ELEC 3300 – Tutorial for LAB6

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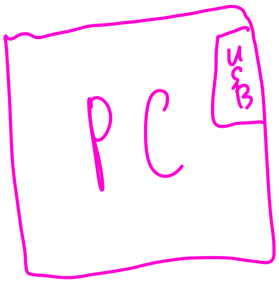
How to communicate to outside world?



1. universal serial bus
2.

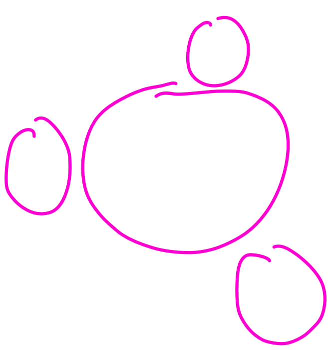
Serial Communication → refers to data being sent serially

→ Google: process of sending data one bit at a time

Parallel Communication → process of sending multiple bits at a time

→ how does it relate to time?

→ 一脚踏两船



serial

Serial and Parallel Communication

- What devices in the computer uses serial/parallel communication ?
- How do you define whether the communication between devices is called
  - Serial ?   Parallel ?
- Most important is that it relates to time…
- Let’s take an example …

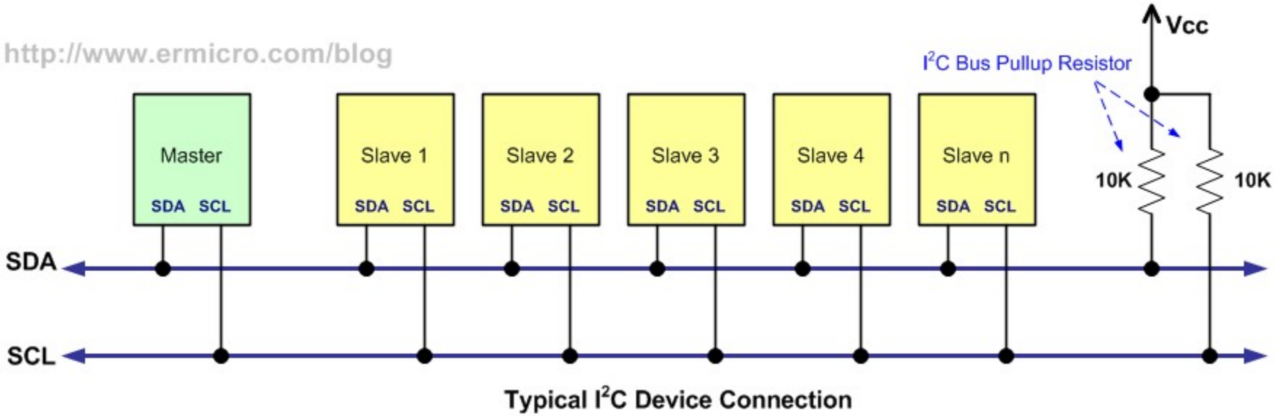
1. Google “two-time” … Chinese Phrase is…
   - Serial ? Parallel ? At the same time ?
2. Eat, Vomit ? …
   - Serial ? Parallel ? At the same time ?

Inter-integrated Circuit (I^2C)

- I^2C is an interface invented by Philips that used as a communication protocol between microcontroller to its peripherals.
- Common bus speed is 100kbits/s
- Most recent is I^2C can work up to 5Mbits/s 2wire ≠ 2 bit
- The main point of I^2C is to use 2-wire for communication, as a result, it sometimes called 2-wire interface, the 2 wires are
  - SCL – Clock → 1 wire
  - SDA – Data → 1 wire 0-communication
    - Use to synchronize all data transfers over the I^2C bus.
  - Both SCL and SDA lines are "open drain" drivers.
- As you can see, data is sending bit by bit via SDA, it is a serial communication.
- There is another serial interface called SPI which use 4-wire in total.

Inter-integrated Circuit (I^2C)

- Typical Connection



Inter-integrated Circuit (I^2C)

- The architecture includes
  - Master device
    - Initiates a transaction on the I^2C bus control all timing
    - Controls the clock signal
    - Possible to have multiple masters, but most system designs have only one.
  - Slave devices
    - Addressed by the master device
  - Both masters and slaves can receive and transmit data bytes. ↗ not necessarily @ the same time
- Full specification can be found in Canvas.
  - THE I^2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000

Inter-integrated Circuit (I^2C)

- Bit Transfer

data will only sample
will sample when clock is in high state

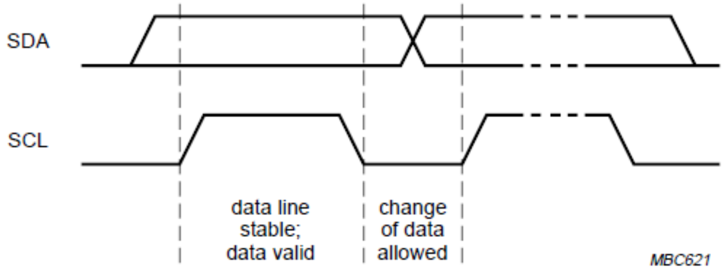


Figure from THE I 2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000 document order number 9398 393 40011 by Philips Semiconductors

Inter-integrated Circuit (I^2C)

- Start and Stop Condition

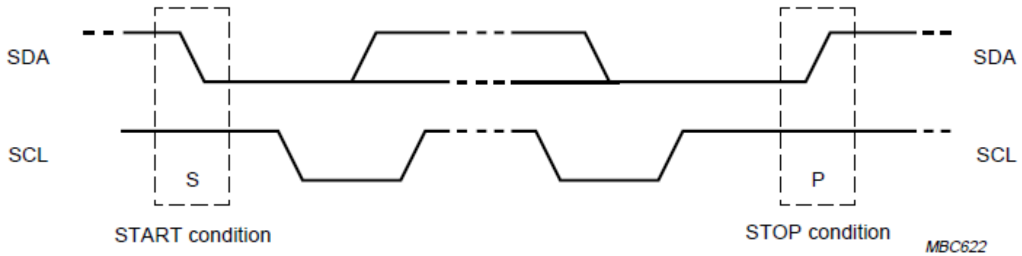


Figure from THE I 2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000 document order number 9398 393 40011 by Philips Semiconductors

Inter-integrated Circuit (I^2C)

- Data Transfer

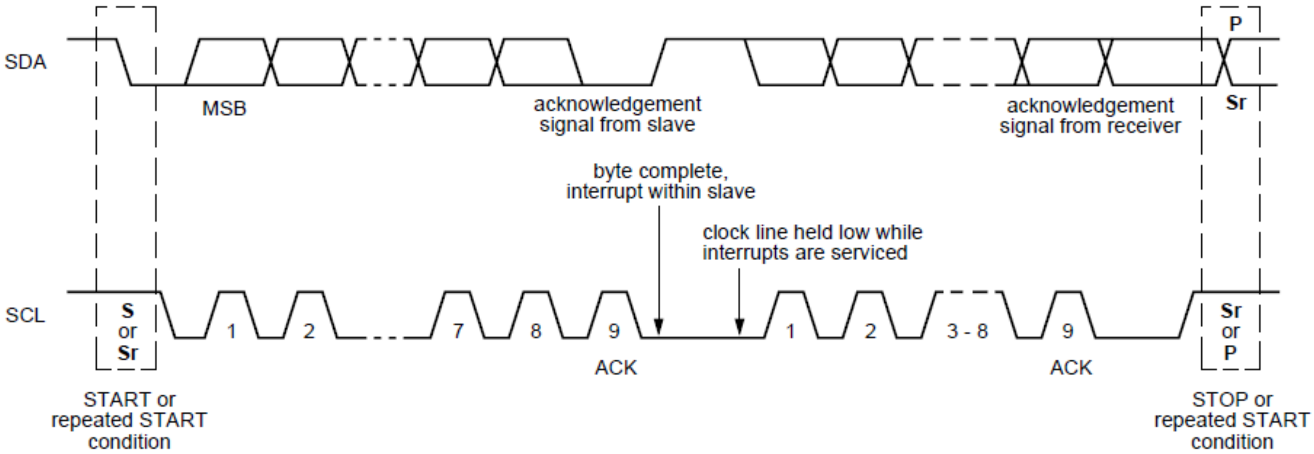


Figure from THE I 2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000 document order number 9398 393 40011 by Philips Semiconductors

