

SAMD21 ARM Cortex-M0+ Microcontroller & Harmony v3 SAM2002 v1.01 Appendix



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



SMART | CONNECTED | SECURE

**CAE Taiwan Team
Microchip Technology Inc.**

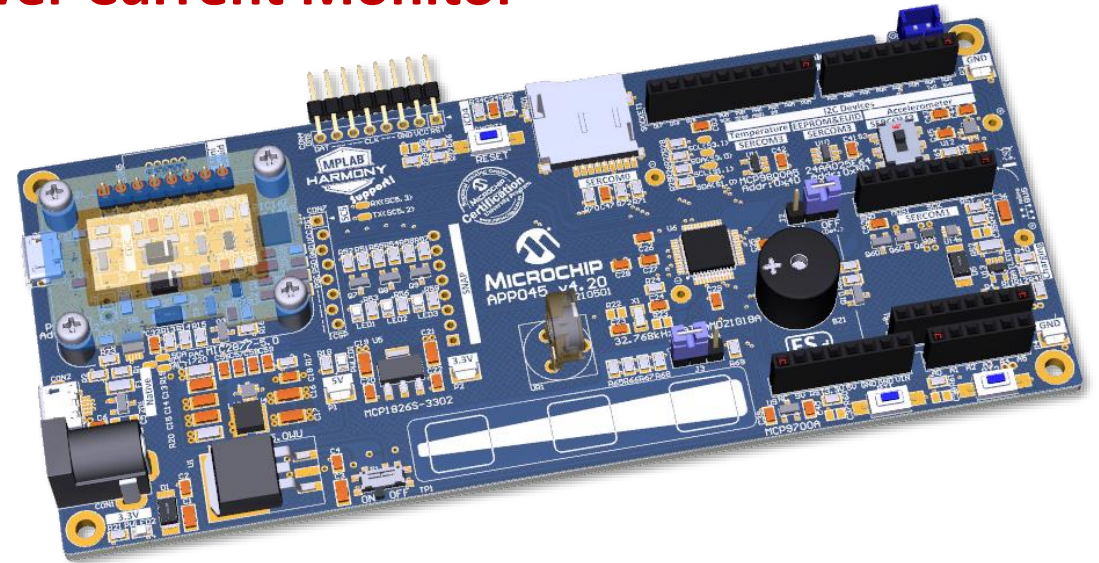
2022 March

SAMD21 EVB APP045 v4

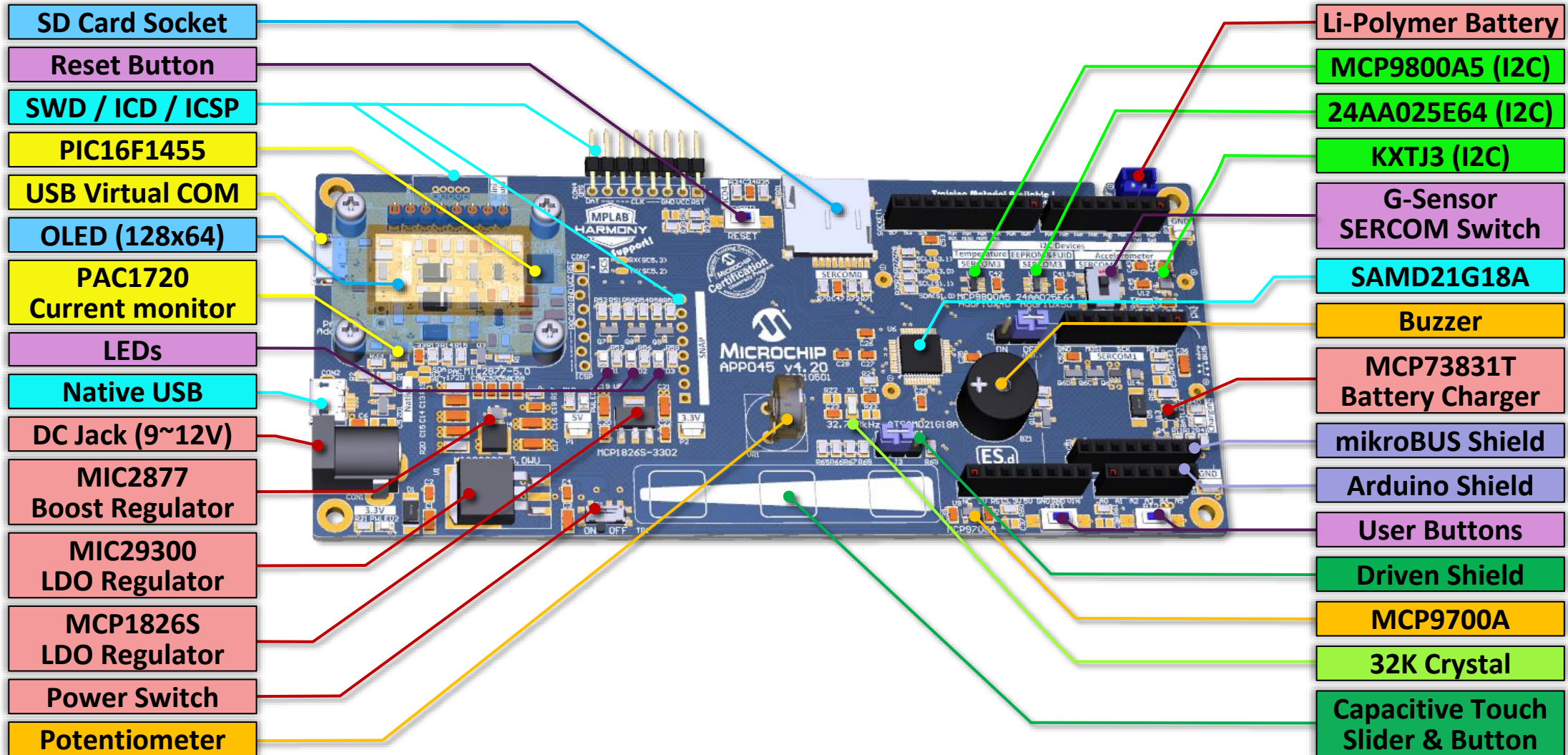
Introduction

APP045 v4 Features

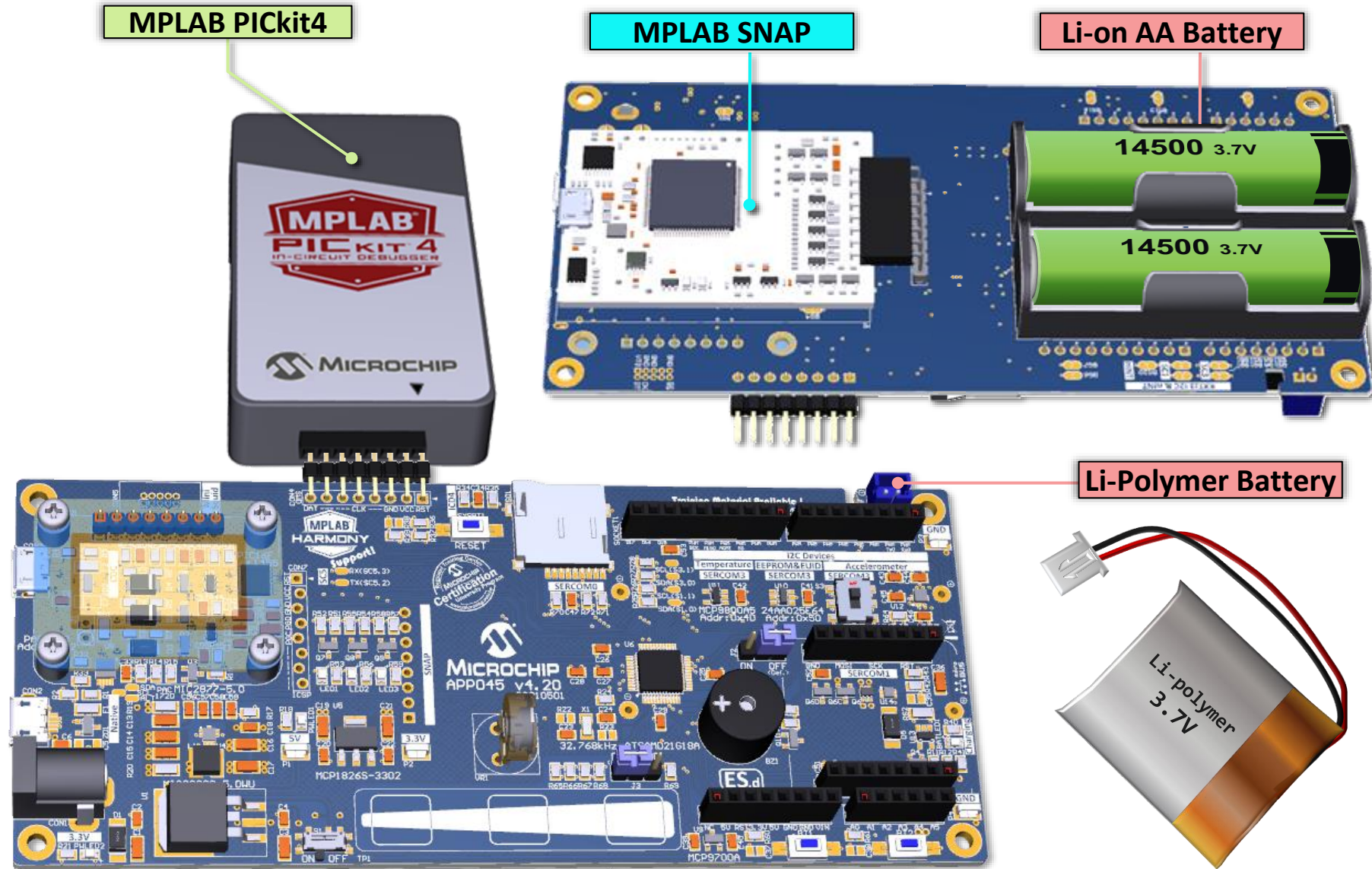
- On board **SAMD21G18A** 32Bit ARM Cortex M0+ Microcontroller
- Support plugged **MPLAB SNAP** external programmer/debugger
- Onboard **USB CDC Virtual COM Port** and **Power Current Monitor**
- Multiple Power Supply Source
- **Support Li-on Battery, boost and charger**
- 2 x Buttons, 3 x LEDs
- 1 x I2C Temperature Sensor
- 1 x I2C EEPROM with Unique ID
- **1 x I2C Accelerometer**
- 1 x MicroSD Socket (SPI interface)
- 1 x SPI OLED (128 x 64, SSD1306 Compliant)
- 1 x Potentiometer, Analog Temperature Sensor and **Buzzer**
- **1 x Capacitive QTouch® Slider & Buttons with Driven Shield**
- **1 x mikroBUS™ Click Board Socket**
- 1 x Arduino® Shield Socket (Arduino M0 Pro board Compliant)



