ENGINE

Teaching online electronics, microcontrollers and programming in Higher Education

Programing of embedded systems

4. I2C Graphic display library

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Declaration

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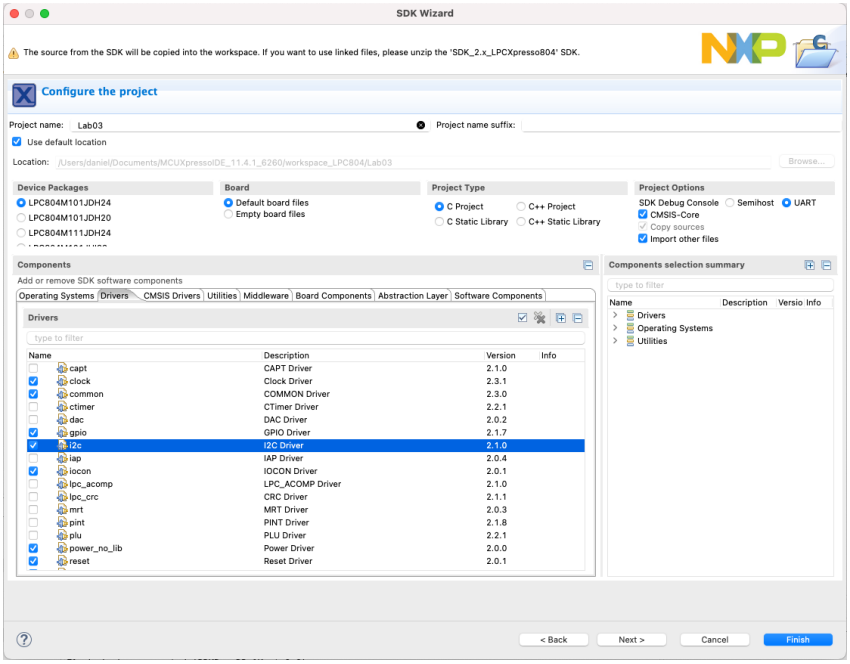
Programing of embedded systems

