Infrared Distance Sensor Development of a Modular Micromouse

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***Abstract*—The need of a modular Micromouse for educational purpose originated an idea of designing an optical sensor able to be plugged or unplugged. The modular robot has to navigate through a maze considering the Applied Power Electronics Conference (APEC) limitations and constraints of a Micromouse. The sensor explained in this paper is an infrared sensor which is composed of an Infrared LED (IR) and a Phototransistor (PT). Although this IR Sensor is designed for some specific distance for our Micromouse, this paper provides sufficient information to develop an IR sensor for other distances. An Arduino UNO was used as the interphase for the sensor to obtain the output voltage signal. The output signal was obtained for specific distances. These data points were plotted and a sensor calibration curve was extracted from a curve fit. Finally, with all the data and testing done we managed to design an IR distance Sensor for 1.5 inch up to 6 inch.**

Keywords—Infrared-LED; proximity sensor; distance sensor; phototransistor; micromoouse;

I. Introduction

The Micromouse is a robot which has to autonomously negotiate a specified maze with the purpose of solving it in the shortest time possible [1]. This robot is known as an interdisciplinary project as it offers a variety of challenges and as such is an attractive STEM project. It is for this reason that is was decided to build a modular version of this robot [2] [3]. The robot was designed considering the dimensions of the maze of the APEC Micromouse competition where each of the cells are 18cm x 18cm unit square and the robot a square region of 25 cm x 25 cm [4]. To be able to navigate through the maze we considered using IR distance Sensor. This type of sensor it provides distance between walls and robot. Also, it provides if there is a wall or not while navigating through the maze. The robot dimension is approximately 4.5 inches this was done based a previous prototype and considering a modular robot. Given the constraint of the maze and of the design it was calculated that the robot would be needing an IR Distance Sensor that could work between the distances of approximately 1 inch up to 6 inch.

This distance constraint was the most important consideration when designing the sensor development approach. First some research was done of reflection laws and the angle of incidence. Then was designed some tower bracket (to hold a case) and case (for IR-LED and PT) for the testing. Finally, with the measurements obtained in the testing we could obtain distance through an ADC of an Arduino and able to design the needed IR-Sensor for the Modular Micromouse.

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II. The Ray Model of Light and Reflection

Since working with IR-LED, PT and using reflection to design this sensor it is best a brief discussion of the Ray Model of Light and Reflection for a better understanding. The ray model assumes that lights travels in straight-line paths, this is called light rays. The light that strikes a surface or object it can either reflected or absorbed. The reflect light of a flat surface it can be used determined an angle of incidence respect to the normal and an angle of reflection respect to the normal [5].

III. Microcontroller , Components and Testing Area

The modular robot is being programmed with an Arduino Uno for convenience this is the microcontroller used for the development of the sensors. The PT the selection was primary decided in its peak sensitivity to 880nm wavelength. It is important in the selection of PT considering the peak sensitive for the wavelength since most them varies its range [6]. Not begin careful PT could response to any light interference causing an unexpected behavior [7]. In case selection of the IR-LED based on Radiant Intensity, Spatial Distribution and the wavelength compatibility of the PT. In Fig. 1 it can be seen the circuit of the PT and how is connected to the Arduino to obtain the voltage lectures from the resistance of the emitter. For this was consider the maximum input voltage of the Analog to Digital Converter (ADC) that is 5V. Since the limit is 5V through the ADC is required to calculate a resistor for reading less than 5V after the emitter.

