ENGINE

Teaching online electronics, microcontrollers and programming in Higher Education

Programing of embedded systems

5. Digital Thermometer I2C

Lead Partner: Warsaw University of Technology

Authors: Daniel Krol

University of Applied Sciences in Tarnow

Erasmus+

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Declaration

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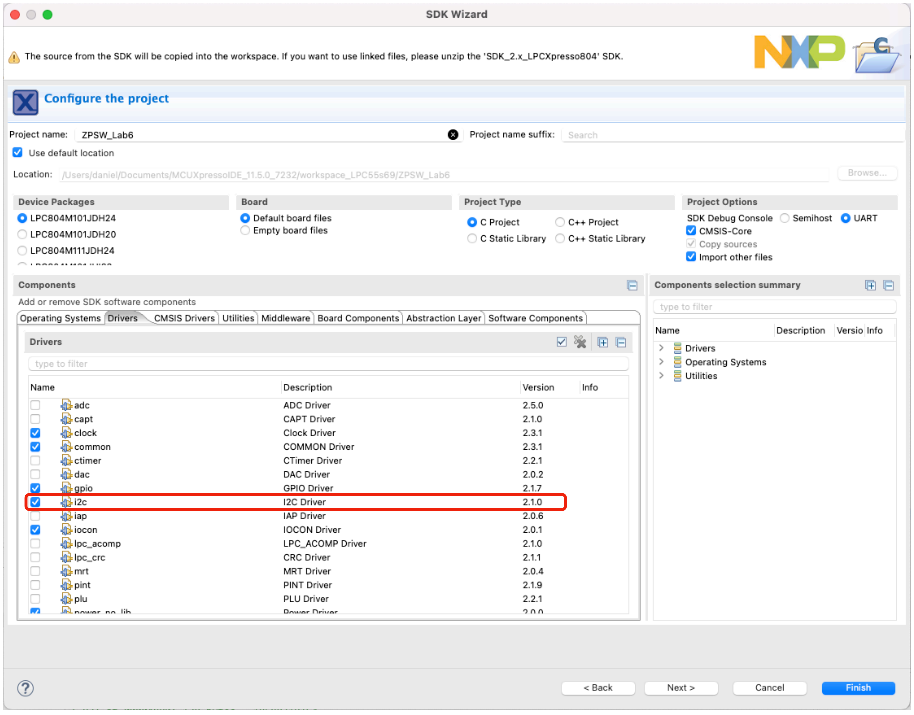
Programing of embedded systems

5. Digital thermometer I2C

I. Configuration of the I2C interface

1. Create a new project for the *LPCXpresso804* board and name it eg *Lab05*. Add the *i2c* driver:



SDK Wizard

The source from the SDK will be copied into the workspace. If you want to use linked files, please unzip the 'SDK_2.x_LPCXpresso804' SDK.

Configure the project

Project name: ZPSW_Lab6 Project name suffix: Search

☑ Use default location

Location: /Users/daniel/Documents/MCUXpressoIDE_11.5.0_7232/workspace_LPC55s69/ZPSW_Lab6 Browse...

Device Packages: ● LPC804M101JDH24 ○ LPC804M101JDH20 ○ LPC804M111JDH24

Board: ● Default board files ○ Empty board files

Project Type: ● C Project ○ C++ Project ○ C Static Library ○ C++ Static Library

Project Options: SDK Debug Console ○ Semihost ● UART; ☑ CMSIS-Core; ☑ Copy sources; ☑ Import other files

Components

Add or remove SDK software components

Operating Systems | Drivers | CMSIS Drivers | Utilities | Middleware | Board Components | Abstraction Layer | Software Components

