LABORATORY 6

PHYSICS 117 (Winter 2017)
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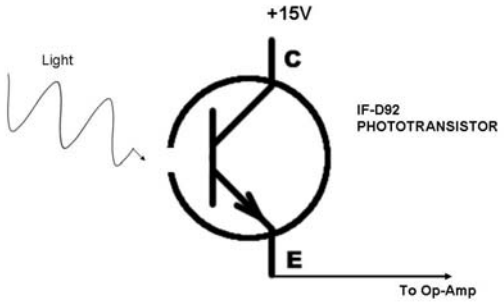
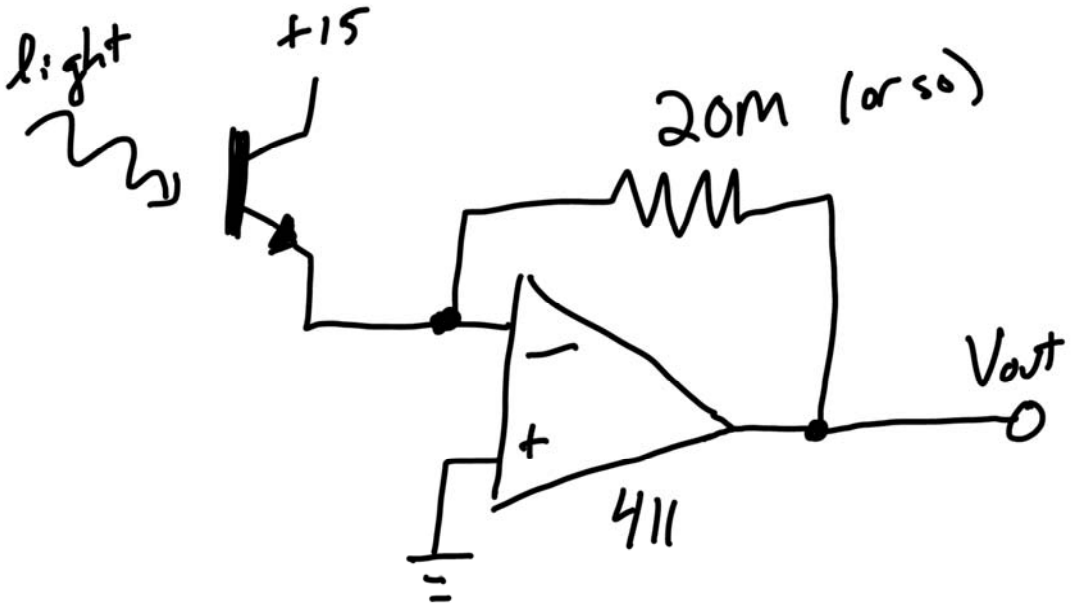
Reading: Sherz & Monk: sections 8.1-8.5

a) Phototransistor:
The IF-92 phototransistor (Emitter is pin 1, with the white dot) turns the small electric current induced by light at the base into a current form C to E as shown:

