



Learning Report – Embedded C



L&T Technology Services



Document History

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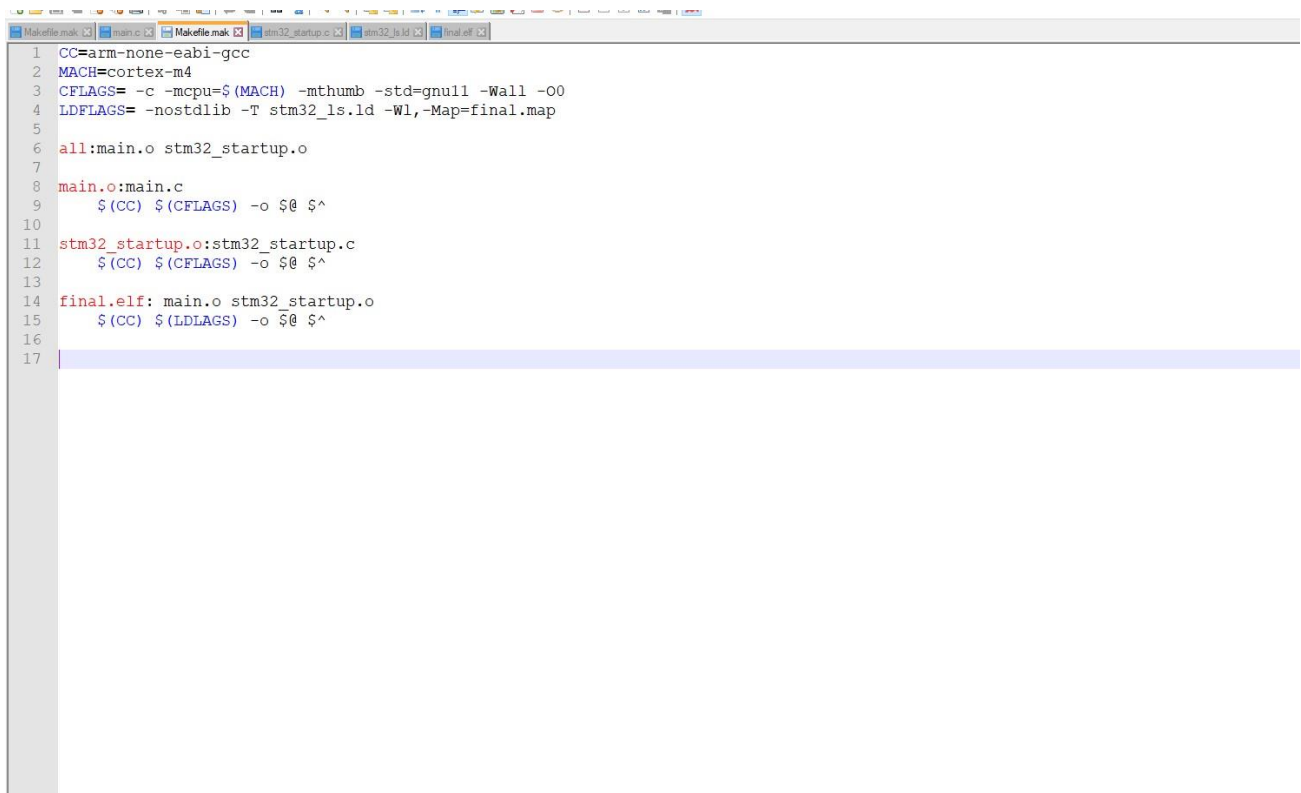
Activity 1 – COMPILATION APPROACH

This is the complete compilation process of the sample program for ARM Cortex Mx processor based boards. Following are the compilation stages of a C program:

1. Preprocessor stage
2. Compilation stage
3. Assembly stage
4. Linking stage

1.1- MAKE FILE

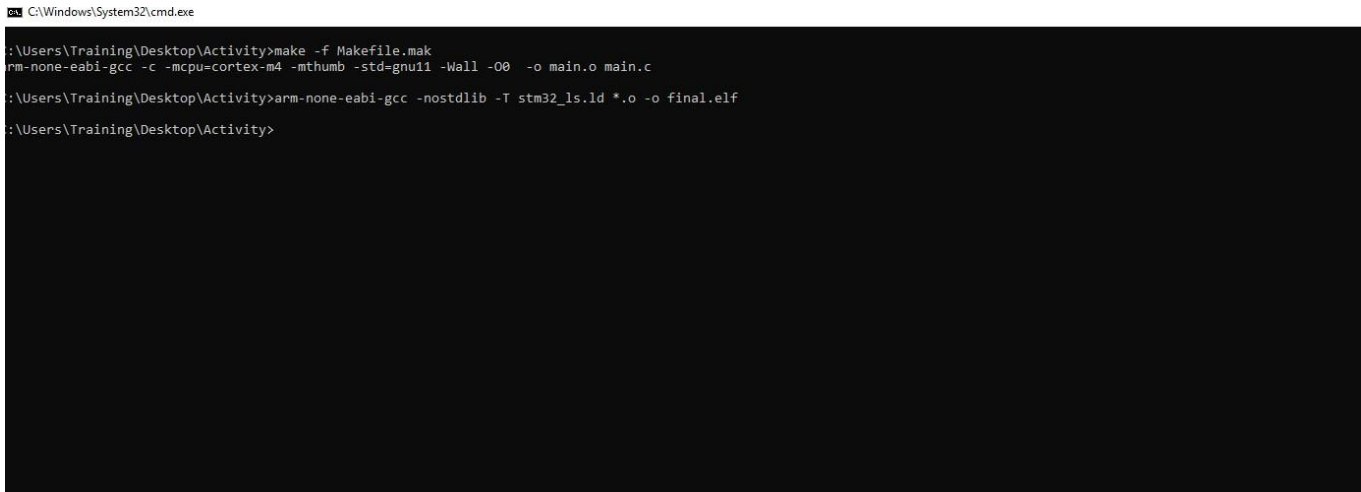
Below is the make file for the sample program:



```
1 CC=arm-none-eabi-gcc
2 MACH=cortex-m4
3 CFLAGS= -c -mcpu=$(MACH) -mthumb -std=gnu11 -Wall -O0
4 LDFLAGS= -nostdlib -T stm32_ls.ld -Wl,-Map=final.map
5
6 all:main.o stm32_startup.o
7
8 main.o:main.c
9     $(CC) $(CFLAGS) -o $@ $^
10
11 stm32_startup.o:stm32_startup.c
12     $(CC) $(CFLAGS) -o $@ $^
13
14 final.elf: main.o stm32_startup.o
15     $(CC) $(LDFLAGS) -o $@ $^
16
17
```

Fig 1.1.1 make file

The command to run this make file in the command prompt is:



```
C:\Windows\System32\cmd.exe
:\Users\Training\Desktop\Activity>make -f Makefile.mak
arm-none-eabi-gcc -c -mcpu=cortex-m4 -mthumb -std-gnu11 -Wall -O0 -o main.o main.c
:\Users\Training\Desktop\Activity>arm-none-eabi-gcc -nostdlib -T stm32_ls.ld *.o -o final.elf
:\Users\Training\Desktop\Activity>
```

Fig 1.1.2 Make command

- **-mcpu=cortex-m4** is used to select our cortex-m4 processor which is used
- **-mthumb** is used to generate the code that executes in ARM state
- **main.o** is the target file
- **main.c** is the dependency

