Final Project Report

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December 6, 2015

Abstract

Throughout the ECE Lab section we have learnt many electronics concepts and applied almost all of them directly or indirectly in our final lab project. Additionally, having taken away a lot from this course, we aimed to make a project that would challenge us academically and intellectually; for our final lab assignment, we made an autonomous line-following robot, that would follow a white line track using RedBot sensors and would use a microphone to light on an LED if a photocell is inactive. In this report, we explain the use of each of the components that were used to make the final vehicle we call **SharkFun**, and the working of the vehicle itself.

1 Introduction

1.1 Problem Statement

For our final project we decided to build something that would help us understand electronic circuits and would also have the functionality required for the the assignment. As a result, we finally settled on making a car that could very accurately traverse through a loop or any white track using RedBot sensors from our kit. It could also detect the presence of light with a photocell and based on that turn ON or OFF a microphone to control an LED when hearing a clap or a bang (challenging!). Once we learnt how to control the sensors, we made minor adjustments to our circuit and tweaked the whole design with an Arduino to control the feedback and give our chassis more mobility.

1.2 Engineering Design Tasks

As engineers, we take on the task of designing a new device with a unique approach which highlights our skills as effective problem solvers. Essentially, to design a semi-autonomous vehicle for our final project we followed 4 essential steps which were necessary in coming up with a solution to the problem statement.

1 We evaluated the challenge by defining goals and the constraints in the problem.

2 We researched by reading our helpful Lab modules and procedures to design many possible solutions.

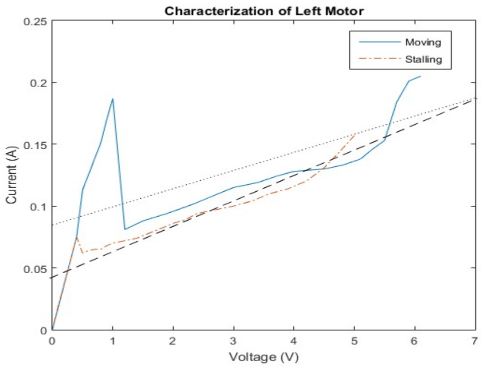
3 After coming up with these solutions, we chose the best possible solution that solved the problem in the most efficient way for our prototype.

4 Testing the solution is the last step in the engineering design algorithm and hence, we performed various tests on the vehicle, tweaked it to make it more functional and tested it on many test cases as necessary.

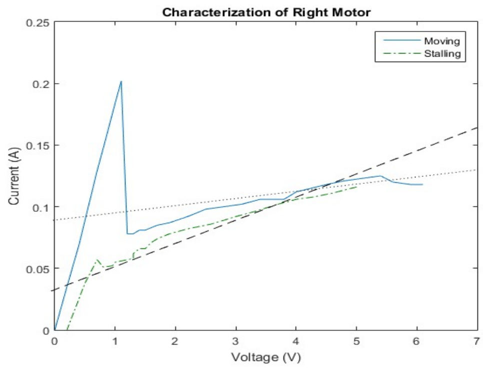
2 Component & Analysis

2.1 Motors

In electronics, a motor is an electrical machine that converts electrical energy into mechanical energy. For our project, the motors had to be controlled so that their duty cycles could be changed and their direction monitored based on the input from the RedBot sensors. When one of the RedBot sensors detected a white strip the motor on the other side would slow down relative to the motor on the same side so that the vehicle could autonomously change direction based on the data input from the RedBot sensors.



(a) Left motor Characterization



(b) Right motor Characterization

Figure 1: Motor Characteristics

2.1.1 Left motor Characteristic

$$I = 0.014645V + 0.084667 \quad (moving) \quad \text{Moving Point - (1.2,0.081)}$$
$$I = 0.020501V + 0.042693 \quad (stalling) \quad \text{Stalling Point - (0.4,0.075)}$$

2.1.2 Right motor Characteristic

$$I = 0.005886V + 0.089083 \quad (moving) \quad \text{Moving Point - (1.2,0.081)}$$
$$I = 0.018806V + 0.032521 \quad (stalling) \quad \text{Stalling Point - (0.4,0.057)}$$

2.2 Silicon NPN Transistor (BC337)

A transistor is formally defined as a semiconductor device which can be used to amplify electrical signals or to switch electrical signals. In our experiment we used two NPN transistors numbered BC337 as our voltage amplifier for the PWM circuit for the motors on both sides.

