EFSL

Embedded FileSystems Library

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Contents

1 Preface

1.1 Project aims

The EFSL project aims to create a library for filesystems, to be used on various embedded systems. Currently we support the Microsoft FAT filesystem family. It is our intention to create pure ANSI C code that compiles on anything that bears the name 'C compiler'. We don't make assumptions about endianness or how the memory alignement is arranged on your architecture.

Adding code for your specific hardware is straightforward, just add code that fetches or writes a 512 byte sector, and the library will do the rest. Existing code can offcourse be used, own code is only required when you have hardware for which no target exists.

1.2 Project status

Efsl currently supports FAT12, FAT16 and FAT32. Read and write has been tested and is stable. Efsl runs on PC (GNU/Linux, development enviroment), TMS C6000 DSP's from Texas instruments, and ATMega's from Atmel. You can use this code with as little as 1.5 kilobyte RAM, however if you have more at your disposal, an infinite amount can be used as cache memory. The more memory you commit, the better the performance will be.

1.3 License

This project is released under the Lesser General Public license, which means that you may use the library and it's sourcecode for any purpose you want, that you may link with it and use it commercially, but that ANY change to the code must be released under the same license. That means, if you add hardware suport, you share it, so that the community may benefit from access to all kinds of hardware.

2 Getting started

2.1 On Linux (file)

Debugging efsl on embedded devices is a rather hard job, because you can't just printf debug strings or watch memory maps easily. Because of that, core development has been performed under the Linux operating system. Under Linux, efsl can be compiled as library and used as a userspace filesystem handler. On Unix- style operating system (like Linux), all devices (usb stick, disc, ...) can be seen as a file, and as such been opened by efsl.

In the following section, we will explain how to get started using efsl as userspace filesystem handler. However, please note that the main focus for efsl is to support "embedded systems", which usually don't even have 1% of the memory you have on a PC. Accessing files on a FAT-filesystem with efsl will be much slower than when accessing these files with the Linux FAT kernel modules.

2.1.1 Download & Compile

Let's get started:

1. Get the latest release of efsl on http://www.efsl.be/ and put it in your homedir
2. Unpack the library (tar xvfj efsl-version.tar.gz)
3. Get inside the directory (cd ∼/efsl)
4. Create a symlink from Makefile-LINUX to Makefile (ln -s Makefile-LINUX Makefile)
5. Copy conf/config-sample-linux.h to conf/config.h (cp conf/config-sample-linux.h conf/config.h)
6. Compile the library (make lib)
7. Find the compiled filesystem library (libefsl.a) in the current directory

If you got any errors with the steps above, please check that that you have the following packages installed: tar, gcc, libgcc, binutils & make.

2.1.2 Example

Since efsl itself is only a library, it's not supposed to do anything out of the box, than just compile. To get started, we'll show here a small example program that opens a file on a disc/usb-stick/floppy that contains a FAT-filesystem and prints it's content to stdout.

First, create a new directory in which you put the compiled efsl-library (libefsl.a) and create a new file called linuxtest.c containing:

```
1  #include <stdio.h>
2  #include <efs.h>
3
4  int main(void)
5  {
6      EmbeddedFileSystem efs;
7      EmbeddedFile file;
8      unsigned short i,e;
9      char buf[512];
10
11     if(efs_init(&efs,"/dev/sda")!=0){
12         printf("Could␣not␣open␣filesystem.\n");
13         return(-1);
14     }
15
16     if(file_fopen(&file,&efs.myFs,"group",'r')!=0){
17         printf("Could␣not␣open␣file.\n");
18         return(-2);
19     }
20
21     while(e=file_read(&file,512,buf)){
22         for(i=0;i<e;i++)
23         printf("\%c",buf[i]);
24     }
25
26     return(0);
27 }
```

Some extra information on the code above:

- Line 1-2: The headerfiles for stdio (used for printf) and efsl are included. When using the basic efsl functions, `efs.h` is the only headerfile of the efsl library that needs to be included.
- Line 6: The object efs is created, this object will contain information about the hardware layer, the partition table and the disc.
- Line 7: The object file is created, this object will contain information about the file that we will open on the efs-object.
- Line 9: A buffer of 512 bytes is allocated. This buffer will be filled by fread with data.
- Line 11-14: Call of `efs_init`, which will initialize the efs-object. To this function we pass:
    1. A pointer to the efs-object.
    2. A pointer to the file that contains the partition table / file system (in this example, we select a device as file).

If this function returns 0, it means that a valid fat partition is found on the device given. If no valid fat-filesystem is found, or the file does not exist, the function returns a negative value. In this example we then print an error message and quit.

- Line 16-19: Call of `file_fopen()` , which will initialize the file-object. To this function we pass:

  1. A pointer to the file-object.
  2. A pointer to the filesystem-object.
  3. A pointer to the filename.
  4. A char containing the the mode (read, write, append).

  If this function returns 0, it means the file has successfully been opened for reading / writing / apending. If the file could not be opened, a negative value is returned.

- Line 21-24: Call of `file_read()` , which will read a given value of bytes (in this example 512) from a file and put it's content into the buffer passed (in this example called buf). This function returns the amount of bytes read, so the while-loop will be executed as long as there are bytes left in the file. The code inside the while-loop will print all characters in the buffer.

