How to create the SPI Flash loader

This is the 9th tutorial in the W25Q Flash series, and today we will see how to create and use the External Loader for the W25Q flash memory with the SPI peripheral. In the **previous tutorial** we saw how to create an external loader using QSPI peripheral. Today's tutorial is going to be somewhat similar, but we will use the SPI peripheral instead of the QSPI.

Using the QSPI peripheral for external flash memories have major advantages like faster speed, memory mapped mode, etc. But we know that not all the STM32 MCUs supports the QSPI mode, specially the popular and cheaper dev boards like F4 discovery, bluepill, F4 nucleo etc. Using SPI flash loader, we can still use the W25Q flash memories to store the data to the external flash using the SPI peripheral

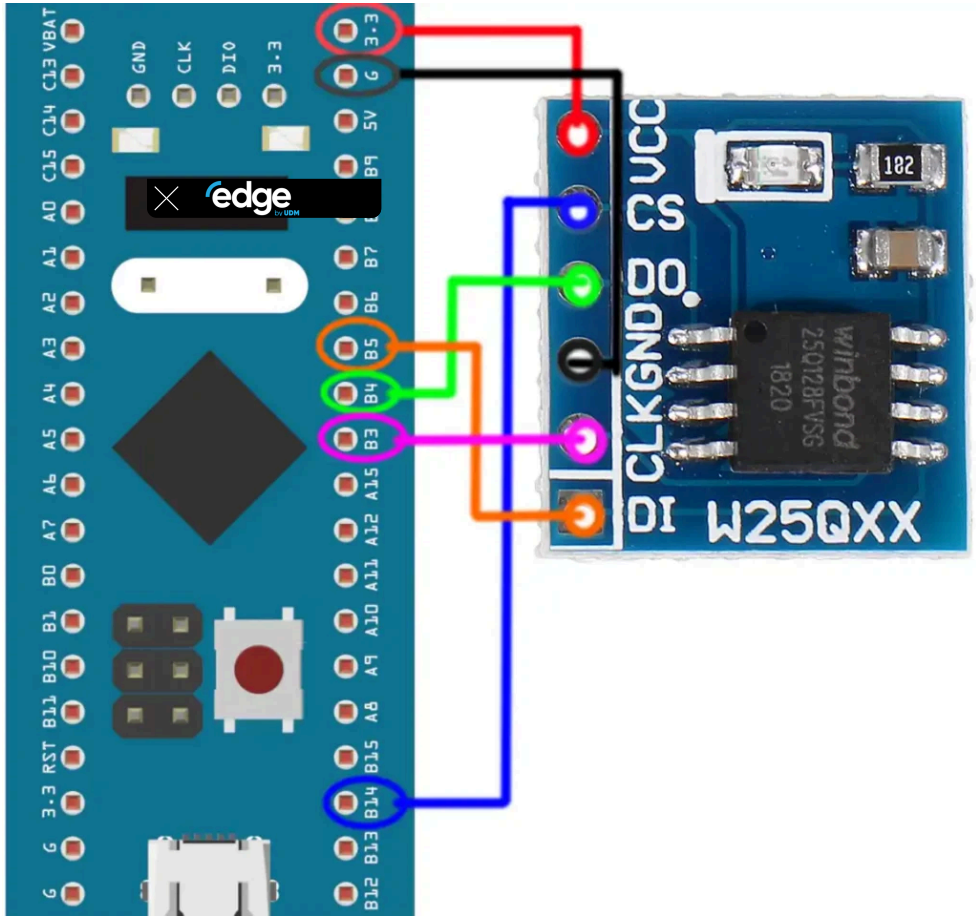
Th

With SPI flash loader, we can use the cube programmer to flash the binary file to the external flash memory, which can contain data like images or fonts. The data can later be read in the IDE itself. Although **we can not use the memory mapped mode**, so the internal flash is not extended in a way.

The process of creating the external loader will be the same as we did in the previous QSPI tutorial. Although I have made some changes in the files used and I will explain those changes here.

Connection

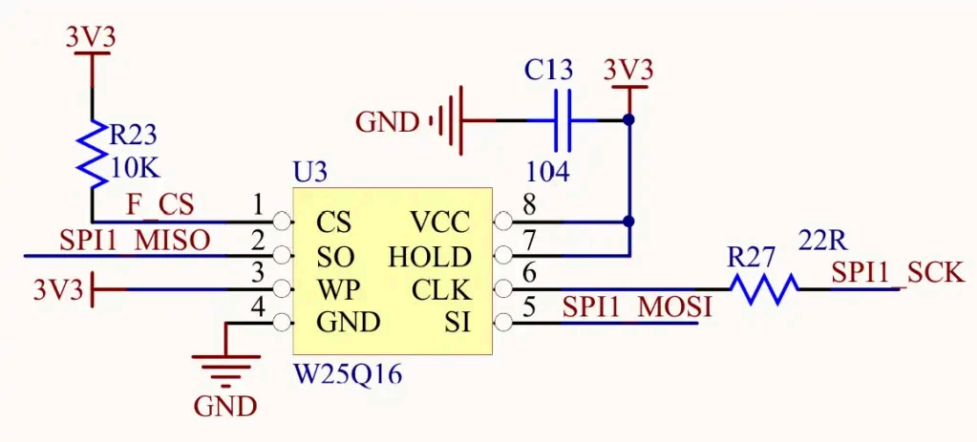
The connection diagram between the Flash module and the STM32 is shown below.



- The **CS** (Chip Select) Pin is connected to the pin PB14. It will be used to select or unselect the slave Device.
- The **DO** (Data Out) pin is connected to the pin PB4 (**MISO**). The device outputs the data on this pin
- The **CLK** (Clock) pin is connected to the pin PB3 (**CLK**). The clock is used to synchronise the master and the slave device.

- The **DI** (Data In) pin is connected to the pin PB5 (**MOSI**). The master send the data to the device on this pin.
- The Device is powered with 3.3v from the MCU itself.

The Module provides 6 pins (including the Vcc and Gnd). But the chip has 8 pins in total. If you have the chip rather than the module, you can connect it as shown below.