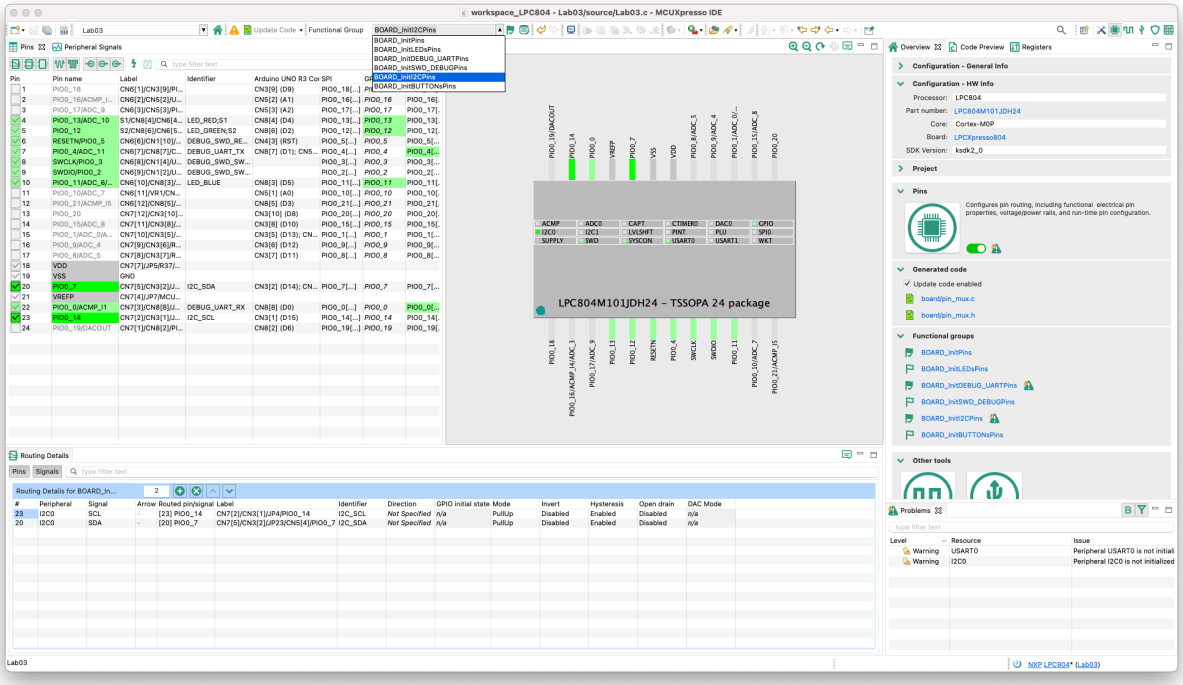
4. I2C Graphic display library

I. Configuration of the I2C interface

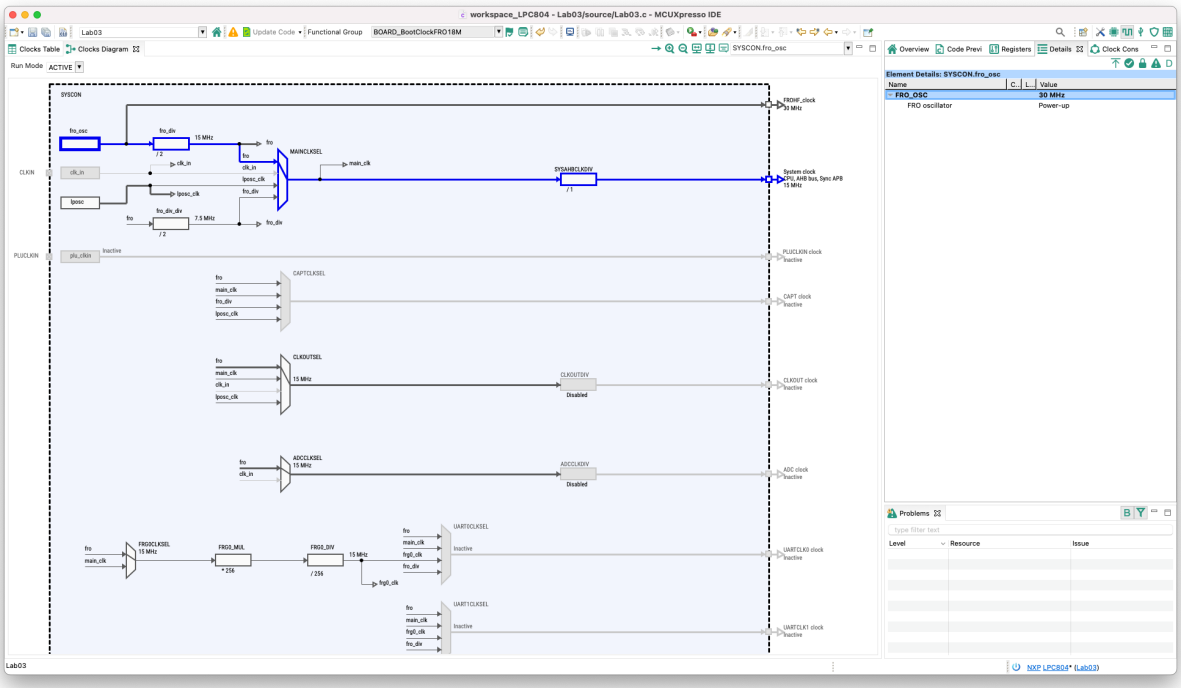
1. Create a new project for the *LPCXpresso804* board and name it eg *Lab03*. Add the *i2c* driver:



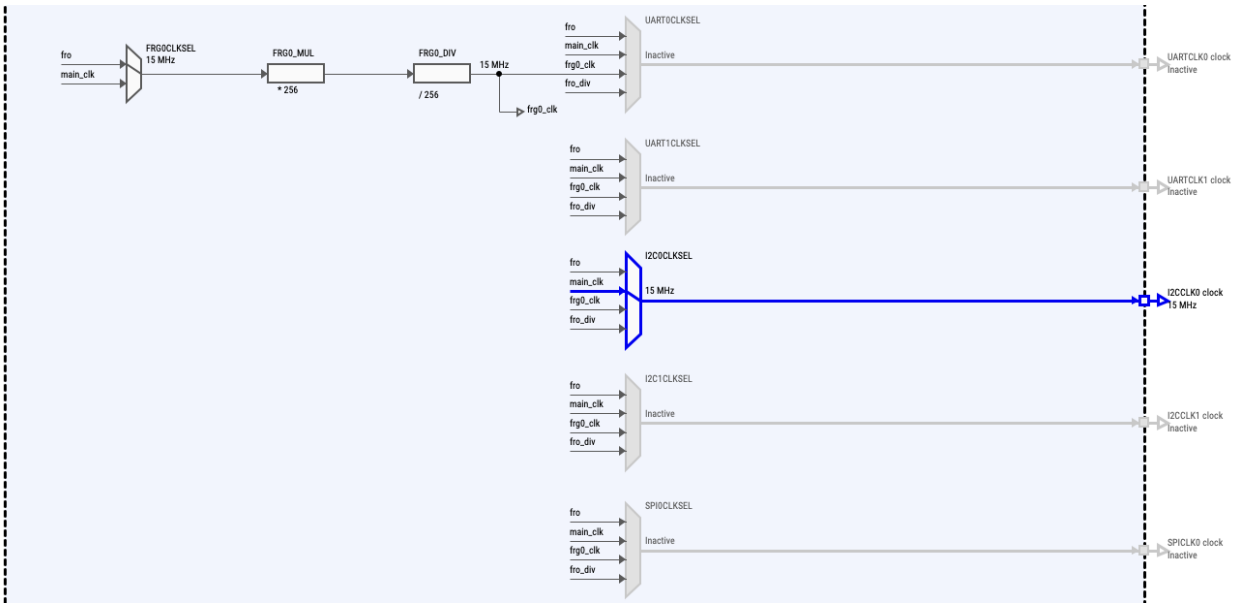
2. Go to Config Tools -> Open Pins. From the *Functional Group* menu select the *BOARD_InitI2CPins* preset, then activate it by selecting the flag icon on the left. The window now shows the automatically configured lines connected to *I2C* interface:



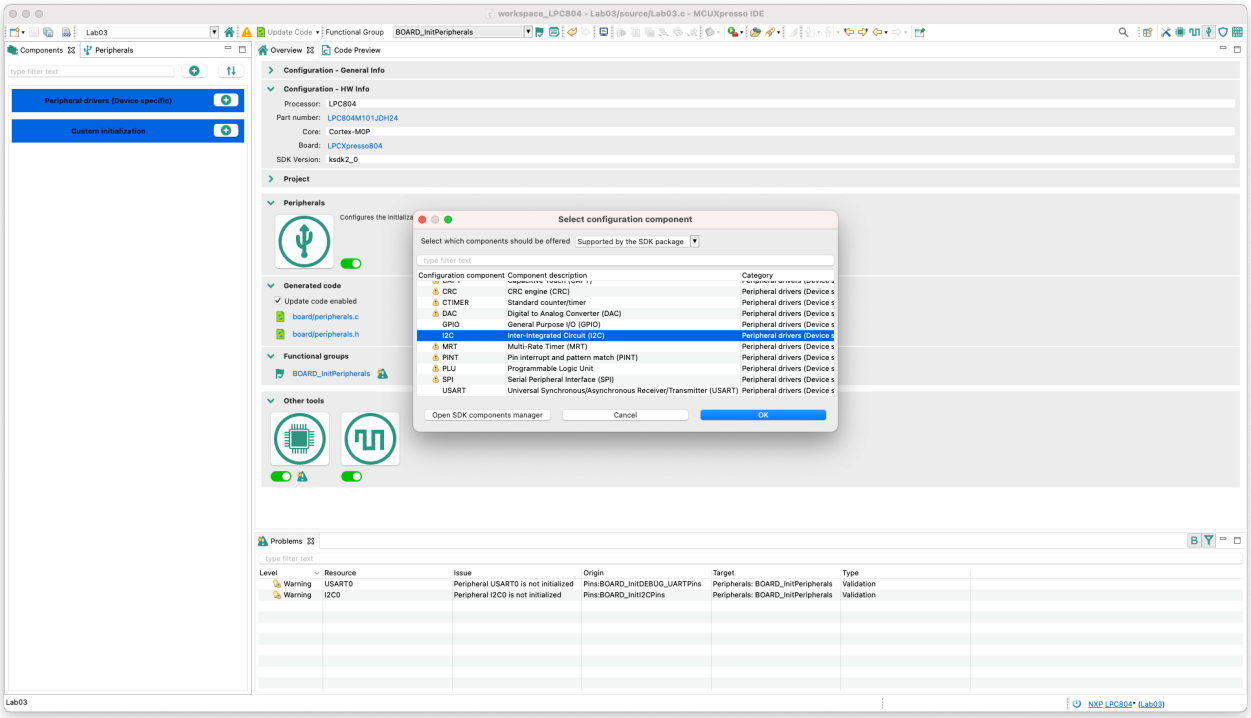
3. Go to the *Clocks* tab and then double-click on the *FRO_OSC* block and change the *FRO_OSC* to 30 MHz clock:



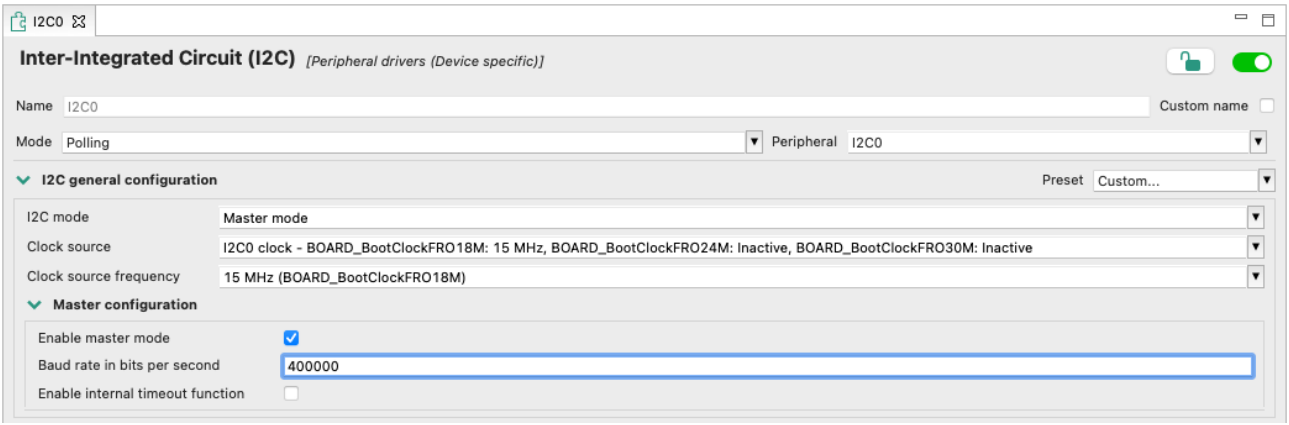
4. Next double-click on the *I2C0CLKSEL* block and set the *main_clk* (15 MHz) clock:



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



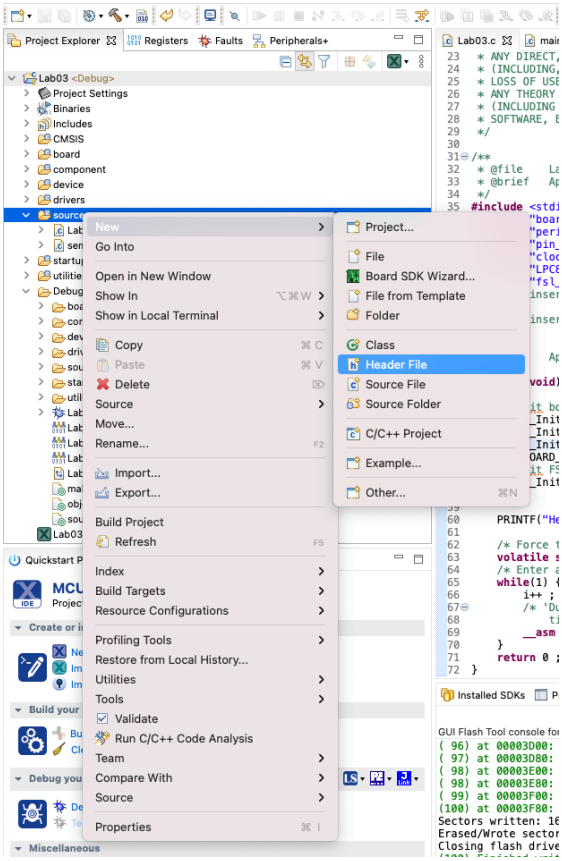
6. Select the *I2C0* interface and change the default baud rate to 400000 bps:



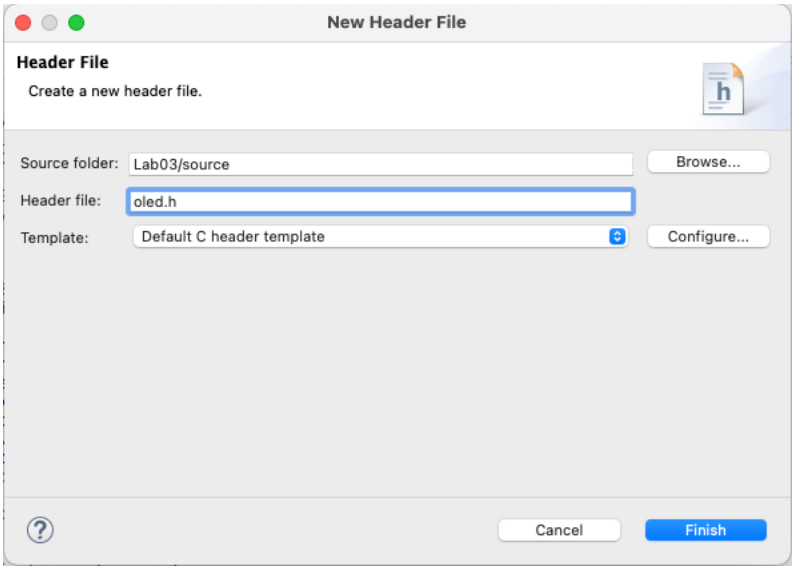
Then click *Update Code* to generate the I2C configuration code.

II. Display library

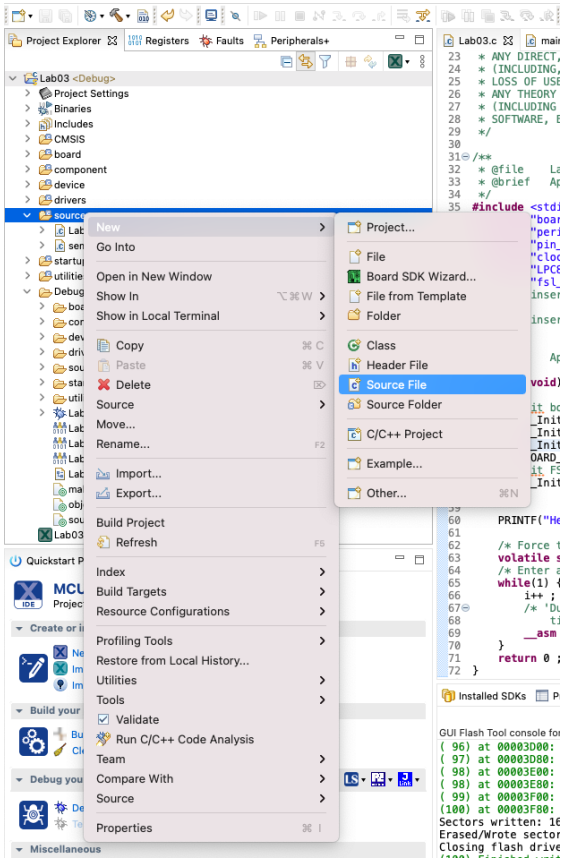
1. Right-click on the *source* folder in *workspace* and select *New->Header File,* as in the picture below:



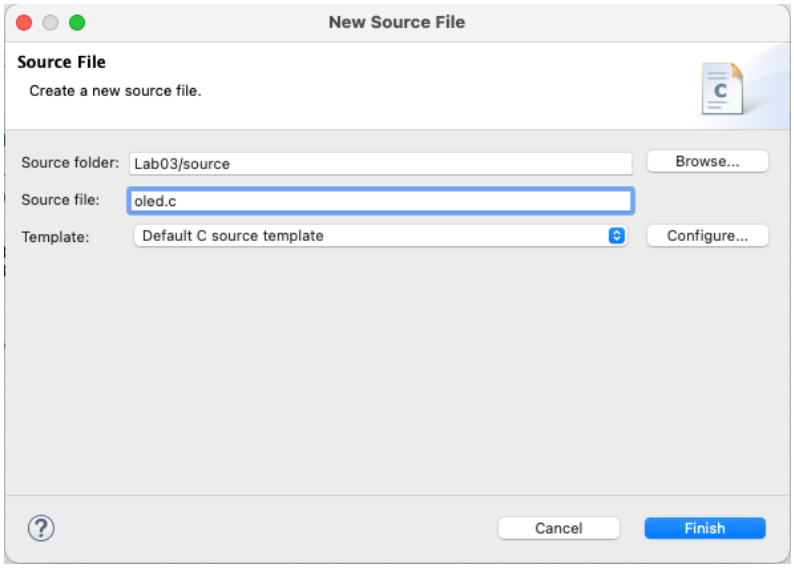
2. Set name *oled.h*:



3. Next, Right-click on the *source* folder in *workspace* and select *New->Source File,* as in the picture below:



4. Set name *oled.c*:



5. Go to the *oled.h* file and add the code as below:

```
#ifndef OLED_H_
#define OLED_H_

#include "fsl_i2c.h"
#include <stdlib.h>

#define I2C_MASTER_SLAVE_ADDR_7BIT 0x3C

#define __SET_COL_START_ADDR()          {OLED_Write_Byte(0x02, OLED_CMD); OLED_Write_Byte(0x10, OLED_CMD);}

#define OLED_CMD               0
#define OLED_DAT               1
#define OLED_WIDTH           128
#define OLED_HEIGHT           64
#define OLED_PAGES          (OLED_HEIGHT / 8)

void OLED_Init(I2C_Type *base);
void OLED_Display_On(void);
void OLED_Display_Off(void);
void OLED_Refresh_Gram(void);
void OLED_Clear_Screen(uint8_t fill);

void OLED_Puts(uint8_t x, uint8_t y, char *text);

#endif /* OLED_H_ */
```

6. Go to the *oled.c* file and add the code as below:

```
#include "oled.h"

static void OLED_Write_Byte(uint8_t chData, uint8_t chCmd);

I2C_Type *I2C_base=NULL;
static uint8_t s_chDispalyBuffer[OLED_WIDTH][OLED_PAGES];
static uint8_t cmd_buff[2];
const unsigned char FontSystem5x8[]=
{
                    0x00,0x00,0x00,0x00,0x00, /* Space */
                    0x00,0x00,0x4f,0x00,0x00, /* ! */
                    0x00,0x07,0x00,0x07,0x00, /* " */
                    0x14,0x7f,0x14,0x7f,0x14, /* # */
                    0x24,0x2a,0x7f,0x2a,0x12, /* 0x */
                    0x23,0x13,0x08,0x64,0x62, /* % */
                    0x36,0x49,0x55,0x22,0x20, /* & */
                    0x00,0x05,0x03,0x00,0x00, /* ' */
                    0x00,0x1c,0x22,0x41,0x00, /* ( */
                    0x00,0x41,0x22,0x1c,0x00, /* ) */
                    0x14,0x08,0x3e,0x08,0x14, /* // */
                    0x08,0x08,0x3e,0x08,0x08, /* + */
                    0x50,0x30,0x00,0x00,0x00, /* , */
                    0x08,0x08,0x08,0x08,0x08, /* - */
                    0x00,0x60,0x60,0x00,0x00, /* . */
                    0x20,0x10,0x08,0x04,0x02, /* / */
                    0x3e,0x51,0x49,0x45,0x3e, /* 0 */
                    0x00,0x42,0x7f,0x40,0x00, /* 1 */
                    0x42,0x61,0x51,0x49,0x46, /* 2 */
                    0x21,0x41,0x45,0x4b,0x31, /* 3 */
                    0x18,0x14,0x12,0x7f,0x10, /* 4 */
                    0x27,0x45,0x45,0x45,0x39, /* 5 */
                    0x3c,0x4a,0x49,0x49,0x30, /* 6 */
                    0x07,0x71,0x09,0x05,0x03, /* 7 */
                    0x36,0x49,0x49,0x49,0x36, /* 8 */
                    0x06,0x49,0x49,0x29,0x1e, /* 9 */
                    0x00,0x36,0x36,0x00,0x00, /* : */
                    0x00,0x56,0x36,0x00,0x00, /* ; */
                    0x08,0x14,0x22,0x41,0x00, /* < */
                    0x14,0x14,0x14,0x14,0x14, /* = */
                    0x00,0x41,0x22,0x14,0x08, /* > */
                    0x02,0x01,0x51,0x09,0x06, /* ? */
                    0x3e,0x41,0x5d,0x55,0x1e, /* @ */
                    0x7e,0x11,0x11,0x11,0x7e, /* A */
                    0x7f,0x49,0x49,0x49,0x36, /* B */
                    0x3e,0x41,0x41,0x41,0x22, /* C */
                    0x7f,0x41,0x41,0x22,0x1c, /* D */
                    0x7f,0x49,0x49,0x49,0x41, /* E */
                    0x7f,0x09,0x09,0x09,0x01, /* F */
                    0x3e,0x41,0x49,0x49,0x7a, /* G */
                    0x7f,0x08,0x08,0x08,0x7f, /* H */
                    0x00,0x41,0x7f,0x41,0x00, /* I */
                    0x20,0x40,0x41,0x3f,0x01, /* J */
                    0x7f,0x08,0x14,0x22,0x41, /* K */
                    0x7f,0x40,0x40,0x40,0x40, /* L */
                    0x7f,0x02,0x0c,0x02,0x7f, /* M */
                    0x7f,0x04,0x08,0x10,0x7f, /* N */
                    0x3e,0x41,0x41,0x41,0x3e, /* O */
                    0x7f,0x09,0x09,0x09,0x06, /* P */
                    0x3e,0x41,0x51,0x21,0x5e, /* Q */
                    0x7f,0x09,0x19,0x29,0x46, /* R */
                    0x26,0x49,0x49,0x49,0x32, /* S */
                    0x01,0x01,0x7f,0x01,0x01, /* T */
                    0x3f,0x40,0x40,0x40,0x3f, /* U */
                    0x1f,0x20,0x40,0x20,0x1f, /* V */
                    0x3f,0x40,0x38,0x40,0x3f, /* W */
                    0x63,0x14,0x08,0x14,0x63, /* X */
```