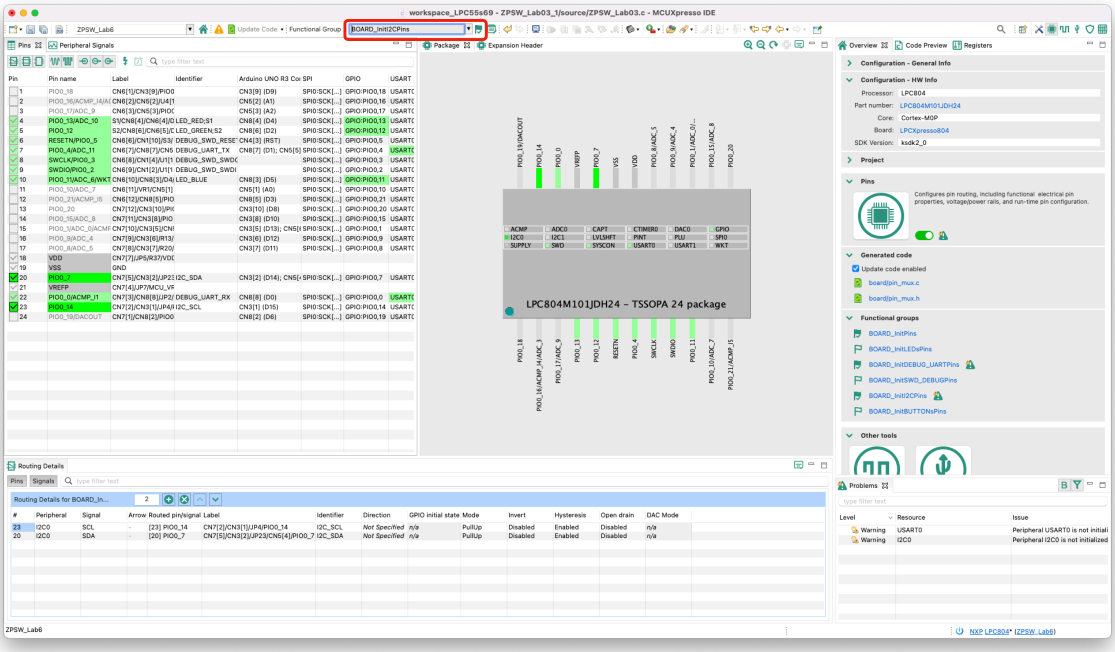
Drivers

	Name	Description	Version	Info
□	adc	ADC Driver	2.5.0	
□	capt	CAPT Driver	2.1.0	
☑	clock	Clock Driver	2.3.1	
☑	common	COMMON Driver	2.3.1	
□	ctimer	CTimer Driver	2.2.1	
□	dac	DAC Driver	2.0.2	
☑	gpio	GPIO Driver	2.1.7	
☑	i2c	I2C Driver	2.1.0	
□	iap	IAP Driver	2.0.6	
☑	iocon	IOCON Driver	2.0.1	
□	lpc_acomp	LPC_ACOMP Driver	2.1.0	
□	lpc_crc	CRC Driver	2.1.1	
□	mrt	MRT Driver	2.0.4	
□	pint	PINT Driver	2.1.9	
□	plu	PLU Driver	2.2.1	
☑	power_no_lib	Power Driver	2.0.0	

Components selection summary

Name	Description	Versio	Info
Drivers			
Operating Systems			
Utilities			

2. Go to Config Tools -> Open Pins. From the *Functional Group* menu select the *BOARD_InitI2CPins* preset, then activate it by selecting the flag icon on the left. The window now shows the automatically configured lines connected to I2C interface:



workspace_LPC55s69 - ZPSW_Lab03_1/source/ZPSW_Lab03.c - MCUXpresso IDE

ZPSW_Lab6 | Update Code | Functional Group: BOARD_InitI2CPins

Pins | Peripheral Signals

Pin	Pin name	Label	Identifier	Arduino UNO R3 Co	SPI	GPIO	USART
□ 1	PIO0_18	CN6[1]/CN3[9]/PIO0		CN3[9] (D9)	SPI0:SCK[...]	GPIO:PIO0,18	USARTC
□ 2	PIO0_16/ACMP_I4/AI	CN6[2]/CN5[2]/U4[1		CN5[2] (A1)	SPI0:SCK[...]	GPIO:PIO0,16	USARTC
□ 3	PIO0_17/ADC_9	CN6[3]/CN5[3]/PIOC		CN5[3] (A2)	SPI0:SCK[...]	GPIO:PIO0,17	USARTC
✓ 4	PIO0_13/ADC_10	S1/CN8[4]/CN6[4]/D	LED_RED;S1	CN8[4] (D4)	SPI0:SCK[...]	GPIO:PIO0,13	USARTC
✓ 5	PIO0_12	S2/CN8[6]/CN6[5]/D	LED_GREEN;S2	CN8[6] (D2)	SPI0:SCK[...]	GPIO:PIO0,12	USARTC
✓ 6	RESETN/PIO0_5	CN6[6]/CN1[10]/S3/	DEBUG_SWD_RESET	CN4[3] (RST)	SPI0:SCK[...]	GPIO:PIO0,5	USARTC
✓ 7	PIO0_4/ADC_11	CN6[7]/CN8[7]/CN5	DEBUG_UART_TX	CN8[7] (D1); CN5[5]	SPI0:SCK[...]	GPIO:PIO0,4	USARTC
✓ 8	SWCLK/PIO0_3	CN6[8]/CN1[4]/U1[1	DEBUG_SWD_SWDC		SPI0:SCK[...]	GPIO:PIO0,3	USARTC
✓ 9	SWDIO/PIO0_2	CN6[9]/CN1[2]/U1[1	DEBUG_SWD_SWDI		SPI0:SCK[...]	GPIO:PIO0,2	USARTC
✓ 10	PIO0_11/ADC_6/WKT	CN6[10]/CN8[3]/D4/	LED_BLUE	CN8[3] (D5)	SPI0:SCK[...]	GPIO:PIO0,11	USARTC
□ 11	PIO0_10/ADC_7	CN6[11]/VR1/CN5[1]		CN5[1] (A0)	SPI0:SCK[...]	GPIO:PIO0,10	USARTC
□ 12	PIO0_21/ACMP_I5	CN6[12]/CN8[5]/PIO		CN8[5] (D3)	SPI0:SCK[...]	GPIO:PIO0,21	USARTC
□ 13	PIO0_20	CN7[12]/CN3[10]/PIC		CN3[10] (D8)	SPI0:SCK[...]	GPIO:PIO0,20	USARTC
□ 14	PIO0_15/ADC_8	CN7[11]/CN3[8]/PIO		CN3[8] (D10)	SPI0:SCK[...]	GPIO:PIO0,15	USARTC
□ 15	PIO0_1/ADC_0/ACMF	CN7[10]/CN3[5]/CN!		CN3[5] (D13); CN5[(	SPI0:SCK[...]	GPIO:PIO0,1	USARTC
□ 16	PIO0_9/ADC_4	CN7[9]/CN3[6]/R13/		CN3[6] (D12)	SPI0:SCK[...]	GPIO:PIO0,9	USARTC
□ 17	PIO0_8/ADC_5	CN7[8]/CN3[7]/R20/		CN3[7] (D11)	SPI0:SCK[...]	GPIO:PIO0,8	USARTC
✓ 18	VDD	CN7[7]/JP5/R37/VDD					
✓ 19	VSS	GND					
☑ 20	PIO0_7	CN7[5]/CN3[2]/JP23	I2C_SDA	CN3[2] (D14); CN5[4	SPI0:SCK[...]	GPIO:PIO0,7	USARTC
✓ 21	VREFP	CN7[4]/JP7/MCU_VR					
✓ 22	PIO0_0/ACMP_I1	CN7[3]/CN8[8]/JP2/	DEBUG_UART_RX	CN8[8] (D0)	SPI0:SCK[...]	GPIO:PIO0,0	USARTC
☑ 23	PIO0_14	CN7[2]/CN3[1]/JP4/F	I2C_SCL	CN3[1] (D15)	SPI0:SCK[...]	GPIO:PIO0,14	USARTC
□ 24	PIO0_19/DACOUT	CN7[1]/CN8[2]/PIO0		CN8[2] (D6)	SPI0:SCK[...]	GPIO:PIO0,19	USARTC