2.1.3 Testing

So now let's test the program:

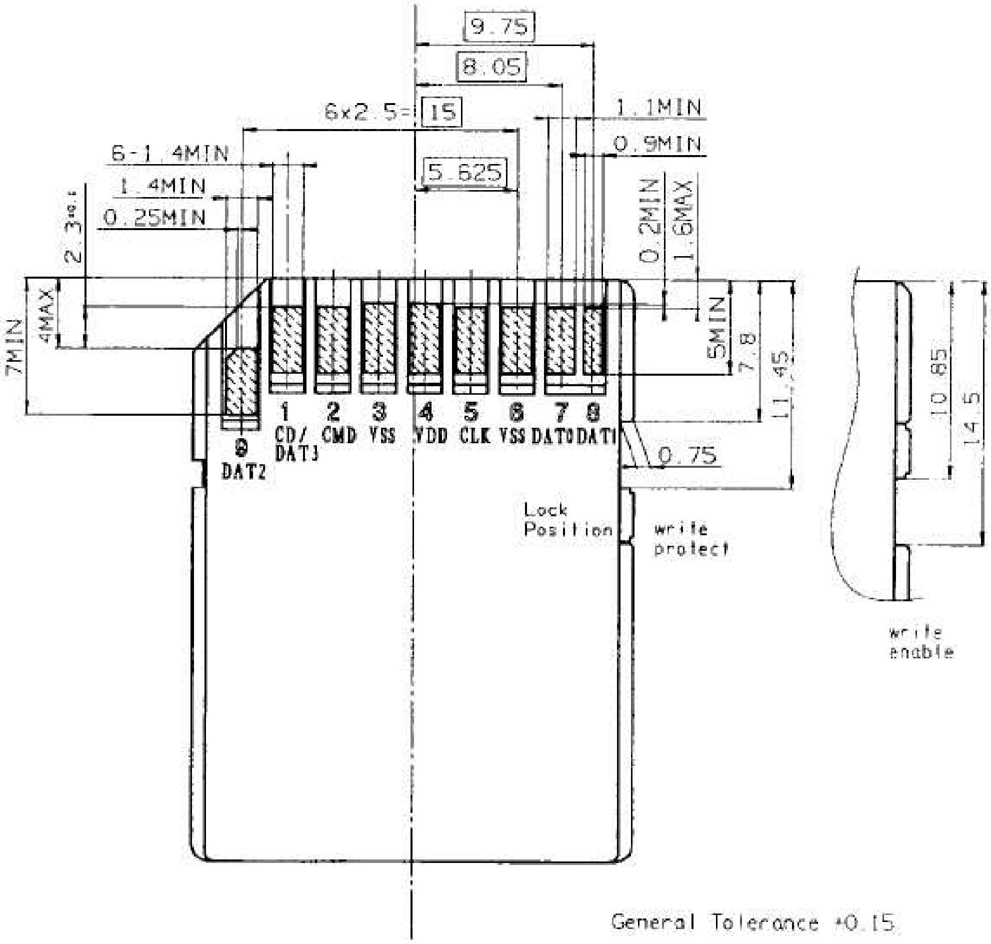
1. Compile the program (gcc -I/home/user/efsl/inc/ -I/home/user/efsl/conf -o linuxtest linuxtest.c -L./ -lefsl).
2. Insert a usb-disc, floppy, mp3-stick, ... with a valid fat-filesystem on it.
3. Mount the device, copy the file /etc/group on it's root dir & umount it.
4. Check that you have permission to access the device (chown username /dev/sda*)
5. Run the program (./linuxtest)

2.2 On AVR (SD-Card)

This section describes how to implement Efsl on a AVR μC connected to an SD-Card (SPI). For getting efsl to compile, the avr-gcc compiler and avr-libc library are requered. On Windows you should install WinAVR (http://winavr.sourceforge.net/), on Linux you can install the packages seperately (http://www.nongnu.org/avr-libc/).

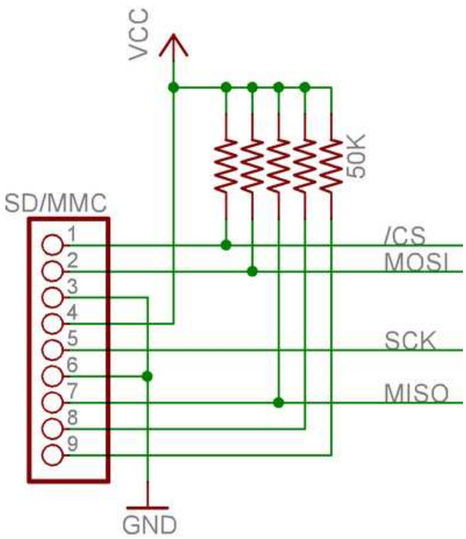
2.2.1 Hardware

First, you need set up a prototype in which you connect the CD, CMD, DAT0 & CLK lines from the SD-Card to /CS, MOSI, MISO & SCK from the Atmega.



Connect the following lines on the SD-card:

- Pin 9 (DAT2) - NC
  (or pull-up to 3.3V)
- Pin 1 (CD) - Any pin on the Atmega128
- Pin 2 (CMD) - MOSI
  (pin 12 on the Atmega128)
- Pin 3 (Vss) - GND
- Pin 4 (Vdd) - +3.3V
- Pin 5 (CLK) - SCK
  (pin 11 on the Atmega128)
- Pin 6 (Vss) - GND
- Pin 7 (DAT0) - MISO
  (pin 12 on the Atmega128)
- Pin 8 (DAT1) - NC
  (or pull-up to 3.3V)



Remark: this schematic includes pull-up's to 3.3V, which can be left off.

Remark 1: Make sure that your μC is running on 3,3V, so you don't damage your SD-Card.

Remark 2: CD is currently static set to PB0, but will become variable in future releases.

2.2.2 Download & Compile

Let's get started:

1. Get the latest release of efsl on http://www.efsl.be/
2. Unpack the library (on Windows, you can use WinACE or WinRAR)
3. Copy Makefile-AVR to Makefile
4. Copy conf/config-sample-avr.h to conf/config.h
5. Compile the library (`make lib`)

Now you should have libefsl.a in the efsl directory.

2.2.3 Example

Since Efsl itself is only a library, it's not supposed to do anything out of the box, than just compile. To get started, we'll show here a small example program that opens an existing file and writes the content to a new file.

