Microcontroller & MCC Melody
PIC1001-Melody v1.00

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

CAE Taiwan
Microchip Technology Inc.

2023 September

Major Course (1/3)

- Microchip 16-bits Microcontroller Introduction
- IDE, Compilers, MCC and Development Tools Introduction
- APP041 8, 16, 32-bits General Purpose EVM Introduction
- Getting Started with First Project
  - Lab0 First Project
- GPIO Architecture
  - Lab1 GPIO Output
  - Lab2 Multi-GPIO Output
  - Lab3 GPIO Input and Output
- Oscillator Architecture
  - Lab4 Clock PRIPLL

Major Course (2/3)

- Interrupt Architecture
- Timer Driver Architecture
  - 💻Lab5 Timer1 Interrupt
  - 💻Lab6 SCCP Timer Interrupt
- OLED Architecture (PPS&SPI)
  - 💻Lab7 OLED Display
  - 💻Lab8 Customize Screen
- 12 Bits High Speed ADC Architecture
  - 💻Lab9 ADC Single Channel
  - 💻Lab10 ADC Multiple Channel

Major Course (3/3)

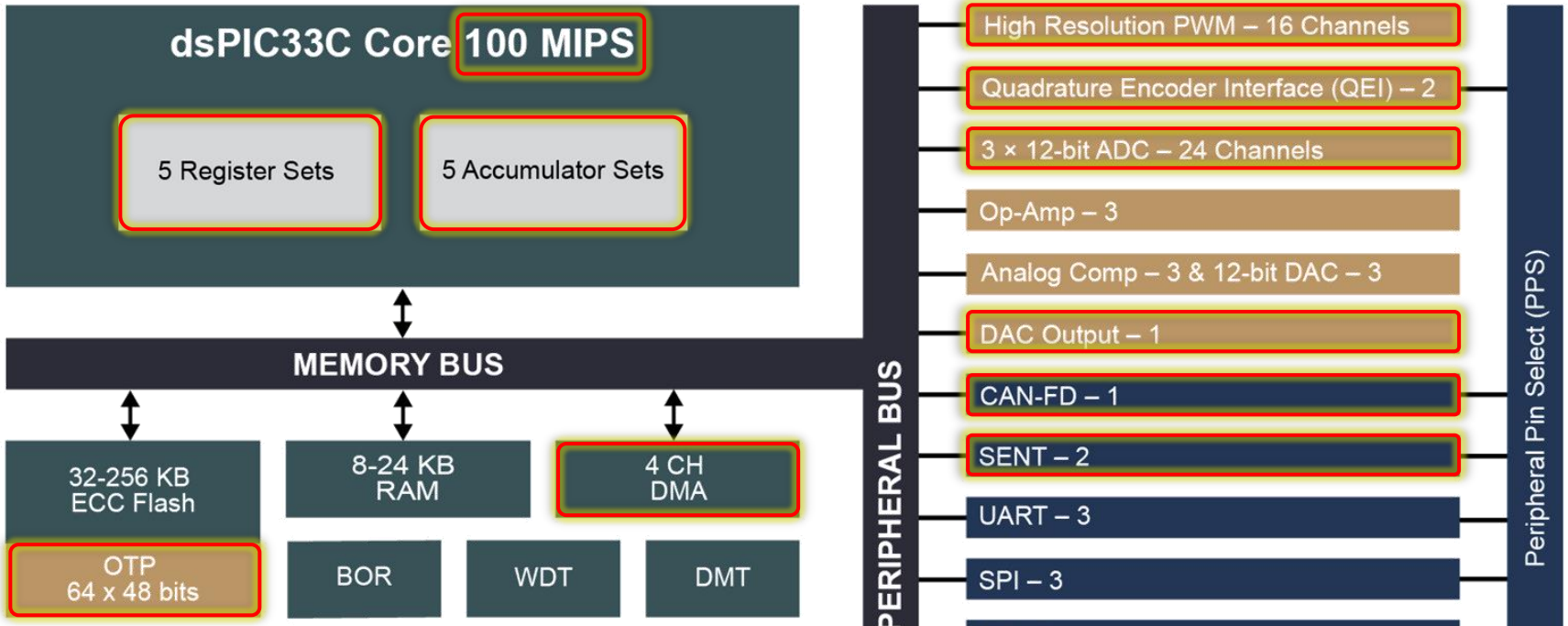
- High Resolution PWM Architecture
  - 💻Lab11 PWM Output
  - 💻Lab12 PWM Duty Adj By ADC
  - 💻Lab13 PWM Buzzer
- UART Architecture
  - 💻Lab14 UART Printf
  - 💻Lab15 UART Communication
- I2C Architecture
  - 💻Lab16 EEPROM Operation
  - 💻Lab17 Temperature Sensor (MCP9800) Operation

Microchip 16-bits Microcontroller Architecture

16-bits PIC/dsPIC® MCU series

- **Microchip 16-bits MCU families include below,**
- PIC24FJ (16 MIPS)
  - Very high CP. Low price and high performance.
- PIC24HJ (40 MIPS)
  - Built-in DMA, upgrade performance to 40 MIPS.
- PIC24EP (70 MIPS)
  - Latest generation of PIC24 series, upgrade performance to 70 MIPS.
- dsPIC33FJ (40 MIPS)
  - Base on PIC24HJ, Built-in DSP.
- dsPIC33EP (60 MIPS)
  - Built-in DSP & USB OTG, upgrade performance to 60 MIPS.
- **dsPIC33CK (100 MIPS)**
  - High Performance, 12-bits High Speed ADC & High-Resolution PWM.
- dsPIC33CH (90 MIPS & 100 MIPS)
  - Dual core with shared resources.

dsPIC33CK256MP508 Family



Operating Voltage: 3.0-3.6 V

Operating Temperature: -40°C to 125°C

AEC-Q100 Grade 1 Qualification

28-pin: SSOP, uQFN (6 x 6 mm)
36-pin: uQFN (5 x 5 mm)
48-pin: uQFN, TQFP (6 x 6 mm, 7 x 7 mm)
64-pin: QFN, TQFP (9 x 9 mm, 10 mm x 10 mm)
80-pin: TQFP (12 x 12 mm)

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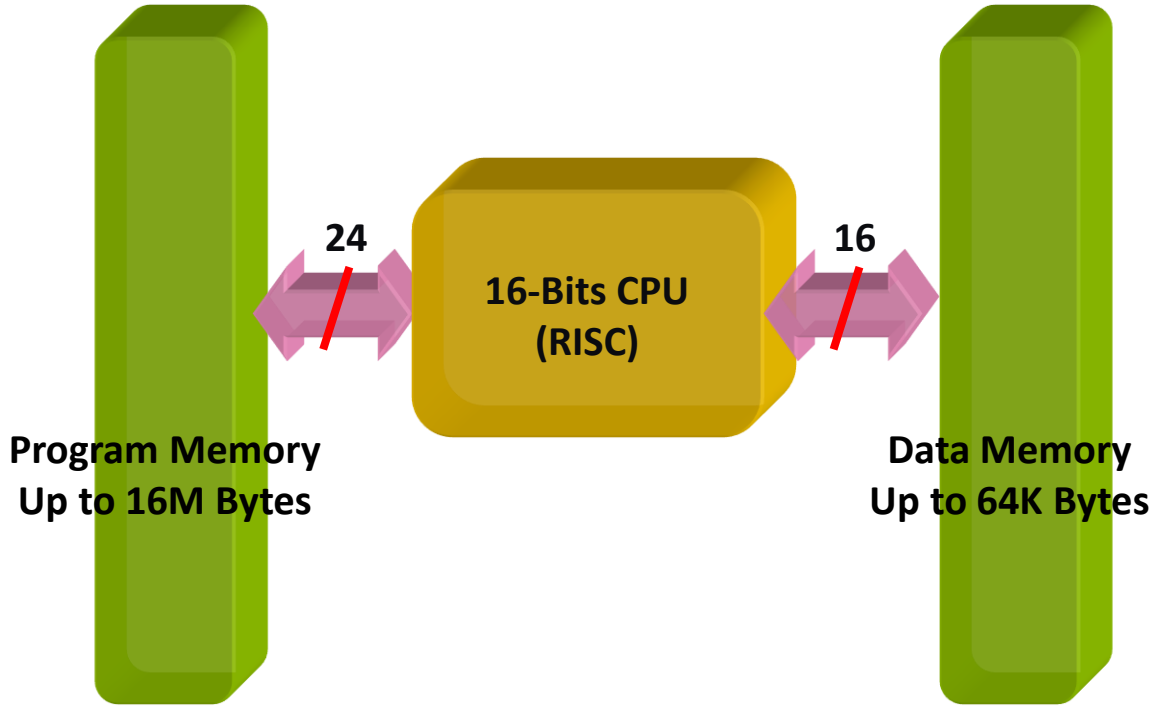
Core Architecture

- Microchip 16-bits PIC/dsPIC® MCU is Harvard architecture.
- This means program and data memory bus are independently.
- Data Memory is 16-bits, Up to 64K Bytes.
- Program Memory is 24-bits, Up to 16 M Bytes.



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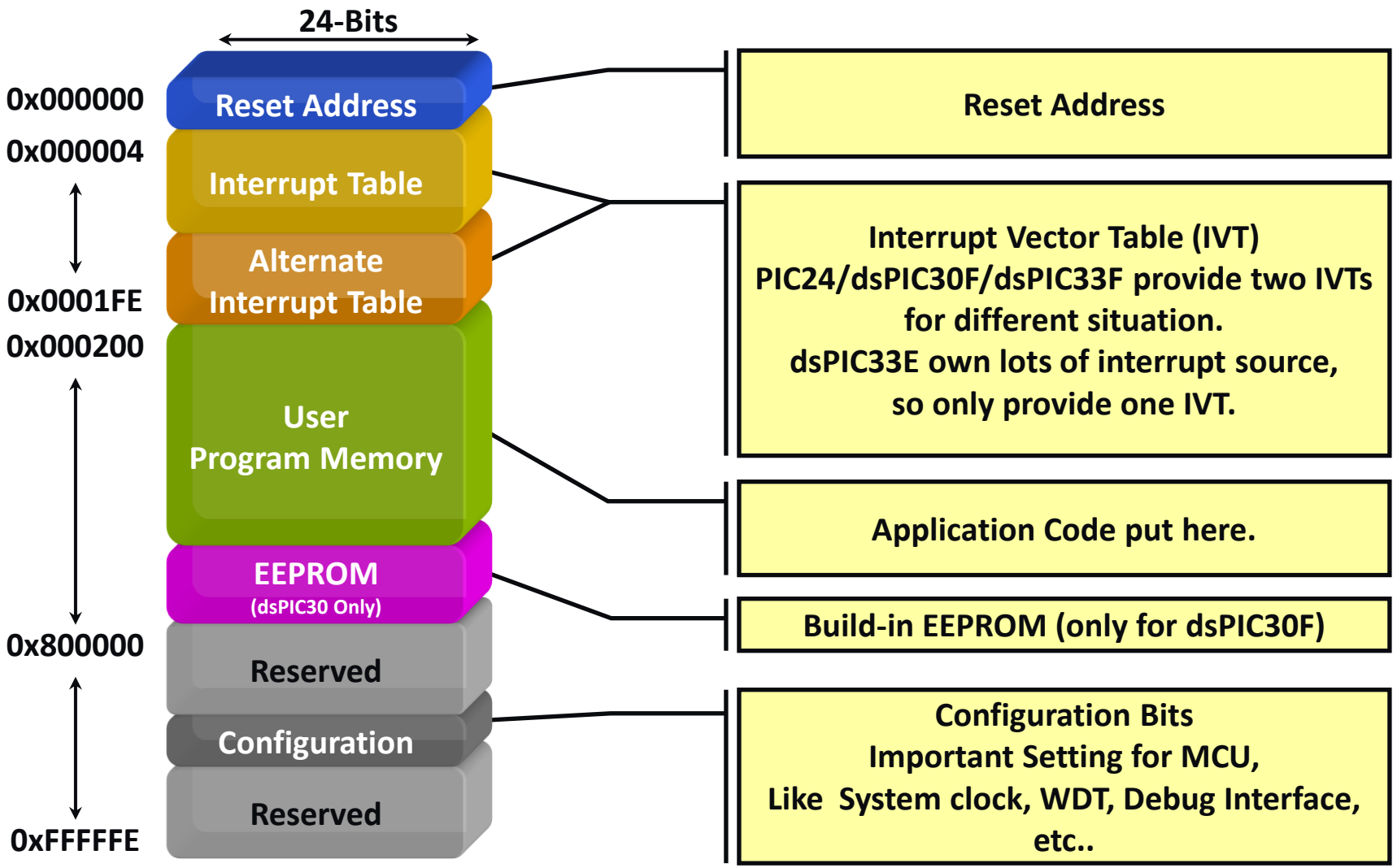
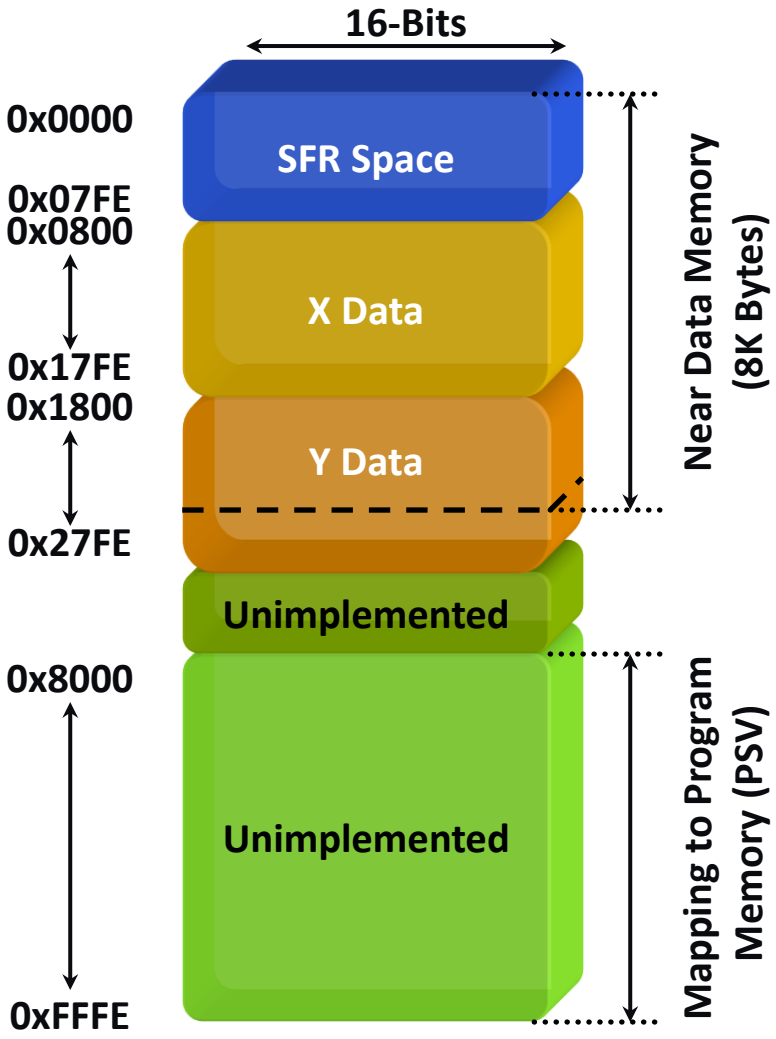
Program Memory Mapping



MICROCHIP

Data Memory Mapping



The 8-Kbyte area is referred as the near data space.
The 64-Kbyte area is referred as the far data space.

The first 2 Kbytes are primarily occupied with Special Function Registers (SFRs).

X Data, Y Data area only for DSP Engine For Dual Access Operation.
All Data is X Data area for PIC24 series.

0x8000 ~ 0xFFFF is mapping area for PSV use.

Machine & Instruction Cycle

- **T_{OSC}(Machine Cycle) :**
  - A machine cycle consists of the steps that a computer's processor executes whenever it receives a machine language instruction. (techopedia)
- **T_{CY}(Instruction Cycle) :**
  - The basic operational process of a computer system.(wiki)
- **dsPIC30 Family**
  - 1 T_{CY} = 4 T_{OSC} . (F_{CY} = F_{OSC} /4)
    Ex:120 MHz > 30 MIPS, T_{CY} = 33nS.
- **PIC24F/PIC24H/dsPIC33 Families**
  - 1 T_{CY} = 2 T_{OSC} . (F_{CY} = F_{OSC} /2)
    Ex:32 MHz > 16 MIPS, T_{CY} = 62.5nS.

X IDE, C Compiler, MCC & Development Tools Introduction

Soft Request In this Course

- **MPLAB® X IDE v6.15** https://www.microchip.com/mplab/mplab-x-ide
- **MPLAB® XC16 v2.10** https://www.microchip.com/mplab/compilers
- **MPLAB® Code Configurator (MCC) v5.3.7**
- **MCC Core v5.5.7**
- **MCC Melody (From X IDE MCC Content Manager)**
  - MCC Melody Core v2.6.1
  - PIC24/dsPIC devices v5.10.1
  - PIC24/dsPIC Hardware Peripheral Initializer v1.0.0
  - Libraries, Drivers, PLIB and System (reference to table)
- **MPLAB® X IDE Packs**
  - dsPIC33CK-MP DFP v1.12.354 (Device Family Pack)
  - SNAP tool packs v2.1.1120 (Tool Firmware Pack)

Drivers	
ADC Multicore	v2.1.2
External Interrupt	v1.0.2
I2C Host	v1.0.4
PWM HS	v2.1.1
SPI_Host	v1.1.0
Timer	v1.1.0
UART	v1.8.0

PLIB	
ADC Multiple SARs	v2.4.2
EXT INTERRUPT	v2.2.0
I2C	2.2.2
MCCP/SCCP	v1.6.2
PWM	v2.3.1
SPI	v1.3.0
Timer	v1.5.2
UART	v1.4.1

System	
Clock	v1.2.0
Clock PLIB	v1.4.2
Configuration Bits	v1.2.1
ICD	v1.0.2
Interrupt	v1.3.1
Main	v1.1.2
Pins	v1.3.0
Pins View	v3.7.0
Reset	v1.1.0

➢ **MCC Core and Libraries Update from X IDE > MCC > Content Manager**

➢ **dsPIC33CK-MP DFP and SNAP TP Update from X IDE > Tools > Packs**

(Lasted Update : 2023/08/31)

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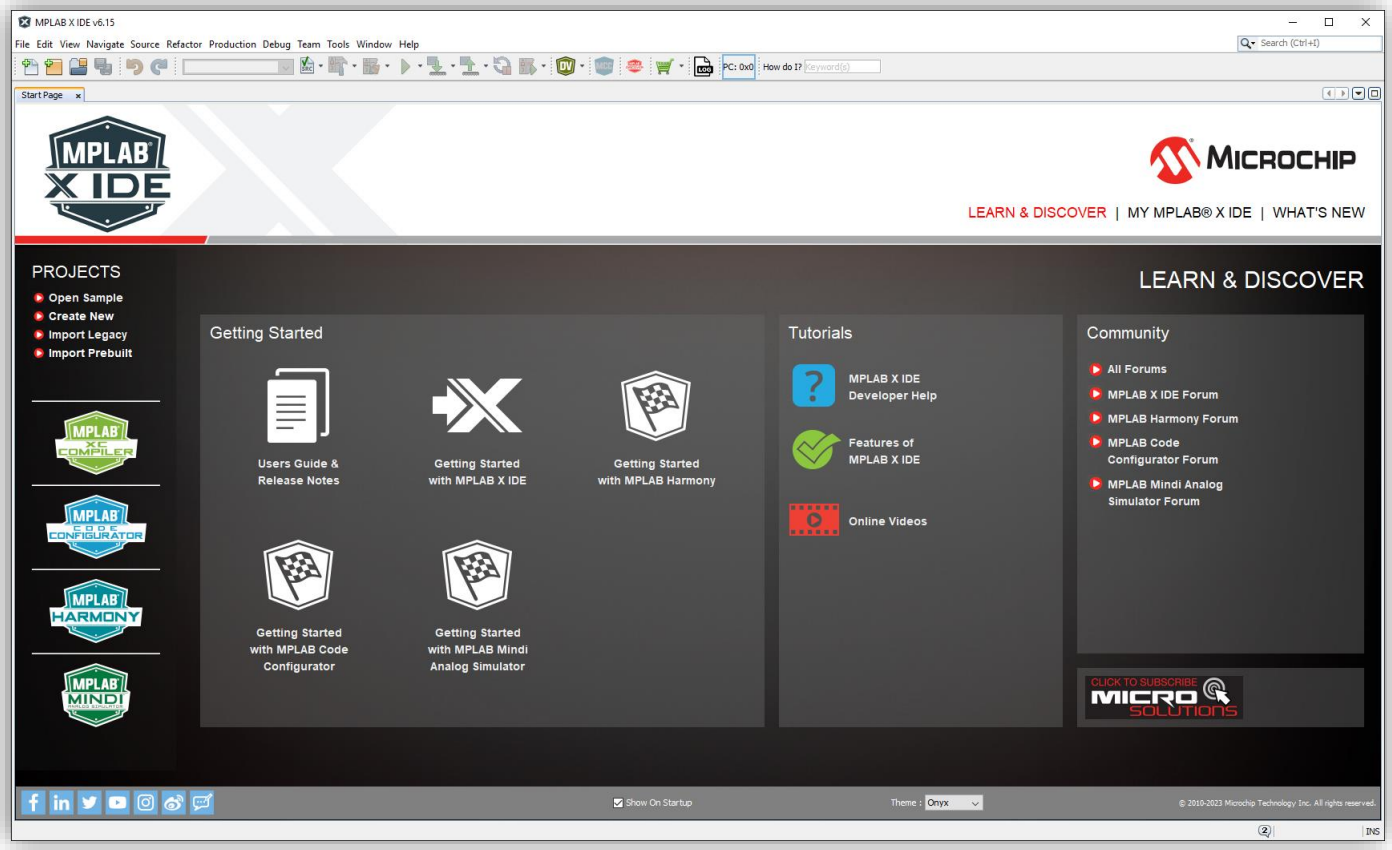
All in One Development Tools

MPLAB® X IDE

- **New generation integrated Development Tools, Support PIC, dsPIC, AVR, CEC and SAM Series MCU/MPU, Provide Plug-in function to extend more advance function. Java Based, Cross platform, Current version is v6.15.**



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C Compiler for 16-bits PIC/dsPIC® MCU

MPLAB® XC Compilers

- **XC16 is new generation C compiler, it's supported all 16-bits PIC/dsPIC® MCU (PIC24F/PIC24H/PIC24E, dsPIC).**
- **Base on GNU C, apply GPL License (GNU General Public License).**
- **Provide standard C libraries (printf, strlen, etc..) and Peripheral Libraries (old versions).**
- **All version you can download from Microchip website. It's provided free version.**

License Type	Installs On	# of Activations	# of Users	Wait Time Between Users	HPA
Workstation License	Workstation	3	1	None	Yes
Subscription License	Workstation	1	1	None	No
Site License	Network	1	Varies by Seat	None	Yes
Network Server License	Network	1	Unlimited	One Hour	Yes
Virtual Machine *	Network	1	N/A	N/A	No
Dongle License	Dongle	N/A	Unlimited	None	No

**This license must be used in addition to a network server or site license to enable the license to work in a virtual machine environment.*

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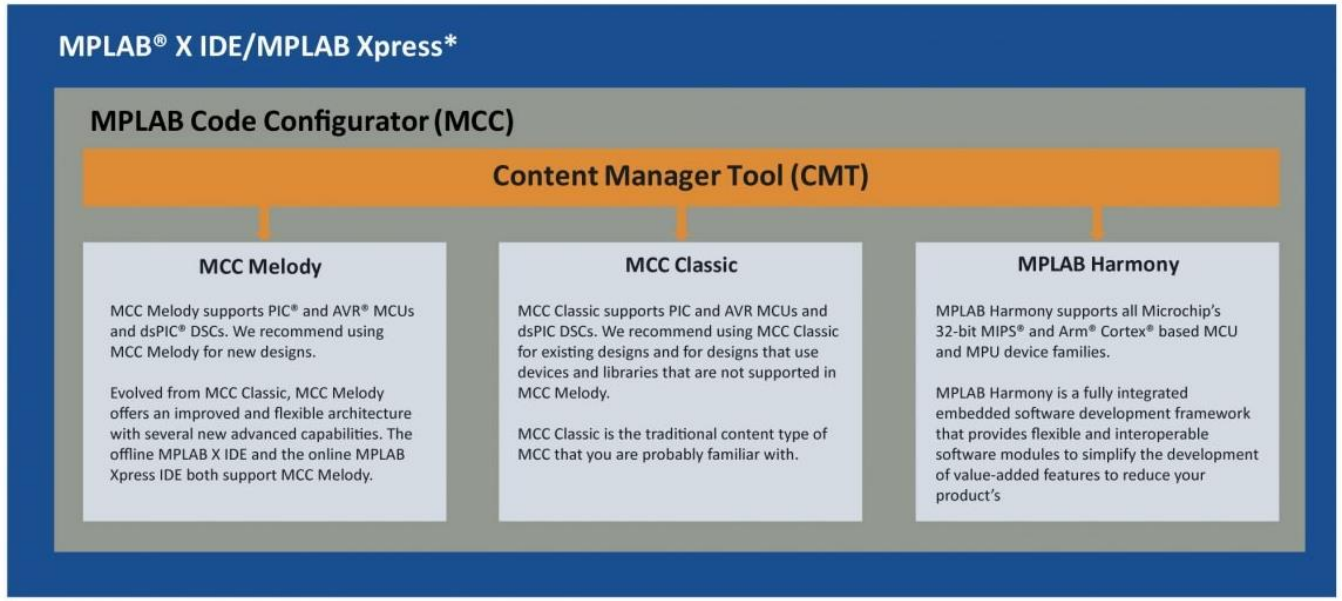
MPLAB® Code Configurator

- MCC is a free, graphical programming environment that generates seamless, easy-to-understand C code to be inserted into your project.
- Supports 8-bits, 16-bits and limited 32-bits PIC® microcontrollers.
- MCC consists of three content types: MCC Melody, MCC Classic and MPLAB Harmony. It offers application libraries and system and peripheral drivers for the development of embedded software.



MPLAB® CODE CONFIGURATOR

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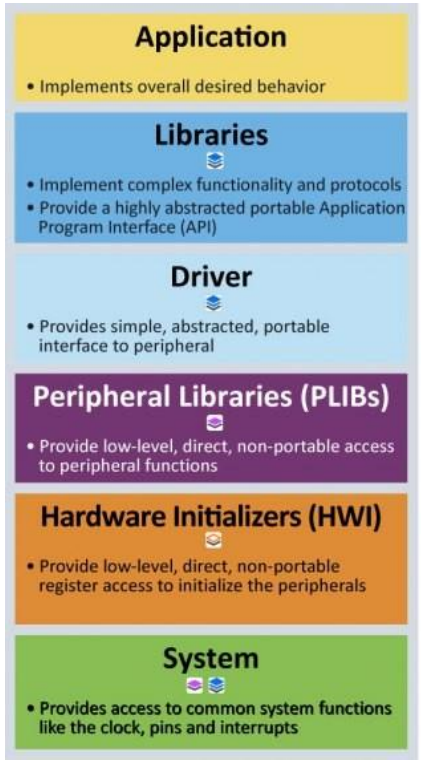
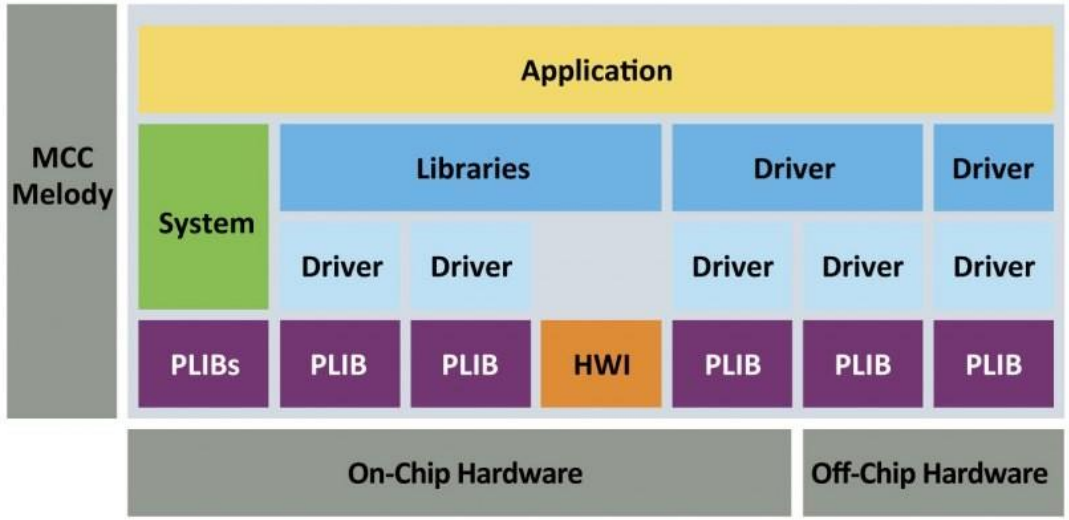
MPLAB® Code Configurator Melody

- Evolved from MCC Classic, MCC Melody offers an improved and flexible architecture to easily configure devices, peripherals and libraries and generate code.
- MCC Melody provides libraries, drivers, Peripheral Libraries (PLIBs) and Hardware Initializers (HWIs) for the development of embedded software for our PIC® and AVR® MCUs and dsPIC® Digital Signal Controllers (DSCs).





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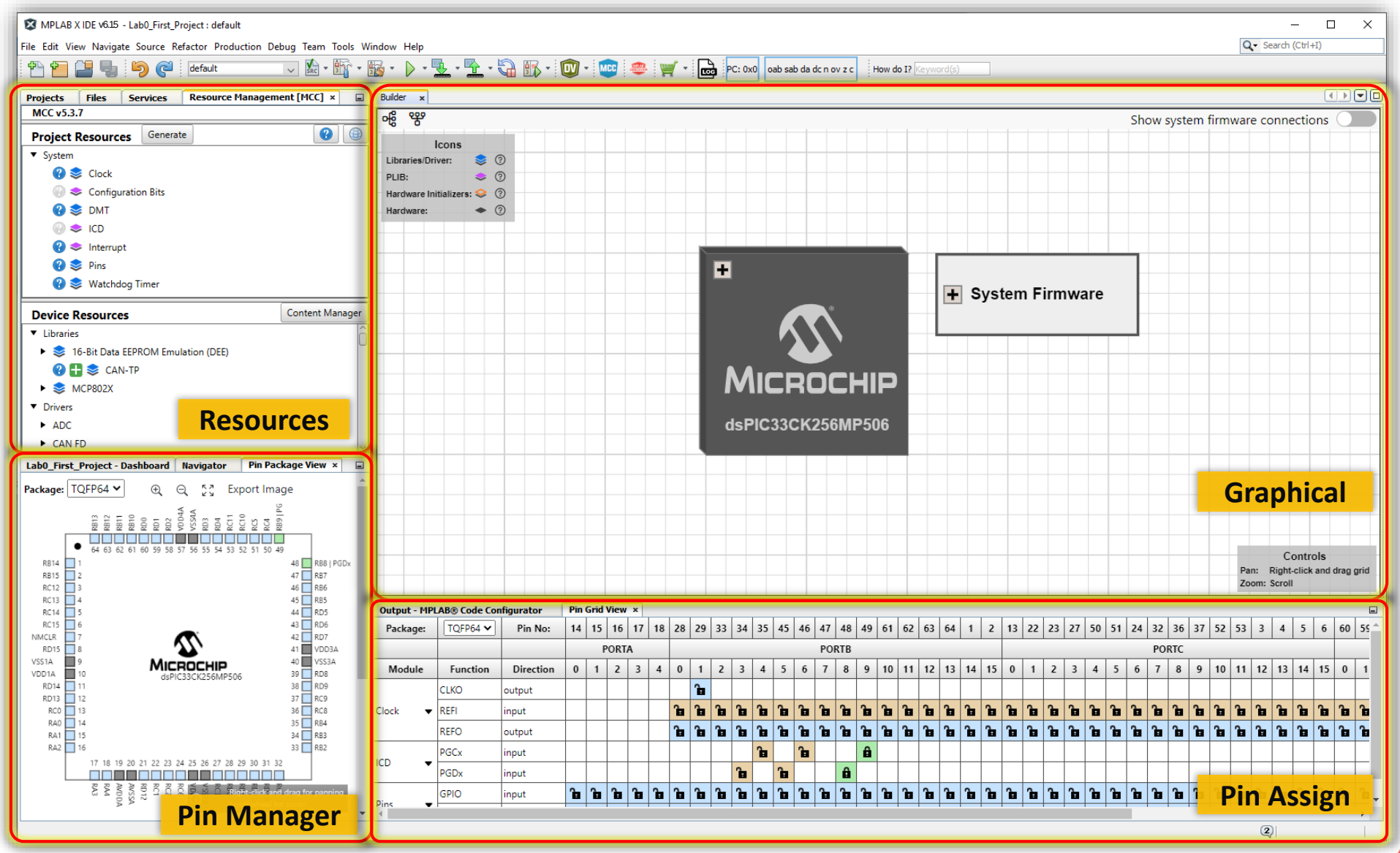
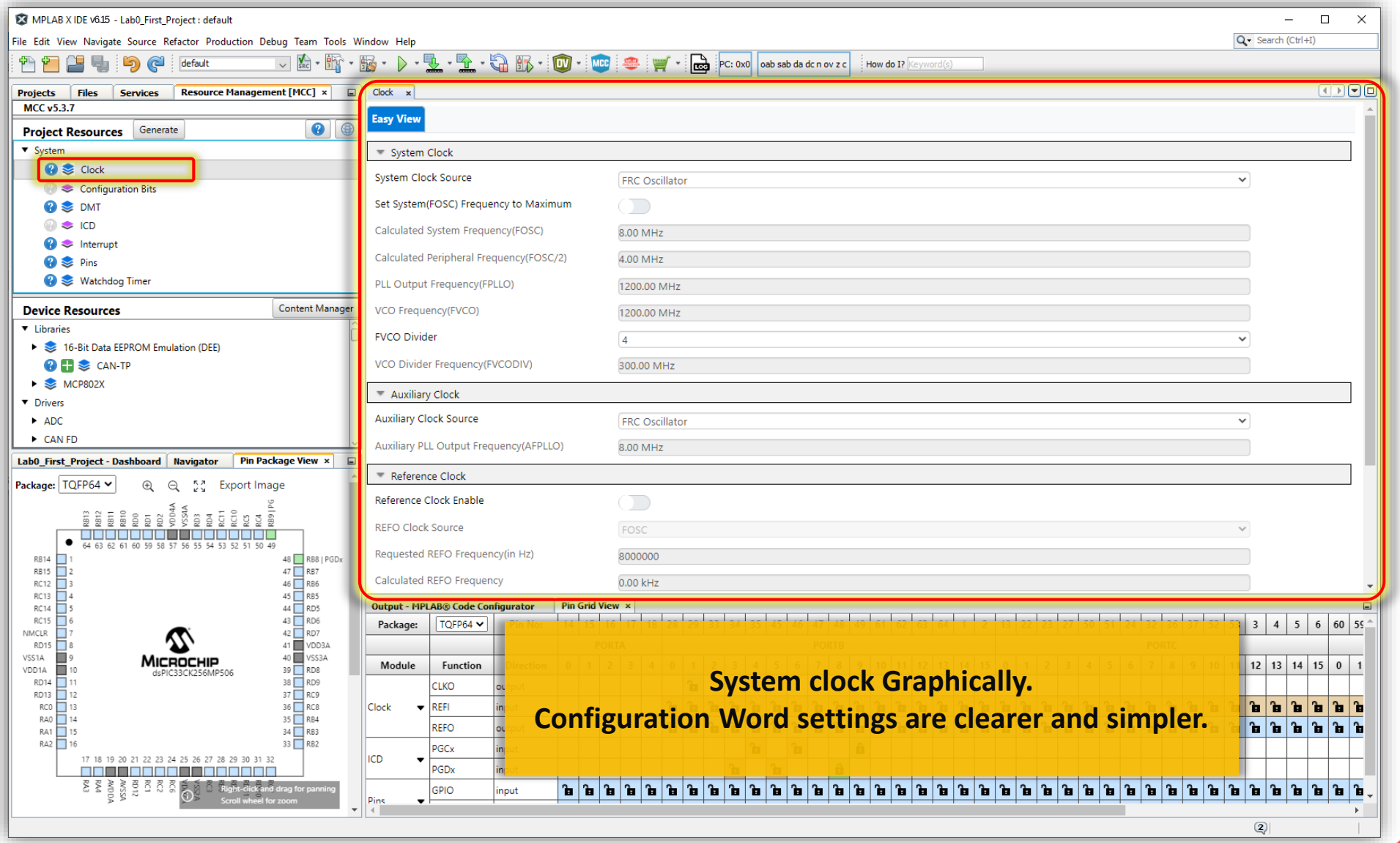
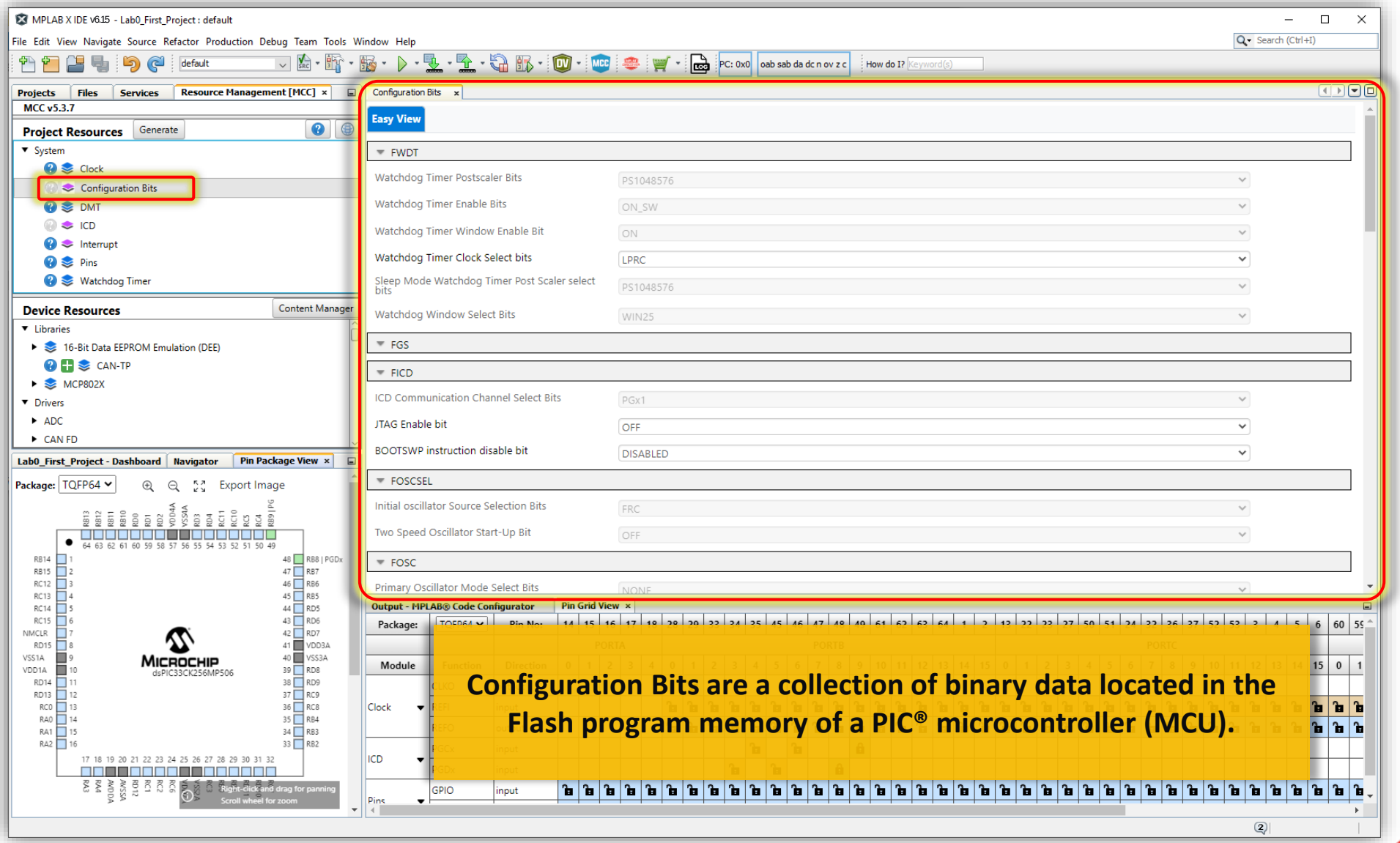
MCC Melody GUI Quick View



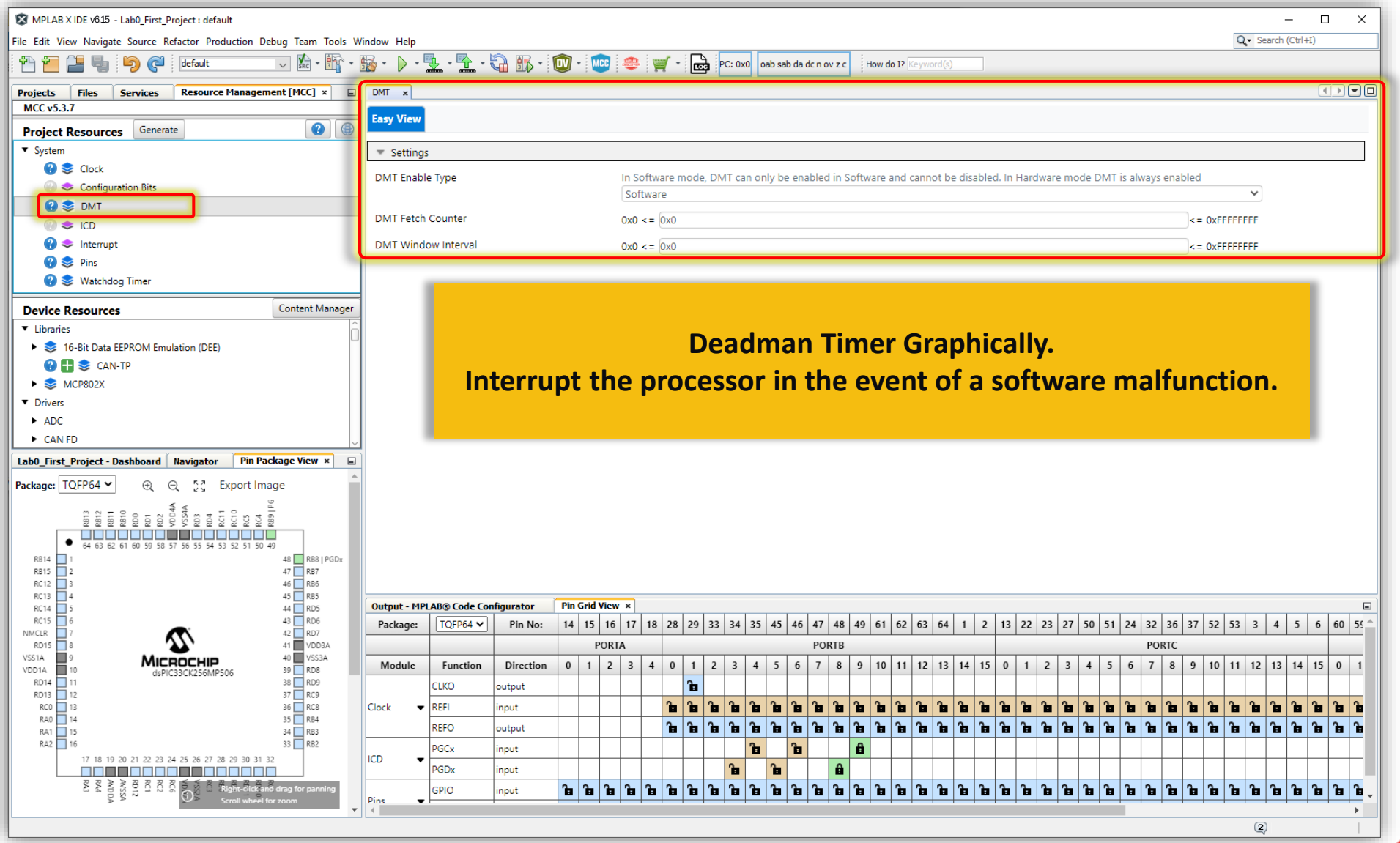
MCC Melody GUI Quick View



MCC Melody GUI Quick View



MCC Melody GUI Quick View



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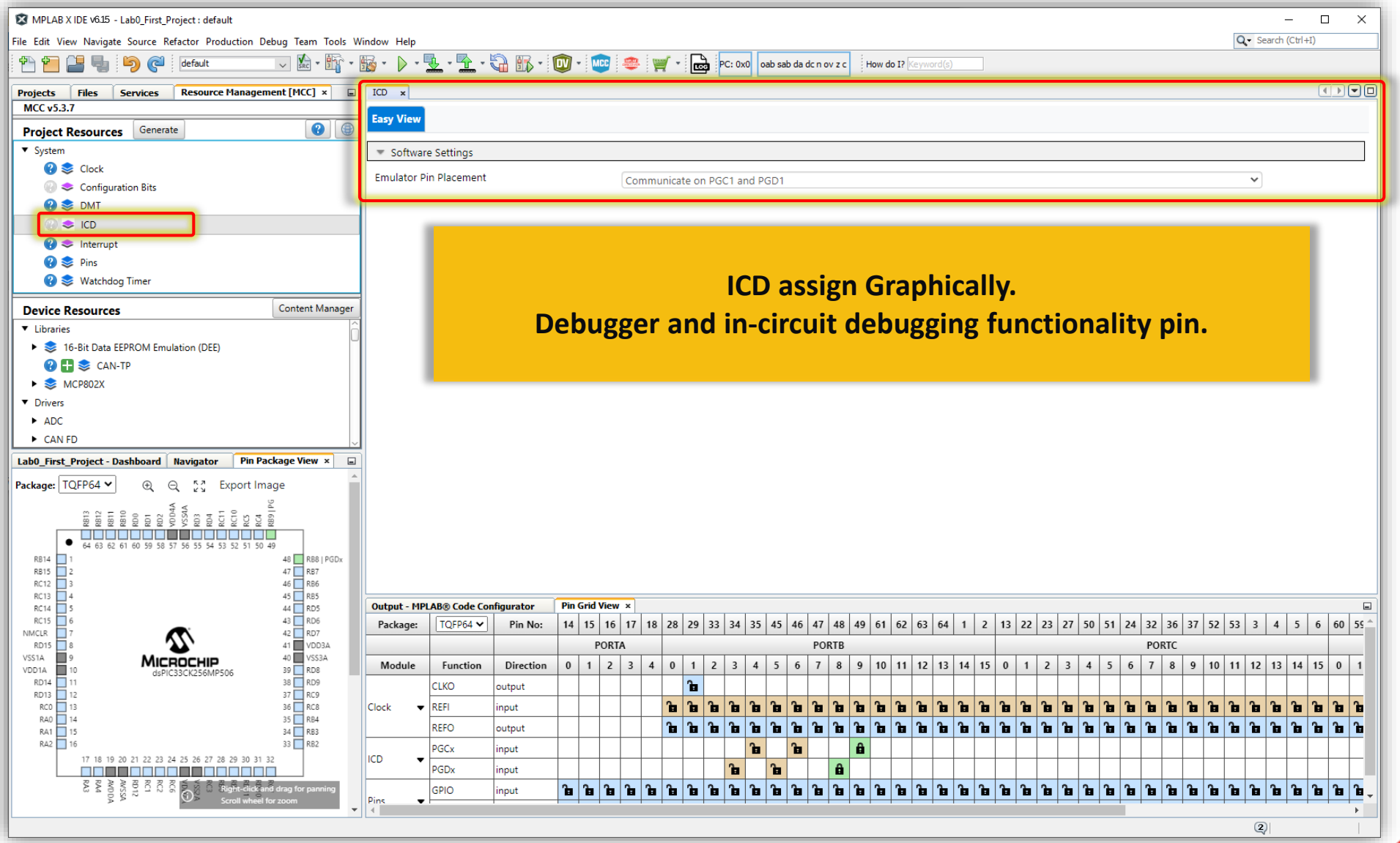
MCC Melody GUI Quick View



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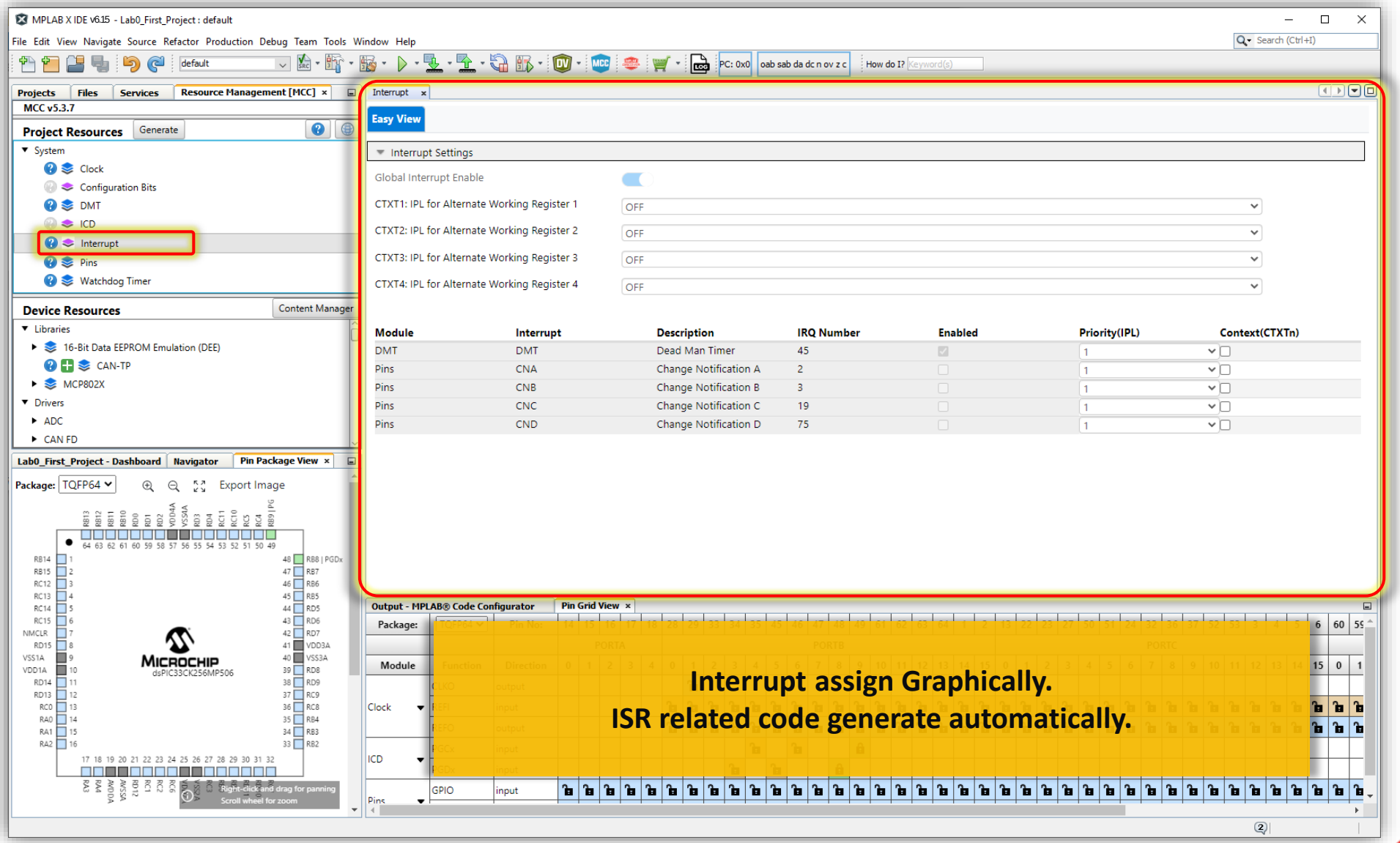
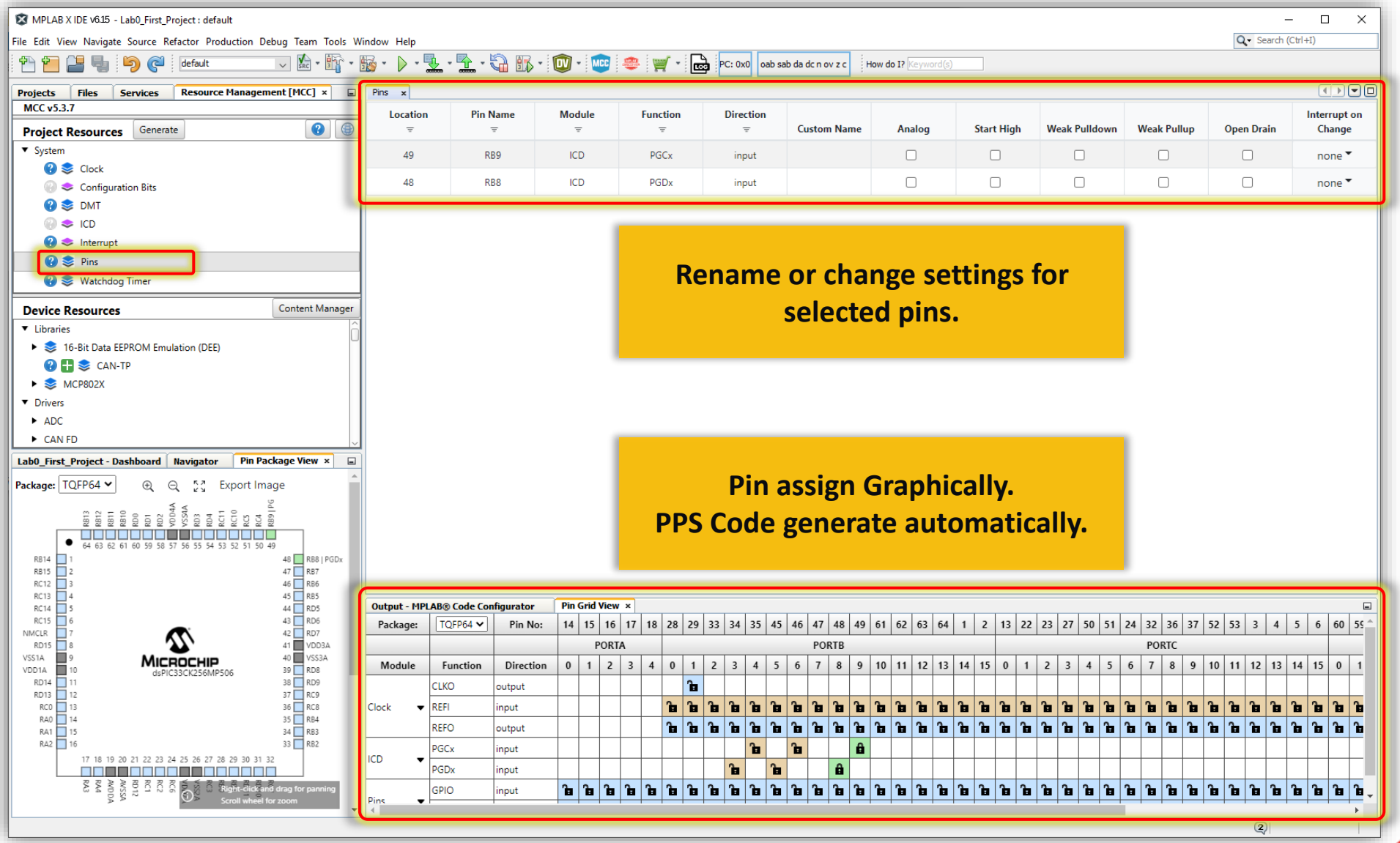
MCC Melody GUI Quick View



MCC Melody GUI Quick View



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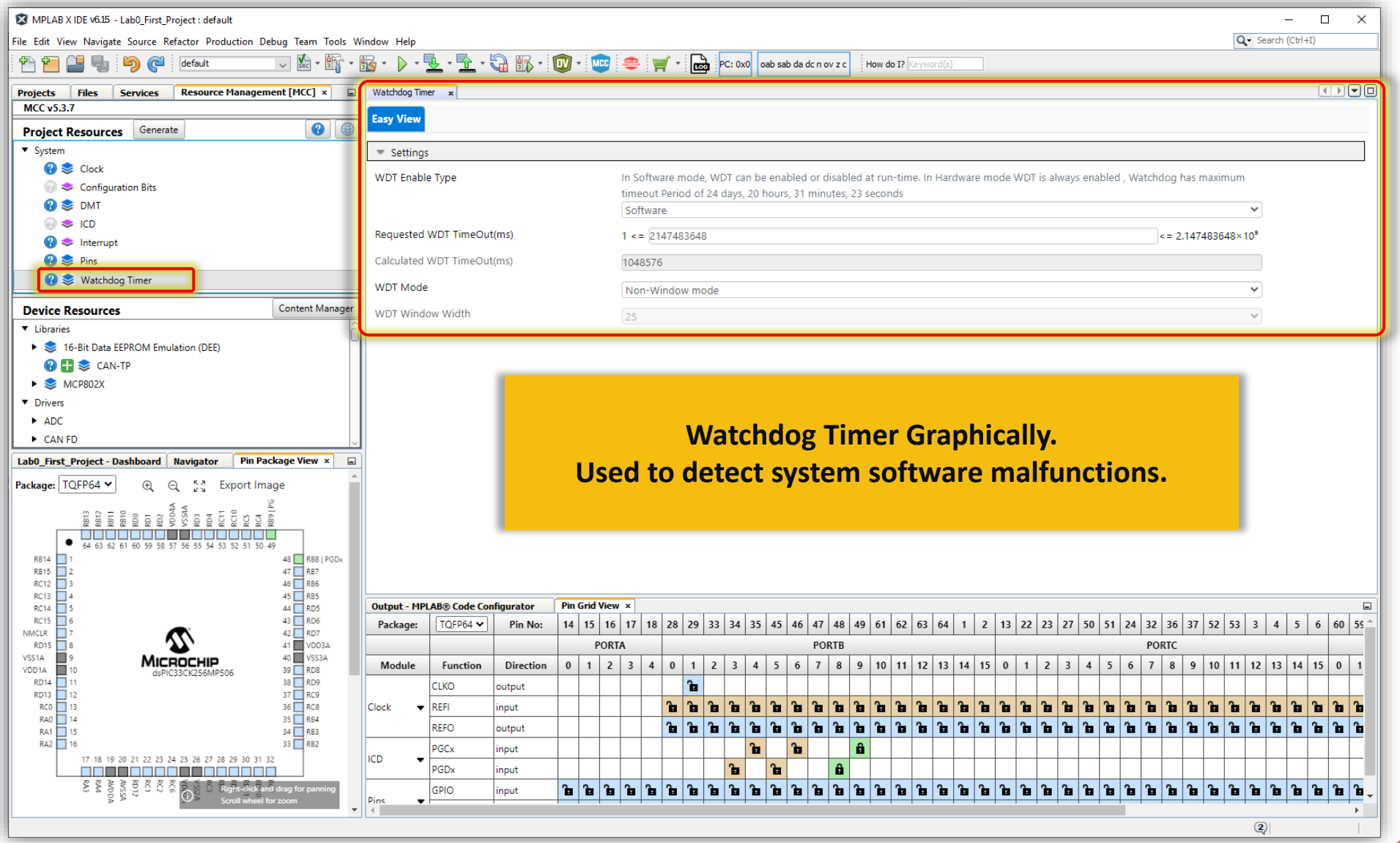
MCC Melody GUI Quick View



MCC Melody GUI Quick View

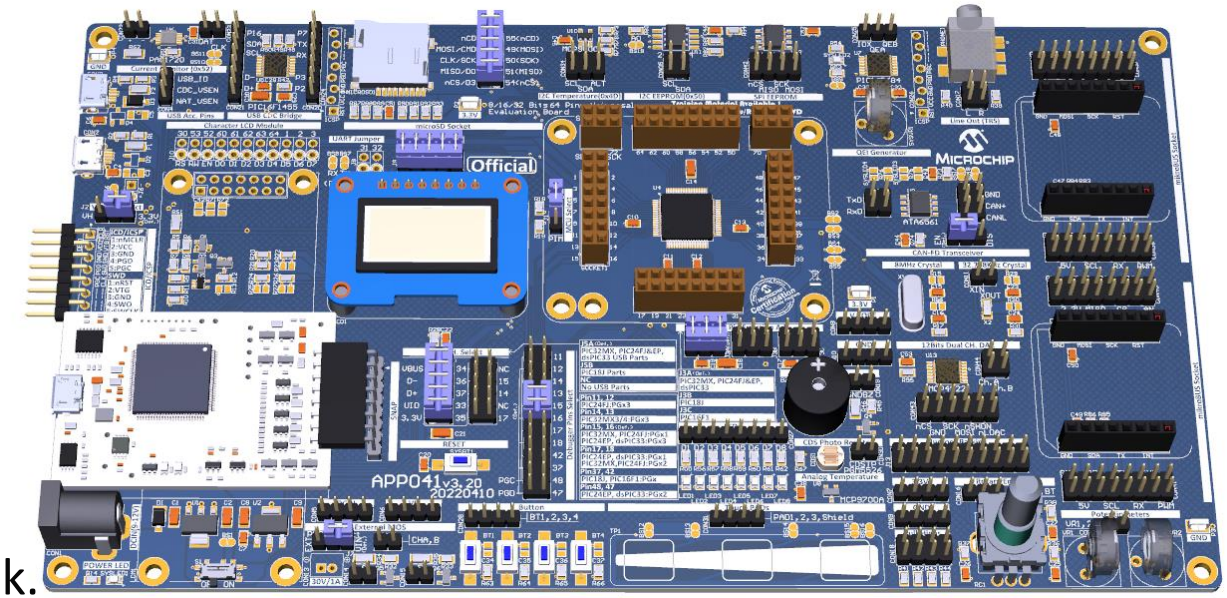
More ?

www.microchip.com/mcc

APP041 8, 16, 32-bits
General Purpose EVM Introduction

8, 16, 32-bits General Purpose EVM

- **APP041 v3.20 is general purpose EVM, it's support 8, 16, and 32-bits 64-pins microcontroller. Built-in PIC24FJ128GB106-I/PT microcontroller at factory.**
  - **Built-in SNAP Debugger/Programmer.**
  - **PIM for easy device swapping.**
  - **Multiply power supply available,**
    - Serial USB Port
    - Native USB Port
    - DC Jack (DC 9 ~ 12V)
  - **Built-on rich components,**
    - LEDs, Buttons, Potentiometer.
    - Temperature and Light Sensor, Buzzer, Phone Jack.
    - Graphic OLED Module, Character LCD Module(Optional).
    - I2C & SPI EEPROM, DAC, ENCODE, QEI, CAN-FD Transceiver.
    - MicroSD Socket, Touch PADs, USB Serial Emulator, MikroBUS Socket.



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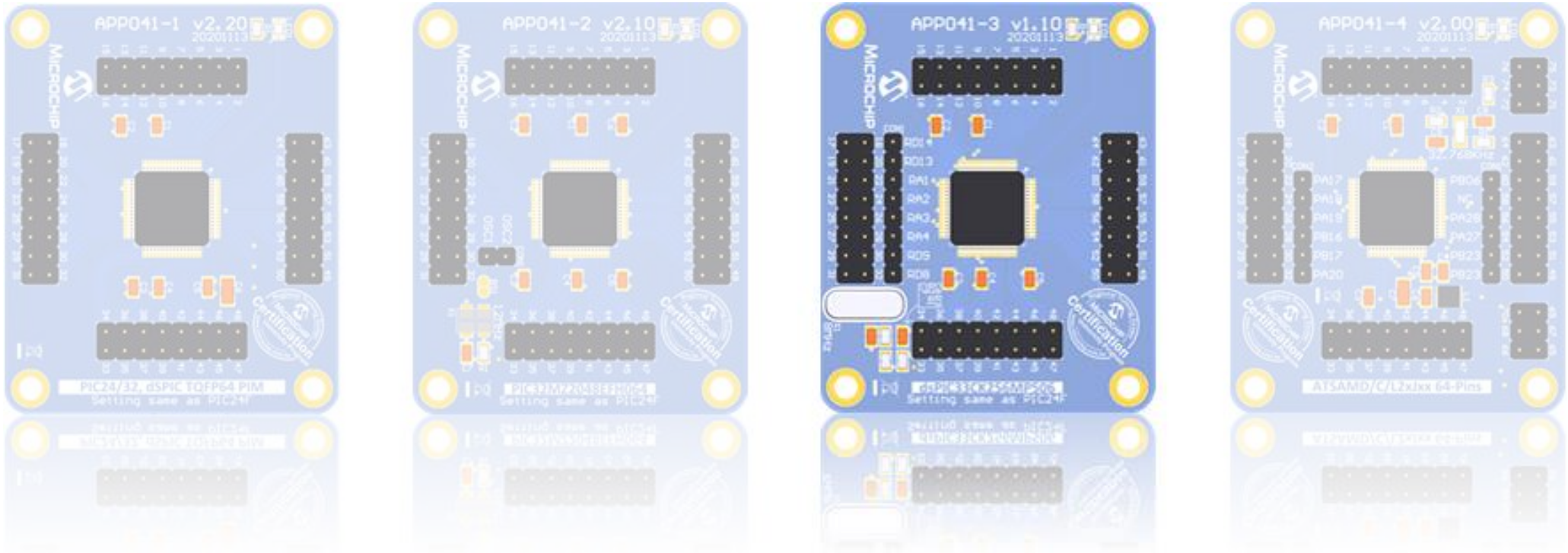
PIM, Plug-In Module

- Rich PIMs to support different microcontroller.
- It’s included PIC18, PIC24, dsPIC33, PIC32, SAMD21, SAMD51, SAML and SAMC series.

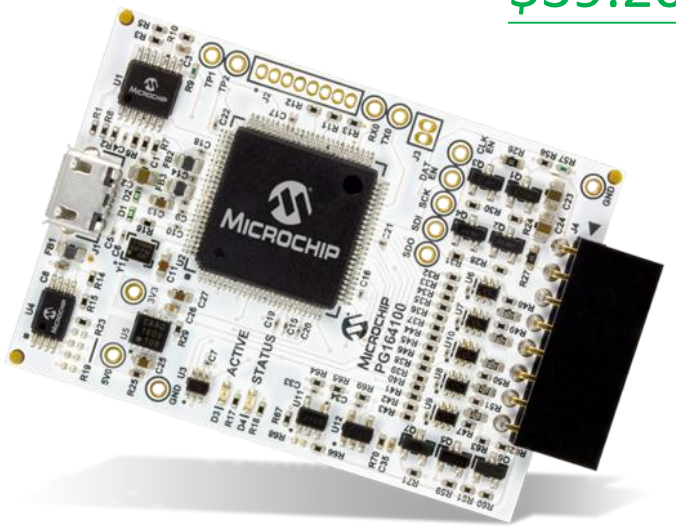


Programmer/Debugger

MPLAB® SNAP (Part No. PG164100)

- **The MPLAB® SNAP In-Circuit Debugger/Programmer allows fast and easy debugging and programming of most PIC®, dsPIC®, AVR, SAM and CEC flash microcontrollers.**
- **Features**
  - Affordable performance
  - Matches silicon clocking speed
  - Target voltage of 1.20V to 5.5V
  - Portable USB-powered
  - CE and RoHS-compliant
  - 8-pin single in-line header
  - Backward compatible for demo boards, headers and target systems using 2-wire JTAG and ICSP

$39.20



MICROCHIP

Programmer/Debugger

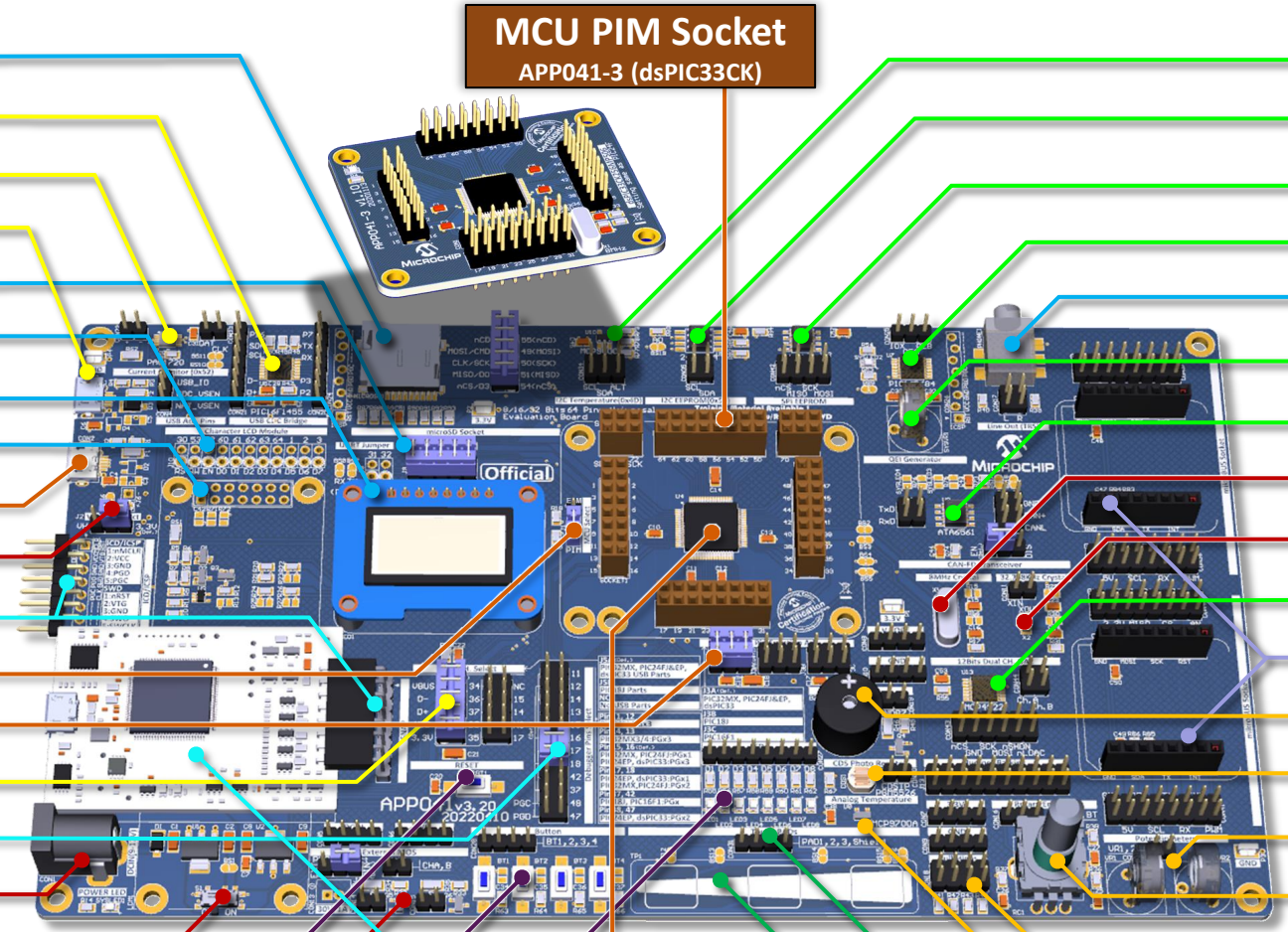
MPLAB® PICkit 5 (Part No. PG164150)

- **The MPLAB® PICkit™ 5 In-Circuit Debugger/Programmer allows fast and easy debugging and programming of all PIC®, dsPIC®, AVR, SAM and CEC flash microcontrollers.**
- **Features**
  - Improved Programmer-to-Go (PTG) support.
    - Connect wirelessly from your smartphone via Bluetooth®
    - Select from multiple saved program images on the SD Card
    - Start programming from the app or by pressing on the logo
  - Supply 150 mA to the target.
  - Option to be self-powered from the target (2.7V to 5V).
  - USB Type-C® connector and cable.
  - No external power needed when the device is powered.
  - Use the 8-pin single in-line header.

$94.99

MICROCHIP

Components



- Micro SD Card Socket
- PIC16F1455 (UART to USB CDC)
- PAC1720 (Current monitor)
- USB Virtual COM
- OLED Pin Select
- Character LCM Pin Select
- OLED (128x64)
- Character LCM (2x16)
- Native USB
- Main Voltage Select
- SWD / ICD / ICSP
- MCU Select
- MCU Pin Function
- USB Pin Select
- Debug Pin Select
- DC Jack (9~12V)
- Power Switch
- MCP1826S (Ext. MOSFET)
- Reset Button
- User Buttons
- LEDs

- MCP9800A5 (Temp Sens-I2C)
- 24AA025E64 (EEPROM-I2C)
- 25LC256 (EEPROM-SPI)
- PIC16F684 (QEI Generator)
- Phone Jack
- QEI-CW/CCW
- ATA6560 (CAN-FD Transceiver)
- 32KHz Crystal
- 8MHz Crystal
- MCP4922 (DAC-SPI)
- mikroBUS Shield
- Buzzer
- CDS Light Sensor
- Potentiometer
- Rotary Encoder
- Pull High Resister
- MCP9700A
- Driven Shield
- Capacitive Touch
  Slider & Button

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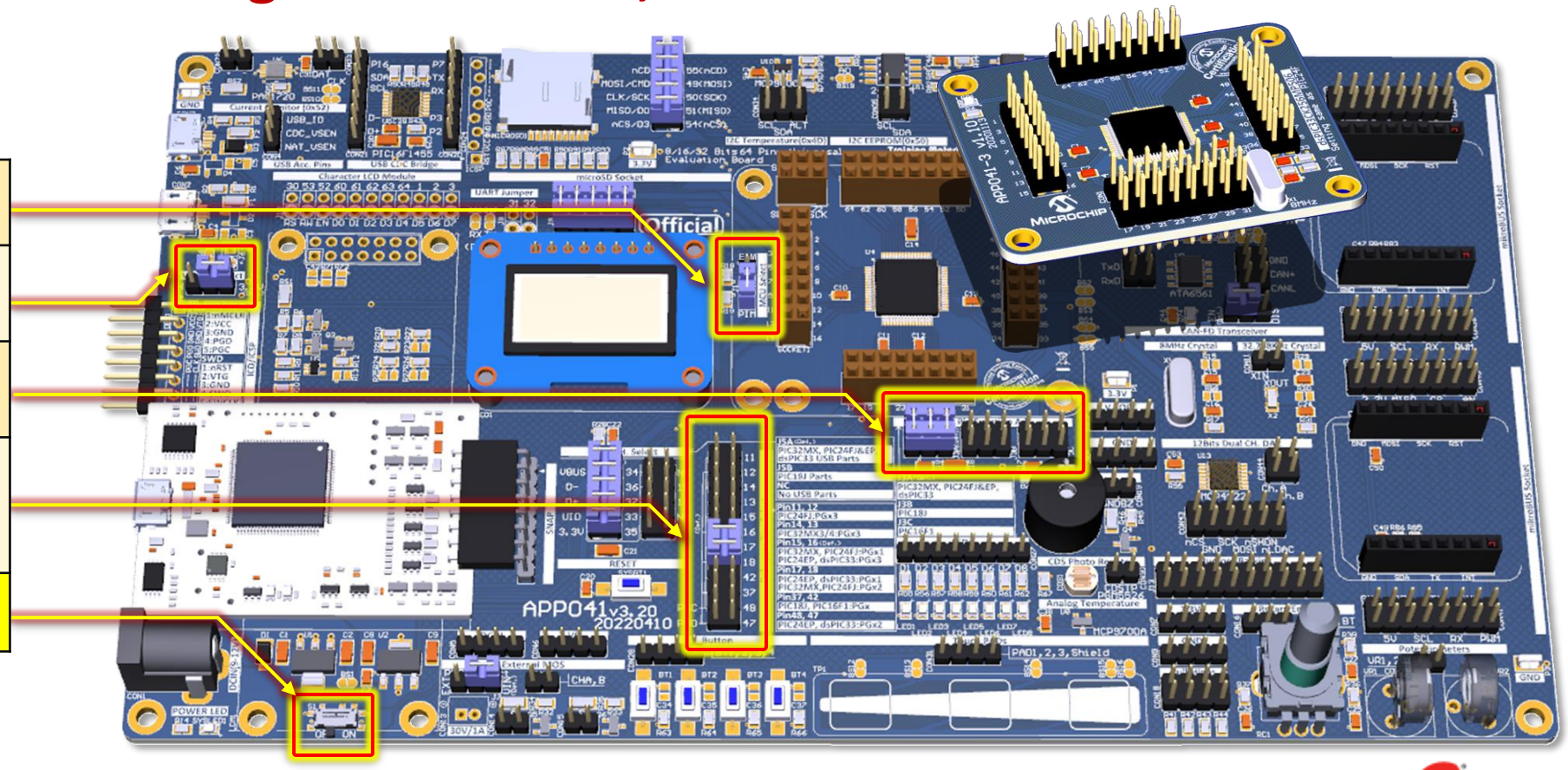
Caution !

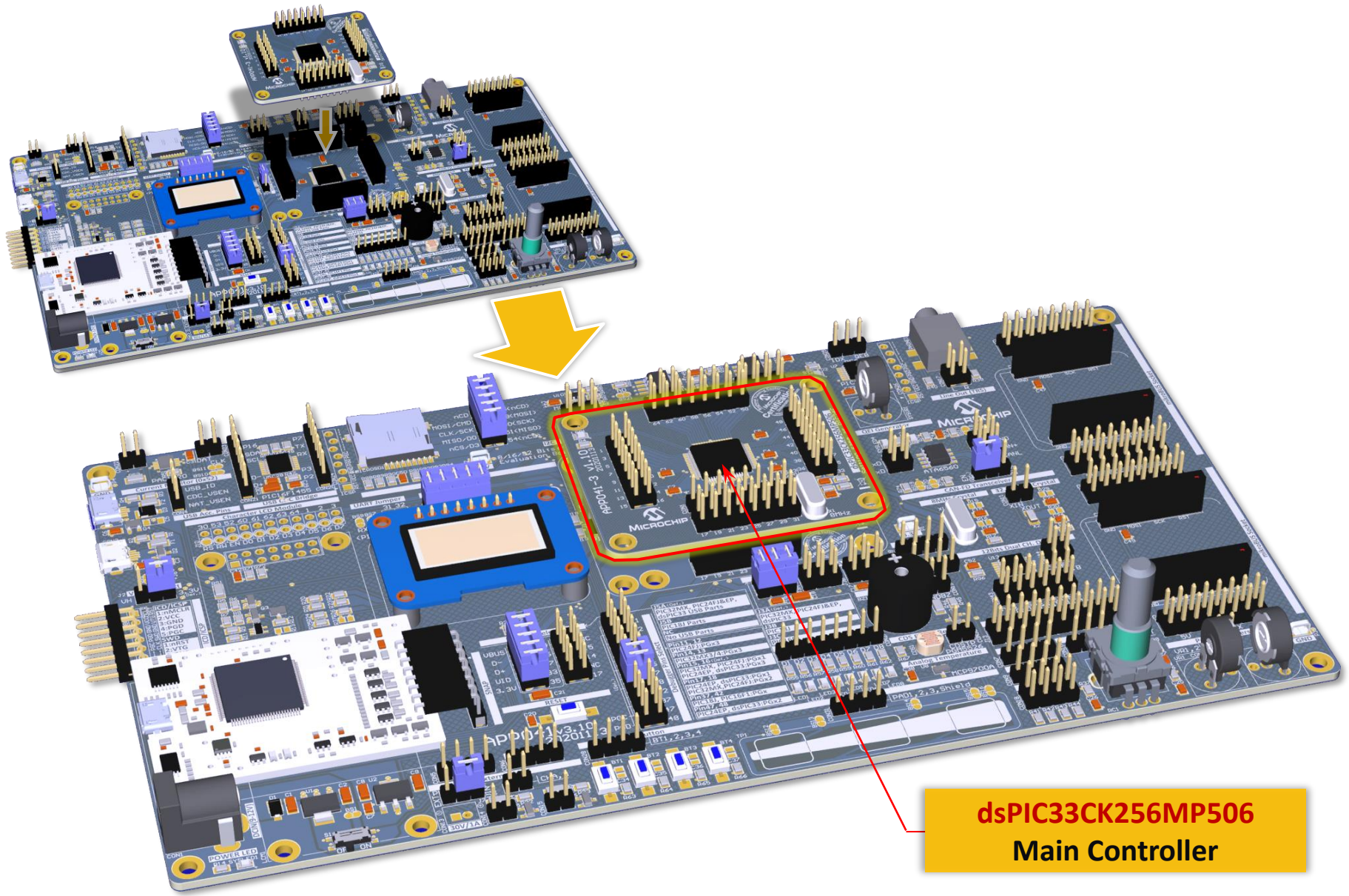
- You must check all jumpers position before power on. Wrong setting will damage silicon and your power source.
- Please confirm all setting shows below, It's for dsPIC33CK256MP506.

J1	PIM
J2	3.3V
J3	J3A
J4	Pin17, 18 (PGx2)
S1	ON



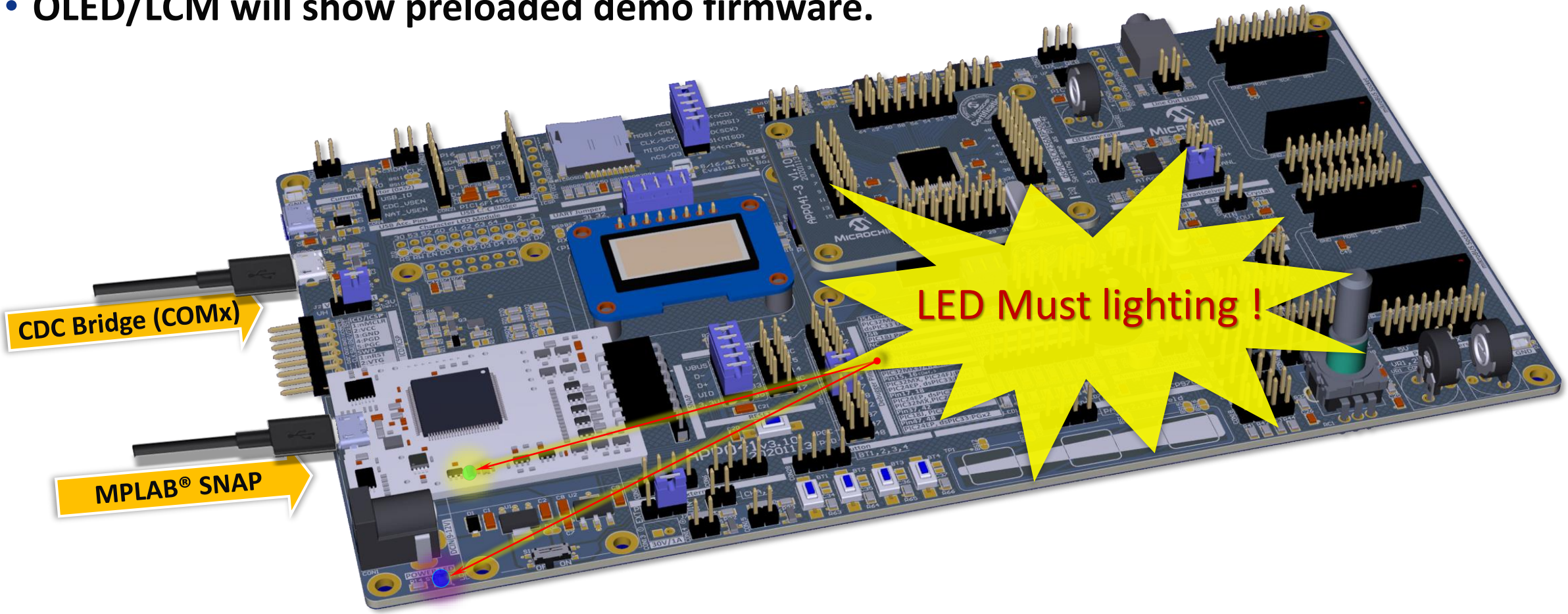
MICROCHIP

Plug-In Module Assembly



Power On & Getting started

- Just plug-in micro-USB cable to COMx and MPLAB® SNAP then confirm power LED (SYSLED1) and ACTIVE LED on MPLAB® SNAP are light or not.
- OLED/LCM will show preloaded demo firmware.

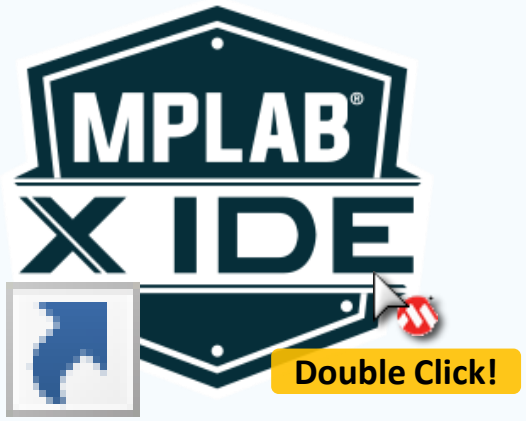


Lab Preparation

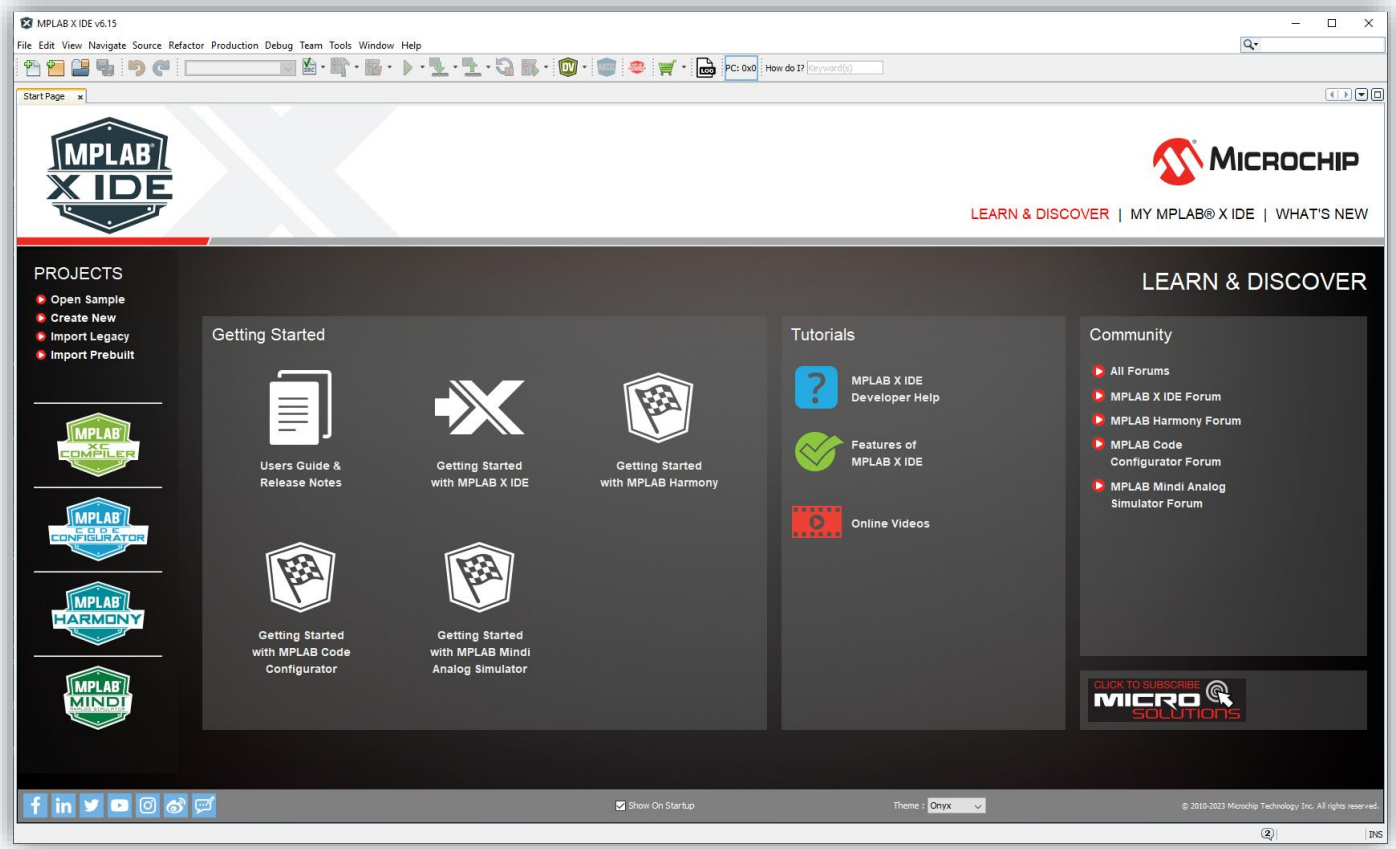
Check Compiler & MCC version

Development Tools Check

- Open **MPLAB X IDE v6.15** firstly.



MPLAB X IDE
v6.15



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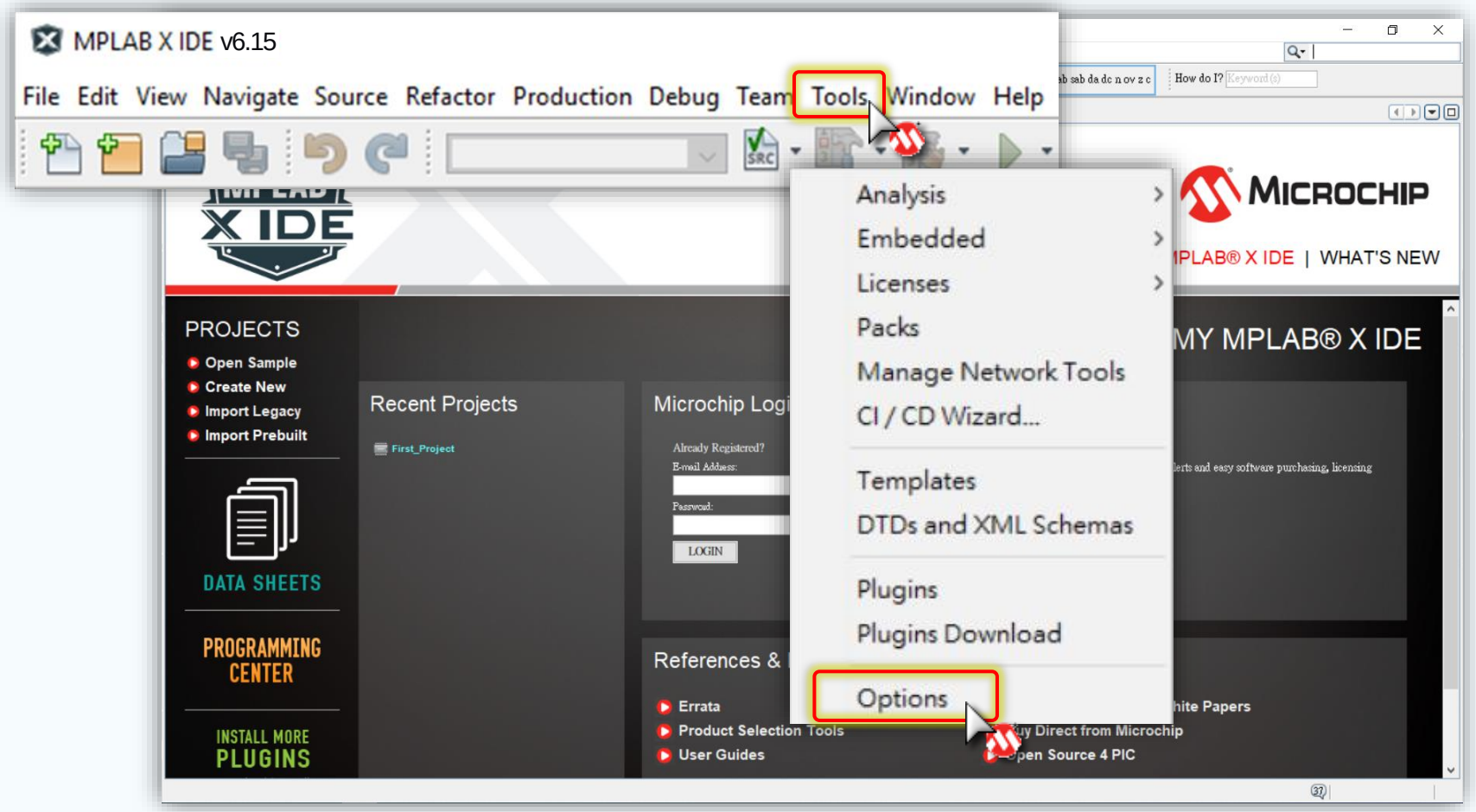
Development Tools Check

Check Compiler Version

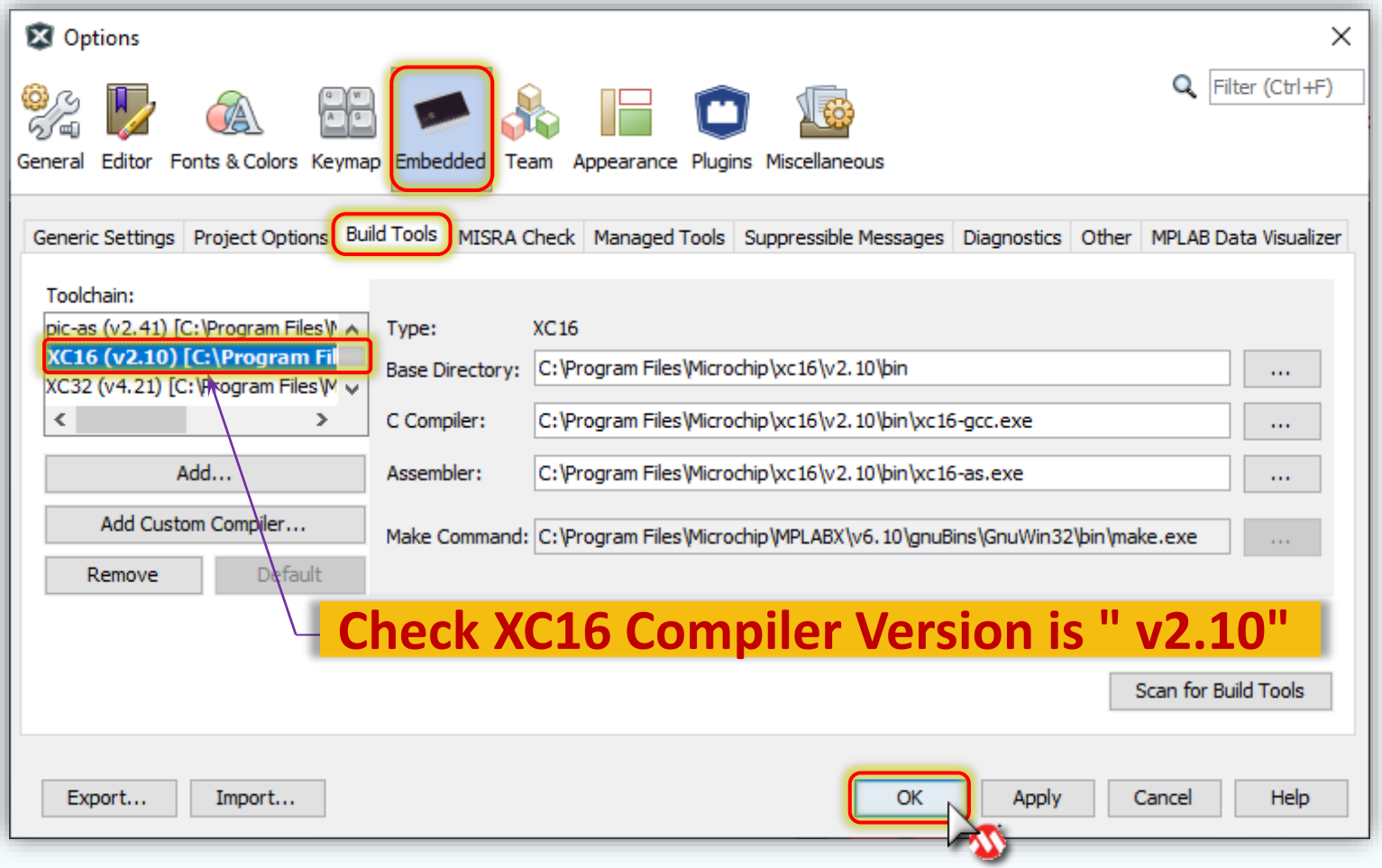
- **Select : Tools > Options**



Development Tools Check

Check Compiler Version

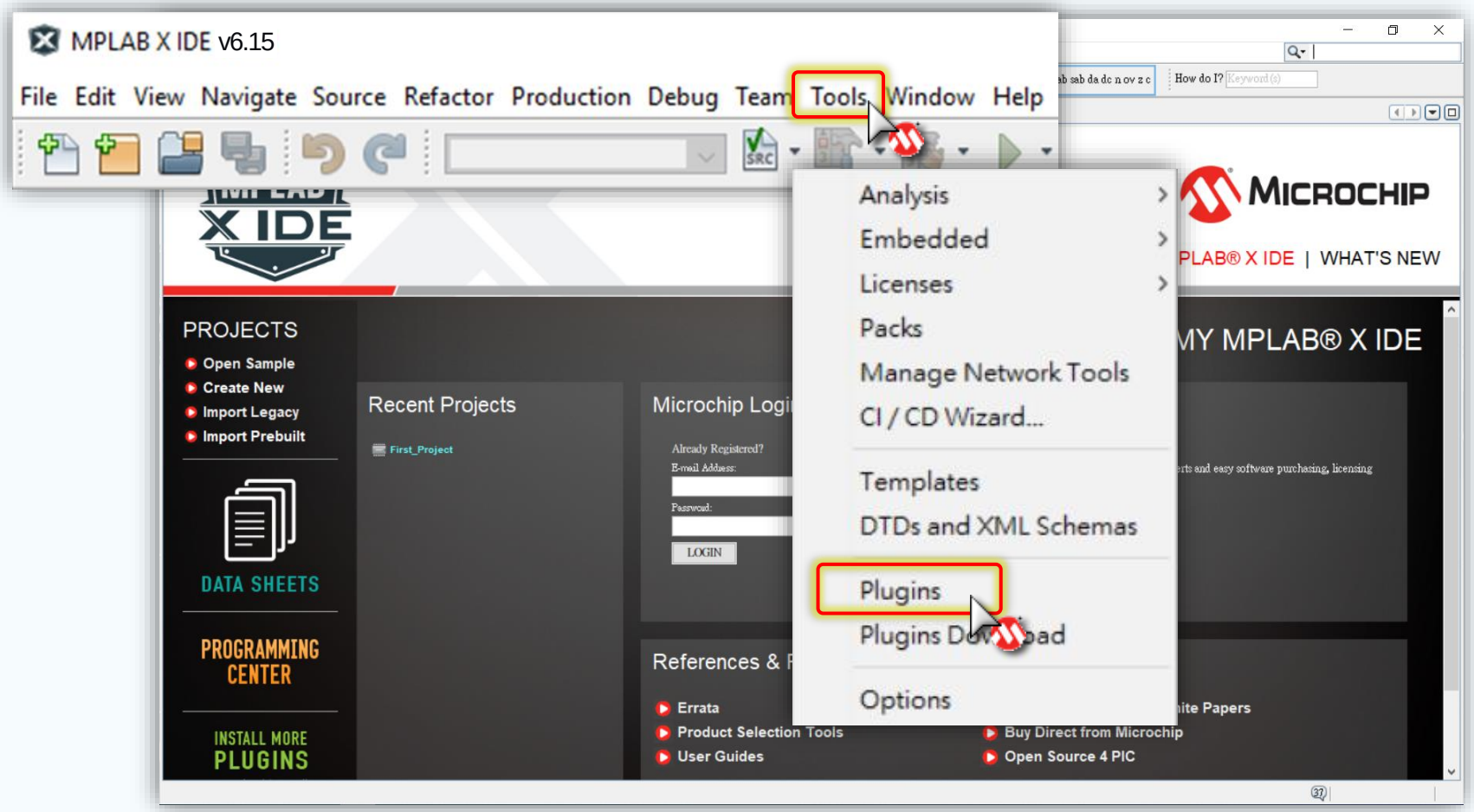
- **Select : Embedded > Build Tools**



Development Tools Check

Check MCC Version

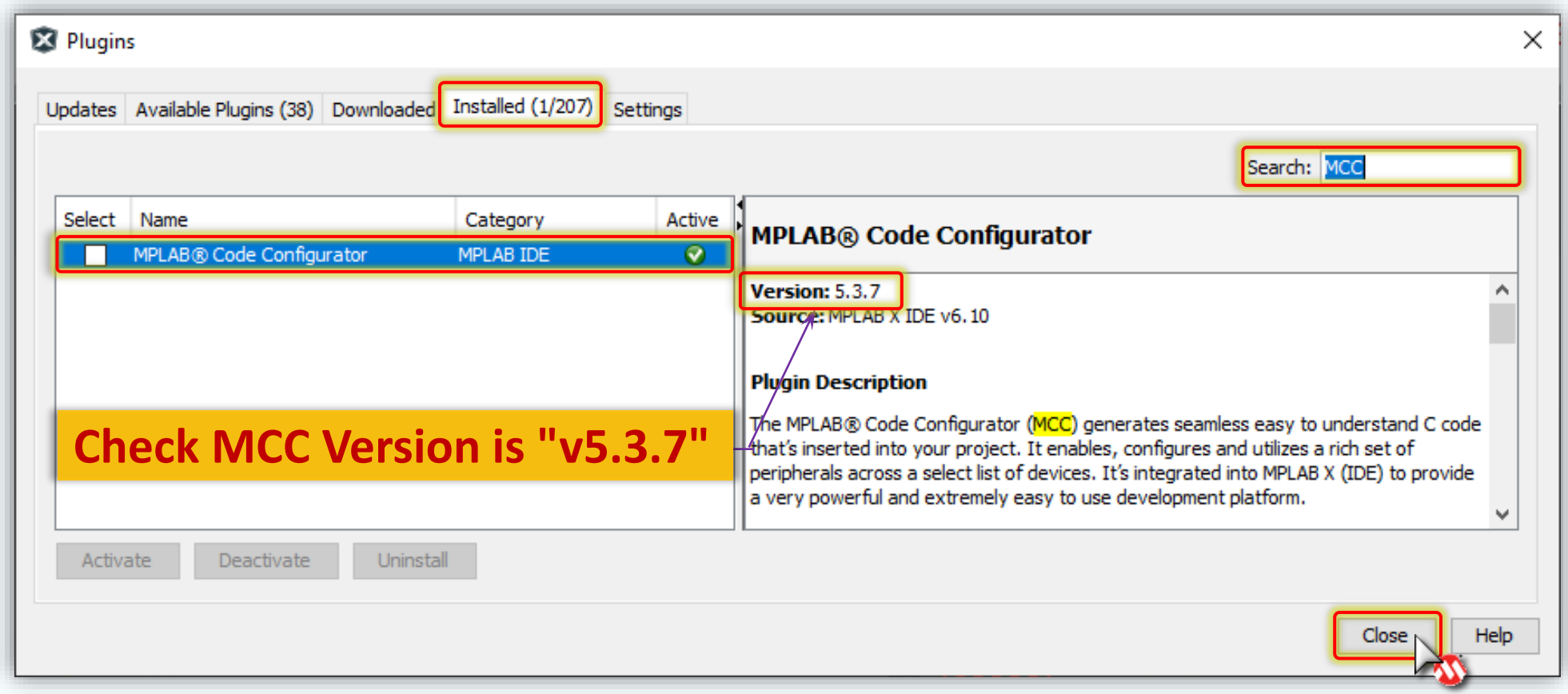
- **Select : Tools > Plugins**



Development Tools Check

Check MCC Version

- **Select : Installed**
  - **Search : "MCC"**



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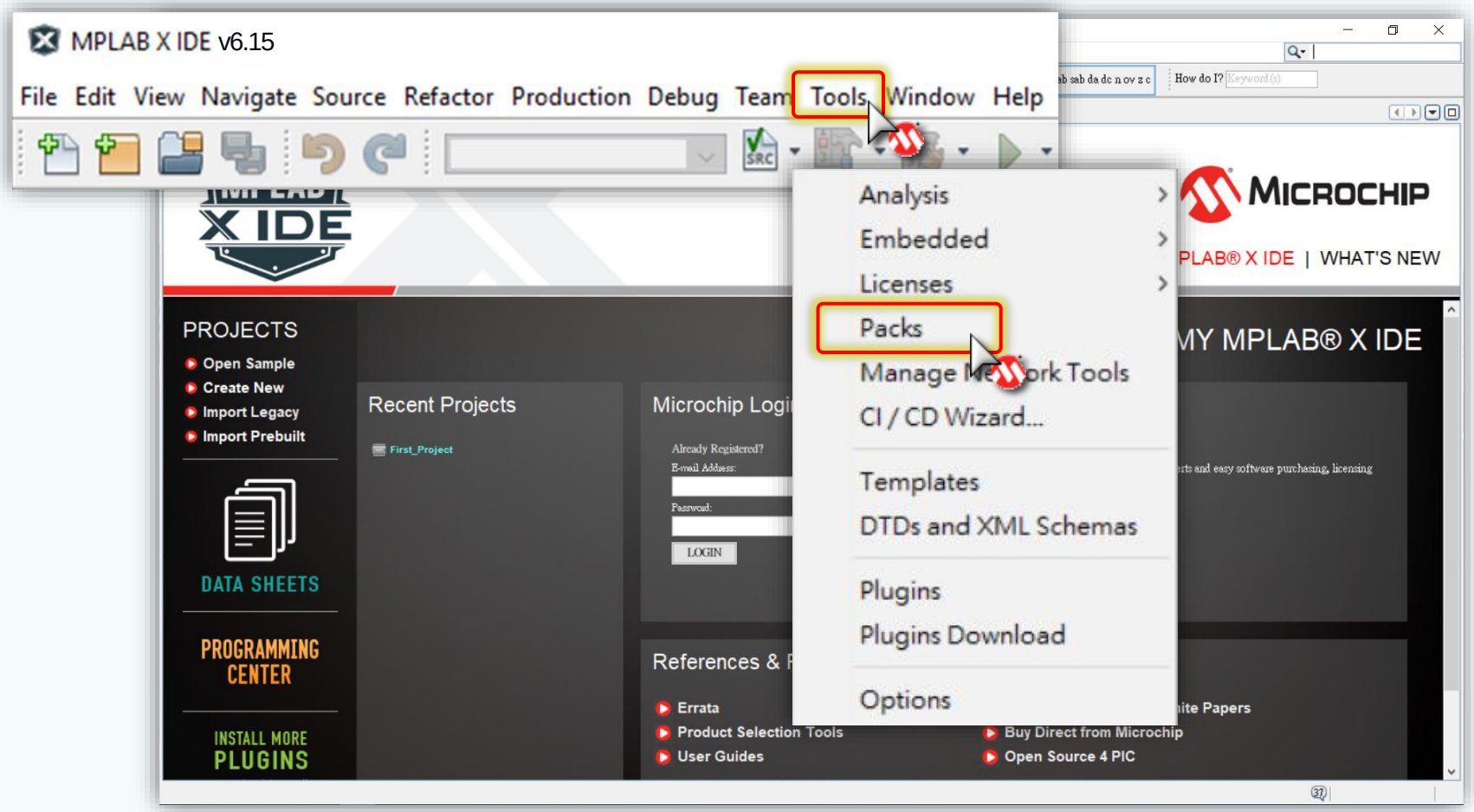
Development Tools Check

Check Packs Version

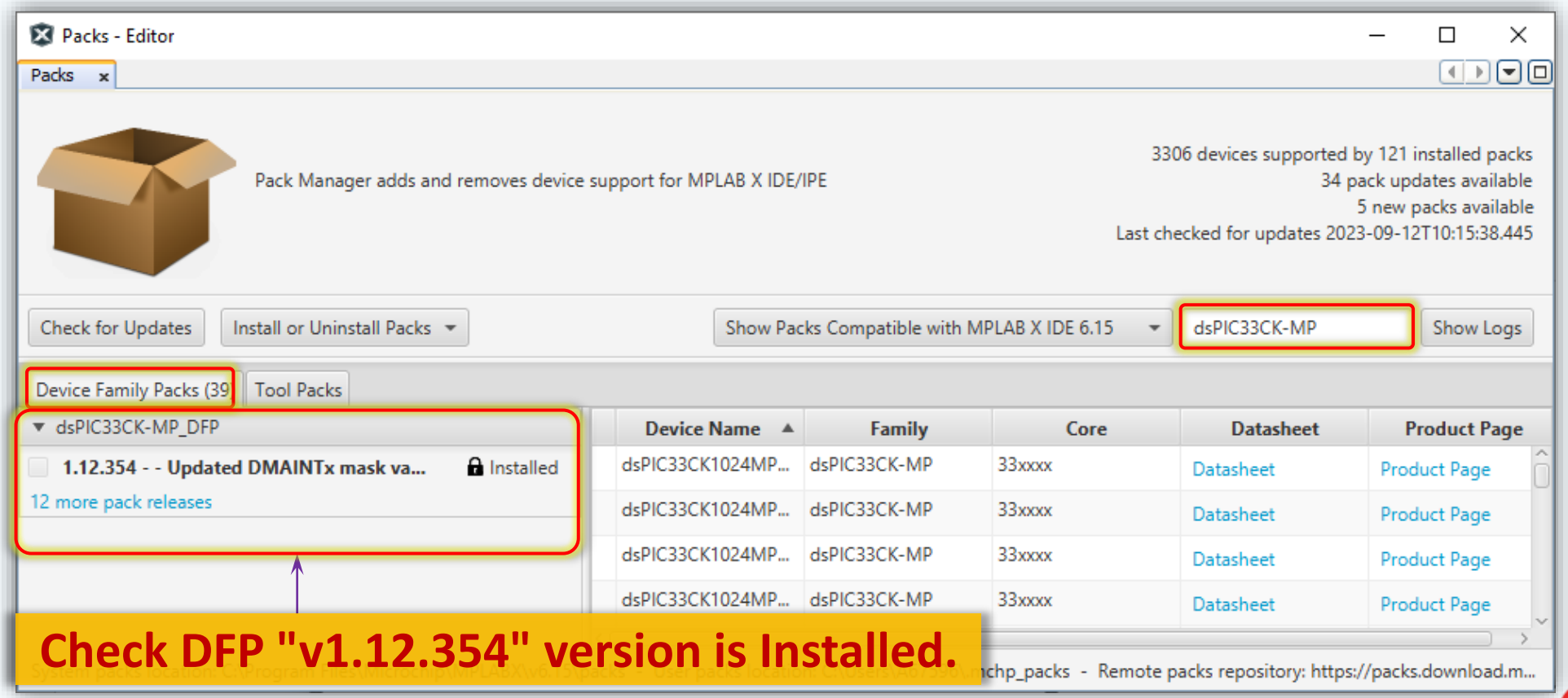
- **Select : Tools > Plugins**



Development Tools Check

Check Packs Version

- **Select : Device Family Packs**
  - **Search : " dsPIC33CK-MP"**

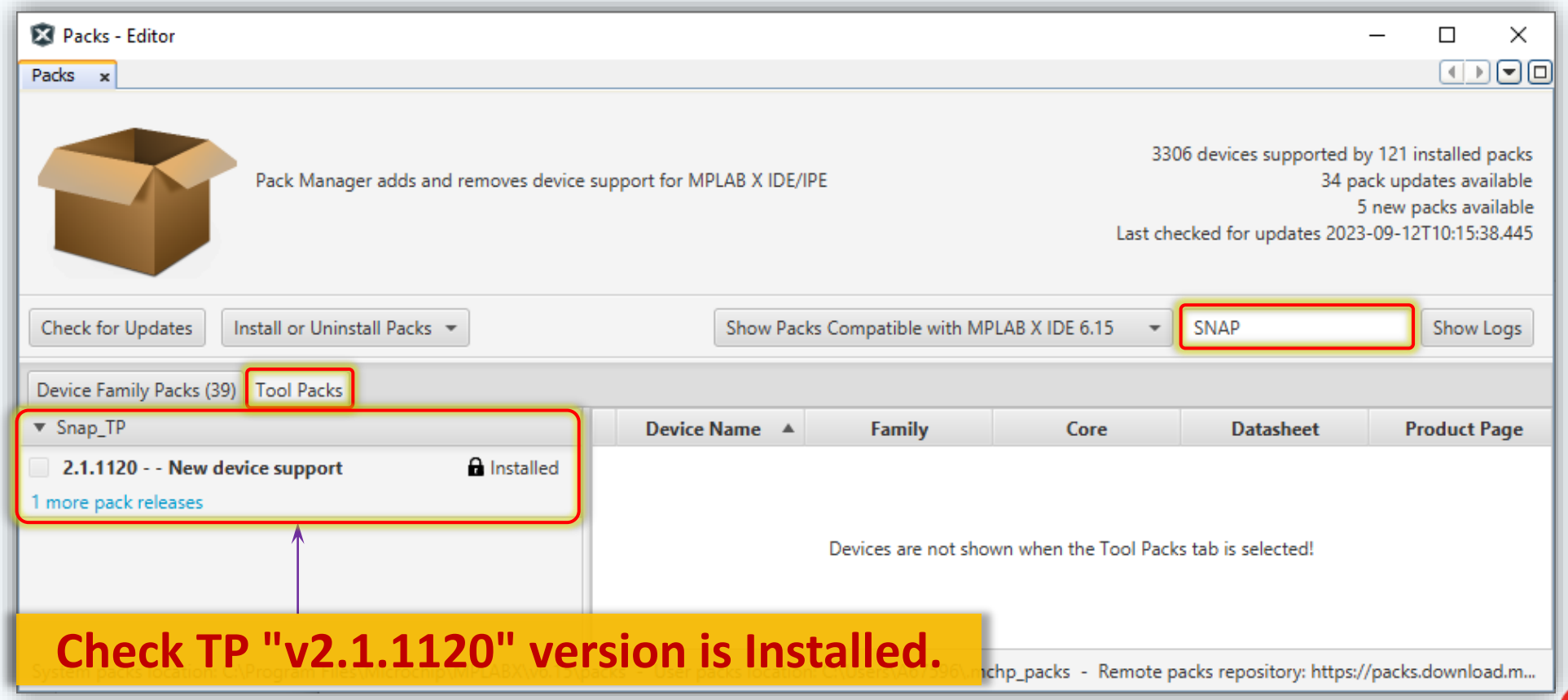


MICROCHIP

Development Tools Check

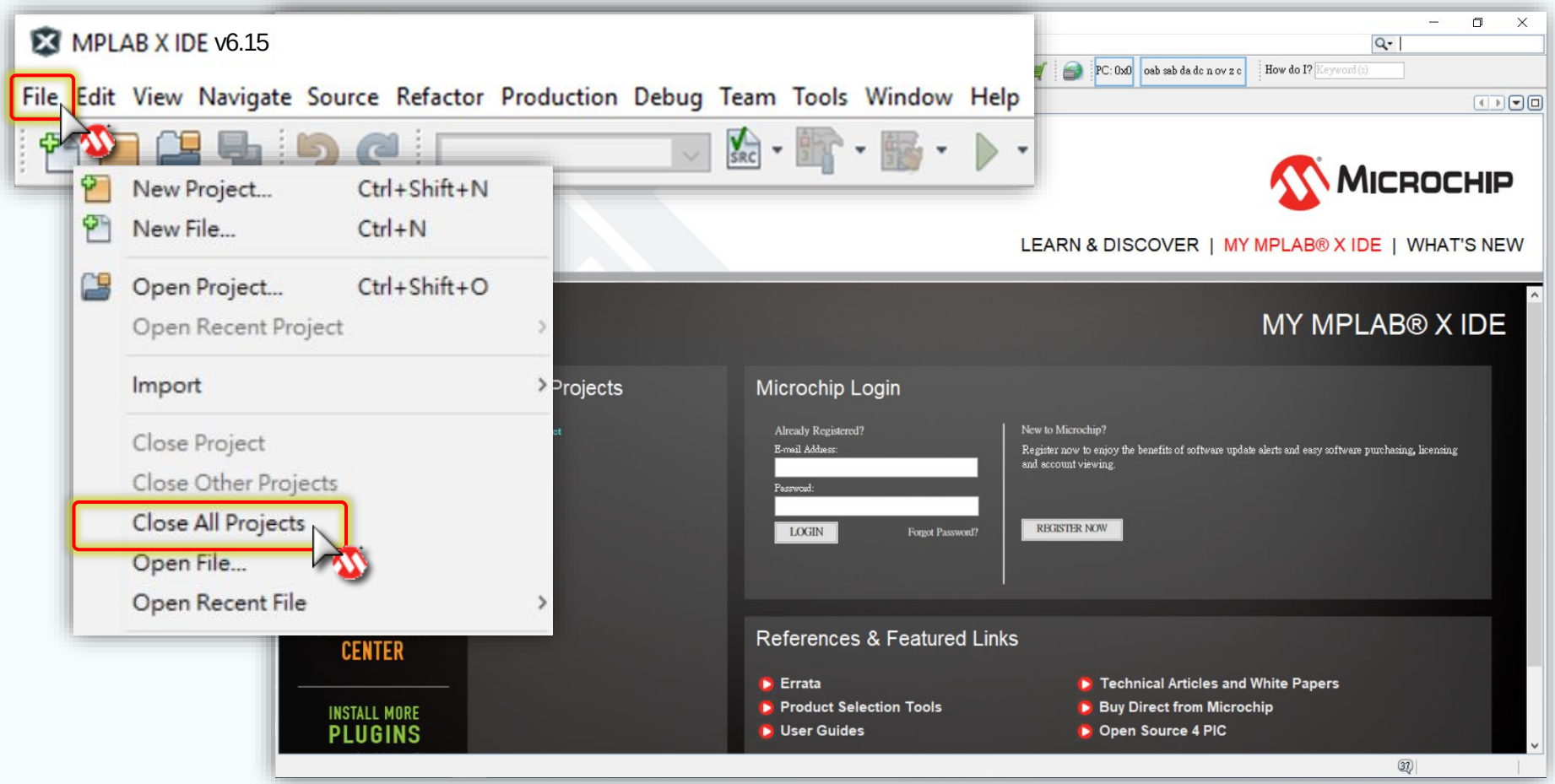
Check Packs Version

- **Select : Tool Packs**
  - **Search : "SNAP"**



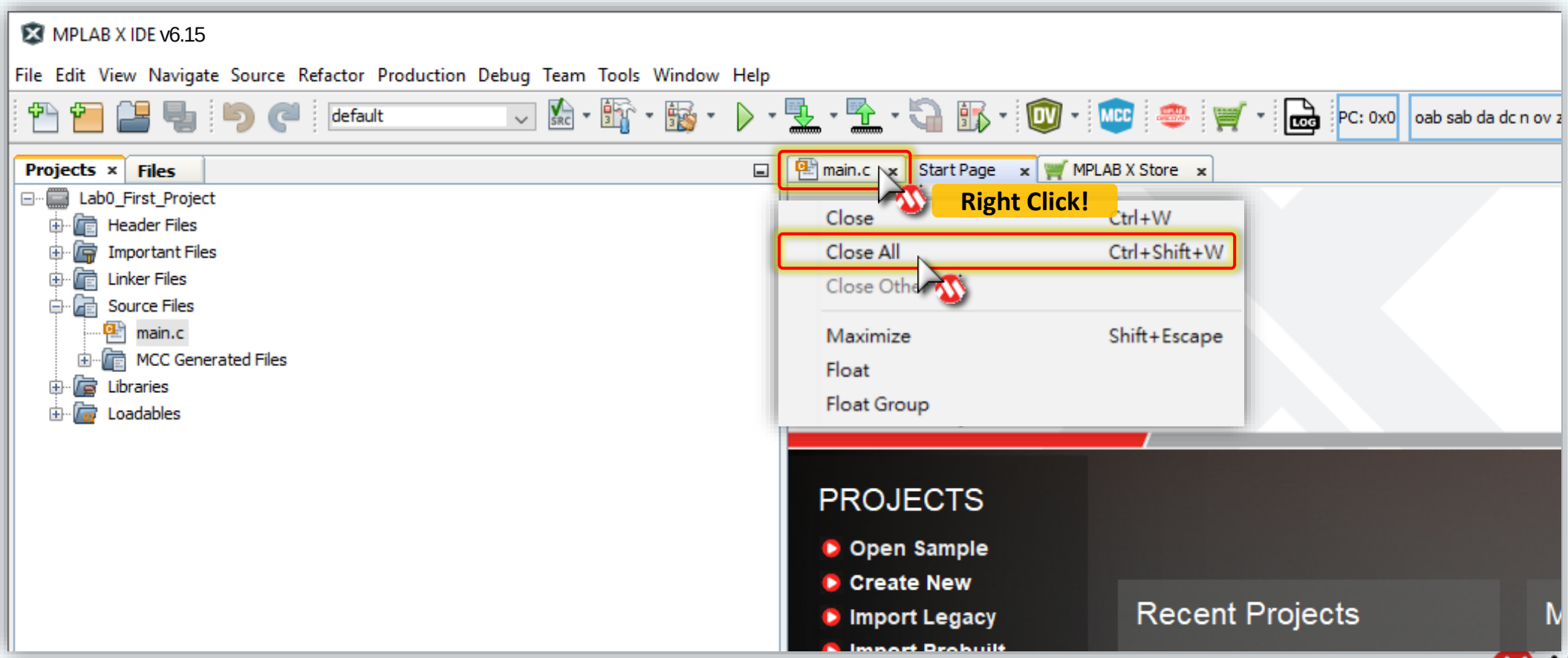
Lab Preparation

- To prevent opened projects to confuse our main project.
- Please select File > Close All Projects.