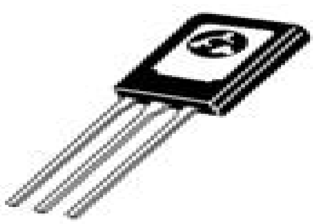


Figure 2: Silicon NPN Transistor (BC337)
Source: `http://bit.ly/1Spy8ii`

2.3 Resistors

Resistors are a chief electrical component in circuits - they are used to reduce current flow and at the same time maintain low voltage levels to prevent short circuits and provide the required current flow in simple circuits. In our project we have used these resistors in several points in the circuit accordingly. The values of our resistances are: $R_1 = 330\Omega, R_2 = 330\Omega, R_3 \rightarrow Photocell, R_4 = 10k\Omega, R_5 = 22k\Omega, R_6 = 10k\Omega, R_7 = 10k\Omega$.

2.4 Arduino Microcontroller (SparkFun)

An Arduino Microcontroller is a multipurpose tool that can be used for many electronics projects as it provides many functions to a particular circuit. For our project we use it to control the vehicle's microphone sensor and the 2 RedBot sensors using C-Language code. After familiarizing with C, we wrote the code to control the sensors ourselves. (*code posted below*)

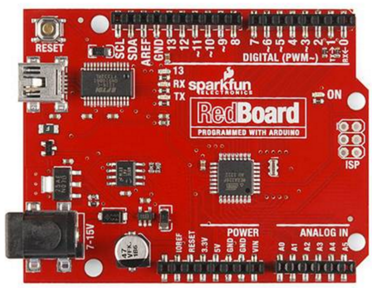


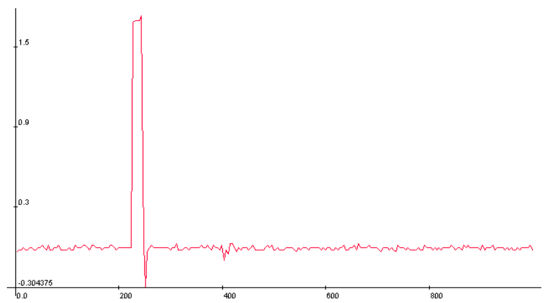
Figure 3: Arduino Microcontroller (SparkFun)
Source: `http://bit.ly/1Xo6sRz`

2.5 Capacitors

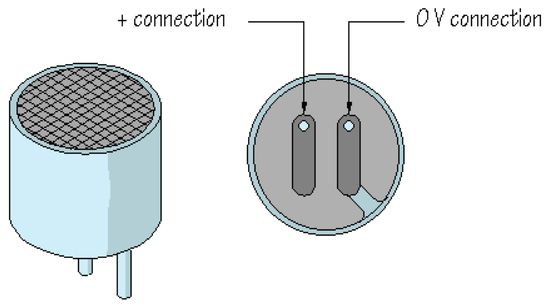
Capacitors are also an essential part of electronic circuits. It's formally defined as a passive two-terminal electrical component used to store electrical energy temporarily in an electric field. We used capacitors in our project in places according to a pre-designed circuit. (ECE 110 gives preliminary circuit component study). The value of our capacitance is: $C_1 = 0.1\,\mu\text{F}$

2.6 Microphone

A microphone is formally defined as an acoustic-to-electric transducer or simply, a sensor that can convert audio signals to electric signals. In our project we used the microphone to detect a clap - essentially a large pressure variation - from its environment and move or stop the vehicle. To control this, we used our own code using the Arduino. *(code posted below)*



