

ENGR 210/EEAP 240
Lab 5

Introduction to the Op-Amp

Purpose: To become familiar with the operational amplifier (OP AMP), and gain experience using this device in electric circuits.

Equipment Required:

- HP 34401A Digital Multimeter
- 2 - 8.2k ohm Resistors
- 1 - 36k ohm Resistor
- 1 - 10k ohm Potentiometer¹
- 1 - 741 OP AMP

Prelab:

Read Sections 4-4 and 4-5 on OP AMPs in the textbook². Review the following handling precautions for semiconductor devices. Use these precautions when handling OP AMPs.

Caution

The OP AMP, like any semiconductor device, can be destroyed by over-current, over-voltage or static discharge. Over-current conditions are usually due to a wiring error. Over-voltage occurs when the power supply voltage exceeds the voltage rating for the device. These conditions can be avoided by ensuring you are using the proper device, and double-checking the circuit layout to catch — and correct — wiring errors. In the laboratory, damage from static discharge is often controlled by the use of grounded anti-static mats on the floor and the work surface. Manufacturers of static-sensitive devices recommend the use of a grounded wrist strap when working on sensitive electronics. You can help avoid damage from static discharge by touching an earth ground before picking up a semiconductor device. Earth grounds are available throughout a modern circuits lab, in the form of any metal case on a grounded instrument. Some power supplies provide a ground lug (or jack) separate from the negative side of the supply. The ground lug provides a good quality connection to earth ground through the third wire (round pin) on the AC power cord. Touching the metal portion of this ground lug will discharge any static electricity you have accumulated, and significantly reduce the likelihood of damaging static-sensitive components.

¹ Actual value is not critical. Basically anything over 1k should be usable.

² Roland E. Thomas and Albert J. Rosa, *The Analysis and Design of Linear Circuits*, Prentice Hall, (New Jersey, 1994)

Procedure:

1. Prepare the power supplies
 - a. Configure the $\pm V_{CC}$ supplies.

1. The schematic of Fig. 1 shows a standard $\pm V_{CC}$ configuration for OP AMPs. The schematic symbols for a battery are used in this schematic to remind us that these supplies need to be a constant DC voltage. They are not signal sources.

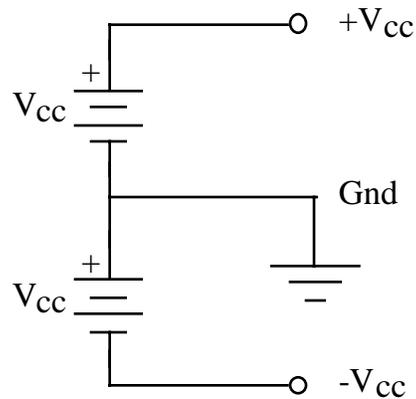


Figure 1. Power Supply Configuration

Your H-P power supply has two variable outputs, a single output supply on the left (which you used for your last lab), and a dual output (which you will use for this lab) on the right. Note that the outputs of these power supplies are not necessarily connected to ground. They often have a “common” output connected which should be connected to the ground of the power supply. Otherwise your power supply voltages may “float” and cause measurement problems.

As shown in Fig. 1, the connection labeled "Gnd" between the V_{CC} supplies is used as a circuit ground. This corresponds to the common binding post (connected to the green common binding post) on your power supply.

2. Adjust the output so the $+V_{CC}$ and $-V_{CC}$ are equal - but opposite in sign - at 15 V.

- b. Configure the signal source.