Lab Preparation

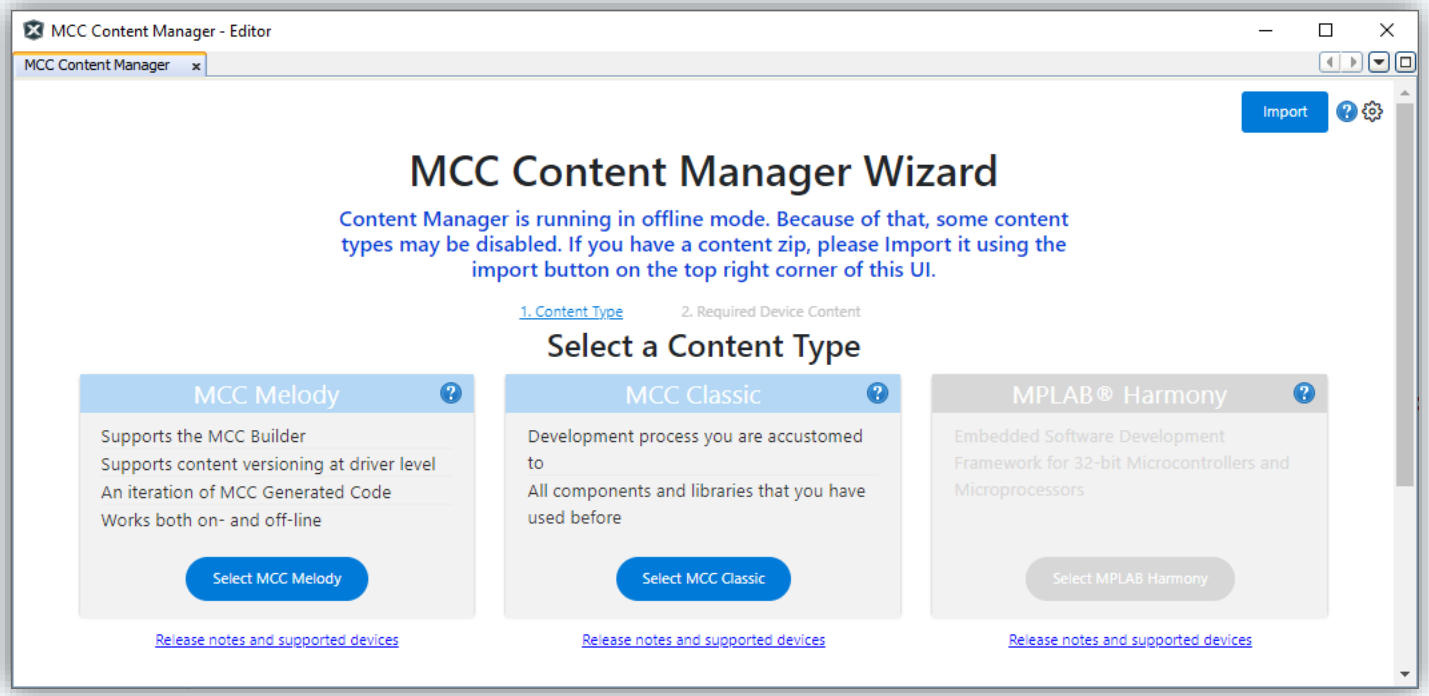
- To prevent opened files to confuse our implementation.
- Please "Right Click" on opened file and choose "Close All"



Lab Preparation

MCC Offline Mode

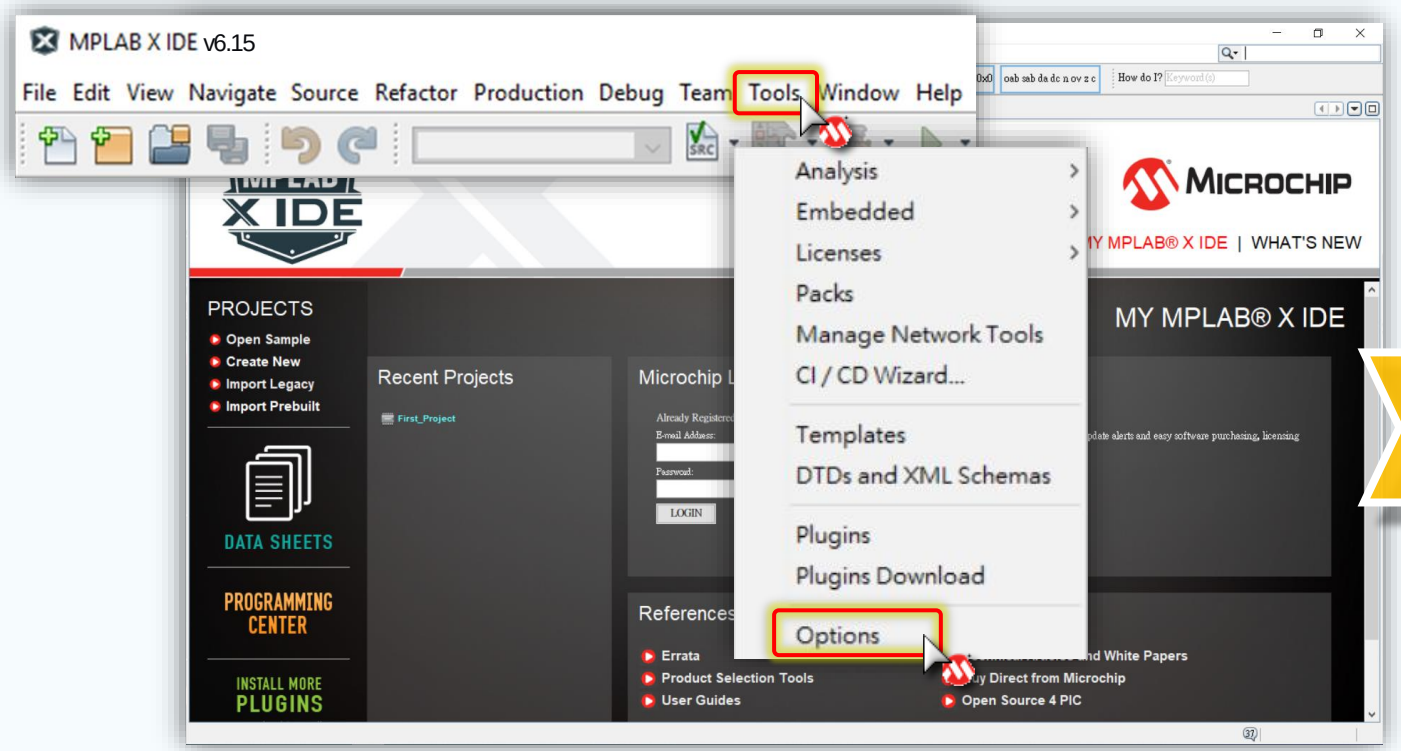
- Generally, using the MCC requires operating in a network environment. If the network environment is not good, there may be problems opening MCC.
- MCC provides a mode that can run without network, named "Offline Mode".
- In offline mode, the online content update function will be disabled, user can add or update MCC content through "import".

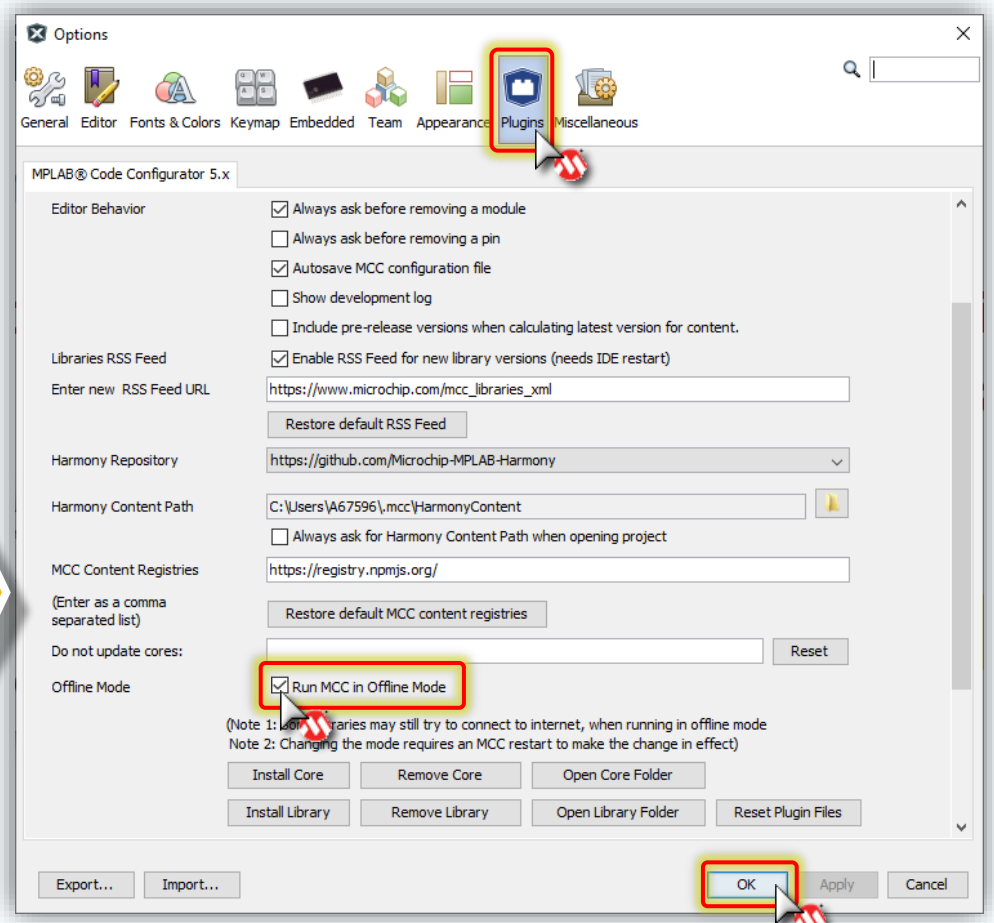


Lab Preparation

MCC Offline Mode (optional feature)

- Select : **Tools > Options**
- Enable the **Plugins > Run MCC in Offline Mode**, then click "**Finish**"





Lab0 First Project

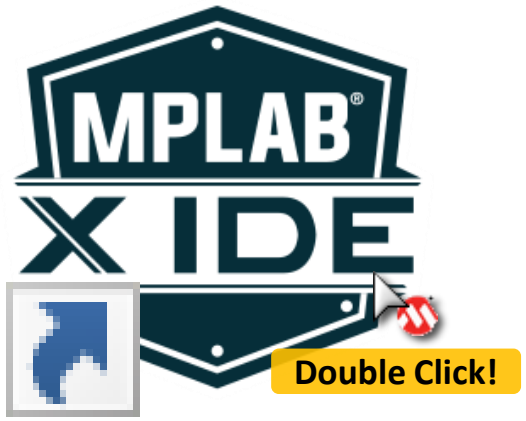
- Try to create your first MPLAB X IDE Project.
- Try to create your first MCC Melody style Project.
- To understanding MPLAB X IDE basic operation.
- Learn how to use edit, build, project manager and program functions.

How to start ?

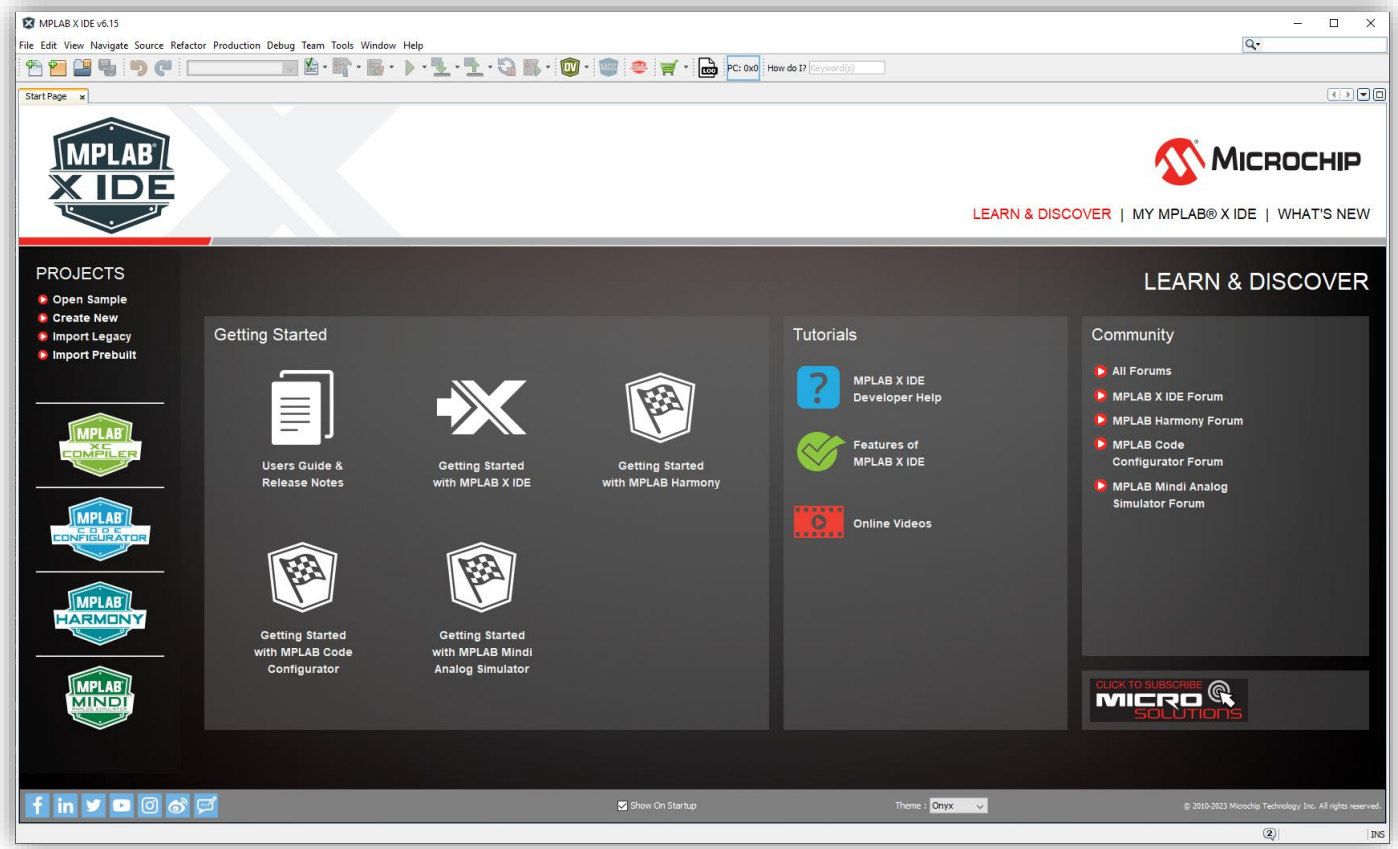
Lab0 First Project

Step 1

- Open **MPLAB X IDE v6.15** firstly.



MPLAB X IDE
v6.15

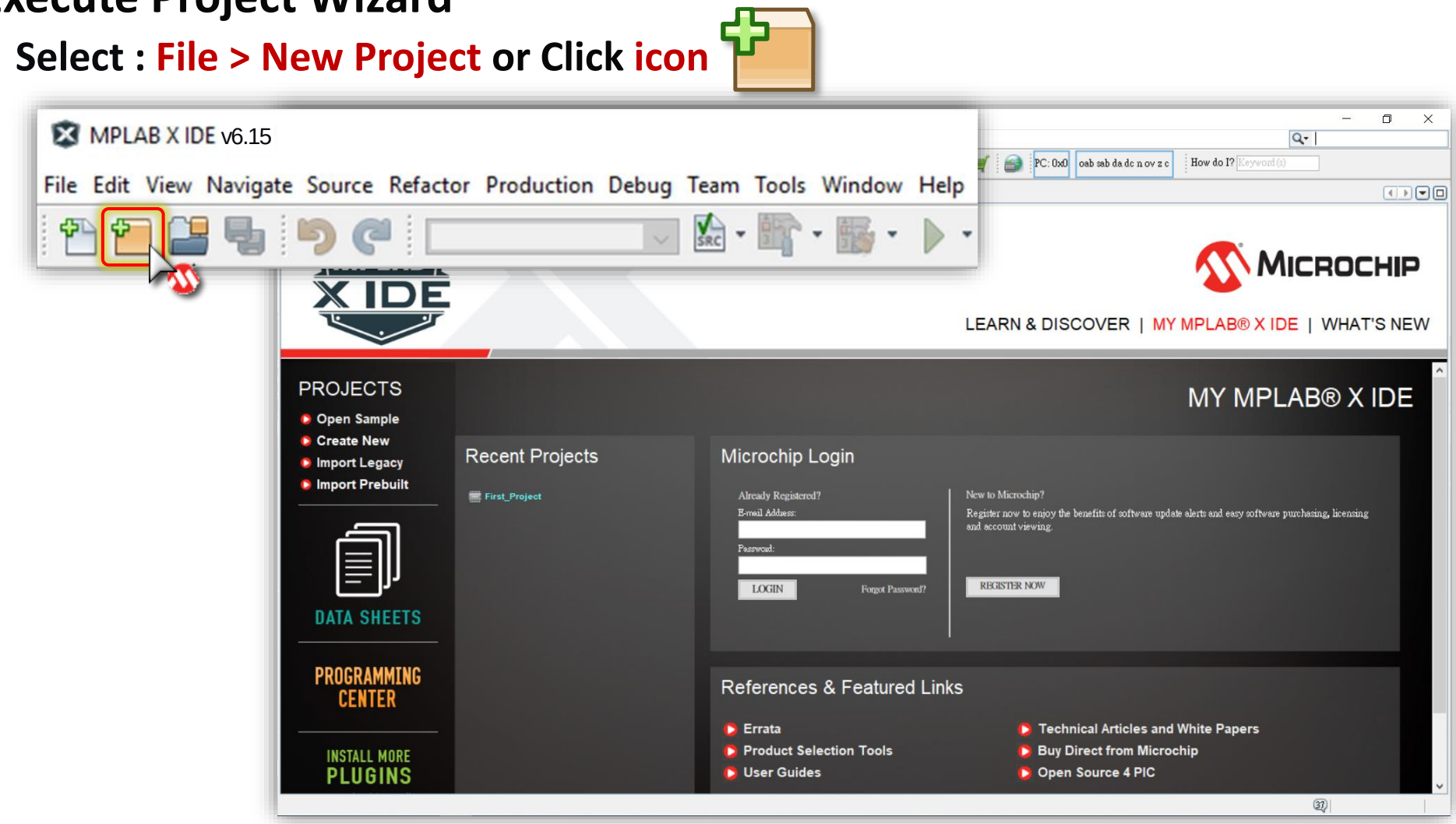


MICROCHIP

Lab0 First Project

Step 2

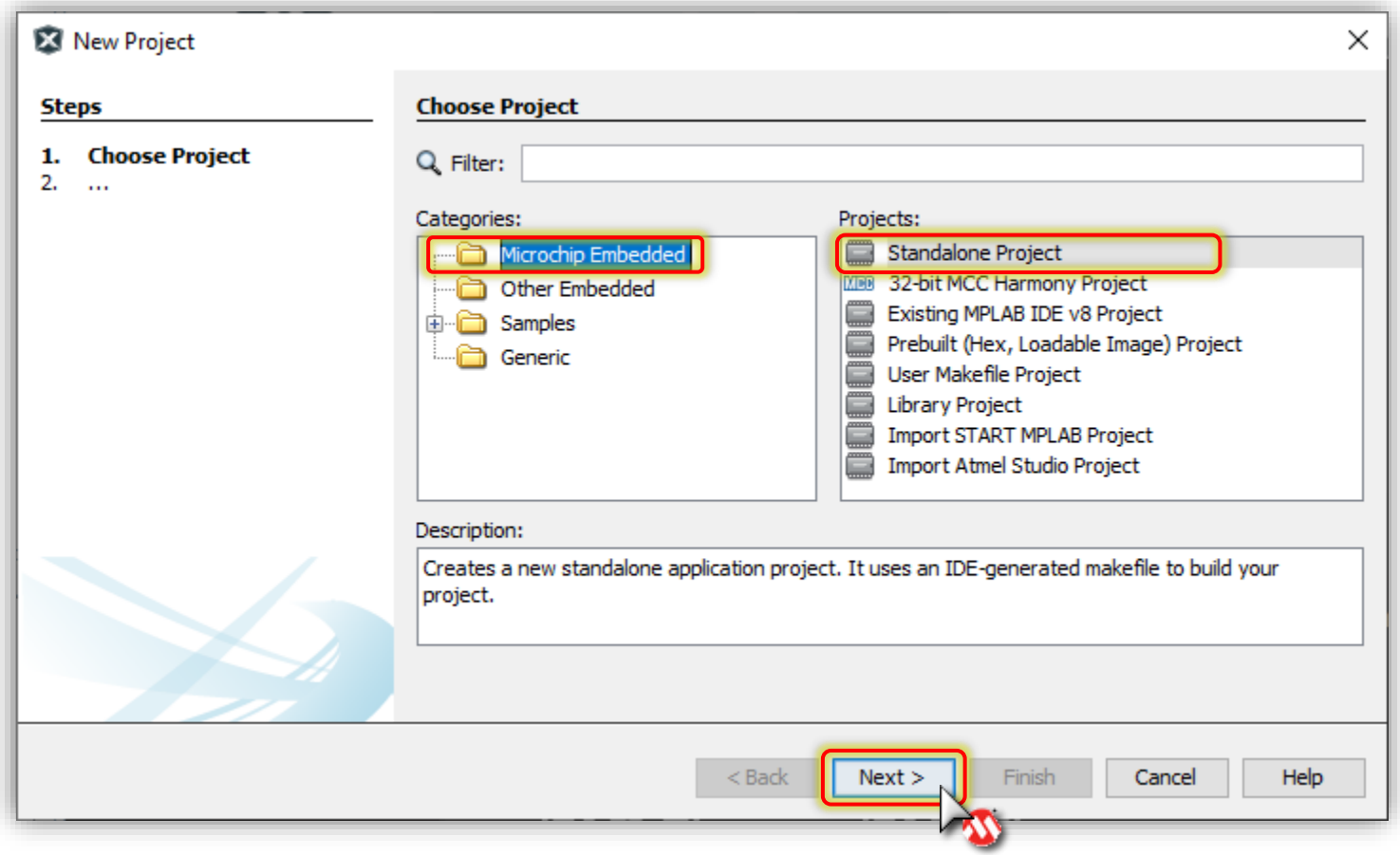
- **Execute Project Wizard**
  - **Select : File > New Project or Click icon**



Lab0 First Project

Step 3

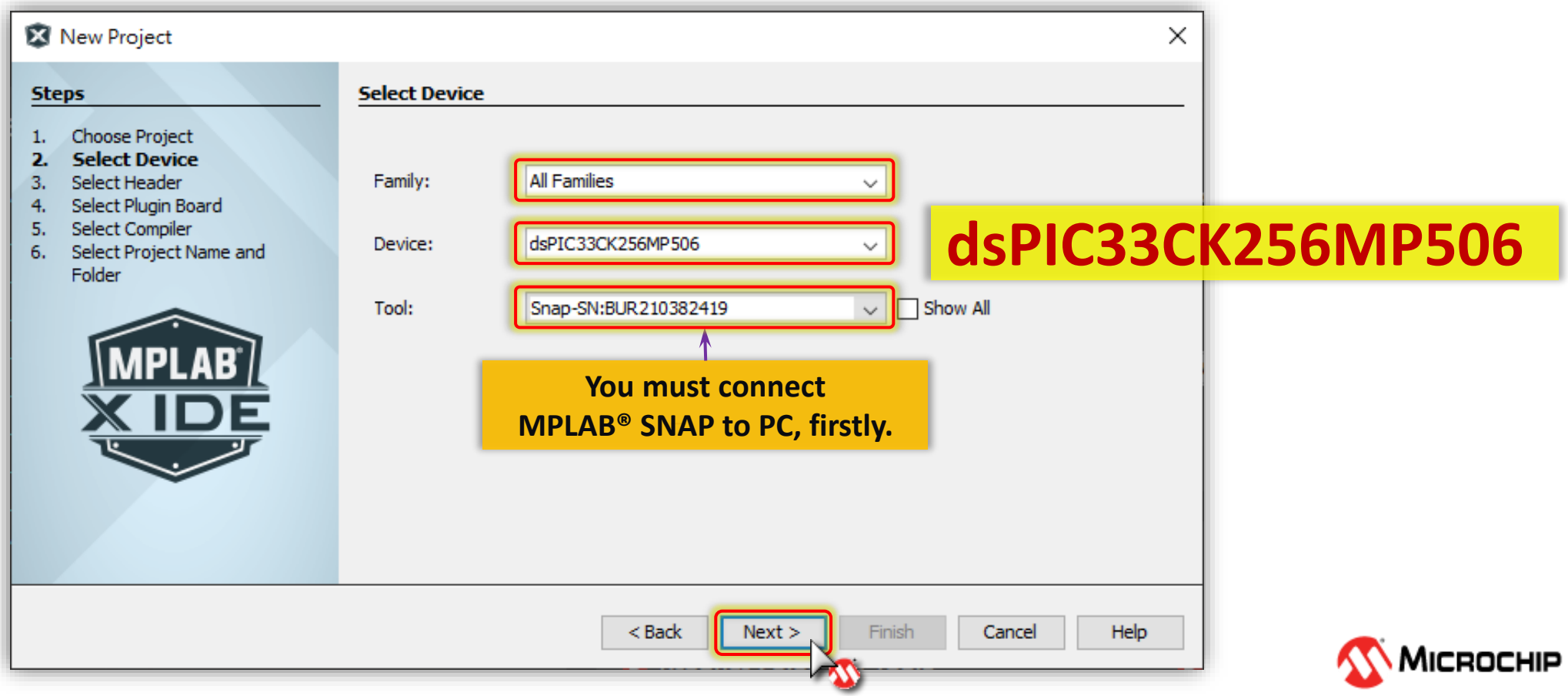
- **Chooses Project :**
  - **Categories: Microchip Embedded, Projects: Standalone Project**



Lab0 First Project

Step 4

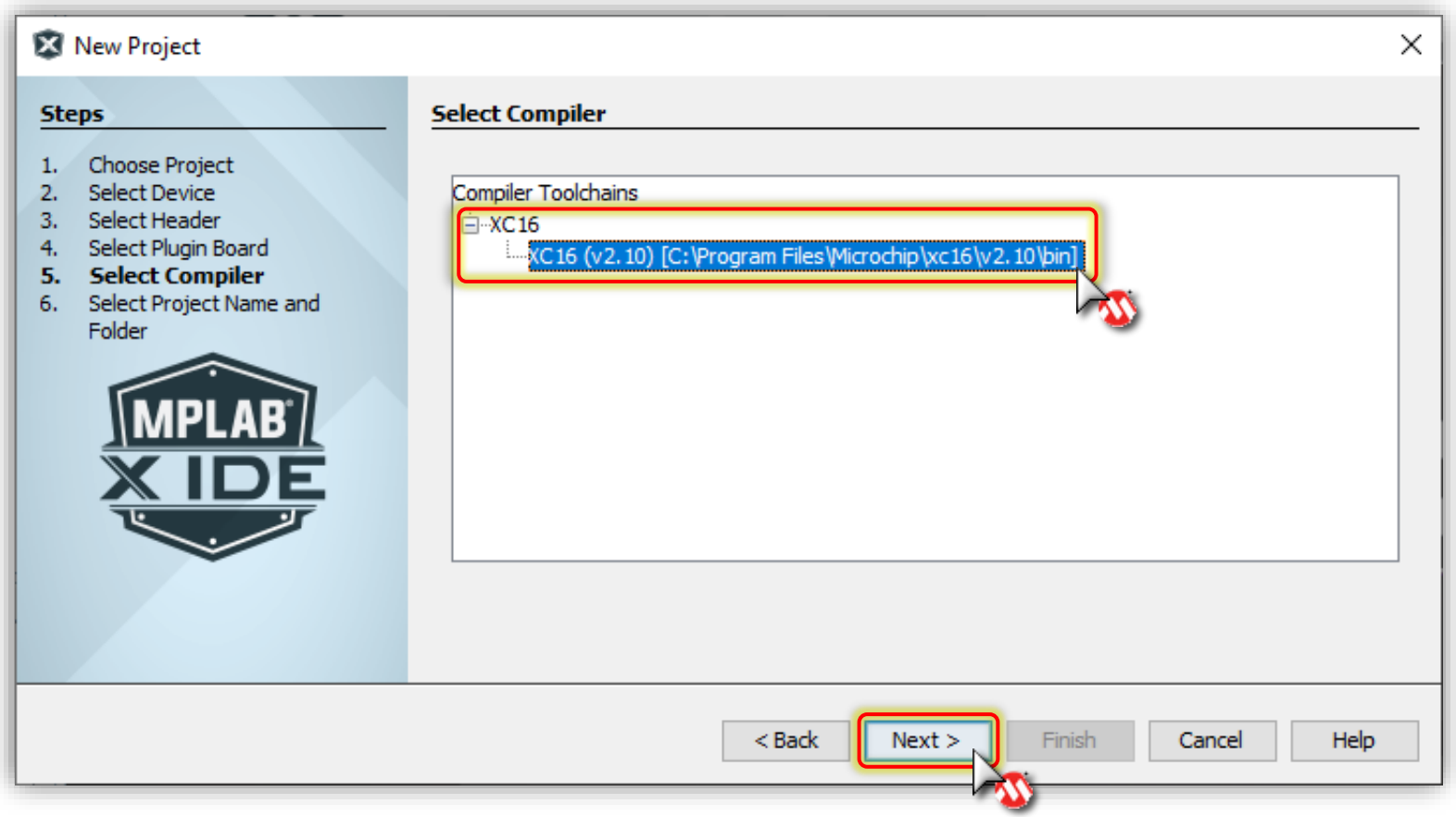
- **Select Target Device :**
  - **Family: 16-bit DSCs (dsPIC33), Device: dsPIC33CK256MP506, Tool: Snap-SN : BURXXXXXXXXX**



Lab0 First Project

Step 5

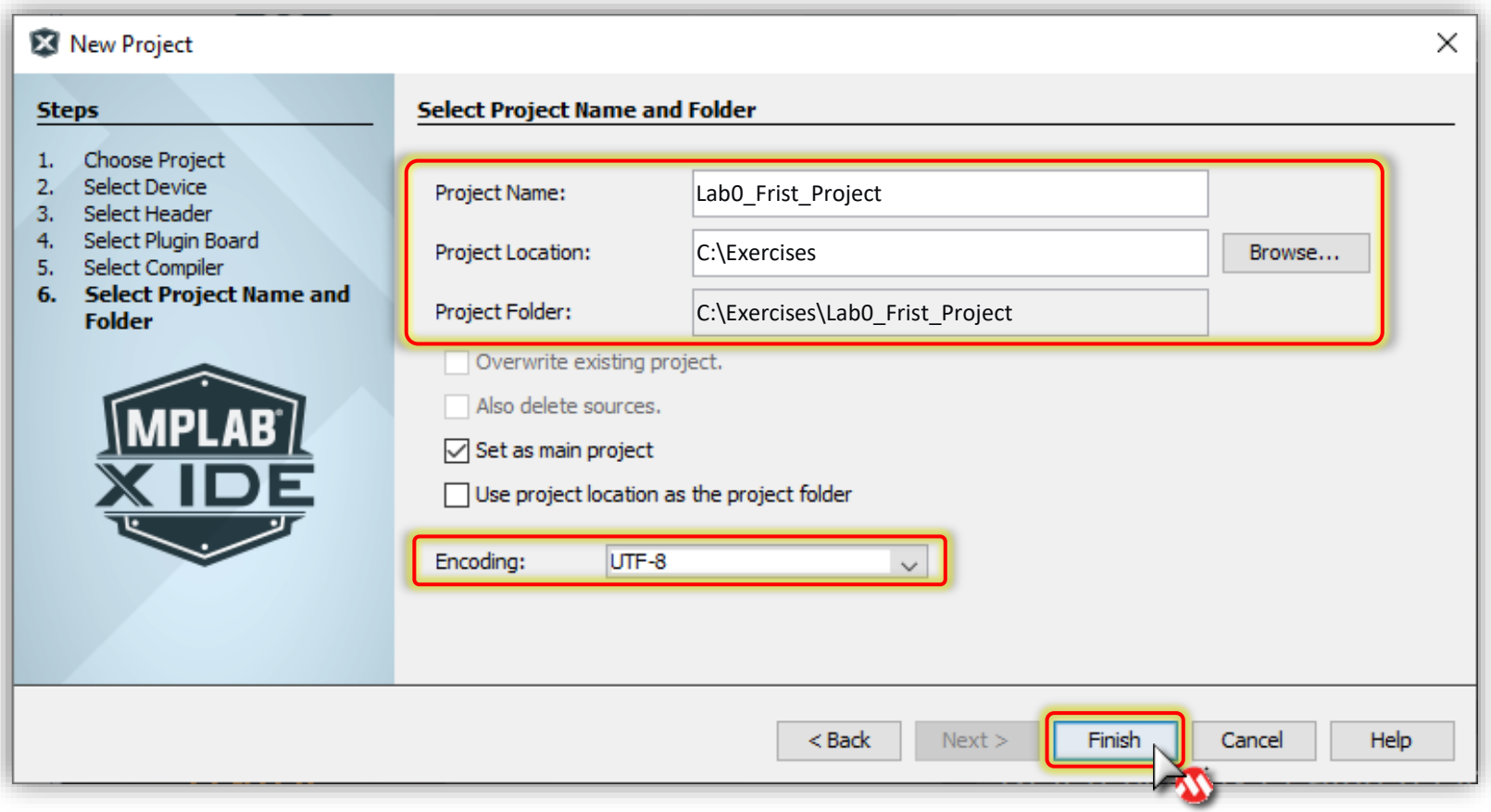
- **Select Compiler :**
  - **Compiler Toolchains: XC16 (v2.10) [C:\Program Files\Microchip\xc16\v2.10\bin]**



Lab0 First Project

Step 6

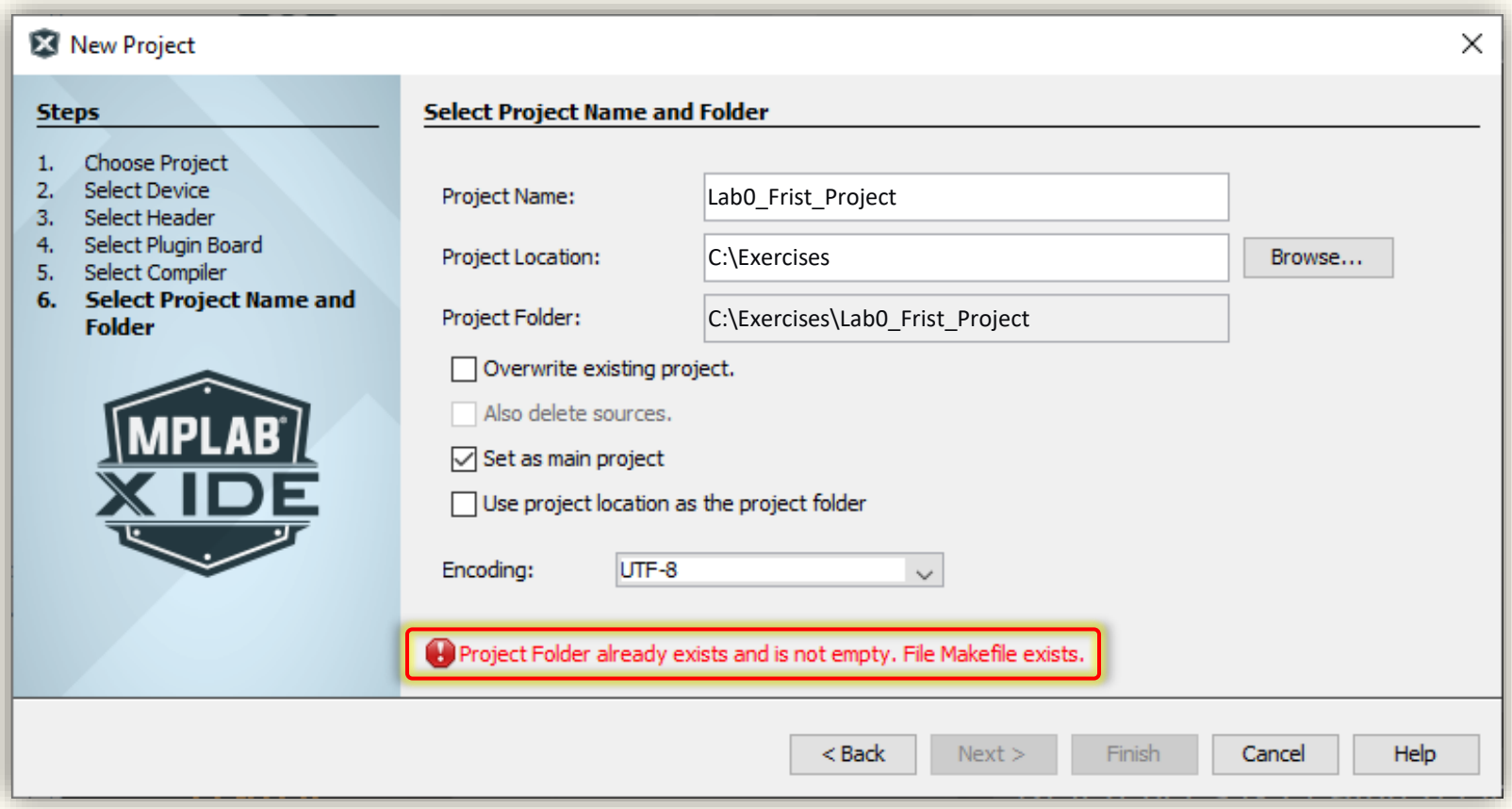
- **Select Project Name and Folder :**
  - **Project Name: Lab0_First_Project , Project Location: C:\Exercises**
  - **Encoding: UTF-8**



Lab0 First Project

Notice

- **If an old project already exist at the same location, you must delete it firstly or change to new project folder.**

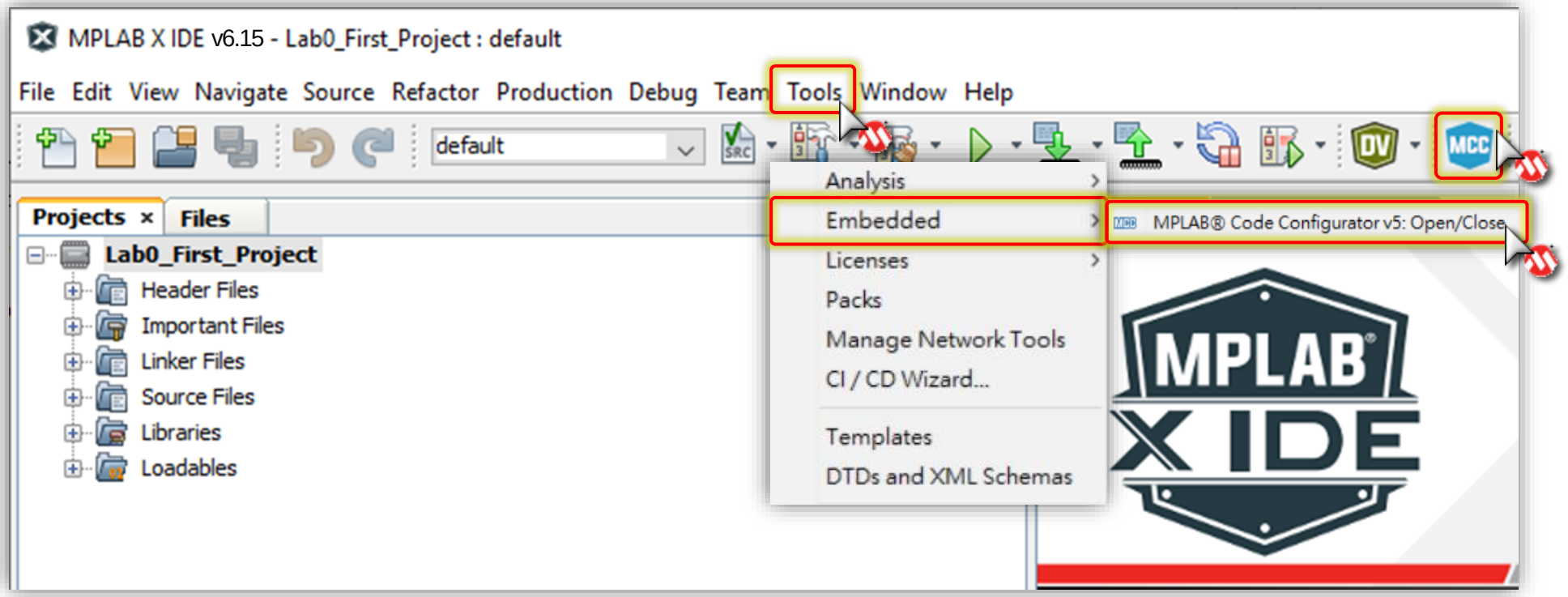


Lab0 First Project

Step 7

- **Execute MCC.**
  - **Tools > Embedded > MPLAB Code Configurator v5: Open/Close**

    or Click 



or

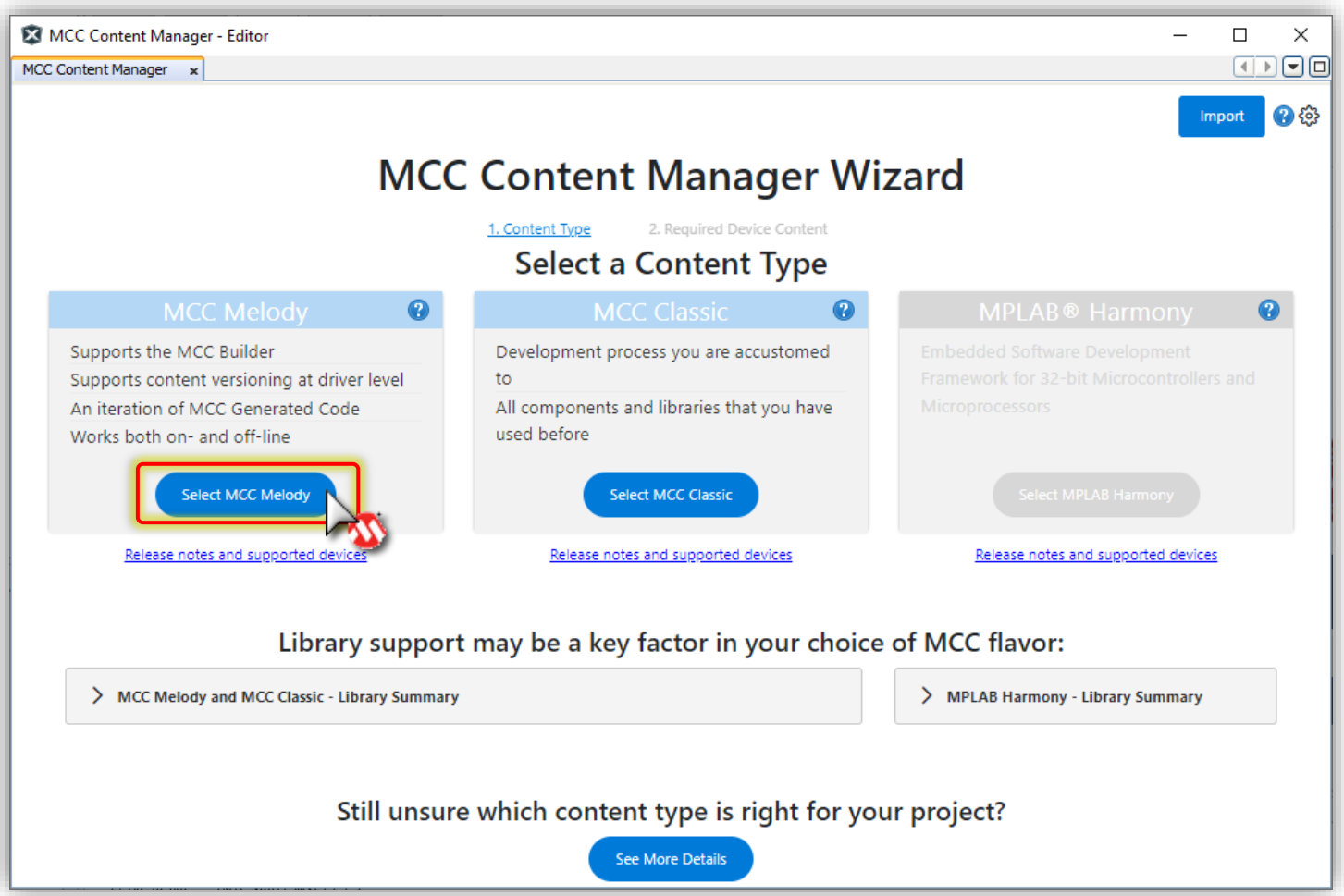
Online Download MCC Framework (Internet Accessible)

MCC Framework Preparation

Lab0 First Project

Step 8 (Online Download MCC Framework)

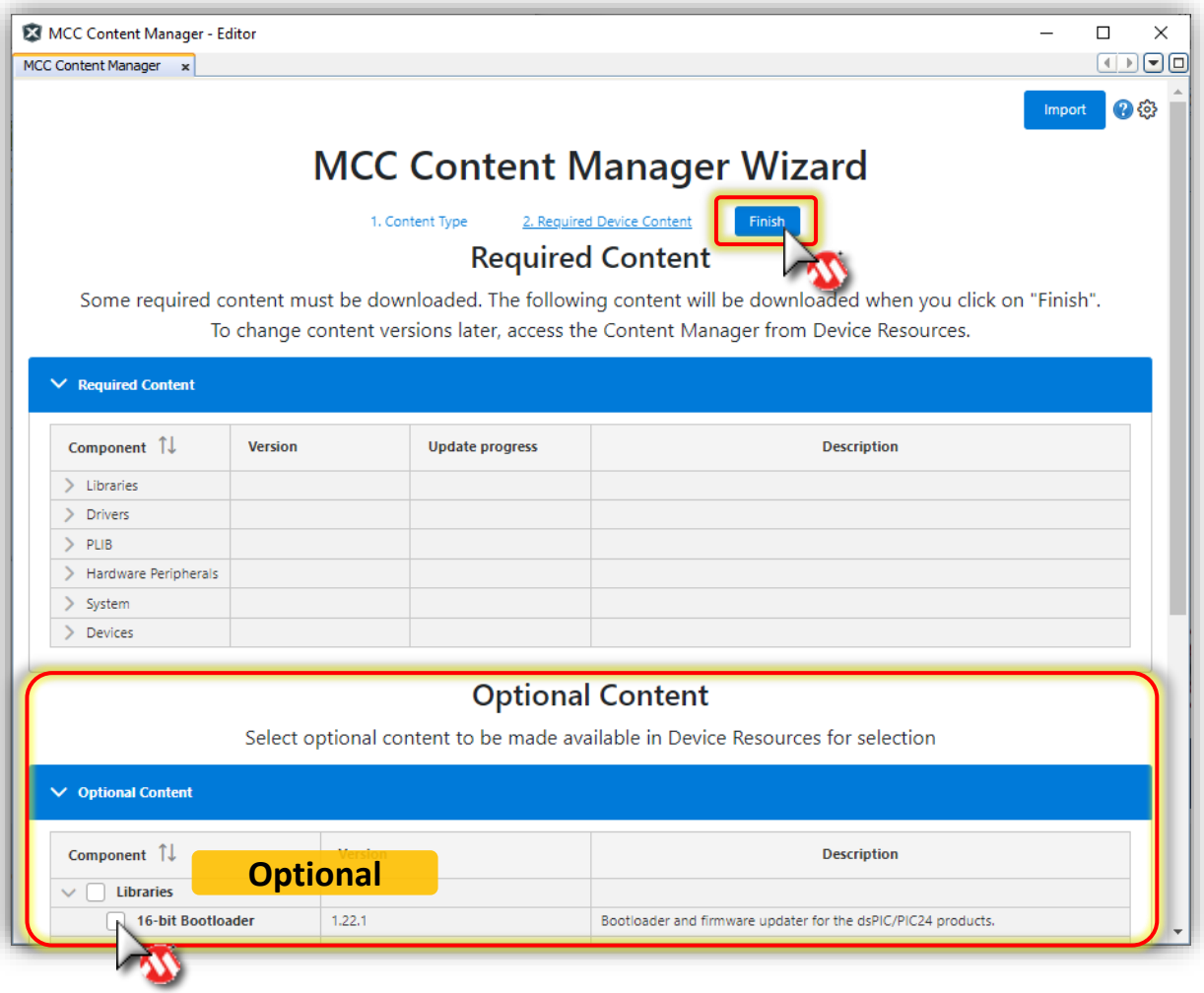
- Click the "**Select MCC Melody**"



Lab0 First Project

Step 9 (Online Download MCC Framework)

- **You can add the available Libraries provided in the Device resource to the project or click "Finish".**



MICROCHIP

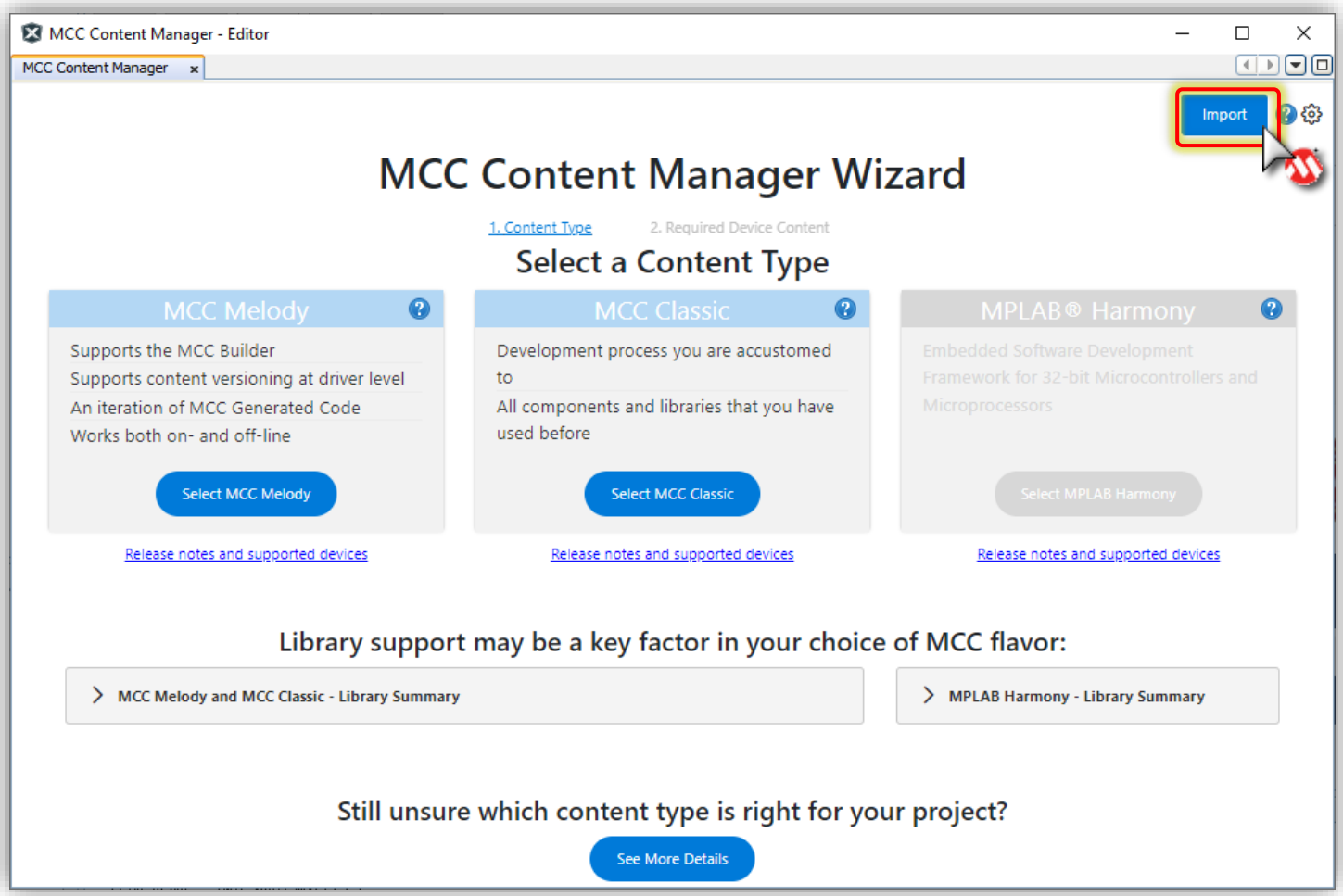
MCC Off-Line Mode
Import Exist MCC Framework
(Internet not Stable)

MCC Framework Preparation

Lab0 First Project

Step 8 (Import Exist MCC Framework)

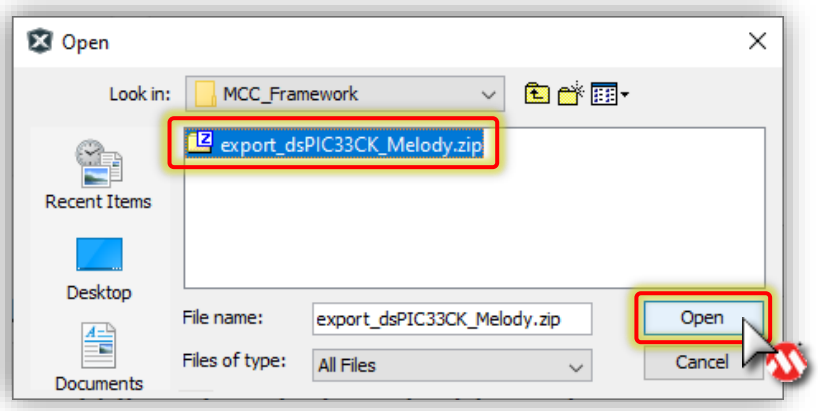
- Click "**Import**“.



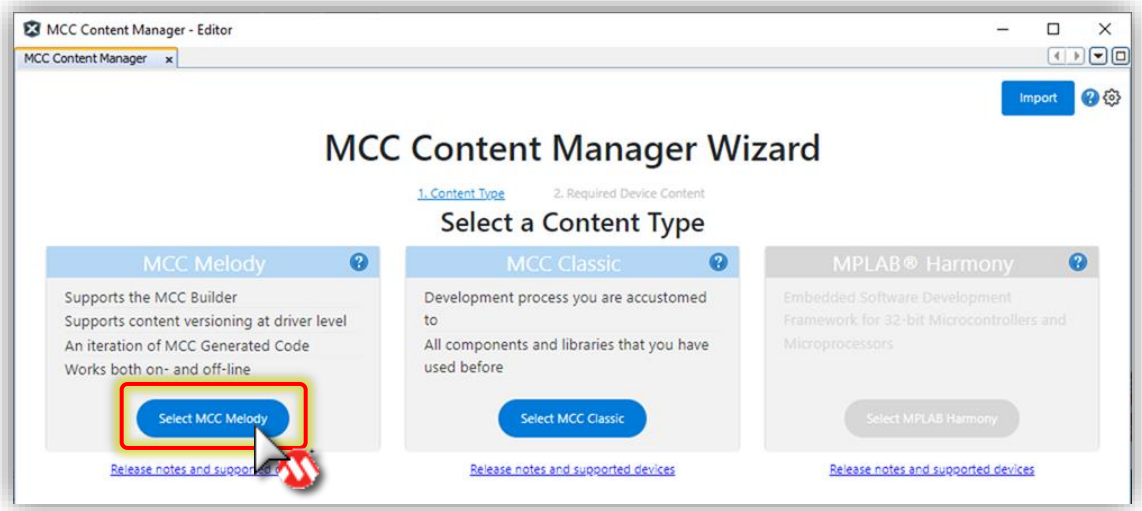
Lab0 First Project

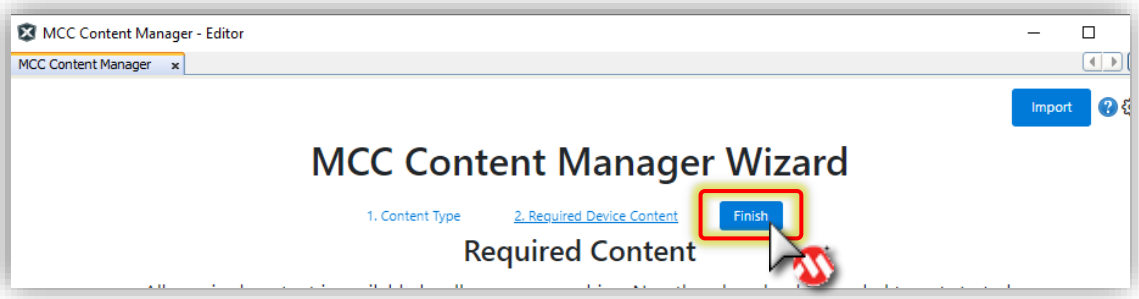
Step 9 (Import Exist MCC Framework)

- Select the exist "Framework Archive (*.zip)“ and click on Open.
- Click the "Select MCC Melody", then click "Finish"



Wait Download Finished

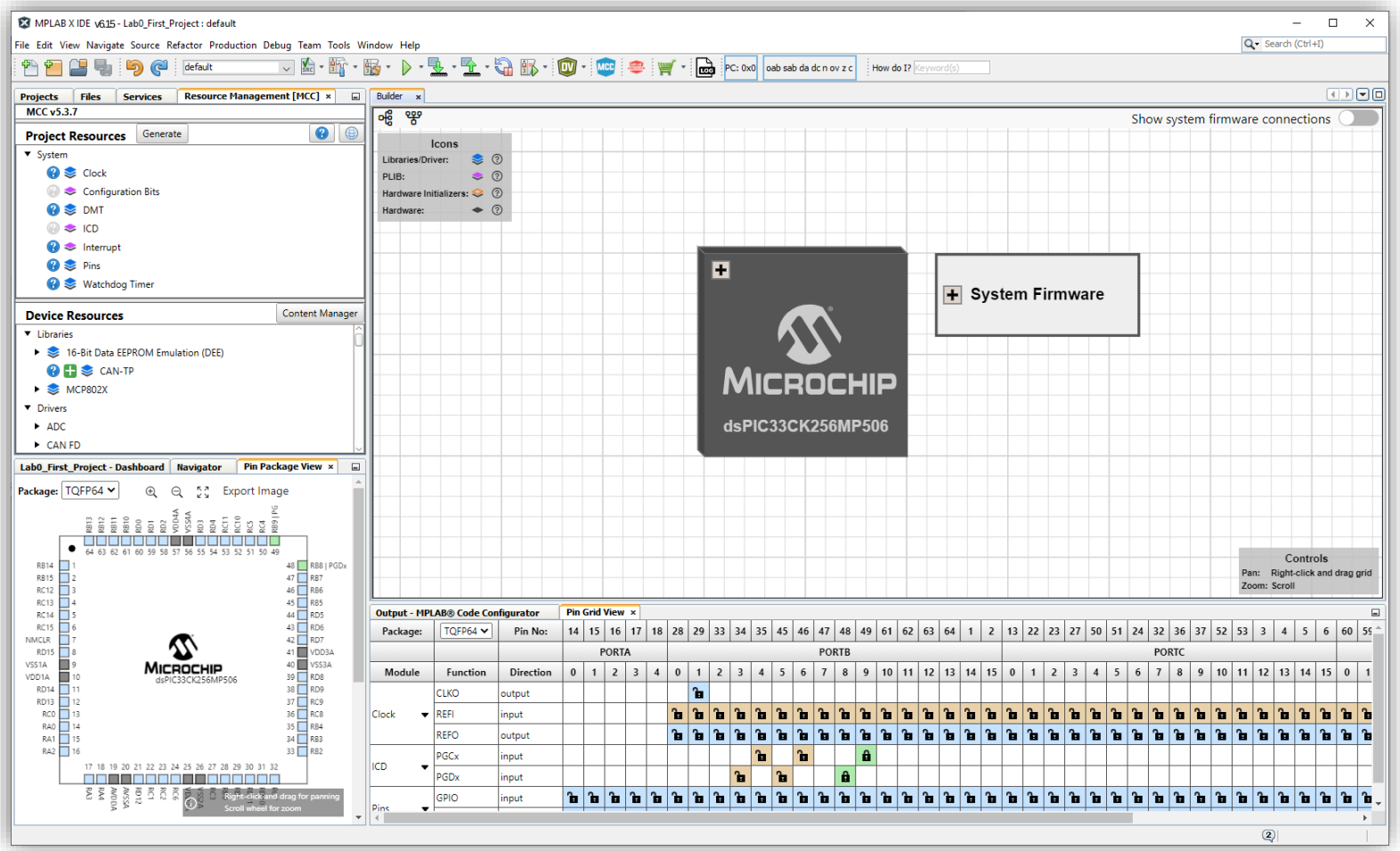




Lab0 First Project

Step 10

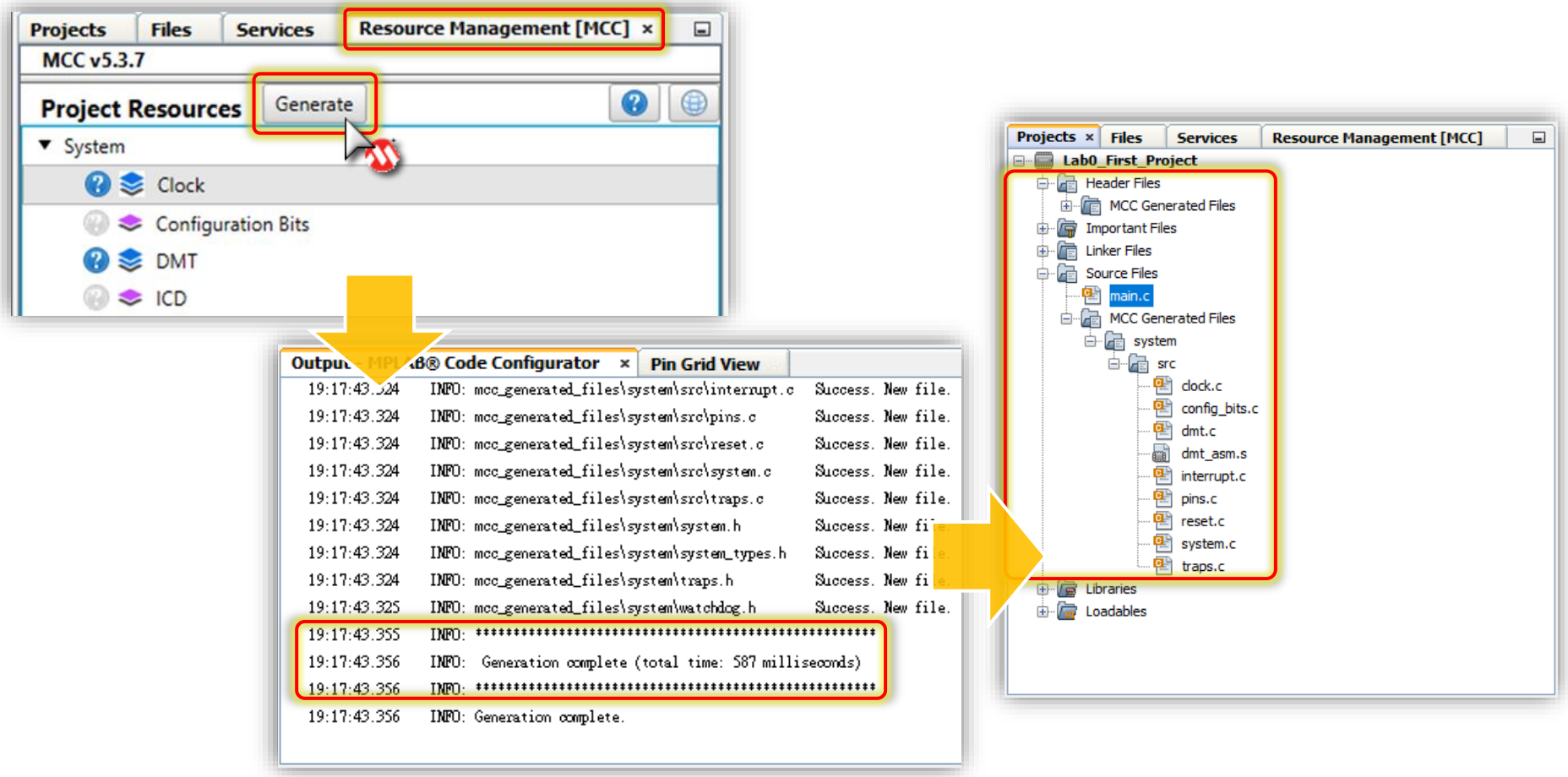
- **MCC Configurator interface show up.**



Lab0 First Project

Step 11

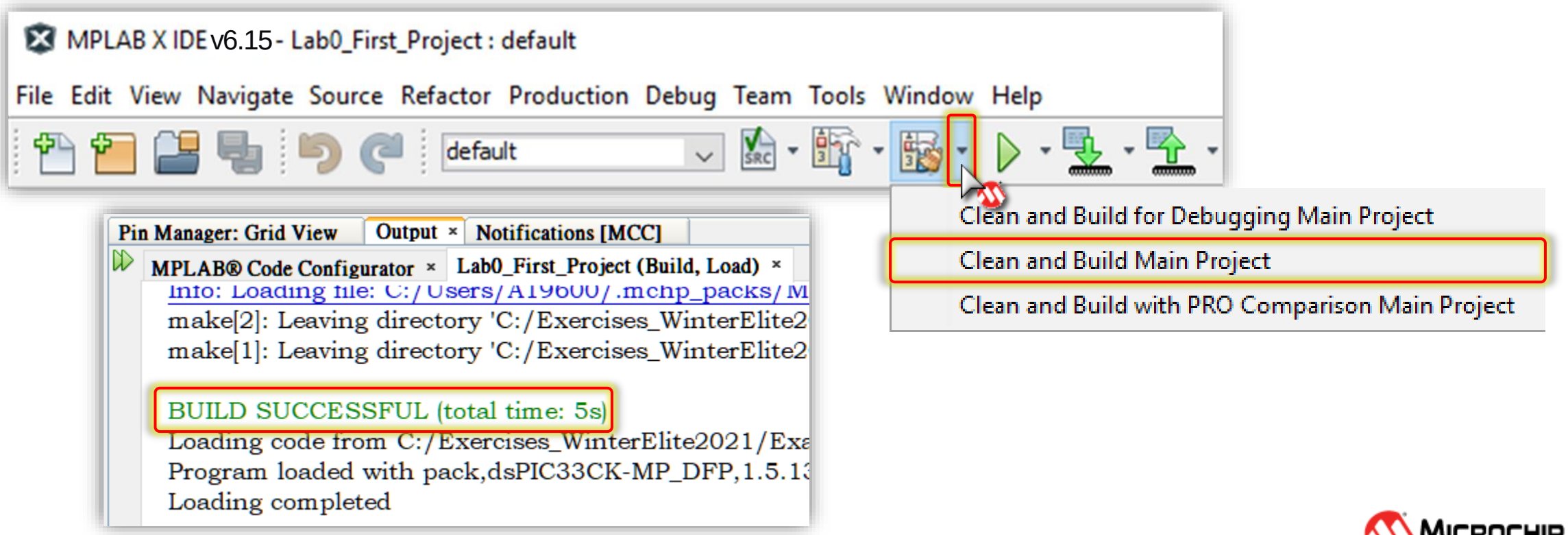
- Click "Generate" Button to get your first MCC Project.
- MCC to generate files include "main.c" automatically.



Lab0 First Project

Step 12

- **Build your first MCC Project.**
  - **Click the "Arrow Button ▾ " near the icon**
  - **Select "Clean and Build Main Project"**
  - **Make sure compiled result is BUILD SUCCESSFUL**

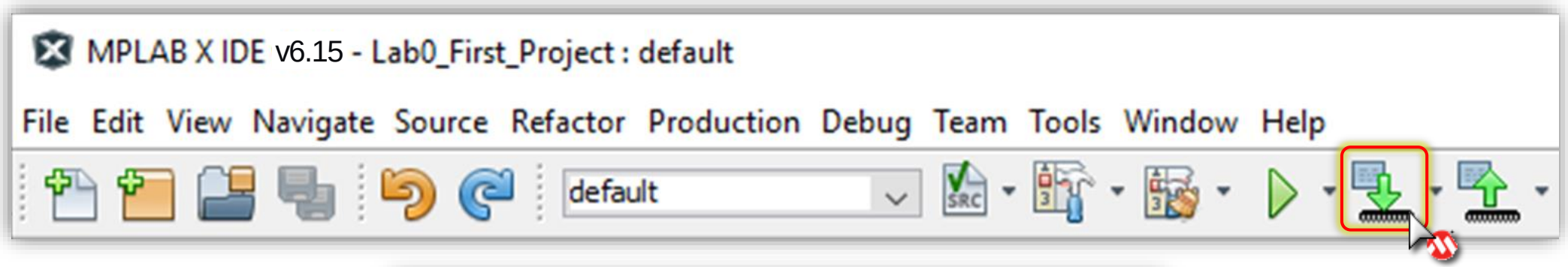


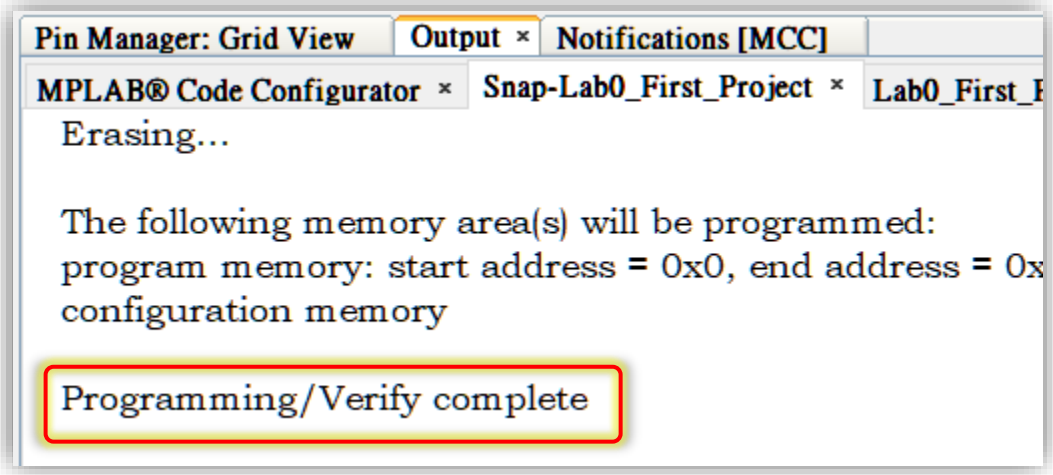
MICROCHIP

Lab0 First Project

Step 13

- Try program compiled firmware to your target board.
  - Select "Make and Program Device Main Project" icon
  - Make sure the result is Programming/Verify complete



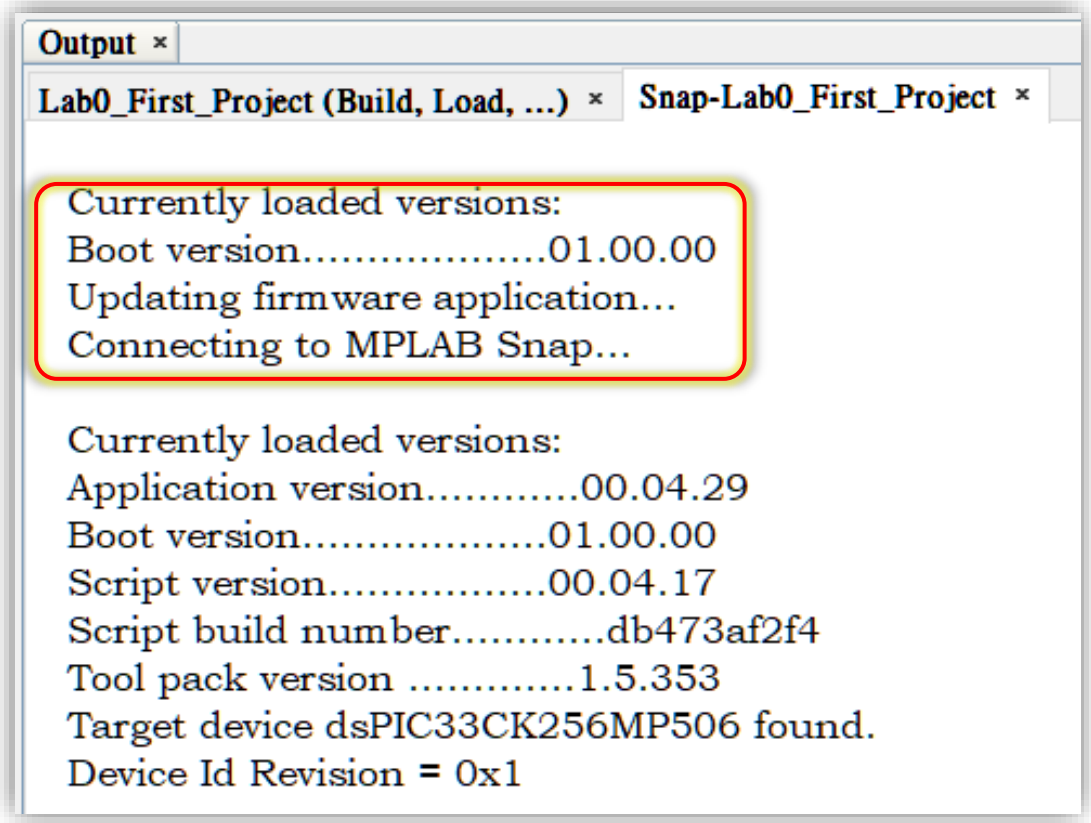


MICROCHIP

Lab0 First Project

Notice

- **MPLAB X IDE will auto upgrade the firmware of SNAP to keep it up to date, it might take couple minutes to wait for finish. Your project will start programming after this.**

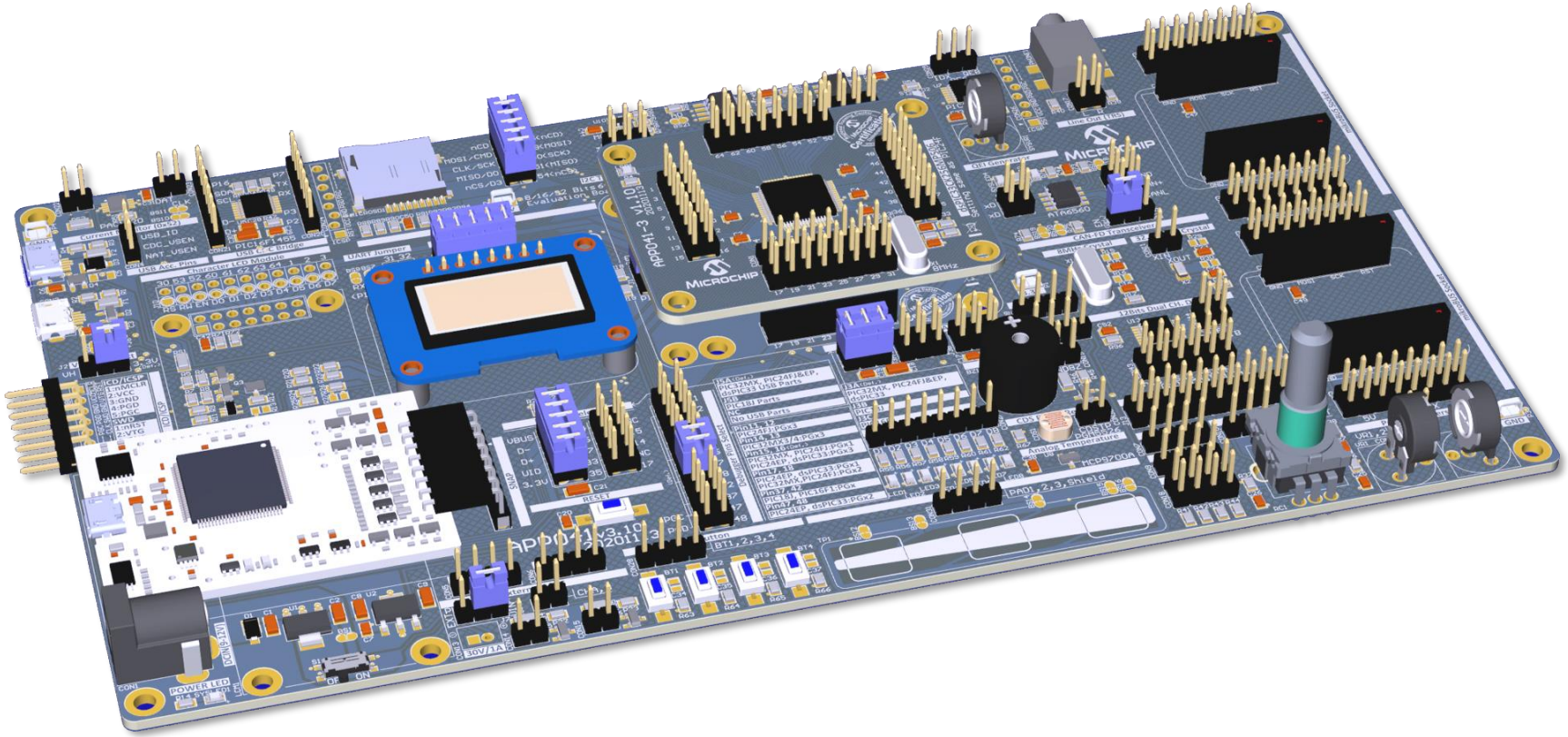


MICROCHIP

Lab0 First Project

Check Point

Nothing happen ????

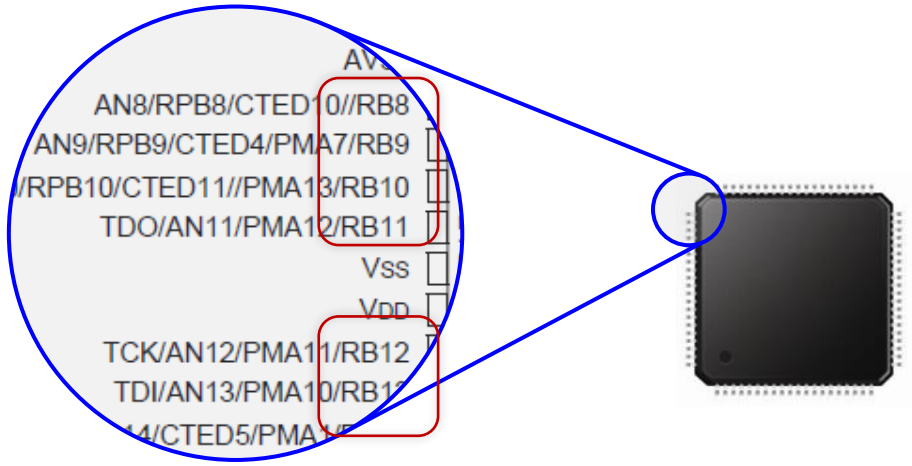


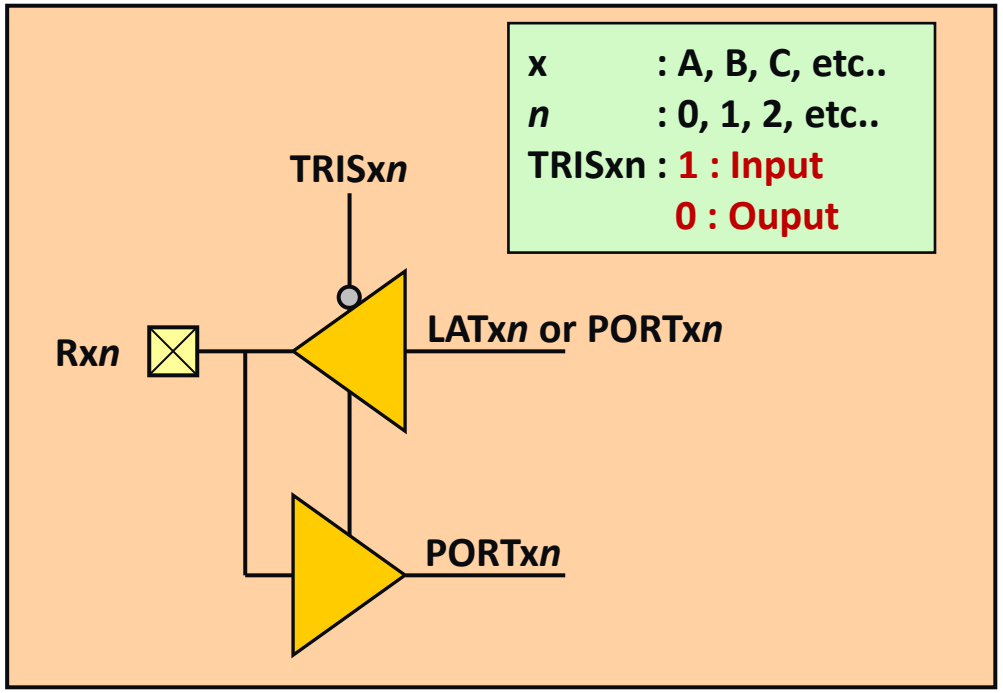
MICROCHIP

GPIO Architecture

GPIO Block Diagram

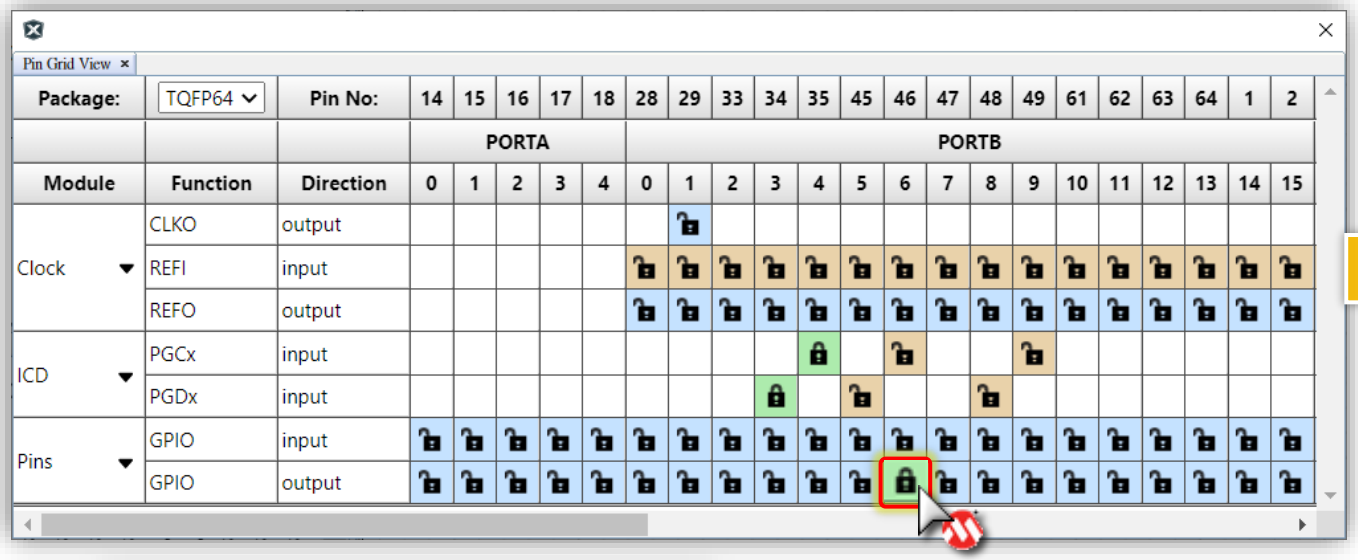
- Please refer to the block diagram, this is the concept for programming model. The real and detail block diagram please refer to the following slide.
- **TRIS**: To determine Input or Output.
  1 for Input, 0 for Output.
- **LAT**: set output drive value for Output pins.
- **PORT**: reaction logical level from Input pins.

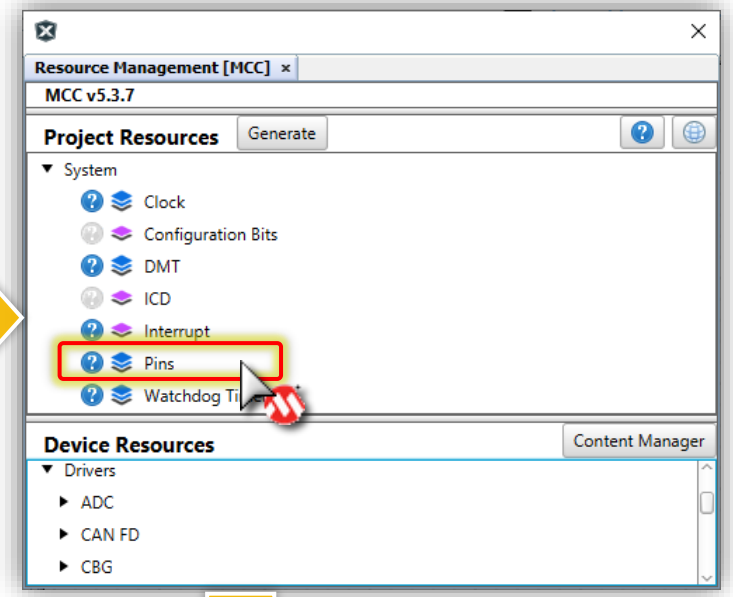


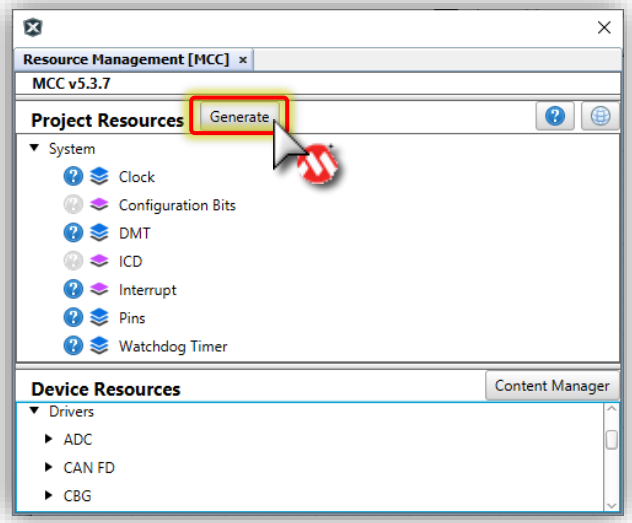


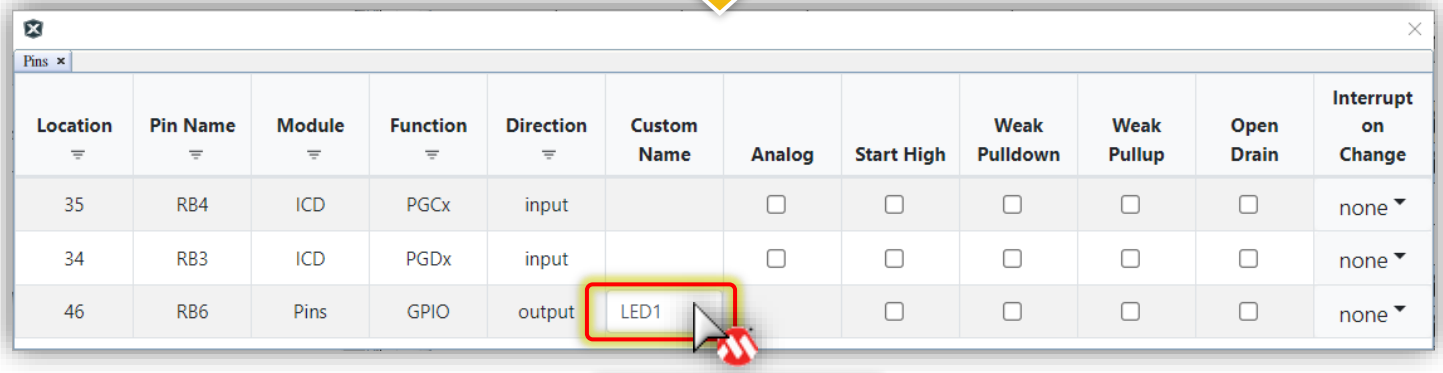
GPIO Setting of MCC

- **Just Click & Select. Code Generate Automatically.**









Click & Rename

MICROCHIP

GPIO Functions of MCC

- **MCC Provide below functions for GPIO:**

  Prototype definition : "pin_manager.h"

  - **void PIN_MANAGER_Initialize (void);**
  - **OUT operation**
    - ***CustomName*_SetHigh();**
    - ***CustomName*_SetLow();**
    - ***CustomName*_Toggle();**
    - ***CustomName*_SetDigitalOutput();**
  - **IN operation**
    - ***CustomName*_GetValue();**
    - ***CustomName*_SetDigitalInput();**

Lab1 GPIO Output

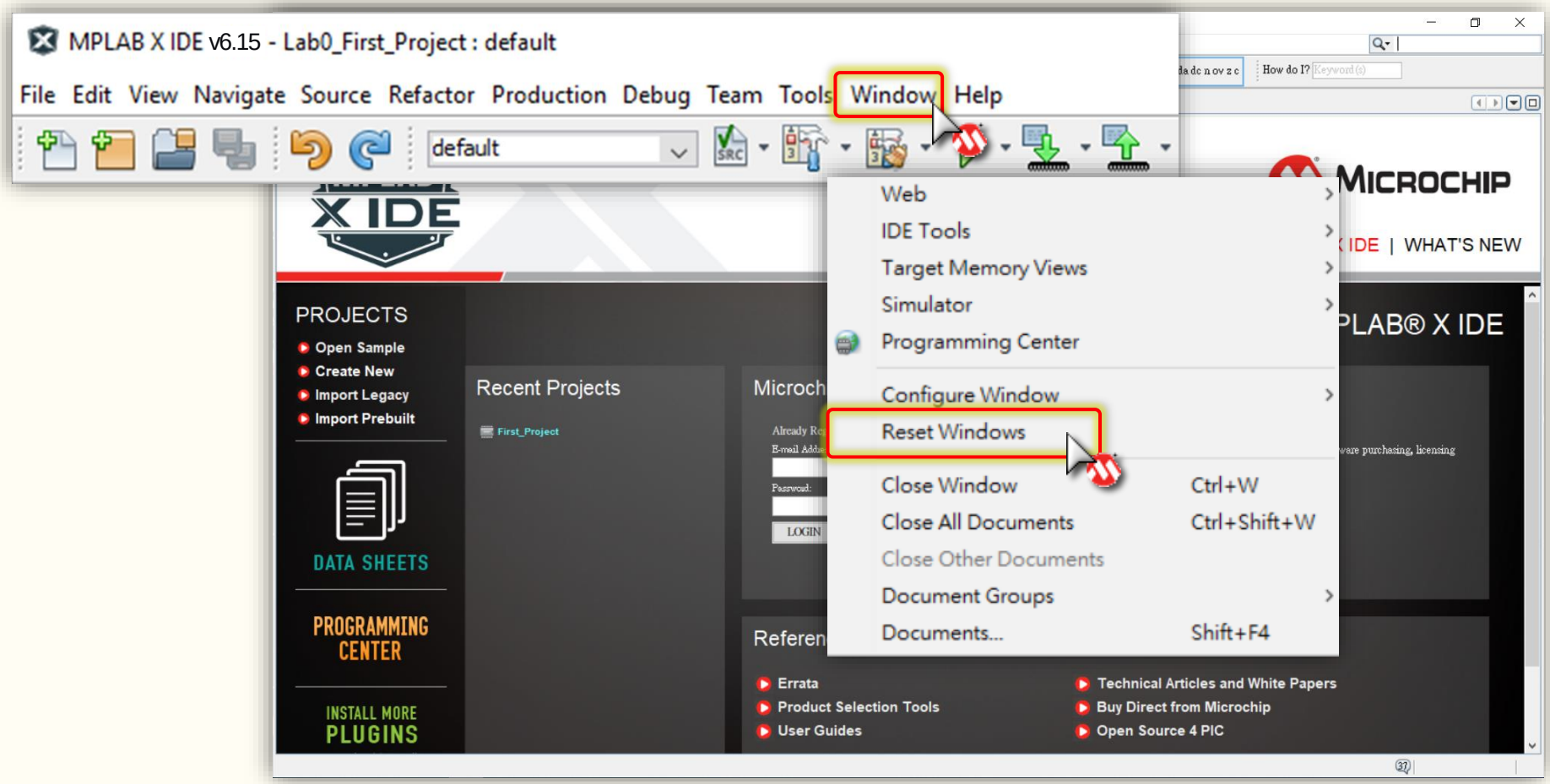
- Base on current project or Open .\Exercises\Lab1_xxx.X to do exercise.
- Try to use MCC to generate your first MCC style code and control GPIO base on MCC style.
- Try to set RB6 to digital output mode, set the initial to bright, and toggle output level in period 500ms ~ 1s roughly.
- Please connect RB6 (Pin11) to LED (LED1) to observe pin status.