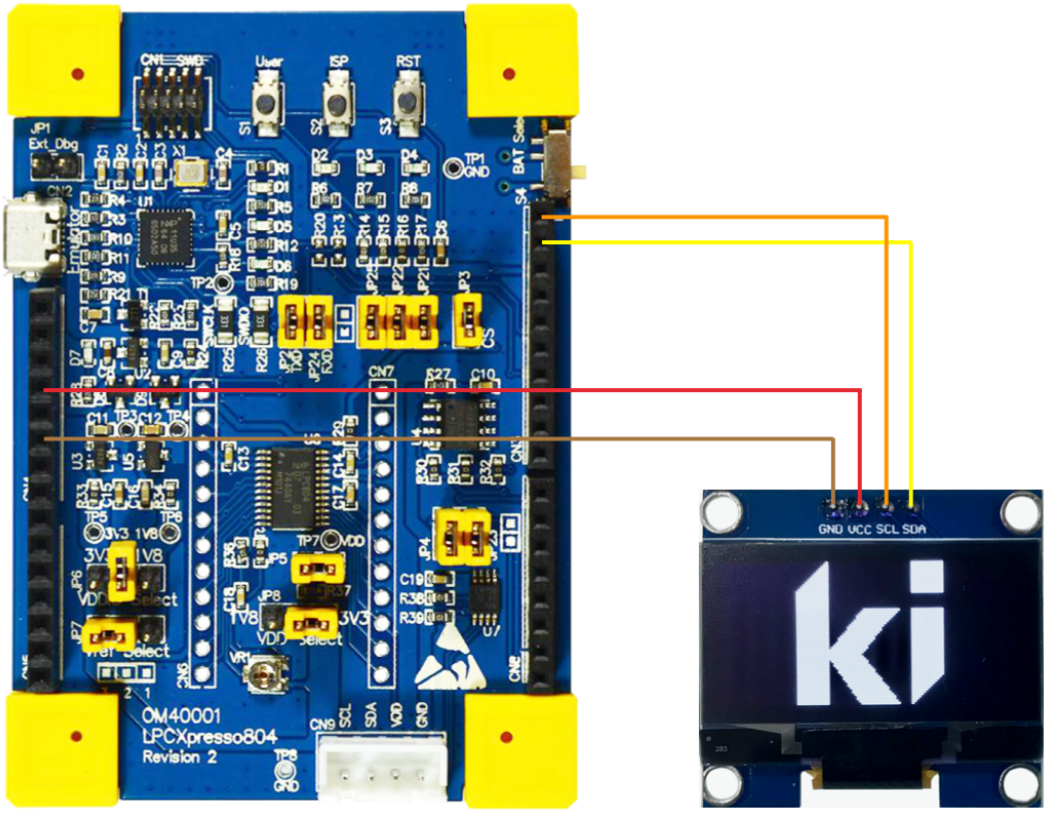
```
                    0x07,0x08,0x70,0x08,0x07, /* Y */
                    0x61,0x51,0x49,0x45,0x43, /* Z */
                    0x00,0x7f,0x41,0x41,0x00, /* [ */
                    0x02,0x04,0x08,0x10,0x20, /* \ */
                    0x00,0x41,0x41,0x7f,0x00, /* ] */
                    0x04,0x02,0x01,0x02,0x04, /* ^ */
                    0x40,0x40,0x40,0x40,0x40, /* _ */
                    0x00,0x00,0x03,0x05,0x00, /* ` */
                    0x20,0x54,0x54,0x54,0x78, /* a */
                    0x7F,0x44,0x44,0x44,0x38, /* b */
                    0x38,0x44,0x44,0x44,0x44, /* c */
                    0x38,0x44,0x44,0x44,0x7f, /* d */
                    0x38,0x54,0x54,0x54,0x18, /* e */
                    0x04,0x04,0x7e,0x05,0x05, /* f */
                    0x08,0x54,0x54,0x54,0x3c, /* g */
                    0x7f,0x08,0x04,0x04,0x78, /* h */
                    0x00,0x44,0x7d,0x40,0x00, /* i */
                    0x20,0x40,0x44,0x3d,0x00, /* j */
                    0x7f,0x10,0x28,0x44,0x00, /* k */
                    0x00,0x41,0x7f,0x40,0x00, /* l */
                    0x7c,0x04,0x7c,0x04,0x78, /* m */
                    0x7c,0x08,0x04,0x04,0x78, /* n */
                    0x38,0x44,0x44,0x44,0x38, /* o */
                    0x7c,0x14,0x14,0x14,0x08, /* p */
                    0x08,0x14,0x14,0x14,0x7c, /* q */
                    0x7c,0x08,0x04,0x04,0x00, /* r */
                    0x48,0x54,0x54,0x54,0x24, /* s */
                    0x04,0x04,0x3f,0x44,0x44, /* t */
                    0x3c,0x40,0x40,0x20,0x7c, /* u */
                    0x1c,0x20,0x40,0x20,0x1c, /* v */
                    0x3c,0x40,0x30,0x40,0x3c, /* w */
                    0x44,0x28,0x10,0x28,0x44, /* x */
                    0x0c,0x50,0x50,0x50,0x3c, /* y */
                    0x44,0x64,0x54,0x4c,0x44, /* z */
                    0x08,0x36,0x41,0x41,0x00, /* { */
                    0x00,0x00,0x77,0x00,0x00, /* | */
                    0x00,0x41,0x41,0x36,0x08, /* } */
                    0x08,0x08,0x2a,0x1c,0x08, /* <- */
                    0x08,0x1c,0x2a,0x08,0x08, /* -> */
                    0xff,0xff,0xff,0xff,0xff, /*  */
};

static void OLED_Write_Byte(uint8_t chData, uint8_t chCmd)
{
          cmd_buff[0] = chCmd ? 0x40 : 0x80;
          cmd_buff[1] = chData;

          if (kStatus_Success == I2C_MasterStart(I2C_base, I2C_MASTER_SLAVE_ADDR_7BIT, kI2C_Write)) {

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

void OLED_Init(I2C_Type *base)
{
          I2C_base=base;
          // simple wait
          for(volatile int i=0; i<1000000; i++);
