Laboratory 2: Exploring the Basic Properties of Op-Amp

ELEC ENG 2CJ4: Circuits and Systems
Instructor: Prof. Jun Chen

1 Objective

The objective of this lab is for you to become familiar with the basic properties of the operational amplifier circuits.

2 Euqipment

The following equipments are used in this laboratory:

- DC voltage source with positive and negative output(±10V); Oscilloscope; Function signal generator
- Resistors: $10k\Omega\times$ 2, $22k\Omega\times$ 2, $27k\Omega\times$ 2, $100k\Omega\times$ 2
- Op-Amp: LMC358

  LM358 Dual operational amplifier (see Figure 1) consists of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply or split supply over a wide range of voltages.

3 Pre-lab Exercises

The circuit symbol of Op-Amp is shown in Figure 2. There are two input terminals (non-inverting and inverting). The corresponding input voltages are denoted by v_p and v_n, respectively. The output voltage v_0 is equal to the difference of the two input voltages multiplied by the gain A_v (which is a big number)

$$v_o = A_v \times (v_p - v_n). \tag{1}$$

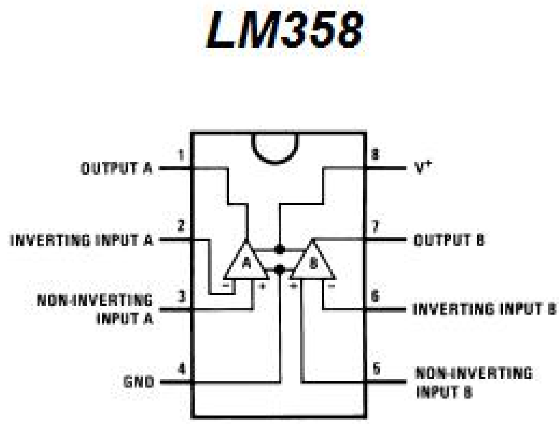

Figure 1: LM358 Dual operational amplifier

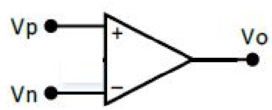

Figure 2: Circuit symbol of Op-Amp

3.1 Circuit Analysis

3.1.1 Analyze the linear active region and the saturation region

The maximum and the minimum output voltages of Op-Amp are limited by the power supplies. This is true for both open-loop, and, as you will find out in the lab, closed-loop configurations. An open-loop configuration is schematically indicated in Figure 3.
Note that the input voltage range (for the linear active region) is given by

$$\frac{-V_{cc}}{A_v} < v_p - v_n < \frac{+V_{cc}}{A_v}. \tag{2}$$

- As a result of the large amplification A_v (say $A_v = 100000$), the input voltage difference (v_p-v_n) must be very small (in order to operate in the linear active region).
- Please analyze and plot the relation between the output voltage v_0 and the input voltage difference v_p-v_n, in which you should mark the linear active region and the saturation region.

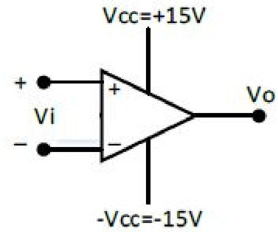

Figure 3: An open-loop configuration

3.1.2 Design and analyze closed-loop circuits

Here we design closed-loop Op-Amp circuits to verify the linearity and nonlinearity of the operational amplifier. Question: Why not use the open-loop circuit directly?

a. Inverting Op-Amp Circuits

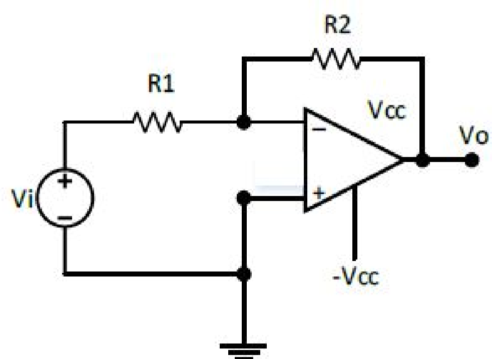

Figure 4: An inverting Op-Amp circuit

b. Noninverting Op-Amp Circuits

Express the gain $A = \frac{v_0}{v_i}$ as a function of R_1 and R_2 for the inverting and the noninverting Op-Amp circuits shown in Figure 4 and Figure 5. Note that this closed-loop gain A is independent of the op-amp open-loop gain A_v.

3.2 Numerical Evaluation

There are two important facts which are useful for analyzing the Op-Amp circuits.

a. The input current is zero.

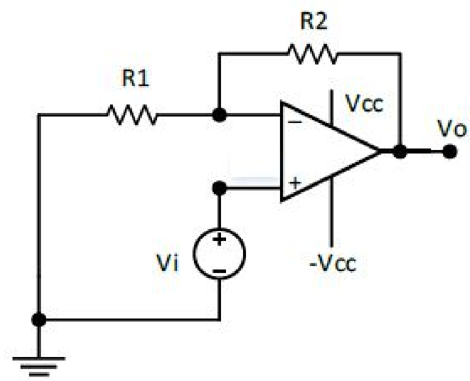

Figure 5: A noninverting Op-Amp circuit

b. The voltage difference between the inverting and non-inverting inputs is zero (when the amplifier is used with negative feedback).

- Suppose $R_1 = 22k\Omega$, $R_2 = 100k\Omega$, $V_{cc}+ = +10V$, $V_{cc}- = -10V$. Determine the linear active region and the saturation region of the inverting and the noninverting Op-Amp circuits shown in Figure 4 and Figure 5.

4 Experiment

In this experiment, construct the Op-Amp circuits in the pre-lab. Use the square-wave output of the function generator to emulate the input signal, where you should only observe the changes of peak to peak magnitude. Suppose $R_1 = 22k\Omega$, $R_2 = 100k\Omega$, $V_{cc}+ = +10V$, $V_{cc}- = -10V$.

- Measure the peak to peak amplitude in scope.
- Compare it with the output of the function generator, and calculate the closed-loop gain A.
- Compare your analytical results with your experimental measures. Depict the linearly active region and the saturation region.
- Include the relevant waveforms in your report.

Repeat the above experiment for the following values: $V_{cc}+ = +5V$, $V_{cc}- = -5V$. Explain your findings.

5 Report

Your report should include the proposed circuits, the relevant theoretical analysis as well as the experimental results.