Operational Amplifiers I

Physics 251

Fall 2022

The purpose of this lab is to make and test some amplifiers which use op amps. Both inverting and non inverting configurations will be made and tested. The basic circuits are shown below in Figures 1 and 2.

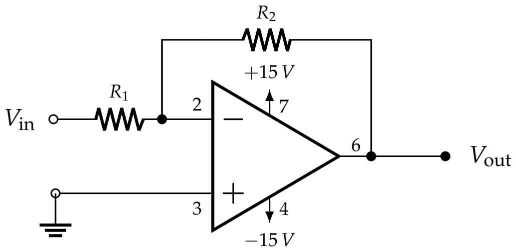

Figure 1: An inverting operational amplifier. Here the gain is

$$G = -\frac{R_2}{R_1}$$

and the input impedance is R_1 and the output impedance is "low".

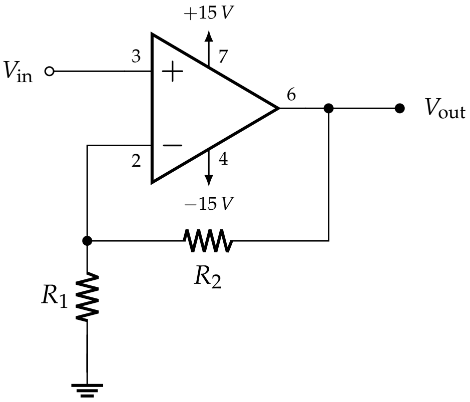

Figure 2: A Non-inverting operational amplifier. Here the gain is

$$G = 1 + \frac{R_2}{R_1}$$

and the input impedance is "high" and the output impedance is "low".

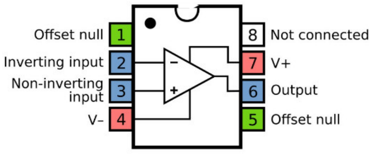

Figure 3: The pin-out for an 8-pin mini DIP op-amp. When in doubt, always look up the data sheet to verify the connections.

Practical Matters

1. Pin out. The location of the connections on a device is sometimes called the pin out. You will be using integrated circuit op amps with 8 pins. The package is called a Dual Inline Package (DIP), and this particular version is referred to as a DIP-8 or sometimes mini DIP package. Pins are numbered in counterclockwise order when the device is viewed from above. A dot or a notch is used to indicate where pin 1 is located. See Figure 3.

2. Power supply connections. You will operate your op amps from the protoboard's built in split supply system which provides +15 and -15 volts. As usual, place an electrolytic capacitor across each supply rail to ground (being careful to use the correct polarity for the electrolytic capacitor).

3. Op amp selection. We have three choices which make sense for this lab. They are the LF411, the TL081 or possibly the LM358 (this part has 2 amplifiers in a single IC). The 411 and TL081

have the same pin out, and the pins line up with the holes on your breadboards. You shouldn't have much trouble getting the IC on the breadboard as long as the pins really line up with the holes. Be careful when removing an IC from a breadboard. It is very easy to bend a pin if you just pull it out. Instead, pry it up with a screwdriver, or *very carefully* pull it up simultaneously from each side.

Perform the following tests on each amplifier

1. Gain as a function of frequency. Plot dB vs $\log(f)$. The maximum peak to peak output voltage will be about 20 volts. You should operate well below this — perhaps in the 5 volt peak to peak region. To keep the output voltage this low with a high gain amplifier might require a voltage divider at the input.

2. Measure the input and output impedances. You may not be able to measure these because they are too high or too low, but you should try. You should at least get upper or lower bounds. Do this with AC at a frequency of 1 kHz.

3. Measure the DC output voltage with zero input (ie input connected to ground). Op amps are supposed to have zero output for zero input.

Procedure/Design Specs

1. Make and evaluate an inverting amplifier with a gain of 10 dB. Use any of the three op amps suggested above. To evaluate an amplifier, check its gain as a function of frequency and make a dB vs $\log(f)$ plot. Check the DC gain as well as the AC gain. You can do the DC check by making a stiff voltage divider that gives, say, 100 mV and connecting it to the input of your amplifier. You can measure the DC output with your multimeter. You should check that "zero in" gives exactly zero out by shorting the amplifier input (not the IC input) and measuring the DC output with the multimeter on its most sensitive scale.

2. Make and evaluate a non inverting amplifier with a gain of 30 dB, again using any of the three IC's.

3. Make a non inverting amplifier with a gain of 55 dB using a 741. Make a plot of gain vs frequency (dB vs $\log(f)$). After completing this part, remove the 741 and replace it with either of the other IC's and measure gain as a function of frequency. Plot the results for both IC's on the same graph. You should see a difference in bandwidth. You should notice that the gain of these amplifiers falls off at high frequency. Find the 3 dB point for each amplifier. This can be obtained from your graph and should be expressed as the frequency at which the gain has dropped by 3 dB.

4. Optional
   You may have noticed another feature of the amplifiers for high frequency signals. The output waveform for large high frequency signals will be distorted, even when the gain is still at the formula value. The distortion is due to slew rate limitations. It is worth taking a further look at this effect, since it is often the real culprit when an amplifier exhibits poor high frequency performance. To see this effect in action, apply a 100 Hz square wave to the input of the last amplifier you made (it should still be on the breadboard). Increase the size of the input signal until the output is about 10 volts peak to peak. Increase the frequency, and observe the output voltage waveform. As frequency increases, the sides of the square wave will start to become slanted and, possibly, curved. What's happening is that you are asking the output voltage to change at too great a rate. Slew rate (usually specified in volts/μsec) tells you the maximum rate of change of the output voltage. By trying large and small amplitude square waves, and comparing with small amplitude sine waves, you can see how slew rate limitations can affect amplifier performance.