AN2659
Application note

STM8 in-application programming (IAP) using a customized user-bootloader

Introduction

This application note is intended for STM8 firmware and system designers who need to implement an in-application programming (IAP) feature in the product they are developing with the STM8 microcontroller.

The STM8 is an 8-bit microcontroller family with a Flash memory for storing the user program code or firmware. IAP makes it possible to update the firmware ‘in situ’, after the microcontroller has been embedded in the final product. The advantage is that the microcontroller board can stay inside its product enclosure. No mechanical intervention is needed to make the update.

IAP is extremely useful for distributing new firmware versions. It makes it easy to add new product features and correct problems throughout the product life cycle.

The user-bootloader firmware source code provided with this application note shows an example of how to implement IAP for the STM8 microcontroller. Use this code as a reference when integrating IAP in your STM8 application. It includes the following features:

- Bootloader activated by external pin (jumper on PCB)
- Flash block programing by executable RAM code management
- Read while write (RWW) feature
- High level C-language usage
- Reduced size of the code (optimized code)
- Support for multiple communication interfaces (SPI , I^2C, and UART)
- UART code compatible with ST Flash loader demonstrator software

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1 Operation theory

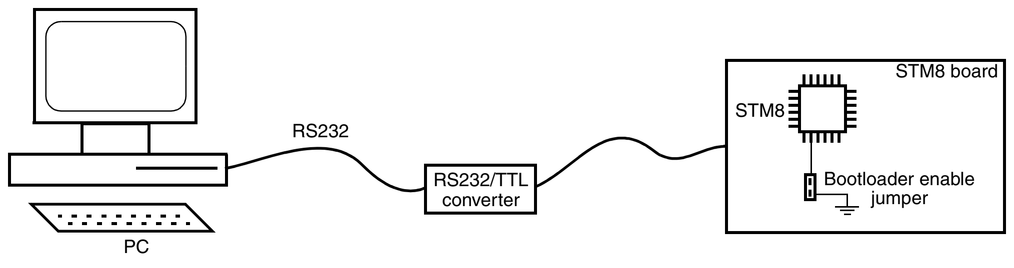
In practice, IAP requires a bootloader implemented in the STM8 firmware that can communicate with an external master (such as a PC) via a suitable communication interface. The new code can be downloaded into the microcontroller through this interface. The microcontroller then programs this code into its Flash memory.

IAP can also be used to update the content of the internal data EEPROM memory, and the internal RAM memory.

This operation is usefull when a microcontroler is already soldered in its final application and needs a firmware update.

Figure 1 shows a typical bootloader application.

Figure 1. Typical bootloader application



The bootloader is that part of the code which runs immediately after a microcontroller reset and which waits for an activation signal (for example, from grounding a specific pin or receiving a token from a communication interface). If activation is successful the code enters bootloader mode. If activation fails (for example due to a timeout or the jumper on the pin not being present) the bootloader jumps directly to the user application code.

In bootloader mode, the microcontroller communicates with the external master device through one of the serial communication interfaces available in it (UART, SPI, I^2C, CAN) using a set of commands. These commands are usually:

- Write to Flash
- Erase Flash
- Verify Flash
- Additional operations such as read memory and execute code from a given address (jump to given address).

The ST proprietary bootloader can be used. It is embedded in the ROM memory of STM8 devices with a program memory greater than 8 Kbytes. In this case, no code development is needed. To use the proprietary bootloader, enable it via the option bytes.

Alternatively, develop a customized bootloader using, for example, a serial communication interface that is not supported in ST versions or in devices where the ST bootloader is not present. Such a bootloader should be stored in the user boot code area (UBC) in the microcontroller. This guarantees protection against unintentional write operations.

2 STM8 devices with built-in ROM-bootloader

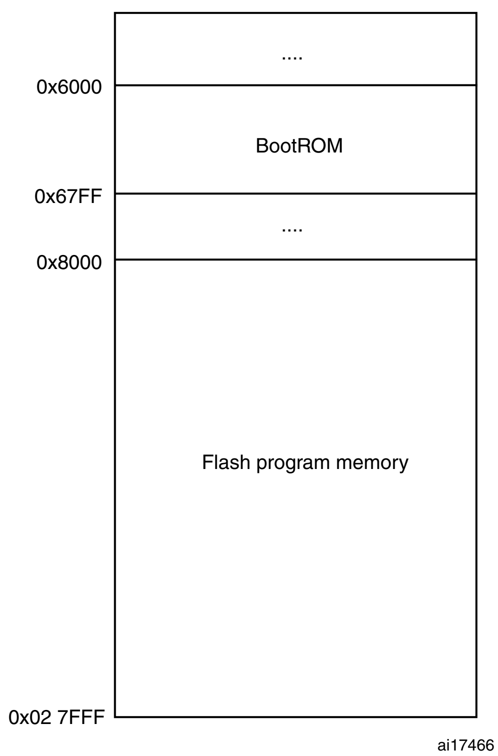
Most STM8 devices have an internal bootROM memory which contains an ST proprietary bootloader. Consequently, they already have a built in IAP implementation (see UM0560: STM8 bootloader).

