Lab 7
Operational Amplifier Applications I

Purpose

This lab studies some of the basic uses of op amps. Because the main use of the op amp is as an amplifier, the three most common configurations will be studied. These include the inverting, non-inverting, and differential amplifier circuits. The lab will also investigate powering an op-amp from a single supply.

Material and Equipment

741 Op Amp, 5 k pot
Assorted Resistors (2k, 39k)

Theory

The primary use of the operational amplifier is as signal amplifier. By using feedback, operational amplifiers can be designed to have a wide range of gains. The op-amp draws very little current into its inputs. This means that the input impedance looking into the inverting and the non-inverting inputs is very large. The open-loop gain is also very large. Assuming the open-loop gain is infinity, we can show that the voltages at the inverting and the non-inverting terminals should be approximately the same (potential) at all the times. Because of this, we say that the two terminals "track" each other. Based on these assumptions, a simple procedure for op-amp analysis can be formed.

Once the op-amp is integrated into a circuit, it can be easily analyzed through the following steps:

- Write the node equation at the inverting terminal.
- Write the node equation at the non-inverting terminal.
- Set the voltage at the inverting terminal equal to the voltage at the non-inverting terminal.
- Solve for the gain.

Inverting Amplifier
One of the most common operational amplifier designs is the inverting amplifier (Figure 7-1). This amplifier can be analyzed by using the above procedure. Remember, no current flows into the op-amp terminals.

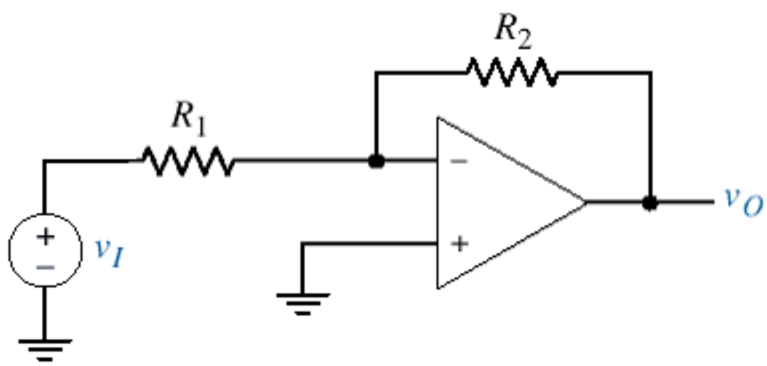

Figure7-1: The inverting amplifier configuration.

The gain of this amplifier is:

$$A_v = \frac{v_O}{v_I} = -\frac{R_2}{R_1}$$

This means that the gain is completely determined by the external resistors as we expected. The negative gain is why the circuit is called an inverting amplifier. This amplifier has an input resistance of approximately R_1.

Non-inverting Amplifier
Another common op-amp configuration is the non-inverting amplifier (Figure 7-2). This amplifier has very high input impedance and does not invert the signal.

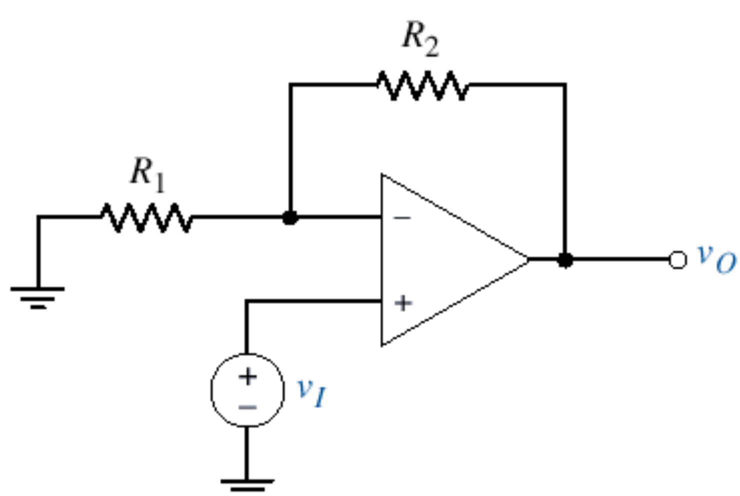

Figure 7-2 : the non-inverting amplifier configuration.

The gain of the non-inverting amplifier is:

$$A_v = \frac{v_O}{v_I} = 1 + \frac{R_2}{R_1}$$

Unity Gain Source Follower
A special case of the non-inverting amplifier is the source follower. In this case, we let the ratio of Rf/Rg go to zero. This is done in practice by replacing Rf with a short circuit and replacing Rg with an open circuit.

The gain of the amplifier is:

$$A_v = \frac{v_O}{v_I} = 1$$

This configuration has the properties of having very high input impedance, very low output resistance, and unity gain. It is used as a "buffer" to isolate a source from its load. It is very useful amplifier for the instrumentation circuits.

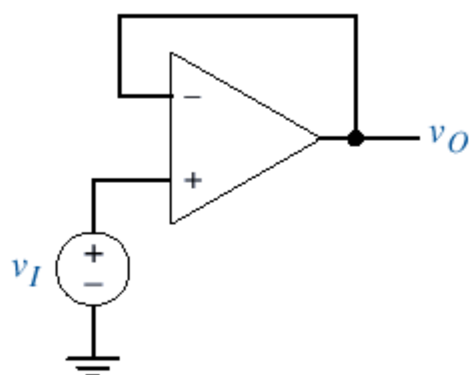

Figure 7-3: The source follower buffer circuit.

Procedure

1) Inverting Amp
   a) Construct an inverting amplifier with R_1=2k, R_2=39k. Calculate numerically value of inverting amplifier gain.
   b) Power the op-amp with +15V and -15V as in last experiment and apply a 1Vp-p, 1kHz sinusoidal input signal to the amplifier.
   c) Increase the input voltage until distortion occurs at the output. Display V_{in} and V_{out} at the same time on the scope. Measure the input voltages V_{in} and V_{out} . From this, calculate the gain of the inverting amplifier. Is this value close to what you have calculated in step 1-a?
   d) Capture the input, output waveforms for your lab report.
   e) Measure the input resistance of the amplifier. In order to do this use 5k resistor (only use the wiper and one end) and put it in series with the R_1 resistor at the input. Adjust the wiper such that the gain reduces to the 50% of the value you measured in step 1-c. When this occurs, remove the pot from the circuit and measure its resistance using a multimeter. This is the value of your input resistance.

2) Non-Inverting Amp , 3) Unity Gain Buffer
   Repeat the above procedure except part e.
   The input resistance of non-inverting and buffer amplifier is infinity for ideal op-amp and for real op-amps this value is very high (see figures 7.2 and 7.3). State why this is true.