ECE 3254
Operational Amplifier I
Laboratory #8 Fall 2009
PRELAB

Name ________________________
Date __________________
Bench ________

Read over entire laboratory #8 and the prelab notes. Show all equations, values, and calculations.

Questions:

1. List the ideal characteristics of the operational amplifier (op-amp). (10 points)

2. For the Ideal Non-Inverting Amplifier in Part I (Figure 8-4), find equations for the input resistance of the amplifier (Ri = Vg / Ig) and the gain (Av = Vo / Vg) of the amplifier in terms of the circuit components (R1, R2, R3, RL).(25 points) (Also enter the equation for the ideal voltage gain on Part I-3 on the Data Sheet.)

3. For the Ideal Inverting Amplifier in Part II (Figure 8-5), find equations for Ri and the gain (Av = Vo / Vg) of the amplifier in terms of the circuit components. Design an amplifier with a gain of -10 and an input resistance Vg/Ig = 10kΩ. Let R3 = R1. Solve for R1, R2, and R3. (30 points) (Enter the resistor values below and in section II-1 on the Data Sheet.)

4. Why would you use a 10X oscilloscope probe to measure the voltage on op-amp input pins? (Hint: see lab page 5) (10 points)

5. For the Ideal Inverting Summer circuit of Figure 8-7, determine the equation for V_O in terms of R_A, R_B, R_C, R_2, V_A, V_B, and V_C. (Also enter this equation in Part IV-2 on the Data Sheet.) (10 points)

6. Use Pspice to simulate the output of the Inverting amplifier of figure 8-5 with the resistor values you calculated in Prelab question 3, R_L = 3.9 kΩ and let V_g = 1000 Hz 1V_{PP} sine wave. The 741 op amp is part uA741.

   Print your schematic with at least your name, the date, and ECE3254 Prelab 7 Inverting Amp in the drawing information box.

   Run your simulation to show two complete output waveforms with enough steps to produce smooth waveforms. (e.g. Run the transient analysis from 0 to 3 ms, with 0.02ms steps.). Use the cursors to identify and measure the maximums and minimums of of the input and output waveforms, and the phase difference. Label the simulation with at least your name and ECE3254 Prelab 7 Inverting Amp. Print the simulation.

   (5 points) Vo = ________________ Vpp, Av = Vo / Vs = ______________ = _____________dB

   Phase difference between input and output = ___________________ (eyeball this)

   (5 points) Print the Pspice schematic and attach the print to this Prelab. (5 points)

   (5 points) Save the simulation results for attachment to the Lab Data Sheet and comparison with the measured Lab results. The simulation print will be graded as part of the Prelab.

ECE 3254
Operational Amplifier I
Laboratory #8
Last Revised: 10-22-2009

OBJECTIVES:

The purpose of this experiment is to study the characteristics of operational amplifiers. We will also see how operational amplifiers, also called op-amps, can be used in circuits as inverting amplifiers, non-inverting amplifiers, and summing amplifiers

EXERCISES:

This laboratory is broken into four parts:

Part I:	Inverting Amplifiers
Part II:	Non-Inverting Amplifiers
Part III:	Voltage Divider Circuit
Part IV:	Summing Amplifier

How to set up your power supplies:

1. Look at the diagram for Part I and note that you need both a plus and minus voltage supply. Before connecting the power supply to the Op Amp, be sure both +/- supplies are set to 15 volts.

2. The power supply ±25V red **+** terminal should be connected to 741 pin 7.
   The power supply ±25V red **-** terminal should be connected to 741 pin 4.
   The power supply ±25V black **COM** terminal must be connected to the circuit ground point (used by the input and output circuits).

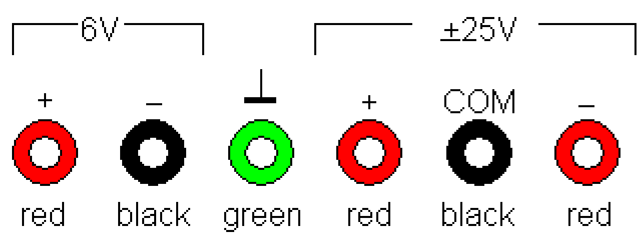
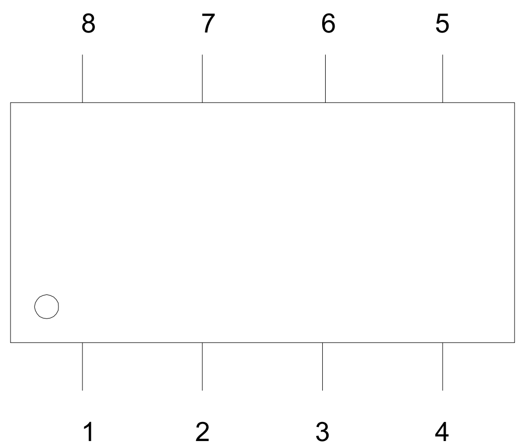


Figure 8-2 Power Supply Output Terminals

3. The V+ and V- always stay at the same pins throughout the experiment. Do not switch them or you will destroy the op amp!