2.1 Implementation details

The built-in ROM-bootloader is located in a dedicated part of the memory called the BootROM. The ROM-bootloader code is fixed (not rewritable) and is specific for each device. The communication interface supported depends on the peripherals present in the given STM8 device and whether they are implemented in the ROM-bootloader. For example, some devices support firmware download through UART/LIN and CAN, some devices support only UART, and others only SPI. Information concerning the supported interfaces can be found in the relevant device datasheet.

Activation of the built-in ROM-bootloader is made by programming the BL[7:0] option byte described in the option byte section of the device datasheet. The bootROM bootloader checks this option byte and if it is enabled, it runs its own code (it waits for the host to send commands/data). If the BL[7:0] option byte is inactive, the bootrom bootloader jumps to the user reset address (0x8000).

Figure 2. Example of STM8S208xx bootloader



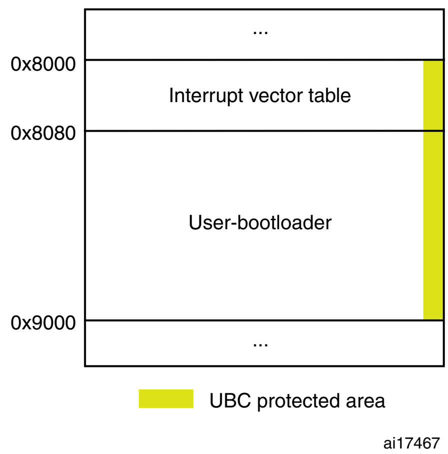
2.2 Adapting IAP master side to ROM-bootloader protocol

To be able to download firmware into the device, the host and bootloader must communicate through the same protocol. This bootloader protocol for STM8 devices is specified in the *STM8 bootloader (UM0560) user manuals* available from http://www.st.com. The same protocol is used in the firmware example provided with this application note. The UM0560 user manual describes all bootloader protocol properties including used interfaces, timeouts, command formats, packet formats, and error management.

3 User-bootloader for STM8 devices

For STM8 microcontrollers which do not include a built-in bootloader or which use a communication protocol (I^2C) not yet supported in the built-in bootloader, user-bootloader firmware can be added and customized at the beginning of the Flash memory.

Figure 3. Example of user-bootloader implementation in the Flash memory

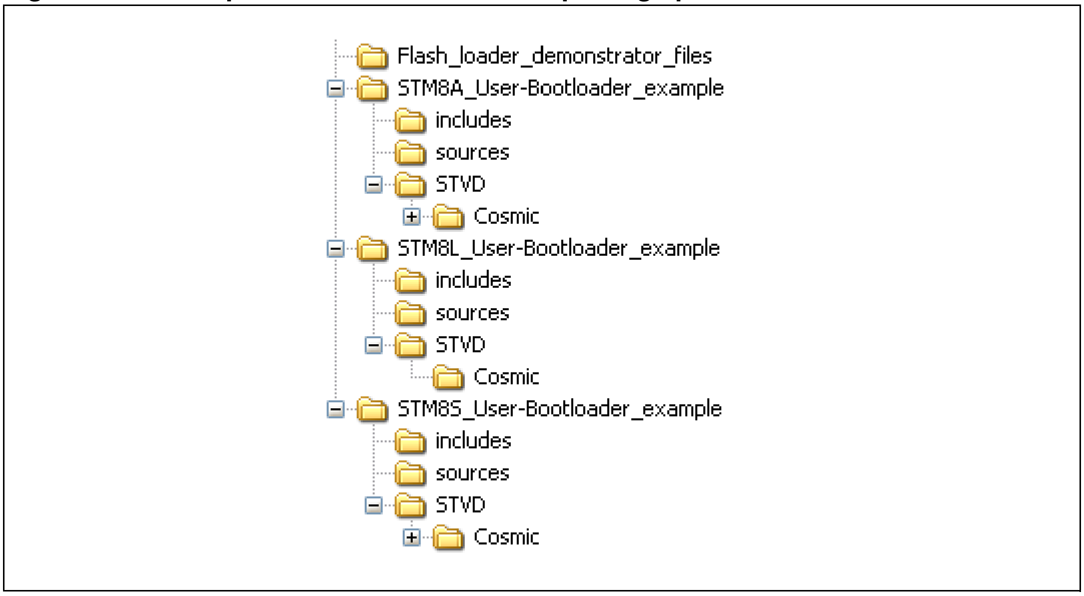


For this purpose, an example of a user-bootloader firmware is provided with this application note. This package is divided into three main subdirectories, each one dedicated to one STM8 family member (STM8A, STM8L, and STM8S). Each directory is composed of the following components:

- **Sources**: containing the firmware source code
- **Includes**: containing the firmware header file (main.h). This file can be edited to configure your user-bootloader (see *Section 3.2: Configuring the user-bootloader firmware example*).
- Flash_loader_demonstrator_files: contain all map files to add in the Flashloader demonstrator install directory to be compatible with the user-bootloader.
- **STVD**: containing a prebuilt project for STVD using a Cosmic or raisonance compiler

Figure 4 shows an example of the the user-bootloader firmware.