How to start ?

MPLAB X IDE Hints

Tips

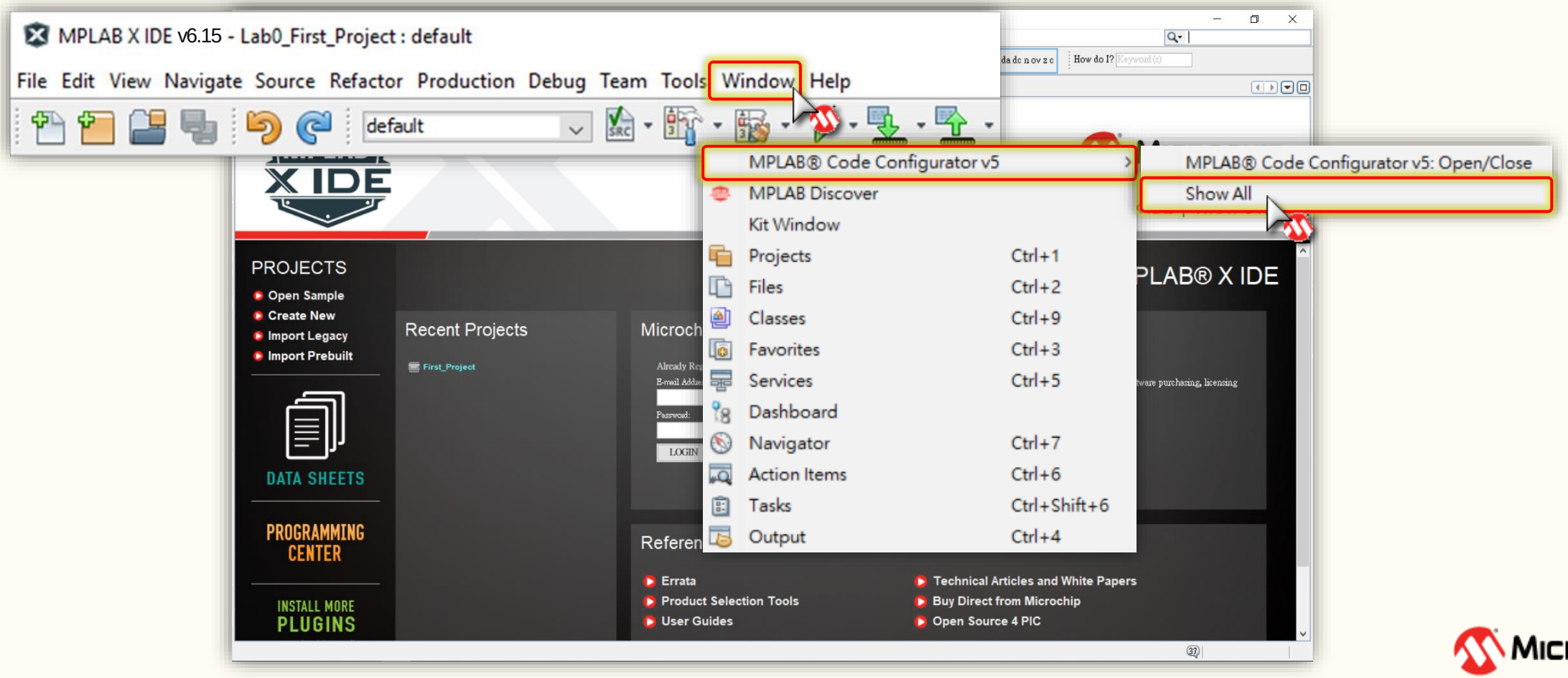
- **Too many windows, You may can’t find the window you want. MPLAB X IDE provide named "Reset Windows" to go back to default layout.**



MCC Hints

Tips

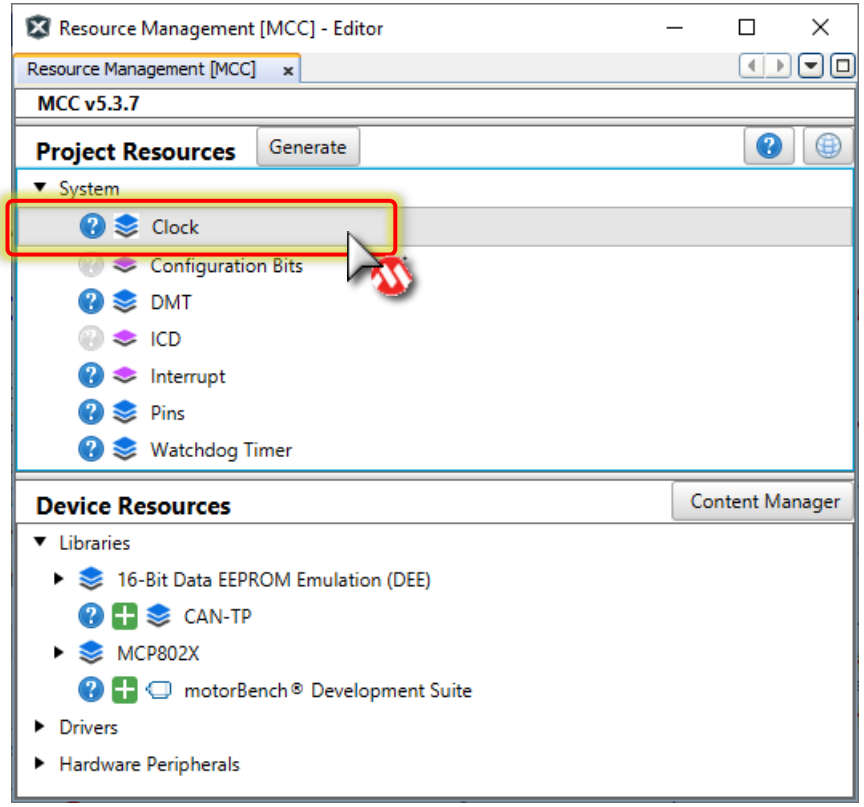
- **After Click MCC executed, you may can’t find the MCC window you want. MCC provide function named "Show All" to show all MCC windows.**

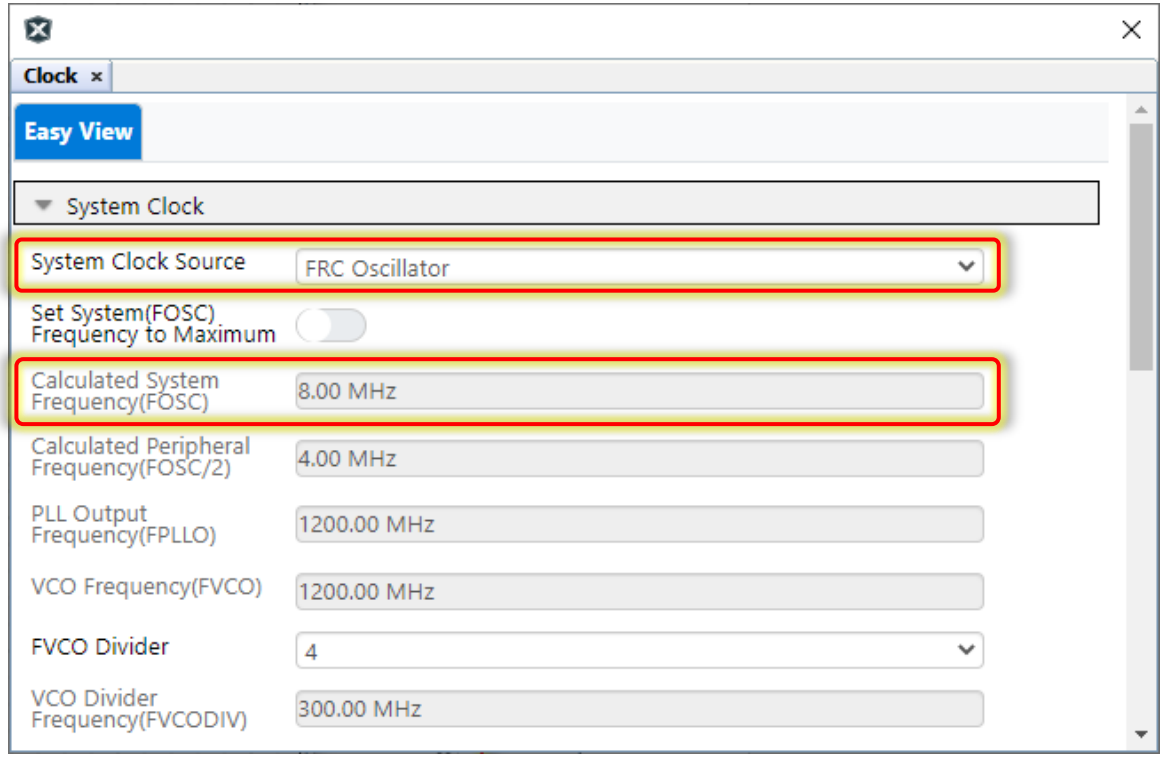


Lab1 GPIO Output

Lab Preparation

- **Check System Clock .**
  - **System Clock : System Clock Source: FRC Oscillator, FOSC: 8.00 MHz.**

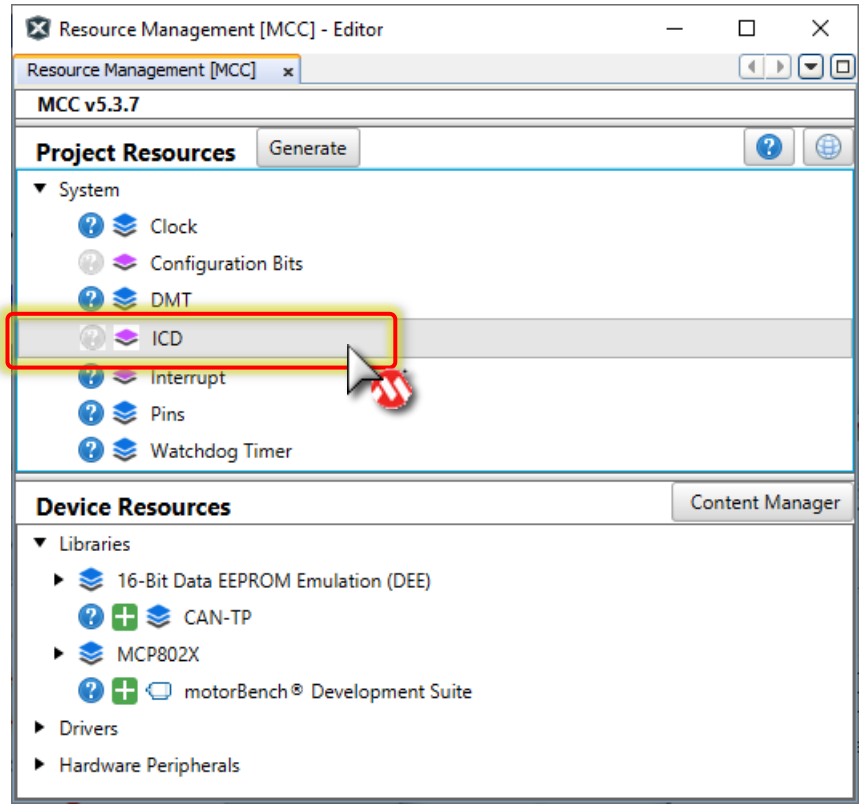


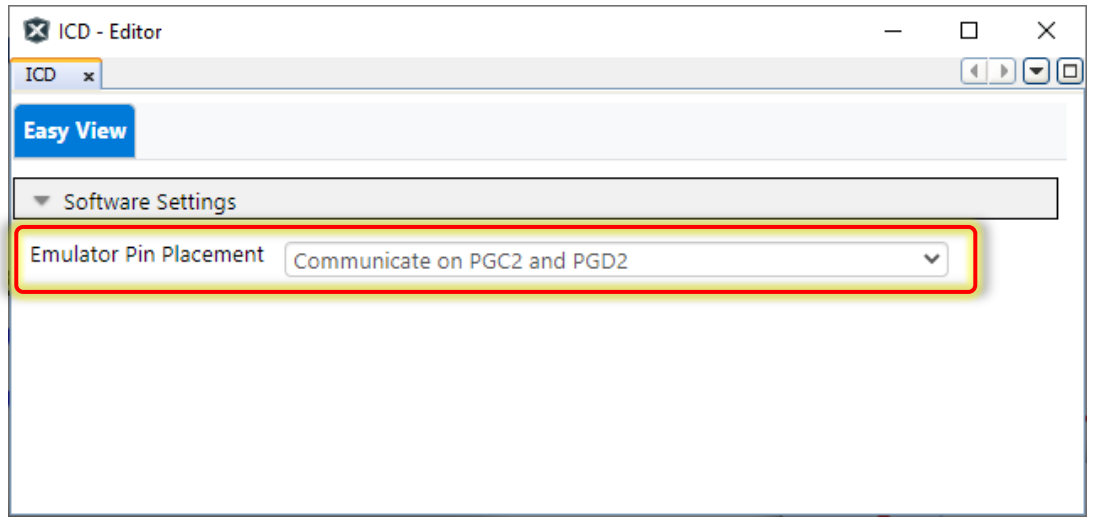


Lab1 GPIO Output

Lab Preparation

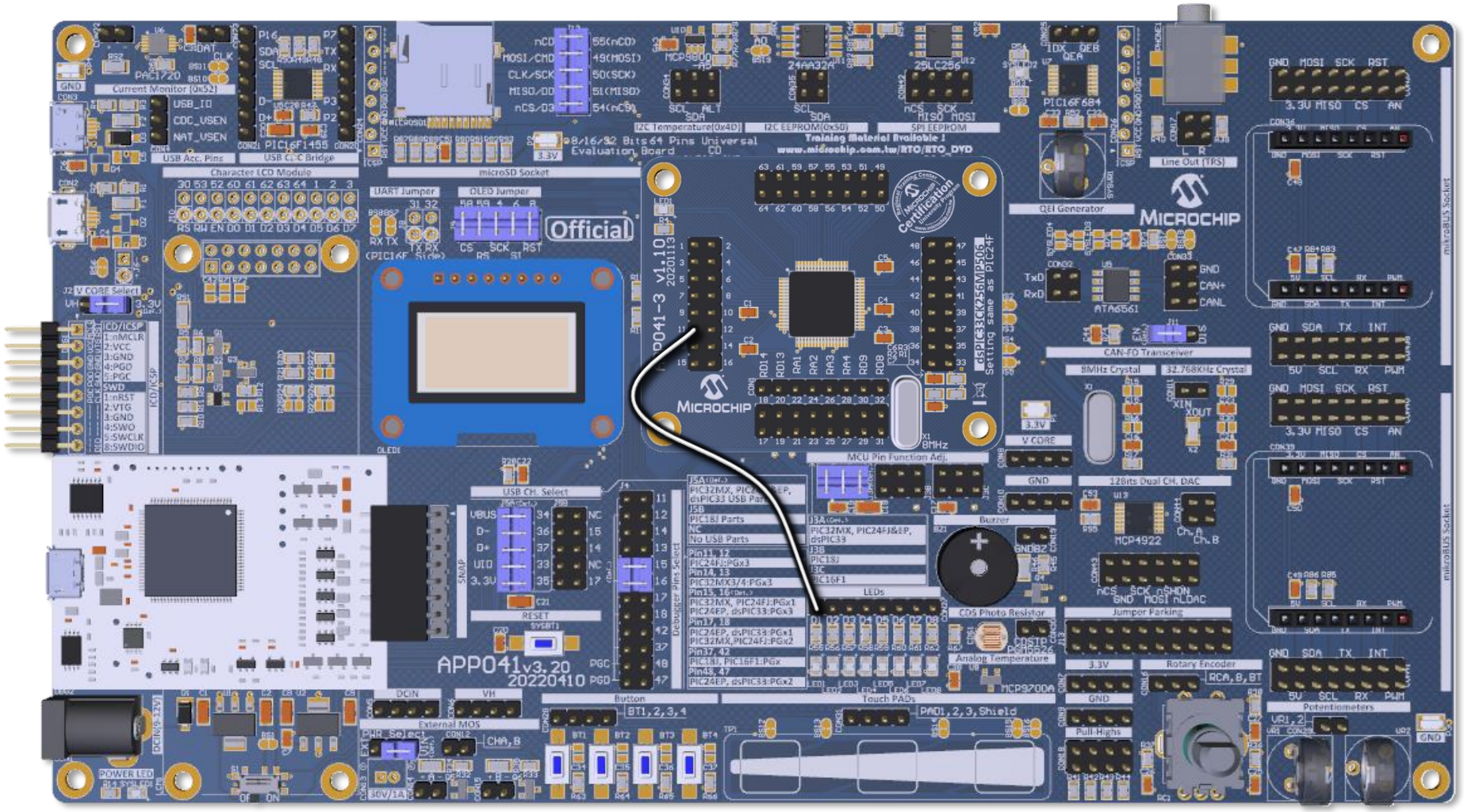
- **Set Debug Interface.**
  - **Software Settings: Emulator Pin Placement: Communicate on PGC2 and PGD2.**





Lab1 GPIO Output

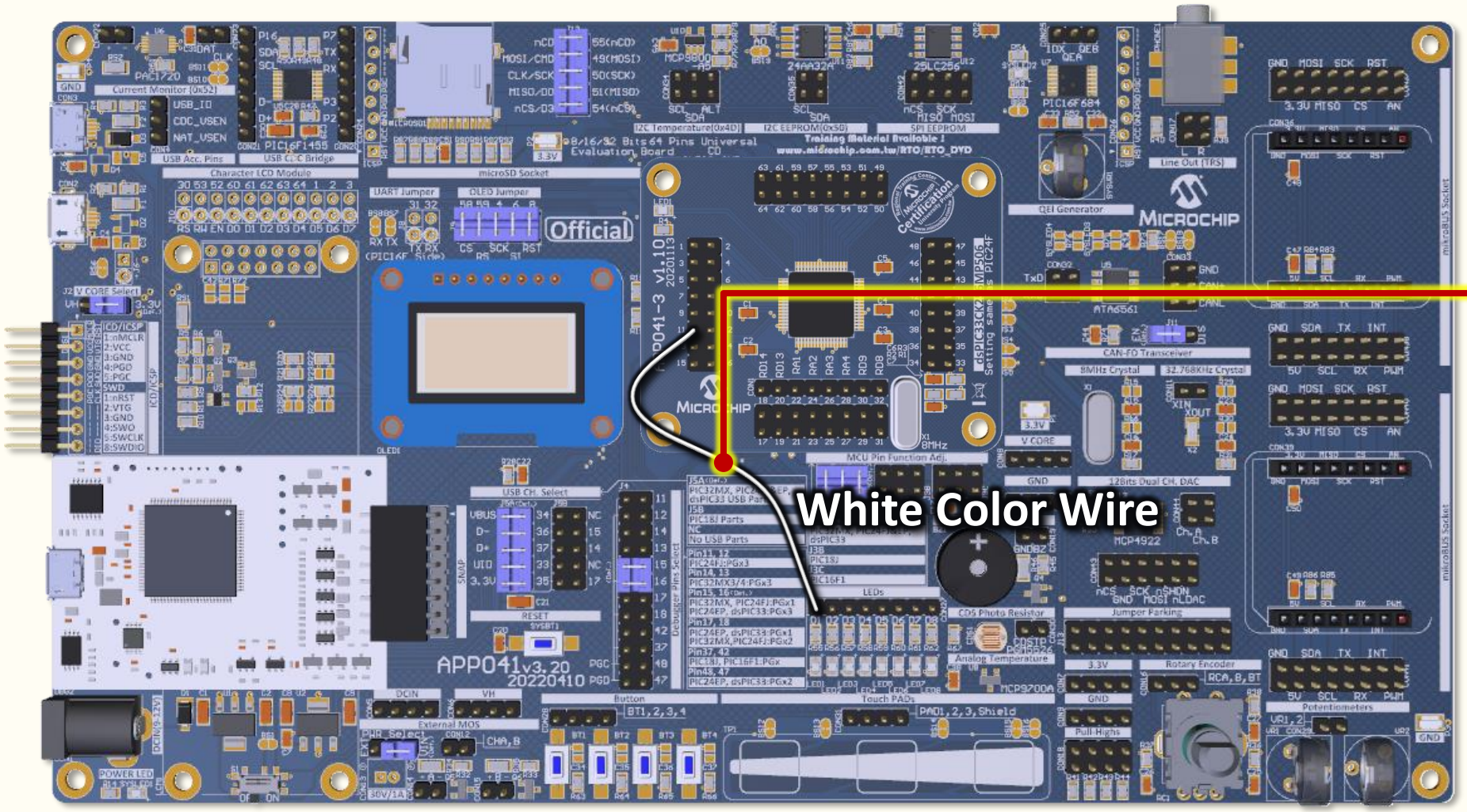
Connection



PIM Pin#		Symbol
11		D1

Lab1 GPIO Output

Note !! Please use the same color wire as presentation slide for easy following debug.



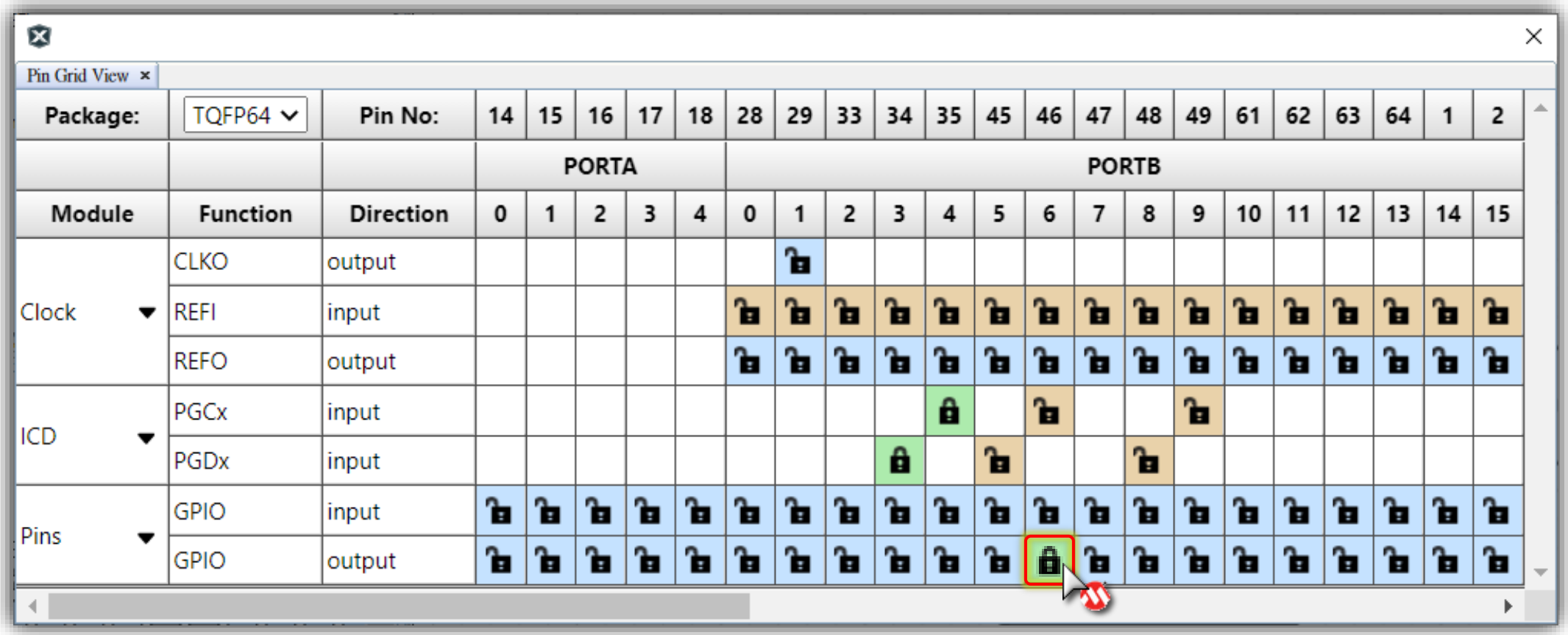
PIM Pin#	Symbol
11	D1

White Color Wire

Lab1 GPIO Output

Step 1

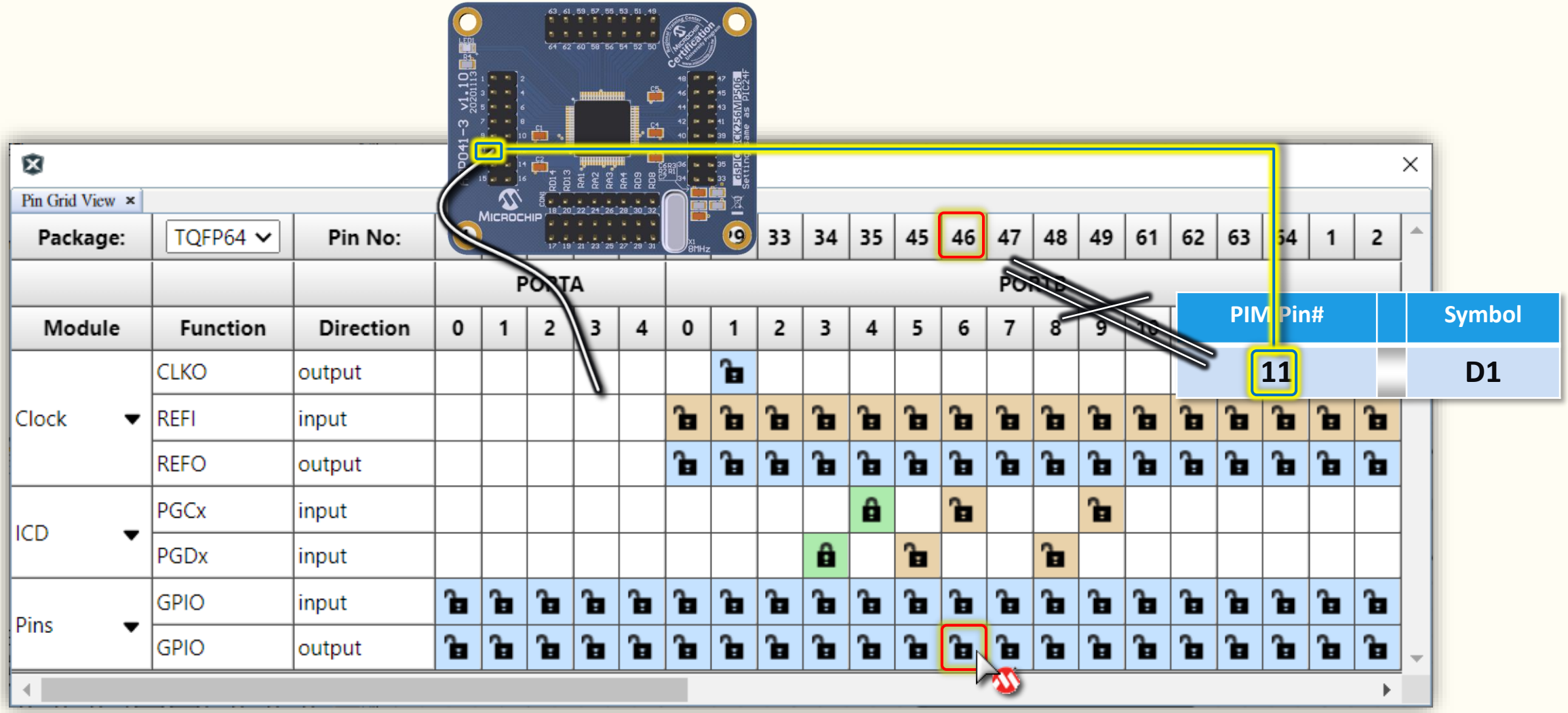
- Set PORTB : RB6 to digital output mode.
  - Pin Manager Gird View : Click RB6 to lock to GPIO output.



MICROCHIP

Lab1 GPIO Output

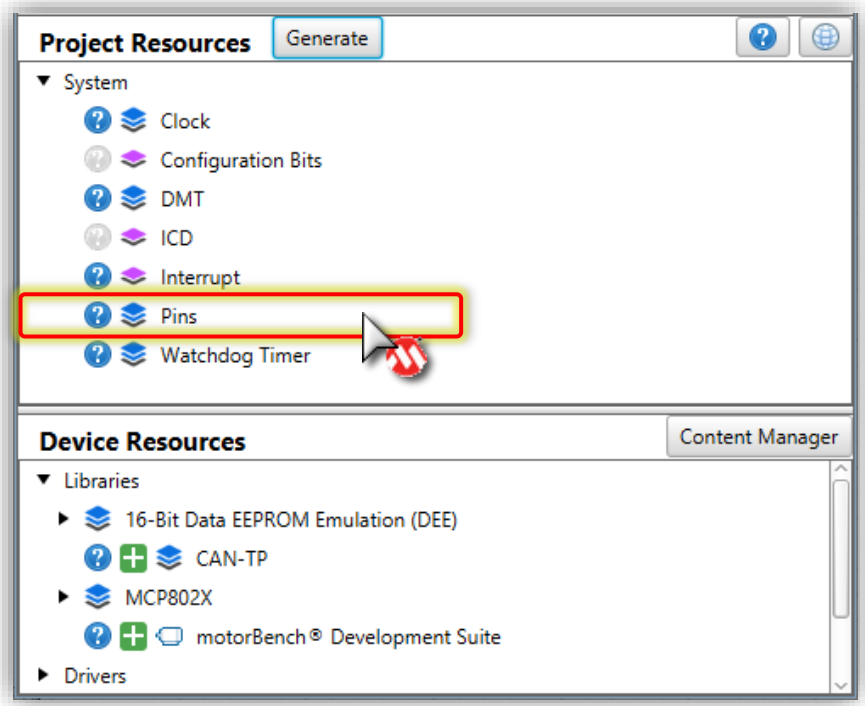
Note !! PIM's Pin number is not equal to real chip Pin number in MCC Pin Grid View.

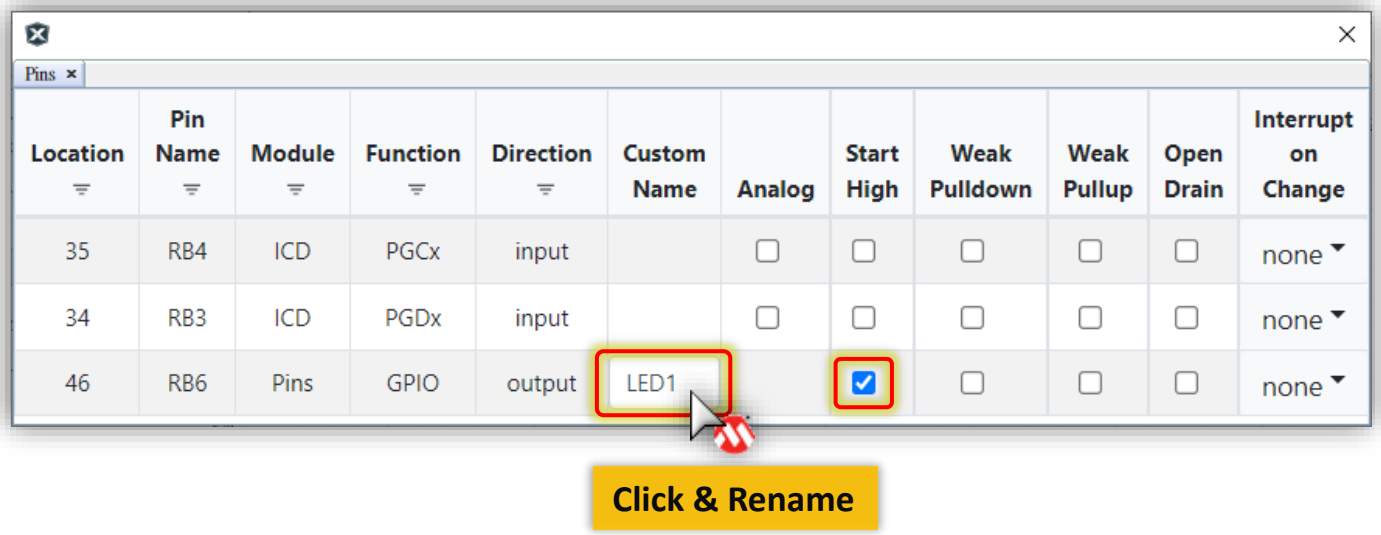


Lab1 GPIO Output

Step 2

- **Set Alias for RB6.**
  - **Pins : RB6 Custom Name → LED1, Check Output, Start High**

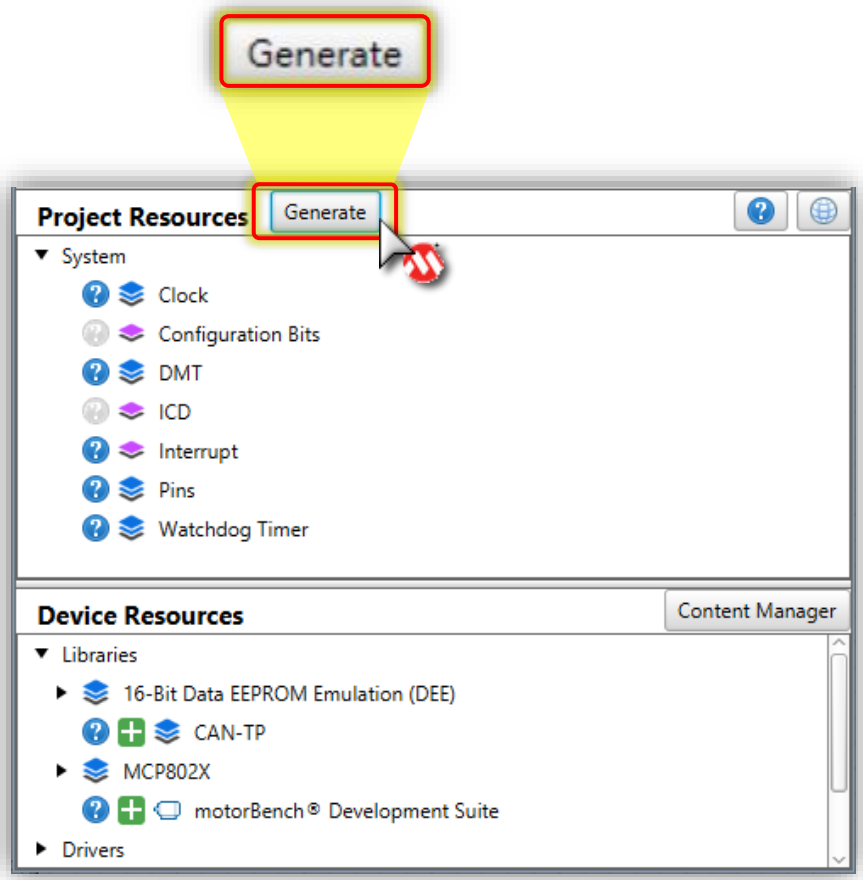


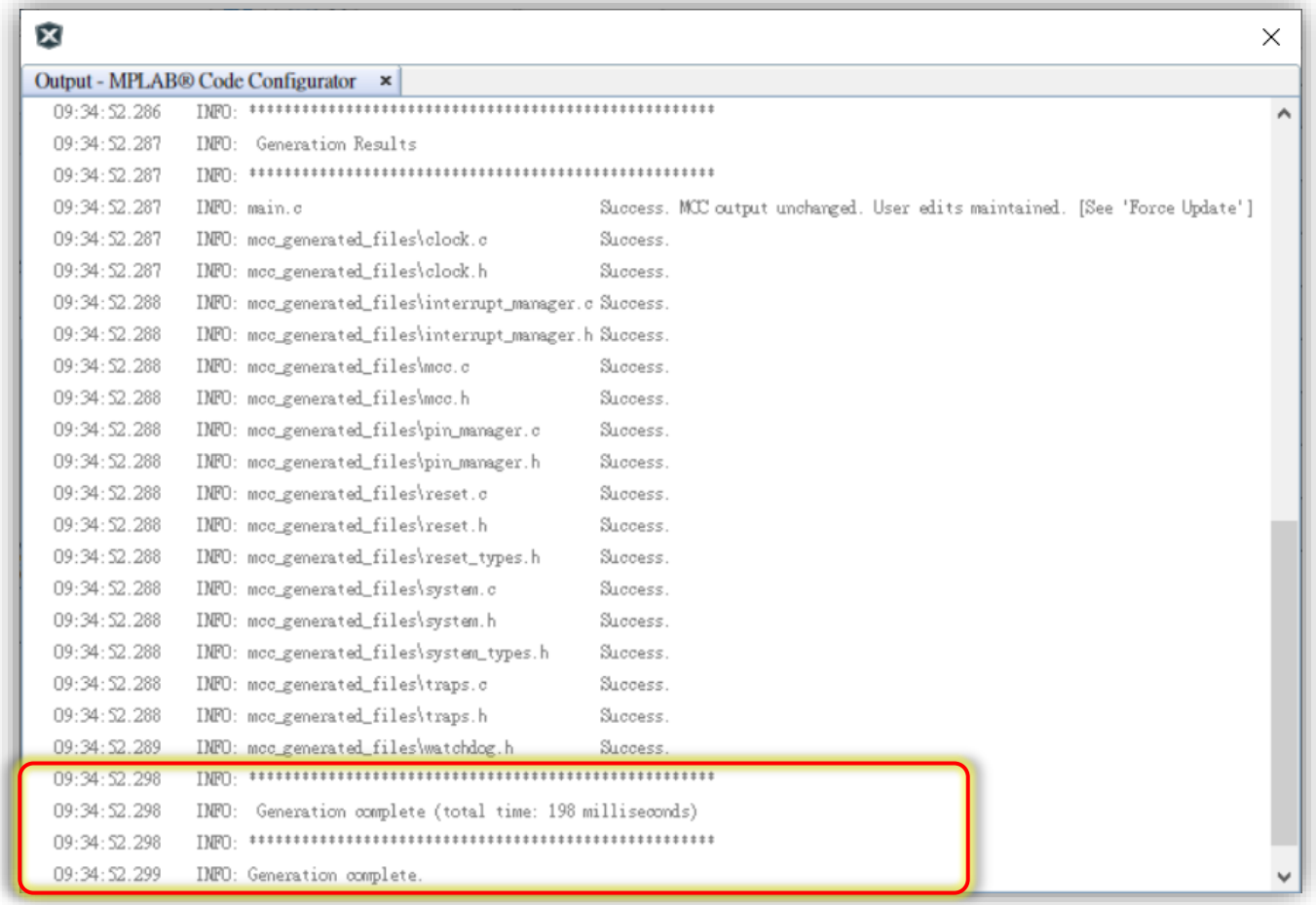


Lab1 GPIO Output

Step 3

- Click "Generate" Button to generate your code.

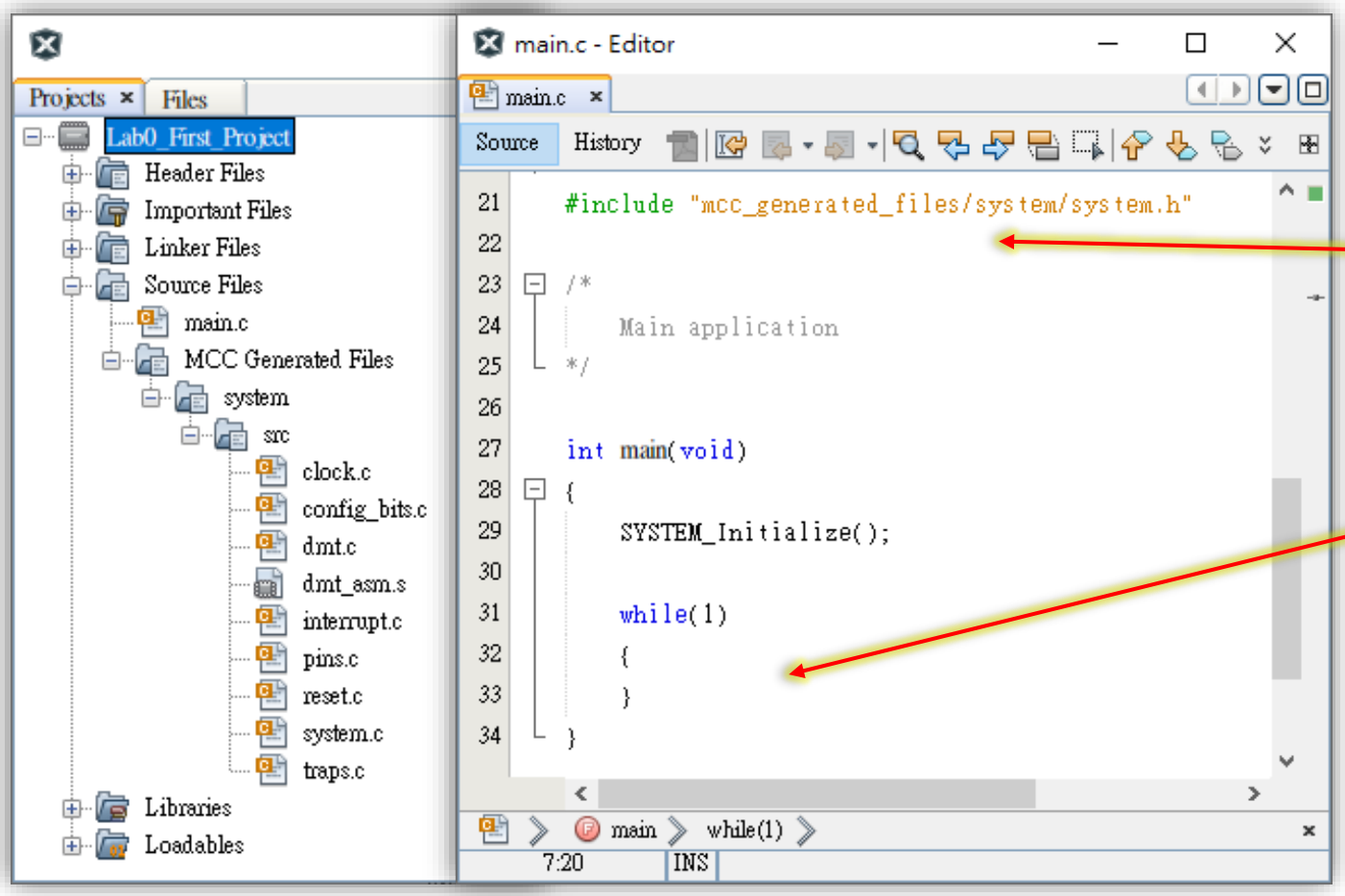




Lab1 GPIO Output

Step 4

- **Try to add code to main function double click "main.c" to view & and add below code segment in it.**



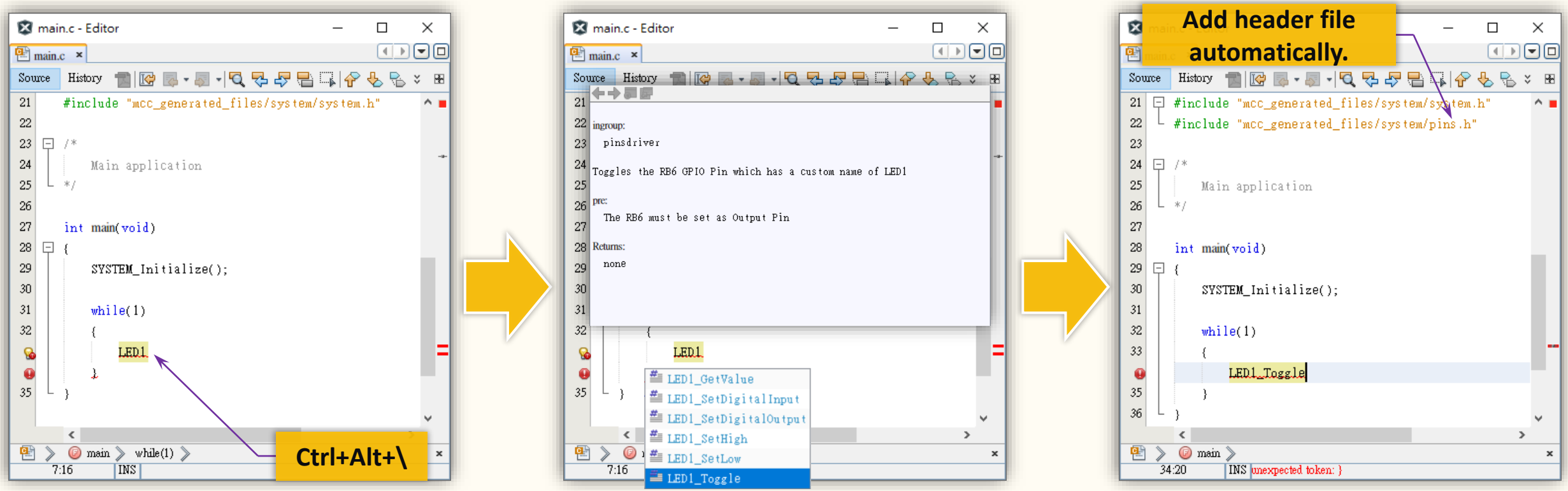
Add below code to main()

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        LED1_Toggle();
        for (i = 0; i < 80000; i++);
    }
}
```

MPLAB X IDE Hints

Tips

- **Hot key "Ctrl + Alt + \"**
  - **Type LED1 first, then use "Ctrl + Alt + \" to find you want.**



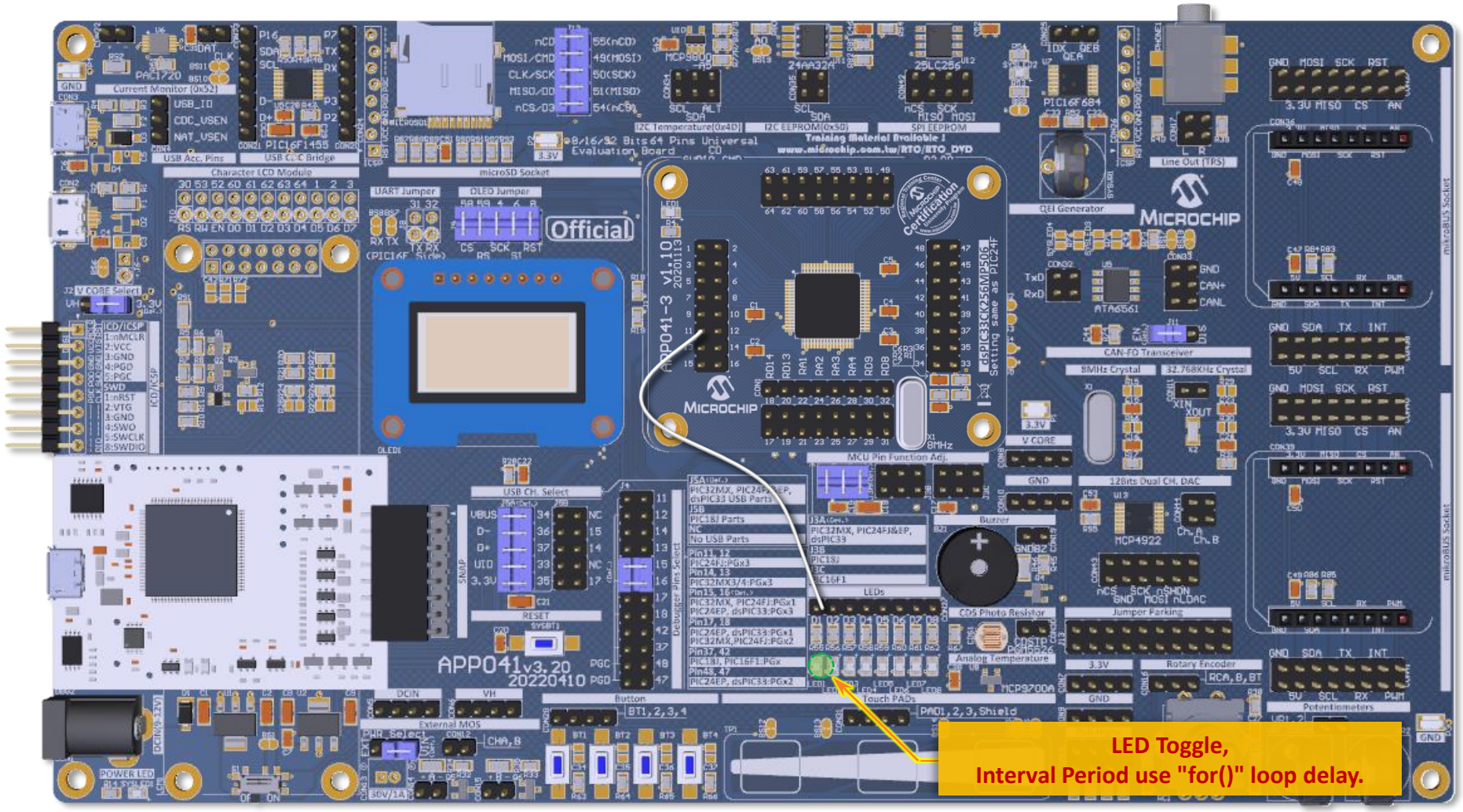
Lab1 GPIO Output

Code Example

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        LED1_Toggle();
        for (i = 0; i < 80000; i++);
    }
}
```

Lab1 GPIO Output

Result



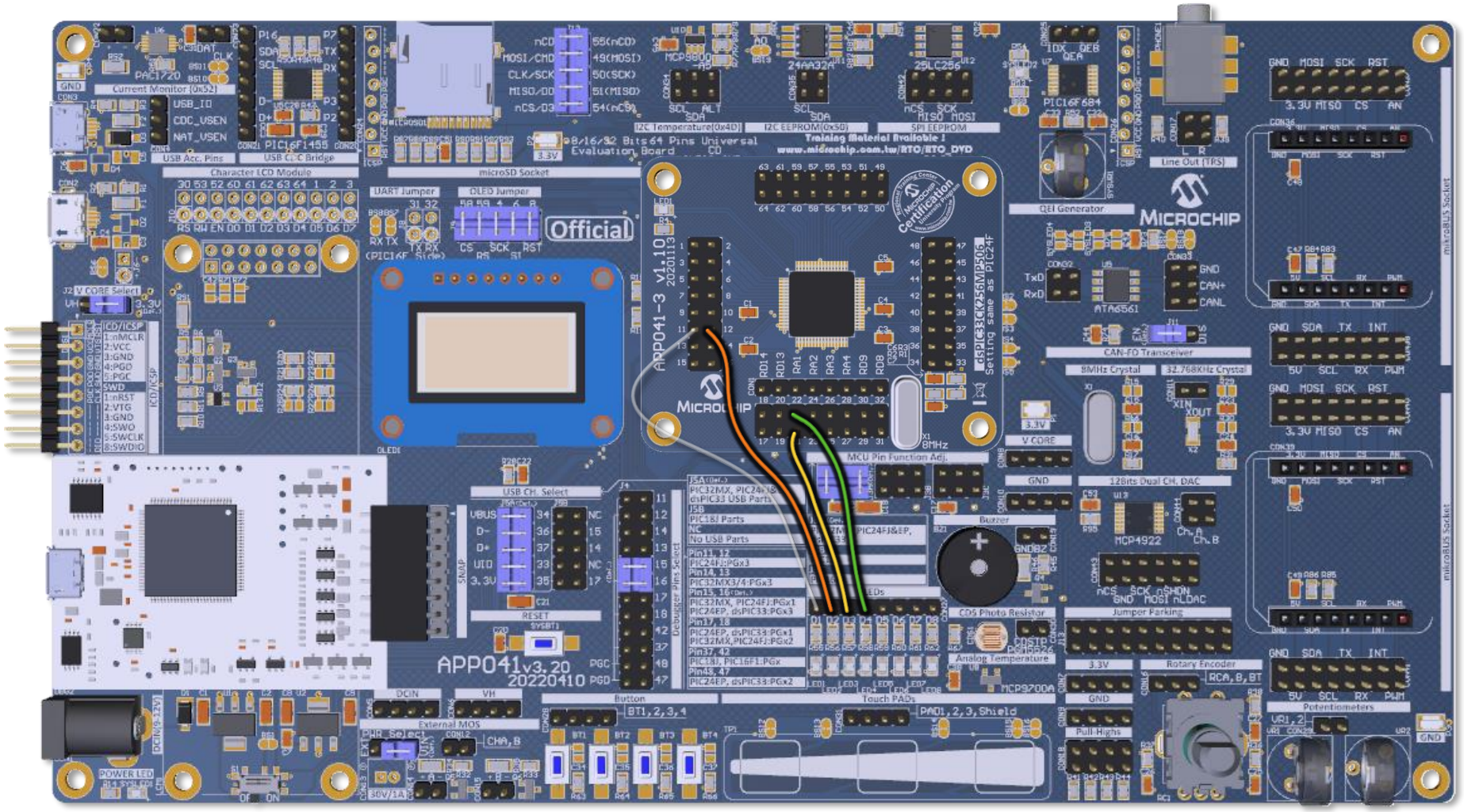
Lab2 Multi-GPIO Output

- Base on current project or Open .\Exercises\Lab2_xxx.X to do exercise.
- Try to set more GPIO pins to digital output mode and make LED flash alternately in period 500ms ~ 1s roughly.
- Please connect
  - RB5 (Pin12) to LED (LED2)
  - RC1 (Pin22) to LED (LED4)
  - RD12 (Pin21) to LED (LED3)

Let’s go!

Lab2 Multi-GPIO Output

Connection



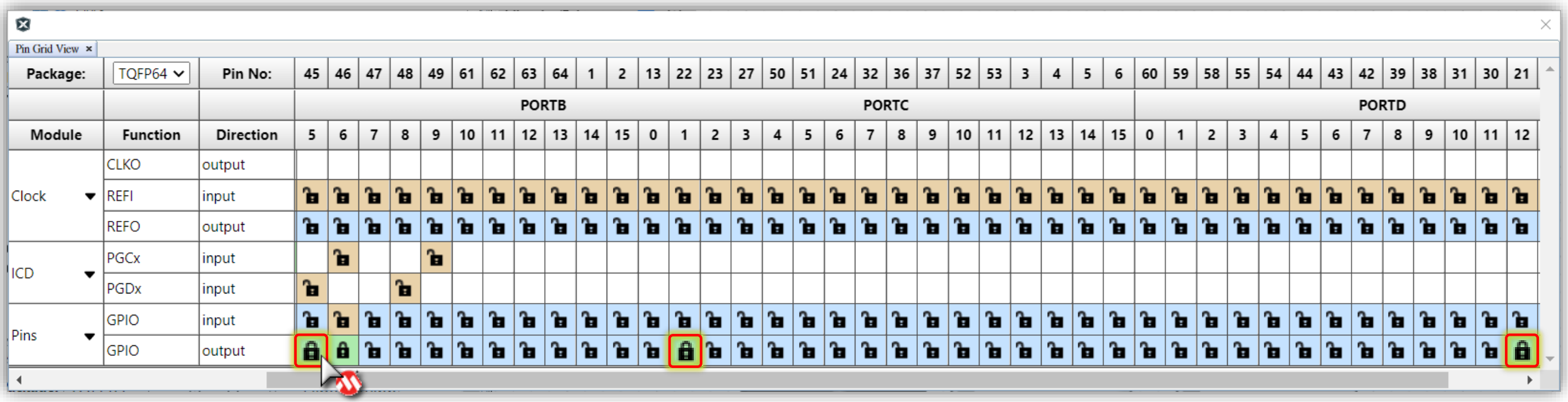
PIM Pin#		Symbol
12		D2
21		D3
22		D4

MICROCHIP

Lab2 Multi-GPIO Output

Step 1

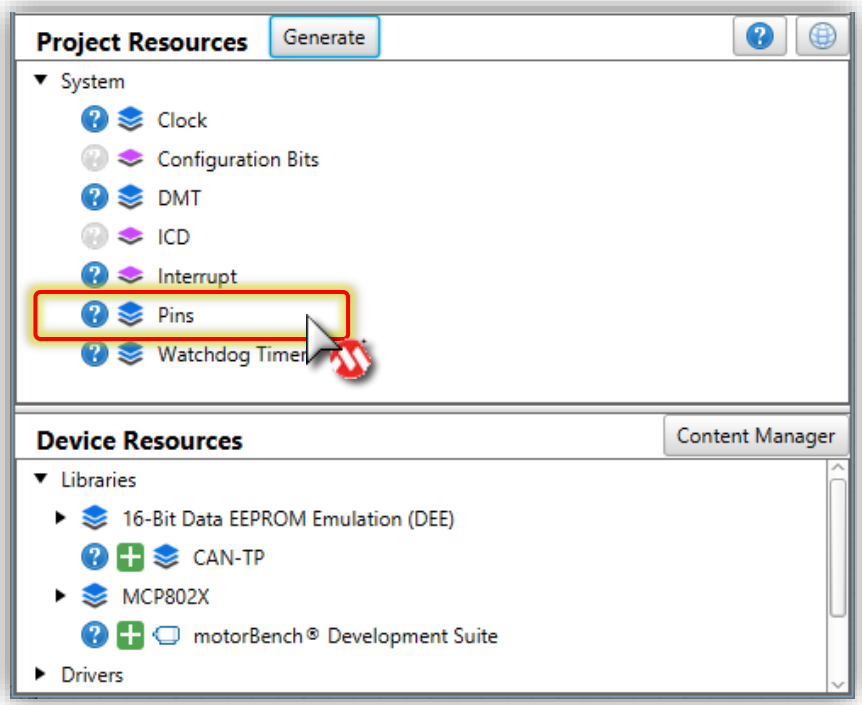
- Set **PORTB : RB5, PORTC : RC1, PORTD : RD12, to digital output mode.**

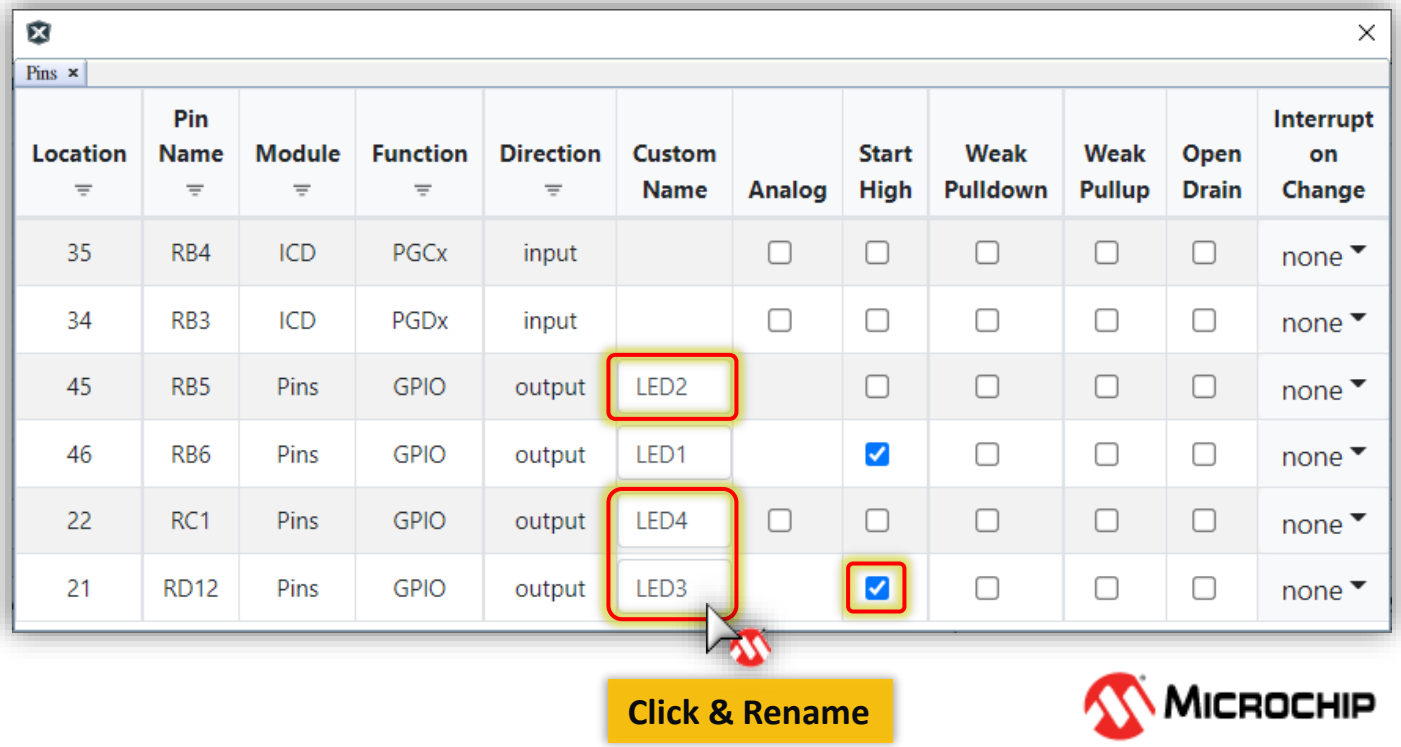


Lab2 Multi-GPIO Output

Step 2

- **Set Alias for RB5, RD12 and RC1.**
  - **Pins : RB5 Custom Name → LED2, Check Output**
  - **Pins : RD12 Custom Name → LED3, Check Output, Start High**
  - **Pins : RC1 Custom Name → LED4, Check Output**



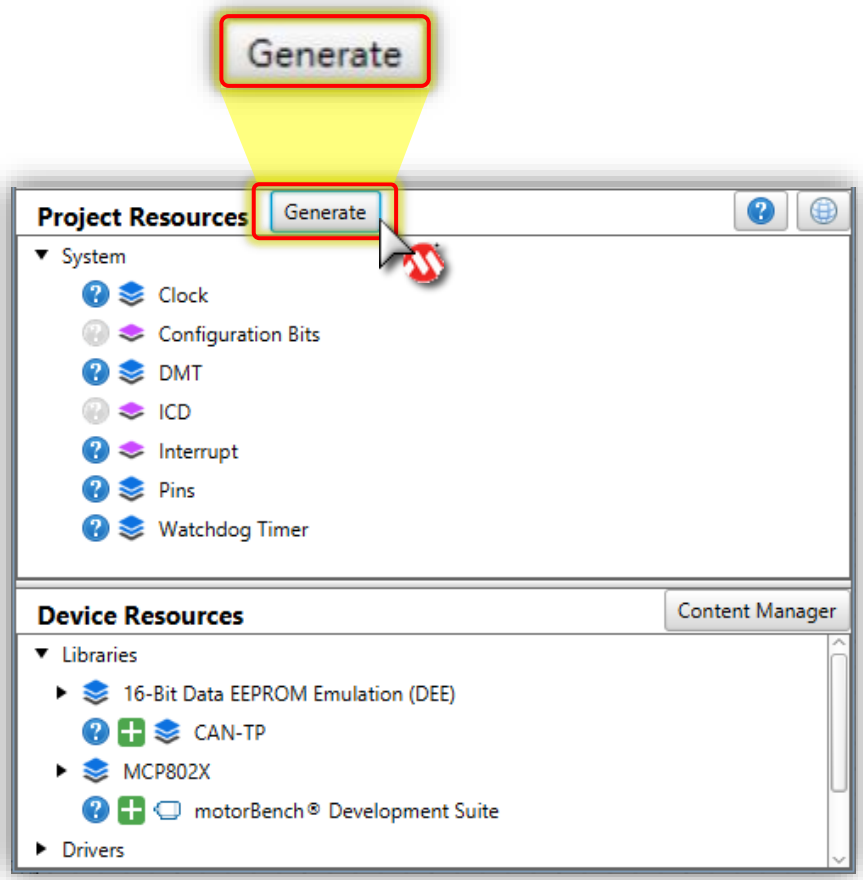


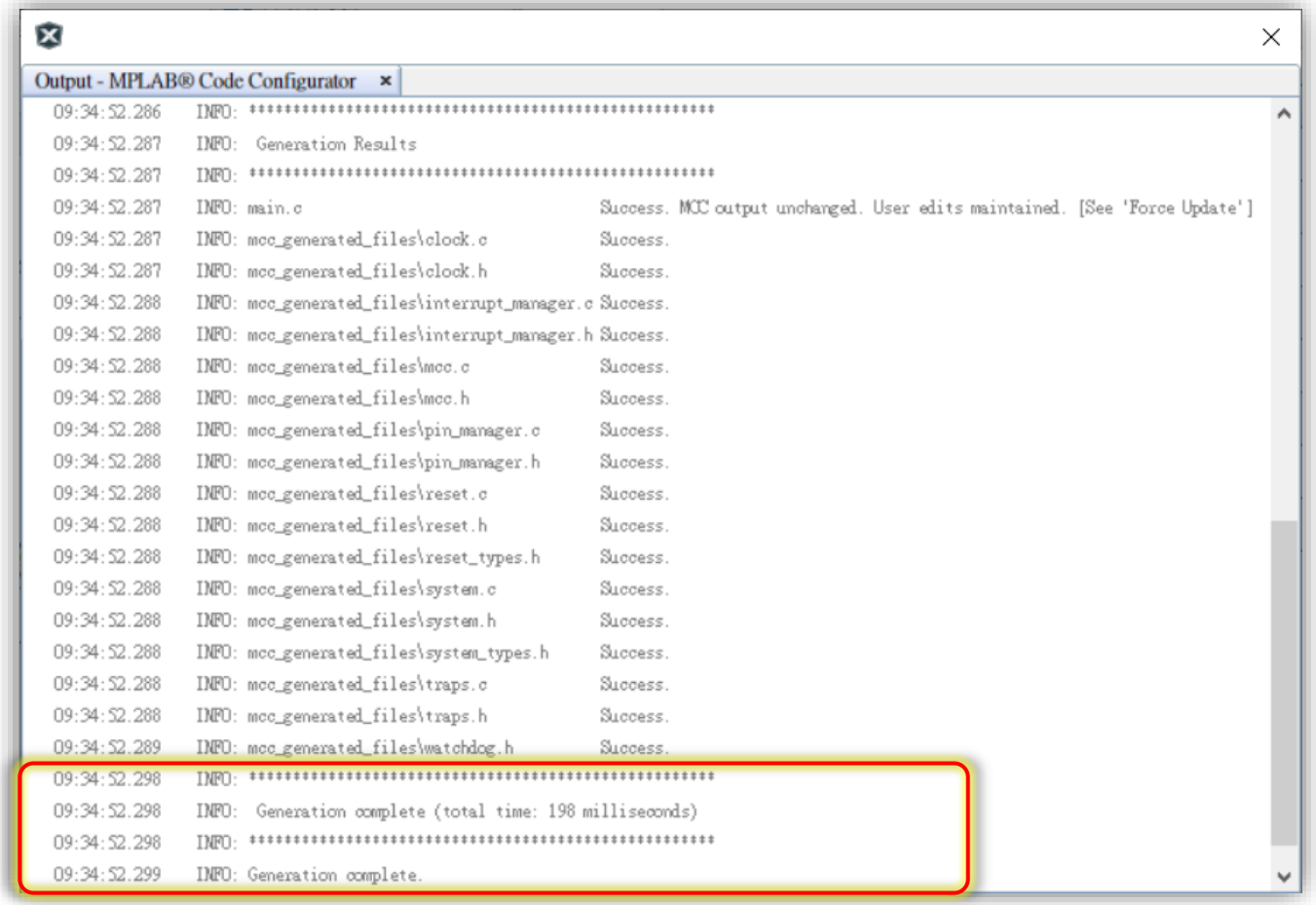
MICROCHIP

Lab2 Multi-GPIO Output

Step 3

- Click "Generate" Button to generate your code.





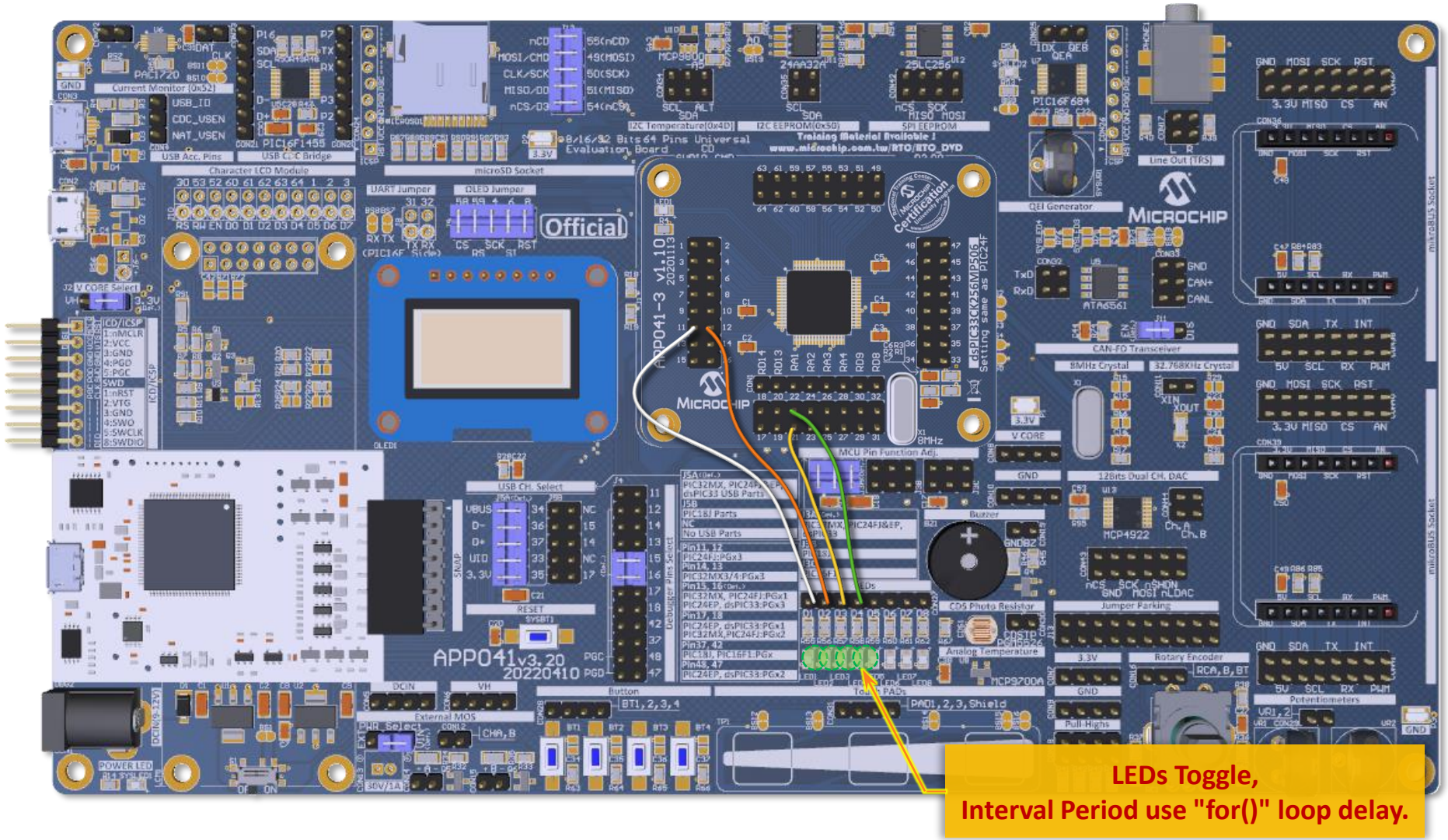
Lab2 Multi-GPIO Output

Code Example

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        LED1_Toggle();
        LED2_Toggle();
        LED3_Toggle();
        LED4_Toggle();
        for (i = 0; i < 80000; i++);
    }
}
```

Lab2 Multi-GPIO Output

Result



Lab3 GPIO Input

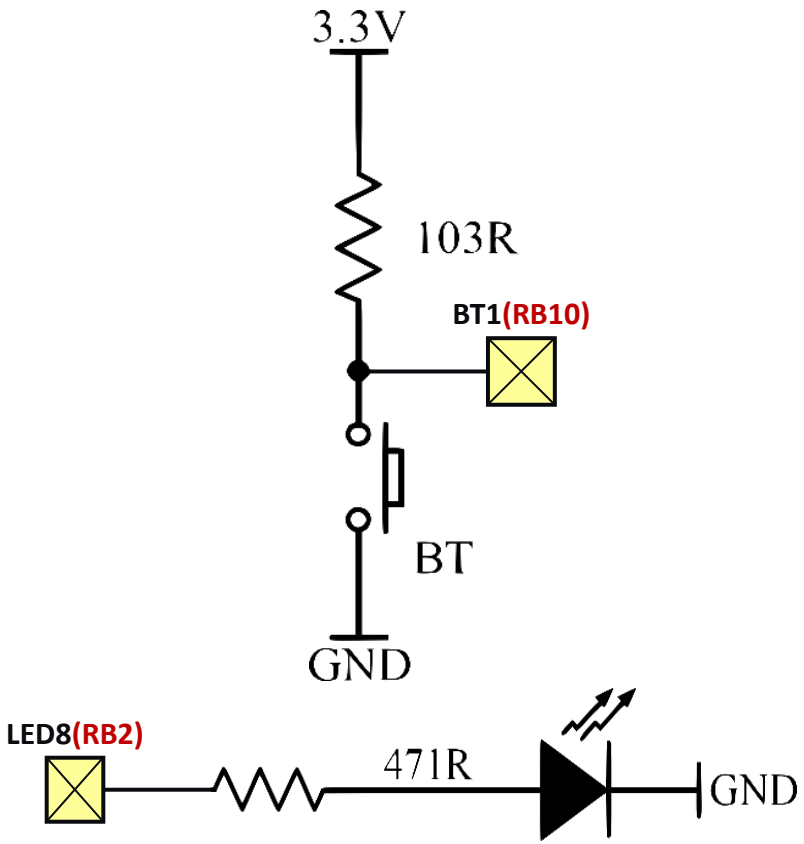
- **Base on current project or Open .\Exercises\Lab3_xxx.X to do exercise.**
- **Try to set RB10 (Pin61) to digital input as get button status.**
- **Try use button to control LED light or dark.**
  - **BT1** Pressed → **LED8** Light.
  - **BT1** Released → **LED8** Dark.
- **Please connect**
  - **RB10 (Pin61)** to **Button (BT1)**,
  - **RB2 (Pin33)** to **LED (LED8)**.

Let’s go!

MICROCHIP

Lab3 GPIO Input

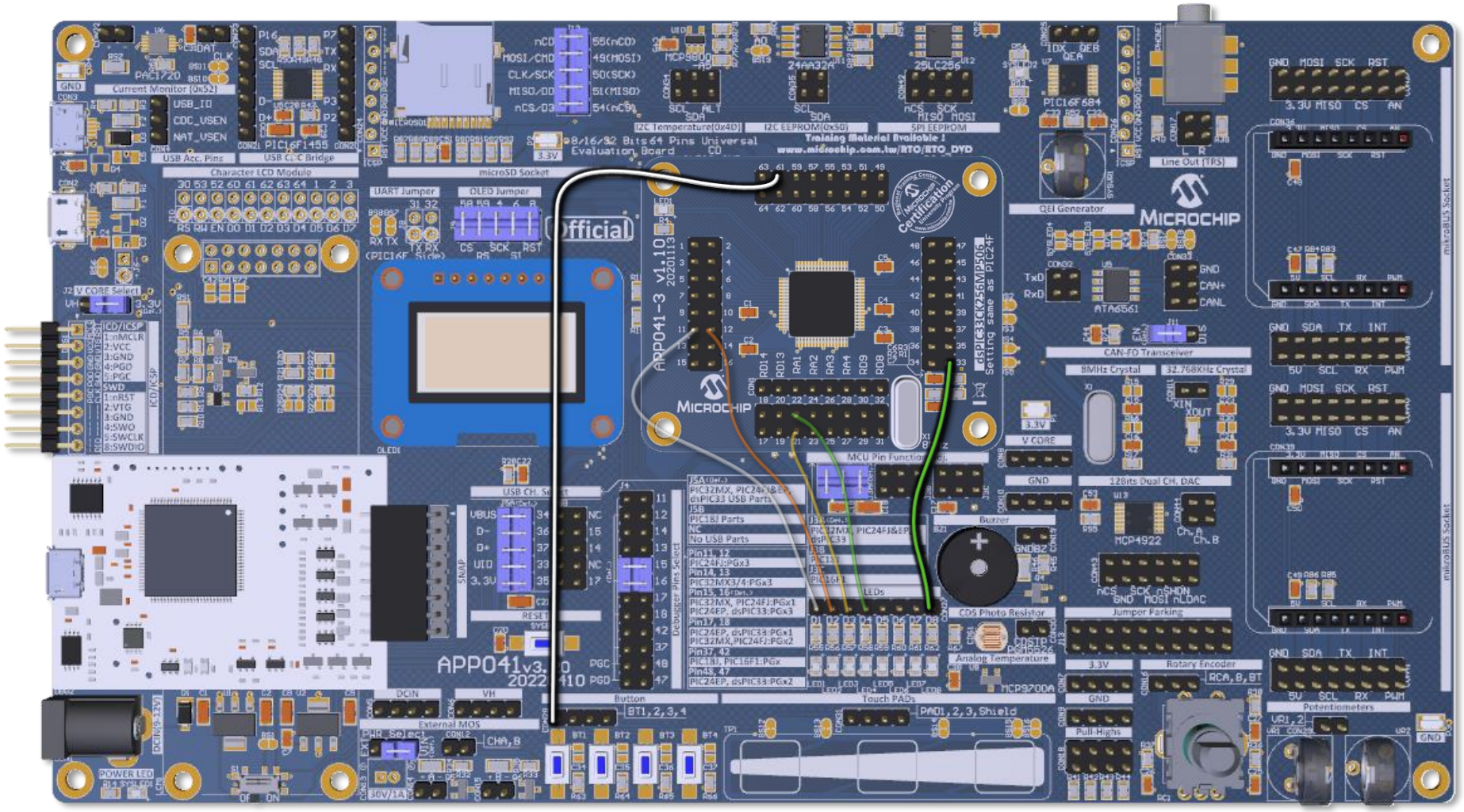
- *CustomName*_GetValue(); function is used for get digital input level from outside. The simple example code shows below:




```
if(BT1_GetValue())
{
   LED8_SetLow();
}
else
{
   LED8_SetHigh();
}
```

Lab3 GPIO Input

Connection

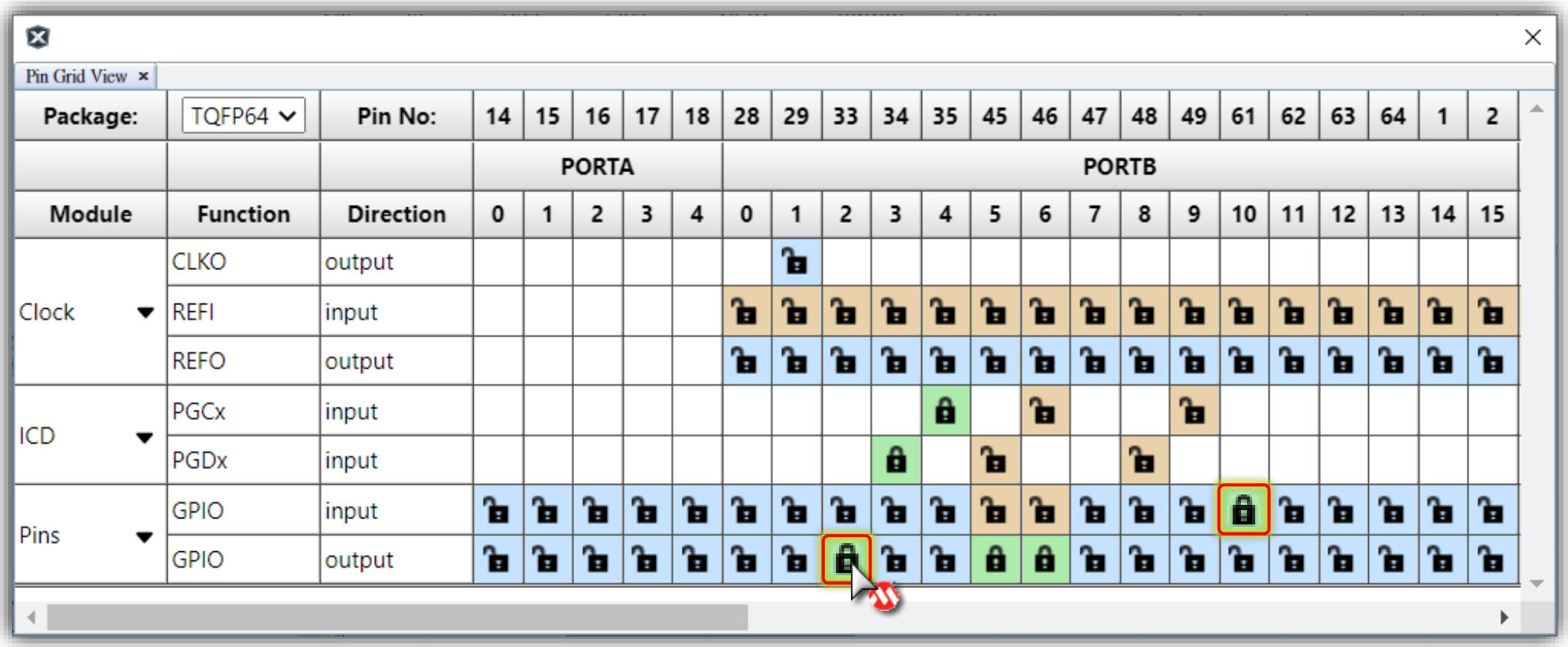


PIM Pin#		Symbol
61		BT1
33		D8

Lab3 GPIO Input

Step 1

- Set PORTB : RB2 to digital output mode.
- Set PORTB : RB10 to digital input mode.

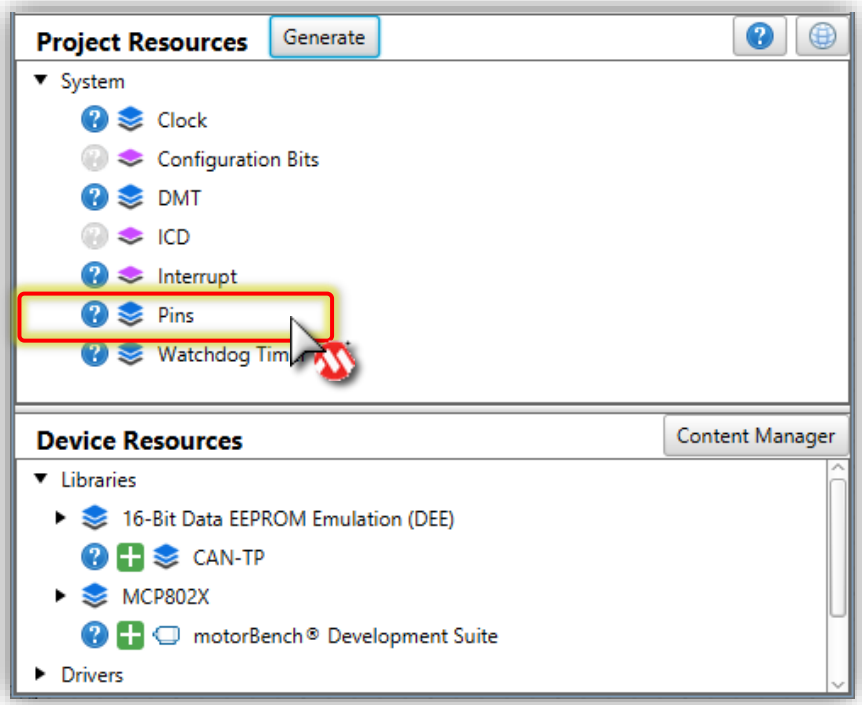


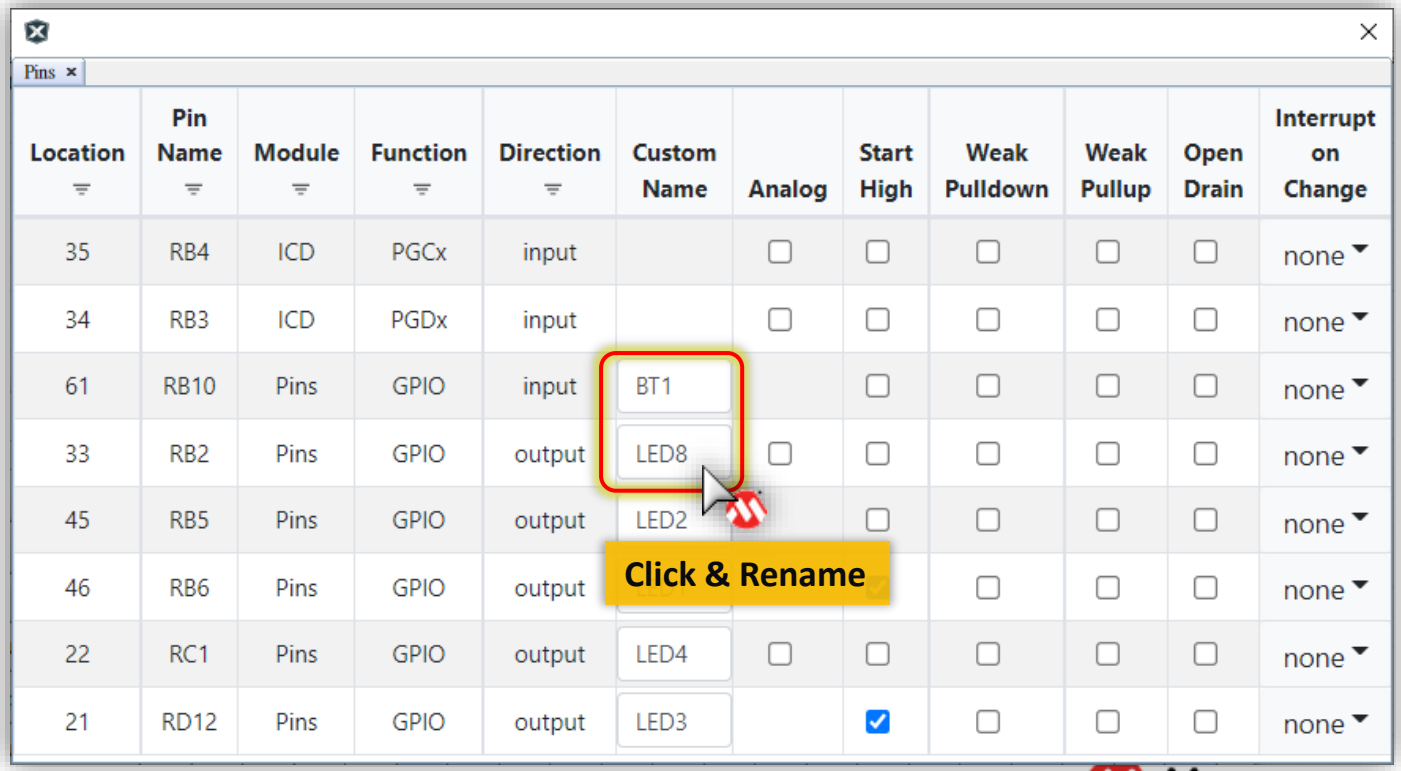
MICROCHIP

Lab3 GPIO Input

Step 2

- **Set Alias for RB2 and RB10.**
  - **Pins : RB2 Custom Name → LED8, Check Output**
  - **Pins : RB10 Custom Name → BT1, Check Input**

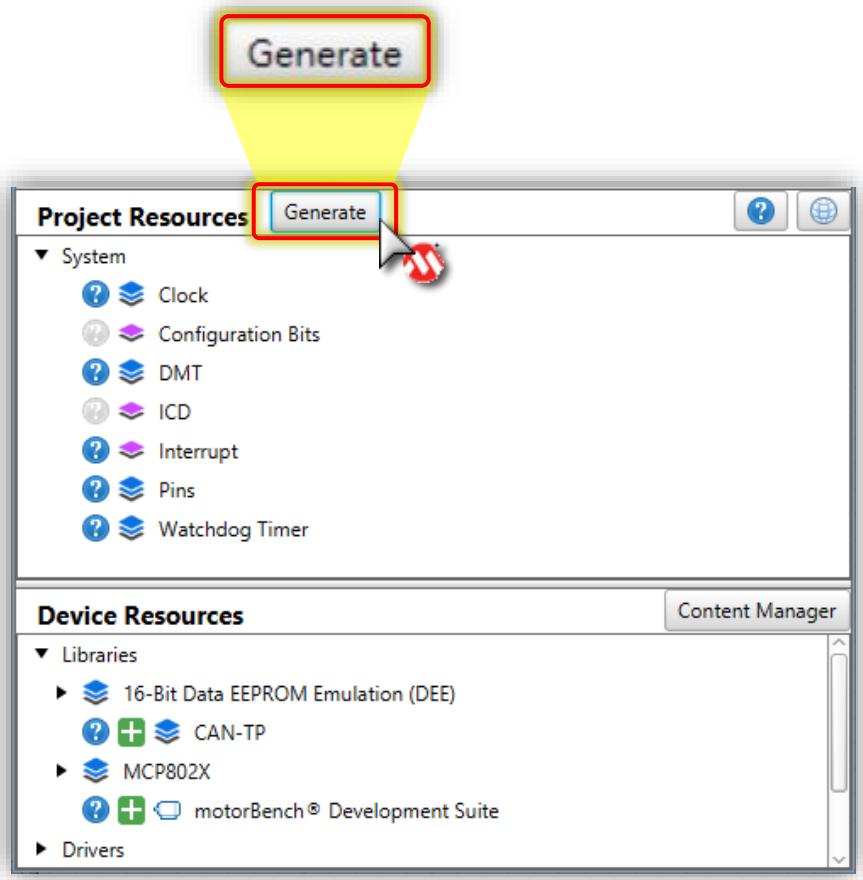


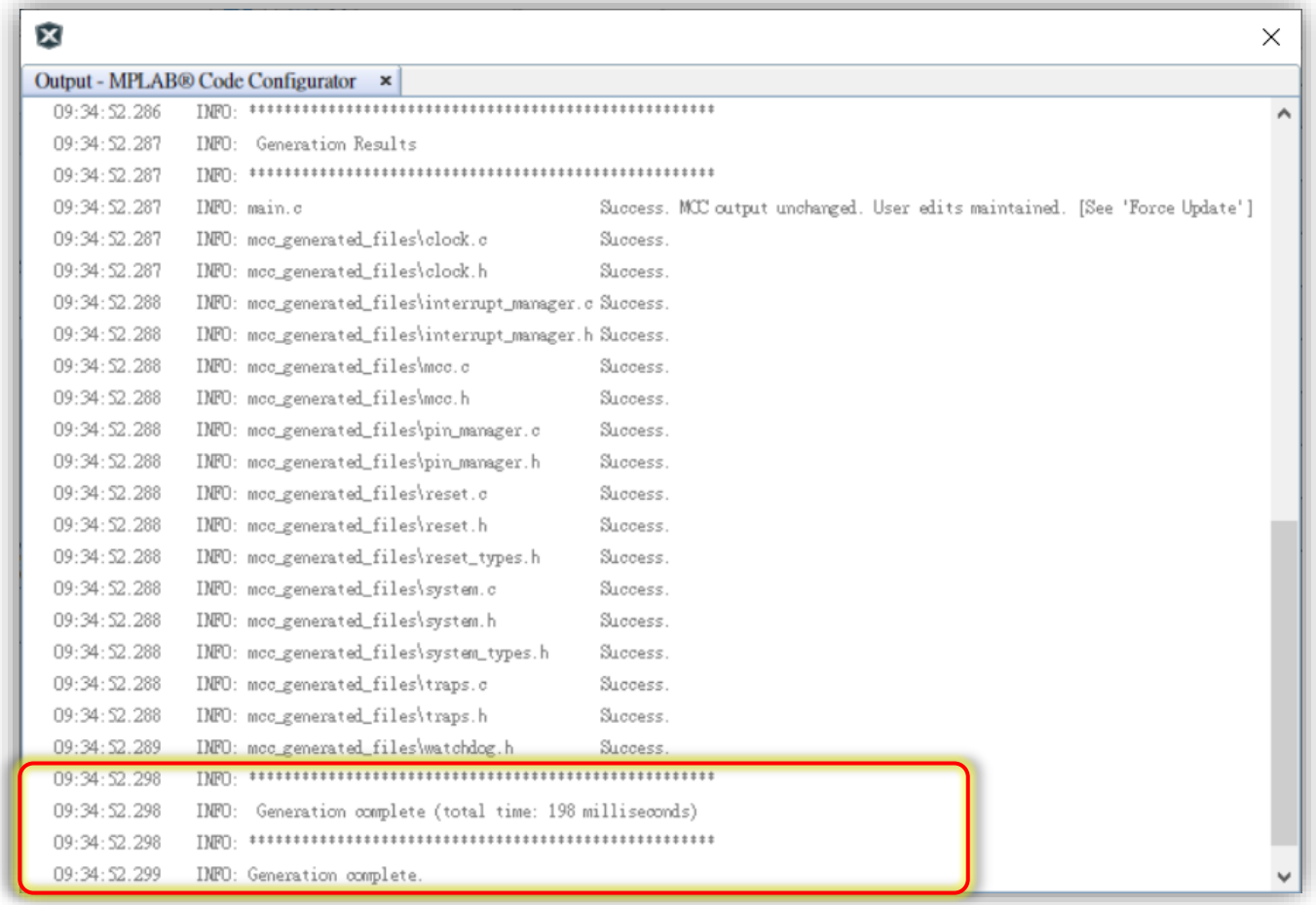


Lab3 GPIO Input

Step 3

- Click "Generate" Button to generate your code.





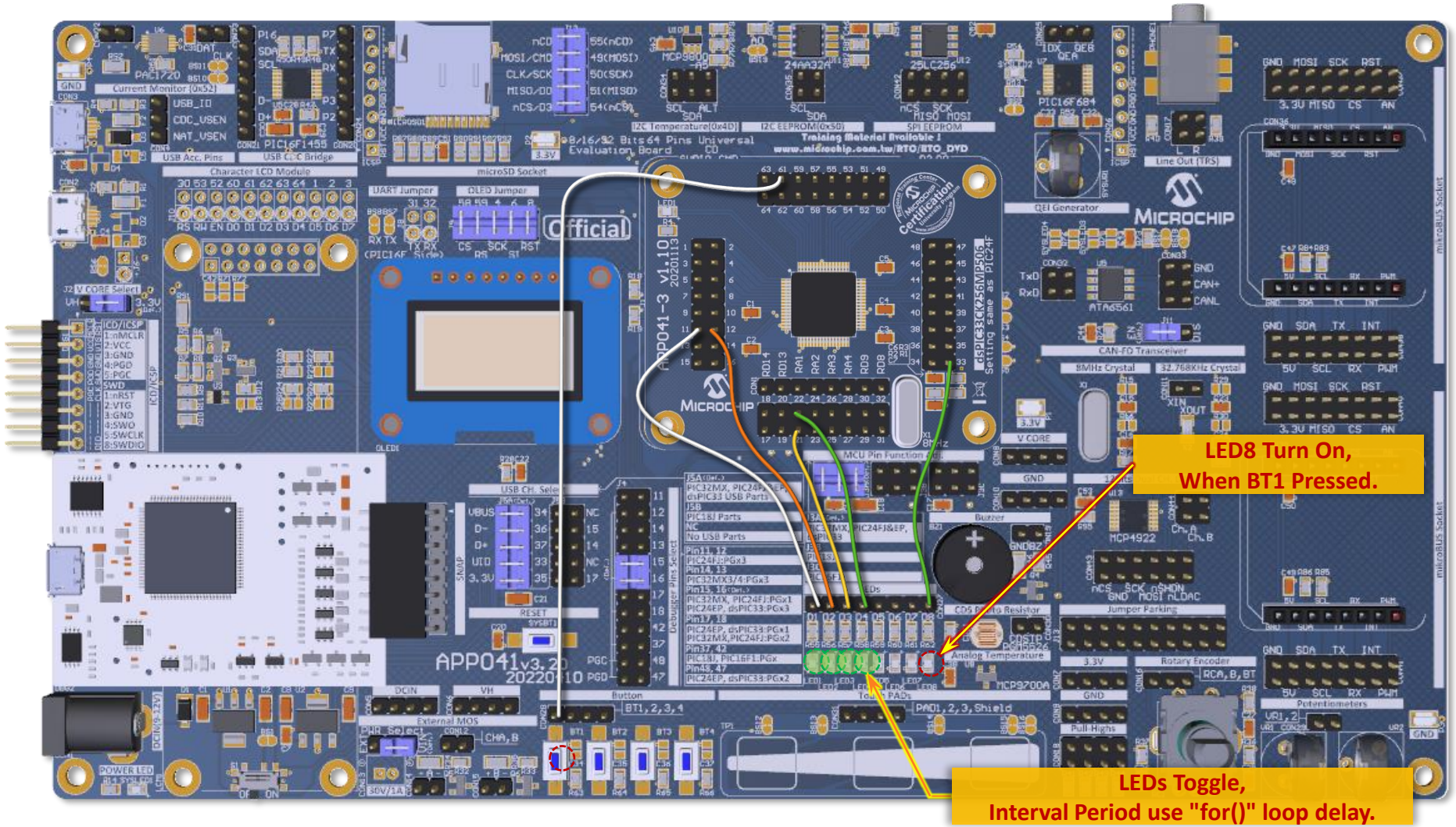
Lab3 GPIO Input

Code Example

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        LED1_Toggle();
        LED2_Toggle();
        LED3_Toggle();
        LED4_Toggle();
        for (i = 0; i < 80000; i++);

        if(BT1_GetValue())
            LED8_SetLow();
        else
            LED8_SetHigh();
    }
}
```

Lab3 GPIO Input

Result



Lab3 GPIO Input

Button Response Discuss

- **Button Response Time Issue ?**
  The software delay will influence the polling interval.
  Try to change coding style to state machine mode.