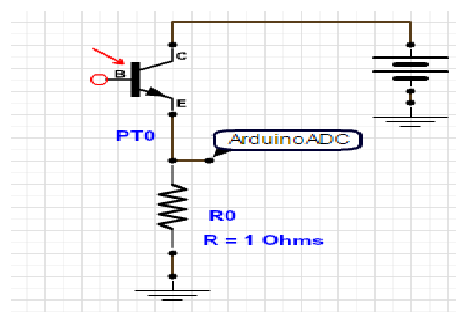

Fig. 1 Photo Transistor circuit with Arduino ADC

IV. Infrared Distance Sensor Development

A. *Sensor chassis development*

The chassis was designed so the PT and LED were sunken in Fig. 7 and would help direct the infrared emission from the LED and close the receiving angle of the PT from unwanted light interference. It was found that this was not enough and a matched set of LED infrared emitter and PT needed to be selected. This is to say that the LED had to emit infrared at the wavelength at which the PT was most sensitive. The PT should also block the visible light spectrum. The back portion of the chassis was left hollow to house the other parts of the circuit needed to complete the sensor connections (see Fig 7).

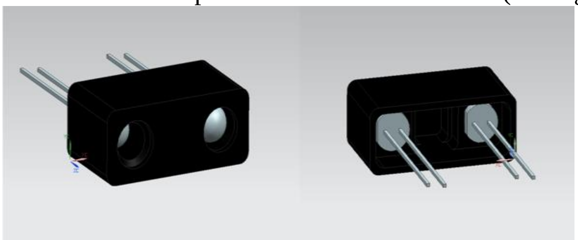

Fig. 2 Computer rendering showing the position of the PT and LED in the chassis.

B. Sensor Testing

During the initial testing, the sensor was attached directly to the breadboard via the legs of the LED and PT. The sensor readings were inaccurate because there was no way to make sure the sensor had the same altitude and angle with respect to the testing setup. Two testing stands were designed and printed. These allowed the repetition of a test without disturbing the sensor alignment. These also allowed the testing of two different sensor positions: vertical, where the LED and PT are aligned vertically (Fig.3) and horizontal (Fig.4) where the LED and transistor are aligned horizontally. In Fig. 5 it can be seen the final layout of testing place with the maze wall. It is important the use of the maze wall because the reflection of light is affected by the surface or color of the object [8]. Not doing this will cause some unexpected results.

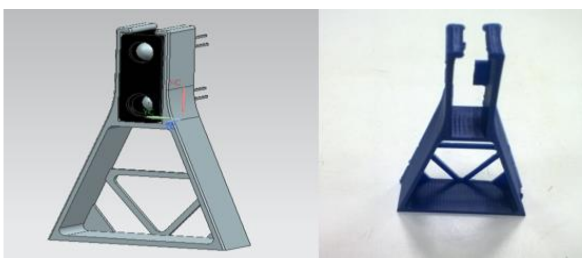

Fig. 3 Computer rendering vertical testing stand with sensor and 3D printed testing stand

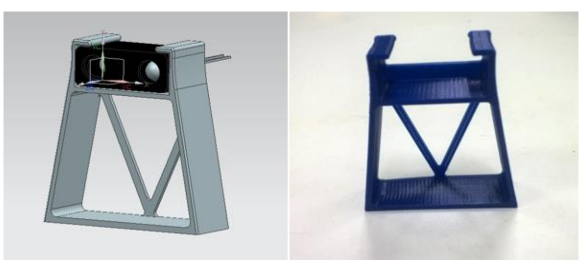

Fig. 4 Computer rendering horizontal testing stand with sensor and 3D printed testing stand

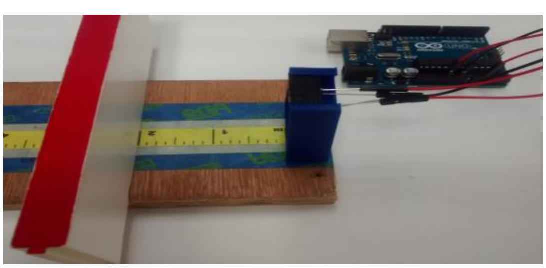

Fig. 5 Testing table with ruler, stand with sensor, maze wall and Arduino One

Initial tests of these positions yielded no difference in curve shape or peak value and peak value location. The difference between the two came when the obstacle was not exactly perpendicular to the direction of the sensor. This would happen when the Micromouse was making a turn inside the maze or if it was incorrectly placed in the maze. The horizontal setup peak value of the curve depended on the angle of the sensor with respect to the obstacle. The vertical alignment had no such problems and was selected for further testing.