Figure 4. Example of the user-bootloader package provided



3.1 User-bootloader firmware example description

The basic program flow of a user bootloader application is described in *Figure 5: Bootloader flowchart*.

After a device reset, a selected GPIO can be used as a bootloader activation signal. Depending on its logical state (0 V or 5 V), the bootloader can be activated or not.

The bootloader configures this GPIO as input mode with pull-up in order to detect any voltage variation. If the pin voltage level is zero (jumper present), the bootloader is activated. Otherwise, the bootloader jumps to the reset address of the user application (if this address is valid).

In the case of bootloader activation, the chosen communication interface is initialized. A timeout count is then activated (i.e. 1 second). If, during this timeout, nothing is received from the given communication interface (UART, SPI, I^2C) the bootloader jumps to the user application reset address.

If the user-bootloader receive a valid activating token byte from the communication interface before the timeout elapses, it then enters memory management mode to perform the following operations:

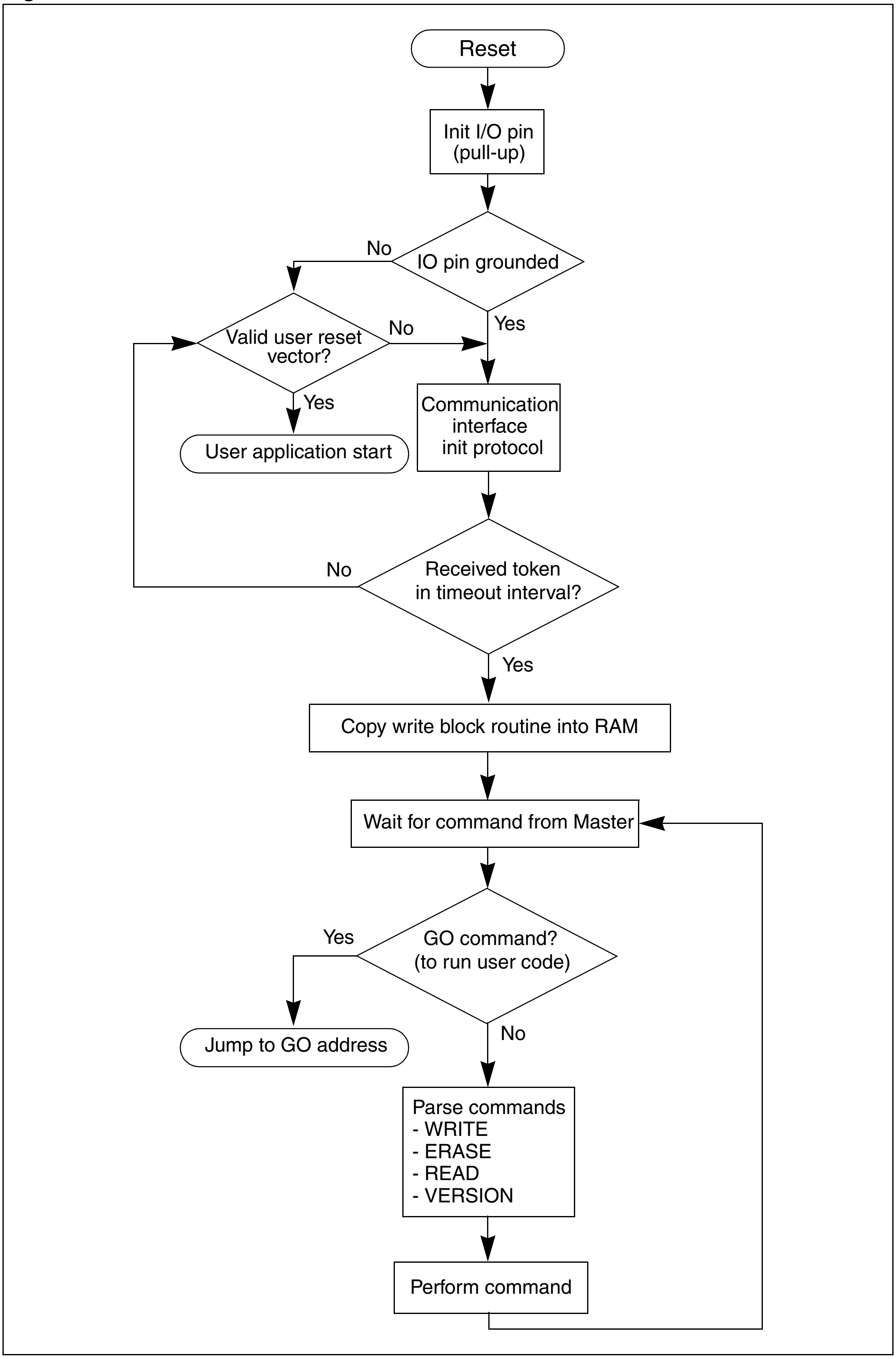
1. Initialize the Flash programming routines by copying the programming functions to RAM.
2. Wait in a loop for a valid command to be received from the master
3. Compute the received command (read, write, erase, version)
4. If a Go command is received, the user-bootloader jumps to the address given in the command.

