Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN 2090 – Laboratory Practice II

Project Report

Analog Line Following Robot

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Abstract

Line following robot is the steppingstone for any robotics enthusiast who starts studying about robotics. This robot has the capability of following a white line on a black background. Our objective was to build the robot to follow a 3 cm wide white line on a black surface and stop at a white line which is perpendicular to the path. Moreover, the whole functionality of the robot was to be controlled using analog circuitry. That is; we are supposed to design the robot using analog components like Op amps, IR sensors and using a motor driving IC. In this report we have illustrated the process of design, implementation and testing of the analog line follower robot that we designed.

1. Introduction

Robotics is the branch of technology that deals with the design, construction, operation and application of robots. A machine capable of carrying out a complex series of actions automatically, which is programmable is defined as a robot. And Line Following refers to the ability of a robot to follow a white line on a black surface. Here the task assigned to us is to build an analog line following robot.

Considering the electronics of the robot, it has been made with five PCBs. The main PCB consists with the sensor panel. Another one is for power supplying. Next one is for the motor and PID controllers which directs the voltage needed for two motors and controls the two motors. And another is for error signal and triangular waveform generation. And the last one is for the motor driving system.

We had to consider one more section apart from the electronics section. It was the physical nature, shape and size of the chassis, type of motors and wheels to be used. Here we have used two dc motors to control the back wheels. Apart from the two back wheels we used a caster wheel for the front of the robot. And six IR sensors were used to detect the position of the white line. And for the chassis, we used a premade chassis and modified as per our requirement.

2. Method

2.1. List of Components Used

2.1.1. Sensor Panel

- TCRT5000 IR Sensor – 6
- LM324N Quad Op Amp IC – 2
- 10k Potentiometer – 1
- 100Ω resistors – 6
- 4.7k resistors – 6
- Connectors

2.1.2. Power supply

- LM7809 Regulator IC – 1
- LM7805 Regulator IC – 1
- 0.1uF capacitor – 8
- Connectors

2.1.3. Error Signal Circuit

- LM324N Quad Op Amp IC – 1
- LED – 6
- 330 Ω resistors – 6
- 10k resistors – 5
- 12k resistors – 2
- 18k resistors – 2
- 33k resistors – 2
- Connectors

2.1.4. PID Controlling Unit

- LM324N Quad Op Amp IC – 1
- 10k Potentiometer – 3
- 0.1uF capacitor – 2
- 10k resistors – 8
- 20k resistors – 1
- Connectors

2.1.5. Triangular Waveform Circuit

- LM324N Quad Op Amp IC – 1
- 0.1uF capacitor – 2
- 100k resistors – 1
- 15k resistors – 1
- 33k resistors – 1
- 47k resistors – 2
- Connectors

2.1.6. Motor Controller Circuit

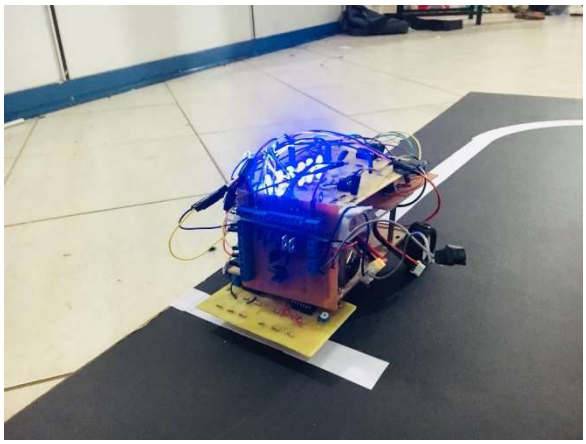
- LM324N Quad Op Amp IC – 2
- 10k Potentiometer – 2
- 0.1uF capacitor – 2
- 10k resistors – 15
- 18k resistors – 2
- Connectors

2.1.7. Motor Driver Circuit

- L293d Motor Driver IC – 1
- LM324N Quad Op Amp IC – 1
- 74LS08N Quad
- 10K resistors - 6
- 18K resistors - 2
- Connectors

2.2. Robot Specifications

- Dimensions -10 cm (width) x 20 cm (length) x 10 cm (height)
- Weight – about 1.5 kg
- Power Supplies – 12V Li-Po Battery & 9V DC Battery
- Motors – 5V DC Motors
- Chassis – Customized Chassis made of Acrylic

