A Line-follower Robot

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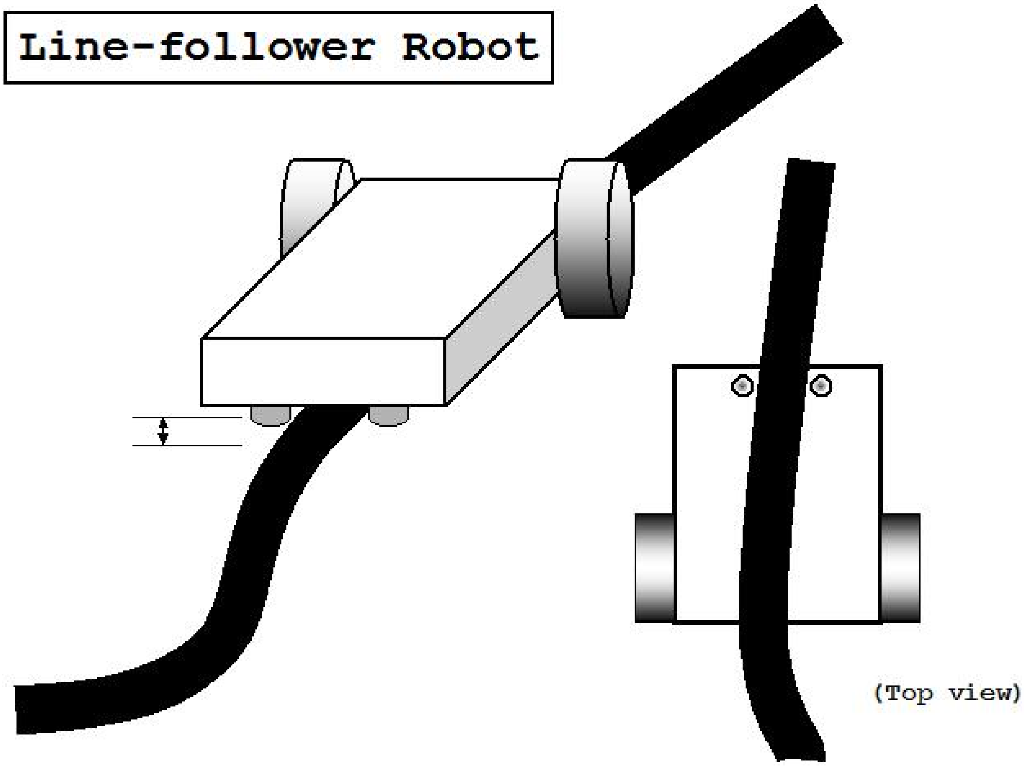


1. Introduction

For my final project, I decided to make a line-follower robot. This simple robot is designed to be able to follow a black line on the ground without getting off the line too much. The robot has two sensors installed underneath the front part of the body, and two DC motors drive wheels moving forward. A circuit inside takes an input signal from two sensors and controls the speed of wheels' rotation. The control is done in such a way that when a sensor senses a black line, the motor slows down or even stops. Then the difference of rotation speed makes it possible to make turns. For instance, in the figure on the right, if the sensor somehow senses a black line, the wheel on that side slows down and the robot will make a right turn.

2. Theory of operation

i) How to sense a black line

The sensors used for the project are Reflective Object Sensors, 0PB710F that are already ready in the Electronic Lab. The single sensor consists of an infrared emitting diode and a NPN Darlington phototransistor. When a light emitted from the diode is reflected off an object and back into the phototransistor, output current is produced, depending on the amount of infrared light, which triggers the base current of the phototransistor. In my case, the amount of light reflected off a black line is much less than that of a white background, so we can detect the black line somehow by measuring the current. (This current is converted to voltage.)

ii) How to control a DC motor

Instead of applying a constant voltage across a DC motor, we repeat switching on and off the motor with a fixed voltage (Vcc) applied to the motor. This is done by sending a train of PWM (Pulse Width Modulation) pulses to a power MOSFET in order to turn it on and off. Then, the motor sees the average voltage while it depends on duty cycle of PWM pulses. The speed of rotation is proportion to this average voltage.