First, create a new directory in which you put the compiled efsl-library (libefsl.a) and create a new file called avrtest.c containing:

```
1  #include <efs.h>
2
3  void hang(void);
4
5  void main(void)
6  {
7      EmbeddedFileSystem efs;
8      EmbeddedFile file_r, file_w;
9      unsigned short i,e;
10     char buf[512];
11
12     if(efs_init(&efs,0)!=0){
13         hang();
14     }
15
16     if(file_fopen(&file_r,&efs.myFs,"orig.txt",'r')!=0){
17         hang();
18     }
19
20     if(file_fopen(&file_w,&efs.myFs,"copy.txt",'w')!=0){
21         hang();
22     }
23
24     while(e=file_read(&file_r,512,buf)){
25         file_write(&file_w,e,buf);
26     }
27
28     file_fclose(&file_r);
29     file_fclose(&file_w);
30
31     fs_umount(&efs.myFs);
32
33     hang();
34 }
35
36 void hang(void)
37 {
38     while((1))
39         _NOP();
40 }
```

Some extra information on the code above:

- Line 1: The headerfile for efsl is included here. When using the basic efsl functions, efs.h is the only headerfile on the efsl library that needs to be included.

- Line 7: The object efs is created, this object will contain information about the hardware layer, the partition table and the disc.
- Line 8: The objects `file_r` and `file_w` are created, these objects will contain information about the files that we will open on the efs-object.
- Line 9: A buffer of 512 bytes is allocated. This buffer will be used for reading and writing blocks of data.
- Line 12: Call of `efs_init()` , which will initialize the efs-object. To this function we pass:

  1. A pointer to the efs-object.
  2. A pointer to the file that contains the partition table / file system (in this example, we select a device as file).

  If this function returns 0, it means that a valid fat partition is found on the SD-card connected. If no valid fat-filesystem is found, or the file does not exist, the function returns a negative value. In this example we then go to an infinite loop to prevent the program to continue.
- Line 16 & 20: Call of `file_fopen()` , which will initialize the file-objects. To this function we pass:

  1. A pointer to the file-object.
  2. A pointer to the filesystem-object.
  3. A pointer to the filename.
  4. A char containing the the mode (read, write, append).

  If this function returns 0, it means the file has successfully been opened for reading / writing / apending. If the file could not be opened (because for example a file already exists), a negative value is returned.
- Line 24: Call of `file_read()` , which will read a given value of bytes (in this example 512) from a file and put it's content into the buffer passed (in this example called buf). This function returns the amount of bytes read, so the while-loop will be executed as long as there are bytes left in the file.
- Line 25: Call of `file_write()` , which will write a given value of bytes (in this example, the amount of bytes that was read by `file_read()`) from the buffer passed to a file. This function returns the amount of bytes written.
- Line 28 & 29: Call of `file_fclose()` , which will close the file-objects.
- Line 31: Call of `fs_umount()` , which will write all buffers to the the SD-card.

2.2.4 Testing

So now let's test the program:

1. Make sure that your directory contains both the example from above called `avrtest.c` and the library `libefsl.a`.
2. Compile the program:
   - On Linux (with avr-gcc): avr-gcc -I/home/user/efsl/inc/ -I/home/user/efsl/conf -ffreestanding -mmcu=atmega128 -Os -o avrtest.o avrtest.c -L./ -lefsl
   - On Windows (with WinAVR): avr-gcc -Ic:\efsl\inc -Ic:\efsl\conf -ffreestanding -mmcu=atmega128 -Os -o avrtest.o avrtest.c -L.\ -lefsl
3. Generate a hexfile (avr-objcopy -j .text -j .data -O ihex avrtest.o avrtest.hex)
4. Connect an SD-card to your Atmega128 with a file called `orig.txt` on it.
5. Flash the hex file into your μC.
   - On Linux: avrdude -P /dev/ttyUSB0 -c stk500 -p m128 -Uflash:w:avrtest.hex
   - On Windows: use Atmel AVR-Studio
6. Reset your μC and wait some time (depending on how big the file `orig.txt` is).
7. Disconnect the SD-card, so you can put it in your cardreader and find out if the file `orig.txt` is copied to `copy.txt`.

2.3 On DSP (SD-Card)

This section will tell you everything you need to know to start using the embedded filesystems library on a TMS Digital Signal Processor from Texas Instruments. The only thing that is required is that you have a McBSP port available, and that your DSP support CLOCKSTOP mode, which is required to connect a SPI compatible device.

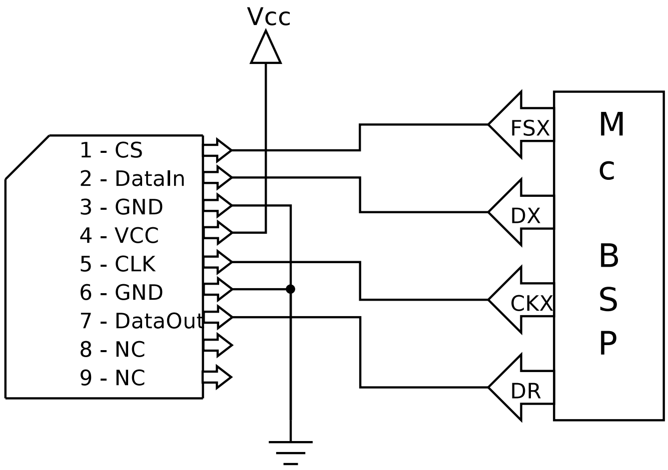
There are special DSP's from TI which have a special MMC/SD card controller, if you want to use this special interface you will have to create a hardware endpoint for it. This section only describes connecting an SD card to a normal McBSP port, since every TI DSP has at least one of them.

2.3.1 Hardware

Connecting the SD card to the McBSP is straightforward, you will have to make 4 data related connections, Vcc and ground, resulting in a 6 wire interface.

SD Card Interface			McBSP Interface	
1	CS	Chip select	FSX	Frame Sync Transmit
2	MOSI	Master out Slave In	DX	Data transmit
3	GND	Supply Ground		
4	Vcc	Supply voltage (3.3 Volt)		
5	Clk	Clock	CLKX	Clock Transmit
6	GND	Supply ground		
7	MISO	Master in Slave out	DR	Data receive
8	NC	Not connected		
9	NC	Not connected		

You can optionally pull the DataIn and DataOut lines up to Vcc with a 10 kiloohm resistor, but we found that this was not required for operation.



