

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
 Department of Electrical Engineering and Computer Science
 6.01—Introduction to EECS I
 Spring Semester, 2008

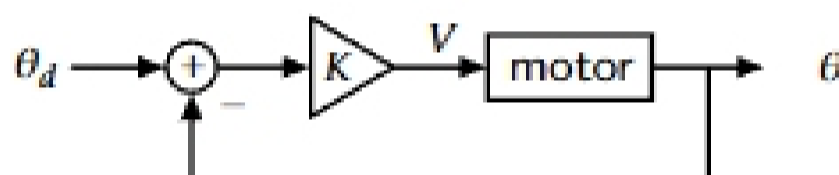
Assignment 8 Revised, Issued: Thursday, April 3

Revised Design Lab: Replaces only the design lab section of the original handout. There are post-lab homework problems in the original handout that you need to do.

Design Lab

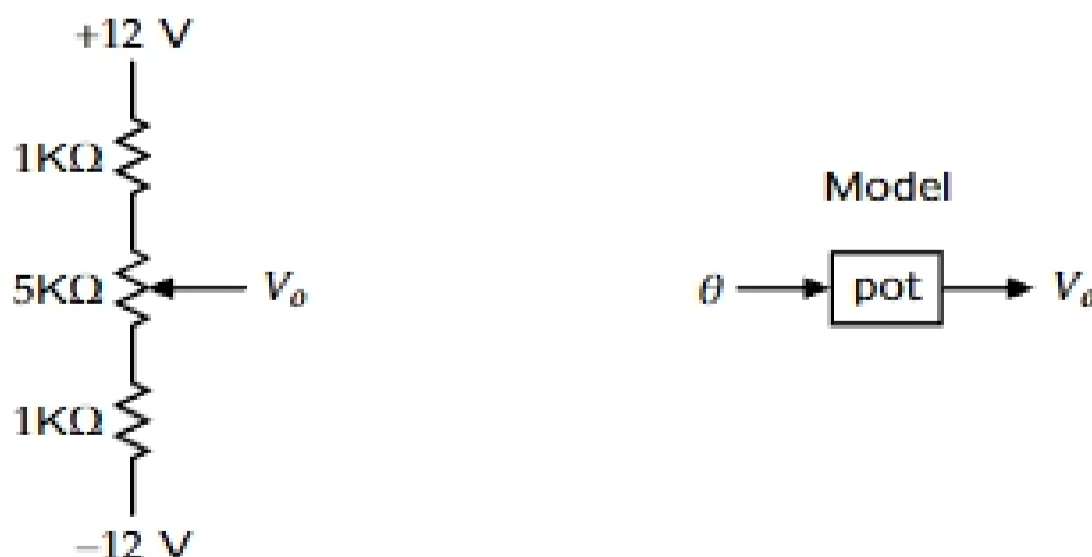
The goal of today's design lab is to build a circuit to control the position of a motor. In later labs, we will use this motor to turn the "head" of our robot.

At a high level, we can think of our motor controller as follows:



We wish to command a desired angle θ_d that is the input to a feedback loop that compares the desired angle to the measured angle θ . The difference is multiplied by a gain K to generate an output voltage V that will cause the motor to turn in a direction to make the measured and desired angles equal.

We cannot conveniently manipulate angles, so we will use potentiometers to convert the angle of their input shaft to a voltage. A potentiometer is a three terminal device. The resistance between the middle and bottom terminals increases in proportion to the angle of the input shaft (θ) and the resistance between the middle and top terminals decreases, so that the sum of the top and bottom resistors is constant (here it is $5\text{K}\Omega$). By connecting a potentiometer as shown below we can create a device that converts θ into a voltage V_o (measured relative to GND).



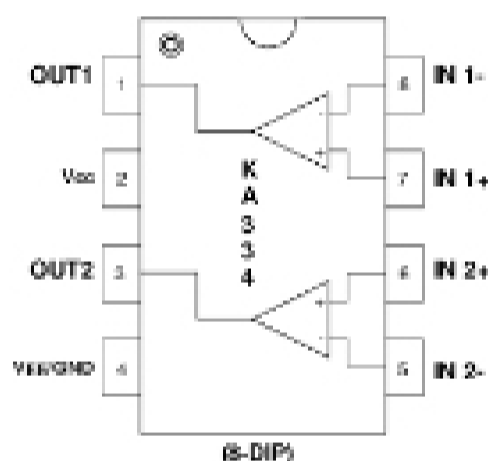
Question 11: Construct the circuit shown above (be sure to adjust the power supplies to $\pm 12\text{V}$ before connecting the circuit.) Mathematically determine the range of V_0 that the device can generate. Measure the range (relative to GND) and compare the measured and calculated ranges.

Question 12: Use the potentiometer from the previous question to drive the voltage input to the motor. Use a Lego motor with adaptor cable and breadboard adapter (6 pins). The motor is connected between pins 5 and 6 of the adaptor. Connect pin 5 to the output of the potentiometer and connect pin 6 to GND. How fast can you get the motor to turn? Explain.

Question 13: Use an op amp to buffer the output of the potentiometer (this is similar to what we did last week when we used an op amp as a buffer between two voltage dividers). Use one of the two op amps in the KA-334 package (see schematic below). Let $V_{cc} = +12\text{ V}$ (pin 2) and $V_{ss} = -12\text{ V}$ (pin 4). Compare the behavior of the motor now to its behavior in the previous circuit. Can you make it go in both directions?

Checkpoint: 30 minutes

- Show the potentiometer controlling your motor. Be sure it can go in both directions.



When we use the motor to position the robot “head,” we will only have access to a $+12\text{ V}$ supply (the robot does not have a -12 V supply). One way to get bidirectional turning from a single $+12\text{ V}$ supply is by generating a “virtual ground” that is midway between 0 V and $+12\text{ V}$.