During testing, it was noted that the maximum intensity recorded by the Arduino could be modified by changing the resistor values of the LED and the transistor, the location of the peak value could not. The location of the peak value is directly related to the viewing angle of the transistor, the emitter angle of the LED and the center to center distance between the two in the chassis. The peak value location was 1.5 inch for the first chassis; it was desired to bring that closer to 1inch. A very simple model, using the law of reflection which does not consider the effects of light diffusion upon reflection, was used to try to visualize what was happening to the infrared light and how the sensor was receiving it. The model was drawn for the peak value distance of 1.5 inch (Fig. 6) and then drawn for the desired 1 inch distance (Fig. 5). The center to center distance was reduced in the 1 inch model so the infrared light rays would intersect the sensor as in the 1.5-inch model (Fig. 6). In Fig 6 and 7 the long rectangle is the obstacle, small rectangle is sensor, circle represents the transistor and angled lines are the light rays.

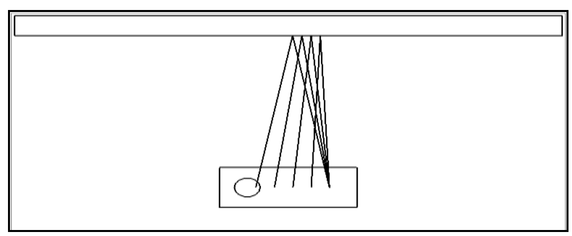

Fig. 6 Law of reflection model for 1.5 inch distance

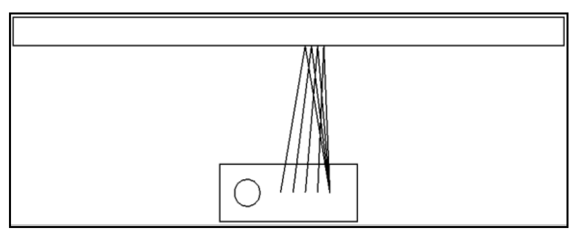

Fig. 7 Law of reflection model for 1" distance

Fig. 8 On the left, first prototype, on the right chassis with modified center to center distance.

C. *Sensor Calibration Curve*

During the sensor development, the original data points were taken by setting a specific distance and then recording 50 data points. The average of these 50 data points was then plotted for each distance. This can be seen in the first plot (Fig. 1) and a peak can be observed at 1.5 inches. The X and Y axes are switched and the resulting curve can be seen in the second plot (Fig. 2). The curve on Fig. 2 cannot be expressed by a simple function of the Arduino ADC so the upper half of the curve, which corresponds to the distance of 1.5 to 6 inches, is taken and plotted (Fig. 3).