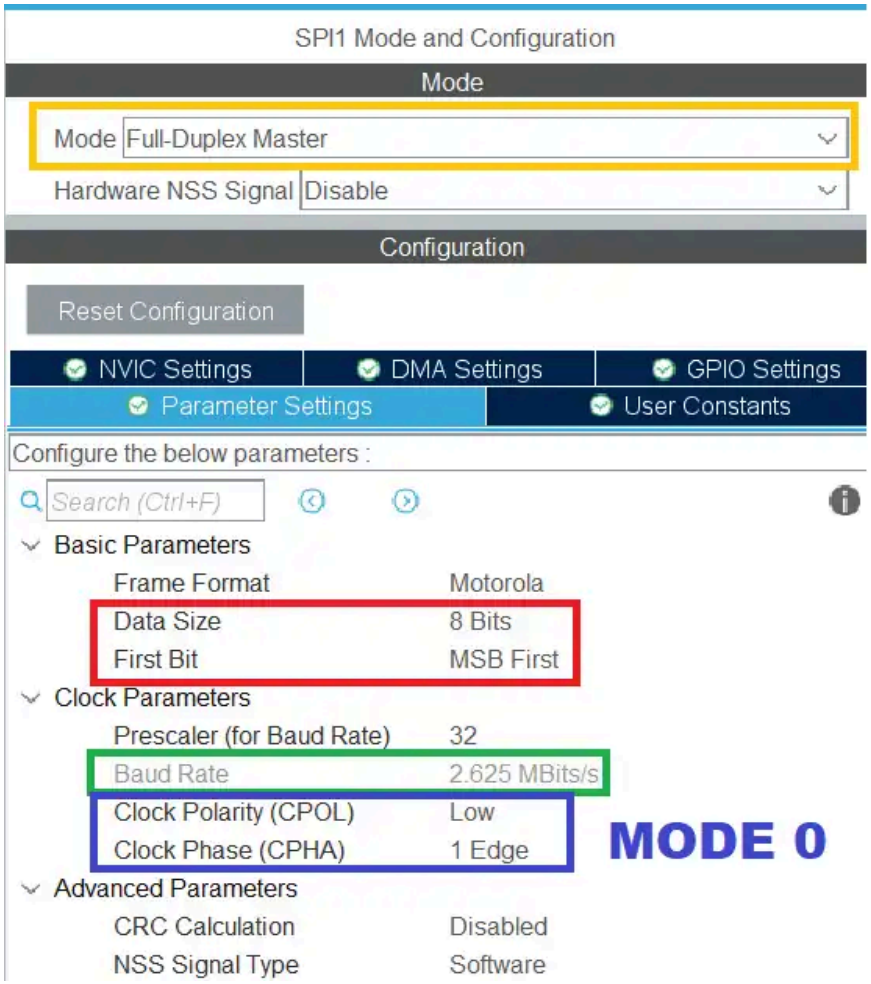


Note that the **WP** (Write Protect) pin is active Low pin, so it must be pulled HIGH when you want to modify the flash, and pulled LOW when you want to disable the modification.

The connections shown above are for the Single SPI mode, not for Dual or Quad modes.

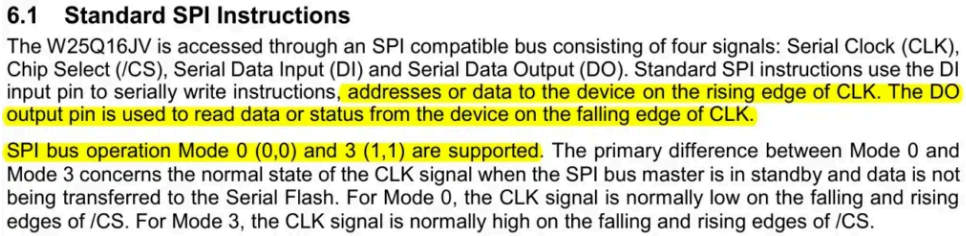
CubeMX Setup

We will enable the SPI in **Full Duplex master mode**. The configuration is shown below.



The Data width is set to **8 bits** and the data should be transferred as the **MSB first**. The prescaler is set such that the Baud Rate is around **2.5 Mbits/sec**.

According to the datasheet of W25Q Flash, the SPI Mode 0 and Mode 3 are supported. Below is the image from the datasheet.