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        LED1_Toggle();
        LED2_Toggle();
        LED3_Toggle();
        LED4_Toggle();
        for (i = 0; i < 80000; i++);

        if(BT1_GetValue())
            LED8_SetLow();
        else
            LED8_SetHigh();
    }
}
```

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        if( i++ > 80000 )
        {
            i = 0;
            LED1_Toggle();
            LED2_Toggle();
            LED3_Toggle();
            LED4_Toggle();
        }

        if(BT1_GetValue())
            LED8_SetLow();
        else
            LED8_SetHigh();
    }
}
```

MICROCHIP

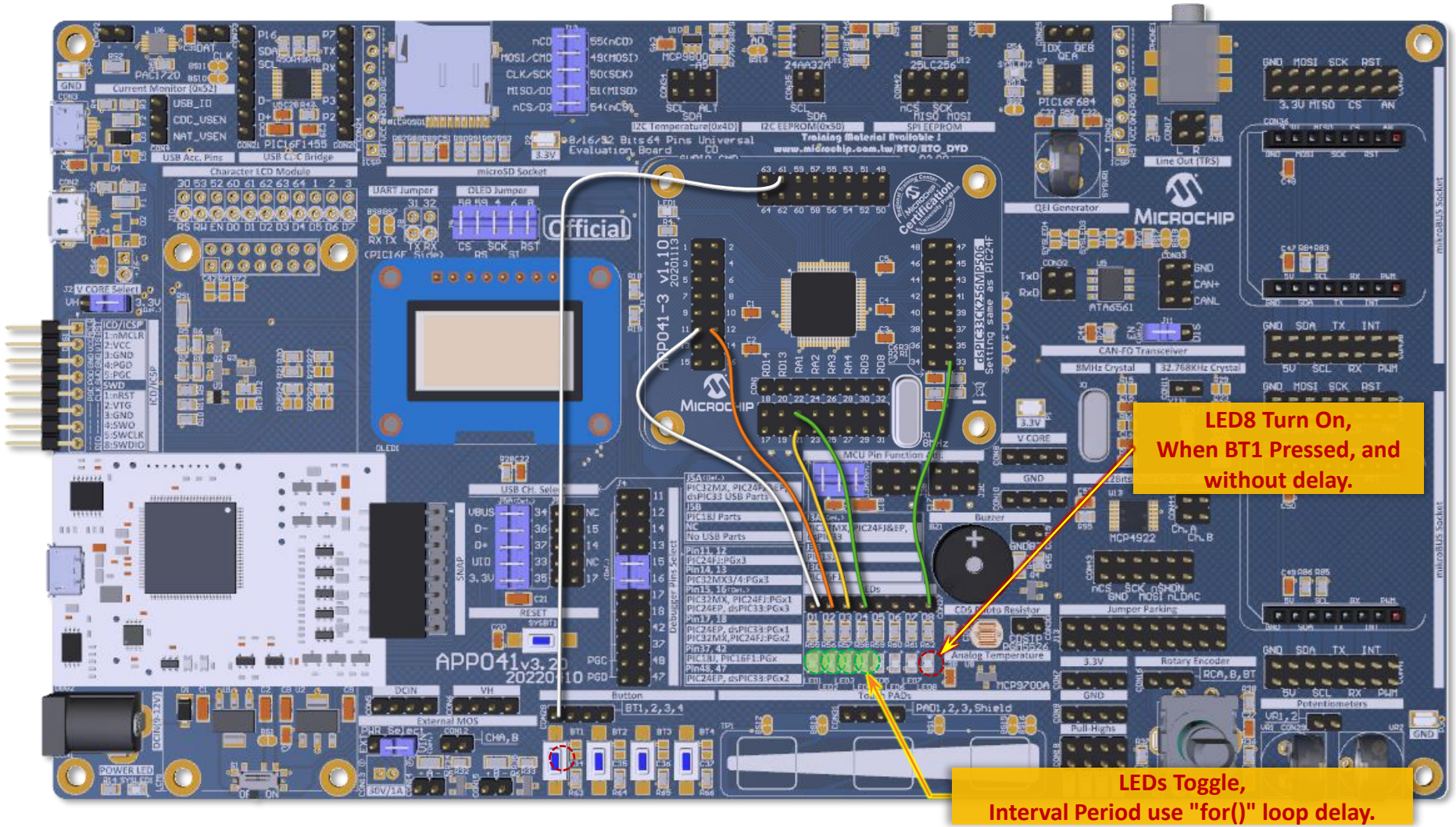
Lab3 GPIO Input

Code Example (State Machine)

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"

uint32_t  i = 0;

int main(void)
{
    SYSTEM_Initialize();

    while (1)
    {
        if( i++ > 80000 )
        {
            i = 0;
            LED1_Toggle();
            LED2_Toggle();
            LED3_Toggle();
            LED4_Toggle();
        }

        if(BT1_GetValue())
            LED8_SetLow();
        else
            LED8_SetHigh();
    }
}
```

Lab3 GPIO Input

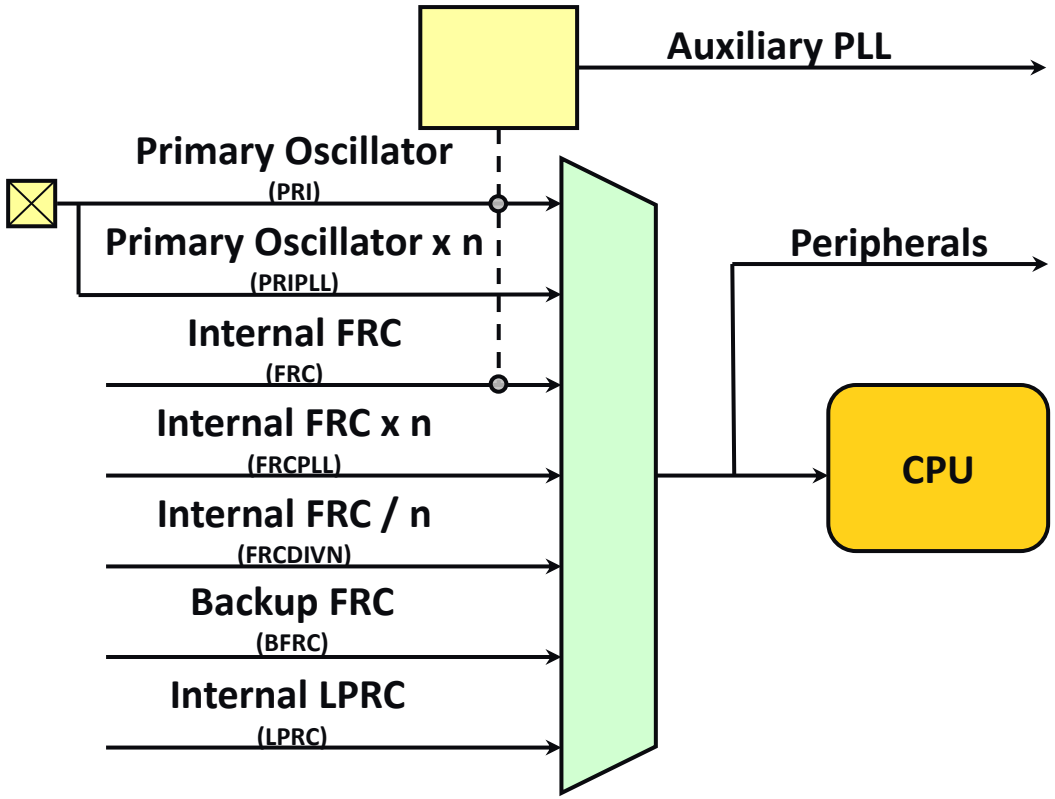
Result (State Machine)



Oscillator Architecture

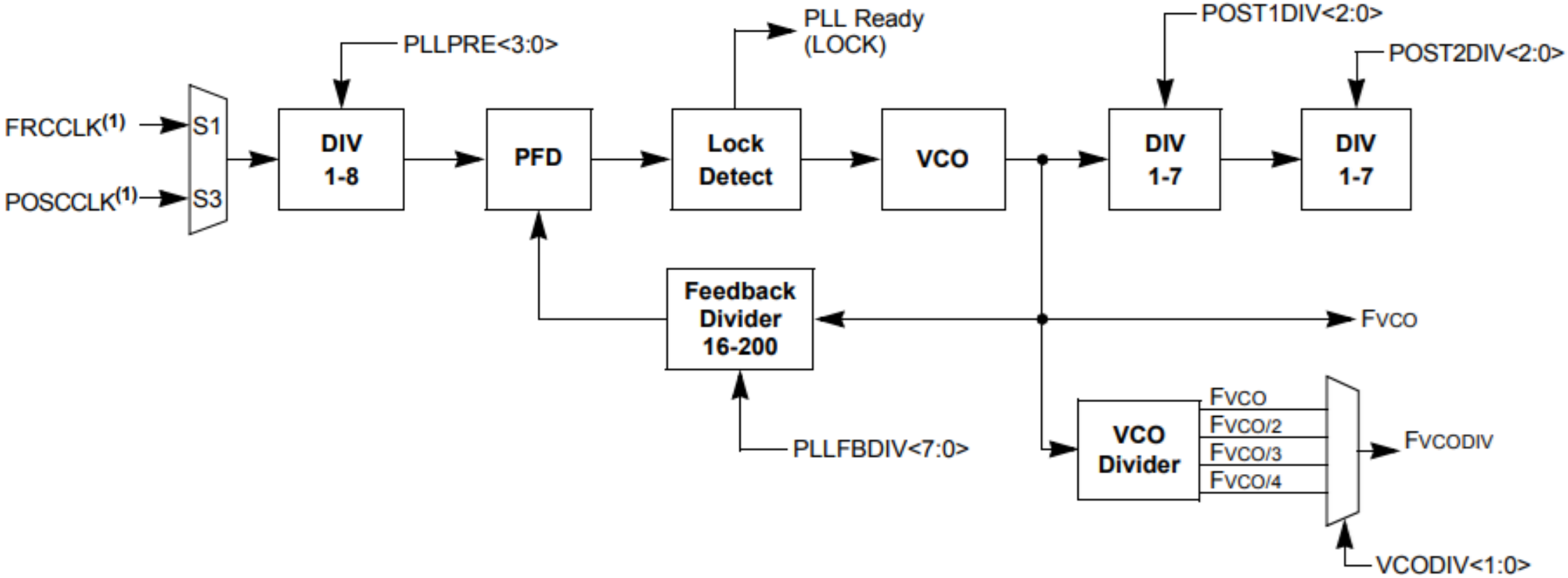
dsPIC33CK Series Clocks

- Microchip dsPIC33CK Series MCU available clock sources are internal Fast RC, Low Power RC and External Crystal or Oscillator, etc..
- The clocks can be divided or multiply by PLL.
- Auxiliary PLL (APLL) Clock Generator to Boost Operating Frequency for Peripherals
- Software-controllable switching between various clock sources.



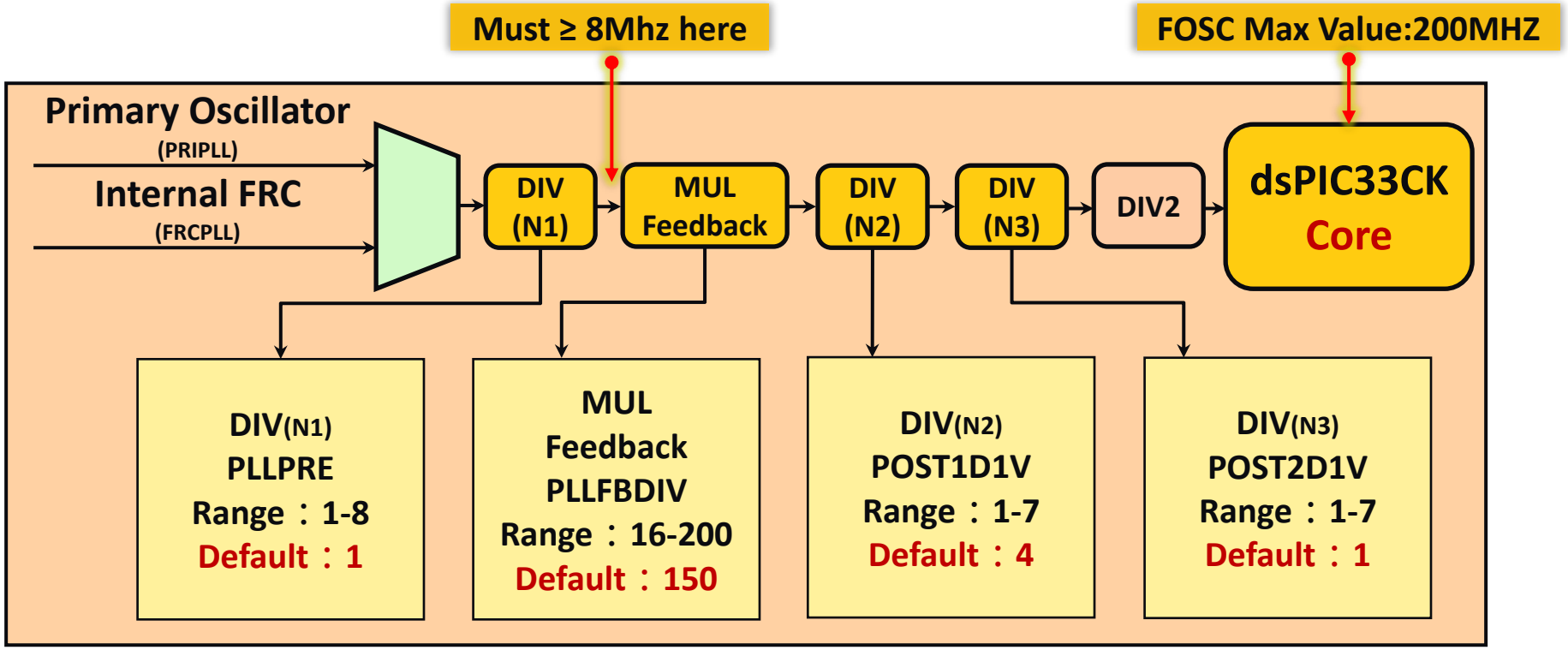
Phase Locked Loop

- **A block diagram of the PLL module.**



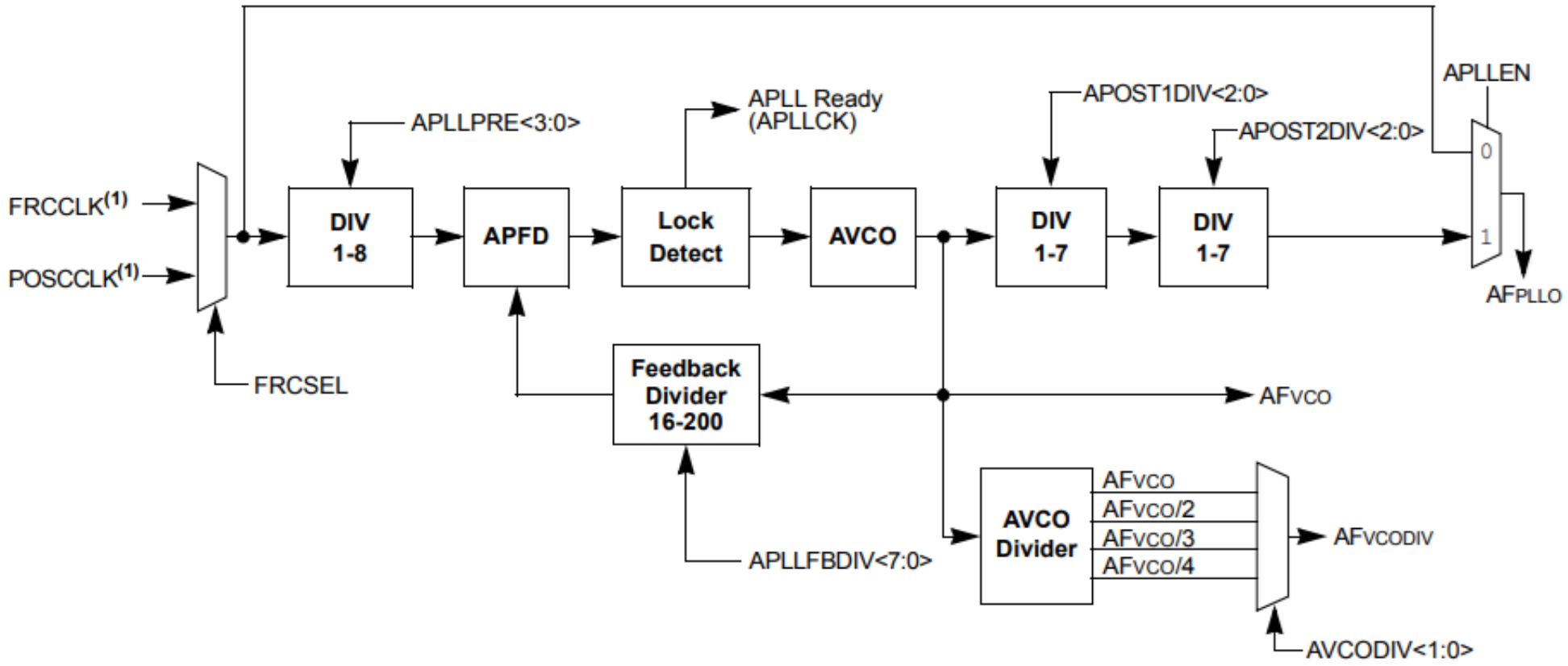
Phase Locked Loop

- Clock input must 8MHz after PLLPRE, which can use Primary Oscillators (Crystal or External Clock) or Internal Fast RC as clock source.



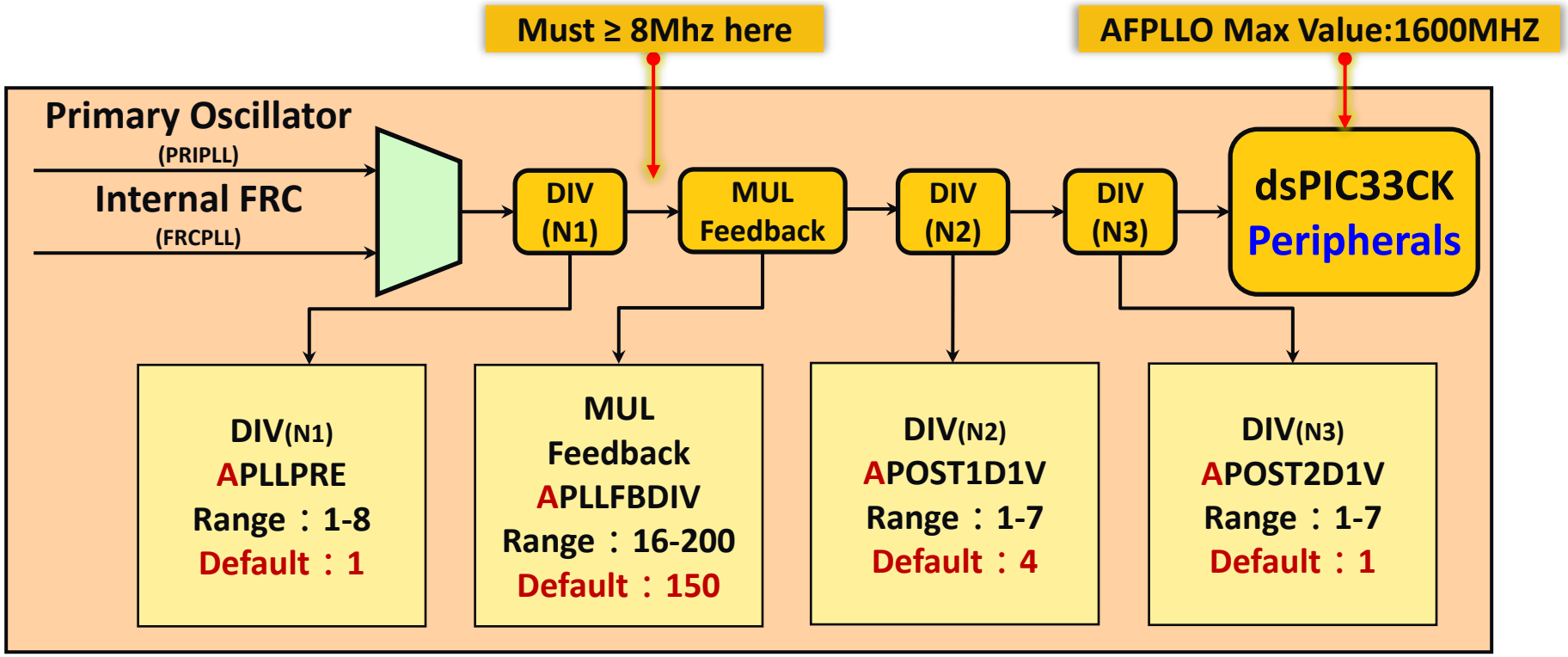
Phase Locked Loop

- **A block diagram of the APLL module.**

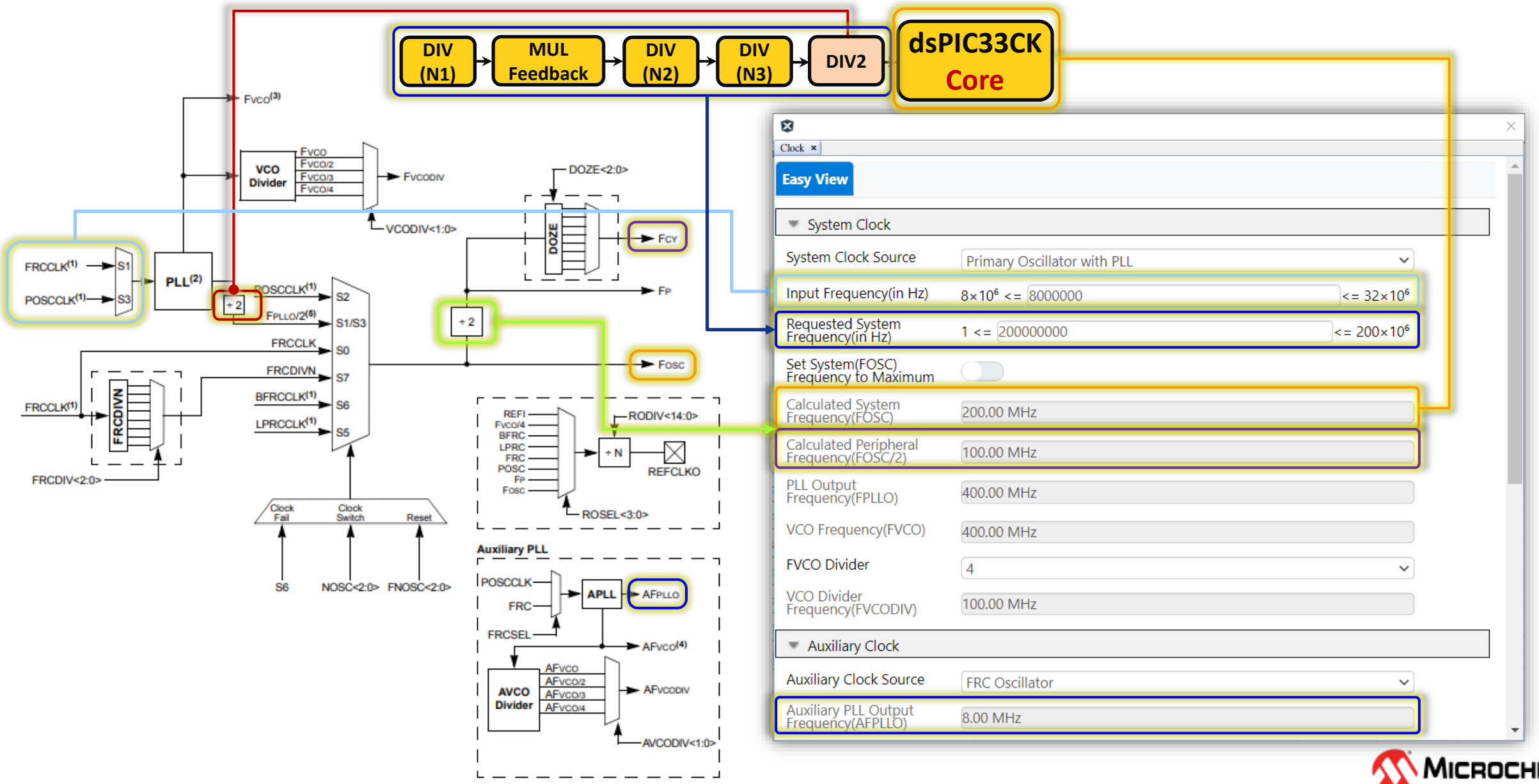


Auxiliary Phase Locked Loop

- Clock input must 8MHz after APLLPRE, which can use Primary Oscillators (Crystal or External Clock) or Internal Fast RC as clock source.



Oscillator Setting of MCC



Lab4 Clock PRIPLL

- Base on current project or Open .\Exams\Lab4_xxx.X to do exercises.
- Try to change system clock from internal Fast RC to External Crystal (8MHz) and enable PLL.
- Try to provide maximum frequency (32MHz) to MCU.

Let’s go!

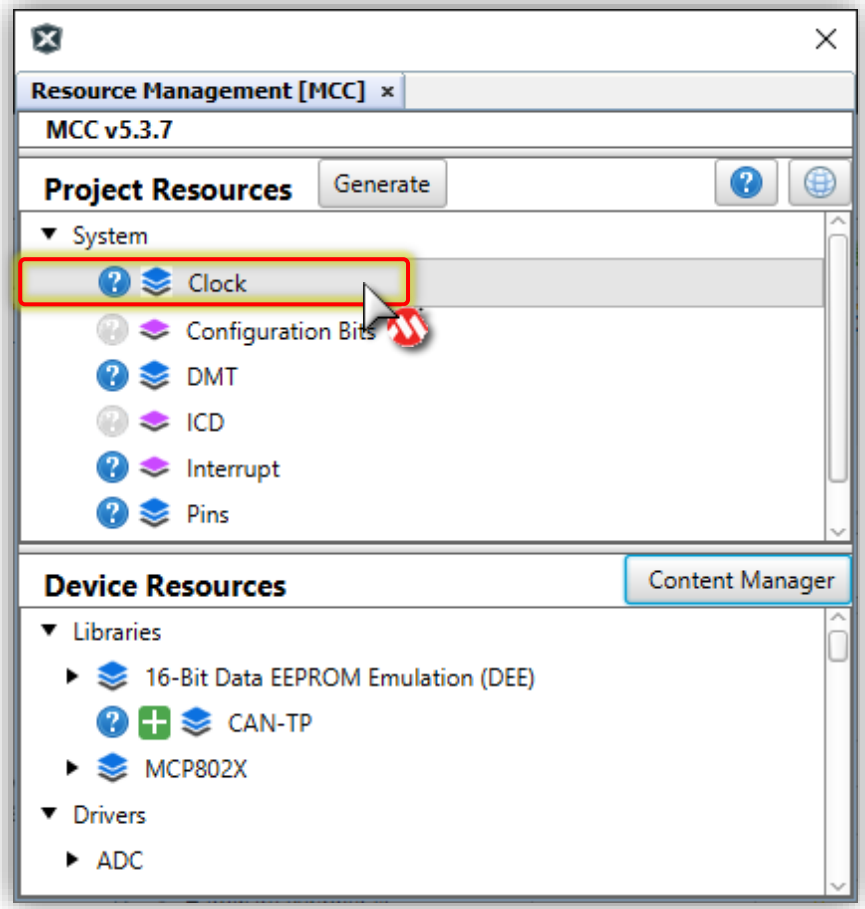
Lab4 Clock PRIPLL

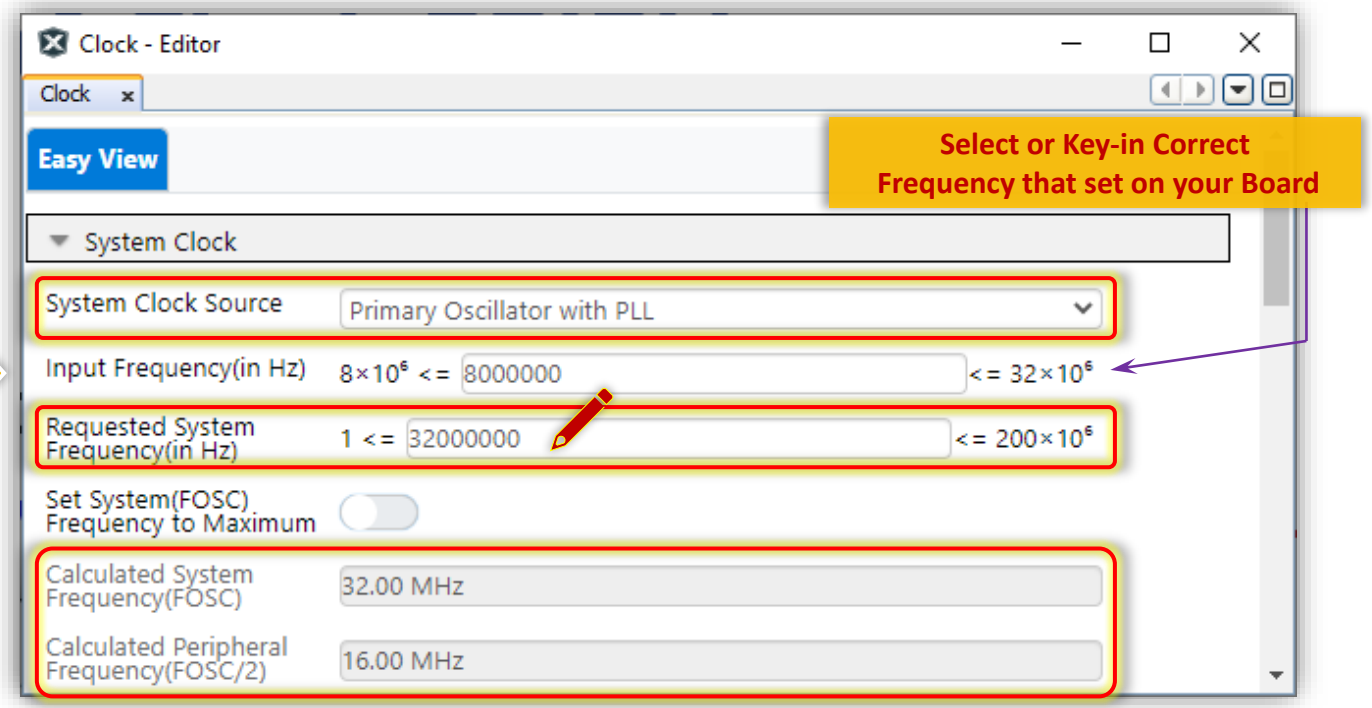
Connection

Lab4 Clock PRIPLL

Step 1

- **Set System**
  - **System Clock: Primary Oscillator with PLL, Requested System Frequency(in Hz) → 32000000.**



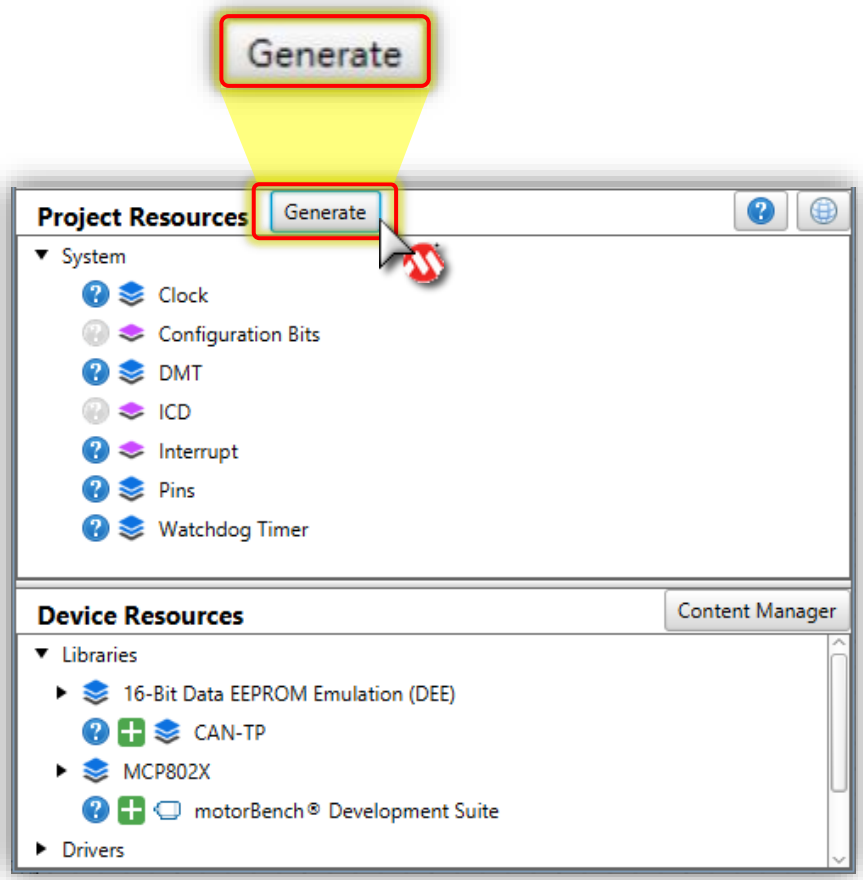


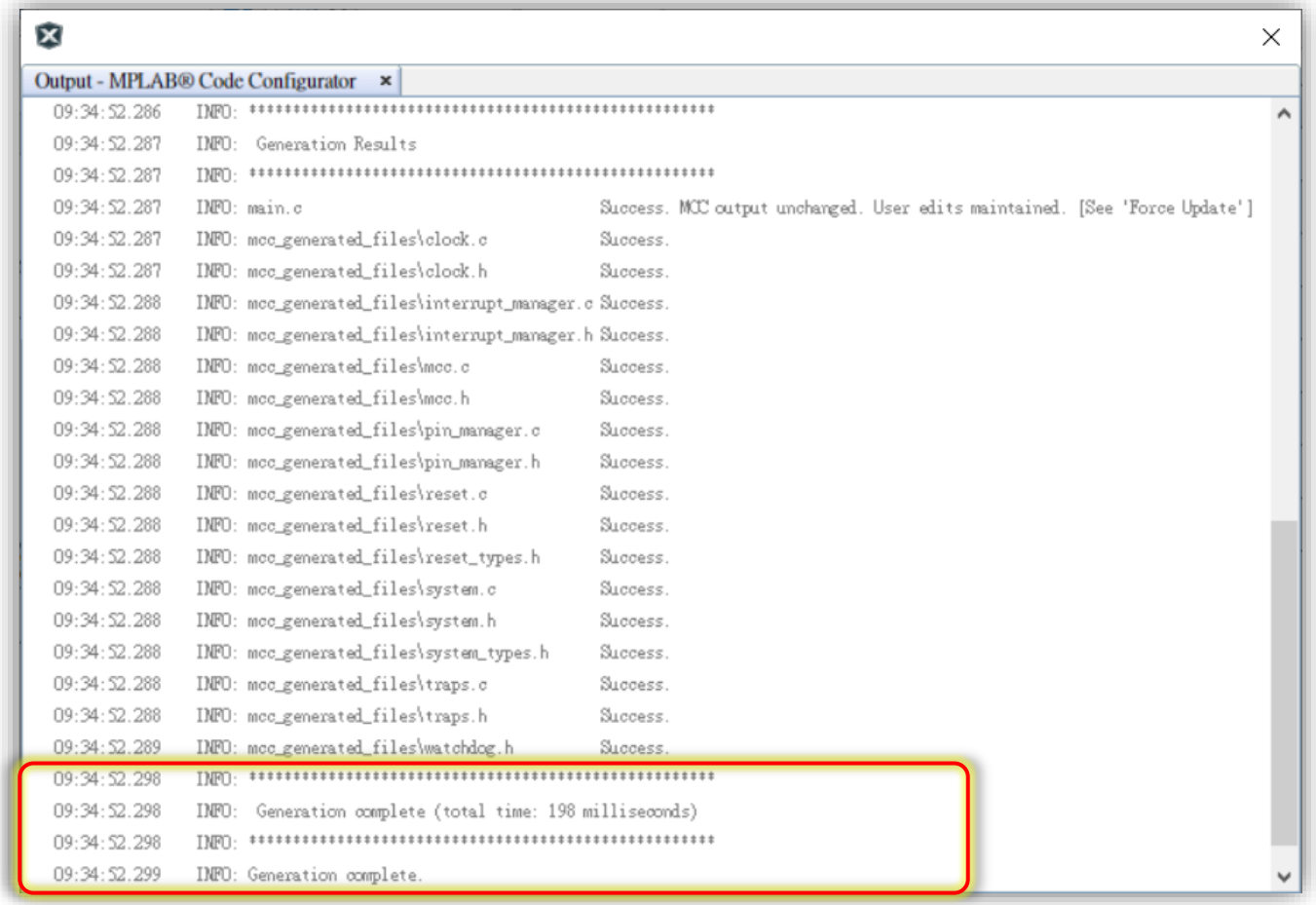
MICROCHIP

Lab4 Clock PRIPLL

Step 2

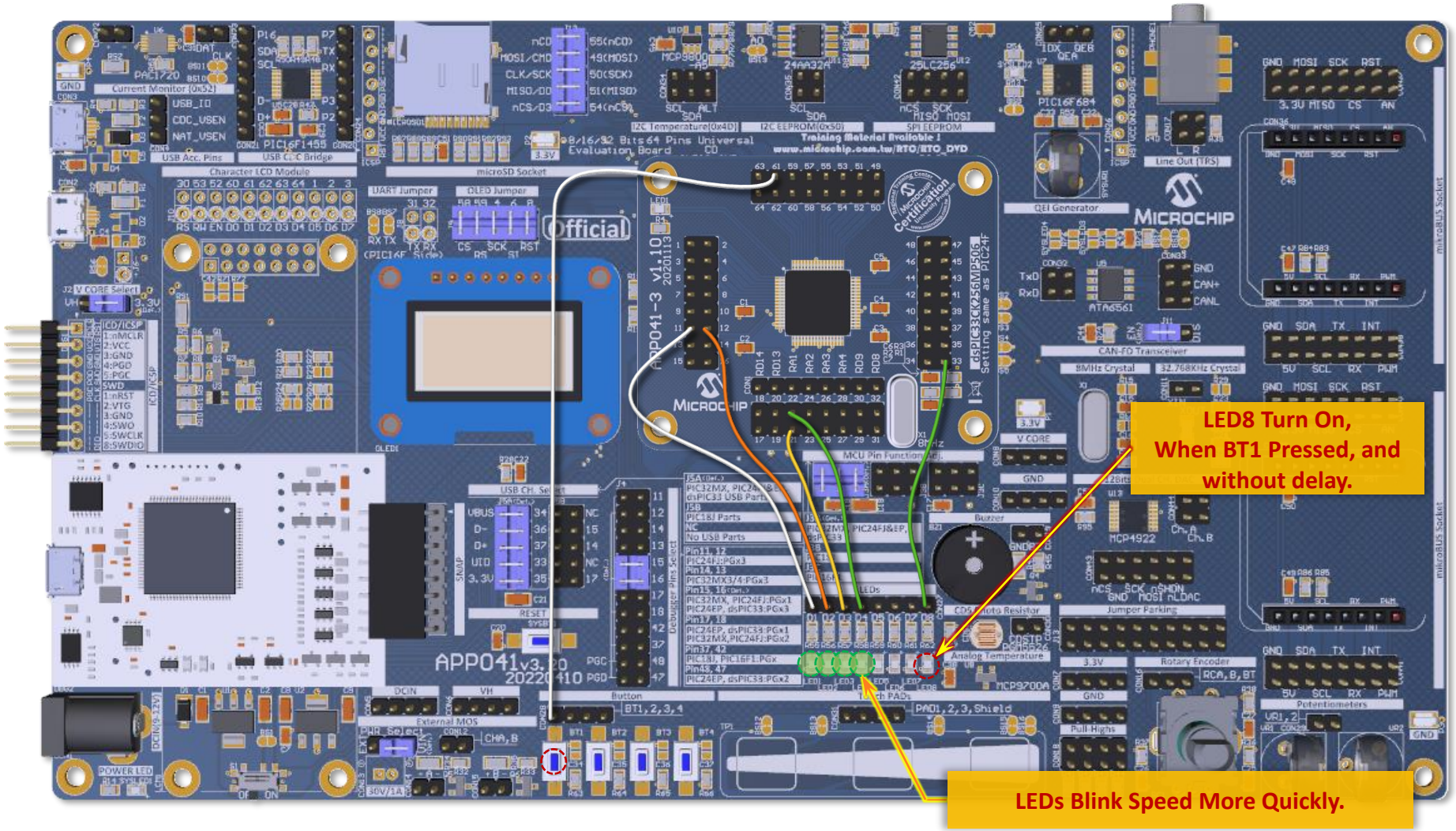
- Click "Generate" Button to generate your code.





Lab4 Clock PRIPLL

Result



Interrupt Architecture

What’s Interrupt ?

- In general, processor is executed in sequence according to the program's flow.
- However, if some peripherals or event needs immediate attention then an interrupt flag been set as high-priority and requiring interrupting current process to serve it.
- Processor will jump to execute the interrupt service routine (ISR, Interrupt Service Routine) to service peripherals or events.

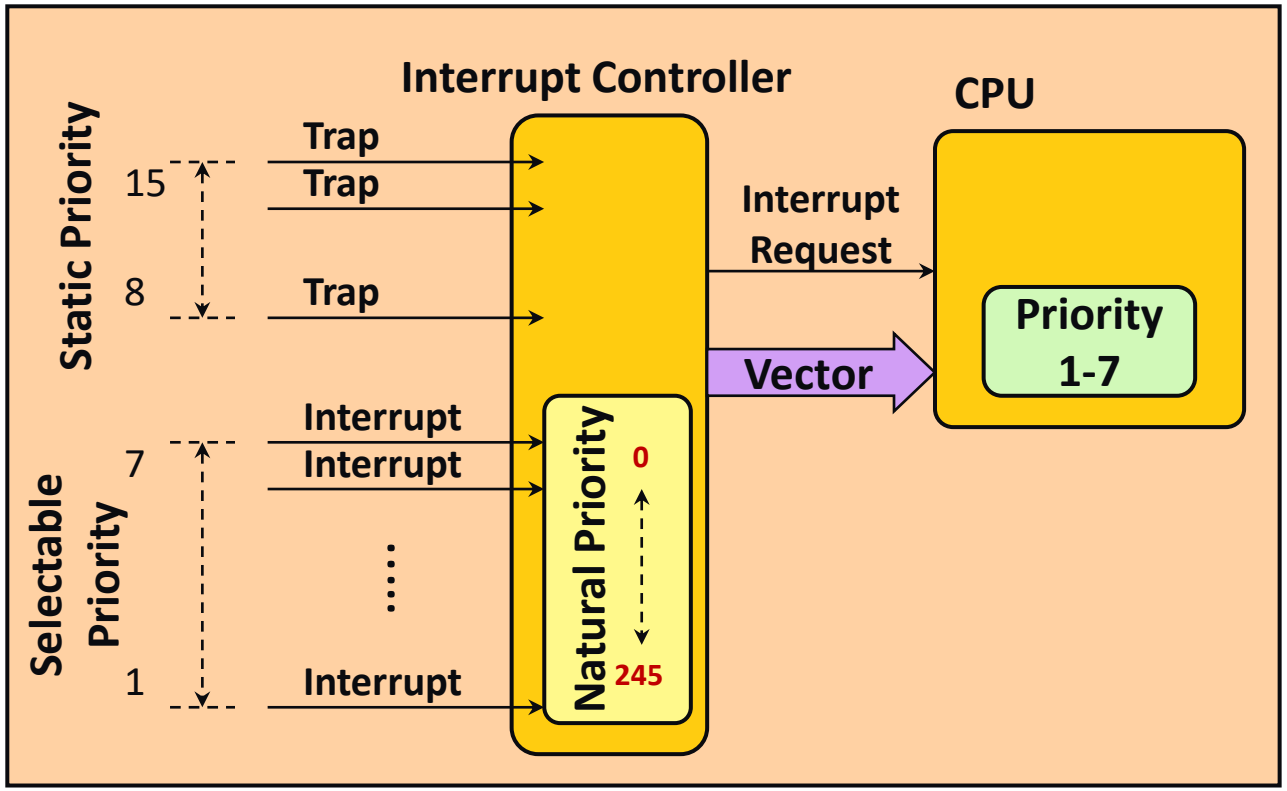
Which events need Interrupt ?

- **For General (maskable)**
  - Time critical event
    As soon as possible, when event occurred.
  - Unpredicted event
    Polling too waste computing time.

- **For Emergency (non maskable)**
  - Stack Overflow/Underflow
  - Math Error
  - Address Error
  - etc..

dsPIC33CK Series Interrupt Architecture

- dsPIC33's Interrupt is Nested Vector Interrupt Controller.
- Provide up to 8 processor exceptions and software traps
- Provide 7 (1~7) user-selectable priority levels. 0 is disable, 7 is the Highest priority.
- IVT/AIVT provide 246 vectors.
- Fixed interrupt entry and return latencies.



Natural Priority

- **If two pending interrupts share the same priority, priority is given to the interrupt with the lowest exception number.** **(.\Microchip\xc16\v2.10\docs\vector_docs\PIC33CK256MP506)**

(lowest interrupt vector address).

Reset – GOTO Instruction	0x000000
Reset – GOTO Address	0x000002
Oscillator Fail Trap Vector	0x000004
Address Error Trap Vector	0x000006
Generic Hard Trap Vector	0x000008
Stack Error Trap Vector	0x00000A
Math Error Trap Vector	0x00000C
Reserved	0x00000E
Generic Soft Trap Vector	0x000010
Reserved	0x000012
Interrupt Vector 0	0x000014
Interrupt Vector 1	0x000016
:	:
:	:
:	:
Interrupt Vector 52	0x00007C
Interrupt Vector 53	0x00007E
Interrupt Vector 54	0x000080
:	:
:	:
:	:

Interrupt Vector Details

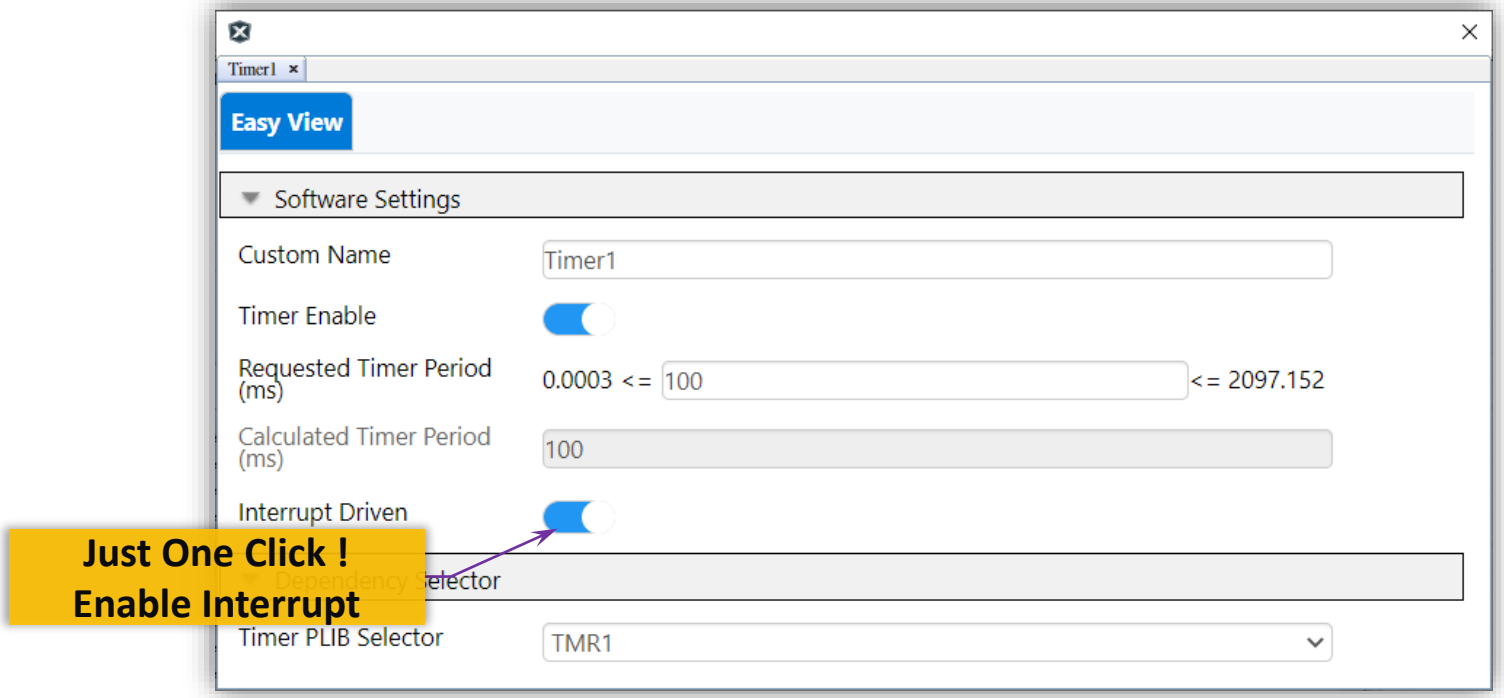
IRQ#	Primary Name	Alternate Name	Vector Function
N/A	_OscillatorFail	_AltOscillatorFail	Oscillator Fail Trap vector
N/A	_AddressError	_AltAddressError	Address error Trap vector
N/A	_HardTrapError	_AltHardTrapError	Generic Hard Trap vector
N/A	_StackError	_AltStackError	Stack Error Trap Vector
N/A	_MathError	_AltMathError	Math Error Trap vector
N/A	_SoftTrapError	_AltSoftTrapError	Generic Soft Trap vector
0	_INT0Interrupt	_AltINT0Interrupt	External Interrupt 0
1	_T1Interrupt	_AltT1Interrupt	Timer 1
2	_CNAInterrupt	_AltCNAInterrupt	Change Notification A
3	_CNBInterrupt	_AltCNBInterrupt	Change Notification B
4	_DMA0Interrupt	_AltDMA0Interrupt	DMA Channel 0
6	_CCP1Interrupt	_AltCCP1Interrupt	CCP1 Capture/Compare Event
7	_CCT1Interrupt	_AltCCT1Interrupt	CCP1 Timer Event
8	_DMA1Interrupt	_AltDMA1Interrupt	DMA Channel 1
9	_SPI1RXInterrupt	_AltSPI1RXInterrupt	SPI1 RX
10	_SPI1TXInterrupt	_AltSPI1TXInterrupt	SPI1 TX
11	_U1RXInterrupt	_AltU1RXInterrupt	UART1 RX
12	_U1TXInterrupt	_AltU1TXInterrupt	UART1 TX

Each peripheral has an assigned.
Vector table is based at address 0x00000000

MICROCHIP

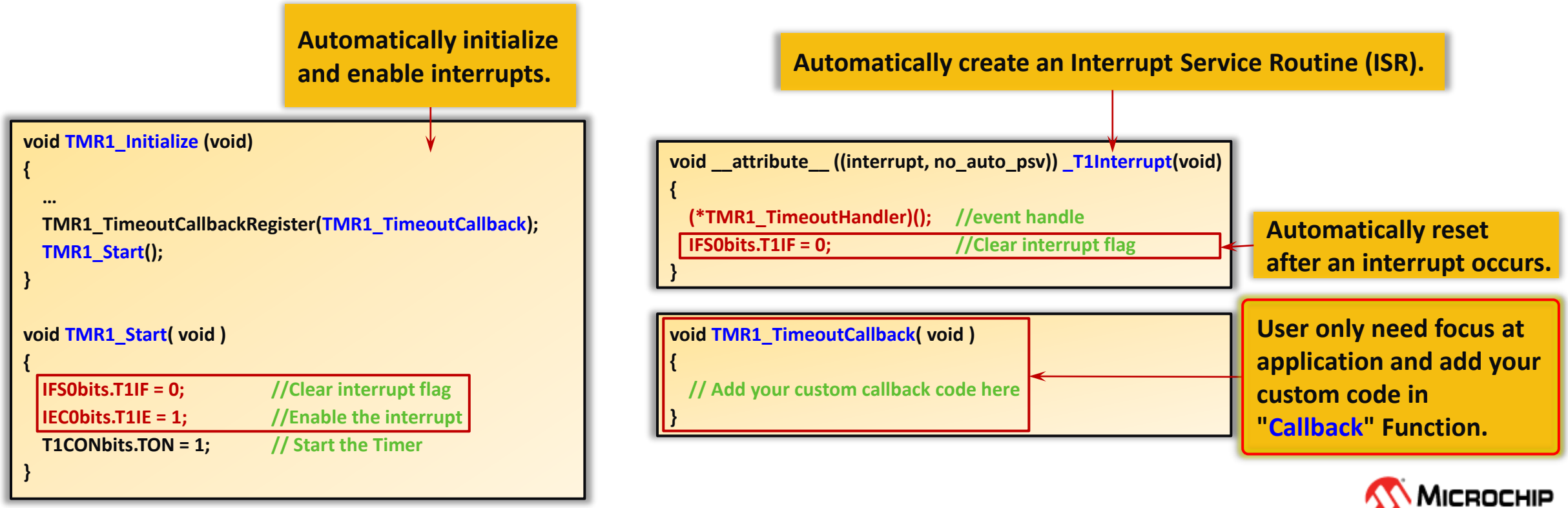
Coding for Interrupt

- **A complete interrupt code segment includes below 3 parts.**
  - Interrupt Service Routine (ISR)
  - Enable Interrupt and Set Interrupt Priority
  - Initial Peripheral to generate Interrupt Request.
- **This is very difficult for beginner, if you use bare metal style to build your code.**
- **MCC could help you to build most all code segment. So, just one click all interrupt relate setting will get ready.**



MCC Melody's Interrupt Function

- MCC Melody will **automatically** enable interrupts, set priority and create interrupt service routines, and provide "**Callback Function**" to user.
- Flag and event handle by handler function automatically, user focus at application only. It's more powerful and easy to understand than operating a bare metal style.



Callback Function

- MCC Melody provides two ways to use the callback function.
- MCC Melody will automatically generate a callback function with the "weak" attribute, user can redefine same name function in your code to replace the default function.
- Or you can use xxxCallbackRegister() to register (hook up) your custom callback function.
- We will focus on using register custom callback function in the following exercises.

tmr1.c

```
void __attribute__ ((weak)) TMR1_TimeoutCallback( void )
{

}
```

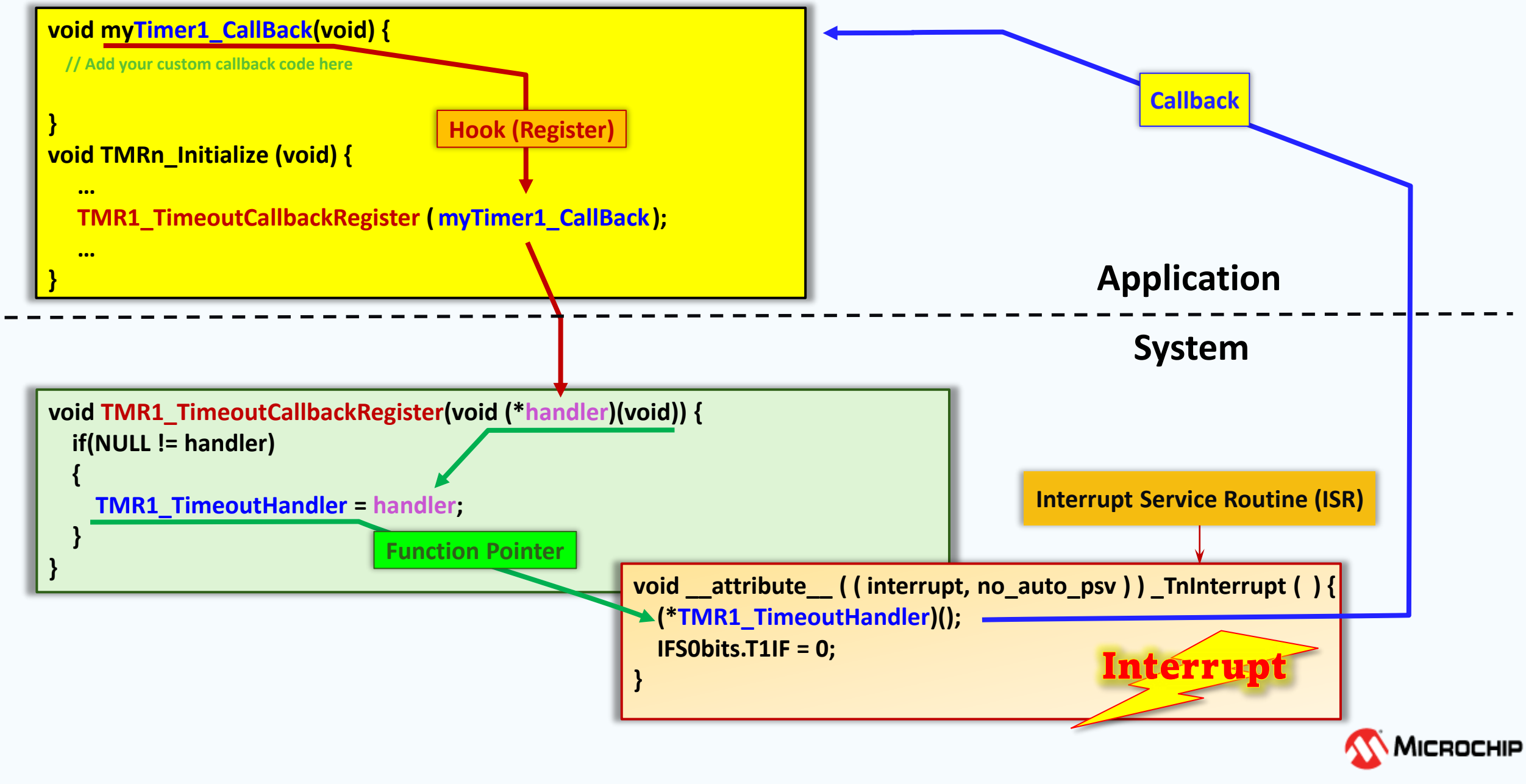
main.c

```
void TMR1_TimeoutCallback( void )
{
   // Add your custom callback code here
}

int main(void)
{
   ...
}
```

main.c

```
void myTimeoutCallback( void )
{
   // Add your custom callback code here
}

int main(void)
{
   TMR1_TimeoutCallbackRegister(&myTimeoutCallback);
   ...
}
```

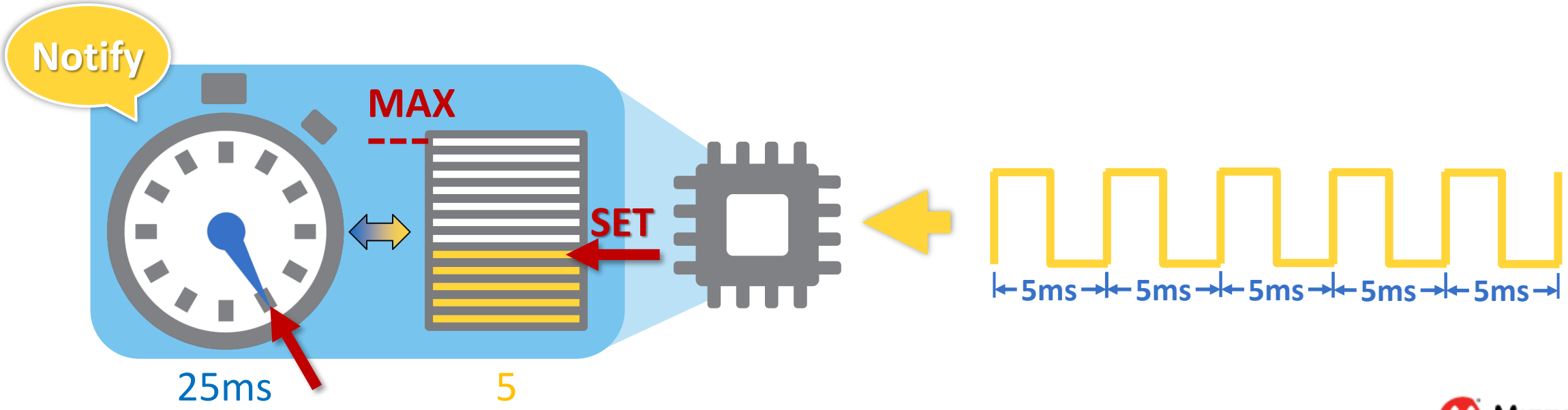
Callback Hook Example



Timer Driver Architecture

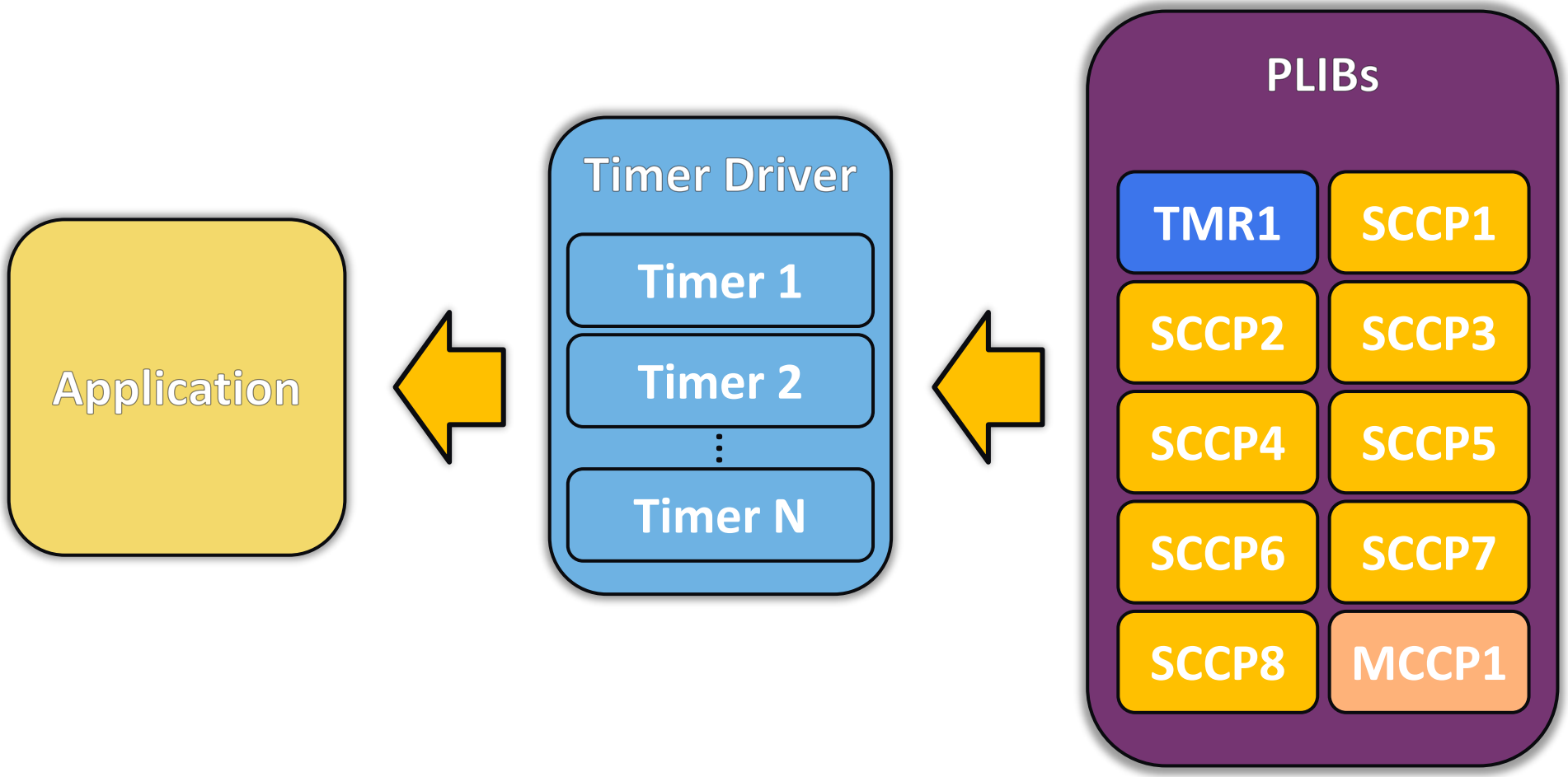
Timer or Counter ?

- **Timer is a clock counter, use to count how many clocks into module after start, we can use the known clock period to calculate time.**
- **Timer can set a notify condition, like overflow, equal some value etc.**
- **Timer supports both polling and interrupt mode.**
  - If interrupt disable : User must check flag, as soon as possible.
  - If interrupt enable : Timer will notify CPU, if condition is true.



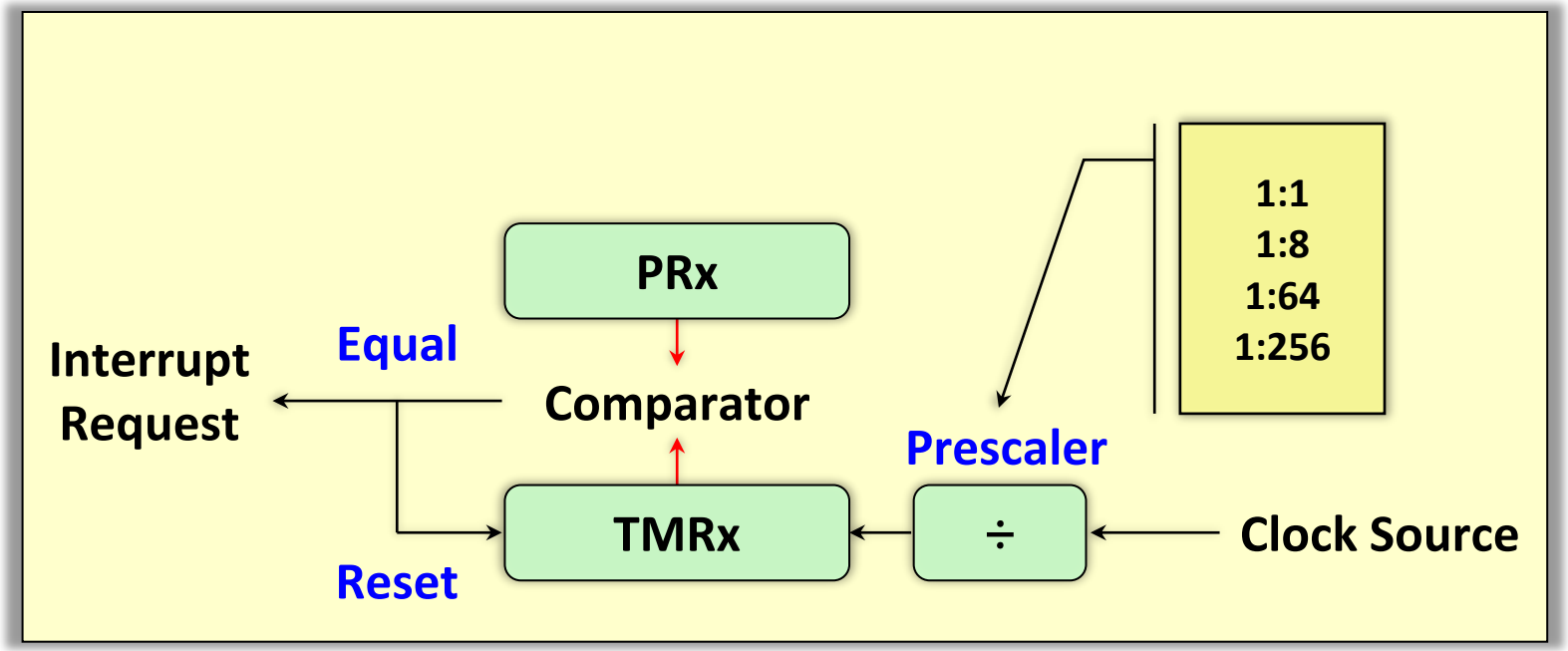
Timer Driver

- Driver provides simple, abstracted, portable interface to peripherals.
- dsPIC33CKMP506 provides 10 sets of peripherals that can be used for Timer Driver, 1 "TMR", 8 "SCCP" and 1 "MCCP", in this section we focus on Timer mode.



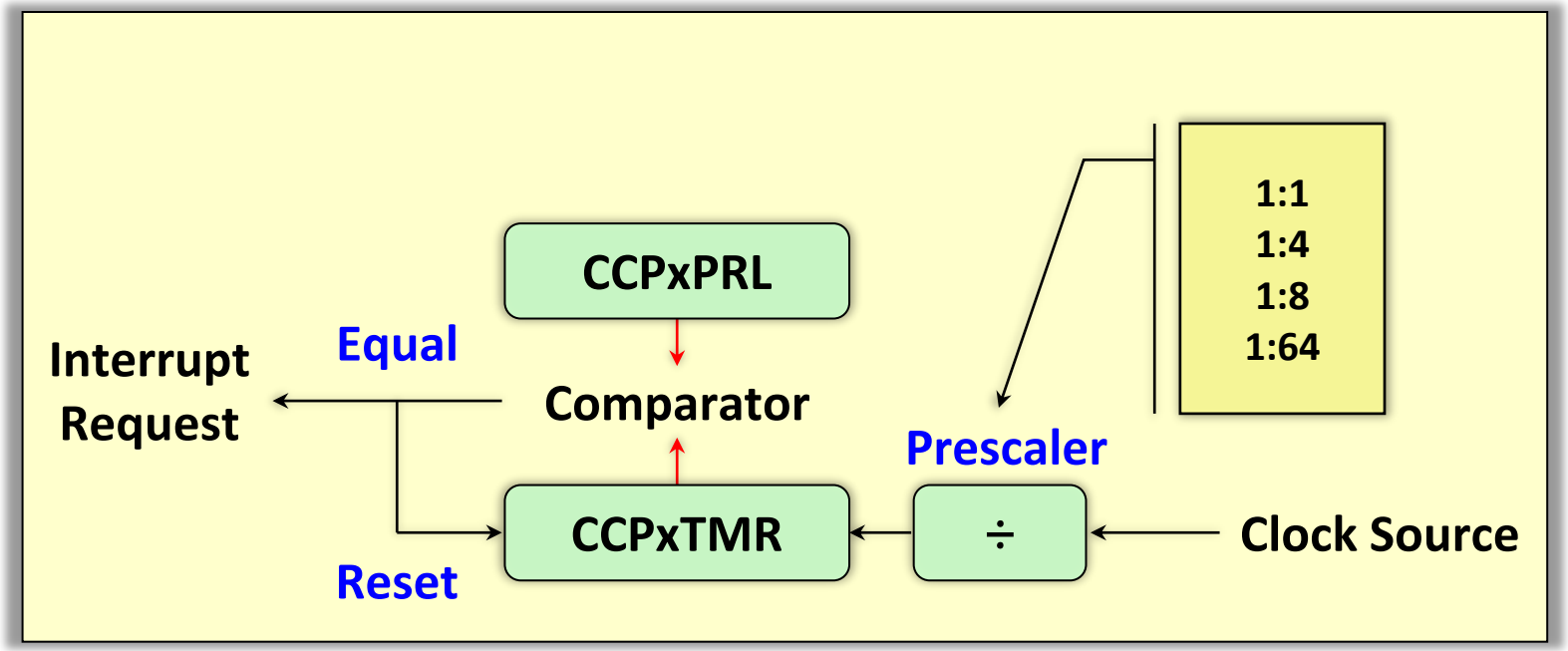
Timer PLIB - TMR

- Please refer to the block diagram, Just a concept. The real and detail block diagram please refer to the following slide.
- Clock into TMRx after prescaler. Comparator continuously compares the values of TMRx and PRx. Asserts an interrupt request while TMRx and PRx equal and then clear TMRx to zero.
- You can fill a value to PRx to determine period you want.



Timer PLIB - SCCP/MCCP with Timer Operation Mode

- Please refer to the block diagram, Just a concept. The real and detail block diagram please refer to the following slide.
- Clock into CCPxTMR after prescaler. Comparator continuously compares the values of CCPxTMR and CCPxPRL. Asserts an interrupt request while CCPxTMR and CCPxPRL equal and then clear CCPxTMR to zero.
- You can fill a value to CCPxPRL to determine period you want.



Functions of Melody Timer Driver

- **Melody Provide below functions for Timer:**
  Prototype definition : "tmr1.h" and "sccp*n*.h"
  - **TIMER_INTERFACE**
    - **(void)** *CustomName*.**Initialize(void);**
    - **(void)** *CustomName*.**Deinitialize(void);**
    - **(void)** *CustomName*.**Start(void);**
    - **(void)** *CustomName*.**Stop(void);**
    - **(void)** *CustomName*.**PeriodSet(uint32_t count);**
    - **(uint32_t)** *CustomName*.**PeriodGet(void);**
    - **(uint32_t)** *CustomName*.**CounterGet (void);**
    - **(void)** *CustomName*.**InterruptPrioritySet(enum INTERRUPT_PRIORITY priority);**
    - **(void)** *CustomName*.**TimeoutCallbackRegister(void (*handler)(void));**

  - **Default *CustomName* is *Timern*.**

Lab5 Timer1 Interrupt

- Base on current project or Open .\Exercises\Lab5_xxx.X to do exercise.
- Try to add Timer Driver using TMR1 and rename it as "myTimer1".
- Try to replace software delay to myTimer1 to control LEDs to change state every 500ms.
- myTimer1 interrupt priority set to level 1.

Let’s go!

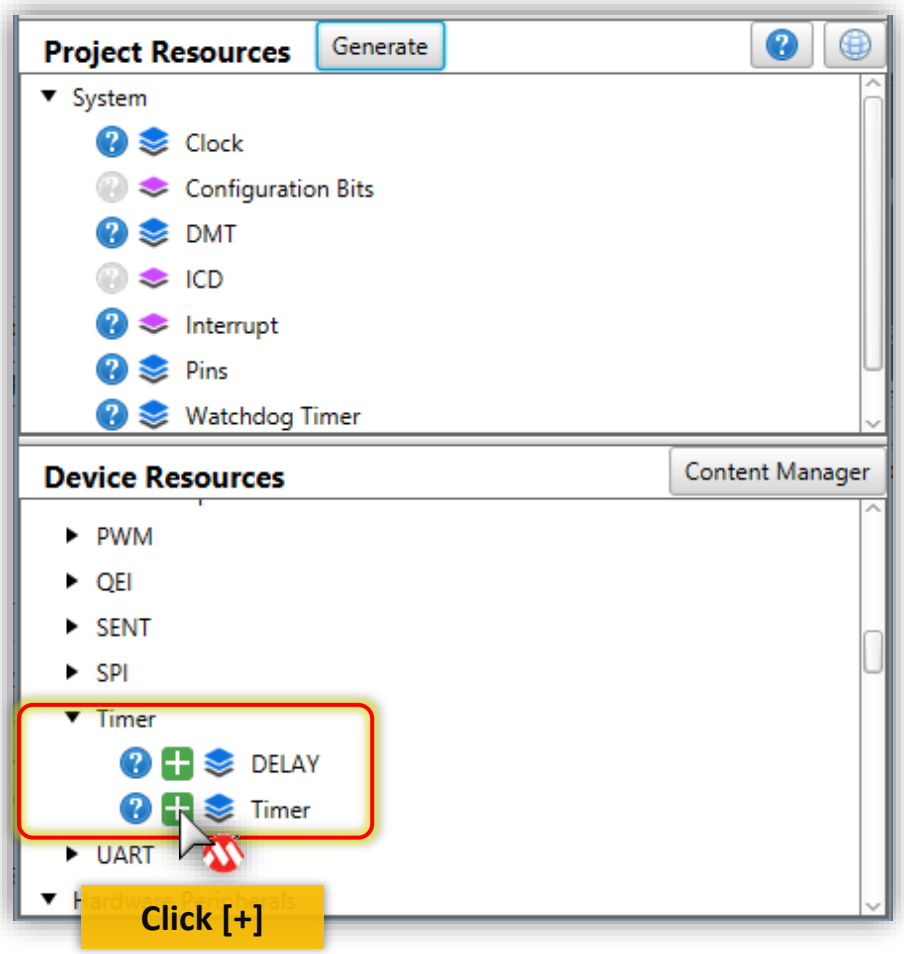
Lab5 Timer1 Interrupt

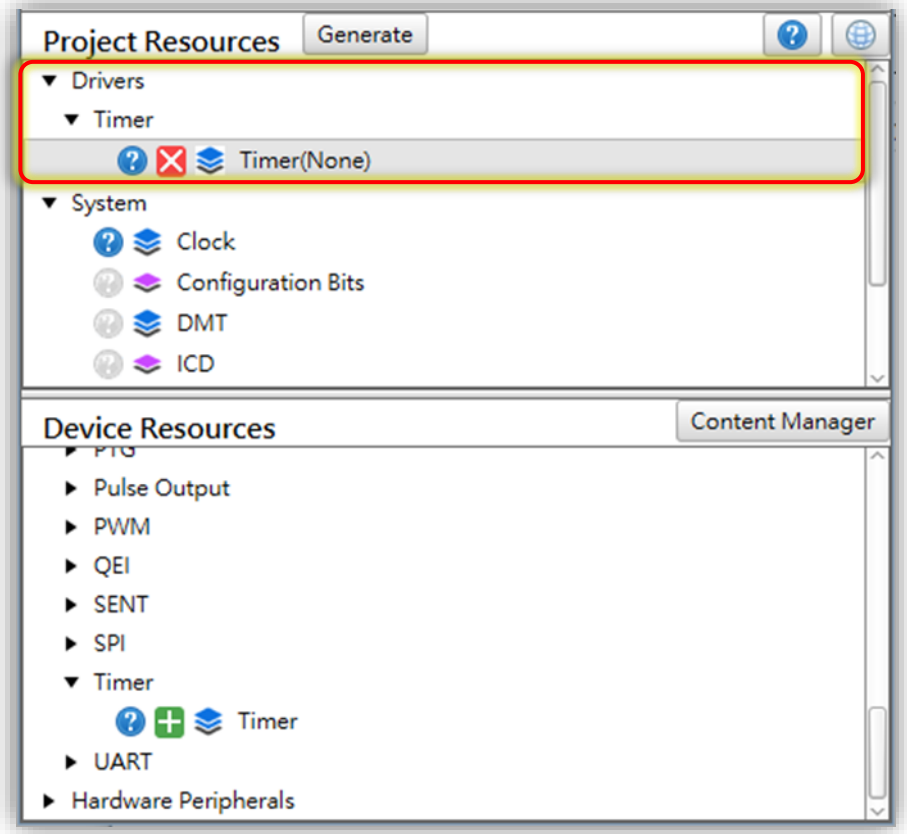
Connection

Lab5 Timer1 Interrupt

Step 1

- Click [+] to add **Timer Driver**.

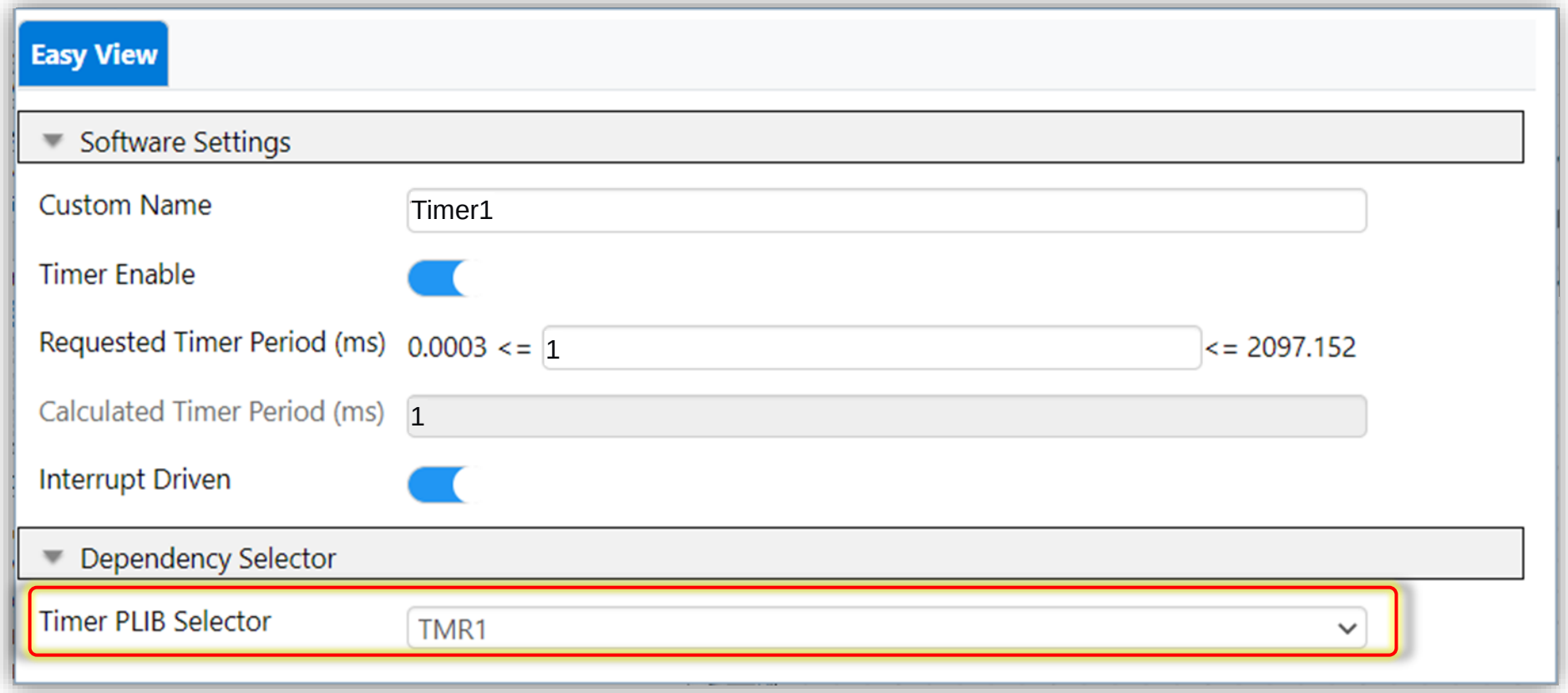




Lab5 Timer1 Interrupt

Step 2

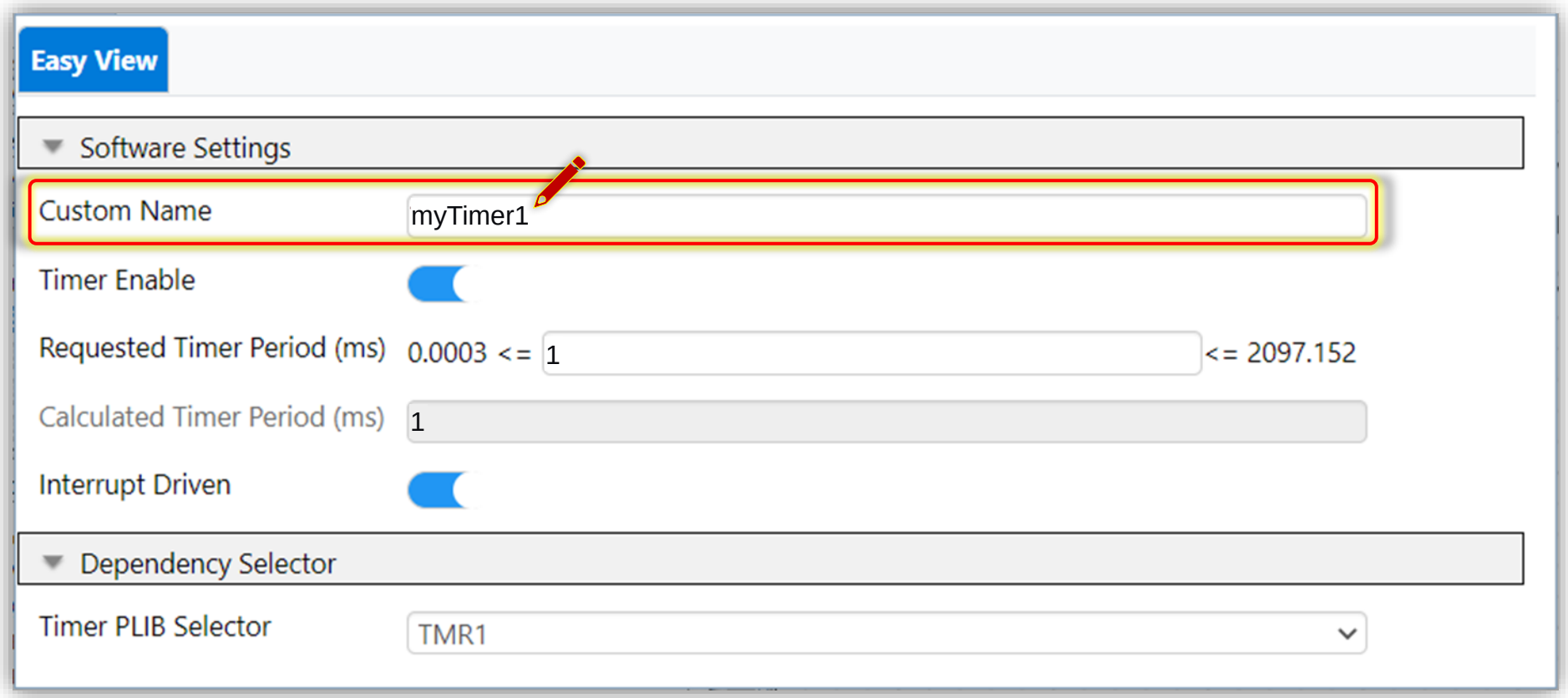
- **Select Timer PLIB to TMR1.**



Lab5 Timer1 Interrupt

Step 3

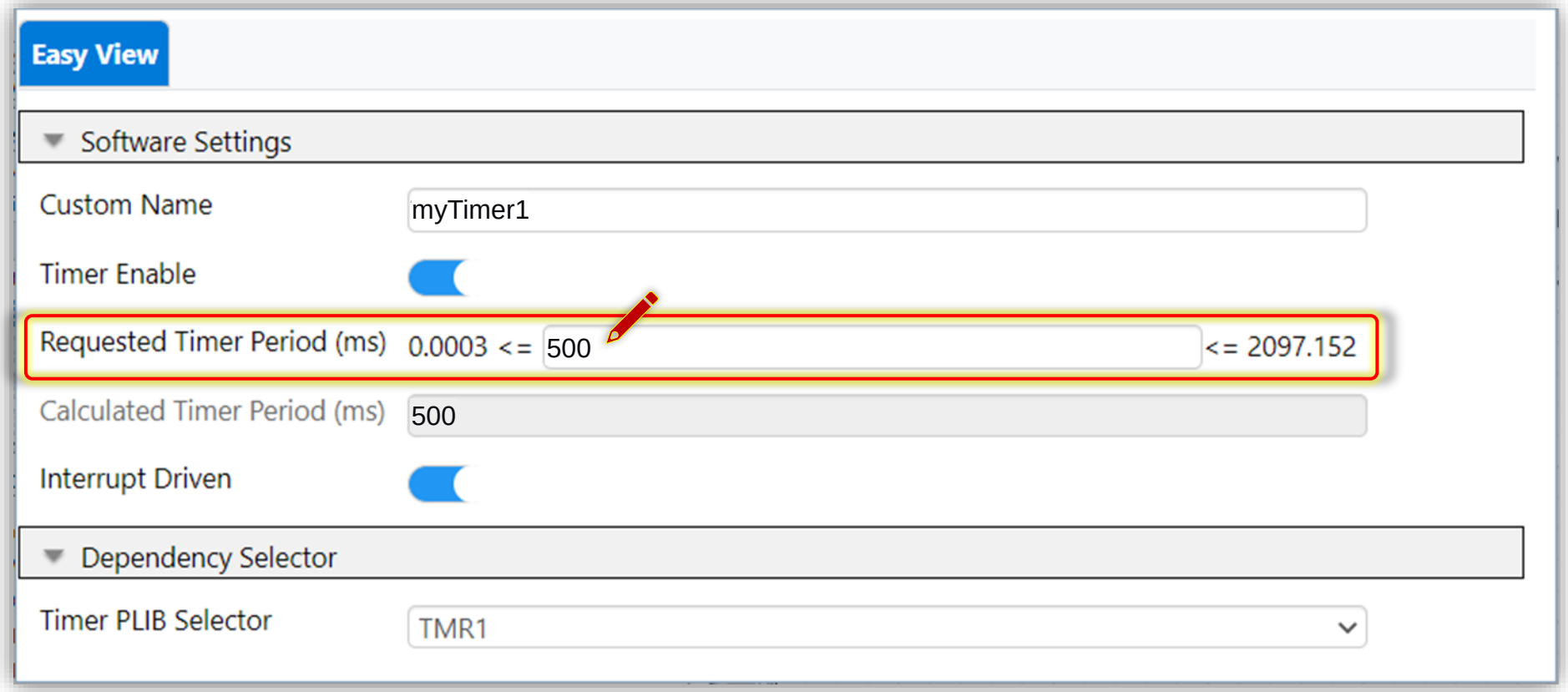
- **Modify the Custom Name to "myTimer1".**



Lab5 Timer1 Interrupt

Step 4

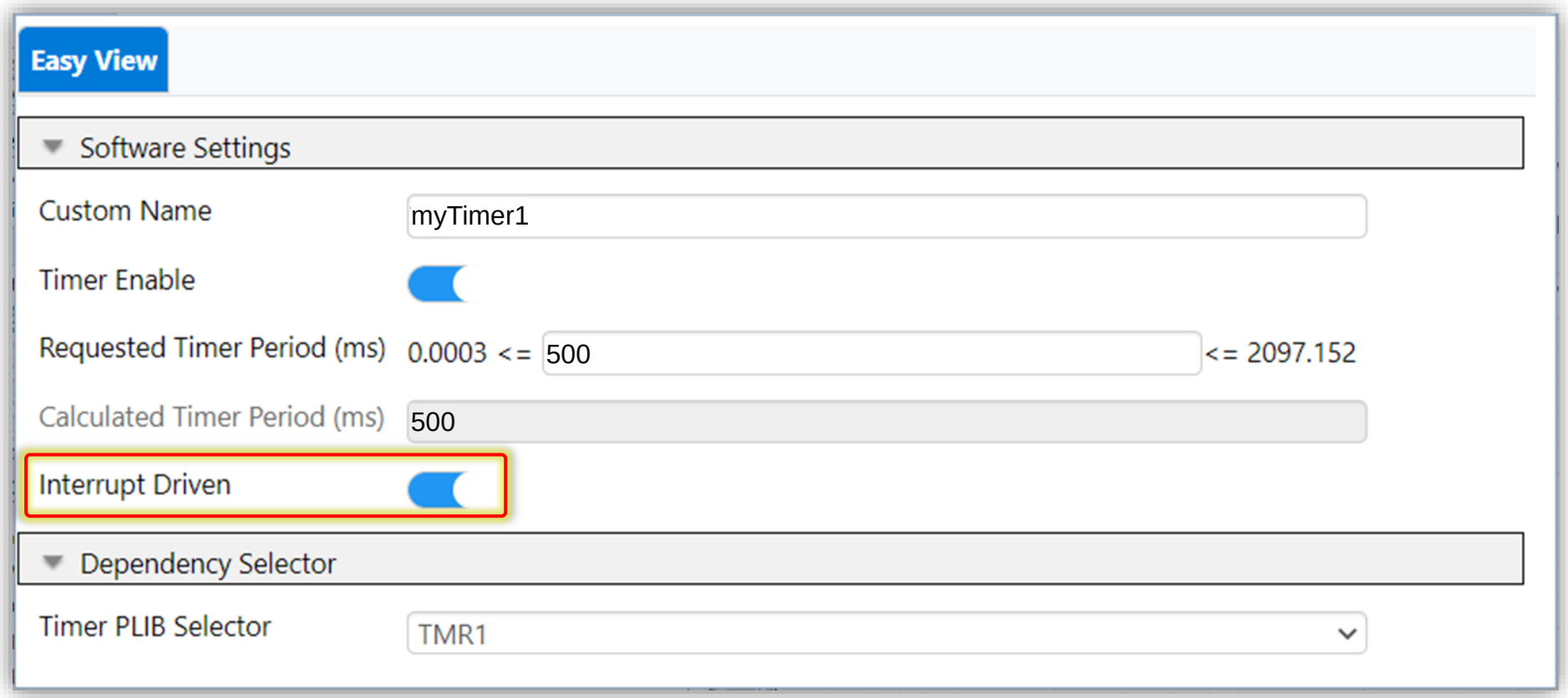
- Set **Requested Timer Period (ms)** : **500**.



Lab5 Timer1 Interrupt

Step 5

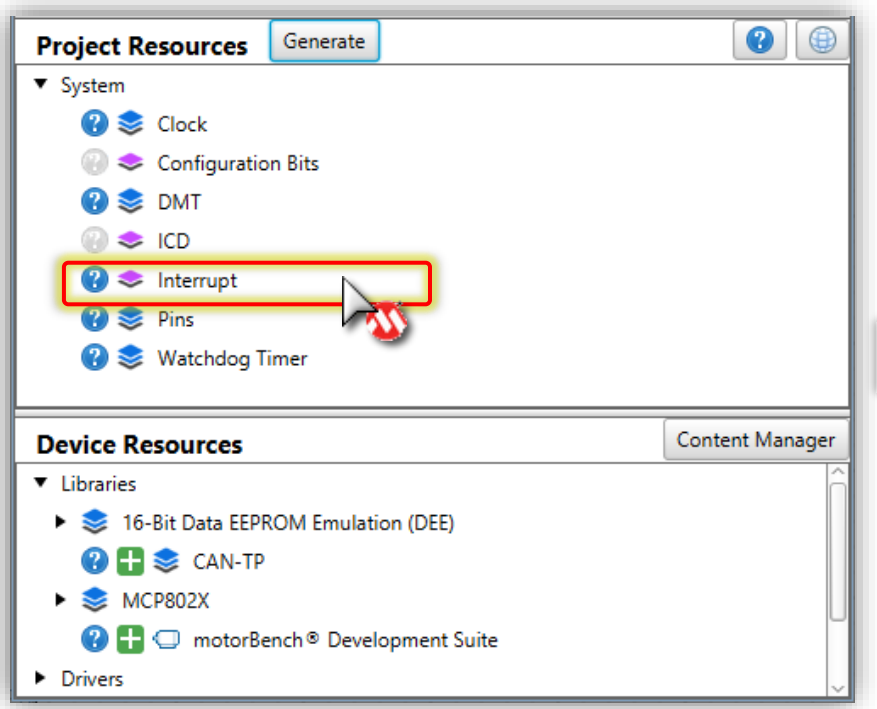
- Check Timer Interrupt is Driven.

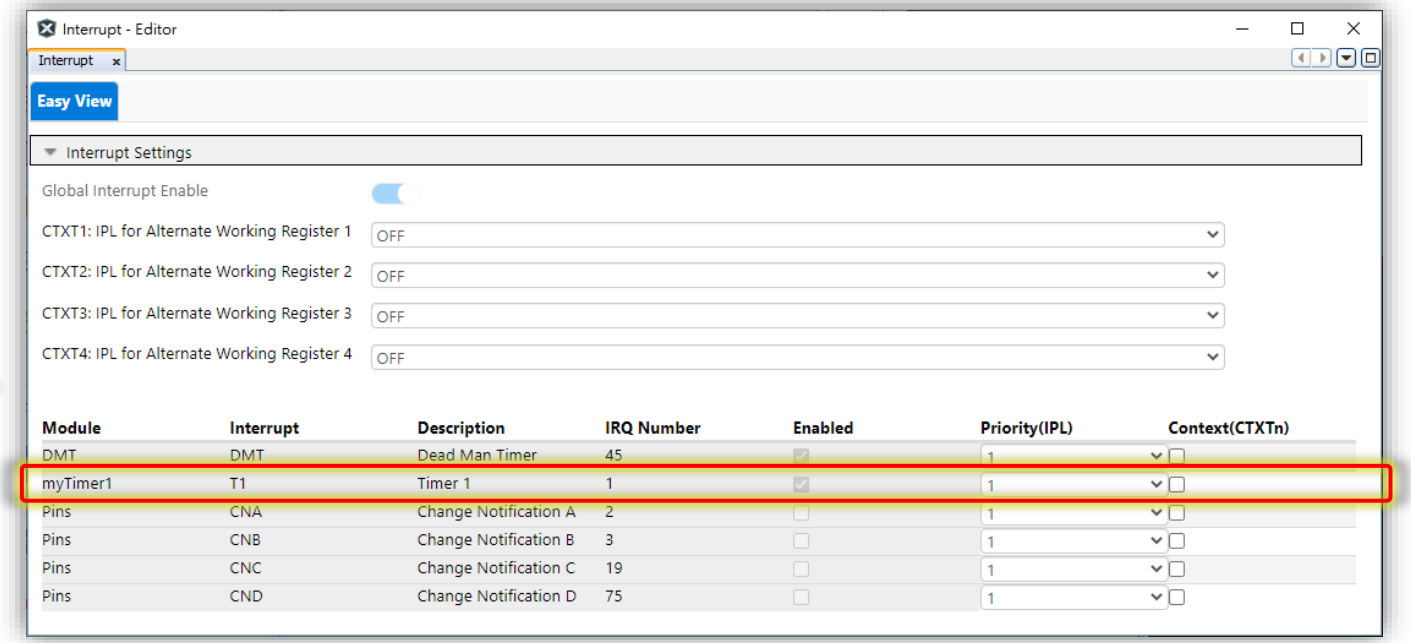


Lab5 Timer1 Interrupt

Step 6

- Check Interrupt status (Timer1) for myTimer1.

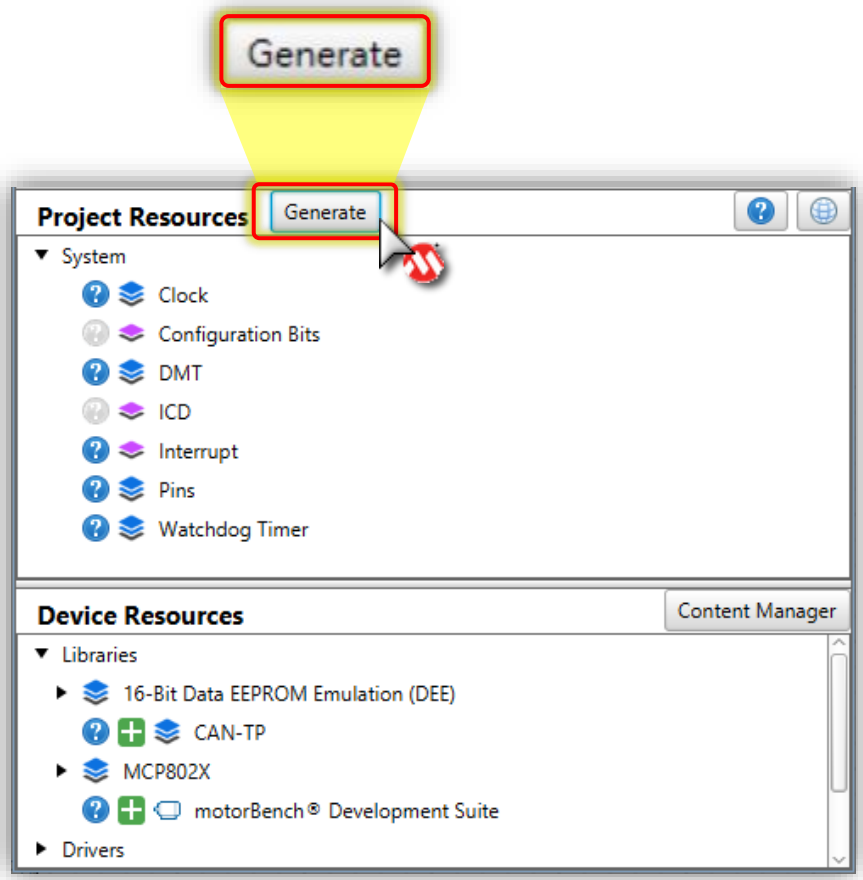


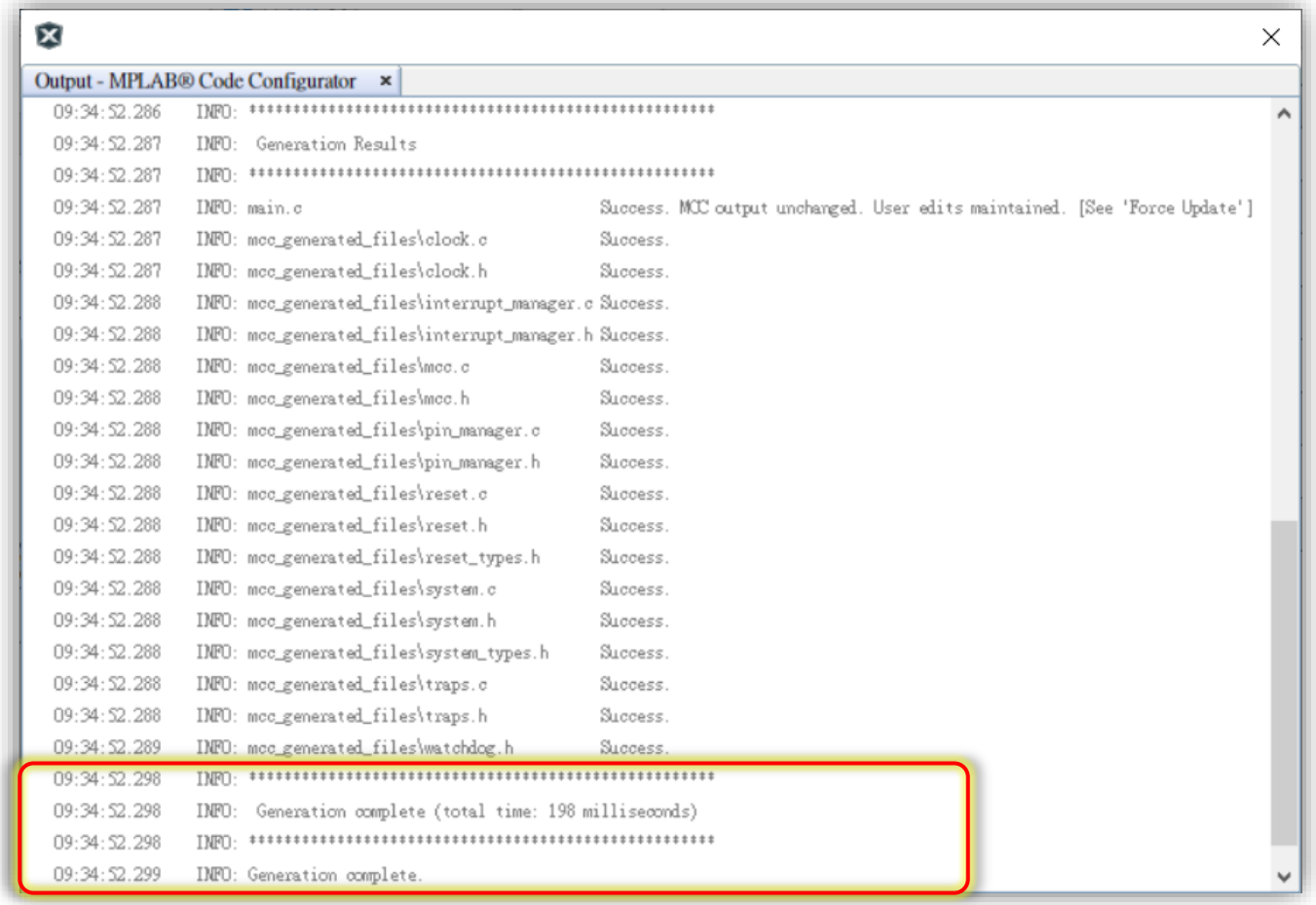


Lab5 Timer1 Interrupt

Step 7

- Click "Generate" Button to generate your code.





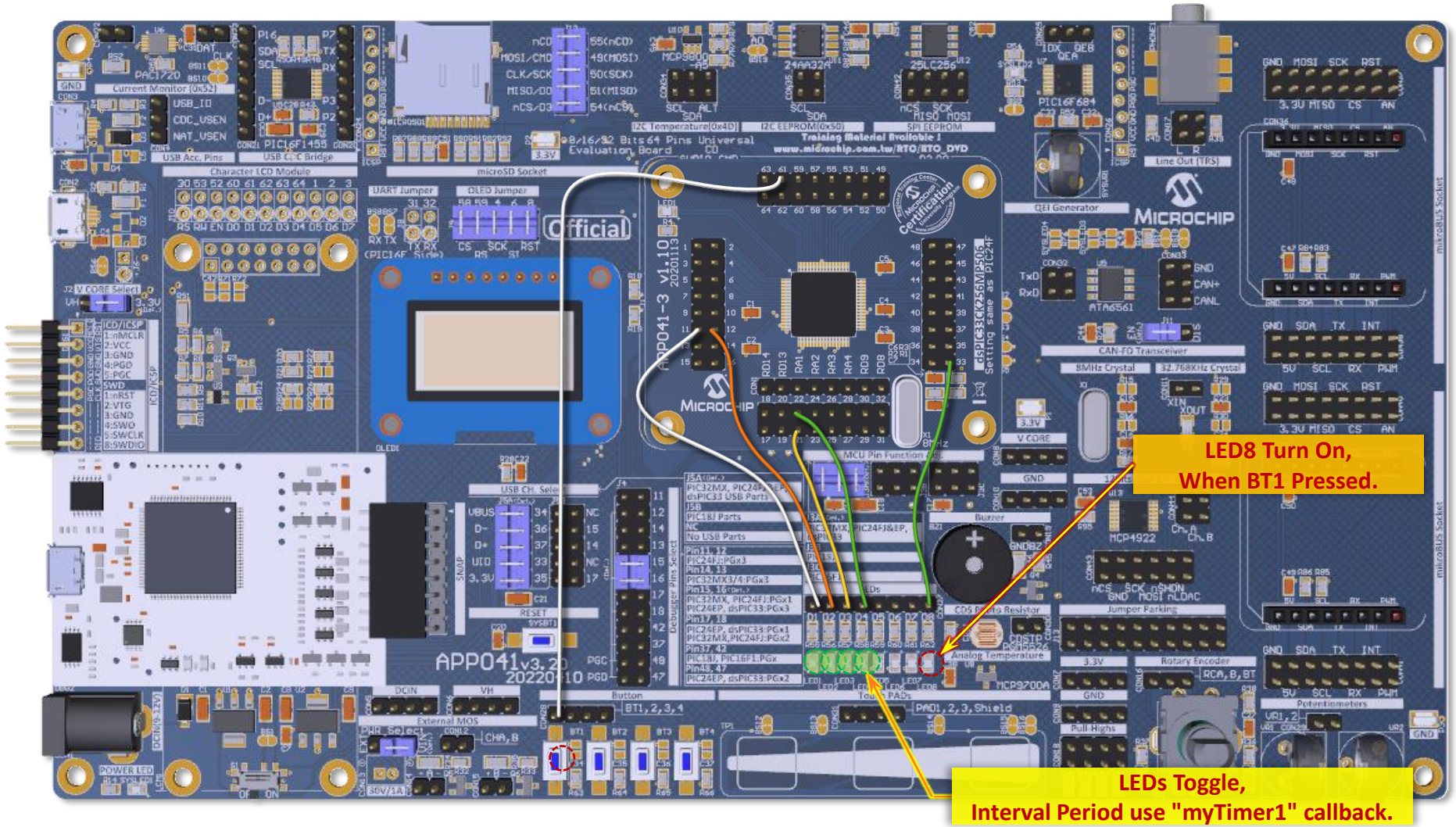
Lab5 Timer1 Interrupt

Code Example

