Lab 9 – Serial Peripheral Interface (SPI) &

LCD Pixel Display

# Youssef Samwel

# [yo800238@ucf.edu](mailto:yo800238@ucf.edu)

# EEL4742C Embedded Systems

Prof. Dr. Zakhia Abichar - Section 00419

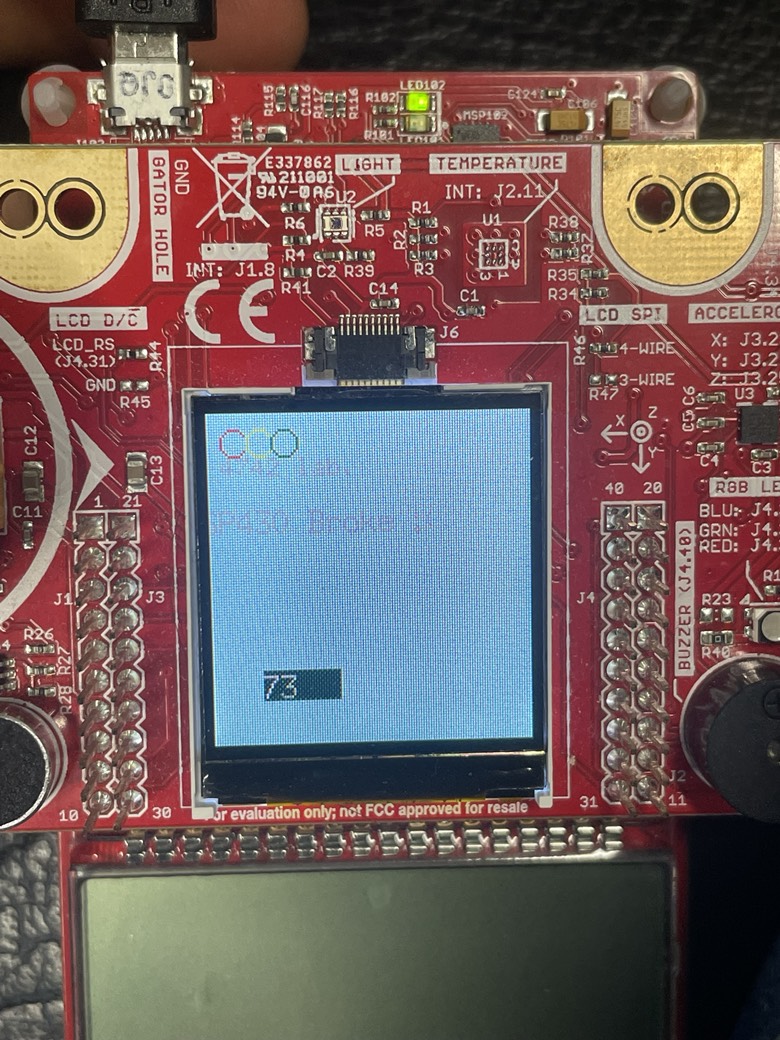
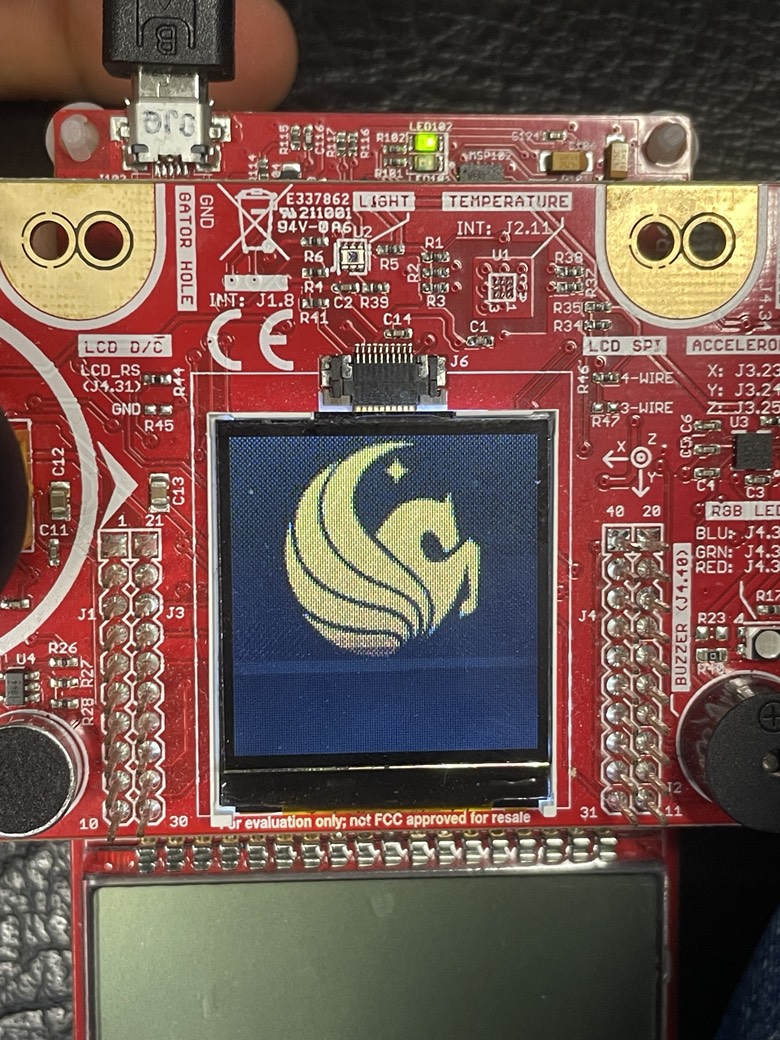
# 4/4/2024