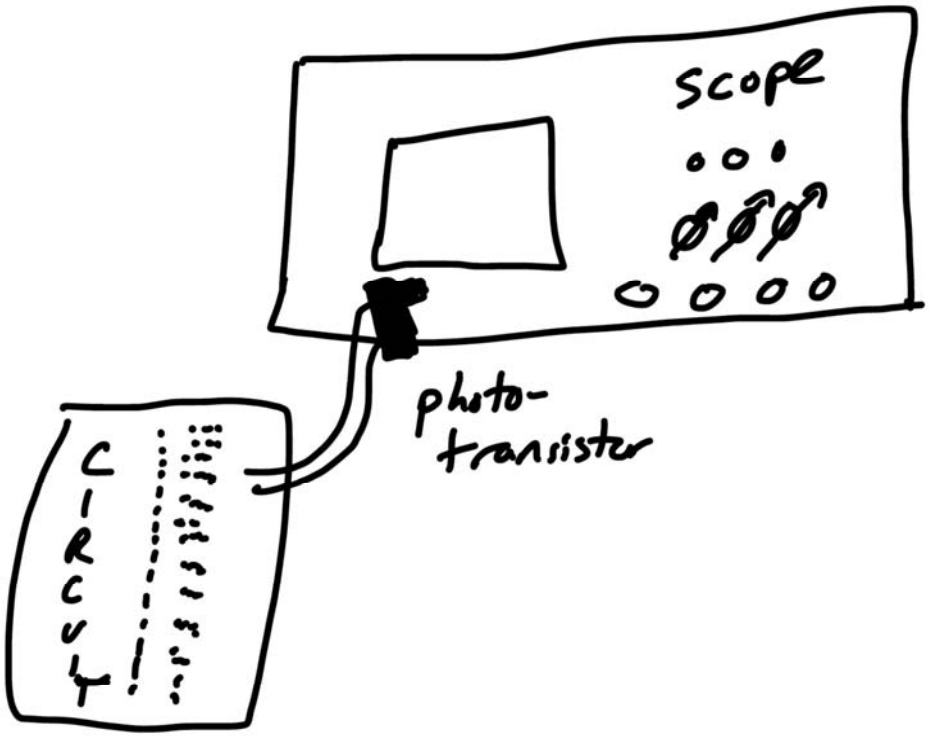


The current produced is very small but we can detect it with the op-amp circuit below:



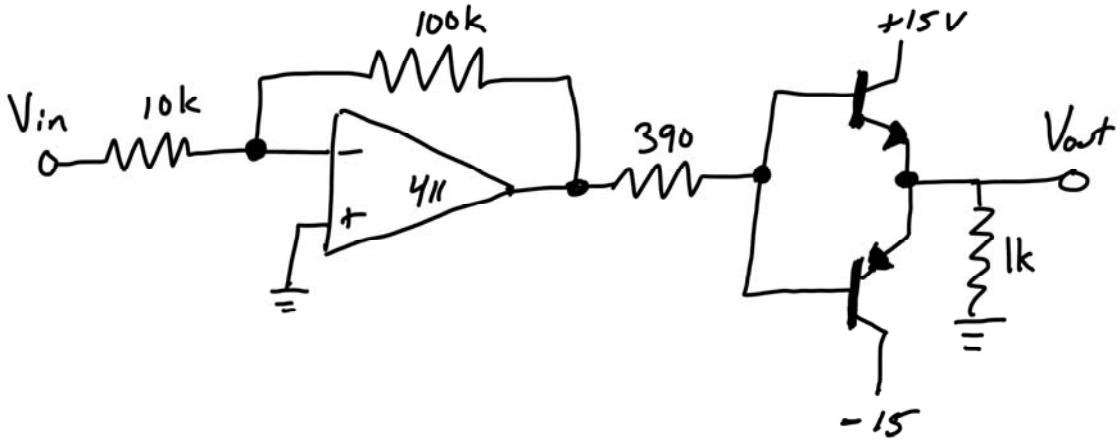
Measure the output voltage and use that to infer the current driven by the phototransistor at E. Assuming β=200, what is the current induced by the light at the base? (This is called the "photocurrent".)

b) Feedback loop
You can make the oscilloscope itself part of the feedback loop. Put the scope at around 250 msec/div and aim your phototransistor at the screen. HINT: For this lab use "auto" trigger mode on your scope since there is nothing to easily provide a trigger. You may need to turn out the lights and experiment with which color channel works the best. You should see the display becomes part of the circuit.