```
#include "mcc_generated_files/system/system.h"
#include "mcc_generated_files/system/pins.h"
#include "mcc_generated_files/timer/tmr1.h"

uint32_t  i = 0;

void myTimer1_Callback(void)
{
   LED1_Toggle();
   LED2_Toggle();
   LED3_Toggle();
   LED4_Toggle();
}

int main(void)
{
   SYSTEM_Initialize();

   myTimer1.TimeoutCallbackRegister(myTimer1_Callback);

   while (1)
   {
      if(BT1_GetValue())
         LED8_SetLow();
      else
         LED8_SetHigh();
   }
}
```

Lab5 Timer1 Interrupt

Result



Lab6 SCCP Timer Interrupt

- Base on current project or Open .\Exercises\Lab6_xxx.X to do exercise.
- Try to add Timer Driver using SCCP1 and rename it as "myTimer2".
- Try to replace software delay to myTimer2 to control LEDs to change state every 1,000ms (1s).
- myTmier2 interrupt priority set to level 2.
- To separate LED1 & LED2, LED3 & LED4 to blink different period.
  - LED1 & LED2 blink by myTimer1 (500ms)
    LED3 & LED4 blink by myTimer2 (1,000ms)

Let's go!

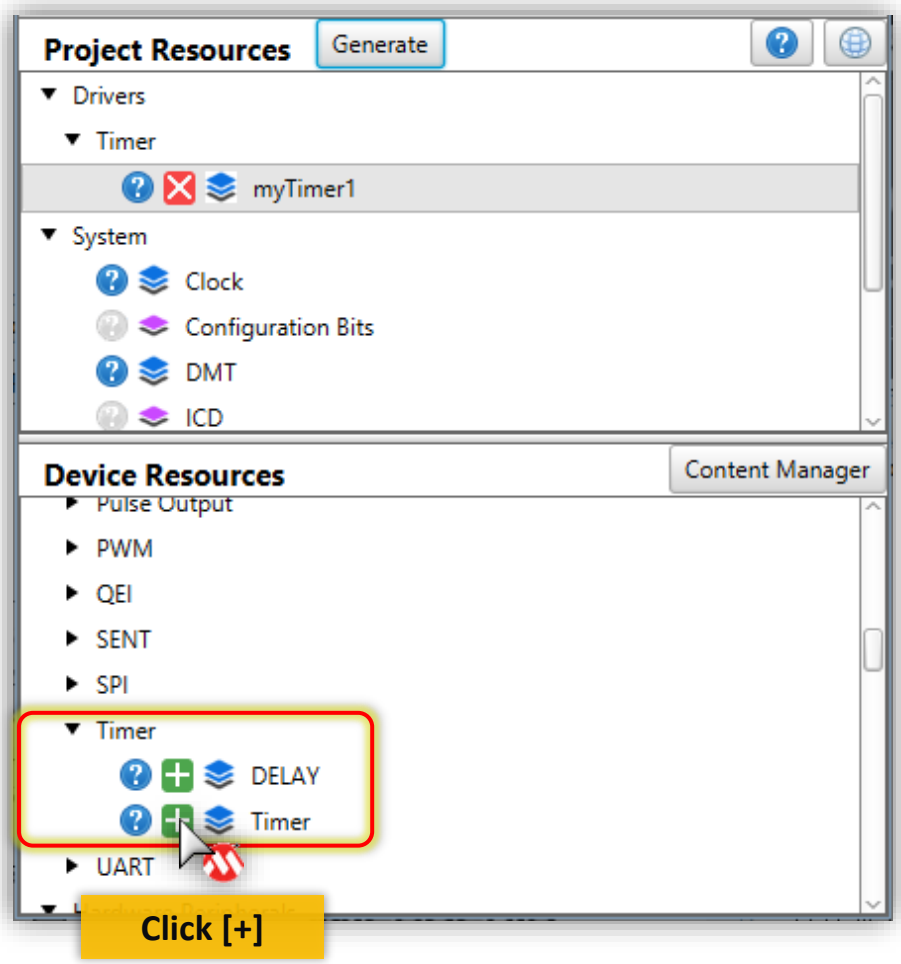
Lab6 SCCP Timer Interrupt

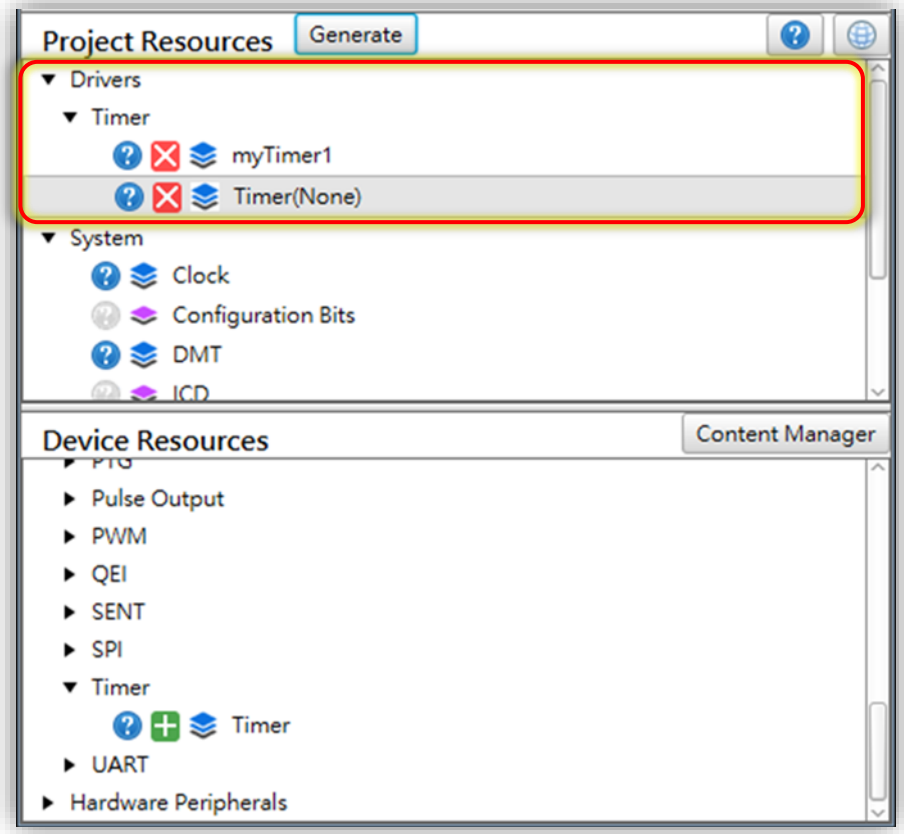
Connection

Lab6 SCCP Timer Interrupt

Step 1

- Click [+] to add **Timer Driver**.

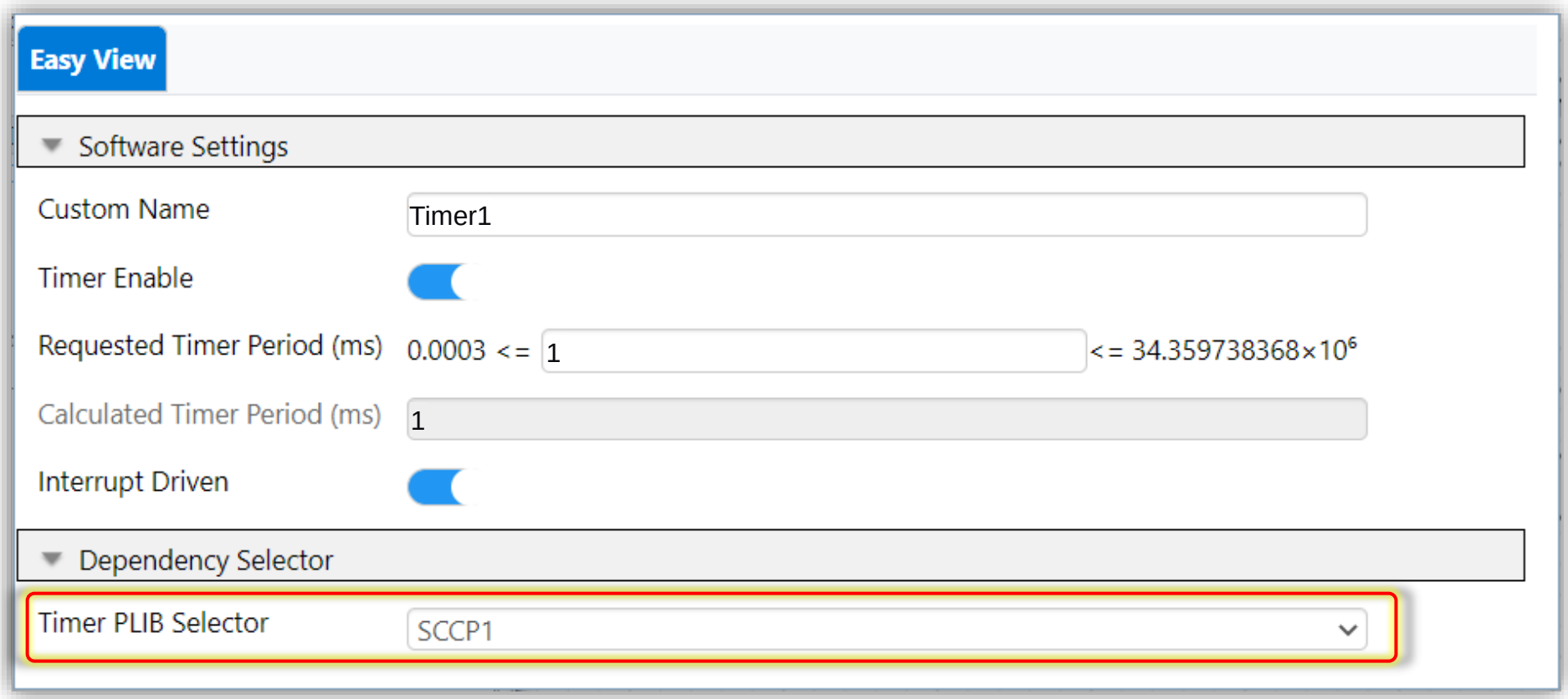




Lab6 SCCP Timer Interrupt

Step 2

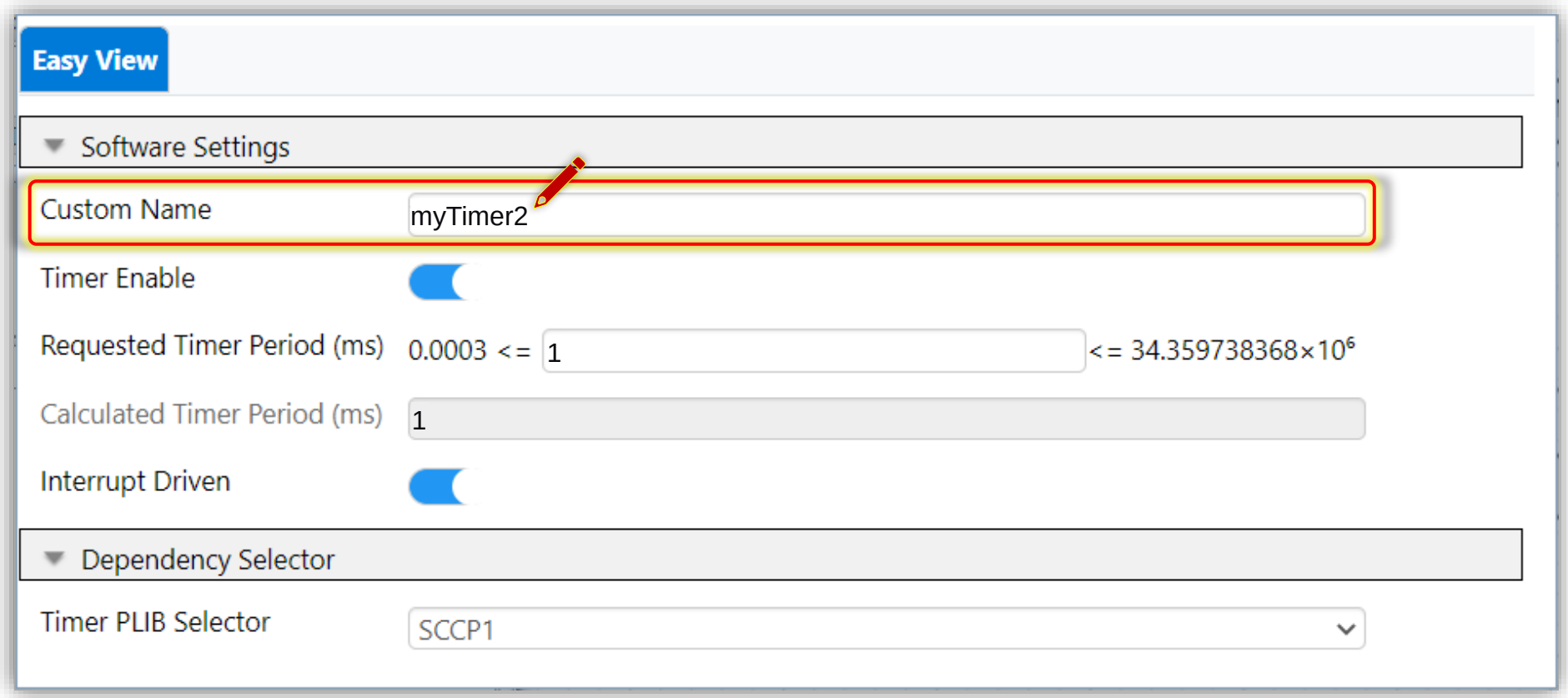
- **Select Timer PLIB to SCCP1.**



Lab6 SCCP Timer Interrupt

Step 3

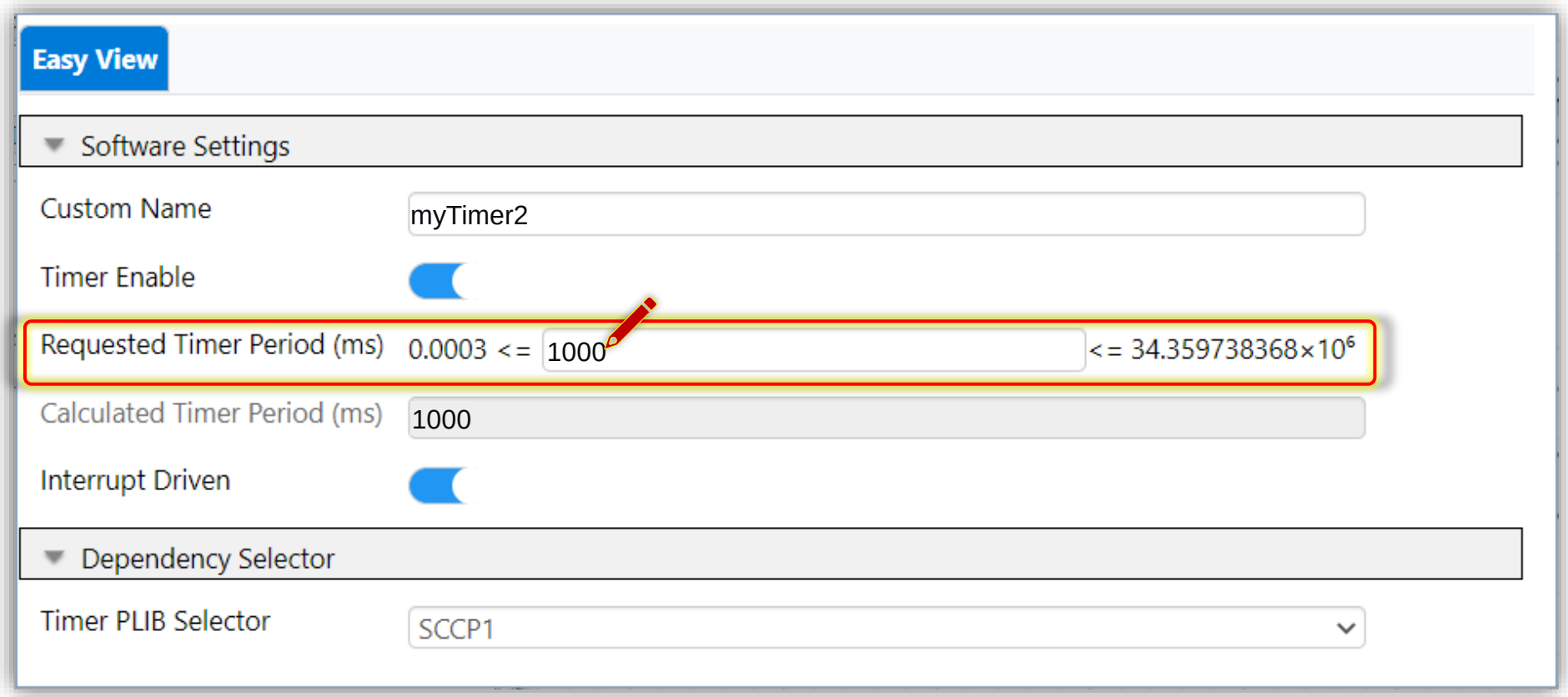
- **Modify the Custom Name to "myTimer2".**



Lab6 SCCP Timer Interrupt

Step 4

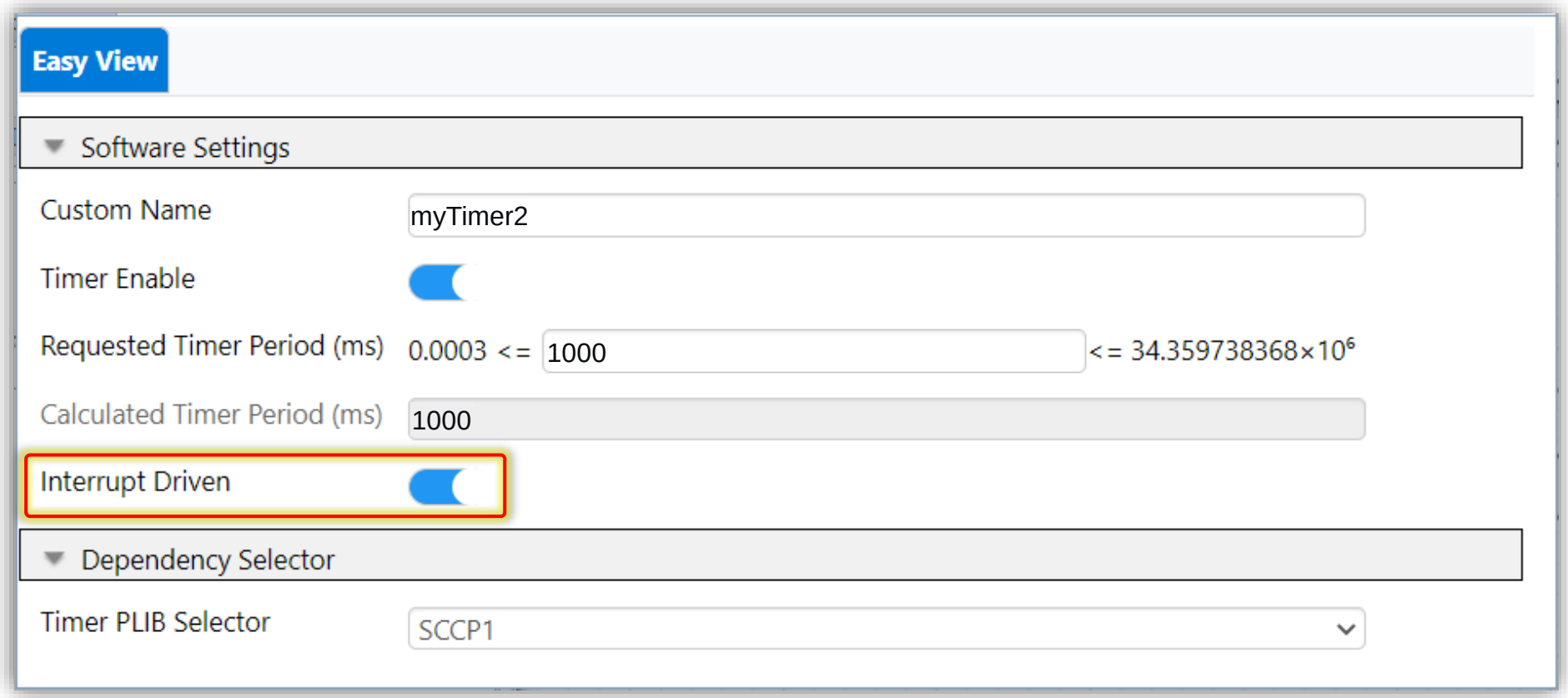
- Set **Requested Timer Period (ms) : 1000.**



Lab6 SCCP Timer Interrupt

Step 5

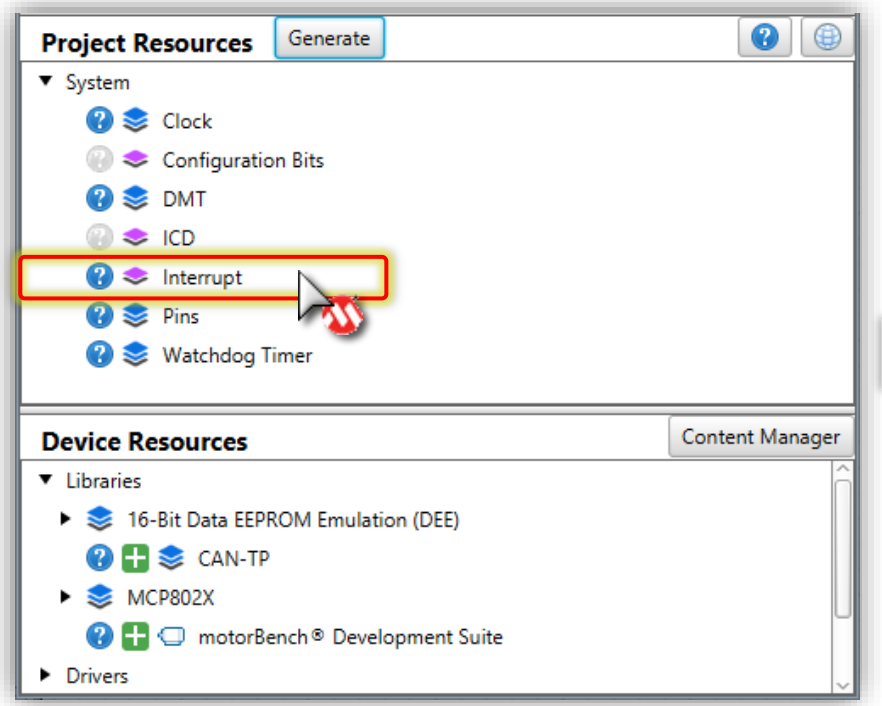
- **Check Timer Interrupt is Driven.**

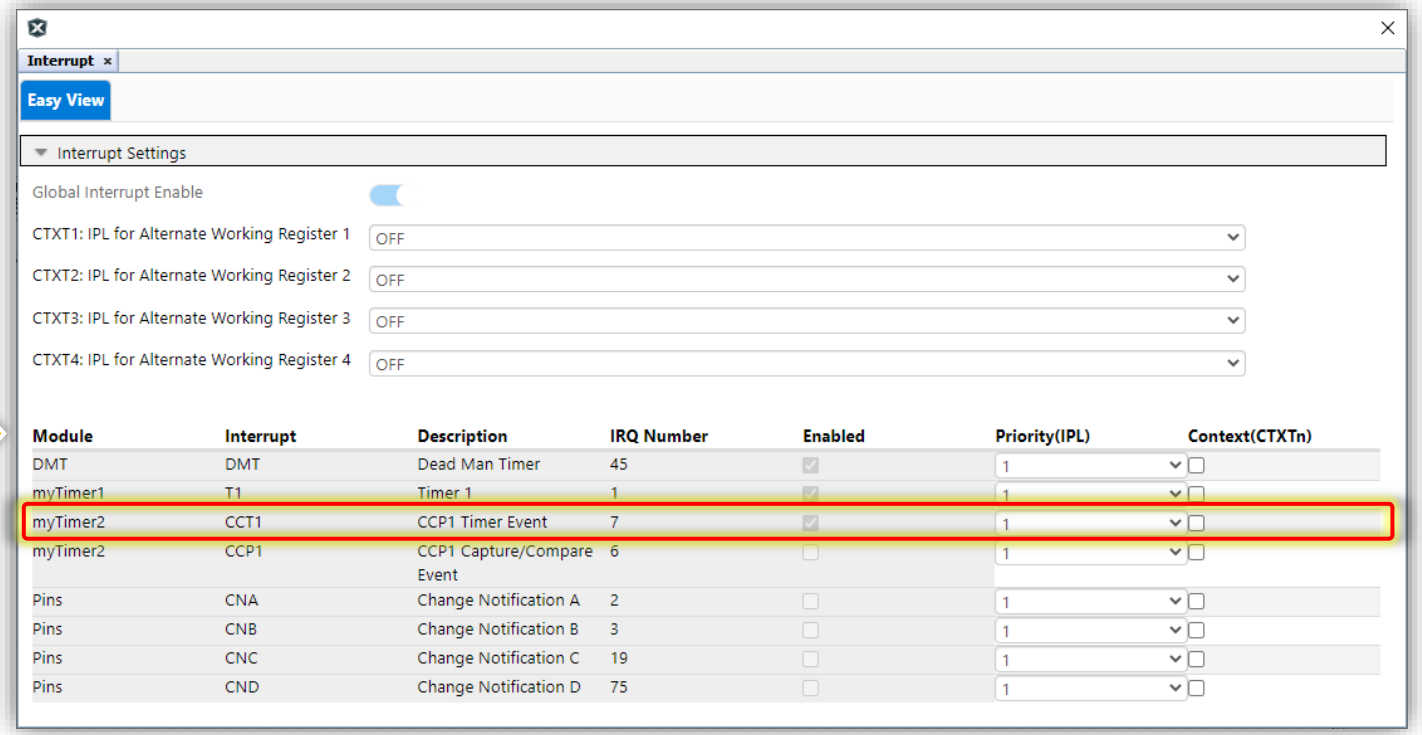


Lab6 SCCP Timer Interrupt

Step 6

- Check Interrupt status (CCP1 Timer Event) for myTimer2.

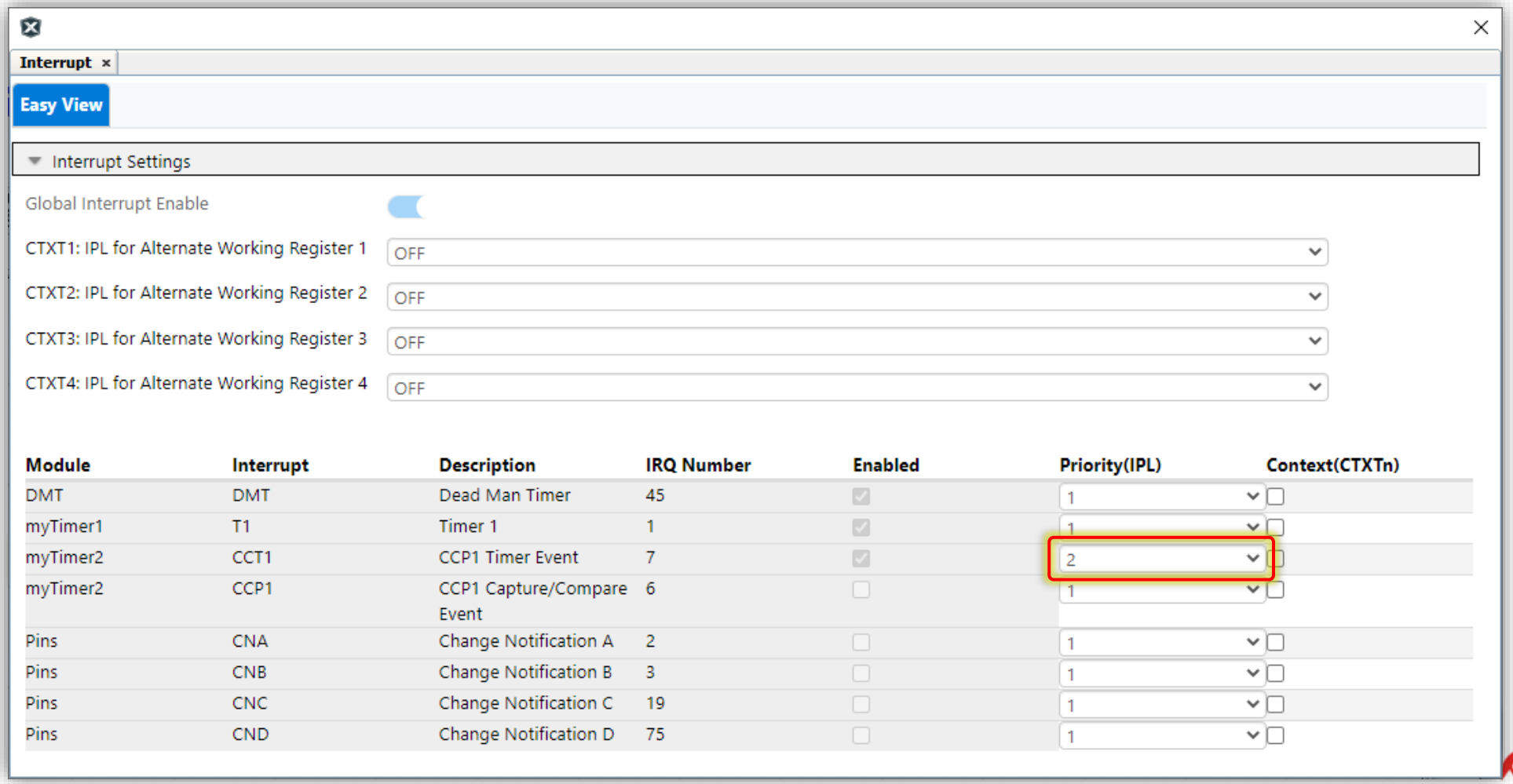




Lab6 SCCP Timer Interrupt

Step 7

- **Modify Timer2 Module's Interrupt Priority for CCT1 Timer Event to 2.**

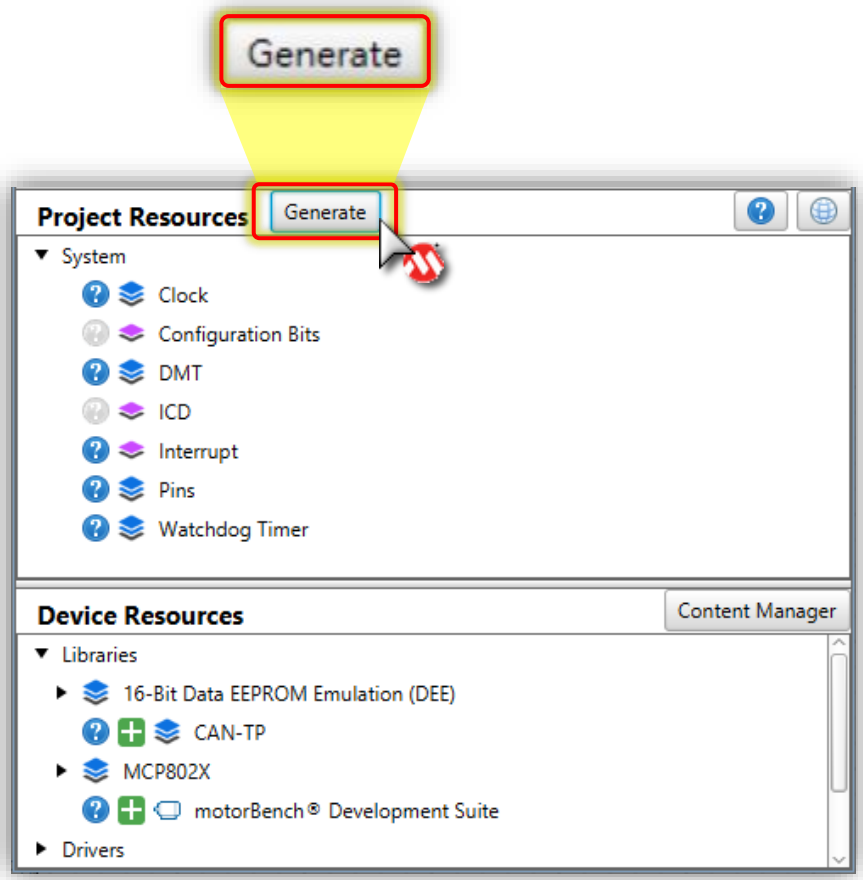


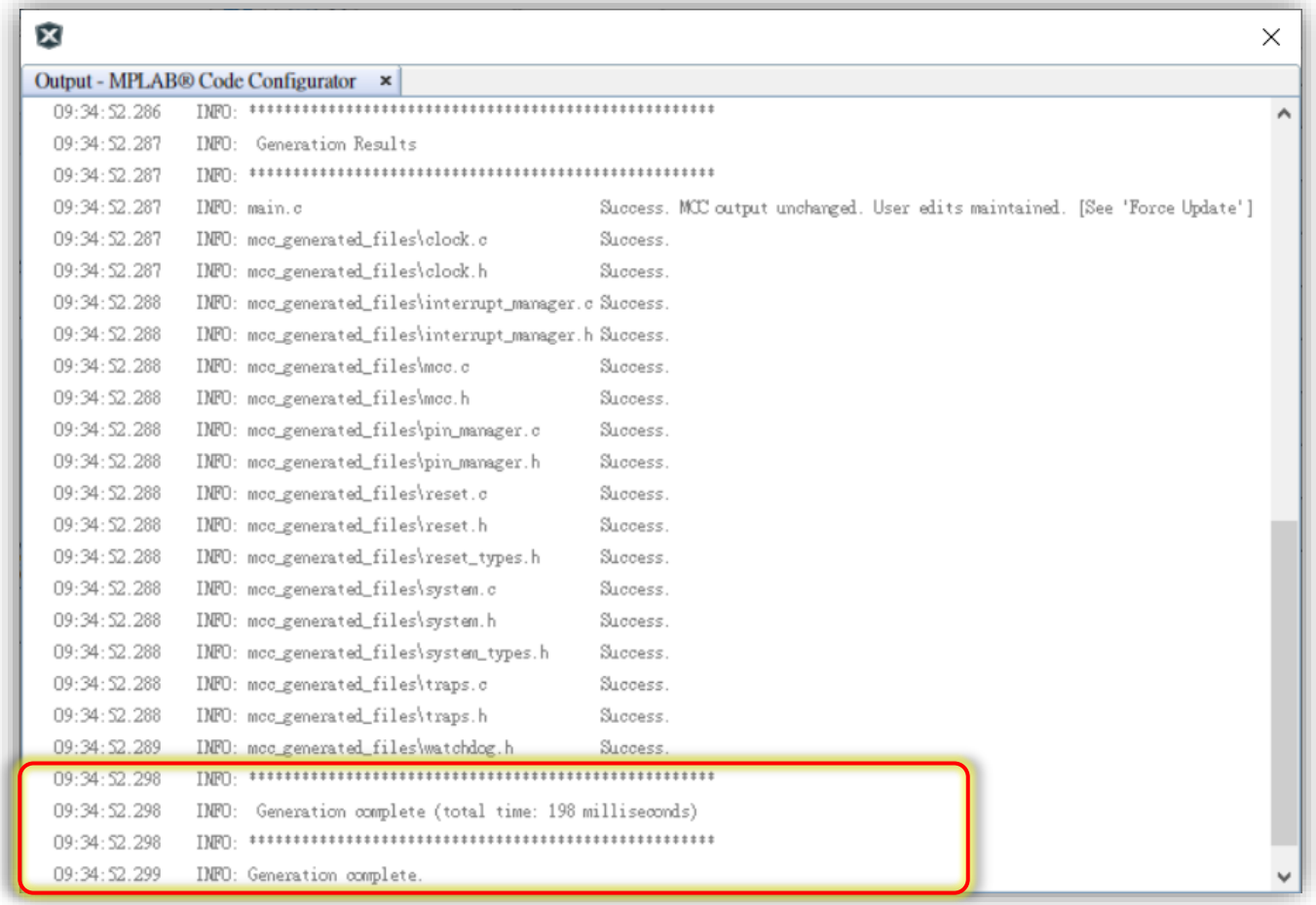
Module	Interrupt	Description	IRQ Number	Enabled	Priority(IPL)	Context(CTXTn)
DMT	DMT	Dead Man Timer	45	☑	1	☐
myTimer1	T1	Timer 1	1	☑	1	☐
myTimer2	CCT1	CCP1 Timer Event	7	☑	2	☐
myTimer2	CCP1	CCP1 Capture/Compare Event	6	☐	1	☐
Pins	CNA	Change Notification A	2	☐	1	☐
Pins	CNB	Change Notification B	3	☐	1	☐
Pins	CNC	Change Notification C	19	☐	1	☐
Pins	CND	Change Notification D	75	☐	1	☐

Lab6 SCCP Timer Interrupt

Step 8

- Click "Generate" Button to generate your code.





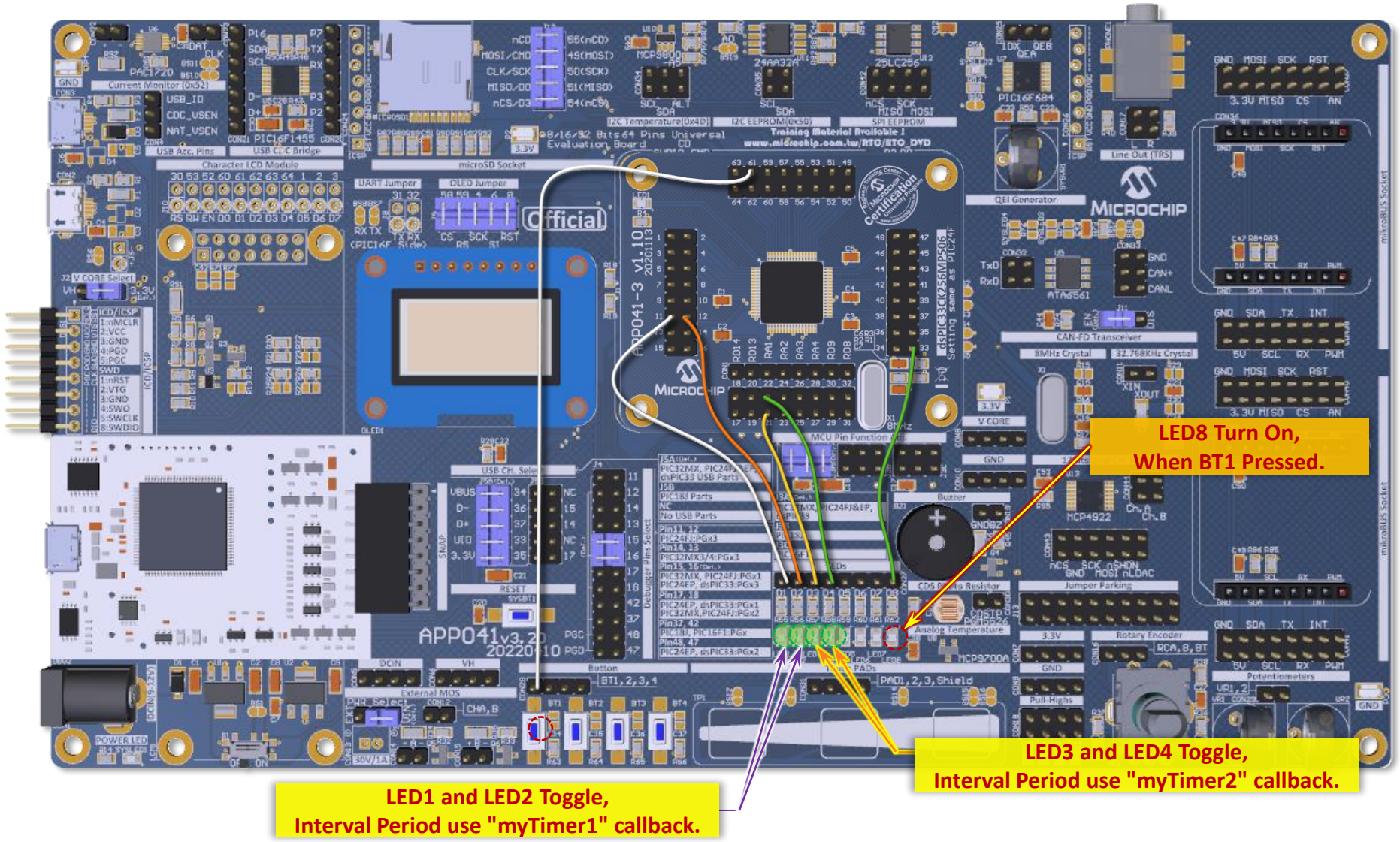
Lab6 SCCP Timer Interrupt

Code Example

```
...
#include "mcc_generated_files/timer/tmr1.h"
#include "mcc_generated_files/timer/sccp1.h"

uint32_t  i = 0;

void myTimer1_Callback(void)
{
   LED1_Toggle();
   LED2_Toggle();
}

void myTimer2_Callback(void)
{
   LED3_Toggle();
   LED4_Toggle();
}

int main(void)
{
   SYSTEM_Initialize();

   myTimer1.TimeoutCallbackRegister(myTimer1_Callback);
   myTimer2.TimeoutCallbackRegister(myTimer2_Callback);

   while (1)
   {
      ...
   }
}
```

Lab6 SCCP Timer Interrupt

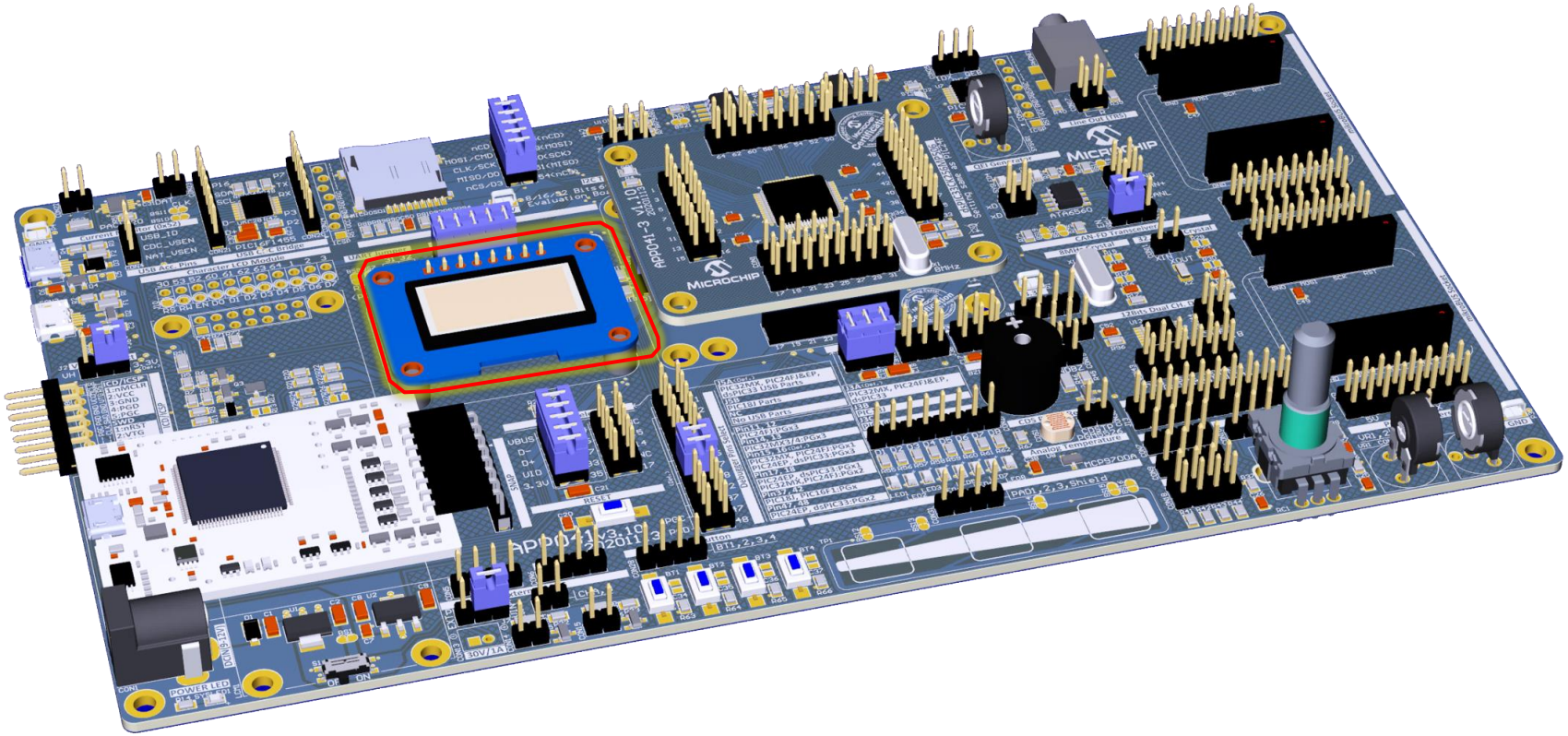
Result



OLED Application (PPS & SPI)

OLED Graphic Display

- OLED (Organic Light-Emitting Diode) with controller
  - 128 x 64 Dot matrix, Monochrome, 3 Wire SPI with 3 External control pins.
- Controller : SSD1306
  - 128 x 64 Dot Matrix OLED/PLED Segment/Common Driver with Controller and SPI communication interface.

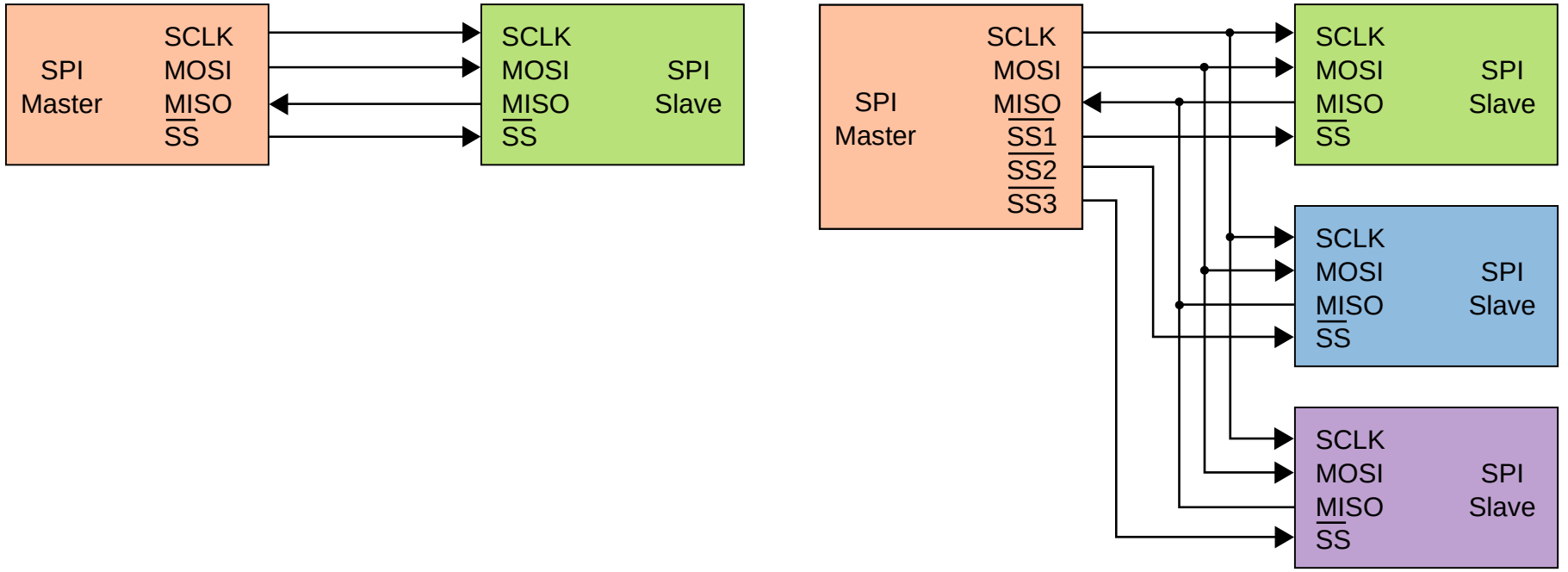


Recourses Requirement for OLED

- **Peripherals : SPI**
  - **3 Wire SPI, Mode 0, SCLK = 8 MHz**
    - Chip Select
    - SCK
    - SDO(MOSI)
- **Peripherals : GPIO**
  - **CS : Chip Select (Enable Chip & Initial Communication)**
    - High : Disable.
    - Low : Enable.
  - **RS : Data / Command select**
    - High : Data.
    - Low : Command.
  - **RESET : Module Reset**
    - High : Normal.
    - Low : Hold Reset.
- **Drivers: Delay Driver**
  - **Timing Control (Block)**

What's SPI

- **SPI, Serial Peripheral Interface**
- **It's a serial communication interface.**
  Synchronous, inside-board level, short distance communication.



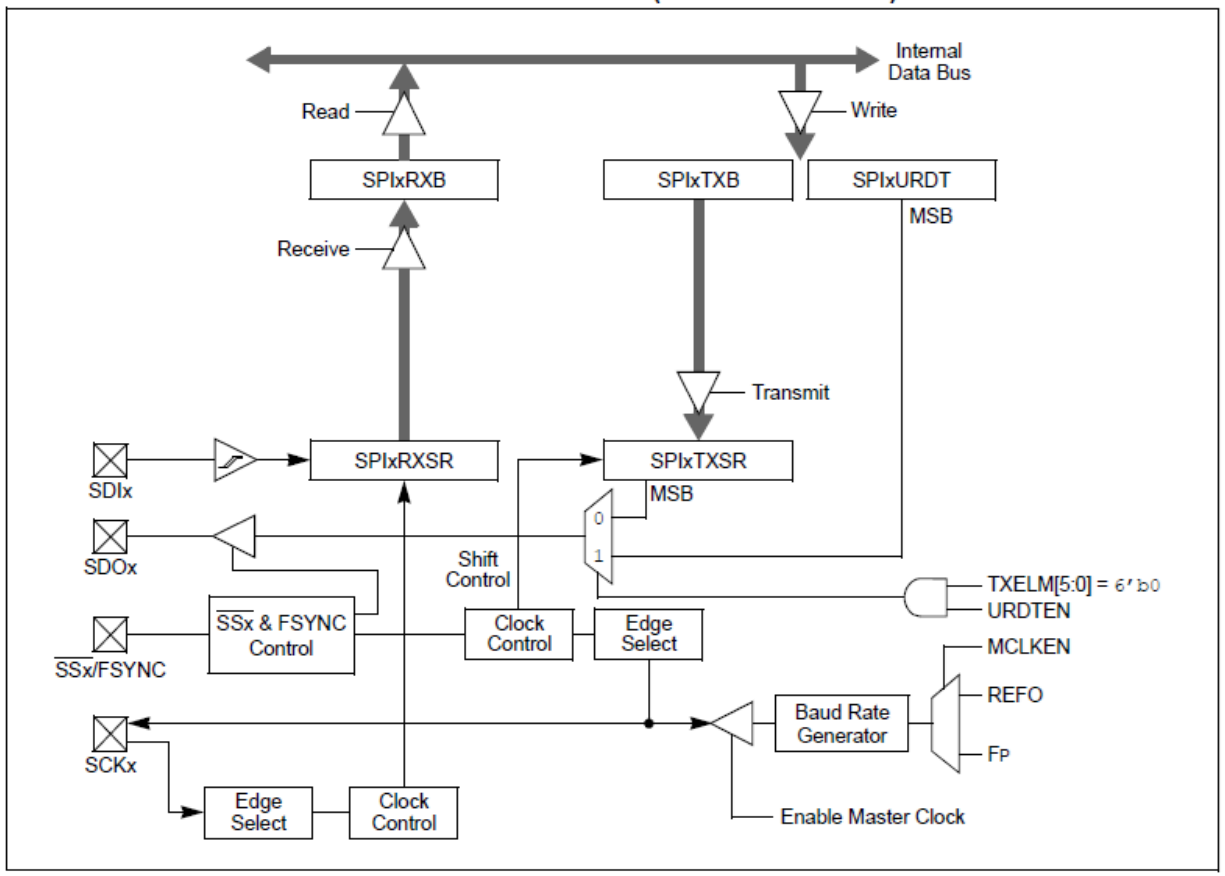
https://zh.wikipedia.org/wiki/%E5%BA%8F%E5%88%97%E5%91%A8%E9%82%8A%E4%BB%8B%E9%9D%A2

MICROCHIP

dsPIC33's SPI Module

- **dsPIC33CK256MP506 Provide 3 SPI module, support limited pin remapping.**
- **Pin Definition :**
  - **SDO (MOSI) :**
    - **Data Out, dsPIC33 to Device.**
  - **SDI (MISO) :**
    - **Data In, Device to dsPIC33.**
  - **SCK (SCLK) :**
    - **Clock Out, dsPIC33 to Device.**
  - **SS (FSYNC) :**
    - **Active-Low Slave Select or Frame Synchronization I/O Pulse**

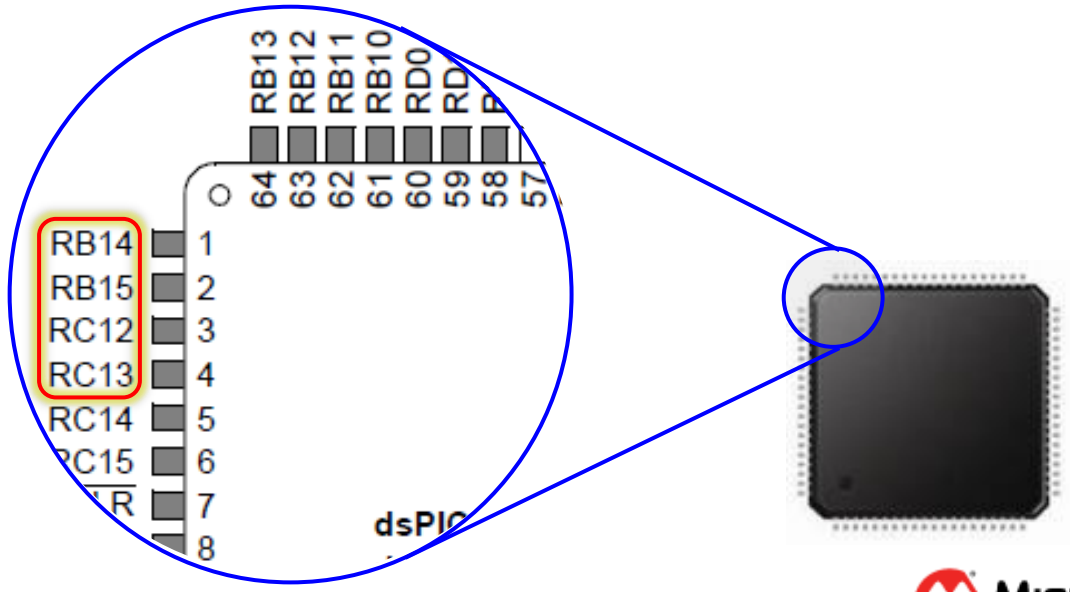
FIGURE 17-1: SPIx MODULE BLOCK DIAGRAM (STANDARD MODE)



What's PPS

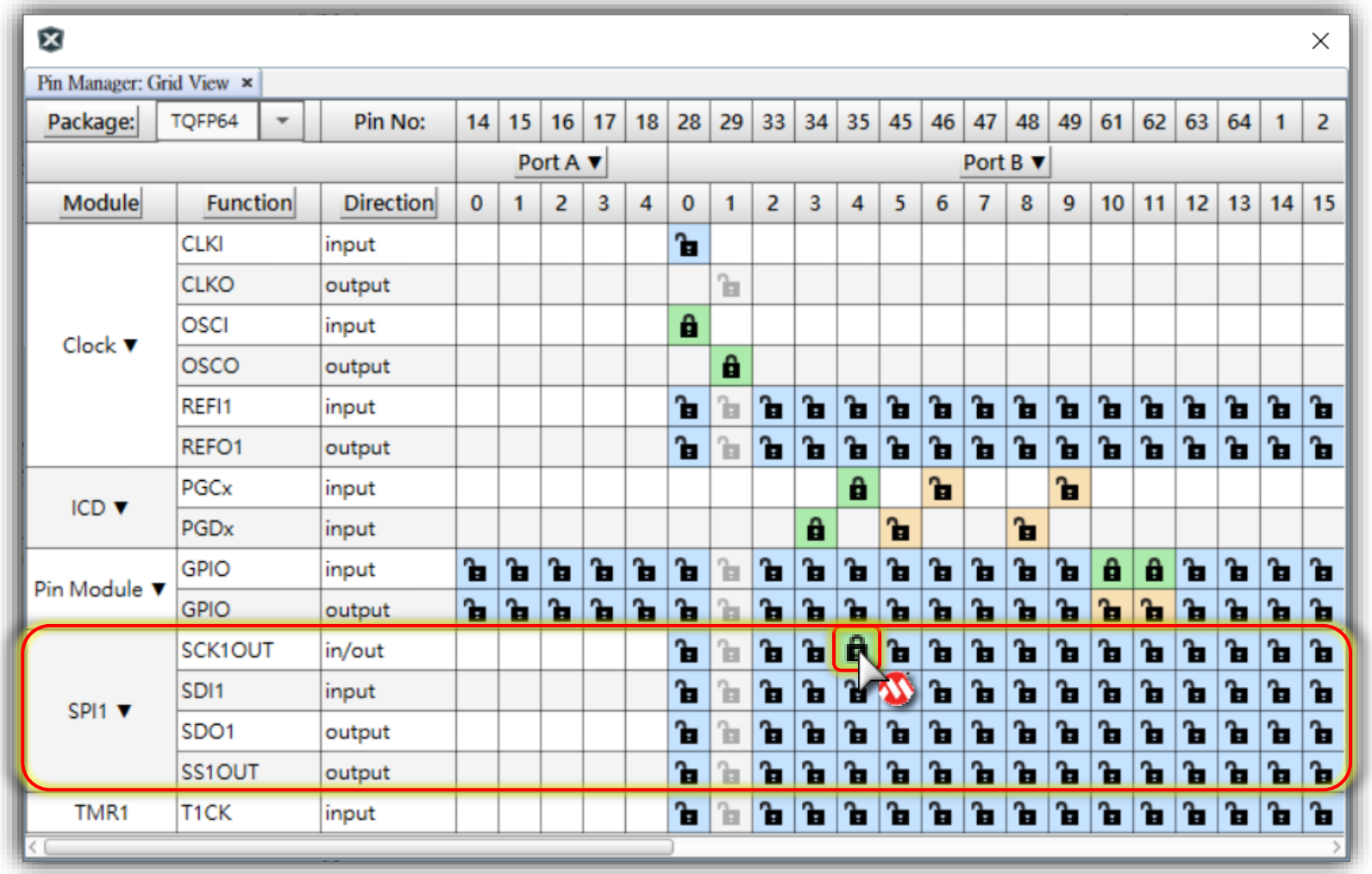
- PPS, Peripheral Pin Select
- Provides a flexible peripheral pins remapping mechanism users can better tailor the microcontroller to their entire application.
- PPS pin definition
  - RP*n* : Input & Output
  - RPI*n* : Input Only
- The peripherals managed by the peripheral pin select are all digital only peripherals.

Pin #	Function
1	**RP46**/PWM1H/PMD5/RB14
2	**RP47**/PWM1L/PMD6/RB15
3	**RP60**/PWM8H/PMD7/RC12
4	**RP61**/PWM8L/PMA5/RC13



PPS Assign Pin at Pin Manager

- **Just one Click on that pin you want to config in :**
  - **Pin Manager : Gird View**



What’s Delay Driver

- The Delay Driver aims to provide an abstraction interface for invoking built-in delay macros across device families.
- Flexible APIs for creating blocking delays in millisecond and microsecond time units, use real instruction cycle (Tcy) to generate time latency to ensure accurate delay.

OLED Functions of myOLEDlib

- **We Provide below functions for OLED:**
  "myOLED_ssd1306.c", "myOLED_ssd1306.h"
  - `void myOLED_Init(void);` /* Initial OLED Module */
  - `void myOLED_ClearScreen(void);` /* Clear Screen */
  - `void myOLED_DrawBitmap(uint8_t column, uint8_t page, uint8_t width, uint8_t height, const uint8_t *byte);` /* Draw Raw Bitmap Picture */
  - `void myOLED_DrawChar(uint8_t column, uint8_t page, uint8_t byte);` /* Draw Single Character */
  - `void myOLED_DrawStr(uint8_t column, uint8_t page, const uint8_t *byte);` /* Draw String */

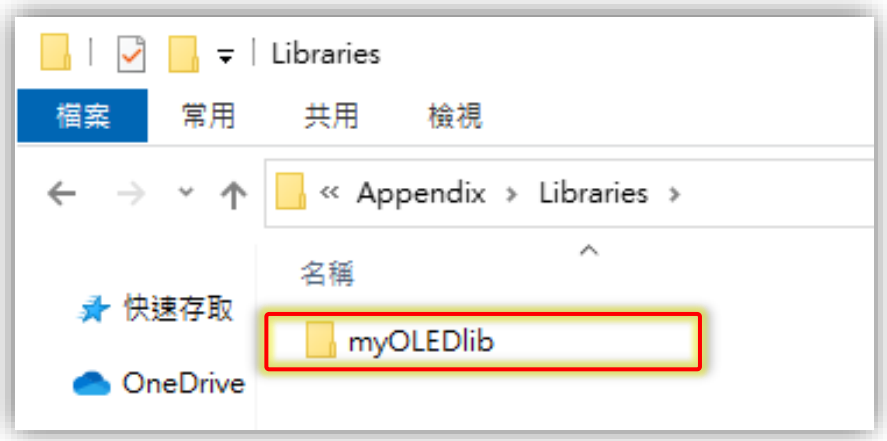
Lab Preparation

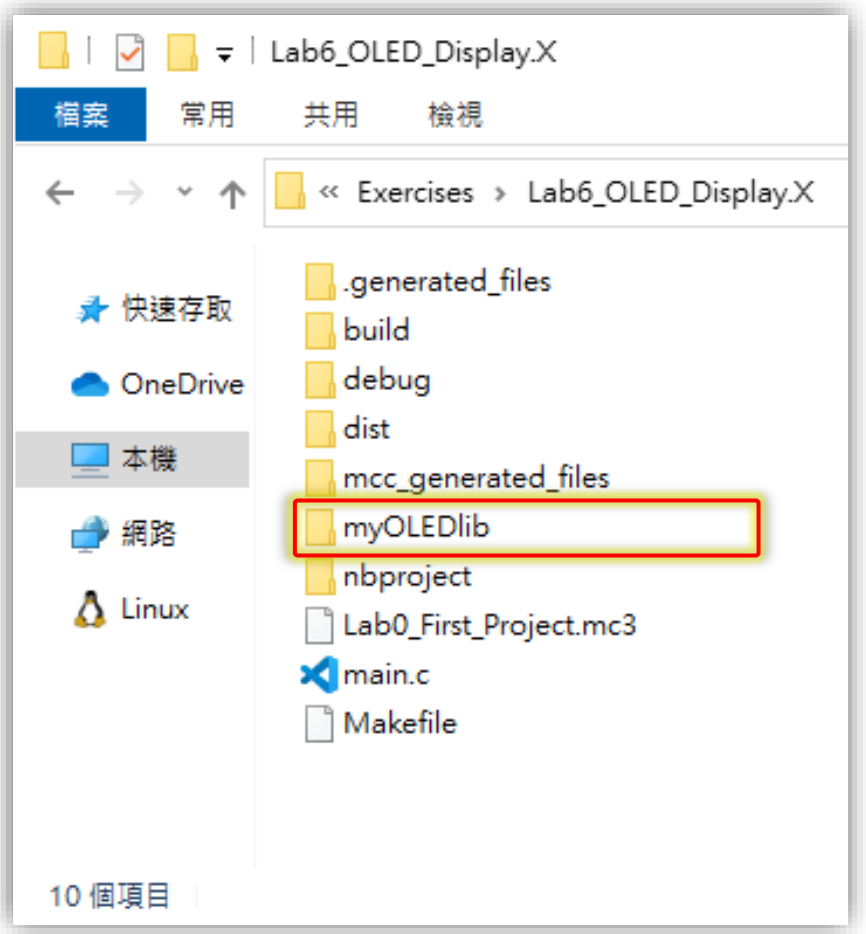
Add OLED Libraries

Lab Preparation

Step 1

- **File Copy paste on folder.**
  - **(\Appendix\Libraries\myOLEDlib** to **\Lab*n*_xxx.X)**



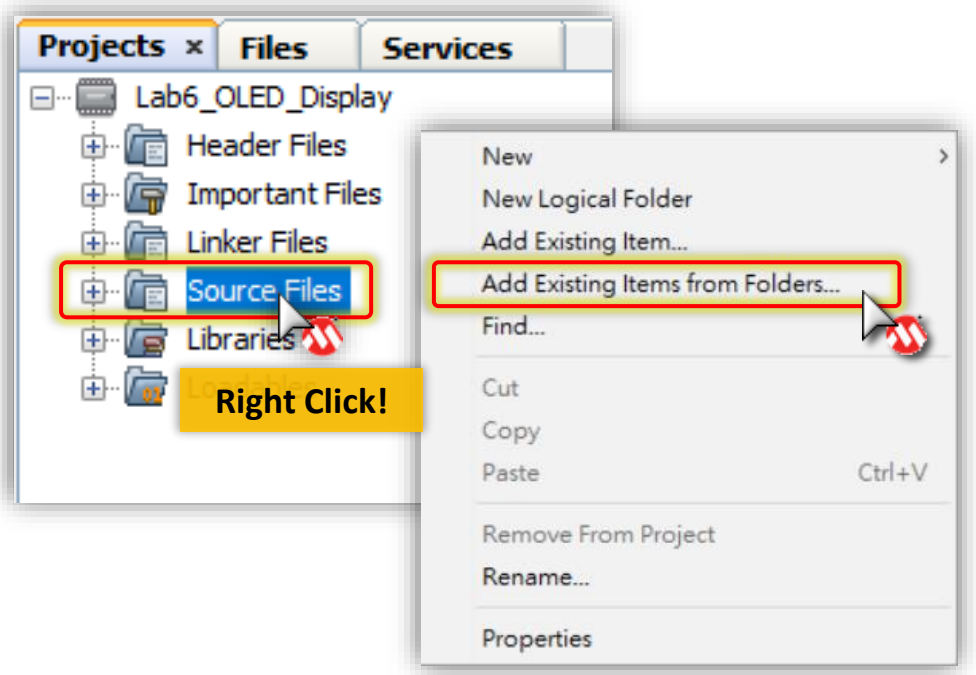


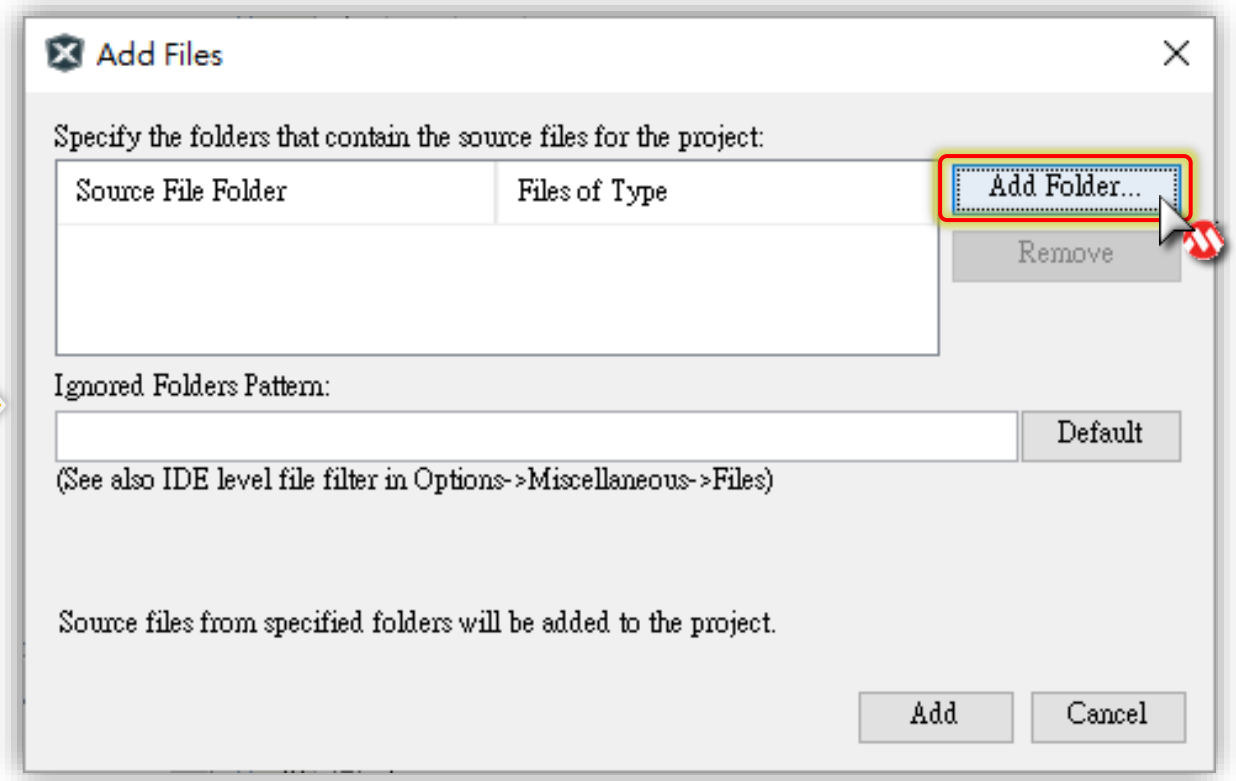
MICROCHIP

Lab Preparation

Step 2

- **Add Existing Folder to Project**
  - Right click on "**Source Files**".
  - Select "**Add Existing Items from Folders**" at Projects Windows.
  - Select "**Add Folder…**".

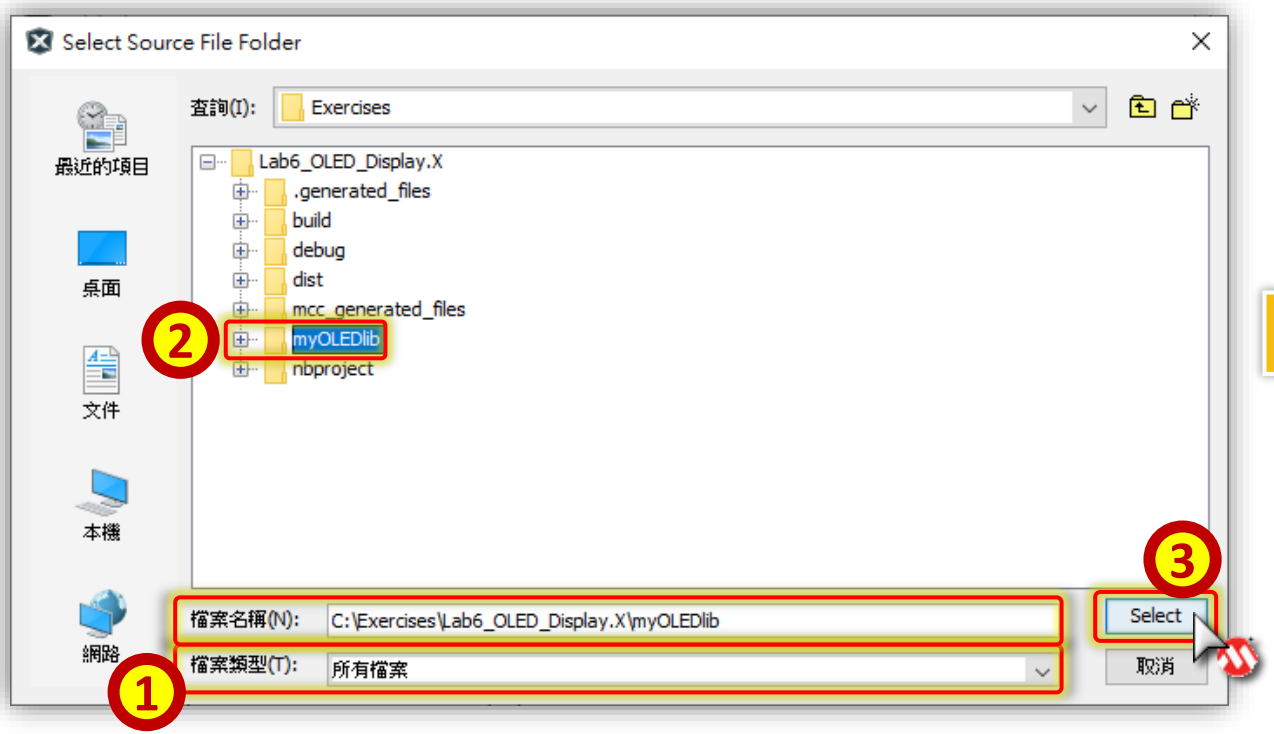


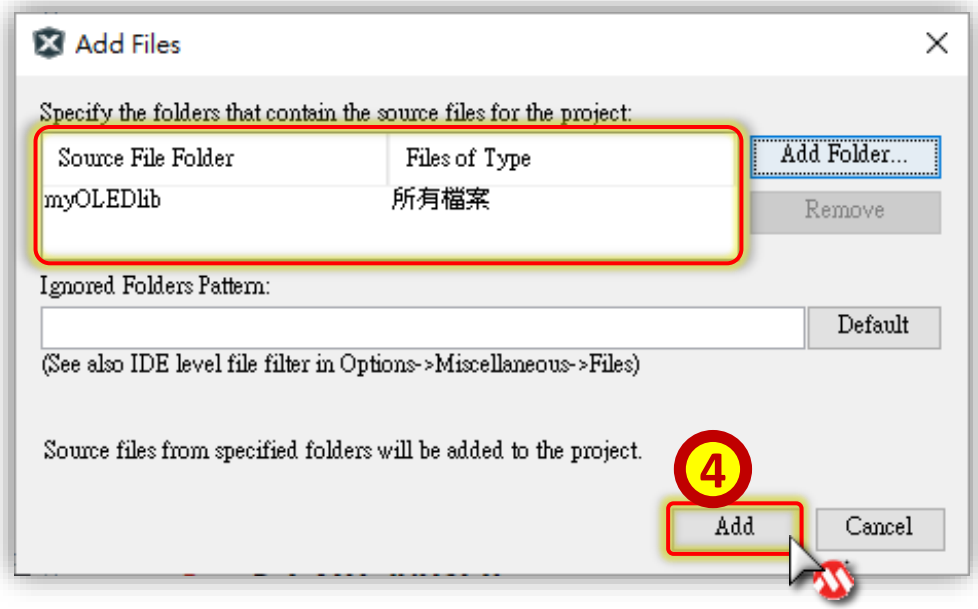


Lab Preparation

Step 3

- **Select myOLEDlib folder to Add**
  - Select File Filter(檔案類型) to : "**All Files (所有檔案)**".
  - Click on folder "**myOLEDlib**".
  - Click "**Select**".
  - Click "**Add**"

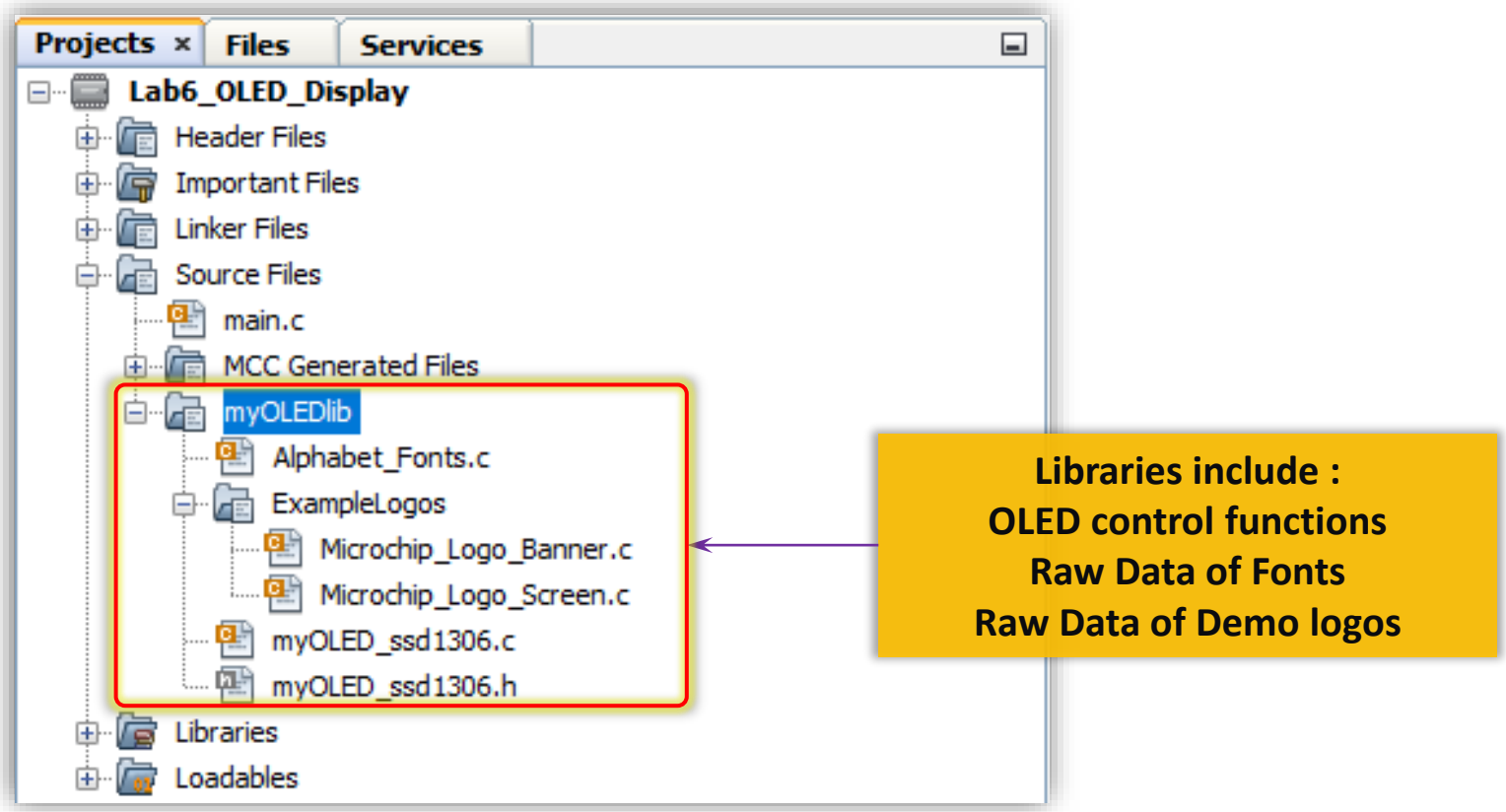




Lab Preparation

Step 4

- **Success to add "myOLEDlib" libraries folder in your Project.**



Lab7 OLED Display

- **Base on current project or Open .\Exercises\Lab7_xxx.X to do exercise**
- **Try to add OLED Library and related resources to project then initial OLED display.**
- **Try to display some information and bitmap logo on OLED display.**

Let’s go!

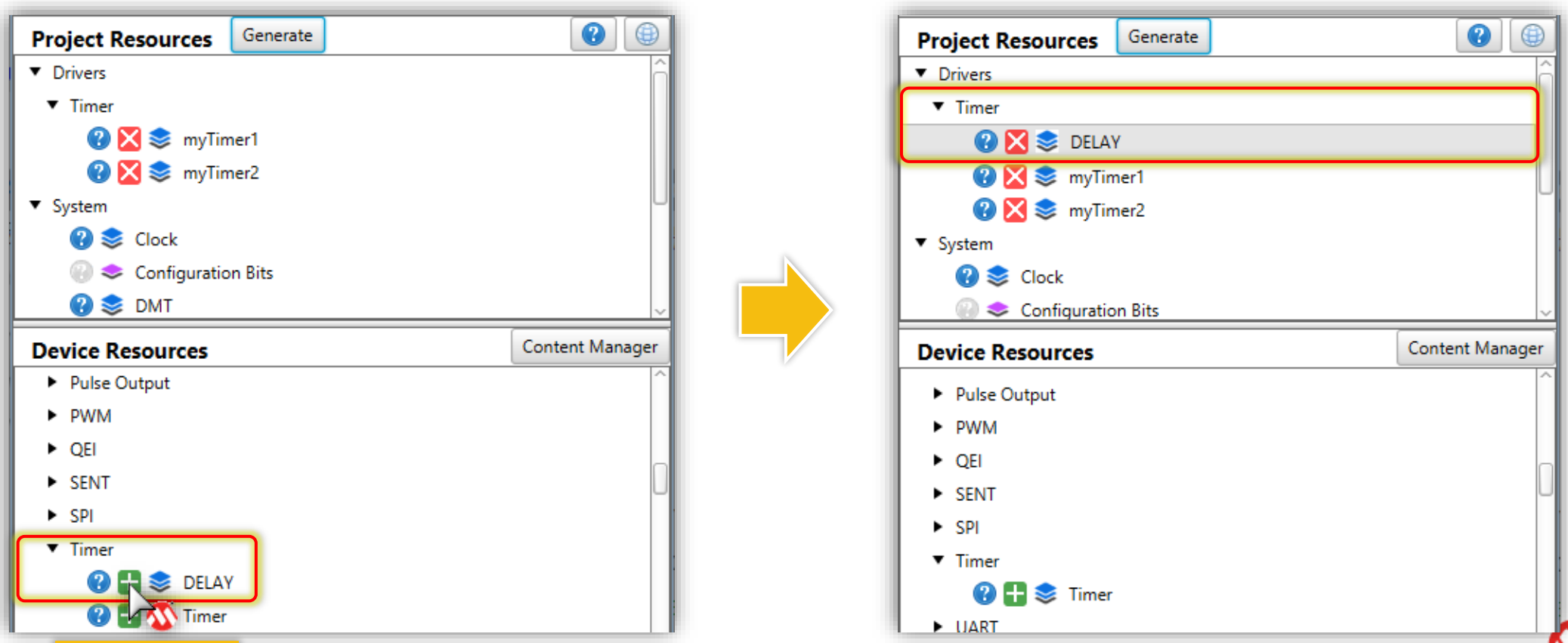
Lab7 OLED Display

Connection

Lab7 OLED Display

Step 1

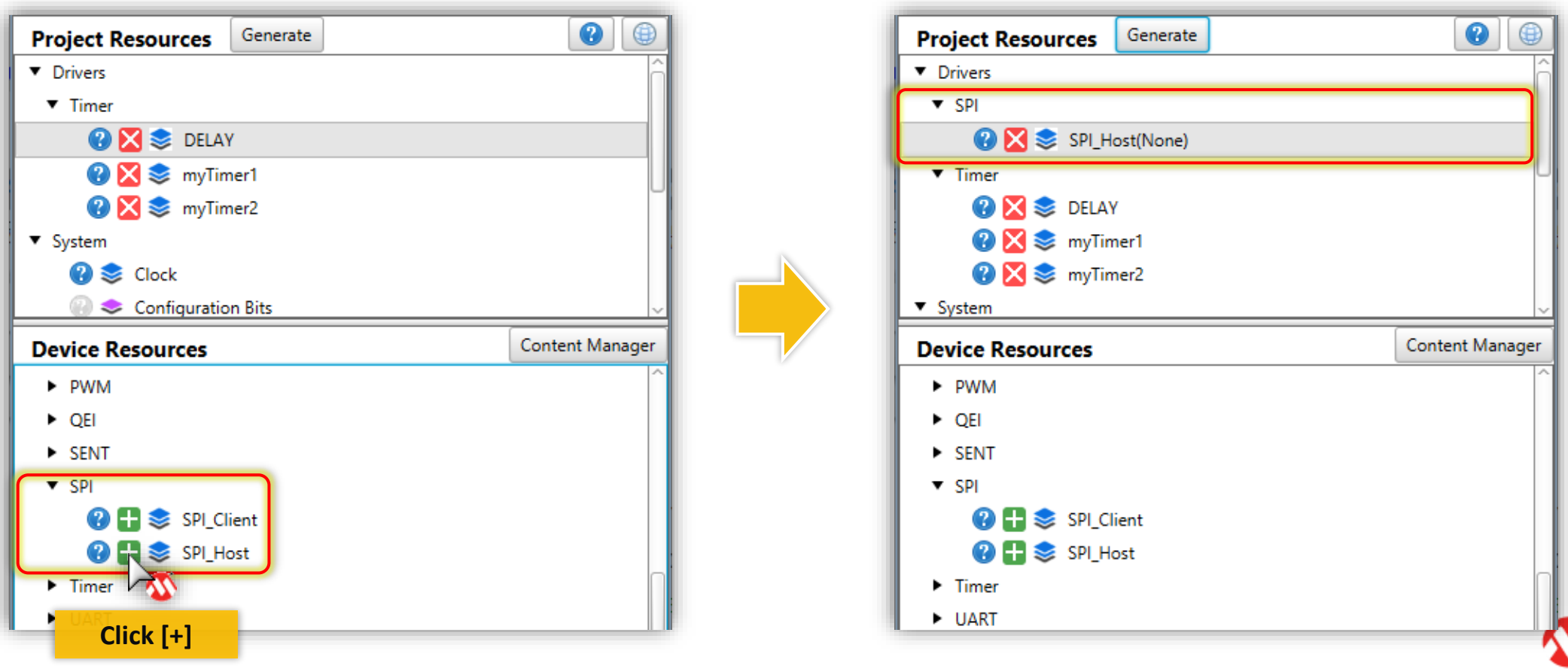
- Click [+] to add Timer > DELAY Module.



Lab7 OLED Display

Step 2

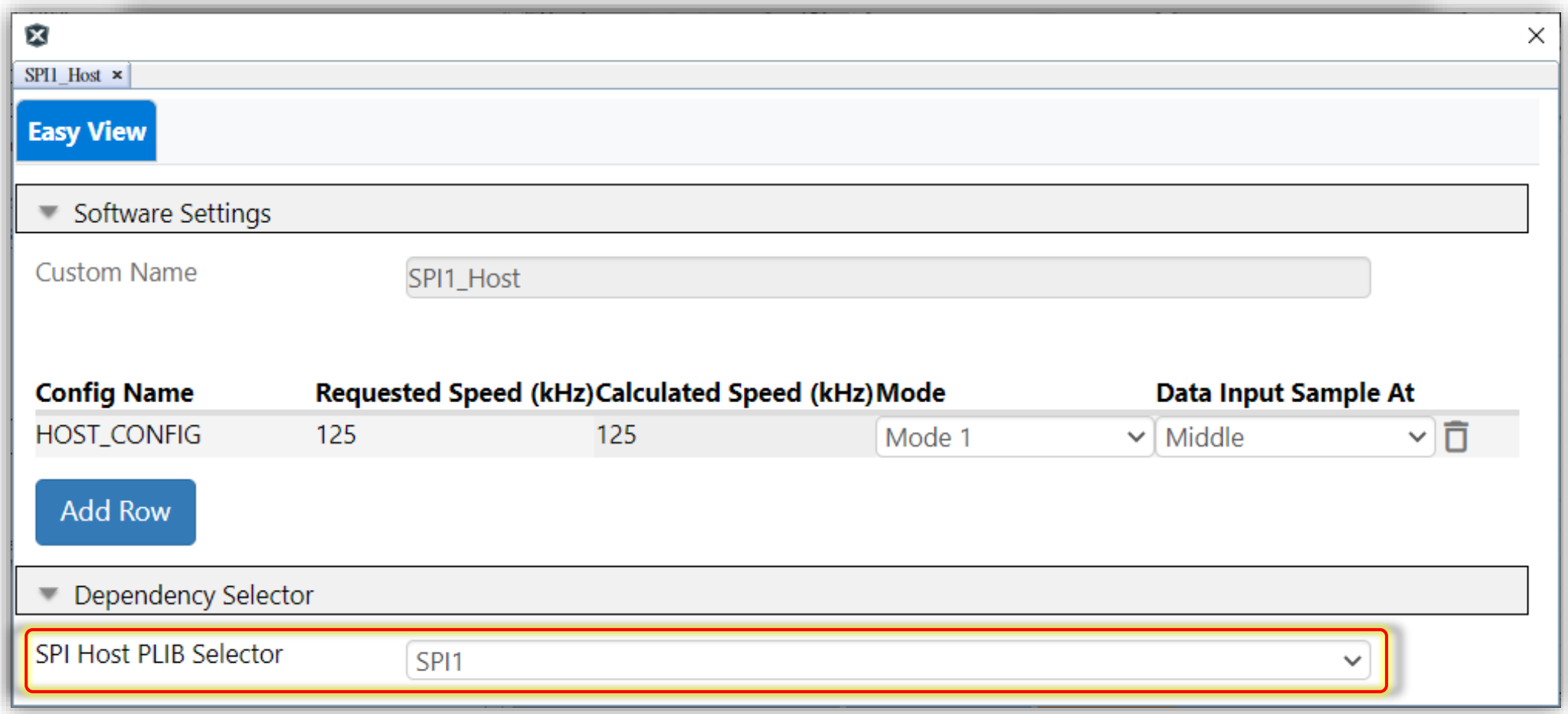
- Click [+] to add SPI > SPI_Host Module.



Lab7 OLED Display

Step 3

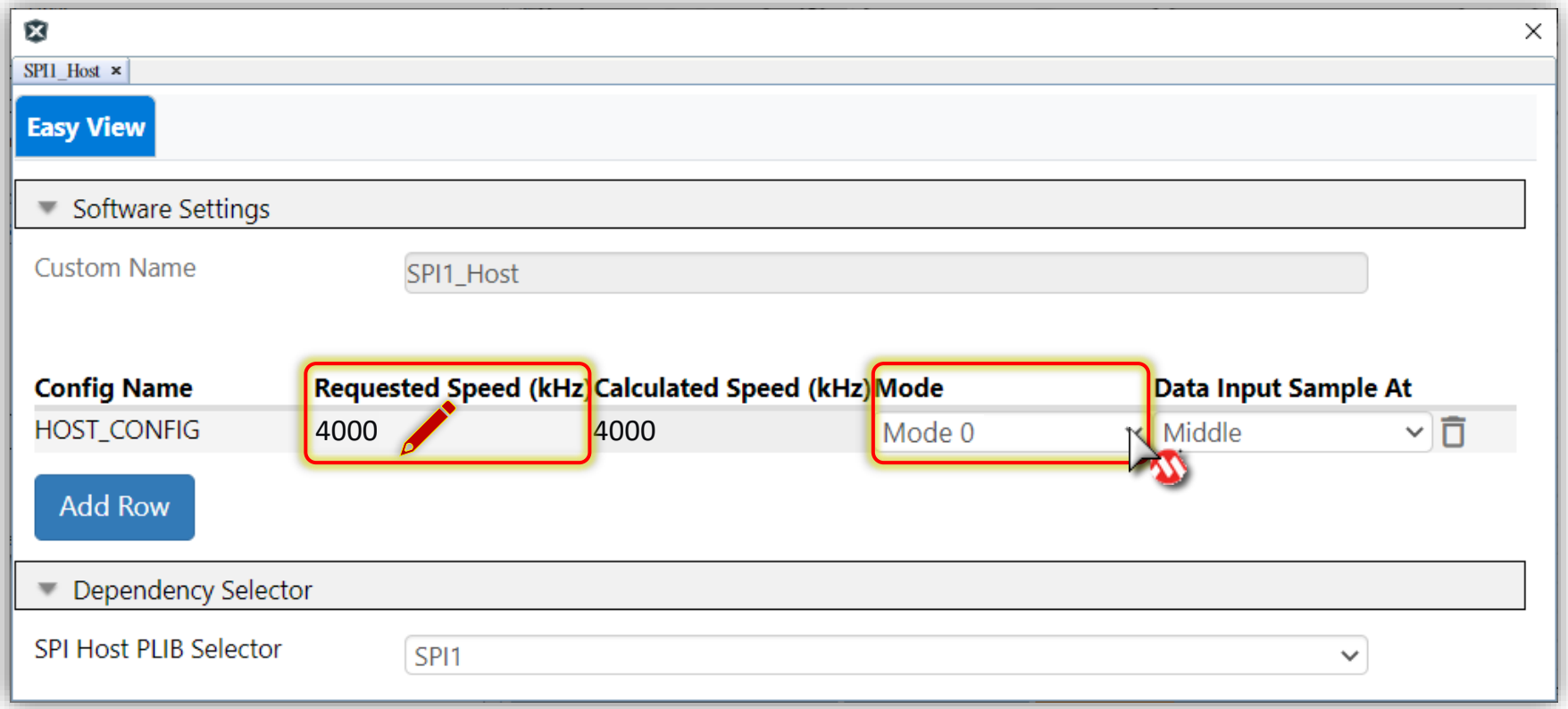
- Set SPI Host PLIB Selector Module → SPI1.



Lab7 OLED Display

Step 4

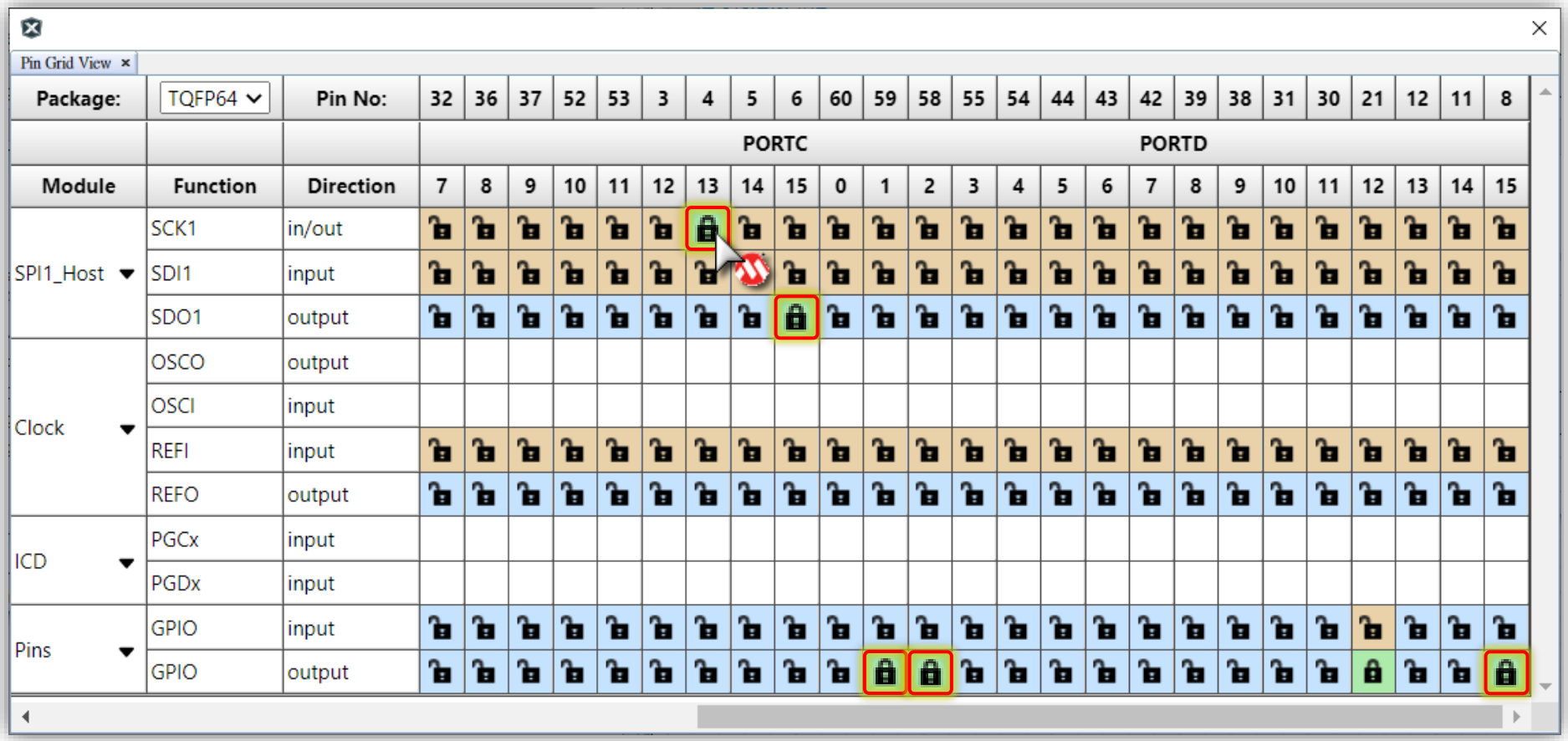
- Set **Requested Speed (kHz)**: 125 → **4000**
- Set **SPI Mode**: Mode 1 → **Mode 0**



Lab7 OLED Display

Step 5

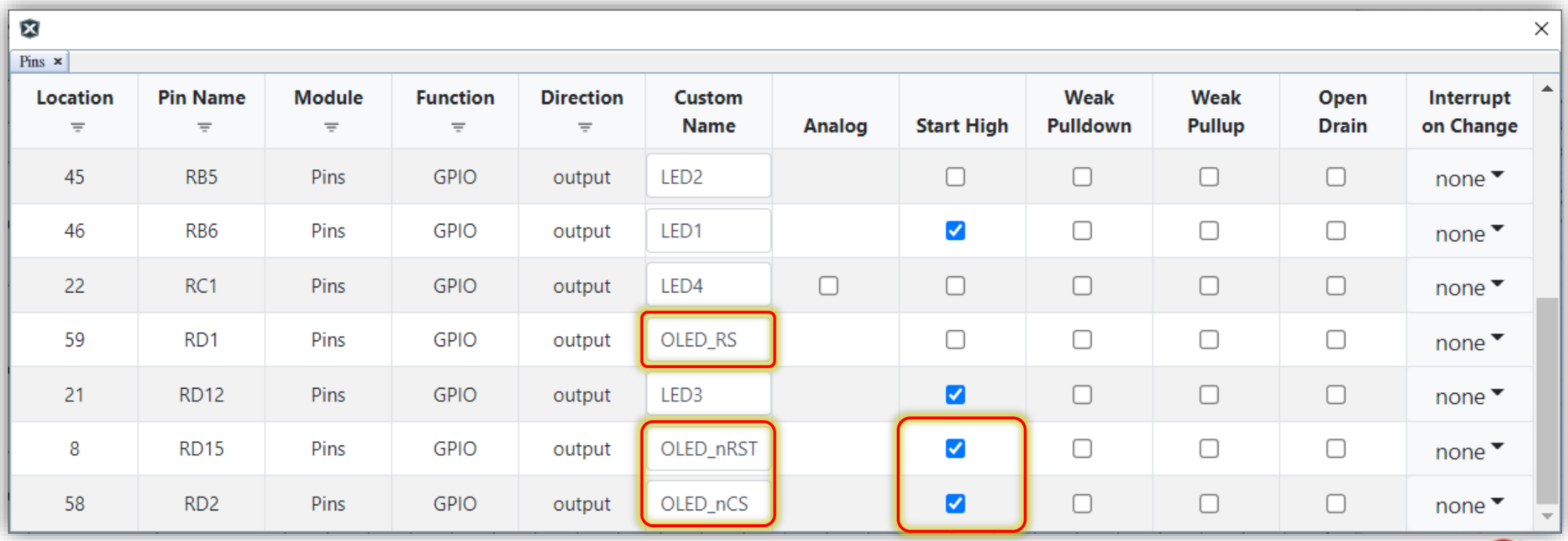
- Set PORTC: RC13 (SCK1), RC15 (SDO1), to PPS SPI Function.
- Set PORTD: RD1 (RS), RD2 (nCS), RD15 (nRST), to digital output mode.



Lab7 OLED Display

Step 6

- **Set Alias for RD1 , RD2 and RD15.**
  - **Pins : RD1 Custom Name → OLED_RS, Check Output**
  - **Pins : RD2 Custom Name → OLED_nCS, Check Output, Start High**
  - **Pins : RD15 Custom Name → OLED_nRST, Check Output, Start High**

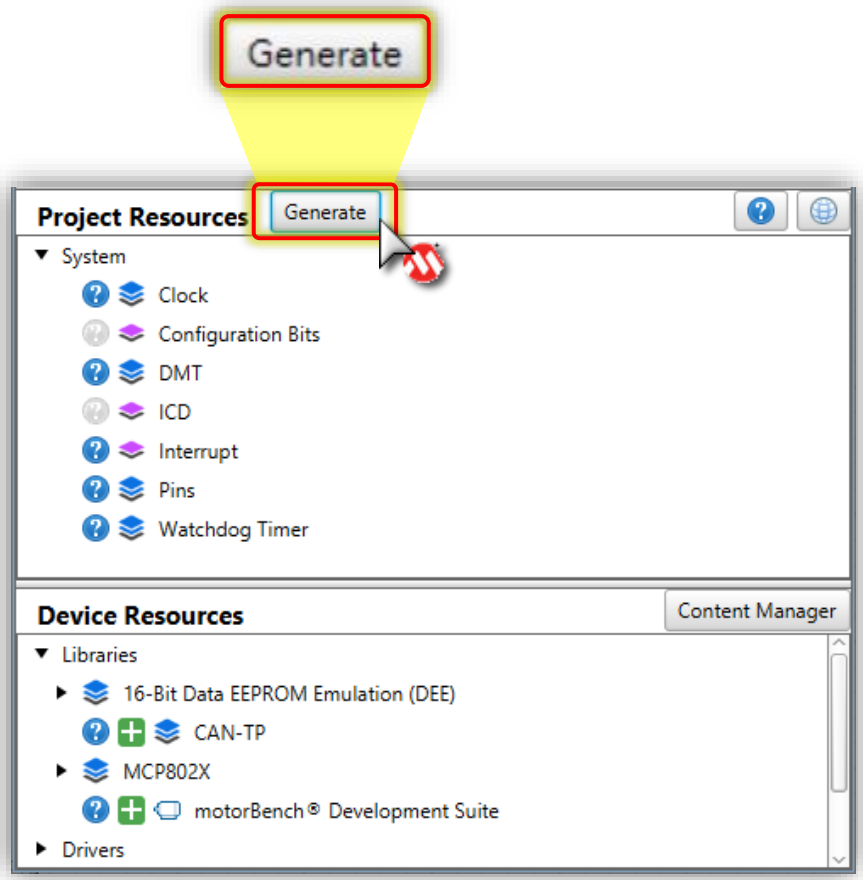


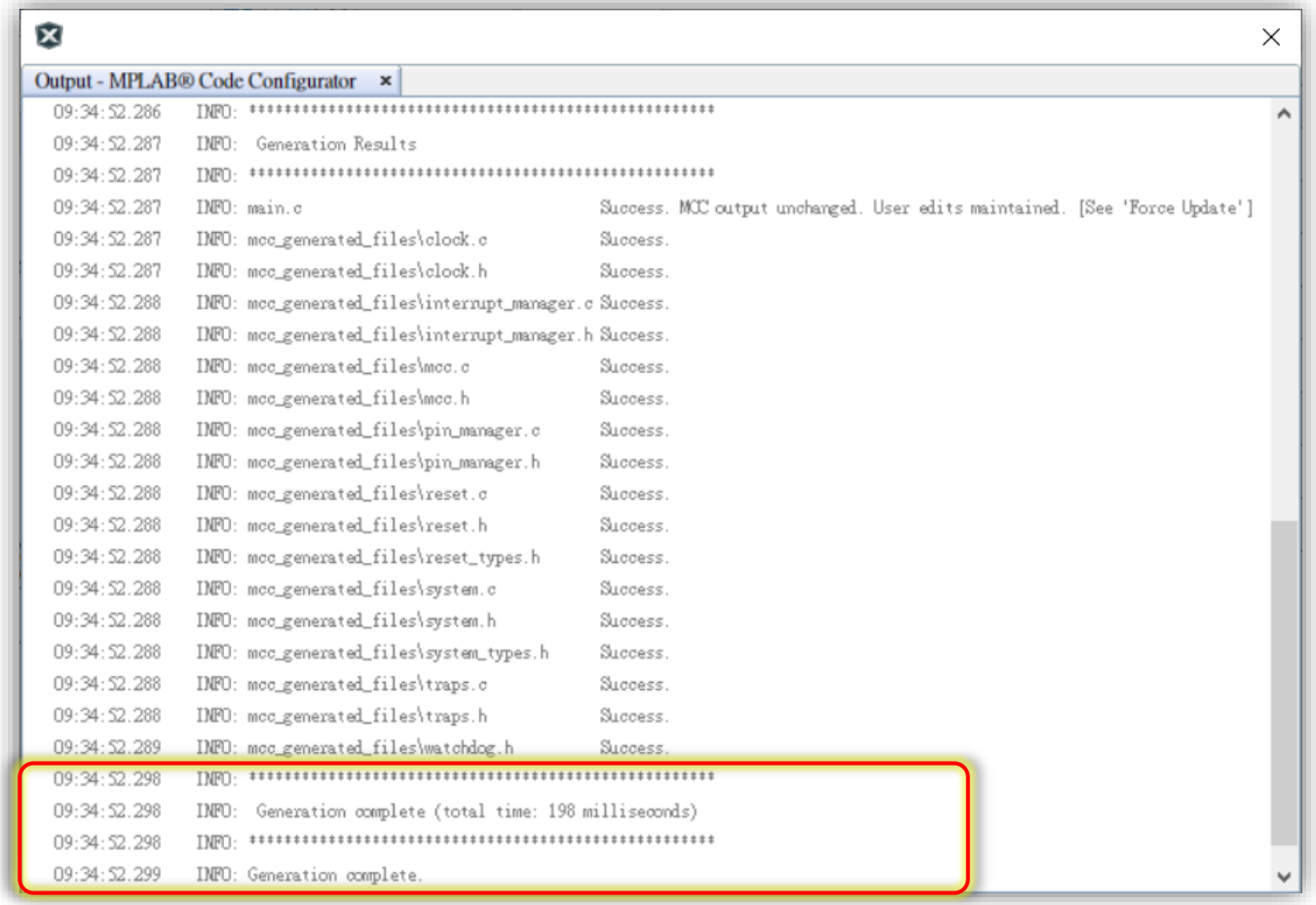
Location	Pin Name	Module	Function	Direction	Custom Name	Analog	Start High	Weak Pulldown	Weak Pullup	Open Drain	Interrupt on Change
45	RB5	Pins	GPIO	output	LED2		☐	☐	☐	☐	none
46	RB6	Pins	GPIO	output	LED1		☑	☐	☐	☐	none
22	RC1	Pins	GPIO	output	LED4	☐	☐	☐	☐	☐	none
59	RD1	Pins	GPIO	output	OLED_RS		☐	☐	☐	☐	none
21	RD12	Pins	GPIO	output	LED3		☑	☐	☐	☐	none
8	RD15	Pins	GPIO	output	OLED_nRST		☑	☐	☐	☐	none
58	RD2	Pins	GPIO	output	OLED_nCS		☑	☐	☐	☐	none

Lab7 OLED Display

Step 7

- Click "Generate" Button to generate your code.





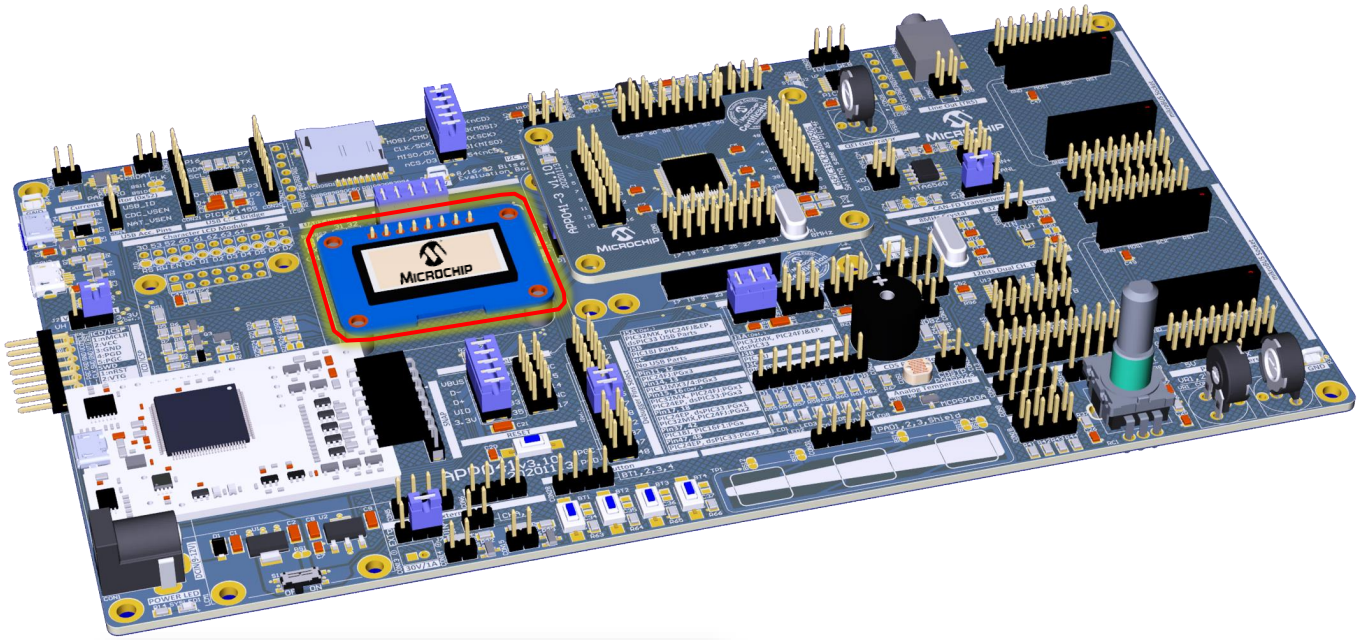
Lab7 OLED Display

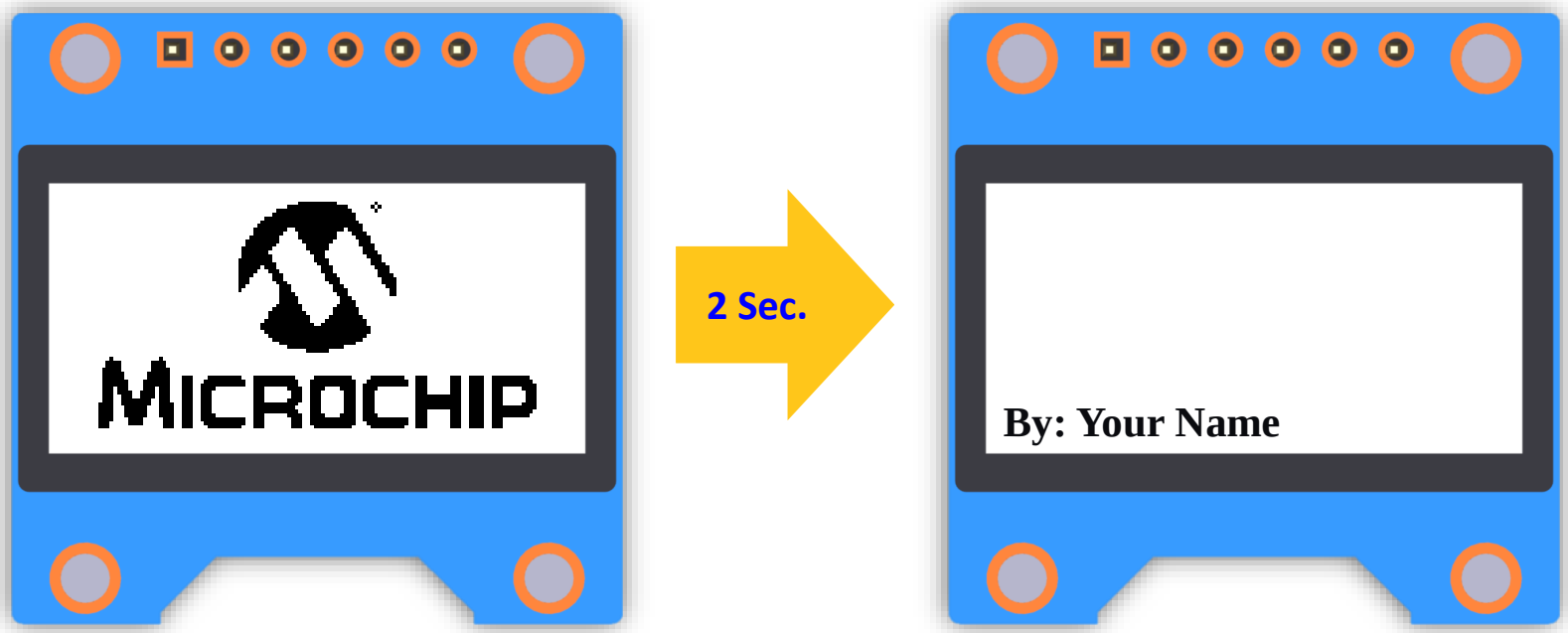
Code Example

```
...
#include "mcc_generated_files/timer/delay.h"
#include "myOLEDlib/myOLED_ssd1306.h"

uint32_t  i = 0;
extern const uint8_t Microchip_Logo_Screen[];
extern const uint8_t Microchip_Logo_Banner[];
...

int main(void)
{
    SYSTEM_Initialize();

    myTimer1.TimeoutCallbackRegister(myTimer1_Callback);
    myTimer2.TimeoutCallbackRegister(myTimer2_Callback);

    myOLED_Init();

    myOLED_ClearScreen();
    myOLED_DrawBitmap(0, 0, 128, 64, Microchip_Logo_Screen);