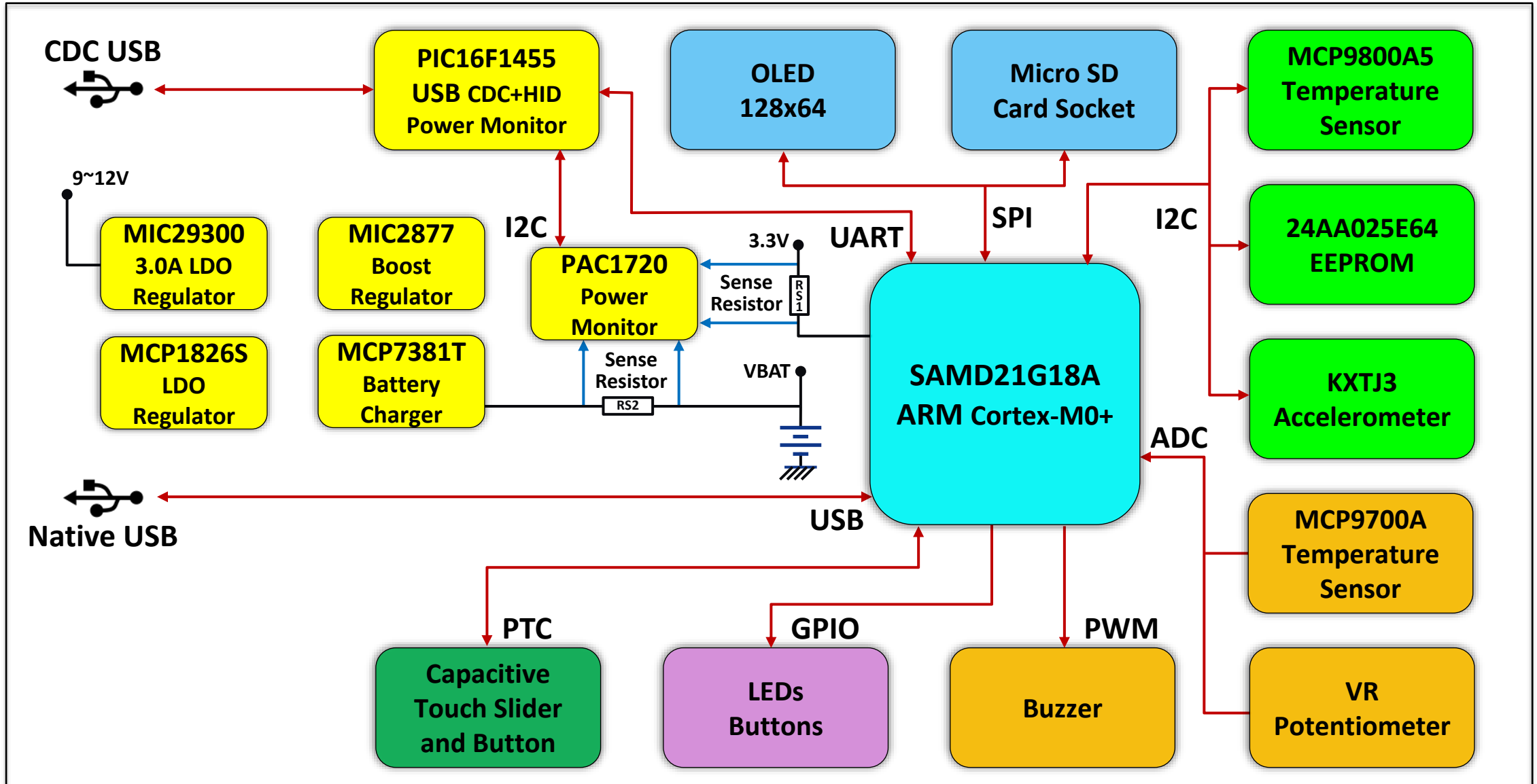
APP045 v4 Overview



APP045 v4 Programmer and Debugger

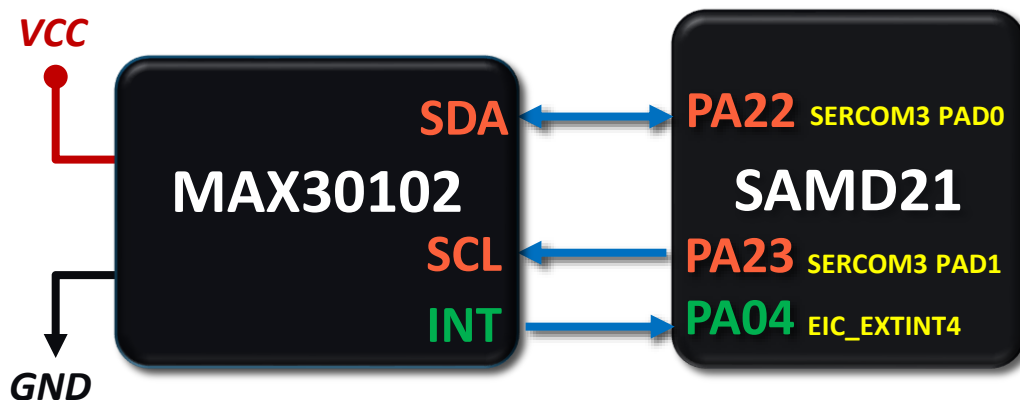
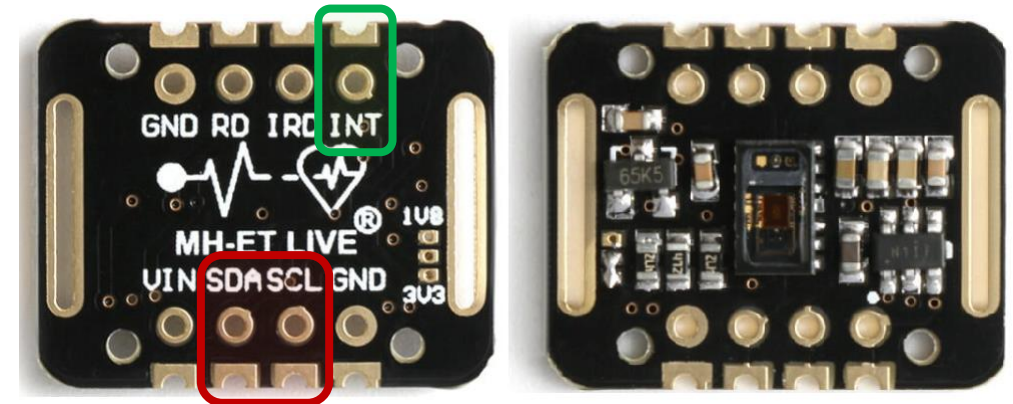


APP045 v4 Block Diagram



⚙️ LabX Heart Rate and Oximeter

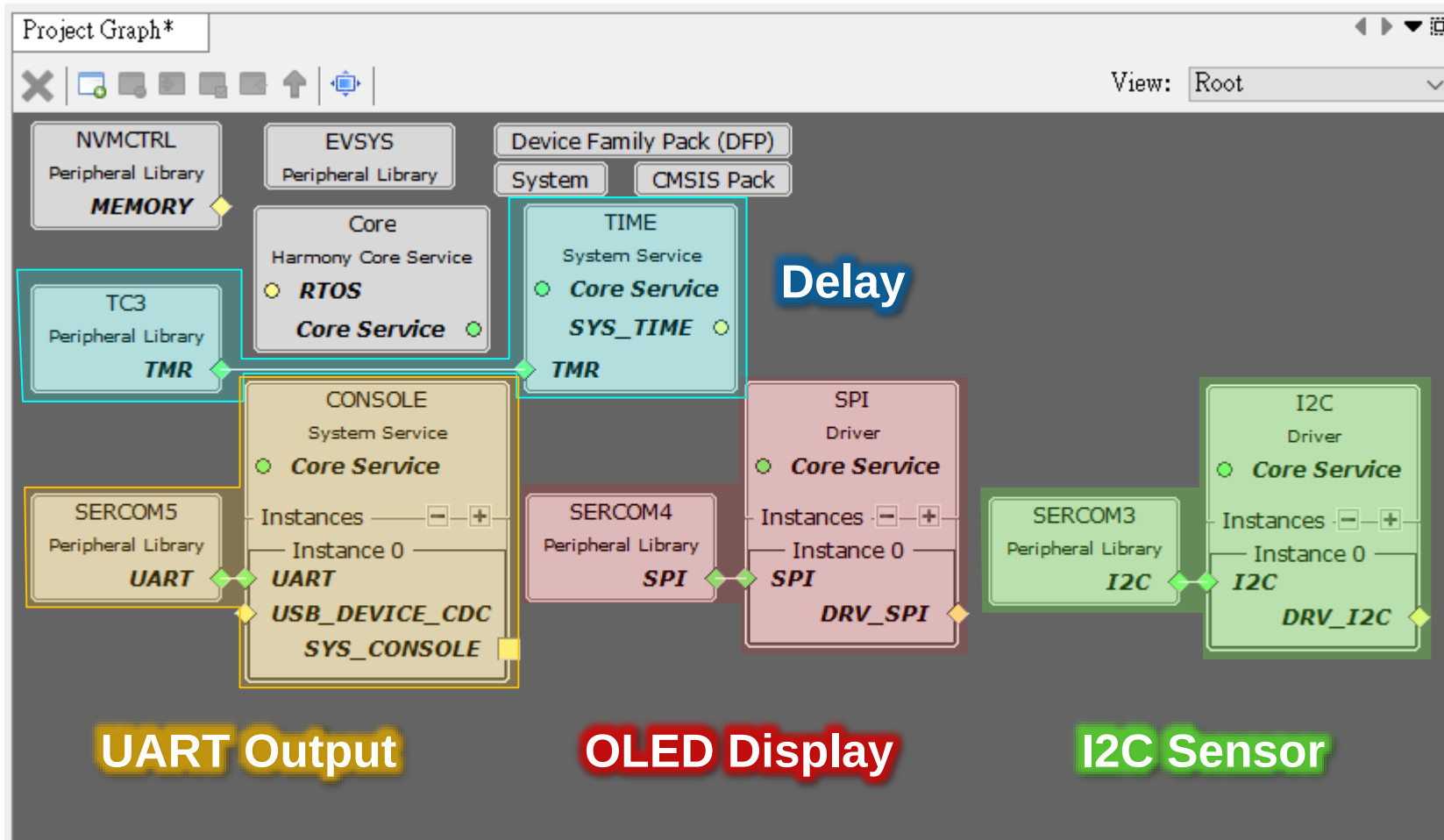
- The Sensor we to use is **MAX30102** (Pulse Oximeter and Heart-Rate Sensor). You can use keyword “**MAX30102 module**” to find the module for this Lab.
- Please wire **MAX30102** module **SDA/SCL** to APP045v4 mikroBUS **SCL(PA22)/SDA(PA23)**, and **optional** wire module's **INT** to mikroBUS **INT(PA04)**.
- The module needs supply **5V**. (Depend module)
- **MAX30102** configuration:
 - **SDA** connect to **PA22** (**SERCOM3 PAD0**)
 - **SCL** connect to **PA23** (**SERCOM3 PAD1**)
 - **INT** connect to **PA04** (**EIC_EXTINT4**) **Optional**
 - Slave address is **0x57**.



