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

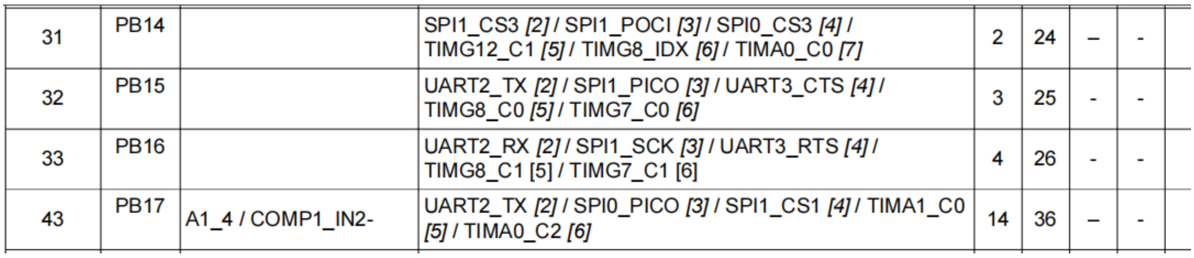
W25Q32 is a common serial flash memory device that uses the SPI (Serial Peripheral Interface) interface protocol. It has high-speed read, write and erase functions and is widely used in high-performance electronic devices such as embedded systems, storage devices, routers, etc. The capacity of W25Q32 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.

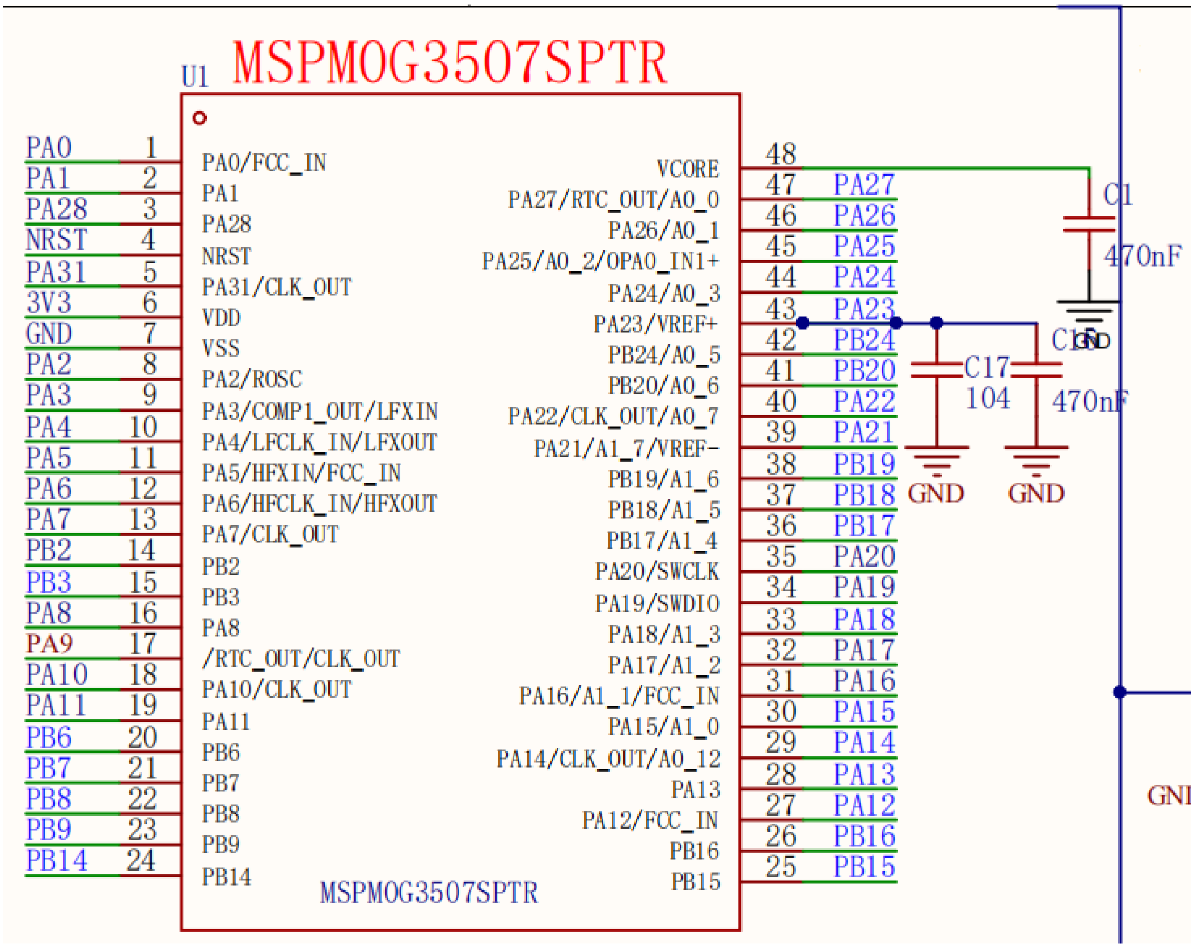
We use the hardware SPI method to drive W25Q32, so we need to determine whether the pin we set has a hardware SPI peripheral interface. In the data sheet, PB14~PB17 can be multiplexed as 4 communication lines of SPI1.



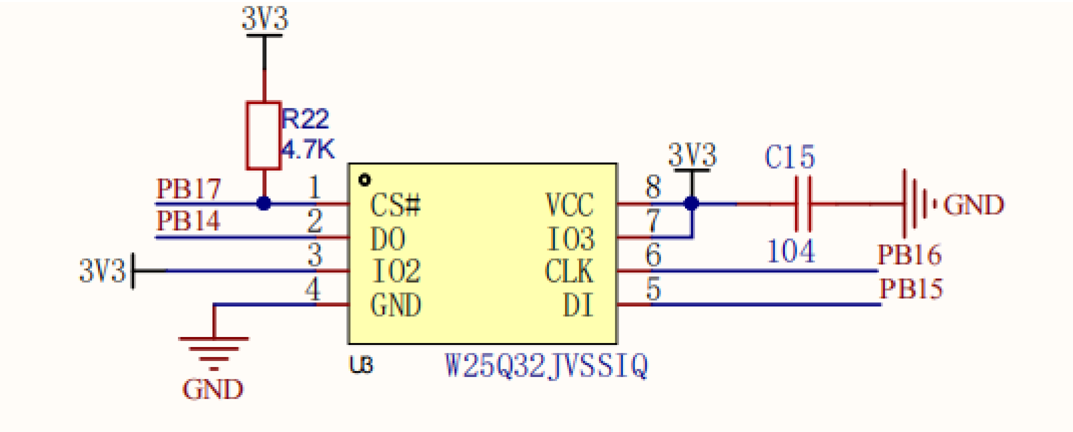
31	PB14		SPI1_CS3 *[2]* / SPI1_POCI *[3]* / SPI0_CS3 *[4]* / TIMG12_C1 *[5]* / TIMG8_IDX *[6]* / TIMA0_C0 *[7]*	2	24	–	-	
32	PB15		UART2_TX *[2]* / SPI1_PICO *[3]* / UART3_CTS *[4]* / TIMG8_C0 *[5]* / TIMG7_C0 *[6]*	3	25	-	-	
33	PB16		UART2_RX *[2]* / SPI1_SCK *[3]* / UART3_RTS *[4]* / TIMG8_C1 [5] / 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.