    DELAY_milliseconds(2000);

    myOLED_ClearScreen();
    myOLED_DrawStr(0, 7, (const uint8_t *) "By: Your Name");

    while (1)
    {
        ...
    }
}
```

Lab7 OLED Display

Result





MICROCHIP

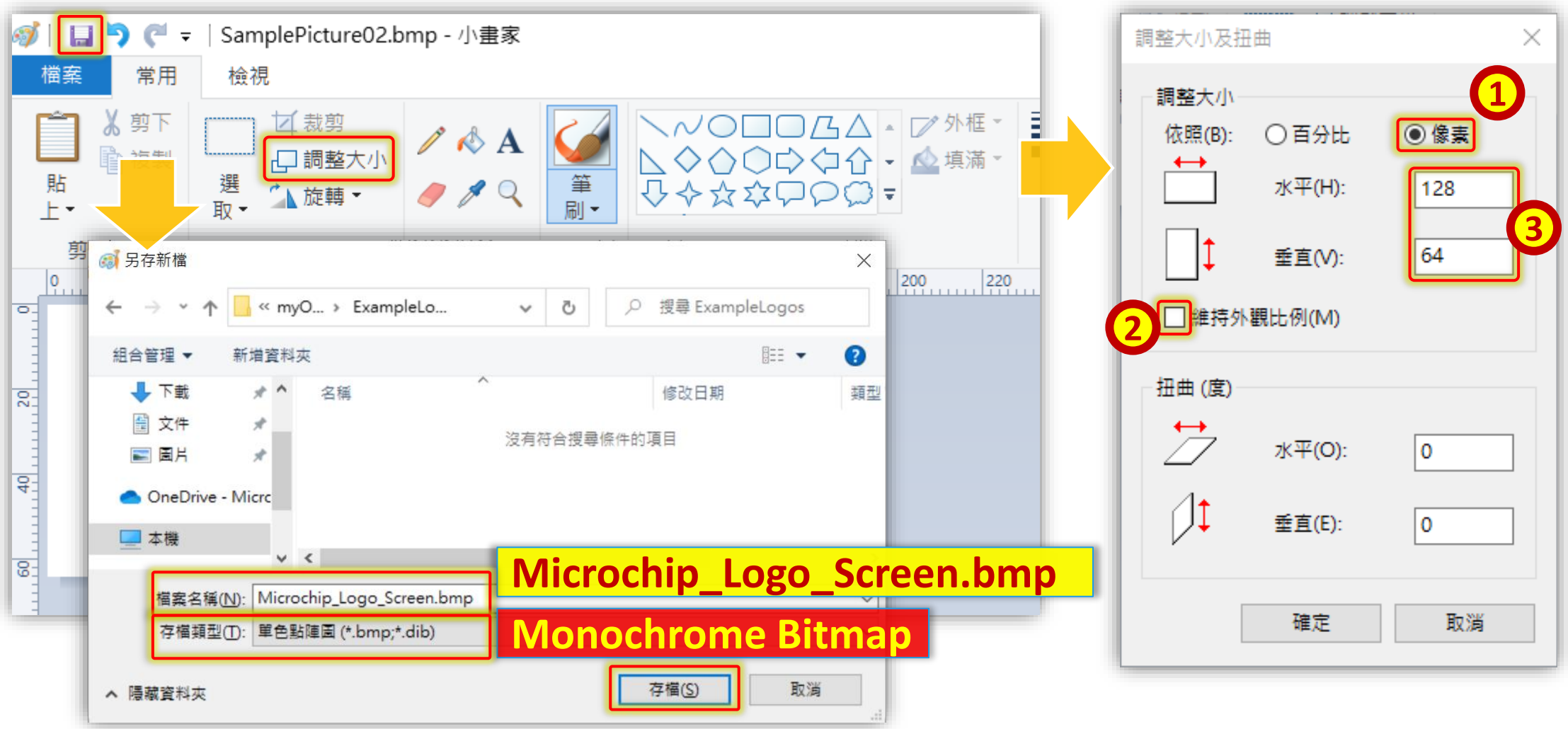
Lab8 Customize Screen

- Base on current project or Open .\Exercises\Lab8_xxx.X to do exercise
- Try to change default Boot Screen to you want to.

Let’s go!

Lab8 Customize Screen

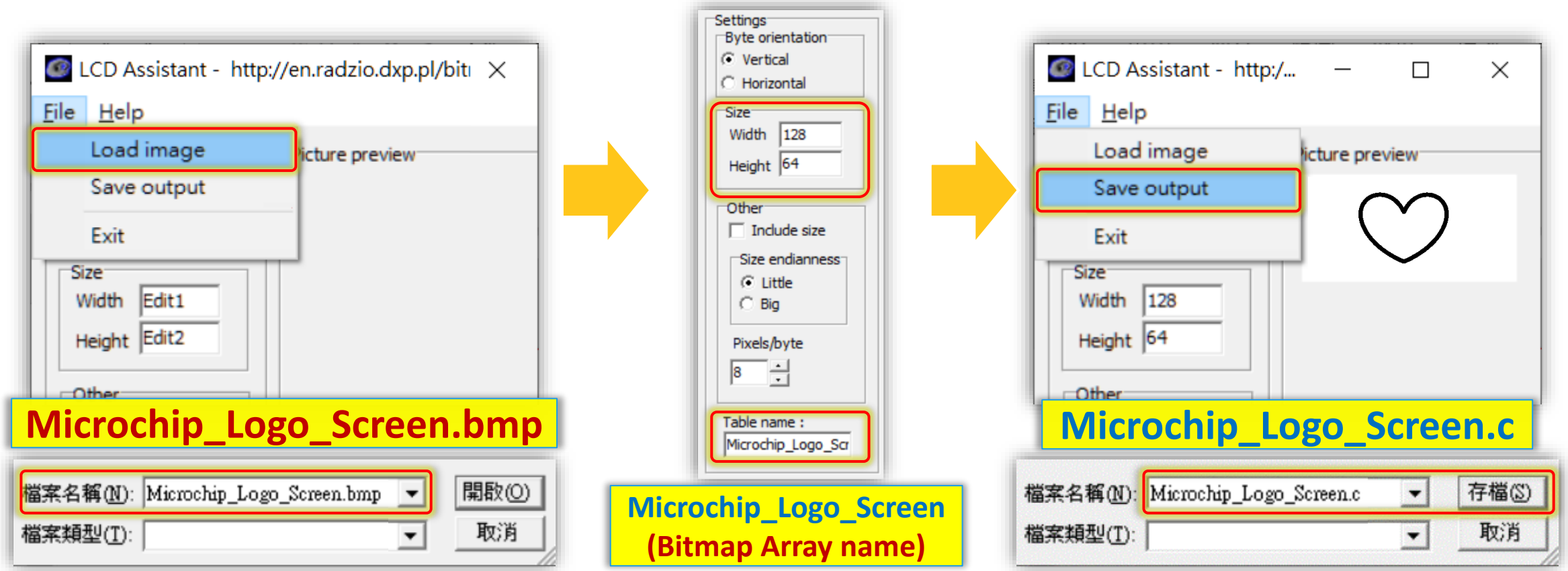
Create your own logo



Lab8 Customize Screen

Create your own logo

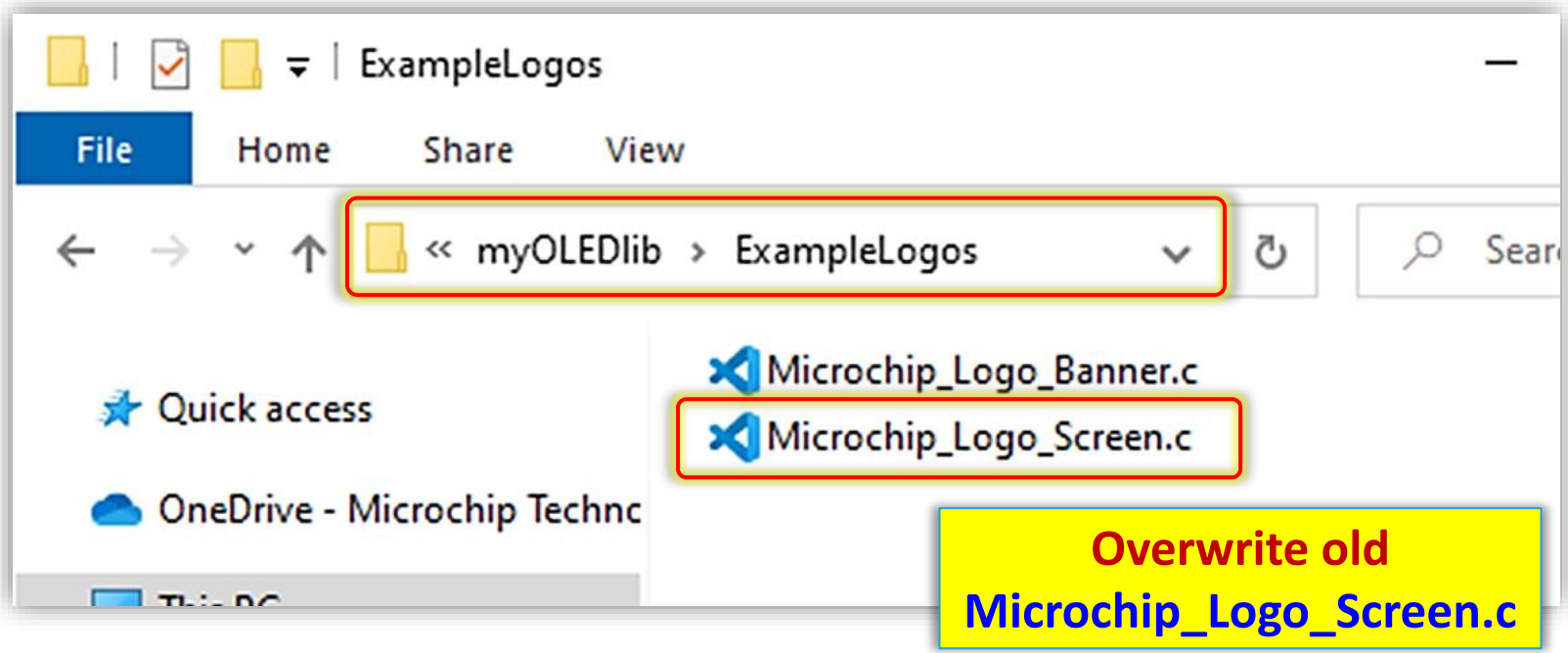
- **Execute \Tools\LCDAssistant.exe**
  Load Microchip_Logo_Screen.bmp and Save output to Microchip_Logo_Screen.c



Lab8 Customize Screen

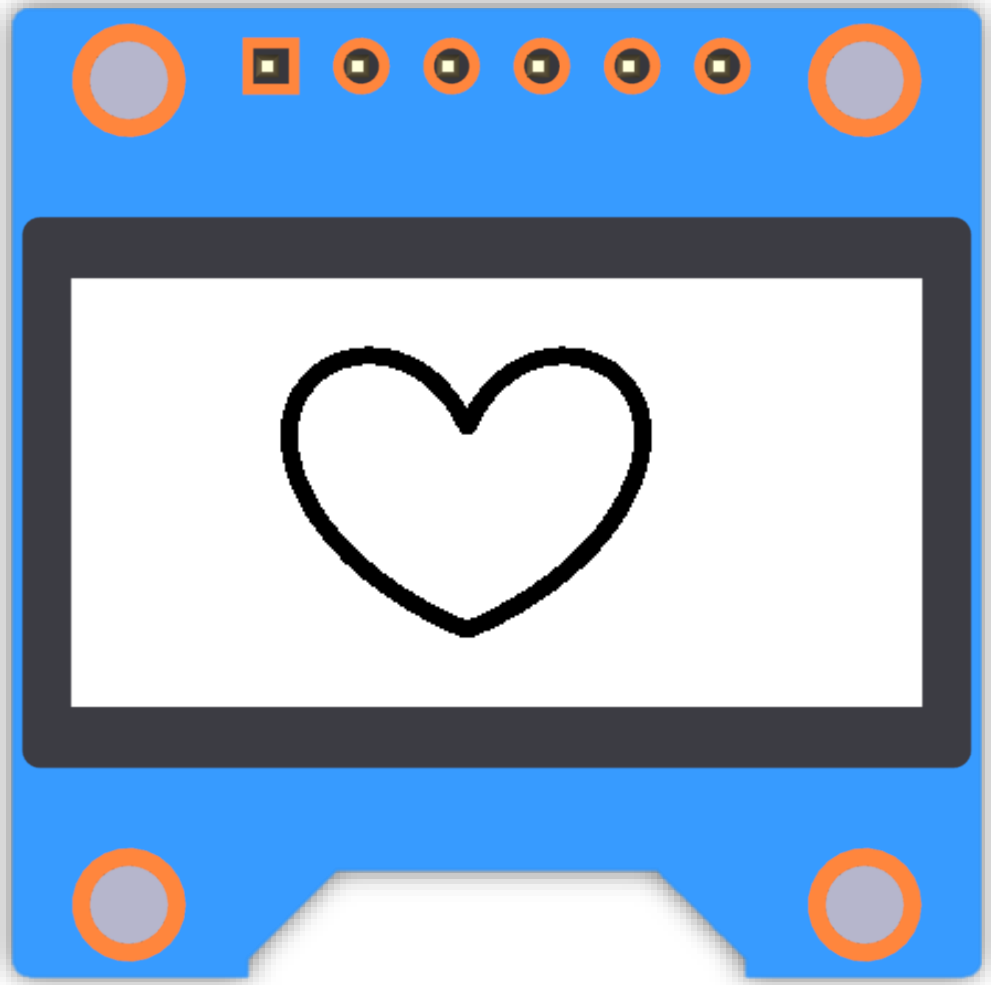
Create your own logo

- **Copy new Microchip_Logo_Screen.c to overwrite old one in folder.**
  - **\Labn_xxx.X\myOLEDlib\ExampleLogos**



Lab8 Customize Screen

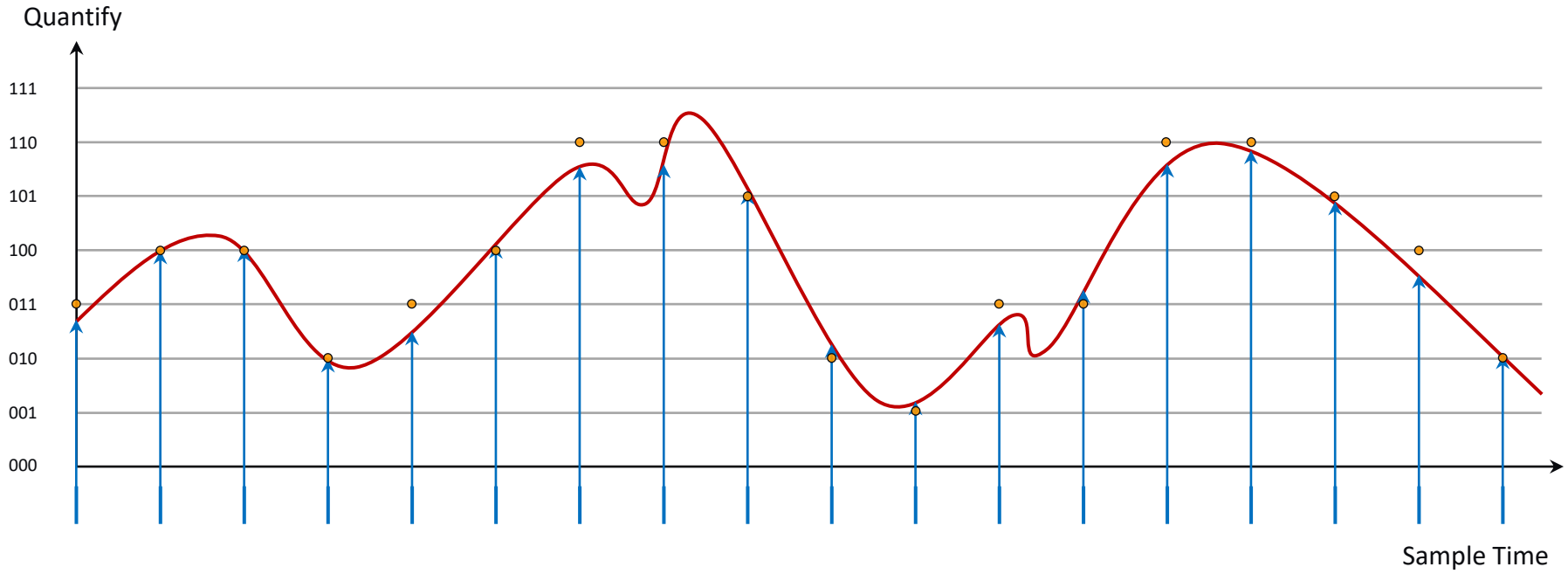
Create your own logo



12 Bits High Speed ADC Application

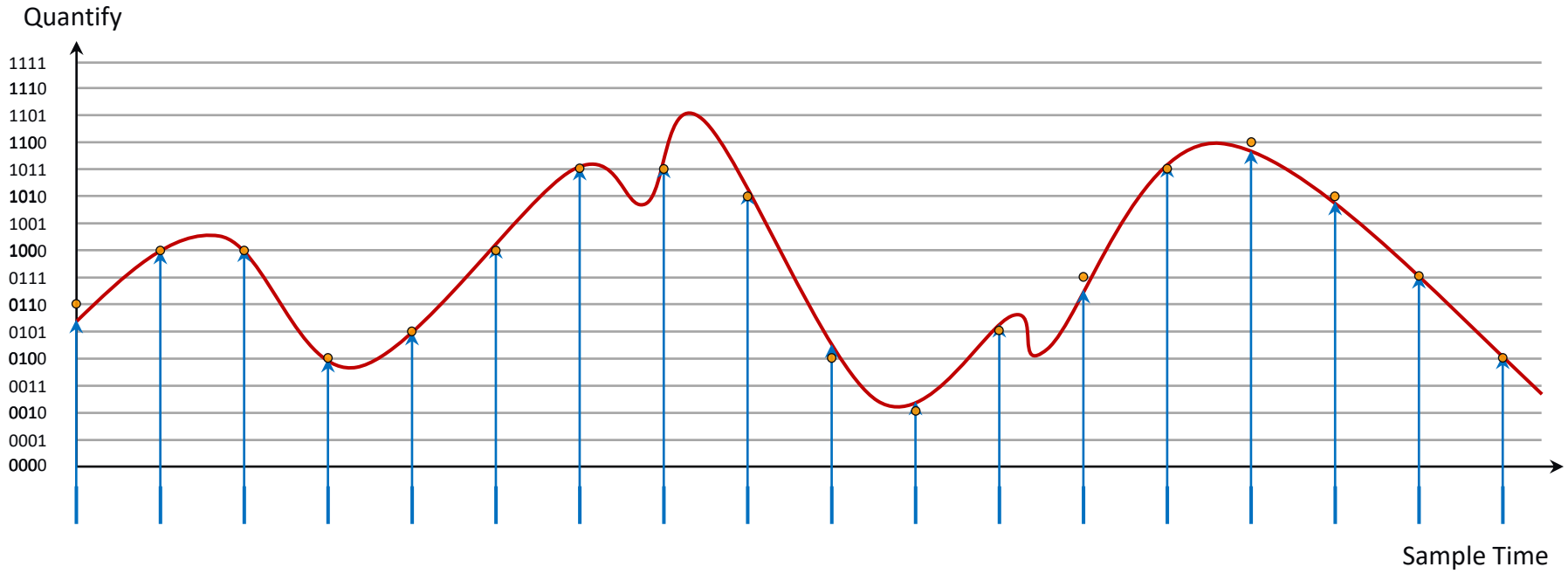
What’s ADC ?

- **The Analog-to-Digital Converter(ADC) converts a signal from the time/amplitude continuous domain into.**
  a time/amplitude discrete domain.



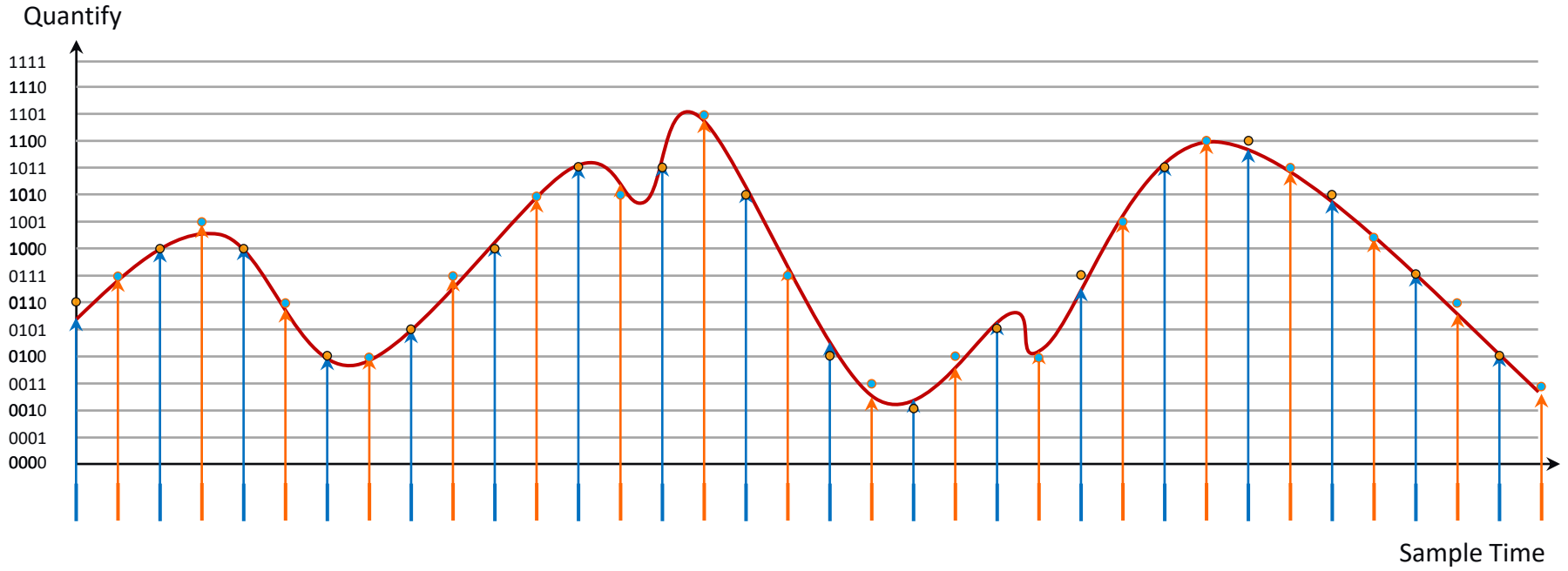
Resolution

- **The resolution of the converter indicates the number of discrete values. The resolution determines the magnitude of the quantization error. (wiki)**



Sample Rate

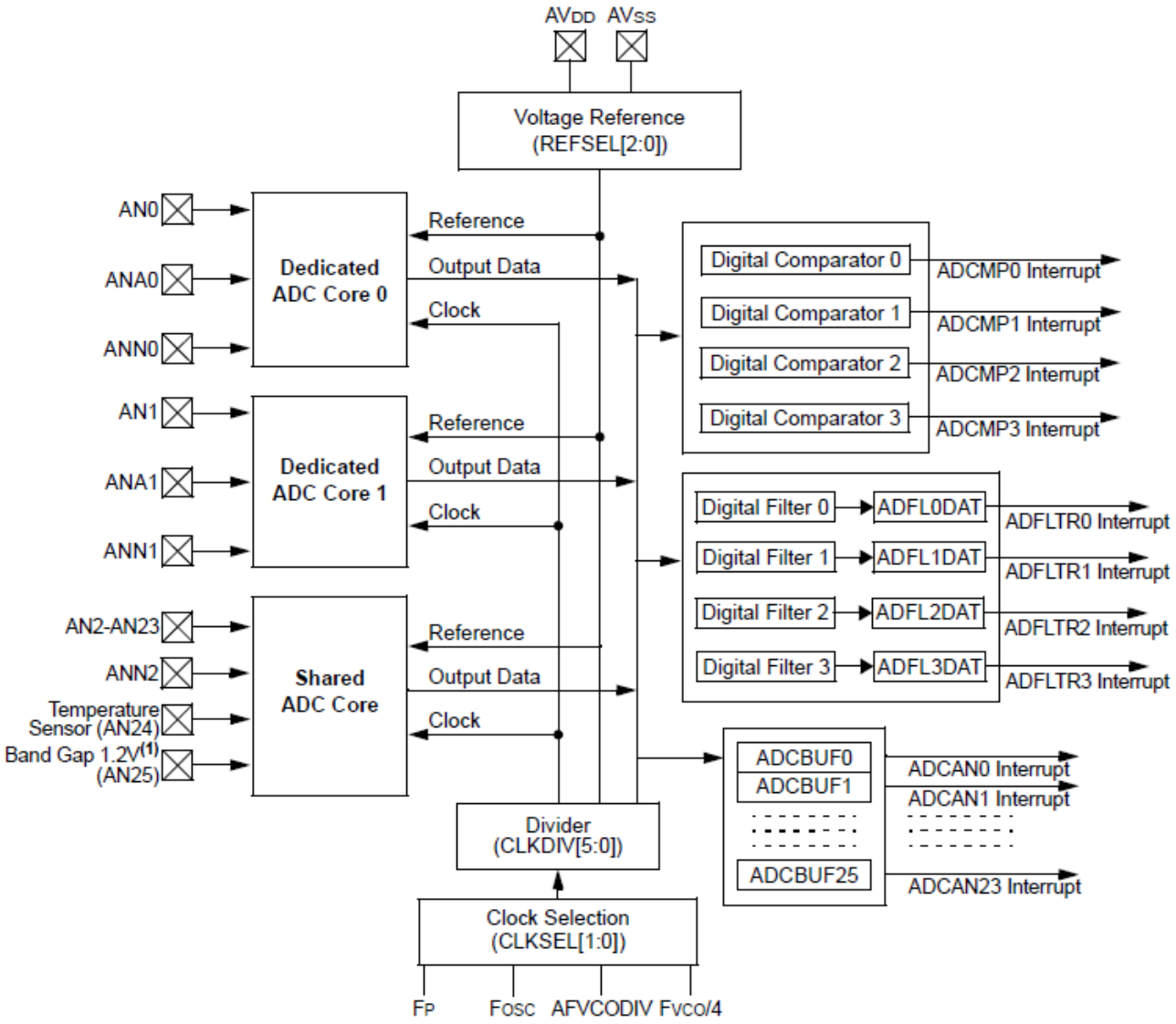
- The analog signal is required to define the rate at which new digital values are sampled from the analog signal.
- This faithful reproduction is only possible if the sampling rate is higher than twice the highest frequency of the signal. (wiki)



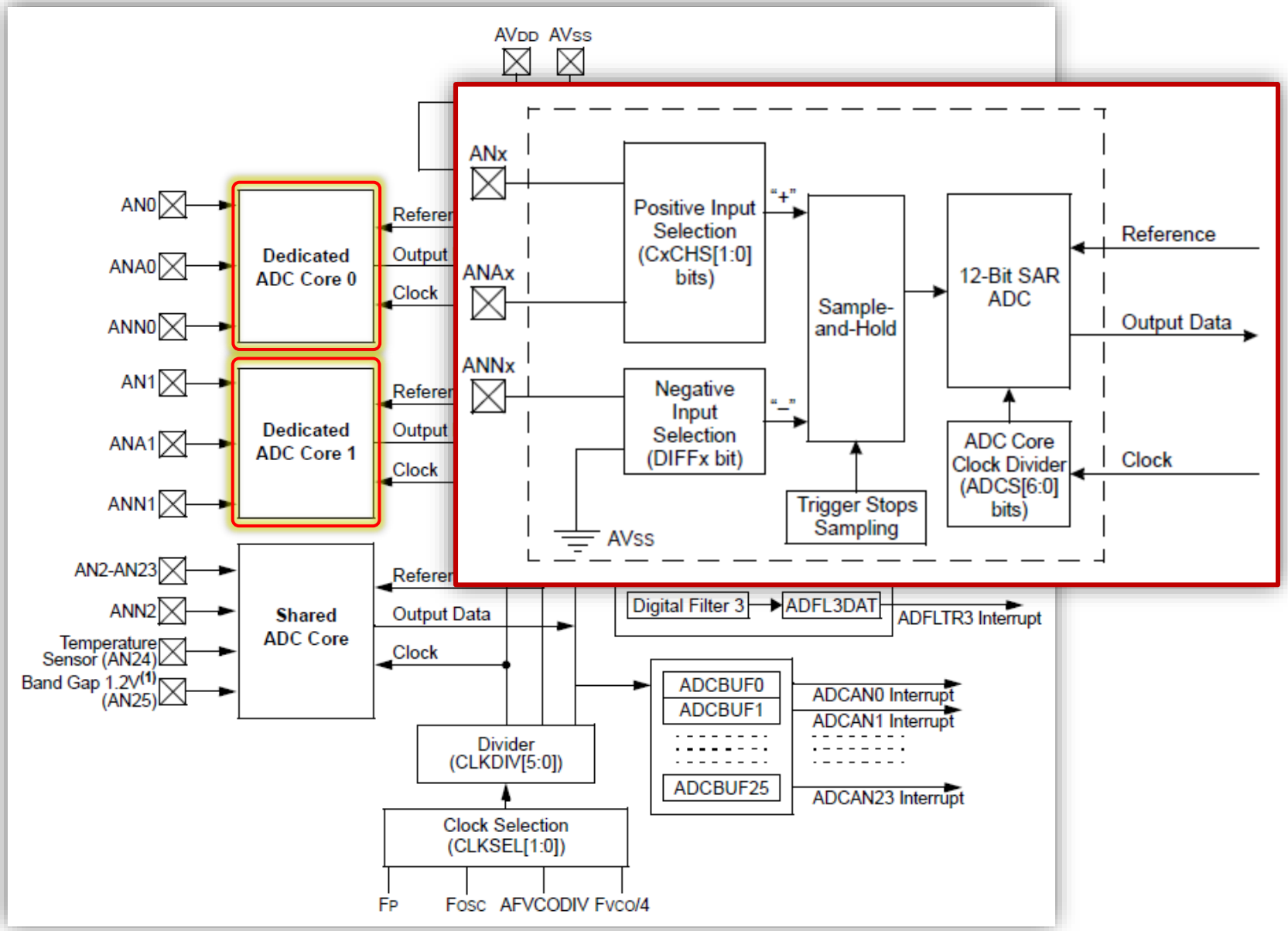
dsPIC33CK ADC Features

- **The High-Speed, 12-Bit Multiple SARs Analog-to-Digital Converter (ADC) includes the following features:**
  - Three ADC Cores: **Two Dedicated Cores** and **One Shared (common) Core**
  - User-Configurable **Resolution of up to 12 Bits**, **Up to 3.5 Msps Conversion Rate** per Channel at 12-Bit Resolution
  - Up to **24 Analog Input Channels**, with a Separate 16-Bit Conversion Result Register for each Input
  - Conversion Result can be Formatted as Unsigned or Signed Data
  - Simultaneous Sampling of up to Three Analog Inputs, Channel Scan Capability
  - Multiple Conversion Trigger Options for each Core, including:
    - PWM triggers from CPU cores
    - MCCP/SCCP modules triggers
    - CLC modules triggers
    - External pin trigger event (ADTRG31)
    - **Software trigger**
  - Four Integrated Digital Comparators with Dedicated Interrupts
  - Four Oversampling Filters with Dedicated Interrupts

dsPIC33CK ADC Module Block Diagram

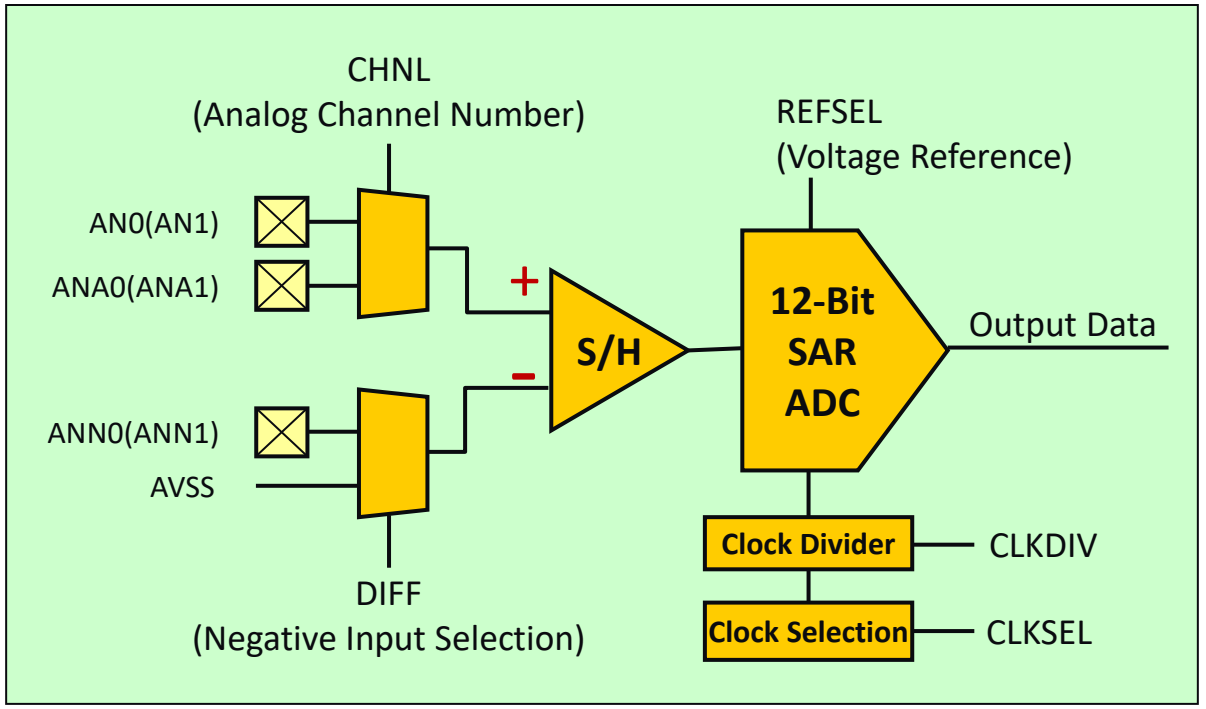


ADC Dedicate Core Block Diagram

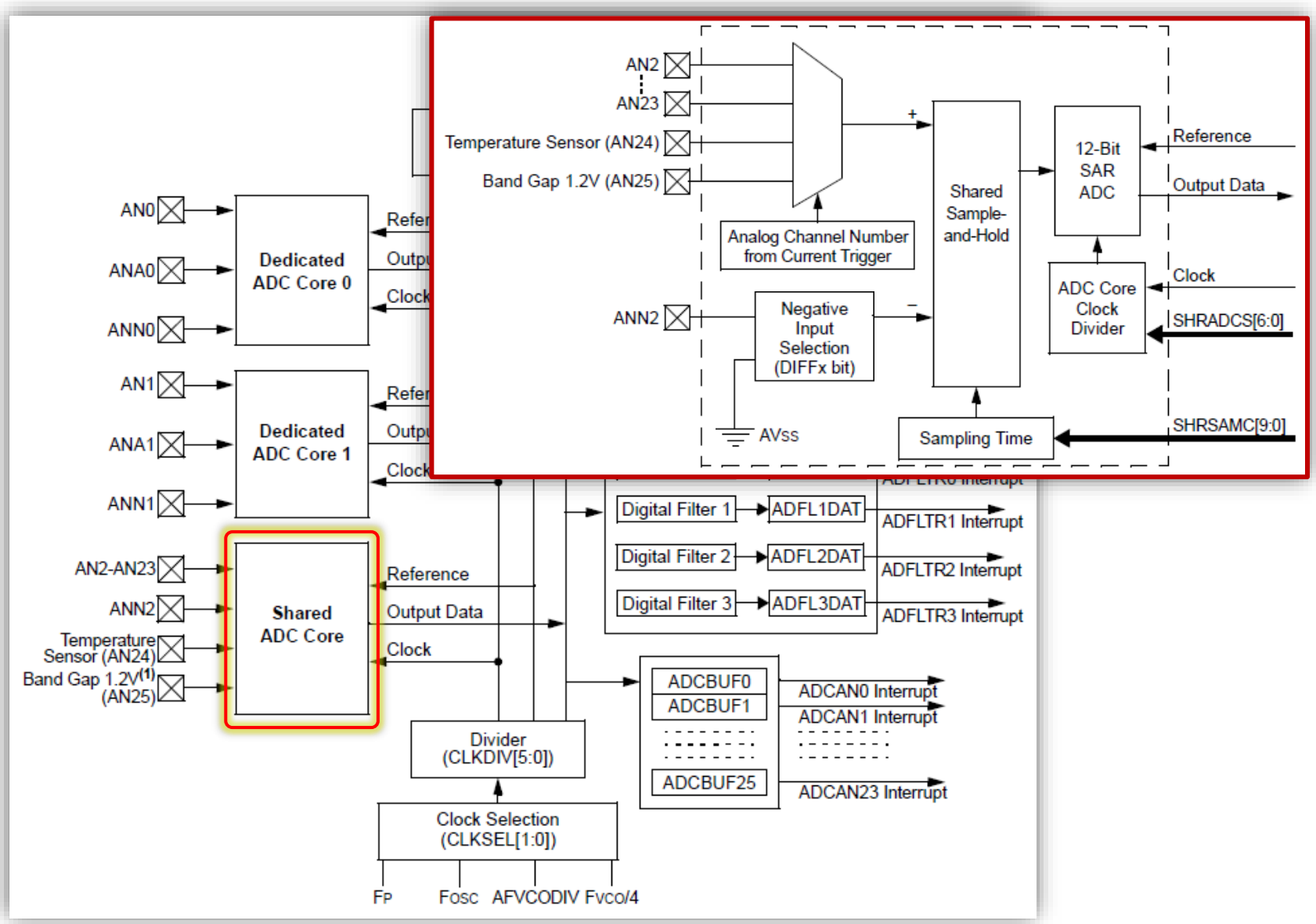


ADC Dedicate Core Channel Selection

- One analog input AN0(AN1) and one alternate input ANA0(ANA1) to connect as Analog Positive input of S/H.
- ANN0(ANN1) or AVSS as Analog Negative input of the S/H.
- The differential input voltage is Positive – Negative.

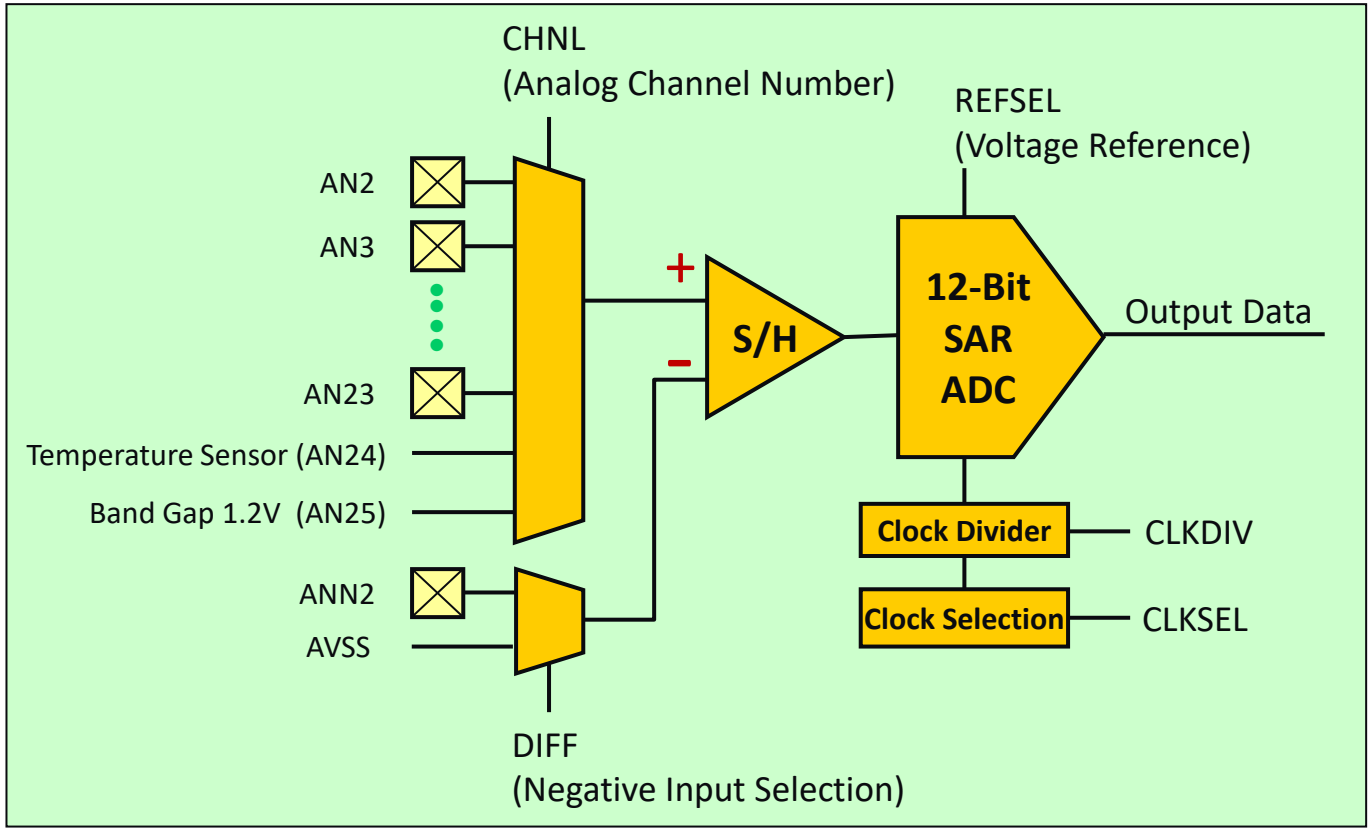


ADC Shared Core Block Diagram



ADC Shared Core Channel Selection

- 24 analog channel inputs to connect as Analog Positive input of S/H.
- ANN2 or AVSS as Analog Negative input of the S/H.
- The differential input voltage is Positive – Negative.



Functions of Melody ADC Driver

- **Melody Provide below functions for Timer:**

  Prototype definition : "adc1.h"

  - **ADC_INTERFACE**
    - (void) *ADC1*.Initialize(void);
    - (void) *ADC1*.Deinitialize(void);
    - (void) *ADC1*.Enable(void);
    - (void) *ADC1*.Disable(void);
    - (void) *ADC1*.SoftwareTriggerEnable(void);
    - (void) *ADC1*.SoftwareTriggerDisable(void);
    - (void *ADC1*.ChannelSelect(enum ADC_CHANNEL channel);
    - (uint16_t) *ADC1*.ConversionResultGet(enum ADC_CHANNEL channel);
    - (bool) *ADC1*.IsConversionComplete(enum ADC_CHANNEL channel);
    - (void) *ADC1*.ResolutionSet(enum ADC_RESOLUTION_TYPE resolution);
    - (void) *ADC1*.CommonCallbackRegister(void(*callback)(void));
    - (void) *ADC1*.Tasks(void);
    - (void) *ADC1*.adcMulticoreInterface->ChannelCallbackRegister(void(*callback)(...));

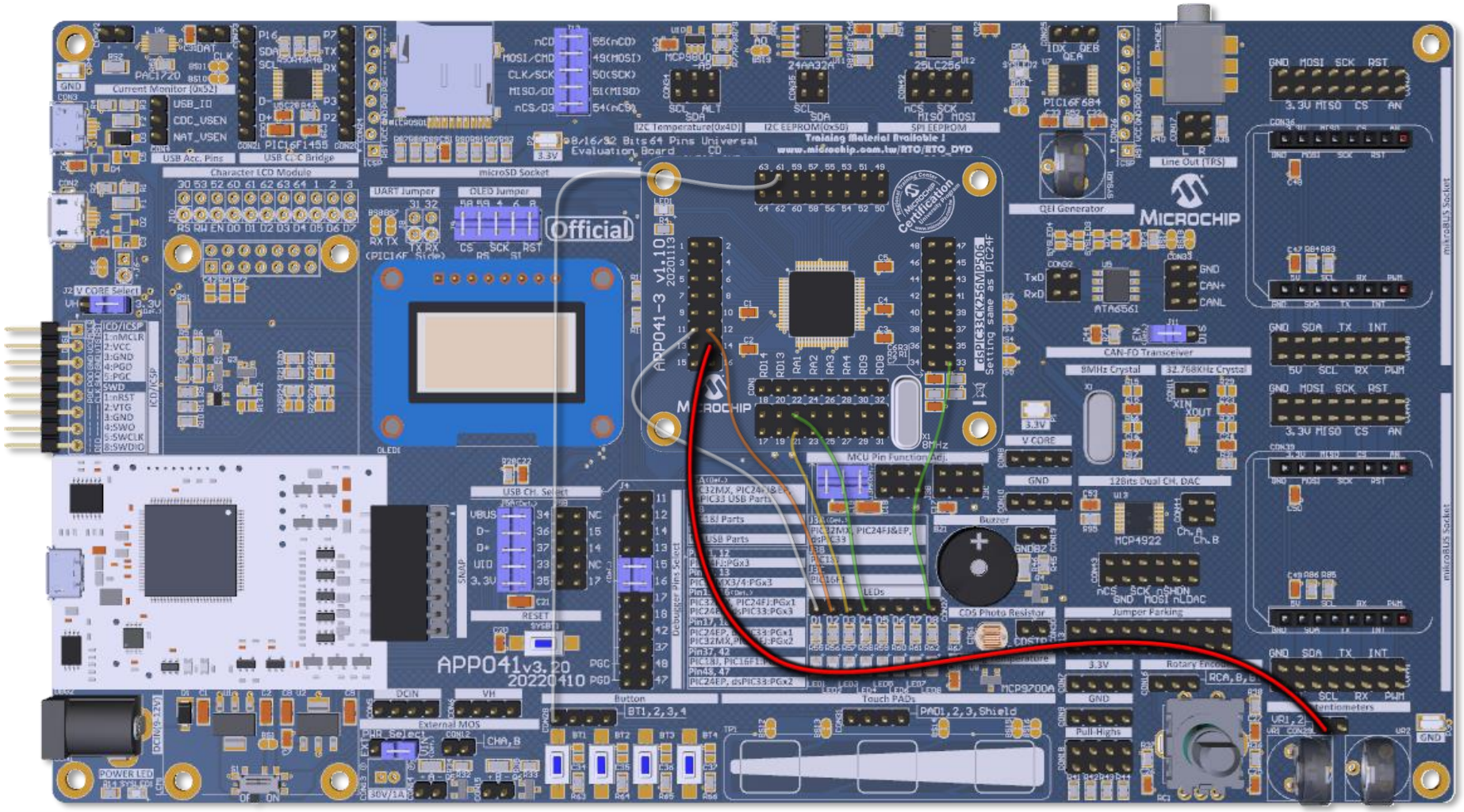
Lab9 ADC Single Channel Periodically

- Base on current project or Open .\Exercises\Lab9_xxx.X to do exercise
- Try to add ADC1 module and conversion Potentiometer (VR1) voltage to shows ADC result on OLED Display.
- Use SCCP1 Timer to software trigger of ADC conversion periodically.
  - ADC Core: Core0
  - Core Channel: AN0
  - Custom Name: "VR1"
  - Trigger Source: Common Software Trigger
  - Interrupt: Enable
- Please connect RA0 (AN0, Pin14) to Potentiometer (VR1) to get analog voltage of potentiometer.

Let’s go!

Lab9 ADC Single Channel Periodically

Connection

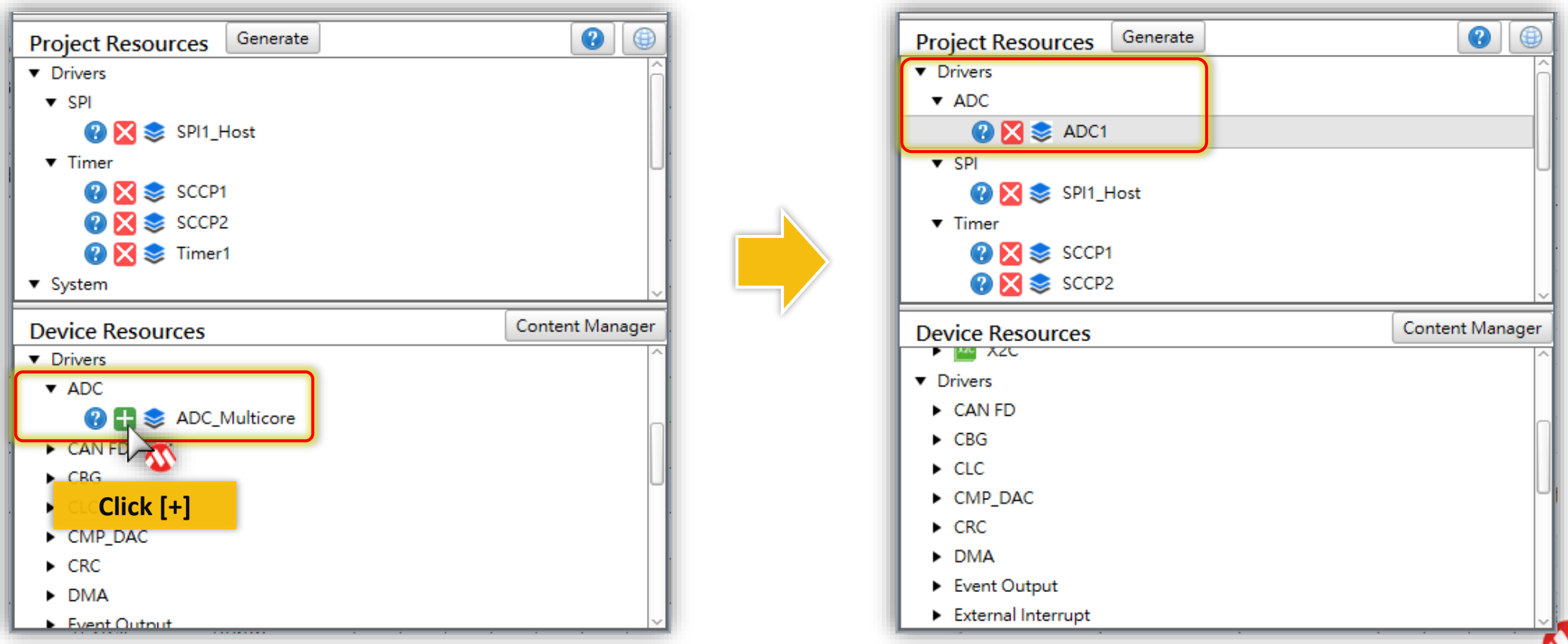


PIM Pin#		Symbol
14		VR1

Lab9 ADC Single Channel Periodically

Step 1

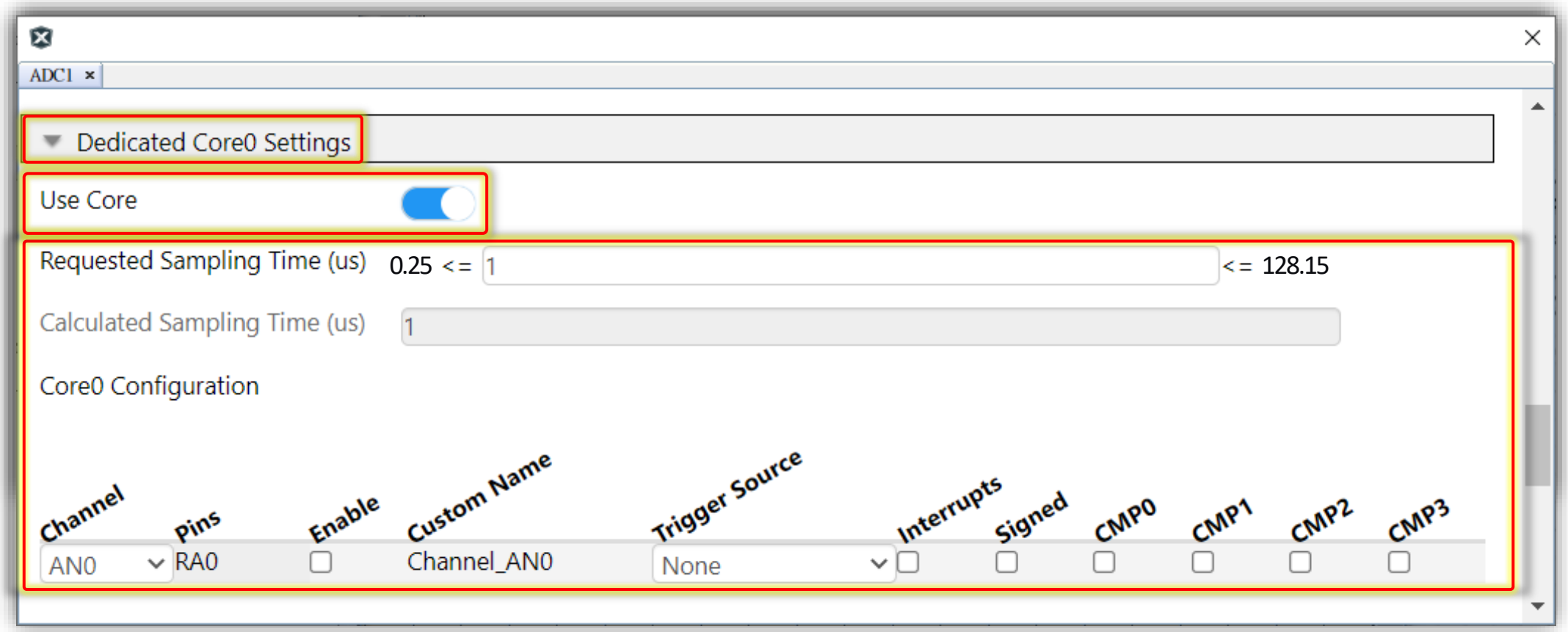
- **Click [+] to add ADC_Multicore Module.**



Lab9 ADC Single Channel Periodically

Step 2

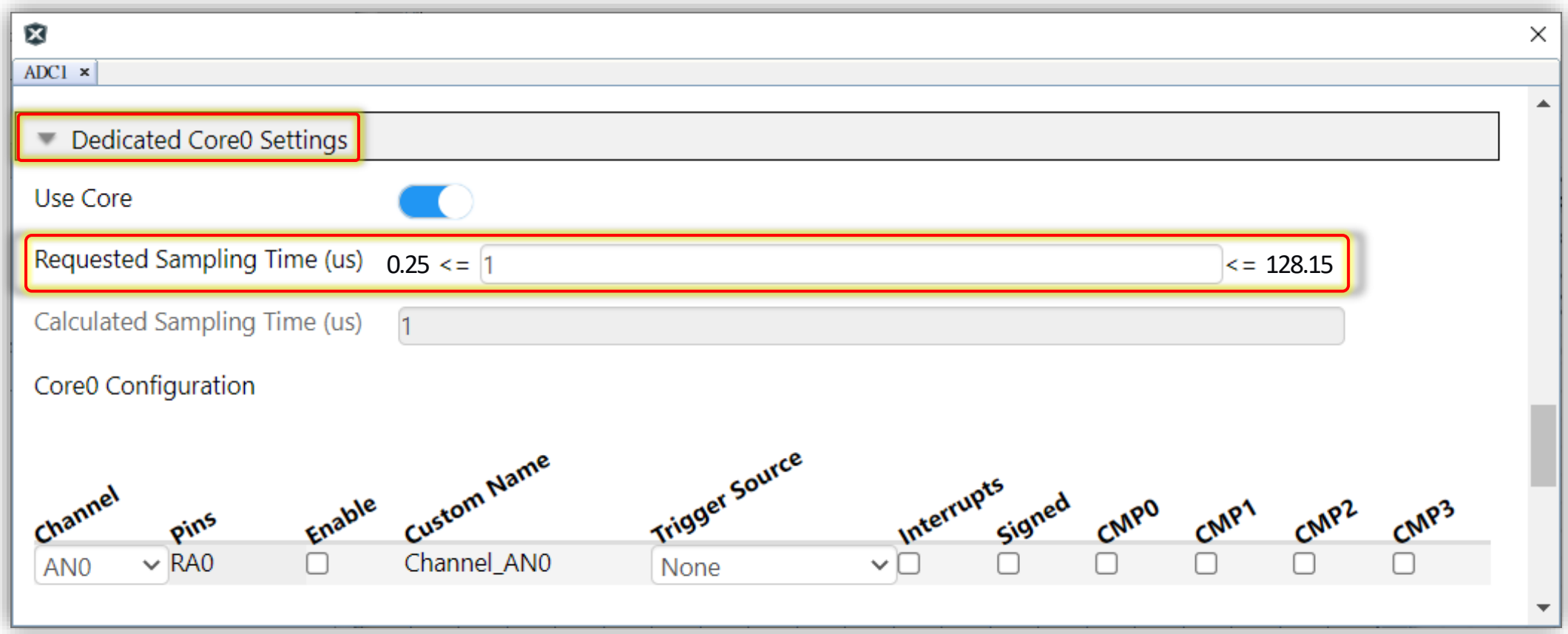
- Enable **dedicated Core0**.



Lab9 ADC Single Channel Periodically

Step 3

- **Check the Requested Sampling Time (us) is 1 of Dedicated Core0.**

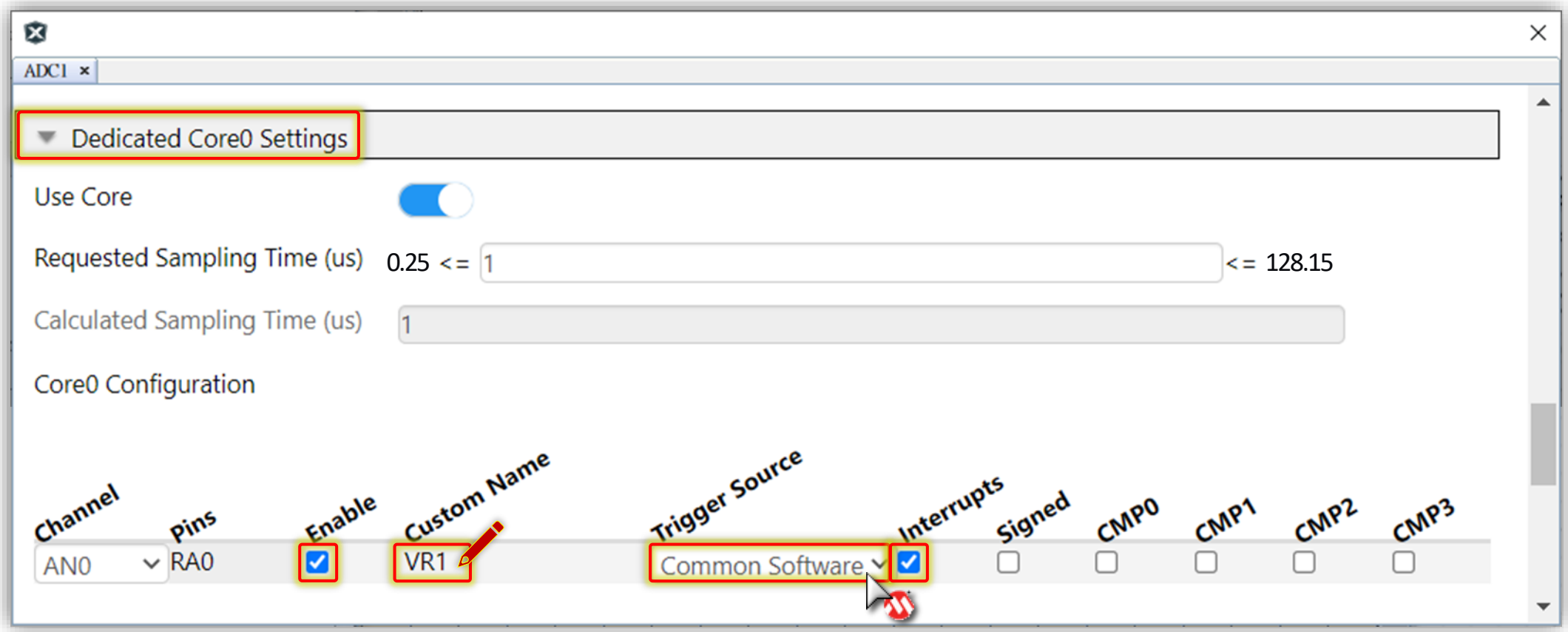


MICROCHIP

Lab9 ADC Single Channel Periodically

Step 4

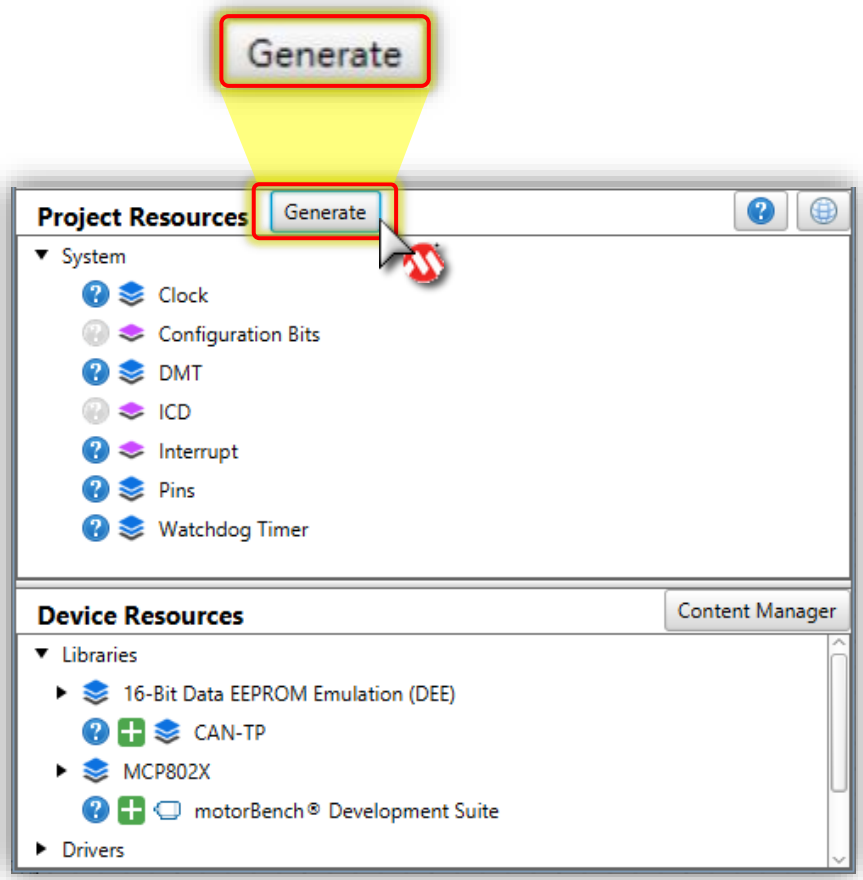
- Enable AN0 and Modify the Custom Name to "VR1".
- Select the Trigger Source to Common Software Trigger and Enable Interrupt.

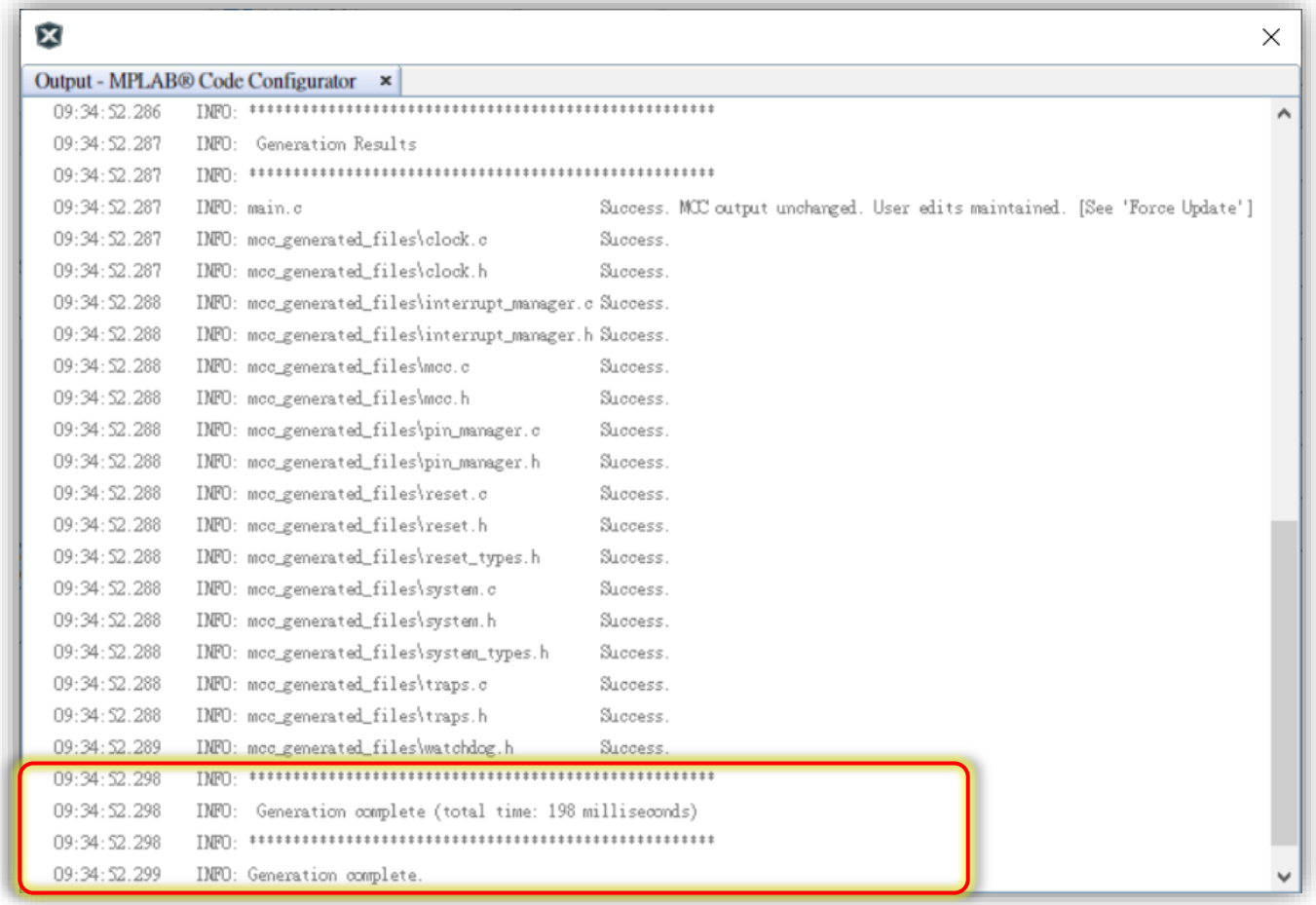


Lab9 ADC Single Channel Periodically

Step 5

- Click "Generate" Button to generate your code.





Lab9 ADC Single Channel Periodically

Code Example

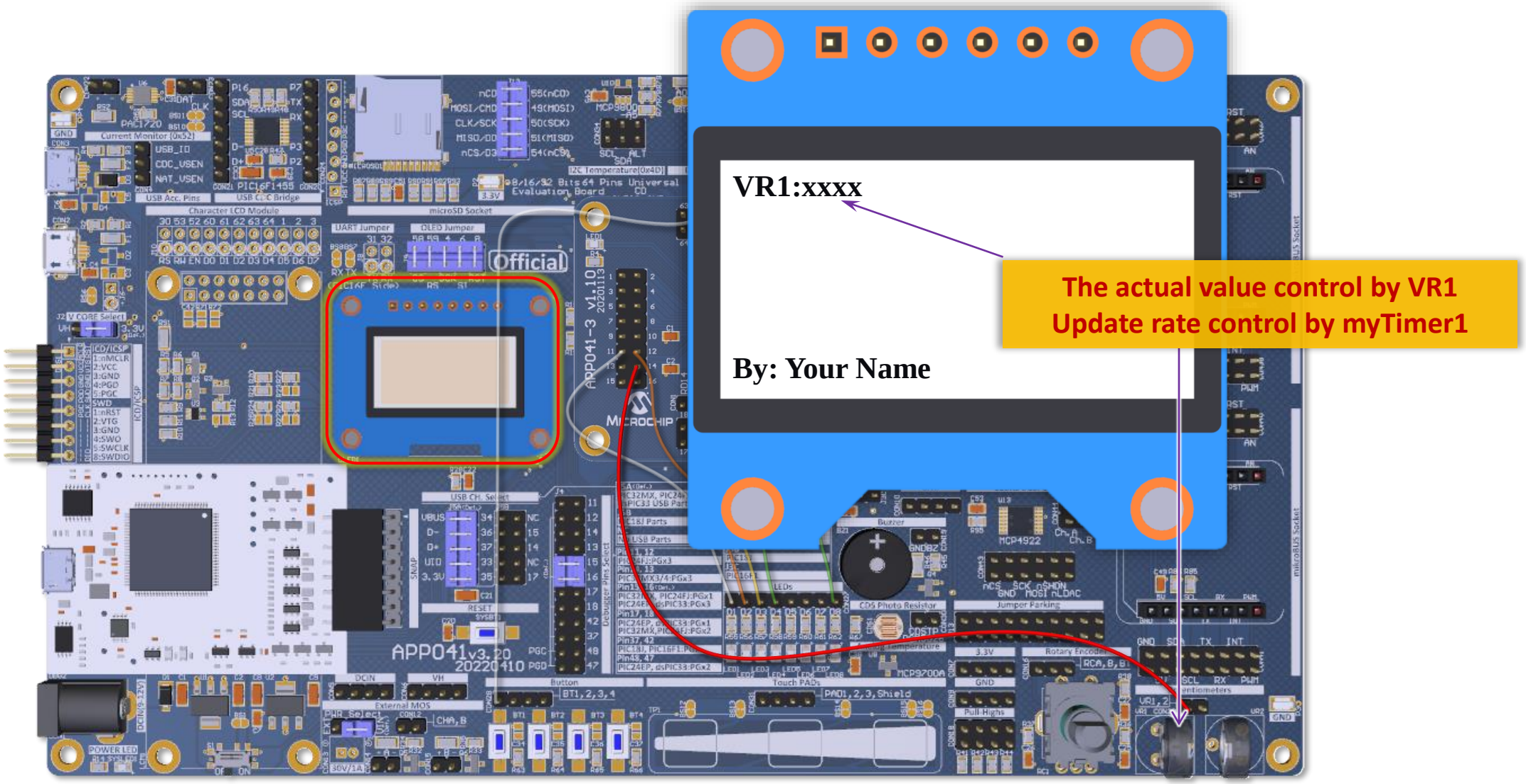
```
#include "myOLEDlib/myOLED_ssd1306.h"
#include "mcc_generated_files/adc/adc1.h"
#include <stdio.h>
...
volatile uint8_t TMR1Flag = 0;
volatile uint8_t VR1Flag = 0;
volatile uint16_t ADC1Buffer[2];
uint8_t StringBuffer[40];

void myTimer1_CallBack(void)
{
   TMR1Flag=1;
   LED1_Toggle();
   LED2_Toggle();
}
...
void ADC1_CallBack(enum ADC_CHANNEL channel, uint16_t adcVal)
{
   if (channel == VR1)
   {
      VR1Flag = 1;
      ADC1Buffer[0] = adcVal;
   }
}

int main(void)
{
   ...
}
```

```
int main(void)
{
   SYSTEM_Initialize();
   ...
   myTimer2.TimeoutCallbackRegister(myTimer2_Callback);
   ADC1.adcMulticoreInterface->ChannelCallbackRegister(ADC1_CallBack);
   ...

   while (1)
   {
      ...
      if(TMR1Flag)
      {
         TMR1Flag=0;
         ADC1.SoftwareTriggerEnable();
      }

      if (VR1Flag)
      {
         VR1Flag = 0;
         sprintf((char *) StringBuffer, "VR1:%4d", ADC1Buffer[0]);
         myOLED_DrawStr(0, 0, StringBuffer);
      }

   }
}
```

myTimer1 Timer for ADC Software Trigger periodically

Lab9 ADC Single Channel Periodically

Result



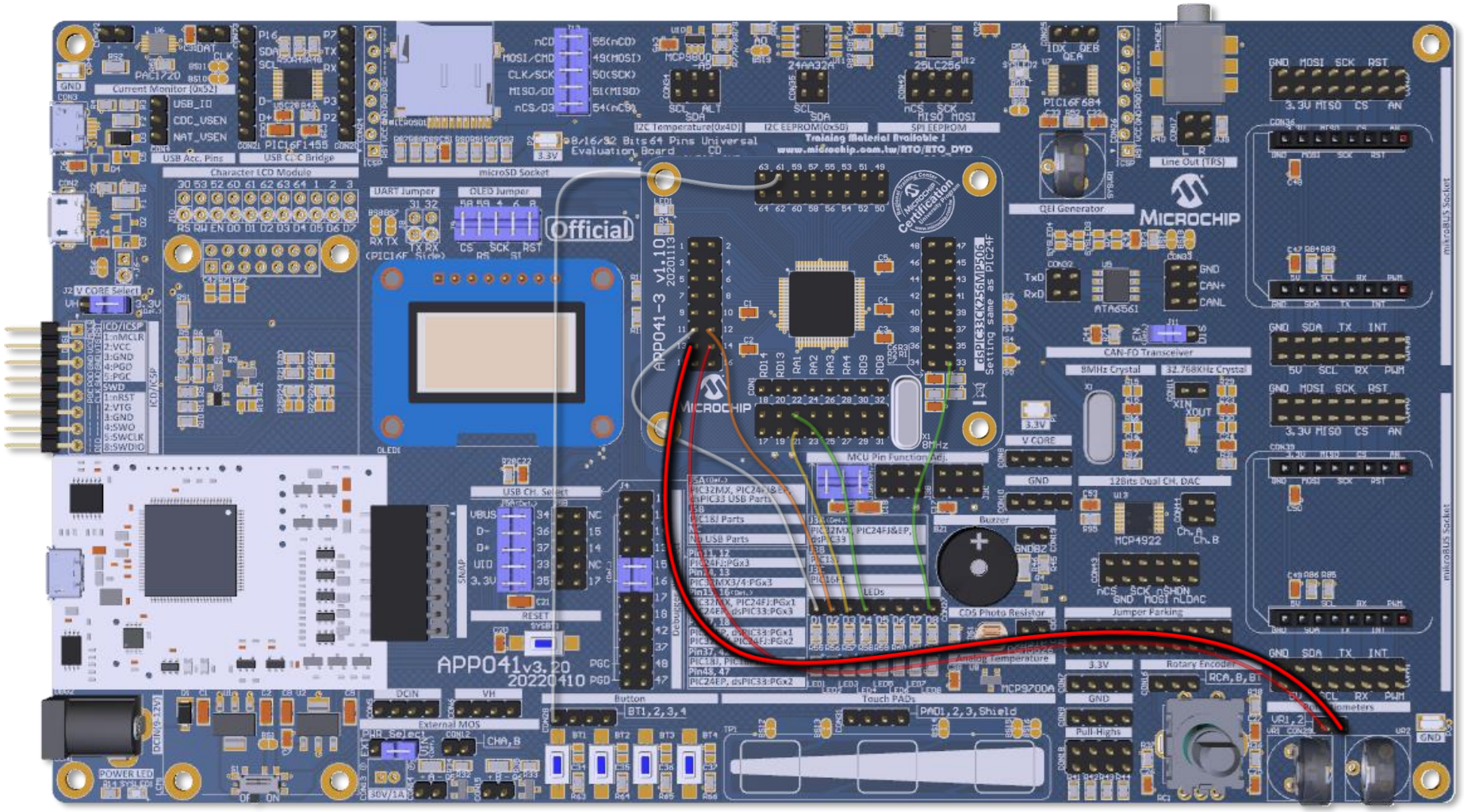
Lab10 ADC Multiple Channel Periodically

- Base on current project or Open .\Exercises\Lab10_xxx.X to do exercise
- Try to add extra channel of ADC1 to get Potentiometer VR2 voltage.
- Use SCCP1 Timer to software trigger of ADC conversion periodically.
  - ADC Core: Shared
  - Core Channel: AN12
  - Custom Name: "VR2"
  - Trigger Source: Common Software Trigger
  - Interrupt: Enable
- Please connect RC0 (AN12, Pin13) to Potentiometer (VR2) to get analog voltage of potentiometer.
- Show both VR1 and VR2 result on OLED Display.

Let's go!

Lab10 ADC Multiple Channel Periodically

Connection

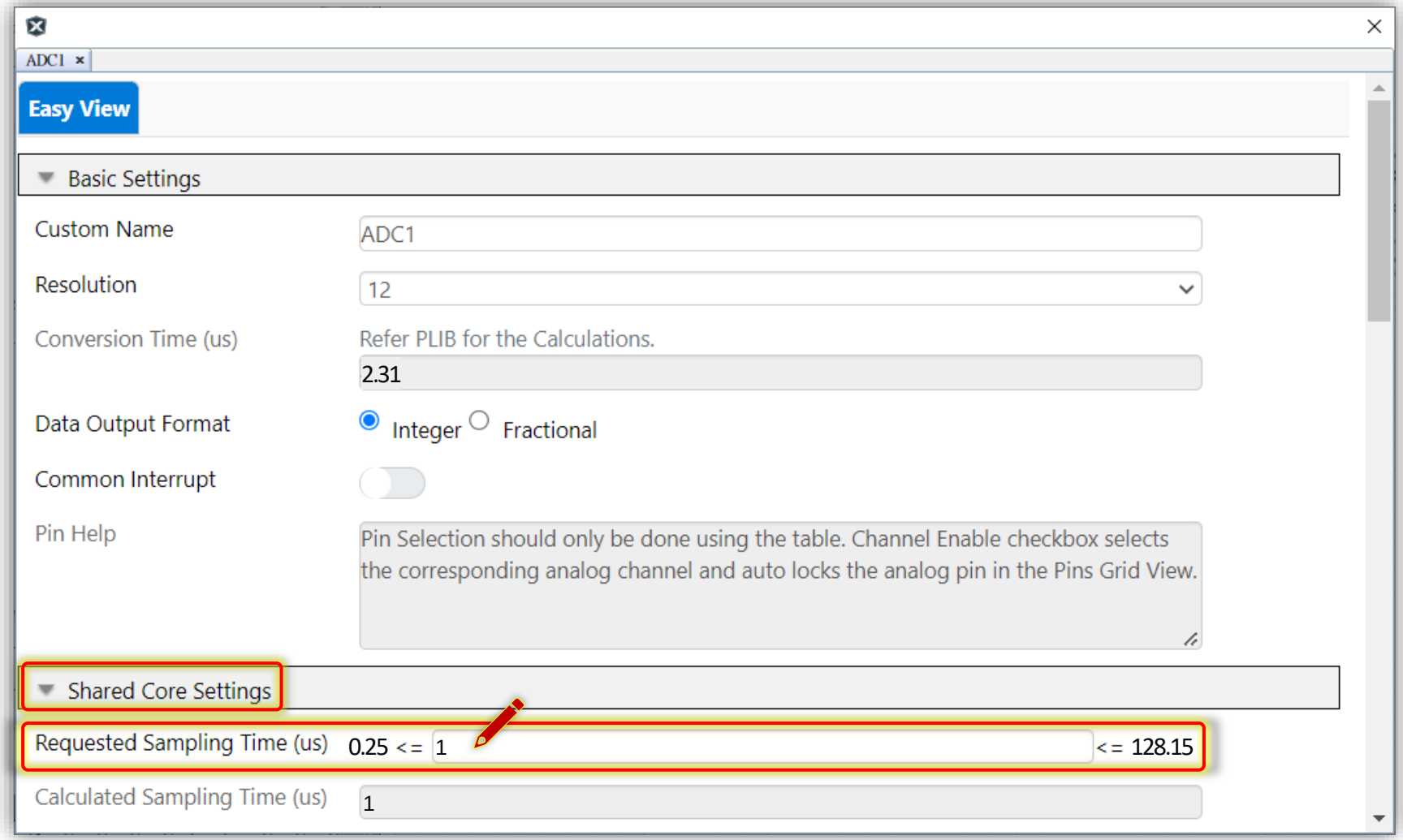


PIM Pin#		Symbol
13		VR2

Lab10 ADC Multiple Channel Periodically

Step 1

- **Check the Requested Sampling Time (us) is 1 of Shared Core.**

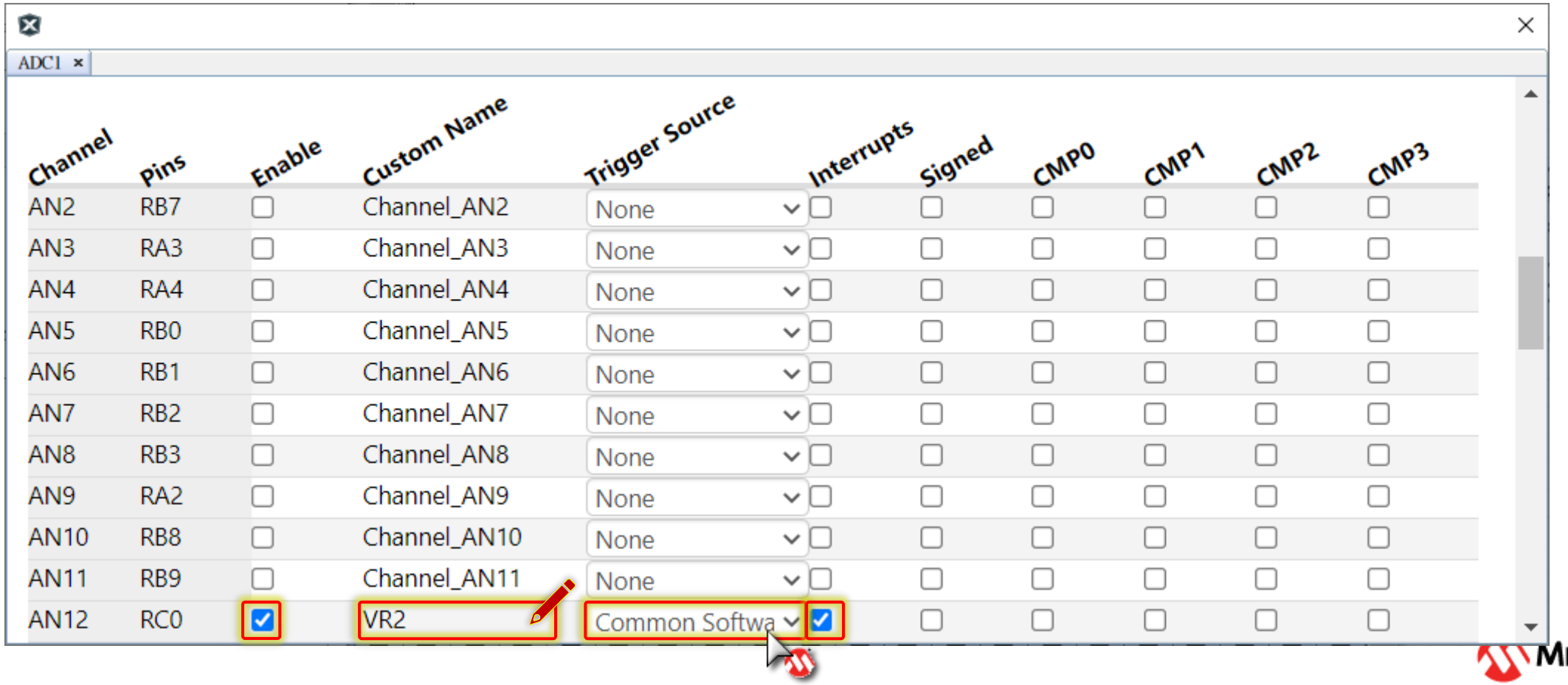


MICROCHIP

Lab10 ADC Multiple Channel Periodically

Step 2

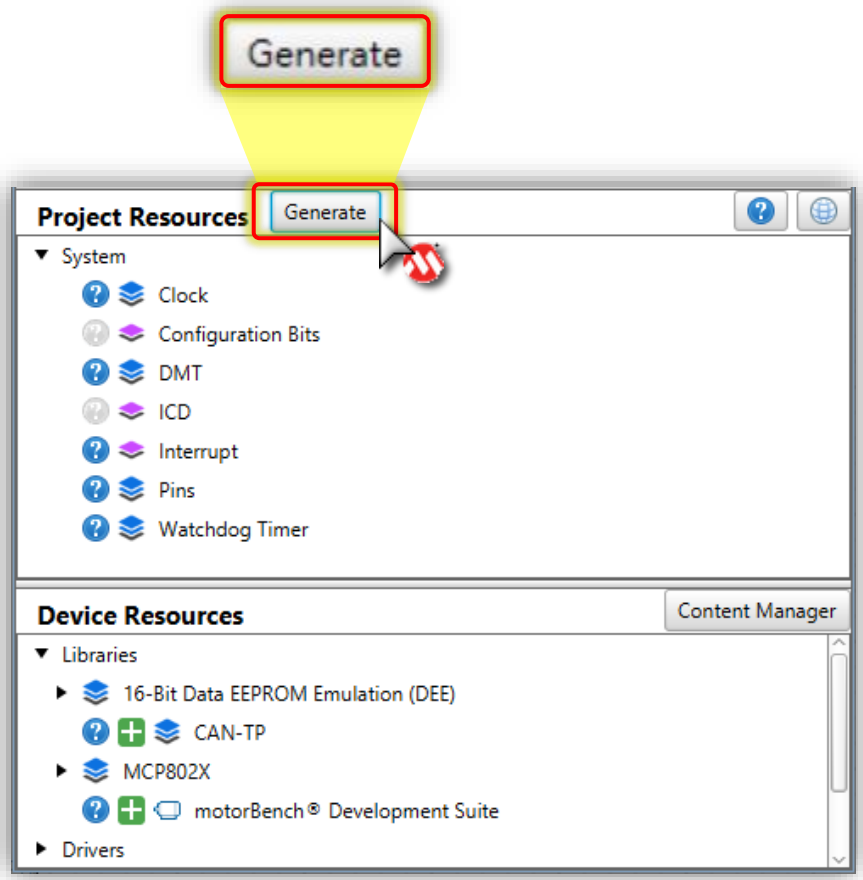
- Enable AN12 and Modify the Custom Name to "VR2".
- Select the Trigger Source to Common Software Trigger and Enable Interrupt.

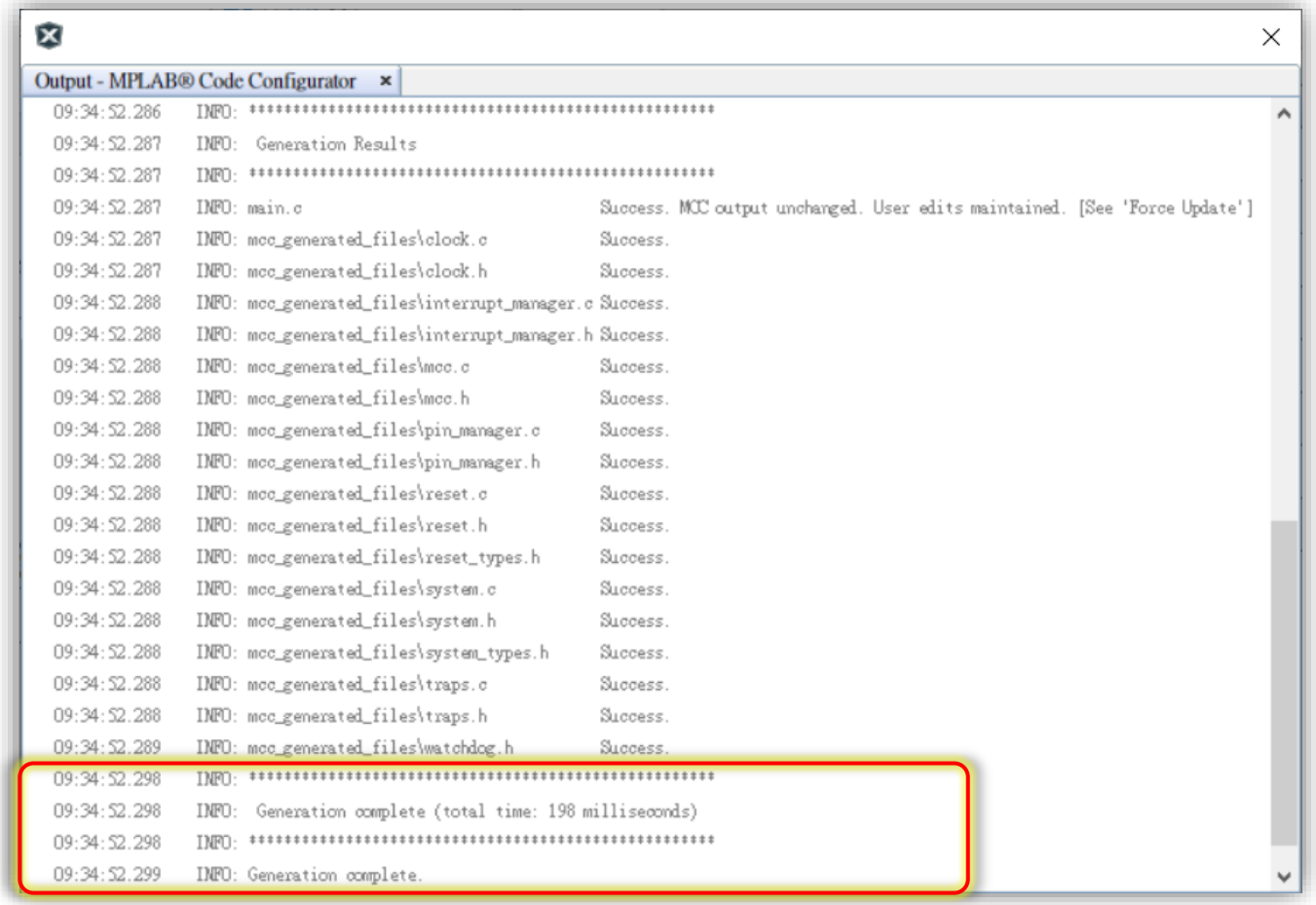


Lab10 ADC Multiple Channel Periodically

Step 3

- Click "Generate" Button to generate your code.





Lab10 ADC Multiple Channel Periodically

Code Example

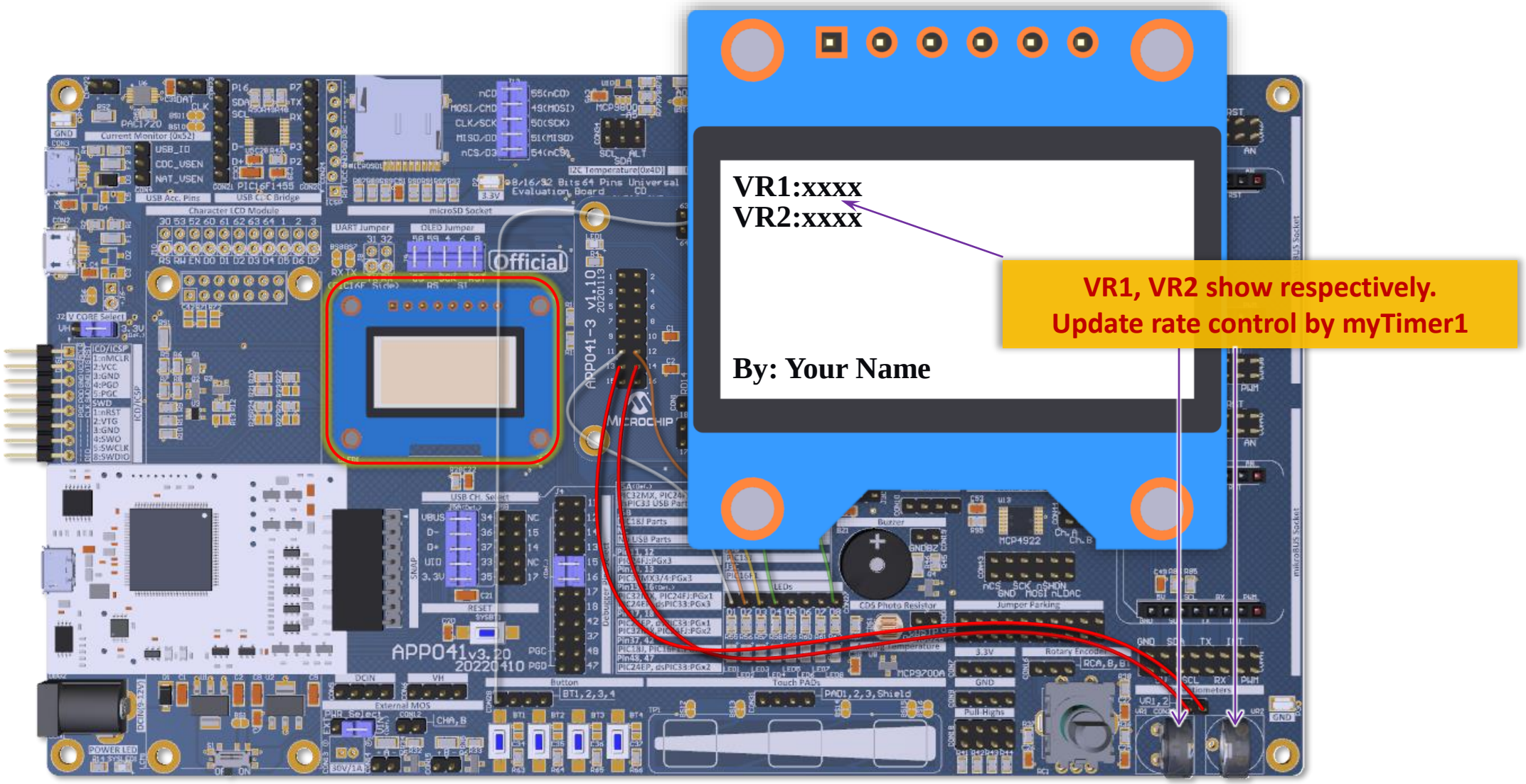
```
...
volatile uint8_t TMR1Flag = 0;
volatile uint8_t VR1Flag = 0;
volatile uint16_t ADC1Buffer[2];
uint8_t StringBuffer[40];
volatile uint8_t VR2Flag = 0;

...
void ADC1_CallBack(enum ADC_CHANNEL channel, uint16_t adcVal)
{
   if (channel == VR1)
   {
      VR1Flag = 1;
      ADC1Buffer[0] = adcVal;
   }
   else if (channel == VR2)
   {
      VR2Flag = 1;
      ADC1Buffer[1] = adcVal;
   }
}

int main(void)
{
   ...
}
```

```
int main(void)
{
   ...
   ADC1.adcMulticoreInterface->ChannelCallbackRegister(ADC1_CallBack);
   ...

   while (1)
   {
      if(TMR1Flag)
      {
         TMR1Flag=0;
         ADC1.SoftwareTriggerEnable();
      }

      if (VR1Flag)
      {
         VR1Flag = 0;
         sprintf((char *) StringBuffer, "VR1:%4d", ADC1Buffer[0]);
         myOLED_DrawStr(0, 0, StringBuffer);
      }

      if (VR2Flag)
      {
         VR2Flag = 0;
         sprintf((char *) StringBuffer, "VR2:%4d", ADC1Buffer[1]);
         myOLED_DrawStr(0, 1, StringBuffer);
      }