Overview | Code Preview | Registers

Configuration - General Info

Configuration - HW Info

Processor: LPC804

Part number: LPC804M101JDH24

Core: Cortex-M0P

Board: LPCXpresso804

SDK Version: ksdk2_0

Project

Pins

Configures pin routing, including functional electrical pin properties, voltage/power rails, and run-time pin configuration.

Generated code

☑ Update code enabled

board/pin_mux.c

board/pin_mux.h

Functional groups

BOARD_InitPins

BOARD_InitLEDsPins

BOARD_InitDEBUG_UARTPins

BOARD_InitSWD_DEBUGPins

BOARD_InitI2CPins

BOARD_InitBUTTONsPins

Other tools

Routing Details

Pins | Signals

Routing Details for BOARD_In... 2

#	Peripheral	Signal	Arrow	Routed pin/signal	Label	Identifier	Direction	GPIO initial state	Mode	Invert	Hysteresis	Open drain	DAC Mode
23	I2C0	SCL	-	[23] PIO0_14	CN7[2]/CN3[1]/JP4/PIO0_14	I2C_SCL	*Not Specified*	*n/a*	PullUp	Disabled	Enabled	Disabled	*n/a*
20	I2C0	SDA	-	[20] PIO0_7	CN7[5]/CN3[2]/JP23/CN5[4]/PIO0_7	I2C_SDA	*Not Specified*	*n/a*	PullUp	Disabled	Enabled	Disabled	*n/a*

Problems

Level	Resource	Issue
Warning	USART0	Peripheral USART0 is not initiali
Warning	I2C0	Peripheral I2C0 is not initialized