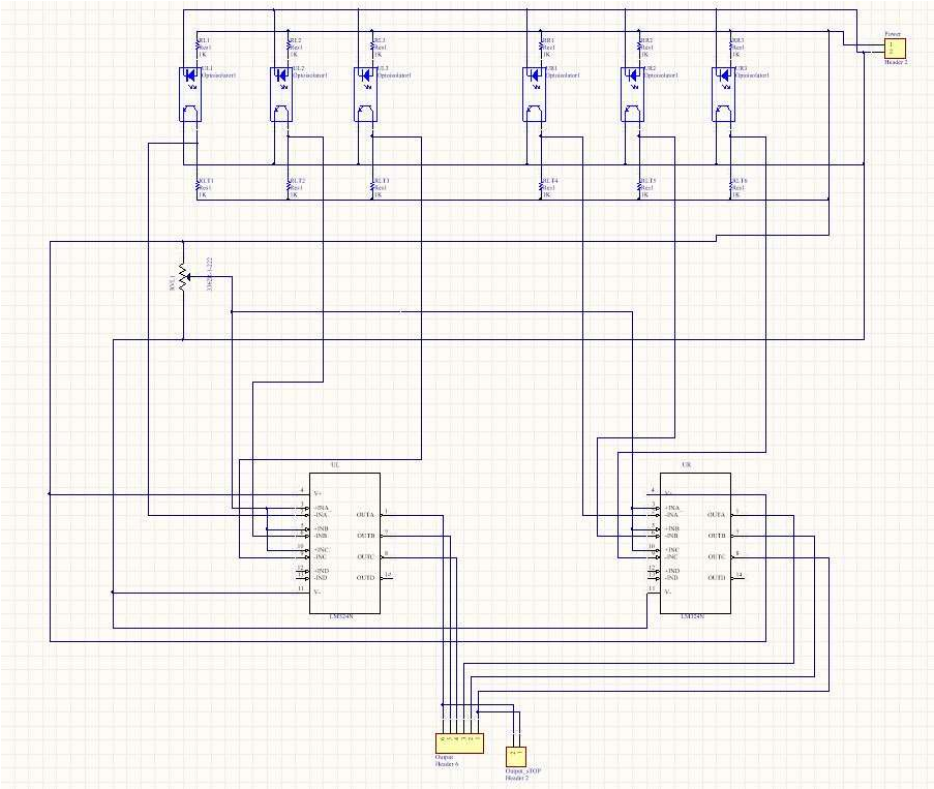


2.3. Circuit Design

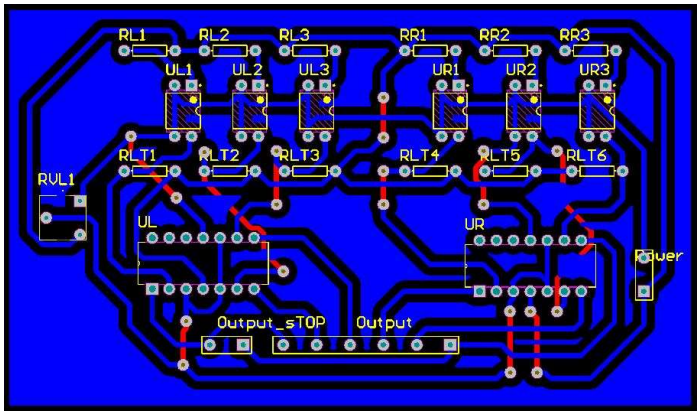
2.3.1. Sensor Panel

The sensor panel we designed consists six TCRT5000 IR sensors. One TCRT5000 sensor consists a photo transistor and an IR emitter. 100 Ω resistors were used to limit the current through the IR emitter so that it can be activated in a proper manner. Here the LM324N Quad Op Amps IC are used to make comparator circuits to compare the analog outputs of the sensors with a threshold voltage. To set this threshold voltage; a 10k potentiometer is used. The digital outputs from the comparators were drawn out through the connectors. We designed a separate PCB for the sensor panel circuit as it should place closely to the arena surface.