(a) Microphone characterization using O-scope

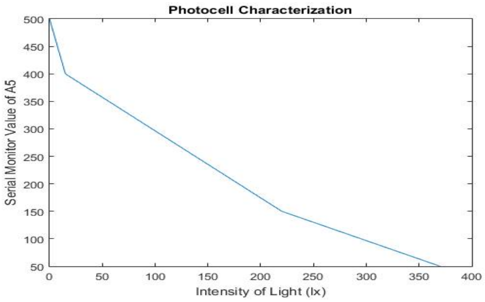


(b) Mic diagram. Source: `http://www.doctronics.co.uk/voltage.htm`

Figure 4: Microphone char. and diagram

2.7 Photocell

A Photocell or a Photoresistor is a light-controlled variable resistor. The way it functions is by decreasing its resistance with increasing light intensity incident on its surface. In our final project we used it in a separate circuit in which when the photocell received no light above a threshold >300 (on the console) then when the microphone detected a sound (like a clap), an LED would light up and would turn off when the microphone 'heard' a clap again. Alternatively, when the photocell did receive light, this function of the microphone did not work.



(a) Photocell characterization

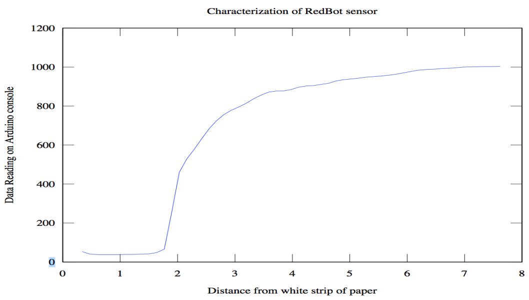
(b) Sample photocell/photoresistor
Source `http://bit.ly/1Q7ZDPJ`

Figure 5: Photocell Characteristics and image

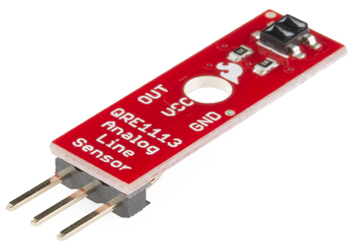
2.8 RedBot Sensors

The RedBot sensor works by detecting reflected light coming from its own Infrared LED. By measuring the amount of reflected light it can detect transitions from dark to light lines and even objects directly in front of it. The sensor has a 3-pin head which connects directly to the Arduino using female-female jumper cables. For our project, we had to write code compatible with our project requirements and hence used the RedBot library to detect lines or objects.

An image of the sensor and the data-readings (the characteristic) as a function of its distance from white paper is attached below.



(a) Characterization of the sensor
(generated with Octave)



(b) Image of the sensor
Source `http://bit.ly/1LFJ5Xr`

Figure 6: RedBot sensor diagram and Characterization

2.9 Light Emitting Diode (LED)

A Light Emitting Diode (LED) is a two-terminal semiconductor diode. An LED is essentially a p-n junction where when a voltage is applied in forward bias it is activated an emits photo-electrons of different wavelengths to produce different colors. In our project we used the LED in coalition with the microphone and the photocell. When the photocell was active (did **not** receive light), the microphone switched on - when the microphone heard a loud clap or tap, the LED switched on and turned off with another tap or sound. When the photocell was inactive, the microphone was switched off and the function did not execute.

Indeed, this has taught us more about working with multiple sensors and with an arduino together. We were able to use a few simple lines of code and work out a solution to perform the above function with the code posted below.

3 Design Consideration

The primary objective of the vehicle is that it has to navigate along a line on a track of white strip paper and has to bend along curves and edges. We plan to add a feature to this car by making it able to stop and start using a microphone. To fulfill this we used 2 RedBot IR sensors and a microphone. The IR sensor observes how far it deviates from the line and, as a result, is able to keep on track. Hence, our 2 sensors were separated by 4 cm so that the vehicle could move smoothly.