# **Project Description**

In In this lab, we will learn using the Serial Peripheral Interface (SPI) to communicate data and use it to interface the pixel display that’s on the BoosterPack board. We will also learn how the graphics software stack works and use it to draw on the pixel display.

# **2.0 Experiment Code**



#ifndef \_\_LAB9\_IMPLEMENTATIONS\_\_

#define \_\_LAB9\_IMPLEMENTATIONS\_\_

#include "Grlib/grlib/grlib.h"    // Graphics library (grlib)

#include "LcdDriver/lcd\_driver.h" // LCD driver

#include <stdio.h>

static Graphics\_Context g\_sContext; // Declare a graphic library context

extern const tImage UCF\_Logo;

extern const tFont g\_sFontfixed7x13;

void lab\_9\_1() {

    char mystring[20];

    // Clear the screen

    Graphics\_clearDisplay(&g\_sContext);

    ////////////////////////////////////////////////////////////////////////////////////////////

    // Print message

    Graphics\_drawStringCentered(&g\_sContext, (int8\_t\*)"Welcome to", AUTO\_STRING\_LENGTH, 64, 30, OPAQUE\_TEXT);

    sprintf(mystring, "EEL 4742C Lab!");

    Graphics\_drawStringCentered(&g\_sContext, (int8\_t\*)mystring, AUTO\_STRING\_LENGTH, 64, 55, OPAQUE\_TEXT);

}

void lab\_9\_2() {

    Graphics\_clearDisplay(&g\_sContext);

    // draw UCF logo

    Graphics\_drawImage(&g\_sContext, &UCF\_Logo, 0, 0);

    Graphics\_setBackgroundColor(&g\_sContext, GRAPHICS\_COLOR\_BEIGE);

    Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_BISQUE);

    // Set the default font for strings

    GrContextFontSet(&g\_sContext, &g\_sFontFixed6x8);

    \_\_delay\_cycles(2e5);

    Graphics\_clearDisplay(&g\_sContext);

    char szBuf[30];

    int len = sprintf(szBuf, "EEL 4742 lab.");

    Graphics\_drawStringCentered(&g\_sContext, (int8\_t\*)szBuf, len, 20, 20, 1);

    Graphics\_setFont(&g\_sContext, &g\_sFontfixed7x13);

    len = sprintf(szBuf, "MSP430 Broke :(");

    Graphics\_drawStringCentered(&g\_sContext, (int8\_t\*)szBuf, len, 40, 40, 1);

    Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_RED);

    Graphics\_drawCircle(&g\_sContext, 10, 11, 5);

    Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_YELLOW);

    Graphics\_drawCircle(&g\_sContext, 20, 11, 5);

    Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_GREEN);

    Graphics\_drawCircle(&g\_sContext, 30, 11, 5);

    int8\_t value = 0;

    while(1) {

        Graphics\_Rectangle rect;

        rect.xMin = 10;

        rect.xMax = 120;

        rect.yMin = 90;

        rect.yMax = 110;

        Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_BEIGE);

        Graphics\_drawRectangle(&g\_sContext, &rect);

               rect.xMin = 20;

               rect.xMax = 50;

               rect.yMin = 99;

               rect.yMax = 110;

               Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_GREEN);

               Graphics\_fillRectangle(&g\_sContext, &rect);

        value++;

        sprintf(szBuf, "%d", value);

        Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_BLANCHED\_ALMOND);

        Graphics\_drawString(&g\_sContext, (int8\_t\*)szBuf, len, 20, 99, 0);

        \_\_delay\_cycles(1e5);

    }

    \_low\_power\_mode\_3();

}

#endif

// This code was ported from TI's sample code. See Copyright notice at the bottom of this file.

