UNIVERSITY OF PENNSYLVANIA
DEPARTMENT OF ELECTRICAL ENGINEERING

ESE UNDERGRADUATE LABORATORY
ESE 205: Electrical Circuits and Systems I Laboratory

Lab: 4
Operational Amplifiers – Basic Characteristics and Applications

Objective

The objective of this lab experiment is to learn how to use the operational amplifier (op-amp). In this experiment some of the basic characteristics of the op-amp would be examined and then some of its applications like the voltage follower and as a comparator will be experimented.

Pre-Lab Assignment

The Operational Amplifier (Op Amp) is an extremely useful device, as we will see in this lab. With the addition of a few external components, an extraordinary variety of functions can be implemented.

The Op Amp is an active element that needs to be supplied with power to operate. A common way to supply this power is shown in Figure 1. Two power supply voltages are used, with equal values denoted by V_{cc} and V_{DD} (or ±VCC) (often in the range of 5 V to 15 V). The common node between the supplies is the ground node. The op amp's output voltage is taken between the output terminal and the ground node. The remaining two terminals are the input of the op amp.

An interesting property of the op-amp is that the output voltage is only a function of the difference of the two input terminals.

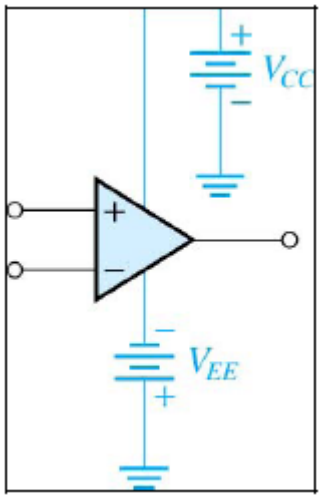

Figure 1: A common method of supplying power to op-amp

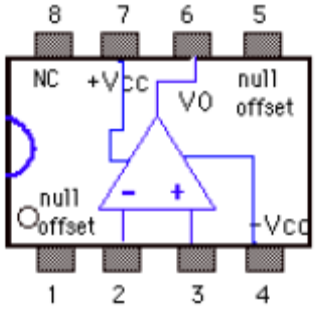

Figure 2: Top view of an op-amp DIP (dual in-line package) chip.

Figure 2 shows the top view of widely used OpAmp type known as the 741. It comes in a package, with metal pins that can be pushed into a breadboard such as the one you will be using for this experiment. With the package viewed from above and positioned as shown (note the dot on the left), the pin numbering is understood to be as indicated. The pins that correspond to the input, output, and power supply connections are shown. When the OpAmp is connected to other elements, extremely small currents flow at its input terminals. For our purposes, these currents can be assumed to be zero.

The most basic function of the op amp is the voltage amplification. However, the output voltage of a real op amp is limited to the range between certain limits that depend on the internal design of the op amp. As shown in Figure 3, when the output voltage tries to exceed these limits, clipping occurs.

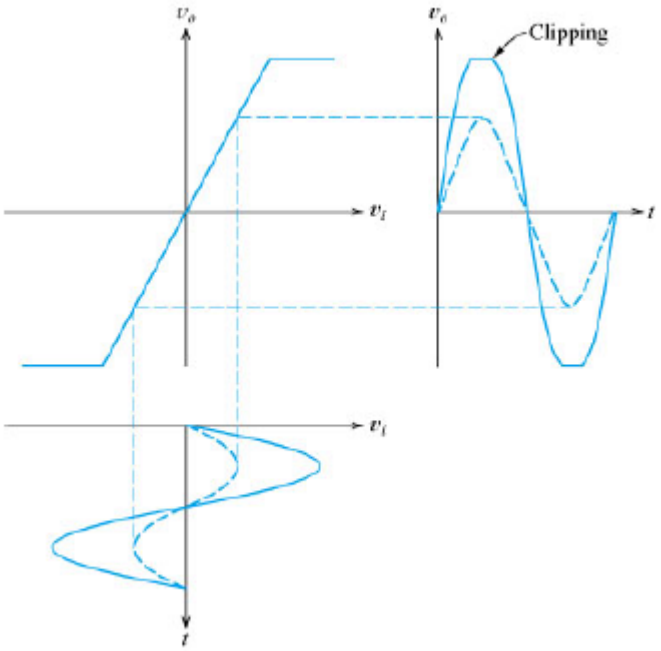

Figure 3: For an op-amp, clipping occurs if the output voltage exceeds certain limits

