

JESFS V1.5

JO'S EMBEDDED SERIAL FILE SYSTEM

Preface

More information about JesFs is on my homepage (<https://joembedded.de>).

I wrote JesFs for my very own needs and my daily work. JesFs was 100% designed for practical use in **“Small and Ultra-Low-Power IoT Devices”**, that must be able to communicate over many different channels and must work reliable for years.

It is very convenient to talk with your devices over Internet. In any case much better than digging holes in the snow in 3000 mtr. altitude and -20°C (what for was the reason to start this project).

The JesFs File System is only the half way: it is only “really complete” with the JesFsBoot – a secure Bootloader - for (almost) all small CPU/MCUs, like ARM 32-Bit-cores, TI's MSP430/432, ...

License Conditions

I have designed this software, because I required it for my own, daily use. Hence I tried to make it as stable and reliable as possible and necessary for the designated applications (which normally are for the scientific or industrial market).

JesFs is licensed under the GNU GENERAL PUBLIC LICENSE Version 3 (GPL v3).

If you would like to use JesFs with other licenses, just send me a mail.

Technical Details – (Serial) NOR-Flash and JesFs

In NOR-Flash only “0” can be written. Normally NOR-Flash is organized in sectors (often something between 128 Bytes and 64k). Sectors can be erased in one Block only! Then all Bits turn to “1”.

Hence, an empty NOR-Flash has all Bytes set to “FF”. Commonly for Serial NOR-Flashes the (smallest) sector size is 4kB (= 4096 Bytes).

Serial NOR-Flash normally is found in 8-pin ICs (like the MX25R8035F with 8*1 MBit (= 1 MB) as used on the CC131x-Launchpads from TI). Common Serial NOR Flash is currently (2019) available up to 16 MB.

Writing “0” is normally possible in any size, from single bits to larger blocks (often called “pages”).

However: erasing a sector is possible only a limited counts (normally 1000-1.000.000). This makes the things a little bit trickier than on a “classical” Disk-Drive. The technical term for this is “wear leveling”: This means: try to erase a sector as seldom as possible (Reading is unlimited!).

JesFs was designed especially for NOR-Flash. Either as (external) serial chip or as (CPU internal) memory.

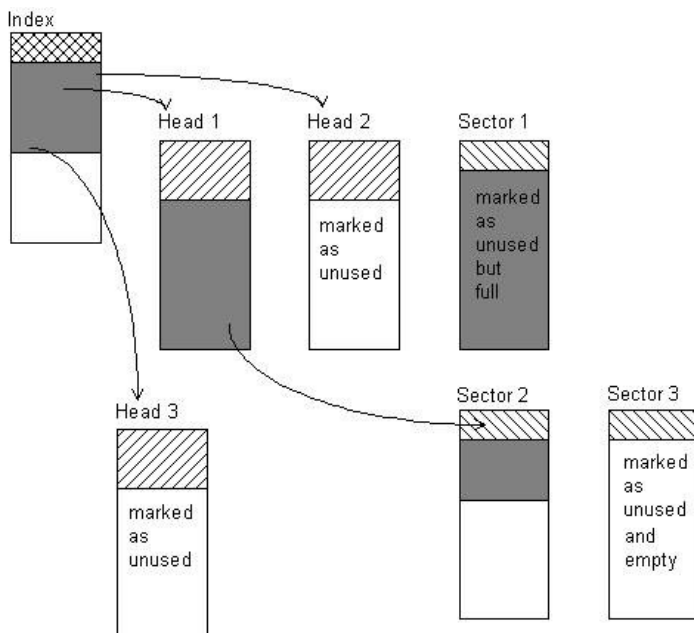
JesFs has 3 levels of usage for sector:

- Index (this is top level, only 1 can exist)
- Head (this is where a file starts)
- Sector (the "Pool", for all the rest).

The Index is never erased! It holds the entries for the "Heads". Each Head represents an either ACTIVE or DELETED file. For new files, JesFs always tries to recycle DELETED Heads. Only if necessary. Sectors from the "Pool" become Heads. Each Head has an entry in the Index. This means: the number of available files is limited by the size of the Index.

