

## EELE 250 Circuits, Devices, and Motors

**Lab #6: Op Amps, Part 1****Scope:**

Study basic Op-Amp circuits: voltage follower/buffer and the inverting configuration.

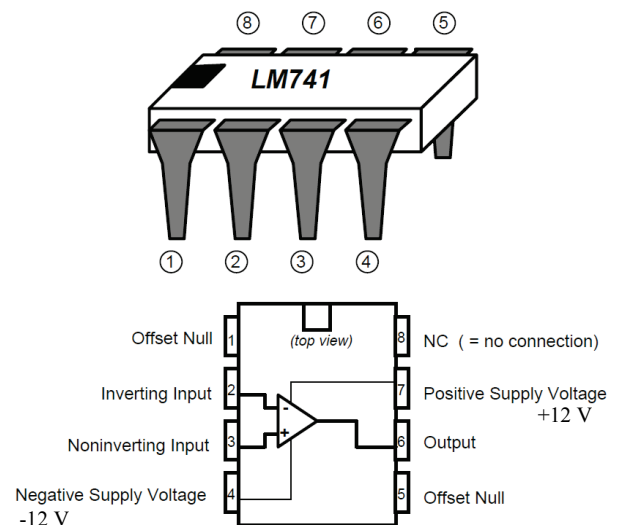
**Home preparation:**

- Review Hambley chapter 14.
- Read through the experiment and plan out each step.
- Create tables in your notebook with the calculated values and space to enter the measured results for the experiment.
- Prepare the calculated results for the circuits you will be measuring in the lab, fill out the **prelab sheets**, **AND write the results in your lab notebook** so you can refer to them during the lab while your prelab is being graded.

**Laboratory experiment:**

This figure shows the 8-pin DIP (Dual Inline Package) version of a type 741 operational amplifier (op-amp) with its terminals labeled. The pins are labeled 1 through 8, counterclockwise, using the notch or stripe on the top of the package to indicate the orientation.

Note that there is no “ground” pin on the op amp package. The op amp’s differential inputs “float” with respect to ground. Sometimes we will connect one of the inputs to ground, but there is no pin that is always grounded.

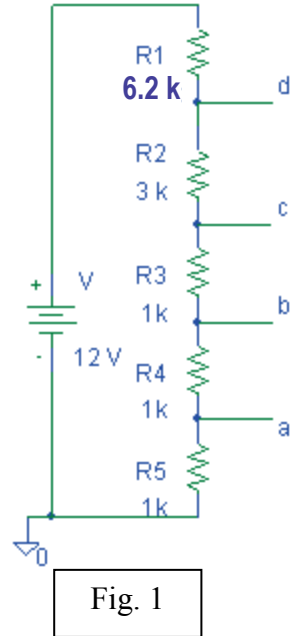


The positive (+12V) and negative (-12V) power supply voltages need to be connected to share the common ground point. The dual output power supplies in the lab can be switched from *independent* operation to *series* mode. When in *series* mode the negative end of the right supply and the positive end of the left supply are internally connected. If you connect this middle point with a jumper cable to chassis ground, you can then set the dual supplies so that the rightmost terminal is +12 volts and the leftmost terminal is -12 volts with respect to the common middle point ground. Note that when switched to *series* mode some of the lab power supplies will go into “slave” mode so that one knob actually controls both supplies.

The *Offset Null* (pins 1 and 5) will not be used in this experiment. Those pins must be left unconnected.

**Experiment**

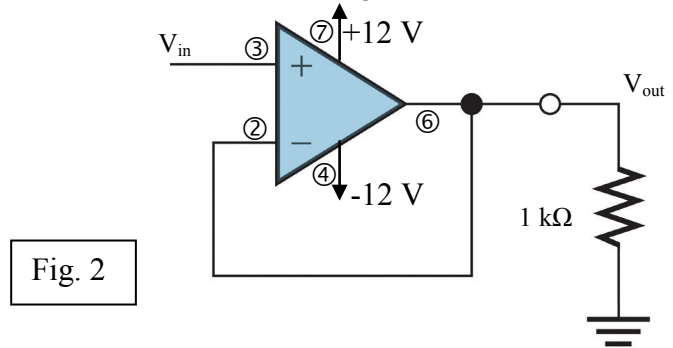
- Using the DMM, carefully adjust the bench DC power supply to produce +12V and -12V with respect to a common ground → see the comments above in the introduction, and ask your lab TA to check your configuration.
- Next build the circuit shown in Figure 1 on your breadboard. Choose resistors with value close to the nominal values listed. This chain of series resistors is a *voltage divider*, assuming all of the resistors conduct the same current. You will use this circuit to create several voltages to use in the rest of the experiment. Measure and record the voltages in column 2 of Table 1 below.
- Note that if a new circuit connection is made that draws or inserts current into any of the nodes *a*, *b*, *c*, or *d*, the corresponding node voltages will change due to the change in the overall current. Try this by temporarily connecting another 1 kΩ resistor between node *b* and ground. Re-measure the node voltages and record them in column 3 of Table 1.



