LCD Display (SPI)

1. Learning Objectives

1. Learn the basic knowledge of SPI communication.
2. Read the data in the flash and display it on the onboard LCD screen.

SPI Protocol

The SPI protocol (Serial Peripheral Interface) is a commonly used synchronous serial communication protocol designed for high-speed, short-distance communication between microcontrollers and external devices. It supports full-duplex communication, that is, data can be sent and received between the master and slave devices at the same time, and is commonly used in devices such as memory chips, sensors, display drivers, and wireless modules.

SPI Hardware Interface

The SPI protocol usually uses four lines for data transmission:

- **SCLK (Serial Clock):** The clock signal generated by the master device is used for synchronous communication.
- **MOSI (Master Output Slave Input):** The master device sends data to the slave device.
- **MISO (Master Input Slave Output):** The slave device sends data to the master device.
- **SS/CS (Slave Select):** The master device activates the target slave device through the chip select signal.

SPI Advantages

- Fast communication speed, suitable for high-bandwidth applications.
- Support full-duplex transmission, improve efficiency.
- Simple hardware implementation, direct interface.
- Support multiple slave device connections.

SPI Determinism

- Lack of standardized error detection mechanism.
- The number of master device pins increases with the number of slave devices.
- The communication distance is limited and is usually used for on-board communication.

2. Hardware Construction

W25Q32 is a common serial flash memory device that uses the SPI (Serial Peripheral Interface) interface protocol. It has high-speed read, write and erase functions and is widely used in high-performance electronic devices such as embedded systems, storage devices, routers, etc. The capacity of W25Q32 is 32 Mbit (ie 4 MB), and the numbers in the model represent different capacity options, such as W25Q16, W25Q64, W25Q128, etc., to meet the needs of different application scenarios.

The memory of the W25Q32 chip is allocated by sector (Sector) and block (Block). Specifically:

- **Sector**: Each sector is 4KB in size.
- **Block**: Each block contains 16 sectors, i.e., a block is 64KB in size.

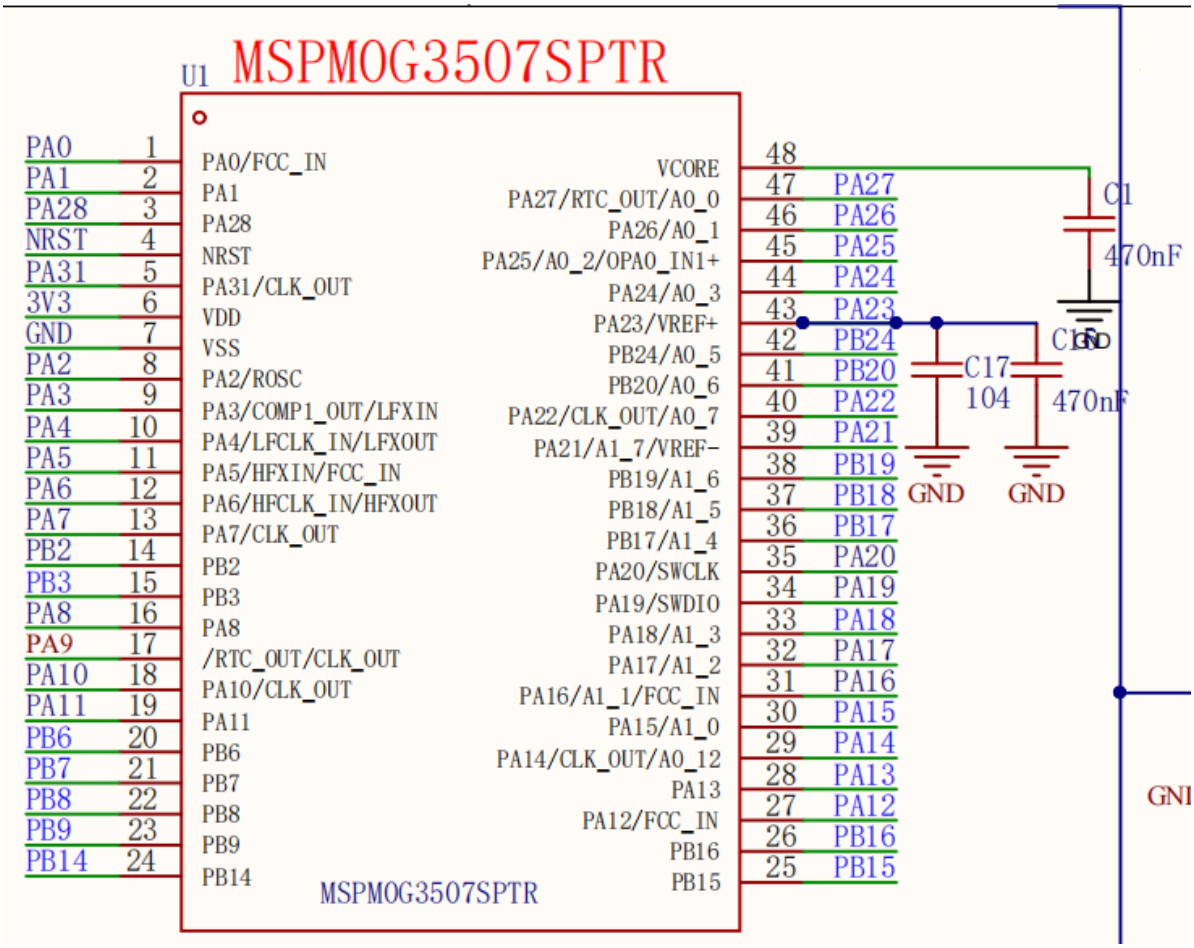
These storage unit structures make data management and storage operations more flexible, and are particularly suitable for embedded systems and storage applications that require frequent read and write operations.

We use the hardware SPI method to drive W25Q32, so we need to determine whether the pin we set has a hardware SPI peripheral interface. In the data sheet, PB14~PB17 can be multiplexed as 4 communication lines of SPI1.

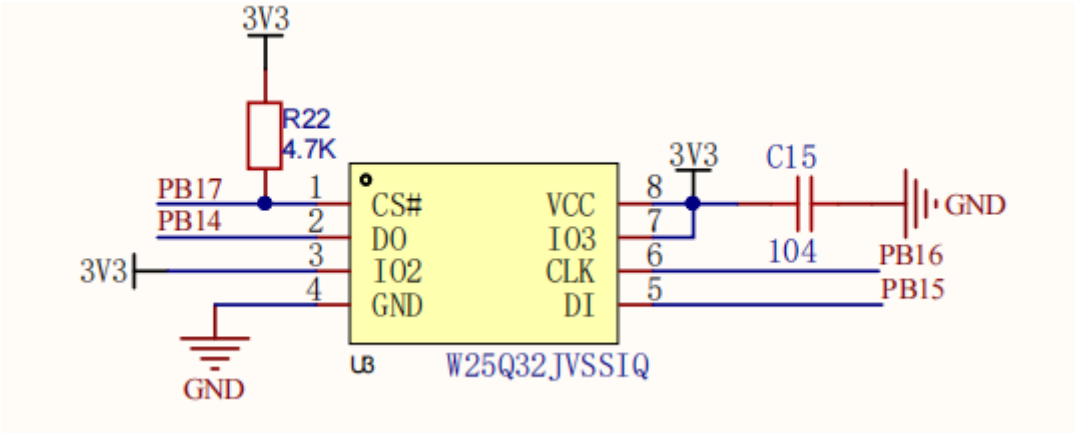
31	PB14		SPI1_CS3 *[2]* / SPI1_POCI *[3]* / SPI0_CS3 *[4]* / TIMG12_C1 *[5]* / TIMG8_IDX *[6]* / TIMA0_C0 *[7]*	2	24	–	-
32	PB15		UART2_TX *[2]* / SPI1_PICO *[3]* / UART3_CTS *[4]* / TIMG8_C0 *[5]* / TIMG7_C0 *[6]*	3	25	-	-
33	PB16		UART2_RX *[2]* / SPI1_SCK *[3]* / UART3_RTS *[4]* / TIMG8_C1 [5] / TIMG7_C1 [6]	4	26	-	-
43	PB17	A1_4 / COMP1_IN2-	UART2_TX *[2]* / SPI0_PICO *[3]* / SPI1_CS1 *[4]* / TIMA1_C0 *[5]* / TIMA0_C2 *[6]*	14	36	–	-

This course does not require additional hardware equipment, and can directly use the onboard LCD screen and external storage flash on the MSPM0G3507 motherboard.

