ECE 110L Spring 2023

Laboratory 4:
Sensors and Displays

Contents

1 Abstract

As part of the IDC, your team will be using a combination of sensors and displays to gather and report information. Though your group may not need to use all the available sensors or displays, we still want you to have some familiarity with them and how to integrate a sensor and a display into a single system.

2 Objectives

After performing this laboratory exercise, students should be able to build a 'bot that uses some combination of:

- Hall effect magnetic sensors
- Color sensors
- Infrared (IR) thermal sensors
- Radio-frequency identification (RFID) readers
- Light-emitting diodes (LEDs)
- Red/Green/Blue light emitting diodes (RGB LEDs)
- Piezoelectric speakers
- Multi-character liquid crystal displays (LCD)

Note: *During the previous lab (Lab 3), you worked on controlling 'bot motion based on signals from an ultrasonic distance sensor. Your familiarity with each sensor implemented in these labs will play a crucial role in your team's ability to succeed throughout the IDC.*

3 Background

Look at the EGRWiki pages for the sensors and displays used in lab. They are at:

- https://egrwiki.com/wiki/ECE_110/Equipment/Hall_Effect_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/Color_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/IR_Thermal_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/RFID_Module
- https://egrwiki.com/wiki/ECE_110/Equipment/LED
- https://egrwiki.com/wiki/ECE_110/Equipment/Built_in_RGB_LED
- https://egrwiki.com/wiki/ECE_110/Equipment/Serial_LCD - includes information on the display and the piezoelectric speaker it comes with

4 Pre-Laboratory Exercises

Go through the CX-BOT Shield Guide on Sakai and the EGRWiki pages for the sensors listed in the table below. Using this guide, determine whether or not the CX-Box has a specified location for each sensor. Then, determine the number of CX-Bot connections required by each sensor or display and the location of these connections based on the example codes on the EGRWiki pages. You will be formatting this information into a table similar to the one pictured below. Make sure to give the specific pin names or numbers. The first one is done for you:

Sensor	**Location on CX-Bot?**	**Pinout**
Hall Effect Magnetic Sensor (A1324)	No special location on CX-Bot shield	– Lead 1: Supply voltage connected to 5 V, either at left or below breadboard – Lead 2: GND connected to ground, either at left or below breadboard – Lead 3: V_{out} connected to an analog input channel, A0 in the example code.
Color Sensor (TCS34725)		
Infrared Thermal Sensor (MLX90614)		
Radio-Frequency Identification Reader (ID-12LA)		
Multi-Character Liquid Crystal Display (27977)		

Pre-lab Deliverable (1): Complete a table similar to the one above table for all 5 sensors by filling in whether or not there is a special location for the sensor on the CX bot, the names for each lead, and where they are connected on the CX-Bot shield.

5 Pre-Laboratory Assignment

The documentation for the pre-lab involves submitting a single PDF file. Your document must include your name, NetID, and the Duke Honor Code statement: "I have adhered to the Duke Community Standard in completing this assignment" at the top. **EACH INDIVIDUAL** should submit their own assignment. Your document should also include the table you created from the Pre-Laboratory Exercise above: **Pre-Lab Deliverabe (1)**.

6 Experimental Exercise

During this lab, you will be building four different combinations of sensors and displays. The fundamental code for each system will be on the relevant Pundit page; your task will be to replicate the hardware and software and then integrate the two systems to work together.

6.1 Hall Effect Sensor and LED

You will be building a magnetic flux detector that will use two LEDs to display when you detect a strong North or South pole. First, go through the pages at:

- https://egrwiki.com/wiki/ECE_110/Equipment/Hall_Effect_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/LED

and make sure you understand the independent operation of each. Build the system presented in the sample code for the Hall effect sensor and make sure your device is working by placing a magnet various distances from the sensor. When the magnet is very close to the sensor, you should get sensor readings close to 0 V or 5 V depending on which pole is close to the sensor - those readings relate to $\pm$500 G in magnetic flux density.

Add code that will:

- Turn on a red light if the magnetic flux density is positive and has a magnitude greater than 200 G, or
- Turn on a green light if the magnetic flux density is negative and has a magnitude greater than 200 G.

Checkpoint (1): Show your TA that your system can identify strong flux densities and their directions.

Deliverable (1): Provide your code and a complete parts list for your flux density classifier. For this and all other parts of this assignment, you can simply state "CX-Bot" to include everything involved with the 'bot itself; for this system, you would need to add two resistors, a red LED, a green LED, an A1324 Hall effect sensor, and wires as needed.