   }
}
```

myTimer1 Timer for ADC Software Trigger periodically

Lab10 ADC Multiple Channel Periodically

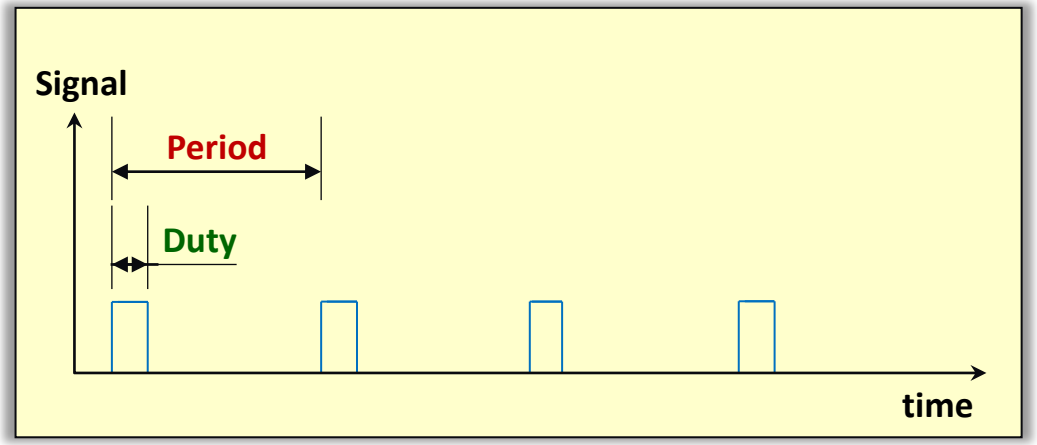
Result



High Resolution PWM Application

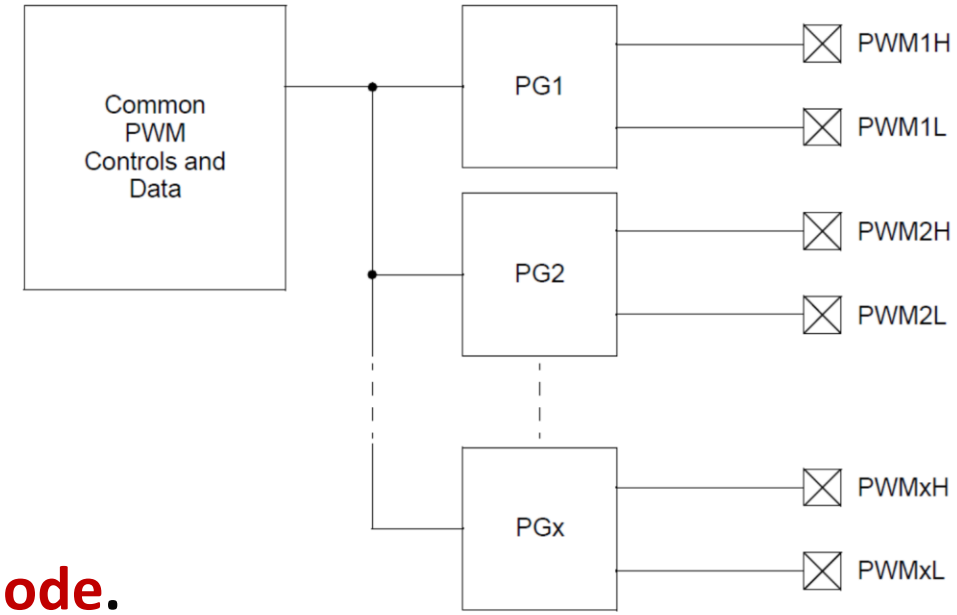
What's PWM

- **The Pulse-width modulation (PWM) Waveform is a modulation technique used to encode a message into a pulsing signal.**
- **Its main use is to allow the control of the power supplied to electrical devices, ex. motor control, ballast, LED, H-bridge, power converters, and other types of power control applications.**
- **There have two important terms**
  - **Period :**
    The single square wave duration.
  - **Duty :**
    The proportion of active time to the regular interval.



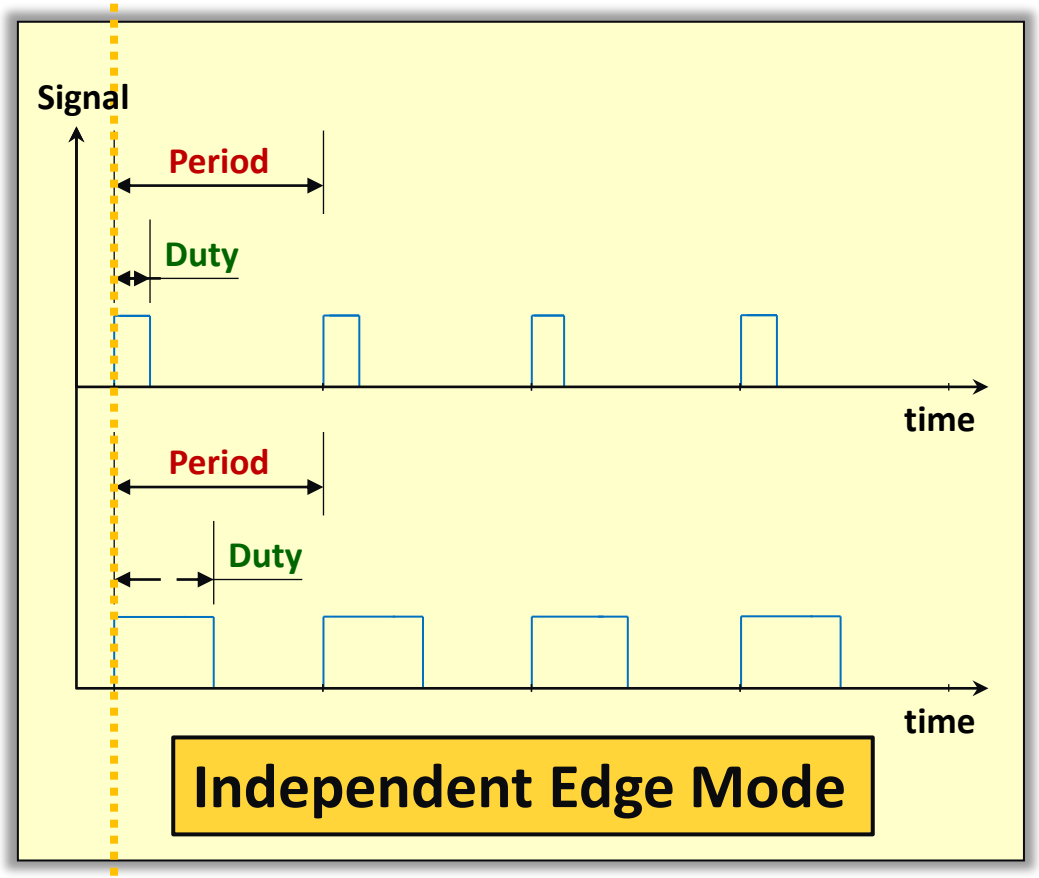
High Resolution PWM

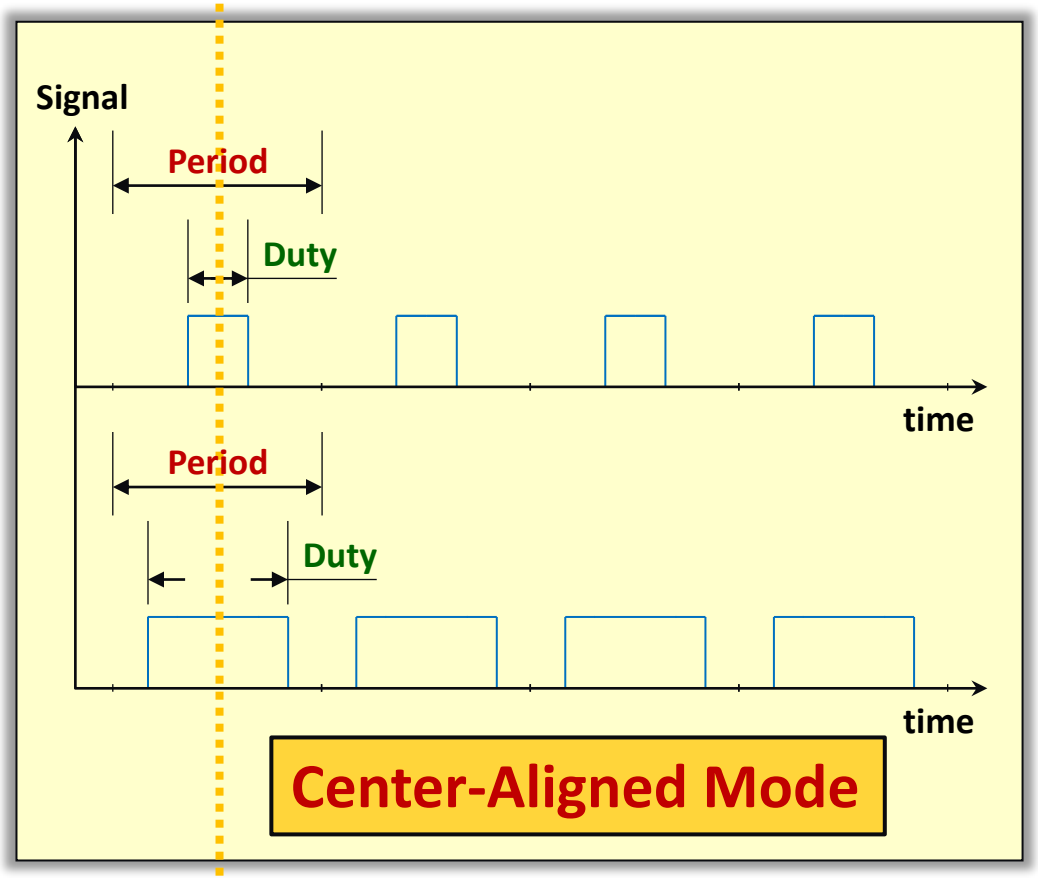
- **This flexible module provides features to support many types of Motor Control (MC) and Power Control (PC).**
- **dsPIC33CK256MP506 include one PWM module provide maximum eight pairs of PWM outputs available.**
- **All PWM has dedicated pins except PWM4, PWM4 could has flexibility of Peripheral Select Pin(PPS).**
- **Support lot of operating modes:**
  - Independent Edge mode.
  - Variable Phase PWM mode.
  - **Center-Aligned mode.**
  - Double Update Center-Aligned mode.
  - Dual Edge Center-Aligned mode.
  - Dual PWM mode.
- **At this section, we focus on Center-Aligned mode.**



Independent Edge Mode vs Center-Aligned Mode

- Independent Edge Mode is a common PWM mode, which is aligned from the starting point of the cycle.
- Center-Aligned Mode aligns from the center of the cycle, currently MCC Melody only supports this mode.





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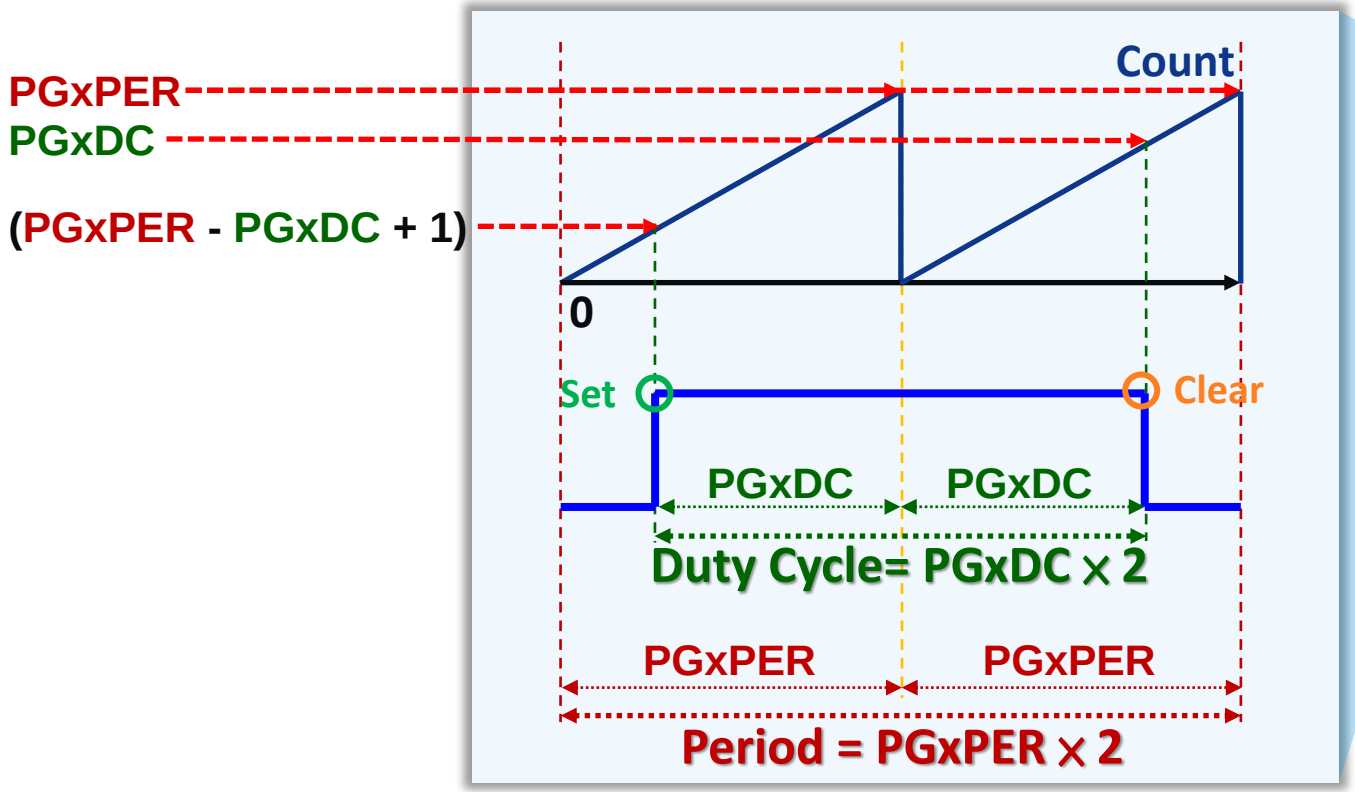
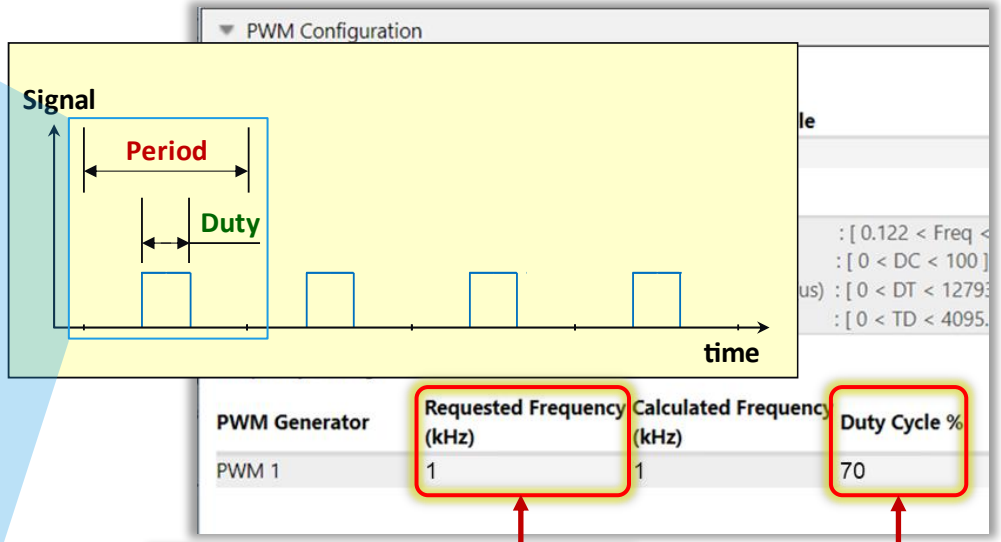
Center-Aligned Mode of High Resolution PWM

- For **Center-Aligned Mode**, signals avoid coincident rising or falling edges between PWM Generators when the duty.
- **PGxDC** : Determines the width of the PWM pulse from the center of the two timer cycles.
- **PGxPER** : Determines the end of the PWM timer count cycle.





Frequency = 1/Period

Duty Cycle % = Duty Cycle/Period

MICROCHIP

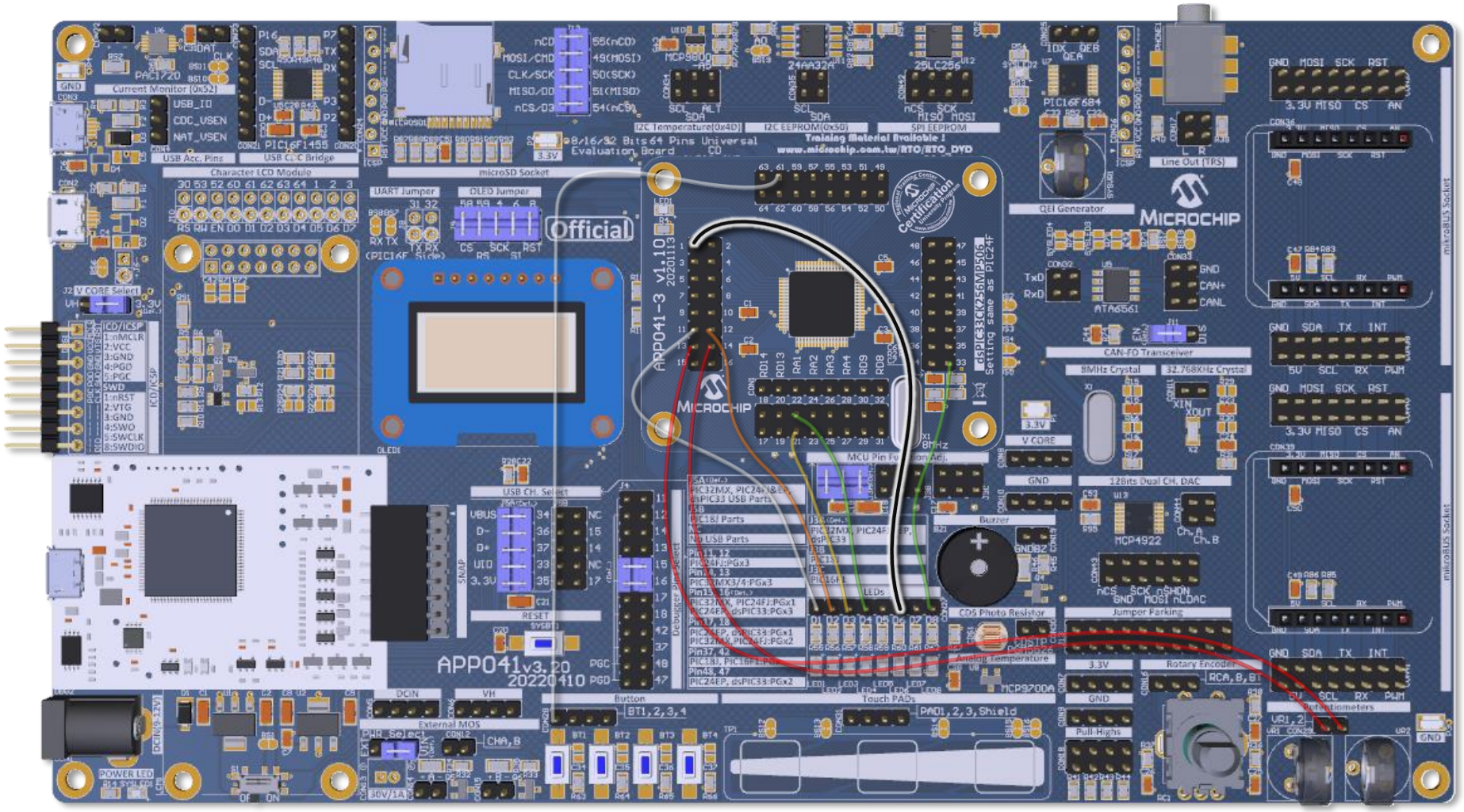
Lab11 PWM Output

- Base on current project or Open .\Exercises\Lab11_xxx.X to do exercise
- Try to initial H.R. PWM-PG1 to Center-Aligned Mode, then use PWM to control LED brightness.
- H.R. PWM-PG1 module clock source set to 16MHz, Frequency is 1KHz, Duty cycle 20%.
- Please connect RB14 (PWM1_H, Pin1) to LED (LED6) to observe LED brightness.

Let’s go!

Lab11 PWM Output

Connection

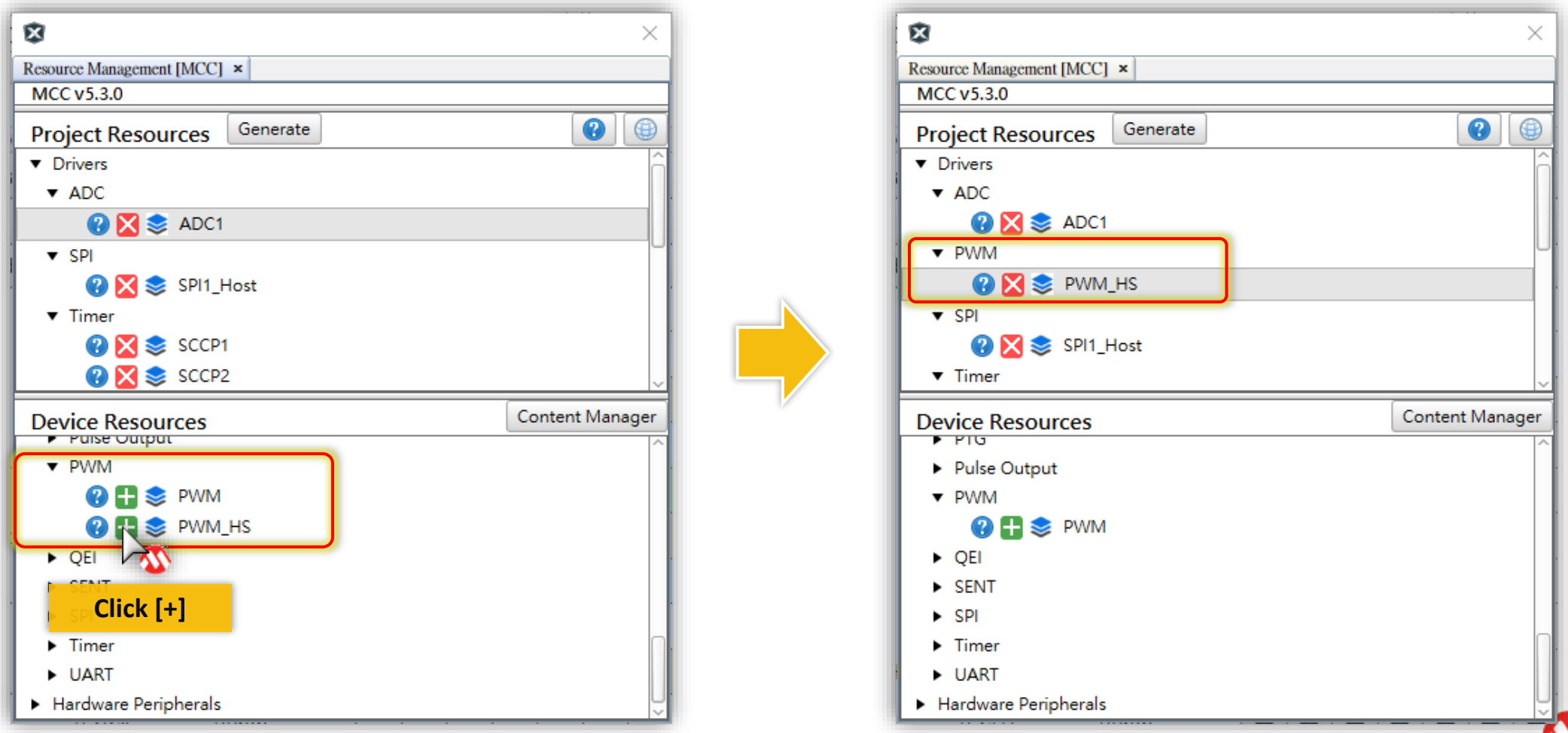


PIM Pin#		Symbol
1		D6

Lab11 PWM Output

Step 1

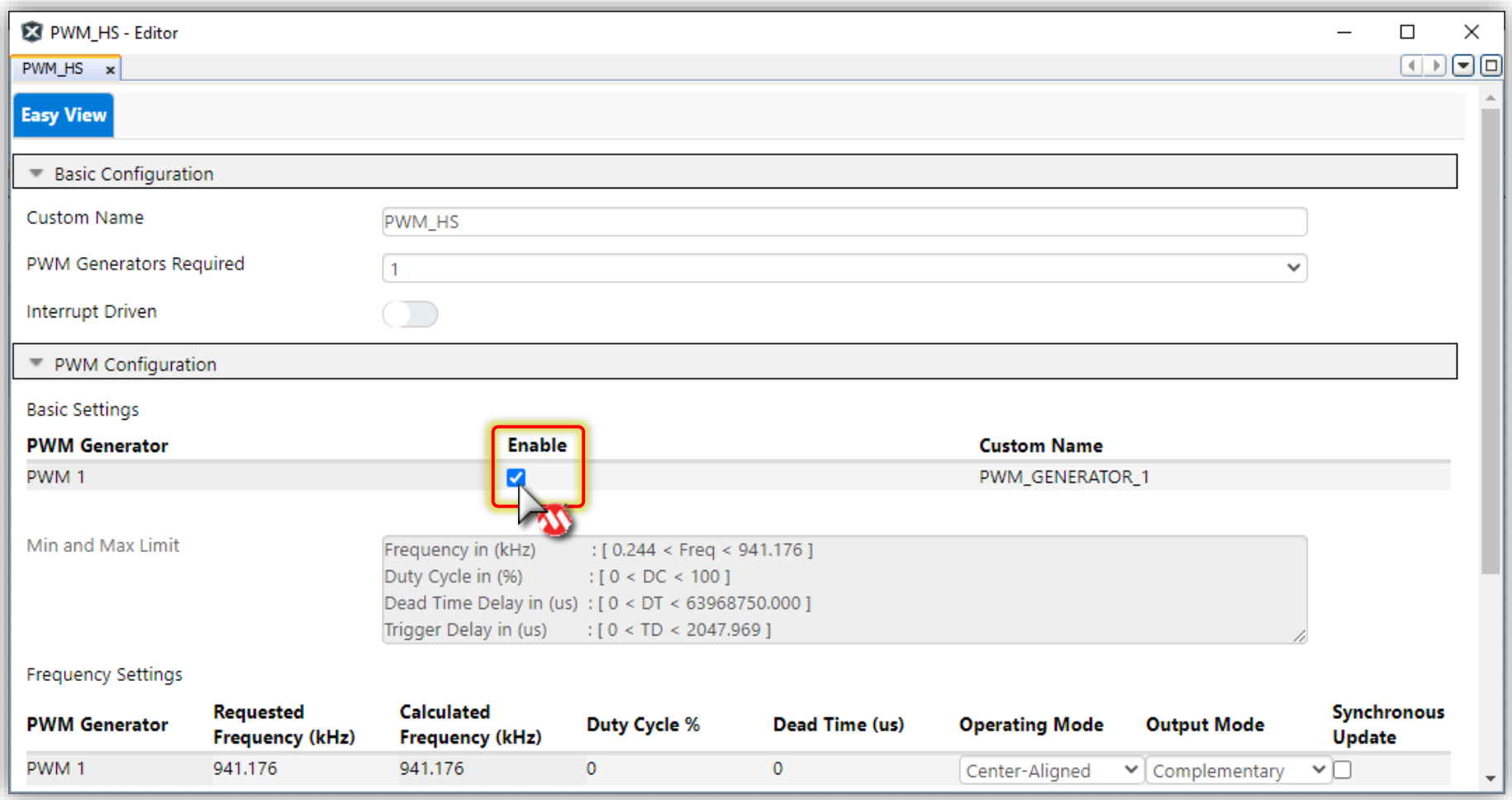
- Click [+] to add PWM > PWM_HS module.



Lab11 PWM Output

Step 2

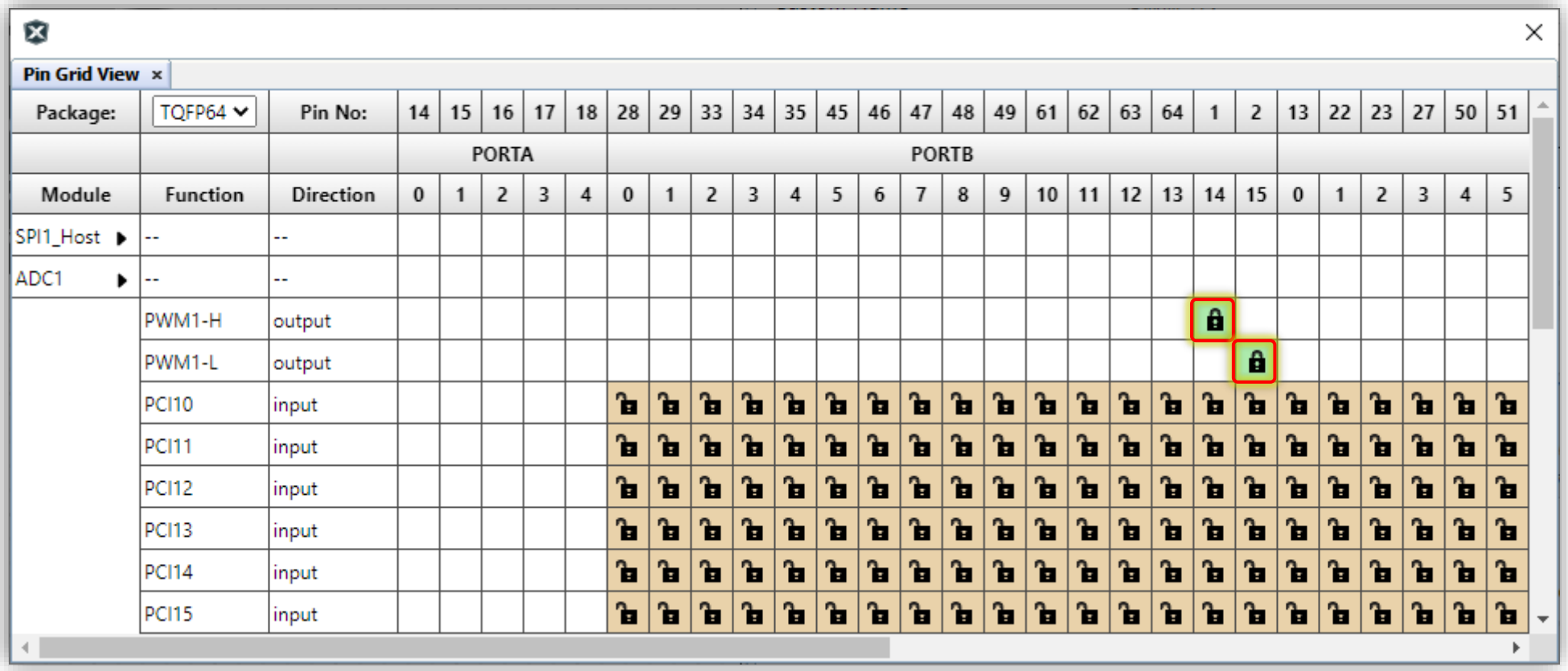
- Enable PWM 1



Lab11 PWM Output

Note

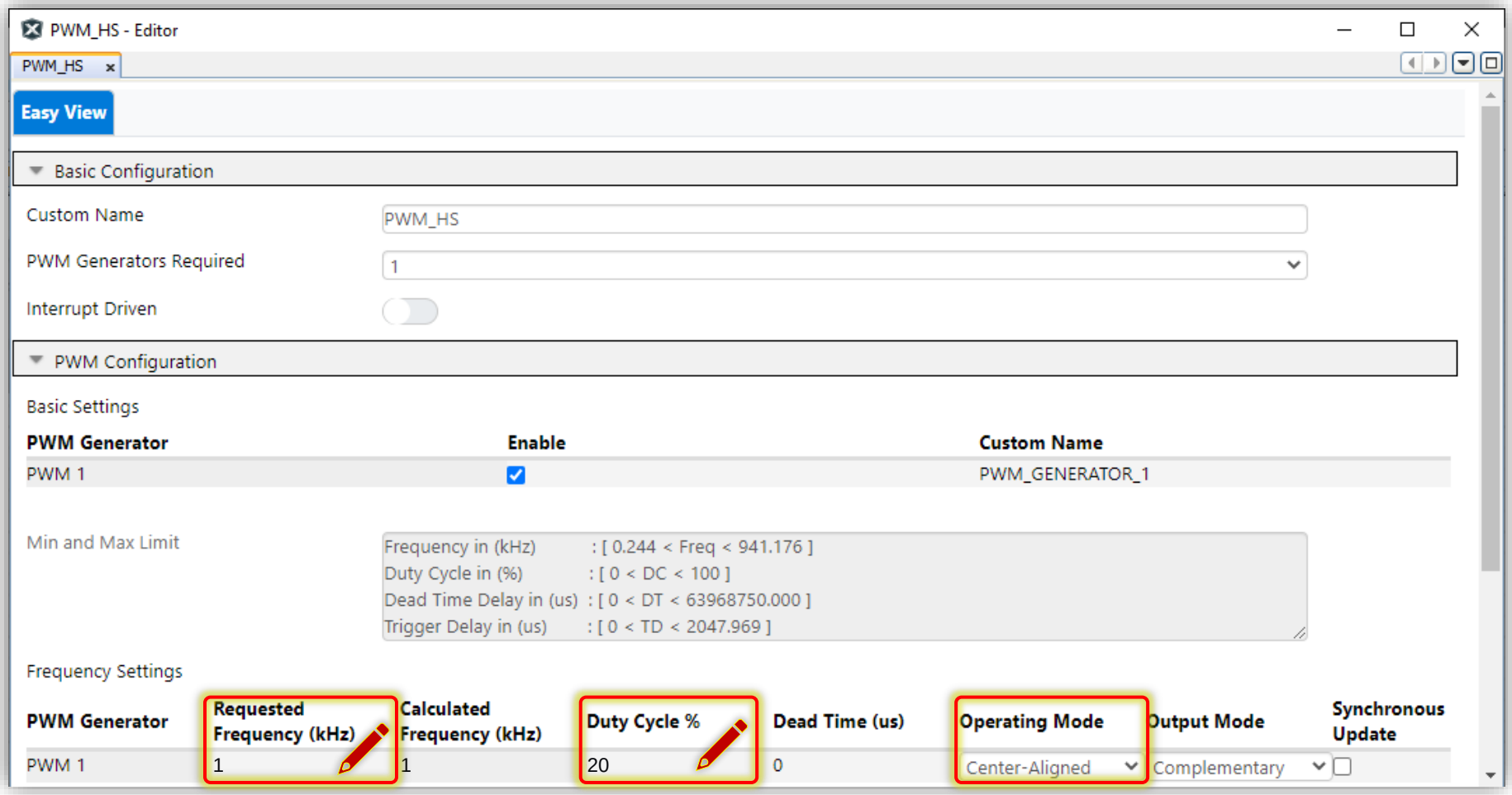
- **The PWM output pin is connected by default.**



Lab11 PWM Output

Step 3

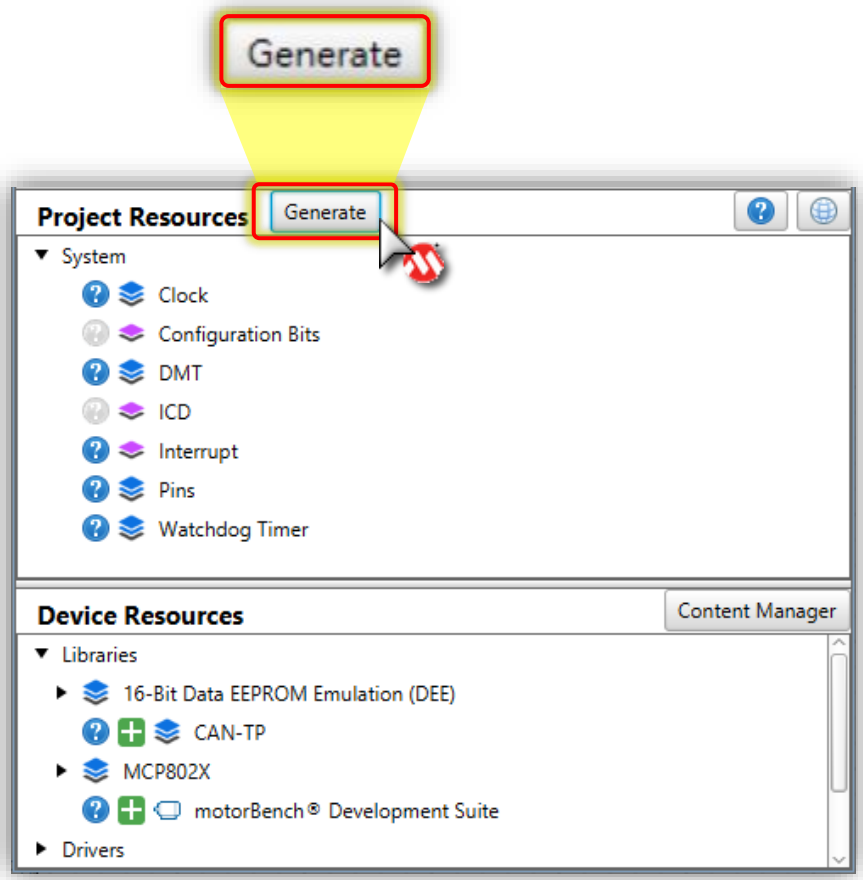
- Modify PWM1 Requested Frequency (kHz) to 1 and Set PWM1 Duty Cycle (%) to 20.
- Check the PWM1 Operating Mode is "Center-Aligned".

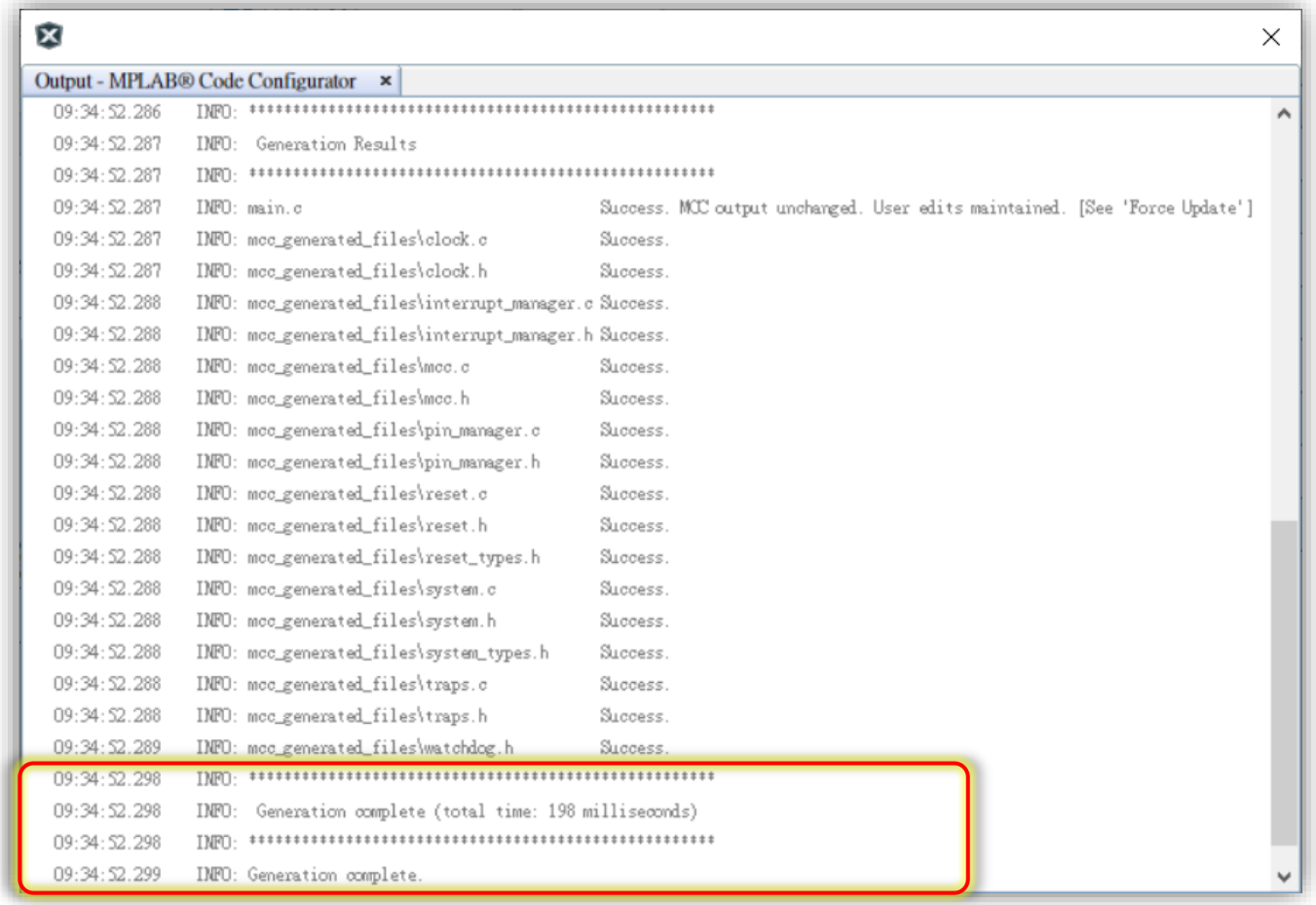


Lab11 PWM Output

Step 4

- Click "Generate" Button to generate your code.





Lab11 PWM Output

Code Example

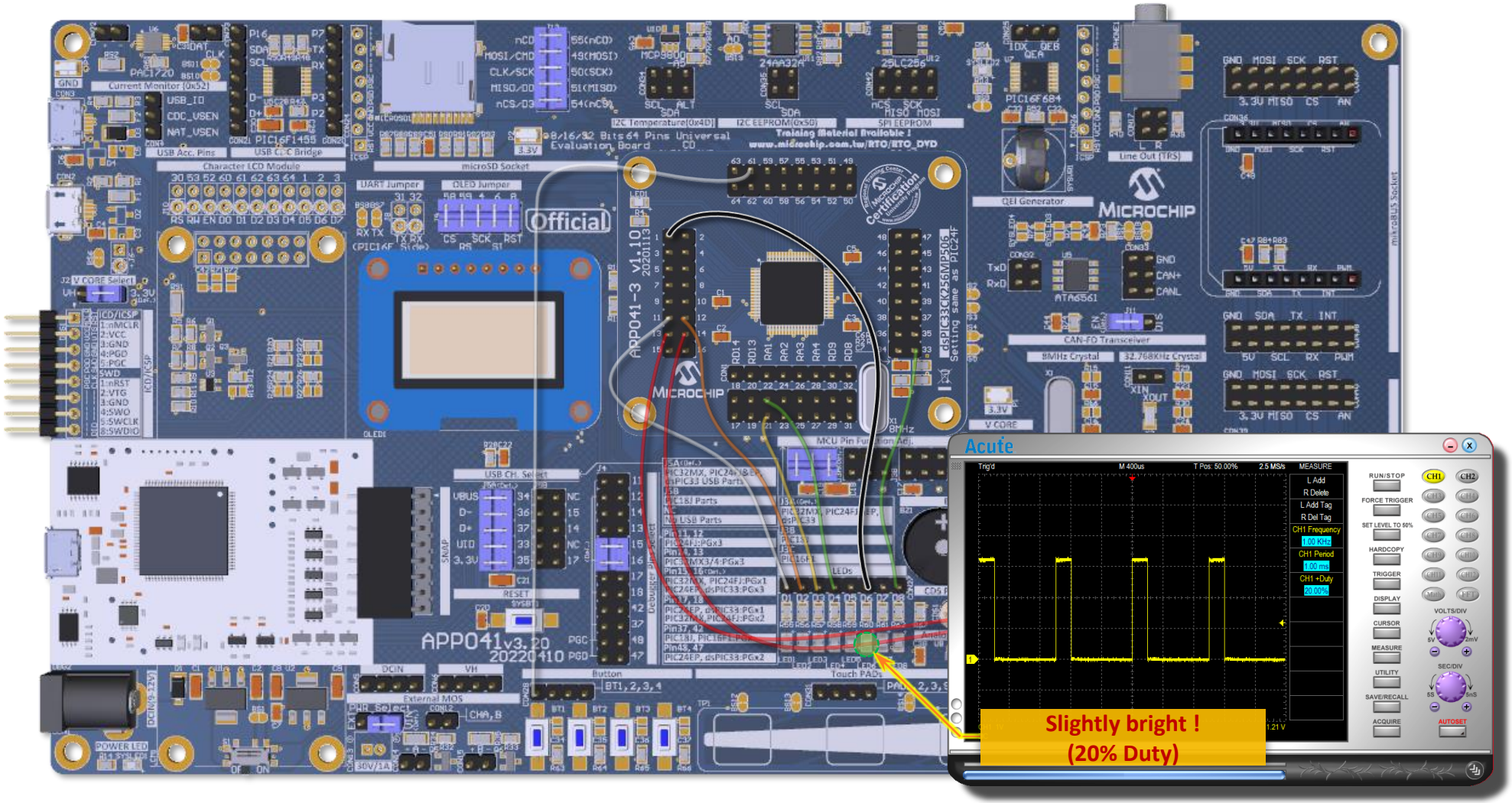
```
#include "myOLEDlib/myOLED_ssd1306.h"
#include "mcc_generated_files/adc1.h"

...
volatile uint8_t SCCP1Flag = 0;
volatile uint8_t VR1Flag = 0;
volatile uint16_t ADC1_VR1_Buffer = 0;
volatile uint8_t VR2Flag = 0;
volatile uint16_t ADC1_VR2_Buffer;

int main(void)
{
    ...
}

...

void ADC1_VR1_CallBack (uint16_t adcVal)
{
    VR1Flag = 1;
    ADC1_VR1_Buffer = adcVal;
}

void ADC1_VR2_CallBack (uint16_t adcVal)
{
    VR2Flag = 1;
    ADC1_VR2_Buffer = adcVal;
}
```

```
int main(void)
{
    ...
    while (1)
    {
        // Add your application code
        ...
        if (SCCP1Flag)
        {
            ...
            ADC1_SoftwareTriggerEnable();
        }
        if (VR1Flag)
        {
            VR1Flag = 0;
            sprintf((char *) StringBuffer, "VR1:%4d", ADC1_VR1_Buffer);
            myOLED_DrawStr(0, 0, StringBuffer);
        }

        if (VR2Flag)
        {
            VR2Flag = 0;
            sprintf((char *) StringBuffer, "VR2:%4d", ADC1_VR2_Buffer);
            myOLED_DrawStr(0, 1, StringBuffer);
        }

    }
    return 1;
}
```

Don't Need Modify Any Code !

Lab11 PWM Output

Result



H.R. PWM Functions of Melody

- **Melody Provide below functions for PWM:**

  Prototype definition : "pwm.h“

  - **PWM_HS_INTERFACE**
    - (void) *PWM_HS*.Initialize (void);
    - (void) *PWM_HS*.Deinitialize (void);
    - (void) *PWM_HS*.Disable(void);
    - (void) *PWM_HS*.Enable(void);
    - (void) *PWM_HS*.GeneratorDisable(enum PWM_GENERATOR genNum);
    - (void) *PWM_HS*.GeneratorEnable(enum PWM_GENERATOR genNum);
    - (void) *PWM_HS*.ModeSet(enum PWM_GENERATOR genNum, enum PWM_MODES mode);
    - (void) *PWM_HS*.PeriodSet(enum PWM_GENERATOR genNum,uint16_t period);
    - (void) *PWM_HS*.DutyCycleSet(enum PWM_GENERATOR genNum,uint16_t dutyCycle);
    - (void) *PWM_HS*.PhaseSelect(enum PWM_GENERATOR genNum, enum PWM_SOURCE_SELECT source);
    - (void) *PWM_HS*.PhaseSet(enum PWM_GENERATOR genNum, uint16_t phase);
    - (void) *PWM_HS*.SoftwareUpdateRequest(enum PWM_GENERATOR genNum);
    - (void) *PWM_HS*.GeneratorEOCEventCallbackRegister(void (*callback)(…)); /* End Of Cycle */

Lab12 PWM Duty Adj By ADC

- Base on current project or Open .\Exercises\Lab12_xxx.X to do exercise
- Try to use Potentiometer (VR1) to control LED (LED6) brightness.
- VR Value (0 ~4095) <-> PWM Duty (0% ~ 100%)
- H.R. PWM Setting same as previous Lab.

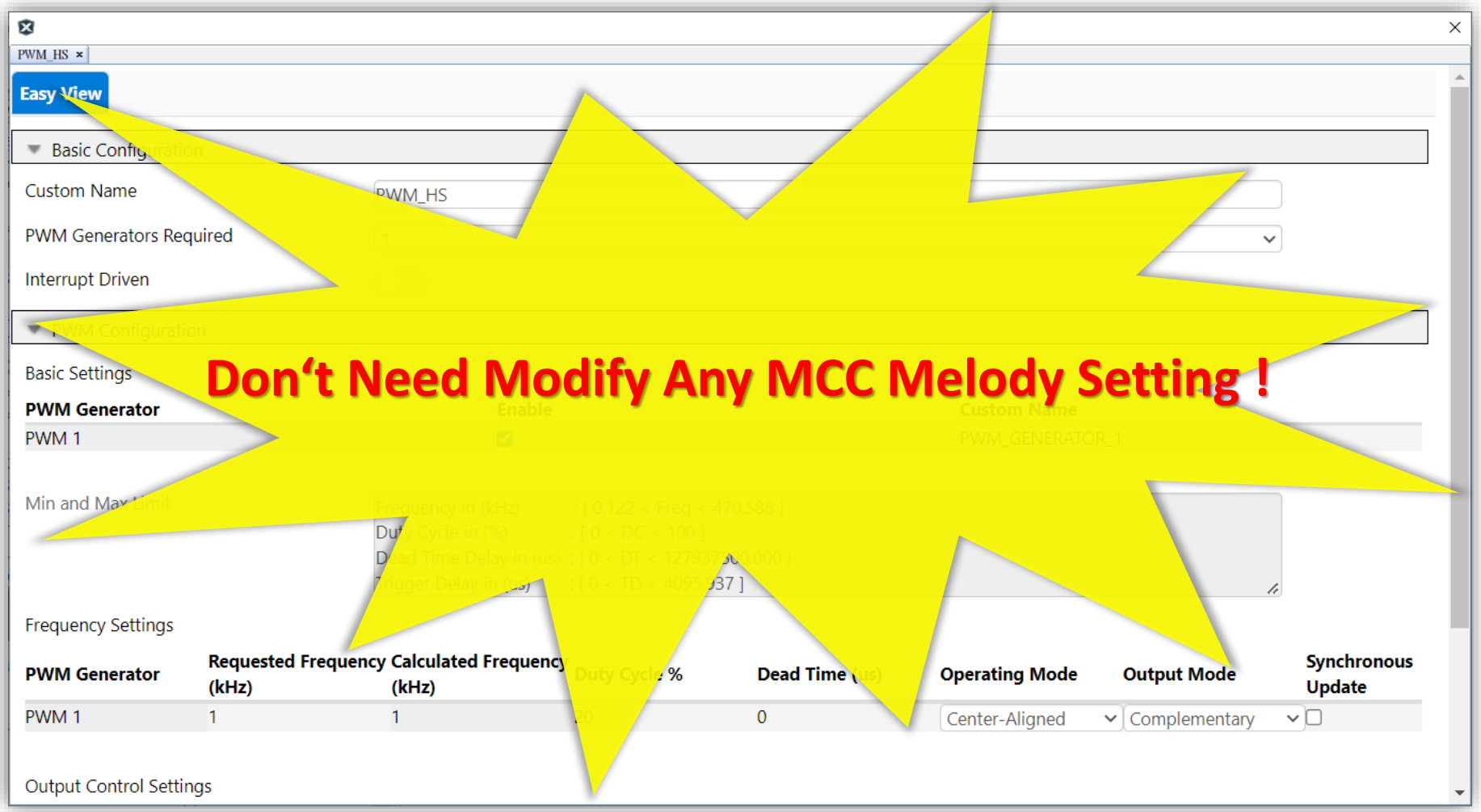
Let’s go!

Lab12 PWM Duty Adj By ADC

Connection

Lab12 PWM Duty Adj By ADC

Notice



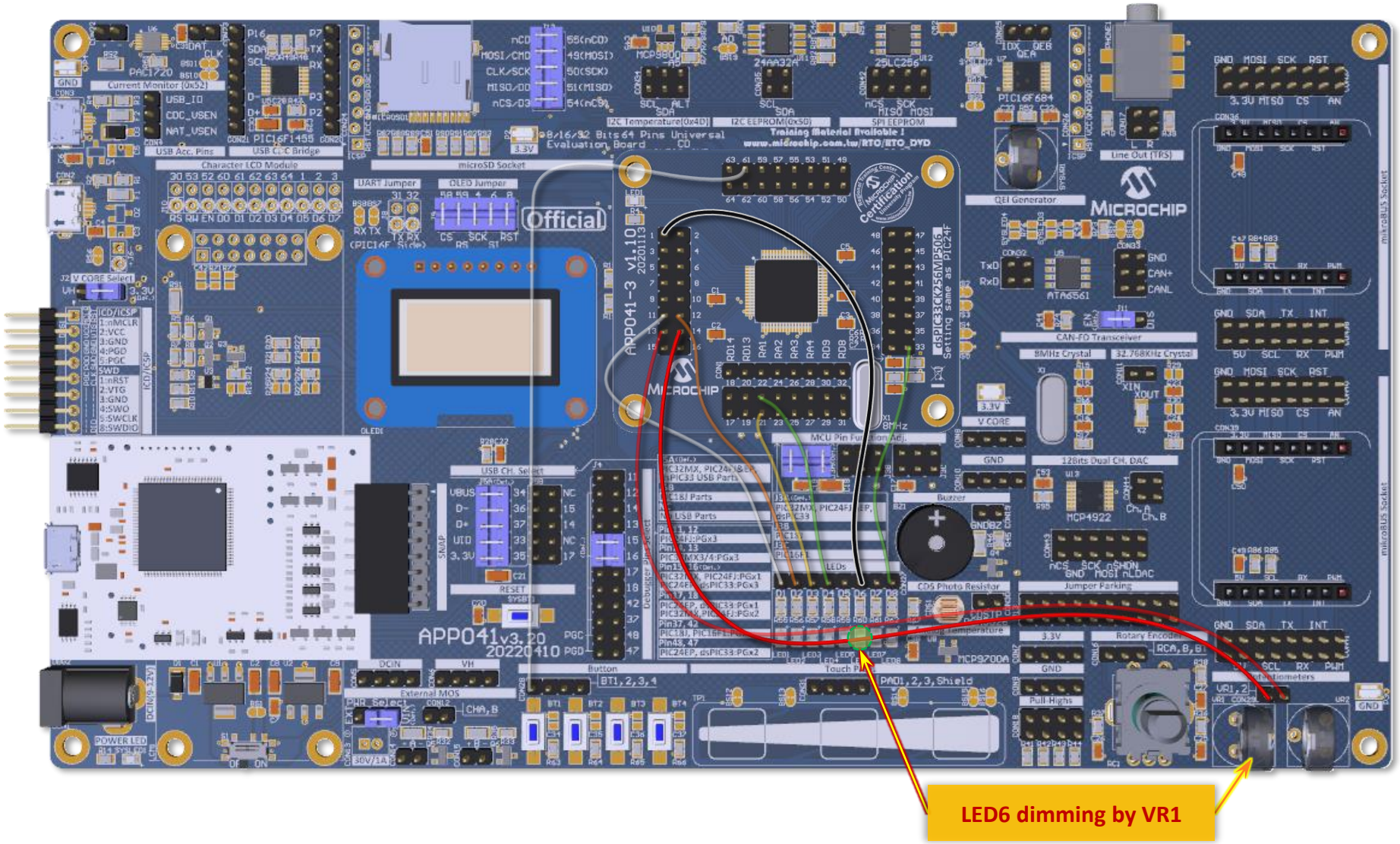
Lab12 PWM Duty Adj By ADC

Code Example

```
...
#include <stdio.h>
#include "mcc_generated_files/pwm_hs/pwm.h"

...

int main(void)
{
    ...

    while (1)
    {
        ...

        if (VR1Flag)
        {
            VR1Flag = 0;
            sprintf((char *) StringBuffer, "VR1:%4d", ADC1Buffer[0]);
            myOLED_DrawStr(0, 0, StringBuffer);

            PWM_HS.DutyCycleSet(PWM_GENERATOR_1, ( (uint32_t) ADC1Buffer[0] * PG1PER) / 4095);
            PWM_HS.SoftwareUpdateRequest(PWM_GENERATOR_1);
        }
    }
}
```

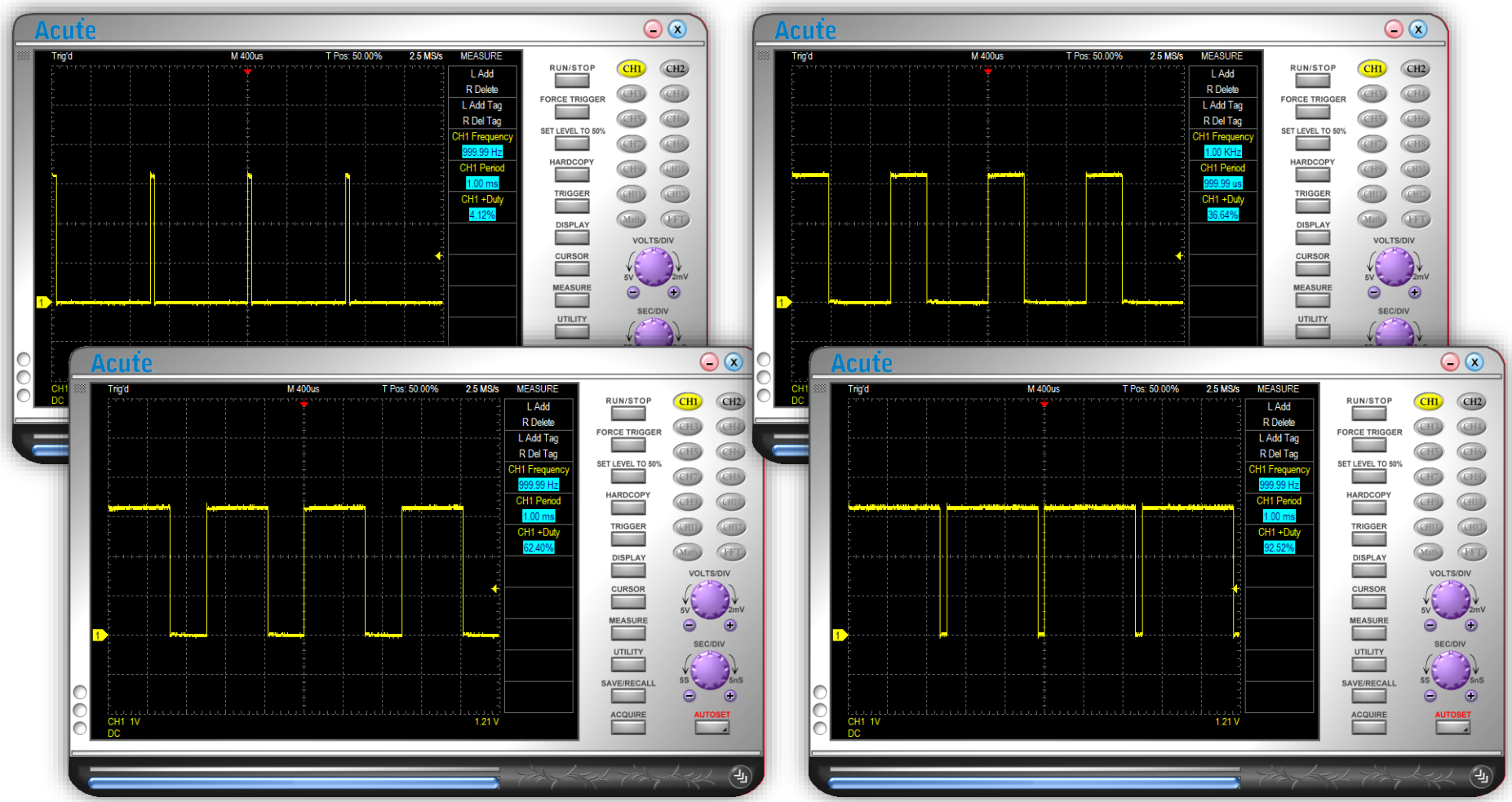
Lab12 PWM Duty Adj By ADC

Result



Lab12 PWM Duty Adj By ADC

Result



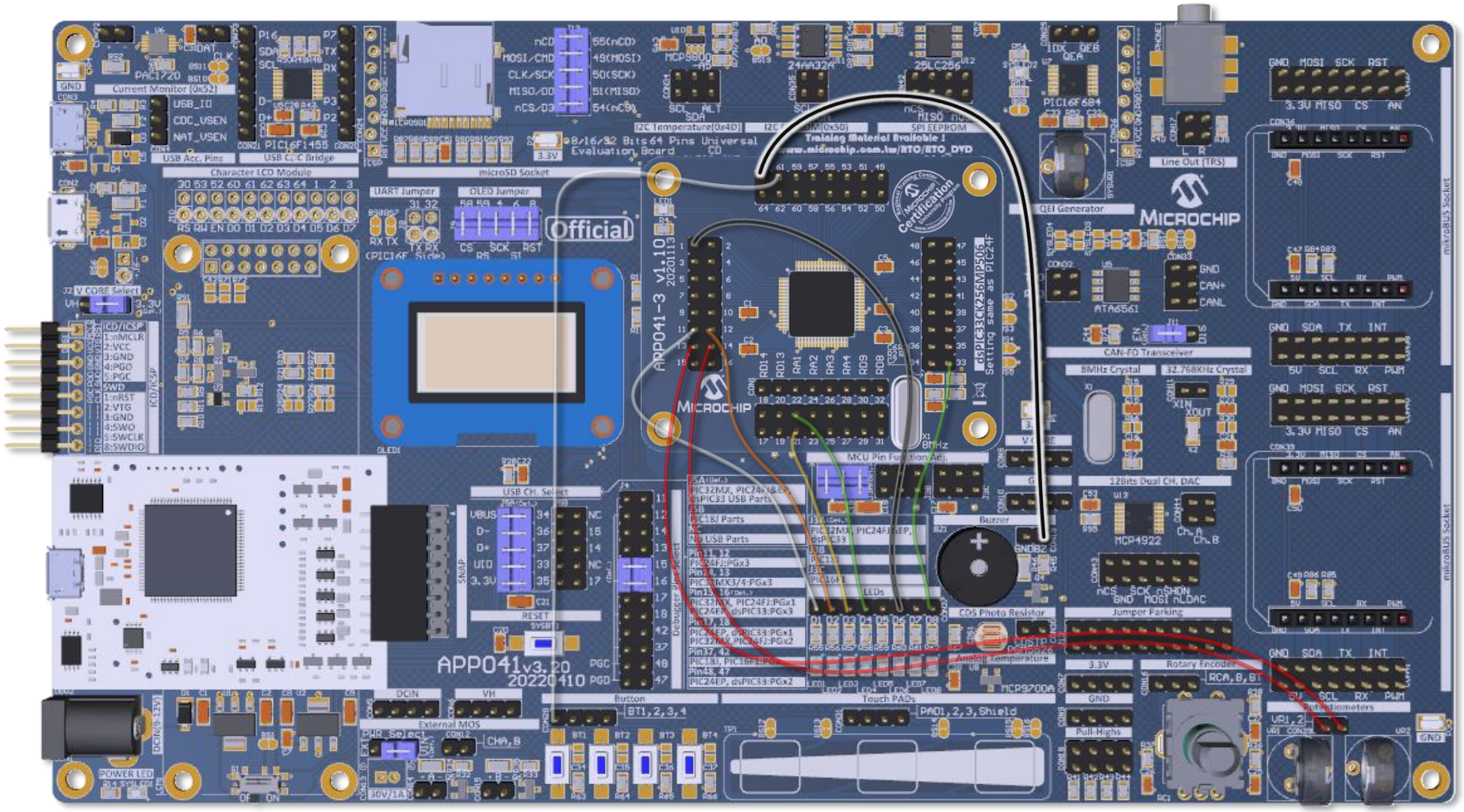
Lab13 PWM Buzzer Tone

- Base on current project or Open .\Exercises\Lab13_xxx.X to do exercise
- Try to initial H.R. PWM - PG2 to output special frequency (Tone) to Buzzer by VR2.
- VR2 Value (0 ~4,095) <-> PWM Frequency (122.07Hz ~ 1kHz)
- Connect RB12 (PWM2_H, Pin63) to Buzzer (BZ) to produce sound.

Let’s go!

Lab13 PWM Buzzer Tone

Connection



PIM Pin#		Symbol
63		BZ

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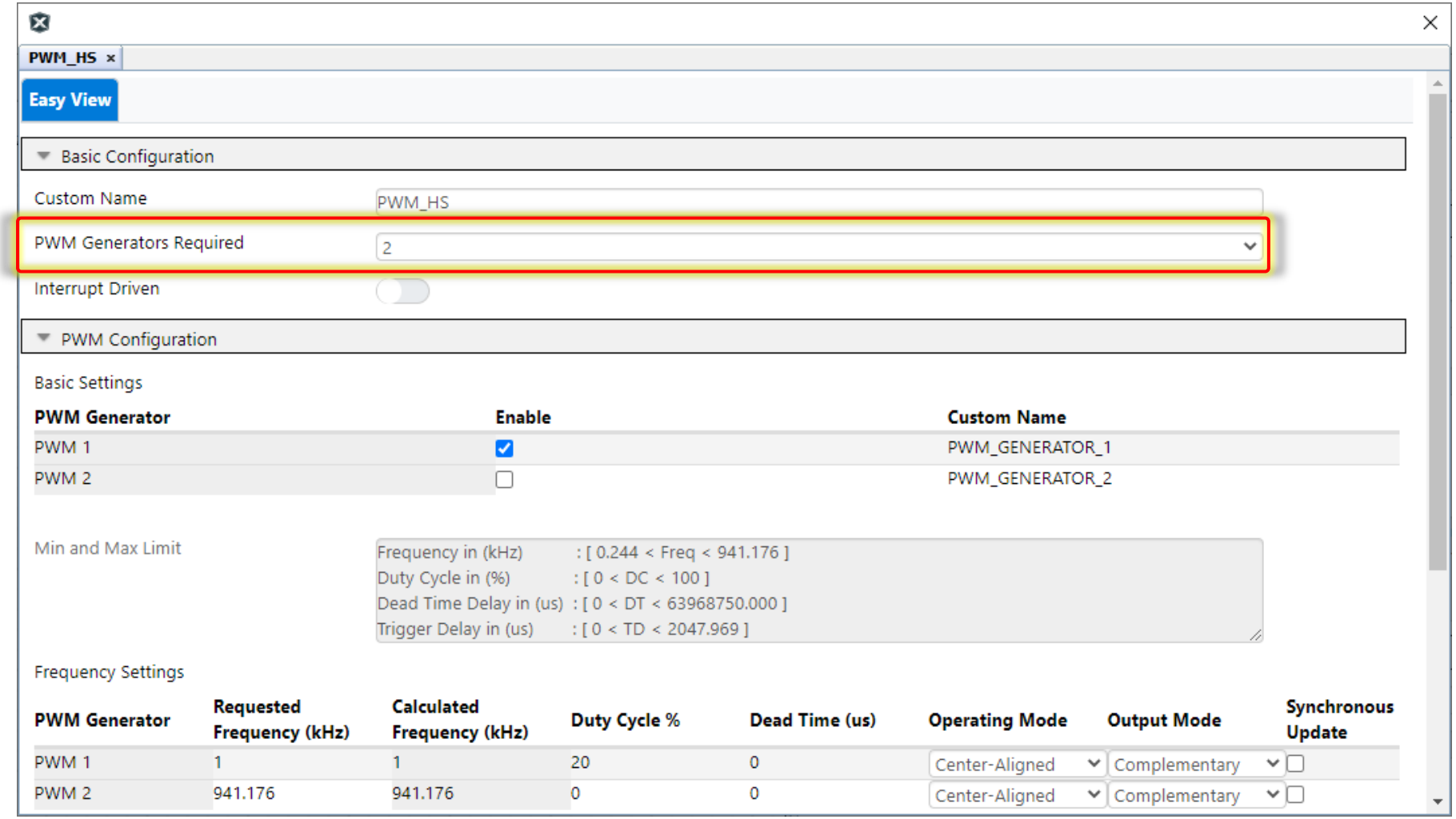
Lab13 PWM Buzzer Tone

Step 1

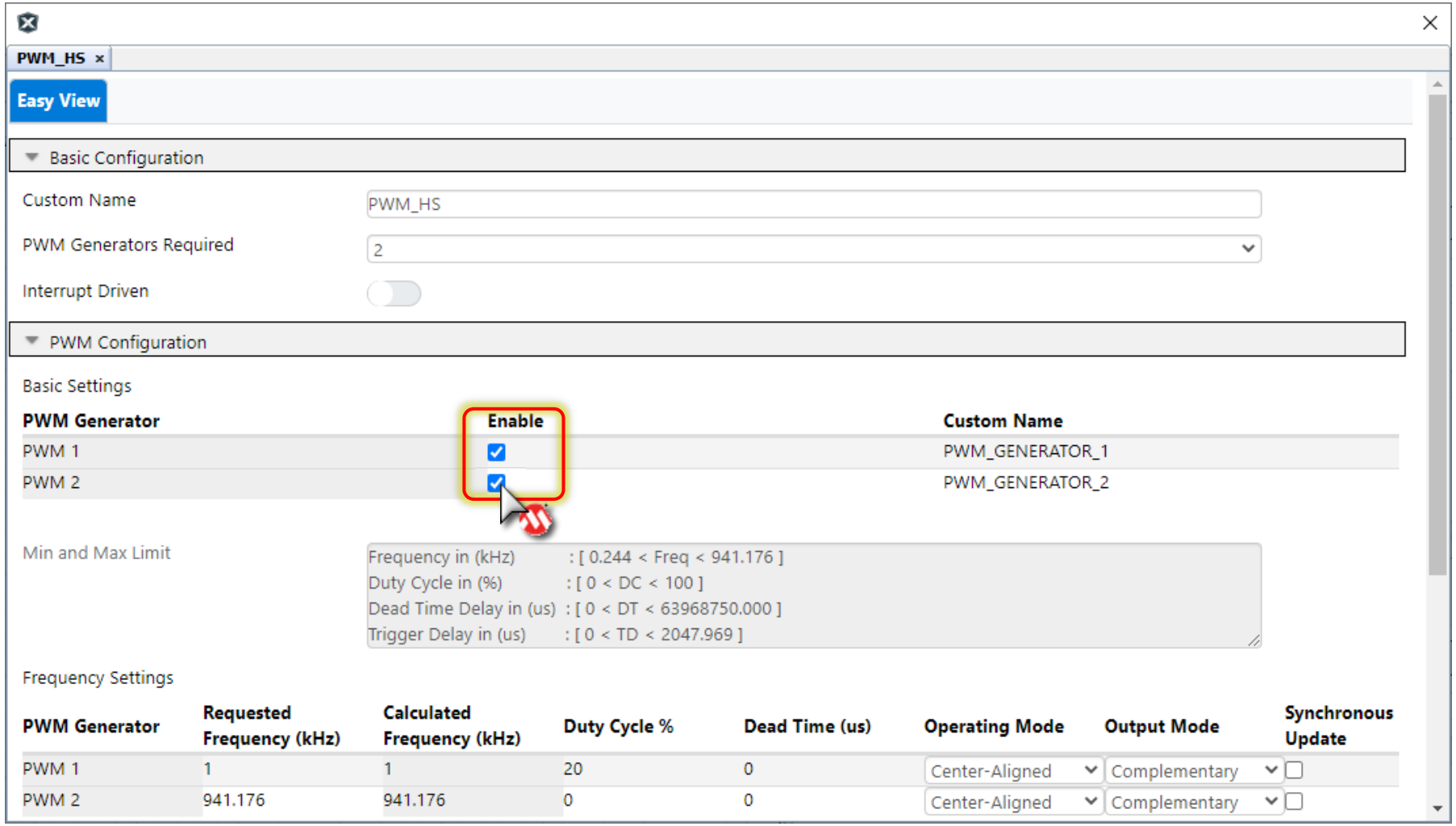
- **Select PWM Generators Required: 1 → 2.**



Lab13 PWM Buzzer Tone

Step 2

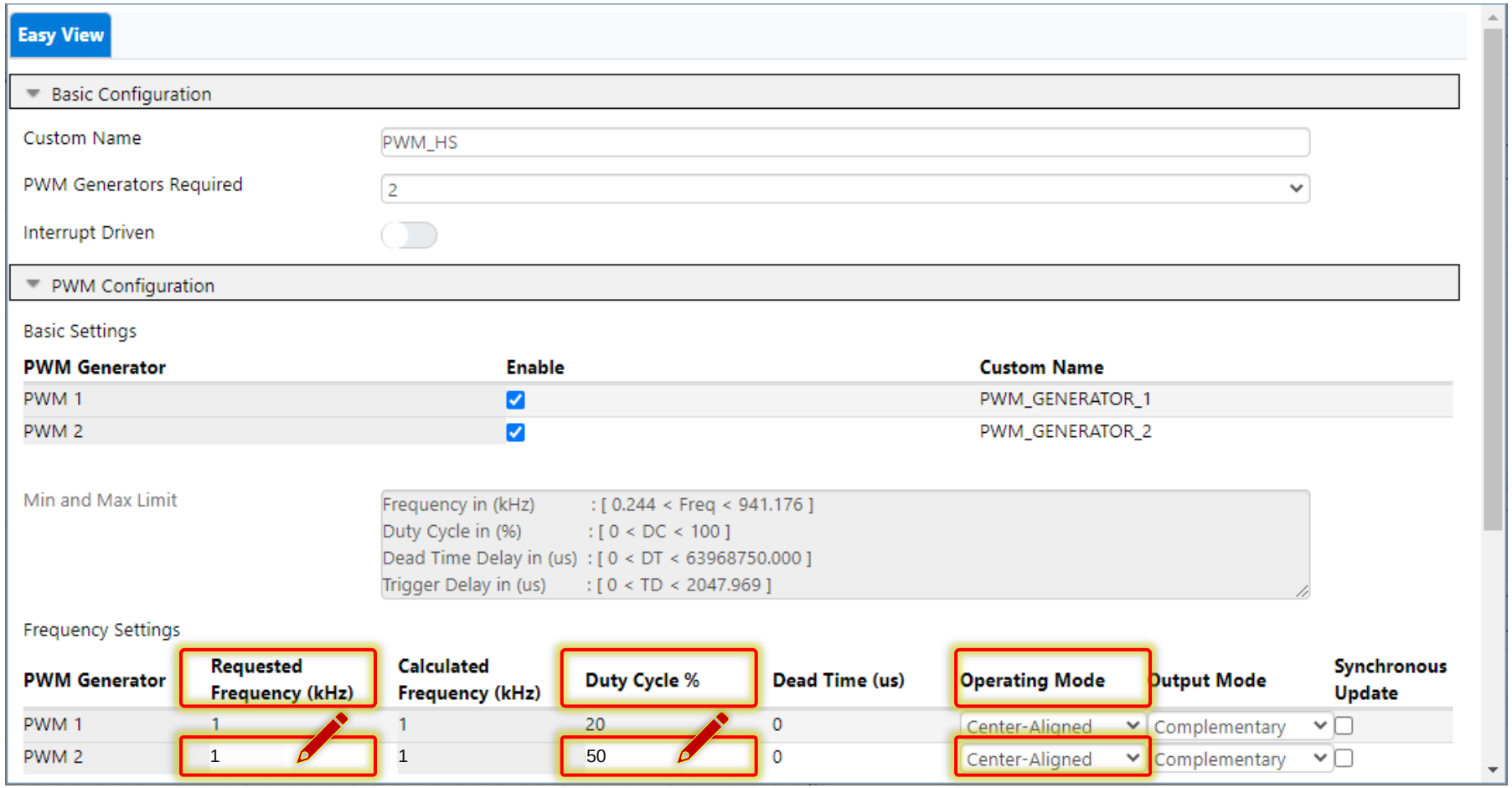
- Enable PWM 2.



Lab13 PWM Buzzer Tone

Step 3

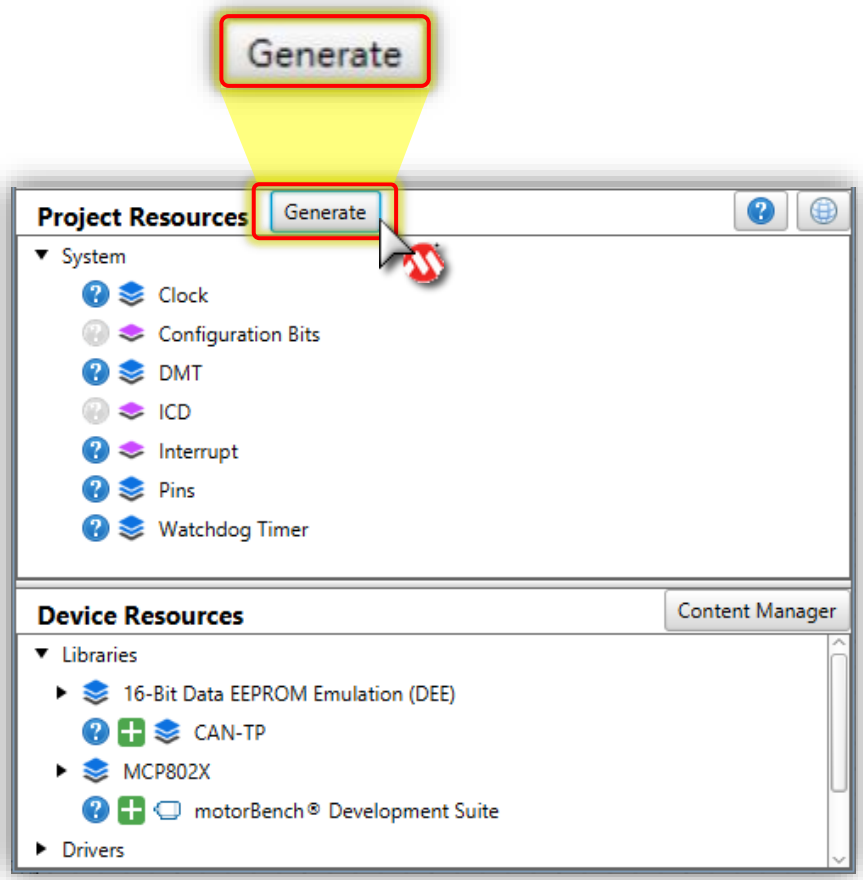
- Modify PWM 2 Requested Frequency (kHz) to 1 and Set Duty Cycle (%) to 50.
- Check the PWM 2 Operating Mode is "Center-Aligned".

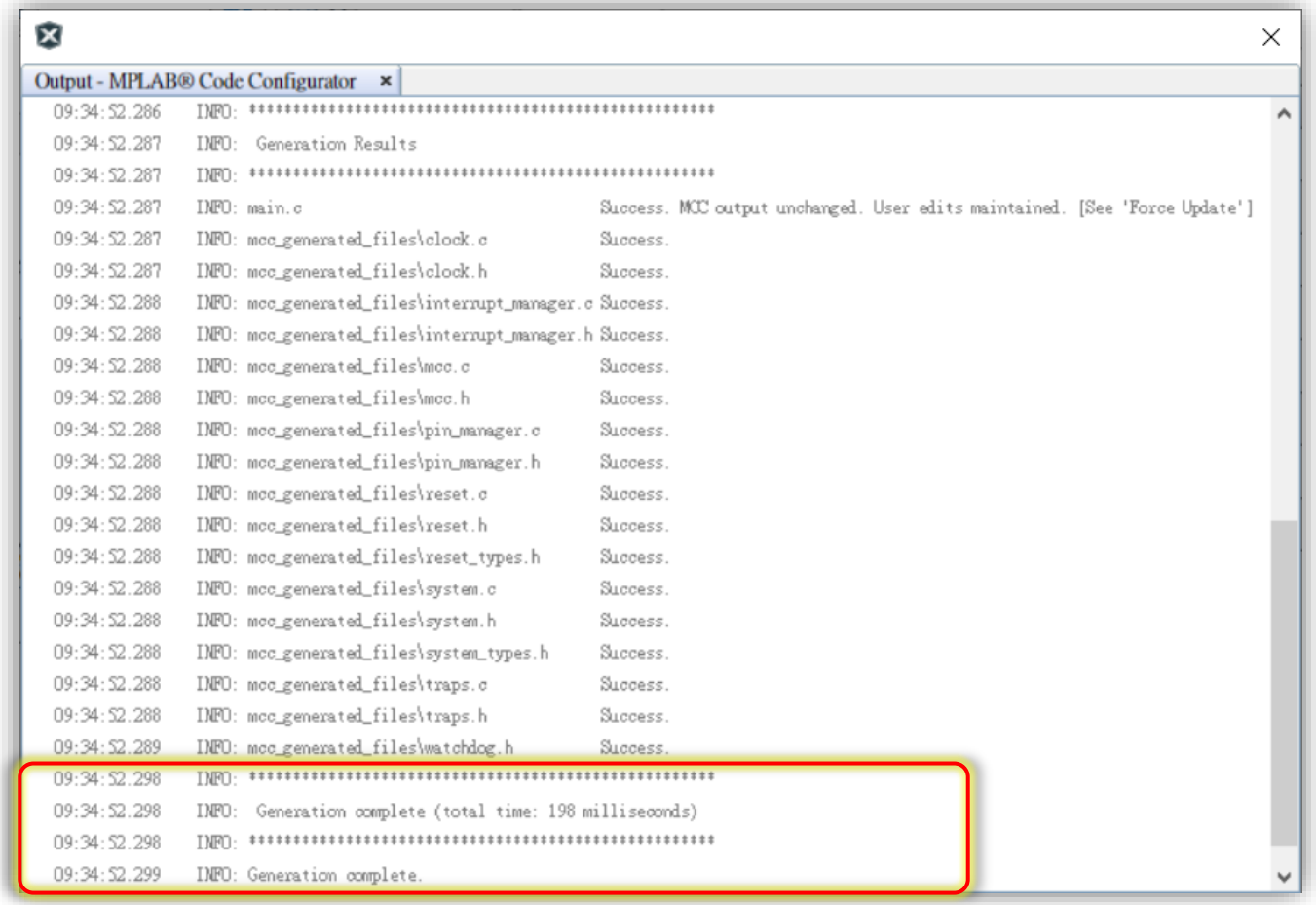


Lab13 PWM Buzzer Tone

Step 4

- Click "Generate" Button to generate your code.



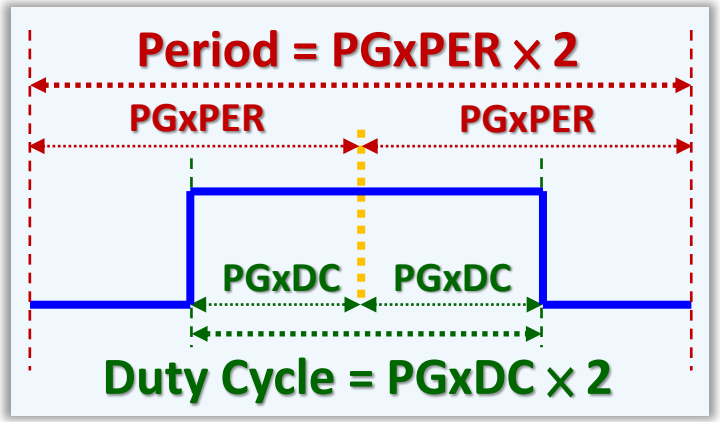


Lab13 PWM Buzzer Tone

Code Example

- **VR2 Value(0 ~ 4095) <-> PWM Frequency (122.07Hz ~ 1kHz)**
  - **PWM Frequency (244.14Hz) : PGxPER = 65535** (maximum count of 16-bits register)
  - **PWM Frequency (1kHz) : PGxPER = 15999**

```
#include <stdio.h>
#include "mcc_generated_files/pwm_hs/pwm.h"
…

int main(void)
{
    …

    while (1)
    {
        …

        if (VR2Flag)
        {
            VR2Flag = 0;
            sprintf((char *) StringBuffer, "VR2:%4d", ADC1Buffer[1]);
            myOLED_DrawStr(0, 2, StringBuffer);

            PWM_HS.PeriodSet(PWM_GENERATOR_2, 65535 - (uint32_t)ADC1Buffer[1] * (65535 - 15999) / 4095 );
            PWM_HS.DutyCycleSet(PWM_GENERATOR_2, PG2PER / 2); //Keep duty cycle at 50%
            PWM_HS.SoftwareUpdateRequest(PWM_GENERATOR_2);
        }

    }
}
```



Center-Aligned Modes

$$F_{PWM} = \left(\frac{F_{PGx\_clk}}{2 \times (PGxPER + 1)}\right)$$

$$244.14Hz = \left(\frac{32MHz}{2 \times (65535 + 1)}\right)$$

$$PGxPER = \left(\frac{F_{PGx\_clk}}{2 \times F_{PWM}}\right) - 1$$

$$15999 = \left(\frac{32MHz}{2 \times 1kHz}\right) - 1$$

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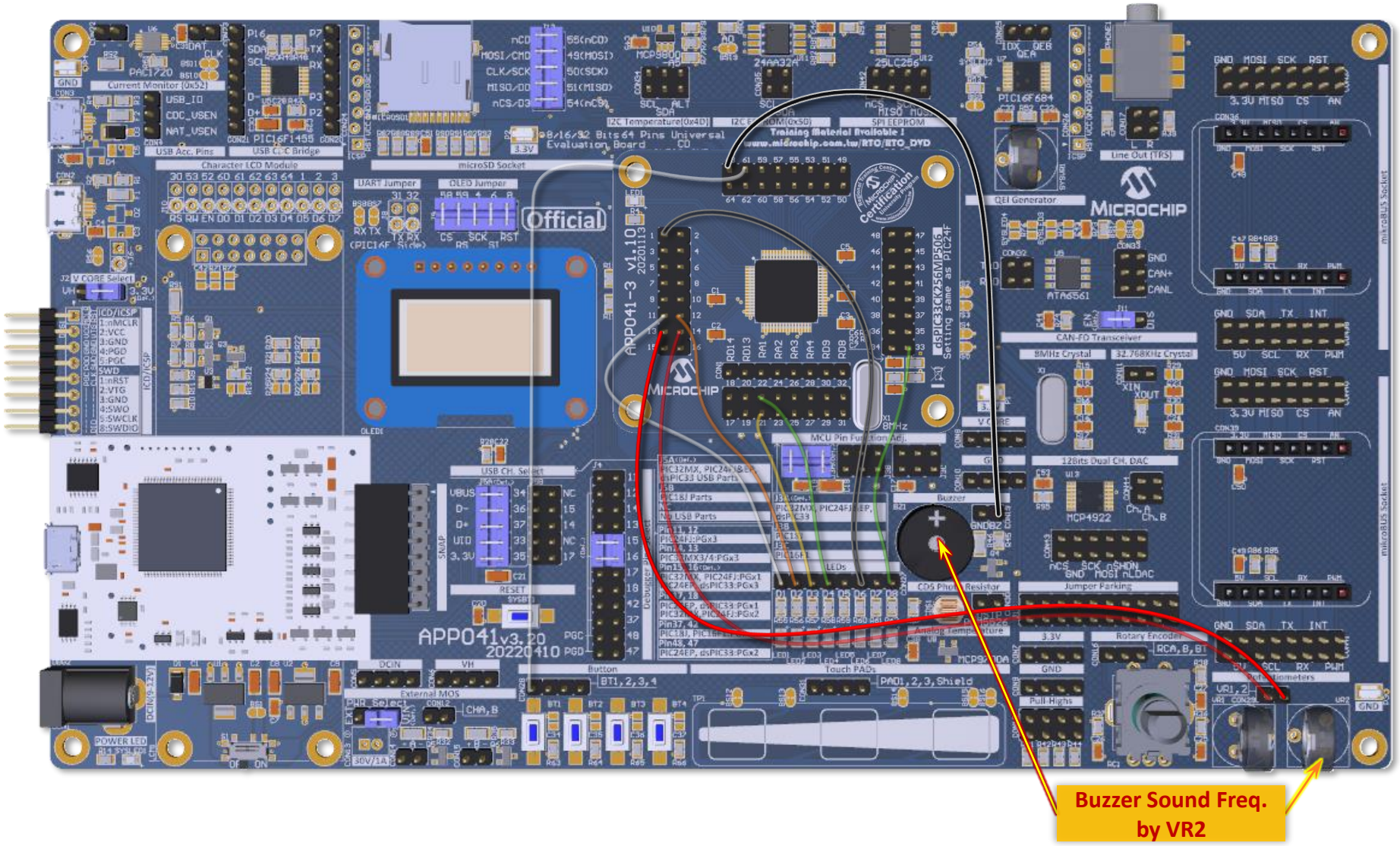
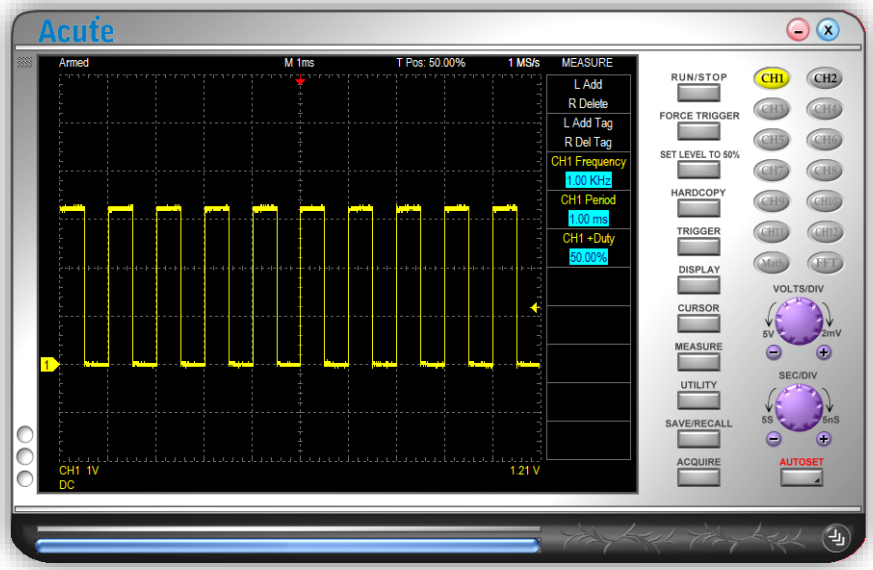
Lab13 PWM Buzzer Tone

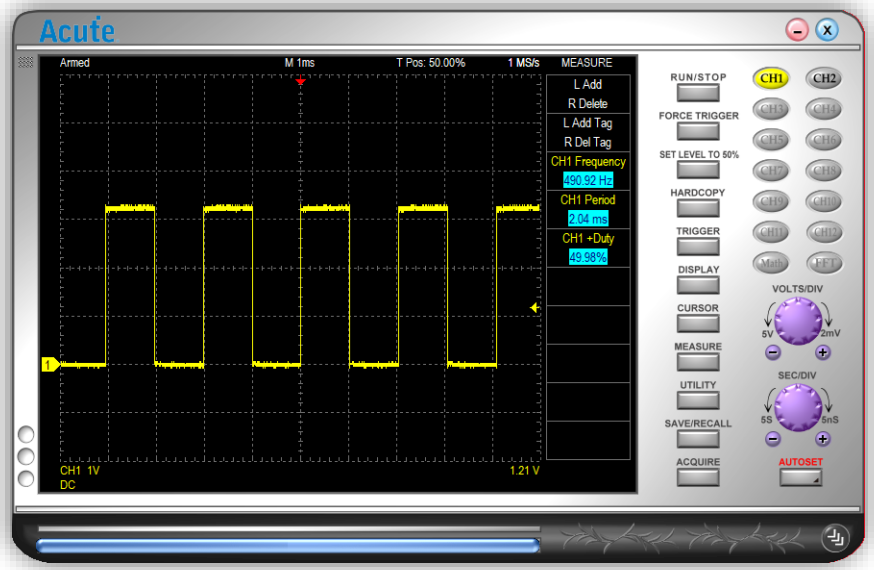
Result

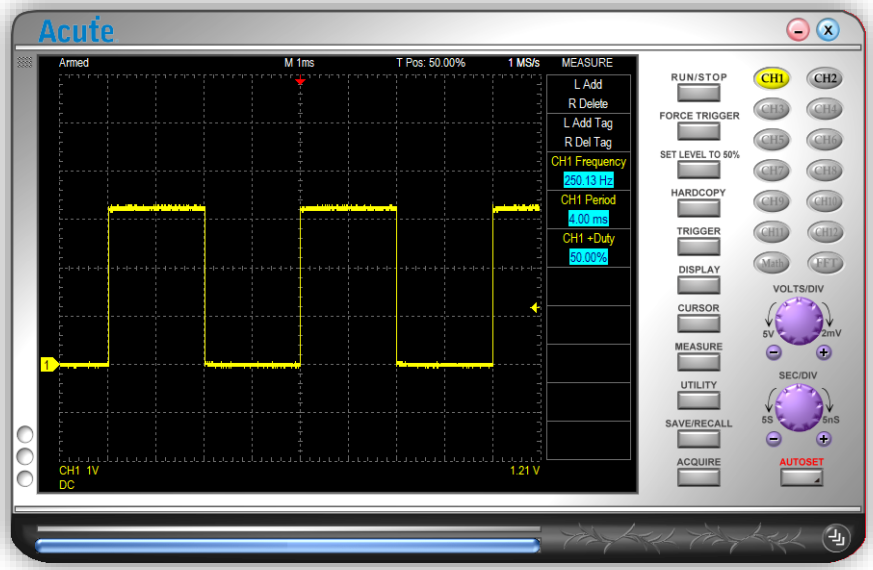


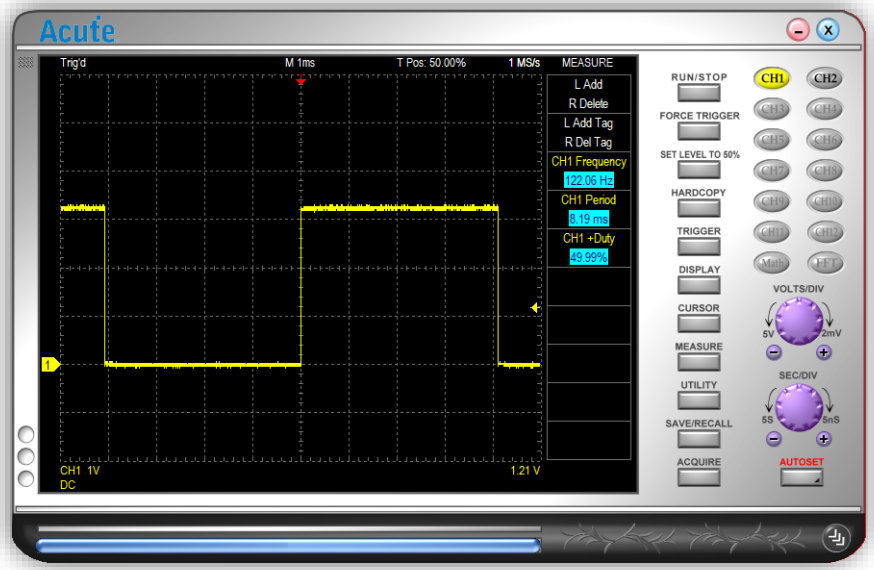
Lab13 PWM Buzzer Tone

Result







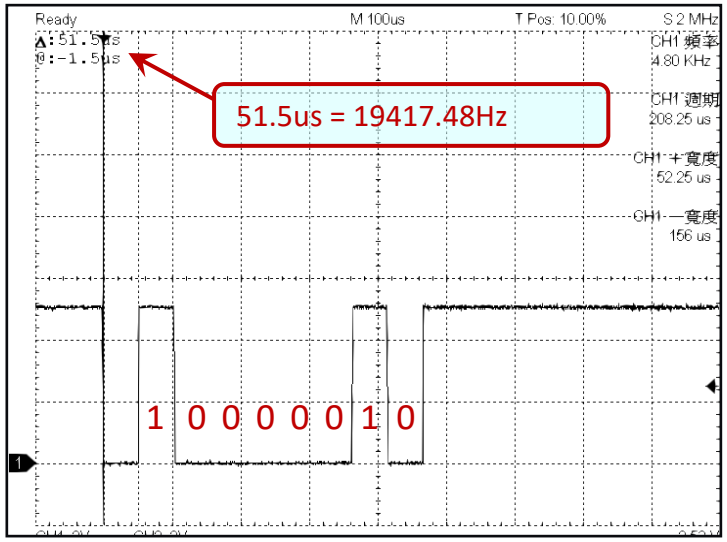


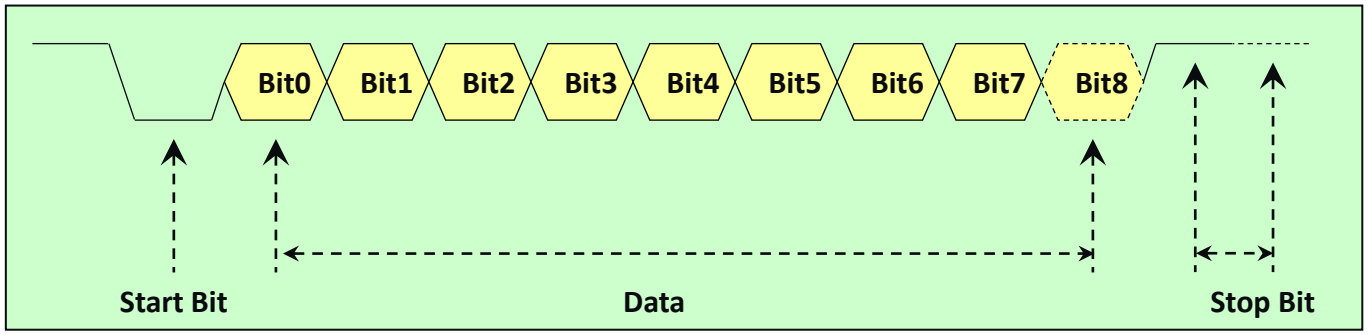
MICROCHIP

UART Application

What’s UART

- UART : Universal Asynchronous Receiver Transmitter.
- The module data exchange through serial communication.
- The data formatting includes 1 start bit, 5 ~ 9 data bits and 1 ~ 2 stop bits.

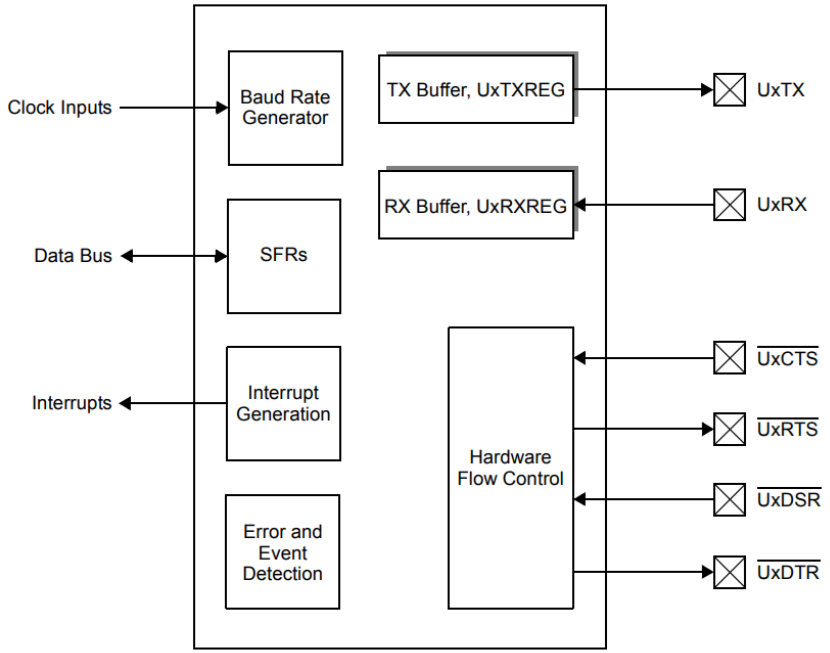




UART Transmit Example : 'A' (0x41), 19,200 bps

dsPIC33CK's UART

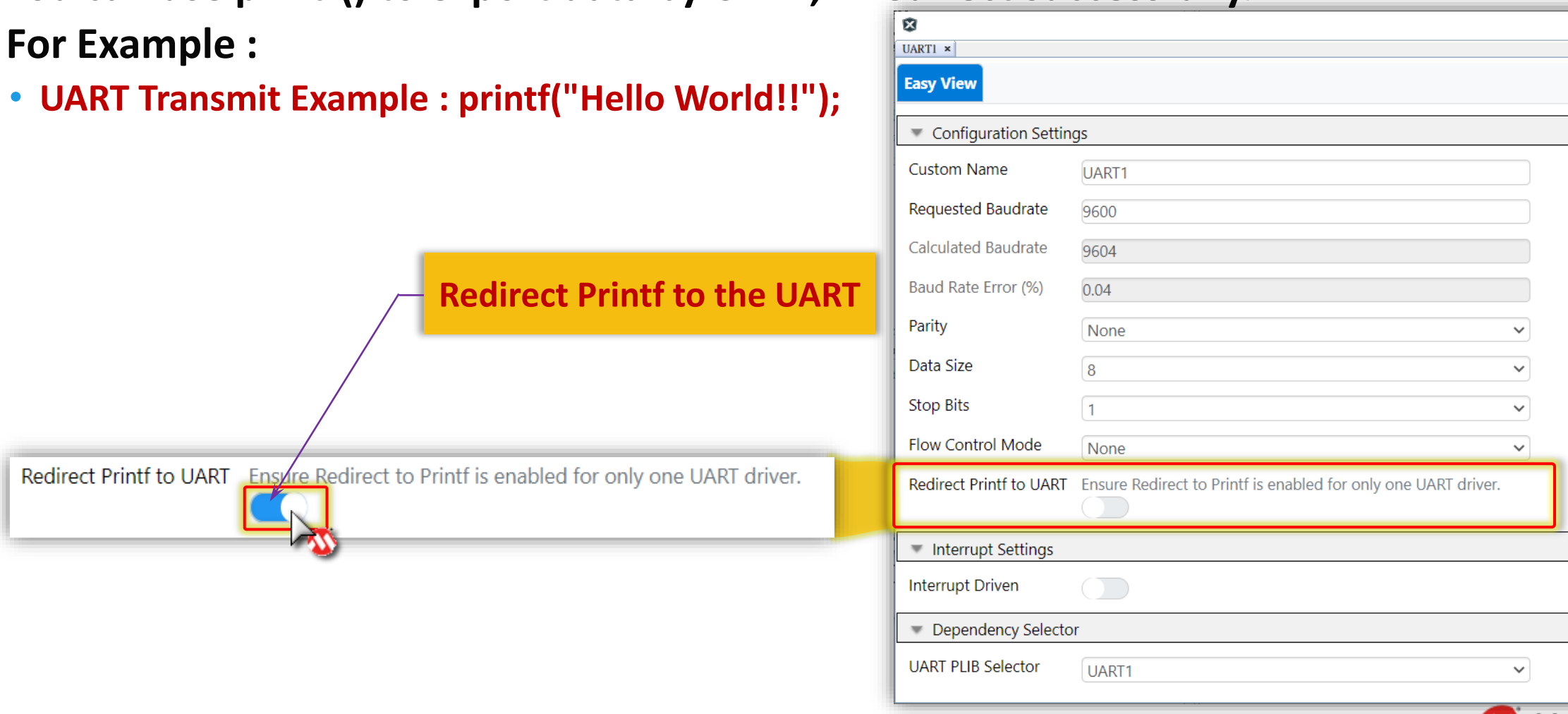
- UART module is full-duplex, asynchronous communication, Support RS-232, RS-485, IrDA and LIN.
- The module also supports hardware flow control, Parity check, Frame Error, Overflow 8 ~ 9 Data Bits.
- 8-Deep FIFO for TX & RX.
- Provide Loopback, Address Detect(RS-485), Auto Baud Detect(LIN bus).



MICROCHIP

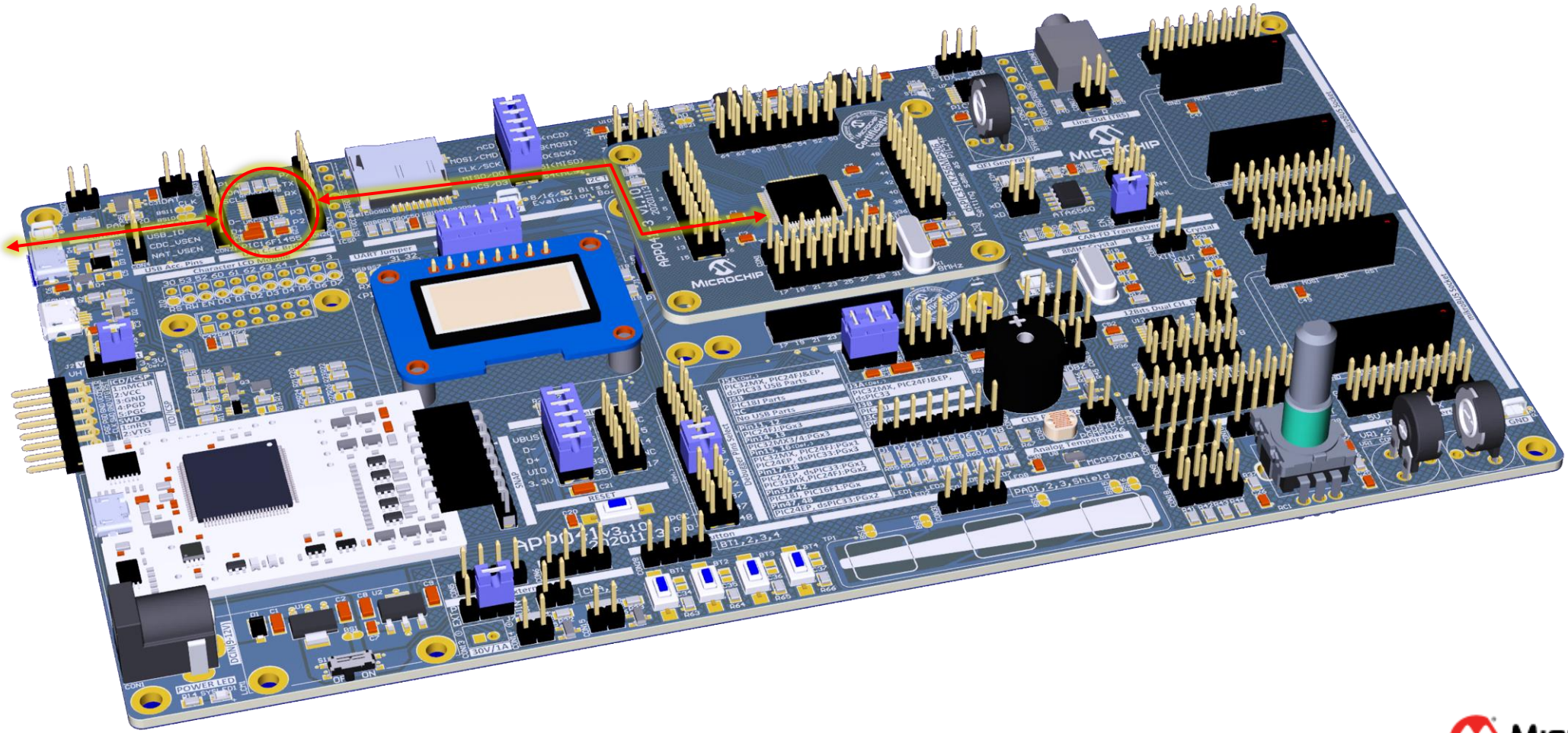
STDOUT Redirect

- MCC provide STDOUT redirect function, It can redirect STDOUT to UART.
- You can use printf() to export data by UART, if redirect successfully.
- For Example :
  - UART Transmit Example : printf("Hello World!!");



USB CDC Emulator

- **The PIC16F1455 already preload USB Serial Emulator firmware (USB Virtual COM Port).**



Lab Preparation

PC Terminal Software Setting

Lab Preparation

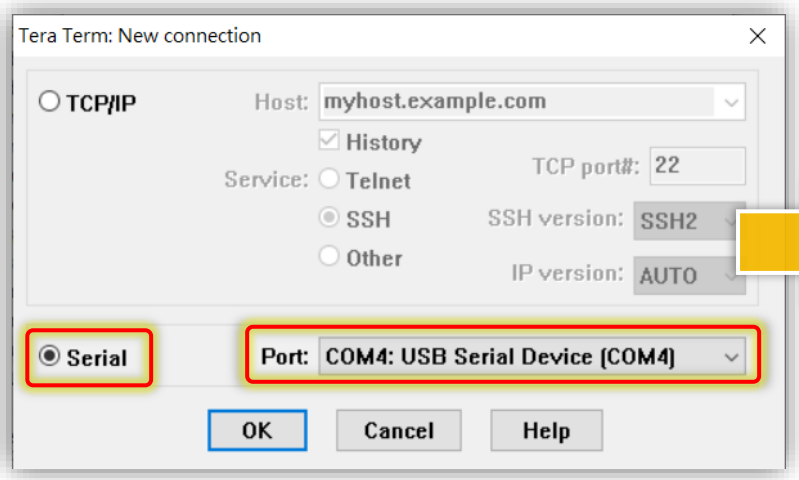
Step 1

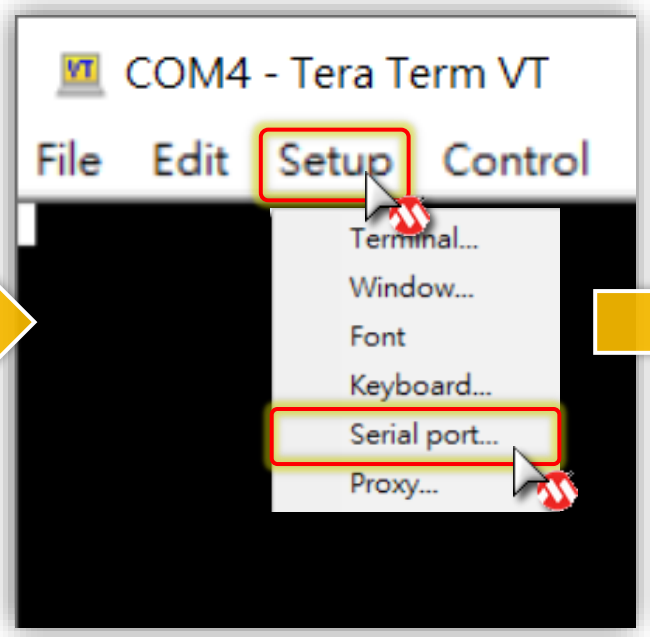
- Please confirm Windows Device Manager on your PC.
- For Window 7, you might need install driver before Labs.
  - Driver at : \Appendix\Serial Emulator Driver\mchpcdc.inf.
- You will see a USB Serial Port (COMx) at Device Manager.

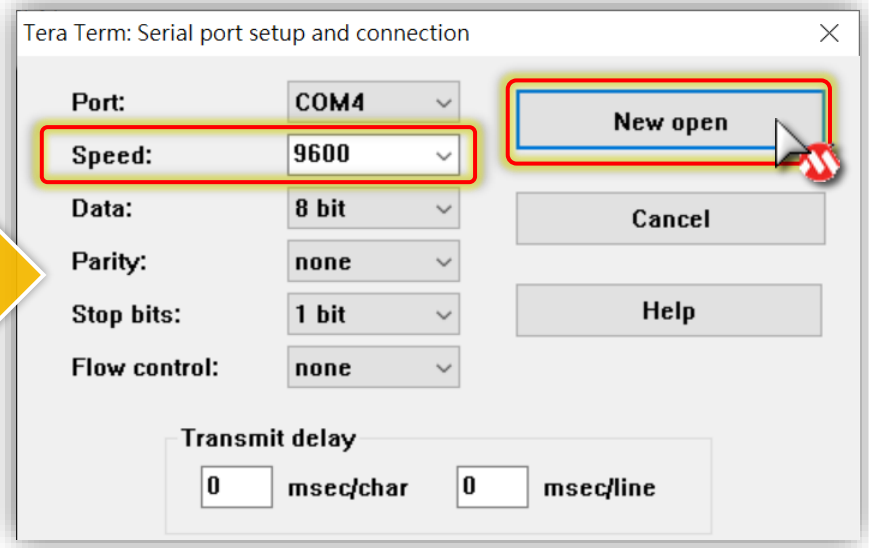
Lab Preparation

Step 2

- Find TeraTerm from your desktop or install it from.
  - http://ttssh2.sourceforge.jp/index.html.en
- Select: Serial → Port: COMx (USB Serial Port).
- Check: Setup → Serial Port → COMx, 9600, 8 bit, none, 1 bit, none.

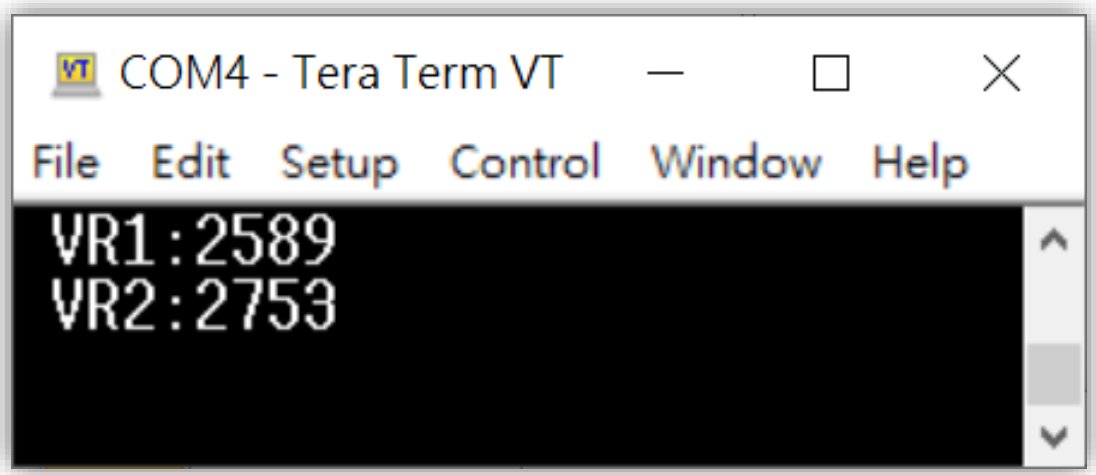






VT100 Console Control

- **Use VT100 command to control Tera Term UART output as**




