



Updating firmware in STM32L1xx microcontrollers through in-application programming using the USART

Introduction

An important requirement for most Flash-memory-based systems is the ability to update the firmware when installed in the end product. This ability is referred to as in-application programming (IAP). The purpose of this application note is to provide general guidelines for creating an IAP application.

The STM32L1xx microcontroller can run user-specific firmware to perform IAP of the microcontroller-embedded Flash memory. This feature allows the use of any type of communication protocol for the reprogramming process. The USART is the example used in this application note.

Contents

1	IAP overview	3
1.1	Principle	3
1.2	IAP driver description	3
2	Running the IAP driver	6
2.1	HyperTerminal configuration	6
2.2	Executing the IAP driver	7
3	IAP driver menu	8
3.1	Downloading an image to the internal Flash memory	8
3.2	Uploading an image from the internal Flash memory	9
3.3	Executing the new program	9
3.4	Disabling the write protection	9
4	STM32L1xx IAP implementation summary	10
5	User program conditions	12
6	Firmware updates	13
7	How to place FLASH programming functions into internal SRAM/FLASH 14	
8	Memory write protection	15
9	Dual bank feature for high-density devices	16
10	Revision history	18

1 IAP overview

Ultra low power medium-density devices are STM32L151xx and STM32L152xx microcontrollers where the Flash memory density ranges between 64 and 128 Kbytes. Ultra low power medium-density devices are implemented in the STMicroelectronics STM32L152-EVAL evaluation board.

Ultra low power medium-density plus devices are STM32L151xx, STM32L152xx and STM32L162xx microcontrollers where the Flash memory density is 256 Kbytes.

Ultra low power high-density devices are STM32L151xx, STM32L152xx and STM32L162xx microcontrollers where the Flash memory density is 384 Kbytes. Ultra low power high-density devices are implemented in the STMicroelectronics STM32L152D-EVAL evaluation board.

1.1 Principle

You should program the IAP driver to the Flash memory base address via the JTAG/SWD interface using the development toolchain of your choice or the factory-embedded boot loader in the System memory area.

The IAP driver uses the USART to:

- Download a binary file from the HyperTerminal to the STM32L1xx's internal Flash memory.
- Upload the STM32L1xx's internal Flash memory content (starting from the defined user application address) into a binary file.
- Execute the user program.

1.2 IAP driver description

The IAP driver contains the following set of source files:

- *main.c*: where the USART initialization and RCC configuration are set. A main menu is then executed from the *menu.c* file.
- *menu.c*: contains the main menu routine. The main menu gives the options of downloading a new binary file, uploading internal Flash memory, executing the binary file already loaded and disabling the write protection of the pages where the user loads his/her binary file (if they are write-protected).
- *flash_if.c*: contains write, erase and disable write protection of the internal Flash memory.
- *common.c*: contains functions related to read/write from/to the USART peripheral.
- *ymodem.c*: is used to receive/send the data from/to the HyperTerminal application using the YMODEM protocol^(a). In the event of a failure when receiving the data, the "Failed to receive the file" error message is displayed. If the data is received

a. The Ymodem protocol sends data in 1024-byte blocks. An error check is performed in data blocks transmitted to the STM32L1xx's internal RAM to compare the transmitted and received data. Blocks unsuccessfully received are acknowledged with an NAK (Negative Acknowledgement). For more details about the Ymodem protocol, refer to existing documentation.

successfully, it is programmed into the internal Flash memory from the appropriate address. A comparison between internal RAM contents and internal Flash memory contents is performed to check the data integrity. If there is any data discrepancy, the “Verification failed” error message is displayed. Other error messages are also displayed when the image file size is greater than the allowed memory space and when the user aborts the task.

- STM32L1xx Standard Peripherals Library.