For an Implementation on Serial NOR-Flash with 4KB sectors of JesFs, the Index can hold up to ca. **1000** entries for Heads.

A Sector is only erased, if required.



Erasing a Sector takes several msec (see the data sheet of the chip). Hence, writing files is much slower than reading.

Serial NOR-Flash is known as very reliable (not like NAND-Flash, often used in USB-memories, which are much faster, but normally required error correction logic). Nevertheless JesFs is able to track a 32-Bit CRC for each file to ensure integrity! Using the CRC32 costs only very little time for the CPU (see Performance Data).

Another very important design topics of JesFs are:

Unclosed Files

This is something, that can not be found in traditional File Systems! Traditionally, every time a File is used (especially written), it must be closed, mainly to update the allocation tables and directories. This is something very sensitive: because if power is lost during "close", the data of the file might be corrupt or -even worse- vanish into the "Data-Nirvana"...

JesFs has NO problems with unclosed files: Because empty NOR-Flash is always “FF”, the end of any file can always be found, as long as you don’t write “FF”s to it.

Hint: A traditional strategy to avoid “FF”s is, to use “Escape Bytes”: this means: If you want to write “FF”, simply write “FE 01” and for “FE” simply write “FE 00”. Or: write ASCII-Text... (Using “Escape Bytes” has an additional advantage, I’ll write something about this in a later document)

Conclusion: With JesFs: Close files that are “fixed”, and let the others open, keeping in mind, not to write “FF” and you will always be able to find your data.

Technical detail: JesFs can scan very quickly over Files to find the end (about 25 usec/Sector on a CC1310-Core). So even the end of a 16Mb File will be found in <100 msec!

More Details about the Performance later in this document.

JesFs Basics

JesFs is a “flat” File System. This means, there are no directories. The number of available files is only limited by either the size of the Index Sector or the total available number of sectors in the Flash Memory (this is e.g. 256 for the MX25R8035F with 1MB as used on the CC131x-Launchpad).

Each Filename can be up to 21 Characters long and can contain any character, except ‘\0’. So “\$abc/hello\world&.bin\$” would be a valid file name!

It is possible to have as many files open simultaneously as you want. The number of open files is only limited by the CPU’s memory, see below.. However: it is only allowed to write with one instance to each file (this is intuitive).

JesFs manages some Flags for the “Outer World”. Currently this is “SF_OPEN_EXT_SYNC”:

- SF_OPEN_EXT_SYNC: These files are marked to be (fully automatically) synced to external Servers or others. There is a PHP framework, that can automatically map files from JesFs to a Internet Server.

(Details about External Access will follow in a separate docu, or visit my homepage).

JesFs consists of several Files:

- The Low Level Hardware driver: “JesFs_ll_XXXX.c” (“JesFs_ll_tirtos.c” for the CC131x, “JesFs_ll_nrf52.c” for nRF52 CPUs, “JesFs_ll_pc.c” for Windows PCs)
- The Hardware-Independent Mid- and High-Level driver: “jesfs_ml_hl.c”
- And the appropriate Header-Files. For the user, only “jesfs.h” is important.
- The additional “tb_tools_XXX.c”-Files contain drivers for UART, Clock, LEDs, etc...

Hint: In “jesfs.h” you may find all necessary data structures and error codes.

JesFS API

JesFS uses 2 types “Descriptors” for alle file access:

- File Descriptors: Each open File requires one. It holds all necessary data (like the current working Sector, current position, CRC, ... Each File Descriptor requires about 28 Bytes (V1.x, see “JesFs.h”)
- Statistic Descriptors: to scan the Directory. Each Statistic Descriptor requires about 30 Bytes (V1.x, see “JesFs.h”)

A 3.rd variable (“sf_info”, size scalable from ca. 164-256 Bytes) holds all static info about the Serial NOR-Flash. That’s all!

