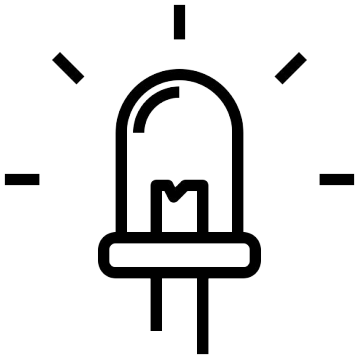
ELECTRICAL AND ELECTRONICS
ENGINEERING
DEPARTMENT



Laboratory Project:
Light Based LED Driver

Laboratory Project - Light Based LED Driver

Objectives

In the EE447 laboratory work, you were expected to familiarize yourself with the operation of TM4C123G and its utility modules. In this final project you are expected to gather the previous experience on the microcontroller with novel information to achieve a multi-functional task. The objectives of the project are as follows:

- Interpretation of the necessities of complex task and encapsulation into sub-task
- Fulfillment of co-operation of utility modules
- Understanding a given complex hardware and compatibility of its components
- Writing a multi-task software for a given complex setup
- Introduction to the serial communication on TM4C123G and utilization of the facility on SPI protocol.

1 Project Definition

In this project, you are expected to build a LED driver system based on an applied light signal. You are going to detect light signal samples with the I2C module using a TSL2561 light sensor, and drive an LED using the GPTM module. To show the current configuration and measurements, you will use a Nokia 5110 LCD, which you will drive using SPI module. You will also use GPIO for the on-board RGB LED and pushbuttons.

The system has two major functions:

1.1 Light Sensing

The system continuously senses luminosity of the light using a TSL2561 light sensor, at a constant integration time. It stores samples in an array of 256 elements. When the array is filled, your system calculates the average luminosity and updates the output elements' states.

1.2 User Interface

The system has three output elements. Firstly, on the LCD screen, detected luminosity value and the low and high threshold values are displayed. Secondly, on-board LEDs are turned on or off according to the detected light. If the light is below low light threshold, red LED must be on and the others must be off. In middle light values, green LED is on. And blue LED must be on, if the light exceeds the high threshold. Finally, the brightness of the output LED is to be adjusted proportional to the last detected light value.

2 Requirements and Restrictions

The overall functionalities of light based LED driver system are described in Section 1. For the sake of simplicity there will be some assumptions about operation. Additionally, there will be restrictions in both the implementation and the hardware to be used.

2.1 Requirements

You will use TSL2561 as a Luminosity/Lux/Light sensor, Nokia 5110 LCD screen, LED and on-board LEDs as the user interface. You may also use a potentiometer or a keypad for threshold setting as a bonus. Following are the functional requirements:

1. The system should have two constant (see item 6) thresholds: low and high light thresholds.
2. If the detected light is in between low and high light thresholds, the brightness of the output LED is adjusted proportional to the detected luminosity. That is the LED should lights up less in low light and more in high light. Additionally,
   - If the detected light is lower than the low threshold, red LED should be on.
   - If the detected luminosity is in between the low and high thresholds, green LED should be on.
   - If the detected luminosity is greater than the high threshold, blue LED should be on.
   - **(BONUS)** When a LED is on, its brightness can change proportional to the detected light.
3. The user should be able to see the configured low and high light thresholds on the screen.
4. The user should be able to see the current light on the screen.
5. The user must set the thresholds using a potentiometer. For this, you need to read the potentiometer using ADC channel.
6. **(BONUS)**
   - Optionally, you may set the thresholds by entering decimal digits using the 4x4 keypad. In this case, the user should press a button on the keypad to enter threshold setting mode. A second press to that button will set the threshold and exit the threshold setting mode.
   - You may display detected luminosity value as a horizontal dot plot graph (time vs luminosity) on the LCD screen.

2.2 Restrictions

2.2.1 Hardware Restrictions

The uses the following components:

1. TSL2561 Luminosity/Lux/Light Sensor
2. NOKIA 5110 LCD Screen
3. 1 Potentiometer (optional)
4. 1 4x4 Keypad (optional)
5. RGB LED Placed on the TM4C123G Board
6. 1 LED

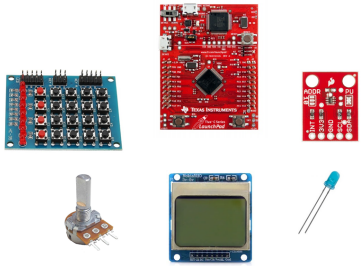


Figure 1: Components

2.2.2 Implementation Restrictions

To ensure the learning outcomes of the course and this laboratory, there are a few restrictions on implementation:

1. TSL2561 must be read using the I2C module.
2. 256 samples should be collected to calculate the detected light value.
3. The output LED must be driven using PWM module and a transistor.