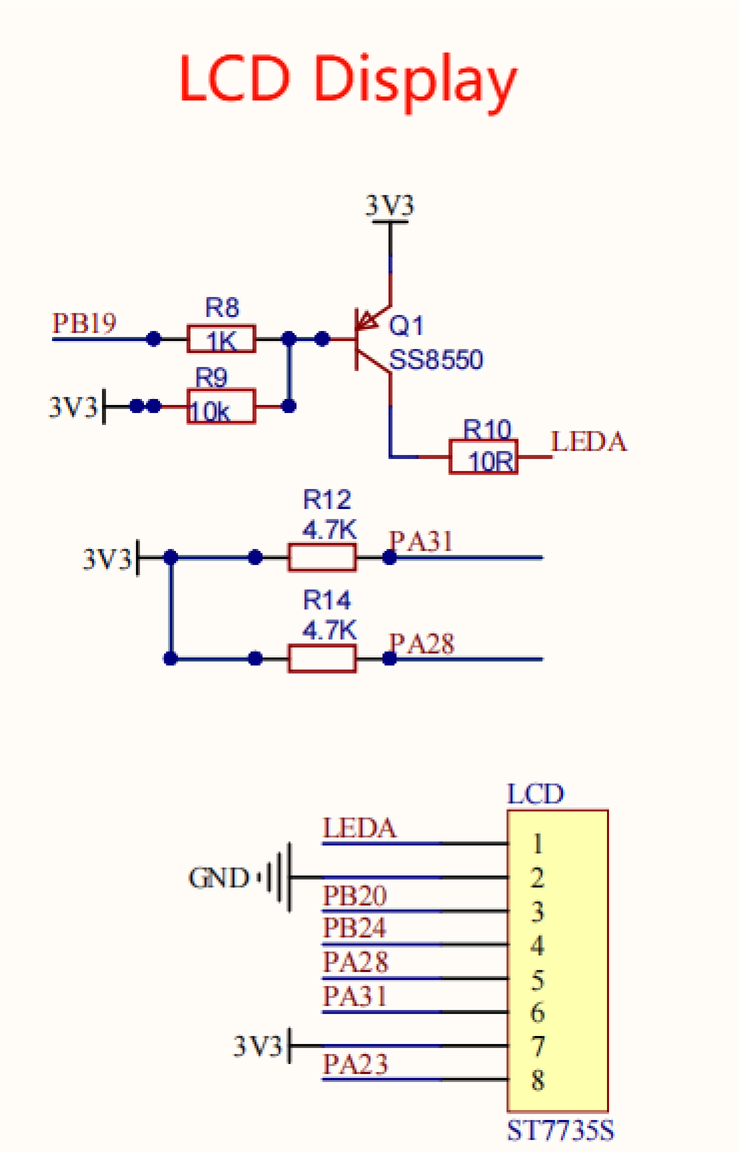
MSPM0G3507 main control diagram:



W25Q32 partial schematic diagram:



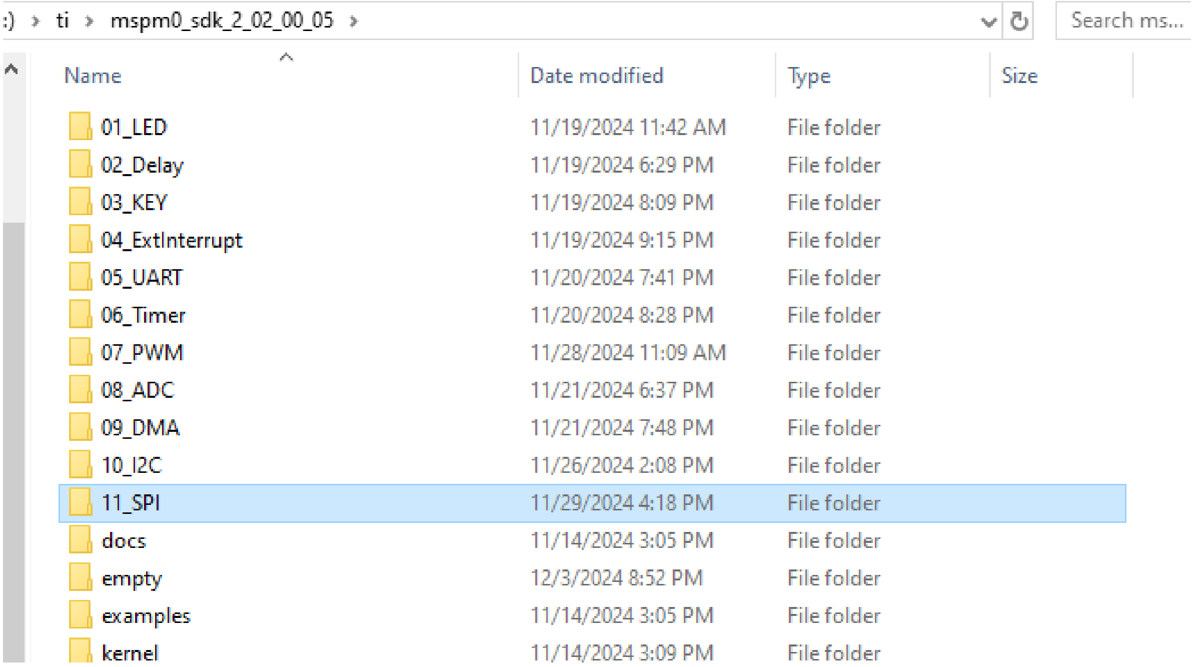
LCD screen partial schematic diagram:



3. Experimental steps

Here we use the template project we provide for introduction.

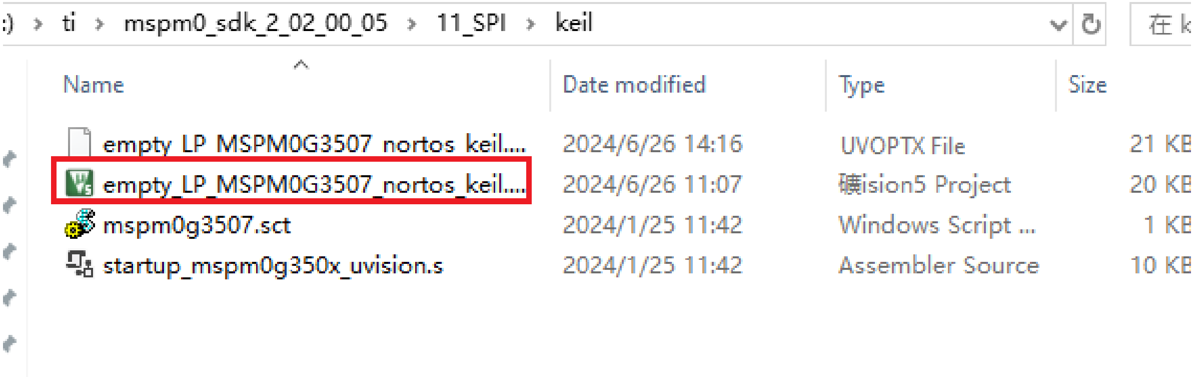
Unzip the template project in the root directory of the SDK, and I rename it to the 11_SPI folder.



Name	Date modified	Type	Size
01_LED	11/19/2024 11:42 AM	File folder	
02_Delay	11/19/2024 6:29 PM	File folder	
03_KEY	11/19/2024 8:09 PM	File folder	
04_ExtInterrupt	11/19/2024 9:15 PM	File folder	
05_UART	11/20/2024 7:41 PM	File folder	
06_Timer	11/20/2024 8:28 PM	File folder	
07_PWM	11/28/2024 11:09 AM	File folder	
08_ADC	11/21/2024 6:37 PM	File folder	
09_DMA	11/21/2024 7:48 PM	File folder	
10_I2C	11/26/2024 2:08 PM	File folder	
11_SPI	11/29/2024 4:18 PM	File folder	
docs	11/14/2024 3:05 PM	File folder	
empty	12/3/2024 8:52 PM	File folder	
examples	11/14/2024 3:05 PM	File folder	
kernel	11/14/2024 3:09 PM	File folder	

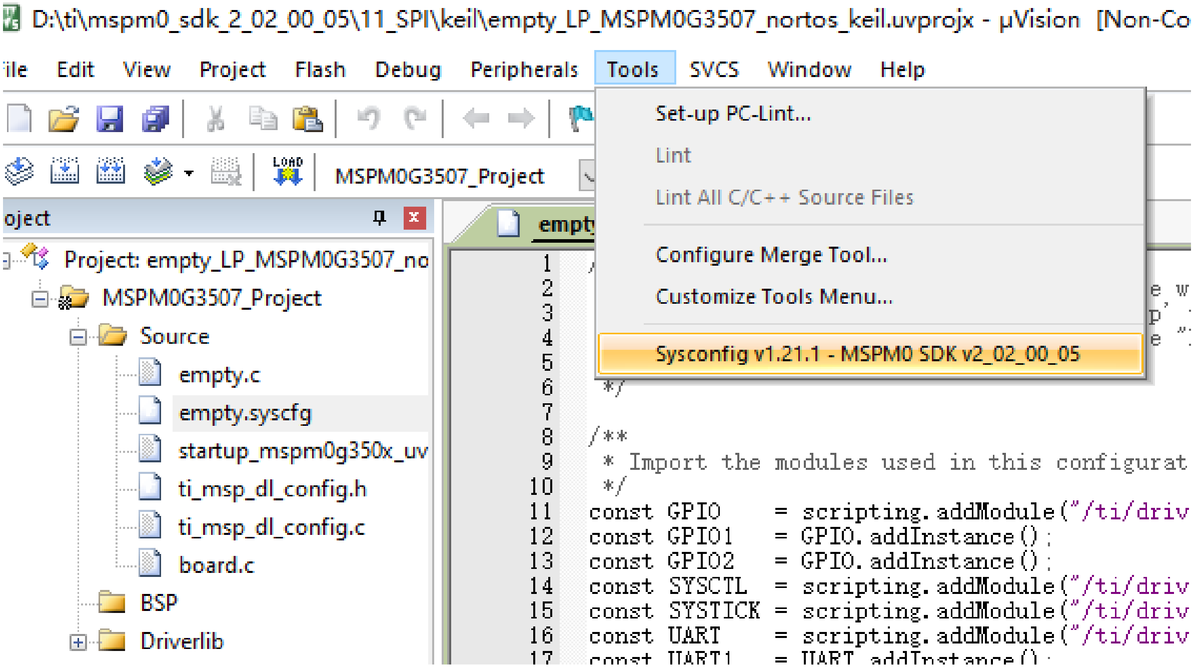
1. Open the SYSCONFIG configuration tool

Then open the project.



