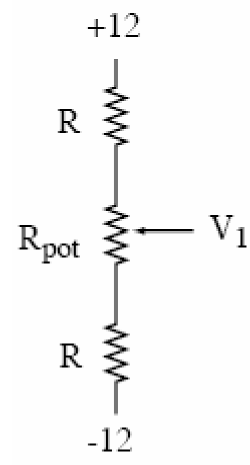
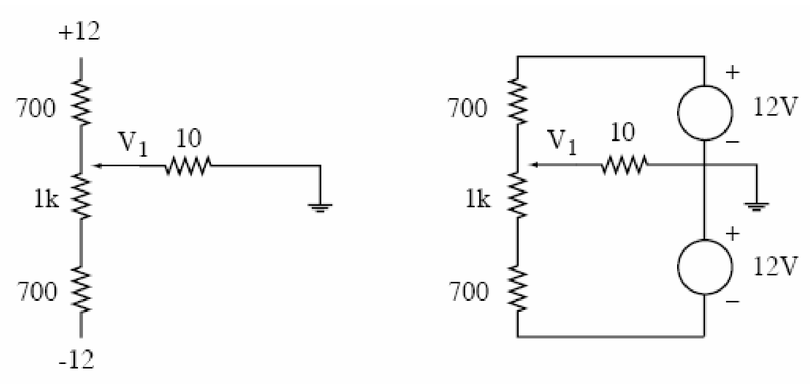
ME 333 Introduction to Mechatronics
Assignment 1



1. In the circuit at right, three resistors connect +12 volts to -12 volts, two of resistance R and one potentiometer (pot) of resistance $R_{pot.}$ The wiper of the pot can move from one end of the pot to the other. Give the resistance R, in terms of R_{pot}, if V_1 reads +5V when the wiper is at one end and -5V when it is at the other end. Also, calculate the power dissipated by the resistors.

For the remaining problems, we let R_{pot} = 1000 ohms and R = 700 ohms.

2. Now we add a 10 ohm resistor between the wiper and ground. This allows current to flow through the wiper, whereas in problem 1 the wiper was free-floating. This new circuit can be drawn in two equivalent ways, as shown below. (Convince yourself they are the same if you are uncertain. The second drawing may make the KVL loop equations clearer.) In both figures, the pot wiper is at the top. Give the voltage V1 when the wiper is at this position. What is V1 when the wiper is at the bottom of its range?



3. Think of the potentiometer as an adjustable control for a user (e.g., a volume button, or a speed control). Then the resistor network with the two resistors and the pot can be thought of as the "signal" or "control" network, and the 10 ohm resistor can be thought of as the load (e.g., a motor). The 10 ohm resistor "loads" the control network: it is no longer able to provide +/- 5V when the load is present. For this simple system, the "input impedance" of the load is just its resistance when looking "into" the load from the point where V_1 is measured, i.e., $\Delta V/\Delta I$, where ΔV is the change in voltage V_1 when the current through the load changes by ΔI. In this case, the input impedance is 10 ohms. The "output impedance" of the control network can be calculated similarly: the change in voltage at V_1 per change in current flowing through the wiper (where the load is unspecified). Ideally, the output impedance of the control circuit would be much lower than the input impedance of the load circuit. Otherwise we have the undesirable "loading" effect.

One way to lower the output impedance of the control network is to scale down the resistances R and R_{pot}. Explain why this would be a bad idea in terms of your answer to problem 1. Note that power is dissipated even when no power is being provided to the load.

4. We would like to isolate the control circuit from the load, so the behavior of the control circuit is not affected by the load. This is achieved by using a current amplifier between the control circuit and the load circuit. From the control network's point of view, an ideal current amplifier would make the amplifier plus load look like it has infinite input impedance. This means the control circuit does not have to source or sink any current from the load, so the load does not affect its behavior. From the load's point of view, an ideal current amplifier would make the control circuit plus amplifier look like it has zero output impedance. In other words, the amplifier is a buffer between the two circuits.

Here we'll build a simple push-pull amplifier out of two bipolar junction transistors (BJTs). Assume the two transistors in the circuit below have a gain of 100.

When the pot wiper is at its top-most position, what is the voltage V_1? What is the current into the base of the push-pull? What is V_{out}? What is the current through the load? What is the input impedance of the amplifier plus load? Is the amplifier an ideal amplifier? What would you change to make it closer to ideal?

When the wiper is at its bottom-most position, which way does current flow through the wiper? Left to right or right to left? Copy the figure below (but with the wiper at its bottom-most position) and label the current flow directions for all currents.