Lab 4: Introduction to Operational Amplifiers

4.1 Goals of this Lab

A first look at operational amplifiers ("op-amps"), their properties, and two fundamental op-amp circuit configurations. We will use the two op-amp types, the 741 and the 411, which have identical external connections and are essentially the same except that the 411 has JFET input transistors and the 741 has bipolar inputs.

4.2 Op-amp Connections and Offset Voltage

Figure 1 gives the connections for the 741 or 411 op-amps housed in the 8 pin dual-in-line (DIP) package, as we will use in lab. We will begin by setting up a 741 op-amp.

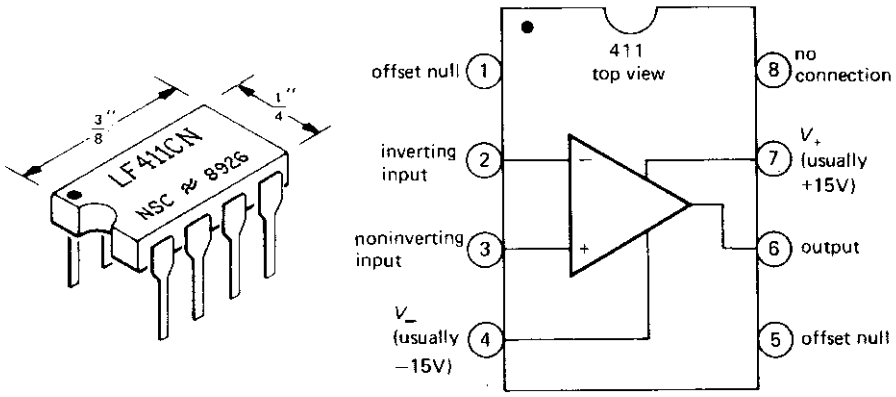

Figure 1: 8-pin DIP package connections for 741 or 411 op-amps.

Obtain a 741 "chip" and connect it in the inverting amplifier configuration shown in Fig. 2. The input DC power connections, V_+ and V_-, should be connected to +15 V and −15 V, respectively. The 10 kΩ variable resistor can be the one provided on your prototype board. Zero any DC offset in the output by grounding the input, observing the output on the oscilloscope (DC coupled!), and adjusting the variable resistor as necessary. If the output is unstable, try placing bypassing capacitors ($\sim 1\ \mu$F) across the input power connections to ground; this can eliminate pickup of unwanted high frequency noise. (Be sure the capacitors are rated for 15 V.)

4.3 Inverting Amplifier

Replace the 100 kΩ resistor with 10 k in the preceding circuit. Input a 1 kHz sine wave. Measure the voltage gain. What is the maximum amplitude ("swing") of the output?

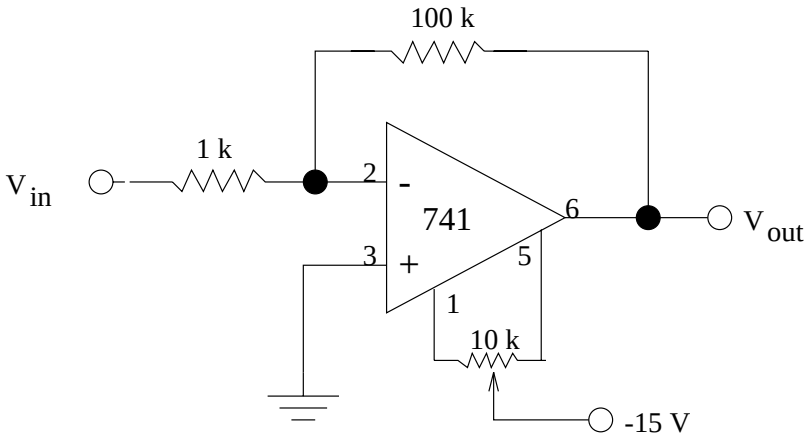

Figure 2: Inverting amplifier using 741 op-amp.