Functions

```
int16_t fs_start(uint8_t mode);
```

Start (or Restart after Deepsleep) JesFS. Perform all necessary scans of the Flash and checks for errors. The more “FS_START_FAST” is slightly faster than “FS_START_NORMAL”, see “JesFs.h”. If the flag “FS_START_RESTART” is also set, Restart after Deepsleep might not be necessary, this is the fastest wakeup.

```
void fs_deepsleep(void);
```

Put the Serial NOR-Flash to Deep Sleep, where it consumes only < 0.5 uA. Currently the MX25Rxxxx (as used on nRF52840 DK (PCA10056) or the CC131x-Launchpad) is top! Others might take more.

```
int16_t fs_format(uint32_t f_id);
```

Dangerous: Erases the Serial NOR-Flash (which might take up to 2 minutes) and prepares JesFs. The parameter “f_id” is currently not used (in V1.0)

```
int32_t fs_read(FS_DESC *pdesc, uint8_t *pdest, uint32_t anz);
```

Reads Bytes from an open file to *pdest. If anz is larger than available, only the available bytes are read. It is possible to set pdest as NULL, then only nothing is read, but it can be used to find the end of unclosed files or simply skip unwanted data. But ONLY for really read bytes (pdest <> NULL) the CRC of the file is updated.

```
int16_t fs_rewind(FS_DESC *pdesc);
```

Resets the file position to 0

```
int16_t fs_open(FS_DESC *pdesc, char* pname, uint8_t flags);
```

Opens a File (either for reading, deleting or writing in “unclosed mode” with the name pname and initialized the Descriptor. Possible Flags are “SF_OPEN_READ”, “SF_OPEN_RAW” or “SF_OPEN_CRC”.

```
int16_t fs_write(FS_DESC *pdesc, uint8_t *pdata, uint32_t len);
```

Opens a File for writing. If the file exists, old data is deleted. If the file does not exist, it will be created, if the Flag "SF_OPEN_CRATE" is set. Optionally the Flag "SF_OPEN_CRC" and/or "SF_OPEN_EXT_HIDDEN" or "SF_OPEN_EXT_SYNC" can be used.

```
int16_t fs_close(FS_DESC *pdesc);
```

Only Files opened for Writing must be closed. By closing, the File Len and optionally the CRC is written.

```
int16_t fs_delete(FS_DESC *pdesc);
```

To delete a File, it must be opened in „SF_OPEN_RAW" mode. After deleting no fs_close() is required!

```
int16_t fs_info(FS_STAT *pstat, uint16_t fno );
```

This functions give access to the Directory. The Index contains a number of entries. For each entry (with number 'fno' the data can be retrieved. Hint: For deleted files still the name of the file is stored, but the data can not be accessed any more...

```
uint32_t fs_get_crc32(FS_DESC *pdesc);
```

Retrieves the CRC32 of the file (provided, that it is existent. Else, it simply will be "FFFFFFF"). Can be used to make an error check of the file.

CRC32 (ISO 3309)

Checksums are crucial to ensure data integrity! The CRC32 is based on a proven industrial standard binary polynomial with an optimized "Hamming-Distance" to detect errors with maximum precision. A CRC32 ensures data integrity, but it is no encryption! You can use the functions also for your purposes.

JesFs Performance

I have made intensive tests of the performance of JesFs. A detailed PDF with some test results is included as „Performance.pdf“.

These are my results:

In READING mode, the speed is in the range of the maximum possible SPI transfer speed, main limiting factor is using or not using CRC32.

- READING transfer speeds are in the Range **0,5 Mbyte/sec – 3.75 Mbyte/sec**.
- READING files in silent mode (e.g. required to find the end of unclosed Files) is in the Range ca. **100 Mbyte/sec** (and this is really fast!).
- WRITING transfer speeds are in the Range **ca. 30-70kByte/sec**.
- JesFs can switch from **Deep Sleep** (with <0.5µA current consumption for some Flash) to **INITIALISED** withing only a few msec.

The bottle neck for READING is the speed of the SPI Interface., the bottle neck for WRITING is the erase time of (previously used) sectors, that must be erased before use. In any case, the transfer speeds are absolutely acceptable for most applications.

The Demos

JesFs was designed for portability and very small footprint (RAM and Code). Included are 3 Demos:

1.) The Demo (on NORDIC's nRF52840 Development Kit PCA10056) with SEGGER Embedded Studio (SES)

The Nordic nRF52840 DK (PCA10056) contains a large 8 Mbyte Serial Flash.