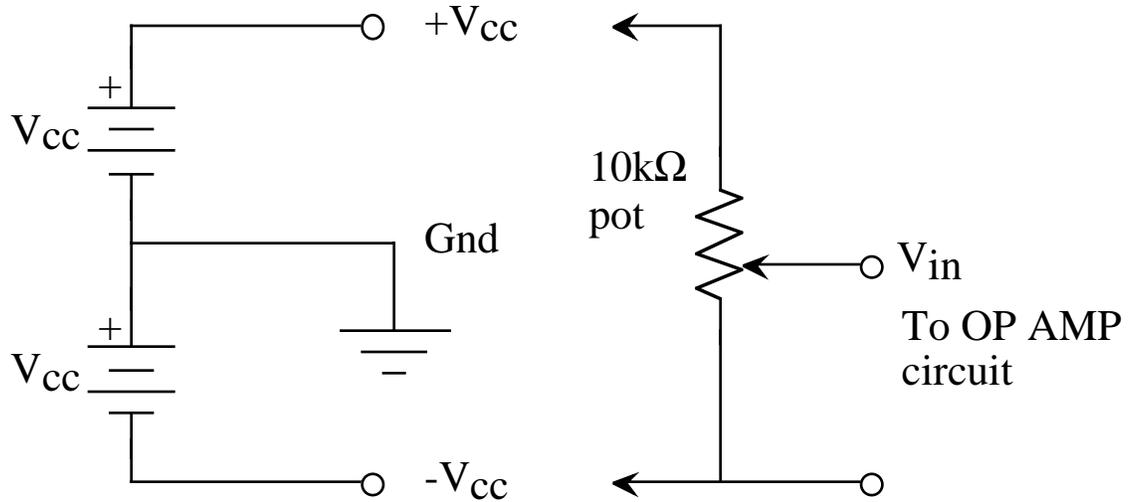


Figure 2: Signal Connections

1. Connect the $\pm V_{CC}$ to the potentiometer as shown in Fig. 2. This will provide a variable-output DC signal source from $-V_{CC}$ to $+V_{CC}$, for input to the OP AMP circuit. Do not attempt to push the connectors for the potentiometer into your protoboard — they are too large for the protoboard and will damage the protoboard. You can instead connect to the potentiometer with alligator clips, or you can use the soldering irons in the instrument room to solder wires to you potentiometer and then connect it to your protoboard.

2. Check the signal source circuit to ensure that it provides the range of voltages desired. The voltmeter should be connected to the center terminal of the potentiometer and the common ground between $\pm V_{CC}$.

c. The way in which the power supplies are connected to each other, and to the potentiometer, produces four nodes, $+V_{CC}$, $-V_{CC}$, V_{in} and ground (GND) or reference. To reduce the risk of connecting the wrong voltage level to your OP AMP, you may want to label each point on the protoboard with its appropriate voltage: V_{in} , $+V_{CC}$, $-V_{CC}$, GND. You can do this by putting a sheet of paper under the protoboard and labeling the connections on the paper. Turn the power supply on and verify that the voltage at each of these points matches your labels. Record actual values for $+V_{CC}$ and $-V_{CC}$, and the maximum positive and negative voltages produced by the signal source circuit, at the node labeled V_{in} in Fig. 2 in Data Table 1.

d. Turn the power supplies off.

2. Connect the OP AMP

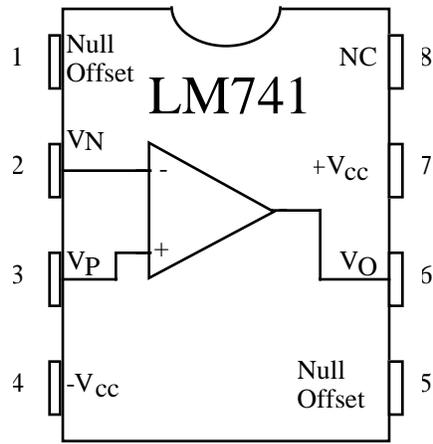


Figure 3 - 741 Connections

a. Study the chip layout of Fig. 3. The standard procedure on DIP (dual in-line package) "chips" is to identify pin 1 with a notch in the end of the chip package. The notch always separates pin 1 from the last pin on the chip. In the case of the 741, the notch is between pins 1 and 8.

Pin 2 is the inverting input, V_N . Pin 3 is the non-inverting input, V_P and the amplifier output, V_O is at pin 6. These three pins are the three terminals that normally appear in an OP AMP circuit schematic diagram. Even though the $\pm V_{CC}$ connections must be completed for the OP AMP to work, they usually are omitted from the circuit schematic to improve clarity.