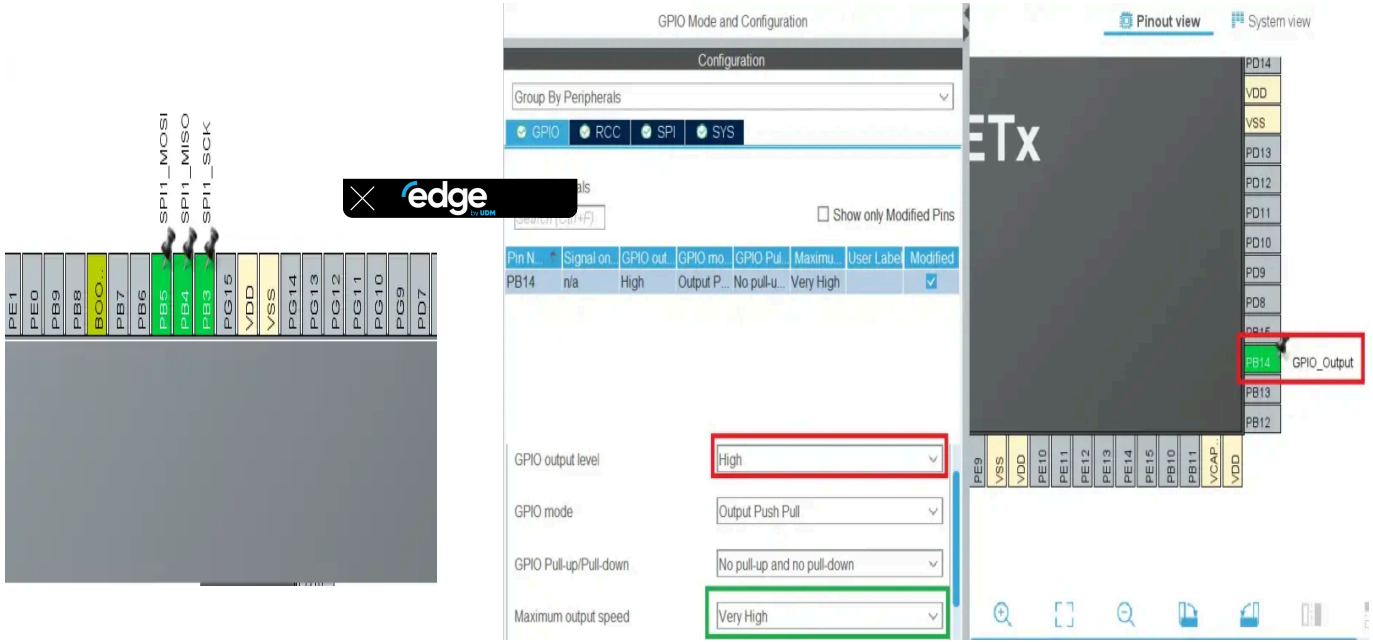
6.1 Standard SPI Instructions

The W25Q16JV is accessed through an SPI compatible bus consisting of four signals: Serial Clock (CLK), Chip Select (/CS), Serial Data Input (DI) and Serial Data Output (DO). Standard SPI instructions use the DI input pin to serially write instructions, addresses or data to the device on the rising edge of CLK. The DO output pin is used to read data or status from the device on the falling edge of CLK.

SPI bus operation Mode 0 (0,0) and 3 (1,1) are supported. The primary difference between Mode 0 and Mode 3 concerns the normal state of the CLK signal when the SPI bus master is in standby and data is not being transferred to the Serial Flash. For Mode 0, the CLK signal is normally low on the falling and rising edges of /CS. For Mode 3, the CLK signal is normally high on the falling and rising edges of /CS.

In the SPI configuration, we keep the Clock Polarity **(CPOL) low** and the Clock Phase **(CPHA) to 1 edge**. Here 1 edge means that the data will be sampled on the **first edge of the clock**. And when the CPOL is Low, the first edge is the **rising edge**. Basically we are using the **SPI Mode 0**.

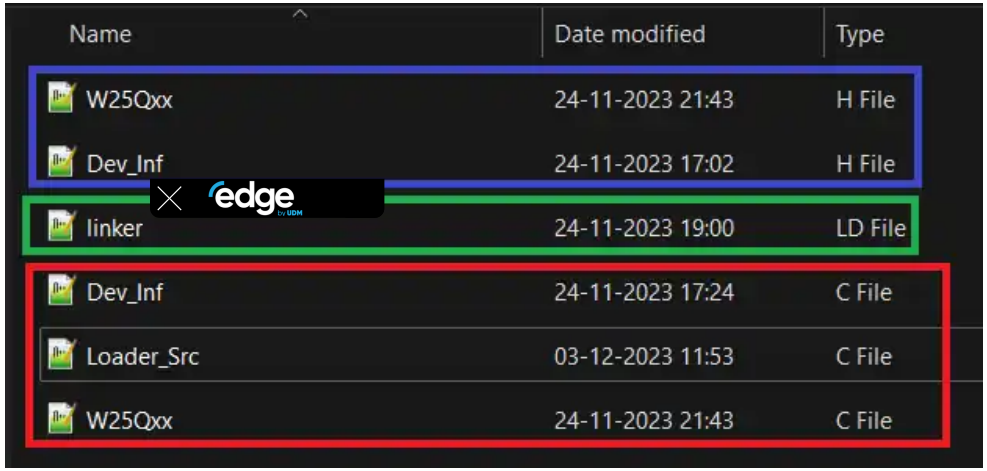
In Full duplex Mode, SPI uses 3 pins, **MOSI**, **MISO** and **CLK**. We need to set one more pin as output so to be used as the Chip Select (**CS**) Pin.



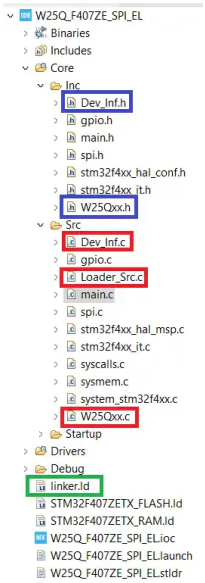
The Pin **PB14** is set as the CS pin. The initial output level is set to **HIGH**. This is because the pin needs to be pulled low in order to select the slave device, so we keep it high initially to make sure the slave device isn't selected. The Output speed is set to **Very High** because we might need to select and unselect the slave at higher rate.

Create the Loader

We need to first copy certain files into our project. You can get the files after downloading the project at the end of this post.



Now copy the ***.c** files in the **src** directory of the project, ***.h** file in the **inc** directory and the **linker** file in the main project folder. The final project structure is shown below.



You can set the Loader name in the **Dev_inf.c** file as shown below. Also make sure to cross check the **QSPI start Address** (0x90000000 in this case) with the reference manual of your

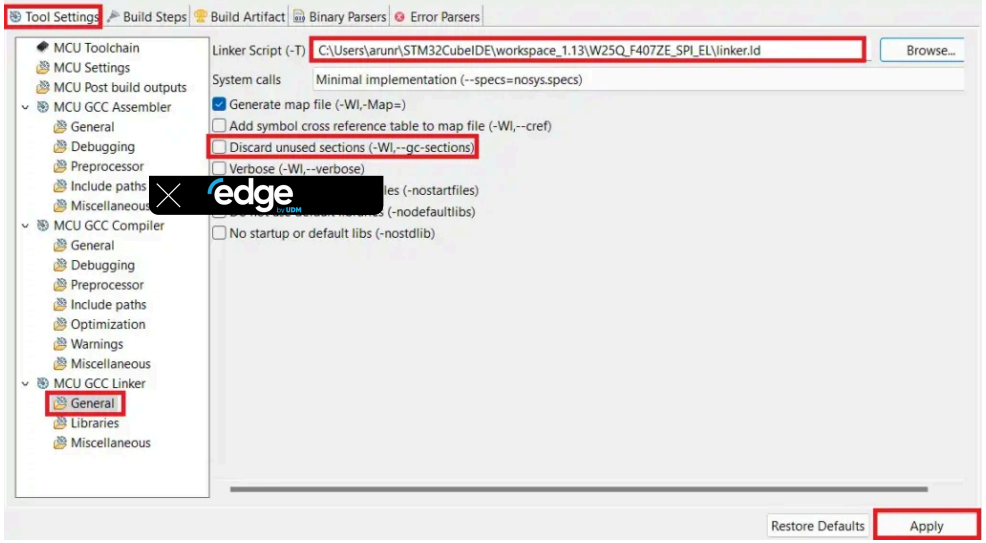
MCU. If the MCU does not has the QSPI address assigned, leave it to 0x90000000, but make sure there is no other peripheral assigned to this address.

```
#else
struct Stora                    geInfo = {
#endif
    "W25Q16_F407ZE_SPI_EL",                 // Device Name + version number
    NOR_FLASH,                          // Device Type
    0x90000000,                         // Device Start Address
    MEMORY_FLASH_SIZE,                  // Device Size in Bytes
    MEMORY_PAGE_SIZE,                   // Programming Page Size
    0xFF,                               // Initial Content of Erased Memory

    // Specify Size and Address of Sectors (view example below)
    {   {
            (MEMORY_FLASH_SIZE / MEMORY_SECTOR_SIZE),  // Sector Numbers,
            (uint32_t) MEMORY_SECTOR_SIZE
        },      //Sector Size

        { 0x00000000, 0x00000000 }
    }
};
```