The frame sync from the McBSP port is used to select the card whenever a databyte has to be transferred, it is connected to the chip select of the SD card. The DX and DR pins are connected to the SDcard's DataIn and DataOut lines respectively. Finally the McBSP will have to generate a clock for the SDcard so that it can perform operations, this is accomplished by connecting the clock transmit line of the McBSP port to the CLK pin of the SDCard.

2.3.2 McBSP configuration

McBSP Register Explanations			
SPCR			Serial Port Control Register
Name	Bit	Value	Value `(0x00001800 | 0x00410001)`
RRST	`0`	`1b`	The serial port receiver is enabled
XRST	`16`	`1b`	The serial port transmitter is enabled
CLKSTP	`12:11`	`11b`	Clock starts on falling edge without delay(see CLKXM)
GRST	`22`	`1b`	Sample rate genrater is pulled out of reset
PCR			Pin Control Register
Name	Bit	Value	Value `0x00000A0C`
CLKXP	`1`	`0b`	Transmit data on the rising edge ofthe clock
FSXP	`3`	`1b`	Frame Sync (Chip select on SD card) is active low
CLKXM	`9`	`1b`	McBSP is a master in SPI mode and generates the clock based on the sample rate generator
FSXM	`10`	`1b`	Frame sync is determined by tge sample rate generator
RCR/XCR			Receive/Transmit Control Register
Name	Bit	Value	Value `0x00010000`
RWDLEN	`7:5`	`000b`	Receive element is 8 bits (1byte) large
XDATDLY	`17:16`	`01b`	1 bit data delay (after frame sync)
SRGR			Sample Rate Genrator
Name	Bit	Value	Value `0x20000002`
CLKSM	`29`	`1b`	The sample rate generator clock is derived from the internal clock
FSGM	`28`	`0b`	The transmit frame sync signal is genrated on every DXR to XSR copy
CLKGDV	`7:0`	`0x02h`	The clock divider

3 User Notes

3.1 Date and time support

The EFSL library supports setting and updating all date and time fields supported by the filesystem. In order to do this the library must know the current time and date at all times. Since it has to run everywhere, there is no standard mechanism to get the date/time, and some systems do not have a clock.

With default configuration there is no date or time support, you have to turn it on manually in the configuration file `config.h` . You will have to uncomment the field named `#define DATE_TIME_SUPPORT` , in order to activate date/time support.

Furthermore you will have to provide the library with date and time information. A set of defines was used for this, when date/time support is not enabled, the defines automatically return `0x0000` for all time and date fields, so there is no performance suffer when you do not need date/time support. If you do need it you will have to provide 6 functions to the library that will tell it the time. Since these functions may get called often, it is highly recommended that you cache the time result somewhere so you can serve the library directly from ram. If you do not do this and your RTC request take a lot of time, you may suffer large losses in read or write operations depending on your hardware.

The six functions are:

- `euint16 efsl_getYear(void)`
- `euint8 efsl_getMonth(void)`
- `euint8 efsl_getDay(void)`
- `euint8 efsl_getHour(void)`
- `euint8 efsl_getMinute(void)`
- `euint8 efsl_getSecond(void)`

Internally the library will recalculate these numbers to match the filesystem that is currently in use.

3.2 efs_init

Purpose

Initializes the hardware and the software layer.

Prototype

`esint8 efs_init(EmbeddedFileSystem *efs, eint8* opts);`

Arguments

Objects passed to `efs_init` :

- `efs` : empty EmbeddedFileSystem object
- `opts` : character string containing options, depending on what interface you are using:
  - Linux: opts points to the path to the device
  - AVR: opts points to the card enable pin (TODO)
  - DSP: opts points to the card enable memory address (TODO)

Return value

Returns 0 if no errors are detected.

Returns non-zero if a low-level error is detected:

- Returns -1 if the interface could not be initialized.
- Returns -2 if the filesystem could not be initialized.

Example

```
#include "efs.h"

void main(void)
{
    EmbeddedFileSystem efsl;
    esint8 ret;

    DBG((TXT("Will init efsl now.\n")));
    ret=efs_init(&efsl,"/dev/sda");
    if(ret==0)
        DBG((TXT("Filesystem correctly initialized.\n")));
    else
        DBG((TXT("Could not initialize filesystem (err \%d).\n"),ret));
}
```

3.3 file_fopen

Purpose

Searches for file and initializes the file object.

Prototype

```
esint8 file_fopen(File *file, FileSystem *fs, eint8 *filename, eint8
mode);
```

Arguments

Objects passed to `file_fopen` :

- `file` : pointer to a File object
- `fs` : pointer to the FileSystem object
- `filename` : pointer to the path + filename
- `mode` : mode of opening, this can be:
  - 'r': open file for reading
  - 'w': open file for writing
  - 'a': open file for appending

Return value

Returns 0 if no errors are detected.

Returns non-zero if an error is detected:

- Returns -1 if the file you are trying to open for reading could not be found.
- Returns -2 if the file you are trying to open for writing already exists.
- Returns -3 if no free spot could be found for writing or appending.
- Returns -4 if mode is not correct (if it is not 'r', 'w' or 'a').

Example

```
#include "efs.h"

void main(void)
{
    EmbeddedFileSystem efsl;
    File file_read, file_write;

```

```
        /* Initialize efsl */
        DBG((TXT("Will init efsl now.\n")));
        if(efs_init(&efsl,"/dev/sda")!=0){
            DBG((TXT("Could not initialize filesystem (err \%d).\n"),ret));
            exit(-1);
        }
        DBG((TXT("Filesystem correctly initialized.\n")));

        /* Open file for reading */
        if(file_fopen(&file_read, &efsl.myFs, "read.txt", 'r')!=0){
            DBG((TXT("Could not open file for reading.\n")));
            exit(-1);
        }
        DBG((TXT("File opened for reading.\n")));

        /* Open file for writing */
        if(file_fopen(&file_write, &efsl.myFs, "write.txt", 'w')!=0){
            DBG((TXT("Could not open file for writing.\n")));
            exit(-2);
        }
        DBG((TXT("File opened for writing.\n")));

        /* Close files & filesystem */
        fclose(&file_read);
        fclose(&file_write);
        fs_umount(&efs.myFs);
    }
```

3.4 file_fclose

Purpose

Updates file records and closes file object.