All commands have a specified format and must be followed by both the user-bootloader and the master. The command specification handles all possibilities and covers error management.

Several specific processing methods must be taken into account to achieve the appropriate action in the memory using the bootloader. These methods are explained in *Section 4: Memory management for IAP*. They include:

- Protection management
- Code execution from RAM depending on memory write method (byte, word, or block programming).

Figure 5. Bootloader flowchart



3.2 Configuring the user-bootloader firmware example

The provided package is configured for STM8S105xx devices with I^2C protocol. The package can be reconfigured easily, without any source code modification, by modifying information in the main.h files (see package description).

The configuration file is divided into three sections (see below). Each section can be modified depending on requirements.

```
/* USER BOOTLOADER PROTOCOL PARAMETERS */
```

This section is used to select a protocol. The user-bootloader firmware example supports three protocols: UART, I^2C, and SPI. Only one protocol can be selected.

```
/* USER USER BOOT CODE Customisation */
```

This section is used for defining byte values (acknowledge, non-acknowledge, and identification), command numbers, and received data buffer structure.

```
/* USER BOOT CODE MEMORY PARAMETERS */
```

This section is used to describe the memory configuration of the STM8 microcontroller. It is mandatory to set up some memory variables corresponding to the memory configuration of the microcontroller, for example, memory size, block size, EEPROM size, and address range. For more informations on these variables please refer to the appropriate device datasheet).

4 Memory management for IAP

4.1 Memory protection

4.1.1 Flash memory protection

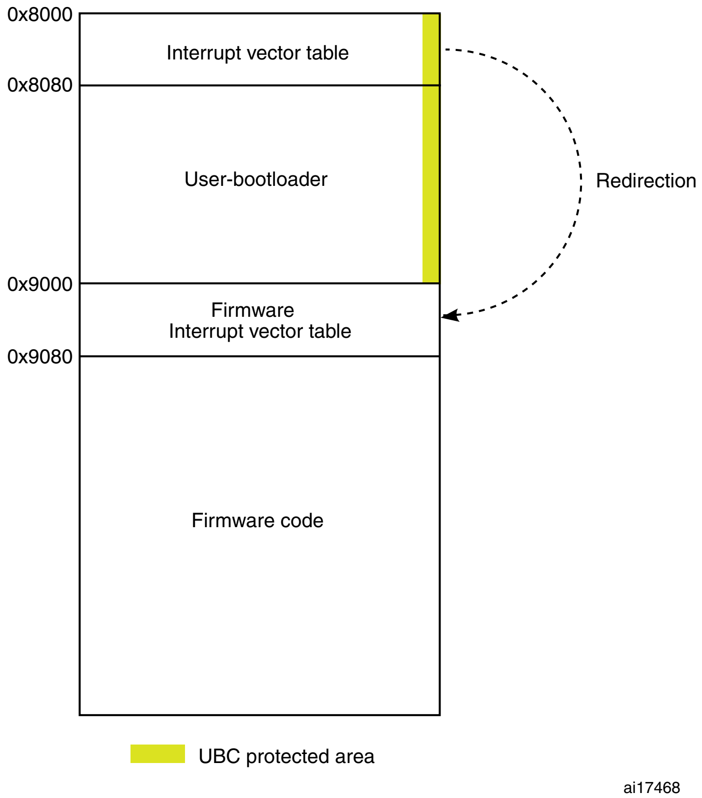
To avoid accidental overwriting of the Flash code memory (for example in the case of a firmware crash) several levels of write protection are implemented in the STM8 microcontroller family.

After an STM8 reset, write access to the Flash memory is disabled. To enable it, firmware must write two unlock keys in a dedicated register. If the unlock keys are correct (0x56, 0xAE), write access to the Flash memory is enabled and it is possible to program the Flash memory using either byte/word or block programming mode. If the unlock keys are incorrect, write access to the Flash memory is disabled until the next device reset. After writing to the Flash memory, it is recommended to enable write protection again by clearing a specific bit in the Flash control register (to avoid accidental write). A similar protection mechanism exists for the Data EEPROM memory, with a specific unlock register and unlock keys (0xAE, 0x56).