CON8 MikroBUS			
1	AN	PWM	16
2	RST	INT	15
3	CS	RX	14
4	SCK	TX	13
5	MISO	SCL	12
6	MOSI	SDA	11
7	3.3V	5V	10
8	GND	GND	9

LabX Heart Rate and Oximeter

- **The Harmony Configuration.**



LabX Heart Rate and Oximeter

- The Harmony Configuration.

SERCOM5

Select SERCOM Operation Mode: USART with internal Clock

Operating Mode: Ring buffer mode

Configure Ring Buffer Size-

TX Ring Buffer Size: 1,024

RX Ring Buffer Size: 128

Receive Enable: ☒

Transmit Enable: ☒

Frame Format: USART frame

Baud Rate in Hz: 115,200

Parity Mode: No Parity

Character Size: 8 Bits

Stop Bit Mode: One Stop Bit

Receive Pinout: SERCOM PAD[3] is used for data reception

Transmit Pinout: PAD[2] = TxD; PAD[3] = XCK

Enable Run in Standby: ☐

SERCOM3

Select SERCOM Operation Mode: I2C Master

Transfer Speed Mode: STANDARD_AND_FAST_MODE

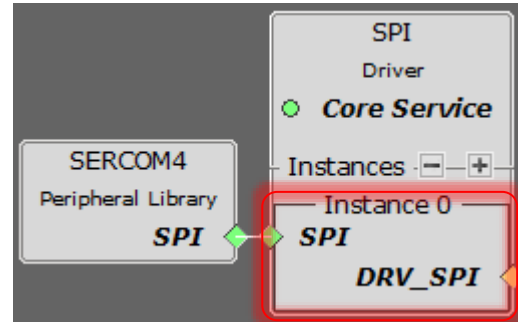
Enable operation in Standby mode: ☐

SDA Hold Time: 50-100ns hold time

I2C Speed in KHz: 400

I2C Trise in nano seconds: 100

Enable 10-bit Addressing: ☐



SPI

PLIB Used: SERCOM4

Number of Clients: 1

Transfer Queue Size: 4

Use DMA for Transmit and Receive?: ☒

DMA Channel For Transmit: 0

DMA Channel For Receive: 1

SERCOM4

Select SERCOM Operation Mode: SPI Master

Enable Interrupts?: ☒

Enable operation in Standby mode: ☐

SPI Data Out Pad: DO on PAD[2], SCK on PAD[3] and SS on PAD[1]

SPI Data In Pad Selection: SERCOM PAD[0]

SPI Data Order: MSB is transferred first

SPI Speed in Hz: 10,000,000

SPI Data Character Size: 8 bits

SPI Clock Phase: The data is sampled on a leading SCK edge and change

SPI Clock Polarity: SCK is low when idle

Enable SPI Master Hardware Slave Select: ☐

SPI Receiver Enable: ☒

SPI Transfer Mode 0 is Selected

✂ LabX Heart Rate and Oximeter

- The Harmony Configuration.

SSD1306_RS
SSD1306_CS

Pin Settings ×									
Order: Ports ▾		Table View		☒ Easy View					
Pin Number	Pin ID	Custom Name	Function	Mode	Direction	Latch	Pull Up	Pull Down	Drive Strength
	PA03	SSD1306_RS	GPIO ▾	Digital	Out ▾	High	☐	☐	NORMAL ▾
	PA08	SSD1306_CS	GPIO ▾	Digital	Out ▾	High	☐	☐	NORMAL ▾
14	PA09	LED2	GPIO ▾	Digital	Out ▾	High	☐	☐	NORMAL ▾
22	PA13		SERCOM4_PAD1 ▾	Digital	Out ▾	n/a	☐	☐	NORMAL ▾
23	PA14	BT1	GPIO ▾	Digital	In ▾	Low	☐	☐	NORMAL ▾
24	PA15	BT2	GPIO ▾	Digital	In ▾	Low	☐	☐	NORMAL ▾
26	PA17	LED3	GPIO ▾	Digital	Out ▾	Low	☐	☐	NORMAL ▾
29	PA20	LED1	GPIO ▾	Digital	Out ▾	High	☐	☐	NORMAL ▾
31	PA22		SERCOM3_PAD0 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾
32	PA23		SERCOM3_PAD1 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾
19	PB10		SERCOM4_PAD2 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾
20	PB11		SERCOM4_PAD3 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾
37	PB22		SERCOM5_PAD2 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾
38	PB23		SERCOM5_PAD3 ▾	Digital	High Impedance ▾	n/a	☐	☐	NORMAL ▾

⚙️ LabX Heart Rate and Oximeter

- The Harmony Configuration.

The screenshot displays the Microchip Harmony Configuration tool interface, divided into two main panels: the Project Graph and the Configuration Options.

Project Graph: This panel shows a hierarchical view of the project components. The 'Core' component is highlighted with a green box. It includes the 'Harmony Core Service' and the 'Core Service'. The 'Core Service' is further detailed with 'RTOS' and 'Core Service' sub-components. Other components visible include 'NVMCTRL' (Peripheral Library, MEMORY), 'EVSYS' (Peripheral Library), 'Device Family Pack (DFP)' (System, CMSIS Pack), 'TIME' (System Service, Core Service, SYS_TIME, TMR), 'TC3' (Peripheral Library, TMR), 'CONSOLE' (System Service, Core Service), 'SERCOM5' (Peripheral Library, UART), 'SERCOM4' (Peripheral Library, SPI), and 'USB_DEVICE_CDC' (SYS_CONSOLE).