Other details like **MEMORY_FLASH_SIZE, PAGE_SIZE, SECTOR_SIZE** will be fetched from the **W25Qxx.h** file.

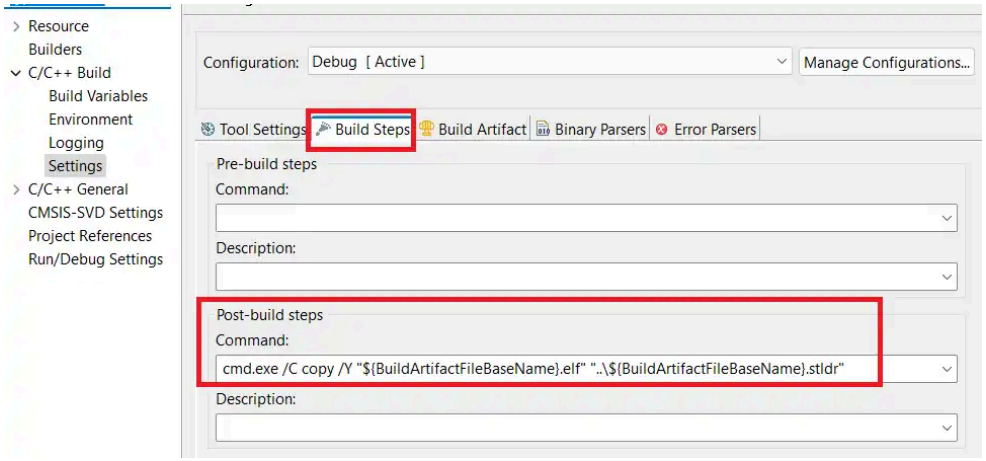
Now we need to set the linker file for the project.

Go to **Project Properties -> C/C++ Build -> Settings -> MCU GCC Linker -> General**.
Here change the **Linker Script** to the Linker file we copied.



As shown above i have changed the **Linker Script** to the **linker.ld** file. Also make sure to uncheck the **Discard unused sections**. After making the changes, click on **Apply**.

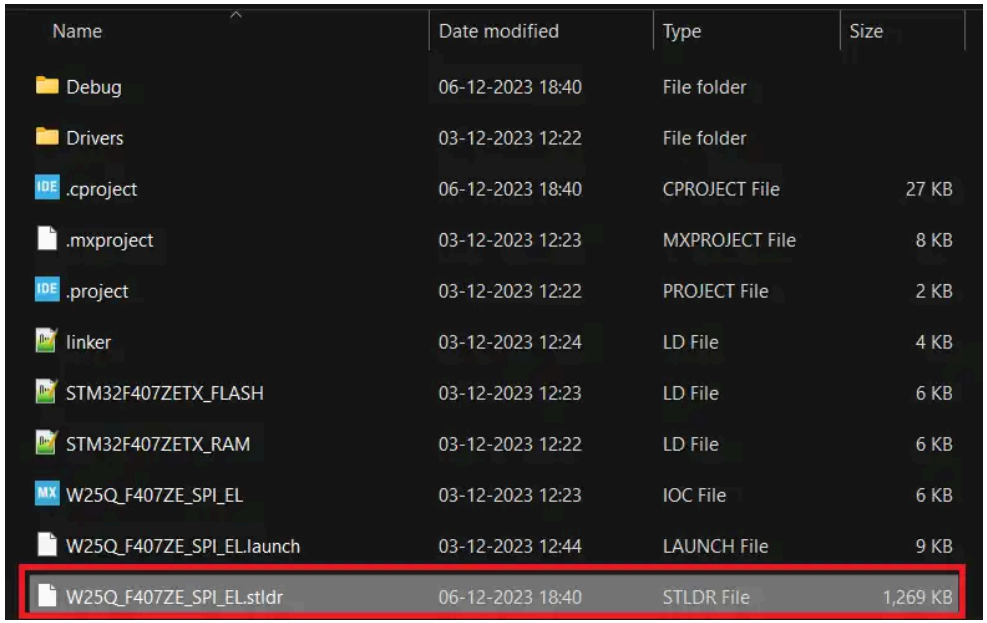
We also need to copy the post build command to the Build Steps tab as shown below.



The command is **cmd.exe /C copy /Y “${BuildArtifactFileBaseName}.elf” “..\${BuildArtifactFileBaseName}.stldr”**. It will copy the stldr file (loader) to the main

project folder.

Now build the code, and you should see the Loader file (***.stldr**) in the main project folder itself. This is shown below.



The files explained

Changes in W25Qxx

There is no major changes in the W25Qxx library files. I used the same files which we created in the previous tutorials of this series and modified them a little.

I added the memory details in the **W25Qxx.h** file as shown below.

```
#define MEMORY_FLASH_SIZE               0x200000 /* 16Mbit =>2Mbyte */
#define MEMORY_BLOCK_SIZE               0x10000   /*  blocks of 64KBytes */
#define MEMORY_SECTOR_SIZE              0x1000    /* 4kBytes */
#define MEMORY_PAGE_SIZE                0x100     /* 256 bytes */
```

Here you only need to change the MEMORY_FLASH_SIZE, if you are using any other chip from winbond. The blocks, sectors and page size remain the same.

i have also added few functions which will be used by the loader source file.

```
void flash_WriteMemory(uint8_t* buffer, uint32_t address, uint32_t buffer_size);
void flash_ReadMemory (uint32_t Addr, uint32_t size, uint8_t* buffer);
```

```
void flash_SectorErase(uint32_t EraseStartAddress, uint32_t EraseEndAddress);
void flash_ChipErase (void);
void flash_Reset (void);
```

Although we already have the functions to Read, Write, erase, etc, but the loader uses a different set of parameters for them. This is why I have defined new functions for the same. The functions are written in the **W25Qxx.c** file.