4.1.2 User boot code protection (UBC)

Additional write protection exists for the programming code itself, to protect the user-bootloader code from being overwritten during IAP. The STM8 family has a user boot code (UBC) area which is permanently write protected. This UBC area starts from the Flash memory start address (0x8000) and its size can be changed by the UBC option byte (see device reference manuals and product datasheets). The boot code area also includes an interrupt vector table (0x8000 to 0x8080). An important point to highlight in order to modify the vector table via IAP, is that the main vector table should be redirected to another vector table located in the rewritable application code area (see *Figure 6*). The only drawback of such redirection, is the increase of the interrupt latency because of the execution of a double jump.

Figure 6. User boot code area and user application area



More detailed information about memory map of specific STM8 device type can be found in the STM8 reference manuals and datasheets.

4.1.3 Vector table redirection

As the initial interupt vector table (address 0x8000 to 0x8080) is write protected by the UBC option, it is mandatory to create another interrupt vector table to be able to modify it by IAP. Vector table redirection is performed in the following way:

- The start of the user application area contains its own interrupt table with the same format as the primary interrupt table.
- The primary interrupt table contains a set of jumps to the user interrupt table. If an interrupt occurs, the user application is automatically redirected from the primary interrupt table to the user interrupt table by one jump.
- The only requirement for the user application is that the user interrupt table must be located at a fixed address. This is because the primary interrupt table is not rewritable and jumps to the user interrupt table at a fixed address value (see *Section 6: Setting up your application firmware for user-bootloader use*).

4.2 Block versus word programming

STM8 microcontrollers contain a Flash type program memory where firmware can be writen. There are two methods for writing (or erasing) Flash program memory:

- Byte/word programming (1 or 4 bytes)
  - Advantages: offers small area programming, code can be executed directly on the Flash program.
  - Disadvantages: program stops during programming, programming speed is slow
- Block programming (128 bytes or 1 Flash block for a given STM8 device)
  - Advantages: offers large area programming with high speed (large blocks)
  - Disadvantages: programming routine must run from the RAM (need to copy programming routine into the RAM).

4.3 RAM versus Flash programming code location

Depending on the selected programming method (see *Section 4.2: Block versus word programming*), the programming code must run from the RAM or from the Flash memory.

If the programming code runs from the Flash memory, use only byte/word programming to program the Flash memory. During Flash memory programming, the code cannot access the Flash memory (the Flash is in programming mode). Therefore, program execution from the Flash is stopped during programming (for several milliseconds) and then continues. This mode is useful in situations where only a small part (a few bytes) of the Flash memory needs to be updated or when it does not matter that programming is (very) slow.

To program a large Flash memory area with optimum speed, block programming mode has to be used. Block programming mode can be performed only by a code located in the RAM. First, copy the programming code into the RAM and then run (jump to) this code. The RAM code can then use block mode to program the Flash. In this mode, programming one block takes the same time as programming one byte/word in byte/word mode. Consequently, programming speed is faster and code execution is not stopped (because it is running from RAM). The only disadvantage of this method is the RAM code management:

- Copying the executable code to the RAM
- Storing the RAM code
- Allocating RAM space for the code
- Compiling the code to be able to run from the RAM

4.3.1 Programming the data EEPROM area

For data EEPROM programming, the programming code does not have to be executed from the RAM. It can be located in the Flash program memory, even if block programming is used. This read-while-write (RWW) feature speeds up microcontroller performance during IAP. Only the data loading phase, the part of code which loads data into the EEPROM buffer, must execute from the RAM. However, during the physical programming phase, which takes more time (several milliseconds), the code runs from the Flash while the data EEPROM memory is programmed in the background. Completion of data EEPROM programming is indicated by a flag. An interrupt can be generated when the flag is set.

4.4 Library support for Flash programming

The STM8 firmware libraries, available from www.st.com, provide developed and verified functions for programming the Flash memory of every STM8 microcontroller family. The functions support byte/word and block programming and make it easier for developers to write their own programming code. The library also includes functions for managing the programming code execution from RAM. These functions are: copy to RAM, execution from RAM, and storing functions in the Flash memory. They are contained in the following files:

- \library\scr\stm8x_flash.c
- \library\inc\stm8x_flash.h

These files contain the complete source code for Flash programming. Refer to the library user manual "\FWLib\stm8s_fwlib_um.chm" for help using the STM8 library.

4.4.1 Flash programming function list

This list gives a short description of the STM8S Flash programming functions (which are the same for STM8A and STM8L devices):

void FLASH_DeInit (void)
Deinitializes the FLASH peripheral registers to their default reset values.

void FLASH_EraseBlock (u16 BlockNum, FLASH_MemType_TypeDef MemType)
Erases a block in the program or data EEPROM memory.

void FLASH_EraseByte (u32 Address)
Erases one byte in the program or data EEPROM memory.

void FLASH_EraseOptionByte (u32 Address)
Erases an option byte.

u32 FLASH_GetBootSize (void)
Returns the boot memory size in bytes.