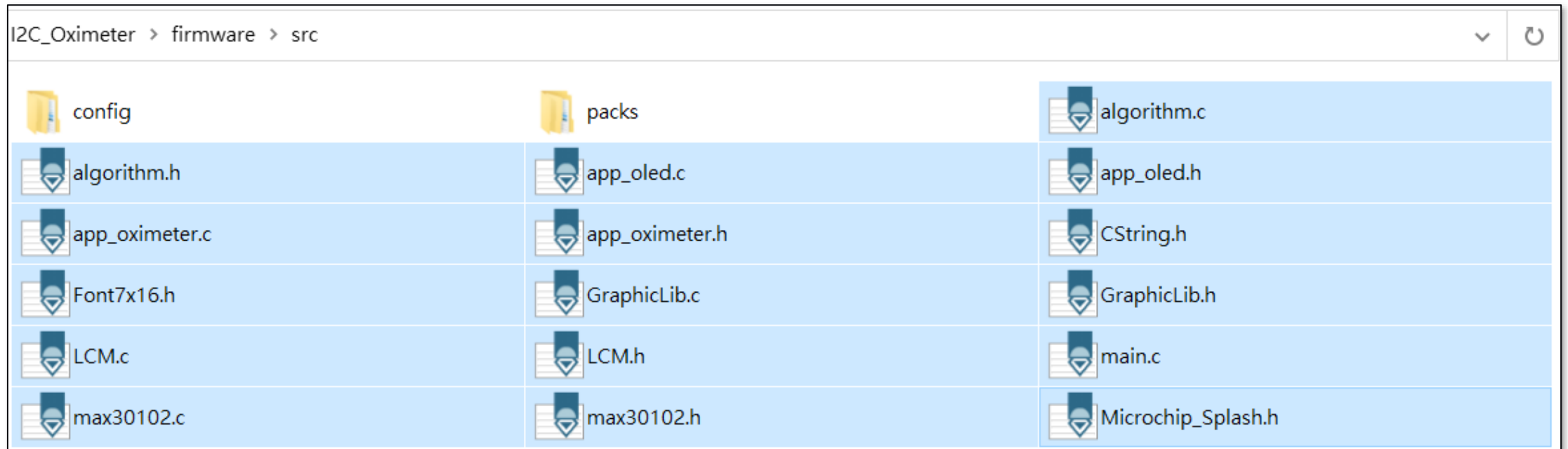
Configuration Options: This panel shows the configuration settings for the project. The 'Core' section is expanded, showing the following options:

- Generate Harmony Application Files** (checked)
- Application Configuration**
 - Number of Applications** (set to 2)
 - Application 0 Configuration**
 - Enable Application 0 Configuration** (checked)
 - Application Name** (app_oled)
 - **** Application name must be valid C-Language identifier and sho
 - Application 1 Configuration**
 - Enable Application 1 Configuration** (checked)
 - Application Name** (app_oximeter)
 - **** Application name must be valid C-Language identifier and sho
- Generate Harmony Driver Common Files** (checked)
- Generate Harmony System Service Common Files** (checked)
- Generate Harmony System Media Files** (unchecked)
- Enable System Interrupt** (checked)
- Enable System Ports** (checked)
- Enable System DMA** (checked)
- Enable System Reset** (unchecked)
- Enable OSAL** (checked)

Handwritten green text labels 'app_oled' and 'app_oximeter' are placed next to the application names in the Configuration Options panel.

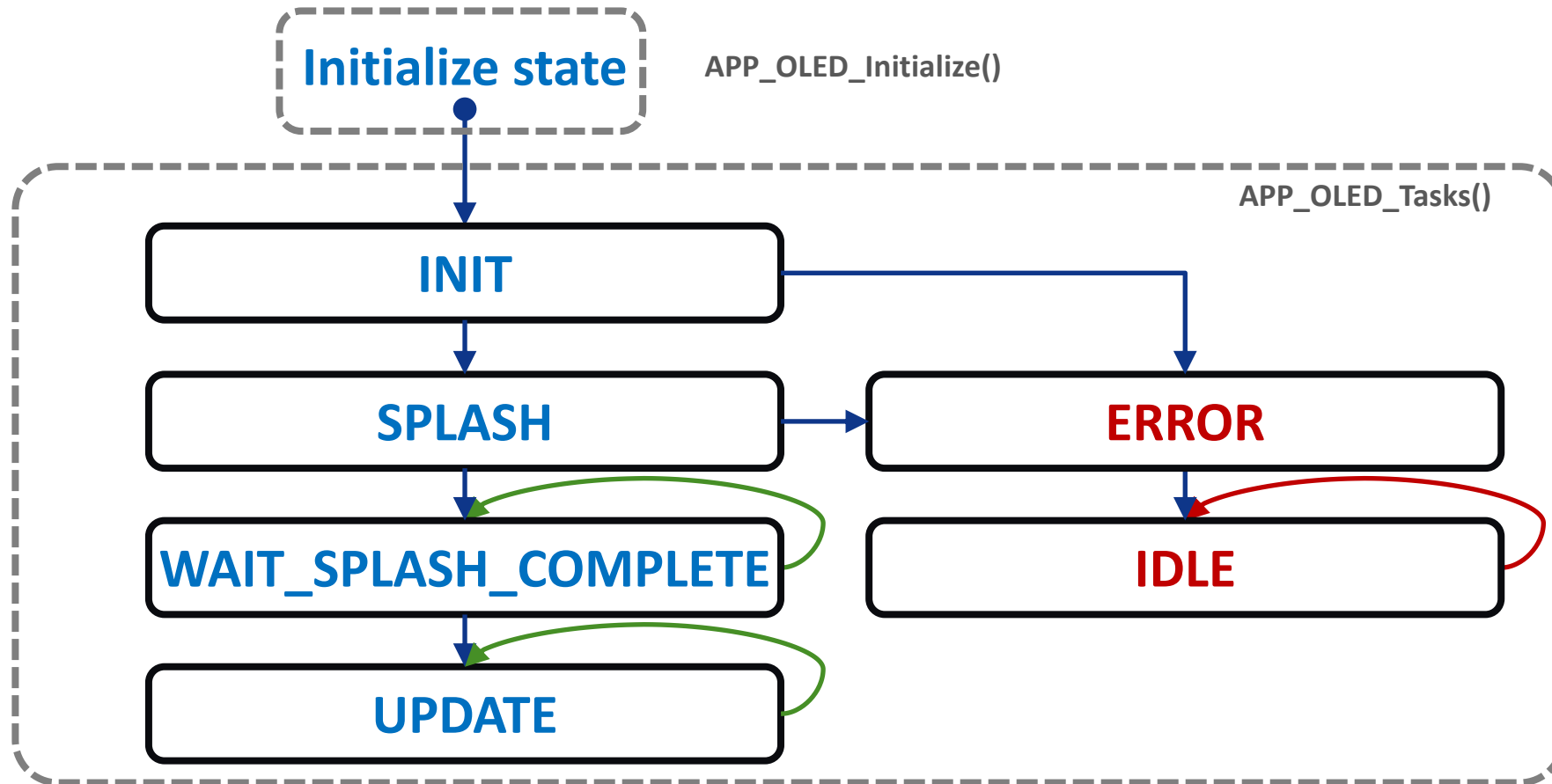
✂ LabX Heart Rate and Oximeter

- **Copy files and overwrite all in your project \src folder.**
 - Graphic library : GraphicLib.c and GraphicLib.h
 - OLED display driver : LCM.c and LCM.h
 - Bitmap and Font pictures : Microchip_Splash.h, Font7x16.h and CString.h
 - MAX30102 driver : max30102.c and max30102.h
 - Oximeter algorithm : algorithm.c and algorithm.h (MAXIM to provided)
 - Main and App state machine : main.c , app_oximeter.c and app_oximeter.h