The null offset pins (1 and 5) provide a way to eliminate any "offset" in the output voltage of the amplifier. The offset voltage (usually denoted by V_{os}) is an artifact of the integrated circuit. The offset voltage is additive with V_O (pin 6 in this case), can be either positive or negative and is normally less than 10 mV. Because the off-set voltage is so small, in most cases we can ignore the contribution V_{os} makes to V_O and we leave the null offset pins open.

Pin 8, labeled "NC", has no connection to the internal circuitry of the 741, and is not used.

b. The goal here is to connect the circuit shown in Fig. 4. This is an easy task . . . if you've done this before! For this lab we'll walk through how to actually wire up an OP AMP.

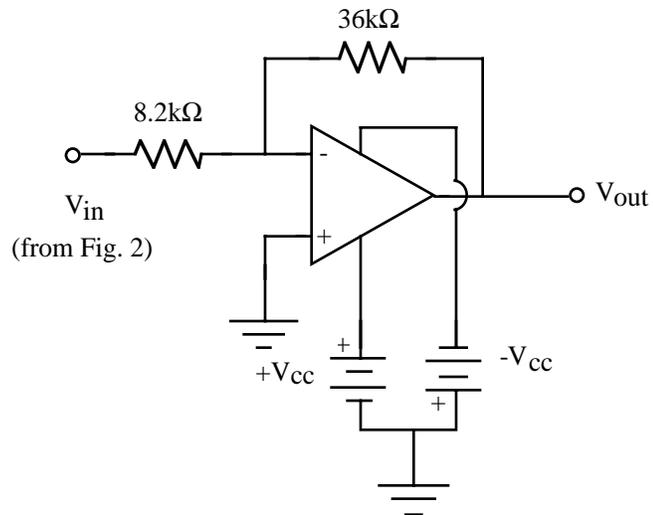


Figure 4 - Actual 741 OP-AMP Circuit

c. Figure 5 represents a first step in transferring our circuit schematic of Fig. 4 into a real circuit. This figure shows all the elements we will use to implement the circuit of Fig. 4.

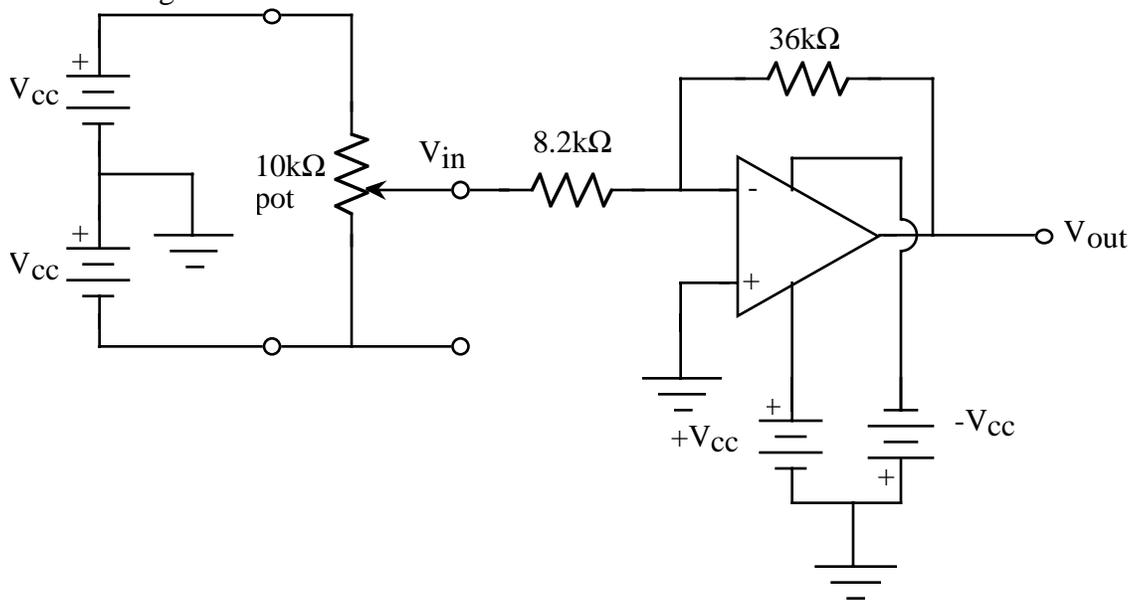


Figure 5

d. Figure 6 translates the schematic of Fig. 5 into a mechanical representation (or pseudoschematic) showing the physical lay out of the circuit and the connections on the protoboard.