Inter-integrated Circuit (I^2C)

- A Complete Data Transfer

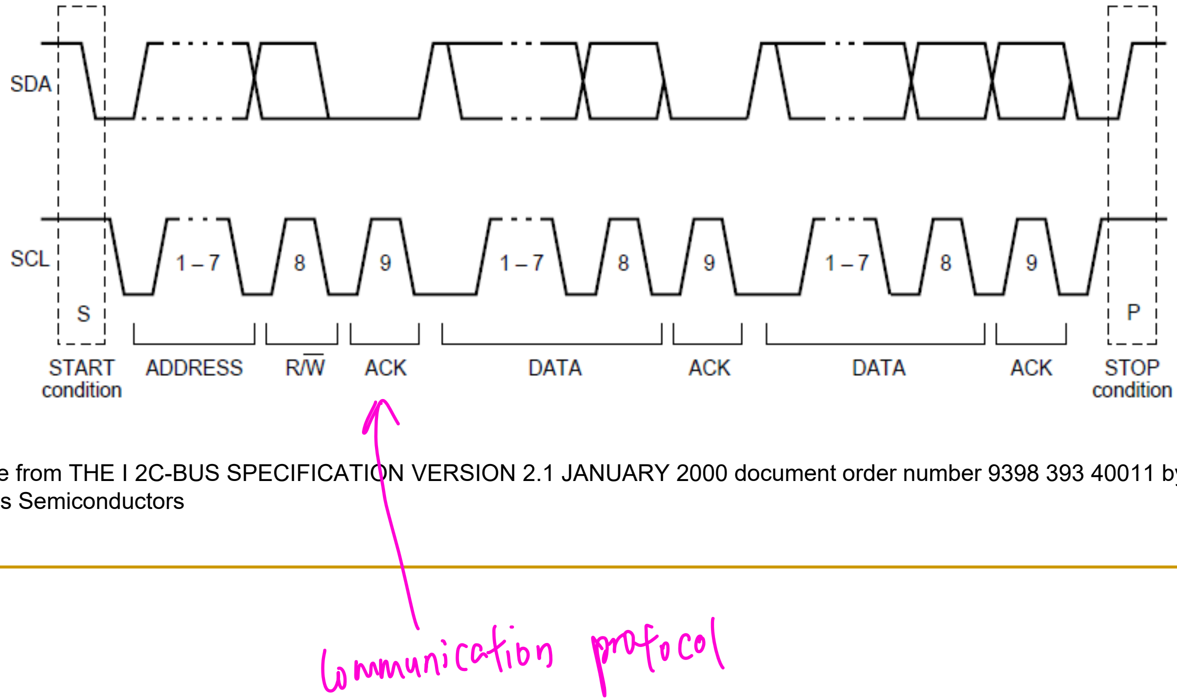


Figure from THE I 2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000 document order number 9398 393 40011 by Philips Semiconductors

Inter-integrated Circuit (I^2C)

- A Complete Data Transfer

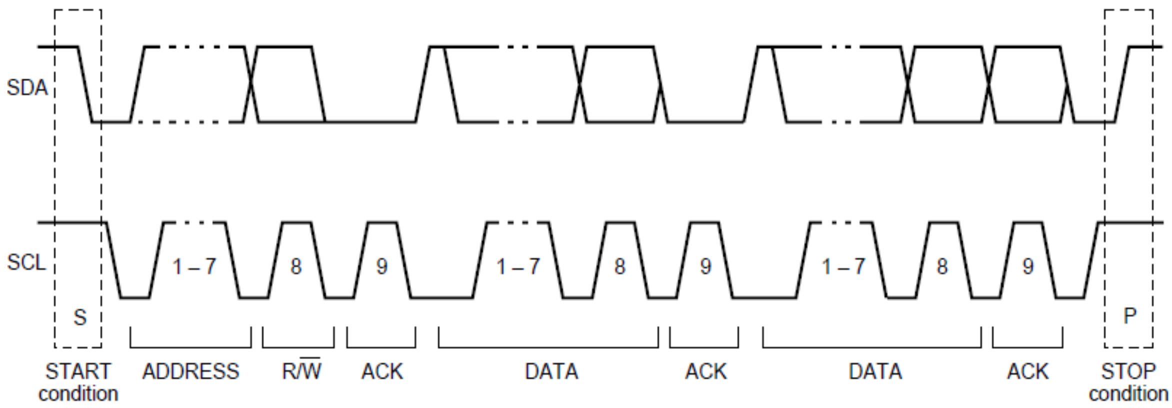
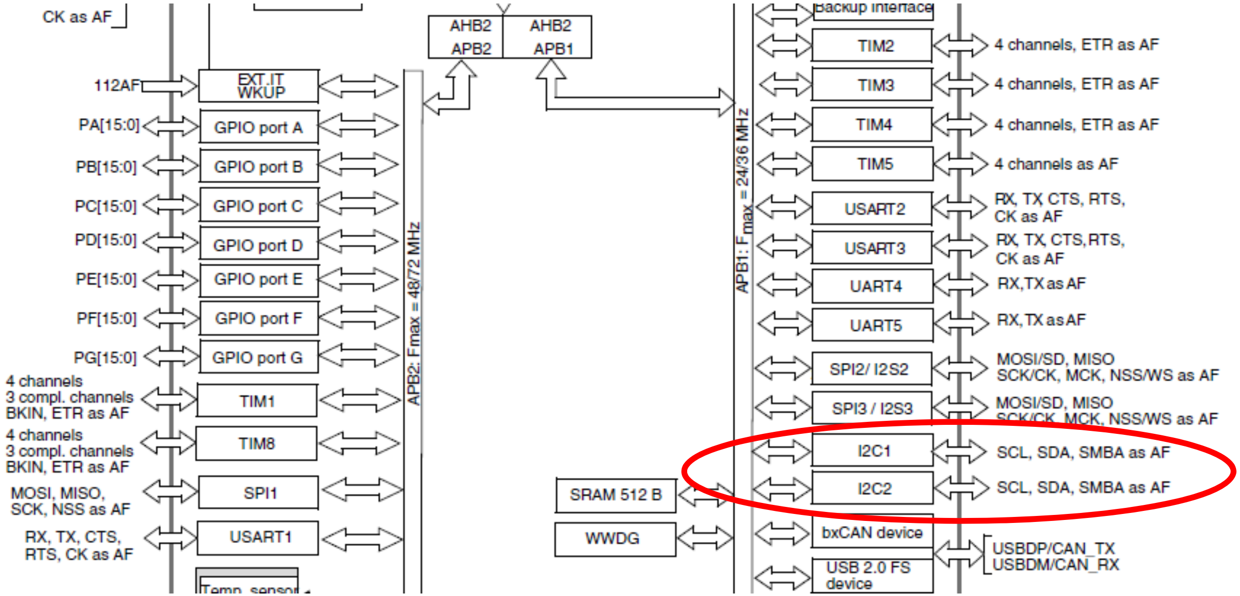


Figure from THE I 2C-BUS SPECIFICATION VERSION 2.1 JANUARY 2000 document order number 9398 393 40011 by Philips Semiconductors

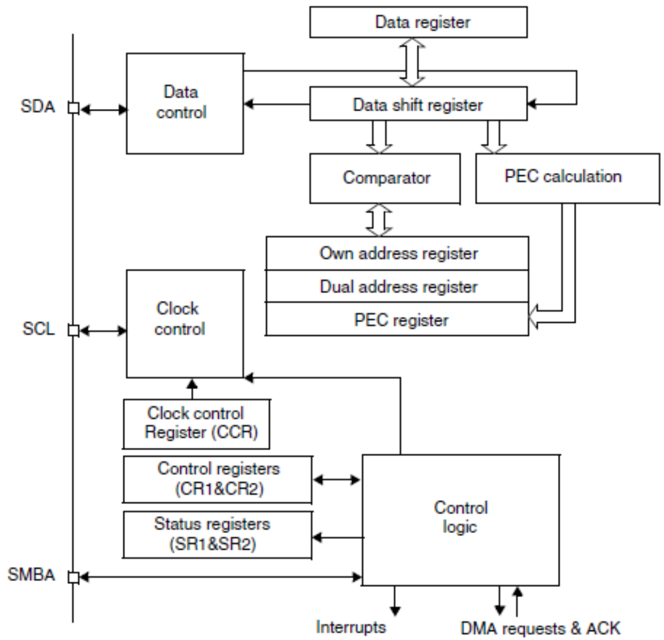
I²C in STM32

- In the STM32F103, there are two I²C Interfaces.



