Linear Operational Amplifier Circuits

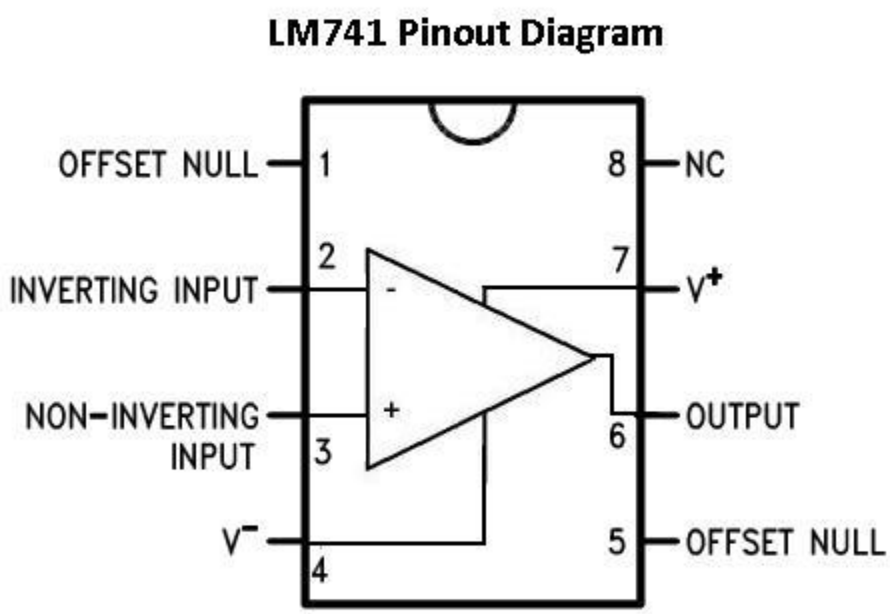
Objective

The goal of this lab is to become proficient in the use and design of several opamp circuits. You will learn to recognize and measure several non-idealities of opamps. Finally, you will design a very useful opamp circuit, the instrumentation amplifier, and take an EKG with it.

Background Information

A. Opamps require positive and negative power supplies. Sometimes the negative supply is ground. If the negative supply is ground, we call that single-supply operation and another ground, sometimes called the analog or signal ground, is introduced halfway between the two rails. In this lab, the positive supply (called V_{DD} or V_{CC}) will be +12 Volts. The negative supply (called $-V_{DD}$, V_{SS}, $-V_{CC}$, or V_{EE}) will be -12 Volts. Thus, analog, or signal, ground equals 0V, which is very convenient.

B. Download the LM324 opamp data sheet from National Semiconductor before coming to lab. Note that the data sheet **assumes** the negative rail will be Ground (pin 11), but we will attach it to V_{SS}. In addition, the output voltage swing specified assumes the negative rail is ground.



Pre-lab Questions 1 (5 pt)

Define the parameters below and give typical values for the LM324 opamp. All of them are summarized on the 1st page under the heading "Features."

1. Unity-gain frequency, f_t
2. Slew-rate, in units of V/μs (**typically 0.5 V/μs for the LM324, omitted on data sheet**)
3. Input-offset voltage, v_{os}
4. Output voltage range, assuming +/- 12-Volt supplies (see notes A. and B. above)
5. DC voltage gain, A_0, in dB

Pre-lab Questions 2 (5 pt)

1. Draw and design an inverting amplifier with a gain of –16V/V.
2. Attach a capacitor of value 0.22μF in parallel with the feedback resistor of your inverting amplifier. At what frequency will the gain be down by 3dB?
3. Draw and design a noninverting amplifier with a gain of 20V/V.

Exercise I: Inverting Amplifier and Output Distortion (40 pt)

The objective of this exercise is to design and build an inverting amplifier. In addition, we explore output distortion due to saturation and slewing.

A. Design an inverting amplifier with gain equal to -8.0 V/V (+/- 5%). Measure the resistor values. Draw the circuit and calculate the expected gain of your amplifier.

B. Using a 500-Hz sinusoid with 500-mV amplitude as the input, plot input and output waveforms from the scope. Take precise amplitude measurements using the DMM. Compare the measured gain with theory using %error. Simulate the circuit in TopSpice

C. Increase the input amplitude until you clearly see distortion in the output signal. Plot the input and output waveforms from the scope. What is the output signal peak-to-peak amplitude when this distortion occurs? ***Note:*** *use scope cursors for this measurement, since the DMM measures RMS and not distortion. Set the scope to DC coupling and check the ground level.* Compare or relate this value to part 4 of the pre-lab quiz.

D. Decrease the input amplitude until the distortion in part C disappears. Now increase the input frequency until you clearly see another type of distortion. Plot the input and output waveforms. Use scope cursors to measure the positive and negative slopes of the output, avoiding crossover distortion. Compare these values to part 2 of the pre-lab quiz.

Exercise II: Non-Inverting Amplifier and Opamp Non-idealities (40 pt)

The objective of this exercise is to construct a non-inverting amplifier with moderate gain. Using this amplifier, we will investigate two more non-idealities of the opamp.

A. Design a non-inverting amplifier with a gain of 20 (+/-5%). Measure the resistors used. Draw the circuit below and calculate the expected gain.

B. Using a 2-kHz sinusoid with 100-mV amplitude as the input, plot the input and output waveforms from the scope. Measure the gain with the DMM and compare to theory. Simulate the design in TopSpice.

C. Increase the input frequency until the output voltage begins to drop. At what frequency is the gain reduced by 3-dB? Draw the input and output waveforms at that frequency **on the same graph**. Relate the frequency to part 1 of the pre-lab quiz.

D. Detach the function generator and ground the input signal. Measure the DC output voltage using the DMM. Draw an equivalent circuit that explains the measured output voltage. Compare or relate your model to part 3 of the pre-lab quiz.

Exercise IV. Summary and Discussion. (10 pt)

The objective of this exercise is to summarize and discuss this 2-week lab. Write approximately one page, using one-and-a-half line spacing, 12-point type (like this document). Include:

- An introductory paragraph that describes the main objectives of the laboratory, listing the major exercises you did.
- One or two paragraphs discussing several things that you learned, such as a new measurement technique or a new troubleshooting technique. Of particular interest are things that you struggled with, e.g., a bad component or wire that needed to be changed, a blown fuse in the DMM, etc.
- A final paragraph that considers how things that you did or learned in the lab could be applied in the electronics industry, e.g., in a new product, in an existing product, in an industrial lab, etc.