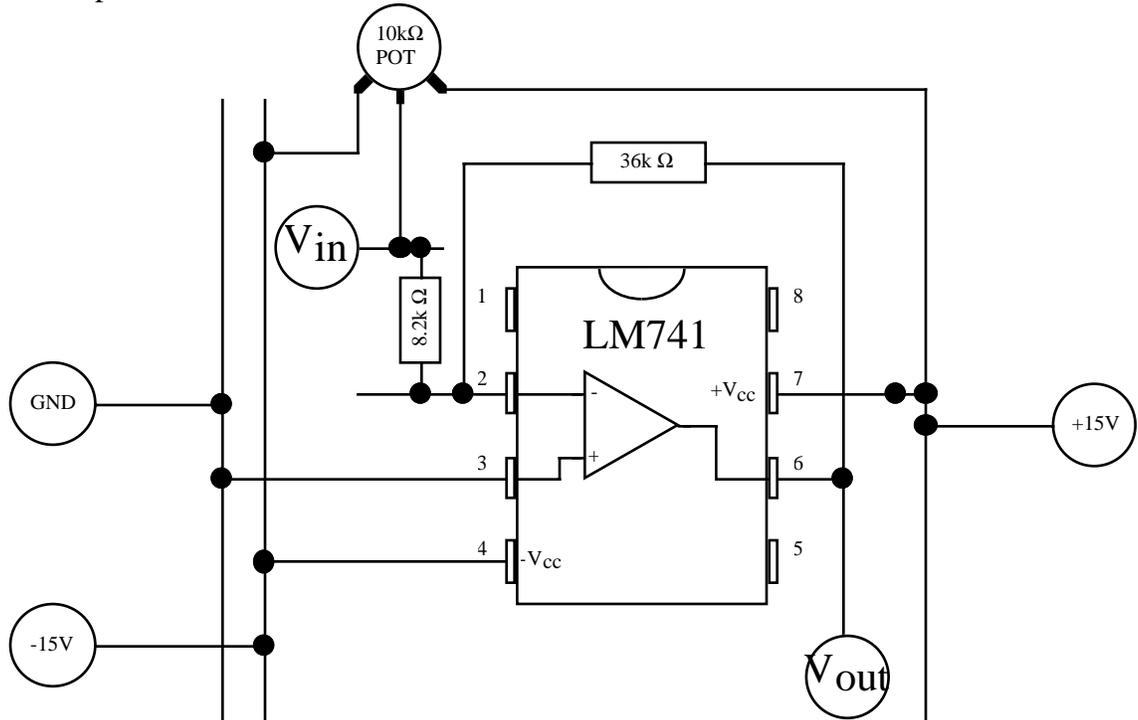


Figure 6

e. Although we won't go through this level of detail in future lab write-ups, it is useful for you to draw a pseudo-schematic for future labs before actually trying to wire your circuit.

3. The inverting amplifier

Carefully measure the values of the resistors that will be used in the circuit of Fig. 4. Record these values in Data Table 2. Use these measured values to compute the circuit gain, K . Also record this value in Data Table 2. With the power supply output off, construct the inverting OP AMP circuit using Fig. 6 as a guide. Check the circuit carefully. Turn on the power supply. Adjust the $10\text{k}\Omega$ ohm potentiometer to achieve a V_{in} of 1 V. Measure V_{in} and V_{out} and verify that the actual $V_{out} = KV_{in}$. If V_{out} is correct, your amplifier circuit is probably working correctly, and you may proceed. If the measured V_{out} is different than KV_{in} by more than 10%, you probably have an error in the circuit. Troubleshoot the circuit until it is operating properly.

a. Turn on the power supply output and for a V_{in} of about -10 V, carefully measure V_{in} and V_{out} . HINT: If the lab is not too busy this is most easily done using two DMMs rather than one. Record V_{in} and V_{out} in Data Table 3. Increment V_{in} by 1 volt, and repeat the measurements. Again record V_{in} and V_{out} in Data Table 3. Collect data in this manner 19 more times, incrementing V_{in} by 1 V after each measurement until $V_{in} = +10$ V. Record your values for V_{in} and V_{out} in Data Table 3. For each line of data in Data Table 3, compute and record KV_{in} and the error between KV_{in} and V_{out} .