The **read** function is exactly how we used in the previous tutorials of this series. The loader uses the Address instead of page+offset, so we need to first extract the page and offset from the address and then call our read function.

```
void flash_ReadMemory (uint32_t Addr, uint32_t Size, uint8_t* buffer)
{
    uint32_t page = Addr/256;  // 1 page occupies 256 bytes
    uint16_t offset = Addr%256;

    W25Q_FastRead(page, offset, Size, buffer);
}
```

Similarly the **sector erase function** we used takes the sector number as the parameter. On the other hand, the loader uses the start sector and end sector address as the parameters. So we extract the sector numbers from the parameter and then call our function.

```
void flash_SectorErase(uint32_t EraseStartAddress, uint32_t EraseEndAddress)
{
    uint16_t startSector  = EraseStartAddress/4096;  // 1 sector occupies 4096 by
    uint16_t endSector = EraseEndAddress/4096;
    uint16_t numSectors = endSector-startSector+1;
    for (uint16_t i=0; i<numSectors; i++)
    {
        W25Q_Erase_Sector(startSector++);
    }
}
```

The **chip erase** and **reset** functions does not have any parameters, so they are called as it is.

```
void flash_ChipErase (void)
{
    W25Q_Chip_Erase();
}

void flash_Reset (void)
{
    W25Q_Reset();
}
```

The **write function** has some changes. The loader itself takes care of when to erase the sector and when to edit the sector, so we don't need to do it ourselves. We will remove the

sector erasing part from our write function and keep the rest of it same. This is shown below.

```
void flash_WriteMemory(uint8_t* buffer, uint32_t address, uint32_t buffer_size)
{
    uint32_t page = address/256;
    uint16_t offset = address%256;
    uint32_t size = buffer_size;
    uint8_t tData[266];
    uint32_t startPage = page;
    uint32_t endPage  = startPage + ((size+offset-1)/256);
    uint32_t numPages = endPage-startPage+1;

    uint32_t dataPosition = 0;

    // write the data
    for (uint32_t i=0; i<numPages; i++)
    {
        uint32_t memAddr = (startPage*256)+offset;
        uint16_t bytesremaining  = bytestowrite(size, offset);
        uint32_t indx = 0;

        write_enable();

        if (numBLOCK<512)   // Chip Size<256Mb
        {
            tData[0] = W25Q_PAGE_PROGRAM;  // page program
            tData[1] = (memAddr>>16)&0xFF;  // MSB of the memory Address
```

Changes in the loader_src file

The original loader files are takes from the **ST's github repo**. These files are written for the QSPI peripheral, therefore we need to modify them to be used with the SPI peripheral.

I will compare both the modified code with the original code, so that you understand how it works.

At first we have the **loader initialization function**.

```
int Init(void) {

.....................

    __HAL_RCC_SPI1_FORCE_RESET();  //
    __HAL_RCC_SPI1_RELEASE_RESET();

    MX_SPI1_Init();
```

```
int Init(void) {
.....................
    __HAL_RCC_QSPI_FORCE_RESET();  //
    __HAL_RCC_QSPI_RELEASE_RESET();


    if (CSP_QUADSPI_Init() != HAL_OK)
        __set_PRIMASK(1); //disable ir
        return LOADER_FAIL;
    }
```

```
    flash_Reset();


    __set_PRIMASK(1); //disable interr
    return LOADER_OK;
}
```

```
    if (CSP_QSPI_EnableMemoryMappedMod
        __set_PRIMASK(1); //disable ir
        return LOADER_FAIL;
    }

    __set_PRIMASK(1); //disable interr
    return LOADER_OK;
}
```

The default initialization function initializes the QSPI and enables the memory mapped mode. Since we can't use the memory mapped mode with the SPI peripheral, we will only initialize the SPI here.

Next is the **write function**.

```
int Write(uint32_t Address, uint32_t S


    __set_PRIMASK(0); //enable interru

    flash_WriteMemory(buffer, Address,
```

```
int Write(uint32_t Address, uint32_t S

    __set_PRIMASK(0); //enable interru

    if (HAL_QSPI_Abort(&hqspi) != HAL_
        __set_PRIMASK(1); //disable ir
        return LOADER_FAIL;
    }

    if (CSP_QSPI_WriteMemory((uint8_t*
```

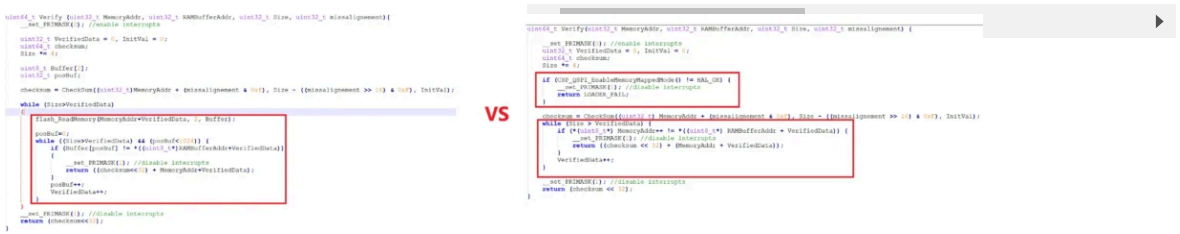
```
    __set_PRIMASK(1); //disable interr
    return LOADER_OK;
}
```

```
    __set_PRIMASK(1); //disable ir
    return LOADER_FAIL;
}

__set_PRIMASK(1); //disable interr
return LOADER_OK;
}
```

Here the original files calls for the QSPI_WriteMemory function. Instead we will call our flash_WriteMemory function, which uses the SPI peripheral to write the data.