1.2- STARTUP CODE

- The startup file is responsible for setting up the right environments to run the code in main.c file.
- Some part of the startup code is target (processor) dependent.
- Role of startup file:
 1. Create a MCU specific vector table for microcontroller.
 2. To write a startup code which initializes .data and .bss section in SRAM.
 3. Call main()

```

1 #include<stdint.h>
2
3 #define SRAM_START 0x20000000U
4 #define SRAM_SIZE (128U * 1024U) //128KB
5 #define SRAM_END ((SRAM_START) + (SRAM_SIZE))
6
7 #define STACK_START SRAM_END
8
9 extern uint32_t _etext;
10 extern uint32_t _edata;
11 extern uint32_t _la_data;
12 extern uint32_t _la_data;
13
14 extern uint32_t _ebss;
15 extern uint32_t _ebss;
16
17 //prototype of main
18
19 int main(void);
20
21 void __libc_init_array(void);
22
23
24 /* function prototypes of STM32F407x system exception and IRQ handlers */
25
26 void Reset_Handler(void);
27
28 void NMI_Handler (void) __attribute__((weak, alias("Default_Handler")));
29 void HardFault_Handler (void) __attribute__((weak, alias("Default_Handler")));
30 void MemManage_Handler (void) __attribute__((weak, alias("Default_Handler")));
31 void BusFault_Handler (void) __attribute__((weak, alias("Default_Handler")));
32 void UsageFault_Handler (void) __attribute__((weak, alias("Default_Handler")));
33 void SVC_Handler (void) __attribute__((weak, alias("Default_Handler")));
34 void DebugMon_Handler (void) __attribute__((weak, alias("Default_Handler")));
35 void PendSV_Handler (void) __attribute__((weak, alias("Default_Handler")));
36 void SysTick_Handler (void) __attribute__((weak, alias("Default_Handler")));
37 void WWDG_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
38 void PVD_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
39 void TAMP_STAMP_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
40 void RTC_WKUP_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
41 void RCC_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
42 void EXTI0_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
43 void EXTI1_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
44 void EXTI2_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
45 void EXTI3_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
46 void EXTI4_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
47 void DMA1_Stream0_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
48 void DMA1_Stream1_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
49 void DMA1_Stream2_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
50 void DMA1_Stream3_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
51 void DMA1_Stream4_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
52 void DMA1_Stream5_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
53 void DMA1_Stream6_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
54 void ADC_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
55 void CAN1_TX_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
56 void CAN1_RX0_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
57 void CAN1_RX1_IRQHandler (void) __attribute__((weak, alias("Default_Handler")));
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```

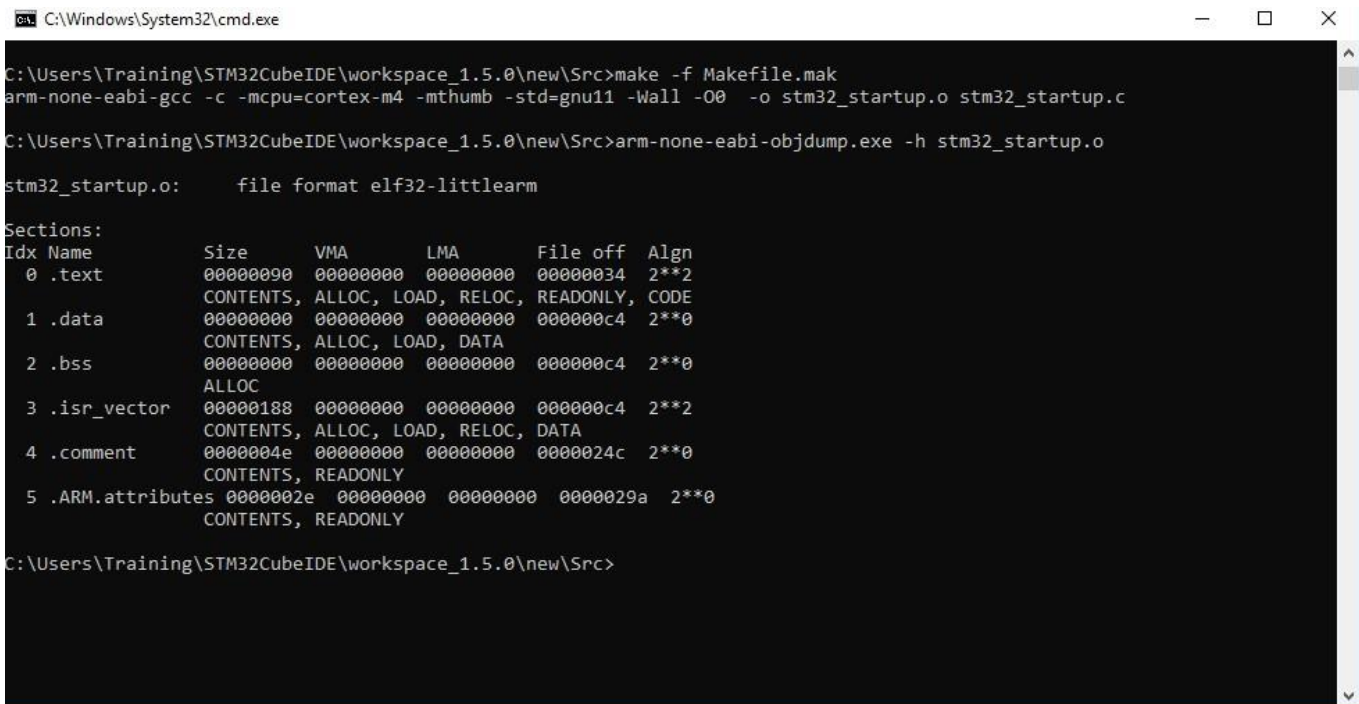
Fig 1.2.1 Startup code

In startup code we use variable attributes to store some variables in the user defined function.

Function attributes:

- Weak: Lets programmer override already defined weak function (dummy function) with the same function name.
- Alias: Lets programmer give any alias name for same function.

The startup.o file generated is of elf executable format, various sections of which are shown below:



```

C:\Windows\System32\cmd.exe

C:\Users\Training\STM32CubeIDE\workspace_1.5.0\new\Src>make -f Makefile.mak
arm-none-eabi-gcc -c -mcpu=cortex-m4 -mthumb -std=gnu11 -Wall -O0 -o stm32_startup.o stm32_startup.c

C:\Users\Training\STM32CubeIDE\workspace_1.5.0\new\Src>arm-none-eabi-objdump.exe -h stm32_startup.o

stm32_startup.o:      file format elf32-littlearm

Sections:
Idx Name              Size      VMA          LMA          File off  Algn
 0 .text              00000090  00000000  00000000  00000034  2**2
CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
 1 .data              00000000  00000000  00000000  000000c4  2**0
CONTENTS, ALLOC, LOAD, DATA
 2 .bss              00000000  00000000  00000000  000000c4  2**0
ALLOC
 3 .isr_vector        00000188  00000000  00000000  000000c4  2**2
CONTENTS, ALLOC, LOAD, RELOC, DATA
 4 .comment           0000004e  00000000  00000000  0000024c  2**0
CONTENTS, READONLY
 5 .ARM.attributes    0000002e  00000000  00000000  0000029a  2**0
CONTENTS, READONLY