b. At $V_{in} = 2$ volts, accurately measure and record V_{in} , $+V_{CC}$, $-V_{CC}$, V_P and V_N in Data Table 4. Circuit Values. If measured using a sensitive voltage scale, a very small difference in V_P and V_N can be measured. Measure and record the voltage difference ΔV_{P-N} .

c. Turn off the power supply output. Without removing the OP AMP, disassemble the circuit of Fig. 6.

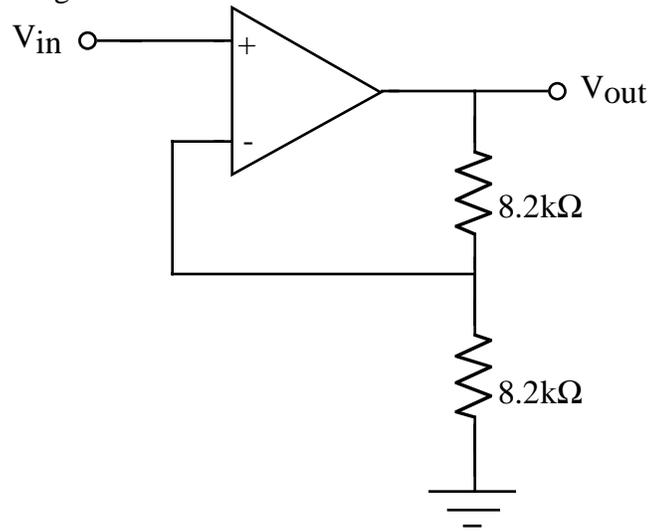


Figure 7

4. The non-inverting amplifier

a. Calculate and record the expected gain for the circuit of Fig. 7 in

Data Table 5.

b. You will use the source circuit of Fig. 2 to provide V_{in} for the non-inverting amplifier of Fig. 7. Draw a circuit diagram similar to Fig. 5 for the schematic of Fig. 7. Record this in Data Table 7. Draw a pseudoschematic similar to Fig. 6 for this circuit and also record this in Data Table 7.

c. Connect the circuit of Fig. 7, using your pseudoschematic as a guide. Test the circuit by verifying that V_{out} is equal to KV_{in} . If not, troubleshoot the circuit until it is operating properly.

d. Starting at a V_{in} of -10 V, make 21 measurements of V_{in} and V_{out} , incrementing V_{in} by 1 V after each measurement. Record V_{in} and V_{out} in Data Table 6. Fill in the remaining two columns of the table with the needed calculated values.

DATA AND REPORT SHEETS

Student Name (Print): _____	Student ID: _____
Student Signature: _____	Date: _____

Data Table 1. DC Voltage Source Measurements

Measurement	Measured Value
+Vcc	
-Vcc	
Vin (maximum positive)	
Vin (maximum negative)	

Data Table 2. Resistor Values

Parameter	Calculated Value	Measured Value	% Difference
8.2 k Ω resistor			
36 k Ω resistor			
K (voltage gain of amplifier)			

WRITE-UP

1. For the inverting amplifier circuit, plot V_{out} , KV_{in} , and error vs. V_{in} (three plots superimposed onto the same graph). Repeat for the non-inverting amplifier circuit. On each graph, draw a vertical line at the transition between the saturated and active regions of operation for these amplifier circuits. Label the mode of operation for each of these regions. Points will be taken off for not doing this.
2. Measure the slope of the curve in the active region. How well does the slope agree with the theoretical gain computed from the measured values of the circuit elements?
3. For the active regions for both circuits, discuss the possible sources of any error between V_{out} and KV_{in} .

If you wish you may use the dual channel VI you wrote for the last lab to collect data instead of the DMM. You can even replace the potentiometer with an analog signal generated by LabVIEW. However, LabVIEW output is a more complicated than analog input — you must first write the data to be output using AO Write (where the data must be a 2D array) and then you must use the AO Start to actually output the data.