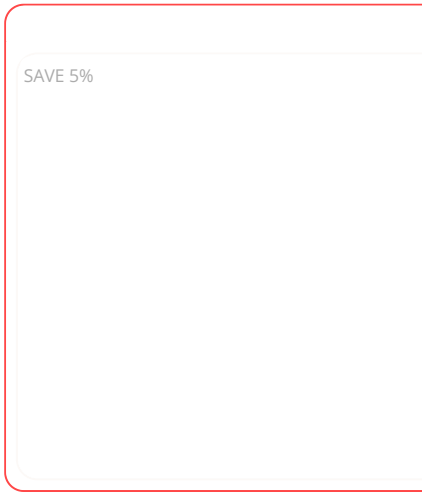
Similar changes are made in the **Read**, **sector erase** and **chip erase** functions. You can download the files and check the code.

There are some major changes in the verify function.



To verify the data, the original code first enables the memory mapped mode and then compares the data at the external memory location. Since we can't use the memory mapped mode, we will read the data from the external memory and then compare it with our data.

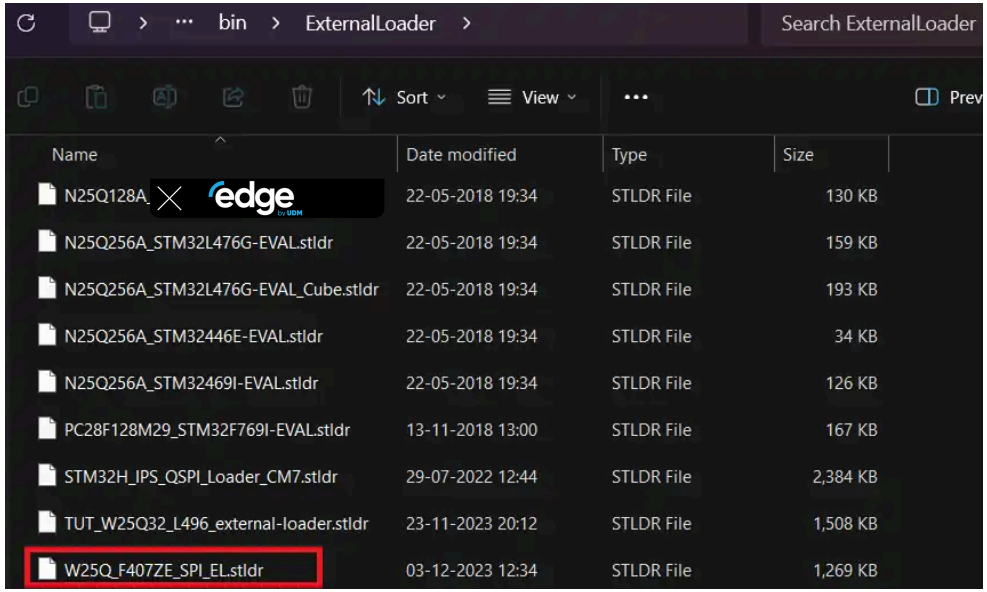
The rest of the operations are same to that of the original file.



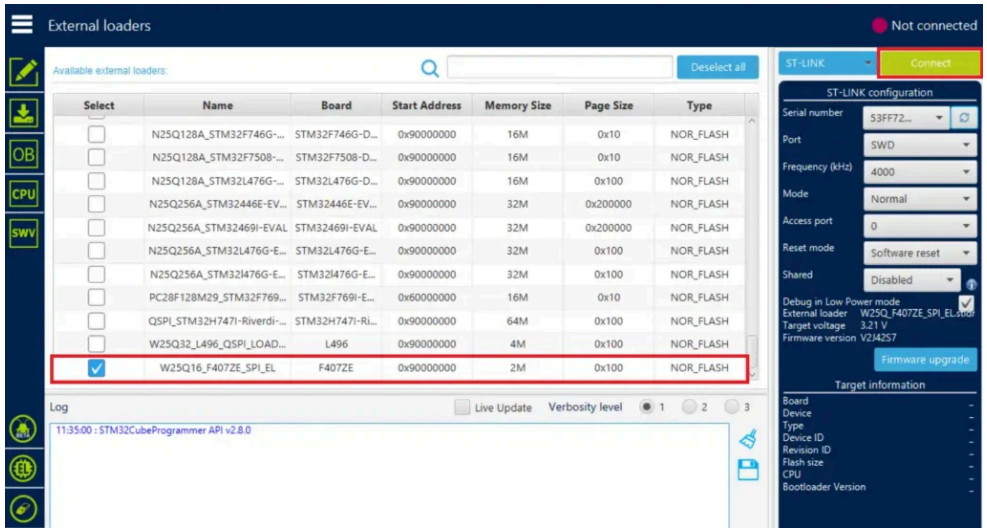
How to use the SPI Loader

As I mentioned earlier, we can use the cube programmer to flash the binary file to the external memory and the loader is needed for this operation.

We need to first copy the Loader to the cubeprogrammer directory. Copy the ***.stldr** file to the **C:\Program Files\STMicroelectronics\STM32Cube\STM32CubeProgrammer\bin\ExternalLoader**

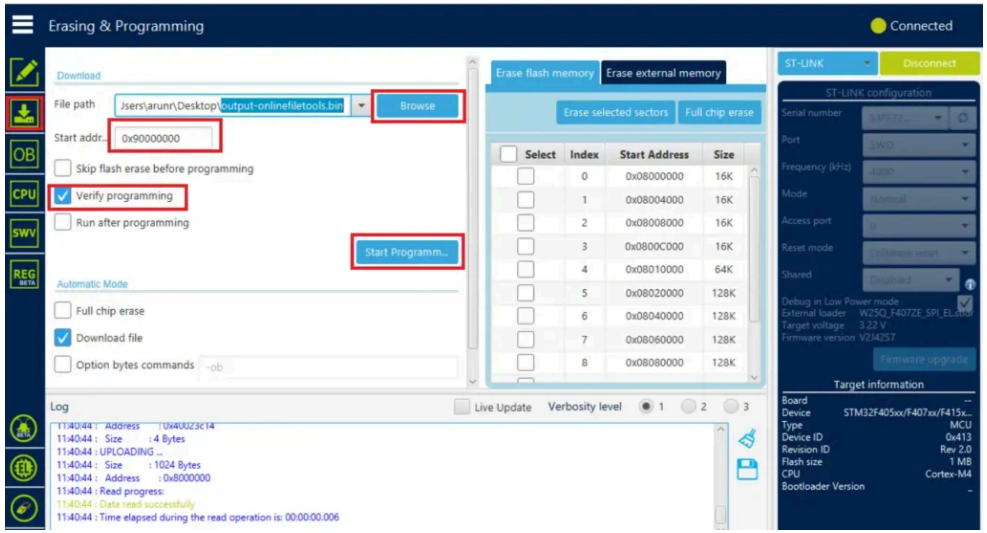


Now open the cube programmer. Go to the **EL** (External Loader) section and select the loader. Then **connect** the board to the programmer.