C:\Users\Training\STM32CubeIDE\workspace_1.5.0\new\Src>

```

Fig 1.2.2: Startup command

1.3- LINKER SCRIPT

- Linkers take one or more object files or libraries as input and combines them to create a single executable file as output.
- Linker scripts decide how different sections of object file should be merged to create an output file.
- Reset handler is the entry point to the application
- Entry command is used to set the “Entry point address” information in the header of final elf file generated.

Syntax: Entry(symbol_name)

Entry(Reset_Handler)

```

4
5 {
6   FLASH(rx):ORIGIN =0x08000000,LENGTH =1024K
7   SRAM(rx):ORIGIN =0x20000000,LENGTH =128K
8 }
9
10 SECTIONS
11 {
12   .text :
13   {
14     *(.isr_vector)
15     *(.text)
16     *(.text.*)
17     *(.init)
18     *(.fini)
19     *(.rodata)
20     *(.rodata.*)
21     . = ALIGN(4);
22     _etext = .;
23   }> FLASH
24
25   _la_data = LOADADDR(.data);
26
27   .data :
28   {
29     _ddata = .;
30     *(.data)
31     *(.data.*)
32     . = ALIGN(4);
33     _edata = .;
34   }> SRAM RT> FLASH
35
36   .bss :
37   {
38     _sbss = .;
39     _bss_start__ = _sbss;
40     *(.bss)
41     *(.bss.*)
42     *(COMMON)
43     . = ALIGN(4);
44     _ebss = .;
45     _bss_end__ = _ebss;
46     . = ALIGN(4);
47     end = .;
48     _end__ = .;
49   }> SRAM
50
51

```



```
C:\Windows\System32\cmd.exe
C:\Users\Training\Documents\Embedded C\STM project\Activity1>arm-none-eabi-gcc -nostdlib -T stm32_ls.ld *.o -o final.elf
c:/program files (x86)/gnu arm embedded toolchain/10 2020-q4-major/bin/../lib/gcc/arm-none-eabi/10.2.1/../../../../arm-none-eabi/bin/ld.exe: stm3
2_startup.o: in function 'Reset_Handler':
stm32_startup.c:(.text+0x80): undefined reference to `_la_data'
collect2.exe: error: ld returned 1 exit status

C:\Users\Training\Documents\Embedded C\STM project\Activity1>arm-none-eabi-gcc -nostdlib -T stm32_ls.ld *.o -o final.elf

C:\Users\Training\Documents\Embedded C\STM project\Activity1>dir
Volume in drive C has no label.
Volume Serial Number is F8FC-05CA

Directory of C:\Users\Training\Documents\Embedded C\STM project\Activity1

23-02-2021  14:29    <DIR>          .
23-02-2021  14:29    <DIR>          ..
23-02-2021  14:29             135,752 final.elf
23-02-2021  14:24             2,034 main.c
23-02-2021  14:24             1,940 main.o
23-02-2021  11:35              220 Makefile.mak
23-02-2021  14:28              662 stm32_ls.ld
23-02-2021  14:27          12,847 stm32_startup.c
23-02-2021  14:24           5,688 stm32_startup.o
                7 File(s)          159,143 bytes
                2 Dir(s)  125,771,227,136 bytes free

C:\Users\Training\Documents\Embedded C\STM project\Activity1>
```

Fig 1.3.1 command to generate final.elf file

1.4- DEBUGGING TECHNIQUES

- The STM32F407VG is embedded with on chip debugger for debugging the code.
- The OCD ON-Chip Debugger aims to provide debugging, in system programming and boundary scan testing for embedded target devices.
- OCD is a free and opensource host application allows you to program, debug, and analyze your applications using GDB.
- It supports various target boards based on different processor architecture.

Activity 2 – IMPLEMENTATION OF PROTOCOLS USING STM IDE

Implementation of protocols for STM32F407VG microcontroller featuring ARM32 bit ARM-cortex M4 with FPU core using HAL library.

2.1 GPIO:

Toggling LED at pin PD12 at GREEN_LED_GPIO_PORT. Serial wire is enabled at pin PA13.

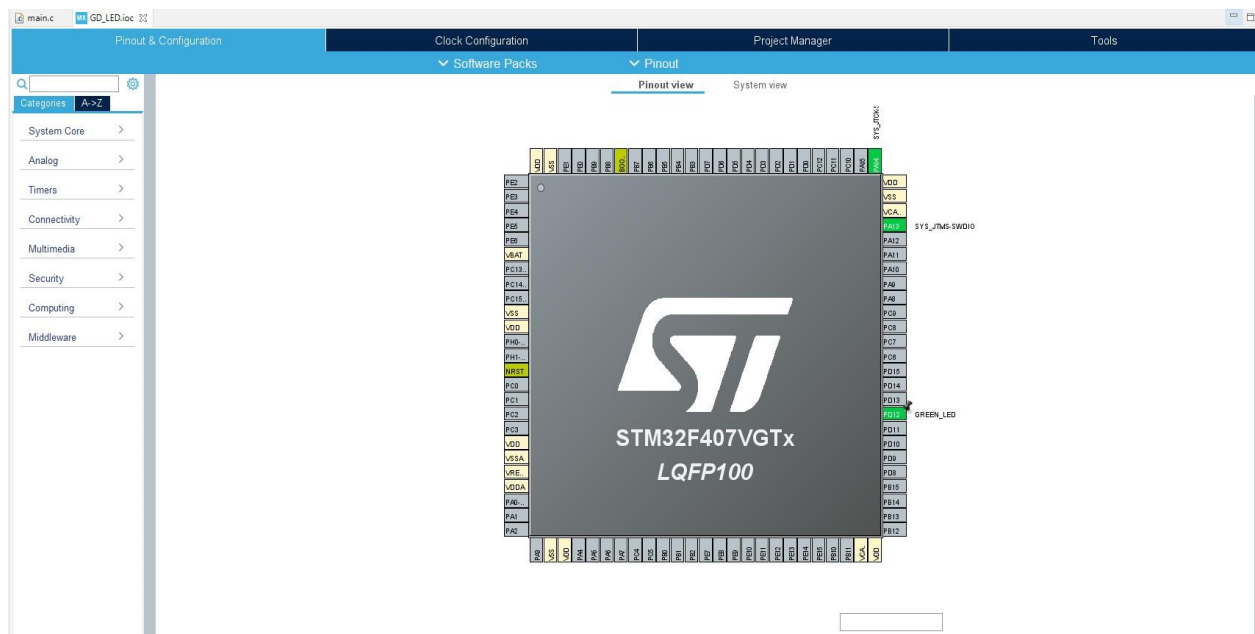


Fig: 2.1.1 GPIO pin configuration

```
/* Initialize all configured peripherals */
MX_GPIO_Init();
/* USER CODE BEGIN 2 */

/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
    HAL_GPIO_TogglePin(GREEN_LED_GPIO_Port, GREEN_LED_Pin);
    HAL_Delay(500);
    /* USER CODE END WHILE */

