

University of Pennsylvania
ESE 112: Introduction to Electrical & Systems Engineering

Lab 6: Light Sensitive Navigation

Objective

- To introduce another passive electrical component called the capacitor
- To introduce light sensitive navigation

Introduction

Light has many applications in robotics and industrial control. Some examples include determining when to activate/deactivate a streetlight at different times of the day (this is something we briefly looked at in lab 2), when to take a picture, or when to deliver water to a crop of plants. In this lab, we will build a light sensor using a photo-resistor and a capacitor that can sense areas with light or dark levels and help the Boe-Bot navigate by seeking out light sources such as a flashlight beam.

Background

Java:

We will continue using procedural programming concepts in order to accomplish the goals for this lab.

Capacitors:



Figure 1: Capacitor Symbol

A capacitor is an electronic component whose main use is to store electrical energy. A capacitor is made up of two metal plates that carry charge. In between these plates is a dielectric, or a non-conducting substance. You charge a capacitor by connecting it to a battery (one end to the positive terminal, and the other to the negative terminal). As electrons flow around the circuit, the capacitor will continue to store energy until the voltage across the capacitor is equal to the voltage of the battery (in a circuit with just a capacitor and a battery). Some capacitors can hold lots of charge while others hold less. Amount of charge (Q) stored is directly proportional to the voltage (V) applied i.e.

$$Q = CV$$

C is the proportionality constant called **Capacitance**, and is measured in Farads (1 Farad = 1 coulomb/1 volt). The capacitance is:

1. Directly proportional to the surface area
2. Inversely proportional to the distance between the plates

3. Directly proportional to the permittivity (of dielectric), which is the ability of a material to transmit (or "permit") an electric field.

Application of a capacitor:

Capacitors are used in applications where a large amount of energy is required in a short amount of time. For example, the flash bulb in your camera is powered using a capacitor. After the capacitor is charged using the battery, the flash can use that large chunk of energy quickly to produce the quick bolt of light. Since capacitors store energy, they are also used to even the flow of current in a circuit. Capacitors can absorb sudden spikes in voltage and can release some energy to compensate for low voltage.

You can also use a capacitor for more basic purposes, such as to determine the relative resistance in a circuit. If you charge a capacitor and then discharge it through a resistor (see Figure 2), you can time how long it takes for the capacitor to discharge. If it takes a long time, then the resistance is high, and vice versa. This is what you'll be doing in this lab.

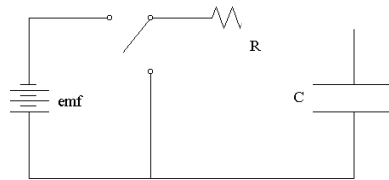


Figure 2: RC circuit

Flashlight Follower:

The goal of the lab is make the Boe-bot follow a flashlight. The light-level detection will be done using RC circuit where resistor will be a photoresistor. The resistance of a photoresistor varies with the amount of light it senses – more light indicates less resistance and vice versa. However, the pins of the Boe-Bot measure only voltage. How to combine the two to command the Boe-Bot to move towards light? By using a capacitor of course! Since the discharge time of a capacitor in a resistor-capacitor (RC) circuit depends on the resistance, it's easy to measure the relative resistance at any given time. First, you will command the Boe-Bot to charge the capacitor. Then, using a special inbuilt method *rcTime* from the CPU class, the Boe-Bot will discharge the capacitor through the resistor and output a time. If the resistance is high, then it will take longer to discharge, and vice versa. You can use this when writing your program to decide when to make the Boe-Bot move and when to make it stop.

