

A Real Head-Turner

Goals:

Design Lab 9 focuses on building and testing the circuit for controlling the robot head designed in [Homework 3](#). You will:

- Demonstrate an analog feedback system to turn the robot head towards light.
- Improve the tracking speed and precision by tuning your circuit.

Resources: This lab should be done with a partner. Each partnership will need a lab **laptop** as well as the following:



Robot



Lamp



Two clip leads



Multimeter



Robot head



Proto board



Two eight-pin connectors



Red cable



Op-amp package



Resistors, as needed



Wirekit

Do `athrun 6.01 getFiles`. The relevant file (in `~/Desktop/6.01/designLab09`) is

- `turnToLightAnalogBrain.py`: Brain that will plot the value of the neck pot versus time.

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Some of the software and design labs contain the command `athrun 6.01 getFiles`. Please disregard this instruction; the same files are available on the 6.01 OCW Scholar site as a .zip file, labeled Code for [Design or Software Lab number].

If you and your partner already completed your design from Homework 3, discuss your circuit designs and simulations with your partner. Pick which circuit you are going to build. Check your circuit design with a staff member.

If you did not complete the design, then finish the design now and then start this lab. We'll re-partner you with someone in a similar situation if we can.

1 Pointing Circuit

As part of **Homework 3**, you designed and analyzed a circuit to build a “head” that will allow the robot to sense and track light. Today, you and your partner will construct, debug, and demonstrate the head.

- Step 1.** Build your circuit on a proto board. Start with a gain that is appropriate for the values of k_s that you measured in **Software Lab 9**, but be sure your circuit can be simply modified to obtain higher or lower gains.

Make your circuit match your CMax layout EXACTLY.

Notice that the wire colors in CMax correspond to the wire colors in the wire kits.

If your circuit matches CMax exactly, it will work, since your simulation already worked!

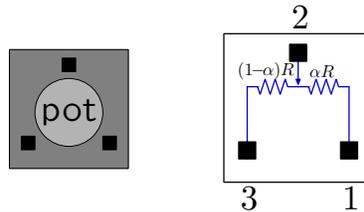
- Connect the robot connector to the yellow cable coming from the robot. Connect the head connector to the front connector (near the eyes) of the head using a red cable. For complete information about the pin-outs of these connectors, see the “Circuit Parts Specifications” page on the 6.01 web site (under the “Reference Material” tab).
- **Make sure that there is no black wire connecting to the motor on the head assembly.** This is a safety precaution for the equipment, in case your circuit is incorrect, and accidentally causes the head to turn out of control.
- Turn on the robot to provide power to your circuit.

Check Yourself 1. Verify that your circuit works by measuring the voltages across the motor, being sure that they behave appropriately as you change the light levels on the eyes. Demonstrate the correct behavior to a staff member, who will give you a black cable with which to connect the motor. *(Remember that a positive voltage drop across the motor will turn the head to the left)*

- Step 2.** Turn off the robot power (which will also turn off power to your circuit), and plug in the black cable. Make sure there is a light in front of the robot to which it can turn, and then turn on the robot power **just long enough to see how your system behaves**, and then turn it back off. If the circuit was wired correctly, the head should turn toward the light. However, if the circuit is wired incorrectly, the head will likely slam against a stop, and the op amp will overheat.¹ If the latter happens, then remove the black wire and retest the the head, as in the previous Check Yourself.

¹ Even if your circuit works correctly, the op-amp may get very hot, so (tempting as it may be), try to avoid touching it.

- Step 3.** Connect the middle pin (pin 2) of the neck potentiometer on the head connector to the first analog input on the robot connector, so that so that the voltage on that analog input is proportional to the pot's α value. The α value is zero when the pot is turned all the way clockwise. The diagram below shows the resistances between the pins of the potentiometer, for reference. Make sure that you connect pins 1 and 3 on the head connector to power and ground respectively.



- Step 4.** Use the brain `turnToLightAnalogBrain.py` to plot the neck potentiometer voltage as a function of time, and report the settle time of the signal. Follow these steps:
1. Unplug the motor (black cable).
 2. Turn the head 45 degrees from the light (in either direction).
 3. Start the brain and **wait a second or two**.
 4. Plug in the motor.
 5. Stop the brain a second or two after the head has stopped moving, or if it is clear that it will not stop moving.

You should see a graph appear, and an estimated settle time will be printed on the soar window. Verify the printed settle time by examining your graph closely. (Sometimes our settle-time estimator is confused if there are minor variations at the end of your graph). The settle time is the number of steps it takes for the head to converge on its final direction (ignoring the initial period in which it is constant, before the cable is plugged in).

- Step 5.** Pick a good gain for your circuit so that you get as fast a response as possible (it shouldn't have significant oscillations, but a little overshoot is fine) over a range of distances from the light. Gather data with at least two different gains in your circuit and at least two distances. Save the graphs and settle times for each.

Checkoff 1.

Wk.9.2.1: Illustrate your circuit and its performance at two different distances with the two gains you investigated. How does the settle time vary with gain and with distance? **Keep your plots and measurements to discuss in your interview.**

2 Analog Bull's Eye

Characterize the speed and precision with which the head tracks light.

- Step 6.** Turn off the power to the robot. Plug the laser connector (small black wire with round connector near the yellow cable coming out of the robot) into the laser on your robot head.

Now turn on the power to the robot, and measure head tracking as you did in Step 4 but using a standing lamp (with a shade). The laser light should strike the shade, ideally in its center!

- Step 7.** Tune your circuit to make the head tracking as accurate as possible. Recall from [Design Lab 7](#) that the photodetectors may not be matched perfectly. Consider how you could improve pointing accuracy arising from mismatched photodetectors. Feel free to discuss your approach with the staff.

Checkoff 2.

Wk.9.2.2: Demonstrate the pointing accuracy of your head. Discuss what you did to your circuit to improve its accuracy. Describe the fundamental limitations to its accuracy.

Remove the 8-pin connectors from your circuit board and put them back where you got them. Label your board with both partners' names on a piece of tape and hand it to a TA for storage; you will need your board next week. You will continue to work with your same partner next week.

Make sure you turn off the power on your multi-meter and your robot.

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