I^{2}C in STM32

- The block diagram of each interface.



I²C in STM32

why not use I2C1? ⇒ being used by FSMC

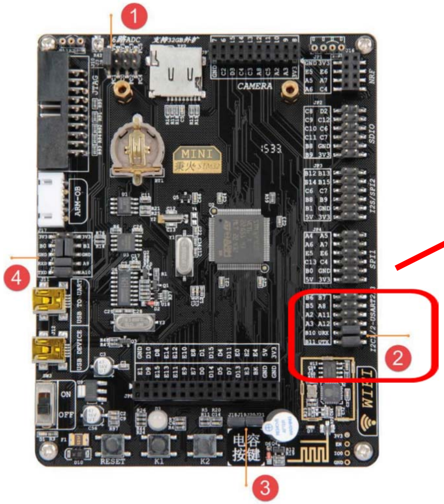
- One of the interface I2C2 is mapped to PB.10 and PB.11

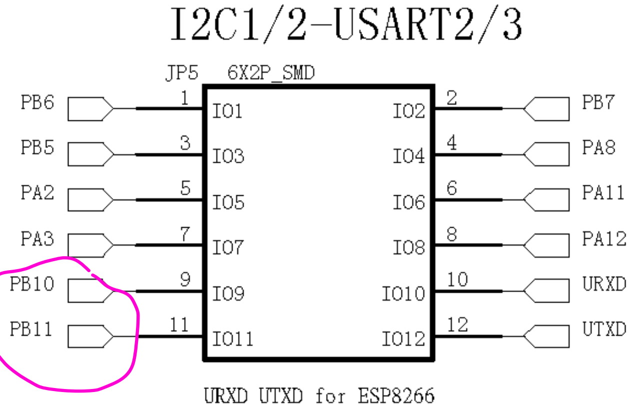
Table 5. High-density STM32F103xx pin definitions (continued)

Pins						Pin name	Type[1]	I / O Level[2]	Main function[3] (after reset)	Alternate functions[4]	
BGA144	BGA100	WLCSP64	LQFP64	LQFP100	LQFP144					Default	Remap
M8	H7	-	-	46	68	PE15	I/O	FT	PE15	FSMC_D12	TIM1_BKIN
M9	J7	G3	29	47	69	PB10	I/O	FT	PB10	I2C2_SCL/USART3_TX[8]	TIM2_CH3
M10	K7	F3	30	48	70	PB11	I/O	FT	PB11	I2C2_SDA/USART3_RX[8]	TIM2_CH4
H7	E7	H2	31	49	71	V_{SS_1}	S		V_{SS_1}		