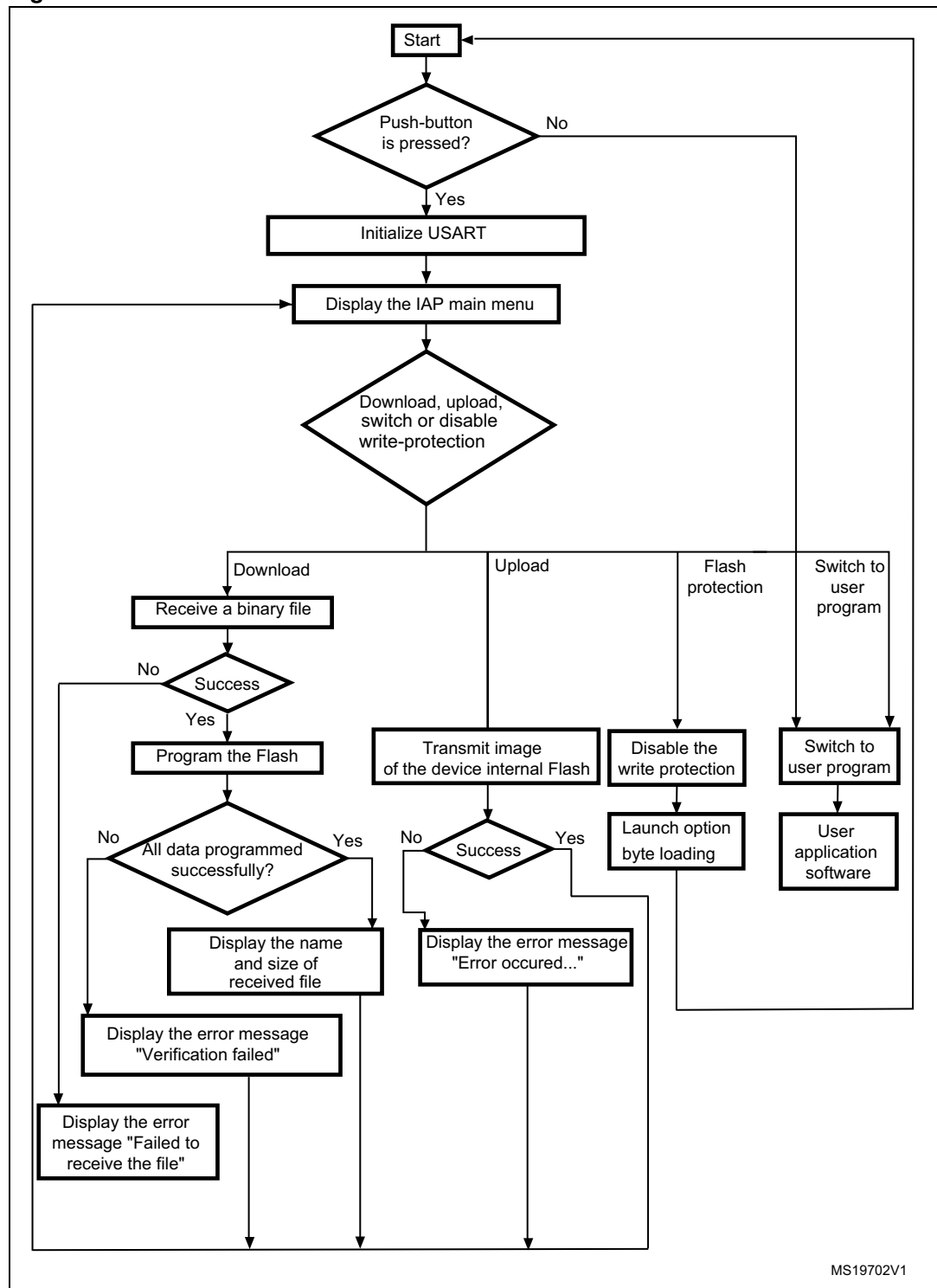
The user can choose to either go to the user application or execute the IAP for reprogramming purposes by pressing a push-button connected to a pin.

- Not pressing the push-button at reset switches to the user application
- Pressing the push-button at reset displays the IAP main menu

Refer to [Table 1. STM32L1xx IAP implementation](#) for more details about the STM32L15xx-EVAL board push-button used to enter the IAP mode.

The IAP flowchart is shown in [Figure 1: Flowchart of the IAP driver](#).

Figure 1. Flowchart of the IAP driver



2 Running the IAP driver

For ultra low power medium-density and medium-density plus devices, the IAP driver is programmed in the Flash memory from Page 0 to Page 47 and the user application occupies the remaining memory space.

For ultra low power high-density devices, the Flash memory implements the dual bank feature (Refer to [Chapter 9: Dual bank feature for high-density devices](#)).

