Pre-Laboratory Assignment

1. Consider the circuit of Figure 1. Using hand analysis, find \( V_{\text{out}} \) as a function of a variable voltage source \( V_{\text{in}} \) assuming that the operational amplifier is not saturated (thus there is negative feedback and the op-amp input node voltages track each other, that is \( V_+ = V_- \)). What is the voltage gain \( V_{\text{out}} / V_{\text{in}} \) of this amplifier circuit?

2. Use your SPICE engine to plot \( V_{\text{out}} \) as a function of \( V_{\text{in}} \) as \( V_{\text{in}} \) is varied from -1.5V to 1.5V. The NationalSemiconductorModels.lib file can be downloaded on the course website and includes a National Semiconductor SPICE model for the LM741 operational amplifier. Place this file in the same directory as your SPICE file. Identify the input voltage range for which the amplifier is in its linear region of operation. Verify the gain calculated in pre-laboratory part 1; place a copy of your graph (as usual) in your laboratory notebook. Explain any differences between your result of pre-laboratory part 1 and your simulation results.

3. Consider the electronic voltmeter of Figure 2. Find the value of \( R_1 \) to make a 10V full scale voltmeter. The meter movement deflection shows the value of \( V_{\text{in}} \).

4. Review your results from part 8 of LAB 3 Basic DC Meter Design.
Procedures

Part One

1. **Make sure there is nothing connected to the variable dual DC power supply.** Turn on the supply and set the supply to provide +12V and -12V. Set the current limit for both supplies to 50mA (this will limit the current in case a circuit is incorrectly wired). Turn the supply OFF.

2. **Make sure that all power supplies are OFF** and construct the circuit of Figure 1. Have your lab instructor inspect your circuit **BEFORE** applying power. Use the variable dual DC power supply of step 1 as the +/-12V supplies. Your lab instructor will show you how to use the waveform generator as variable DC source \( V_{in} \).

3. Carefully record measurements of \( V_{in} \) and \( V_{out} \) as \( V_{in} \) is varied from -1.5V to 1.5V in steps of 0.5V. Use a table. Plot the experimental data points on your curve produced in pre-laboratory part 2.

4. Connect oscilloscope CH 1 to \( V_{in} \) and CH 2 to \( V_{out} \). Set the waveform generator to produce a -1.5V to 1.5V triangle waveform. Place your oscilloscope in XY mode. Adjust the settings to display the voltage transfer characteristic. Compare to the result of pre-laboratory part 2.

5. Set the waveform generator to produce a DC voltage of 0V.

6. **TURN OFF THE WAVEFORM GENERATOR AND POWER SUPPLY. DO NOT DISASSEMBLE YOUR CIRCUIT.**
Figure 3. Electronic Voltmeter Wiring Diagram

Part Two

7. Verify the value of R1 for your voltmeter design with your lab instructor. Set a resistor substitution box to the value of R1.

8. As always, be sure the circuit power is OFF. Modify your circuit realization of Figure 1 to create the circuit of Figure 2 as follows (a wiring diagram is provided in Figure 3). Replace R1 with the resistor substitution box. Replace R2 with the meter movement INSURING THAT THE METER MOVEMENT POLARITY MATCHES THE FIGURE.

9. Have the lab instructor check your circuit before proceeding.

10. Apply power to the electronic voltmeter and turn on the waveform generator. Set $V_{\text{in}}$ to 1V
using the waveform generator and check that the operational amplifier output voltage $V_{out}$ is 1V. Do not continue until this is working.

11. Briefly press the meter movement button. Verify that the meter movement deflects. Do not continue until this is working.

12. Now set $V_{in}=10V$. Hold in the meter movement button. If the meter deflection is not full scale ask your lab instructor to help you make SMALL adjustments to R1 to calibrate the meter. **DO NOT** do this on your own.

13. Repeat part 8 of [LAB 3 Basic DC Meter Design](#) using your electronic voltmeter by connecting two 100k ohm resistors in series between the 12V supply and circuit ground. Measure and record the value of the voltage across the grounded 100k ohm resistor using your electronic voltmeter and digital multimeter (it should be about 6V). Also record the value measured by the basic voltmeter design of Lab 3.

**Analysis**

1. Find the percentage error between the calculated, simulated, and experimental gain for the amplifier circuit of Figure 1.

2. Why doesn’t the resistance of the meter movement affect the value of R1 in the electronic voltmeter? Is this good or bad?

3. How does the performance of the electronic voltmeter compare to the basic voltmeter of [LAB 3 Basic DC Meter Design](#) as recorded in part 10? What is the reason for this difference?

4. What is the primary advantage of your electronic voltmeter of Figure 2 as compared to the basic voltmeter designed in [LAB 3 Basic DC Meter Design](#). What is the primary disadvantage?

**Credits and Copyright**

Adapted from material developed by current and former ECE faculty, including Professor Joseph Kelemen. Reza Khani, Yazid Al Kraimeen, and Juan Villanueva contributed to the development of this lab.

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