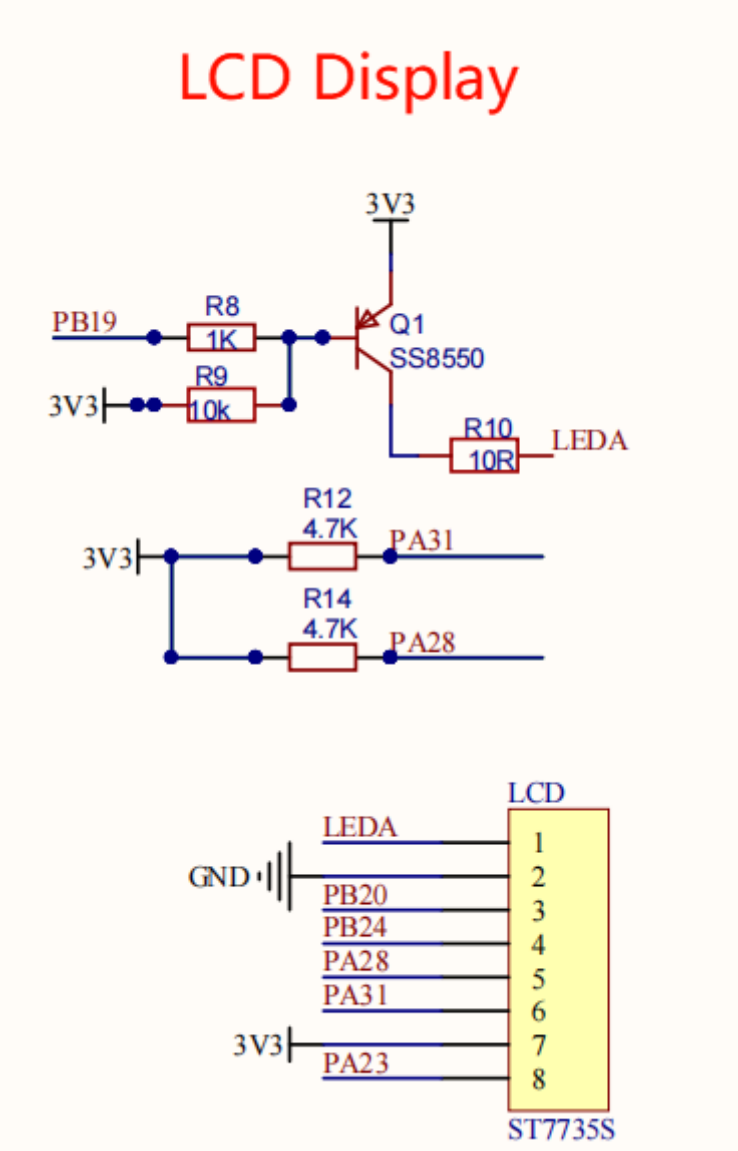
MSPM0G3507 main control diagram:



W25Q32 partial schematic diagram:



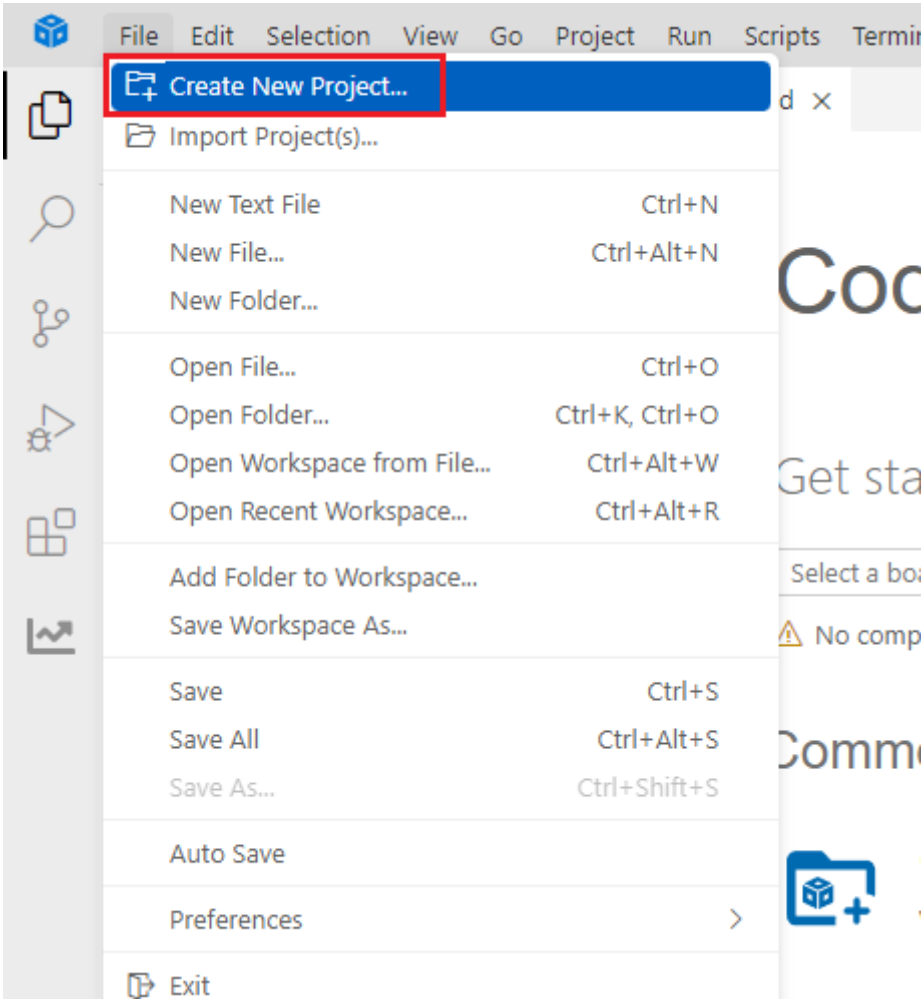
LCD screen partial schematic diagram:

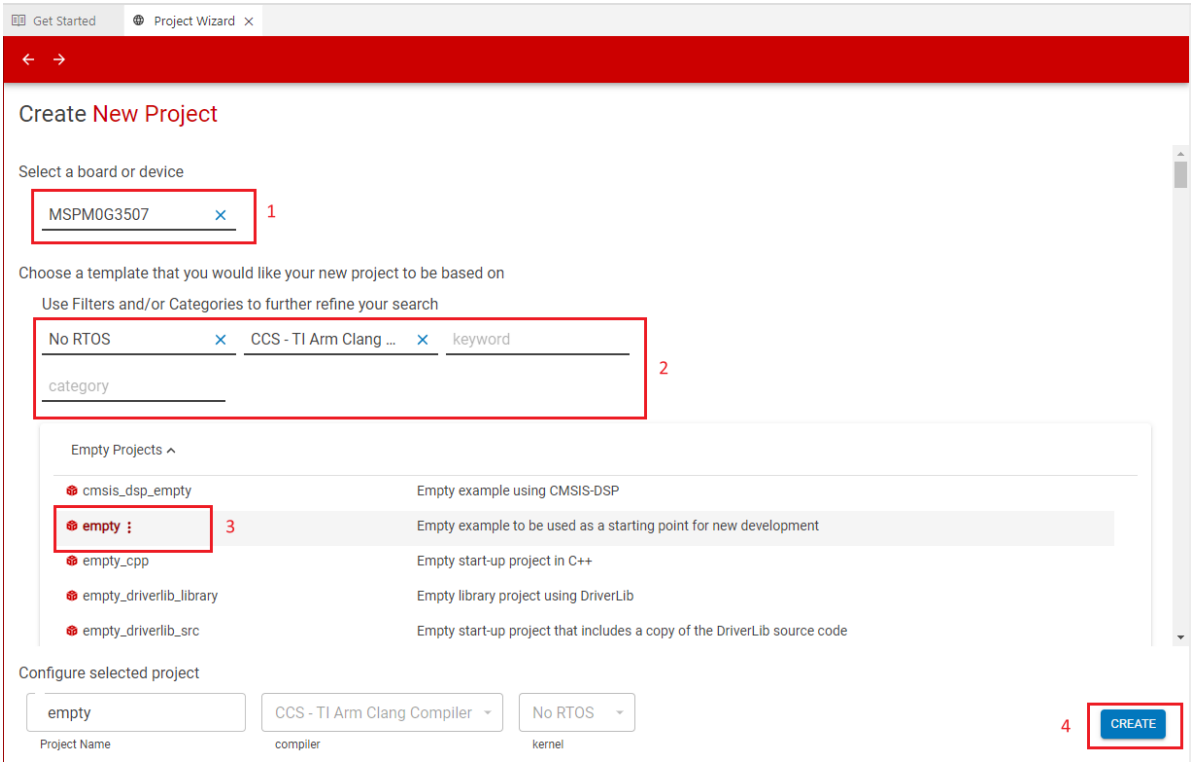


3. Experimental steps

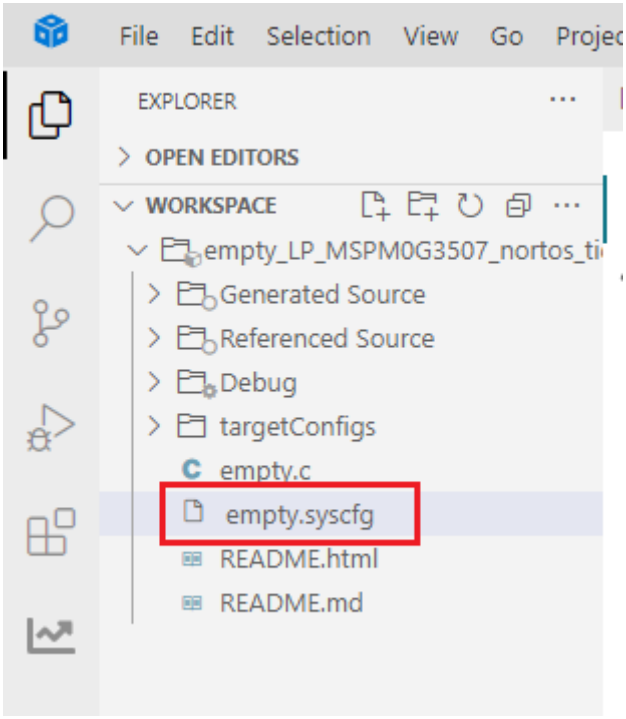
1. Open the SYSCONFIG configuration tool

Create a blank project empty in CCS.