Name	Date modified	Type	Size
empty_LP_MSPM0G3507_nortos_keil....	2024/6/26 14:16	UVOPTX File	21 KB
empty_LP_MSPM0G3507_nortos_keil....	2024/6/26 11:07	礦ision5 Project	20 KB
mspm0g3507.sct	2024/1/25 11:42	Windows Script ...	1 KB
startup_mspm0g350x_uvision.s	2024/1/25 11:42	Assembler Source	10 KB

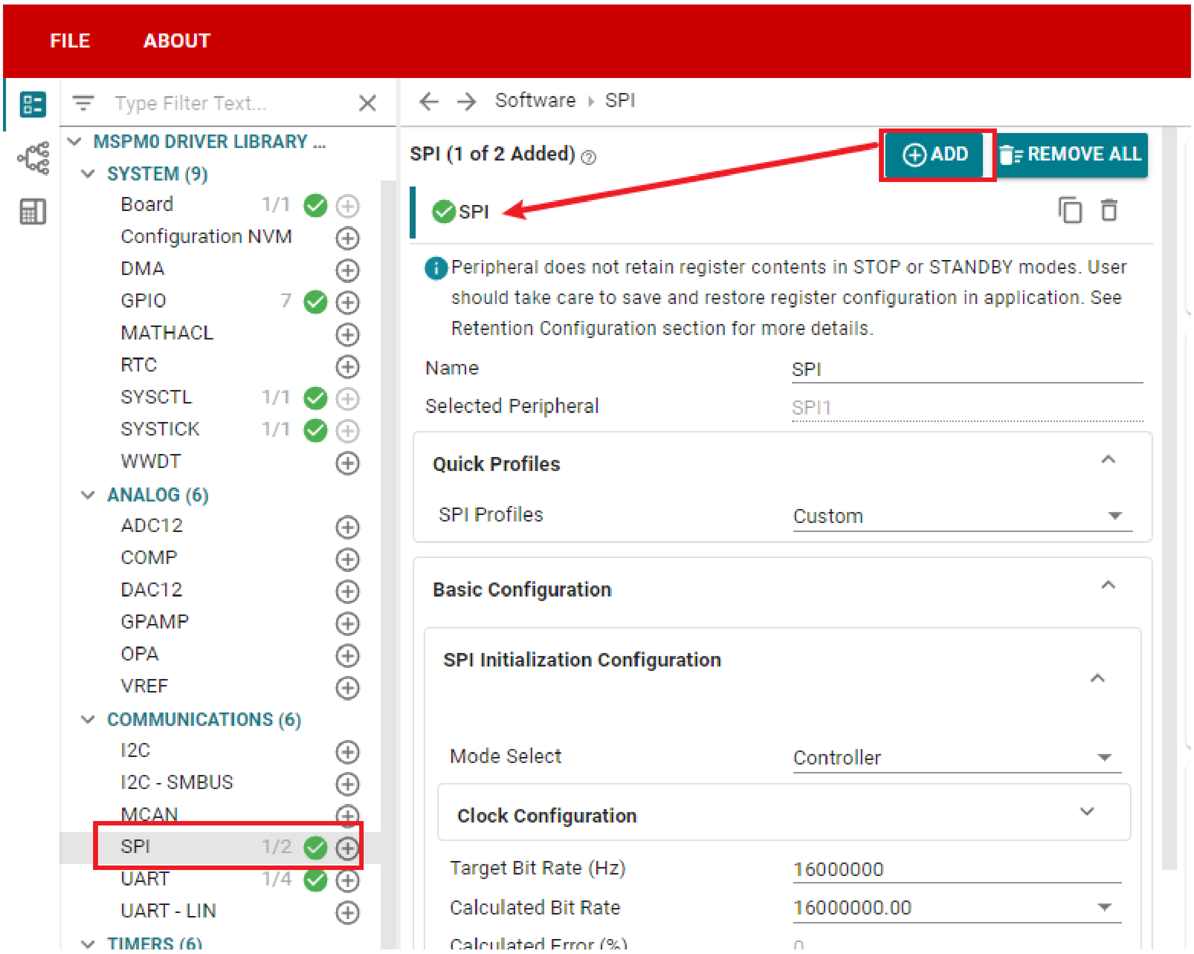
Open the empty.syscfg file in the Keil main interface. With the empty.syscfg file open, open the SYSCONFIG GUI interface.



D:\ti\mspm0_sdk_2_02_00_05\11_SPI\keil\empty_LP_MSPM0G3507_nortos_keil.uvprojx - µVision [Non-Co
ile Edit View Project Flash Debug Peripherals Tools SVCS Window Help
MSPM0G3507_Project
Set-up PC-Lint...
Lint
Lint All C/C++ Source Files
Configure Merge Tool...
Customize Tools Menu...
Sysconfig v1.21.1 - MSPM0 SDK v2_02_00_05
oject
Project: empty_LP_MSPM0G3507_no
MSPM0G3507_Project
Source
empty.c
empty.syscfg
startup_mspm0g350x_uv
ti_msp_dl_config.h
ti_msp_dl_config.c
board.c
BSP
Driverlib
empty

```
/**
 * Import the modules used in this configurat
 */
const GPIO    = scripting.addModule("/ti/driv
const GPIO1   = GPIO.addInstance();
const GPIO2   = GPIO.addInstance();
const SYSCTL  = scripting.addModule("/ti/driv
const SYSTICK = scripting.addModule("/ti/driv
const UART    = scripting.addModule("/ti/driv
const UART1   = UART.addInstance();
```

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



SPI (1 of 2 Added)

SPI

Peripheral does not retain register contents in STOP or STANDBY modes. User should take care to save and restore register configuration in application. See Retention Configuration section for more details.