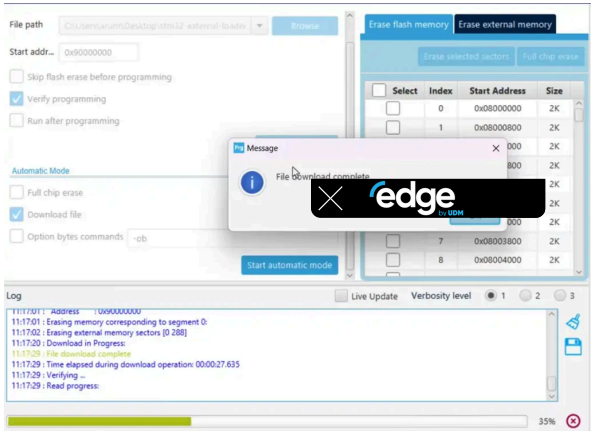


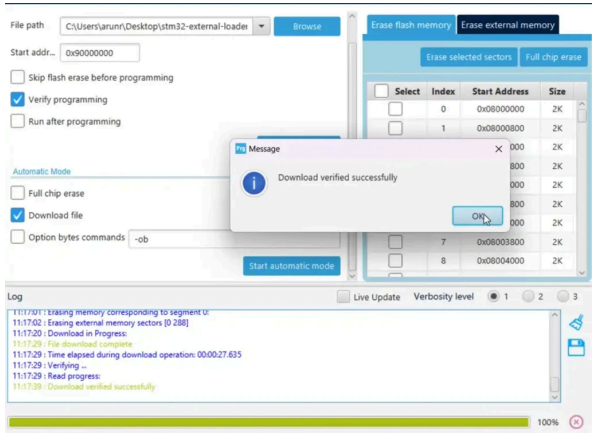
We will program the bin file directly to the flash memory. You can download a test binary file from https://onlinefiletools.com/generate-random-binary-file.

Go to the **Download** se[redacted]the ***.bin**, **enter** the QSPI Start Address, and start **programming**.



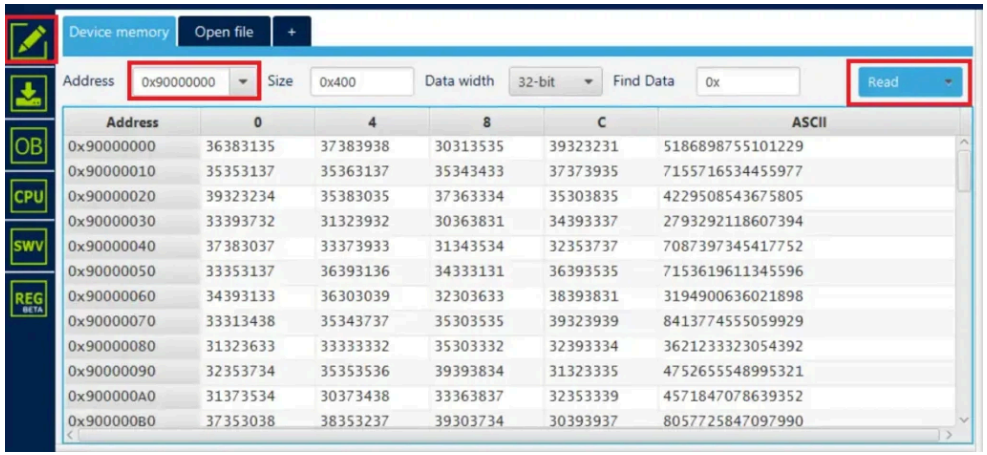
You should see 2 notifications, the first one will pop up once the file has been downloaded to the memory, and another when the downloaded file has been verified.





The file has been downloaded and verified means that the external loader is working fine.

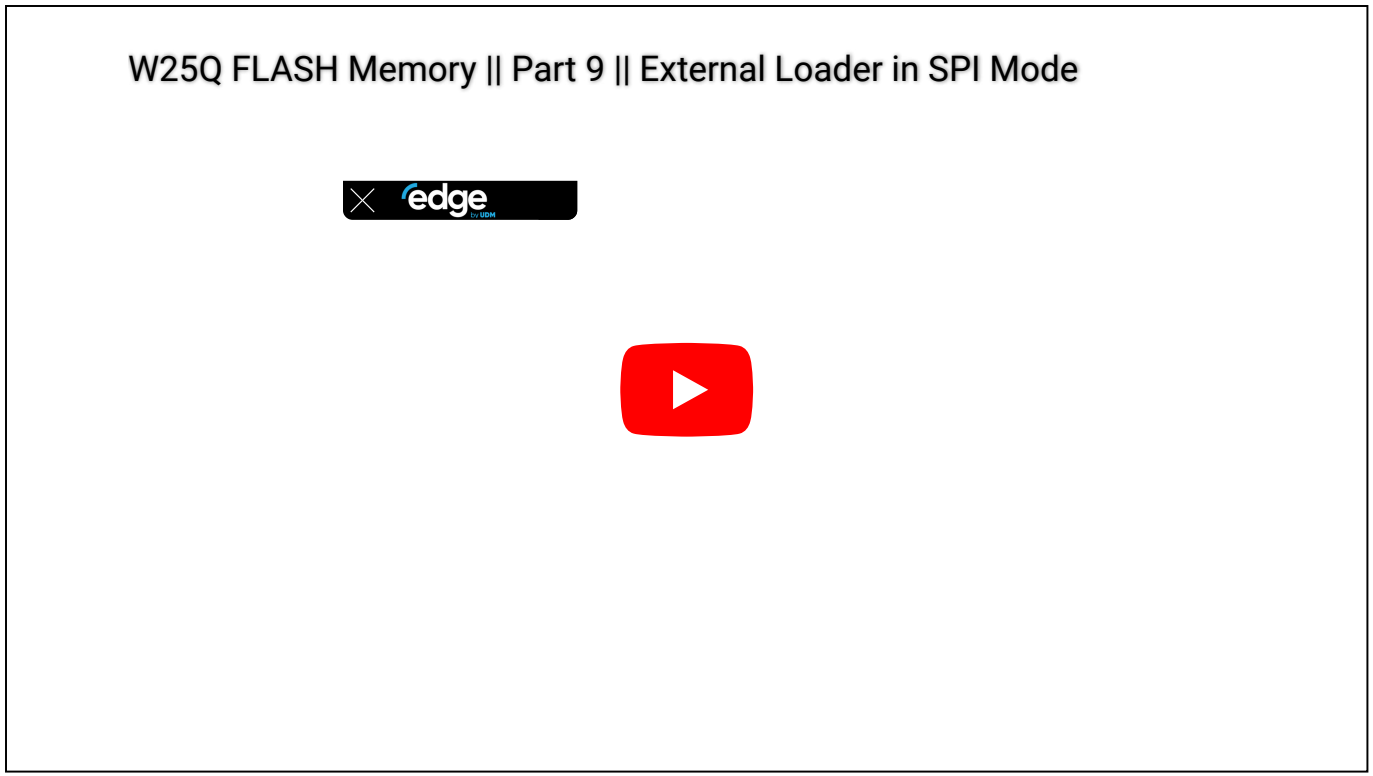
You can see the content of the external flash in the **memory tab**.