Schematic of the Sensor Panel



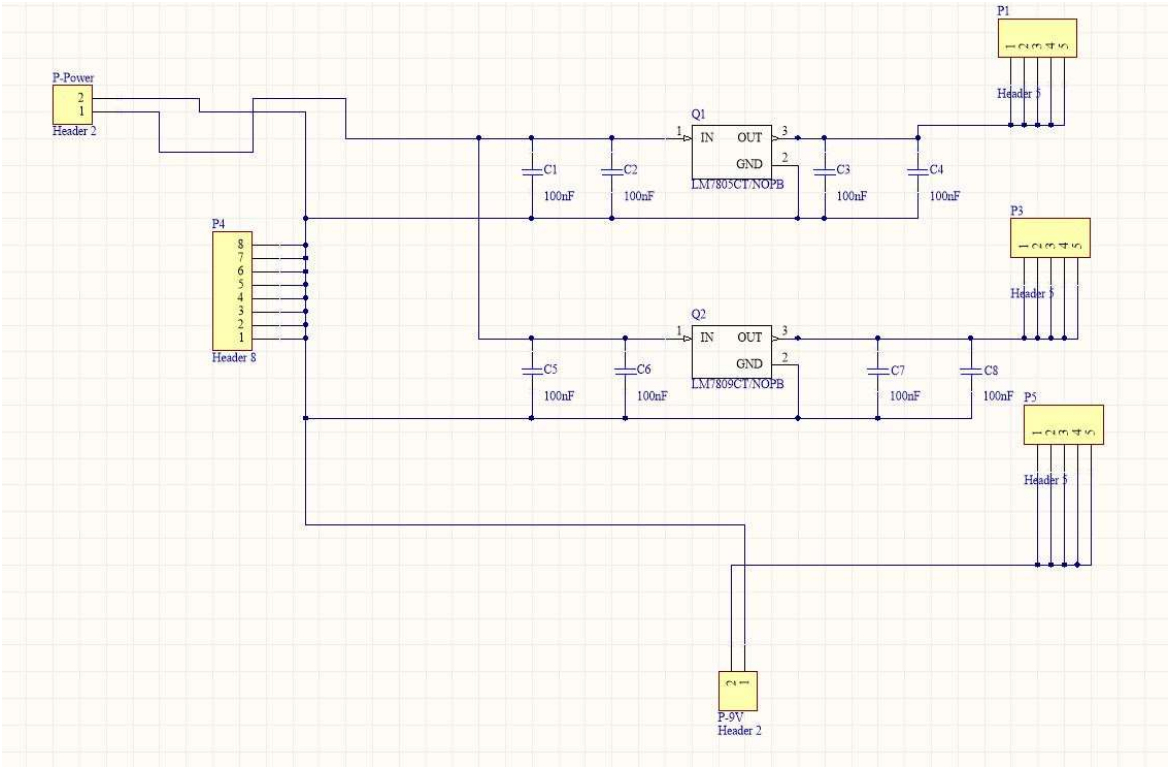
Layout of the Sensor Panel



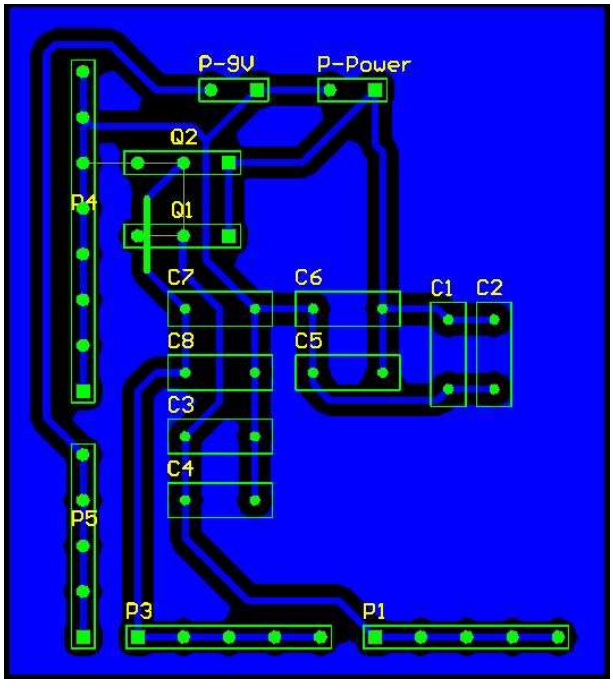
2.3.2. Power Supply

For the proper functioning of the robot it requires different voltage values for different components such as +5V, + 9Vand -9V. LM7805 and LM7809 regulating ICs were used to produce the +5V and +9V by the input voltage of 12 which supplied by a Li-Po Battery. -9V is generated by separate 9V DC battery. A separate PCB was designed for the power supply circuit also.