Name: SPI

Selected Peripheral: SPI1

Quick Profiles

SPI Profiles: Custom

Basic Configuration

SPI Initialization Configuration

Mode Select: Controller

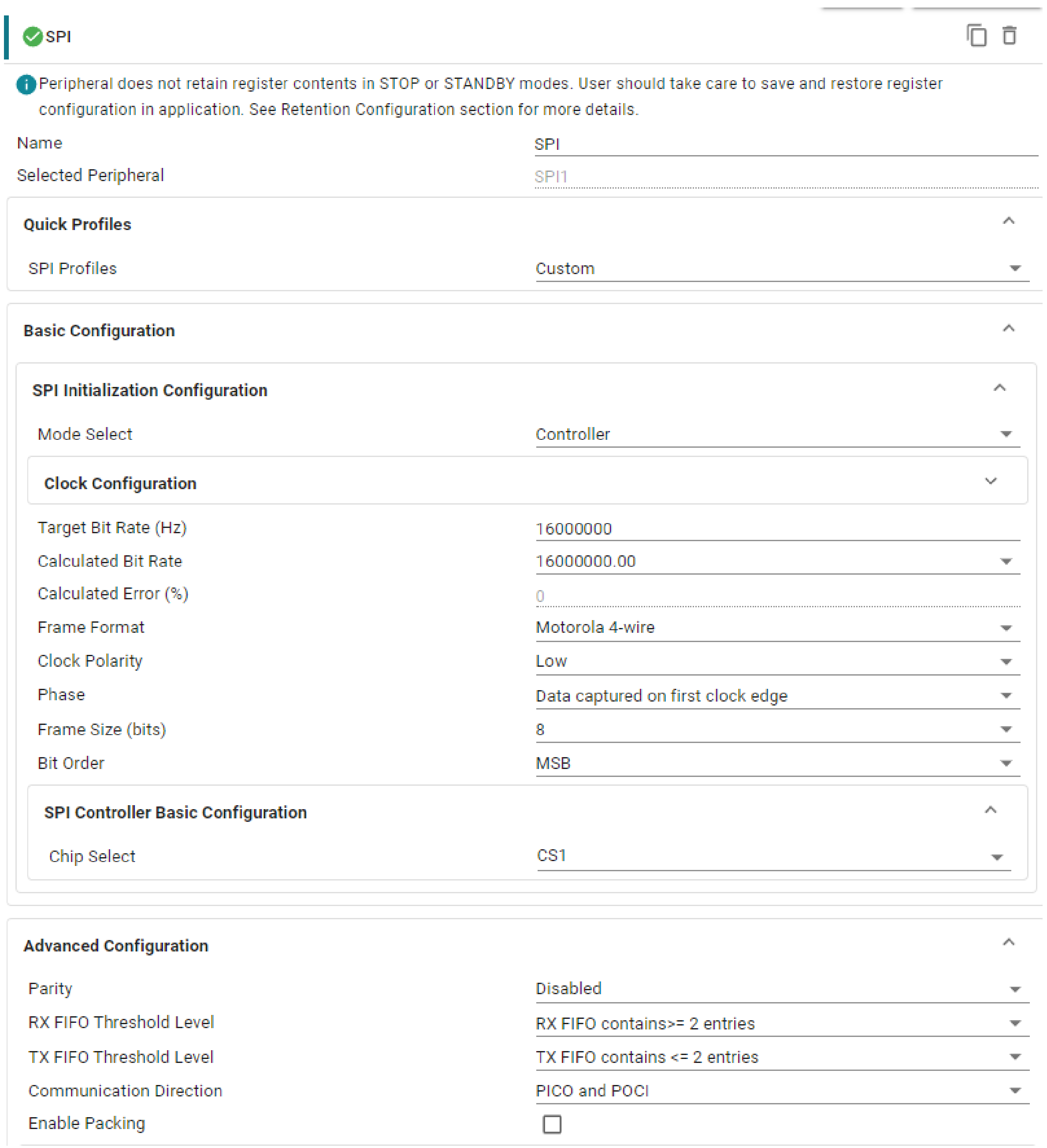
Clock Configuration

Target Bit Rate (Hz): 16000000

Calculated Bit Rate: 16000000.00

Calculated Error (%): 0

2. SPI parameter configuration



SPI

Peripheral does not retain register contents in STOP or STANDBY modes. User should take care to save and restore register configuration in application. See Retention Configuration section for more details.

Name	SPI
Selected Peripheral	SPI1

Quick Profiles

SPI Profiles	Custom

Basic Configuration

SPI Initialization Configuration

Mode Select	Controller

Clock Configuration

Target Bit Rate (Hz)	16000000
Calculated Bit Rate	16000000.00
Calculated Error (%)	0
Frame Format	Motorola 4-wire
Clock Polarity	Low
Phase	Data captured on first clock edge
Frame Size (bits)	8
Bit Order	MSB

SPI Controller Basic Configuration

Chip Select	CS1

Advanced Configuration

Parity	Disabled
RX FIFO Threshold Level	RX FIFO contains>= 2 entries
TX FIFO Threshold Level	TX FIFO contains <= 2 entries
Communication Direction	PICO and POCI
Enable Packing	□

Parameter description:

Mode Select: SPI master-slave mode selection. Select Controller (host) here

Target Bit Rate (Hz): SPI frequency configuration. Fill in 16000000, SPI clock maximum 16MHZ

Calculated Bit Rate: The actual frequency calculated by the software according to the configuration

Calculated Error (%): Calculated frequency error

Frame Format: SPI mode. Select Motorola 4-wire, 4-wire mode

Clock Polarity: SPI clock polarity configuration. Select LoW, polarity is low

Phase: SPI phase configuration. Configured as Data captured on first clock edge, the first phase capture number

Frame Size (bits): Data bit size. Configured as 8-bit data frame

Bit Order: Data order. Configured as MSB, high bit first

Chip Select: Chip select line configuration. Select CS1. It is not important here, we will choose to control CS by software later, not using hardware

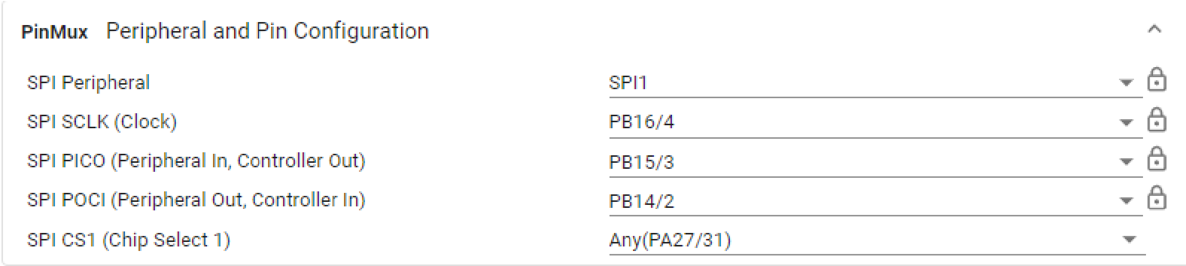
Parity: Whether to enable SPI parity. Select Disabled, do not enable

RX FIFo Threshold Level: Configure RX FIFO interrupt trigger level. Configured as RX FIFO contains>= 2 entries

TX FIFo Threshold Level: Configure TX FIFO interrupt trigger level. Configured as TX FIFO contains <= 2 entries

Communication Direction: SPI communication direction. Configured as PICo and PoCI, both sending and receiving

Enable Packing: Whether to enable 32-bit transmission mode. Don't enable it here



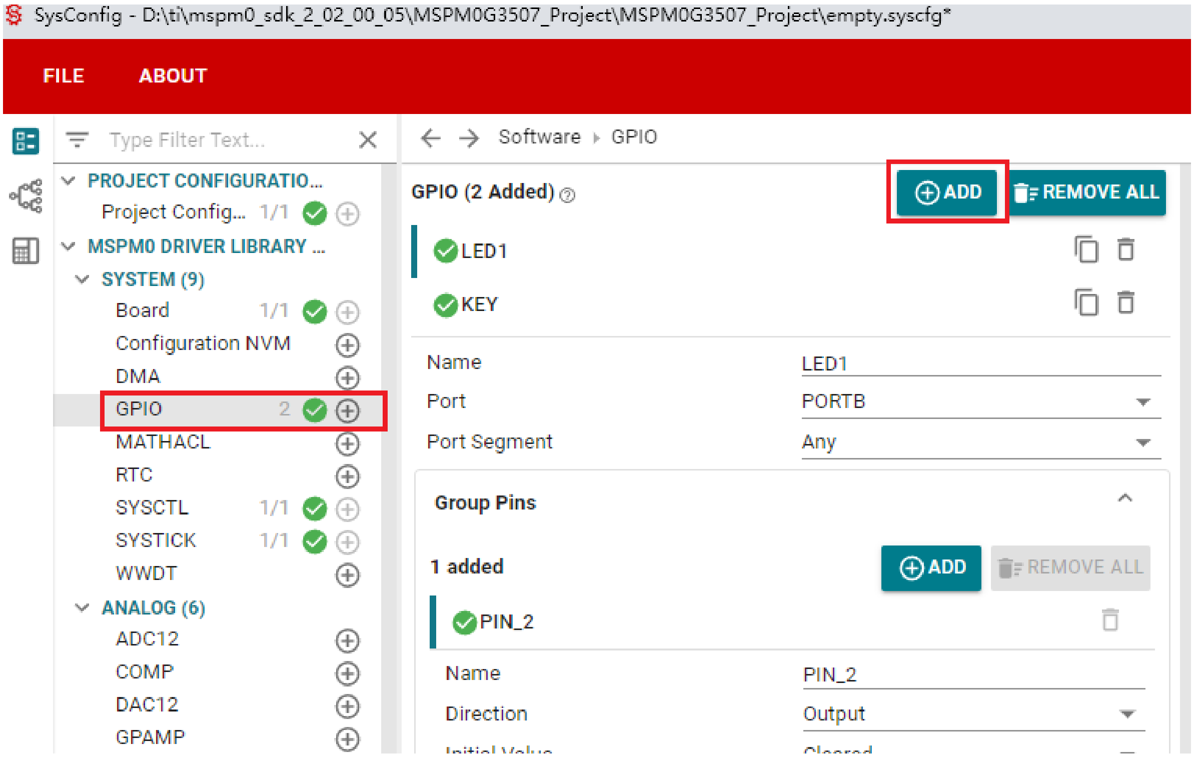
PinMux Peripheral and Pin Configuration

SPI Peripheral	SPI1
SPI SCLK (Clock)	PB16/4
SPI PICO (Peripheral In, Controller Out)	PB15/3
SPI POCI (Peripheral Out, Controller In)	PB14/2
SPI CS1 (Chip Select 1)	Any(PA27/31)

Configure the CS pin casually first, and we will use the software method of CS later.