#include <LcdDriver/lower\_driver.h>

#include "msp430fr6989.h"

#include "Grlib/grlib/grlib.h"

#include <stdint.h>

void HAL\_LCD\_PortInit(void)

{

    /////////////////////////////////////

    // Configuring the SPI pins

    /////////////////////////////////////

    // Configure UCB0CLK/P1.4 pin to serial clock

    // Dir: X Sel1: 0 Sel0: 1 LCDSz: 0

    P1SEL1 &= ~BIT4;

    P1SEL0 |= BIT4;

    // Configure UCB0SIMO/P1.6 pin to SIMO

    // Dir: X Sel1: 0 Sel0: 1 LCDSz: 0

    P1SEL1 &= ~BIT6;

    P1SEL0 |= BIT6;

    // OK to ignore UCB0STE/P1.5 since we'll connect the display's enable bit to low (enabled all the time)

    // OK to ignore UCB0SOMI/P1.7 since the display doesn't give back any data

    ///////////////////////////////////////////////

    // Configuring the display's other pins

    ///////////////////////////////////////////////

    // Set reset pin as output

    P9DIR |= BIT4;

    // Set the data/command pin as output

    P2DIR |= BIT3;

    // Set the chip select pin as output

    P2DIR |= BIT5;

    return;

}

void HAL\_LCD\_SpiInit(void)

{

    //////////////////////////

    // SPI configuration

    //////////////////////////

    // Put eUSCI in reset state and set all fields in the register to 0

    UCB0CTLW0 = UCSWRST;

    // Fields that need to be nonzero are changed below

    // Set clock phase to "capture on 1st edge, change on following edge"

    UCB0CTLW0 |= UCCKPH;

    // Set clock polarity to "inactive low"

    UCB0CTLW0 &= ~UCCKPL;

    // Set data order to "transmit MSB first"

    UCB0CTLW0 |= UCMSB;

    // Set data size to 8-bit

    UCB0CTLW0 &= ~UC7BIT;

    // Set MCU to "SPI master"

    UCB0CTLW0 |= UCMST;

    // Set SPI to "3-pin SPI" (we won't use eUSCI's chip select)

    UCB0CTLW0 &= ~UCMODE\_3;

    // Set module to synchronous mode

    UCB0CTLW0 |= UCSYNC;

    // Set clock to SMCLK

    // either 2 or 3 ??

    UCB0CTLW0 |= UCSSEL\_3;

    // Configure the clock divider (SMCLK is from DCO at 8 MHz; run SPI at 8 MHz using SMCLK)

    UCB0BRW = 1;

    // Exit the reset state at the end of the configuration

    UCB0CTLW0 &= ~UCSWRST;

    // Set CS' (chip select) bit to 0 (display always enabled)

    P2OUT &= ~BIT5;

    // Set DC' bit to 0 (assume data)

    P2OUT &= ~BIT3;

    //\*/

    return;

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

// Writes a command to the CFAF128128B-0145T.  This function implements the basic SPI

// interface to the LCD display.

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void HAL\_LCD\_writeCommand(uint8\_t command)

{

    // For command, set the DC' bit to low before transmission

    P2OUT &= ~BIT3;

    // Wait as long as the module is busy

    while (UCB0STATW & UCBUSY);

    // Transmit data

    UCB0TXBUF = command;

    // Set DC' bit back to high

    P2OUT |= BIT3;

}

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

// Writes a data to the CFAF128128B-0145T.  This function implements the basic SPI

// interface to the LCD display.

//\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void HAL\_LCD\_writeData(uint8\_t data)

{

    // Wait as long as the module is busy

    while (UCB0STATW & UCBUSY);

    // Transmit data

    UCB0TXBUF = data;

}

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EEL 4742C - UCF

Code that prints a welcome message to the pixel display.