Schematic of the Power Supply



Layout of the Power Supply



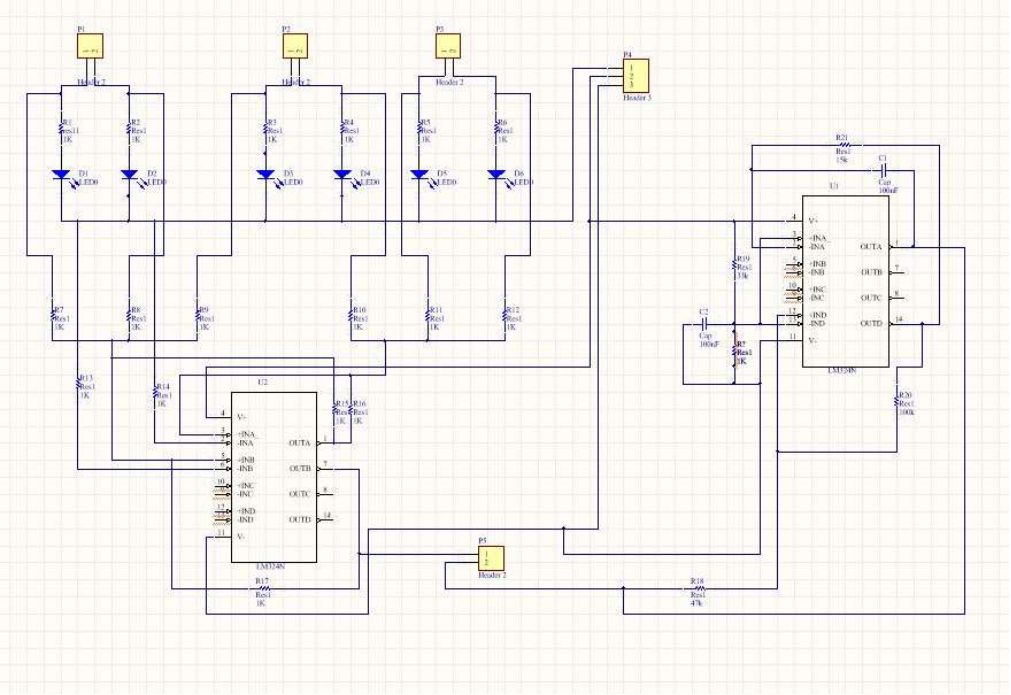
2.3.3. Error Signal Circuit

The LEDs are used to display the grading of the digital outputs of the sensors. The scaling adder circuits which is used to add the digital outputs with different gains are designed using LM324N Quad Op Amp IC. By applying different gains to the different sensor outputs; the magnitude of the error is set proportional to the deviation from the white line. The generated error signal denotes the position of the robot with respect to the white line. The error signal circuit was designed with along the triangular waveform circuit on the same PCB.

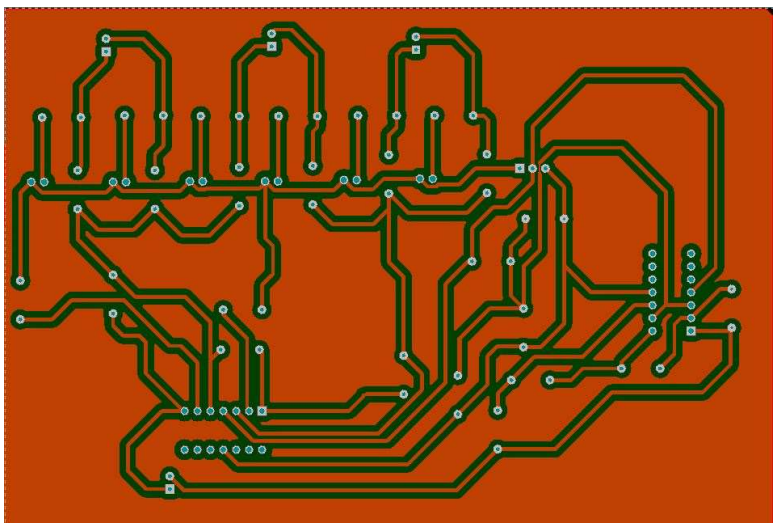
2.3.4. Triangular Waveform Circuit

The two Op Amps n the LM324N Quad Op Amp ICs are used in this circuit. One is for generating a square wave and the second one is for generating a triangular waveform by integrating the generated square wave. The capacitors and the resistors in the circuit are used to vary the characteristic values of the generated triangular waveform as needy. The circuit is mounted along with the error signal circuit on a same PCB.