By PWM method, it's easier to control the DC motor than by directly controlling the voltage across it. All we have to do is to modulate pulse width, in order words, a duty cycle. Also, a power MOSFET consumes only negligible power in switching.

3. Circuit diagram

My circuit consists of two parts: PWM (Pulse Width Modulation) part and a sensor part. First, we take a look at the sensor part. The photodiode turns on the phototransistor and then the output current is converted to output voltage through the first op-amp circuit. The R6 is a variable resistor, so that we can tune the scale of output voltage. The second op-amp circuit is added to change the polarity of voltage. (Positive CV is necessary later.) One thing we should know is that -Vcc to Vcc of voltage rail is needed, not from 0 to Vcc.

In the circuit built-up, LM747 Dual Operational Amplifiers were used.

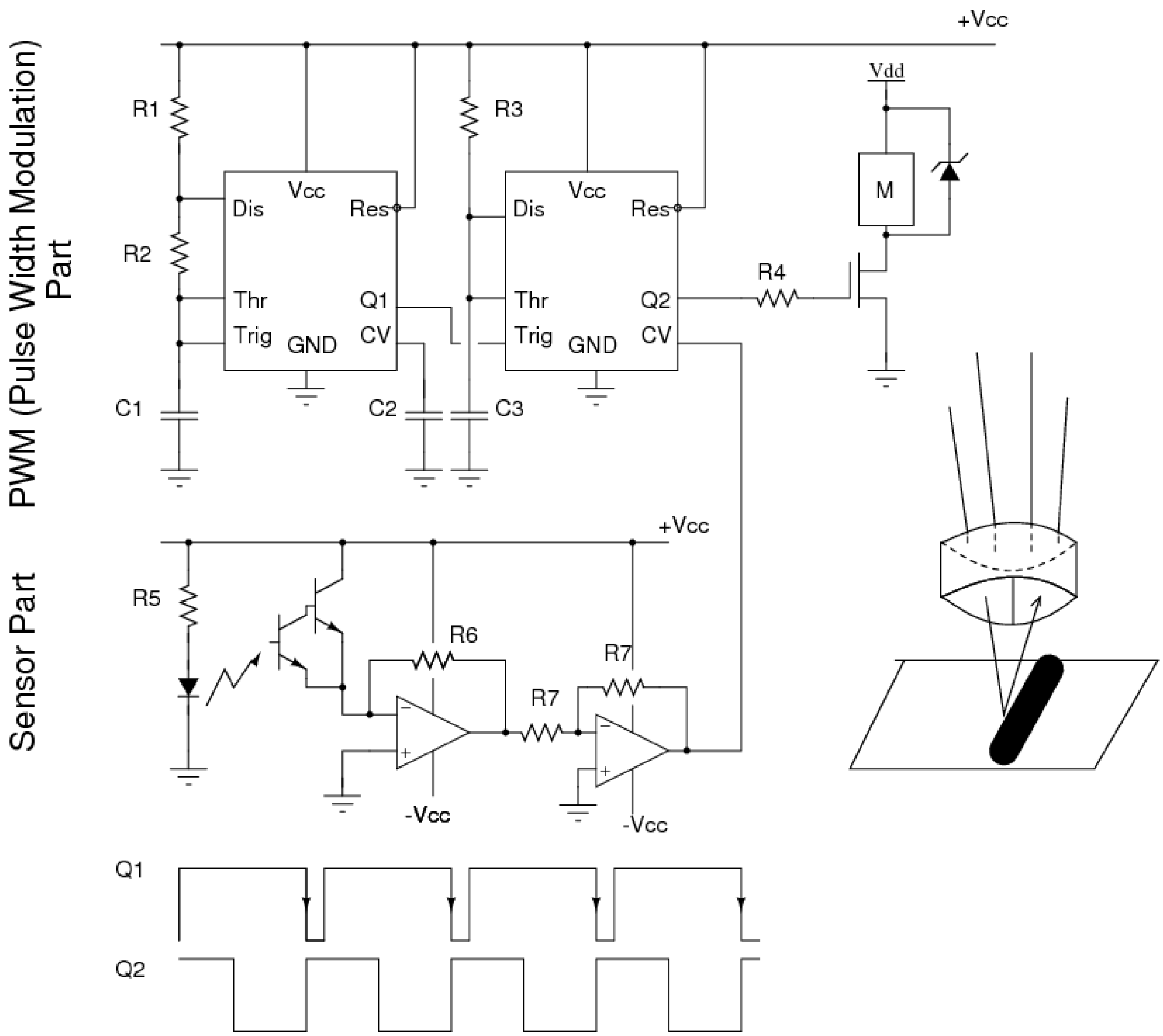
Second, in the PWM section, two 555 timers (LM555) are used to produce a pulse-width modulated train of pulses. The timer on the left works in astable mode to generate regular square-wave pulses. The frequency is fixed by the values of R1, R2 and C1 here. Then, this output Q1 is connected to the trigger pin of the second timer that works in monostable mode this time. As you can see in the diagram, at a falling edge of Q1, a pulse is triggered and stays high during some time. The time (width of a pulse) is purely determined by the value of R3 and C3 if CV (Control Voltage) pin is not connected at all. (Look at the pulse diagrams of Q1 and Q2 at the bottom of the circuit diagram.) CV plays a role of changing the threshold level of a timer. (Without CV, threshold = 2/3 * Vcc) CV just becomes the triggering voltage level. Therefore, the higher the CV is, the longer it takes time until discharge. In this way, the duty cycle of output pulses Q2 can be controlled. Back to my circuit, the output voltage of the sensor part provides CV. For instance, if any sensor senses a black line, the current from the photodiode decreases, the CV drops, the duty cycle gets low and the motor slows down.