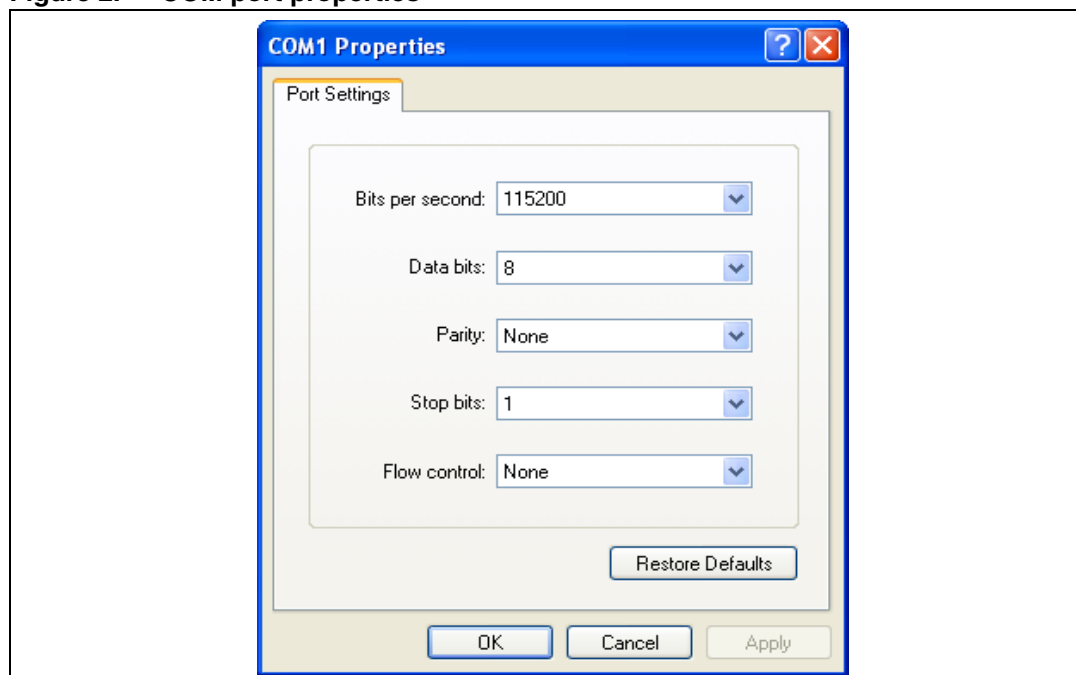
The IAP driver can be programmed in Bank1 (from Page 0 to Page 47) and the user application occupies the rest of Flash memory or Bank2.

The IAP driver can be programmed in Bank2 (from Page 768 to Page 814) and the user application occupies the rest of Bank2 or Bank1.

2.1 HyperTerminal configuration

To use the IAP, the user must have a PC running HyperTerminal or other Terminal program that supports **ymodem protocol**. In this document, the HyperTerminal is used. The following figure shows the HyperTerminal configuration.

Figure 2. COM port properties



Note: The baud rate value of 115,200 bps is used as an example.

Care must be taken when selecting the system clock frequency. To guarantee successful communication via the USART, the system clock frequency in the end application must be such that a baud rate equal to 115,200 bps can be generated.