Does the output reproduce input triangle or square wave forms? Increase the frequency of the input sine wave. At what frequency (approximately) does the amplifier no longer reproduce the input well? (It may be necessary to use one of the high-frequency signal generators.)

4.3.1
Measure the input impedance by putting an additional 1 kΩ resistor in series at the input. This forms a voltage divider with the input impedance. (Note that here you are measuring the Z_{in} of the *entire* inverting amplifier circuit, not the intrinsic Z_{in} of the op-amp, which is very large.) Use a 1 kHz sine wave as the input signal.

Try measuring the output impedance by loading the output with a capacitor and resistor as you did last week for the emitter follower. Since the output current is limited to a few mA, a small input signal is required. It may be difficult to do more than place an upper limit on Z_{out}.

4.4 Slew Rate

Figure 3 shows an op-amp in a configuration analogous to the transistor emitter follower. It is used here to study op-amp "slew rate", which is a measure of the speed of the device. To study this, we will input a square wave, and note the slope of the transitions between the two levels of the square wave on the oscilloscope. This slope, usually reported in units of V/μs, is the slew rate.

4.4.1
Start by measuring the slew rate of the 741 op-amp. To obtain a good measurement, the outputs should not be near saturation (±15 V). The "up" and "down" slewing may be different. Compare with the claimed 741 slew rate of 0.5V/μs.

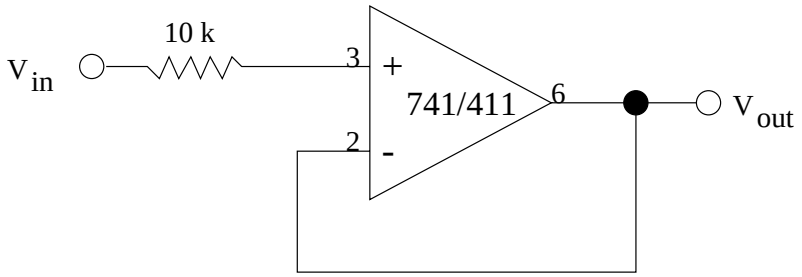

Figure 3: Circuit to measure op-amp slew rate.

4.4.2
Repeat for a 411 op-amp. Compare with the claim of 15V/μs. Input a sine wave and note at what frequency the output begins to drop for an input of a few volts. For a slew rate S, the op-amp amp should be able to deliver a a sine wave of constant amplitude A up to a maximum frequency $f_{\max} = S/(2\pi A)$. Check that this roughly agrees with the slew rate measured with the square wave.

4.5 Non-inverting Amplifier

Construct the non-inverting amplifier of Fig. 4. Determine its voltage gain using a 1 kHz sine wave input. Measure the input impedance, as before, using an input series resistor (in the 100 k to 1 M range). In this case we are measuring the intrinsic Z_{in} of the op-amp. Beware of the limitations of your measuring device: Is its Z_{in} large compared to the op-amp? Also, the Z_{in} could have a capacitive, as well as a resistive, component. Check this by varying the input frequency.

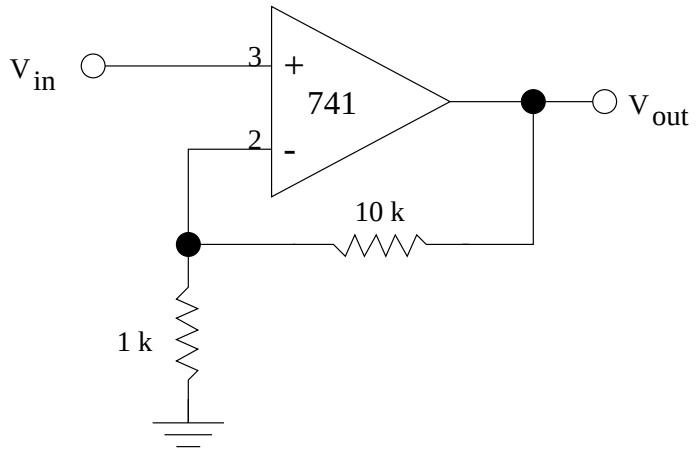

Figure 4: Non-inverting amplifier.