3. Pin parameter configuration

Find the GPIO column on the left, click to enter, and add several groups of GPIO.



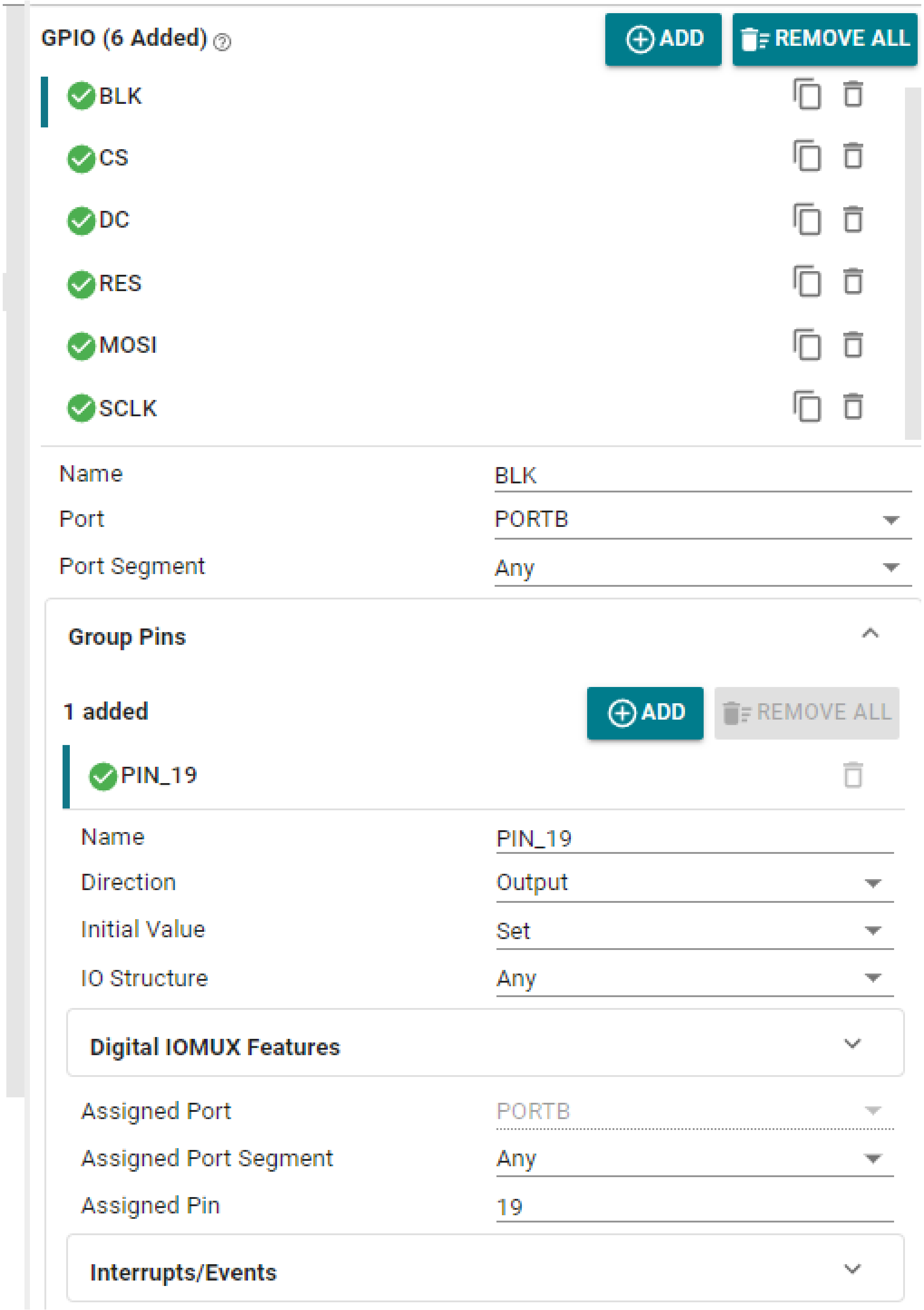
SysConfig - D:\ti\mspm0_sdk_2_02_00_05\MSPM0G3507_Project\MSPM0G3507_Project\empty.syscfg*

Name	LED1
Port	PORTB
Port Segment	Any

Name	PIN_2
Direction	Output
Initial Value	Cleared

LCD screen

Backlight **BLK**:



Name	BLK
Port	PORTB
Port Segment	Any

Group Pins

1 added

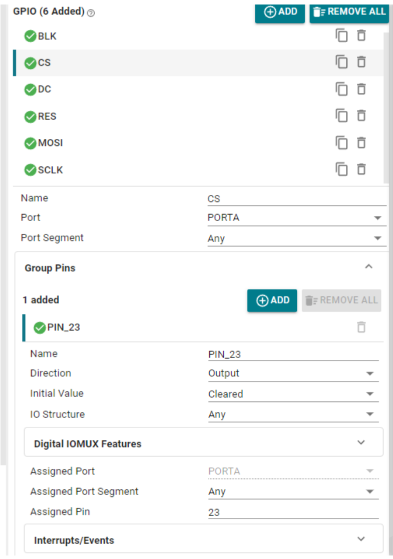
Name	PIN_19
Direction	Output
Initial Value	Set
IO Structure	Any

