Introduction

µTasker is an operating system designed especially for embedded applications where a tight control over resources is desired along with a high level of user comfort to produce efficient and highly deterministic code.

The operating system is integrated with TCP/IP stack and important embedded Internet services along side device drivers and system specific project resources.

µTasker and its environment are essentially not hardware specific and can thus be moved between processor platforms with great ease and efficiency.

However the µTasker project setups are very hardware specific since they offer an optimal pre-defined (or a choice of pre-defined) configurations, taking it out of the league of "board support packages (BSP)" to a complete "project support package (PSP)", a feature enabling projects to be greatly accelerated.

Very often there is a requirement for software updates in the field and where possible over the Internet. There are several methods which can be used, each with its advantages and disadvantages. The µTasker boot-loader support is optional in the µTasker and chooses a technique to allow Internet enabled uploads of application software based on several IP techniques (TFTP, FTP, HTTP POST etc.) as well as optional serial methods using an absolute minimum of boot software space. It allows complete uploads of application software including operation system, driver, interrupt and TCP/IP stack code for maximum flexibility but also with reliability as top priority; failed uploads will not result in disaster but can be repeated (or are automatically repeated) until successful.

As an option, the loaded code can be first encrypted to a form which can be distributed without being interpretable as final machine code. This protects the delivered code from being reverse engineered or used in other unauthorised projects.

In addition to the described method of uploading new code to internal FLASH, the uTasker project supports also uploading to external SPI based FLASH, which enables programs almost as large as the internal FLASH to be uploaded since it doesn't need to share this internal FLASH space.

µTasker boot-loader strategies

The µTasker boot-loader strategy can be configured depending on the project requirements. The following options are possible:

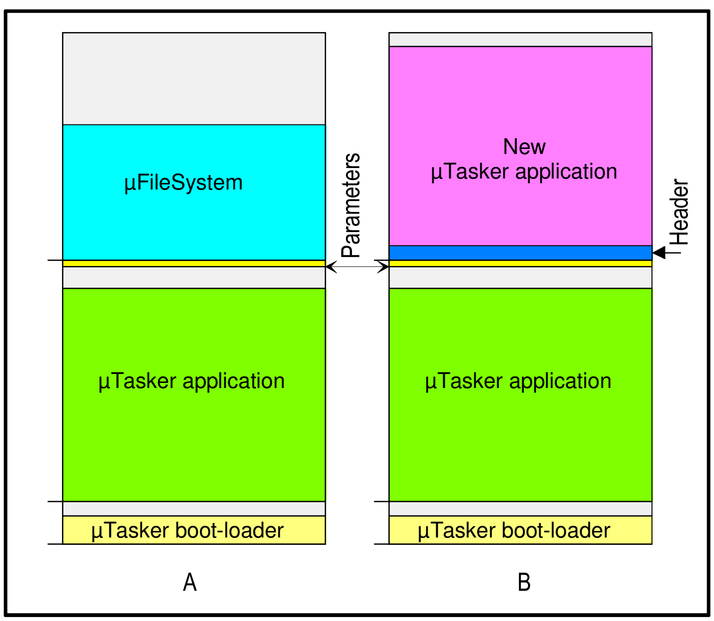
- TFTP upload support integrated in the boot loader (Ethernet, ARP and UDP)
- Serial loader support integrated in the boot loader
- Override options to force serial or TFTP uploads (eg. Input port state at reset)
- Override of IP configuration option (eg. Input port state at reset) to enable a board with unknown configuration to be contactable via Ethernet – useful mainly together with TFTP support
- µTasker "***bare-minimum***" loader

µTasker "bare-minimum" loader

The "***bare-minimum***" loader is the base for all other configurations. It supports safe updates of new application software which has been prepared by the previous application and as such has the advantage of requiring an absolute minimum amount of space in FLASH. However this solution can also be a very powerful solution since it still can enable the safe update of entire software, including unrestricted operating system, driver and TCP/IP stack patches, over the Internet.

The µTasker "***bare-minimum***" loader is a normal small standalone program. It doesn't have any of its own network capabilities and doesn't configure the Ethernet interface. It requires no further options to be enabled to achieve its goals.