A complete Project (built with **nRF5 SDK v16.0.0**) is included in

```
../JesFsDemo/platform_nRF52/pca10056/ses/  
JesFsDemo_pca10056.emProject
```

Because SES works best with relative pathes, copy the project into your nRF5 SDK v16.0.0 installation directory. In my case the SDK is installed in:

```
C:/nordic/nRF5_SDK_16.0.0_98a08e2
```

and the BlackBox Demo is installed in:

```
C:/nordic/nRF5_SDK_16.0.0_98a08e2/own_projects/test/JesFsDemo/...
```

Now the demo should compile without errors!

The PCA10056 Developemnt board offers a virtual COM-Port „115200 Bd 8N1“

2.) The Demo (on TI's CC1310-ARM)

Very simple! The demo is based on a standard project on the CC13x0-Launchpad. Probably it will work with most others of the Wireless Simple-Link CPUs CC13xx/26xx Family too, but for my work, I used a CC1310- and a CC1350-Launchpad together with CCS Vers. >= 7.x.

Install the “TI-RTOS empty-Project” via Resource-Explorer and remove the File “empty.c”. Instead, “Add Files”, “Link” or “Copy” the Files from the “JesFs”-Demo”, as shown on the following images.

After starting, you'll see a prompt '>' where you can test the API functions. Enjoy it!

Hint: The XDS110-Emulator of the CC1310-Launchpad offers a Serial COM-Port. However, I found it not very reliable. I prefer a separate COM-Port (based on a Low-Cost 3.3V-TTL-UART-cable form FTDI-CHIP, but many others ar OK too...).

3.) The Demo (on Windows (WIN32))

Here simply the driver for the serial Flash is replaced by the "JesFs_II_pc.c". This is allow testing JesFs and developing software on the PC. More infos in "JesFs_main.c".

The Secure JesFs-Bootloader (for almost all ARM Cortex M0-M4F)

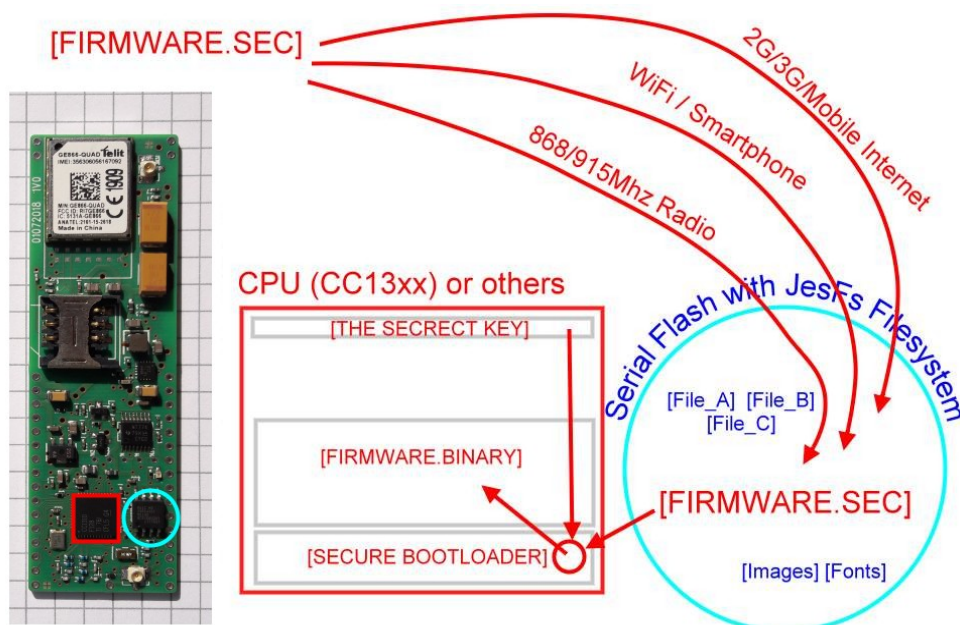
The JesFs-Bootloader works "Hand-in-Hand" with the JesFs-Filesystem. Or in other words: it can directly read files and transfer it to the CPU's memory.