Materials

- 4 ¼" spacers and screws
- Boe-Bot unit with Javelin Stamp
- 5 AA batteries
- Battery Booster
- Cardboard and tape (to act as divider)
- USB cable
- Javelin Stamp IDE
- Boe-Bot Parts Kit
 - 220Ω Resistors (2)
 - Photoresistors (2)
 - 0.01 μF capacitors (2)
 - Wires

Pre-Lab Questions

1. You have to raise the circuit board on your Boe-Bot to accommodate the flashlight under it. You should have received four long screws and four spacers in lab last week. Make sure you exercise caution through the rest of these steps as the circuit board is delicate.
 1. Remove the four screws holding the circuit board to the chassis.
 2. Lift off the circuit board from the Boe-Bot and place it nearby. It will still be connected to the servos. You don't have to remove the connection – just keep the circuit board close to the Boe-Bot.
 3. Place one spacer on top of the original mounting spacer. Place the circuit board on top and screw it in.
 4. Now place the diagonally opposite spacer and screw the circuit board into that.
 5. Complete the assembly for the other two screws.
 6. You should now have a raised circuit board on your Boe-Bot, which will help to house the flashlight.
2. Build the following circuits on your Boe-Bot.

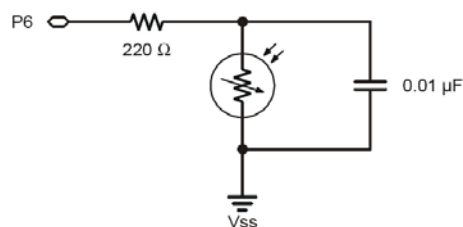


Figure 3: Photoresistor/Capacitor Circuit 1 (left)

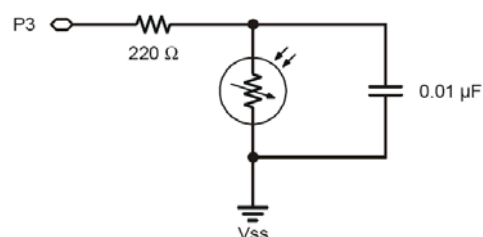


Figure 4: Photoresistor/Capacitor Circuit 2 (right)

3. Position your photoresistors so that they point a couple of inches ahead of the Boe-Bot, toward the ground. This way, they will be able to sense a light shone on the ground.

Lab Instructions

1. You should already have your circuits built on your Boe-Bot.
2. In order to program your Boe-Bot to sense various light levels, you have to know what the discharge time of the capacitor is in ambient light and in bright light.
3. To do this, you will connect your Boe-Bot to the computer and measure the discharge time in various light levels and various robot positions.
4. Write a test program that charges both capacitors and then discharges them using the *rcTime* method (see the Javelin Stamp CPU class documentation on the ESE112 website for syntax information). The program should then output the time value to the messages window.
5. Download and run this program. Make sure the Boe-Bot is still connected to your computer.
6. Record the discharge time and the light level (ambient, bright, low, etc.).
7. Repeat for various light levels and various robot positions (90°, 180°, etc.).
8. You should now have a list of discharge times and light levels.
9. Analyze these values and find an average discharge time for ambient light and for bright light.
10. Define a variable for ambient light time and bright light time in your program so you can use these values in your program.
11. Write a program that makes the Boe-Bot move towards light. When the light shines on the ground in front of the Boe-Bot, it should move towards it (forward, left, or right). You can exercise considerable leeway in the design of your program, with some restrictions:
 - a. You must include at least one method other than the main method
 - b. Use your Navigation class from the Whisker lab to make the Boe-Bot navigate
12. Now pair up with another group. Make one Boe-Bot the follower and one the leader. The leader Bot should have flashlight at its back end. The follower Bot should follow the leader along its path.
 - a. The leader should travel on a predetermined path of your choice. The follower should trace that same path.
 - b. Both groups should take turns as follower and as leader.

Extra Credit:

Collaborate with as many groups as possible and make a chain of Boe-Bot followers controlled by flashlights.

Post-Lab Questions

1. Describe your Flashlight program/algorithm using a flowchart.
2. Give a brief explanation of methods and or classes involved to accomplish the task.
3. What difficulties did you face when working with another group for leader-follower setup? How did you overcome them?
4. If we replace 0.01uF capacitor with 0.1uF, which circuit do you think fares better in bright light - the one with the larger or smaller capacitance? What is the effect as the surroundings get darker? Do you notice any symptoms that would indicate one or the other capacitance would work better in a darker environment?