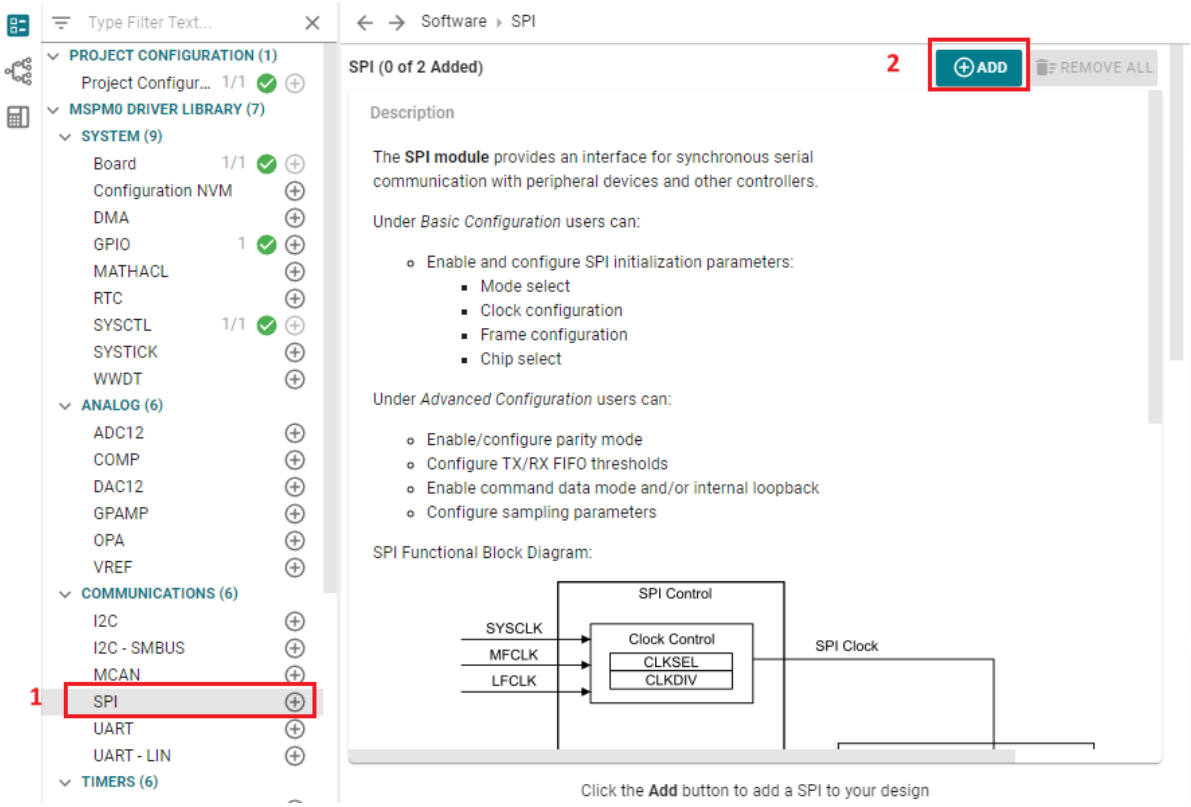


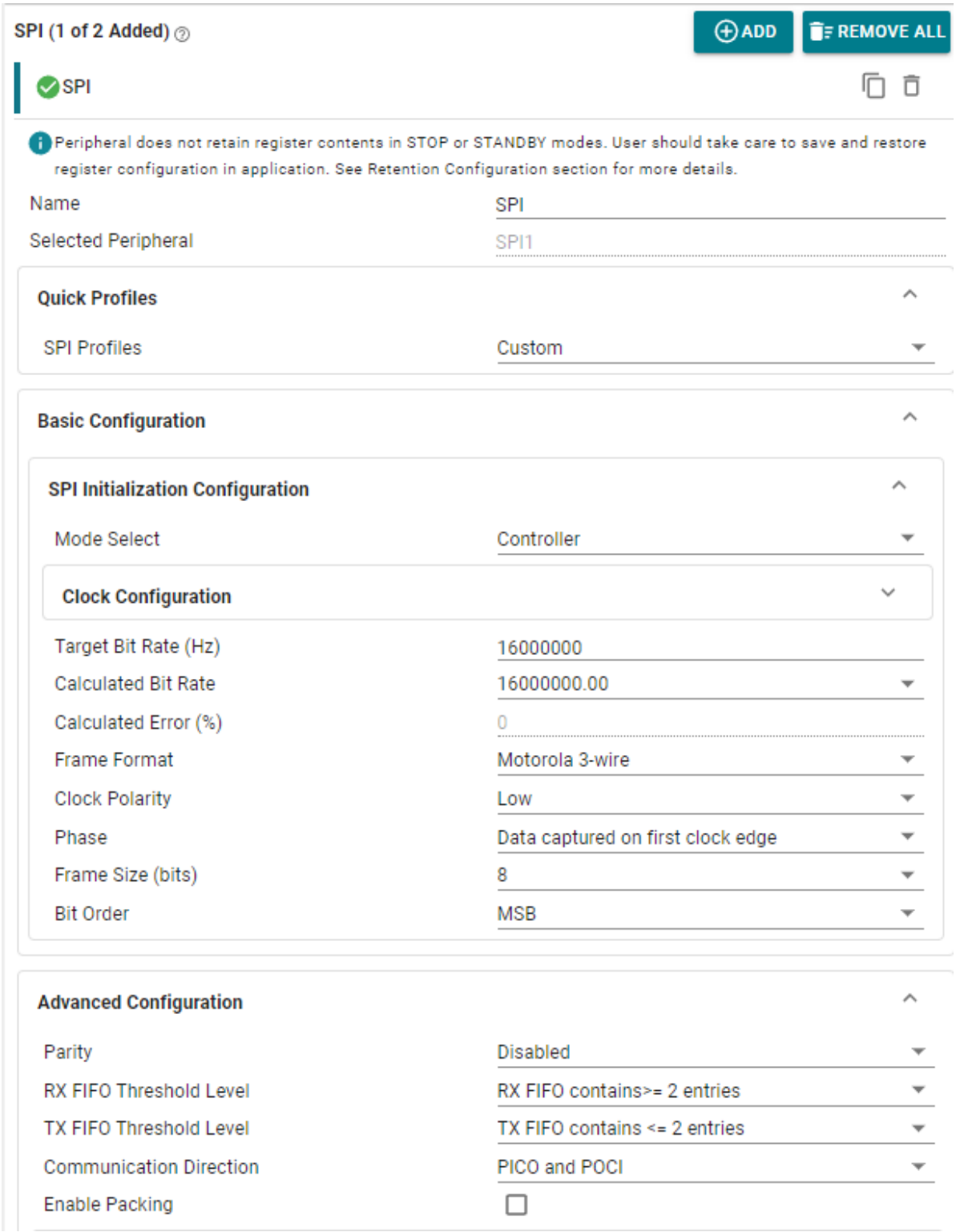
Find and open the empty.syscfg file in the left workspace of CCS.



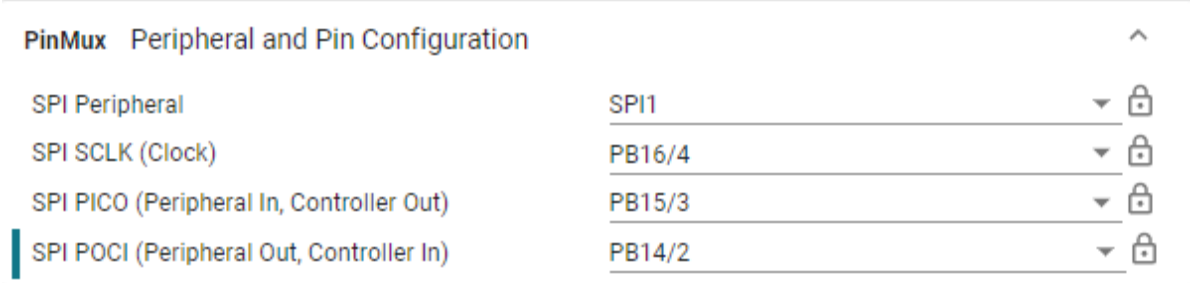
2. SPI parameter configuration

Find the SPI column on the left, click to enter, and add SPI peripherals.