    /* USER CODE BEGIN 3 */
}
/* USER CODE END 3 */
```

Fig: 2.1.2 GPIO configuration code

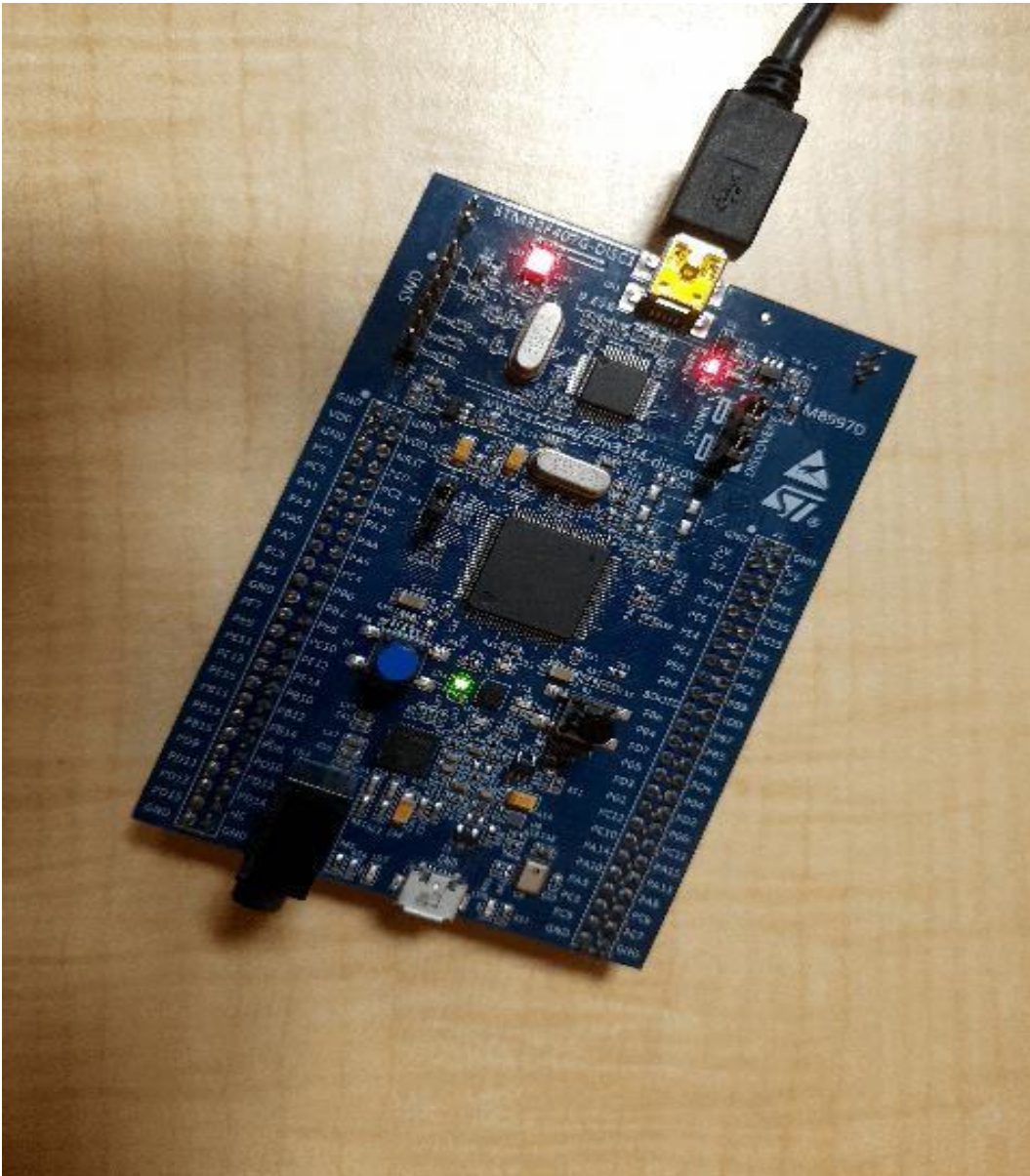


Fig: 2.1.2 LED toggling

2.2 EXTI :-

Blue button at PA0 works as an external interrupt.

When the blue button is pressed the Green LED at pin PD12 toggles.

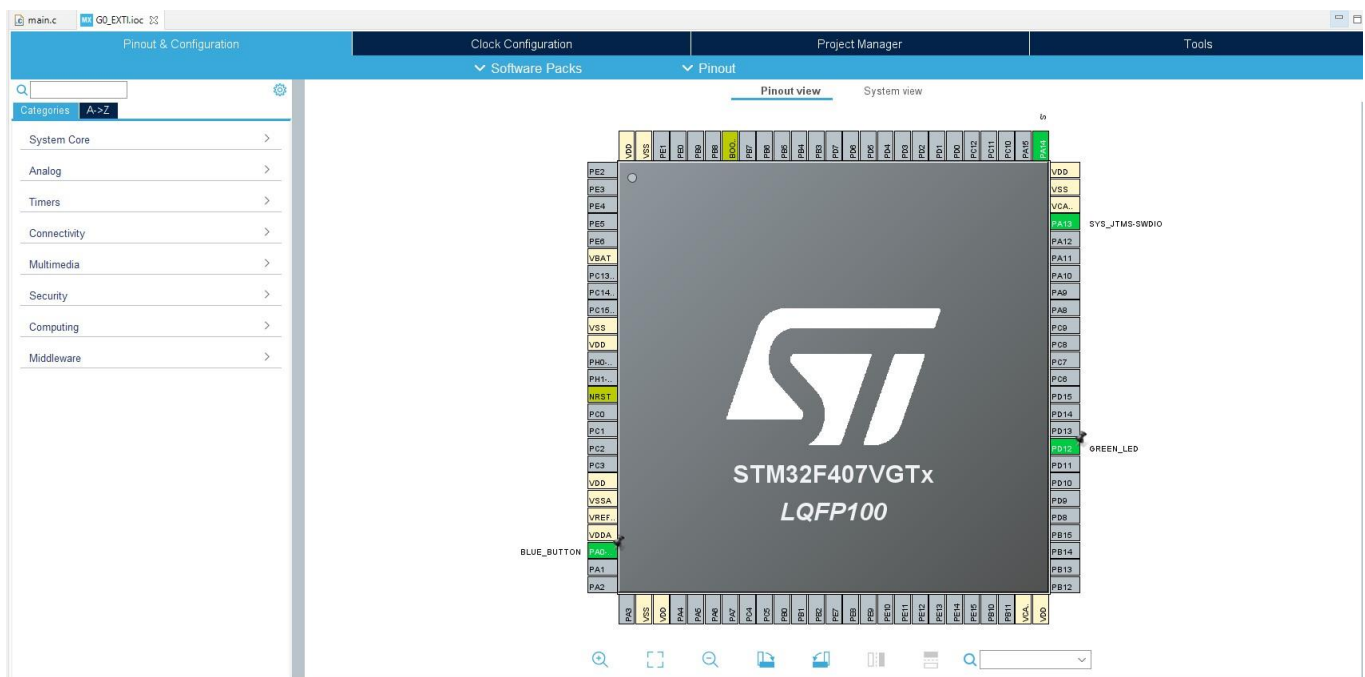


Fig: 2.2.1 EXTI pin configuration

In the main.c file a flag is initialized and if the flag == 1, the condition under the if loop executed to toggle the LED at PD12.

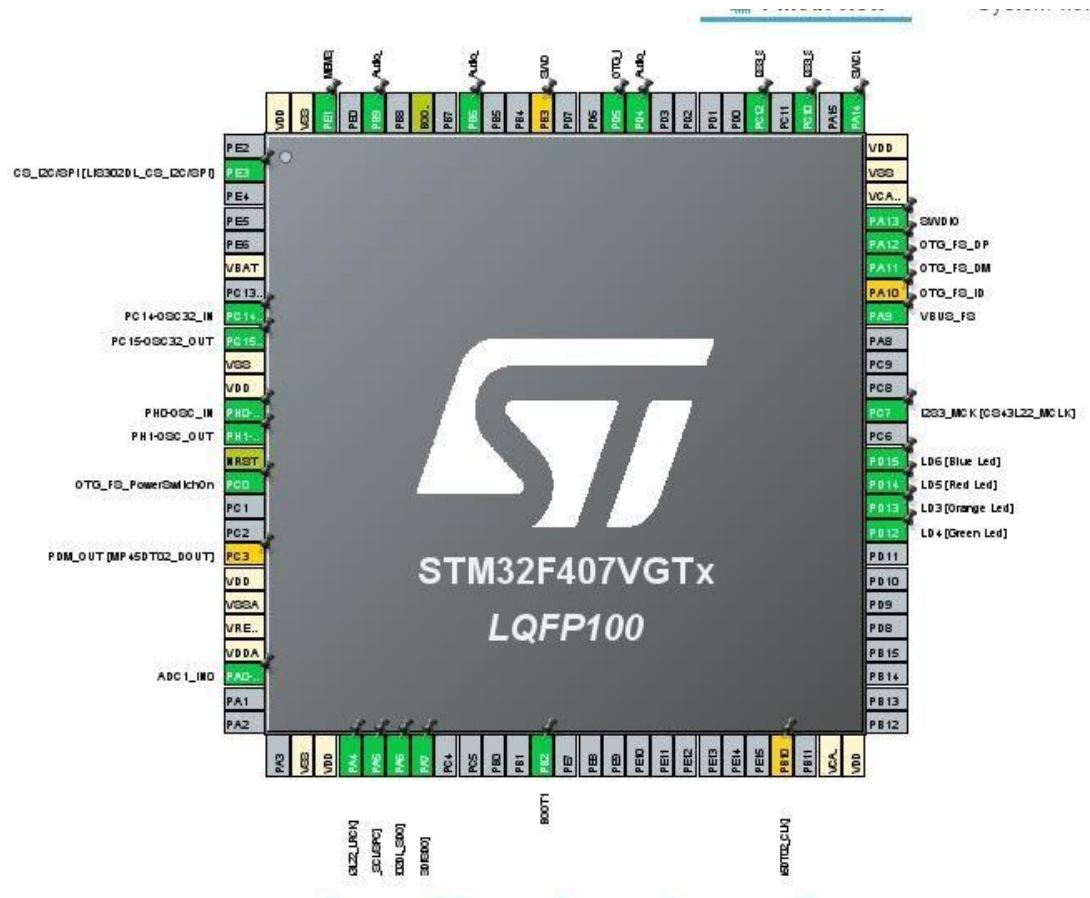
```

