

Lab 5: Op Amps

Objectives:

- become familiar with the properties of op amps (with and without negative feedback)
- use the Golden Rules to understand the behavior of op amps in circuits
- observe and analyze several different types of op-amp circuits

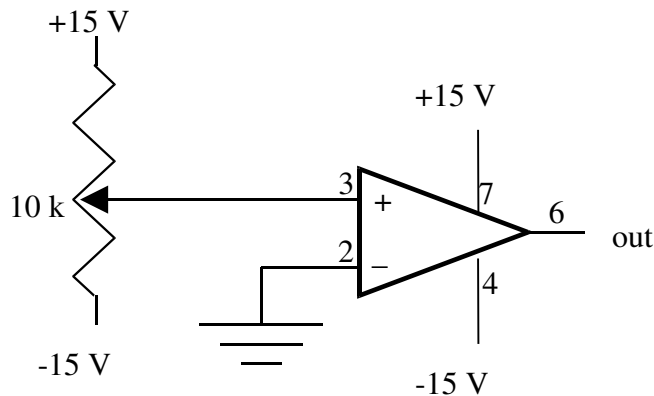
General notes:

- The DIP (dual in-line package) chip should straddle the trench in the breadboard (that's what the trench is there for!)
- We don't always show power to the chip on the circuit diagram, but it always needs to be there (usually ± 15 V). Check your breadboard supplies and adjust them to be fairly close to ± 15 V.
- If you see "fuzz" on your output voltages, try putting a small capacitor (few tenths of a μ F) between each of the power supplies and ground (to act as a short for very high frequencies; this will tend to eliminate the oscillations that cause the "fuzz").

5-1 Open-loop gain

Set up an LF411 in the circuit shown below. Note that there is no feedback. Do the Golden Rules apply here? Why or why not?

Watch the input and the output voltage as you slowly twiddle the potentiometer to change the input voltage. What does the output voltage do? Why? Hint: the LF411 open-loop gain specification is 200 V/mV. To get 15 V or less out, what would the difference in voltage between the two inputs have to be? (And what are the chances you can adjust the pot this precisely?)

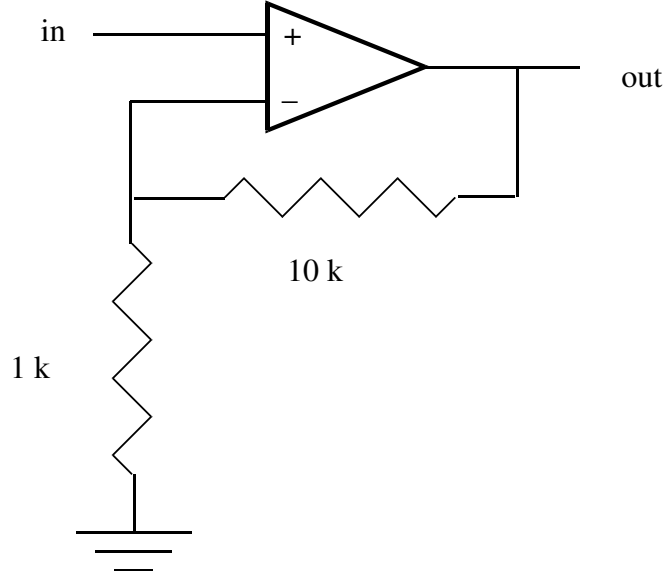


5-2 Non-inverting amplifier

Build the circuit below. Note that we use a voltage divider to make the op amp output voltage larger than the input voltage. Look at the voltage at the inverting input; what is it? Is it what you expect, and why?

Predict the voltage gain using the Golden Rules. Now measure the voltage gain for a 1 kHz sine wave. Is there agreement? Sketch or describe (frequency, amplitude, phase) V_{in} and V_{out} at 1 kHz.

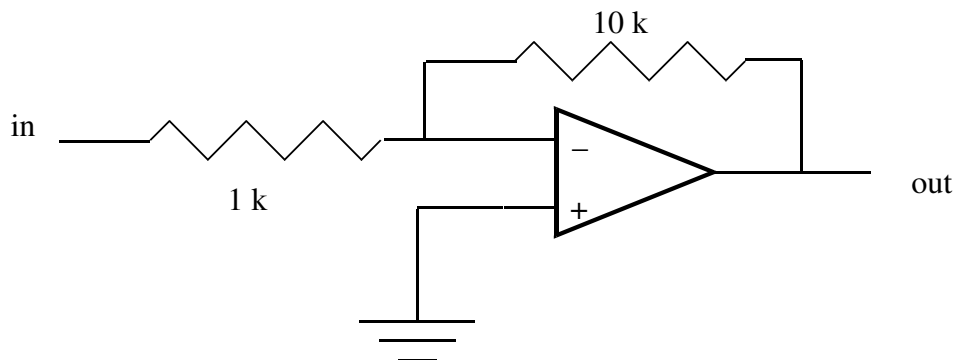
Increase V_{in} till it produces clipping of the output; at what voltages (+ and -) is the output clipped? Sketch V_{in} and V_{out} for a slightly larger voltage than produces clipping.