4. When you are ready to turn the power on, always turn the DC supplies on first, then apply the AC signal.

5. To turn the circuit off always remove the AC signal first and then the turn off the DC supply.
   A pin out diagram of the 741 op-amp is shown in Figure 8-3. The smallest and largest pin numbers are adjacent to the notch or dot.



- pin 2 is inverting input
- pin 3 is non-inverting input
- pin 4 is V- supply, pin 7 is V+ supply
- pin 6 is V_o the output voltage
- pins 1 & 5 are offset null connections (not used in this experiment), pin 8 is not used

Figure 8-3 741 OpAmp pin connections

Part I: THE NON-INVERTING AMPLIFIER

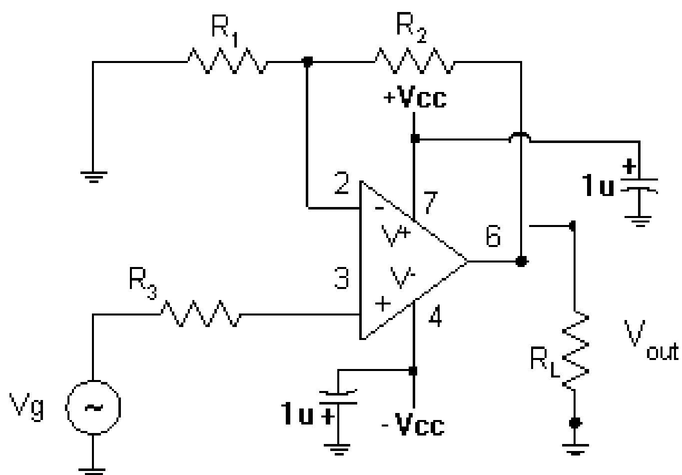


Figure 8-4 Non-Inverting Amplifier

1. Carefully insert the op amp into *right half* of the protoboard so that the 741 straddles the center divider. NOTE: BE CAREFUL so that you do not damage the fragile IC pins.

   Set Vcc = 15V and -Vcc = -15V. DO NOT exceed +15 volts on pin 7 or –15 volts on pin 4
   Monitor V_i and V_o at all times on the scope!

2. Construct circuit of Fig 8-4 with $R_1 = R_2 = 10$ kΩ, $R_3 = 4.7$ kΩ, $R_L = 3.9$ kΩ. Measure and record, on the data sheet, the actual values of your resistors before you construct the circuit. Connect 1μF bypass capacitors from pin 4 to ground and from pin 7 to ground. (These capacitors bypass the power supply connections and reducing both noise and the tendency of the OpAmp to oscillate.)

3. Let V_g = 1000 Hz $1V_{PP}$ sine wave. Monitor V_o and V_g on the scope to ensure no distortion of the output waveform. Use the oscilloscope to measure V_g, V_o, and the output phase, and calculate the voltage gain V_o/V_g. Record your measurements, calculations, and observations on the Data Sheet.

PART II: THE INVERTING AMPLIFIER

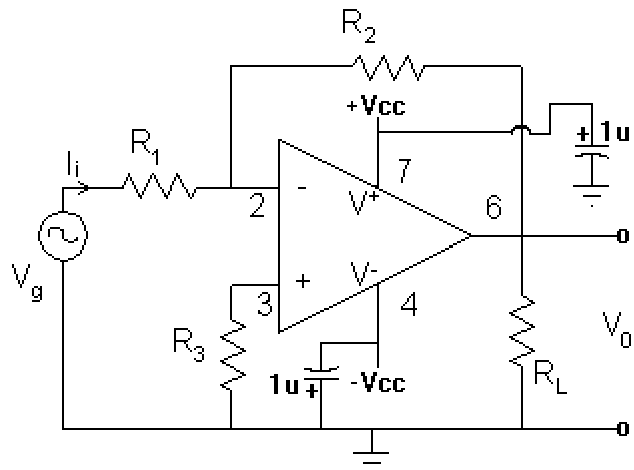


Fig 8-5 Inverting Amplifier

1. Construct the circuit in Figure 8-5. **R_i = 10kΩ Ideal gain Vo/Vg= -10**
R_L = 3.9 kΩ. Set Vcc = 15V and -Vcc = -15V. Use 1µF bypass capacitors.

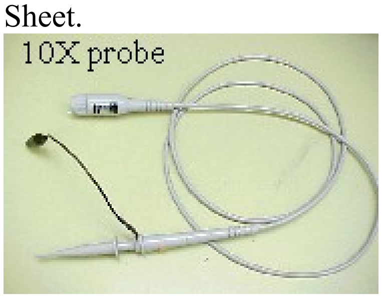
Measure and record, on the Data sheet, the actual values of R_1, R_2, R_3, and R_L before you build the circuit.