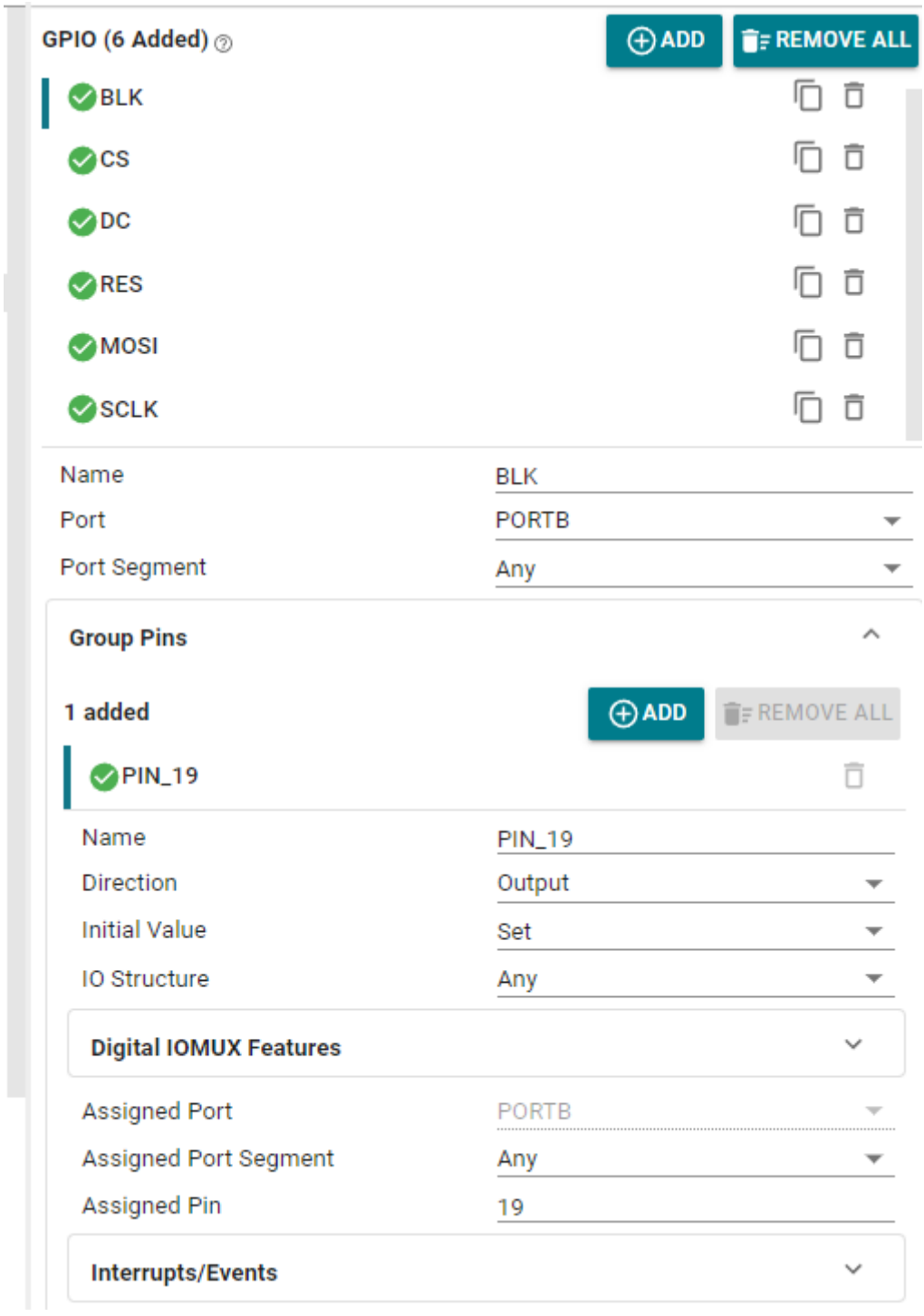
In most SPI protocols, the chip select is always pulled low during the entire timing when sending and receiving, and the chip select of the SPI peripheral will be pulled high after each frame is sent and received, so the CS chip select line needs to be independently controlled by the MCU's IO port, and there is no way to use the CS pin of the SPI peripheral. **Here, the GPIO method (software method) is used to control the output of the CS pin.**



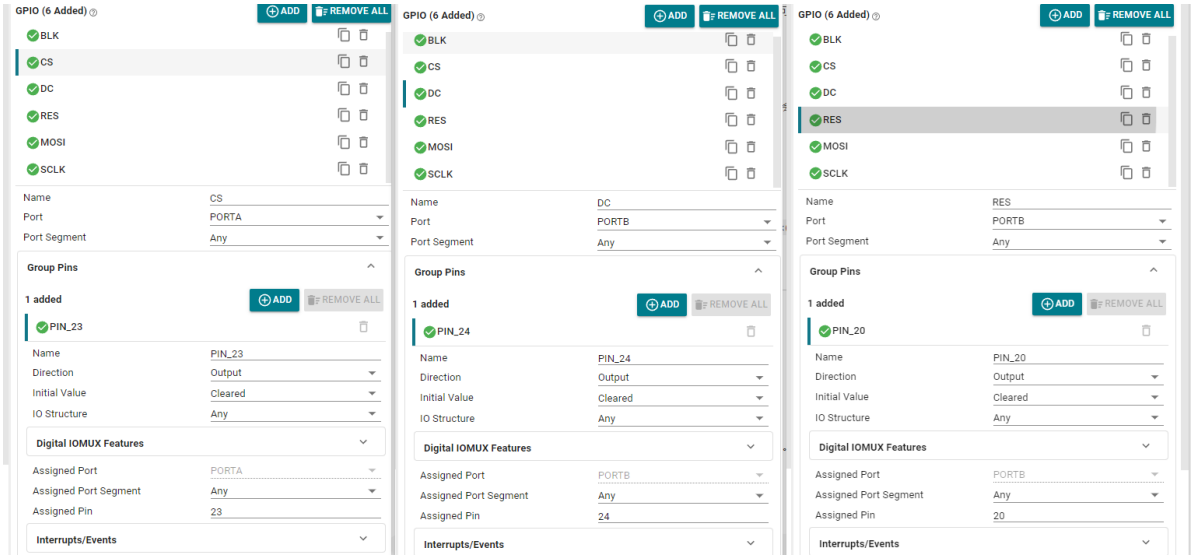
3. Pin parameter configuration

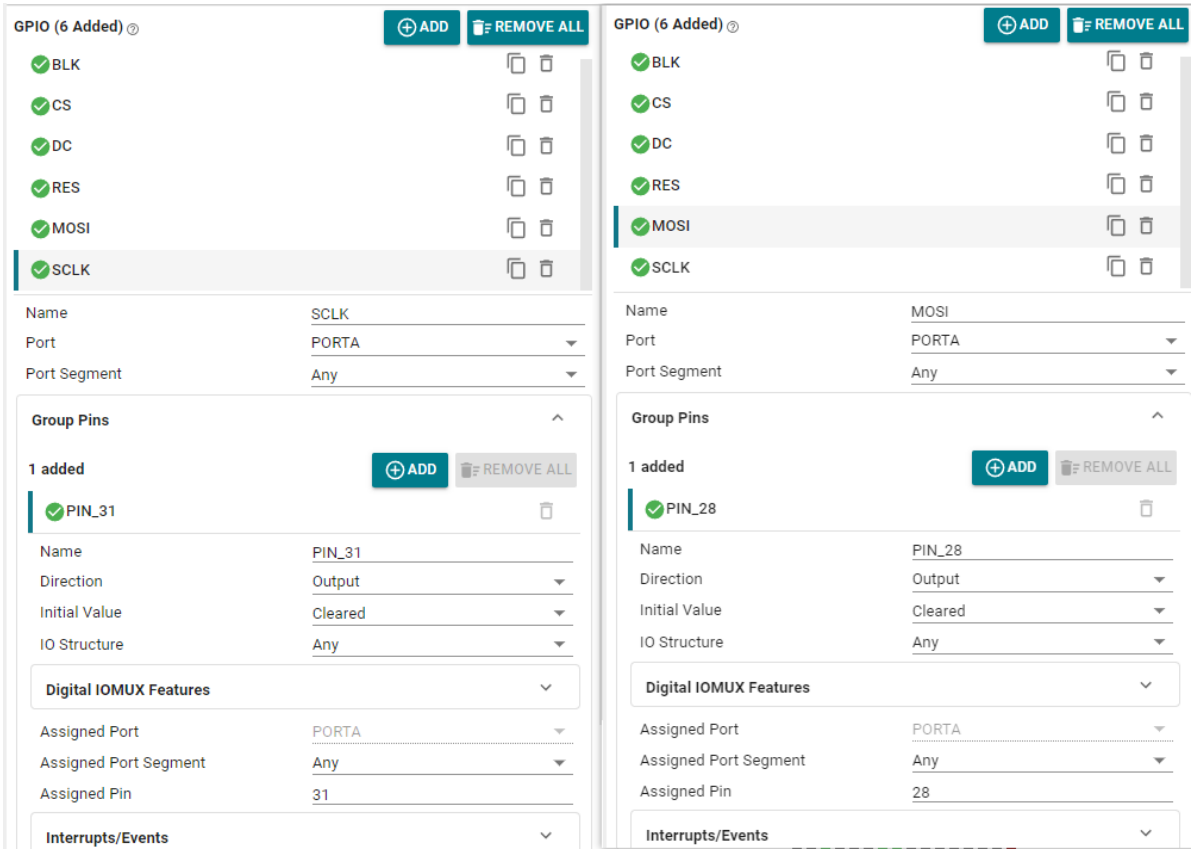
LCD screen

Backlight **BLK**:



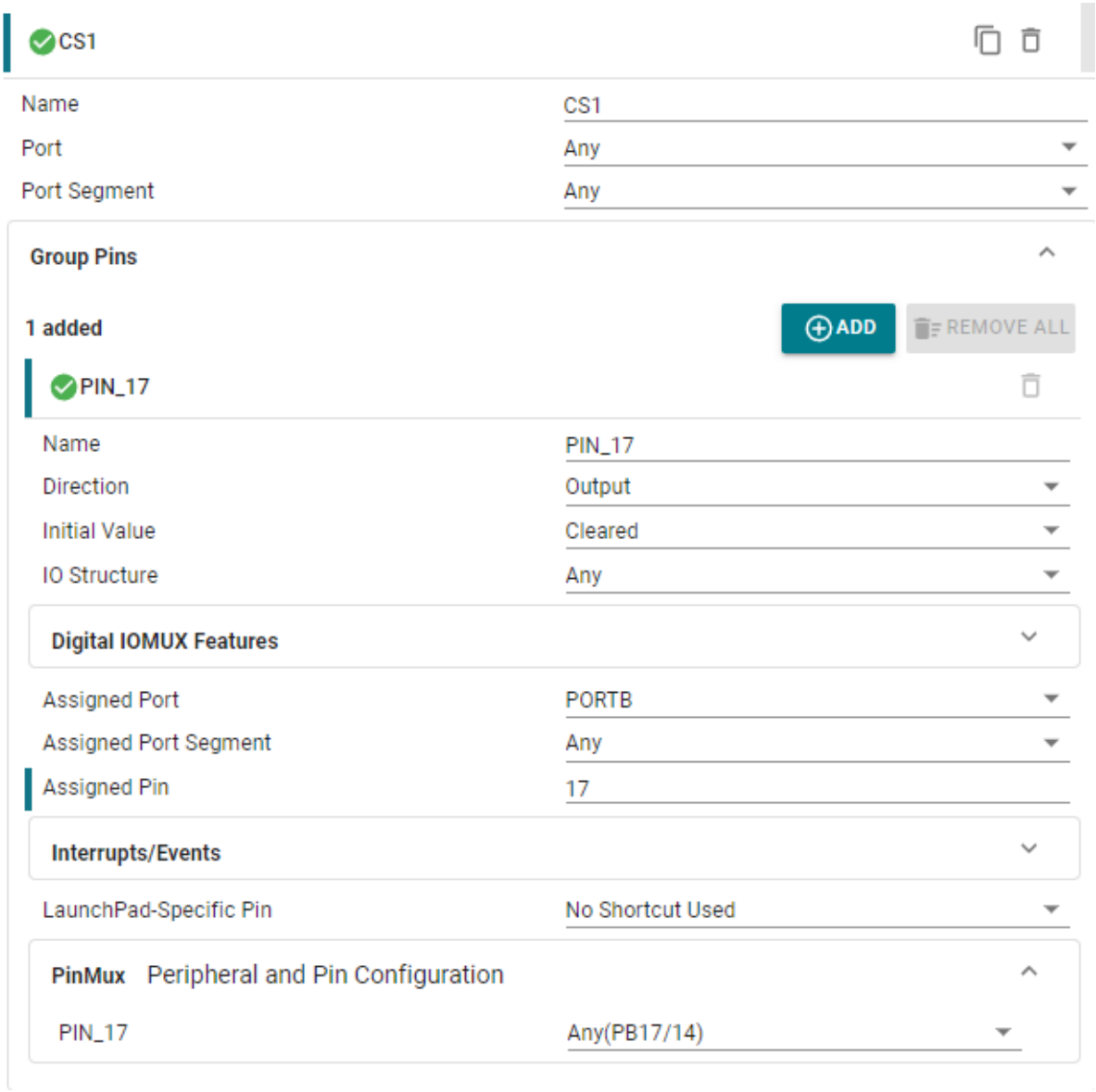
CS, DC, RES, MOSI, SCLK are as follows:





External Flash

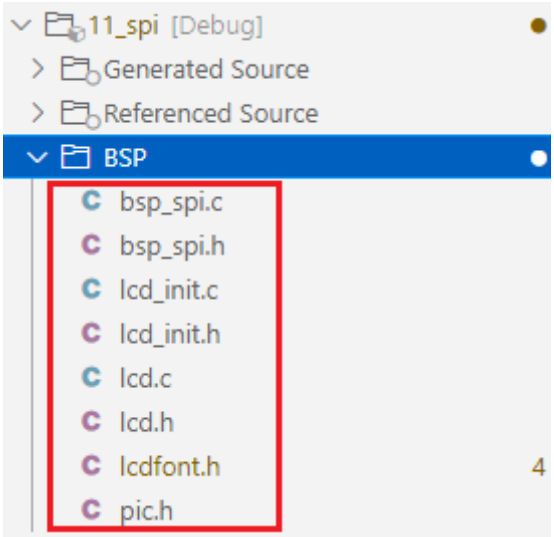
CS1:



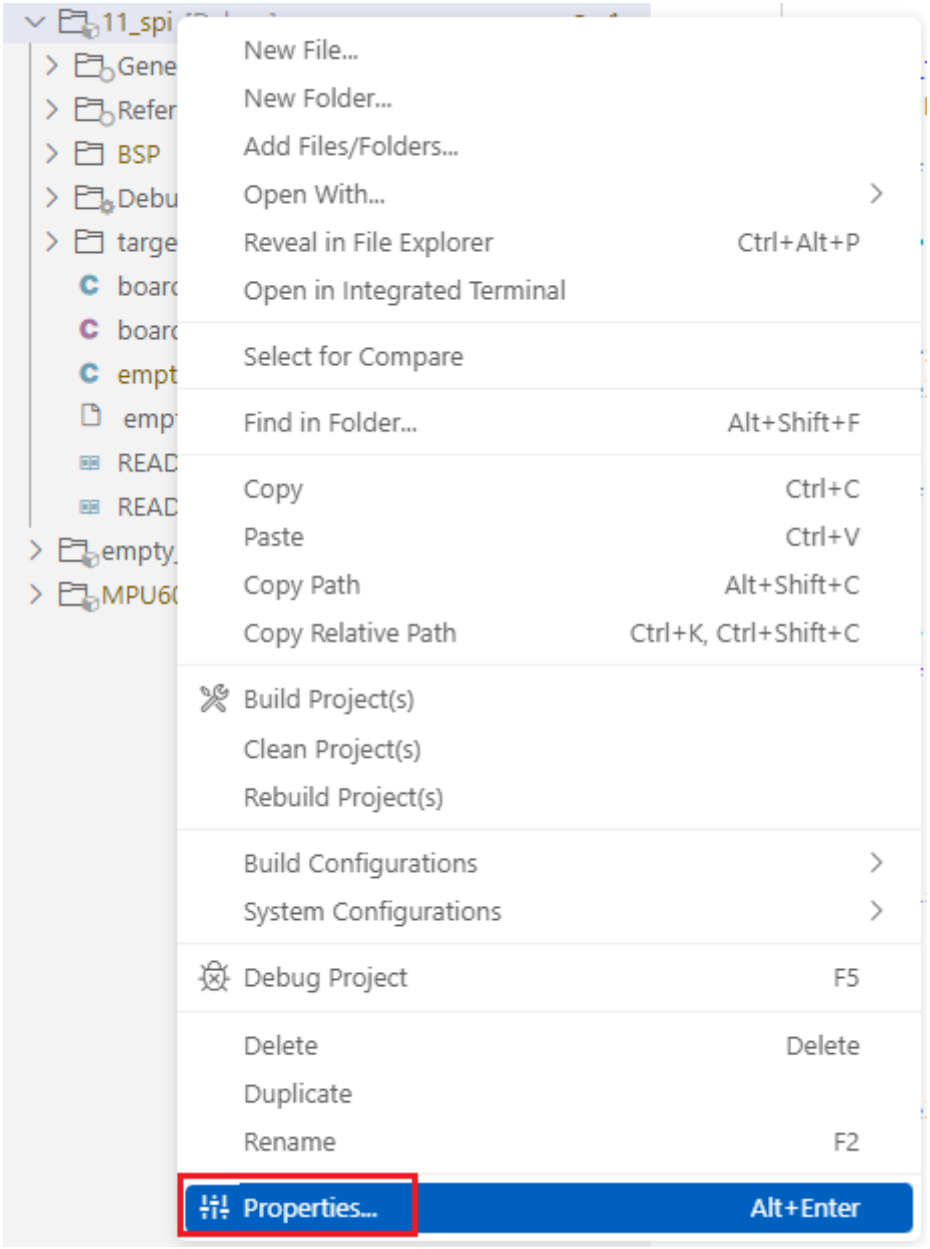
4. Use of SPI protocol

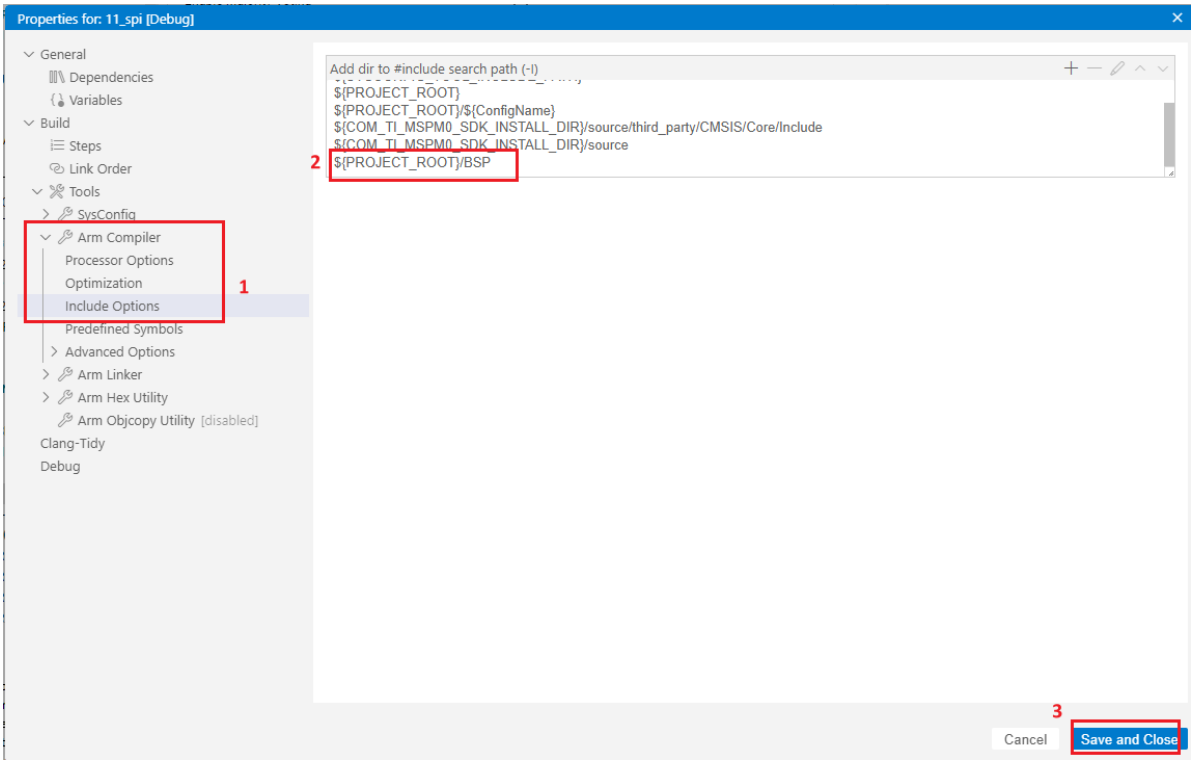
We create a new folder under the project folder: `BSP`. Create four more files under the BSP folder, namely `lcd.c`, `lcd.h`, `bsp_spi.c` and `bsp_spi.h`.

Include the following LCD display drivers and fonts, and put them in the BSP folder



Update the header file path and right-click the project folder.


11_spi
Gene
Refer
BSP
Debu
targe
boarc
boarc
empt
READ
READ
empty_
MPU6(
New File...
New Folder...
Add Files/Folders...
Open With...
Reveal in File Explorer Ctrl+Alt+P
Open in Integrated Terminal
Select for Compare
Find in Folder... Alt+Shift+F
Copy Ctrl+C
Paste Ctrl+V
Copy Path Alt+Shift+C
Copy Relative Path Ctrl+K, Ctrl+Shift+C
Build Project(s)
Clean Project(s)
Rebuild Project(s)
Build Configurations
System Configurations
Debug Project F5
Delete Delete
Duplicate
Rename F2
Properties... Alt+Enter


Properties for: 11_spi [Debug]
General
Dependencies
Variables
Build
Steps
Link Order
Tools
SysConfig
Arm Compiler
Processor Options
Optimization
Include Options
Predefined Symbols
Advanced Options
Arm Linker
Arm Hex Utility
Arm Objcopy Utility [disabled]
Clang-Tidy
Debug
1
Add dir to #include search path (-I)
${PROJECT_ROOT}
${PROJECT_ROOT}/${ConfigName}
${COM_TI_MSPM0_SDK_INSTALL_DIR}/source/third_party/CMSIS/Core/Include
${COM_TI_MSPM0_SDK_INSTALL_DIR}/source
2
${PROJECT_ROOT}/BSP
3
Cancel
Save and Close

5. Write program

Define the operation interface and related functions of the LCD display

lcd.h

```
#ifndef __LCD_H
#define __LCD_H
#include <stdint.h>


void LCD_Fill(uint16_t xsta,uint16_t ysta,uint16_t xend,uint16_t yend,uint16_t
color);//指定区域填充颜色 Specify area fill color
void LCD_DrawPoint(uint16_t x,uint16_t y,uint16_t color);//在指定位置画一个点 Draw a
point at the specified location
void LCD_DrawLine(uint16_t x1,uint16_t y1,uint16_t x2,uint16_t y2,uint16_t
color);//在指定位置画一条线 Draw a line at the specified position
void LCD_DrawRectangle(uint16_t x1, uint16_t y1, uint16_t x2, uint16_t
y2,uint16_t color);//在指定位置画一个矩形 Draw a rectangle at the specified location
void Draw_Circle(uint16_t x0,uint16_t y0,uint8_t r,uint16_t color);//在指定位置画一
个圆 Draw a circle at the specified location

void LCD_ShowChinese(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示汉字串 Display Chinese character string
void LCD_ShowChinese12x12(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示单个12x12汉字 Display a single 12x12 Chinese
character
void LCD_ShowChinese16x16(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示单个16x16汉字 Display a single 16x16 Chinese
character
void LCD_ShowChinese24x24(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示单个24x24汉字 Display a single 24x24 Chinese
character
void LCD_ShowChinese32x32(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示单个32x32汉字 Display a single 32x32 Chinese
character

void LCD_ShowChar(uint16_t x,uint16_t y,uint8_t num,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示一个字符 Display a character
void LCD_ShowString(uint16_t x,uint16_t y,const uint8_t *p,uint16_t fc,uint16_t
bc,uint8_t sizey,uint8_t mode);//显示字符串 Display String
uint32_t mypow(uint8_t m,uint8_t n);//求幂 Power
void LCD_ShowIntNum(uint16_t x,uint16_t y,uint16_t num,uint8_t len,uint16_t
fc,uint16_t bc,uint8_t sizey);//显示整数变量 Display integer variables
void LCD_ShowFloatNum1(uint16_t x,uint16_t y,float num,uint8_t len,uint16_t
fc,uint16_t bc,uint8_t sizey);//显示两位小数变量 Display variables with two decimal
places

void LCD_ShowPicture(uint16_t x,uint16_t y,uint16_t length,uint16_t width,const
uint8_t pic[]);//显示图片 Show image


//画笔颜色 Brush Color
#define WHITE            0xFFFF
#define BLACK            0x0000
#define BLUE             0x001F
#define BRED             0XF81F
```

```
#define GRED                0XFFE0
#define GBLUE               0X07FF
#define RED                 0xF800
#define MAGENTA             0xF81F
#define GREEN               0x07E0
#define CYAN                0x7FFF
#define YELLOW              0xFFE0
#define BROWN               0XBC40 //棕色  Brown
#define BRRED               0XFC07 //棕红色 Brown red
#define GRAY                0X8430 //灰色 Gray
#define DARKBLUE            0X01CF //深蓝色 Dark blue
#define LIGHTBLUE           0X7D7C //浅蓝色 Light blue
#define GRAYBLUE            0X5458 //灰蓝色 Gray blue
#define LIGHTGREEN          0X841F //浅绿色 Light green
#define LGRAY               0XC618 //浅灰色(PANNEL),窗体背景色 Light gray (PANNEL),
window background color
#define LGRAYBLUE           0XA651 //浅灰蓝色(中间层颜色) Light gray blue (middle layer
color)
#define LBBLUE              0X2B12 //浅棕蓝色(选择条目的反色) Light brown blue
(inverted color of selected item)

#endif
```

Next is the LCD display driver

lcd.c (only part of it is captured here, please check the project source code for details)

```
#include "lcd.h"
#include "lcd_init.h"
#include "lcdfont.h"
#include "board.h"


/******************************************************************************
      函数说明：在指定区域填充颜色
      入口数据：xsta,ysta   起始坐标
                xend,yend   终止坐标
                color       要填充的颜色
      返回值：  无
      Function description: Fill the specified area with color
      Input data: xsta, ysta starting coordinates
                  xend, yend ending coordinates
                  color the color to be filled
      Return value: None
******************************************************************************/
void LCD_Fill(uint16_t xsta,uint16_t ysta,uint16_t xend,uint16_t yend,uint16_t
color)
{
    uint16_t i,j;
    LCD_Address_Set(xsta,ysta,xend-1,yend-1);//设置显示范围 Set the display range
    for(i=ysta;i<yend;i++)
    {
        for(j=xsta;j<xend;j++)
        {
            LCD_WR_DATA(color);
        }
    }
```

```
}

/******************************************************************************
      函数说明：在指定位置画点
      入口数据：x,y 画点坐标
                color 点的颜色
      返回值：  无
      Function description: Draw a point at the specified position
      Input data: x, y coordinates of the point
                  color color of the point
      Return value: None
******************************************************************************/
void LCD_DrawPoint(uint16_t x,uint16_t y,uint16_t color)
{
    LCD_Address_Set(x,y,x,y);//设置光标位置  Set the cursor position
    LCD_WR_DATA(color);
}
...
```

bsp_spi.h

```
#ifndef _BSP_SPI_H__
#define _BSP_SPI_H__

#include "board.h"

//CS引脚的输出控制
//x=0时输出低电平
//x=1时输出高电平
//CS pin output control
//x=0 when output is low level
//x=1 when output is high level
#define SPI_CS(x)  ( (x) ? DL_GPIO_setPins(CS1_PORT,CS1_PIN_17_PIN) :
DL_GPIO_clearPins(CS1_PORT,CS1_PIN_17_PIN) )

uint16_t W25Q32_readID(void);//读取W25Q32的ID Read the ID of W25Q32
void W25Q32_write(uint8_t* buffer, uint32_t addr, uint16_t numbyte);
 //W25Q32写数据 W25Q32 write data
void W25Q32_read(uint8_t* buffer,uint32_t read_addr,uint16_t
read_length);//W25Q32读数据 W25Q32 Read Data
#endif
```