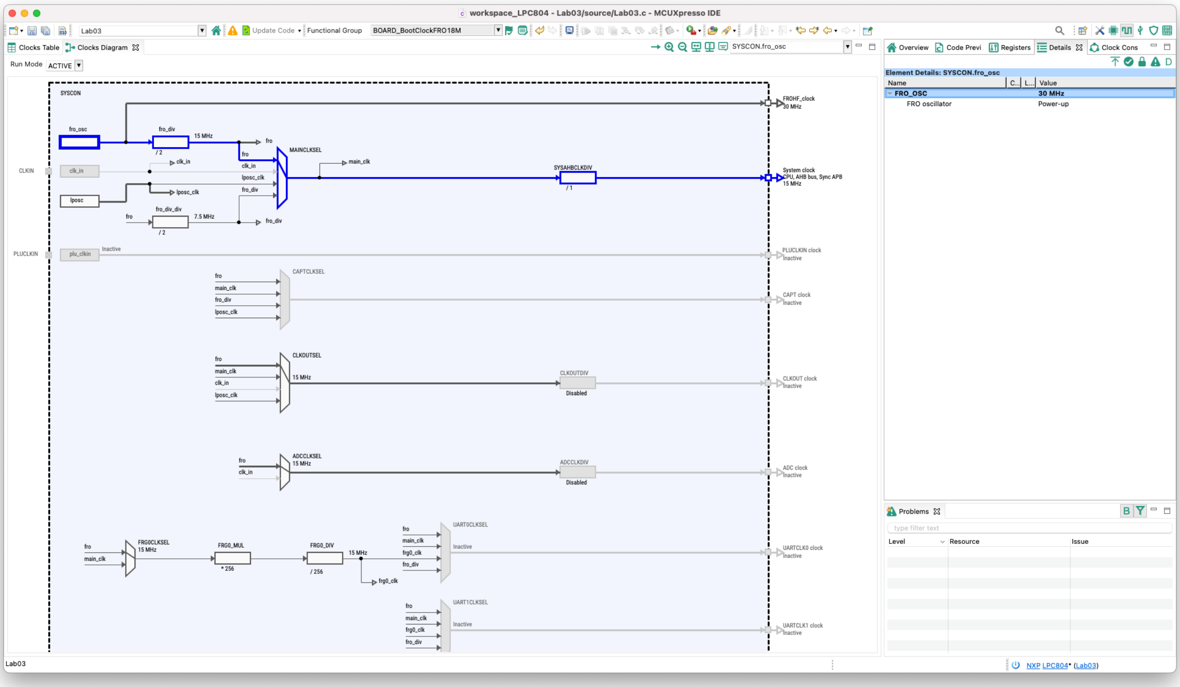
ZPSW_Lab6

NXP LPC804* (ZPSW_Lab6)

Programing of embedded systems

5. Digital thermometer I2C

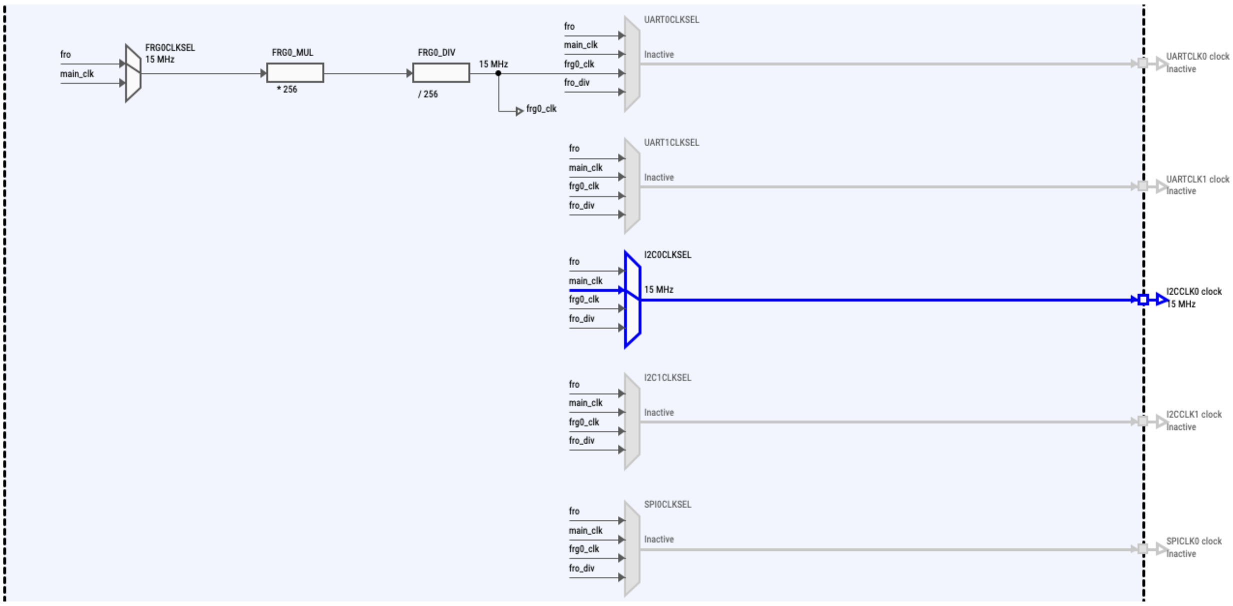
3. Go to the *Clocks* tab and then double-click on the *FRO_OSC* block and change the *FRO_OSC* to 30 MHz clock:



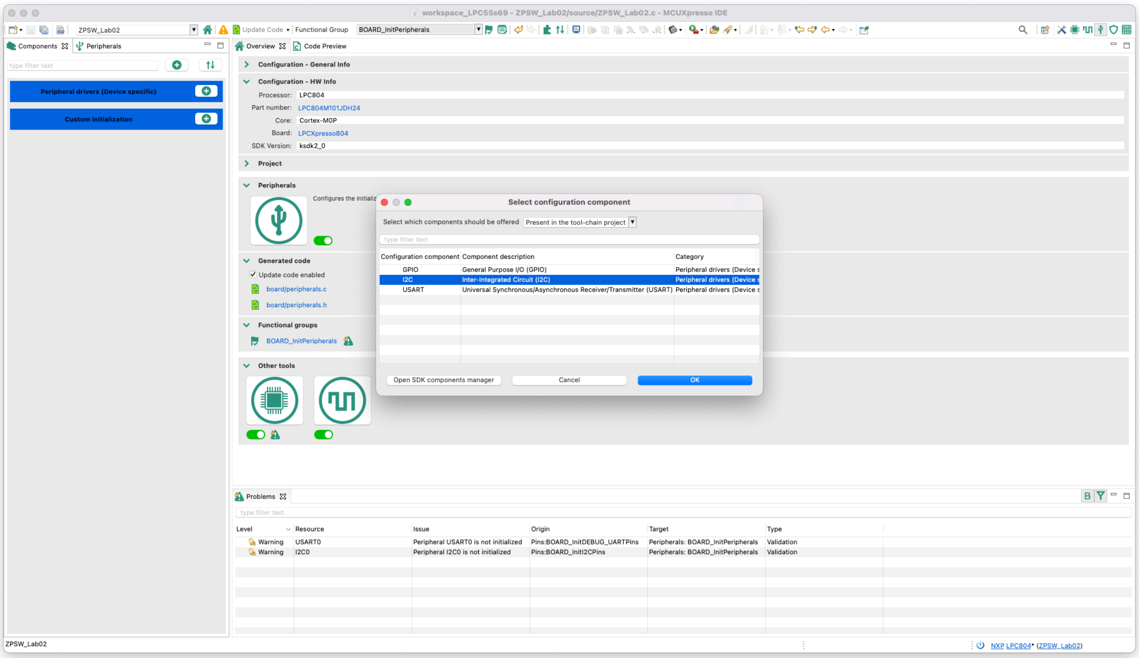
Element Details: SYSCON.fro_osc

Name	C...	L...	Value
FRO_OSC			30 MHz
FRO oscillator			Power-up

4. Next double-click on the *I2C0CLKSEL* block and set the *main_clk* (15 MHz) clock:



5. Go to the Peripherals tab and then click on *Peripheral* drivers and select *I2C* from the list:



Processor: LPC804
Part number: LPC804M101JDH24
Core: Cortex-M0P
Board: LPCXpresso804
SDK Version: ksdk2_0

☑ Update code enabled
board/peripherals.c
board/peripherals.h

Select configuration component

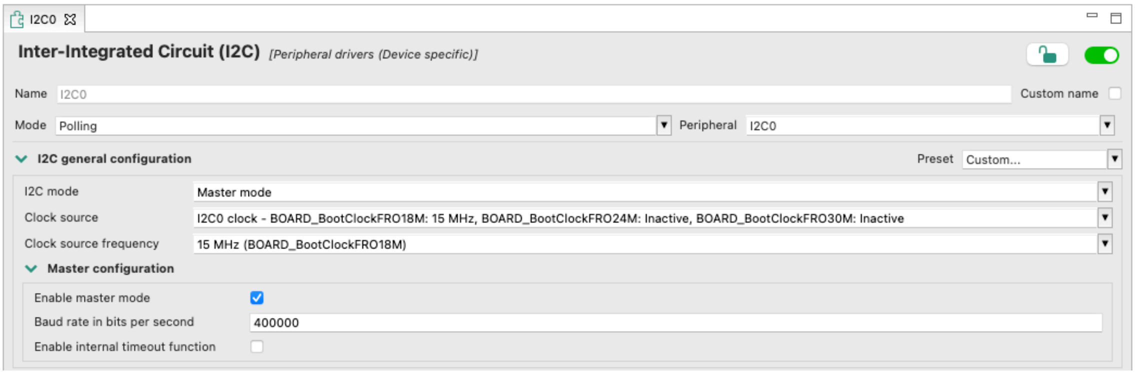
Select which components should be offered: Present in the tool-chain project

Configuration component	Component description	Category
GPIO	General Purpose I/O (GPIO)	Peripheral drivers (Device s
I2C	Inter-Integrated Circuit (I2C)	Peripheral drivers (Device s
USART	Universal Synchronous/Asynchronous Receiver/Transmitter (USART)	Peripheral drivers (Device s

Open SDK components manager | Cancel | OK

Level	Resource	Issue	Origin	Target	Type
Warning	USART0	Peripheral USART0 is not initialized	Pins:BOARD_InitDEBUG_UARTPins	Peripherals: BOARD_InitPeripherals	Validation
Warning	I2C0	Peripheral I2C0 is not initialized	Pins:BOARD_InitI2CPins	Peripherals: BOARD_InitPeripherals	Validation

6. Select the *I2C0* interface and change the default baud rate to 400 000 bps:



Inter-Integrated Circuit (I2C) *[Peripheral drivers (Device specific)]*

Name: I2C0 — Custom name □

Mode: Polling — Peripheral: I2C0

I2C general configuration — Preset: Custom...