43
44 /* USER CODE BEGIN PV */
45 uint8_t flag = 0;
46 /* USER CODE END PV */
47
48 /* Private function prototypes -----*/
49 void SystemClock_Config(void);
50 static void MX_GPIO_Init(void);
51 /* USER CODE BEGIN PFP */
52
53 /* USER CODE END PFP */
54
55 /* Private user code -----*/
56 /* USER CODE BEGIN 0 */
57
58 /* USER CODE END 0 */
59
60 /**
61  * @brief The application entry point.
62  * @retval int
63  */
64 int main(void)
65 {
66     /* USER CODE BEGIN 1 */
67
68     /* USER CODE END 1 */
69
70     /* MCU Configuration-----*/
71
72     /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
73     HAL_Init();
74
75     /* USER CODE BEGIN Init */
76
77     /* USER CODE END Init */
78
79     /* Configure the system clock */
80     SystemClock_Config();
81
82     /* USER CODE BEGIN SysInit */
83
84     /* USER CODE END SysInit */
85
86     /* Initialize all configured peripherals */
87     MX_GPIO_Init();
88     /* USER CODE BEGIN 2 */
89
90     /* USER CODE END 2 */
91
92     /* Infinite loop */
93     /* USER CODE BEGIN WHILE */
94     while (1)
95     {
96         /* USER CODE END WHILE */
97
98         if(flag){
99             HAL_GPIO_TogglePin(GREEN_LED_GPIO_Port, GREEN_LED_Pin);
100             HAL_Delay(500);
101             flag = 0;
102         }
103     }
104     /* USER CODE BEGIN 3 */
105
106     /* USER CODE END 3 */

```

Fig: 2.2.1 EXTI configuration code

2.3 ADC



2.4 SPI