The JesFs-Bootloader takes only 8kB of code, so still a huge amount is left for the user's firmware. And: using true C as a programming language is much easier, more flexible and normally MUCH faster scripts...

Firmware-Updates with JesFs is completely SAFE: Because the firmware is AES encrypted by default (AES-128-CBC). There is NO CHANCE to modify the secured firmware outside of the CPU! The AES encryption key is only known to the software developer and is stored inside of the CPU.

Of course, JesFs-Filesystem can work stand alone and does not require the JesFs-Bootloader. Also during (local) development of the software, a bootloader is normally not required. Only later for the products, that often could be very far away.

The documentation for the JesFs-Bootloader will follow soon.



Many ways to get Firmware and Data secure into your IoT Device
if using a Filesystem and a Secure Bootloader

Addendum: Demo images

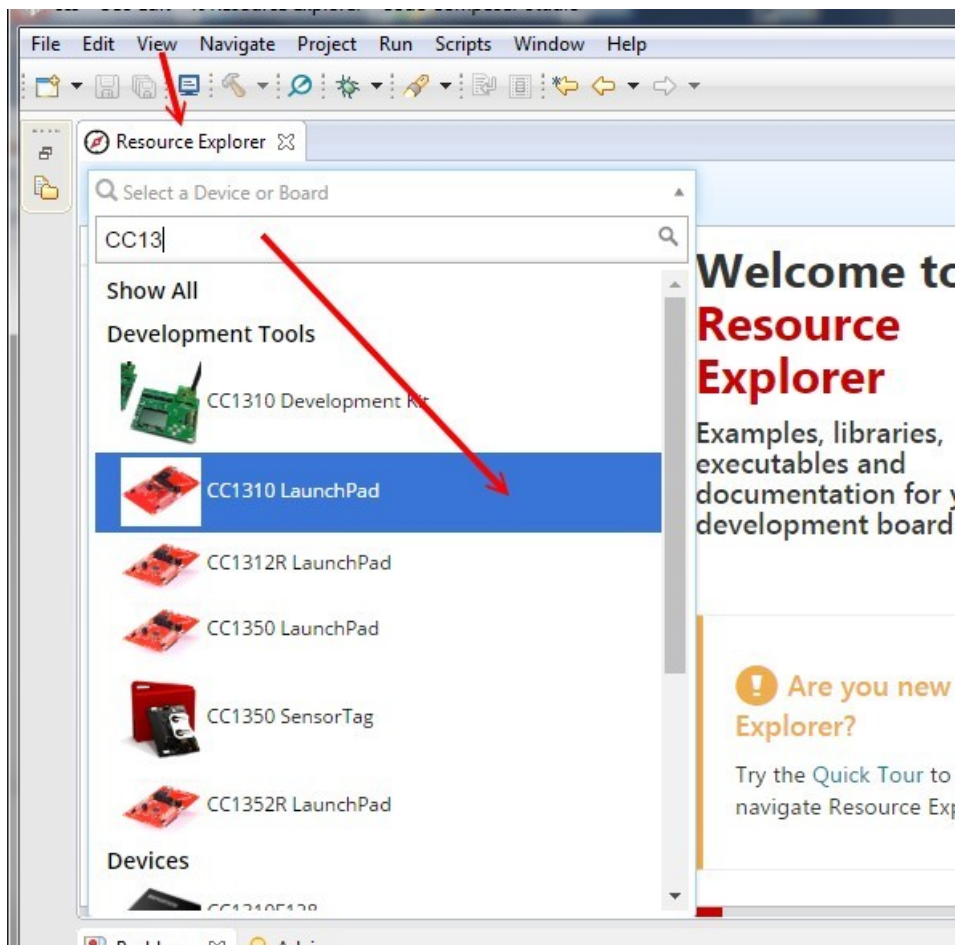
Running the Demo on a nRF52840 DK (PCA10056)

Simply copy the files as described above and start the projecz.