Schematic of the Error Circuit and Triangular waveform Circuit



Layout of the Error Circuit and Triangular waveform Circuit



2.3.5. PID Controlling Unit

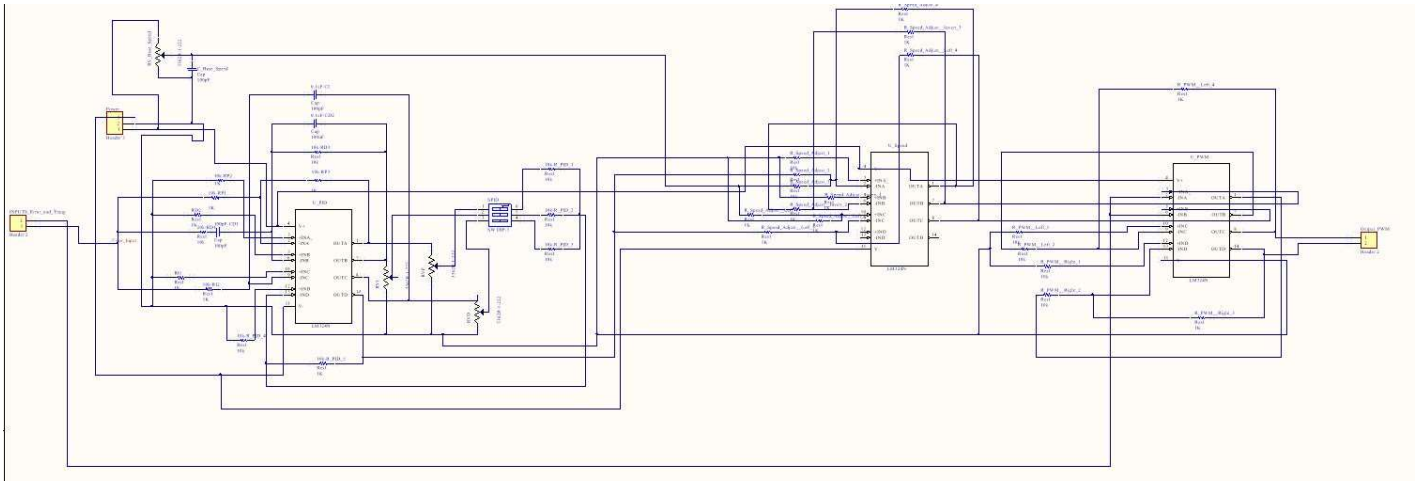
PID controllers use a control loop feedback mechanism to control process variables. Here the error signal is controlled by the PID controller. The PID controller has three controls such as; proportional controller, integral controller and derivative controller. The three controlling mechanisms are done by using Op Amps by using their various applications. The three potentiometers are used to fine-tune the outputs of each controllers before summed. Another Op Amp adder is used to sum the three controller outputs together. The circuit for the PID controlling circuit was designed along with the motor controller circuit on the same PCB.

2.3.6. Motor Controller Circuit

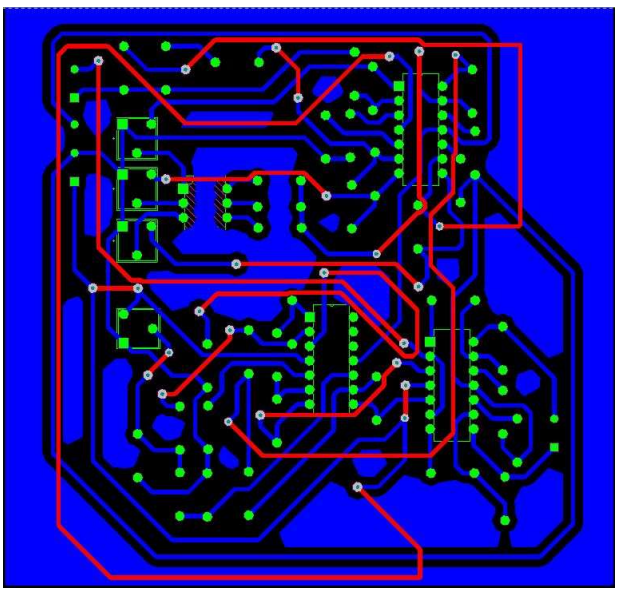
The base speed of the line following robot can be controlled by adjusting a 10k potentiometer set between 9V and 0V. A 0.1uF capacitor is added to enable soft start.

Before giving two PWM signals into the motor driver, it should be amplified. Therefore, here we used two Op-Amps. The IC with those Op-Amps is LM324. First, we amplified left and right PWM signals by 0.55 gain (5/9) using inverting amplifier. Then using a unit gain inverting amplifier, we can have the same polarity to the signals. For convenience the motor controller circuit is mounted with the PID controller circuit in the same PCB.

