CS281: Computer Systems

PreLab 06: Ohm's Law and DC Motor Control

The purpose of this prelab is to familiarize ourselves with various circuit equations concerning voltage, resistance and current. We will use this basic circuit knowledge to control the position of a servo motor.

Ohm's Law

Ohm's law, the most fundamental circuit law, gives us a basic understanding of electronic circuit design. Consider a circuit composed of a resistor that is wired to GROUND and +5 volts (see Figure 1).

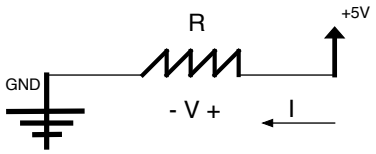

Figure 1: Basic Circuit

We say that we have a voltage of 5 volts applied across the resistor. This forces a current to flow from the positive terminal (+5 volts) to the negative terminal (+0 volts at ground). The resistor acts as an impediment for the current, preventing it from flowing easily. As an analogy, consider the instance of pushing water through a garden hose. You might envision the current as water. The voltage is the force pushing the water. The greater the force pushing the water, the greater the flow. The resistor is the hose through which the water must flow, and resistance is like the diameter of the hose. A high resistance (small diameter hose) restricts the water flow more while a small resistance (large diameter hose) allows more water to flow through.

This relationship is governed mathematically by Ohm's Law:

$$V = IR$$

where V is the voltage (in volts), I is the current (in amperes), and R is the resistance (in Ohms).

Voltage Divider

Now consider the circuit in Figure 2. This circuit features two resistors in *series* meaning that the current must flow through resistor 1 and then through resistor 2

in a serial fashion. Though the voltage drops 5 volts overall along the whole circuit path, some of the voltage drops across resistor R_1 and the other portion of voltage drops across resistor R_2; the values of the resistance determine the percentage of voltage drop across each one.

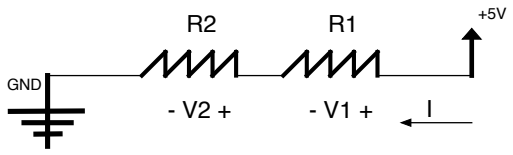

Figure 2: Voltage Divider

Resistors in series *add* to compute a total effective resistance.

$$R = R_{total} = R_1 + R_2$$

We then use this basic fact to compute voltage drop across resistors in series.

$$\begin{aligned} V = V_1 + V_2 = IR = I(R_1 + R_2) \\ I = \frac{V}{R} = \frac{5}{R_1 + R_2} \\ V_1 = IR_1 = R_1 \left(\frac{5}{R_1 + R_2} \right) = 5 \left(\frac{R_1}{R_1 + R_2} \right) \end{aligned}$$

This circuit is called a voltage divider because we divide the overall voltage (+5 Volts) into two parts: $V_1 = 5\frac{R_1}{R_1+R_2}$ and $V_2 = 5\frac{R_2}{R_1+R_2}$. By selecting the appropriate values for R_1 and R_2 we can "select" a desired voltage in the middle of the circuit that is something between 0 and +5 volts.

A potentiometer (POT) is a variable resistor that acts as a voltage divider. In a potentiometer, the total resistance is fixed (usually something like 1k Ohms or 10k Ohms), but the values for R_1 and R_2 can be selected by turning a knob. Your breadboard has a 1K POT and a 10K POT. We will use these to dial in various voltages between 0 and 5 volts.

Servo Motors

Servo motors come in two types: standard and full rotation. A standard servo motor turns through a limited arc, usually 180 degrees, while a full rotation servo is

capable of continuous rotation. We will use standard servos in our lab. Standard servos are used in light industry and hobby applications as positioning actuators – they turn to position a knob, dial, or other physical device. For example, a hobbyist's radio controlled airplane might have four servo motors: one to control the speed of the motor (throttle), one to control the tail rudder, one for the tail flaps (elevator), and one for the wing flaps (ailerons).

Figure 3: Servo Motor

A servo motor has three control wires. The red wire is power (+5v), the brown/black wire is ground, and the yellow wire is the control line. Servo motors are positioned using a technique called Pulse Width Modulation (PWM). A square wave is sent along the control line. This square wave must have a 20ms period. The length of the "high part" of the pulse determines the position. See Figure 4 for a wave-form diagram.

Pulse Width	Servo Position
1.0ms	-90 degrees
1.5ms	0 degrees
2.0ms	90 degrees

Questions

1. If you have two 10K Ohm resistors and one 1k Ohm resistor, what different voltages can you "build" using a voltage divider circuit with your breadboard +5volt power supply?

2. How can you extend the voltage divider circuit to include more than two resistors?

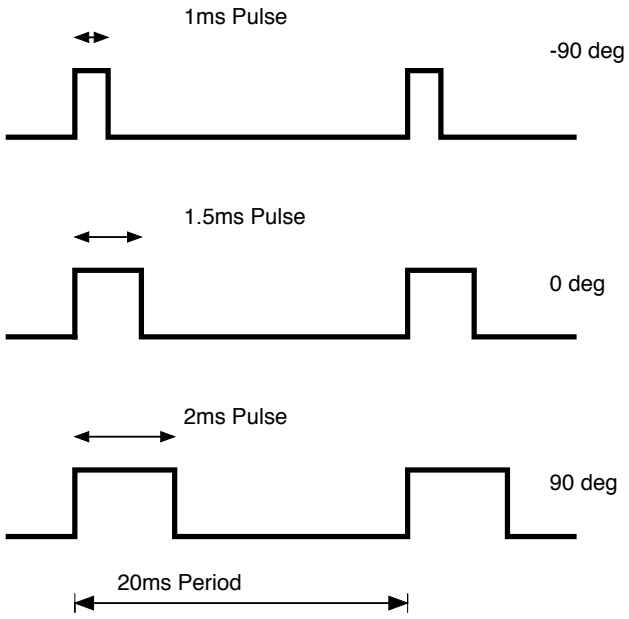

Figure 4: Servo Pulse Diagram

3. Now use the three resistors listed above in all possible combinations to compute new voltage divider values.

4. Load the `arduino.cc` webpage. Find the ”reference” section of the website. Within the reference page, there is a ”Libraries” section. Find the ”Servo” library. List the methods (functions) supported by this library; give a one-sentence description of how each one works.