I^2C in MINI-V3

- In MINI-V3 development board, Locate PB.10 and PB.11



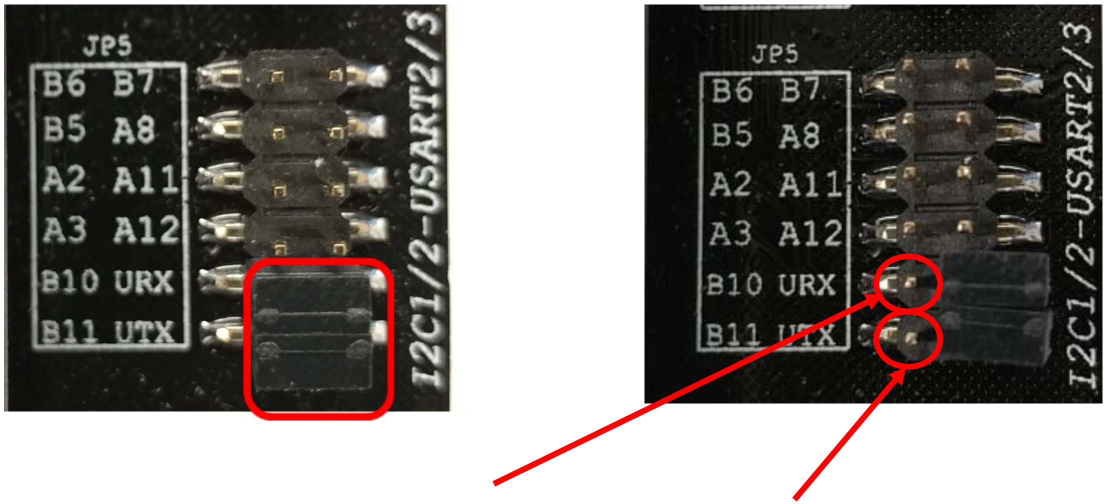


URXD UTXD for ESP8266
PB10: USART3_TXD
PB11: USART3_RXD
BY DEFAULT 9 10 11 12 CONNECTED BY JUMPERS

by default used as serial port for wifi module

I²C in MINI-V3

- Remove the Jumpers to access PB.10 and PB.11



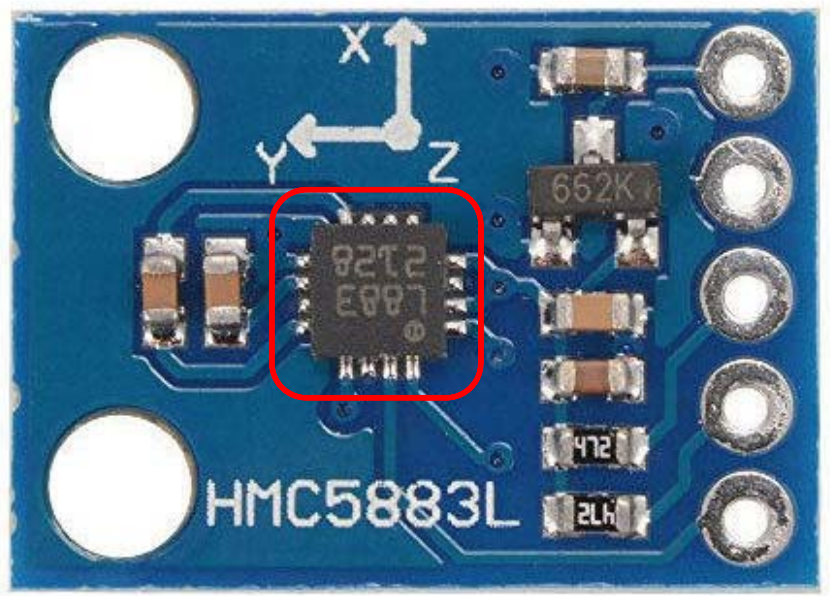
SCL PB.10

SDA PB.11

HMC5883L IC Module GY273

- HMC5883L is a digital 3-Axis Digital Compass IC

HMC5883L



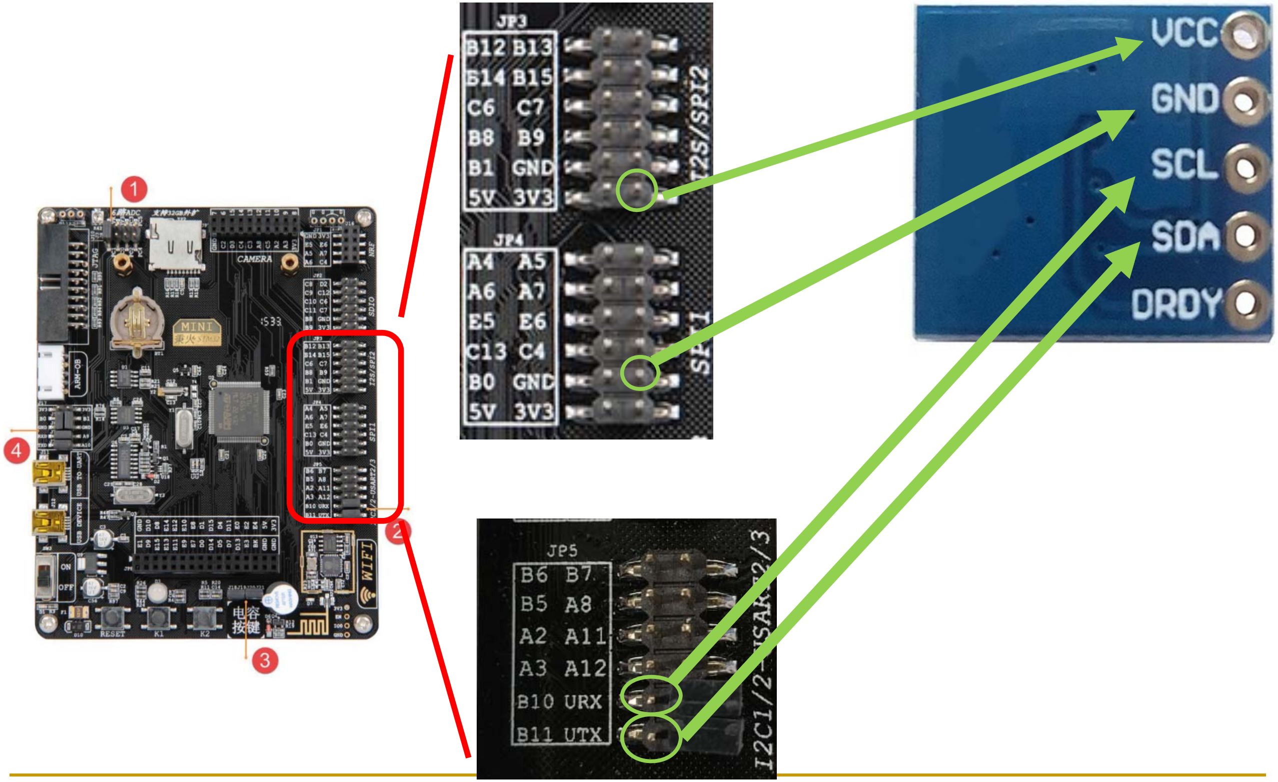
HMC5883L IC Module GY273

- HMC5883L back side

data ready } interrupt

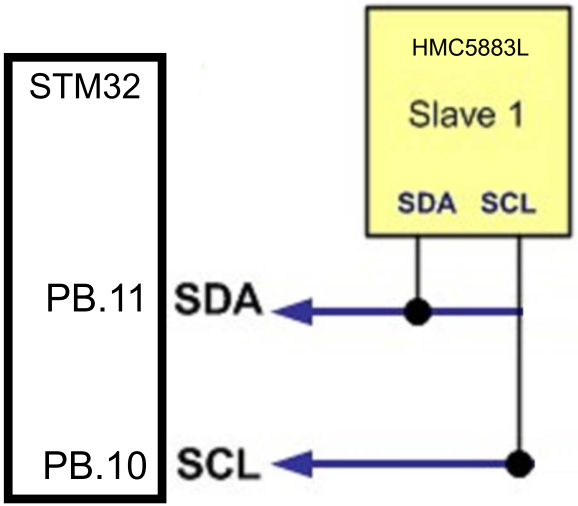
no need for this lab.

LAB6 Connection



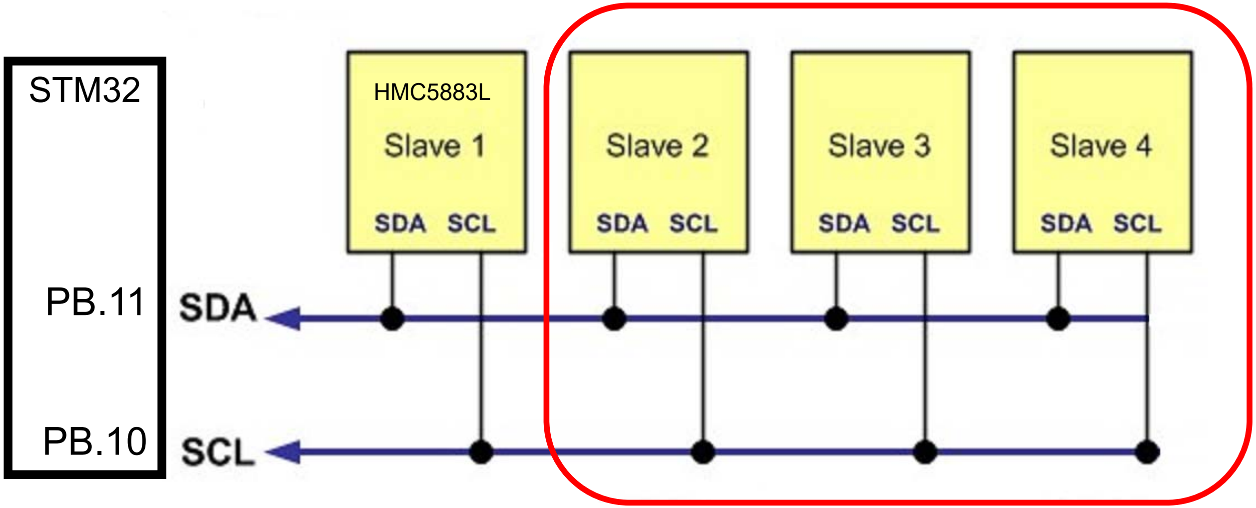
Connection to STM32

- You can consider the connection of module like this



Connecting different I2C devices

- Please note that you can connect more devices like this



How to send information to ONLY slave 4 a specific set of information.

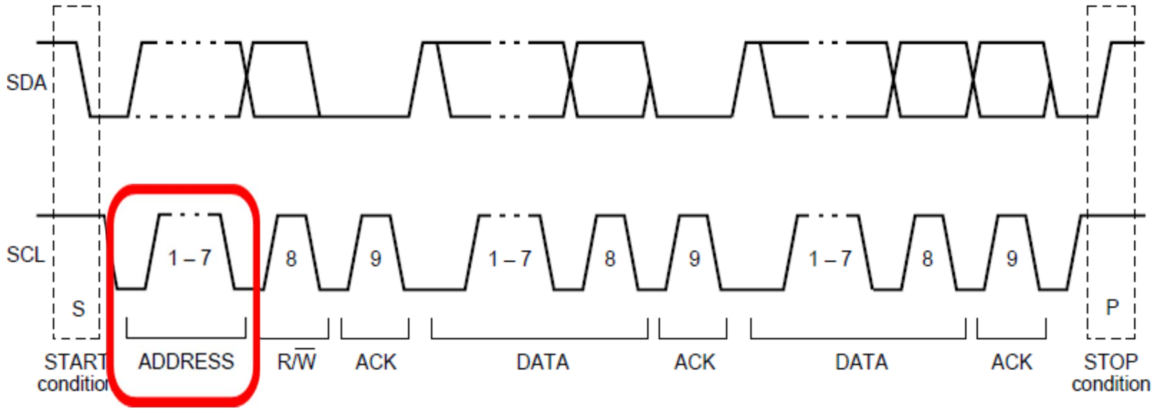
In other words, how does stm32 know which slave it is writing to.

How to communicate ?

- Let’s think about if the Master wants to write a byte to one device, what information should the Master gives out ?

Device/Slave Address

- Each device communicating with I^{2}C should have a device/slave address, so that to know who is talking to.



- From specification, this address should be 7-bit

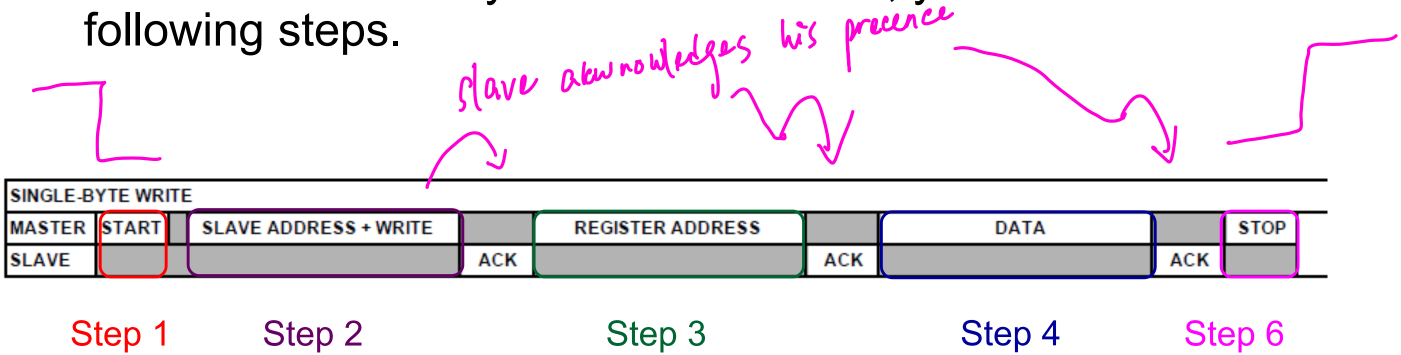
Device/Slave Address

- Below shows the 7-bit Device/slave address of the HMC5883L
  - HMC5883L – 0x1E   Shifted Left one bit = 0x3C

- Note: Sometimes datasheets will present in a shifted left function (it actually depends on the code, you should pay attention on this)

Write Timing Diagram

- In order to write a byte to an I²C device, you need to do the following steps.