```

19  /* USER CODE END Header */
20  /* Includes -----*/
21  #include "main.h"
22  #include "usb_host.h"
23
24
25  ADC_HandleTypeDef hadc1;
26
27  I2C_HandleTypeDef hi2c1;
28
29  I2S_HandleTypeDef hi2s3;
30
31  SPI_HandleTypeDef hspi1;
32
33
34  /* Private function prototypes -----*/
35  void SystemClock_Config(void);
36  static void MX_GPIO_Init(void);
37  static void MX_I2C1_Init(void);
38  static void MX_I2S3_Init(void);
39  static void MX_SPI1_Init(void);
40  static void MX_ADC1_Init(void);
41  void MX_USB_HOST_Process(void);
42
43
44  uint32_t adc_value;
45
46  int main(void)
47  {
48
49      HAL_Init();
50
51      SystemClock_Config();
52
53      MX_GPIO_Init();
54      MX_I2C1_Init();
55      MX_I2S3_Init();
56
57
58
59
60      while (1)
61      {
62
63          MX_USB_HOST_Process();
64
65          HAL_ADC_Start(&hadc1);
66
67
68          if(HAL_ADC_PollForConversion(&hadc1, 5) == HAL_OK){
69              adc_value= HAL_ADC_GetValue(&hadc1);
70          }
71
72
73      }
74
75      HAL_ADC_Stop(&hadc1);
76      HAL_Delay(100);
77
78  }
79
80
81  }
82
83
84  void SystemClock_Config(void)
85  {
86      RCC_OscInitTypeDef RCC_OscInitStruct = {0};
87      RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
88      RCC_PeriphCLKInitTypeDef PeriphClkInitStruct = {0};

```

Fig: Configuration code

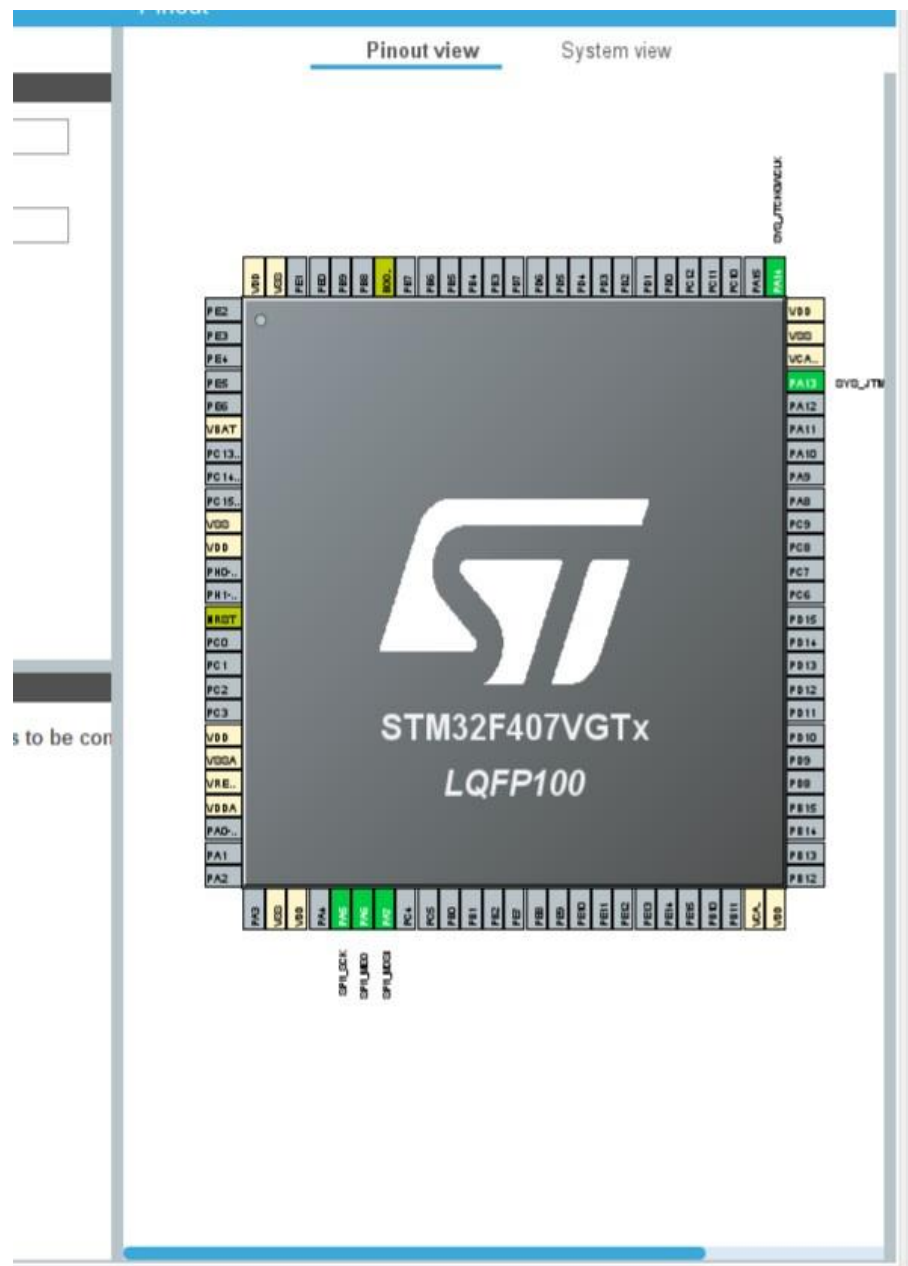
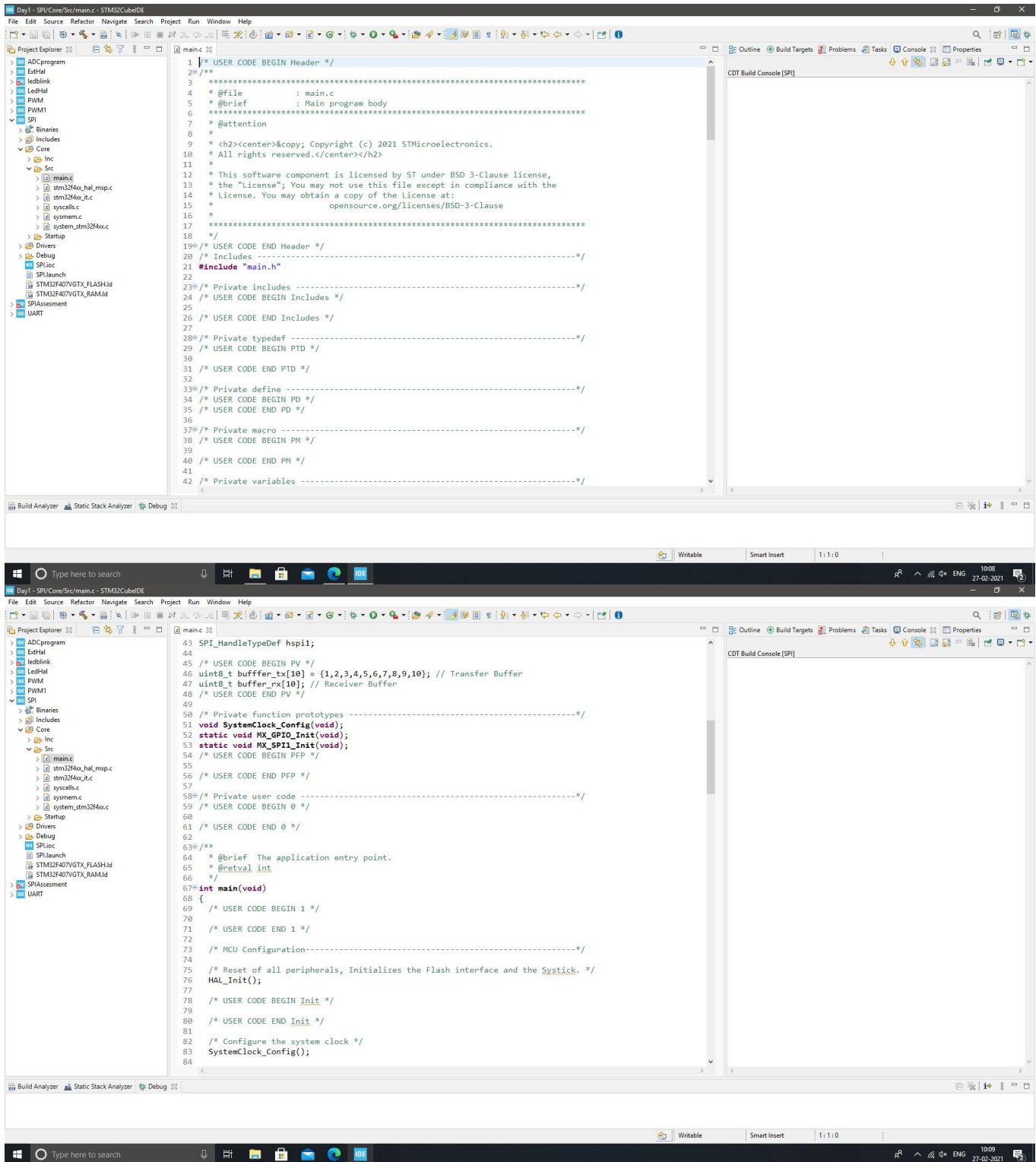
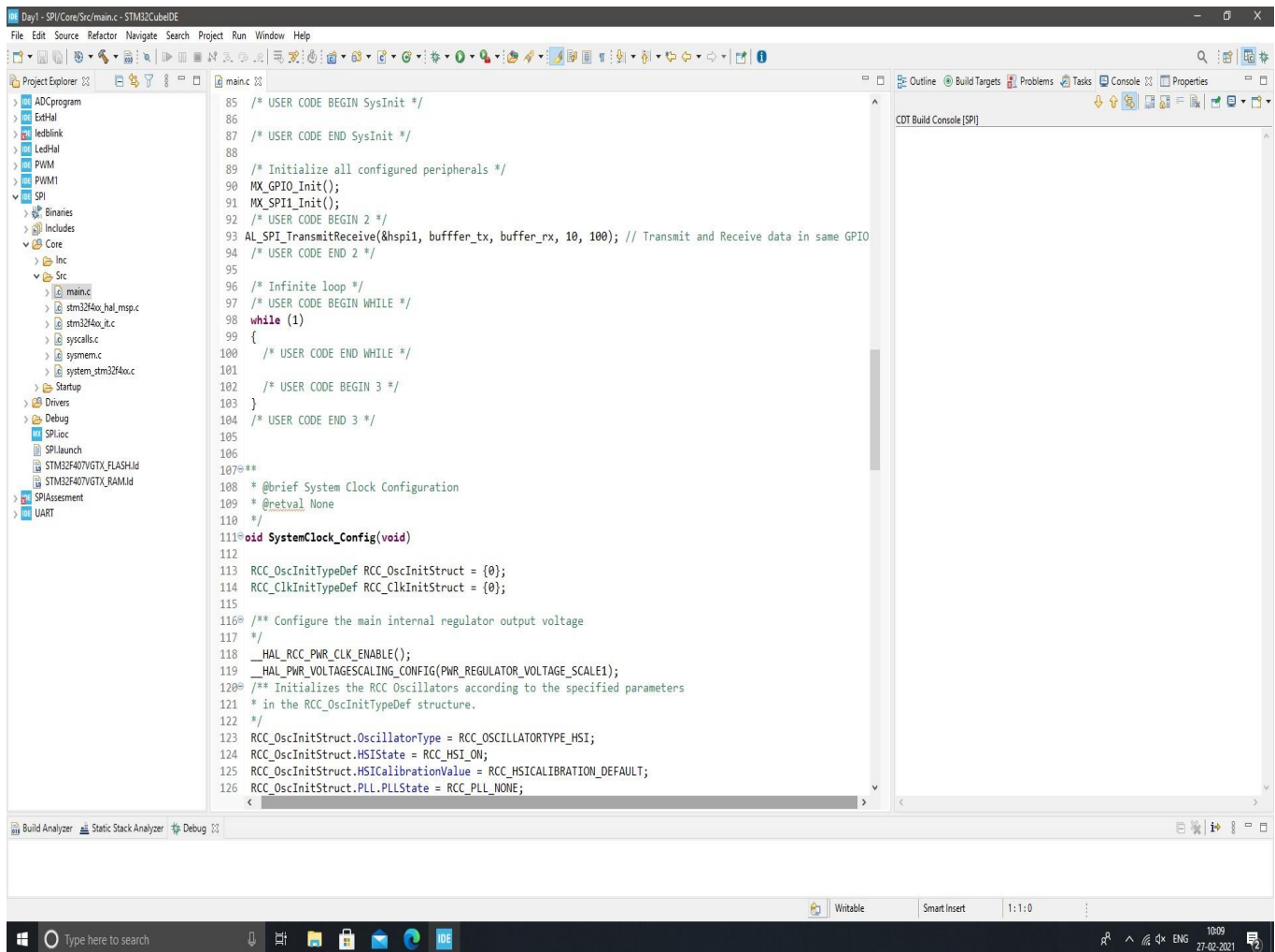


Figure: 2.4.1 SPI Pin configuration