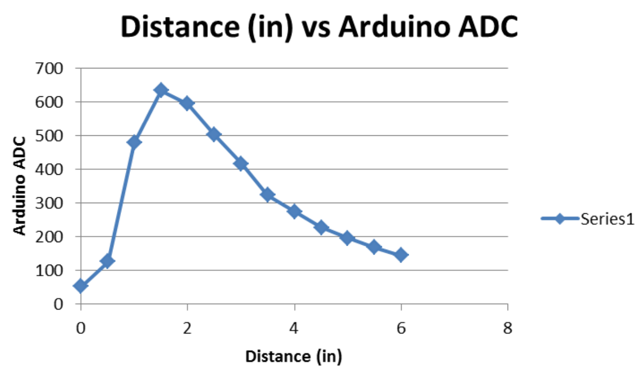

Figure 9 Original data points of 1.5 inches. Distance (in) vs Arduino ADC

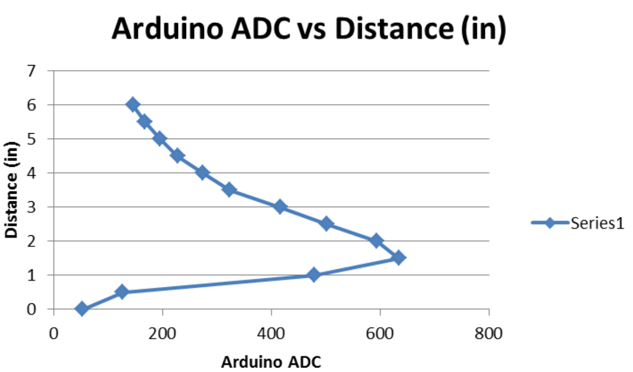

Figure 10 X and Y axes switched from original 1.5 inches. Arduino ADC vs Distance (in)

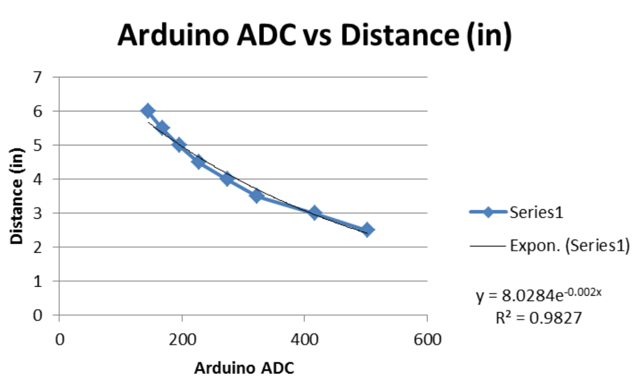

Figure 11 Selected data points for calibration curve

An exponential fit is then performed on the remaining data points which give the equation:

$$Y = 8.0284e^{-0.002x} \quad (1)$$

In equation (1) Y is the distance and X is the Arduino ADC now the equation can be rewritten as (2):

$$Distance = 8.0284e^{-0.002 * ArduinoADC} \quad (2)$$

The equation (2) can be coded into the Arduino code used to control the micro mouse, but the Arduino library math.h must be included. The distance value given by the equation will be in inches.

V. Conclusion

For the development of this proximity sensor using IR-LED and PT different elements and theories where taken in consideration. By the results obtained it was able, not to prove only the reflection law, but to stablish an equation to be able to determine the distance from 1.5 inches up to 6 inches. Also with this results it could change and re-design for 1 inch up to 6 inch. This process could be repeat for this specific PT and IR-LED without any inconvenience. For other PT and IR-LED is suggested read its datasheet before applying the procedure done in this paper.

References

[1] S. García-Vergara, J. P. D. León, Y. J. Díaz-Mercado and E. I. Ortiz-Rivera, "An integrated undergraduate research experience in control, power electronics, and design using a Micromouse," *2010 IEEE Frontiers in Education Conference (FIE)*, Washington, DC, 2010, pp. T3D-1-T3D-6.

[2] G. Lopez, D. Ramos, K. Rivera, K. del Valle, A. Rodriguez and E. I. O. Rivera, "Micromouse: An autonomous robot vehicle interdisciplinary attraction to education and research," *2015 IEEE Frontiers in Education Conference (FIE)*, El Paso, TX, 2015, pp. 1-5.

[3] C. Molina *et al.*, "The use of unmanned aerial vehicles for an interdisciplinary undergraduate education: Solving quadrotors limitations," *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, Madrid, 2014, pp. 1-6.

[4] APEC MICROMOUSE CONTEST RULES. 1st ed 2009. Web. 14 Aug. 2016.

[5] Giancoli, Douglas C. Physics For Scientists & Engineers With Modern Physics. 4th ed. Upper Saddler River: Pearson Prentice Hall. Print.

[6] Sun LED, “T-1 3/4 (5mm) INFRARED EMITTING DIODE,” XTHI12BF datasheet, Dec 2013.

[7] Farchid , “QSD122, QSD123, QSD124 Plastic Silicon Infrared Phototransistor,” QSD123 datasheet, Sept. 2012.