I2C mode: Master mode
Clock source: I2C0 clock - BOARD_BootClockFRO18M: 15 MHz, BOARD_BootClockFRO24M: Inactive, BOARD_BootClockFRO30M: Inactive
Clock source frequency: 15 MHz (BOARD_BootClockFRO18M)

Master configuration

Enable master mode: ☑
Baud rate in bits per second: 400000
Enable internal timeout function: □

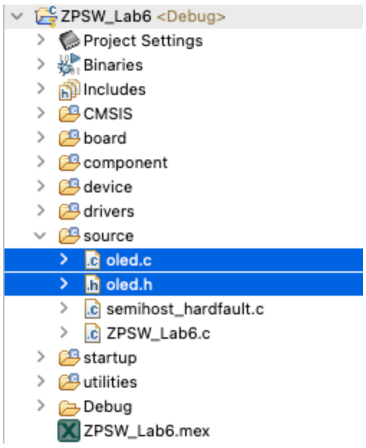
Then click *Update Code* to generate the I2C configuration code.

Programing of embedded systems

5. Digital thermometer I2C

II. Graphic display

1. Add the OLED display library to the project (drag files to workspace):



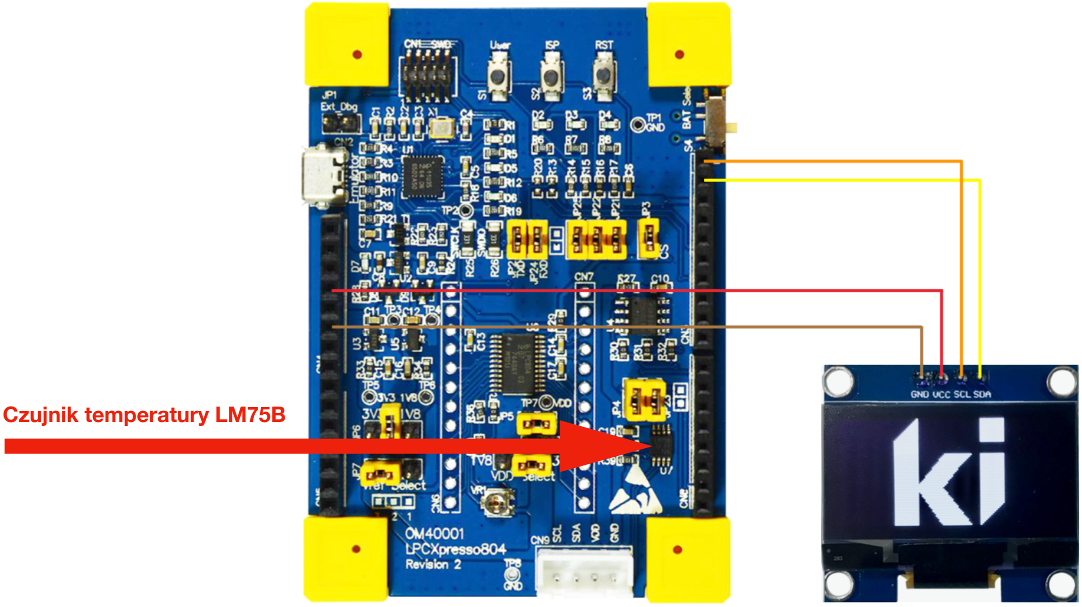
```
ZPSW_Lab6 <Debug>
  Project Settings
  Binaries
  Includes
  CMSIS
  board
  component
  device
  drivers
  source
    oled.c
    oled.h
    semihost_hardfault.c
    ZPSW_Lab6.c
  startup
  utilities
  Debug
  ZPSW_Lab6.mex
```

2. Go to the main project file and modify the code as below:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"
#include "oled.h"
/*
 * @brief   Application entry point.
 */
int main(void) {
          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif
          /* Initialize OLED */
          OLED_Init(I2C0_PERIPHERAL);
          OLED_Draw_Bitmap(LogoKI);
          OLED_Refresh_Gram();

          while(1) {
          }
          return 0 ;
}
```

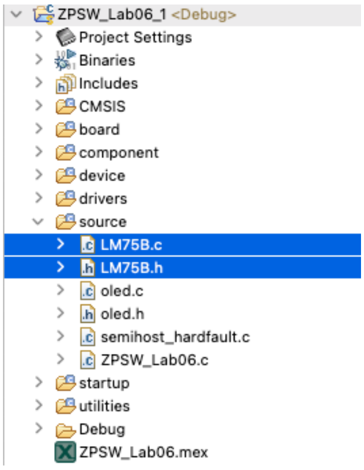
3. Connect the display to the prototype board according to the diagram below:



4. Build a project, program the microcontroller and check the operation.

III. LM75B library

1. Create thermometer library files. To do this, right-click on the source folder in workspace and then select *New-> Header File* and name it *LM75B.h*.
2. Similarly, by right-clicking on the source folder in workspace, select *New-> Source File* and name it *LM75B.c*:



```
ZPSW_Lab06_1 <Debug>
  Project Settings
  Binaries
  Includes
  CMSIS
  board
  component
  device
  drivers
  source
    LM75B.c
    LM75B.h
    oled.c
    oled.h
    semihost_hardfault.c
    ZPSW_Lab06.c
  startup
  utilities
  Debug
  ZPSW_Lab06.mex
```

3. Go to the *LM75.h* file and add the code:

```
#ifndef LM75B_H_
#define LM75B_H_

#include "fsl_i2c.h"