The visual style of the user interface on Nokia LCD screen is up to you as long as you fulfill the requirements specified in Section 2.1. To be eligible for bonus points from the project, you have to fulfill the requirements described in Section 2.1 by satisfying the restrictions described in Section 2.2.

2.2.3 Programming Language Restrictions

- In order to program Nokia 5110 LCD screen, only ARM assembly language must be used. That is, calling any other C function/subroutine etc. is strictly forbidden.
- C programming language will be used for the remaining sections.

3 Tips

You will need to use interrupts and configure the priority of the interrupts. Recall that to configure an interrupt, you should know the interrupt number of the interrupt source you plan to use so that you can decide which NVIC registers (see page 141 of [1]) to be configured. You can find the interrupt number of an interrupt source from the table in page 104 of [1].

Under the given restrictions, you will read the I2C using I2C interrupt handler and drive the output LED using a hardware PWM. Thus, you may do other repetitive tasks in an endless loop inside main. An example algorithm for the main loop is given below.

1. Wait for I2C handler to store 256 readings in the array
2. Calculate the average
3. Turn on/off the corresponding LEDs and update the brightness of the output LED
4. If more than a second has elapsed after the last LCD update, show the luminosity value on LCD
5. Loop back to 1.

Note: For detailed information about I2C module in TM4C123 see page 997 of [1].

4 Background Information: Serial Peripheral Interface

Serial transmission involves sending one bit at a time, such that the data is spread out over time. Compared to parallel communication, many fewer lines are required to transmit data. This requires fewer pins but adds complexity. Serialized data is not generally sent at a uniform rate through a channel. Instead, there is usually a burst of regularly spaced binary data bits followed by a pause, after which the data flow resumes. Packets of binary data are sent in this manner, possibly with variable-length pauses between packets, until the message has been fully transmitted.

In synchronous systems, separate channels are used to transmit data and timing information. The timing channel transmits clock pulses to the receiver. Upon receipt of a clock pulse, the receiver reads the data channel and latches the bit value found on the channel at that moment.

The Serial Peripheral Interface (SPI) is a synchronous serial communication interface specification used for short distance communication, primarily in embedded systems and in this project it will be used. SPI involves a master and a slave, or multiple slaves. SPI interfacing involves 3 or more wires, consisting of a clock, serial data out, serial data in, and chip select if necessary. The master MCU basically sets the clock rate for the slaves, asks a specific one to listen up using the chip select port, and sends them commands via its serial data out port, and expects to receive the output from the slave through the serial data in port.

4.1 Synchronous Serial Interface in the TM4C

The TM4C has four Synchronous Serial Interface modules (SSI). The SSI is used to send synchronous serial communication to other devices, and can be configured to follow various protocols. We will use SPI in this lab, which requires that we specify which device will be sending data (Master), and which device(s) will be receiving data (Slave). When sending, the data is sent loaded into a FIFO buffer, and sent out according to the configured bit rate. Each FIFO buffer is 16 bits wide, and 8 locations deep. The size of the data can be configured to be from 4 to 16 bits wide depending on your needs.

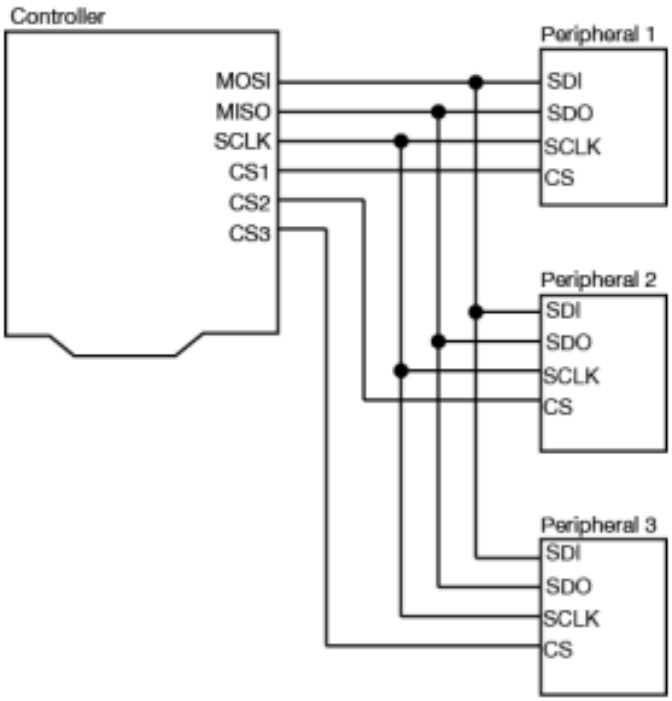


Figure 2: Synchronous Serial Interface in the TM4C

The pin connections for all SSI ports are labeled in Figure 2. When using Synchronous Serial Commu-

nication, there are typically 4 pins (lines).