Prototype

`esint8 file_fclose(File *file);`

Arguments

Objects passed to `file_fopen` :

- `file` : pointer to a File object

Return value

Returns 0 if no errors are detected.

Returns non-zero if an error is detected.

Example

```c
#include "efs.h"

void main(void)
{
    EmbeddedFileSystem efsl;
    File file;

    /* Initialize efsl */
    DBG((TXT("Will init efsl now.\n")));
    if(efs_init(&efsl,"/dev/sda")!=0){
        DBG((TXT("Could not initialize filesystem (err \%d).\n"),ret));
        exit(-1);
    }
    DBG((TXT("Filesystem correctly initialized.\n")));

    /* Open file for reading */
    if(file_fopen(&file, &efsl.myFs, "read.txt", 'r')!=0){
        DBG((TXT("Could not open file for reading.\n")));
        exit(-1);
    }
    DBG((TXT("File opened for reading.\n")));

    /* Close file & filesystem */
    fclose(&file);
```

```
        fs_umount(&efs.myFs);
    }
```

3.5 file_read

Purpose

Reads a file and puts it's content in a buffer.

Prototype

`euint32 file_read (File *file, euint32 size, euint8 *buf);`

Arguments

Objects passed to `file_read` :

- `file` : pointer to a File object
- `size` : amount of bytes you want to read / put in buf
- `buf` : pointer to the buffer you want to store the data

Return value

Returns the amount of bytes read.

Example

```c
#include "efs.h"

void main(void)
{
    EmbeddedFileSystem efsl;
    euint8 buffer[512];
    euint16 e, f;
    File file;

    /* Initialize efsl */
    DBG((TXT("Will init efsl now.\n")));
    if(efs_init(&efsl,"/dev/sda")!=0){
        DBG((TXT("Could not initialize filesystem (err \%d).\n"),ret));
        exit(-1);
    }
    DBG((TXT("Filesystem correctly initialized.\n")));

    /* Open file for reading */
    if(file_fopen(&file, &efsl.myFs, "read.txt", 'r')!=0){
        DBG((TXT("Could not open file for reading.\n")));
        exit(-1);
    }
    DBG((TXT("File opened for reading.\n")));
```

```
        /* Read file and print content */
        while((e=file_read(&file,512,buffer))){
            for(f=0;f<e;f++)
                DBG((TXT("\%c"),buffer[f]));
        }

        /* Close file & filesystem */
        fclose(&file);
        fs_umount(&efs.myFs);
    }
```

3.6 file_write

Purpose

Reads a file and puts it's content in a buffer.

Prototype

`euint32 file_write(File *file, euint32 size, euint8 *buf)`

Arguments

Objects passed to `file_read` :

- `file` : pointer to a File object
- `size` : amount of bytes you want to write
- `buf` : pointer to the buffer you want to write the data from

Return value

Returns the amount of bytes written.

Example

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

void main(void)
{
    EmbeddedFileSystem efsl;
    euint8 *buffer = "This is a test.\n";
    euint16 e=0;
    File file;

    /* Initialize efsl */
    DBG((TXT("Will init efsl now.\n")));
    if(efs_init(&efsl,"/dev/sda")!=0){
        DBG((TXT("Could not initialize filesystem (err %d).\n"),ret));
        exit(-1);
    }
    DBG((TXT("Filesystem correctly initialized.\n")));

    /* Open file for writing */
    if(file_fopen(&file, &efsl.myFs, "write.txt", 'w')!=0){
        DBG((TXT("Could not open file for writing.\n")));
        exit(-1);
    }
```

```
        DBG((TXT("File opened for reading.\n")));

        /* Write buffer to file */
        if( file_write(&file,strlen(buffer),buffer) == strlen(buffer) )
            DBG((TXT("File written.\n")));
        else
            DBG((TXT("Could not write file.\n")));

        /* Close file & filesystem */
        fclose(&file);
        fs_umount(&efs.myFs);
    }
```

3.7 mkdir

Purpose

Creates a new directory.

Prototype

`esint8 mkdir(FileSystem *fs,eint8* dirname);`

Arguments

Objects passed to `mkdir` :

- `fs` : pointer to the FileSystem object
- `dir` : pointer to the path + name of the new directory

Return value

Returns 0 if no errors are detected.

Returns non-zero if an error is detected:

- Returns -1 if the directory already exists.
- Returns -2 if the path is incorrect (parent directory does not exists).
- Returns -3 if no free space is available to create the directory.

Example

```
#include "efs.h"

void main(void)
{
    EmbeddedFileSystem efsl;

    /* Initialize efsl */
    DBG((TXT("Will init efsl now.\n")));
    if(efs_init(&efsl,"/dev/sda")!=0){
        DBG((TXT("Could not initialize filesystem (err %d).\n"),ret));
        exit(-1);
    }
    DBG((TXT("Filesystem correctly initialized.\n")));

    /* Create new directories */
    if(mkdir(&efs.myFs,"dir1")==0){
        mkdir(&efs.myFs,"dir1/subdir1");
```

```
            mkdir(&efs.myFs,"dir1/subdir2");
            mkdir(&efs.myFs,"dir1/subdir3");
        }