1. Inverting Amplifier:

Simulate the Inverting amplifier shown in Figure 4 in MultiSIM for Av = -50.
Where for an Inverting amplifier,

$$A_v = \frac{v_o}{v_{in}} = -\frac{R_2}{R_1}$$

Select the larger of the two resistors in the above gain equation to be equal to 100 kΩ, and come up with a value for

the other. Use a combination of standard resistor values for the second resistor, such that your actual value of Av is approximately within ±1% of the desired value.

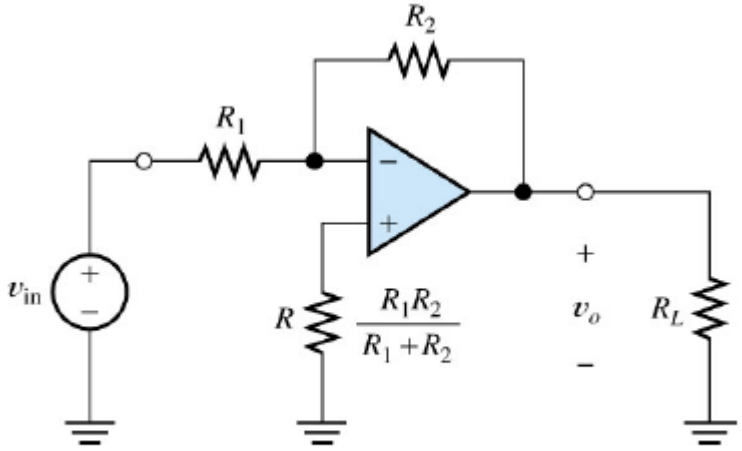

Figure 4. Inverting Amplifier.

Use an ideal 3-terminal OpAmp model (from the Analog IC parts bin). Double click on the OpAmp and set the positive and negative voltage swings to +15 V and -15 V, respectively.

Use the function generator to produce a sinusoid at the input of the amplifier and use the two channels of the oscilloscope to view the input and the output waveforms simultaneously. Set the amplitude of the function generator to 200 mV and measure the output amplitude and the phase shift between the input and output waveform at 10 Hz, 1 kHz, and 100 kHz.

Does the phase and/or amplitude of the amplifier output changes with frequency?
What happens if you change the amplitude of the function generator to 1 V?

If you use either a 10 MΩ resistor or a 1 kΩ resistor for the larger of the two resistors that determine Av, and adjust the other resistor so that your actual Av is still within ±1% of the desired value of .50, will any of the above results change?

2. Non-Inverting Amplifier:

Repeat 1 for the Non-Inverting amplifier configuration shown in Figure 5. Take Av =50.
For an Non-Inverting amplifier,

$$A_v = \frac{v_o}{v_{in}} = 1 + \frac{R_2}{R_1}$$

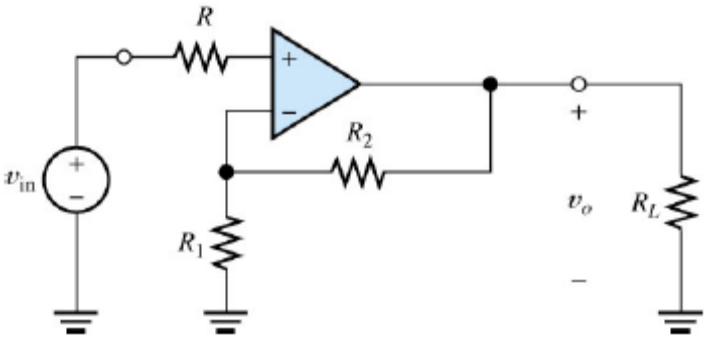

Figure 5. Non-Inverting amplifier.