Third, the PWM pulses are supplied to the gate of a power MOSFET (IRF520) to switch the DC motor on and off. Then, the DC motor only sees the average voltage proportional to the duty cycle of the pulses. When CV is high, so is the duty cycle and the motor turns fast.

In my robot, the distance between sensors and the ground is fixed. So, when a sensor is off the black line (The sensor sees white paper.), CV keeps its maximum value and both motors keep turning in a constant speed. As soon as the sensor enters the black line part, CV drops down and thus duty cycle decreases, which means the slowdown of a wheel.

* Component Values:
R1=6K, R2=1K, R3=20K, R4=10, R5=82, R6=5K(variable), R7=1K
C1=1μF, C2=0.1μF, C3=0.1μF,

Line-follower Robot Circuit Diagram



4. Building the robot

Before starting to build a real circuit, I built is on the lab breadboard and verified everything worked fine. Then, I bought a blank breadboard from ECE storeroom. I put together each electronic part and wires on the board and soldered them all. (The work would have been much easier to use a PCB (Printed Circuit Board).) After that, I checked if there is any bad connection, and tested if the circuit generates correct pulses at each point. (i.e. Q1 and Q2) This whole work took quite a time, much longer than I expected.

For a robot body, I bought a container and two flying wheel toys at the Wal-Mart. With

every part ready, I drilled holes to fix two DC motors, some supporting aluminum plates and sensors in front

5. Result

For a test, I held my robot in the air and I approached a white paper to sensors. Then, both wheels rotated as expected and they slowed down when either the paper moved away or sensors passed across a black line. Next, I put it down on the track, but unfortunately, it didn't move. I found the torque of motors not enough to drive my robot. Even though the chosen DC motor was slowest and gave highest torque among other DC motors in the lab, it wasn't enough. For solving this problem, I will have to find a suitable DC motor with large torque.

Overall, the robot project wasn't successful, but it was quite a fun to go through all the process. I also realized that there were many things to consider practically such as installation of motors, building up a circuit by soldering and putting all parts together. This experience hopefully would be helpful in the future work.

Some snapshots of my robot are on the next page.