The shaded areas represent when the device is listening

process of writing 1 byte

Write function in I^2C

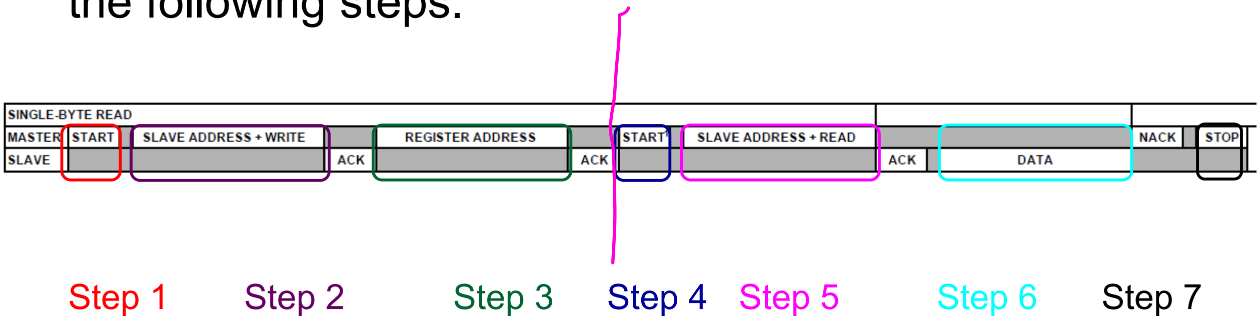
- Steps for a typical I^2C Write function

1. Send a start sequence
2. Send the I2C address of the slave with the R/W bit low (even address)
3. Send the internal register number you want to write to
4. Send the data byte
5. [Optionally, send any further data bytes]
6. Send the stop sequence.

Note: Actually, you need to check the status after each step.

Read Timing Diagram

- In order to read a byte form an I²C device, you need to do the following steps.



The shaded areas represent when the device is listening

Read function in I^2C

- A typical read function by I^2C as follows

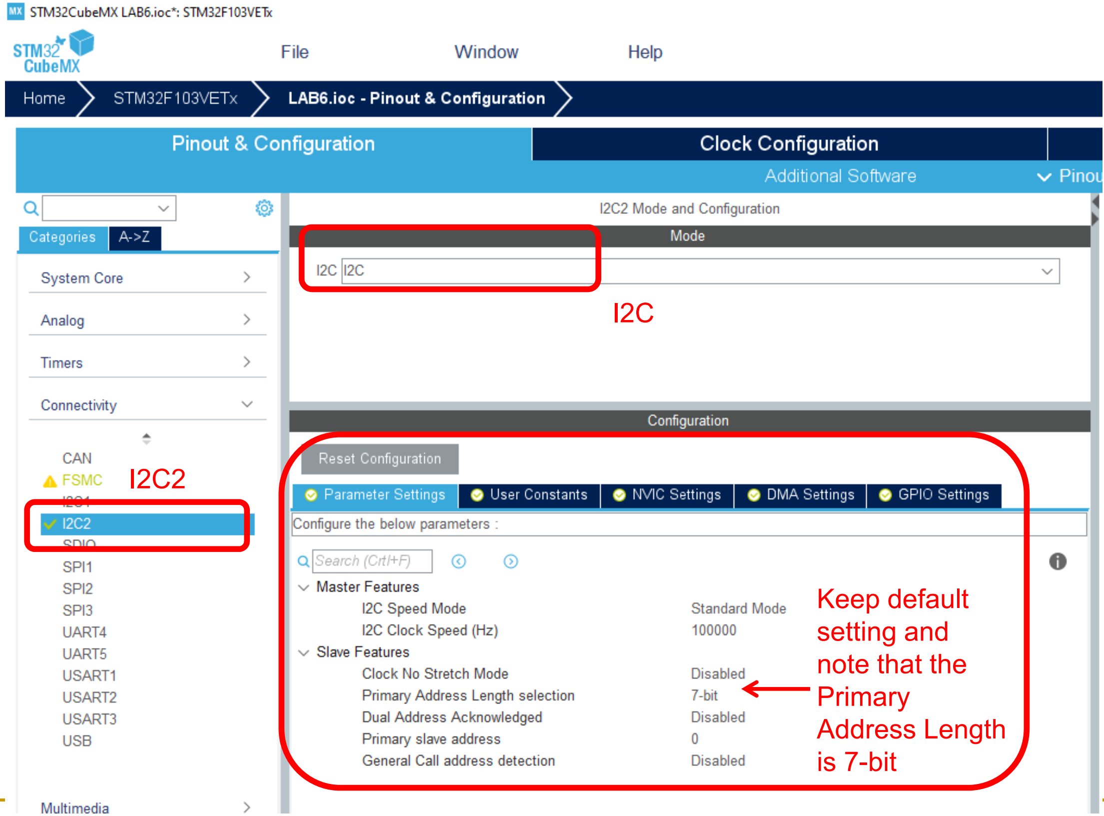
1. Send a start sequence
2. Send the read address with the R/W bit low (even address)
3. Send the lower read address
4. Send a start sequence again (repeated start)
5. Send the read address with the R/W bit high (odd address)
6. Read data byte
7. Send the stop sequence.

Note: Actually, you need to check the status after each step.

Configuration of I2C in CubeMX

- In this LAB, we need to use the LCD to display the value.
- Please refer to the Tutorial for CubeMX and Tutorial for LAB3 to create a project that allows you to use the LCD Display.
- Or you may start your LAB6 by using the LAB3 as a starting point.