2.2 Executing the IAP driver

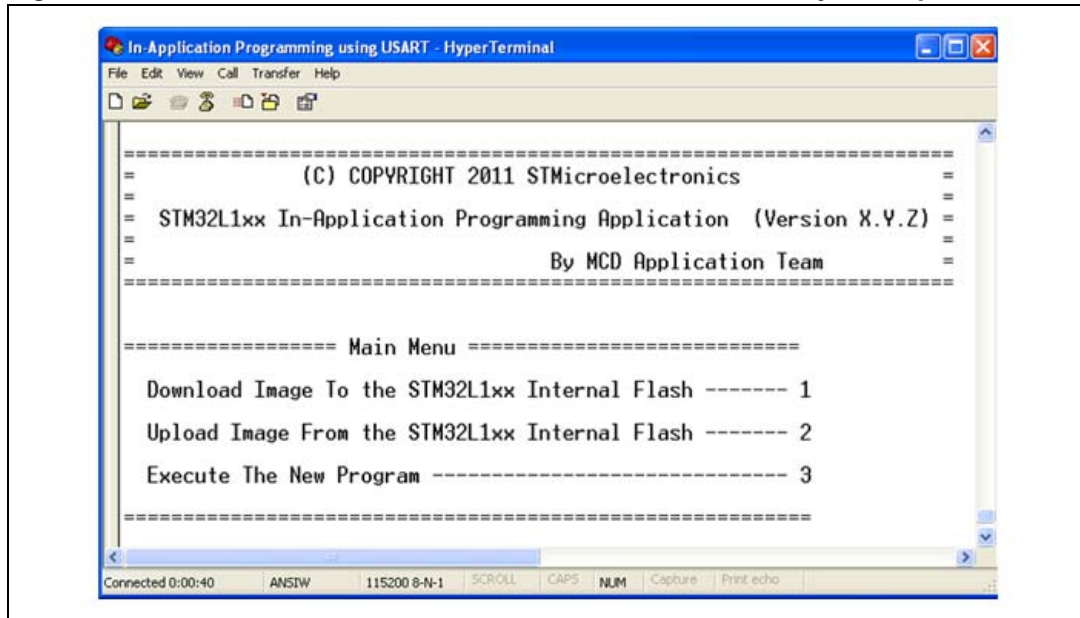
As an example in this application note, pressing the pin connected to the push-button allows the IAP driver to run.

By pressing the push-button at reset, the user can run the IAP driver to reprogram the STM32L1xx's internal Flash memory. It is not mandatory to use the push-button; the user can apply a signal to this pin with respect to its active level. Refer to [Table 1: STM32L1xx IAP implementation](#).

3 IAP driver menu

Running the IAP displays the following menu in the HyperTerminal window.

Figure 3. IAP Driver menu when the STM32L1xx Flash memory is not protected



3.1 Downloading an image to the internal Flash memory

To download a binary file via HyperTerminal to the STM32L1xx's internal Flash memory, do as follows:

1. Press **1** on the keyboard to select the **Download Image To the STM32L1xx Internal Flash** menu
2. Select **Send File** in the **Transfer** menu
3. In the **Filename** field, type the name and the path of the binary file you want to download
4. From the protocol list, select the **Ymodem** protocol
5. Click on the **Send** button

As a result, the IAP driver loads the binary file into the STM32L1xx's internal Flash memory from the defined base address and displays the binary file name and size in the HyperTerminal window.

3.2 Uploading an image from the internal Flash memory

To upload a copy of the internal Flash memory started from the user application address, do as follows:

1. Press 2 on the keyboard to select **Upload image from the STM32L1xx internal Flash** menu.
2. Select **Receive File** in the **Transfer** menu.
3. Select the directory to save the binary file.
4. From the protocol list, select the **Ymodem** protocol.
5. Click on the **Receive** button.