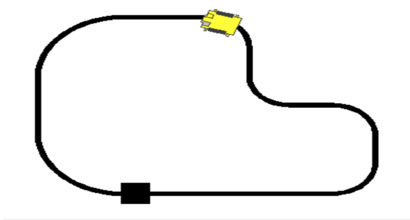


Figure 7: Test track for the vehicle with curved corners
Source: `http://bit.ly/1PTRAGf`

4 Line follower circuit

4.1 Code

The following is our Arduino code for the line-follower circuit which includes the PWM circuit with 2 IR RedBot sensors. *(comments explain working of code)*

```
#include <RedBot.h>
RedBotSensor IRSensorL = RedBotSensor(A3);
RedBotSensor IRSensorR = RedBotSensor(A2);
int a,b;
void setup() {
  Serial.begin(9600);
  Serial.println("Welcome to the Simple Follower!");
  pinMode(5,OUTPUT); // connects pin to output
  pinMode(6,OUTPUT);
}
void loop() { //repeats after code block ends
  a = IRSensorL.read(); //connects to the right IR sensor
  b = IRSensorR.read(); //connects to the left IR sensor
  if (a > 700 && b < 700 ) { /* if statement for case where *a* detects a white strip and *b* detects black surface */
    analogWrite(6,98);
    analogWrite(5,0);
    delay(280); // delay added for code to loop
  }
  else if (a < 700 && b > 700 ) { /* else if statement for case where *b* detects a white strip and *a* detects black surface */
      analogWrite(5,75);
      analogWrite(6,0);
      delay(280);
  }
  else { // else statement for case where *a* and *b* detect WW or BB
      analogWrite(5,85);
      analogWrite(6,75);
  }
  Serial.println("IR Sensor Reading:\t"); // prints sensor data
  Serial.println(a);
  Serial.println("\t");
  Serial.println(b);
  Serial.println("\n");
}
```

4.2 Documentation

To make the line follower circuit we used the RedBot sensors' header file - RedBot.h which contained the necessary pre-processed functions in it's library. The code used the setup() function that essentially acts as the C main function. Pin 6 was connected to the LHS IR sensor and Pin 5 was connected to the RHS IR sensor.

The essence of this code lies in the loop function - a function in the RedBot.h library which repeats itself after the code ends in its block. a and b read the data from the console for the Left and Right sensors respectively. The block contains an if-else-if statement to account for the multiple cases encountered by the 2 IR sensors on White (W) and Black (B) surfaces. The first if statement covers the case where the sensor 'a' on the right detects the white strip but 'b' on the left detects a black surface (here, the car is moving to the left) - this causes analogWrite to power the left motor to a reading of 98 and puts the right motor down to 0 so that the vehicle can move to the right. Alternatively, for the second case, it's a similar statement but for the opposite side which is used to move the vehicle to the left. Furthermore, the third (else) statement is for the case where 'a' and 'b' both detect WW and BB where the car moves forward by powering both the motors - the analog numbers were adjusted by a qualitative idea of the weight on both sides of the vehicle.

5 Multi-sensor circuit

5.1 Code

The following is our Arduino code for the multi-sensor circuit which includes a microphone, a photocell and an LED. *(comments explain working of code)*

```
int a,b,c=0;

void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
pinMode(9,OUTPUT); // pin 9 is connected to the LED
}

void loop() {
  // put your main code here, to run repeatedly:
a=analogRead(0); // pin 0 *read* connects to the microphone
b=analogRead(5); // pin 5 *read* connected to light sensor (photocell)
Serial.println(b);

if(a>20 && b>300 && c==0) { // when light sensor is covered - reading>300
  digitalWrite(9,HIGH); // pin 9 switches LED on
  c=1;

}
else if(a>20 && b>300 && c==1)  {
  digitalWrite(9,LOW); // pin 9 switches LED off
  c=0;
}
}
```

5.2 Documentation

The circuit was a specialized circuit that improved our understanding of electronics and Arduino code. We used a photocell that was used to control a microphone. When the photocell was covered, the microphone turned on and could be controlled to switch ON and OFF an LED with a clap but not when the photocell was OFF.