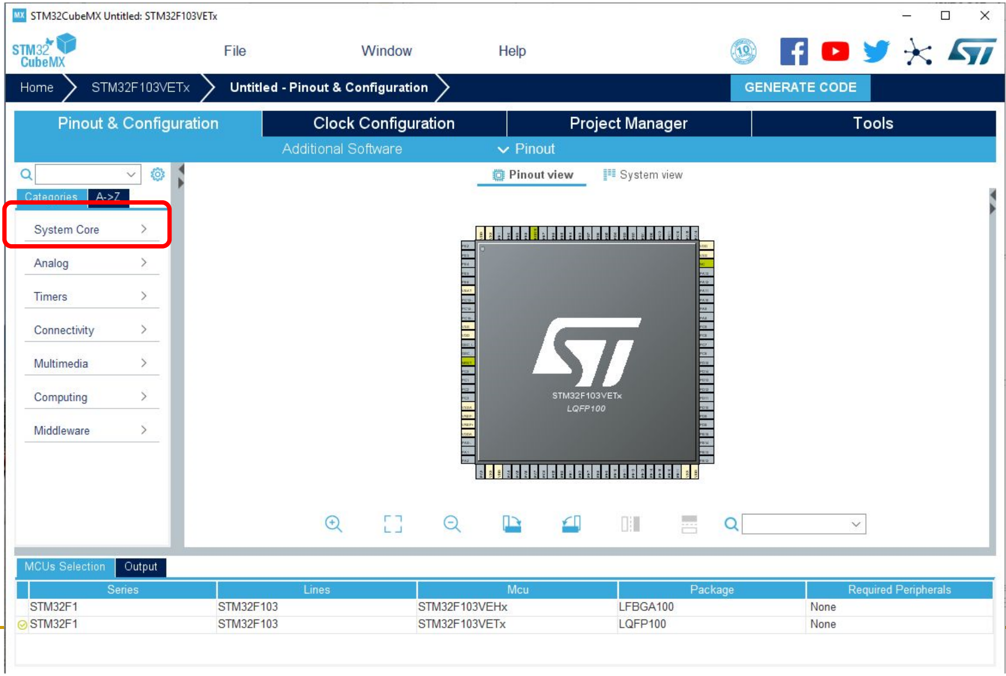
Configuration of I2C2 in CubeMX



You can then Generate the Project Template

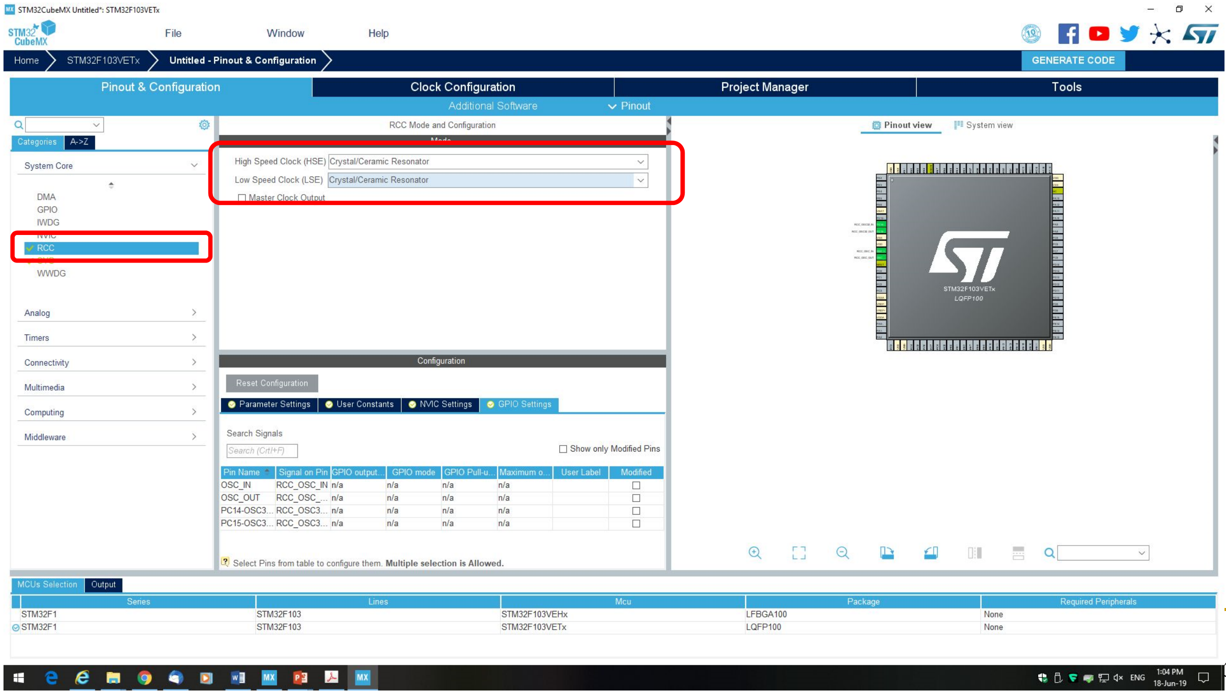
Set Clock

- You will go to this screen, first we need to set the clock, Expand System Core



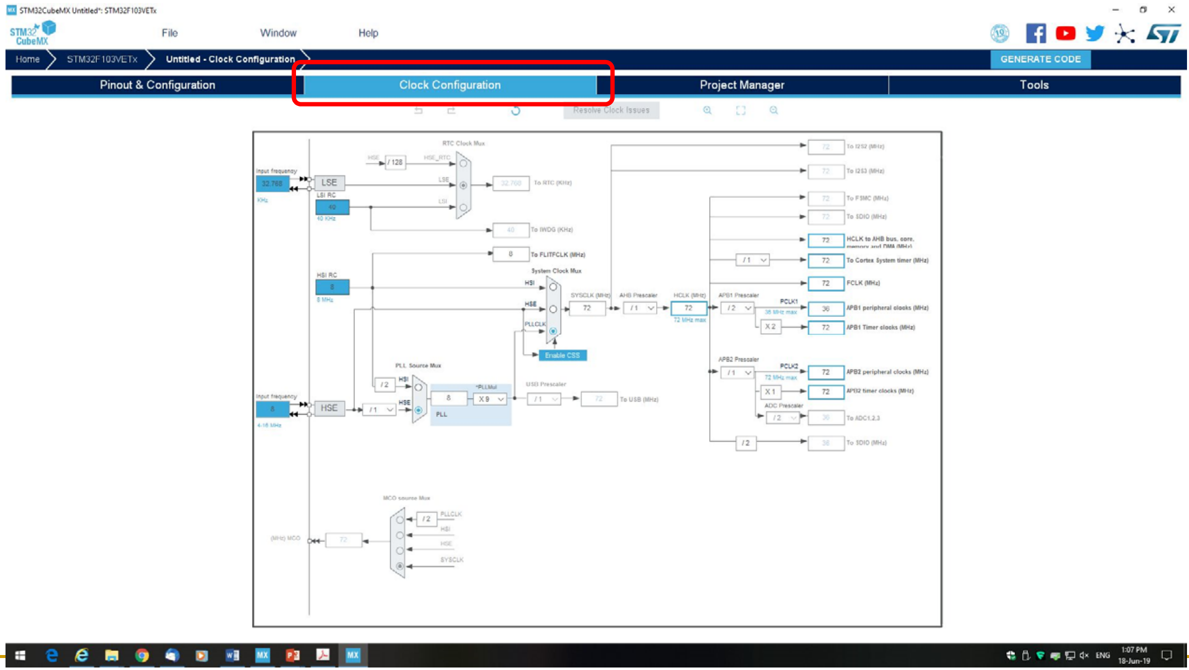
Change Clock to Crystal

- Click RCC, enable the High Speed Clock and Low Speed Clock to
  - Crystal/Creamic Resonator