```
1  /* USER CODE BEGIN Header */
2  /**
3   * @file
4   * @brief : Main program body
5   * @attention
6   *
7   * <h2><center>&copy; Copyright (c) 2021 STMicroelectronics.
8   * All rights reserved.</center></h2>
9   *
10   * This software component is licensed by ST under BSD 3-Clause license,
11   * the "License"; You may not use this file except in compliance with the
12   * License. You may obtain a copy of the License at:
13   * opensource.org/licenses/BSD-3-Clause
14   *
15   */
16  /*
17   */
18  /* USER CODE END Header */
19  /* Includes -----*/
20  #include "main.h"
21  /* Private includes -----*/
22  /* USER CODE BEGIN Includes */
23  /* USER CODE END Includes */
24  /* Private typedef -----*/
25  /* USER CODE BEGIN PTD */
26  /* USER CODE END PTD */
27  /* Private define -----*/
28  /* USER CODE BEGIN PD */
29  /* USER CODE END PD */
30  /* Private macro -----*/
31  /* USER CODE BEGIN PM */
32  /* USER CODE END PM */
33  /* Private variables -----*/
34  /* USER CODE BEGIN PV */
35  /* USER CODE END PV */
36  /* Private function prototypes -----*/
37  void SystemClock_Config(void);
38  static void MX_GPIO_Init(void);
39  static void MX_SPI1_Init(void);
40  /* USER CODE BEGIN PFP */
41  /* USER CODE END PFP */
42  /* Private user code -----*/
43  /* USER CODE BEGIN 0 */
44  /* USER CODE END 0 */
45  /**
46   * @brief The application entry point.
47   * @retval int
48   */
49  int main(void)
50  {
51  /* USER CODE BEGIN 1 */
52  /* USER CODE END 1 */
53  /* MCU Configuration -----*/
54  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
55  HAL_Init();
56  /* USER CODE BEGIN Init */
57  /* USER CODE END Init */
58  /* Configure the system clock */
59  SystemClock_Config();
60  }
```



The screenshot shows an IDE window titled 'Day1 - SPI/Core/Src/main.c - STM32CubeIDE'. The main editor displays the following C code:

```
85 /* USER CODE BEGIN SysInit */
86
87 /* USER CODE END SysInit */
88
89 /* Initialize all configured peripherals */
90 MX_GPIO_Init();
91 MX_SPI1_Init();
92 /* USER CODE BEGIN 2 */
93 AL_SPI_TransmitReceive(&hspi1, buffer_tx, buffer_rx, 10, 100); // Transmit and Receive data in same GPIO
94 /* USER CODE END 2 */
95
96 /* Infinite loop */
97 /* USER CODE BEGIN WHILE */
98 while (1)
99 {
100 /* USER CODE END WHILE */
101
102 /* USER CODE BEGIN 3 */
103 }
104 /* USER CODE END 3 */
105
106
107 /**
108  * @brief System Clock Configuration
109  * @retval None
110  */
111 void SystemClock_Config(void)
112 {
113   RCC_OscInitTypeDef RCC_OscInitStruct = {0};
114   RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
115
116   /** Configure the main internal regulator output voltage
117   */
118   __HAL_RCC_PWR_CLK_ENABLE();
119   __HAL_PWR_VOLTAGESCALING_CONFIG(PWR_REGULATOR_VOLTAGE_SCALE1);
120   /** Initializes the RCC Oscillators according to the specified parameters
121   * in the RCC_OscInitTypeDef structure.
122   */
123   RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSI;
124   RCC_OscInitStruct.HSIState = RCC_HSI_ON;
125   RCC_OscInitStruct.HSICalibrationValue = RCC_HSICALIBRATION_DEFAULT;
126   RCC_OscInitStruct.PLL.PLLState = RCC_PLL_NONE;
```

The Project Explorer on the left shows the file structure of the STM32CubeIDE project, including folders for ADcProgram, ExtHal, I2c, LedBlink, LedHal, PWM, PWM1, SPI, and various source files like main.c, stm3240x_hal_msp.c, stm3240x_it.c, syscalls.c, system.c, and system_stm3240x.c. The SPI folder is expanded, showing the SPI.c file. The Console window on the right is titled 'COT Build Console [SPI]' and is currently empty. The status bar at the bottom shows 'Writtable', 'Smart Insert', '1:1:0', and the date '27-02-2021'.

Fig: 2.4.2 SPI configuration code

2.5 UART

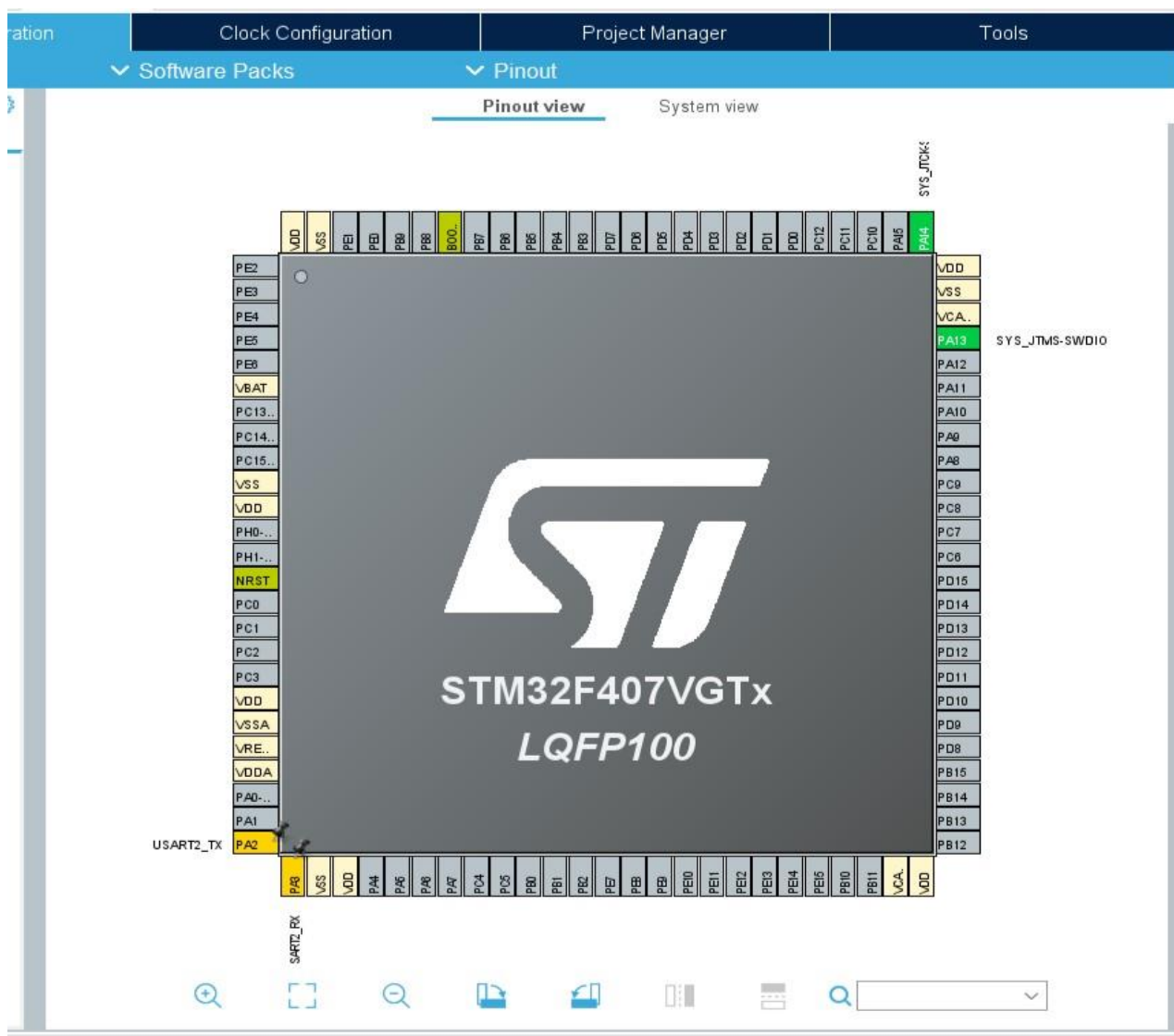


Fig: 2.5.1 UART Pin configuration

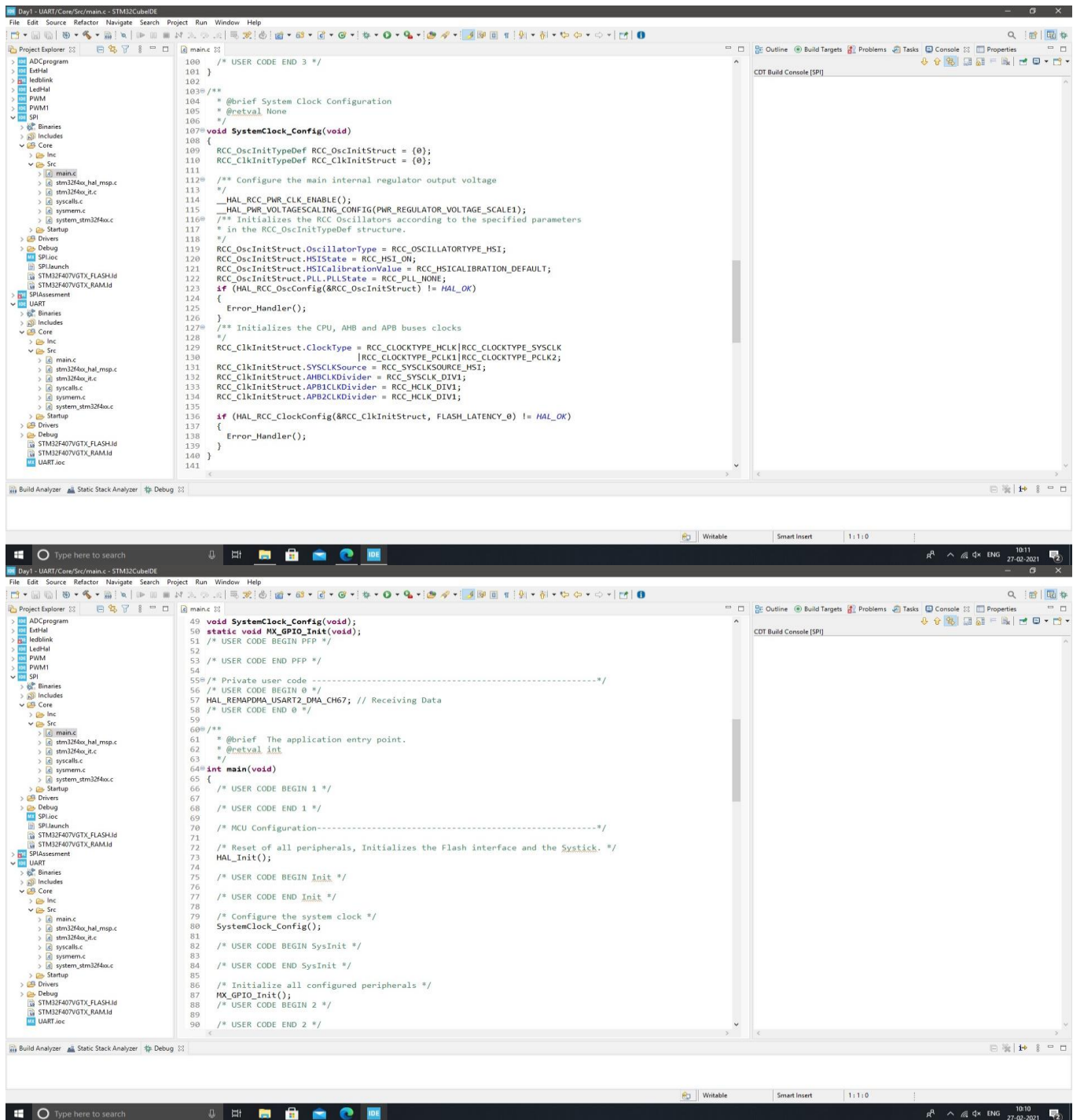


Fig: 2.5.2 UART configuration code