- RX (MOSI) – Receiving data line
- TX (MISO) – Sending (transmitting) data
- Clk (SCLK) – The clock each bit is synched with
- Fss – Used to tell the slave that data is being sent

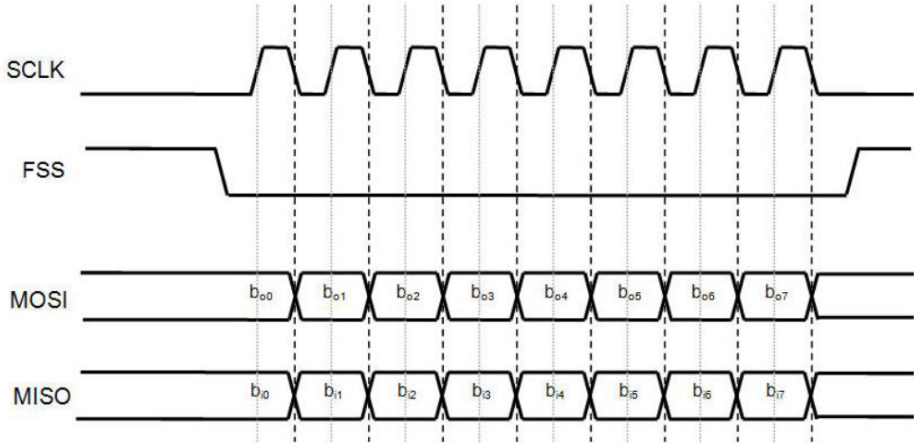


Figure 3: How SPI signals change as data is sent

4.2 SPI Configuration

In order to have Nokia 5110 functioning, 3 separate configurations are required, first of which is GPIO where the corresponding I/O pins are initialized to work as SPI pins. In the second part, the SPI module on the TM4C123 is configured to be compatible with LCD. Finally, in the NOKIA 5110 configuration part, the display is initialized for communication and to receive data to be displayed.

The Nokia 5110 uses SPI signals to receive commands, text, and images to be displayed. As to be noticed in Figure 4 on the SPI signals that there is only one data output signal. The LCD somehow, needs to distinguish whether the data being sent is data meant to be displayed, or if it is a command meant to control the screen. This is done not through the SPI module, but "manually" through a GPIO pin. The Nokia screen has a pin named Data/Command (DC). When the DC signal is low, the Nokia interprets the incoming SPI bits as a command. Similarly, if the DC signal is high, the SPI bits are interpreted as data to be displayed. The DC signal can be set high or low long before the last bit is sent.

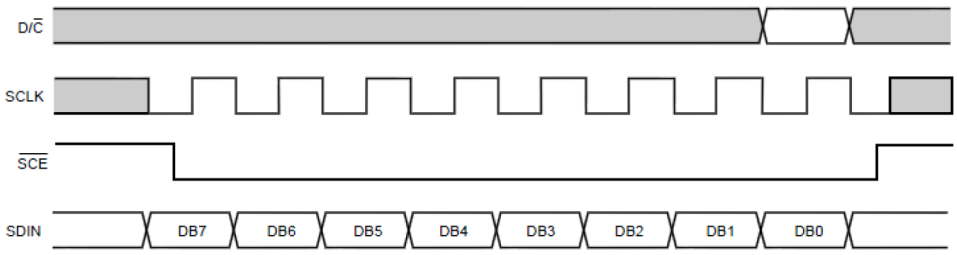


Figure 4: How the DC signal is timed with the SPI signals

For GPIO and SPI configuration parts, you may refer to page 965 of the TM4C123 Datasheet for details and 967 for register map.

GPIO Configuration:

1. Enable the clock for GPIOx **(RCGCGPIO)**
2. Wait until GPIOx is ready **(PRGPIO)**
3. Configure the CLK, CS (FSS), MOSI (Tx), and MISO(Rx) pins as a digital pin **(DEN)**
4. Set directions for the pins **(DIR)**
5. Configure the CLK, CS (FSS), MOSI (Tx), and MISO(Rx) pins for their alternate function **(AFSEL)**
6. Configure the CLK, CS (FSS), MOSI (Tx), and MISO(Rx) port control pins to route the SSI interface to the pins **(PCTL)**.