Digital IOMUX Features

Assigned Port	PORTB
Assigned Port Segment	Any
Assigned Pin	19

Interrupts/Events

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



Name	CS
Port	PORTA
Port Segment	Any

Group Pins

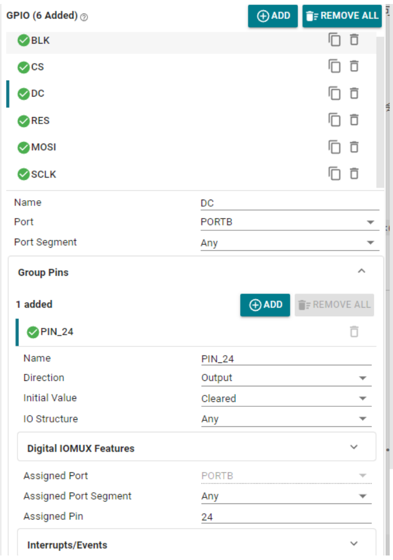
1 added

Name	PIN_23
Direction	Output
Initial Value	Cleared
IO Structure	Any

Digital IOMUX Features

Assigned Port	PORTA
Assigned Port Segment	Any
Assigned Pin	23

Interrupts/Events



Name	DC
Port	PORTB
Port Segment	Any

Group Pins

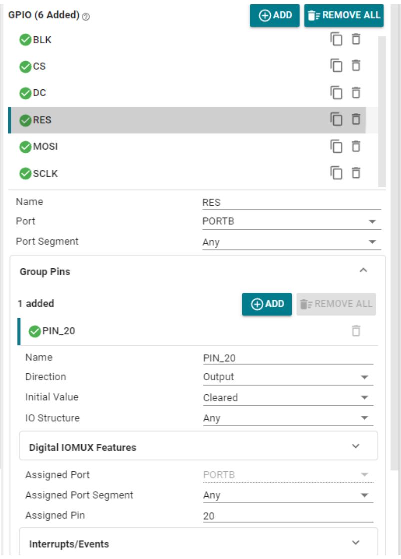
1 added

Name	PIN_24
Direction	Output
Initial Value	Cleared
IO Structure	Any

Digital IOMUX Features

Assigned Port	PORTB
Assigned Port Segment	Any
Assigned Pin	24

Interrupts/Events



Name	RES
Port	PORTB
Port Segment	Any

Group Pins

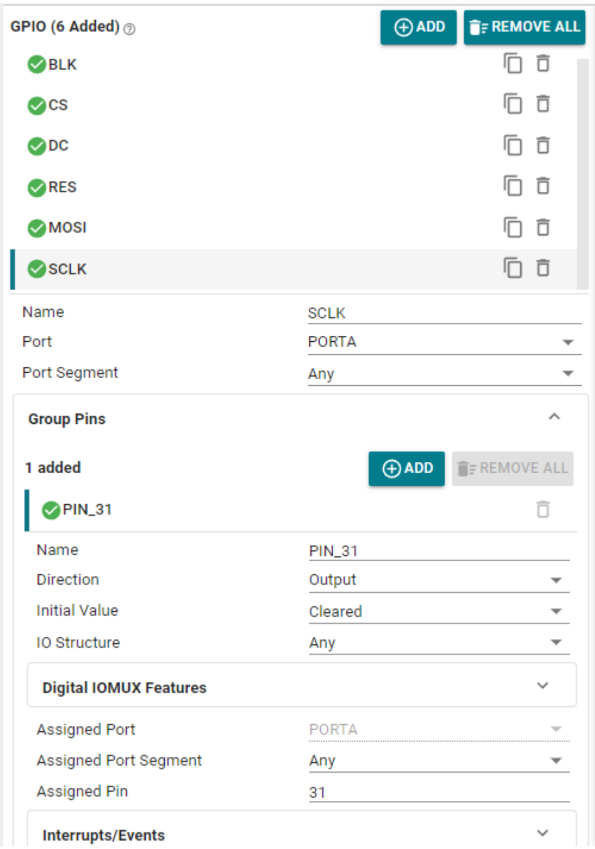
1 added

Name	PIN_20
Direction	Output
Initial Value	Cleared
IO Structure	Any

Digital IOMUX Features

Assigned Port	PORTB
Assigned Port Segment	Any
Assigned Pin	20

Interrupts/Events



Name SCLK
Port PORTA
Port Segment Any

Group Pins

1 added

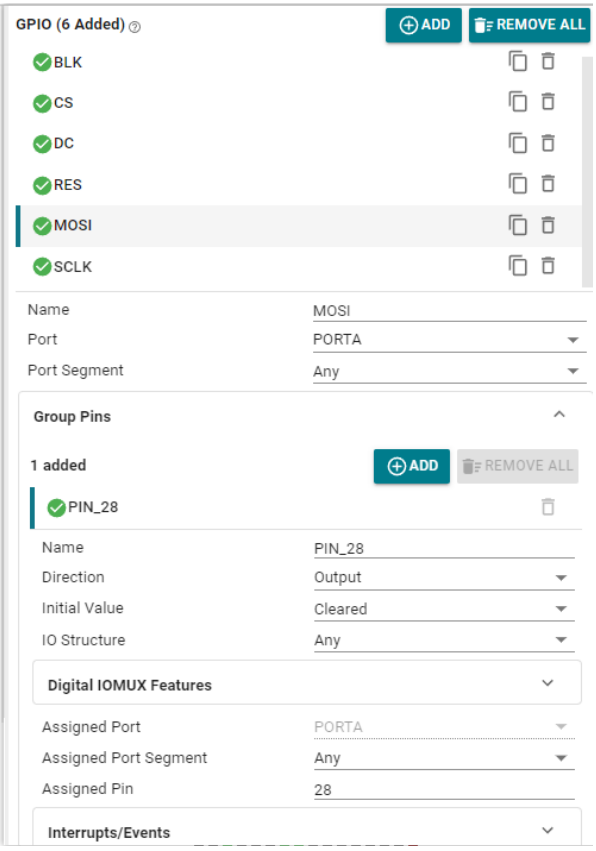
PIN_31

Name PIN_31
Direction Output
Initial Value Cleared
IO Structure Any

Digital IOMUX Features

Assigned Port PORTA
Assigned Port Segment Any
Assigned Pin 31

Interrupts/Events



Name MOSI
Port PORTA
Port Segment Any

Group Pins

1 added

PIN_28

Name PIN_28
Direction Output
Initial Value Cleared
IO Structure Any

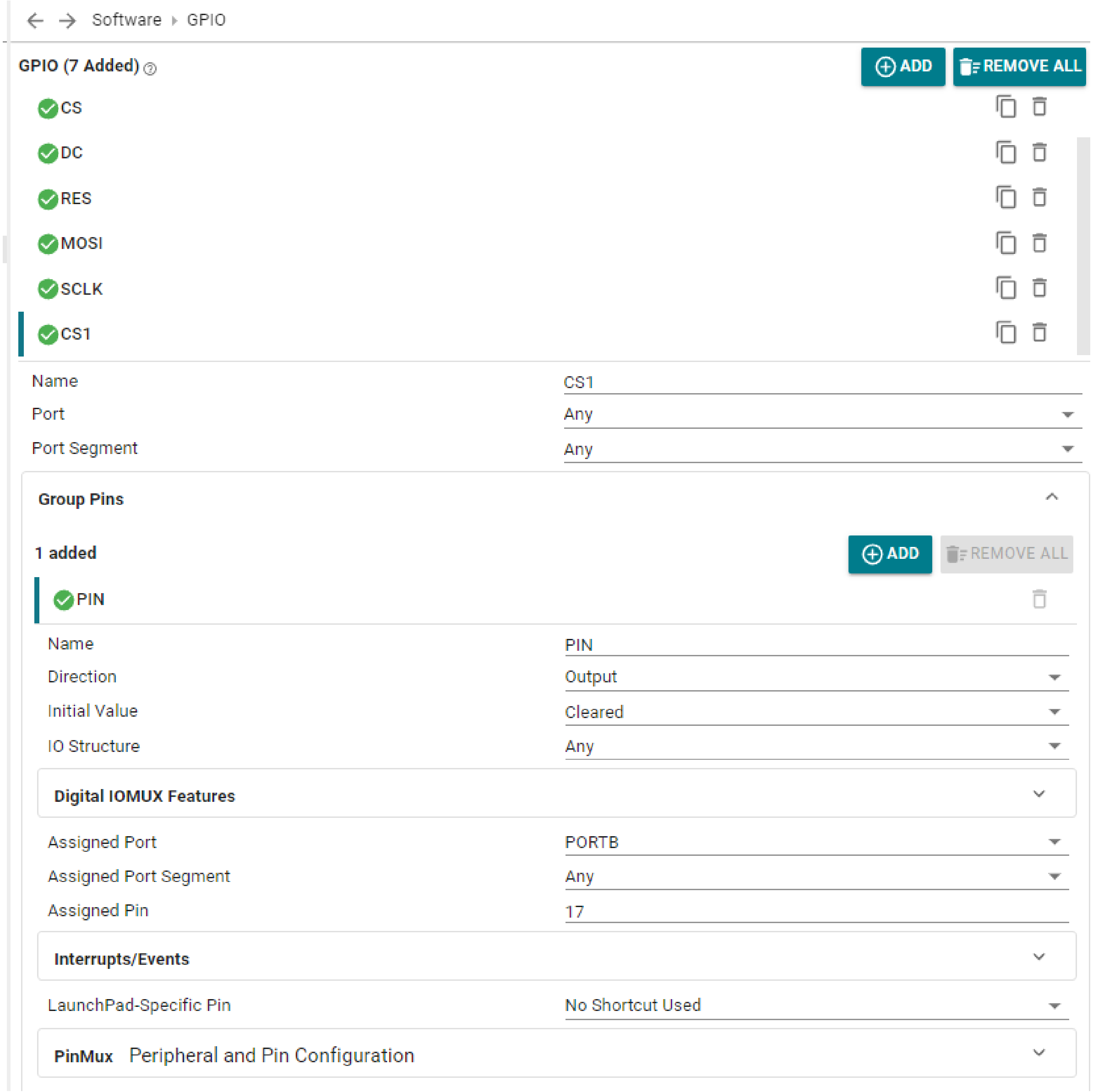
Digital IOMUX Features

Assigned Port PORTA
Assigned Port Segment Any
Assigned Pin 28

Interrupts/Events

External Flash

CS1



GPIO (7 Added)