FlagStatus FLASH_GetFlagStatus (FLASH_Flag_TypeDef FLASH_FLAG)
Checks whether the specified Flash flag is set or not.

FLASH_LPMode_TypeDef FLASH_GetLowPowerMode (void)
Returns the Flash behavior type in low power mode.

FLASH_ProgramTime_TypeDef FLASH_GetProgrammingTime (void)
Returns the fixed programming time.

void FLASH_ITConfig (FunctionalState NewState)
Enables or disables the Flash interrupt mode.

void FLASH_Lock (FLASH_MemType_TypeDef MemType)
Locks the program or data EEPROM memory.

*void FLASH_ProgramBlock (u16 BlockNum, FLASH_MemType_TypeDef MemType, FLASH_ProgramMode_TypeDef ProgMode, u8 * Buffer)*
Programs a memory block.

void FLASH_ProgramByte (u32 Address, u8 Data)
Programs one byte in the program or data EEPROM memory.

void FLASH_ProgramOptionByte (u32 Address, u8 Data)
Programs an option byte.

void FLASH_ProgramWord (u32 Address, u32 Data)
Programs one word (4 bytes) in the program or data EEPROM memory.

u8 FLASH_ReadByte (u32 Address)
Reads any byte from the Flash memory.

u16 FLASH_ReadOptionByte (u32 Address)
Reads one option byte.

void FLASH_SetLowPowerMode (FLASH_LPMode_TypeDef LPMode)
Select the Flash behavior in low power mode.

void FLASH_SetProgrammingTime (FLASH_ProgramTime_TypeDef ProgTime)
Sets the fixed programming time.

void FLASH_Unlock (FLASH_MemType_TypeDef MemType)
Unlocks the program or data EEPROM memory.

FLASH_Status_TypeDef FLASH_WaitForLastOperation (FLASH_MemType_TypeDef MemType)
Waits for a Flash operation to complete.

Note: The STM8 library package also contains examples that show how to use these functions in the final source code. Write your own code based on these examples.

5 Configuring the Cosmic compiler for RAM code execution

Block programming must be executed from the RAM memory. Therefore, the code to be copied into the RAM must be compiled and linked to be run in the RAM address space but it is stored in the Flash memory.

It is possible to write a simple programming code assembly, taking care with the RAM addressing and then storing this code in the Flash (example, the code uses only relative addressing or RAM addresses). However, it is more efficient to use compiler support for this purpose. Cosmic compiler support (described below) has these features built-in. Two processing methods can be used:

- Creating a segment in the STVD project
- Creating a memory segment in the Cosmic linker file

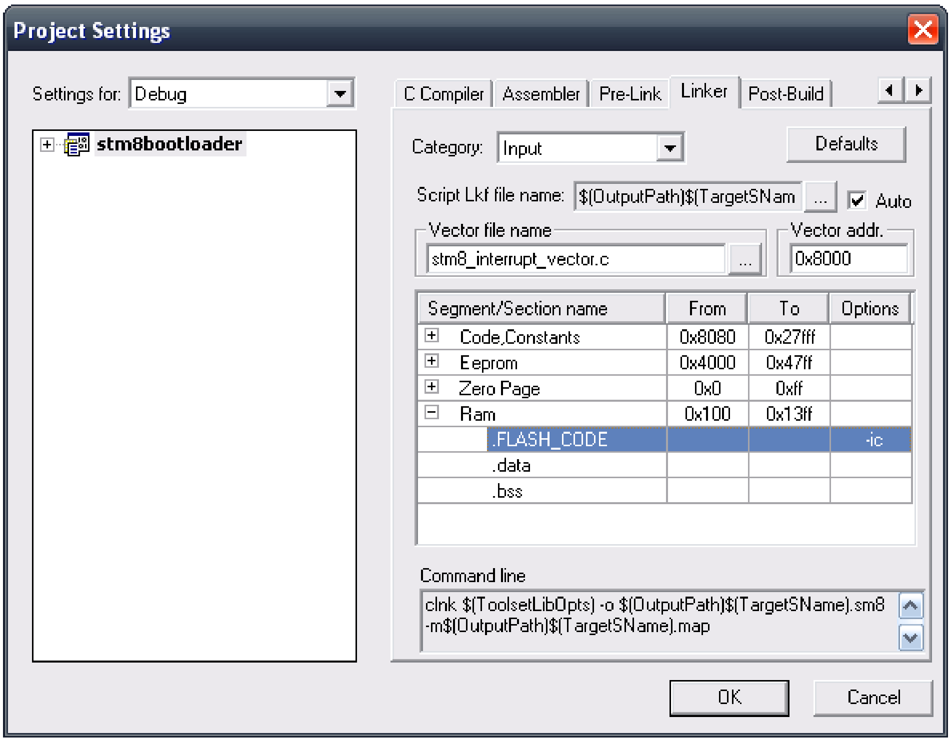
5.1 Creating a segment in the STVD project