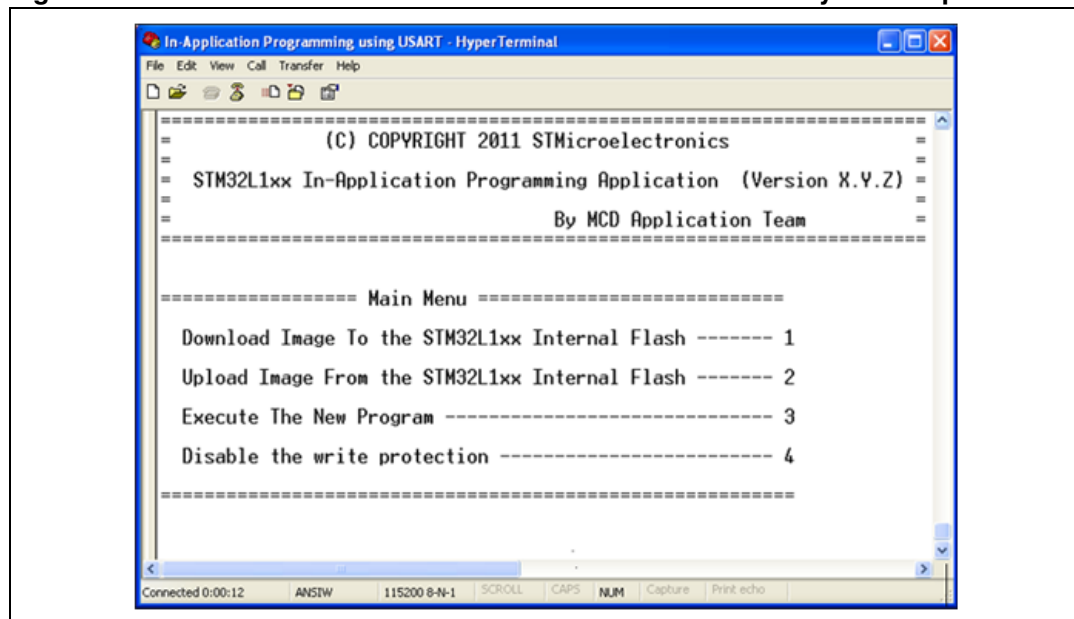
3.3 Executing the new program

Once the new program has been loaded, press 3 on the keyboard to select the **Execute The New Program** menu and execute the code.

3.4 Disabling the write protection

When the IAP starts, it checks the Flash memory pages where the user program is to be loaded to see if any are write-protected. If it is the case, the menu shown in [Figure 4](#) appears.

Figure 4. IAP Driver menu when the STM32L1xx Flash memory is write-protected



Prior to downloading the new program, the write protection must be disabled. To do so, press 4 (**Disable the write protection**) on the keyboard. The write protection is disabled and a system reset is generated to reload the new option byte values. After resuming from reset, the menu shown in [Figure 3](#) is displayed if the key push-button is pressed.

Note: In this application, the read protection is not supported, so the user has to verify that the Flash memory is not read-protected.

4 STM32L1xx IAP implementation summary

[Table 1](#) provides a summary of the STM32L1xx IAP implementation.

Table 1. STM32L1xx IAP implementation

Firmware			Option byte ⁽¹⁾	Hardware	
IAP program	User application	Image upload		Push-button	USART
Low power medium-density devices (STM32L152-EVAL)					
The IAP program is located at 0x8000000. The Flash routines (program/erase) are executed from the Flash memory except half-page program routine which is executed from internal SRAM. The size of this program is about 8 Kbytes and programmed on page 0 to page 47	The user application (image to be downloaded with the IAP) will be programmed starting from address 0x8003000 ⁽²⁾ . The maximum size of the image to be loaded is 116 Kbytes (page 48 - page 511)	The image is uploaded with the IAP from the STM32L1xx Internal Flash. The maximum size of the image to be uploaded is 116 Kbytes (page 48 - page 511)	-	Push-button (active level: high): Key push-button connected to pin PA.0	USART2 used
Low power high-density devices (STM32L152D-EVAL)					
IAP(Bank1) and User app (rest of Flash)					
The IAP program is located at 0x8000000. The Flash routines (program/erase) are executed from the Flash memory except half-page program routine which is executed from internal SRAM ⁽³⁾ . The size of this program is about 8 Kbytes and programmed on page 0 to page 47	The user application (image to be downloaded with the IAP) will be programmed starting from address 0x8003000 ⁽²⁾ . The maximum size of the image to be loaded is 376 Kbytes (page 48 - page 1535)	The image is uploaded with the IAP from the STM32L1xx Internal Flash (Bank1 and Bank2). The maximum size of the image to be uploaded is 372 Kbytes (page 48 - page 1535)	Set BFB2 in order to boot from Bank1	Push-button (active level: high): Key push-button connected to pin PA.0	USART1 used
IAP(Bank1) and User app (Bank2)					
The IAP program is located at 0x8000000. The Flash routines (program/erase) are executed from the Flash memory. The size of this program is about 8 Kbytes and programmed on page 0 to page 47	The user application (image to be downloaded with the IAP) will be programmed starting from address 0x8030000 ⁽²⁾ . The maximum size of the image to be loaded is 192 Kbytes (page 768 - page 1535)	The image is uploaded with the IAP from the STM32L1xx Internal Flash (Bank2). The maximum size of the image to be uploaded is 192 Kbytes (page 768 - page 1535)	Set BFB2 in order to boot from Bank1	Push-button (active level: high): Key push-button connected to pin PA.0	USART1 used

Table 1. STM32L1xx IAP implementation (continued)