Schematic of the PID and Motor Controller Circuit



Layout of the PID and Motor Controller Circuit

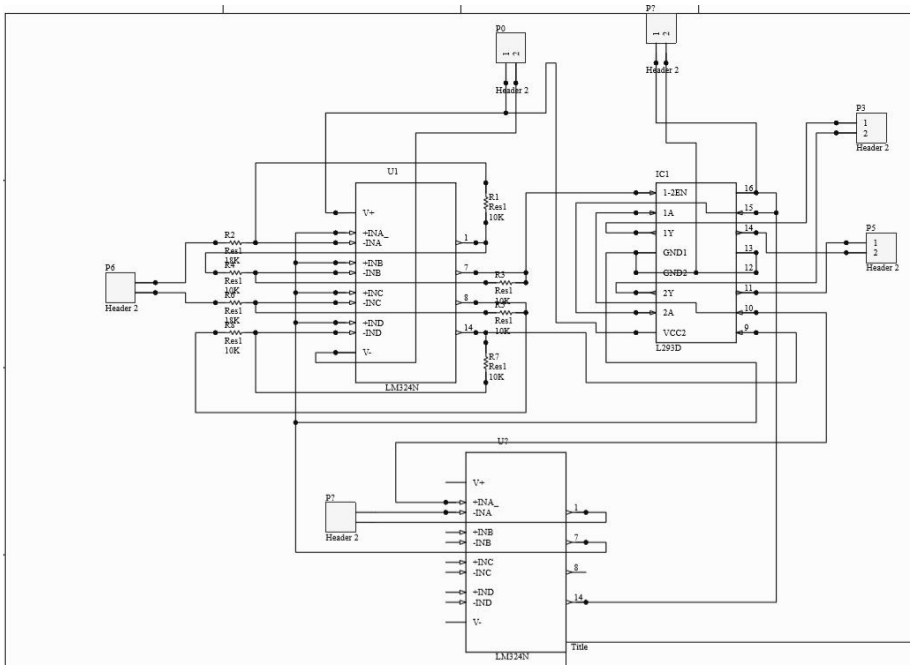


2.3.7. Motor Driver Circuit

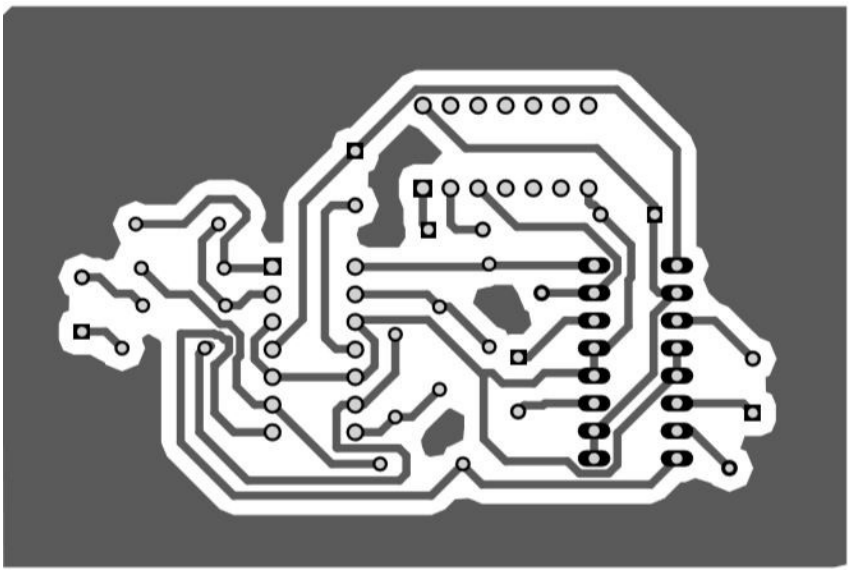
Due to the fact that the analog currents are not enough to drive the motors, we used a separate L293d motor controller IC. This is a dual motor H bridge motor controller with enable inputs. Then we gave Left and Right PWM signals to enable inputs and 1 0 pattern is given as the inputs for the motors to continuously rotate the motors to the front. PWM signals which are generated according to the sensor inputs are used to control the speed of the two motors so that the robot follows the line. Supply voltage is 5V because the two motors have 5V rated voltage.

The robot is supposed to stop when it come across with a white line perpendicular to the following line. In that moment, sensors at both edges will be high. In other cases, at least one of the edge sensors is low. Therefore, the digital outputs are made logically AND using a 74LS08 AND gate IC. After that the output is connected as one input signal for both motors replacing 0 while maintaining 1 at the other input signal.

Schematic of the Motor Driver Circuit



Layout of the Motor Driver Circuit



2.4. Designing of the Robot

To design the discussed circuits; we used Altium Designer software and we have designed 5 PCBs covering all those circuits. The five PCBs are as follows.

