3L04

Lab 5 – Photosensors & PWM

Muqtadir Hussain

400250481

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Abstract:

In this lab the first experiment involved using a photoresistor and the effect of light intensity on its resistance value. A light was shown at the photoresistor at various distances and the resulting resistance recorded from the serial monitor. In the second experiment we use an infrared sensor to determine the effects of obstacles on infrared detection due to changes in environmental transmission, absorption and reflection. The third experiment introduced us to the manipulation of microcontroller digital signals through pulse width modulation which was then applied again to alternate light intensities of an LED and its corresponding affect on a photoresistor. This significance of this lab is that it shows us the pros and cons of various transceivers and their reliability and effectiveness in different applications.

Introduction:

In this lab we assemble photosensor circuits and use them to make a series of measurements. We examine both the photoresistor sensor and an infrared sensor. The lab also sheds lights on the working principle of pulse width modulation which are a very useful control scheme for electronics.

Experimental Methods:

Experiment 1

The first experiment is conducted with the photoresistor module. On a flat table surface, a ruler is affixed and the photoresistor module (connected to the Arduino with the appropriate loaded code) is placed at the 0 inch mark. The photoresistors functionality is then confirmed by pointing a light source (iPhone flashlight) at it from different distances and observing the values on the serial monitor. Once confirmed, the experiment is then carried out. After completely darkening the surrounding environment by turning off all the lights in the room and closing curtains, the flashlight is pointed at the photoresistor from 5 different distances and the value from the serial monitor is recorded for each. This is repeated a total of 5 times for each distance.

Experiment 2

The second experiment is conducted with the IR Sensor module. The sensor is set up with the Arduino and the appropriate code is loaded. The sensitivity is reduced to ensure that there is no interference from background IR sources. A TV remote is used for the IR emitter in this experiment. The sensor is placed on the edge of a table and the IR blaster is pointed towards it. The sensor would trigger at various distances but an optimal distance where it triggered consistently was found to be approximately 30 cm. Various objects are then placed in front of the sensor in an attempt to block the IR signal coming from the emitter and the observations are recorded.

Experiment 3

The rotary encoder is first set up with the Arduino and RGB LED module as shown in fig 5a. Once the code is loaded, the encoder is rotated clockwise and counter-clockwise and the behaviour of the LED is observed and recorded. The encoder is then replaced with the photoresistor as shown in fig 5b. The LED is setup directly across the photoresistor and is placed with a gap of approximately 6 cm. The code is loaded and runs through a series of loops changing the PWM value automatically. The built in Arduino serial plotter is used to record our observations of the photoresistor voltage with changing PWM.

Results:

Experiment 1

The recorded data for the first experiment with the photoresistor module is as follows:

Serial Monitor Value	Distance = 1 inch	Distance = 3.5 inches	Distance = 5 inches	Distance = 6.5 inches	Distance = 8 inches
Trial 1	0.24	0.8	1.4	2.08	2.79
Trial 2	0.23	0.81	1.38	2.09	2.8
Trial 3	0.22	0.82	1.39	2.11	2.77
Trial 4	0.23	0.79	1.4	2.05	2.76
Trial 5	0.22	0.8	1.39	2.08	2.79

Table 1: Photoresistor Data

Experiment 2

The distance at which the IR sensor triggered consistently was found to be approximately 30 cm. The three materials used to block the signal were a 3-ply face mask, single sheet of paper and a notebook. The face mask did not block off the signal entirely as there was some success in triggering the sensor from 30 cm away however it was quite inconsistent and the button on the emitter had to be pressed multiple times. The sheet of paper failed to block the signal and the sensor would trigger almost every time which meant the IR radiation passed through the paper successfully. The notebook, as expected blocked off the signal entirely and there was no detection from the sensor.

Experiment 3

Rotating the rotary encoder clockwise would make the LED brighter whereas rotating it counter-clockwise would make it dimmer. It would take 4 turns for the LED to reach maximum brightness and then turn off again (0 to 255 and then back to 0)

With the photoresistor placed directly across the LED and the code cycling through different PWM values, the following plot is obtained from the serial plotter:

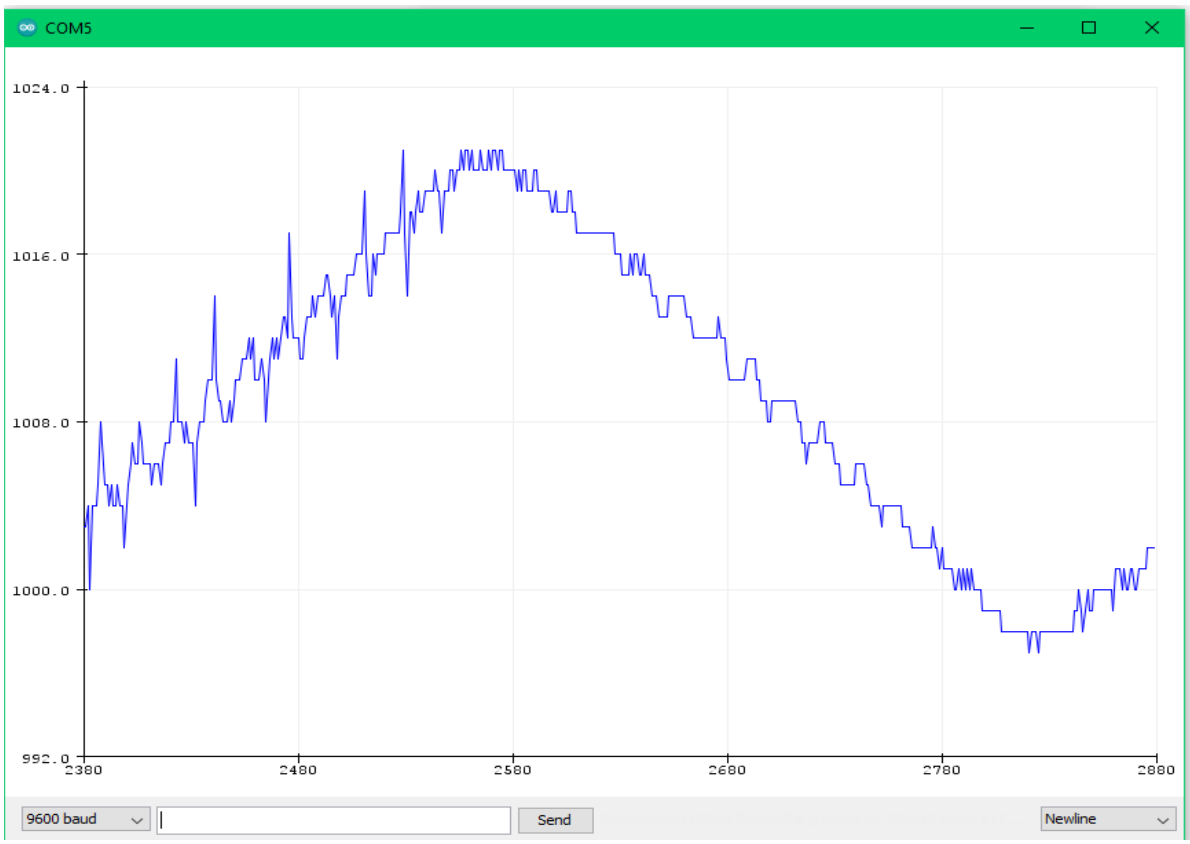

Figure 2: Arduino Serial Plotter 1

As the light became brighter, the slope of the plot was negative and the voltage was dropping whereas when the light was dimmed, the slope was positive and the voltage was increasing. This makes sense as dimmer light means lower intensity and therefore higher resistance and resistance is directly proportional to voltage.

Discussion:

Experiment 1

Distance (inches)	Average S/M Value	Standard Deviation (error)
1	0.228	0.008367
3.5	0.804	0.011402
5	1.392	0.008367
6.5	2.082	0.021679
8	2.782	0.016432

