the file we found if its empty
if( file.size == 0)
       FSremove (file.filename);
```

FindNext

The FindNext function will locate the next file in the current working directory that matches the naming and attribute criteria specified by the last call of FindFirst or FindFirstpgm on the SearchRec object that is passed into the function.

Syntax

```
int FindNext (SearchRec * rec);
```

Parameters

rec – Pointer to the structure that will contain file information if a file is found

Return Values

Returns 0 on success

Returns -1L otherwise

Precondition

FindFirst or FindFirstpgm is called successfully

Side Effects

None

Example

```
SearchRec file;
unsigned char attributes = ATTR_MASK;
char name[] = "*.*";

// Find any file or directory
if (FindFirst (name, attributes, &file))
{
       // Error
       ...
}
// Find the next file or directory
if( FindNext (&file))
{
       // Error
       ...
}
```

FSfprintf

The FSfprintf function will write a formatted string to a file.

Syntax

```
int FSfprintf (FSFILE *fptr, const char * fmt, ...)
```

Parameters

fptr	–	Pointer to a file to write to
fmt	–	The string to write (specified in ROM)
...	–	Format specifiers

Return Values

Returns the count of characters written on success

Returns -1L otherwise

Precondition

The file to be written to has been opened successfully.

Side Effects

None

Remarks

The FSfprintf function formats output, passing the characters to the specified stream. The format string is processed one character at a time and the characters are output as they appear in the format string, except for format specifiers. A format specifier is indicated in the format string by a percent sign, %; following that, a well-formed format specifier has the following components. Except for the conversion specifier, all format specifiers are optional.

1. Flag Characters
   - '-' – The result of the format conversion will be left justified.
   - '+' – By default, a sign in only prefixed to a signed conversion if the result is negative. Including this flag will prefix a '+' sign if the result of a signed conversion is positive.
   - '0' – This flag will prefix leading zeros to the result of a conversion until the result fills the field width. If the '-' flag is specified, the '0' flag will be ignored. If a precision is specified, the '0' flag will be ignored.
   - ' ' – The space flag will prefix a space to the result of a signed conversion if the result is positive. If the space flag and the '+' flag are both specified, the space flag will be ignored.
   - '#' – This flag will present the "alternate form" of a conversion. For the o conversion, the result will be increased in precision such that the first digit of the result will be 0. For the x conversion, a 0x will be prefixed to the result. For the X conversion, a 0X will be prefixed to the result. For the b conversion, a 0b will be prefixed to the result. For the B conversion, a 0B will be prefixed to the result.
2. Field Width

   The field width specifier follows the flag specifiers. It determines the minimum number of characters that result from a conversion. If the result is shorter than the field width, the result is padded with leading spaces until it has the same size as the field width. If the '0' flag specifier is used, the result will be padded with leading zeros. If the '-' flag specifier is used, the result will be left justified, and will be followed by trailing spaces.

   The field width may be specified as an asterisk character, *. In this case, a 16-bit argument will be read from the list of format specifiers to specify the field width. If the value is negative, it is as if the '-' flag is specified, followed by a positive field width.

3. Field Precision

   The field precision specifies the minimum number of digits present in the converted value for integer conversions, or the maximum number of characters in the converted value for a string conversion. It is indicated by a period (.) followed by an integer value or by an asterisk (*). If the field precision is not specified, the default precision of 1 will be used.

   If the field precision is specified by an asterisk character, a 16-bit argument will be read from the list of format specifiers to specify the field precision.

4. Size Specification

   The size specification applies to any integer conversion specifier or pointer conversion specifier. The integer conversion specifiers are as follows: the size specifler will determine what type of argument is read from the format specifier list. For the n conversion, the size specifier for each pointer type corresponds to the specifier for that data type. So to convert something to a Long Long Pointer, you would use the specifier for a long long data type with the n conversion.

TABLE B-3: SIZE SPECIFIERS

Argument Type	C18	C30
signed char, unsigned char	hh	hh
short int, unsigned short int	h	h
short long, unsigned short long	H	—
intmax_t, uintmax_t	j (32-bit)	j (64-bit)
long, unsigned long	1	1
long long, unsigned long long	—	q
size_t	z	z
sizerom_t	Z	—
ptrdiff_t	t	t
ptrdiffrom_t	T	—

5. Conversion Specifiers
   - c – The int argument will be converted to an unsigned char value and the character represented by that value will be written.
   - d,i – The int argument is formatted as a signed decimal.
   - o – The unsigned int argument will be converted to an unsigned octal.
   - u – The unsigned int argument will be converted to an unsigned decimal.
   - b, B – The unsigned int argument will be converted to an unsigned binary.
   - x – The unsigned int argument will be converted to and unsigned hexadecimal. The characters, a, b, c, d, e and f, will be used to represent the decimal numbers 10-15.
   - X – The unsigned int argument will be converted to an unsigned hexadecimal. The characters, A, B, C, D, E and F, will be used to represent the decimal numbers 10-15.
   - s – Characters from the data memory array of char argument are written until either a terminating '\0' character is seen ('\0' is not written) or the number of chars written is equal to the precision.
   - S – Characters from the program memory array of char arguments are written until either a terminating '\0' character is seen ('\0' is not written) or the number of chars written is equal to the precision. In C18, when outputting a far rom char *, make sure to use the H size specifier (%HS).
   - p – The pointer to void the (data or program memory) argument is converted to an equivalent size unsigned integer type and that value is processed as if the x conversion operator had been specified. In C18, if the H size specifier is present, the pointer is a 24-bit pointer; otherwise, it is a 16-bit pointer.
   - P – The pointer to void the (data or program memory) argument is converted to an equivalent size unsigned integer type and that value is processed as if the X conversion operator had been specified. In C18, if the H size specifier is present, the pointer is a 24-bit pointer; otherwise, it is a 16-bit pointer.
   - n – The number of characters written so far shall be stored in the location referenced by the argument, which is a pointer to an integer type in data memory. The size of the integer type is determined by the size specifier present for the conversion, or a 16-bit integer if no specifier is present.
   - % – A literal percent sign will be written.

If the conversion specifier is invalid, the behavior is undefined.

Example

```
unsigned long long hex = 0x123456789ABCDEF0;
FSfprintf (fileptr, "This is a hex
number:%#20X%c%c", 0x12ef, 0x0D, 0x0A);
FSfprintf (fileptr, "This is a bin
number:%#20b%c%c", 0x12ef, 0x0D, 0x0A);
FSfprintf (fileptr, "%#26.22qx", hex);


// Output:
// This is a hex number:              0x12EF
// This is a bin number:  0b0001001011101111
//     0x0000123456789ABCDEF0
```

APPENDIX C: LIBRARY DIRECTORY

TABLE C-1: LIBRARY DIRECTORY ORGANIZATION(1)

Directory	Content
MDD File System-PIC18-CF-DynMem-UserDefClock	Sample project for PIC18 using the CompactFlash® interface, user-defined clock values and dynamic file object allocation
MDD File System-PIC24-SD-StatMem-RTCC	Sample project for PIC24F using the SD card interface, the Real-Time Clock and Calendar (RTCC) module and static file object allocation
Microchip\MDD File System	C files for MDD file system
Microchip\PIC18 salloc	C file for PIC18 dynamic memory allocation
Microchip\Include	Contains miscellaneous include files, including a standard data type definition file
Microchip\Include\MDD File System	Include files for MDD File System
Microchip\Include\PIC18 salloc	Include file for C18 dynamic memory allocation

Note 1: These directories are relative to the installation directory.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
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