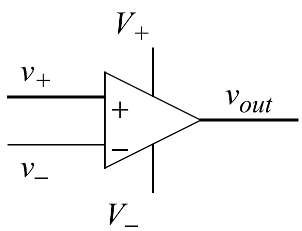
Physics 375, Laboratory 12
Operational Amplifiers

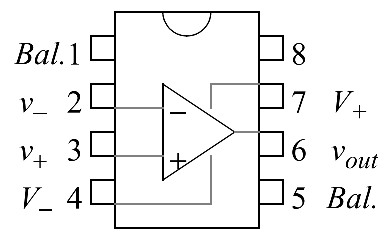
Overview

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, high input impedance, and very low output impedance. The 741 op-amp is an integrated circuit that 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. Inverting Amplifier

Build the circuit in figure 1 using $V_+ = +15$ V and $V_- = -15$ V for the op amp. Use sine waves of 0.1 V amplitude (or as small as is measurable) for v_{in}.

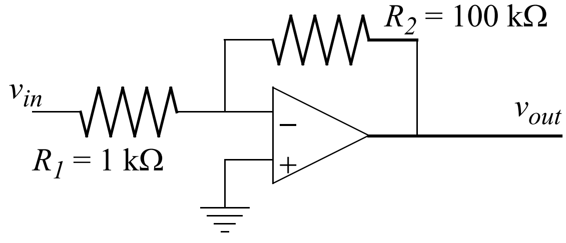


Figure 1: Inverting Amplifier

Measure v_{in} and v_{out} with the DMM set for AC volts (or mV). 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 $\log_{10}(f)$ to make a Bode plot.

2. Amplifier Bias

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

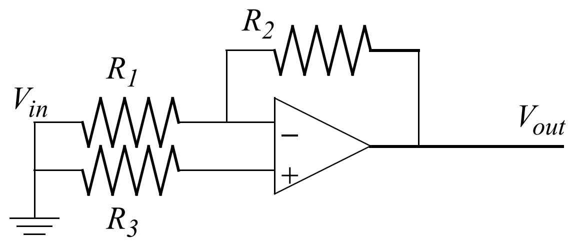


Figure 2: Amplifier Bias and Offset

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 (ie. a wire). Measure V_{out} again with R_1 = 10 kΩ, and R_2 = 1 MΩ. Both measurements use the following equation,

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

The two sets of resistors and measured voltages gives two versions of the equation with V_{io} and I_B as unknowns. Solve the two equations to get values for the unknowns V_{io} and I_B.

3. Amplifier Offset

Replace the wire at R_3 in figure 2 with parallel resistors equal to R_1 and R_2. Repeat measurements of V_{out} for both sets of resistors R_1 and R_2 used in part 2. 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} using the two sets of measurements as in part 2.