#define LM75_REG_TEMP (0x00) // Temperature Register
#define LM75_REG_CONF (0x01) // Configuration Register
#define LM75_ADDR     (0x48) // LM75 address

void  LM75B_Init(I2C_Type *base);
float LM75B_Read();

#endif /* LM75B_H_ */
```

4. Go to the *LM75.c* file and add the code:

```
#include "LM75B.h"

static I2C_Type *I2C_base=NULL;

void LM75B_Init(I2C_Type *base) {

        I2C_base=base;

        char data_write[2];

        data_write[0] = LM75_REG_CONF;
        data_write[1] = 0x02;

        if (kStatus_Success == I2C_MasterStart(I2C_base, LM75_ADDR, kI2C_Write)) {

                I2C_MasterWriteBlocking(I2C_base, &data_write[0], 2, kI2C_TransferDefaultFlag);
                I2C_MasterStop(I2C_base);
        }
}

float LM75B_Read() {

        char data_read[2];
        char data_write[1];
        float temp;
        int16_t v;

        data_write[0] = LM75_REG_TEMP;

        if (kStatus_Success == I2C_MasterStart(I2C_base, LM75_ADDR, kI2C_Write)) {

                I2C_MasterWriteBlocking(I2C_base, &data_write[0], 1, kI2C_TransferNoStopFlag);
```

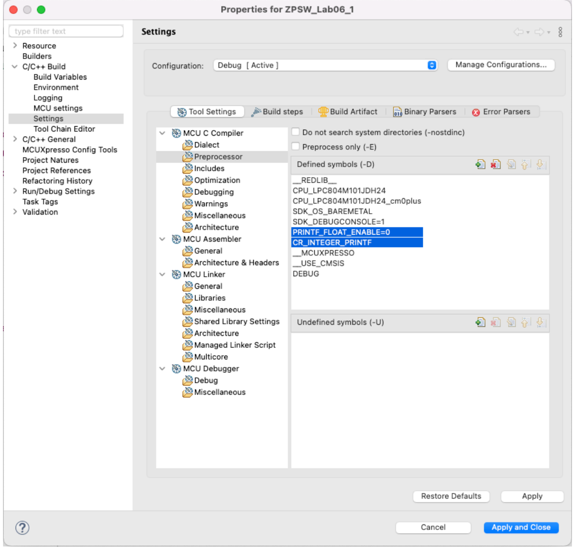
```
                    I2C_MasterRepeatedStart(I2C_base, LM75_ADDR, kI2C_Read);
                    I2C_MasterReadBlocking(I2C_base, &data_read[0], 2, kI2C_TransferDefaultFlag);

                    I2C_MasterStop(I2C_base);
          }

          v= (data_read[0] << 8) | data_read[1];
          temp = v / 256.0; // temperature value in Celsius

          return temp;
}
```

5. Go to project settings. Right-click on the project name, select *Properties* and then *Settings -> Preprocessor*. Change the *PRINTF_FLOAT_ENABLE* flag to 1 and remove the *CR_INTEGER_PRINTF* flag:



Configuration: Debug [Active]

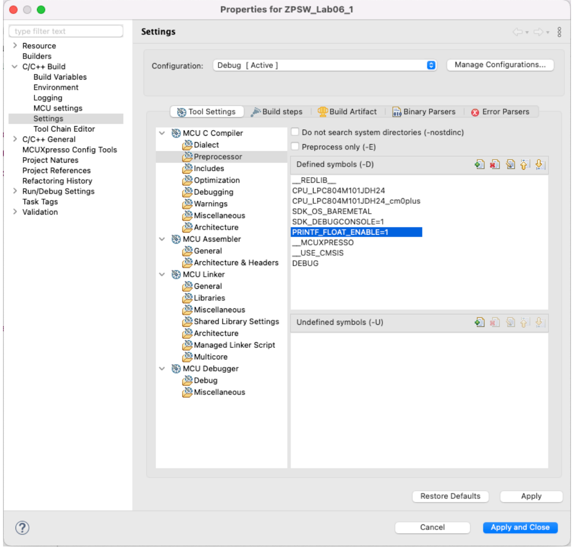
□ Do not search system directories (-nostdinc)

□ Preprocess only (-E)

Defined symbols (-D)

```
__REDLIB__
CPU_LPC804M101JDH24
CPU_LPC804M101JDH24_cm0plus
SDK_OS_BAREMETAL
SDK_DEBUGCONSOLE=1
PRINTF_FLOAT_ENABLE=0
CR_INTEGER_PRINTF
__MCUXPRESSO
__USE_CMSIS
DEBUG
```

Undefined symbols (-U)



Configuration: Debug [Active]

□ Do not search system directories (-nostdinc)

□ Preprocess only (-E)

Defined symbols (-D)

