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

**Design Lab 9, Issued: Tuesday, April 8**

**All questions in this lab must be written up and handed in as part of problem set 9.**

# Homework due In Design Lab

**Question** 9: Design and draw the circuit diagram for an op amp circuit to compute $v_1 - v_2$, where $v_1$ and $v_2$ are the voltages coming out of the two potentiometers (refer to revised design lab 8 handout for details).

# Design Lab

## Finish your position controller

See revised design lab 8 for a detailed explanation.

**Question** 10: Construct your circuit for computing $v_1 - v_2$. Turn the potentiometers and measure the change in output voltage that is produced. Can you set the potentiometers so that the output is +6? So that it is -6?

**Question** 11: Connect up the motor so that the feedback system drives the motor angle $\theta$ to equal $\theta_d$. Does the motor turn to a stable position when you turn on power? Change the angle of potentiometer 1 ($\theta_d$). Does the motor position change accordingly?

**Checkpoint: 60 minutes**

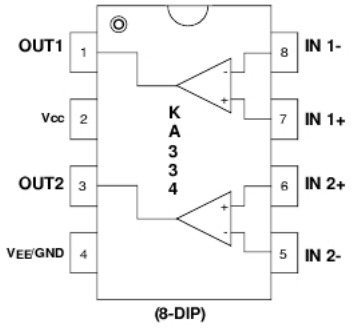
- Show the potentiometer controlling your motor. The head should move smoothly and have a symmetric range of motion to the left and right.

  Explain how this system is different from the way you were controlling a motor with a pot in the previous checkpoints.

## The Eyes Have It

Our goal for the rest of this week's lab is to design and build a system that causes the robot's head to 'look' in the direction of a strong light. We will do this by mounting two photo-resistors on the top ("face") board of the robot head, and then designing a circuit that will cause the head to rotate so that the two photo-resistors are 'seeing', or are exposed to, the same light level. It will also be necessary to add some mechanism that puts one of them in a shadow when the board is not pointed directly at the light source.

Here is the pin-out diagram for the KA-334 package again:




**Question** 12: Design a circuit for controlling the robot head based on the photo-resistors. There are many very complex ways to approach this, but there is also a simple solution, just involving your virtual ground and an amplifier. It should satisfy the constraint that you use only three wires going to between the "face" (where you add only the photo-resistors) and the board below. Draw the circuit.

**Question** 13: Arrange for there to be a shadow on a photo-resistor so that the board can be made to rotate toward the light. Ask an LA for ideas about how to do this.

**Question** 14: Now, build up the photo-sensing circuit, and connect it to the motor. It should rotate the head toward the side of the photo-resistor measuring the highest light level. Demonstrate that the head does indeed turn toward a bright light. You might need to experiment with the "nose" (device for shadowing the photo-sensors) or the placement of the photo-resistors to get it to work well.

**Checkpoint: 120 minutes**

- Show your robot head turning toward the light.

## Gainfully Employed

Now, we're interested in understanding what happens when we change the gain in this control system. We have some new potentiometers, which look just like our old potentiometers, except that they have a red mark on them, and behave like our old potentiometers, except they have a maximum resistance of 50KΩ instead of 5KΩ.

**Question** 15: Find a way to put one of these new potentiometers into your control circuit (without adding any additional op-amps), and add or change an existing resistor so that by turning the potentiometer, you can generate gains that span, at least, the range 0.2 to 10. Draw the schematic. Determine what resistance in the pot will generate an overall system gain of 0.5. Determine what resistance in the pot will generate an overall system gain of 10.

**Question** 16: Build the circuit. Test and describe its behavior for a gain of 0.5 and of 10.

**Question** 17: At what gain does the motor stop responding? Intuitively, why does that happen? At what gain does the system become unstable? Intuitively, why does that happen? (You may need to go outside the range of gains suggested above in order to push the system to these limits; if you have to do more than turn the potentiometer to do so, please describe what changes you made to your circuit).

**Checkpoint: End of lab**

- Show your robot head behaving in three noticeably different ways, with three different gains.

## Post-lab Homework

**Question** 18: Show what resistors you would have to add or change in your answer to question 9 in order to compute $K(v_1 - v_2)$ for $K = 2$. How about for $K = 10$?

**Question** 19: There are two errors that would have been easy to make in your design for question 9. The first would have been to turn the head to the left when you turn the control pot to the right (and vice versa). What error in your circuit would have caused that to happen? (Draw a circuit diagram showing a small change to your circuit that would have made it exhibit this problem).

**Question** 20: The other error is to generate positive feedback, instead of negative feedback; that is, to send a larger correction to the motor when the error gets smaller. What error in your circuit would have caused that to happen? (Draw a circuit diagram showing a small change to your circuit that would have made it exhibit this problem).

## Concepts covered in this lab

- Design of simple buffers and differential amplifiers
- Closed loop sensory-motor control of a system.