- Sensor Panel
- Power Supply
- Error Signal and Triangular Waveform Circuit
- PID Control and Motor Controller Circuit
- Motor Driving Circuit

The whole process of PCB designing, printing, drilling and soldering was done by ourselves.

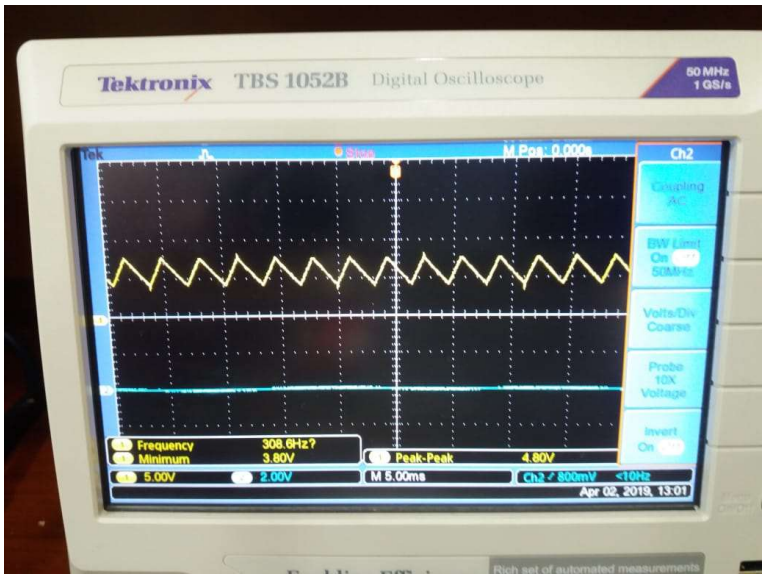
For the chassis of the robot; we used a premade one and modified as per the requirement. And for power up the robot, we used a 12V Li-Po Battery and a 9V DC battery. The motors that we used to rotate the back wheels are 5V DC motors. Apart from the two back wheels, we used a caster wheel for the front. After all the testing done separately for each PCB, all the PCBs were assembled to the chassis and connected using jumpers.

3. Results

Since the complexity is much high in the whole procedure, we divided the whole task into sub tasks and work on them separately. So, all the PCBs were tested separately before assembling. And after ensuring of the proper functioning of all PCBs they were assembled together.

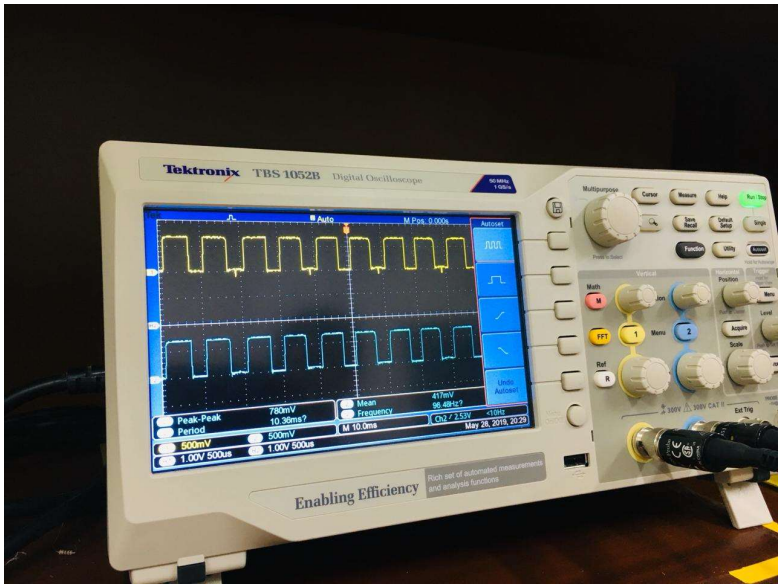
Some photographs that we took during our implementation of the analog line following robot are discussed below.