```
__REDLIB__
CPU_LPC804M101JDH24
CPU_LPC804M101JDH24_cm0plus
SDK_OS_BAREMETAL
SDK_DEBUGCONSOLE=1
PRINTF_FLOAT_ENABLE=1
__MCUXPRESSO
__USE_CMSIS
DEBUG
```

Undefined symbols (-U)

6. Go to the main program file and modify the code:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"
#include "oled.h"
#include "LM75B.h"

char sbuff[32];
float temp;

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          /* Initialize OLED */
          OLED_Init(I2C0_PERIPHERAL);
          OLED_Draw_Bitmap(LogoKI);
          OLED_Refresh_Gram();

          /* Initialize LM75 */
          LM75B_Init(I2C0_PERIPHERAL);

          while(1) {

                    OLED_Clear_Screen(0);

                    temp = LM75B_Read();

                    sprintf(sbuff, "t: %.3f C", temp);
                    OLED_Puts(0,0, sbuff);

                    OLED_Refresh_Gram();
          }
          return 0 ;
}
```

7. Build the project, program the chip and check the temperature reading (you can gently touch the LM75B chip to change the temperature).

IV. Simple GUI

1. Add a 7-segment display simulation for temperature display:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"
#include "oled.h"
#include "LM75B.h"

char sbuff[32];
float temp;

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          /* Initialize OLED */
          OLED_Init(I2C0_PERIPHERAL);

          /* Initialize LM75 */
          LM75B_Init(I2C0_PERIPHERAL);

          while(1) {

                    temp = LM75B_Read();

                    OLED_Clear_Screen(0);

                    OLED_7segf(0, 4, temp, 4, 1, 1);
                    OLED_Puts(105, 1, "C");

                    OLED_Refresh_Gram();
          }
          return 0 ;
}
```

2. Build the project, program the chip and check the temperature reading.
3. Add a bargraph:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"
#include "oled.h"
#include "LM75B.h"

char sbuff[32];
float temp;

#define T_MIN       0
#define T_MAX       40


void Bargraph(uint8_t x, uint8_t y, uint8_t w, uint8_t h, float min, float max, float v) {

          if(v<min) {
                    v=min;
          }
          if(v>max) {
                    v=max;
          }
          v = ((v-min)*w)/(max-min);

          OLED_Draw_Rect(x , y, x+w-1, y+h-1, 1);
          OLED_Draw_Fill_Rect(x+2, y+2, x+v-3 , y+h-3, 1);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          /* Initialize OLED */
          OLED_Init(I2C0_PERIPHERAL);

          /* Initialize LM75 */
          LM75B_Init(I2C0_PERIPHERAL);

          while(1) {

                    temp = LM75B_Read();

                    OLED_Clear_Screen(0);

                    OLED_7segf(0, 4, temp, 4, 1, 1);
                    OLED_Puts(105, 1, "C");

                    Bargraph(0, 45, 128, 8, T_MIN, T_MAX, temp);

                    sprintf(sbuff, "%d", T_MIN);
                    OLED_Puts(0, 7, sbuff);
                    sprintf(sbuff, "%3d", T_MAX);
                    OLED_Puts(110, 7, sbuff);

                    OLED_Refresh_Gram();
          }
          return 0 ;
}
```

4. Build the project, program the chip and check the temperature reading.

V. Exercises

1. Check barograph indications for different ranges *T_MIN* and *T_MAX*..
2. Implement a moving average filter a certain number of measurements given by the equation:

$$y(n) = \frac{1}{N}\sum_{k=0}^{N-1} x(n-k) \text{ dla } n = 0, 1, 2, 3, \ldots$$

in *FilterAVG* function:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"
#include "oled.h"
#include "LM75B.h"

char sbuff[32];
float temp;

#define T_MIN       0
#define T_MAX       40
#define N 16

float FilterAVG(float x) {


}
```

```c
void Bargraph(uint8_t x, uint8_t y, uint8_t w, uint8_t h, float min, float max, float v) {

        if(v<min) {
                v=min;
        }
        if(v>max) {
                v=max;
        }
        v = ((v-min)*w)/(max-min);

        OLED_Draw_Rect(x , y, x+w-1, y+h-1, 1);
        OLED_Draw_Fill_Rect(x+2, y+2, x+v-3 , y+h-3, 1);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

        /* Init board hardware. */
        BOARD_InitBootPins();
        BOARD_InitBootClocks();
        BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
        /* Init FSL debug console. */
        BOARD_InitDebugConsole();
#endif
        /* Initialize OLED */
        OLED_Init(I2C0_PERIPHERAL);

        /* Initialize LM75 */
        LM75B_Init(I2C0_PERIPHERAL);

        while(1) {

                temp = LM75B_Read();
                temp = FilterAVG(temp);

                OLED_Clear_Screen(0);

                OLED_7segf(0, 4, temp, 4, 1, 1);
                OLED_Puts(105, 1, "C");

                Bargraph(0, 45, 128, 8, T_MIN, T_MAX, temp);

                sprintf(sbuff, "%d", T_MIN);
                OLED_Puts(0, 7, sbuff);
                sprintf(sbuff, "%3d", T_MAX);
                OLED_Puts(110, 7, sbuff);

                OLED_Refresh_Gram();
        }
        return 0 ;
}
```