The µTasker "***bare-minimum***" loader assumes that at start-up one of the following two states exists.



State A is the initial and normal condition. A µTasker application exists in FLASH at the application's start position and there is no new software waiting to be updated. Note that the case where only the µTasker boot-loader exists is not normally a valid case – the initial load (which will normally be performed using BDM) is loaded together with the first µTasker application. [If the µTasker boot-loader contains also serial loading support, the application can of course be loaded in a second step].

When the µTasker boot-loader recognises state A it simply allows the µTasker application to start operating. Details about starting the application and the configuration of the application program are given later in this document.

State B exists thanks to the support built in to the µTasker application, which has allowed a new version of a µTasker application to be programmed into the region in FLASH reserved for it. This will usually be performed over the internet (network). It is not the boot loader which is responsible for loading this!

The new µTasker application includes also a small header which allows the µTasker boot-loader to recognise it as a valid copy of code and to also verify its integrity. This is extremely important since the device will lose its IP uploading support if an unsuitable program were to be loaded in place of the original one.

It is also clear that both the old and new µTasker applications must fit into the available non-volatile space. This is due to the fact that one of the programs must at all times be intact in order to guaranty that the update can not fail and leave the device in an unusable state. It is not however absolutely necessary that this is in the internal FLASH. If additional serial FLASH is available this can be optionally supported. As long as the internal FLASH has adequate space, it is usually easy to justify using a device with more FLASH than the actually application needs alone due to the valuable additional feature that the IP uploading support represents.

It is also important to note that the space used to store the µTasker application may overlap with the µTasker file system used during normal operation. For example a M52235 with 256k FLASH can use a 128k file system for web pages and other data alongside the application code of up to 120k. A new µTasker application can be loaded to the file system area ready for programming. No additional FLASH would be required in this example, although the contents of the file system will usually also have to be restored (eg. via FTP) after the upload procedure is complete.

If external SPI FLASH is used to save the uploaded code this restrictions doesn't apply. See the SPI FLASH section for more details.

Procedure

The µTasker boot-loader is always the first program started after a reset.

It first checks to see whether there is a new µTasker application waiting to be programmed. To be recognised as a valid new µTasker application it must have a valid header and its integrity must be verified according to the header contents. The header is detailed later.

If there is no new application waiting, the normal application will be started. (If the µTasker boot-loaded supports a serial loading method it may also first check that the application is present or offer the serial download if it is not. It may also offer a download menu when a specific input port in held in a defined state at reset.)

Should a new and valid µTasker application we waiting to be programmed, the original application will be deleted. It should be noted that a restart of the device during this phase is not dangerous since the delete will be simply repeated.

After the delete phase has terminated the new µTasker application is copied to the application code space.

The new application is now verified according to the integrity check in the header, to be sure that there were no errors when copying.

Finally the copy of the µTasker application is deleted and the device is reset.

It can be shown that a power fail or other error can be tolerated at any part of the procedure and that the final reset is equivalent to a standard start with the µTasker application programmed.

Code Header

In order to ensure that the µTasker boot-loader doesn't attempt to program unsuitable code and also to guaranty the integrity of the loaded code a small header is used. The header consists of 8 additional bytes as follows:

```
unsigned long  ulCodeLength;
unsigned short usMagicNumber;
unsigned short usCRC16;
```

The header can be added to the program code by using a simple utility program which accepts a normal binary file, calculates its check sum and adds these 8 bytes to the beginning of the file. This utility program is supplied with the µTasker project (in the tools directory) and is called `uTaskerConvert.exe`

The code length is then used to verify the size of the received code and also for the verification of its CRC value. The magic number is used as a version number and also as simple verification of the compatibility of code otherwise respecting the format – the magic number can be set for a project and kept secret (although it could be eves dropped from the upload traffic).

The CRC is calculated over the complete code (without header) plus a secret block of variable length data common to the boot software and also the generation program but not visible in the transmission. This offers protection against malicious uploads since the check sum must be correct over the visible code and also some secret code.

The µTasker boot-loader checks for a valid waiting software and also when verifying that the newly loaded software has indeed been copied without errors. Only when the new µTasker application has been successfully tested against its CRC value will the backup version finally be deleted.