We can use the cube programmer to flash a binary file to the SPI flash memory. We will use this idea to flash the images, fonts or videos needed for the display, to the external flash, and then read them later in the project.

LVGL have the tools to generate the binary files for the images and fonts. On the other hand, the touchGFX can directly use the SPI flash using the external loader. I will make tutorials on both, the LVGL and the touchGFX, with the SPI flash.

Check out the Video Below



DOWNLOAD SECTION

Info

You can help with the development by DONATING

To download the code, click DOWNLOAD button and view the Ad. The project will download after the Ad is finished.

DOWNLOAD **DONATE**

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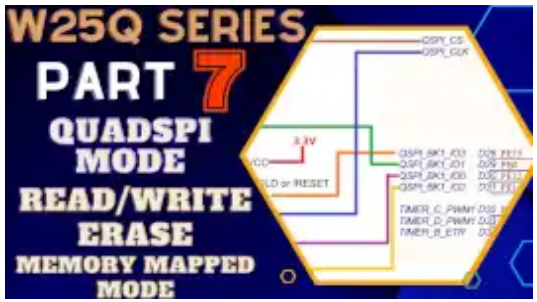
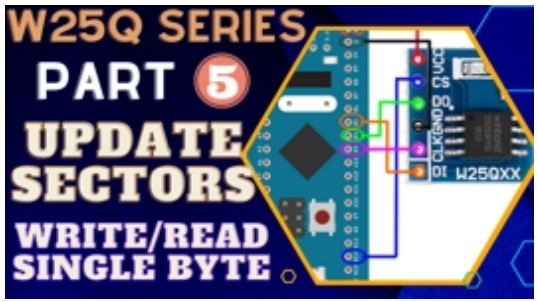
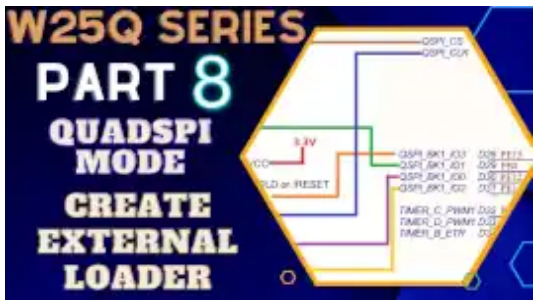


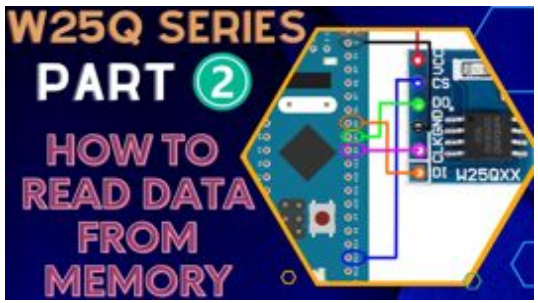
W25Q Flash Series || Part 7 || QUADSPI Write, Read, Memory



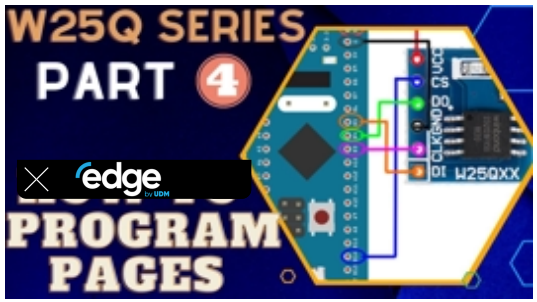
W25Q Flash Series || Part 5 || how to update sectors



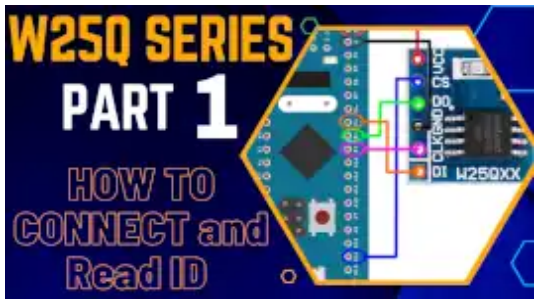
W25Q Flash Series || Part 8 || QUADSPI External Loader



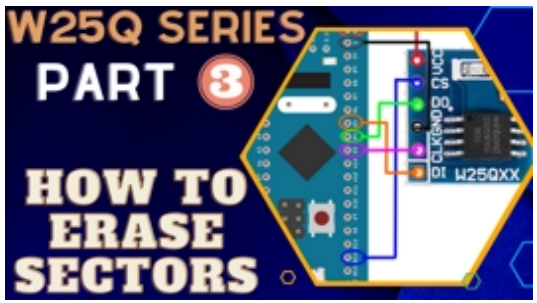
W25Q Flash Series || Part 2 || Read Data from Device



W25Q Flash Series || Part 4 || How to Program Pages



W25Q Flash Series || Part 1 || Read ID



W25Q Flash Series || Part 3 || How to Erase Sectors

W25Q Flash Series || Part 6 || Integers floats and 32bit Data

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