- CS
- DC
- RES
- MOSI
- SCLK
- CS1

Name: CS1

Port: Any

Port Segment: Any

Group Pins

1 added

- PIN

Name: PIN

Direction: Output

Initial Value: Cleared

IO Structure: Any

Digital IOMUX Features

Assigned Port: PORTB

Assigned Port Segment: Any

Assigned Pin: 17

Interrupts/Events

LaunchPad-Specific Pin: No Shortcut Used

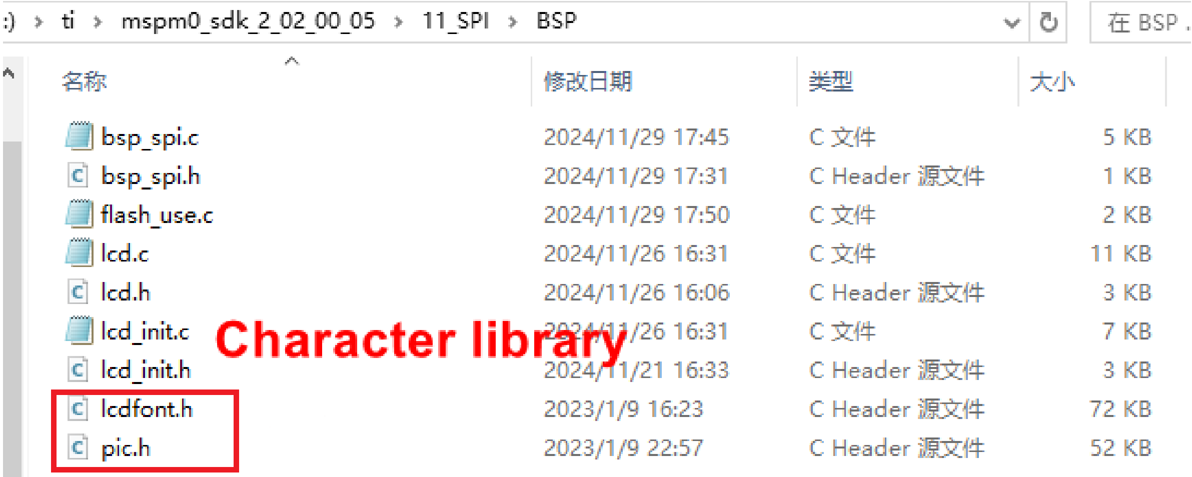
PinMux Peripheral and Pin Configuration

Save and exit.

3. SPI protocol usage

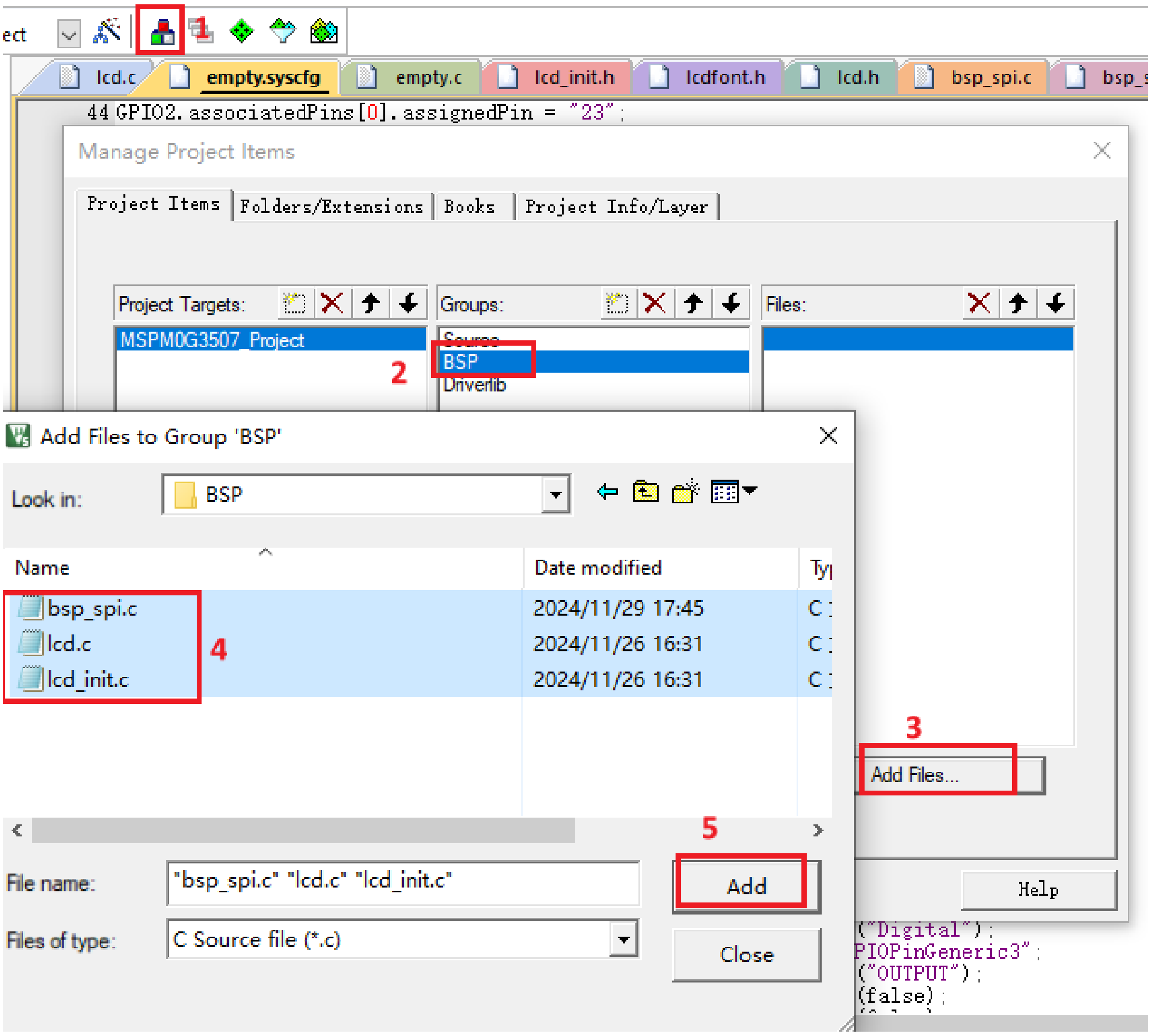
We create four new files in the project template, namely lcd.c, lcd.h, bsp_spi.c and bsp_spi.h. Save them in the BSP folder of the project.

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



名称	修改日期	类型	大小
bsp_spi.c	2024/11/29 17:45	C 文件	5 KB
bsp_spi.h	2024/11/29 17:31	C Header 源文件	1 KB
flash_use.c	2024/11/29 17:50	C 文件	2 KB
lcd.c	2024/11/26 16:31	C 文件	11 KB
lcd.h	2024/11/26 16:06	C Header 源文件	3 KB
lcd_init.c	2024/11/26 16:31	C 文件	7 KB
lcd_init.h	2024/11/21 16:33	C Header 源文件	3 KB
lcdfont.h	2023/1/9 16:23	C Header 源文件	72 KB
pic.h	2023/1/9 22:57	C Header 源文件	52 KB

Open the project manager, click BSP, and add the files we created and copied before to the BSP.



```
44 GPIO2.associatedPins[0].assignedPin = "23";
```

Project Targets: MSPM0G3507_Project

Groups: Source, BSP, Driverlib

Look in: BSP

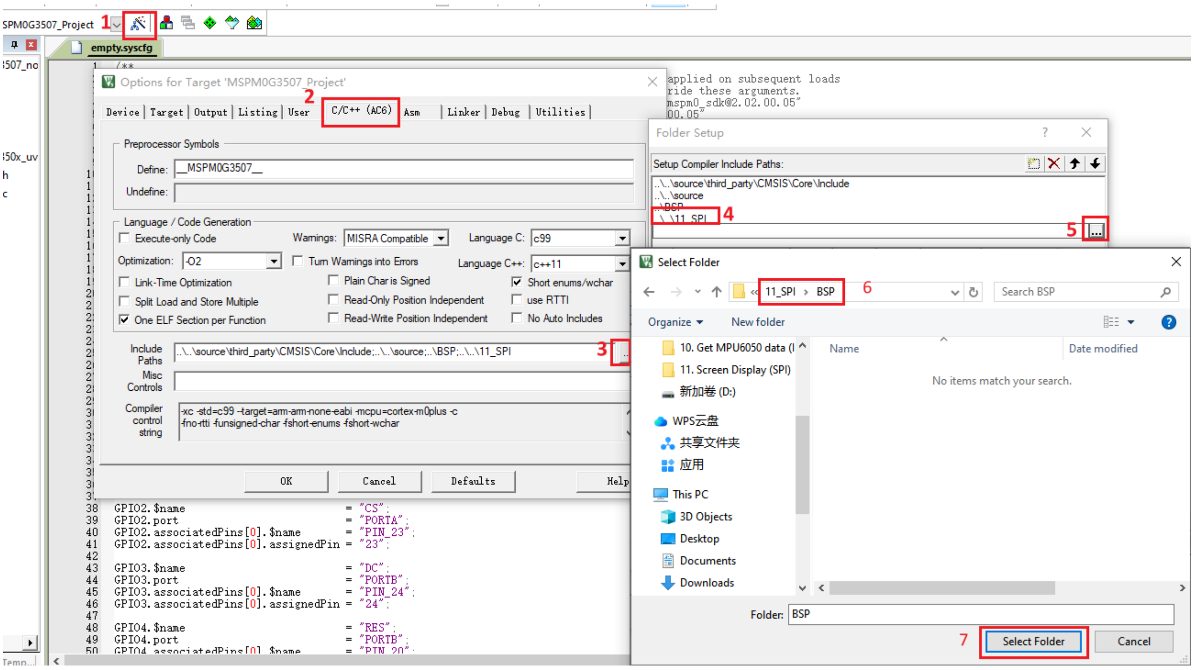
Name	Date modified	Typ
bsp_spi.c	2024/11/29 17:45	C
lcd.c	2024/11/26 16:31	C
lcd_init.c	2024/11/26 16:31	C

File name: "bsp_spi.c" "lcd.c" "lcd_init.c"

Files of type: C Source file (*.c)

```
("Digital");
PIOPinGeneric3";
("OUTPUT");
(false);
```

Update the header file path.