Firmware			Option byte ⁽¹⁾	Hardware	
IAP program	User application	Image upload		Push-button	USART
Low power high-density devices (STM32L152D-EVAL)					
IAP(Bank2) and User app (Bank1)					
The IAP program is located at 0x8030000. The Flash routines (program/erase) are executed from the Flash Memory. The size of this program is about 8 Kbytes and programmed on page 768 to page 814	The user application (image to be downloaded with the IAP) will be programmed starting from address 0x8000000 ⁽²⁾ . The maximum size of the image to be loaded is 192 Kbytes (page 0 to page 767)	The image is uploaded with the IAP from the STM32L1xx Internal Flash (Bank1). The maximum size of the image to be uploaded is 192 Kbytes (page 0 to page 767)	Reset BFB2 in order to boot from Bank2	Push-button (active level: high): Key push-button connected to pin PA.0	USART1 used
IAP and User app (Bank2)					
The IAP program is located at 0x8030000. The Flash routines (program/erase) are executed from the Flash Memory except half-page program routine which is executed from internal SRAM ⁽³⁾ . The size of this program is about 8 Kbytes and programmed on page 768 to page 814	The user application (image to be downloaded with the IAP) will be programmed starting from address 0x8033000 ⁽²⁾ . The maximum size of the image to be loaded is 180 Kbytes (page 815 to page 1535)	The image is uploaded with the IAP from the STM32L1xx Internal Flash (Bank2). The maximum size of the image to be uploaded is 180 Kbytes (page 815 to page 1535)	Reset BFB2 in order to boot from Bank2	Push-button (active level: high): Key push-button connected to pin PA.0	USART1 used

1. Refer to [Chapter 9: Dual bank feature for high-density devices](#) only for the STM32L15xx Low power high-density devices.
2. The user application location address is defined in the `flash_if.h` file as `"#define APPLICATION_ADDRESS 0x08003000"`. To modify it, change the default value to the desired one as described in [Table 2: Firmware updates](#).
3. Refer to [Table 2: Firmware updates](#).

The STM32L1xx IAP package comes with:

- Source files and pre-configured projects for the IAP program (under *Project\STM32L1xx_IAP* directory)
- Source files and pre-configured projects that build the application to be loaded into the Flash memory using the IAP (under *Project\STM32L1xx_IAP\binary_template* directory).

The readme.txt file provided within this package describes step by step how to execute this IAP application.