	Pre-lab predicted voltage	Measured in lab (part 2)	Measured with 1kΩ resistor inserted from <i>b</i> to ground (part 3)
V <sub>a</sub>			
V <sub>b</sub>			
V <sub>c</sub>			
V <sub>d</sub>			

When done with step 3, remember to remove the 1kΩ resistor you attached between node *b* and ground. Leave the rest of the voltage divider connected--you will use it in the next parts of the experiment.

- TURN OFF THE BENCH SUPPLY and carefully insert one of your 741 op amps into the breadboard. The best way to set up this circuit is to CAREFULLY insert the op amp DIP so that it straddles one of the grooves in your breadboard and the pins slide into the breadboard holes: this allows connections to be made separately to each pin on the amplifier package. Refer to the diagram in the introduction to identify which pin on the package corresponds to which terminal on the schematic diagram. Once the chip is inserted, connect the power supplies and a jumper wire between pins 2 and 6 to create the *voltage follower* circuit, or voltage buffer, with a 1 kΩ load, as shown in Figure 2.

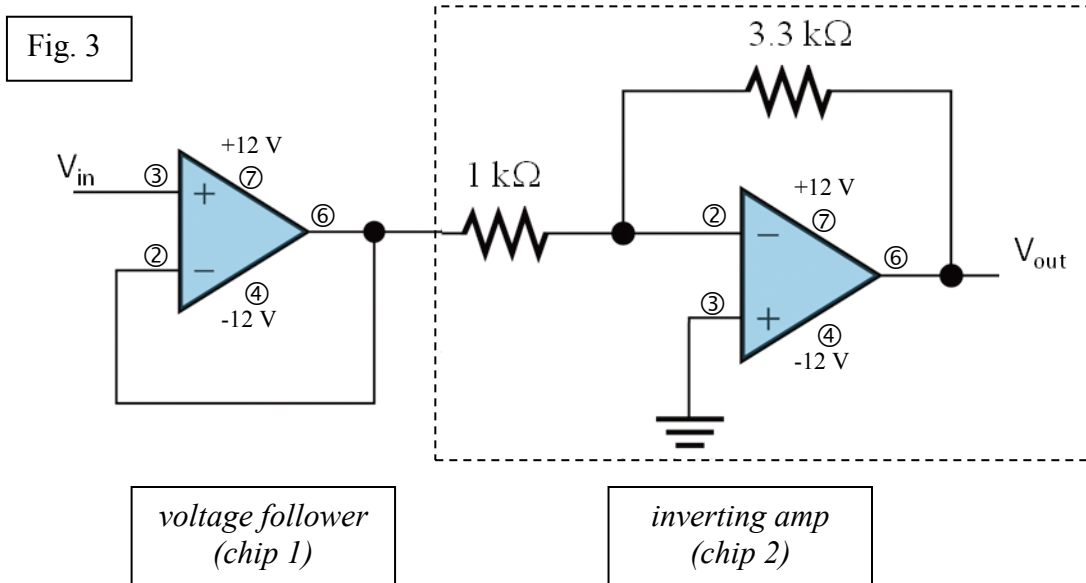


- Turn on the bench power supply with the +12 and -12 voltages powering the op amp, and in Table 2 record  $V_{in}$  and  $V_{out}$  when the voltage follower circuit is connected one by one to nodes *a*, *b*, *c*, and *d* of the voltage divider.

Table 2			
With $V_{in}$ connected to	Pre-lab predicted $V_{out}$	$V_{in}$ measured in lab	$V_{out}$ measured in lab (part 5)
$V_a$			
$V_b$			
$V_c$			
$V_d$			

In your notebook, comment on the result of using the voltage follower to drive the 1 kΩ resistor, compared to what happened in part 3 when the 1 kΩ load was connected directly to the nodes in the divider circuit. Specifically, note that the voltage follower draws negligible current from the voltage divider, but provides sufficient current to drive the 1kΩ load.

- TURN OFF THE POWER SUPPLY.
- Now take a second op amp chip from your kit and insert it also onto the breadboard. Make external connections to the +12 and -12 power supply for the second chip and attach resistors to create an *inverting amplifier* configuration driven by the previous *voltage follower* circuit, as shown in Figure 3.



8. Turn on the power supply so that both chips are active, and in Table 3 record  $V_{in}$  and  $V_{out}$  when the two-chip circuit is connected one by one to nodes  $a, b, c, d$  of the voltage divider.

