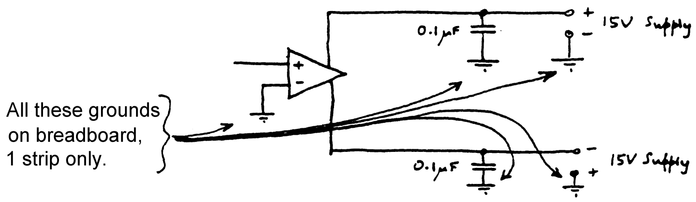
Physics 334
Notes for Lab 6 – Introduction to OpAmps

February 16, 2009

Lab manual sections **8-1, 8-2, 8-3, 8-4, 8-5, 8-6 a), 8-7; 8-8 is highly optional.**.

Advice:

- Use x10 probes for *all* 'scope measurements.
- *Minimize* the number of wires and connections. Think about how to lay out circuits so that you need very few, preferably no small jumpers.
- Unless you can't, bring power supply leads directly to the circuit, that is, avoid using the bus strips along side the breadboard.
- Wire up all circuits completely and double check your wiring before applying power or any stimulus signal from the function generator.
- Line up the opamp carefully with the holes on the breadboard. Gently straighten any legs that don't line up prefectly with a pair of needle-nose pliers before inserting. Be sure the IC straddles the breadboard "trench" then gently press the opamp straight down into the breadboard, making sure the legs slide straight into the breadboard.
- When removing an opamp or other IC, slide a pair of angled forceps under the IC and gently pry up in the center of the chip to remove.
- Bypass the power supplies on the breadboard with capacitors, as shown below. This keeps AC signal currents from developing significant Ohm's-law voltages across the small but non-zero resistances of the wires. Such voltages can cause oscillations or errors.



- Color code supply wires consistently: Red for +, black for − and green or white for ground.

- Remove all extra wires and connections when not in use.

If you keep your circuits both clean and reasonably tight, you will get better results. Analog circuits, especially high-gain ones are sensitive to spurious capacitance and noise.

8-1. In this exercise, note we we are intentionally violating a cardinal rule of most op amp circuits: There is no negative feedback. We are doing this to examine the opamp's open loop characteristics. This is not, however, a way that you'll normally wire an opamp. Always look for negative feedback in a "normal" opamp circuit.

If you try to measure the open loop gain directly by measuring a ΔV at the input and comparing it with the ΔV at the output (about 28 volts), you may find that you can't make a fine enough adjustment on the pot. Try replacing the 10k pot with two 4.7k resistors on either side of a 1 or 2k pot, if you like.

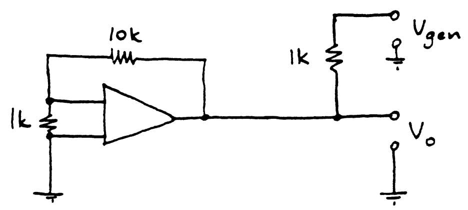
Be careful of a common pitfall: having the pot slider all the way to one side may put ± 15V in the input. This may forward bias the input FET and cause the output to swing to the opposite "rail" (supply voltage). Avoid this by setting the slider in the middle *first*, and then hunting for the critical spot near the middle.

Don't work too hard on this exercise. The main point is to see that the op-amp gain is really big. If the op-amp gain is 200,000, what voltage change on the input would produce a 28 volt change at the output?

8-2. "Linearity" means "how well matched are the input and output waveforms in terms of their shape".

If your circuit output goes "to the rail" (plus or minus 15 volts), be sure to check that: 1 - You have + and - supply power wired. 2 - You have a ground connection wired. 3 - You have negative feedback and have not confused the inverting and non-inverting terminals.

Ignore the last paragraphs ("Measure the output impedance ..."). The output impedance is so low that attempts to measure it by putting a low-value resistor across the output are doomed. A better way is to connect the input to ground (right at the chip; put the 1k across pins 2 and 3), and then inject a sine-wave into the *output* through a resistor R. Measure with a scope the small sine-wave voltage V_{o} between the output and ground. The arrangement makes a voltage divider out of R and Z_{out}, so $V_{\text{o}}/V_{\text{gen}} = Z_{\text{out}}/(R + Z_{\text{out}})$, and since Z_{out} is small, $Z_{\text{out}} \approx R(V_{\text{o}}/V_{\text{gen}})$.



8-3. The warnings in this section relate to the presence of the 'scope impedance. You can get around this problem by measuring the waveforms at the *output* of the op-amp. Measure the *output* amplitude before and after putting a 1M resistor in series with the input. The idea here is that you're seeing how much the opamp circuit loads a signal with a much higher output impedance, that you obtain by adding the 1M resistor. Again, the best you may be able to do is get an upper bound for Z_{in}. Same trick of looking at the output holds for finding C_{in}.

8-4. *Don't* measure Z_{in} and Z_{out} (you already know the answer). *Do* see what happens at high frequency. Apply a sine wave of about 2 volts peak-to-peak and vary the frequency from 100Hz to the highest you can get out of the generator. Comment on your observations.

8-5. Build and study only the first current source (Fig. L8.8). Measure the current and compliance (maximum output voltage across the 10k "load") of the current source and compare it with what you expect these specifications to be from the circuit design (i.e., theoretically).

8-6. **Do part a) only.** Use an FPT-100. It looks like a transistor (3 leads) but has a clear window on the top. You may be beset with HF oscillations ("fuzz" on the scope display); try the remedy suggested by the manual, and put some bypass caps, close to the op-amp, between the supply pins and ground. You will likely see a large 60Hz signal—this comes from the fluorescent lights. Check this by holding your hand over the diode: the signal should drop. Ignore the question about "percentage modulation" in both (a) and (b), but do measure the average DC level, and calculate the photocurrent.

8-7. Do as instructed. Use a small (a few volts or so) signal of your choice from the function generator for the signal in.

8-8. Optional : Do this exercise as the manual says, but make the following changes: (1) add the speaker in *series* with the 1k resistor at the output, *not in parallel*; (2) ignore the warnings about maximum safe amplitude, but make the output be about 2 volts peak-to-peak. Compare the waveforms seen at the op-amp's output to the push-pull's output for both types of feedback connections.

This push pull circuit is of course the same circuit you saw last week. See how nice opamps are for getting rid of some undesirable little circuit quirks like diode drops? More next week!

Warning: Be careful about wiring the push-pull stage: the emitters are wired together. Don't make the common error of wiring the 3904's emitter to the 3906's collector.