Setting up the µTasker project, preparing and uploading the file

The µTasker project requires the following small modification to be able to operate together with the "***bare-minimum***" loader.

- Its start address must be set to correspond to the start address in the "***bare-minimum***" loader. This can be set in the linker file.
  This is set up, for example, in the CodeWarrior .lcf file in the memory definition like this. In this case 0x800 (2k) has been left at the beginning of FLASH for a µTasker boot-loader is up to 2k. Also the length of the FLASH block has been reduced by the same amount
  ```
      flash   (RX)   : ORIGIN = 0x0000800, LENGTH = 0x0003F800
  ```

The project is otherwise compatible, including the use of the interrupt vector table. The µTasker project includes a project setup for the boot-loader and an application for "***bare-minimum***" loader.

When the project is compiled a binary image should be created. This can usually be set up in the linker configuration of the project.

Finally the output file is converted to a format with the necessary header. Here is an example of calling the `uTaskerConvert.exe` utility to add a header with a magic number of 0x1234 to the input binary file `uTasker_demo.bin`

```
uTaskerConvert uTasker_demo uTasker_update.bin -0x1234
-a748b6531124
```

The secret block can be of any length up to 100 bytes and in the example is made up of 6 bytes 0xa7, 0x48, 0xb6, 0x53, 0x11, 0x12

The output file `uTasker_update.bin` can then be uploaded to the target using whatever method is supported by the presently loaded µTasker application code. The following shows a typical solution using the HTTP POST method which is demonstrated in the standard µTasker demo project assuming that the upload support is available and activated.

A standard Web Browser input allows the user to select a file to be loaded from the user's hard disc. In this example the user has already selected a file with the name sw1.bin - the format of which has been prepared to include the necessary header.

By clicking on the SW Update button the Browser sends this file using the HTTP POST method. The µTasker application software saves the received data to FLASH at the required location and commands a reset of the board. This starts the µTasker boot-loader update procedure as previously described, after which the new software will be started.

It is important to note that the uploaded code is either posted to a dedicated FLASH memory region or to within or overlapping the µTasker file system. It is not posted to the card parameter region so that the IP configuration of the board remains intact. If this were not *respected it would be possible to lose user settings and should thus be avoided. The coordination of the posting itself is resolved in the µTasker application code.*

If external SPI FLASH is used to save the uploaded code this restrictions doesn't apply. See the SPI FLASH section for more details.

SPI FLASH Support

The µTasker boot-loader can be configured to operate together with external SPI FLASH. SPI FLASH chips enable relatively large amounts of data to be stored in a small device (eg. 512k to 2Meg in SO-8 housing) connected by a high speed SPI (Serial Peripheral Interface) interface. Not only are the devices small but their connection is simple due to the low number of pins.

The "Bare-Minimum" Boot loader operation is equivalent but instead of needing the new code to be copied to a region in internal FLASH, the new code can be copied to the external device. This allows uploads of new code without requiring it to be stored in the internal file system. This means that no data will have to be overwritten (if the code needs to borrow space in the file system). In some circumstances it allows also larger code to be uploaded and updated – up to the complete size of the internal flash, minus the size of the Bare-Minimum Boot loader itself.

The boot loader size tends to be a little larger than when only internal FLASH is used due to the fact that it must have both the internal FLASH driver and also an external SPI FLASH driver.

When using the Boot Loader with external SPI FLASH, the define SPI_SW_UPLOAD is added to the project set up (config.h). See the processor-specific guide for more details.

µTasker boot-loader example for the Freescale™ Coldfire M5223X

The details of the realisation are rather processor specific and so it is necessary to have a good understanding of the processor it is running on. So we must learn some specifics of the device to understand its restrictions and how and why the solution has been shaped for it.

When the Coldfire starts it automatically reads two long words from the exception vector table. The first is its initial stack pointer value and the second is the initial program counter value. Since the exception vector table is located at reset at the address 0x00000000, in FLASH in the M5223X, it is clear that the µTasker boot-loader must reside at the beginning of FLASH so that it can coordinate the initialisation of the system.