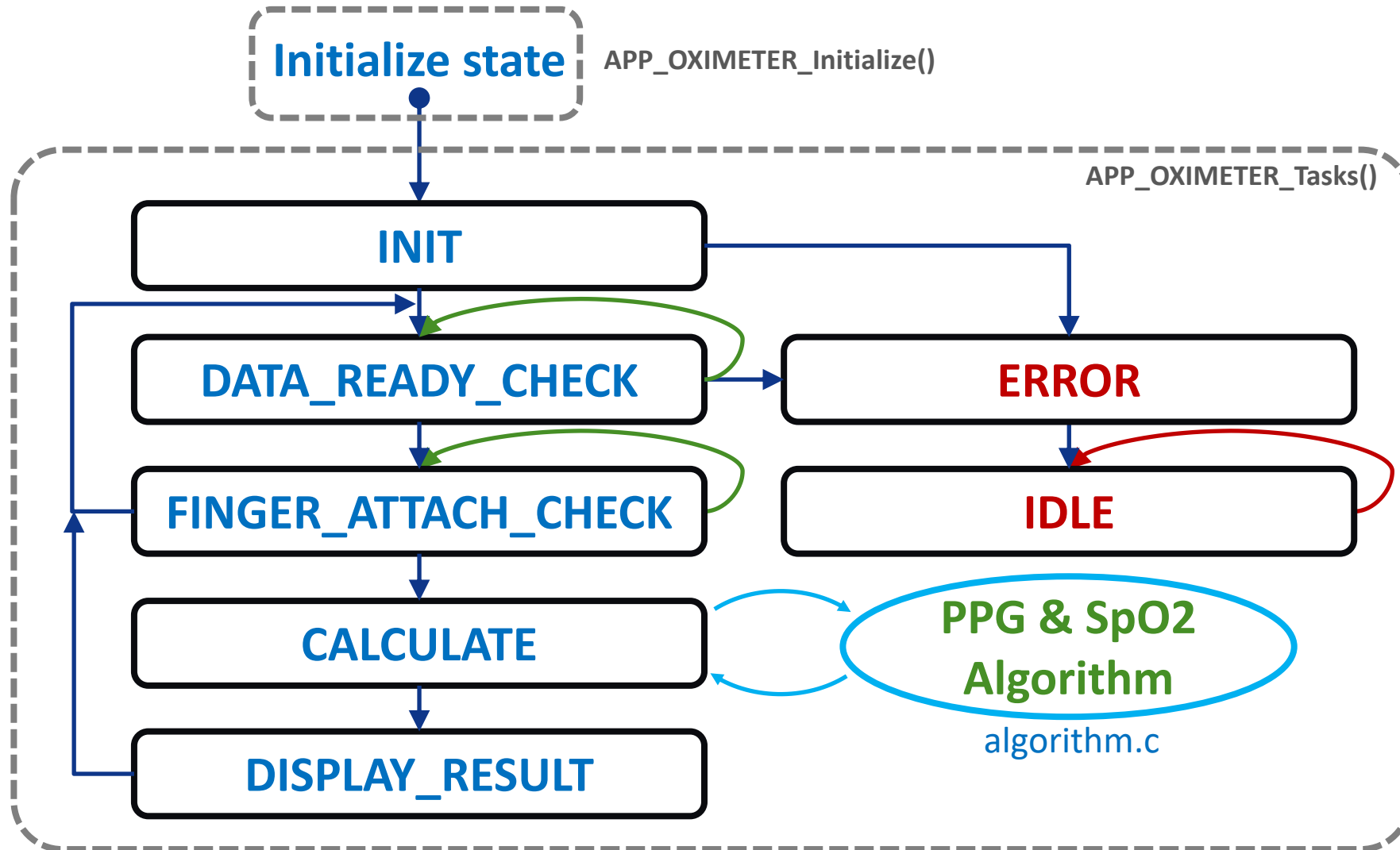
⚙️ LabX Heart Rate and Oximeter

- The state machine we want to implement in “`app_oled.c`” as below.