Adjust the signal generator V_g for 0.5volts peak (1.0V_{pp}) to obtain undistorted output voltage at 1000 Hz.

2. For f = 1000 Hz sine wave. Use the oscilloscope to measure V_g, V_o, and the output phase, and calculate the voltage gain V_o/V_g. Record your measurements and calculations on the Data Sheet. If your amplifier gain is not close to the expected gain, troubleshoot your circuit before proceeding.

Disconnect V_g , connect the Ohmmeter to the amplifier input, and measure the input resistance, R_i, seen by the source.

3. **Reconnect the signal source** and use a 10X probe to measure the voltages from the inverting input (pin 2) to ground and from the non-inverting input (pin 3) to ground. A 10X probe increases the 1 MΩ scope input to 10 MΩ at the probe tip. When the probe resistance is increased, the loading effect of the probe on the high impedance op-amp input pins is reduced. The probe also divides the voltage by 10 as the signal is transferred from the probe tip to the scope input. A small metal pin on the probe's BNC connector tells the scope to automatically scale the displayed waveform. You can verify that the scope is correctly scaling the waveform by pressing the input button for the channel to which you have attached the probe; you should see Auto Probe 10:1 in the lower right corner of the display. **Autoscale the scope to display the waveform.** Record your measurements on the Data Sheet.



PART III: VOLTAGE DIVIDER

(TURN OFF DC SUPPLY DURING ALL CONSTRUCTION)

1. Leave the inverting amplifier on the right side of the protoboard and construct the voltage divider given in Figure 8-6 on the left side of your breadboard.

   Note: You need to change the power supply voltages to +12 and -12V.

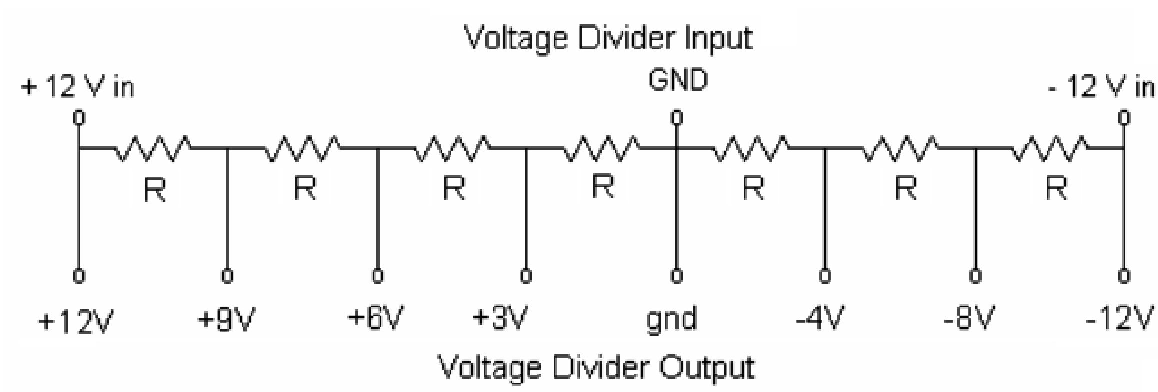


Figure 8-6 Voltage Divider Circuit

2. Use R = 100 Ω. Measure and record your voltages at each point with respect to ground, and verify the above values to within 10%; if they are not, troubleshoot your circuit.

   Leave this circuit intact and use it to supply the required voltages in Part IV.

PART IV: SUMMING AMPLIFIER

1. Construct the circuit in Figure 8-7.

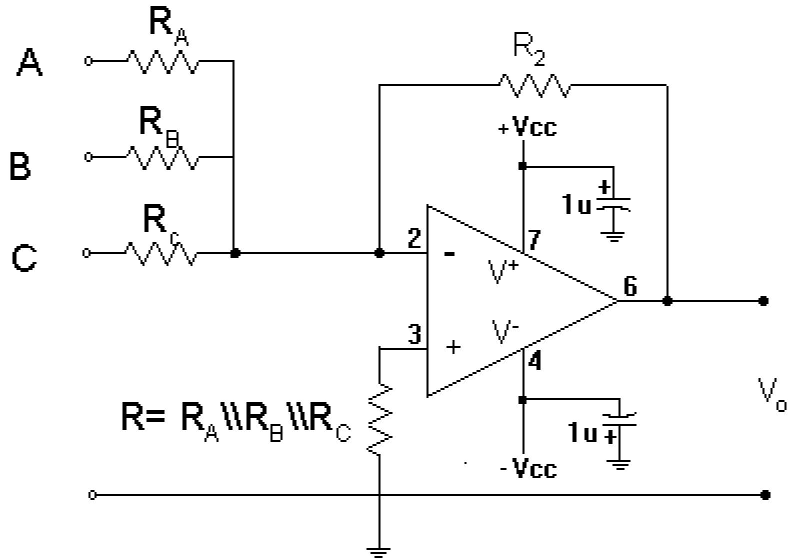


Figure 8-7 Inverting Summer Circuit

2. Let $R_A = R_B = R_C = R_2 = 8.2\ k\Omega$, and R= 2.7K (the equivalent value for a parallel combination of R_A, R_B, and R_C). Use +Vcc =12V and -Vcc = -12V **(note the voltage change!** These can be taken from the voltage divider connection**).**