The initial program counter, read from FLASH location 0x00000004, is the start address of the µTasker loader code.

The exception vector table includes in total 256 vectors, including the SP and PC and it is typical to reserve 1k of space at the start of FLASH to contain the interrupt vector addresses used later by the code. Of course the µTasker loader has no idea where these will later be located once the user code has been installed and so the exception vector table is not used in FLASH but rather the code starts directly at the location 0x00000008, thus utilising the FLASH as efficiently as possible.

Note the following complication in the M5223X: *The locations between the addresses 0x400 and 0x417 are read on reset and used to configure some FLASH control registers. Therefore the µTasker boot-loader sets up the compiler and linker to position zeros in these locations. If this is not done, the FLASH configuration can leave FLASH blocks with protection against instruction accesses and so to program failure.*

The stack pointer is set to the top of internal SRAM, positioned by default between 0x20000000 and 0x2000ffff (32k in all M5223X devices). Therefore the content of the first FLASH locations are defined:

```
0x00000000: 0x20008000
0x00000004: 0x00000008
0x00000008: First instruction of µTasker boot-loader
...
...
...
0x00000400: 00000000
0x00000404: 00000000
0x00000408: 00000000
0x0000040c: 00000000
0x00000410: 00000000
0x00000414: 00000000
0x00000418: Further µTasker boot-loader code
...
...
```

The "***bare-minimum***" loader requires less that 2k in the M5223X and so the application starts at 0x00000800 (the second FLASH sector).

Although the start address of the µTasker application has been moved from its usual starting address of 0x00000000 to 0x00000800, no further code changes are necessary. The µTasker boot-loader takes over the normal reset procedure of loading the stack pointer with the first long word and setting the PC with the second long word and so the reset vector retains its function. The µTasker project sets up the interrupt vectors at the start of SRAM, rather than leaving them in FLASH and so this is also compatible.

Please see also the processor-specific boot loader document for full details of using it with the µTasker boot-loader.

Encryption option

Often it is undesirable that the software which is up be updated to the remote device is available in a readable form. In order to make it difficult for the program content to be interpreted, the Boot Loader supports also an optional encryption/decryption function. Whether encryption is used or not is defined in the project setup and also in the use of the conversion utility.

When the conversion utility performs encryption it has the following use:

```
uTaskerConvert uTasker_demo uTasker_update.bin -0x1234
-a748b6531124 -ab627735ad192b3561524512 -17cc - f109
```

The additional parameters cause the encryption step to be performed.

`ab627735ad192b3561524512` is an encryption key which is used to transform the data content. It must have a length dividable by 4) and its length determines the strength of the coding.

`17cc` is used to prime a pseudo-random number generator used during the process (should not be zero) which must also match.

`F109` is a shift value in the code which makes it much more difficult to break using brute-force techniques. Without this shift it would be much easier to match known code patterns at the start of the file. Since the start code can be anywhere in the data this avoids this possible weakness.

The header added to the upload file is increased slightly in length due to the need for a second CRC.

```
unsigned long  ulCodeLength;
unsigned short usMagicNumber;
unsigned short usCRC16;
unsigned short usRAWCRC;
```

In this case usCRC16 is the check sum of the encrypted file (as it is stored during the upload) and usRAWCRC is the check sum of the real code (before encryption) so that successful decryption can also be verified.

The decryption process is an additional step in the Boot Loader which is performed when the code is copied to its executable position in FLASH.

It is advisable to always use a different magic numbers for projects with and without encryption. This ensures that encrypted data will never be copied to its executable location by a project without decryption support.

The encryption method can be used with both internal FLASH and also external SPI FLASH.

Conclusion

This document has described in detail the operation and use of the “bare-minimum” method as implemented by the µTasker boot-loader.

The advantage of this method is that the boot code occupies only one FLASH sector (2k) and still allows safe software uploads over the Internet. The document has also described the code size limitations of this method (when not using external SPI FLASH) and will be extended in future editions with further optional support of serial and TFTP loading methods. Their realisation and operation will be explained, including their corresponding advantages and disadvantages.

Modifications

18.11.2006-0.02 Secret key added

25.08.2007-0.03 Encryption added. External SPI FLASH support capability added.