5-3 Inverting amplifier

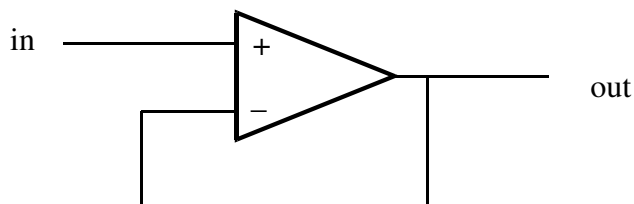
Build the circuit below. Look at the voltage at the inverting input; what is it? Is it what you expect, and why? Predict the voltage gain using the Golden Rules. (Should it be the same as for the previous amplifier?) Now measure the voltage gain at 1 kHz. Is there agreement? Sketch or describe V_{in} and V_{out} at 1 kHz.

Predict R_{in} , then measure R_{in} by putting an appropriate resistor in series with the input. Does the result agree with what you expect?



5-4 Op-amp follower

Build the follower below. Put in a signal from the function generator. Look at V_{in} and V_{out} on the scope, and sketch or describe them. Change the frequency and amplitude of V_{in} ; what happens to V_{out} ? (Do you see why this circuit is called a “follower”? How is it similar to the transistor emitter follower circuit you built earlier?)



Try to measure the input resistance (R_{in} , which should be very large) at 1 kHz by using a 10 M resistor in series with the input. If you get an answer of 10 M, stop and think about what else is in the circuit that has an impedance of 10M! What does this result imply about R_{in} of the follower?

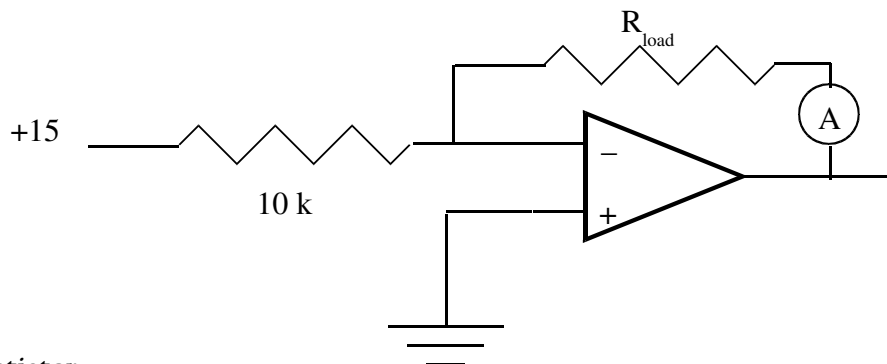
The slew rate of the op amp is the maximum rate at which it can change the output voltage. Put the circuit back in the original follower configuration. Switch the input to square waves and set $f=10$ kHz. Adjust the amplitude of the function generator so that V_{out} is as large as possible. Measure the slew rate by measuring dV_{out}/dt (use a straight section of the voltage rise; you'll have to play with the scope controls to make the interesting part of the signal easily visible). Compare the slew rate on the rise to the slew rate on the fall—do the rates differ? Compare your measured slew rates to the values listed in the LF411 data sheet. Repeat for the LM741 (which has the same pinout as the 411).

Suppose you want to use the follower on an input signal consisting of a sine wave of 10 V peak-to-peak. What is the maximum frequency you can use before the output signal begins to be distorted by the finite slew rate of the amplifier? Make a prediction for the maximum frequency, then set up the situation and describe or sketch what happens when you exceed that frequency.

5-5 Current source

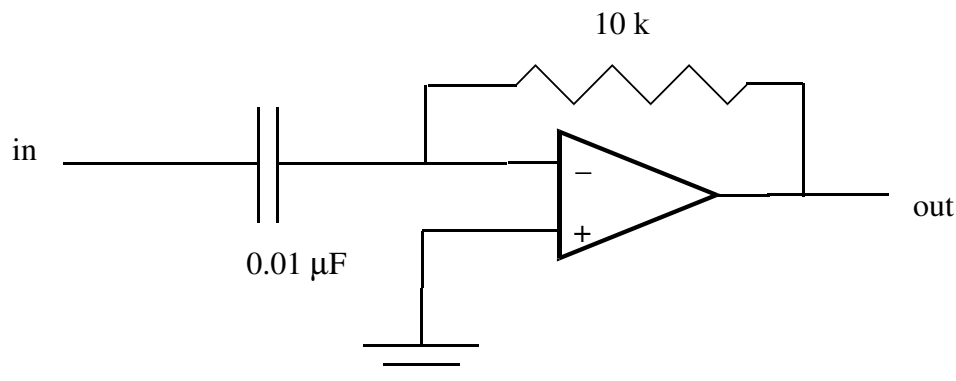
In designing circuits, the ability to produce a source of constant current rather than constant voltage can be useful. The trick is to keep the current constant despite variations in load resistance. The circuit below is one way to do this. Use the Golden Rules to calculate what the current should be in the load for this circuit (your answer shouldn't depend on R_{load}).