\*/

#include "msp430fr6989.h"

#include "Grlib/grlib/grlib.h"    // Graphics library (grlib)

#include "LcdDriver/lcd\_driver.h" // LCD driver

#include <stdio.h>

#include <math.h>

#include "lab9.h"

#include "shader1.h"

#define WIDTH 128

#define HEIGHT 128

#define redLED BIT0

#define greenLED BIT7

#define S1 BIT1

#define S2 BIT2

extern void HAL\_LCD\_writeCommand(uint8\_t command);

extern void HAL\_LCD\_writeData(uint8\_t data);

extern void HAL\_LCD\_writeCommand(uint8\_t command);

void Initialize\_Clock\_System();

// Function to draw a pixel at (x, y) with color

void draw\_pixel(float r, float g, float b)

{

    uint16\_t red = r \* 0b11111;

    uint16\_t green = g \* 0b111111;

    uint16\_t blue = b \* 0b11111;

    uint16\_t pixelValue = (red << 11) | (green << 5) | (blue);

    // We're in 16-bit pixel mode

    HAL\_LCD\_writeData(pixelValue & 0xFF);

    HAL\_LCD\_writeData((pixelValue >> 8) & 0xFF);

}

void run\_shader1()

{

    iTime += 0.01;

    uint16\_t x, y;

    for (y = 0; y < 128; y++)

    {

        for (x = 0; x < 128; x++)

        {

            vec2 uv;

            uv.x = x;

            uv.y = y;

            vec3 fragColor;

            mainImage(&fragColor, uv);

            draw\_pixel(fragColor.r, fragColor.g, fragColor.b);

        }

    }

}

// \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void main(void)

{

    char mystring[20];

    // Configure WDT & GPIO

    WDTCTL = WDTPW | WDTHOLD;

    PM5CTL0 &= ~LOCKLPM5;

    // Configure LEDs

    P1DIR |= redLED;

    P9DIR |= greenLED;

    P1OUT &= ~redLED;

    P9OUT &= ~greenLED;

    // Configure buttons

    P1DIR &= ~(S1 | S2);

    P1REN |= (S1 | S2);

    P1OUT |= (S1 | S2);

    P1IFG &= ~(S1 | S2); // Flags are used for latched polling

    // Set the LCD backlight to highest level

    P2DIR |= BIT6;

    P2OUT |= BIT6;

    // Configure clock system

    Initialize\_Clock\_System();

    ////////////////////////////////////////////////////////////////////////////////////////////

    // Graphics functions

    Crystalfontz128x128\_Init(); // Initialize the display

    // Set the screen orientation

    Crystalfontz128x128\_SetOrientation(0);

    // Initialize the context

    Graphics\_initContext(&g\_sContext, &g\_sCrystalfontz128x128);

    // Set background and foreground colors

    Graphics\_setBackgroundColor(&g\_sContext, GRAPHICS\_COLOR\_BLACK);

    Graphics\_setForegroundColor(&g\_sContext, GRAPHICS\_COLOR\_WHITE);

    // Set the default font for strings

    GrContextFontSet(&g\_sContext, &g\_sFontFixed6x8);

    HAL\_LCD\_writeCommand(CM\_DISPON);

    // lab\_9\_1();

    lab\_9\_2();

    //while (1)

    //{

     //   // configure the dispaly

     //   Crystalfontz128x128\_SetDrawFrame(0, 0, 127, 127);

      //  HAL\_LCD\_writeCommand(CM\_RAMWR);

       // run\_shader1();

    //}

}

// \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

void Initialize\_Clock\_System()

{

    // DCO frequency = 8 MHz (default value)

    // MCLK = fDCO/2 = 4 MHz

    // SMCLK = fDCO/1 = 8 MHz

    CSCTL0 = CSKEY;                  // Unlock clock module config registers

    CSCTL3 &= ~(BIT2 | BIT1 | BIT0); // DIVM = 000

    CSCTL3 |= BIT0;                  // DIVM = 001 = /2

    CSCTL3 &= ~(BIT6 | BIT5 | BIT4); // DIVS = 000 = /1

    CSCTL0\_H = 0;                    // Relock clock module config registers

    return;

}

# **3.0 Student Q&A**

Which SPI mode does the configuration correspond to?

Mode 0

1. Is SPI implemented as simplex or full-duplex in this experiment?

simplex

2. What SPI clock frequency did we set up in this lab?

8 MHz

3. What I2C clock frequency did we set up in this lab?

1 MHz

4. What is the maximum SPI clock frequency that is supported by the eUSCI module? Look in the microcontroller’s data sheet in Table 5-18. 5. Show how you computed the I2C clock divider in the last part.

16 MHz

# **4.0** **Conclusion**

In conclusion, Lab 9 provided a hands-on exploration of SPI communication and its application in interfacing with a pixel display. By configuring SPI in Mode 0 with an 8 MHz clock frequency, we successfully demonstrated drawing capabilities on the display. Operating in simplex mode, we efficiently transmitted data and computed the I2C clock divider for optimal performance. This lab enhanced our understanding of SPI fundamentals and equipped us with valuable skills in hardware interfacing and communication protocols.