The initialization of SPI has been configured in SYSCONFIG, but we still need to prepare the SPI read and write steps. To ensure the success of sending and receiving data, when sending, you need to ensure that the data in the send buffer is sent, that is, the send buffer is empty, before the next data can be sent; when receiving, you need to ensure that there is data in the receive buffer before receiving.

bsp_spi.c (only part of it is intercepted here, please refer to the project source code for details)

```
#include "bsp_spi.h"


uint8_t spi_read_write_byte(uint8_t dat)
{
        uint8_t data = 0;
```

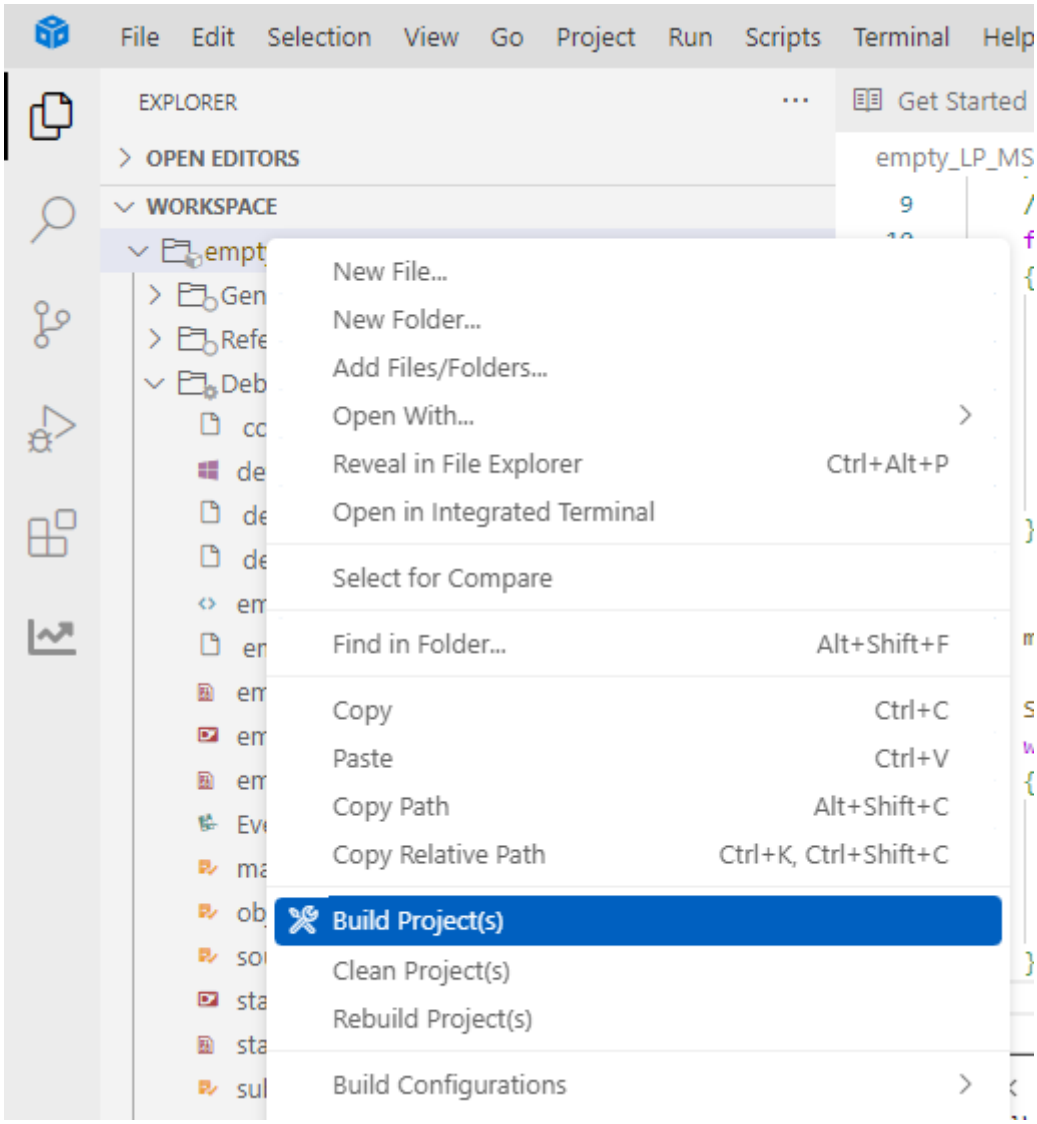
```
        //发送数据 Sending Data
        DL_SPI_transmitData8(SPI_INST,dat);
        //等待SPI总线空闲 Wait for the SPI bus to be idle
        while(DL_SPI_isBusy(SPI_INST));
        //接收数据 Receiving Data
        data = DL_SPI_receiveData8(SPI_INST);
        //等待SPI总线空闲 Wait for the SPI bus to be idle
        while(DL_SPI_isBusy(SPI_INST));

        return data;
}
...
```

Then write the following code in the empty.c file

```
#include "ti_msp_dl_config.h"
#include "board.h"
#include "lcd_init.h"
#include "lcd.h"
#include "pic.h"
#include "bsp_spi.h"
#include <stdint.h>
#include <stdio.h>


int main(void)
{
    unsigned char buff[10] = {0};

    //开发板初始化 Development board initialization
    board_init();

    delay_ms(100);//等待部署 Waiting for deployment

    //读取W25Q32的ID Read the ID of W25Q32
    printf("ID = %X\r\n",W25Q32_readID());

    //读取0地址的5个字节数据到buff Read 5 bytes of data from address 0 to buff
    W25Q32_read(buff, 0, 7);

    //串口输出读取的数据 Serial port outputs the read data
    printf("buff = %s\r\n",buff);

    //往0地址写入5个字节长度的数据 ABCD Write 5 bytes of data ABCD to address 0
    W25Q32_write("Yahboom", 0, 7);
    delay_ms(100);

    //读取0地址的5个字节数据到buff Read 5 bytes of data from address 0 to buff
    W25Q32_read(buff, 0, 7);

    //串口输出读取的数据 Serial port outputs the read data
    //  printf("buff = %s\r\n",buff);

    SYSCFG_DL_init();

    LCD_Init();//LCD初始化 LCD Initialization
```

```
    LCD_Fill(0,0,LCD_W,LCD_H,WHITE);
    LCD_ShowPicture(20,45,120,29,gImage_pic1);
    LCD_ShowString(10,0,"Hello!",BLACK,WHITE,16,0);
    // LCD_ShowChinese(50,20,"亚博智能",BLACK,WHITE,16,0);

    // 显示 buff 中的内容在同一行上 Display the contents of buff on the same line
    int x = 54;  // 起始 x 坐标 Starting x coordinate
    for (int i = 0; i < 7; i++)
        {
        char str[2] = {buff[i], '\0'};  // 每次取一个字符 Take one character at a
time
        LCD_ShowString(x, 25, str,BLACK, WHITE, 16, 0);  // 显示字符 Display
Characters
        x += 8;  // 每个字符的宽度为 8，x 坐标向右偏移 Each character is 8 wide and
has an x-coordinate offset to the right.
    }

    while (1)
    {

    }
}
```

6. Compile



Once the compilation is successful, you can download the program to the development board.

4. Program Analysis

- lcd.c

```
/*****************************************************************************
      函数说明：显示图片
      入口数据：x,y起点坐标
                length 图片长度
                width  图片宽度
                pic[]  图片数组
      返回值：  无
      Function description: Display image
      Input data: x, y starting point coordinates
                  length Image length
                  width Image width
                  pic[] Image array
      Return value: None
*****************************************************************************/
void LCD_ShowPicture(uint16_t x,uint16_t y,uint16_t length,uint16_t width,const uint8_t pic[])
{
    uint16_t i,j;
    uint32_t k=0;
    LCD_Address_Set(x,y,x+length-1,y+width-1);
    for(i=0;i<length;i++)
    {
        for(j=0;j<width;j++)
        {
            LCD_WR_DATA8(pic[k*2]);
            LCD_WR_DATA8(pic[k*2+1]);
            k++;
        }
    }
}
```

The `LCD_ShowPicture` function draws the picture at the specified starting point `(x, y)`, sets the display area according to the given length and width, and writes the color data of each pixel to the LCD by traversing the picture array to complete the picture display.

```
/*****************************************************************************
      函数说明：显示字符串
      入口数据：x,y显示坐标
                *p 要显示的字符串
                fc 字的颜色
                bc 字的背景色
                sizey 字号
                mode:  0非叠加模式  1叠加模式
      返回值：  无
      Function description: Display string
      Input data: x, y display coordinates
                  *p string to be displayed
                  fc color of the word
                  bc background color of the word
                  sizey font size
                  mode: 0 non-overlay mode 1 overlay mode
      Return value: None
*****************************************************************************/
void LCD_ShowString(uint16_t x,uint16_t y,const uint8_t *p,uint16_t fc,uint16_t bc,uint8_t sizey,uint8_t mode)
{
    while(*p!='\0')
    {
        LCD_ShowChar(x,y,*p,fc,bc,sizey,mode);
        x+=sizey/2;
        p++;
    }
}
```

The `LCD_ShowString` function is used to display a string at the specified coordinates `(x, y)`, and calls the `LCD_ShowChar` function in sequence to draw each character in the string. At the same time, the character spacing is adjusted according to the font size. Both overlay mode and non-overlay mode display are supported.

```
/******************************************************************************
      函数说明：显示汉字串
      入口数据：x,y显示坐标
                *s 要显示的汉字串
                fc 字的颜色
                bc 字的背景色
                sizey 字号 可选 16 24 32
                mode:  0非叠加模式  1叠加模式
      返回值：  无
      Function description: Display Chinese character string
      Input data: x, y display coordinates
                  *s Chinese character string to be displayed
                  fc character color
                  bc character background color
                  sizey font size optional 16 24 32
                  mode: 0 non-overlay mode 1 overlay mode
            Return value: None
******************************************************************************/
void LCD_ShowChinese(uint16_t x,uint16_t y,uint8_t *s,uint16_t fc,uint16_t bc,uint8_t sizey,uint8_t mode)
{
    while(*s!=0)
    {
        LCD_ShowChinese16x16(x,y,s,fc,bc,sizey,mode);
        s+=2;
        x+=sizey;
    }
}
```

The `LCD_ShowChinese` function is used to display a Chinese character string at the specified coordinates `(x, y)`. It draws each Chinese character by calling the `LCD_ShowChinese16x16` function one by one and adjusts the display position of the next Chinese character according to the font size. It supports both overlay mode and non-overlay mode display.