The first step to create a segment in the STVD project is to define one section in your code, example ”FLASH_CODE”, and put your Block programming function inside. This is done using the following code:

```
...
//set code section to FLASH_CODE placement
#pragma section (FLASH_CODE)
void FlashWrite(void)
{
...
}
void FlashErase(void)
{
...
}
//set back code section to default placement
#pragma section ()
...
```

The second step is to set the linker in your project settings window by clicking on **Project>Settings**, then clicking on access to **Linker tab,** and then selecting **”input”** category. In this way you can dedicate a memory area to your defined section, **“.FLASH_CODE”,** in the RAM . **Option “-ic”** must also be associated with this section (see *Figure 7: Define linker memory section in STVD*).

Figure 7. Define linker memory section in STVD



5.2 Creating a memory segment in the Cosmic linker file

The second way to configure the Cosmic compiler for RAM code execution is to create a special memory segment which is defined in the linker file (*.lkf) and marked by the flag *"-ic"*. An example of a RAM space segments definition in the linker file is as follows:

```
# Segment Ram:
+seg .data -b 0x100 -m 0x500 -n .data
+seg .bss -a .data -n .bss
+seg .FLASH_CODE -a .bss -n FLASH_CODE -ic
```

This example defines a RAM space from address 0x100. Firstly, the .data and .bss sections are defined. Then, the code defines a moveable .FLASH_CODE section where the routines for Flash memory erase and write operations are located. This section must be marked by option *"-ic"* (moveable code).

Into the marked *"-ic"* section, put functions which should be compiled/linked for RAM execution but which are stored in the Flash memory. This is done in the source code by definiting a section as shown below:

```
...
//set code section to FLASH_CODE placement
#pragma section (FLASH_CODE)
void FlashWrite(void)
{
...
}
void FlashErase(void)
{
...
}

//set back code section to default placement
#pragma section ()
...
```

5.3 Finishing and checking the configuration

By using either one of the above processes (*Creating a segment in the STVD project* or *Creating a memory segment in the Cosmic linker file*), the *"FlashWrite()"* and *"FlashErase()"* functions are compiled and linked for RAM execution (in the section *"FLASH_CODE"*) but their code is placed in the Flash memory (after the *".text"* and *".init"* sections). This can be seen in the generated map file:

Example of final map file:

```
                               --------
                               Segments
                               --------
start 00008080 end 00008500 length  1152 segment .text
start 00000000 end 00000000 length     0 segment .bsct
start 00000000 end 00000003 length     3 segment .ubsct
start 00000003 end 00000098 length   149 segment .RAM
start 00000098 end 00000098 length     0 segment .share
start 00000100 end 00000100 length     0 segment .data
start 00000100 end 00000100 length     0 segment .bss
start 00000100 end 000001F0 length   240 segment .FLASH_CODE, initialized
start 00008510 end 00008600 length   240 segment .FLASH_CODE, from
start 00008000 end 00008080 length   128 segment .const
start 00008500 end 00008510 length    16 segment .init
```

The map file shows the location of the *"FLASH_CODE"* sections. One section is for storage in the Flash (it is stored in the map file marked *"from"*). The other section is for execution (it is stored in the map file marked *"initialized"*).

Finally, the microcontroller firmware must copy these sections from the Flash to the RAM before calling the RAM functions. The Cosmic compiler supports this copying by a built-in function *"int _fctcpy(char name)"* which copies a whole section from a source location in the Flash to a destination location in the RAM using the following code:

```
void main(void)
{
    ...
    //copy programming routines to Flash
    _fctcpy('F');

    /* Define flash programming Time*/
    FLASH_SetProgrammingTime(FLASH_PROGRAMTIME_STANDARD);

    /* Unlock Program & Data memories */
    FLASH_Unlock(FLASH_MEMTYPE_DATA);
    FLASH_Unlock(FLASH_MEMTYPE_PROG);

...
}
```