Table 2: Average S/M Value at 5 distances with associated error

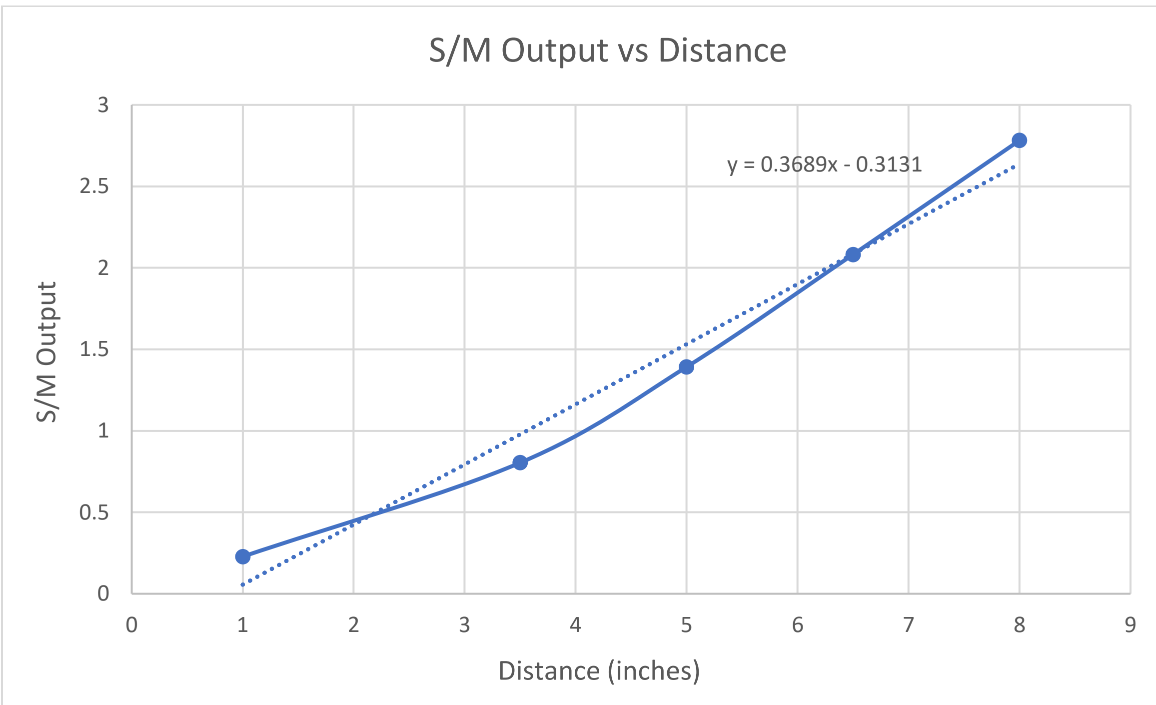

Figure 1: Resistance vs Distance

The standard deviation was too small to include in the plot and were therefore not added due to lack of visibility. The standard deviation at each distance however is shown in Table 2. The most valid curve applicable to our plot was a linear line as it was the line of best fit. Therefore it is reasonable to assume that the relation between the distance of the light source and the corresponding photoresistor resistance is almost linear for this set of values at least. Knowing from the equation $Rph = \frac{A}{I}$, the resistance is inversely proportional to the intensity of light where the intensity of light, I is proportional to $\frac{1}{d^2}$. This is seen in our plot which shows that when the light source is closer to the module (high intensity), the resistance is low and vice versa.

Lasers emit light through amplification by stimulated emission of radiation. Lasers differ from other sources of light in that they emit light which is coherent. This spatial coherence allows a laser to be focused to a tight spot and stay narrow over great distances without any divergence and dispersion. This concentration leads to lasers having an extremely high intensity even over large distances. If the laser light going to the photoresistor is too bright then it will become saturated. The resistance would remain low even over large distances if a laser was used in this experiment instead of a normal LED flashlight.

Experiment 2

IR radiation does not have enough energy to induce electronic transitions. Absorption of IR is restricted to compounds with small energy differences in the possible vibrational and rotational states. For a molecule to absorb IR, the vibrations or rotations within a molecule must cause a net change in the dipole moment of the molecule. Most materials absorb some IR wavelengths although it may be only a small percent. In our scenario, a lot had to do with the thickness of our obstacles as the thinner single sheet of paper was not able to absorb all the radiation and allowed some of it to be transmitted whereas the thicker notebook was able to either reflect or absorb all the radiation thus completely blocking off the signal.

The biggest difference between IR sensor vs. ultrasonic sensors is the way in which the sensor works. Ultrasonic sensors use sound waves (echolocation) to measure how far away you are from an object. On the other hand, IR sensors use Infrared light to determine whether or not an object is present. Accuracy and reliability are big differentiators in these sensors. Most often, ultrasonic sensors will provide more reliable and accurate data than IR sensors. If you want an accurate, numerical representation of distance for your project, one should choose an Ultrasonic sensor. However, if one only needs to know if an object is present or not, then an IR sensor is easier to implement.

IR sensors use an infrared transmitter and receiver to emit and detect objects. Popular applications for IR sensors include line following for mobile robots, Tripwires, Flame Detection, and even motion detection (PIR).

Ultrasonic sensors use soundwaves to transmit and receive information over a duration. The duration is then converted to a distance measurement based on the Speed of Sound in air (340 m/s) or any other medium. Ultrasonic sensors can be used on mobile robots to avoid objects or on submarines to measure the depth of the ocean.

The appropriate transceiver for each of the following applications would be:

a) An autonomous vehicle: Both infrared transceivers for the instant detection of objects in the vehicles surroundings and ultrasonic sensors for measuring the distance accurate distances of obstacles from the vehicle.

b) A hobbyist robotics project: IR sensors are extremely cheap and easy to implement and could be used effectively with an obstacle avoiding robot car for example. As soon as the robot detects an obstacle in its vicinity it changes directions to avoid collision.

c) A long-range measuring device: An ultrasonic transceiver would be appropriate for a long range measuring device as they use the reflection and detection of transmitted soundwaves, along with the speed of light in the given medium to determine the accurate distance an object is away from the sensor.

Experiment 3:

Digital signals can only output ON (max) or OFF (min) values. In some scenarios, the voltage needs to be manipulated to create a sort of analog voltage. PWM is a concept which is used to simulate this analog voltage which could be any value between the maximum and minimum. The PWM pin on a microcontroller takes a value between the integers 0 and 255 to generate an effective average voltage on the pin by cycling between max and min accordingly (similar to RMS voltage).

Results from step 3 and 4 discussed in results section.

Conclusion:

Photoresistors are useful devices which can be used in circuits to vary internal resistance based on environmental light factors. A useful application of such a sensor is the dimming of smartphone screens based on the lighting in the environment to increase viewing comfort. Furthermore IR sensor and Ultrasonic sensors are both extremely useful sensors in the automation industry with each having its own pros and cons.

Appendix:

Calculation of standard deviation in experiment 1 using excel built in function STDEV.S

References:

1. https://teaching.shu.ac.uk/hwb/chemistry/tutorials/molspec/irspec1.htm
2. https://sciencing.com/materials-absorb-infrared-rays-8044395.html
3. https://en.wikipedia.org/wiki/Laser
4. https://www.learnrobotics.org/blog/ir-sensor-vs-ultrasonic-sensor/