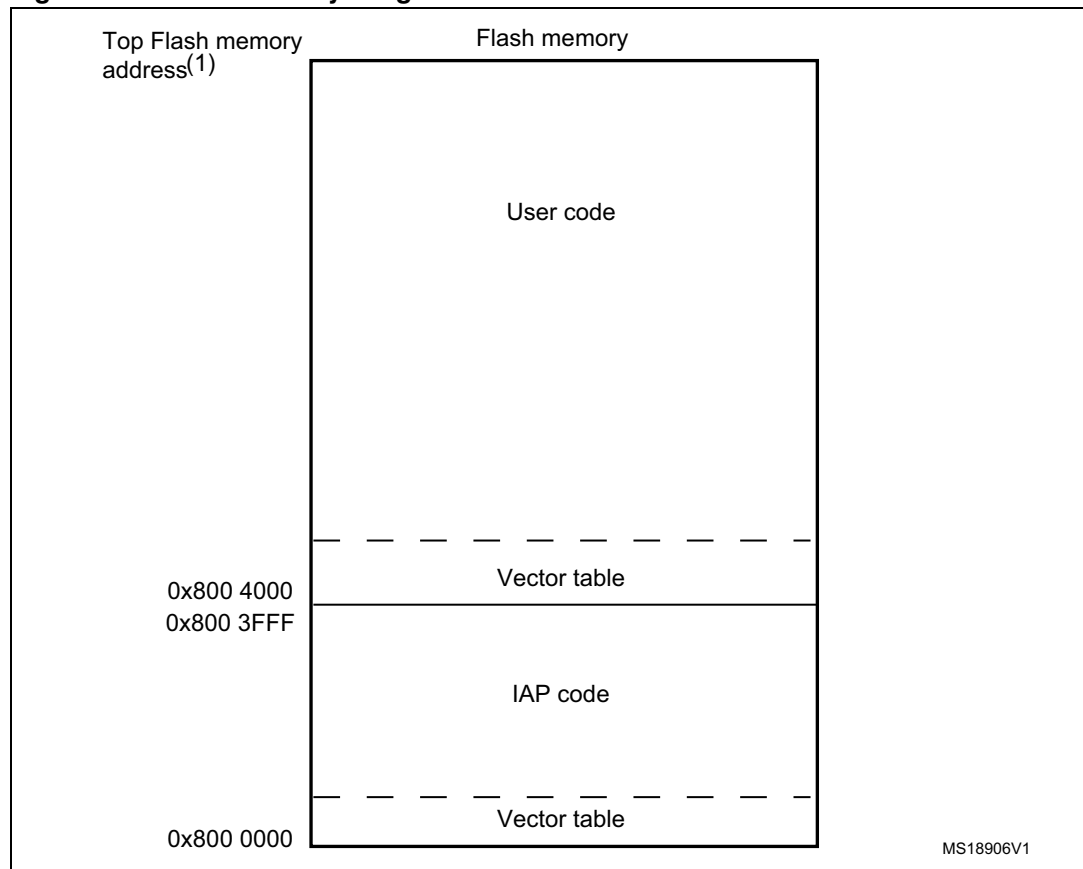
5 User program conditions

The user application to be loaded into the Flash memory using IAP should be built with these configuration settings:

1. Set the program load address at 0x08003000, using your toolchain linker file
2. Relocate the vector table at address 0x08003000, using the “NVIC_SetVectorTable” function.

An example application program to be loaded with the IAP application is provided with preconfigured projects.

Figure 5. Flash memory usage



1. Top Flash memory address is equal to:
0x0801 FFFF for ultra low power medium-density devices,
0x0805 FFFF for ultra low power high-density devices.

6 Firmware updates

Table 2. Firmware updates

Cases	Defines to be updated in <code>flash_if.h</code>	Flash routines (half-page program) executed from
IAP(Bank1) and User application (Rest of Flash)	<pre>#define USER_FLASH_LAST_PAGE_ADDRESS 0x0805FF00 #define APPLICATION_ADDRESS 0x08003000 #define FLASH_START_ADDRESS 0x08000000</pre>	Internal SRAM (user code to be programmed in Bank1 (0x08003000 - 0x0802FF00))
IAP(Bank1) and User application (Bank2)	<pre>#define USER_FLASH_LAST_PAGE_ADDRESS 0x0805FF00 #define APPLICATION_ADDRESS 0x08030000 #define FLASH_START_ADDRESS 0x08000000</pre>	Flash BANK1 (user code to be programmed in Bank2 (0x08030000 - 0x0805FF00))
IAP(Bank2) and User application (Bank1)	<pre>#define USER_FLASH_LAST_PAGE_ADDRESS 0x0802FF00 #define USER_FLASH_END_ADDRESS 0x0802FFFF #define APPLICATION_ADDRESS 0x08000000 #define FLASH_START_ADDRESS 0x08030000</pre>	Flash BANK2 (user code to be programmed in Bank2 (0x08000000 - 0x0802FF00))
IAP and User application (Bank2)	<pre>#define USER_FLASH_LAST_PAGE_ADDRESS 0x0805FF00 #define APPLICATION_ADDRESS 0x08033000 #define FLASH_START_ADDRESS 0x08030000</pre>	SRAM (user code to be programmed in Bank2 (0x08033000 - 0x0805FF00))

7 How to place FLASH programming functions into internal SRAM/FLASH

Half-page write is only possible from the SRAM or from Bank1 to Bank2 and vice versa. Depending on the cases named above, the return value of `FLASH_ProgramHalfPage()` function in the `stm32l1xx_flash_ramfunc.c` file should be updated as described in the table below.

Table 3. Update to the return value of `FLASH_ProgramHalfPage()`

IAP(Bank1) and User application (Rest of Flash)	<code>__RAM_FUNC FLASH_ProgramHalfPage(uint32_t Address, uint32_t* pBuffer)</code>
IAP(Bank1) and User application (Bank2)	<code>FLASH_Status FLASH_ProgramHalfPage(uint32_t Address, uint32_t* pBuffer)</code>
IAP(Bank2) and User application (Bank1)	<code>FLASH_Status FLASH_ProgramHalfPage(uint32_t Address, uint32_t* pBuffer)</code>
IAP and User application (Bank2)	<code>__RAM_FUNC FLASH_ProgramHalfPage(uint32_t Address, uint32_t* pBuffer)</code>

8 Memory write protection

The write protection should be disabled to the sector where the user code will be programmed.