6.2 Color Sensor and On-Board RGB LED

You will be building a color replicator that will use a color sensor to determine the color of an object and then an on-board RGB LED to replicate the color. First, go through the pages at:

- https://egrwiki.com/wiki/ECE_110/Equipment/Color_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/Built_in_RGB_LED

and make sure you understand the independent operation of each. Build the system presented in the sample code for the color sensor and make sure your device is working by placing different colors of paper in front of the sensor. With this hardware still in place, go through the "Interactive Colors" sample code for the Built-in RGB LED. Now integrate the two sample codes so that instead of getting RGB values from the user via the Serial Monitor, the program will get RGB values from the sensor and deliver them to the RGB LED. Your system should still use the Serial Monitor to report the R, G, and B level being displayed.

Checkpoint (2): Show your TA that your system can correctly match colors. If you have difficulty distinguishing colors, you can also use the RGB values to check your system.

Deliverable (2): Provide your code and a complete parts list for your color replicator.

6.3 IR Thermal Sensor and LCD Piezoelectric Speaker

You will be building a temperature monitoring and alarm system. First, go through the pages at:

- https://egrwiki.com/wiki/ECE_110/Equipment/IR_Thermal_Sensor
- https://egrwiki.com/wiki/ECE_110/Equipment/LCD_Display

and make sure you understand the independent operation of each. Note for this exercise you will be using the speaker attached to the LCD to make sounds.

Connect the IR thermal sensor using the instructions in the "Hardware Hookup" section of the sample code for it. Make sure your device is working by estimating the temperature of the room, pointing the device at your forehead (which should be warmer than the room), and pointing your device at a container of ice (which will be provided). With that system in place, build the system presented in the "Music and Text" sample code for the LCD and make sure your device is working by playing the song. Now integrate the two sample codes so that your LCD will report the temperature on the Serial Monitor every ten seconds and, if the measured temperature is below 50 degrees, play the opening notes of "Ice Ice, Baby," by David Bowie, Freddie Mercury, John Deacon, Brian May, Roger Taylor, Earthquake, Vanilla Ice, and M. Smooth. Those seventeen notes are:

Duration	Scale	Note
Eighth	3	A
Eighth	3	A
Eighth	3	A
Sixteenth	3	A
Sixteenth	3	A
Eighth	3	A
Eighth	3	D
Eighth	3	rest
Eighth	3	A
Eighth	3	A
Eighth	3	A
Eighth	3	A
Sixteenth	3	A
Sixteenth	3	A
Eighth	3	A
Eighth	3	D
Quarter	3	rest

Checkpoint (3): Show your TA that your system can correctly measure temperature and react to cold.

Deliverable (3): Provide your code and a complete parts list for your cold indicator system.

6.4 RFID and 16x2 LCD

You will be building an RFID reader that can read an RFID tag and then displays it on the LCD. First, go through the pages at:

- https://egrwiki.com/wiki/ECE_110/Equipment/RFID_Module
- https://egrwiki.com/wiki/ECE_110/Equipment/LCD_Display

and make sure you understand the independent operation of each. Note for this exercise you will be using the LCD but not the attached speaker.

Connect the RFID reader to the dedicated bus on the CX-Bot and run the "Simple" code for the RFID reader to see the full collection of characters the device provides for a tag. Note that some of the characters are not letters or numbers but rather special codes to indicate the start of the transmission, a line feed, a carriage return, and an end of transmission.

Next, run the "Simple with Storage" code for the RFID reader. This one does very similar processing, but the end result is a character array with the letters and numbers of the RFID tag stored in it.

Now run the "Music and Text" code for the LCD again, paying careful attention to the lines that print text to the display. Once you understand that, go back to the "Simple with Storage" code for the RFID reader and copy it into a new file. Edit the code so that the tag is not only displayed in the Serial Monitor, but so it is also displayed on the LCD. The LCD should be back-lit with neither a cursor nor a blinking space. The tag should always be printed starting in the top left corner of the display.

Checkpoint (4): Show your TA that your system can accurately determine and display RFID tag information

Deliverable (4): Provide your code and a complete parts list for your RFID tag reader and display.

7 Assignment

The assignment for this laboratory involves submitting a single PDF file. Your document must include your name, NetID, and the Duke Honor Code statement: "I have adhered to the Duke Community Standard in completing this assignment" at the top. **EACH INDIVIDUAL** should submit their own assignment. The documentation for this laboratory includes the code and parts list for each of the four exercises:

1. **Hall Effect Sensor and LED** 6.1
    - A complete parts list for your flux density classifier.
    - Arduino code for your flux density classifier.
2. **Color Sensor and On-Board RGB LED** 6.2
    - A complete parts list for your color replicator.
    - Arduino code for your color replicator.
3. **IR Thermal Sensor and LCD Piezoelectric Speaker** 6.3
    - A complete parts list for your cold indicator system.
    - Arduino code for your cold indicator system.
4. **RFID and 16x2 LCD** 6.4
    - A complete parts list your RFID tag reader and display.
    - Arduino code for your RFID tag reader and display.

This file should be uploaded to the ECE 110L Laboratory **Gradescope** site by the assignment deadline. Each student must submit their own **INDIVIDUAL** assignment.