6 Circuit Schematics & Analysis

6.1 Circuit Diagram

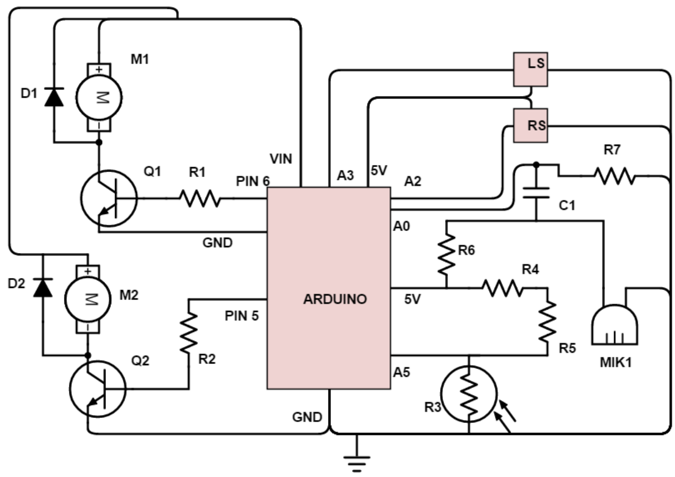


Figure 8: Circuit diagram of our project (created Using DigiKey)

6.2 Circuit Analysis

We used 2 motor-drive subcircuits to control the motors. Each motor-drive subcircuit is connected to a digital PWM pin on the Arduino so that we can control the speed of the motor using analogWrite. We used V_{IN} in the Motor drive circuits instead of a battery as in Lab 7 and 8. For the mic circuit, we connected as shown in the circuit schematic with the MIC being connected to the GND at one end and a node with a 100 nF capacitor and a 10 kΩ resistor at the other end. This 10 kΩ resistor is connected to 5V. The capacitor is connected to another node which contains the connection to A0 and 10 kΩ resistor. This second 10 kΩ resistor is connected to the GND. For the light sensor, we connected 10 kΩ and 22 kΩ resistors in series. This series connection is connected to 5V at one end and the photocell at the other. A5 is also connected at this other node. The other end of the photocell is connected to GND.

6.3 Block Diagram

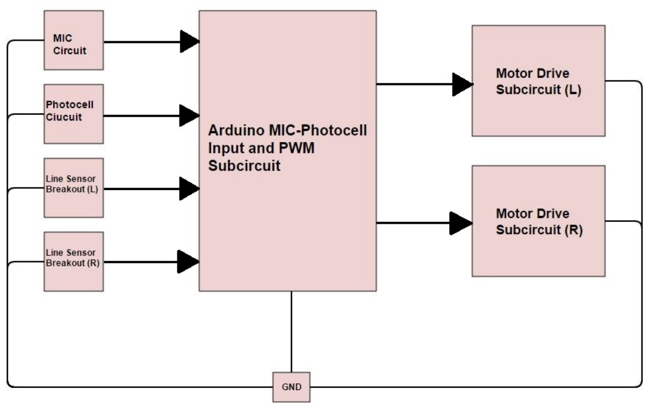


Figure 9: Block diagram of circuit (created using DigiKey)

6.4 Block Diagram Explanation

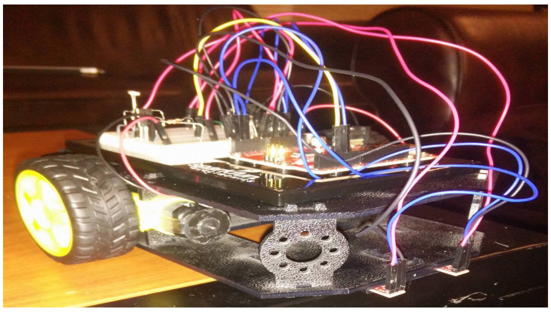
The Mic circuit is connected to the arduino. This gives input based on the sound it hears. The photocell circuit is also independently connected to the arduino. This gives input based on its light reading. Both the line sensors are connected to the arduino using analog pins A2 and A3. The sensors are also connected to 5V and GND. The arduino based on these 4 inputs, gives an unique analogWrite value to each motor drive subcircuit which drive the motor.