Set up the circuit below. Try several values of R_{load} from 1 k to 10k and record the current in the load for each. How well does the circuit work as a current source over this range? Then try a load of 20k. What happens, and why?



5-6 Differentiator

Set up the circuit below. Try it with square waves at around 1 kHz. If the input and output don't look like you expect, read the *note* below. Sketch input and output. Also try it with triangles and sines. In what way(s) is this circuit an improvement over the passive RC-filter-based integrator you built earlier in the semester?



Note: at high frequencies the phase introduced by the differentiator adds to the phase produced in the op amp and the negative feedback becomes positive, causing instabilities. To get around this problem, you can try adding a small capacitor (say, 560 pF) in parallel with the feedback resistor. This capacitor will have little effect at low frequencies (because it has a large impedance at low frequencies), but will serve as a short for higher frequencies.

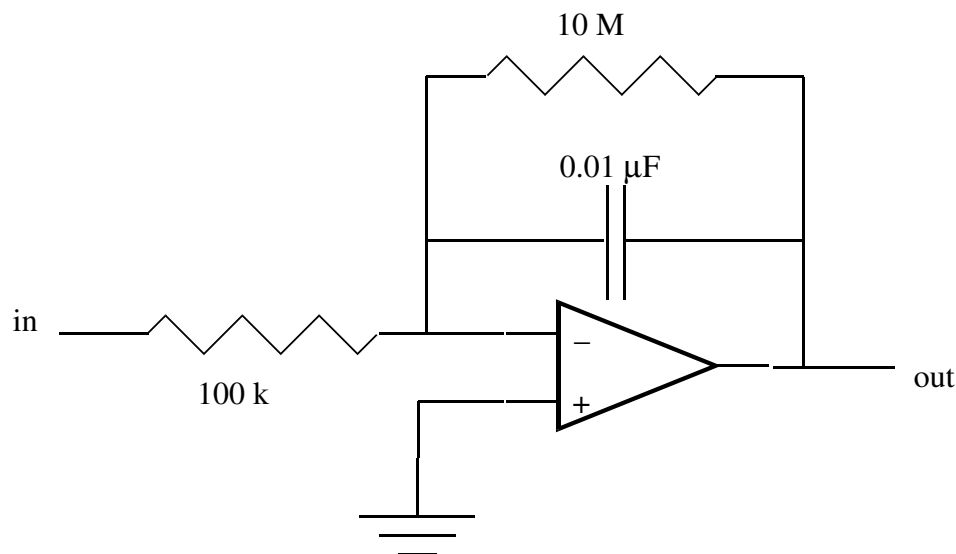
For a triangle wave input with peak $V = V_{in}$, use the Golden Rules to derive an expression for the peak V_{out} in terms of R, C , the frequency, and V_{in} . Use this to calculate V_{out} for a input triangle wave of frequency 1 kHz and amplitude 0.5 V, then measure for your circuit and compare calculated to measured.

5-7 Integrator (optional)

Set up the circuit below. Try it with square waves at around 1 kHz. Sketch input and output and measure V_{in} and V_{out} . Also try triangle and sine wave inputs; is the output what you expect?

Use the Golden Rules to derive an expression for V_{out} (peak) if the input is a square wave with peak $V = V_{in}$. The expression should depend on R, C , the frequency, and V_{in} . Does this expression give you the correct value for V_{out} in the case you measured above?

What is the function of the 10 M resistor? Try removing it. Explain what happens, and why.



5-8 Current-to-voltage converter

In many cases, we want to take a small current and convert it to a voltage. For example, a photodiode or phototransistor produces a current proportional to the light intensity falling on it, but a voltage proportional to that current is easier to work with. A large resistor will produce a reasonably-sized voltage from a small current, but a large resistor has impedance properties that are often not useful in a circuit. A better solution is an op-amp based current-to-voltage converter, shown below.

Use the I-to-V converter to look at the current from a PN168 phototransistor, hooked up as shown below (the longer leg is the emitter). Carefully sketch the output signal (be sure to show where ground is). What is the average voltage output? What average current from the phototransistor does this correspond to?

What is the frequency of the output signal? Why does it have that frequency?

Cover the photodiode with your hand and describe what happens to the output. Try shining a flashlight on the phototransistor. Explain what happens and why.

What could you do to prevent the output from saturating if you wanted to measure the intensity of the brighter light from the flashlight?