- bsp_spi.c

```
/*****************************************************
 * 函 数 名 称：W25Q32_read
 * 函 数 功 能：读取W25Q32的数据
 * 传 入 参 数：buffer=读出数据的保存地址  read_addr=读取地址   read_length=读去长度
 * 函 数 返 回：无
 * 作       者：LC
 * 备       注：无
 * Function name: W25Q32_read
 * Function function: Read W25Q32 data
 * Input parameters: buffer = storage address of read data read_addr = read address read_length = read length
 * Function return: None
 * Author: LC
 * Notes: None
*****************************************************/
void W25Q32_read(uint8_t* buffer,uint32_t read_addr,uint16_t read_length)
{
        uint16_t i;
        //拉低CS端为低电平 Pull the CS end to a low level
        SPI_CS(0);
        //发送指令03h Send instruction 03h
        spi_read_write_byte(0x03);
        //发送24位读取数据地址的高8位
        // Send the high 8 bits of the 24-bit read data address
        spi_read_write_byte((uint8_t)((read_addr)>>16));
        //发送24位读取数据地址的中8位
        // Send the middle 8 bits of the 24-bit read data address
        spi_read_write_byte((uint8_t)((read_addr)>>8));
        //发送24位读取数据地址的低8位
        // Send the low 8 bits of the 24-bit read data address
        spi_read_write_byte((uint8_t)read_addr);
        //根据读取长度读取出地址保存到buffer中
        // Read the address according to the read length and save it in the buffer
        for(i=0;i<read_length;i++)
        {
            buffer[i]= spi_read_write_byte(0XFF);
        }
        //恢复CS端为高电平 Restore the CS end to a high level
        SPI_CS(1);
}
```

The `W25Q32_read` function is used to read data from the W25Q32 flash chip. The function first starts SPI communication by pulling the CS pin low, then sends the read command (0x03) and the high, middle, and low bytes of the read address. Next, the data is read byte by byte and stored in the provided buffer (`buffer`) according to the specified read length. Finally, the function restores the CS pin to a high level to end the data transfer. This process ensures that the specified length of data is read from the specified address.

```
/*********************************************************
 * 函 数 名 称: W25Q32_write
 * 函 数 功 能: 写数据到W25Q32进行保存
 * 传 入 参 数: buffer=写入的数据内容        addr=写入地址        numbyte=写入数据的长度
 * 函 数 返 回: 无
 * 作       者: LC
 * 备       注: 无
 * Function name: W25Q32_write
 * Function function: Write data to W25Q32 for storage
 * Input parameters: buffer = data content to be written addr = write address numbyte = length of written data
 * Function return: None
 * Author: LC
 * Notes: None
*********************************************************/
void W25Q32_write(uint8_t* buffer, uint32_t addr, uint16_t numbyte)
{
    unsigned int i = 0;
    //擦除扇区数据 Erase sector data
    W25Q32_erase_sector(addr/4096);
    //写使能 Write enable
    W25Q32_write_enable();
    //忙检测 Busy detection
    W25Q32_wait_busy();
    //写入数据 Write data
    //拉低CS端为低电平 Pull CS to low level
    SPI_CS(0);
    //发送指令02h Send instruction 02h
    spi_read_write_byte(0x02);
    //发送写入的24位地址中的高8位
    // Send the high 8 bits of the 24-bit address to be written
    spi_read_write_byte((uint8_t)((addr)>>16));
    //发送写入的24位地址中的中8位
    // Send the middle 8 bits of the 24-bit address to be written
    spi_read_write_byte((uint8_t)((addr)>>8));
    //发送写入的24位地址中的低8位
    // Send the low 8 bits of the 24-bit address to be written
    spi_read_write_byte((uint8_t)addr);
    //根据写入的字节长度连续写入数据buffer
    // Continuously write data buffer according to the length of the written byte
    for(i=0;i<numbyte;i++)
    {
        spi_read_write_byte(buffer[i]);
    }
    //恢复CS端为高电平 Restore CS end to high level
    SPI_CS(0);
    //忙检测 Busy detection
    W25Q32_wait_busy();
}
```

The `W25Q32_write` function is used to write data to the W25Q32 flash chip. First, the function erases the sector data at the target address. Then, it enables the write operation and checks if the chip is busy. Next, the function sends a write command (0x02) and a data address (24-bit address) to the chip through the SPI interface, and writes the data byte by byte according to the specified write length. Finally, the function waits for the write operation to complete and restores the CS pin to a high level to ensure that the data is written correctly and the chip is in an idle state.

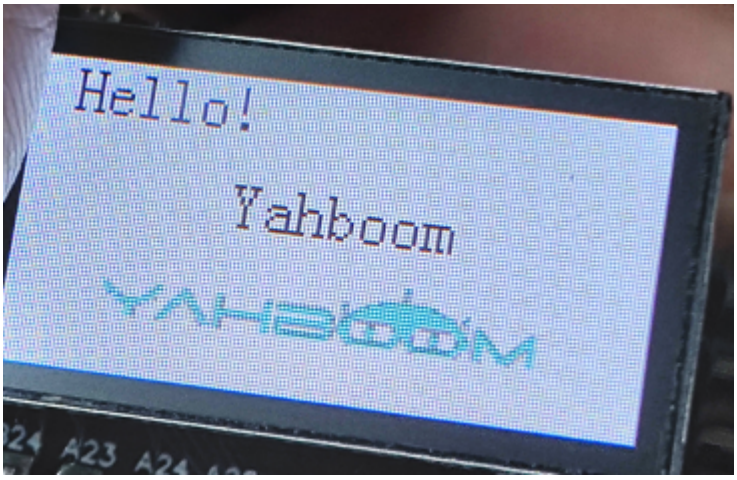
- empty.c

```c
int main(void)
{
    unsigned char buff[10] = {0};

    //开发板初始化 Development board initialization
    board_init();

    delay_ms(100);//等待部署 Waiting for deployment

    //读取W25Q32的ID Read the ID of W25Q32
    printf("ID = %X\r\n",W25Q32_readID());

    //读取0地址的5个字节数据到buff Read 5 bytes of data from address 0 to buff
    W25Q32_read(buff, 0, 7);

    //串口输出读取的数据 Serial port outputs the read data
    printf("buff = %s\r\n",buff);

    //往0地址写入5个字节长度的数据 ABCD Write 5 bytes of data ABCD to address 0
    W25Q32_write("Yahboom", 0, 7);
    delay_ms(100);

    //读取0地址的5个字节数据到buff Read 5 bytes of data from address 0 to buff
    W25Q32_read(buff, 0, 7);

    //串口输出读取的数据 Serial port outputs the read data
    //  printf("buff = %s\r\n",buff);

    SYSCFG_DL_init();

    LCD_Init();//LCD初始化 LCD Initialization
    LCD_Fill(0,0,LCD_W,LCD_H,WHITE);
    LCD_ShowPicture(20,45,120,29,gImage_pic1);
    LCD_ShowString(10,0,"Hello!",BLACK,WHITE,16,0);
    // LCD_ShowChinese(50,20,"亚博智能",BLACK,WHITE,16,0);

    // 显示 buff 中的内容在同一行上 Display the contents of buff on the same line
    int x = 54;  // 起始 x 坐标 Starting x coordinate
    for (int i = 0; i < 7; i++)
        {
        char str[2] = {buff[i], '\0'};  // 每次取一个字符 Take one character at a time
        LCD_ShowString(x, 25, str,BLACK, WHITE, 16, 0);  // 显示字符 Display Characters
        x += 8;  // 每个字符的宽度为 8，x 坐标向右偏移 Each character is 8 wide and has an x-coordinate offset to the right.
    }

    while (1)
    {

    }
}
```

The main functions of this program are to initialize the development board, read and write data from the W25Q32 flash chip, and display the read content through the LCD. First, the program initializes the development board and related hardware. Then, it reads the chip ID of the W25Q32 and outputs it through the serial port. Next, the program reads 7 bytes of data from the starting address (address 0) of the flash memory to the `buff` array and outputs this data through the serial port. Next, it writes the string "Yahboom" to address 0 of the flash memory and reads and displays this data again. Finally, the program initializes the LCD screen, displays a welcome message and a picture, and displays the read `buff` data character by character on the same line on the screen.

5. Experimental phenomenon

After the program is downloaded, the text "Hello!", the data in the flash, and the logo of Yabo Smart will be displayed in lines on the LCD display.


Hello!
Yahboom
YAHBOOM