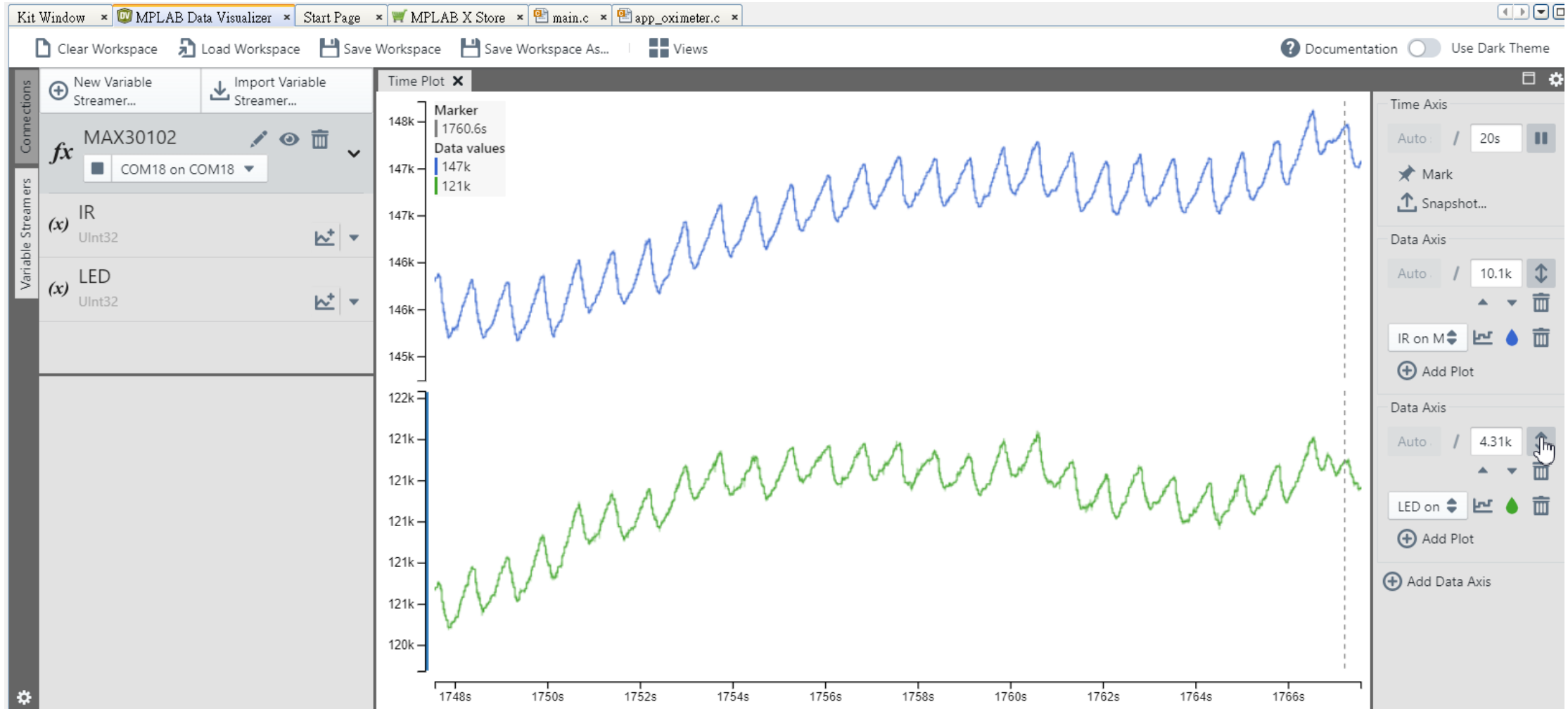
⚙️ LabX Heart Rate and Oximeter

- The state machine we want to implement in “[app_oximeter.c](#)” as below.



LabX Heart Rate and Oximeter

- Raw PPG signal in MPLAB Data Visualizer



⚙️ LabX Heart Rate and Oximeter

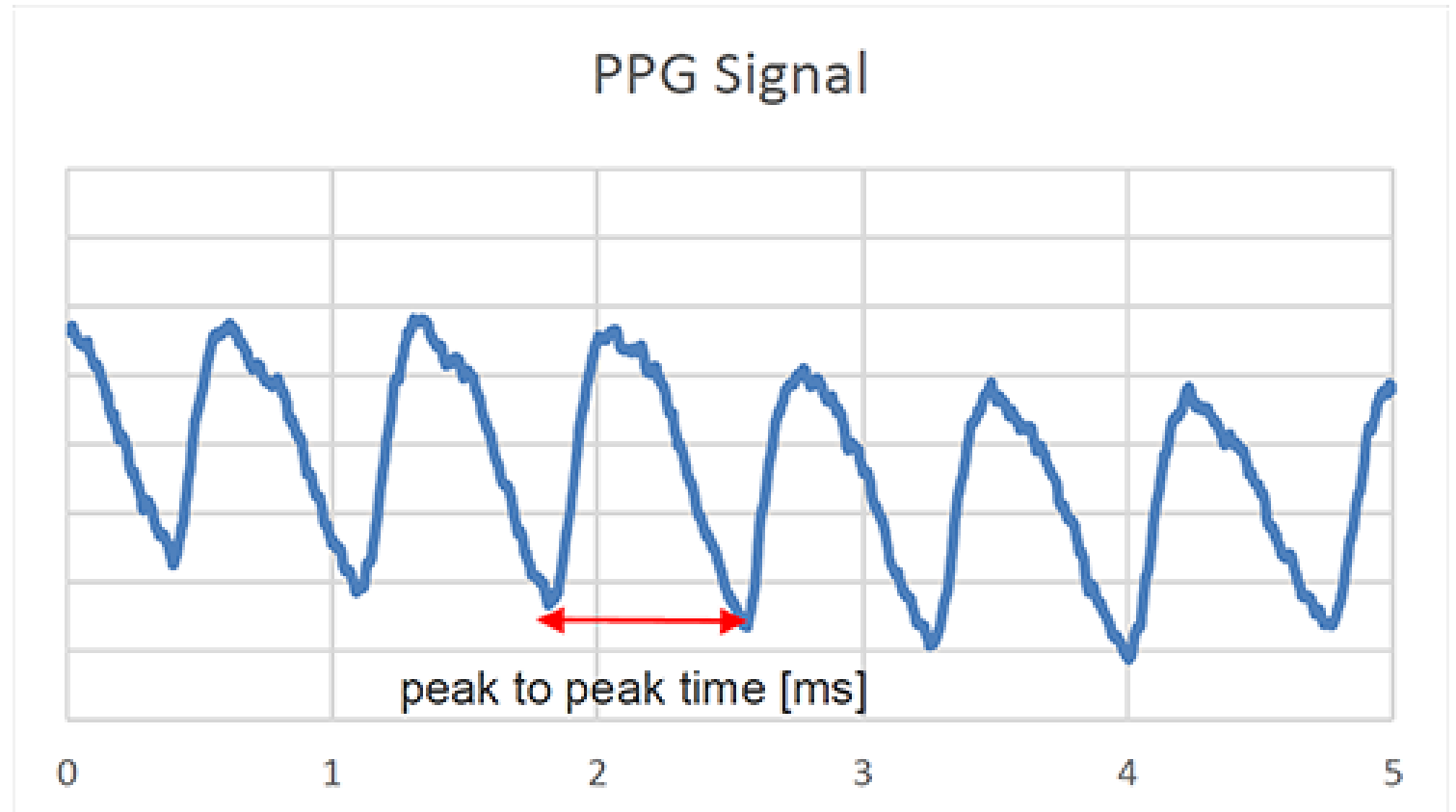
- **PPG Algorithms**

Time domain :