          // SH_1106 configuration sequence
          OLED_Write_Byte(0xAE, OLED_CMD);
          OLED_Write_Byte(0x02, OLED_CMD);
          OLED_Write_Byte(0x10, OLED_CMD);
          OLED_Write_Byte(0x40, OLED_CMD);
          OLED_Write_Byte(0xB0, OLED_CMD);
          OLED_Write_Byte(0x81, OLED_CMD);
          OLED_Write_Byte(0xFF, OLED_CMD);
          OLED_Write_Byte(0xA1, OLED_CMD);
          OLED_Write_Byte(0xC8, OLED_CMD);
          OLED_Write_Byte(0xA8, OLED_CMD);
          OLED_Write_Byte(0x3F, OLED_CMD);
          OLED_Write_Byte(0xD3, OLED_CMD);
          OLED_Write_Byte(0x00, OLED_CMD);
          OLED_Write_Byte(0xD5, OLED_CMD);
          OLED_Write_Byte(0x80, OLED_CMD);
          OLED_Write_Byte(0xD9, OLED_CMD);
          OLED_Write_Byte(0x1F, OLED_CMD);
          OLED_Write_Byte(0xDA, OLED_CMD);
          OLED_Write_Byte(0x12, OLED_CMD);
          OLED_Write_Byte(0xDB, OLED_CMD);
          OLED_Write_Byte(0x40, OLED_CMD);
          OLED_Write_Byte(0xAD, OLED_CMD);
          OLED_Write_Byte(0x8B, OLED_CMD);

          OLED_Clear_Screen(0x00);
          OLED_Refresh_Gram();
          OLED_Display_On();
}

void OLED_Display_On(void)
{
          OLED_Write_Byte(0x8D, OLED_CMD);
          OLED_Write_Byte(0x14, OLED_CMD);
          OLED_Write_Byte(0xAF, OLED_CMD);
}

void OLED_Display_Off(void)
{
```

```
          OLED_Write_Byte(0x8D, OLED_CMD);
          OLED_Write_Byte(0x10, OLED_CMD);
          OLED_Write_Byte(0xAE, OLED_CMD);
}

void OLED_Refresh_Gram(void)
{
          for (uint8_t i = 0; i < OLED_PAGES; i ++) {
                    OLED_Write_Byte(0xB0 + i, OLED_CMD);
                    __SET_COL_START_ADDR();
                    for (uint8_t j = 0; j < OLED_WIDTH; j ++) {
                              OLED_Write_Byte(s_chDispalyBuffer[j][i], OLED_DAT);
                    }
          }
}

void OLED_Clear_Screen(uint8_t fill)
{
          for (uint8_t i = 0; i < OLED_PAGES; i ++) {
                    OLED_Write_Byte(0xB0 + i, OLED_CMD);
                    __SET_COL_START_ADDR();
                    for (uint8_t j = 0; j < OLED_WIDTH; j ++) {
                              s_chDispalyBuffer[j][i] = fill;
                    }
          }
}

void OLED_Puts(uint8_t x, uint8_t y, char *text)
{
          uint8_t i,j=0;
          char c;

          while(text[j] && j<21) {
                    c=text[j]-32;
                    for (i = 0; i < 5; i ++) {
                              s_chDispalyBuffer[x+i+(6*j)][y] = FontSystem5x8[5*c+i];
                    }
                    s_chDispalyBuffer[x+i+(6*j)][y]=0;
                    j++;
          }
}
```

