Pre-Laboratory Assignment

1. Consider the circuit of Figure 1. Using hand analysis, find \( V_{out} \) as a function of a variable voltage source \( V_{in} \) 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 \( V_{out} / V_{in} \) of this amplifier circuit?

2. Use LTspice® to plot \( V_{out} \) as a function of \( V_{in} \) as \( V_{in} \) is varied from -1.5V to 1.5V. The NationalSemiconductorModels.lib file can be downloaded from 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 linear operation of the amplifier. Verify the gain calculated in pre-laboratory step 1; place a copy of your graph (as usual) in your laboratory notebook. Your gains should closely match.

![Non-Inverting Voltage Amplifier](image1.png)

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 \( V_{in} \).

4. Review your results from the Basic DC Meter Design laboratory procedures step 16 where the voltage across a 100kΩ resistor was measured.
Procedures

Non-Inverting Amplifier

1. **Make certain nothing is 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 5mA (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. The drawing of Figure 3 will be useful if you note that in this case the meter movement and resistor substitution box are simply resistors. Have your lab instructor inspect your circuit **BEFORE** applying power. Use the variable dual DC power supply of laboratory procedures step 1 as the +/-12V supplies. Your lab instructor will show you how to use the waveform generator as the 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 step 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 step 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.**
Electronic Voltmeter

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 construct the circuit of Figure 2 as shown in Figure 3. R1 is replaced with the resistor substitution box. R2 is replaced with the meter movement. **ENSURE 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 \( V_{\text{out}} \) is approximately 1V (the voltage across the meter movement should be low). 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 \( V_{\text{in}}=10V \). Hold in the meter movement button. If the meter deflection is not full scale ask your lab instructor to help you make \textbf{SMALL} adjustments to R1 to calibrate the meter. \textbf{DO NOT} do this on your own.

13. Use your electronic voltmeter to measure \( V_1 \) in the circuit of Figure 3 of the Basic DC Meter Design laboratory using your electronic voltmeter by connecting two 100k ohm resistors in series across 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 the Basic DC Meter Design laboratory procedures step 16b.

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 DC Meter Design voltmeter as investigated in laboratory procedures step 13? 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 the Basic DC Meter Design laboratory? 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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