$$\text{HeartRate} = 60 / \text{duration} * \text{Number of Peaks}$$

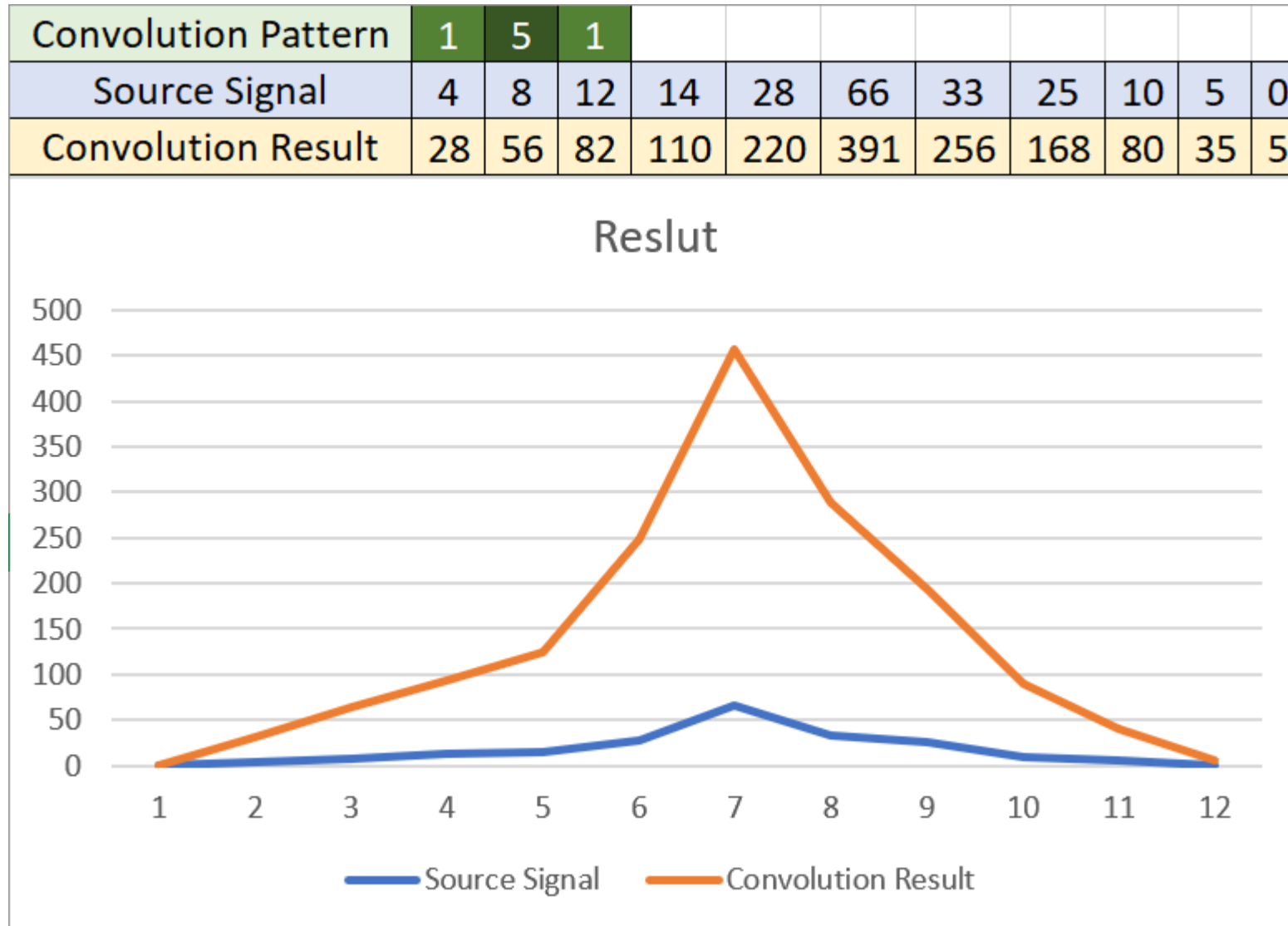
Frequency domain : Use FFT

$$\text{HearRate} = \text{Freq} * 60$$



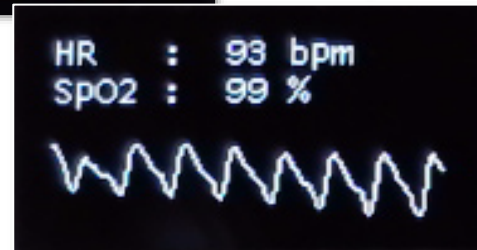
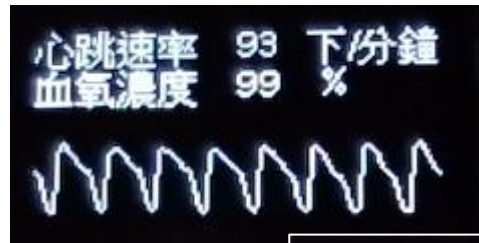
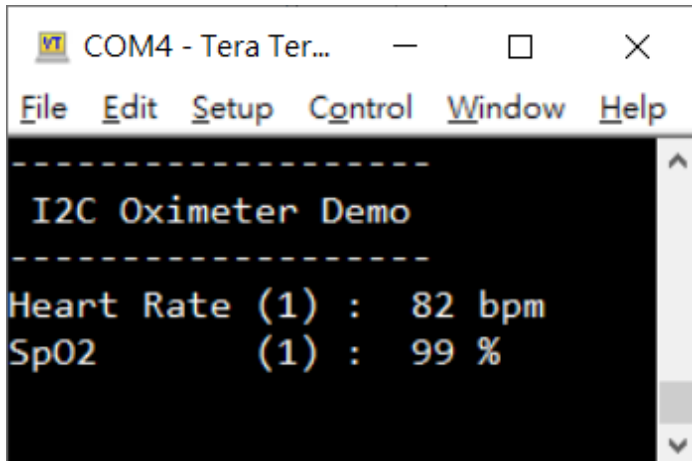
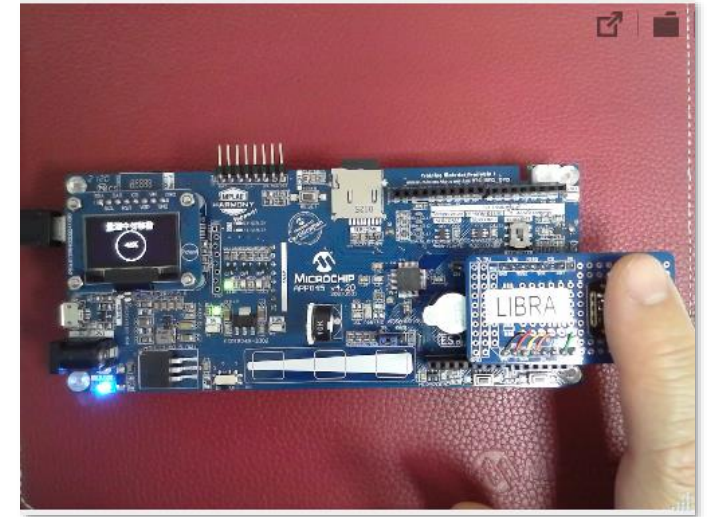
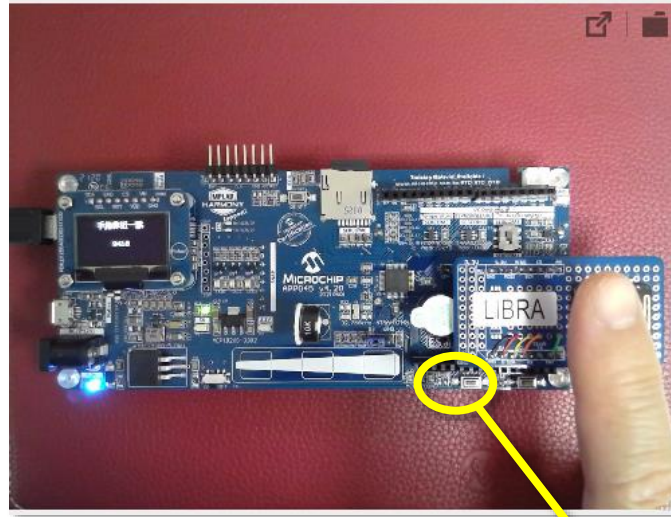
⚙️ LabX Heart Rate and Oximeter

- Find Peak Algorithm (Example)



✖ LabX Heart Rate and Oximeter

- Result Demo



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