        /* Close filesystem */
        fs_umount(&efs.myFs);
}
```

4 Developer notes

4.1 Integer types

Standard C data types have the annoying tendency to have different sizes on difference compilers and platforms. Therefore we have created 9 new types that are used everywhere throughout the library. When you implement your platform you should check if any of the existing one matches your hardware, or create a new one.

Here's an overwiew:

Type	Size	Signedness
`eint8`	1 byte	default to platform
`esint8`	1 byte	signed
`euint8`	1 byte	unsigned
`eint16`	2 bytes	default to platform
`esint16`	2 bytes	signed
`euint16`	2 bytes	unsigned
`eint32`	4 bytes	default to platform
`esint32`	4 bytes	signed
`euint32`	4 bytes	unsigned

You will find the relevant code in the file types.h in the directory inc/ .

4.2 Debugging

Since debugging on every device is completely different, a DBG macro is implemented. On Linux for example, this macro will print the string given to the screen (using printf). On AVR, it will send debug strings through the UART. For compatibilty with other devices, it is necessary that you always use the DBG-macro instead of a device-specific debugging commands.

Because AVR-GCC puts strings in sram memory by default, every string should be surrounded by the TXT-macro. On AVR, this macro will put the string in program memory (flash), on any other device, this macro will be ignored.

Example of a debug string:
`DBG((TXT("This is test nr %d of %d.\n"),id,total));`

4.2.1 Debugging on Linux

On linux, debugging strings are sent to stdout using printf.

To enable debugging, set DEBUG in config.h .

4.2.2 Debugging on AVR

On AVR, debugging strings are sent through the UART and can be read using a terminal like minicom (linux) or hyperterminal (windows). Standard, the first UART is used, but this can be changed in `debug.c` to the second UART.

To enable debugging:

- Set DEBUG in `config.h`
- Set CLK to the clock speed of your AVR in `config.h`
- Set BAUDRATE to the baudrate you want in `config.h`
- Initialize debugging in your program by calling `debug_init()`

Remark: when you use the serial port in your main program, make sure you use a different UART than the one efsl is using when sending debug string.

4.2.3 Debugging on DSP

On DSP, debugging strings are sent to Code Composer using the printf function.

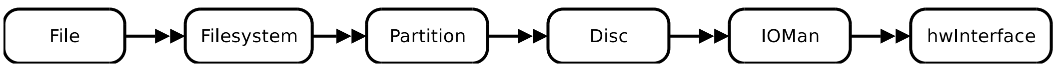
To enable debugging, set DEBUG in `config.h` .

Remark: this will only work when using a DSK-kit.

4.3 Adding support for a new endpoint

This section will describe step by step how to write an hardware endpoint. You will be required to write your own endpoint in case non of the existing endpoints matches your hardware.

First let's have a look at how EFSL is structured internally.



As you can see we have created a lineair object model that is quite simple. The file en filesystem object deal with handling the filesystem specific stuff. Below that we find the Partition object that is responsible for translating partition relative adressing into disc-based LBA adressing.

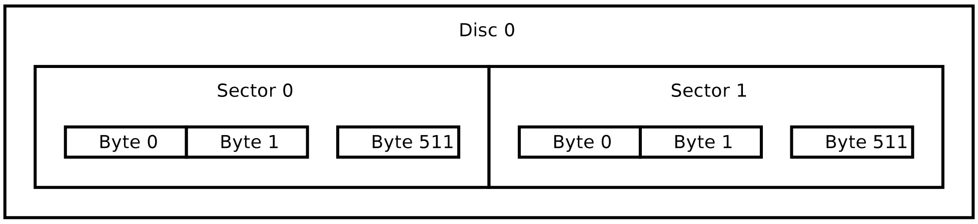
The Disc object hold the partition table, and has a direct link to a cache manager, IOMan. In IOMan, all requests for disc sectors come together. IOMan will perform checks to see if sectors have to be read from disc (or from memory), or written back to disc. In the latter case (reading or writing to disc), a request is made to the hardware layer.

The hardware interface has 3 responsabilities :

- Initialise the hardware

- Read sectors from disc
- Write sectors to disc

All requests are *sector*based, a sector is a 512 byte piece from the disc, that is aligned to a 512 byte boundary.



In this example we will create a new endpoint that will add support for data over pidgeon carrier for the EFSL. Initialising the hardware will require feeding the pidgeon and telling it where the data is. Reading/Writing will entail giving the bird the sector and letting it fly.

Perform the following steps:

1. Choose a name for your endpoint
   You will need this name to create the required defines in the sourcecode. For our example I've chosen the name `PIDGEON_CARRIER`. For consistency the final name is then `HW_ENDPOINT_PIDGEON_CARRIER`.

2. Verify the sizes of integers
   Open `inc/types.h` and create a new entry for pidgeon carriers. Perhaps one of the existing sets is identical to yours and you can copy-paste it.

3. Add your endpoint to `interface.h`
   Locate the file `interface.h` located in the directory `inc/` Add a pidgeon entry (located above the `#else ... NO INTERFACE DEFINED`)

```
#if defined(HW_ENDPOINT_0)
        #include "interfaces/0.h"
#elif defined(HW_ENDPOINT_1)
        #include "interfaces/1.h"
#elif defined(HW_ENDPOINT_PIDGEON_CARRIER)
        #include "interfaces/pidgeon.h"
#else
        #error "NO_INTERFACE_DEFINED - see interface.h"
#endif
```

4. Select your endpoint in `conf/config.h`

5. Create your sourcefiles
   Create a header file in `inc/` and a sourcefile in `src/interfaces`. In this example I'm using `pidgeon.h` and `pidgeon.c`.

6. Add your object file to the Makefile Take the Makefile that works best on your platform (they should all work with GNU/Make), or create a new

one, using the existing one's as a template. Make sure to include your new pidgeon object to the library. If you have an 'ar' like utility you can create a static library, else you may have to create a new project containing all required source files.

The basic framework is now complete, now all that's left to do is to write the code that will perform the actual flying work.

4.3.1 hwInterface

This structure represents the underlying hardware. There are some field that are required to be present (because EFSL uses them), but you may put in as much or a little as your driver requires to access the hardware.

As always in embedded design it is recommended to keep this structure as small as possible.

Example:

```
struct hwInterface{
    /* Field created for THIS hardware */
    Pidgeon pidgeon;

    /* Obligatory fields */
    euint32 sectorCount;
};
typedef struct hwInterface hwInterface;
```

4.3.2 if_initInterface

This function will be called one time, when the hardware object is initialised by `efs_init()` . This code should bring the hardware in a ready to use state.

The function's prototype is
`esint16 if_initInterface(hwInterface *hw, euint8* opts);`

Optionally but recommended you should fill in the hw-¿sectorCount field with the number of sectors. This field is used to validate sectorrequests.

An example of a initInterface function :

```
esint16 if_initInterface(hwInterface *hw, euint8* opts)
{
    /* Parse options */
    parse_options(opts); /* Your application may not need options */

    /* Check hardware state */
    if(!alive(hw->pidgeon)){
        //printf("De duijf is doojd meneer\n");
        return(DEAD_PIDGEON); /* #define DEAD_PIDGEON -1 */
    }

    /* Initialise hardware */
```

```
    feed(hw->pidgeon);
    pet (hw->pidgeon);

    /* Get sectors count */
    hw->numSectors = ask_pidgeon_num_sectors(hw->pidgeon);

    return(0);
}
```

4.3.3 if_readBuf

This function is responsable to read a sector from the disc and store it in a user supplied buffer. You will receive the hardware object, an address and a pointer to memory for storing the buffer.

Please be very careful to respect the boundaries of the buffers, since it will usually be IOMan calling this function, and if you have a buffer overflow you might corrupt the cache of the the next buffer, which in turn may produce extremely rare and impossible to retrace behaviour.

The function prototype is:
`esint16 if_readBuf(hwInterface *hw,euint32 address, euint8* buf);`

The address is an LBA address, relative to the beginning of the disc. Should you be accessing an old harddisc, or a device which uses some other form of addressing you will have to recalculate the address to your own addressing scheme. Please note that there is no support for sectors that are not 512 bytes large.

```
esint8 if_readBuf(hwInterface* hw,euint32 address,euint8* buf)
{
    Message new_message;

    new_message.address = address;
    new_message.command = READ;