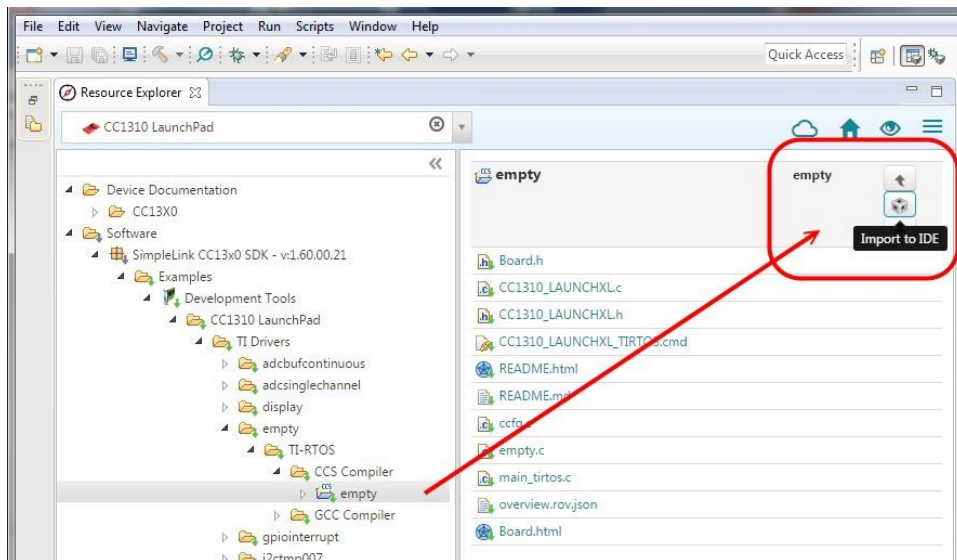
Continue with „Terminal“

Running the Demo on an CC1310 (or any other CC13xx/CC26xx)-Launchpad

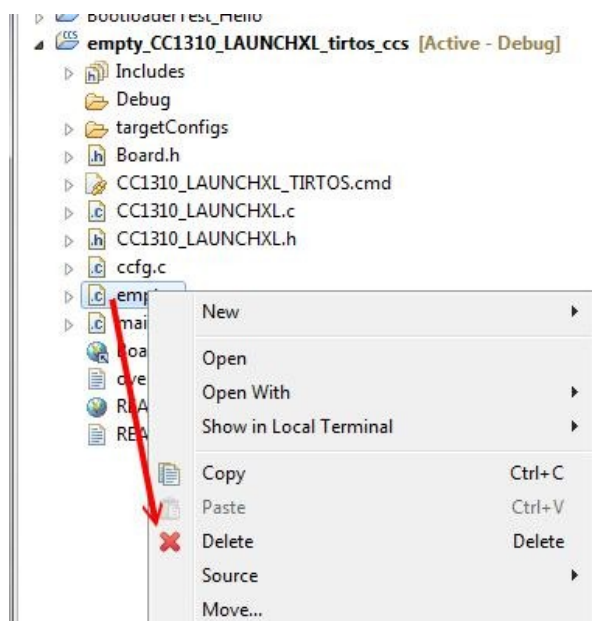
Running the Demo on a Launchpad is very simply too. However, Best way is to modifa the Example project “Empty”:



