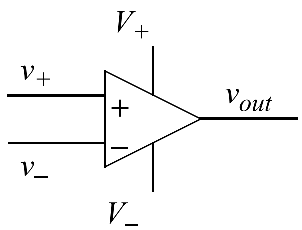
Physics 395, Laboratory 12
Operational Amplifiers

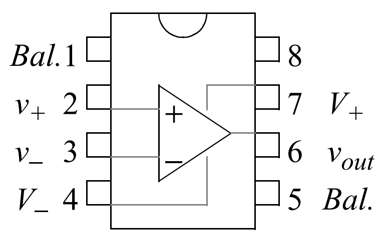
Overview

The purpose of these experiments is to measure the basic parameters of an operational amplifier, including gain, bias, and noise rejection, and to use operational feedback to form an amplifier.

Background

An operational amplifier (op-amp) is a differential amplifier with very high gain, very high input impdance, and very low output impedance. The 741A op-amp is an integrated circuit thaat comes in an 8-pin dual in-line package (DIP). The connections for the chip looking down with the notch facing up is:





The op-amp is specified as an amplifier by the gain A_0, input impedance Z_{in}, and output impedance Z_{out}. The op-amp also has specifications as a differential amplifier for the input bias current I_B which is the average input current, an input offset current I_{io} which is the difference in input currents, and an input voltage offset V_{io}. The behavior of the op-amp is $V_{out} = A_0(v_+ - v_-)$. For large gain, low input current amplifiers used with feedback to the negative input there are two rules to follow:

1. **$I_+ = I_- = 0$.** *The input currents are 0.*
2. **$v_+ - v_- = 0$.** *The input voltage difference is 0.*

1. Op-Amp Parameters

Connect a 741A op-amp on the Powerace breadboard, and use the +15 V and -15 V suppies to power the chip.

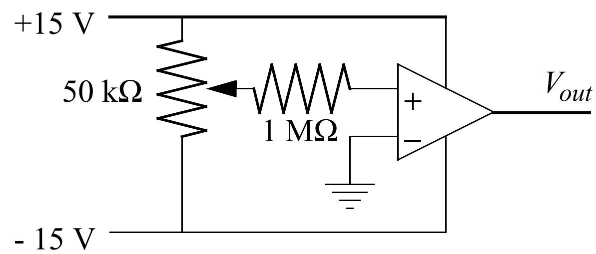


Figure 1: Op-Amp Parameter Measurement

Use the DMM to measure the voltage V_{out} as a function of v_+. How close to 0 V can v_+ be and still have V_{out} at the maximum or minimum. Estimate the minimum value of the gain A_0. Measure the voltage difference across the 1 MΩ resistor and estimate the maximum current flowing into the op-amp. How well does the op-amp satisfy the requirements of no input current and very large gain?

2. Amplifier Bias and Offset

Wire the op-amp with power supplies of +/- 15 V to form an inverting amplifier as shown.

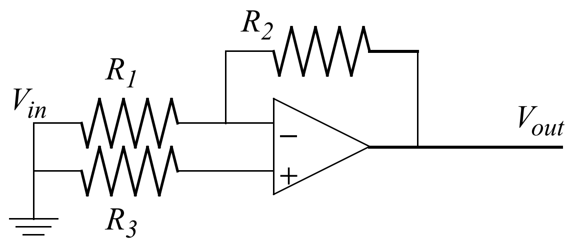


Figure 2: Amplifier Bias and Offset

Use the DMM to measure V_{out} and any resistors used in this part. Begin with values of R_1 = 1 kΩ, R_2 = 100 kΩ, and R_3 = 0 Ω. Measure V_{out} again with R_1 = 10 kΩ, and R_2 = 1 MΩ. Use the follwo-ing equation and the two measurements of V_{out} to determine V_{io} and I_B.

$$V_{out} = -\frac{R_2}{R_1}V_{in} + \left(1 + \frac{R_2}{R_1}\right)V_{io} + I_B R_2$$

Use a value of R_3 equal to the equivalent parallel resistance of R_1 and R_2, and repeat measure-ments of V_{out} for both sets of resistors R_1 and R_2 used before. The equation is now:

$$V_{out} = -\frac{R_2}{R_1}V_{in} + \left(1 + \frac{R_2}{R_1}\right)V_{io} + I_{io} R_2$$

Solve for V_{io} and I_{io}. Add a 50 kΩ potentiometer between pins 1 and 5 of the chip with -15 V on the center tap, and adjust the potentiometer until V_{out} = 0 V. Measure V_{io} and I_{io} again.

3. Amplifier Noise Rejection

Use the circuit from the end of part 2 and use the DMM on AC mV to measure output noise v_{out}. Replace the +15 V supply from the Powerace and use the variable power supply instead. Measure on a DC scale. Graph V_{out} as a function of the power supply voltage and determine the power supply rejection ratio (PSRR) = $\Delta V_{out}/ \Delta V_{CC}$ in dB.

4. Inverting Amplifier

Build the circuit in figure 3 with +/- 15 V supplies and use sine waves of the minimum output voltage (using the -20 dB switch) for v_{in}.

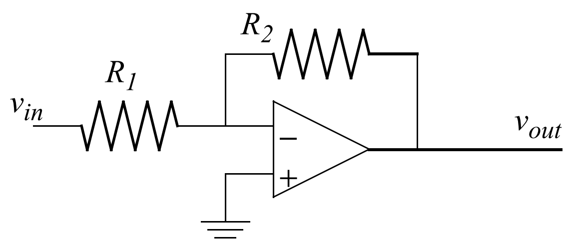


Figure 3: Inverting Amplifier

Measure v_{in} and v_{out} with the DMM set for AC volts (or mV). Use R_1 = 1 kΩ, and R_2 = 100 kΩ, and measure the gain A as a function of the frequency f for 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz. Graph A in dB vs $\log_{10}(f)$. Measure Z_{in} and Z_{out} at 100 Hz and at 100 kHz.