7. Go to the main file of the project and add 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_Puts(30, 2, "Hello world");
          OLED_Refresh_Gram();

          while(1) {

          }
          return 0 ;
}
```

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



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

10. Add more functions to the display library: *OLED_Draw_Point*, *OLED_Draw_Line* and *OLED_Draw_Bitmap*.
11. Go to the *oled.h* file and add the code as below:

```
#ifndef OLED_H_
#define OLED_H_

#include "fsl_i2c.h"
#include <stdlib.h>

#define I2C_MASTER_SLAVE_ADDR_7BIT 0x3C

#define __SET_COL_START_ADDR()          {OLED_Write_Byte(0x02, OLED_CMD); OLED_Write_Byte(0x10, OLED_CMD);}

#define OLED_CMD                         0
#define OLED_DAT                         1
#define OLED_WIDTH                 128
#define OLED_HEIGHT          64
#define OLED_PAGES          (OLED_HEIGHT / 8)

void OLED_Init(I2C_Type *base);
void OLED_Display_On(void);
void OLED_Display_Off(void);
void OLED_Refresh_Gram(void);
void OLED_Clear_Screen(uint8_t fill);

void OLED_Puts(uint8_t x, uint8_t y, char *text);
void OLED_Draw_Point(uint8_t x, uint8_t y, uint8_t point);
void OLED_Draw_Line(uint8_t x0, uint8_t y0, uint8_t x1, uint8_t y1);

#endif /* OLED_H_ */
```

12. Then add code to the end of file *oled.c*:

```
void OLED_Draw_Point(uint8_t x, uint8_t y, uint8_t point)
{
	uint8_t pos, bx, temp = 0;

	if (x >= OLED_WIDTH || y >= OLED_HEIGHT) {
		return;
	}
	pos = y / 8;
	bx  = y % 8;
	temp = 1 << (bx);
	if (point) {
		s_chDispalyBuffer[x][pos] |= temp;
	} else {
		s_chDispalyBuffer[x][pos] &= ~temp;
	}
}

void OLED_Draw_Line(uint8_t x1, uint8_t y1, uint8_t x2, uint8_t y2)
{
	uint8_t  x, y;
	int16_t addx, addy, dx, dy, P;

	dx = abs(x2 - x1);
	dy = abs(y2 - y1);
	x = x1;
	y = y1;
	addx = (x1 > x2) ? -1 : 1;
	addy = (y1 > y2) ? -1 : 1;

	if(dx >= dy) {
		P = 2*dy - dx;
		for(int16_t i=0; i<=dx; i++){
			OLED_Draw_Point(x,y,1);
			if(P < 0){
				P += 2*dy;
				x += addx;
			}else{
				P += 2*(dy - dx);
				x += addx;
				y += addy;
			}
		}
	} else {
		P = 2*dx - dy;
		for(int16_t i=0; i<=dy; i++){
			OLED_Draw_Point(x,y,1);
			if(P < 0){
				P += 2*dx;
				y += addy;
			}else{
				P += 2*(dx - dy);
				x += addx;
				y += addy;
			}
		}
	}
}
```

13. Go to the main file of the project and add 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);

	uint8_t i=0;
	while(1) {

		OLED_Clear_Screen(0);
		OLED_Draw_Line(0, i % OLED_HEIGHT, OLED_WIDTH, OLED_HEIGHT - (i % OLED_HEIGHT));
		i++;

		OLED_Refresh_Gram();
	}
```

```
        return 0 ;
}
```

III. Exercises

1. Write your own functions that draw dashed lines and a circle:

```
void OLED_Draw_Dotline(uint8_t x1, uint8_t y1, uint8_t x2, uint8_t y2);

void OLED_Draw_Circle(uint8_t x, uint8_t y, uint8_t radius);
```