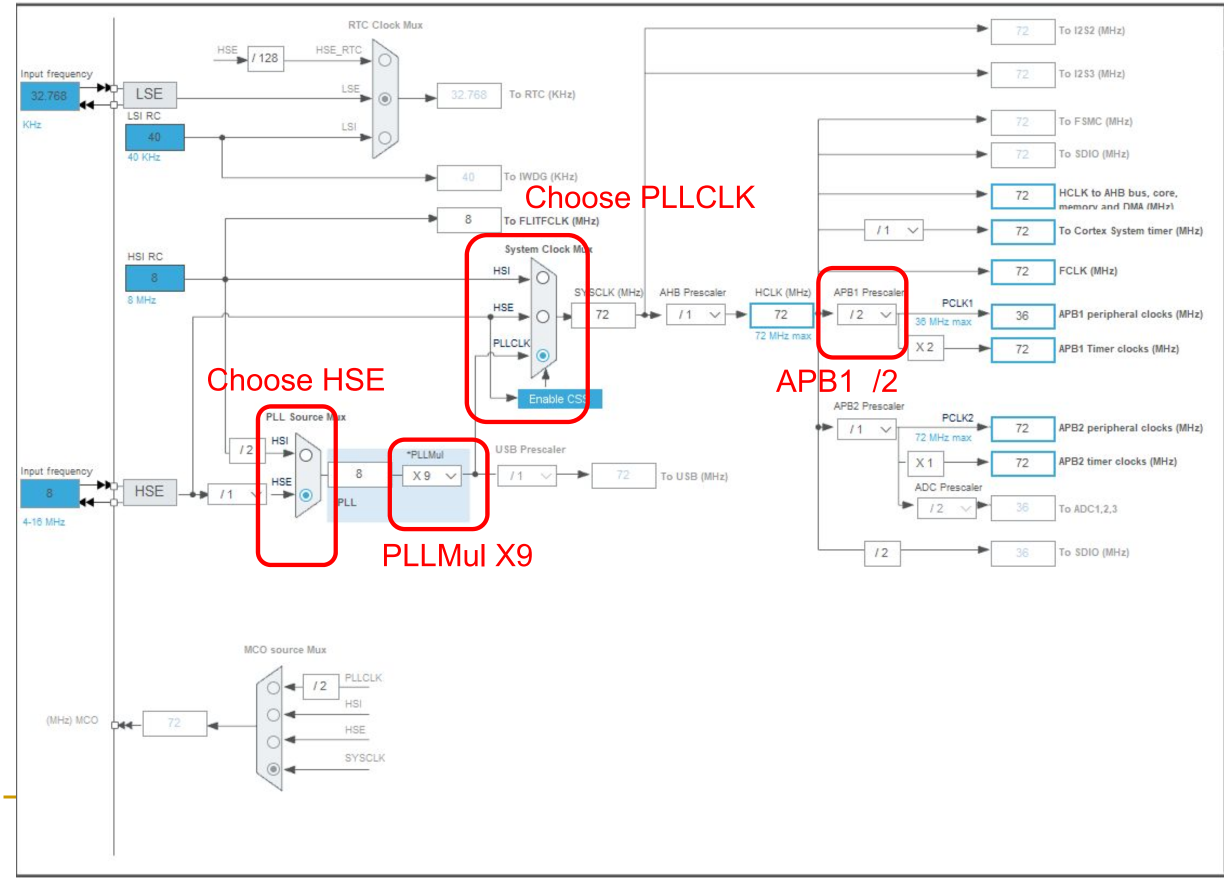


Clock Configuration

- Go to Clock Configuration

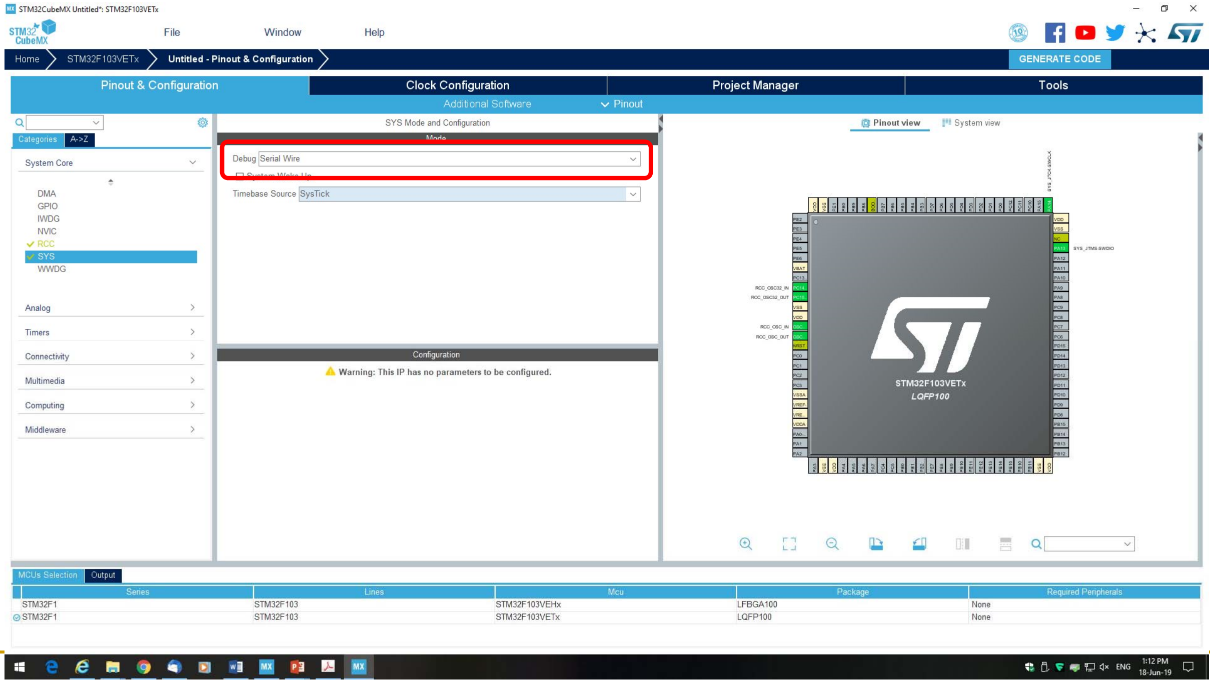


Clock Configuration



Communicate with Debugger

- Go to Pinout & Configuration, in SYS, Choose Serial Wire for Debug



I^2C Initialization

- After code generation, in main.c you will notice that there is a I2C interface

```
I2C_HandleTypeDef hi2c2;
```

- The STM32 will perform the necessary timing for shifting out and shifting in the bits by using the I2C HAL library functions.

CubeMX BUG on I^{2}C

- There is a well-known BUG on CubeMX created project templates that using I2C functions.
- Basically, it is because the clock initialization.
- It should be easy to ask your best friend for solution.
- But, what I want to say here is …
- CubeMX only helps on creating the project templates and perform initializations.
- However, if things are not working as expected 
- It would still be 

who find out the problem and solve it

CubeMX BUG on I^2C

- You can refer to the 2 links (suggestions) below

http://www.programmersought.com/article/1434906261/;jsessionid=0C43BB39CA543A816A14EA5B4B0C004C

http://www.sonsivri.to/forum/index.php?topic=62967.0

- Hint: You might need to modify the file

  `stm32f1xx_hal_msp.c`

I²C HAL Functions available to you

- In I²C HAL Library, there is a Mem_Read function

```
HAL_StatusTypeDef HAL_I2C_Mem_Read(I2C_HandleTypeDef *hi2c, uint16_t
DevAddress, uint16_t MemAddress, uint16_t MemAddSize, uint8_t *pData,
uint16_t Size, uint32_t Timeout)
/**
  * @brief  Read an amount of data in blocking mode from a specific memory address
  * @param  hi2c Pointer to a I2C_HandleTypeDef structure that contains
  *                the configuration information for the specified I2C.
  * @param  DevAddress Target device address: The device 7 bits address value
  *         in datasheet must be shifted to the left before calling the interface
  * @param  MemAddress Internal memory address
  * @param  MemAddSize Size of internal memory address
  * @param  pData Pointer to data buffer
  * @param  Size Amount of data to be sent
  * @param  Timeout Timeout duration
  * @retval HAL status
  */
```

0x1E won't work

I^2C HAL Functions available to you

- In I^2C HAL Library, there is a Mem_Write function

```
HAL_StatusTypeDef HAL_I2C_Mem_Write(I2C_HandleTypeDef *hi2c, uint16_t
DevAddress, uint16_t MemAddress, uint16_t MemAddSize, uint8_t *pData,
uint16_t Size, uint32_t Timeout)
```

```
/**
  * @brief  Write an amount of data in blocking mode to a specific memory address
  * @param  hi2c Pointer to a I2C_HandleTypeDef structure that contains
  *                the configuration information for the specified I2C.
  * @param  DevAddress Target device address: The device 7 bits address value
  *         in datasheet must be shifted to the left before calling the interface
  * @param  MemAddress Internal memory address
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  * @param  pData Pointer to data buffer
  * @param  Size Amount of data to be sent
  * @param  Timeout Timeout duration
  * @retval HAL status
  */
```

0x1E won't work

I^2C HAL Functions available to you

- Example

  If you want to read one byte stored in address 0x6C at HMC5883L (DevAddress is 0x1E), using I2C2

```
HAL_I2C_Mem_Read(&hi2c2,0x1E<<1,0x6C,1,&data,1,100);

where data is a uint8_t variable.
```

  So, if you want to read one byte stored in address 0x00 at HMC5883L, what should you write ?

I^{2}C HAL Functions available to you

- Example

If you want to write one byte (say, 0xFF) to address 0x30 on HMC5883L (DevAddress is 0x1E), using I2C2

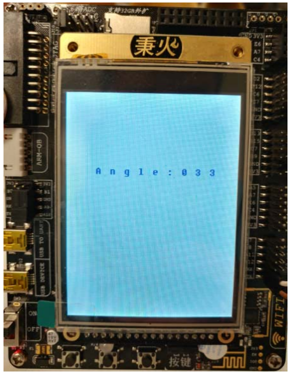
```
HAL_I2C_Mem_Write(&hi2c2,0x1E<<1,0x30,1,&data,1,100);
```

```
where        uint8_t data = 0xff
```

So, if you want to write one byte (say 0xAB) to address 0x20 on HMC5883L, what should you write ?

LAB6 – Task 1

- In this LAB, you are required to get the information from the Digital Compass and display the information on the LCD Screen. 0 – 359 degree. Below is just an example, you can display even more information



- As it is the last LAB, you need to think how to fill the code in the while(1) loop to complete the task.