6.5 Characterization Explanation

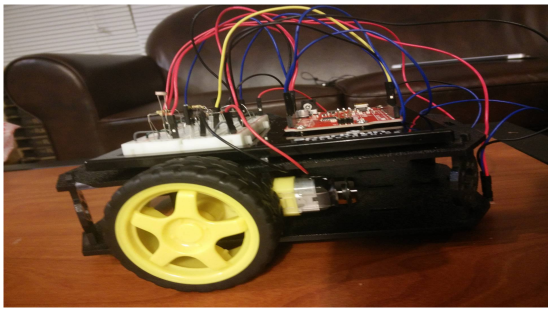
For the MIC characterizations, nothing was changed except an oscilloscope was connected to the MIC in the original circuit. We then clapped to see the spike in the oscilloscope. For the Photocell characterization, we reprogrammed the arduino to serial print the analog value of the Photocell subcircuit. We then used an app on the phone called LuxMeter from Android App Store to measure the Lux (intensity of light) in the room. We created different light situations like no light, dim light, bright light throughout the room to measure the values of light intensity from the app and the values from serial monitor. During this, we kept the phone's sensor and the light sensor right beside each other. We then plotted these values.

7 Conclusion

After designing the circuit required, assembling the circuit on the breadboard and having tested in multiple times with many test cases, we could build our autonomous vehicle which followed the white line track and switched mobility based on the claps from the environment just like a semi-autonomous vehicle!



(a) Front-Side view of chassis w/ circuit
(Redbot sensors attached)



(b) Side view of chassis
(Motor, Arduino, Circuit visible)

Figure 10: Photos of Final Lab Project

8 Self-Evaluation & Future Projects

We can say with utmost certainty that the takeaway from a project like this is definitely going to help in the future. Having designed an autonomous vehicles moving with cues from its environment we feel equipped with the tools to learn more about circuits and implement more complex circuits. Having learnt about using Microcontrollers, simple electrical components, microphones, photocells and RedBot sensors, we are planning to take this project further by adding more sensors to improve and increase functionality. One idea for a future project is to add a heat sensor so that the car can move in a direction with a depression on the heat map - we plan on doing this using concepts of computer vision and machine learning to analyze the heat map and finding the minima on the map; a potential application of this is that the vehicle and autonomously change directions in case of a fire. Indeed, a project like this will be a great learning experience just like our final project was.

9 References

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https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/FLEXSENSORREVA1.pdf

2 ECE 110 - Experiment 9 - Navigation
https://courses.engr.illinois.edu/ece110/fa2015/content/labs/Experiments/experiment.9.procedures.FA15.v10.pdf

3 RedBoard by SparkFun - Programmed with Arduino
http://www.robotgear.com.au/Product.aspx/Details/733-RedBoard-by-SparkFun-Programme

4 2N5192G ON Semiconductor — Mouser
http://www.mouser.com/ProductDetail/ON-Semiconductor/2N5192G/?qs=vLkC5FC1VN$\%2Fa3d2jm7wSkw\%3D\%$3D

5 Sensors
http://ixda.gatech.edu/resources/files/scott-sensors.pdf

6 Resistor - Wikipedia, the free encyclopedia
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7 Capacitor - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/Capacitor

8 Ceramic Capacitor >> Capacitor Guide
http://www.capacitorguide.com/ceramic-capacitor/

9 Transistor - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/Transistor

10 Light-emitting diode
https://en.wikipedia.org/wiki/Light-emitting_diode

11 Photoresistor
https://en.wikipedia.org/wiki/Photoresistor

12 What is a light-emitting diode?
http://www3.nd.edu/~lemmon/courses/ee224/web-manual/web-manual/lab1/node6.html

12 Blink : codebender https://codebender.cc/how_it_works

13 ECE 110 - Final Report Rubric
https://courses.engr.illinois.edu/ece110/fa2015/content/labs/Experiments/experiment.11.procedures.FA15.v10.pdf

14 Images from DigiKey
http://www.digikey.com/schemeit/

15 PDF for photocell/photoresistor by egr.msu.edu
http://www.egr.msu.edu/classes/ece480/capstone/spring15/group13/assets/isaacappnote.docx.pdf

16 Voltage Dividers
http://www.doctronics.co.uk/voltage.htm