Table 4. Memory write protection

IAP(Bank1) and User application (Rest of Flash)	Write protection should be disabled (WRP, WRP1 and WRP2) except for the sectors where the IAP code is programmed.
IAP(Bank1) and User application (Bank2)	Write protection should be disabled for BANK2 (some sector from WRP1 and WRP2).
IAP(Bank2) and User application (Bank1)	Write protection should be disabled for BANK1 (WRP and some sectors of WRP1)
IAP and User application (Bank2)	Write protection should be disabled for BANK2 (WRP1 and WRP2) except for the sectors where the IAP code is programmed.

The WRP register controls the write protection from Sector 0 to Sector 31 (128 Kbytes).

The WRP1 register controls the write protection from Sector 32 to Sector 63 (128 Kbytes).

The WRP2 register controls the write protection from Sector 64 to Sector 95 (128 Kbytes).

9 Dual bank feature for high-density devices

For STM32L15xx high-density devices (these devices have two Flash memory banks: Bank1 and Bank2), an additional boot mechanism is available which allows booting from Bank2 or Bank1 (depending on the BFB2 bit status (bit 19 in the user option bytes @ 0x1FFFF800)).

At startup, if BFB2 option bit is reset and the boot pins are in the boot from main Flash memory configuration, the device boots from Flash memory Bank1 or Bank2, depending on the activation of the bank.

The active banks are checked in the following order: Bank2, followed by Bank1. The active bank is identified by the value programmed at the base address of the bank (corresponding to the initial stack pointer value in the interrupt vector table).

1. When the BFB2 bit is reset, after reset, the device boots from the System memory and executes the embedded code which implements the dual bank mode:
 - a) First, the code checks Bank2. If it contains a valid code (see Note below), it jumps to the application located in Bank2.
 - b) If the Bank2 code is not valid, it checks Bank1 code. If it is valid (see Note below), it jumps to the application located in Bank1.
 - c) If both Bank2 and Bank1 do not contain valid code (see Note below), no jump to Flash banks is executed.
2. When BFB2 bit is set (default state), the dual bank boot mechanism is not performed.

Note: The code is considered as valid when the first data (at the bank start address, which should be the stack pointer) points to a valid address into the internal SRAM memory (stack top address). If the first address points to any other location (out of the internal SRAM), the code is considered not valid.

For more details, a dual bank Boot mode example (FLASH\Dual_Boot) is provided within the STM32L15xx Standard Peripheral Library available on www.st.com.

To change the BFB2 status, add the following functions to your code:

```
/* Reset BFB2 bit to enable boot from Flash Bank2 */
FLASH_Unlock();
FLASH_OB_Unlock();
FLASH_ClearFlag(FLASH_FLAG_EOP|FLASH_FLAG_WRPERR |
FLASH_FLAG_PGAERR |
FLASH_FLAG_SIZERR | FLASH_FLAG_OPTVERR | FLASH_FLAG_OPTVERRUSR);
FLASH_OB_UserConfig(OB_IWDG_SW, OB_STOP_NoRST, OB_STDBY_NoRST);
FLASH_OB_BORConfig(OB_BOR_LEVEL1);
/* BFB2 option bit will be reset then a system (SW) reset will be
generated. After startup from reset, the device will boot from
Bank2. */
if (FLASH_OB_BootConfig(OB_BOOT_BANK2) == FLASH_COMPLETE)
{
/* generate System Reset to load the new option byte values */
FLASH_OB_Launch();
}
```

10 Revision history

Table 5. Revision history

Date	Revision	Changes
06-Apr-2011	1	Initial release.
27-Jan-2012	2	Ultra low power high-density devices introduced in Chapter 1: IAP overview . Chapter 2: Running the IAP driver updated. Table 1: STM32L1xx IAP implementation updated. 4 new chapters added: - Chapter 6: Firmware updates , - Chapter 7: How to place FLASH programming functions into internal SRAM/FLASH , - Chapter 8: Memory write protection , - Chapter 9: Dual bank feature for high-density devices .

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