```
printf("\033[2J");      // Clear screen
printf("\033[?25l");    // Hide cursor
printf("\033[y;xH");    // Set cursor to (x,y)
                        // Left-up corner is from (1,1)
```

Let's go!

Lab14 UART printf

- Base on current project or Open .\Exercises\Lab14_xxx.X to do exercise
- Try to add UART1 module then output "Boot Elapsed:xx" and VR1, VR2 ADC value to PC via UART1 module as we did on OLED display.
- UART1 set to 9600, N, 8, 1, No flow control.
- UART has connected by PCB layout.
  dsPIC33CK RC7 (UART1-U1TX, Pin32) <-> PIC16 RC5 (RX, Pin5)
  dsPIC33CK RD10 (UART1-U1RX, Pin31) <-> PIC16 RC4 (TX, Pin6)

Let’s go!

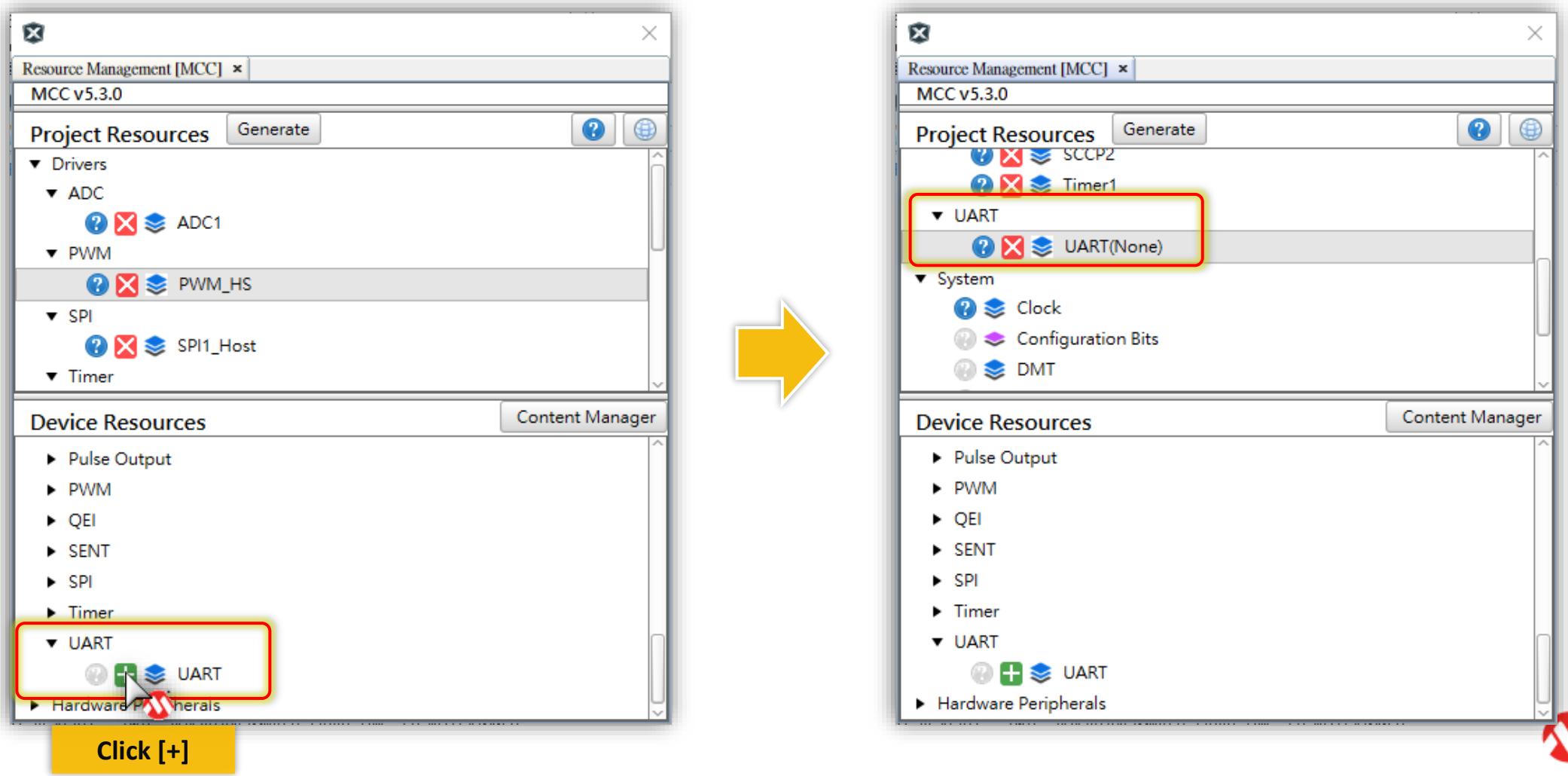
Lab14 UART printf

Connection

Lab14 UART printf

Step 1

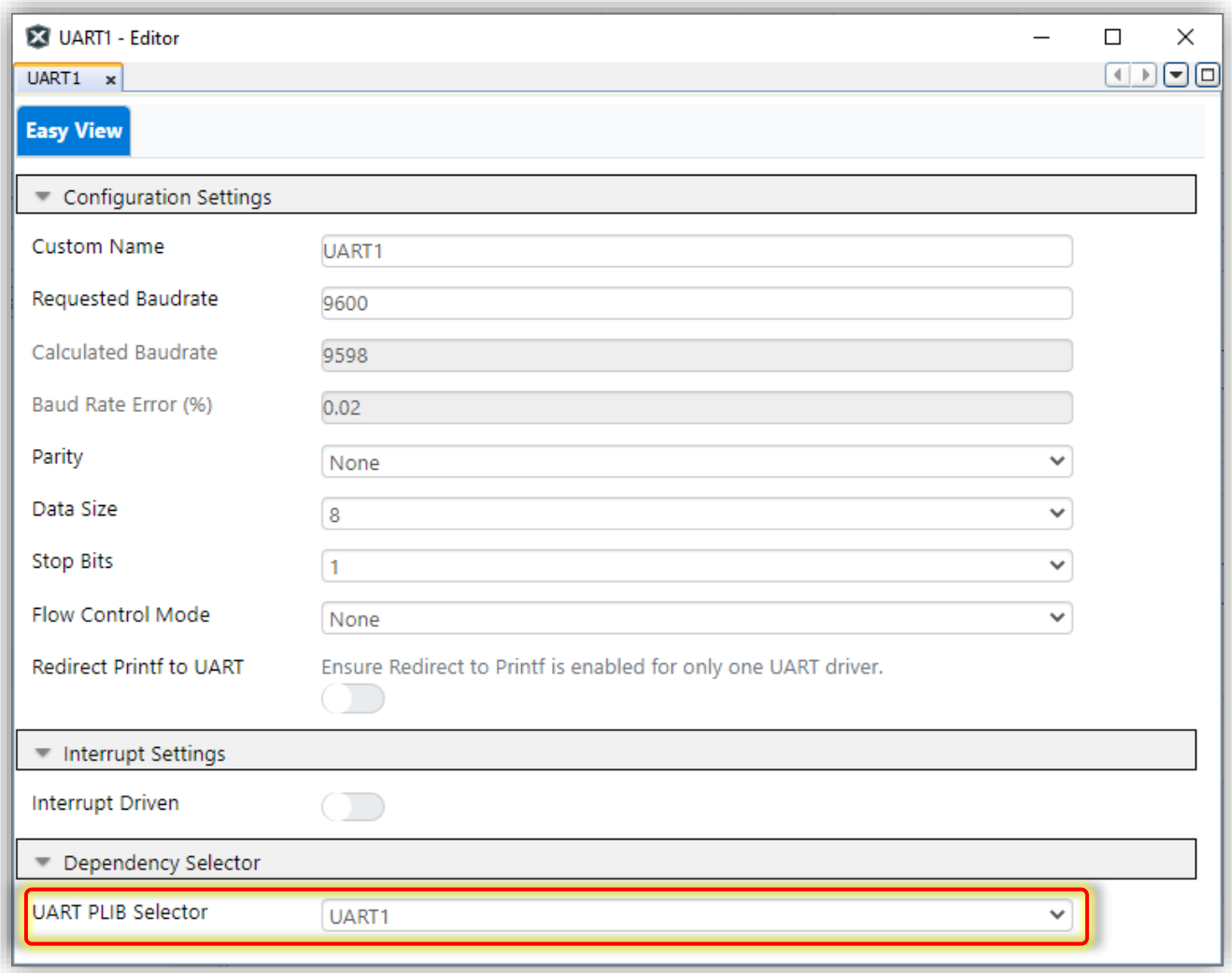
- Click [+] to add UART > UART Module.



Lab14 UART printf

Step 2

- Set UART PLIB Selector Module → UART1.

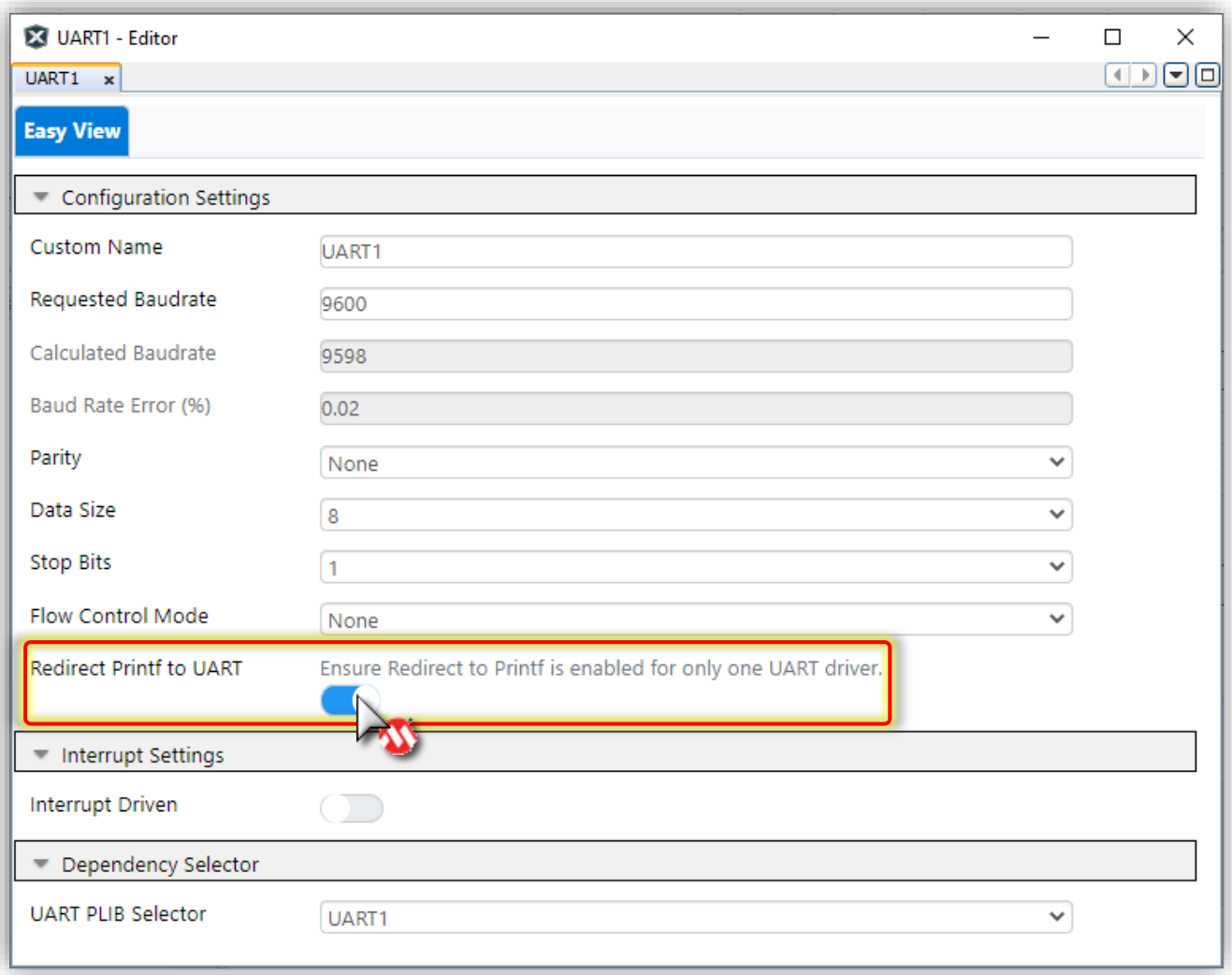


MICROCHIP

Lab14 UART printf

Step 3

- Set Enable Redirect Printf to UART.

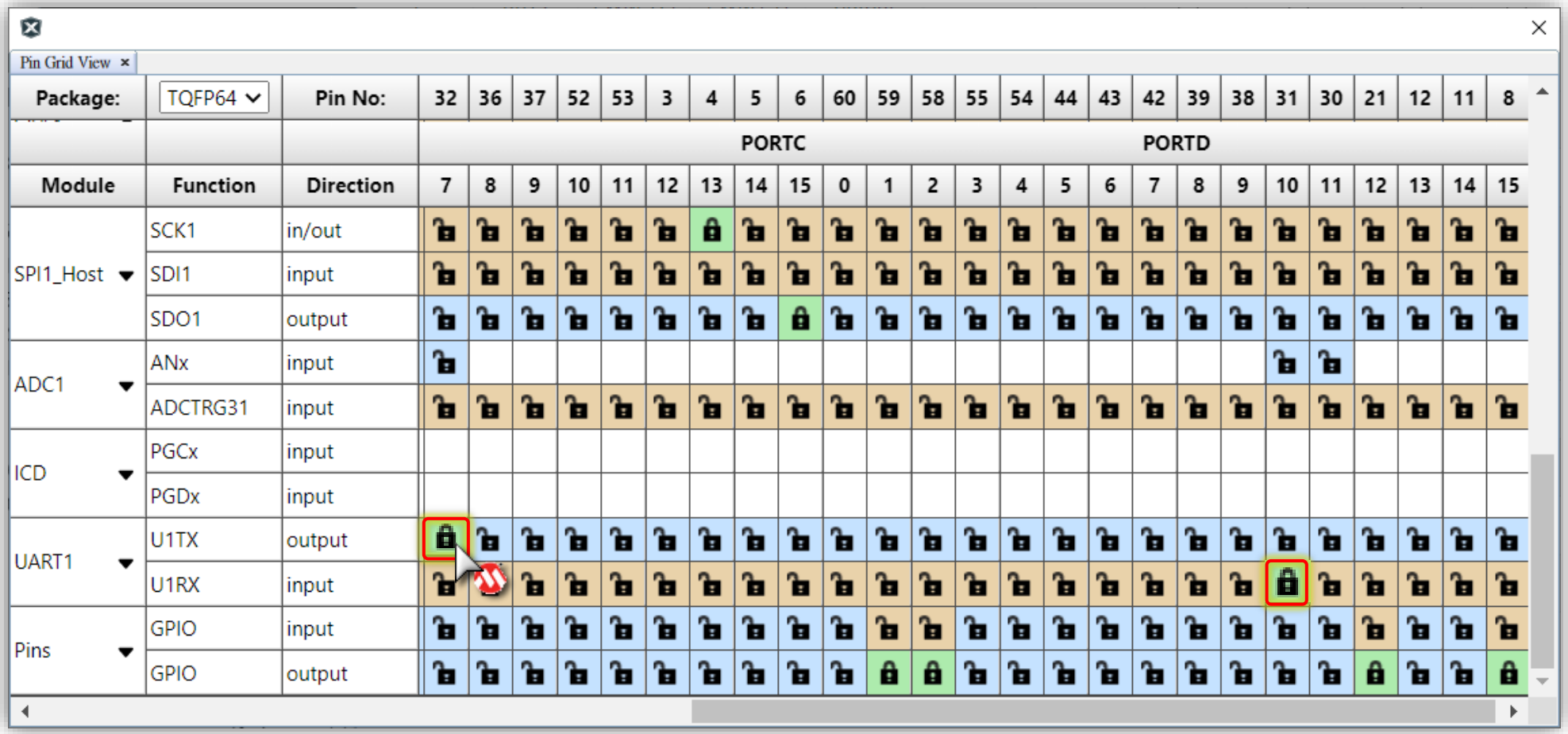


MICROCHIP

Lab14 UART printf

Step 4

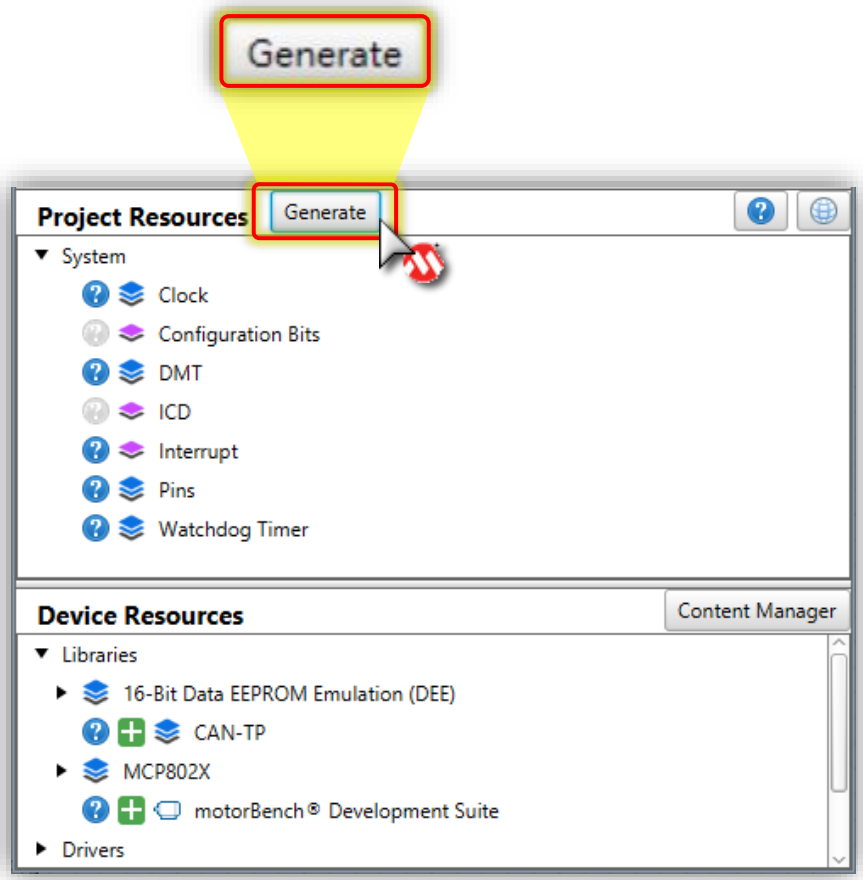
- Set PORTC: RC7 (U1TX) to UART TX Function.
- Set PORTD: RD10 (U1RX) to UART RX Function.

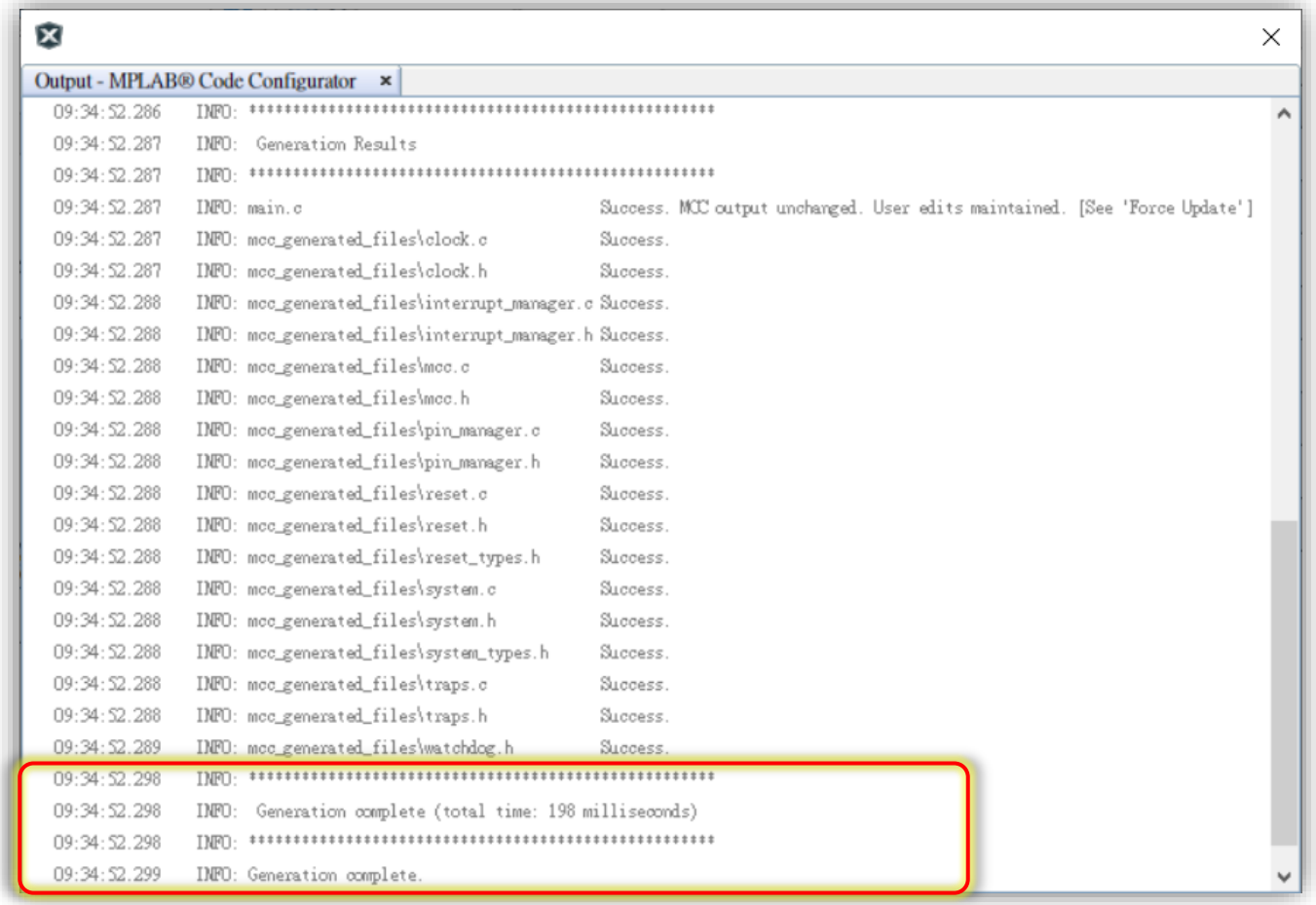


Lab14 UART printf

Step 5

- Click "Generate" Button to generate your code.





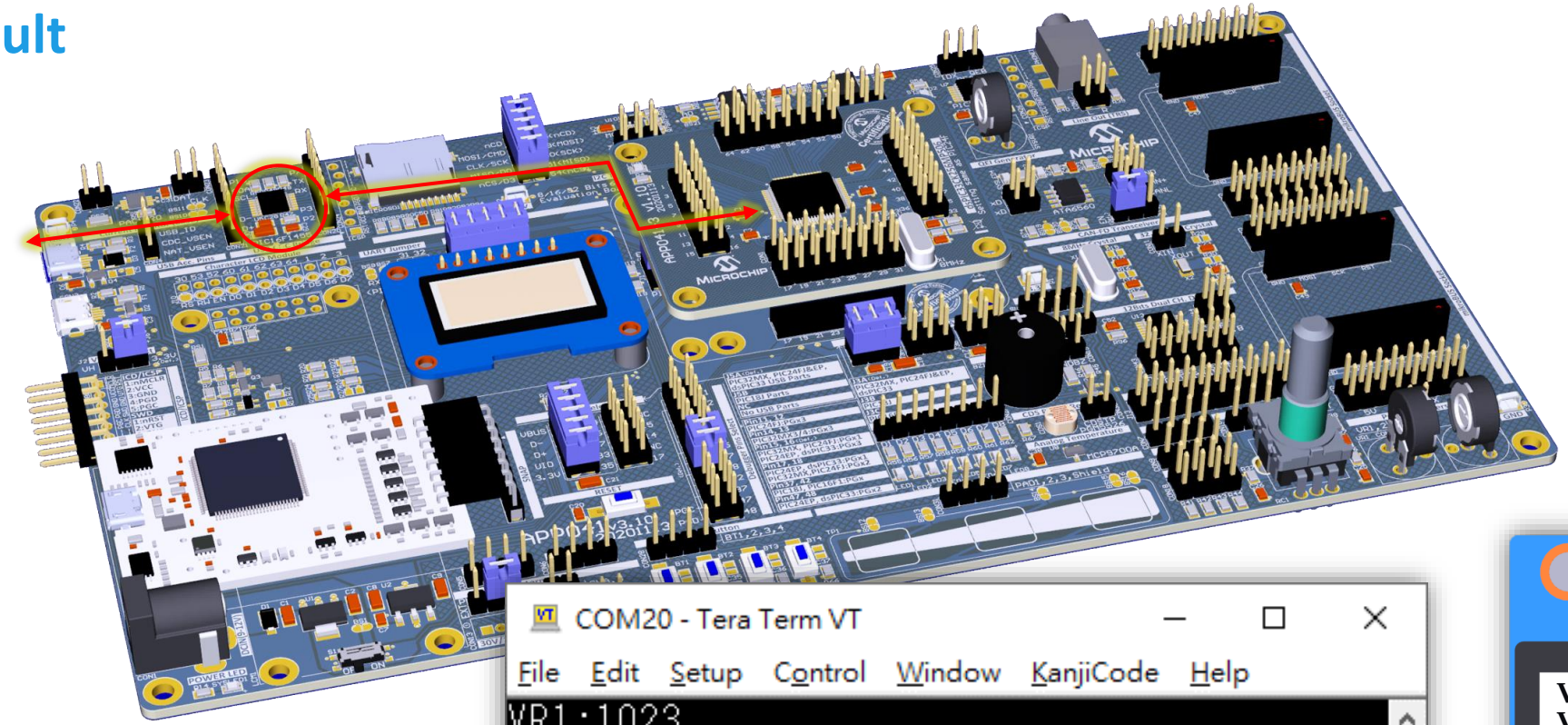
Lab14 UART printf

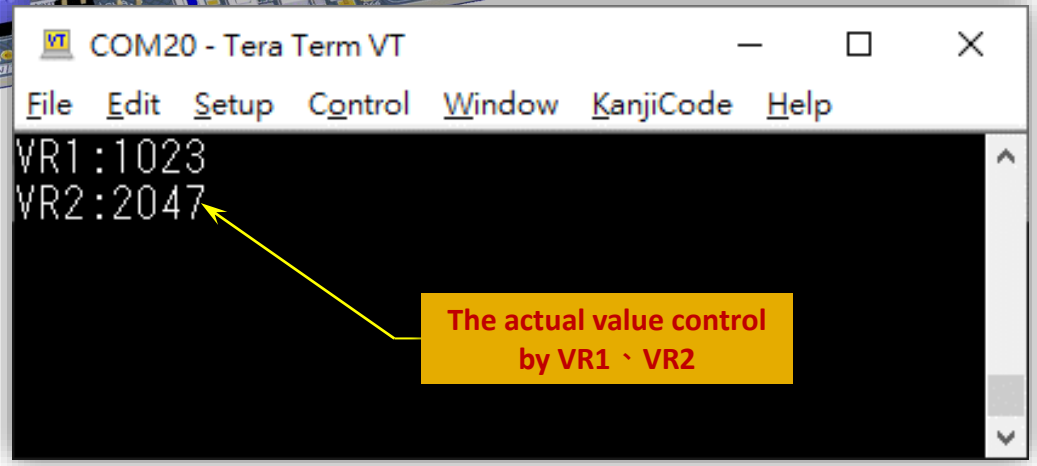
Code Example

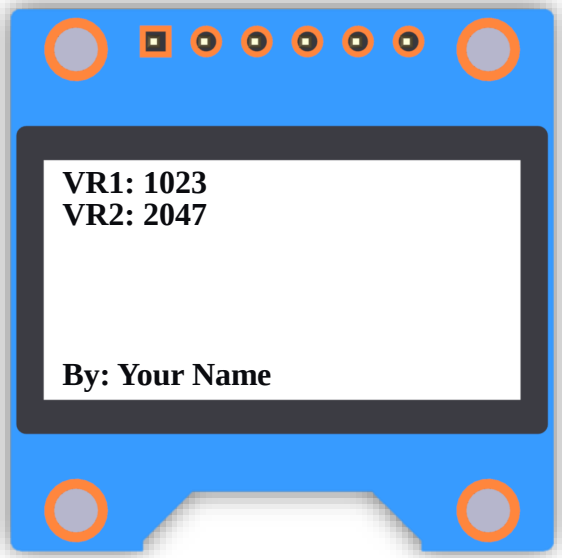
```
int main(void)
{
   …

   printf("\033[2J");
   printf("\033[?25l");

   while (1)
   {
      …
      if (VR1Flag)
      {
         VR1Flag = 0;
         sprintf((char *) StringBuffer, "VR1:%4d", ADC1Buffer[0]);
         myOLED_DrawStr(0, 0, StringBuffer);
         printf(" \033[1;1H%s\r\n", StringBuffer);
         …
      }

      if (VR2Flag)
      {
         VR2Flag = 0;
         sprintf((char *) StringBuffer, "VR2:%4d", ADC1Buffer[1]);
         myOLED_DrawStr(0, 1, StringBuffer);
         printf(" \033[2;1H%s\r\n", StringBuffer);
         …
      }

   }
}
```

Lab14 UART printf

Result







UART Interrupt

- Polling mode not easy to catch that the data from PC to UART.
- This is very easy if enable UART interrupt to be received it.
- Receive and transmit buffer(queue) are implemented ready, so ease to use and don’t worrying data lost.

UART Functions of Melody

- **Melody Provide below functions for UART:**

  Prototype definition : "uart*n*.h"

  - **UART_INTERFACE**
    - **(void)** *UARTn_Drv*.Initialize(void);
    - **(void)** *UARTn_Drv*.Deinitialize(void);
    - **(uint8_t)** *UARTn_Drv*.Read(void);
    - **(void)** *UARTn_Drv*.Write(uint8_t txData);
    - **(bool)** *UARTn_Drv*.IsRxReady(void);
    - **(bool)** *UARTn_Drv*.IsTxReady(void);
    - **(bool)** *UARTn_Drv*.IsTxDone(void);
    - **(void)** *UARTn_Drv*.TransmitEnable(void);
    - **(void)** *UARTn_Drv*.TransmitDisable(void);

Lab15 UART Communication

- Base on current project or Open .\Exercises\Lab15_xxx.X to do exercise
- Try to enable UART1 interrupt to be received UART data come from PC.
- To set a suitable received buffer size.
- Shows received character on OLED display and echo it to PC.

Let’s go!

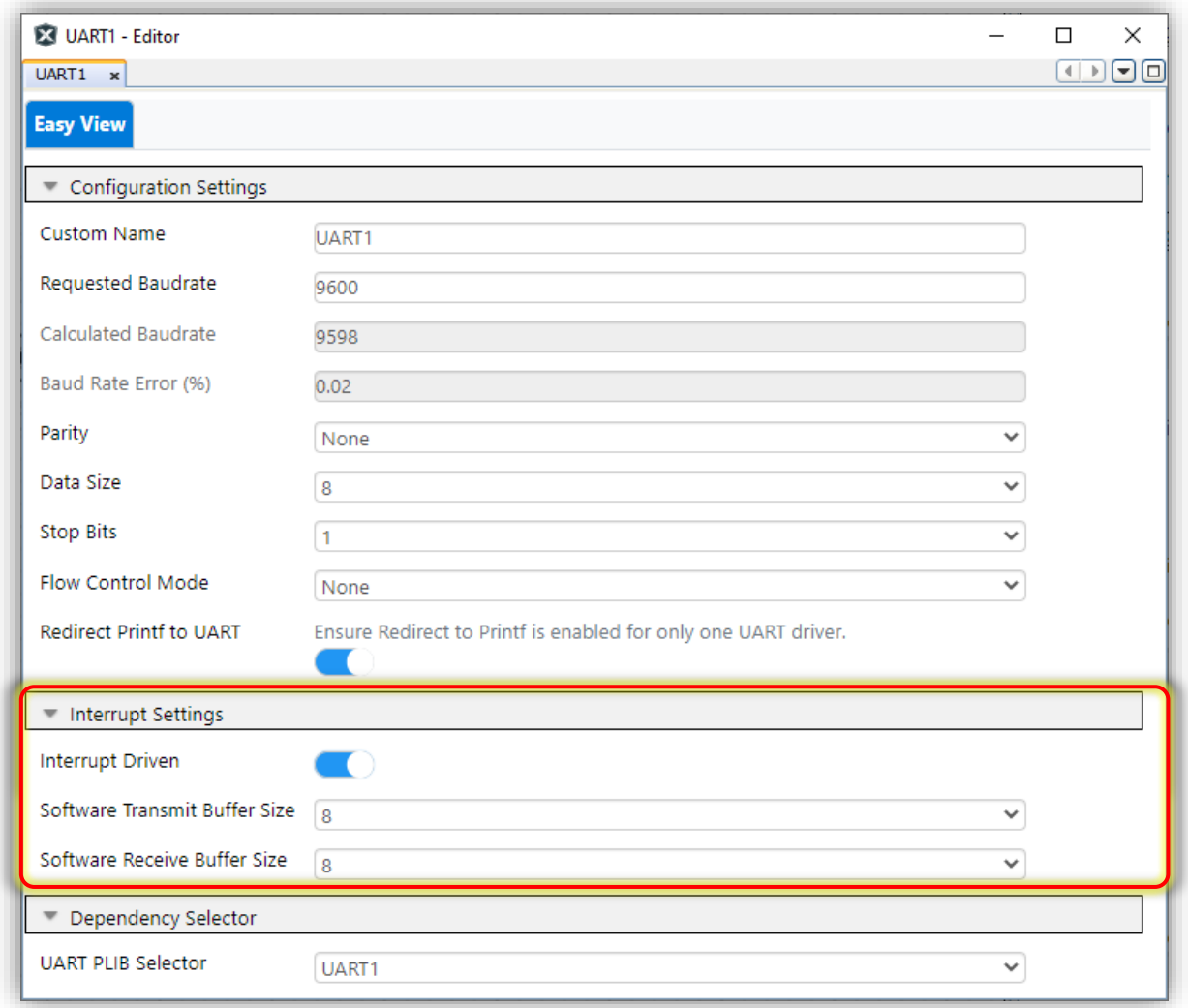
Lab15 UART Communication

Connection

Lab15 UART Communication

Step 1

- Set Enable UART Interrupt Driven.



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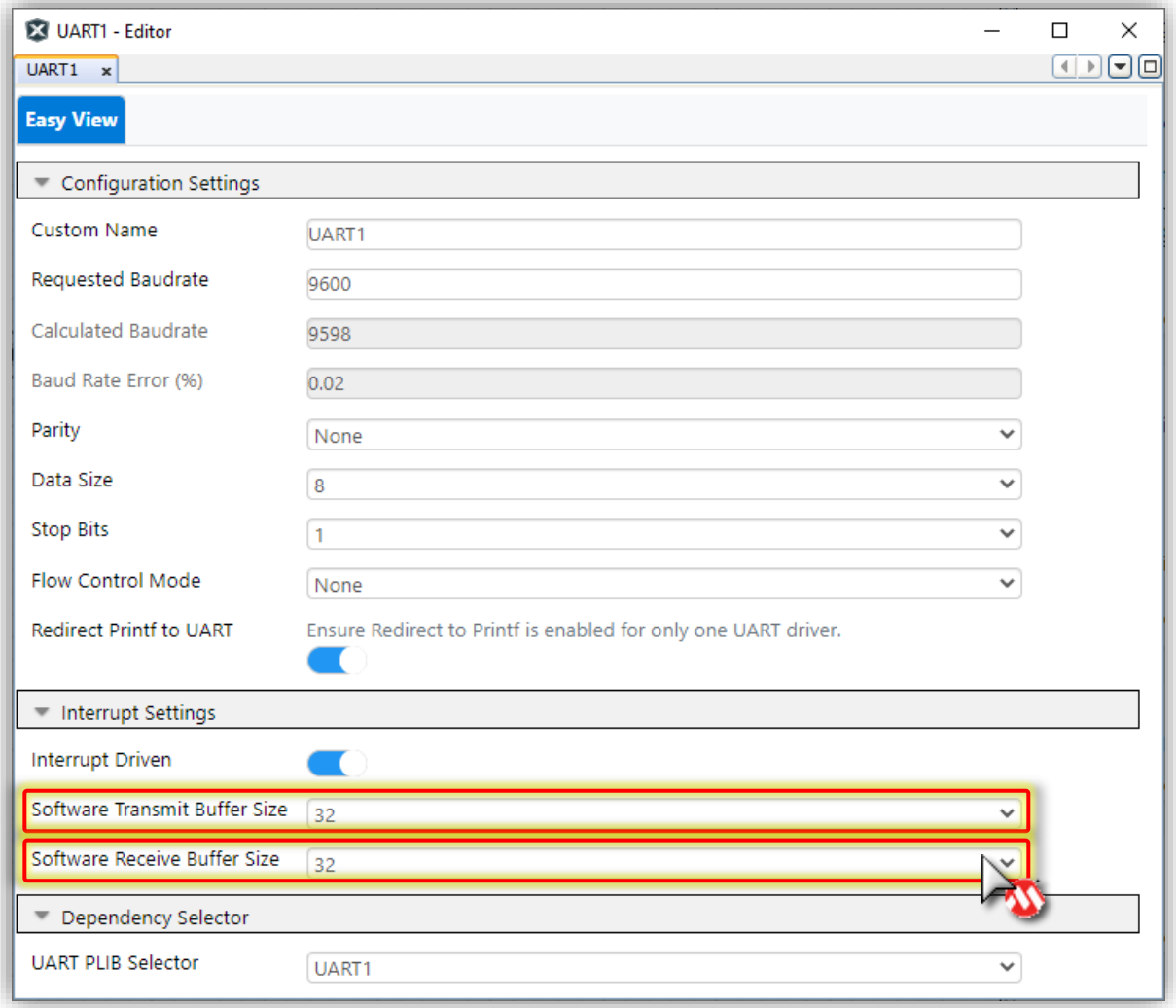
Lab15 UART Communication

Step 2

- Select Software Buffer Size (Transmit and Receive) to 32.

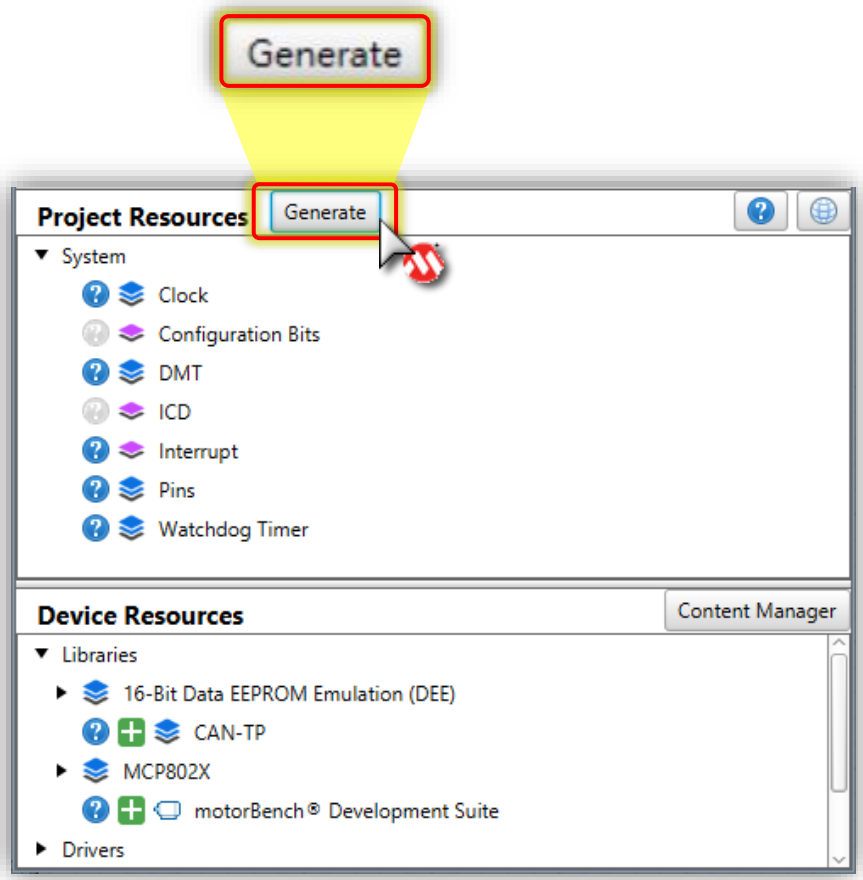


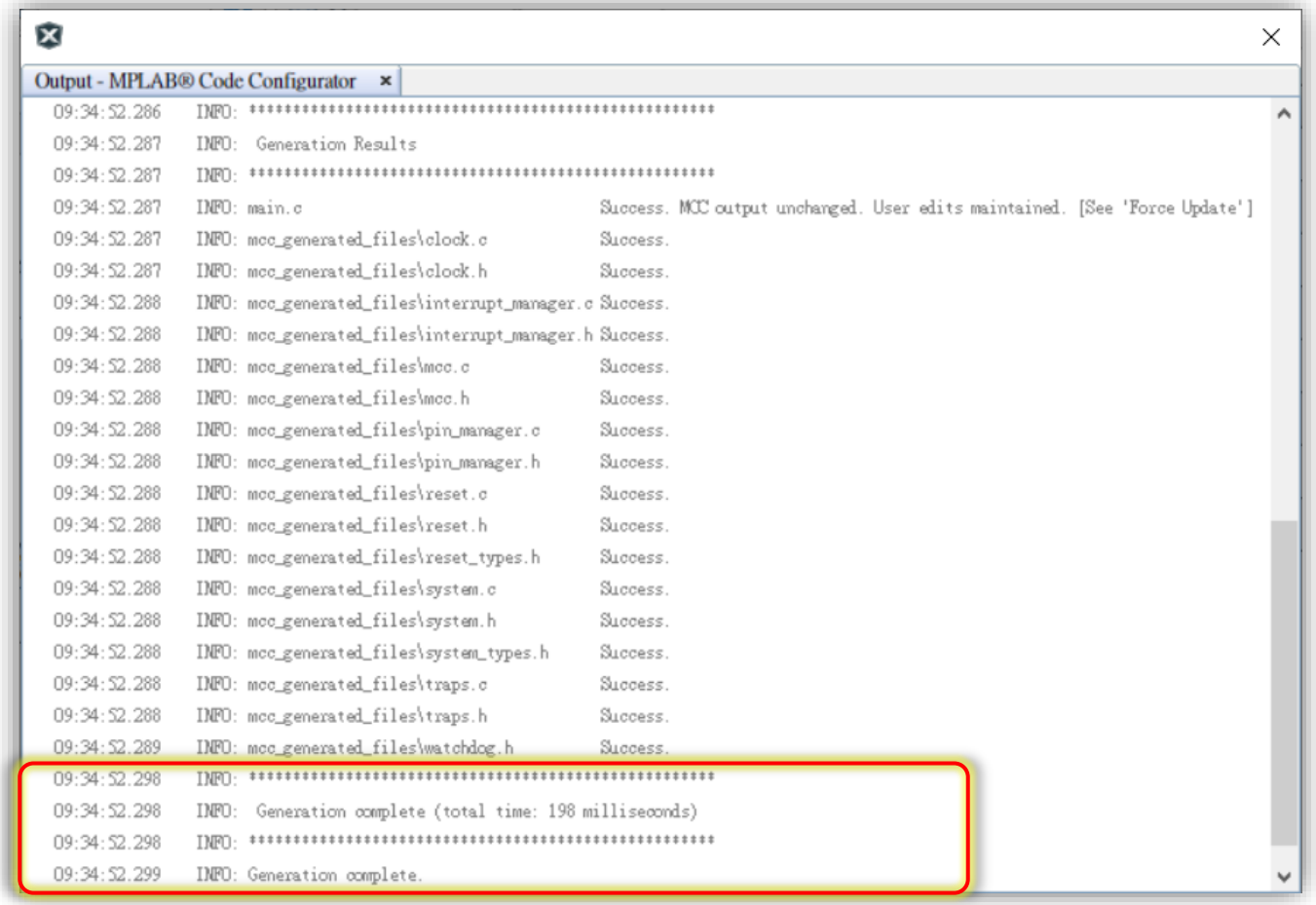
MICROCHIP

Lab15 UART Communication

Step 3

- Click "Generate" Button to generate your code.





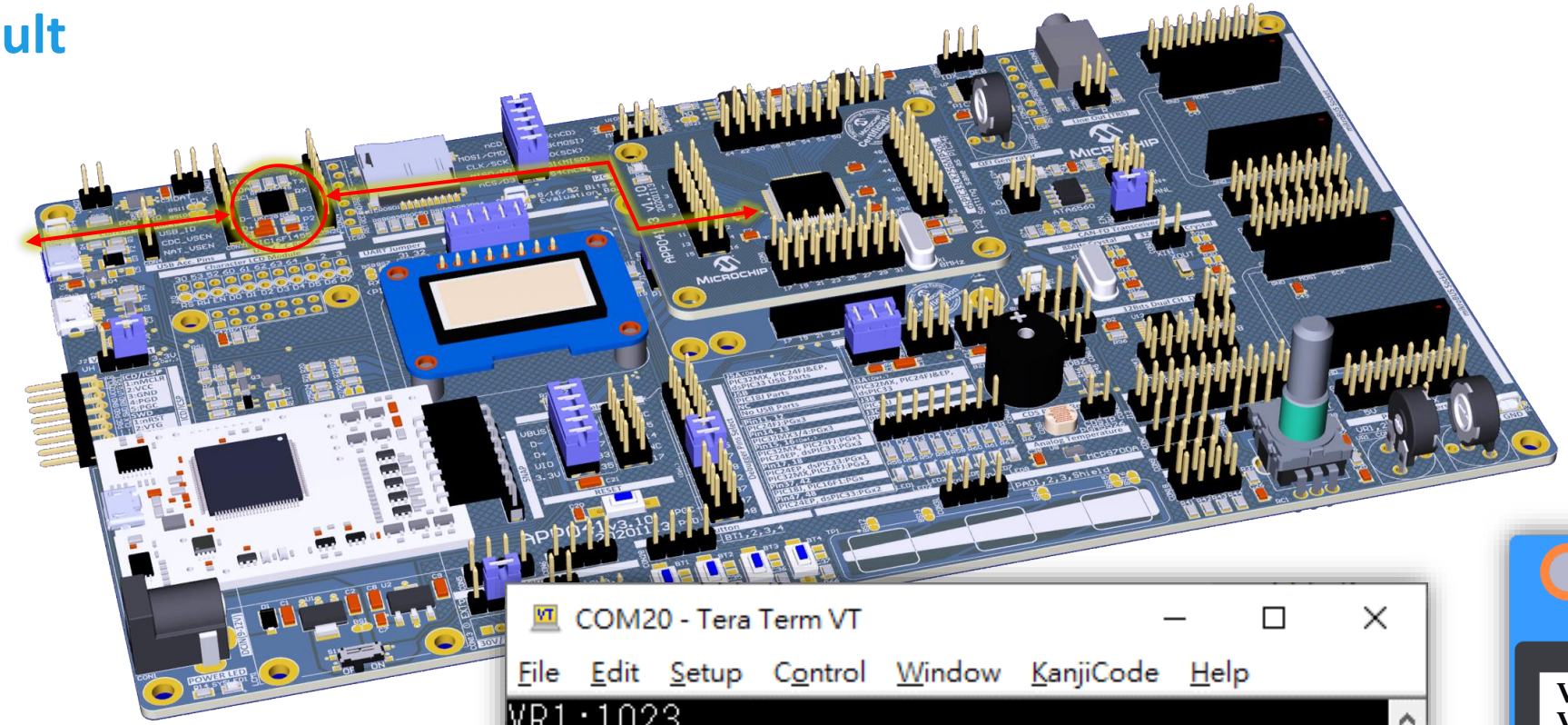
Lab15 UART Communication

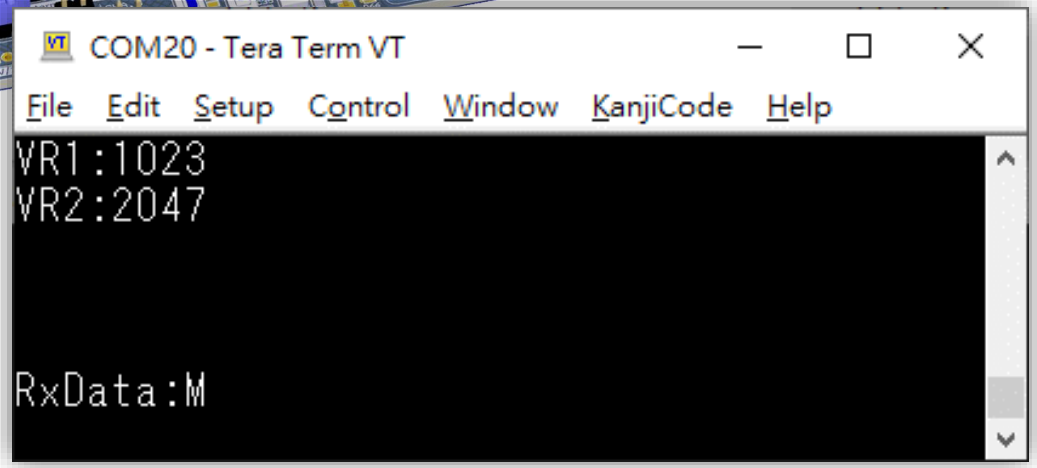
Code Example (Use UART Rx Callback)

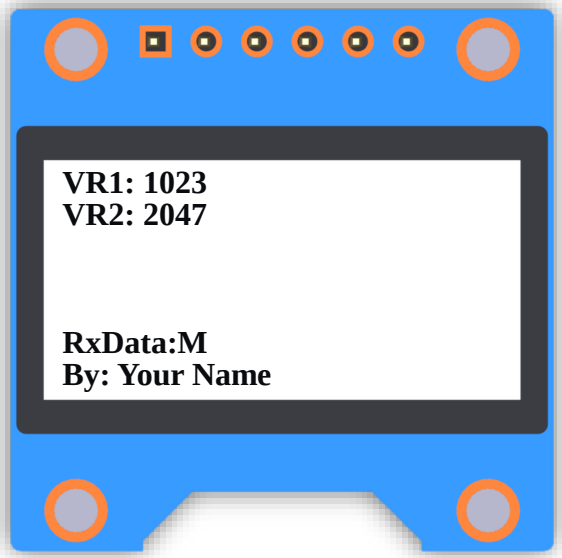
```
#include "mcc_generated_files/pwm_hs/pwm.h"
#include "mcc_generated_files/uart/uart1.h"
…
volatile uint8_t VR2Flag = 0;
volatile uint8_t UART1_Rx_Done = 0;

void ADC1_CallBack(enum ADC_CHANNEL channel, uint16_t adcVal) { … }

void UART1_Rx_CallBack(void)
{
   UART1_Rx_Done = 1;
}

int main(void)
{  …
   ADC1.adcMulticoreInterface->ChannelCallbackRegister(ADC1_CallBack);
   UART1_Drv.RxCompleteCallbackRegister(UART1_Rx_CallBack);
   …

   while (1)
   {
      …

      if (UART1_Rx_Done)
      {
         UART1_Rx_Done = 0;
         sprintf((char *) StringBuffer, "RxData:%1c", UART1_Drv.Read());
         myOLED_DrawStr(0, 6, StringBuffer);
         printf(" \033[6;1H%s\r\n", StringBuffer);
      }
    }
}
```

Lab15 UART Communication

Result





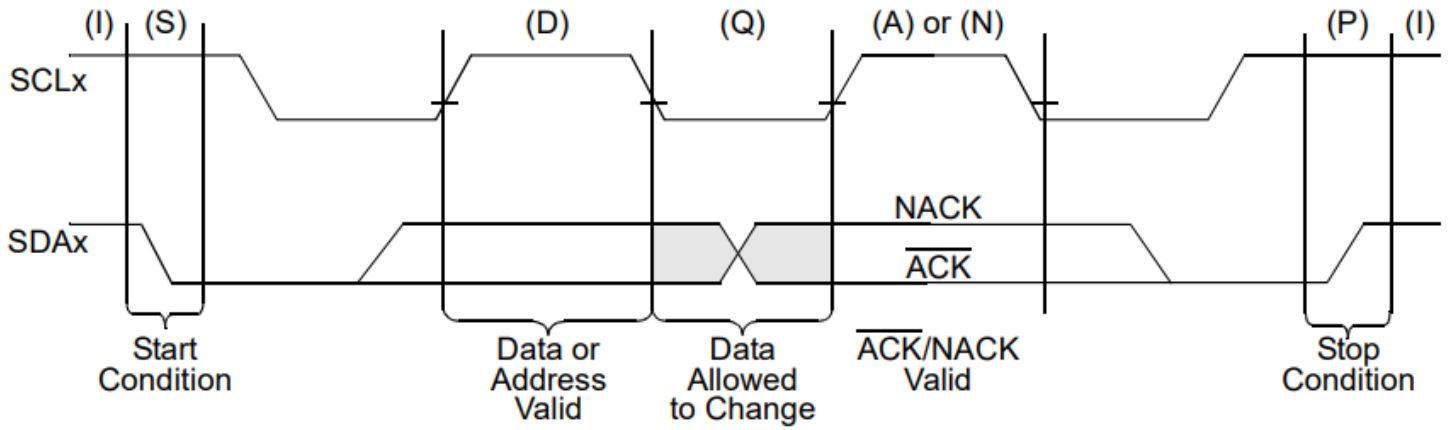


MICROCHIP

I2C Application

What's I2C

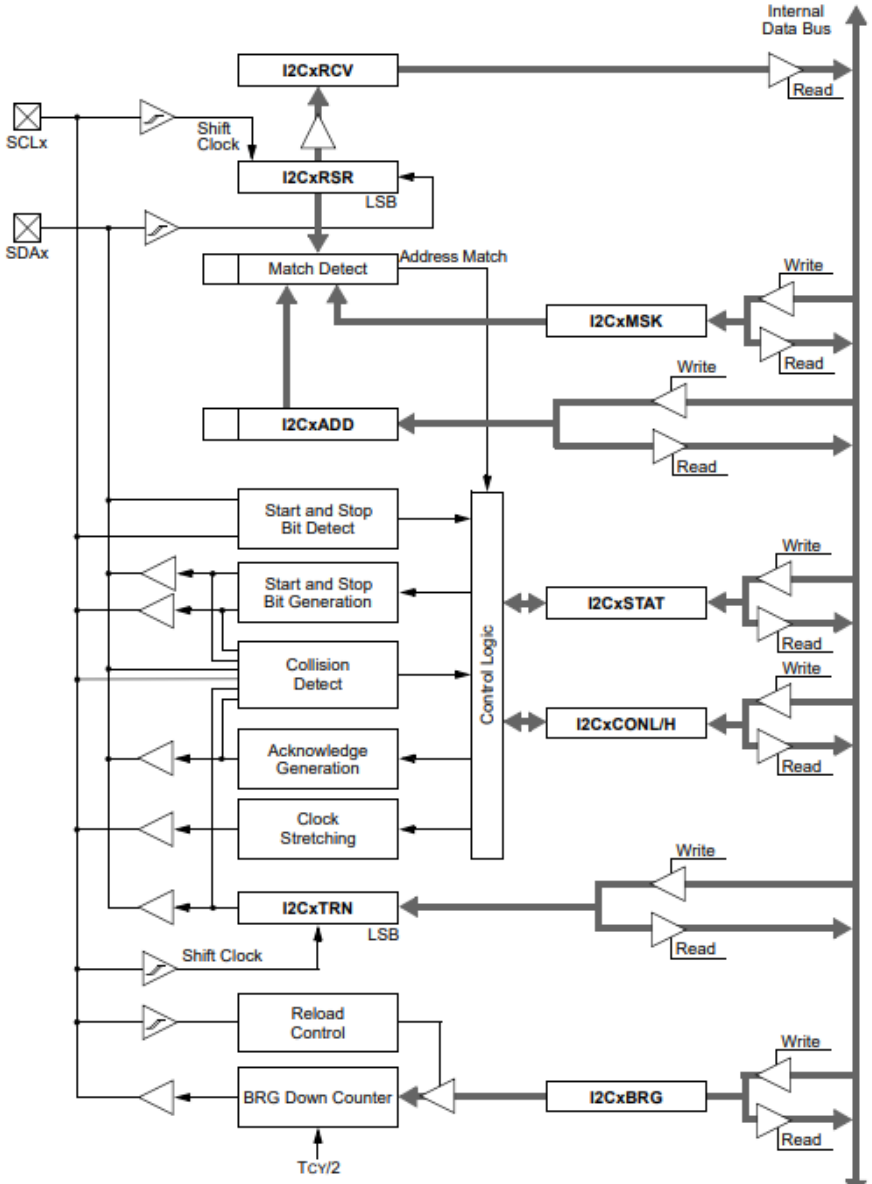
- I2C, Inter-Integrated Circuit
- It's a serial communication interface.
  Synchronous, inside-board level, short distance communication.
- The data is clocked along with a clock signal(SCL).
- The clock signal controls when data is changed and when it should be read.
- Since I2C is synchronous, the clock rate can vary, unlike asynchronous (RS-232 style) communications.



MICROCHIP

dsPIC33's I2C Module

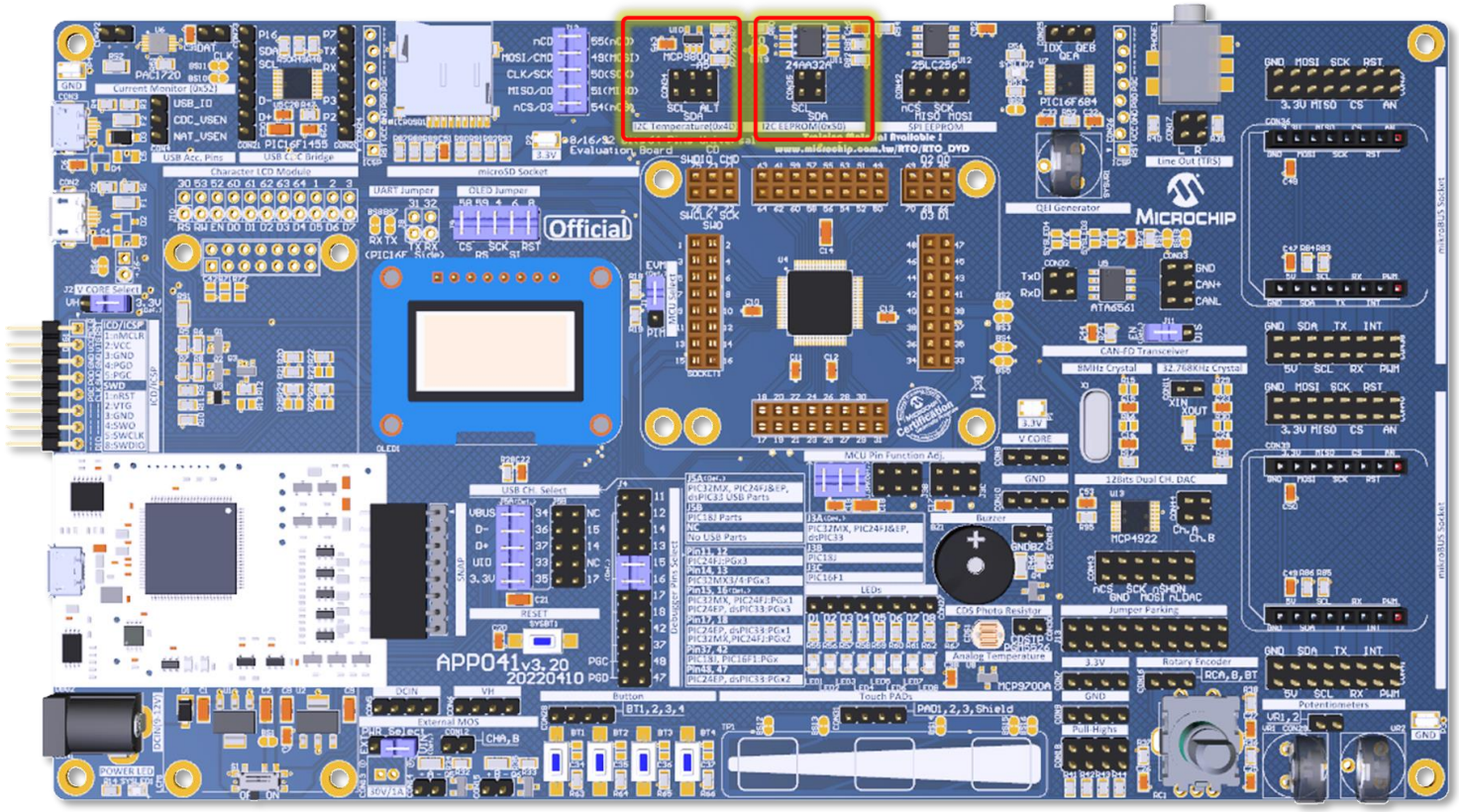
- **dsPIC33CK256MP506 Provide three I2C modules.**
- **Support 7, 10 Bits Device Addresses and General Call Address.**
- **Provide Clock Stretching.**
- **Both 100 kHz and 400 kHz Bus Specifications.**
- **SMBus Compatible Voltage Thresholds.**
- **Pin Definition :**
  - **SCL (Serial Clock)**：Clock, dsPIC33 <-> Device.
  - **SDA (Serial Data)** ：Data In/Out, dsPIC33 <-> Device.



MICROCHIP

I2C Devices

- **Temperature Sensor (MCP9800)：**
  - MCP9800 is a digital temperature sensor converted to digital word with a user selectable 9 to 12-bit Sigma-Delta Analog to Digital Converter. ±0.5°C (typical) at +25°C
- **EEPROM (24AA32A)：**
  - 24AA32A is a 32Kb I2C EEPROM has a Page Write capability for up to 32 bytes of data.



MICROCHIP

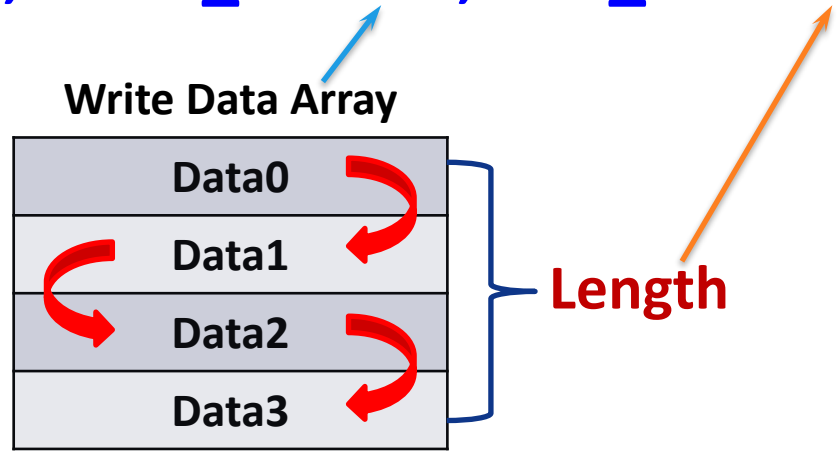
I2C Functions of Melody

- **Melody Provide below functions for I2C:**
  Prototype definition : "i2c*n*.h"
  - **UART_INTERFACE**
    - (void) *I2Cn_Drv*.Initialize(void);
    - (void) *I2Cn_Drv*.Deinitialize(void);
    - (bool) *I2Cn_Drv*.IsBusy(void);
    - (bool) *I2Cn_Drv*.Write(uint16_t address, uint8_t *data, size_t dataLength);
    - (bool) *I2Cn_Drv*.Read(uint16_t address, uint8_t *data, size_t dataLength);
    - (bool) *I2Cn_Drv*.WriteRead(uint16_t address, uint8_t *writeData, size_t writeLength, uint8_t *readData, size_t readLength);
    - (void) *I2Cn_Drv*.HostCallbackRegister(void (*callback)(void));
    - (bool) *I2Cn_Drv*.TransferSetup(struct I2C_TRANSFER_SETUP *setup, uint32_t srcClkFreq);
    - (enum I2C_HOST_ERROR) *I2Cn_Drv*.ErrorGet(void)

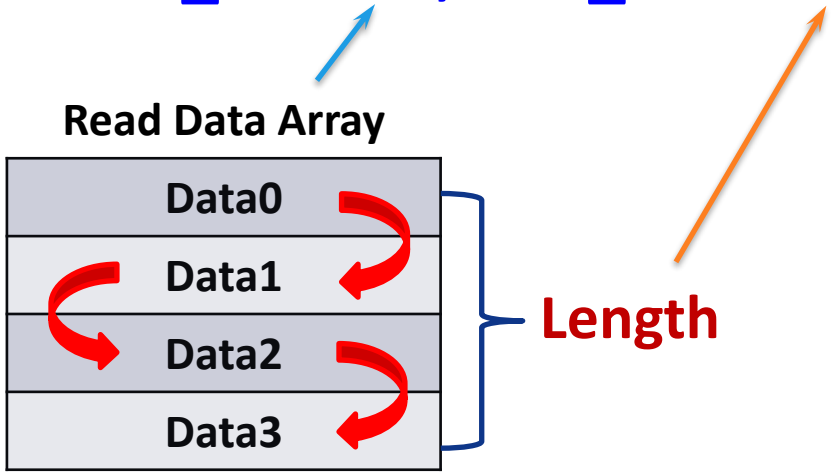
- **I2C Function is non-block function. This means all function running by interrupt. Operation not execute immediate after function call.**

I2C Functions Introduction

- bool I2Cn_Drv.Write(uint16_t address, uint8_t *data, size_t dataLength);

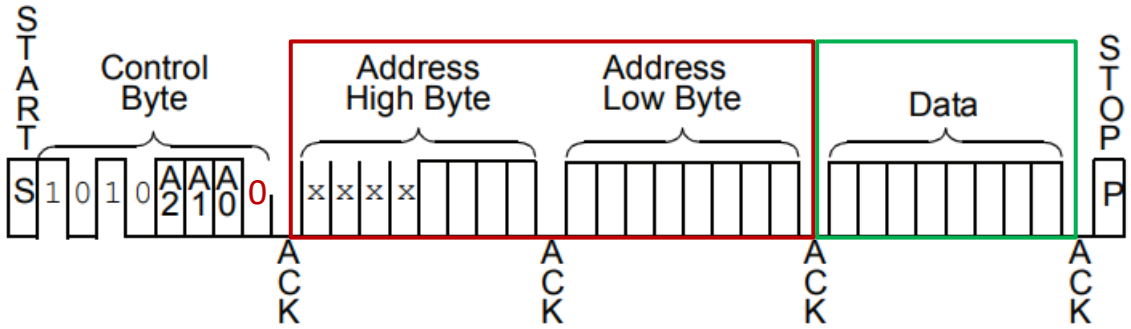


- bool I2Cn_Drv.Read(uint16_t address, uint8_t *data, size_t dataLength);

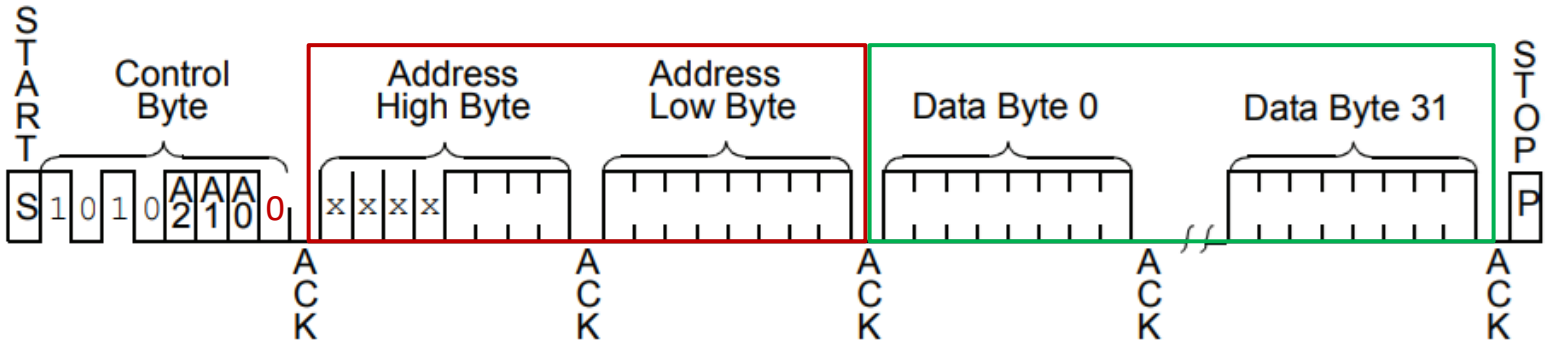


EEPROM Write (24AA32A)

- **BYTE WRITE:** I2Cn_Drv.Write(); //Data Array Length = 2+1



- **PAGE WRIYE:** I2Cn_Drv.Write(); //Data Array Length = 2+n

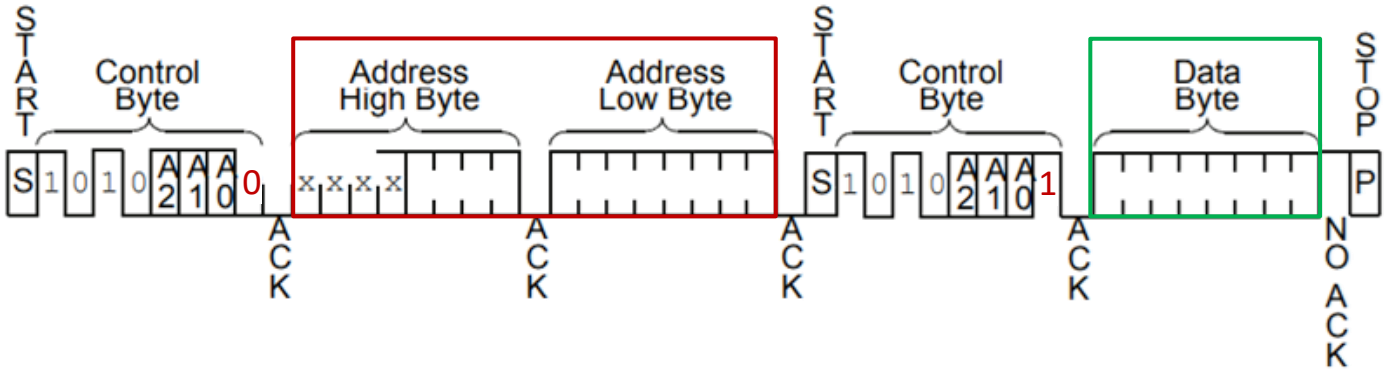


- **At this section, we focus on PAGE WRITE.**

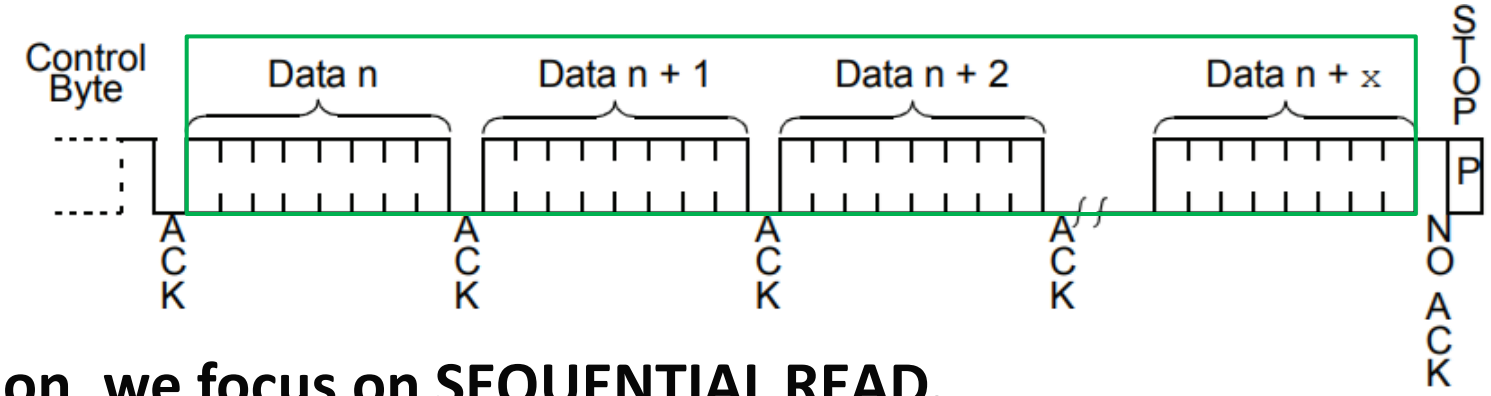
MICROCHIP

EEPROM Read (24AA32A)

- **RANDOM READ: I2Cn_Drv.Write() + I2Cn_Drv.Read(); //Data Array Length = 2+1**



- **SEQUENTIAL READ: I2Cn_Drv.Write() + I2Cn_Drv.Read(); //Data Array Length = 2+n**



- **At this section, we focus on SEQUENTIAL READ.**

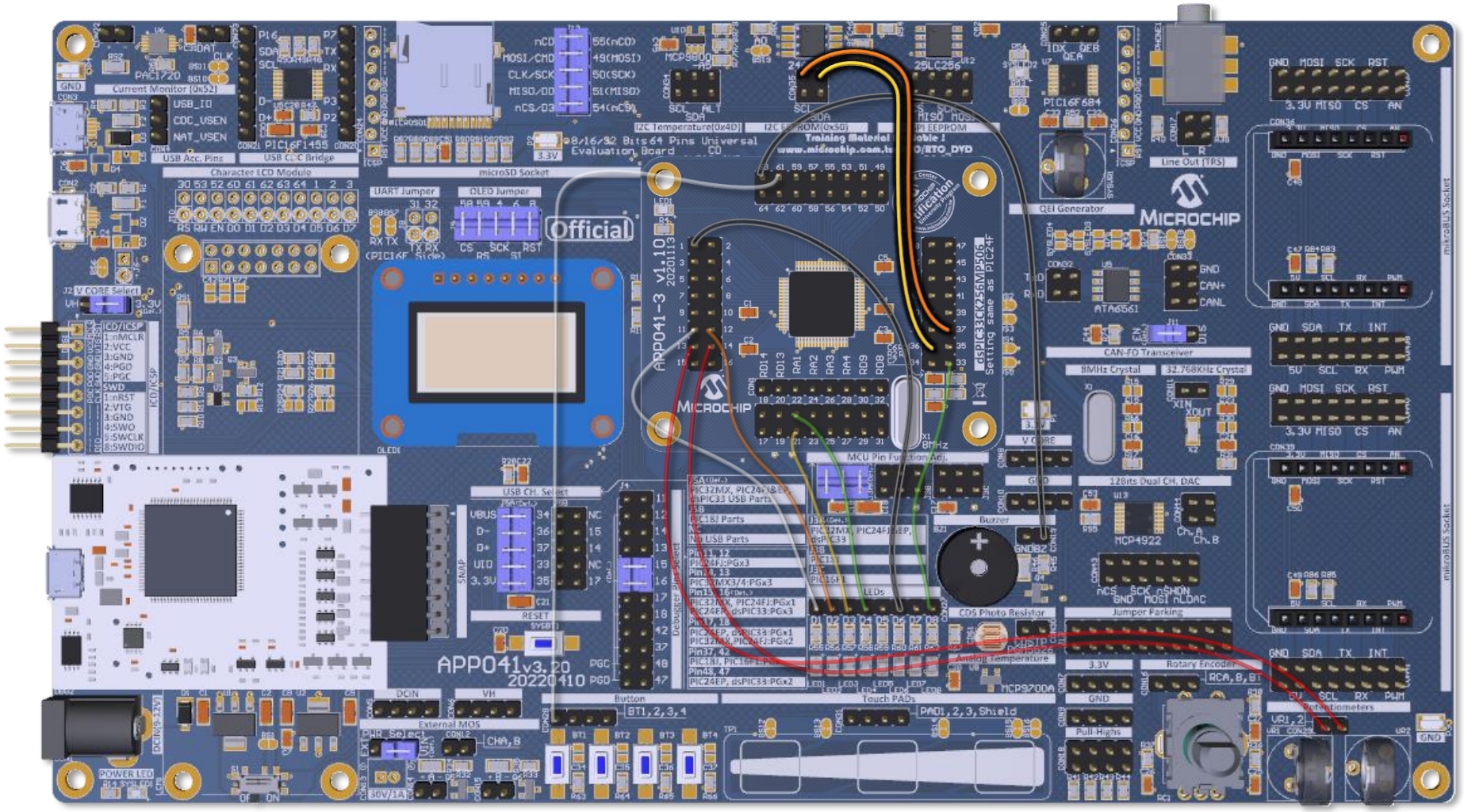
Lab16 EEPROM

- Base on current project or Open .\Exams\Lab16_xxx.X to do exercises
- Try to add I2C1 module then write the value into the EEPROM and Show on OLED display.
- I2C1 clock set to 100kHz,
- Read the value from EEPROM and Show on OLED display.

Let’s go!

Lab16 EEPROM

Connection

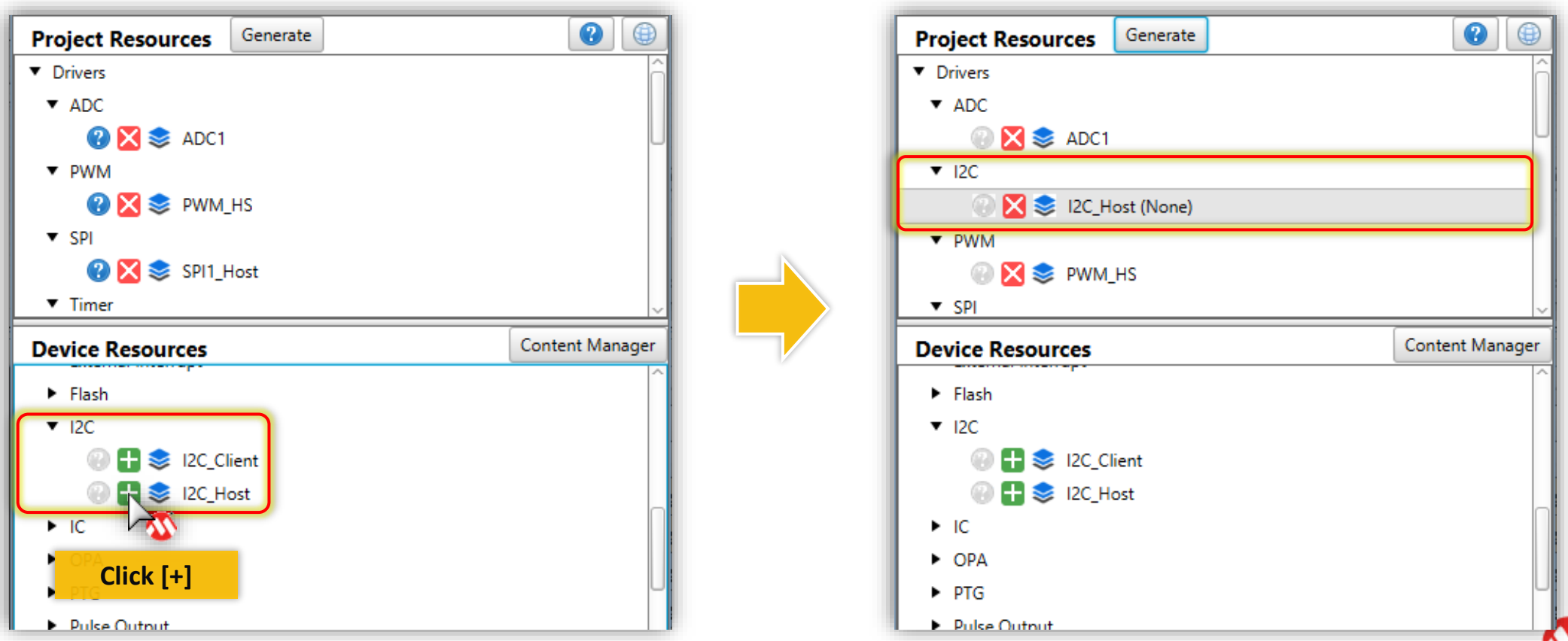


PIM Pin#		Symbol
36		SDA (EEPROM)
37		SCL (EEPROM)

Lab16 EEPROM

Step 1

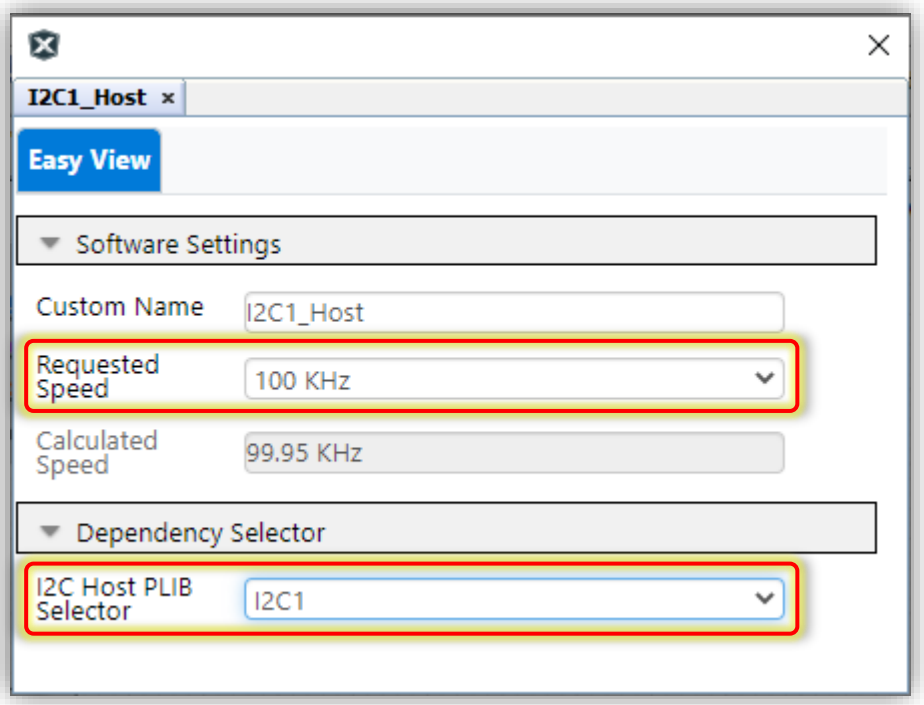
- Click [+] to add I2C > I2C_Host Module.



Lab16 EEPROM

Step 2

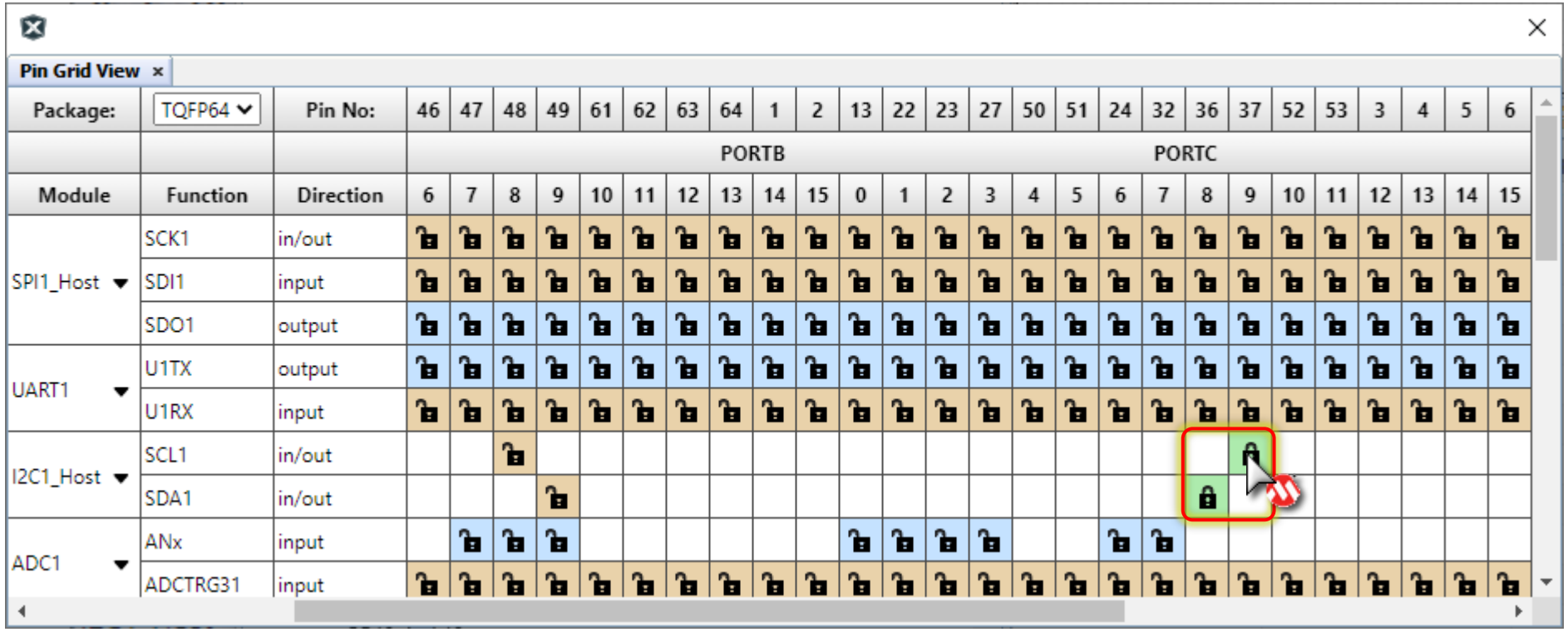
- Set I2C1_Host > Dependency Selector → I2C1.
- Check Requested Speed is 100 kHz.



Lab16 EEPROM

Step 3

- Change I2C1_Host SCL1 and SDA1 Pin to PORTC: RC8 (SDA1), RC9 (SCL1).

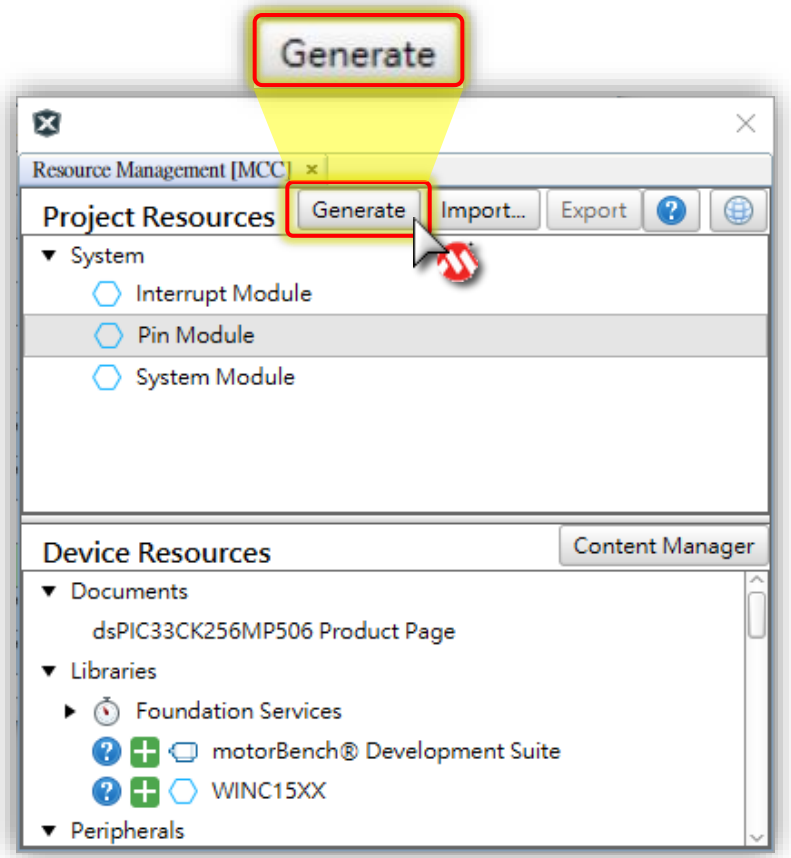


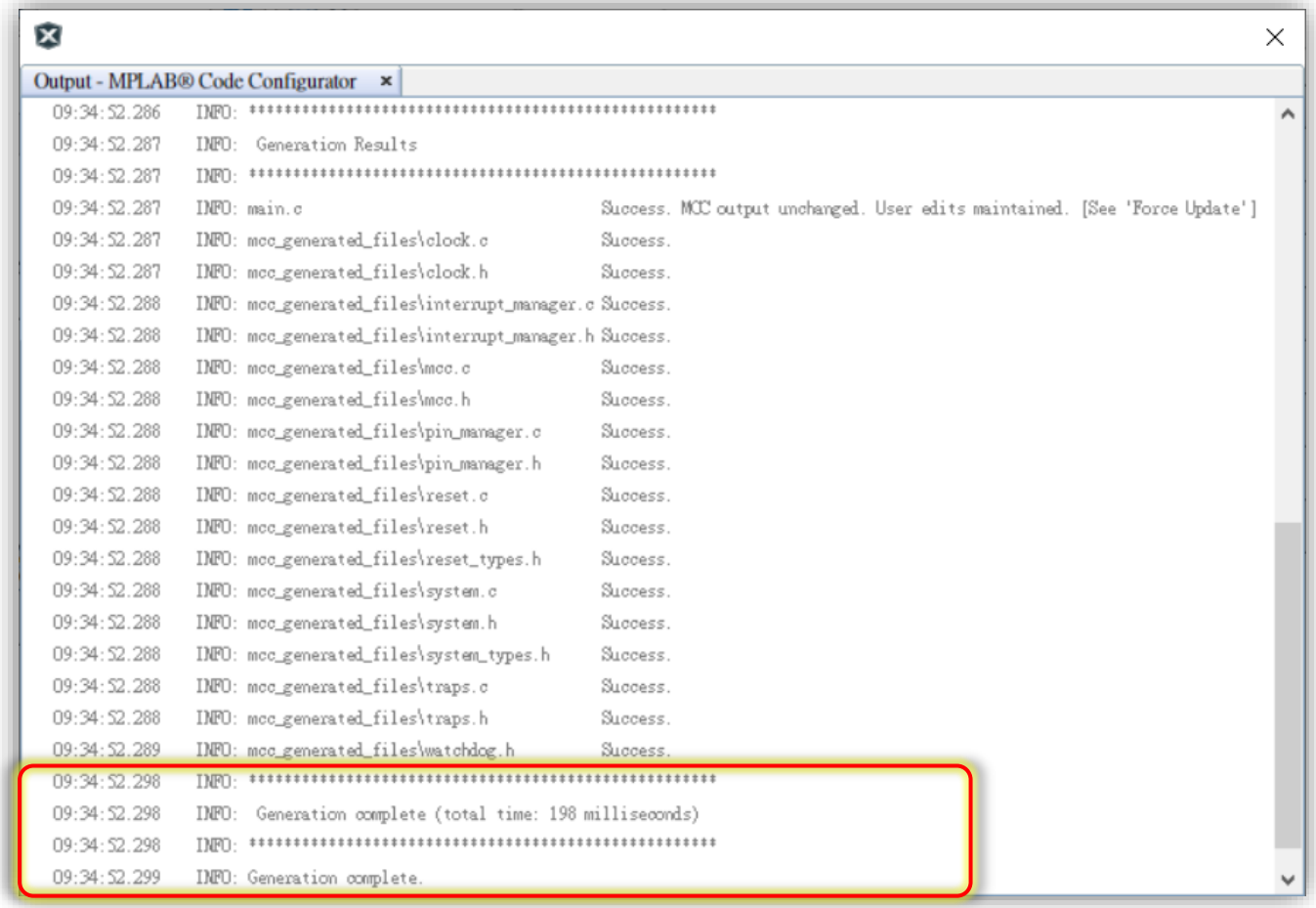
MICROCHIP

Lab16 EEPROM

Step 4

- Click "Generate" Button to generate your code.





Lab16 EEPROM

Code Example

```
...
#include "mcc_generated_files/uart/uart1.h"
#include "mcc_generated_files/i2c_host/i2c1.h"
...
volatile uint8_t UART1_Rx_Done = 0;

#define EEPROM_Address 0x50

uint8_t BT_Flag = 0;
uint8_t I2C_EEPROM_Write_Data[4];
uint8_t I2C_EEPROM_Read_Data[2];
...
int main(void)
{
    while (1)
    {
        if (BT1_GetValue()) {
            if(BT_Flag == 0) {
                BT_Flag = 1;
            }
            LED8_SetLow();
        } else {
            if(BT_Flag == 1) {
                BT_Flag = 0;
                static uint8_t i = 0;
                if (++i > 100) i = 0;
                I2C_EEPROM_Write_Data[0] = 0x00;
                I2C_EEPROM_Write_Data[1] = 0x00;
                I2C_EEPROM_Write_Data[2] = i;
                I2C_EEPROM_Write_Data[3] = i << 1;
                I2C1_Host.Write(EEPROM_Address, I2C_EEPROM_Write_Data, 4);
                while (I2C1_Host.IsBusy());
            }
            LED8_SetHigh();
        }
        ...
    }
}
```

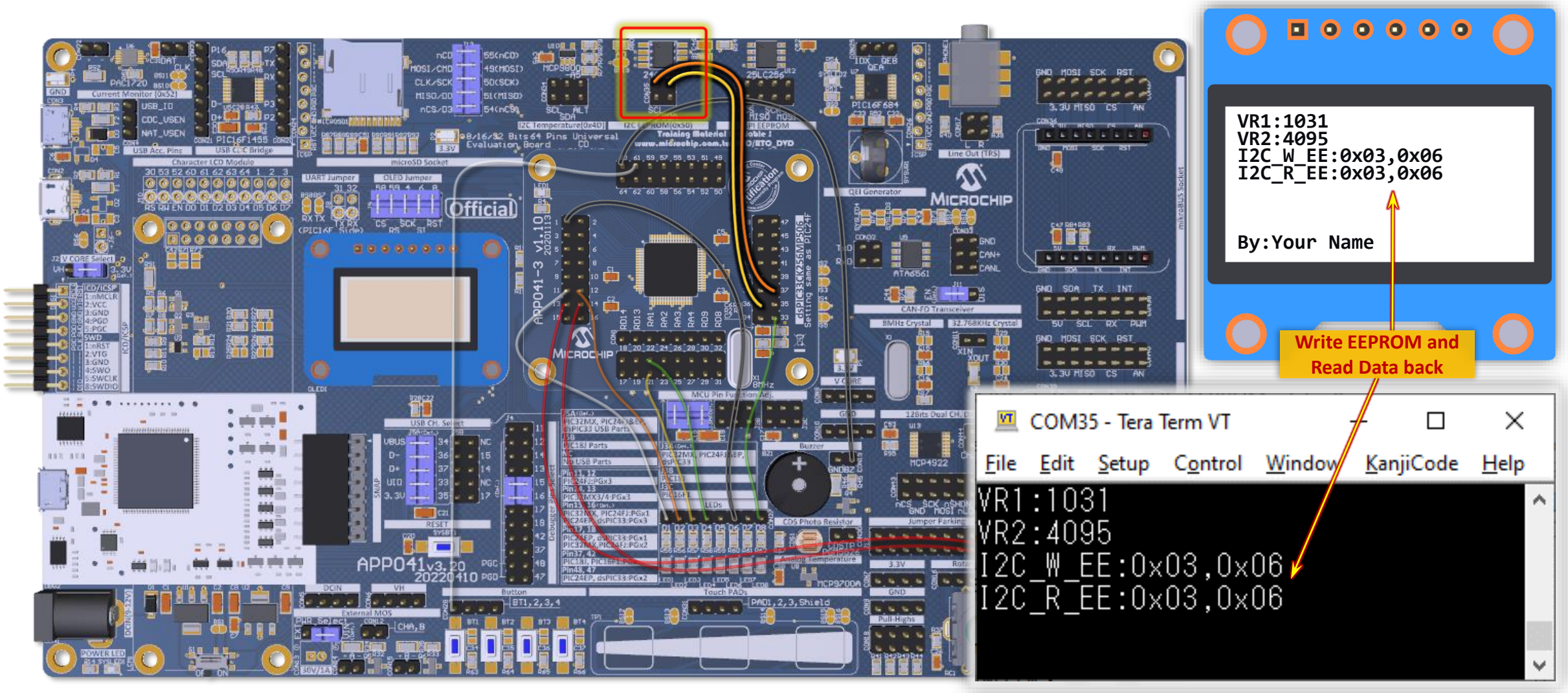
Lab16 EEPROM

Code Example

```
int main(void)
{
    ...
    while (1)
    {
        ...
        if (TMR1Flag)
        {
            TMR1Flag=0;
            ADC1.SoftwareTriggerEnable();

            I2C_EEPROM_Write_Data[0] = 0x00;
            I2C_EEPROM_Write_Data[1] = 0x00;
            I2C1_Host.WriteRead(EEPROM_Address, I2C_EEPROM_Write_Data, 2, I2C_EEPROM_Read_Data, 2);
            while (I2C1_Host.IsBusy());

            sprintf((char *) StringBuffer, "I2C_W_EE:0x%02X,0x%02X", I2C_EEPROM_Write_Data[2], I2C_EEPROM_Write_Data[3]);
            printf("\033[3;1H%s", StringBuffer);
            myOLED_DrawStr(0, 2, StringBuffer);

            sprintf((char *) StringBuffer, "I2C_R_EE:0x%02X,0x%02X", I2C_EEPROM_Read_Data[0], I2C_EEPROM_Read_Data[1]);
            printf("\033[4;1H%s", StringBuffer);
            myOLED_DrawStr(0, 3, StringBuffer);
        }
        ...
    }
}
```

Lab16 EEPROM

Result



MCP9800 Read & Configuration

- First, Set ADC resolution & resolution & other config you want.
- Secondly, Read ADC value maximum valid 12 bits. (2 Bytes).

TABLE 5-1: BIT ASSIGNMENT SUMMARY FOR ALL REGISTERS

Register Pointer P1 P0	MSB/ LSB	Bit Assignment 7	6	5	4	3	2	1	0
Ambient Temperature Register (T_A)									
0 0	MSB	Sign	2^6°C	2^5°C	2^4°C	2^3°C	2^2°C	2^1°C	2^0°C
	LSB	2^{-1}°C	2^{-2}°C	2^{-3}°C	2^{-4}°C	0	0	0	0
Sensor Configuration Register (CONFIG)									
0 1	LSB	One-Shot	Resolution		Fault Queue		ALERT Polarity	COMP/INT	Shutdown
Temperature Hysteresis Register (T_{HYST})									
1 0	MSB	Sign	2^6°C	2^5°C	2^4°C	2^3°C	2^2°C	2^1°C	2^0°C
	LSB	2^{-1}°C	0	0	0	0	0	0	0
Temperature Limit-Set Register (T_{SET})									
1 1	MSB	Sign	2^6°C	2^5°C	2^4°C	2^3°C	2^2°C	2^1°C	2^0°C
	LSB	2^{-1}°C	0	0	0	0	0	0	0

Lab17 Temperature Sensor

- Base on current project or Open .\Exams\Lab17_xxx.X to do exercises
- Try to set MCP9800 ADC resolution to 12 bits.
- Read the value from Temperature Sensor and Show on OLED display.

Let’s go!

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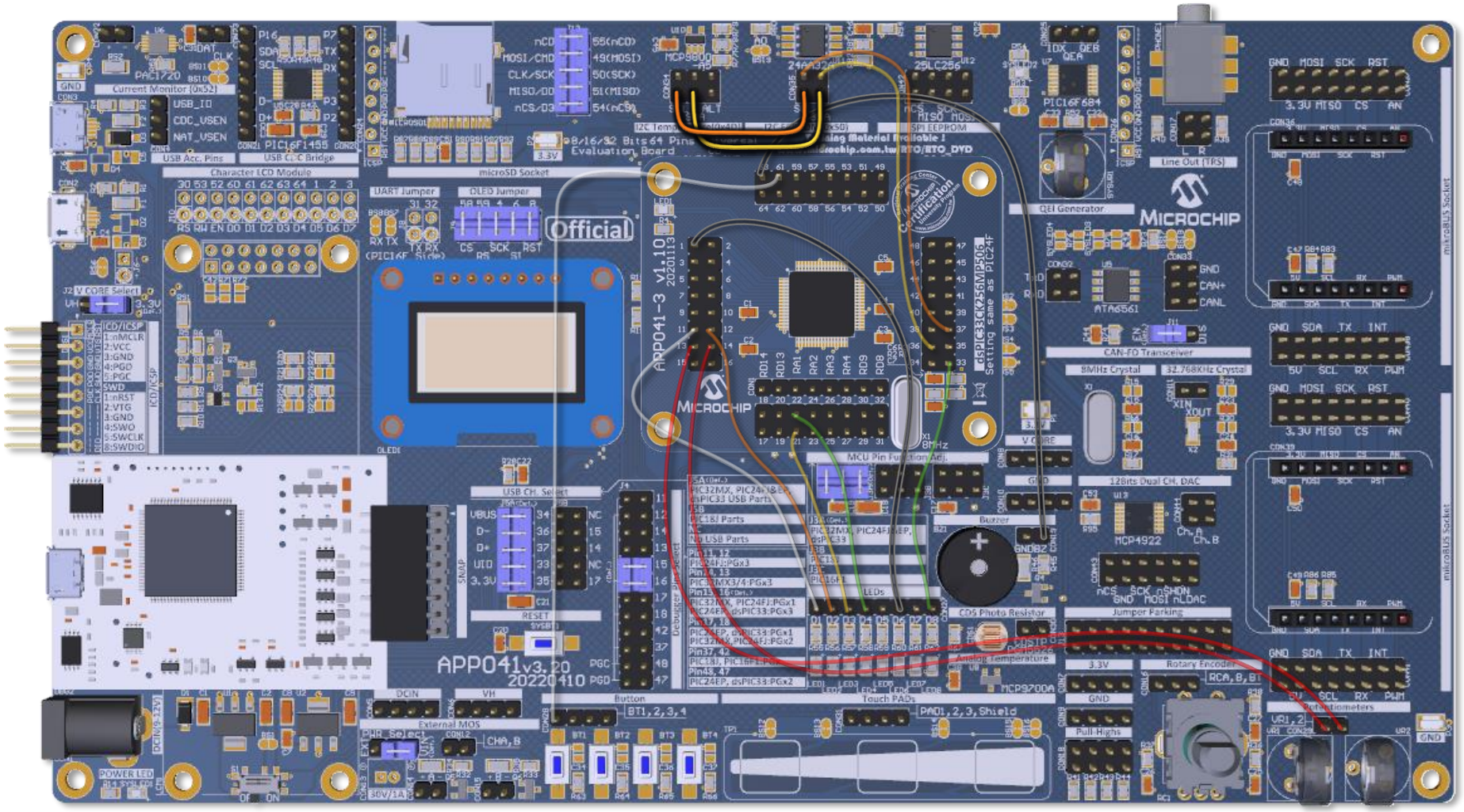
Lab17 Temperature Sensor

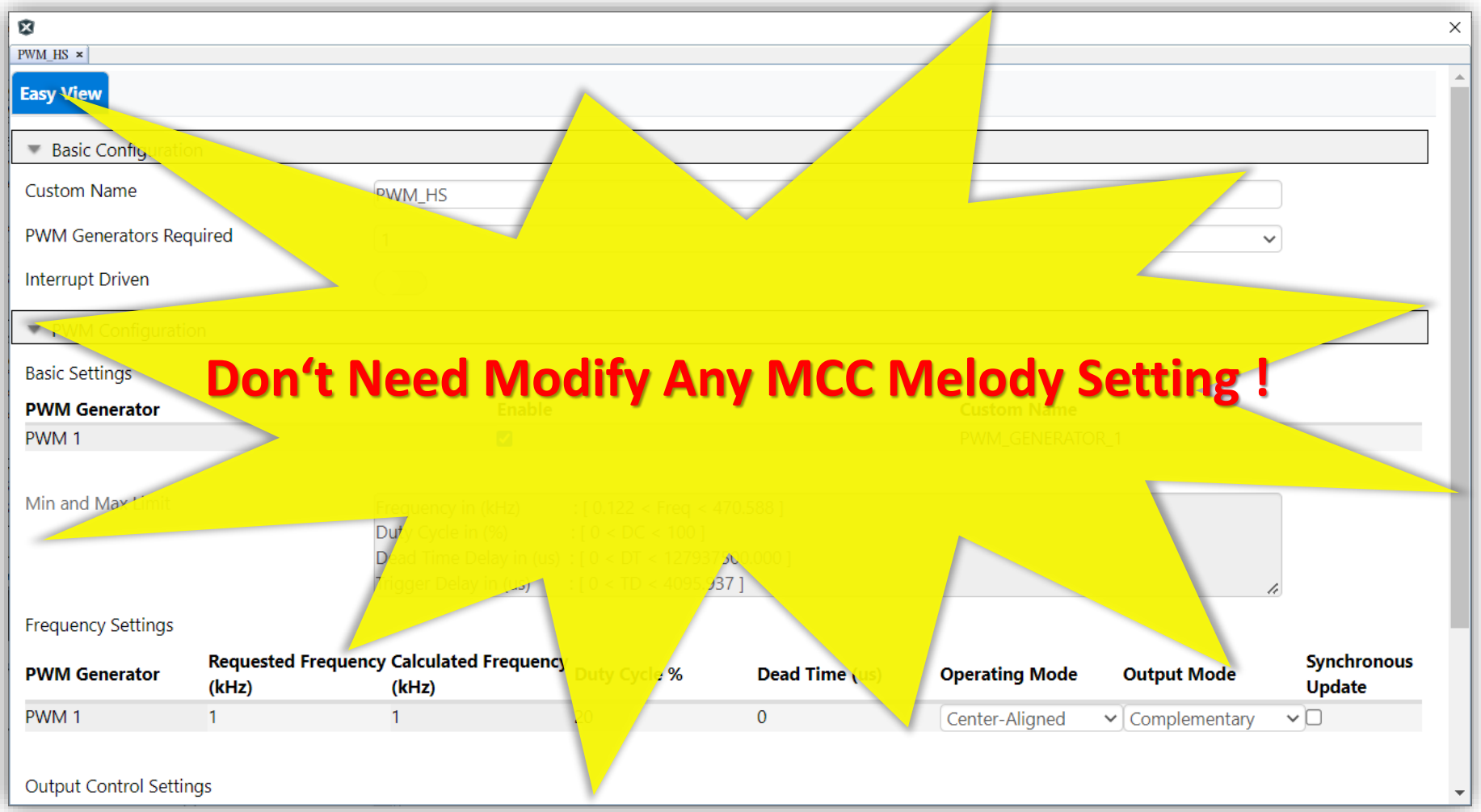
Connection



PIM Pin#		Symbol
SDA (EEPROM)		SDA (Temp.)
SCL (EEPROM)		SCL (Temp.)

Lab17 Temperature Sensor

Notice



Lab17 Temperature Sensor

Code Example

```
#include "mcc_generated_files/i2c1.h“
…

uint8_t I2C_EEPROM_Read_Data[2];
…

#define MCP9800_Address             0x4D
#define MCP9800_REG_CONFIG          0x01
#define MCP9800_Register            0x60
#define MCP9800_REG_TA              0x00

uint8_t MCP9800_Write_Data[2];
uint8_t MCP9800_Read_Data[2];

int main(void)
{
   …
   printf("\033[?25l");

   MCP9800_Write_Data[0] = MCP9800_REG_CONFIG;
   MCP9800_Write_Data[1] = MCP9800_Register;
   I2C1_Host.Write(MCP9800_Address, MCP9800_Write_Data, 2);
   while (I2C1_Host.IsBusy());
   MCP9800_Write_Data[0] = MCP9800_REG_TA;
   I2C1_Host.Write(MCP9800_Address, MCP9800_Write_Data, 1);
   while (I2C1_Host.IsBusy());

   while (1)
   {
    …
   }
}
```

Lab17 Temperature Sensor

Code Example

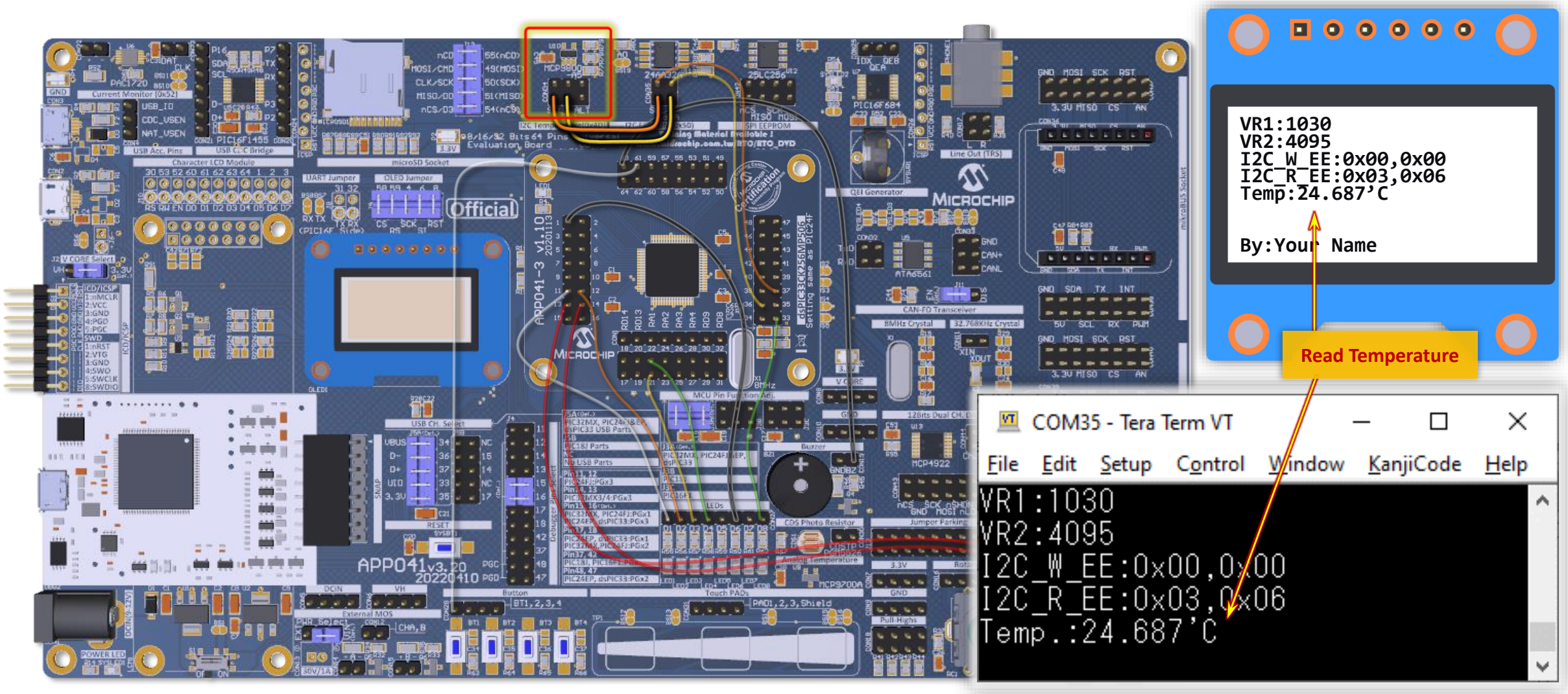
```
int main(void)
{
   ...
   while (1)
   {
      ...
      if (TMR1Flag)
      {
         TMR1Flag=0;
         ADC1.SoftwareTriggerEnable();
         ...

         I2C1_Host.Read(MCP9800_Address, MCP9800_Read_Data, 2);
         while (I2C1_Host.IsBusy());

         sprintf((char *) StringBuffer, "Temp.:%2d.%03d'C", (int) (MCP9800_Read_Data[0]&0x7F), (int) (MCP9800_Read_Data[1] >> 4)*1000 / 16);
         printf("\033[5;1H%s", StringBuffer);
         myOLED_DrawStr(0, 4, StringBuffer);
      }
      ...
   }
}
```

Lab17 Temperature Sensor

Result



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