ELE339, Electronics I Laboratory

LAB 10 - Operational Amplifier Properties

Pre-Lab

Objective:
Operational amplifiers (op-amps) are versatile building block used in linear and non-linear circuit applications. In this lab, we will investigate some very simple op-amp circuit to reveal specific op-amp features and some practical limitations such as finite gain and bandwidth, offset, slew rate limitations and saturation.

Opamp Basics

Figure 1 shows the symbol for a basic 5-terminal op-amp.

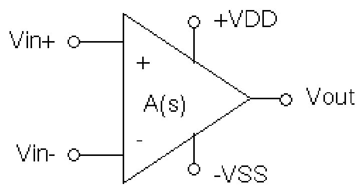

Figure 1: 5-terminal symbol of an op-amp.

If operated in the linear mode, the op-amp acts a differential (voltage) amplifier with very high input impedance, low output impedance and a frequency depended linear gain given by

$$V_{out} = (V_{in+} - V_{in-}) \frac{A_0}{1 + s / \omega_0} \qquad (1)$$

where A_0 is the open-loop gain, ω_0 the corner frequency (in rad/s) and $s=j\omega$ the complex (Laplace) frequency. Typical values for A_0 range from 100,000-1,000,000 while the corner frequency lies somewhere between 10Hz and 100 Hz. Since JFET or MOSFET op-amps feature extremely high input impedances, their input currents are typically neglected. In case the amplifier input voltage becomes too high, the op-amp output will saturated near the respective power rail and thus no longer acts as a linear circuit element. Another non-linear features of the op-amp is the finite slew rate (SR), which introduces harmonic distortion.

Tasks:

1. Consider the linear circuit in figure 2a and find an expression for its transfer function V_{out}/V_{in} if the amplifier gain is given by equation (1). What is the purpose of this circuit?
2. Consider the circuit in figure 2b and find its transfer function for R_1=1kΩ and R_2=10kΩ. Assume A_0=100,000, $\omega_0=2\pi$x50Hz and use a log-log scale to plot **magnitude** and **phase** of this transfer function (Bode plot).
3. Repeat task 2 for the circuit given in figure 2c. What is the difference between circuit 2b and 2c?
4. Circuit 2d, although very similar to circuit 2c, represents a non-linear op-amp application (why?). To find out the purpose of this circuit, assume the input is a triangular voltage of +/- 2V swing and sketch the resulting output voltage if the op-amp saturates at +/- 10V. R_1 and R_2 are 1kΩ and 10kΩ, respectively. To do so, assume the input features a repetition rate of 1kHz. Draw input and output on the same time scale in your sketch.

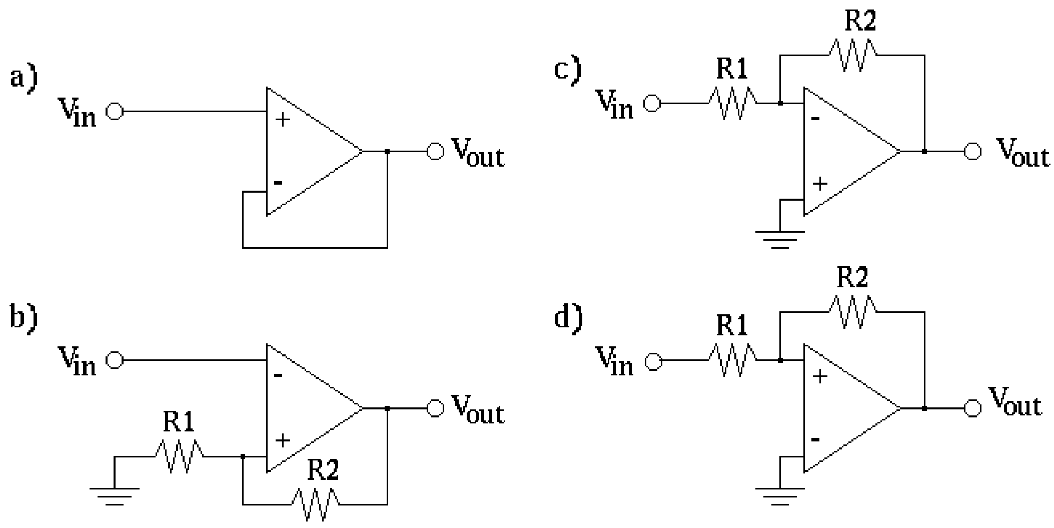

Figure 2: Simple linear and non-linear op-amp circuits.

Experimental

5. Connect an LF356 op-amp as shown in figure 2a on your Protoboard using +/- 10V supplies. Measure its output if the input remains grounded (use the volt meter with a mV scale). What is the significance of the measured output voltage?
6. Observe the output of circuit 2a with the scope if you apply a sinusoidal input of 10V amplitude. Can you explain the observed output waveform?
7. Build circuit 2b on your board using +/-10V supplies and set R_1 and R_2 equal to 1kΩ and 10kΩ, respectively. Connect the input to a sinusoidal source of 0.7V amplitude and observe input and output on your scope while you increase the frequency from 1kHz to 1MHz using 5 steps per decade (what are the 5 numerical frequency values per decade?). Does the resulting output voltage represent a linear mapping of the input? Provide a quantitative answer!
8. Build the circuit in figure 2d using +/-10V supplies and select R_1 and R_2 as specified in task 4. The input is as previously described in task 4 and observe the input and the output on your scope. Does the scope display confirm your prediction? Explain potential differences!