    pidgeon_send(hw->pidgeon,new_message); /* Launches the pidgeon */
    while(!pidgeon_returned(hw->pidgeon)); /* Wait until the bird is back */
    memcpy(new_message.data,buf,512); /* Copy buffer */
    return(0);
}
```

4.3.4 if_writeBuf

The function `if_writeBuf` works exactly the same as it's reading variant.

4.4 I/O Manager

The IOManager that is the second lowest layer of the embedded filesystems library is responsible for coordinating disk input and output, as well as managing a caching system. This documentation describes the second implementation of IOMan, which includes features such as :

- Delayed write
- Buffer reference statistics
- Buffer exportable to users
- Support for cached direct I/O as well as indirect I/O
- Can allocate memory itself (on the stack), or you can do it yourself (heap)

4.4.1 General operation

Because of the limited memory nature of most embedded devices for which this library is intended several design decisions were made to minimize memory usage. Some of these required that some concessions be made. One of them is that there is no memory protection, since most devices don't have the memory to support this, or lack the ability to protect memory.

When IOMan receives a request for a sector, it will make sure it has the sector in it's own memory cache and then give the caller a `euint8*` pointer to that cache. The user is then free to do operations on that memory, and when it is done it should tell IOMan so. Several things can go wrong with this: you can request a sector for reading, and then write in the cache, thereby corrupting it. Or you can request a sector, but never release it (sort of a memory leak), which may result in very bad performance, and a deadlocked I/O manager.

But, taking into account that very little memory is required for operation, if you follow the I/O man rules, you will get a pretty clever caching object that will make writing new filesystems a simple job.

4.4.2 Cache decisions

Whenever ioman receives a request to fetch a sector, be it read or write, it will have to make sure it has, or can get the sector you want. It follows a certain path to do this.

1. First of all it will scan it's cache range to see if it already has the sector. If it is found, and it was a write request, the cache is marked writable. Usage and reference get incremented and a pointer is then returned to the requester. If the buffer cannot be found, ioman proceeds to step 2.
2. When an item is not in cache, it has to be fetched from the disc, the best place to store it is in memory that does not contain anything usefull yet. Ioman will search for a place that is currently not occupied by anything. If it is found, the sector will be placed on that spot and a pointer returned. Else, ioman proceeds to step 3.
3. Since there is no other choice than to overwrite an already existing cache, ioman will try to find one that is the least interesting. First it will search for caches that are marked not writable, and have no users. Ioman will then select the one that has the least references. If there are none, it will search for caches that don't have users and are writable. Once again the

one with the least references is returned. Since it is writable ioman will flush it to disc first. After that the requested sector is put there and a pointer returned. If it cannot find any caches that have no users it will go to step 4.

4. Since every cache spot is in use ioman will have to select one for overallocation. Since this selection is dependant on many factors and is rather complex, a points system is used. The algorithm considers every cache place and allocated a certain number of points to it, lower means that it is a better candidate for overallocation. Fifty percent of the points goes to the cache being marked writable, since having to write a sector is expensive. Another 35 percent goes to how many overallocations have already been done on that spot. It doesn't make sense to always overalloc the same buffer, it is better to spread this. The remaining 15 percent is determined by the number of references to the sector.

   After a function has selected the best candidate, ioman will overwrite that spot with the new sector. It will also push the status and sectornumber onto that cache's retrieval stack, so that when the sector is released, the older sector can be retrieved. If this fails go to step 5.

5. When ioman gets here it will return a (nil) pointer and flag an error.

4.4.3 Functions

I/O Manager Functions	
`ioman_init`	`esint8 (IOManager *ioman, hwInterface *iface, euint8* bufferarea)`
This function is called to initialize the internal state of the I/O manager. It should be the first function you call on an ioman object. Failure to do so will result in undefined behaviour. The function clears all internal variables to a default safe state, and sets up it's memory region. There are two possibilities, if you supply a 0 pointer then a function will be called that contains a static variable with a size of 512 * `IOMAN_NUMBUFFERS` , else, it will be assumed that you allocated that memory yourself and the pointer you provided will be used.	
`ioman_reset`	`void (IOManager *ioman)`
This function is called from the initialisation function, it does the actual reset of all variables.	
`ioman_pop`	`esint8 (IOManager *ioman,euint16 bufplace)`
This function fetches settings (sector number, usage and status register) from stack `bufplace` and puts it back on the main registers. It will return 0 on succesful pop, and -1 on error, or when there are no elements to pop.	
`ioman_push`	`esint8 (IOManager *ioman,euint16 bufplace)`
This function pushes the settings of cache `bufplace` onto that cache's stack. It does not destroy the data in the main registers. It will return 0 for a successful push, and -1 on error, or when there is no more space to push a new element.	
`ioman_readSector`	`esint8 (IOManager *ioman,euint32 address,euint8* buf)`

<table>
<tr><th colspan="2">I/O Manager Functions (continued)</th></tr>
<tr><td colspan="2">This function does the actual reading from the hardware, it is the one and only function that calls <code>if_readBuf()</code> , here a retry on failure policy could be implemented. This function will correctly stream errors upwards. All calls made to this function in the iomanager are checked for their return value, so errors propagate correctly upwards.
The address it receives is relative to the beginning of the disc, no assumptions about <code>buf</code> may be made, it can be withing ioman's cache memory range, but it could also be a buffer from userspace.
The function will return 0 on success and -1 on failure.</td></tr>
<tr><td><code>ioman_writeSector</code></td><td><code>esint8 (IOManager *ioman, euint32 address, euint8* buf)</code></td></tr>
<tr><td colspan="2">This function does the actual writing to the hardware, it is the one and only function that calls <code>if_writeBuf()</code> , here a retry on failure policy could be implemented. This function will correctly stream errors upwards. All calls made to this function in the iomanager are checked for their return value, so errors propagate correctly upwards.
The address it receives is relative to the beginning of the disc, no assumptions about <code>buf</code> may be made, it can be withing ioman's cache memory range, but it could also be a buffer from userspace.
The function will return 0 on success and -1 on failure.</td></tr>
<tr><td><code>ioman_getSector</code></td><td><code>euint8* (IOManager *ioman,euint32 address, euint8 mode)</code></td></tr>
<tr><td colspan="2">This function is the one that is called most from the higher library routines. It is the function that will present you with a pointer to memory containing sector number <code>address</code> . There are several modes that you can select or combine.
<table>
<tr><td><code>IOM_MODE_READONLY</code></td><td>This attribute says to ioman that it needs a buffer only for reading. This does not mean that you are allowed to write to it, doing so results in undefined behaviour. You cannot combine this option with the <code>IOM_MODE_READWRITE</code> option.</td></tr>
<tr><td><code>IOM_MODE_READWRITE</code></td><td>This attribute says to ioman that it would like not only to read from but also to write to that buffer. When you release the sector your changes will be written to disc. This may not happen immediately though, if you want to force it take a look at the <code>ioman_flushRange()</code> function. This option cannot be combined with the <code>IOM_MODE_READONLY</code> option.</td></tr>
<tr><td><code>IOM_MODE_EXP_REQ</code></td><td>This option tell the iomanager that the request is exceptional, for example that the request is unlikely to happen again. The library adds this flags to the options when requesting the bootrecord, to prevent it from getting a high rating, which should prevent it from being removed from the cache.</td></tr>
</table>
These options can be combined by ORing them together.</td></tr>
<tr><td><code>ioman_releaseSector</code></td><td><code>esint8 (IOManager *ioman,euint8* buf)</code></td></tr>
</table>

<table>
<tr><th colspan="2">I/O Manager Functions (continued)</th></tr>
<tr><td colspan="2">This function tells ioman that you are done with one of the cache elements and that it can do it's bidding with it. Forgetting to call this function may result in deadlocked iomanagers.</td></tr>
<tr><td>ioman_directSectorRead</td><td>esint8 (IOManager *ioman,euint32 address, euint8* buf)</td></tr>
<tr><td colspan="2">This is a variant of the normal getsector. Sometimes you need a sector from the disc, but all you want to do with it is export it directly to userbuffers. It would be foolish to force a caching of that sector if there is external space available for it.
This function will fetch sector address from disc and place it in the memory pointed to by buf . Should there be a free spot available the sector will be cached there, so that it may be used in the future. If the sector was available from cache in the first place, it will simply be memCpy() 'd from the cache to the userspace buffer.</td></tr>
<tr><td>ioman_directSectorWrite</td><td>esint8 (IOManager *ioman,euint32 address, euint8* buf)</td></tr>
<tr><td colspan="2">This function is based on the same philosophy as ioman_directSectorRead() , however, contrary to what the name may lead to believe it also passes through a caching layer. If there is an unused spot (or the sector is in cache), the userbuffer will be copied to that spot and will remain there until the space is needed or a flush is forced.</td></tr>
<tr><td>ioman_flushRange</td><td>esint8 (IOManager *ioman,euint32 address_low, euint32 address_high)</td></tr>
<tr><td colspan="2">This function is used to ask ioman to flush all sectors to disc that are in a specific range. For example you might want to flush a specific range of your filesystem without needlessly disturb other parts. The range is address_low <= n => address_high . Offcourse only sectors that are marked as writable are flushed to disc.</td></tr>
<tr><td>ioman_flushAll</td><td>esint8 (IOManager *ioman)</td></tr>
<tr><td colspan="2">This function will cause ioman to flush out all cache units that are marked writable. If they do not have any users, they will lose their writable mark.</td></tr>
</table>

5 Legal notes

This library is subject to the Lesser General Public License version 2.1. We have chosen this license in stead of the BSD license because we feel strongly that more efford was needed in the field of quality software in the embedded field.

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