- 1.) Select your Launchpad in the Resource Explorer

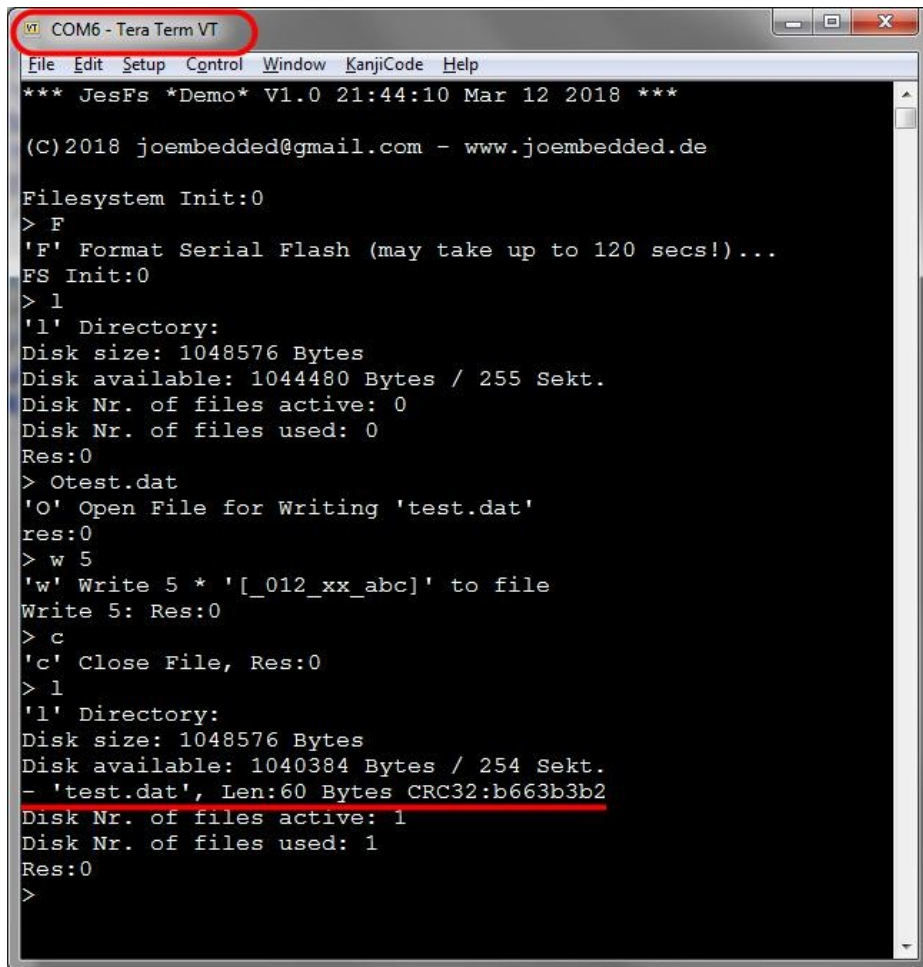


2.) Import "empty"



3.) Delete "empty.c" and copy /add all JesFs-Files to the directory.

4.) The last step is to add **CC13XX_CC26XX** as Preprocessor Definition (Project Options -> Preprocessor Definitions)



```
COM6 - Tera Term VT
File Edit Setup Control Window KanjiCode Help
*** JesFs *Demo* V1.0 21:44:10 Mar 12 2018 ***

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Filesystem Init:0
> F
'F' Format Serial Flash (may take up to 120 secs!)...
FS Init:0
> l
'l' Directory:
Disk size: 1048576 Bytes
Disk available: 1044480 Bytes / 255 Sect.
Disk Nr. of files active: 0
Disk Nr. of files used: 0
Res:0
> Otest.dat
'O' Open File for Writing 'test.dat'
res:0
> w 5
'w' Write 5 * '[_012_xx_abc]' to file
Write 5: Res:0
> c
'c' Close File, Res:0
> l
'l' Directory:
Disk size: 1048576 Bytes
Disk available: 1040384 Bytes / 254 Sect.
- 'test.dat', Len:60 Bytes CRC32:b663b3b2
Disk Nr. of files active: 1
Disk Nr. of files used: 1
Res:0
>
```

5.) Start a Terminal. Above you see the sequence:

O test.dat opens "test.dat" for Writing

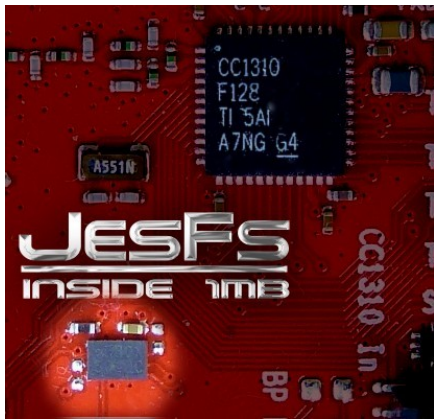
W 5 writes 5 times [_012_xx_abc]

c closes the file – and voila:

v (formerly 'l') shows it in the directory.

***** Have fun! And thanks for your Interest! *****

- Jo -



1MB – up to >200 Files – only 2x3 mm



The very small RC-CC1310F module from radiocontrolli.com has already 2MB built in.