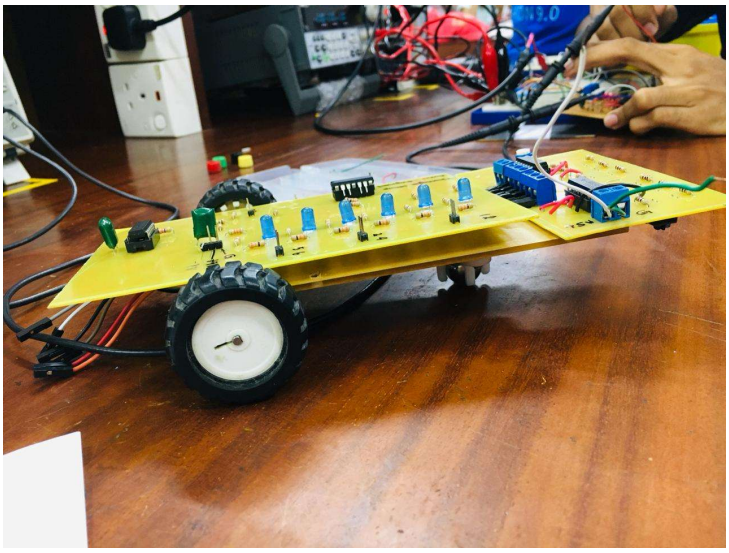
To obtain the triangular waveform properly, we have to do some adjustments to the potentiometers.



Triangular Waveform

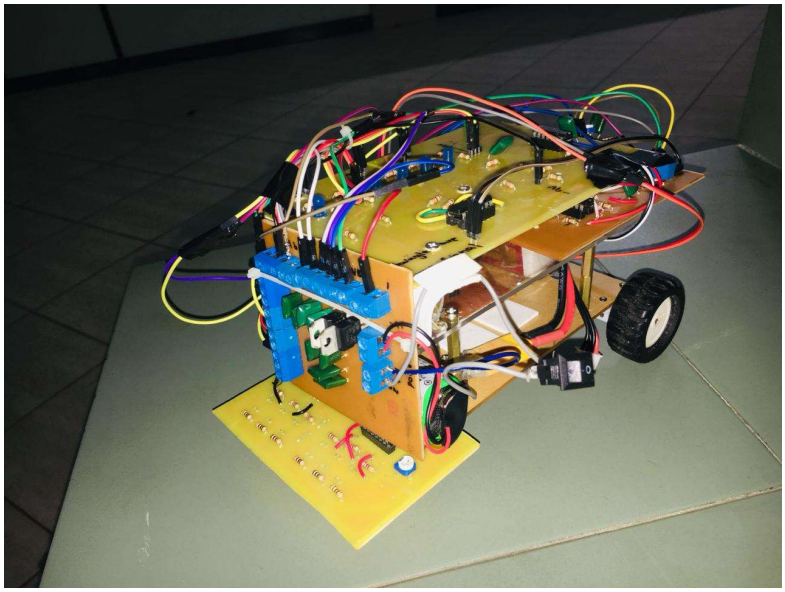
The two PWM signals when the line is in the middle of sensor panel (i.e. the error is zero)





Assembling the PCBs to the chassis

Fully assembled Analog Line Following Robot



4.Debuging

After assembling all the circuits there were few test runs to evaluate the performance of the robot. In this process we encountered with following problems. To address these problems, we had to make few adjustments to our circuits.

1. The motors couldn't be driven according to the PWM signal
    - The peak value of the PWM signal was a very small value which was on milli volt range. We had to increase the gain of the PWM signal.
2. When the error is zero, the rotation speeds of the motors were different
    - There was a little duty cycle difference between two PWM signals when the error is zero. We had to give two different base speeds to the two wheels.
3. Robot didn't respond correctly to the stop condition.
    - The 74LS08 IC was not in a working condition. We had to replace the IC.

- Test run of the robot can be seen by scanning this QR code

5. Discussion

The main objective of the project was to build a robot that has the capability to follow a white line on a black surface. Furthermore, it has to be designed using analog circuitry. It was a challengeable task because we have to implement the whole project using only analog components. After several weeks of hard work, a robot was built to perform the above task and this section of the report describes what was experienced during the process.

First and foremost, we must identify and design the circuits which are necessary for the functionality of the robot. Then after we tested our circuits on bread boards and done some modifications as per the need. Also, we have to tune some components in the circuits so that we were able to have a proper output. However, this task was somewhat challenging as some research had to be done to figure out the optimum components.

Next the PCB layouts were designed using the Altium Designer software. Then we printed our PCBs by ourselves and tested the circuits once again using the PCBs. Sometimes we have to reprint PCBs due to some errors. After clarifying all the issues of the PCBs; all the PCBs were assembled on the chassis and connected using the jumper wires. Then also we have to do some modifications for the circuits since we haven't got the proper output. Afterall, we were able to come up with a functioning analog line following robot.

In conclusion it can be stated that although the project was somewhat challenging mainly due to our lack of experience, the learnings will definitely be useful for the upcoming projects.

6.References

- http://www.will-moore.com/analog-line-follower
- http://www.ermicro.com/blog/?p=1908
- https://en.wikipedia.org/wiki/PID_controller