HMC5883L – On-chip Registers

- HMC5883L is controlled and configured via a number of on-chip registers. The table below lists the registers and their access. All address locations are 8 bits.

Address Location	Name	Access
00	Configuration Register A	Read/Write
01	Configuration Register B	Read/Write
02	Mode Register	Read/Write
03	Data Output X MSB Register	Read
04	Data Output X LSB Register	Read
05	Data Output Z MSB Register	Read
06	Data Output Z LSB Register	Read
07	Data Output Y MSB Register	Read
08	Data Output Y LSB Register	Read
09	Status Register	Read
10	Identification Register A	Read
11	Identification Register B	Read
12	Identification Register C	Read

HMC5883L – Initialization

- The initialization for the HMC is written on page 18 of the datasheet, using single measurement mode.

1. Write CRA (00) – send 0x3C 0x00 0x70 (8-average, 15 Hz default or any other rate, normal measurement)
2. Write CRB (01) – send 0x3C 0x01 0xA0 (Gain=5, or any other desired gain)

DevAddress MemAddress Data

- It can be achieved by

```
HAL_I2C_Mem_Write(&hi2c2,HMC5883L_Addr<<1,0x00,1,&CRA,1,100);
HAL_I2C_Mem_Write(&hi2c2,HMC5883L_Addr<<1,0x01,1,&CRB,1,100);
```

- where

```
HMC5883L_Addr = 0x1E; uint8_t CRA = 0x70; uint8_t CRB = 0xA0;
```

HMC5883L – Getting Data

- For each measurement query:

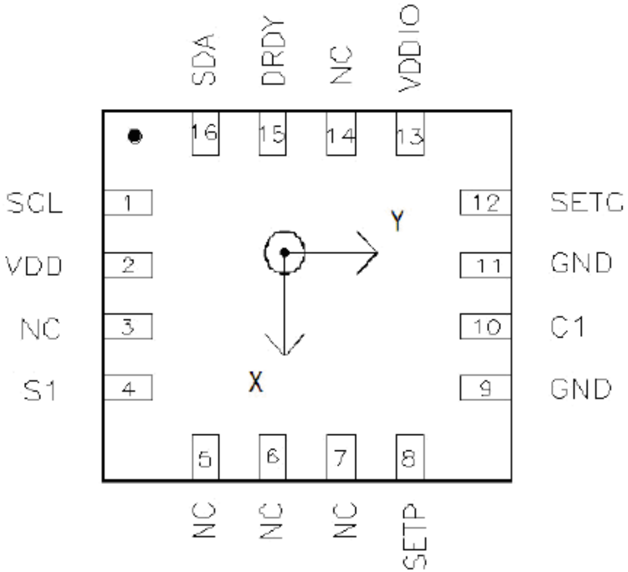
1. Write Mode (02) – send 0x3C 0x02 0x01
   - Write the Mode Register (02) with value 01.
2. Wait 6 ms or monitor status register or DRDY hardware interrupt pin
3. Read X, Z, Y values from registers
4. Convert three 16-bit 2’s compliment hex values to decimal values and assign to X, Z, Y respectively.

HMC5883L – X, Y, Z

- Refer to Page 15, 16 of the Datasheet, X, Y, Z are three values stored in 6 registers namely
  - X – (MSB) DXRA (LSB) DXRB
  - Y – (MSB) DYRA (LSB) DYRB
  - Z – (MSB) DZRA (LSB) DZRB
- The value stored in the corresponding registers is a 16-bit value in 2’s complement form, whose range is 0xF800 to 0x07FF.
- Actually, you need X and Y values only.

HMC5883L – X, Y

- Arrow indicates direction of magnetic field that generates a positive output reading in Normal Measurement configuration.



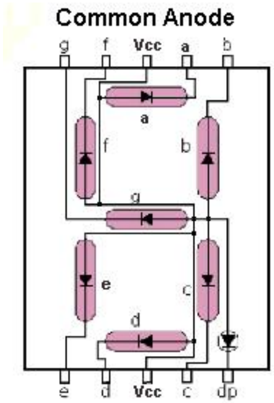
TOP VIEW (looking through)

Presenting the output

- Things to consider
- You got X and Y, how to get an angle out of them ?
  - Which trigonometry function you need ? → Refer to math.h
  - Remember that values of X and Y are signed. How does it relates to the angle ?
  - You need to pay attention to the data type for the variables, it might help you in simplifying your calculation.
- Once you got the angle, how can you use the LCD functions you developed before to display your result to LCD ?

LAB6 – Task 2

- In order to let you familiar with the board.
- I want you to display the last digit using a 7-segment LED externally. (e.g. if LCD is displaying 236, the 7-segment LED should display 6)
- You will be given a Common Anode 7-segment LED



LAB6 – Task 2 Connection

- The connection of the 7-segment LED will depends on your student ID.
- Example, if your student ID is 21234567, you need to check accordingly to the Pin Set below.

Pin Set	Actual Pin Number on STM32	Default Function of the pin on 100pin STM32F103VET6
A	67	PA8
B	56	PD9
C	45	PE14
D	34	PC5
E	23	PA0
F	12	OSC_IN
G	21	VREF+

LAB6 – Task 2

- Differs from LAB2, as this LAB we used the LCD and I^2C, some pins that originally available for you might not be available now.
- You are strongly suggested to check the datasheets and the schematics available on Canvas.
- You are **REQUIRED** to check all the pins as shown on next page.
- Please note that the student ID 21234567 as an example, you are **REQUIRED** to use your student ID for Task 2.

LAB6 – Task 2 Connection

Pin Set	Actual Pin Number on STM32	Default Function of the pin on 100pin STM32F103VET6	I/O function ?	Alternate Functions	Function on the MINI V3 Development Board	Can use for 7-segment LED ?
A	67	PA8	Yes	91	PB5	✗
B	56	PD9	Yes	09	PC15-OSC32-OUT	
C	45	PE14	Yes	40	PE9	✓
D	34	PC5	Yes	54	PB15	
E	23	PA0	Yes	65	PC8	✓
F	12	OSC_IN	No	06	VBAT	
G	21	VREF+	No	20	VREF-	

20 6 5 4 0 91

LAB6 – Task 2 Connection

Pin Set	Actual Pin Number on STM32	Default Function of the pin on 100pin STM32F103VET6	I/O Function	Alternate Functions	Function on the MINI V3 Development Board	Can use for 7-segment LED ?
A	67	PA8	Yes	USART1_CK/ TIM1_CH1(8)/MCO	Speaker	Yes, if we remove the jumper for the Speaker No, if we do not remove the jumper
B	56	PD9	Yes	FSMC_D14	LCD Data bus 14	No, as this LAB used LCD
C	45	PE14	Yes	FSMC_D11	LCD Data bus 11	No, as this LAB used LCD
D	34	PC5	Yes	ADC12_IN15	ADC12_IN15 Camera FIFO RCLK	Yes, as this LAB not used ADC and Camera
E	23	PA0	Yes	WKUP/USART2_CTS(8) ADC123_IN0 TIM2_CH1_ETR TIM5_CH1/TIM8_ETR	K1 on the Development Board	No, as there is no external connector for PA0 on the Development Board
F	12	OSC_IN	No			
G	21	VREF+	No			

LAB6 – Task 2 Connection

- For example, if the student ID is 21234567, refer to the last page, I can only use pin set D.

Pin Set	Actual Pin Number on STM32	Default Function of the pin on 100pin STM32F103VET6	I/O function ?	Alternate Functions	Function on the MINI V3 Development Board	Can use for 7-segment LED ?
D	34	PC5	Yes	ADC12_IN15	ADC12_IN15 Camera FIFO RCLK	Yes, as this LAB not used ADC and Camera

- You are **REQUIRED** to use *ALL* the pin sets available according to your student ID to connect to the 7-segment LED.
- Other then the pin sets required, you are then free to choose the unused I/O pins of STM32 to connect to the 7-segment.
- You are **REQUIRED** to show to the TA, together with your student ID
  1. The filled table on your LAB Sheet
  2. Your corresponding program and hardware

LAB6 – Task 2 Procedure

- Basically you need to control the 7 pins on and off.
- However, you need to build your own decoding table. (i.e. how to display 1, 2, 3, 4 … 0)
- Please connect the V_{cc} of the 7-segment to 3.3V with a resistor.
- Enjoy ☺

END