In-lab Assignment

A. Equipment:

1. Digital multimeter (HP34401A)
2. Triple output programmable power supply (HP E3631A): set at +15V, -15V (with 100mA current limit)
3. Protoboard
4. Blue box with cables and connectors
5. Resistors
6. One 741 op-amp
7. PC
8. Electronics Workbench (Optional)

B. Procedure

Inverting Amplifier:

Hook up the inverting amplifier of figure 6, with R_{in} = 10 k and R_f = 100 k. Using a 1 kHz sinusoidal input signal with an amplitude of approximately 1 V, look at the input and output.

Verify that the amplifier inverts. Measure the gain and compare with what you expect. Replace the 100 k feedback resistor with 10 k. What gain do you predict and observe now?

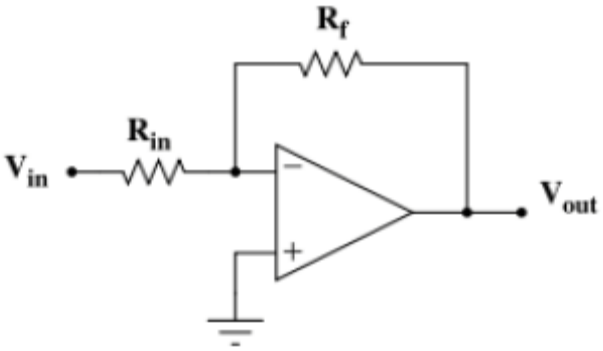

Figure 6: Inverting amplifier

Non – Inverting Amplifier:

Set up the non-inverting amplifier circuit of figure 7 with R_1 = 10 k. With a 1 kHz sinusoidal input, measure the gain with R_2 = 100k and with R_2 = 10k. Compare with what you expect. Verify that the amplifier is non-inverting.

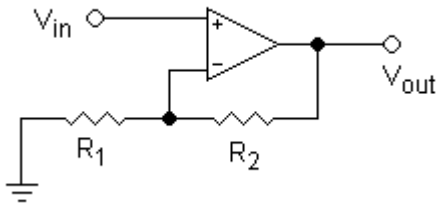

Figure 7: Non – inverting amplifier

Voltage Follower:

As shown in figure 8, connect the output of the op-amp directly to the '-'input and connect the output of the function generator to the '+' input of the op-amp.

After turning on the power, confirm that the input and output signals are identical and that the voltage follower is non-inverting. Record the input and output amplitudes.

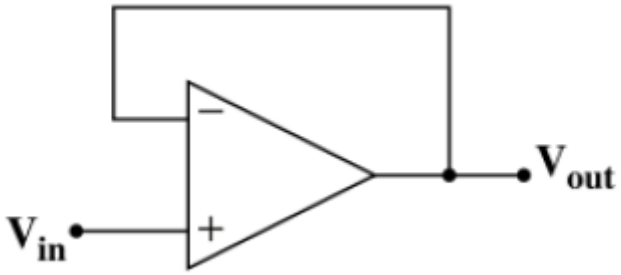

Figure 8: 741 as a voltage follower

Comparator:

With no negative feedback, the saturated output that results allows the op-amp to be used as a voltage comparator – a circuit that tells you whether an input voltage is higher or lower than a 'threshold' voltage. Since op-amps are not specifically engineered for open loop operation, it is not a very good voltage comparator, but in some situations an open loop 741 comparator is perfectly adequate.

Start by applying a 1 kHz sine wave to the input (pin 2) and ground pin 3. Observe what the circuit is doing.

Now raise the input frequency to 100 kHz. Notice that the output 'square wave' is not very square.

For each case studied, sketch the output waveform and measure the output amplitude and DC offset. Explain your measurements.

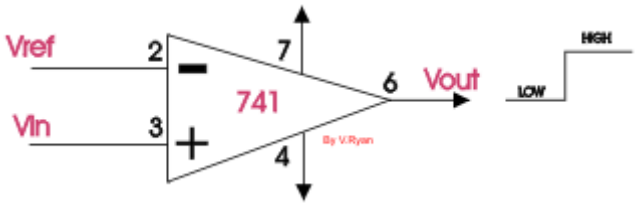

Figure 9: 741 as a comparator

Capture the output waveforms wherever necessary to be pasted in your lab notebook as well as your report.

Back to EE205 Homepage
Created by Jan Van der Spiegel: Feb. 20, 1997.
Updated by Jorge Juan Santiago Aviles and Preethi Gopu: August 14, 2006