Preprocessor Symbols

Define: __MSPM0G3507__

Undefine:

Language / Code Generation

☐ Execute-only Code

Warnings: MISRA Compatible

Language C: c99

Optimization: -O2

☐ Turn Warnings into Errors

Language C++: c++11

☐ Link-Time Optimization

☐ Plain Char is Signed

☑ Short enums/wchar

☐ Split Load and Store Multiple

☐ Read-Only Position Independent

☐ use RTTI

☑ One ELF Section per Function

☐ Read-Write Position Independent

☐ No Auto Includes

Include Paths: ..\..\source\third_party\CMSIS\Core\Include;..\..\source;..\BSP;..\..\11_SPI

Misc Controls:

Compiler control string: -xc -std=c99 --target=arm-arm-none-eabi -mcpu=cortex-m0plus -c -fno-rtti -funsigned-char -fshort-enums -fshort-wchar

```
applied on subsequent loads
ride these arguments.
mspm0_sdk@2.02.00.05"
00.05"
```

Setup Compiler Include Paths:

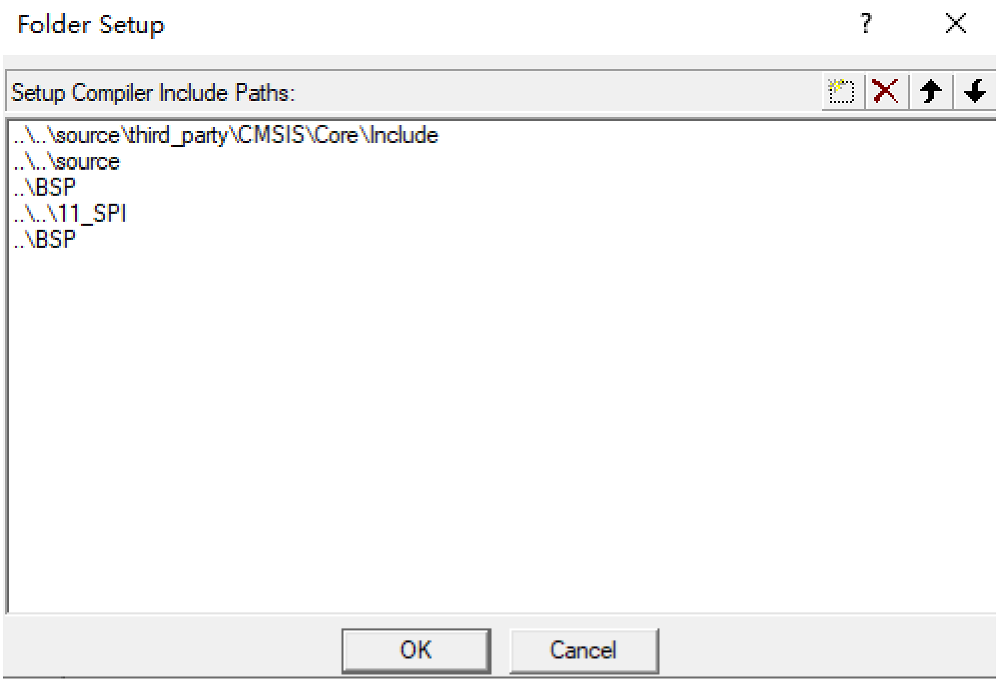
```
..\..\source\third_party\CMSIS\Core\Include
..\..\source
..\BSP
..\..\11_SPI
```

« 11_SPI › BSP

Search BSP

Folder: BSP

```
GPIO2.$name                        = "CS";
GPIO2.port                         = "PORTA";
GPIO2.associatedPins[0].$name      = "PIN_23";
GPIO2.associatedPins[0].assignedPin = "23";

GPIO3.$name                        = "DC";
GPIO3.port                         = "PORTB";
GPIO3.associatedPins[0].$name      = "PIN_24";
GPIO3.associatedPins[0].assignedPin = "24";

GPIO4.$name                        = "RES";
GPIO4.port                         = "PORTB";
GPIO4.associatedPins[0].$name      = "PIN_20";
```



Folder Setup

Setup Compiler Include Paths:

```
..\..\source\third_party\CMSIS\Core\Include
..\..\source
..\BSP
..\..\11_SPI
..\BSP
```

4. Write the 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)

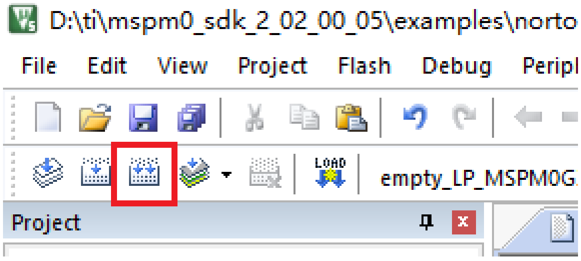
```
#include "bsp_spi.h"


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;
}
...
```

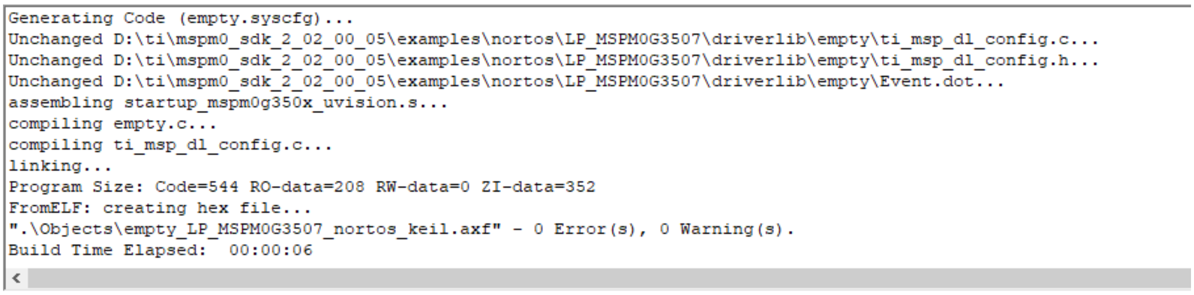
Then write the following code in the empty.c file

```
#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);

    // 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)
    {

    }
}
```

5. Compile

Click the Rebuild icon. The following prompt appears, indicating that the compilation is complete and there are no errors.





```
Generating Code (empty.syscfg)...
Unchanged D:\ti\mspm0_sdk_2_02_00_05\examples\nortos\LP_MSPM0G3507\driverlib\empty\ti_msp_dl_config.c...
Unchanged D:\ti\mspm0_sdk_2_02_00_05\examples\nortos\LP_MSPM0G3507\driverlib\empty\ti_msp_dl_config.h...
Unchanged D:\ti\mspm0_sdk_2_02_00_05\examples\nortos\LP_MSPM0G3507\driverlib\empty\Event.dot...
assembling startup_mspm0g350x_uvision.s...
compiling empty.c...
compiling ti_msp_dl_config.c...
linking...
Program Size: Code=544 RO-data=208 RW-data=0 ZI-data=352
FromELF: creating hex file...
".\Objects\empty_LP_MSPM0G3507_nortos_keil.axf" - 0 Error(s), 0 Warning(s).
Build Time Elapsed:  00:00:06
```

4. Program Analysis

- lcd.c

```
/******************************************************************************
      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);
        }
    }
}
```

The `LCD_Fill` function fills the specified color in the area between the specified starting coordinates `(xsta, ysta)` and the ending coordinates `(xend, yend)`. It completes the area filling operation by setting the display range and looping to write color data.

```
/******************************************************************************
      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

```
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);

    // 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 of the screen.

5. Experimental phenomenon

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