Question 14: Reconnect power to the op amp so that it uses a single $+12\text{ V}$ supply, i.e., connect $V_{cc} = +12\text{ V}$ (pin 2) and $V_{ss} = \text{GND}$ (pin 4). Use a second op amp to generate a “virtual ground” signal. Modify your previous op amp circuit so that it uses the virtual ground to allow the motor to turn in both directions.

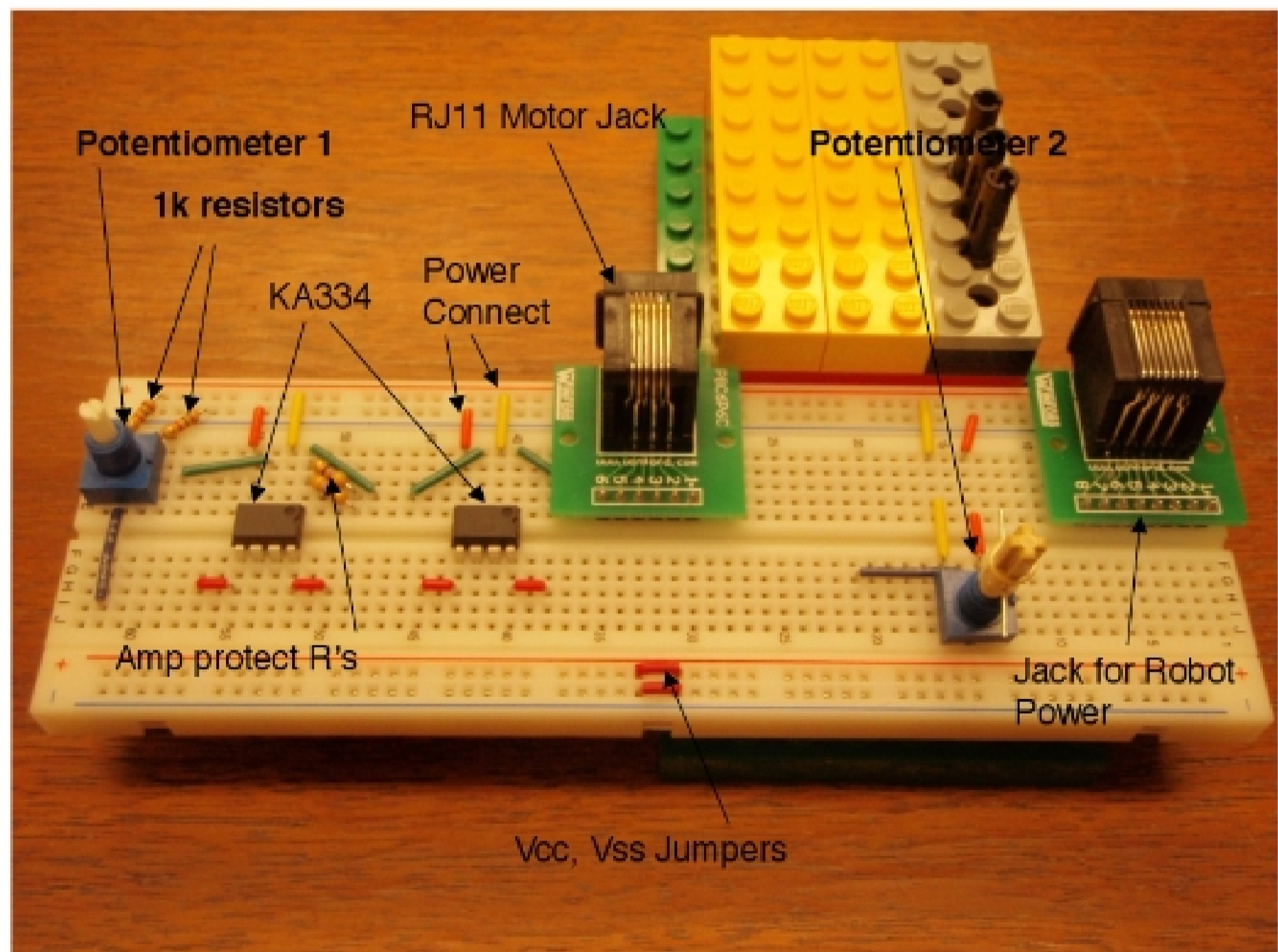
Be careful about the following:

- Your ‘virtual ground’ should be halfway between the power supply rails. (So that the power supply rails become ± 6 with respect to the virtual ground.)
- Henceforth, think of this as ground, think of what was formerly $+12$ as $+6$ (it is 6 volts higher than ground), and think of what was formerly 0 as -6 (it is 6 volts lower than ground). Remember that what matters is the relative voltages.

Checkpoint: 60 minutes

- Show the potentiometer controlling your motor, with a +6 and -6 supply. Be sure it can go in both directions.

For the remainder of today's lab, you will need a "head assembly," which you can obtain from the staff. These head assemblies have circuitry that is pre-built on the "bottom board." The "top board," which is mounted so that it can be swiveled by a Lego gear motor, has no circuitry on it right now. Examine and familiarize yourself with the circuitry on the bottom board (shown below). You will note that there are two KA334 op-amps, wired for power but not for input or output.



The photograph of the bottom board (above) shows the following:

1. Potentiometer 1: This 'pot' is connected between the power supply and ground rails by two 1k resistors. The potentiometer has a total resistance of 5k Ω , just like the example you started this lab with.
2. Potentiometer 2: When you get the head assembly, this potentiometer will be connected to the bottom of the Lego motor. It is connected to the power and ground rails directly (not through resistors).