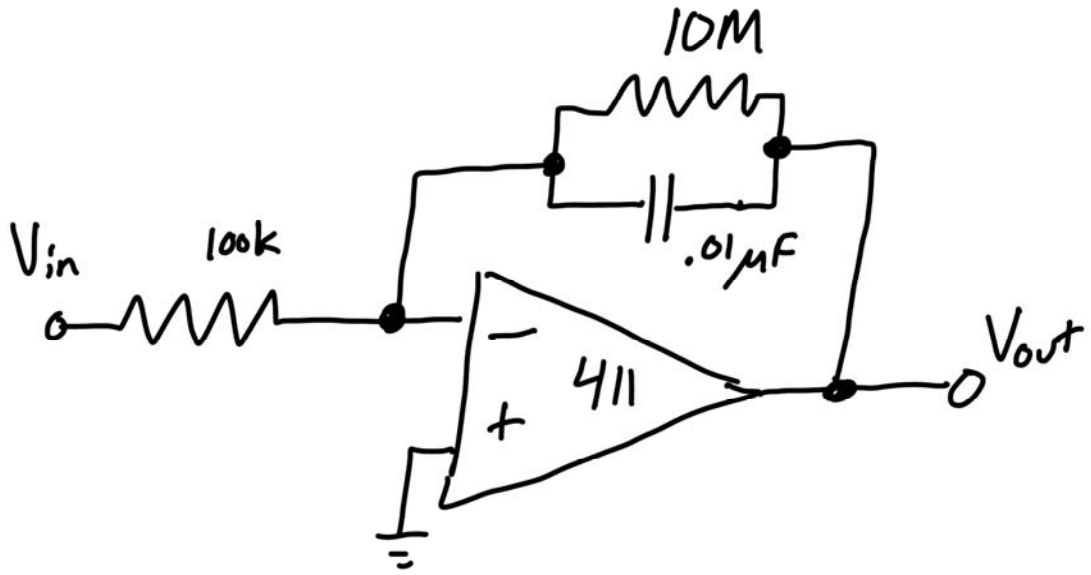
c) Op-amp plus push-pull

Connect an op-amp amplifier to a push-pull "buffer" as shown below. Why might you want a circuit like this? Drive it with a sine wave of a few kHz and amplitude a few volts and notice you still see the crossover distortion.



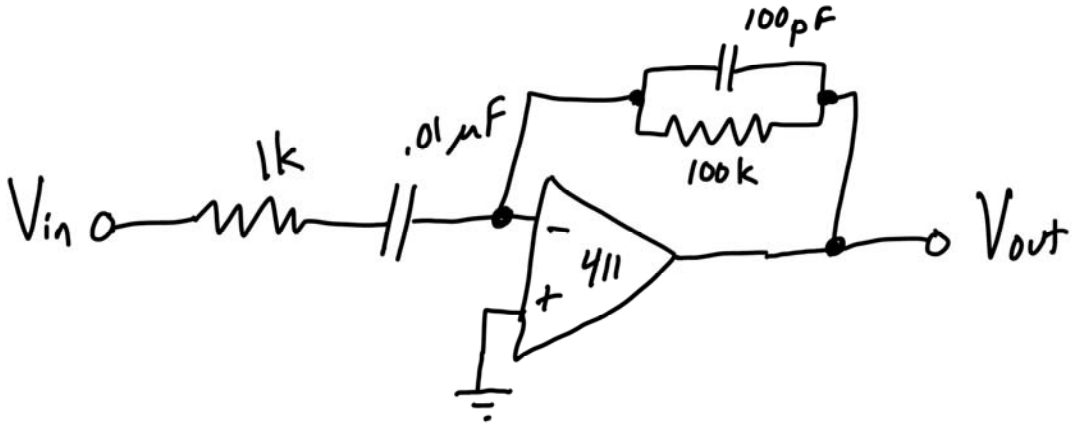
Now connect the feedback resisitor to the output of the push-pull instead of the output of the op-amp. Why does it get better? HINT: You can look at the output of the op-amp directly while you are doing this. Pretty clever! If you drive it fast enough, you should see it start to fail. Why?

d) Integrator. Build the circuit below:



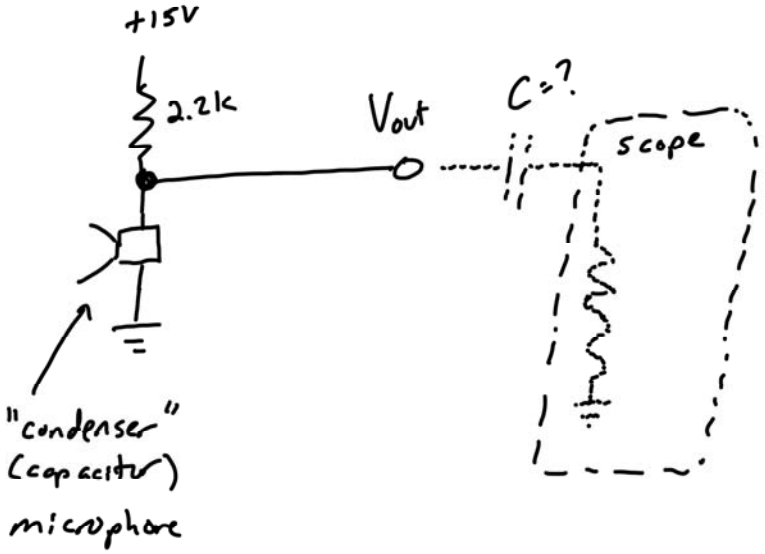
Drive it with a 1kHz square wave and then a triangle wave and predict the output shape and amplitude. What is the function of the 10M resistor? Try removing it.

e) Differentiator: Build the circuit below:



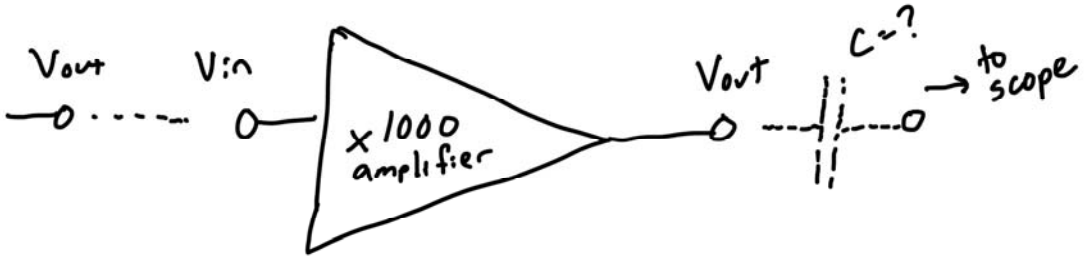
Try driving it with various shape waveforms and show it is a differentiator. Show that you can calculate the output shape and level of a sawtooth wave.

f) Audio Detector: You will build an audio amplifier to see your own speech. First note you can connect the microphone using the following circuit:



As the capacitor plates move, the voltage drop for the charge on the plates changes slightly. There is a large DC offset, so attach a high pass filter with f_{3dB} at about 100 Hz. If the resistor of your filter is your scope, what capacitor do you need? Why did we choose about 100 Hz?

You should see the signal (it helps to whistle and cup your hands around the mic) but it is low voltage and very noisy. Now pass your signal (after the capacitor, so you are not passing DC) through a x1000 amplifier you can build with your op-amp:



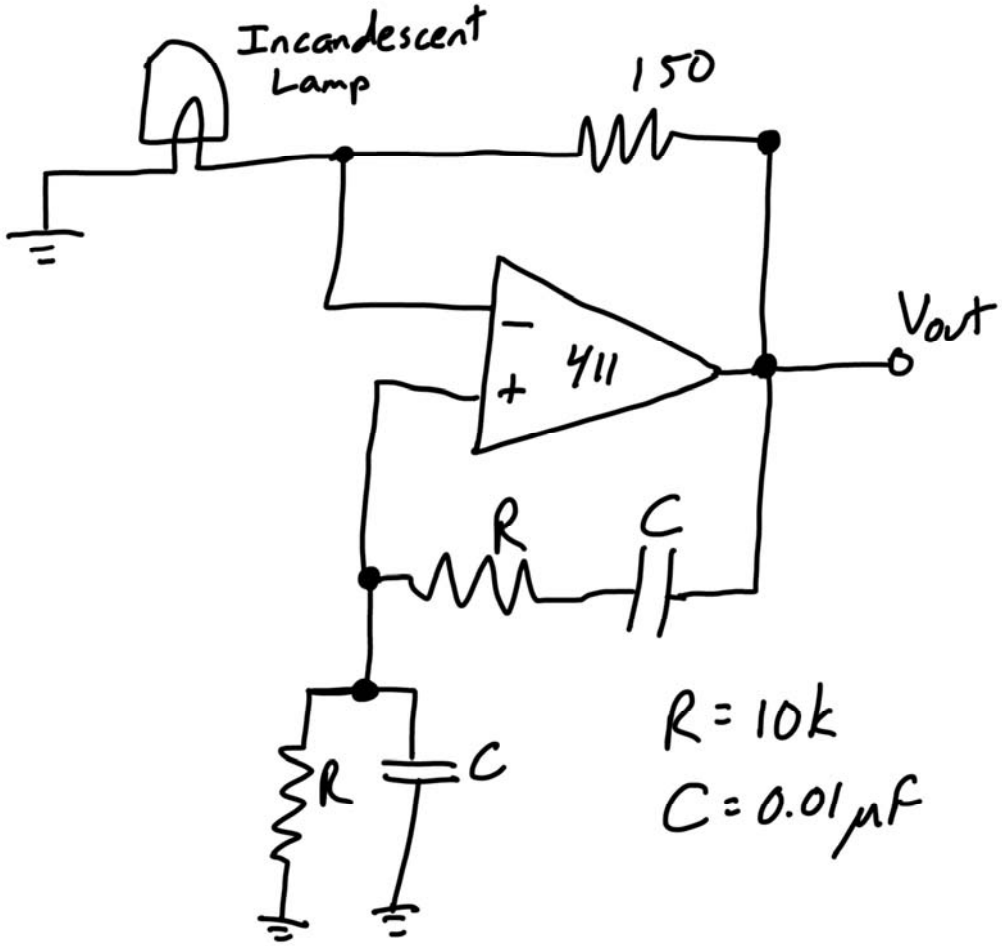
The output may have some DC on it, you can filter the op-amp output again as you did before. You should see a nice clear signal as you whistle and speak. Can you see your whistle on the fourier transform?

Now set the scale on the oscilloscope to 1.0 sec per division and talk into the microphone. You should see the visual voice recordings that FBI agents use in the movies. (Hint: this is a rare case where you need to "auto" trigger so the scope displays in real time, rather than waiting 10 seconds. This is known as "scan" mode, and is like an old-fashioned chart-recorder.)

OPTIONAL: I found that when I added the op-amp, it put a significant large DC signal on its input and output. Do you know why? (HINT: I don't know.)

g) Other feedback:
Build the now-familiar inverting amplifier with an op-amp. But replace the feedback resistor with a diode with a cathode connected to the output. Drive the circuit with a sawtooth wave that is offset so it is always positive. (You could have oriented the diode the other way as long as this signal was always negative.) Assuming a simple model for the I-V curve of your diode, does the shape of the output make sense? . Explain what function you see using the basic op-amp rules. HINTS: You should use two channels of the scope: one to look at the signal from the function generator and the other to be the output. Since the output of the circuit is "inverted", under the channel menu set your scope to "invert" so you may more readily recognize the function. Mathematically speaking, why did you need to make your signal always positive?

h) Positive feedback
Make the circuit below, which is William Hewlett's (of Hewlett-Packard fame) master's thesis from 1939:



You should see a sine wave at the frequency you can calculate. (If the negative feedback is not working, you will see a square wave that hits the rails.) This is an example of positive feedback put to good use. The lamp is providing negative feedback. (Hint take a

look at page 216 in the Hayes & Horowitz old lab book or section 5.17 of the Horowitz and Hill hardcover). If you see noise, remember what we said to try with large capacitors on the power supplies. Now replace the lamp with an equivalent resistor---does it still work? What key property of the lamp is different than the resistor? HINT: I could only get this to work with the small-bulb lamp (P/N 7219) but you can try the larger bulb with a different feedback resisitor.