   Now, using the voltage divider constructed in Part III, measure and record V_O for various combinations of input voltages.

3. Summer operation is not limited to DC voltages. Let V_B = 3 VDC, and V_C =-4 VDC. Use the function generator to set $V_A = 3\text{Sin}(2\pi 2000t)$. Be Careful here… $3\text{Sin}\omega t$ = ?? Vpp. Use a BNC-T to feed V_i to Scope Channel 2 for phase measurement.

   Calculate the equation of the output signal you would you expect to see. Record this equation on the Data Sheet.

   Using $V(t) = A + B\sin(2\pi ft)$, determine and record, on the Data Sheet, the expected values for A, B and f.

4. Measure the summer output with scope CH1, and use a BNC-T to feed $3\text{Sin}(2\pi 2000t)$, from the function generator, to scope CH2 for a phase reference. Use the scope "Quick Measure" to determine the summer output. Record your results on the Data Sheet.

   Capture the input waveform from the function generator and the summer output waveform as a jpeg. Position the cursors to measure the maximum and minimum of Vo. Print the jpeg. Title your print, label the generator and output waveforms, write your name(s) on the print, and attach the print to your Data Sheet.

5. (5 points) Shut down Windows, return cables to racks, return parts to correct drawer bins, return adapters to container, turn off bench power, clear bench, and place seat under bench.

ECE 3254 Lab 8 Data Sheet **Date**______________ **Bench**_________
100 points total
Names: ________________________ ______________________ ______________________
by first name: 2nd alphabetically – wiring 3rd alphabetically – Labview 1st alphabetically– data sheet

PART I: THE NON-INVERTING AMPLIFIER

2. Measured resistor values R_1 = ________, R_2 = __________, R_3 = _________, R_L = ________

3. V_g = _________ V_o =_________ Phase = __________ V_o / V_g = __________

From the Prelab: V_O/V_g = _______________(eq) **=** __________ (value for R_1=R_2=10k)

Compare your measured gain with the predicted gain and explain any differences between expected and measured results.

PART II: THE INVERTING AMPLIFIER

1. ***From Prelab:*** R_1= ____________, R_2=___________, R_3=_____________

Measured resistor values R_1 = ________, R_2 = __________, R_3 = _________, R_L = ________

2. V_g = _________ V_o =_________ Phase = __________ V_o / V_g = __________

Measured R_i = ____________

How do the measured output voltage, gain and phase compare to the design values and Pspice simulations?

R_i should be equal to the measured value of R_1. Calculate the % error and explain what is responsible for this error. (Hint: see prelab notes)

3. Invert Input voltage (Pin 2) = ________mV_{PP}, Average voltage = ___________ mV

Non-invert Input voltage (Pin 3) =________ mV_{PP} , Average voltage=___________mV

Compare these measured voltages. They should be equal and have no voltage; why aren't they?

PART III: VOLTAGE DIVIDER

2. Actual voltage produced by the voltage divider

+12 V	____________	- 4 V	____________
+ 9 V	____________	- 8 V	____________
+ 6 V	____________	- 12 V	____________
+ 3 V	____________		

PART IV: SUMMING AMPLIFIER

2. ***From the prelab***, V_O =

What functions will the OpAmp circuit be performing?

	Measured V_O	Expected V_O
If V_A = 3V, V_B = 3V, V_C = 3V, then V_O =	____________	___________
If V_A = 3V, V_B = 6V, V_C = -4V, then V_O =	____________	___________
If V_A = -8V, V_B = 6V, V_C = 0V, then V_O =	____________	___________
If V_A = 9V, V_B = 6V, V_C = 3V, then V_O =	____________	___________

In the last case, why doesn't $V_O = -(V_A + V_B + V_C) = -18V$? (Hint: see the prelab notes)

3. Expected output signal equation =

Expected A = ________, B= _________, f = ___________

4. Vpp = _____________ Frequency = _______________ Phase = _____________

Vmax = ____________ Vmin = ___________ DC offset = ___________

From the results above, your measured values for A, B, and f are:

A = _____________ B= _______________ f = _______________

Do the measured results match your expected output? If not, what was unexpected, and what would explain the difference(s)?