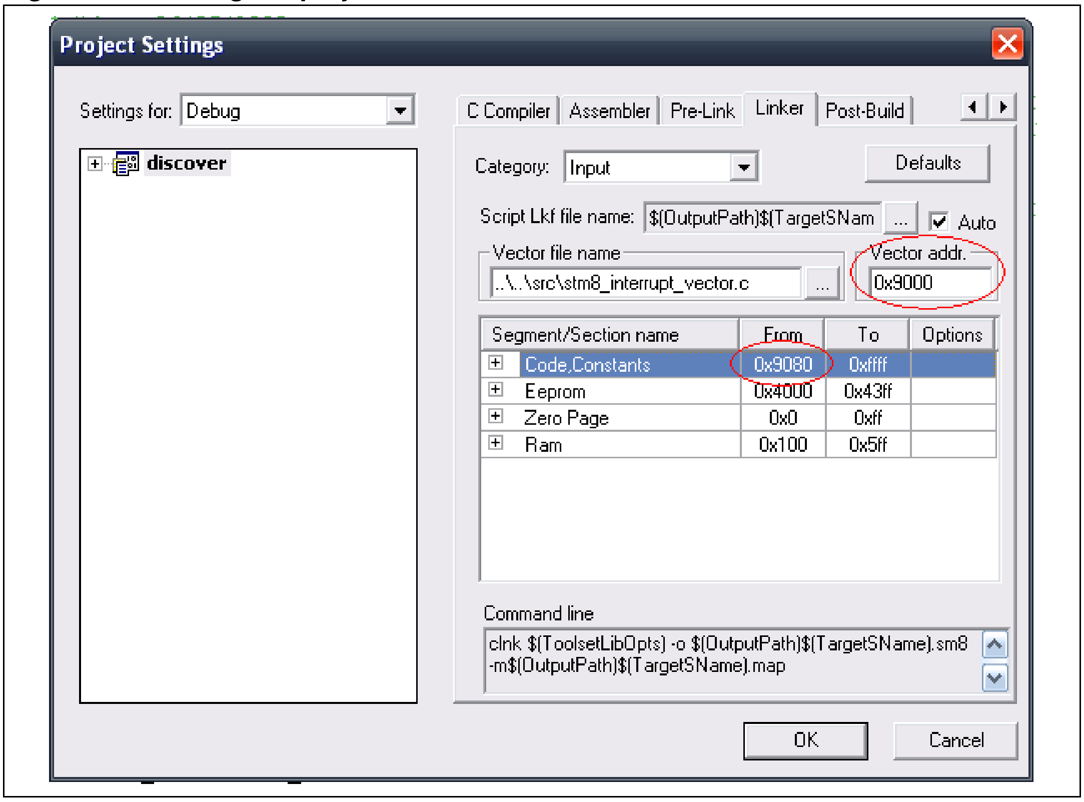
Just after the program starts, the RAM section is copied from the Flash into the RAM by the function *"_fctcpy('F')"*. The function parameter 'b' is the first character of the section name defined in the linker file (*"F"* as *"FLASH_CODE"* - see linker file *on page 19*) .

The firmware can then call any of the FLASH_xxx() functions in the RAM and execution is done only from RAM.

6 Setting up your application firmware for user-bootloader use

The application firmware and the user-Bootloader firmware must be developped as two different projects. The user-bootloader firmware occupies the UBC part of the memory (with an address range at the beginning of the Flash memory, see *Figure 6: User boot code area and user application area*). To correctly program your application firmware using the user-bootloader, you need to shift the start and vector table addresses of your application. This avoids any Flash memory write in the area reserved for the user-bootloader. This is done in STVD by modifying the linker configuration. You can access the linker by clicking on **Project>Settings,** then clicking on access to **Linker tab,** and then selecting the **"input"** category. In this way, you can move your vector table and the "Code,Constants" section according to the size of the user-bootloader being used (see *Figure 8*).

Figure 8. Setting the project start and vector table addresses in STVD



To finish the setup, your new vector table address must be in line with the define variable (`MAIN_USER_RESET_ADDR`) in your user-bootloader project main.h. This is done using the following code:

```
...
#define MAIN_USER_RESET_ADDR 0x9000ul
...
```

7 Conclusion

The STM8 microcontroller fully supports IAP programming. This feature allows the internal STM8 firmware to erase and write to any of its internal memories including the Flash program memory, data EEPROM memory, and RAM memory. The short programming times (inherent in such advanced technology) can be further decreased by using fast programming mode (if the destination memory is erased). The STM8 RWW feature allows the microcontroller to stay at a high performance level even during Flash and/or EEPROM memory programming.

The user-bootloader application presented here, provides designers with an IAP implementation that they can use to add IAP support into their own final products. The bootloader code is designed to run in the STM8 family of microcontrollers.

7.1 Features in the final user-bootloader application

- Bootloader activated by an external pin (jumper on PCB)
- Interrupt table redirection
- Executable RAM code management
- Library support for easier programming
- RWW feature
- High level C-language usage
- Support for multiple communication interfaces (UART, SPI, I^2C)

8 Revision history

Table 1. Document revision history

Date	Revision	Changes
20-Feb-2010	1	Initial release
10-Jun-2010	2	Document updated to include the whole STM8 family (STM8A, STM8L, and STM8S). Content of document restructured and rewritten.
25-Aug-2011	3	Updated document references to bootloader manual in *Section 2.2*