SPI Configuration:

1. Enable the clock for SSIx **(RCGCSSI)**
2. Wait for the SSI peripheral to be ready **(PRSSI)**
3. Disable the SPI interface **(CR1)**
4. Set the clock rate of the SPI Clock **(CPSR, CR0)** accordingly. Please mind the maximum data rate that the LCD is capable of working with.
5. Set the data size to be 8-bits and Freescale mode **(CR0)**
6. Set the SPI mode **(CR0)** accordingly.
7. Re-enable the SPI interface **(CR1)**

For Nokia 5110 LCD configuration you may refer to Nokia5110Datasheet.pdf provided along with the project manual, where a detailed version of the instruction set and data transmission graphs are provided for clarification.

NOKIA 5110 Configuration:

NOTE: Please do not try to connect and turn on the backlight of the display early on in development. It requires 5V which is different than the Vcc of 3.3V. Instead, make sure you can correctly drive the display without the backlight. Even then, the backlight is still optional, so you may not connect it at all if the content of the display is visible under normal conditions.

1. To initialize the Nokia screen first toggle the Reset pin by holding it low for 100ms then setting it high.
2. Send the following commands to initialize the display
   - Set H=1 for Extended Command Mode, V=0 for Horizontal Addressing
   - Set V_{OP}. You may need to sweep values between 0x[B0-C0] for correct operation.
   - Set temperature control value. You may need to sweep values between 0x[04-07] for correct operation.
   - Set voltage bias value as 0x13.
   - Set H=0 for Basic Command Mode
   - Configure for Normal Display Mode
   - Set Cursor to detemine the start address
3. Send data to be displayed.

INSTRUCTION	D/$\overline{C}$	COMMAND BYTE								DESCRIPTION
		DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
(H = 0 or 1)										
NOP	0	0	0	0	0	0	0	0	0	no operation
Function set	0	0	0	1	0	0	PD	V	H	power down control; entry mode; extended instruction set control (H)
Write data	1	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	writes data to display RAM
(H = 0)										
Reserved	0	0	0	0	0	0	1	X	X	do not use
Display control	0	0	0	0	0	1	D	0	E	sets display configuration
Reserved	0	0	0	0	1	X	X	X	X	do not use
Set Y address of RAM	0	0	1	0	0	0	Y_2	Y_1	Y_0	sets Y-address of RAM; $0 \le Y \le 5$
Set X address of RAM	0	1	X_6	X_5	X_4	X_3	X_2	X_1	X_0	sets X-address part of RAM; $0 \le X \le 83$
(H = 1)										
Reserved	0	0	0	0	0	0	0	0	1	do not use
	0	0	0	0	0	0	0	1	X	do not use
Temperature control	0	0	0	0	0	0	1	TC_1	TC_0	set Temperature Coefficient (TC_x)
Reserved	0	0	0	0	0	1	X	X	X	do not use
Bias system	0	0	0	0	1	0	BS_2	BS_1	BS_0	set Bias System (BS_x)
Reserved	0	0	1	X	X	X	X	X	X	do not use
Set V_{OP}	0	1	V_{OP6}	V_{OP5}	V_{OP4}	V_{OP3}	V_{OP2}	V_{OP1}	V_{OP0}	write V_{OP} to register

Figure 5: Instruction Format

It is possible to write data into the address of memory (DDRAM) of the Nokia LCD continuously and values of X-Address and Y-Address will be increased automatically. In this case, there are 2 methods to configure the operation format of address; firstly, Vertical Addressing Mode (V=1), 1 value of Y-Address will be increased every time; and secondly, Horizontal Addressing Mode (V=0), 1 value of X-Address will be increased every time. One may use either addressing as pleased; however it is to be noted that when the cursor is set to an arbitrary location, a very short delay, in the order of nsec is required for the cursor to settle.

5 Deliverables

You are supposed to attempt the project work in group of two. Groups will be determined by course instructors and teaching assistants.

- **Preliminary Report:** A summary of the framework (including flowcharts and pseudo codes), at most 3 pages. **Deadline: 25.12.2022**
- **Final Report:** A full description of your work, including photos of your setup and relevant portions of code you may need to explain certain key points. Full source codes are not required in your report. Please clearly indicate how you fulfill the requirements by satisfying the restrictions. Moreover, your codes should be well-commented. **Deadline: 08.01.2023**
- **Source Code:** A zipped Keil μvision project folder with fully executable codes is to be uploaded to ODTUClass. **Deadline: 08.01.2023**
- **Lab Demo:** Demonstration of the operation of the project. **Date: TBA**

References

[1] TI, "Tiva™ tm4c123gh6pm microcontroller data sheet." http://www.ti.com/lit/ds/spms376e/spms376e.pdf.