Table 3			
With $V_{in}$ connected to	Pre-lab predicted $V_{out}$	$V_{in}$ measured in lab	$V_{out}$ measured in lab (part 8)
$V_a$			
$V_b$			
$V_c$			
$V_d$			

9. Turn off the power supply and disconnect the voltage follower output from the inverting amplifier.
10. Turn the supply back on, and make the measurements once more using just the inverting amplifier configuration alone (input via the  $1k\Omega$  resistor) (Fig. 4) connected one by one to nodes  $a, b, c, d$  of the voltage divider and record your results in Table 4.

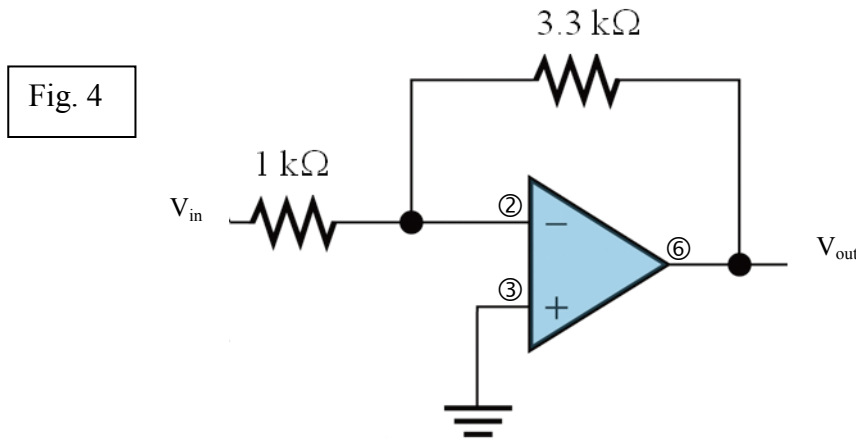


Table 4			
With $V_{in}$ connected to	Pre-lab predicted $V_{out}$	$V_{in}$ measured in lab	$V_{out}$ measured in lab (part 10)
$V_a$			
$V_b$			
$V_c$			
$V_d$			

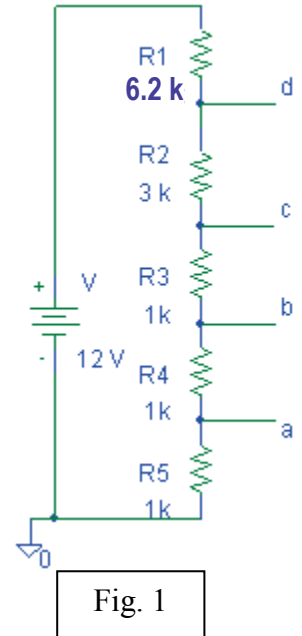
*Comment on the result of having the voltage divider circuit connected to the inverting amplifier configuration without the voltage follower circuit in between.*

## PRELAB SHEETS

Perform the calculations before coming to lab, and show a summary of your work.

### Voltage divider

- For the circuit of Fig. 1, determine the node voltages  $a$ ,  $b$ ,  $c$ ,  $d$  with respect to ground, and place the values in column 1 below. Explain your work.
- Next, with another 1kΩ resistor added between node  $b$  and ground, repeat your calculation of the node voltages  $a$ ,  $b$ ,  $c$ ,  $d$  and place the values in column 2. Explain the effect of adding the 1kΩ resistor.



	Pre-lab predicted node voltage	Pre-lab predicted node voltage with a 1kΩ resistor inserted from $b$ to ground
$V_a$		
$V_b$		
$V_c$		
$V_d$		

### Voltage follower

- If the input to the voltage follower circuit of Fig. 2 is connected one by one to nodes  $a$ ,  $b$ ,  $c$ ,  $d$ , of the five resistor circuit of Fig. 1, what is the expected output voltage?

	Pre-lab predicted $V_{in}$	Pre-lab predicted $V_{out}$ from voltage follower
$V_a$		
$V_b$		
$V_c$		
$V_d$		

**Voltage follower and inverting amplifier**

4. If the input to the two-amplifier circuit of Fig. 3 is connected one by one to nodes *a*, *b*, *c*, *d*, of the voltage divider, what is the expected output voltage? Explain.

	Pre-lab predicted $V_{in}$	Pre-lab predicted $V_{out}$ from Fig. 3 circuit
$V_a$		
$V_b$		
$V_c$		
$V_d$		

**Inverting amplifier without voltage follower**

5. If the input to the inverting amplifier circuit of Fig. 4 is connected one by one to nodes *a*, *b*, *c*, *d*, of the voltage divider, what is the expected output voltage? Explain your work.

	Pre-lab predicted $V_{in}$	Pre-lab predicted $V_{out}$ from Fig. 4 circuit
$V_a$		
$V_b$		
$V_c$		
$V_d$		