Background

The objective of this lab is to understand the op-amp and analyze the properties of various circuits that can be built using one. Op-amps allow us to transform two small input voltages into a higher output voltage. A unity-gain circuit was first built using two resistors, one at the negative input voltage and one on the negative feedback from the output, as well as a potentiometer at the output. The voltage amplifier was then analyzed by adjusting the potentiometer to achieve certain output voltage gains. To understand how op-amps could be used as adders and subtractors, we built an adder circuit consisting of two inputs in the negative input, and a subtractor circuit consisting of one input voltage in each of the inputs for the op-amp.

Procedure

Op-amps are amplifiers that take in two input voltages (one negative and one positive) and output a voltage with a larger magnitude than the input voltage. Op-amp circuits are primarily built in two ways: open-loop and closed-loop. This is determined by whether there is a feedback loop from the output voltage into the input voltage.

In an open-loop op-amp circuit, there is no feedback to the input voltage from the output voltage. Input voltages tend to be very small in magnitude compared to the output voltage, so the open-loop gain, A, is typically large in magnitude (and infinite in an ideal case). The op-amp used in this lab has an open-loop gain of $A = 2 * 10^5$. Using this, we can calculate the output voltage using the following equation:

$$v_{out} = A(v^{+} - v^{-}) \qquad (1)$$

where V^+ and V^- are the two input voltages.

However, we are more interested in closed-loop op-amp circuits. These circuits feed the output voltage back into one of the inputs of the op-amp. Figure 1 below shows the closed-loop op-amp circuit for the first and second parts of this lab, which is an inverting voltage amplifier. Since the voltage at the input nodes of the op-amp are no longer small in magnitude in comparison to the output voltage, we can define a new gain, G, the closed-loop gain.

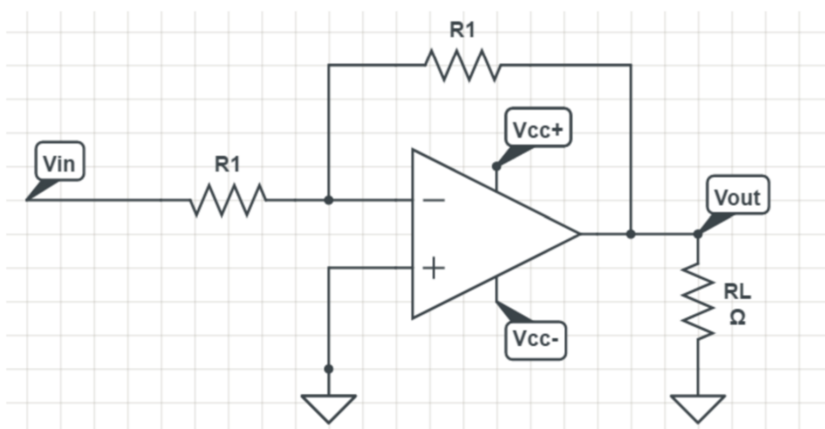

Figure 1: Schematic for Inverting Op-Amp Circuit

We can begin our exploration into the various closed-loop op-amp circuits by starting with an inverter op-amp circuit. By performing nodal analysis on the circuit in Figure 1, we can obtain the following expression for gain for the op-amp:

$$G = \frac{-AR_f}{R_1+R_f+AR_1} \qquad (2)$$

where R_1 is the resistor between V_{IN} and the input node of the op-amp, R_f is the resistor in the feedback loop, and A is the open-loop gain. Since the open-loop gain is typically large in magnitude (and infinite in the ideal case), we can assume:

$$AR_1 \gg R_1 + R_f \qquad (3)$$

and we can assume G is therefore equal to:

$$G = \frac{-AR_f}{AR_1} = -\frac{R_f}{R_1} \qquad (4)$$

In the first scenario, we are looking to achieve unity gain. The term "unity gain" refers to a circuit whose gain is equal to one, meaning the input voltage is equal to the output voltage (in this case, G = -1 since this is an inverting circuit). We can easily see that R_1 and R_f must be equal for this to occur. As a result, we will test this assumption later using equal resistance values of 1 kΩ.

Once we achieve unity gain, we can begin to obtain other values for the gain. We can achieve this by adjusting the resistance value in the feedback loop, R_f. Since R_1 is a fixed value, G and R_f are directly proportional, and to achieve higher gains, we can simply increase the feedback resistance. For example, to achieve a gain of G = 2, we can double the feedback resistance to a value of R_f = 2 kΩ.

The second op-amp circuit that we will explore is the non-inverting op-amp circuit. This is like the inverting op-amp circuit, except V_{IN} is instead applied to the positive terminal of the op-amp instead of the negative terminal. The circuit is shown in Figure 2 below.

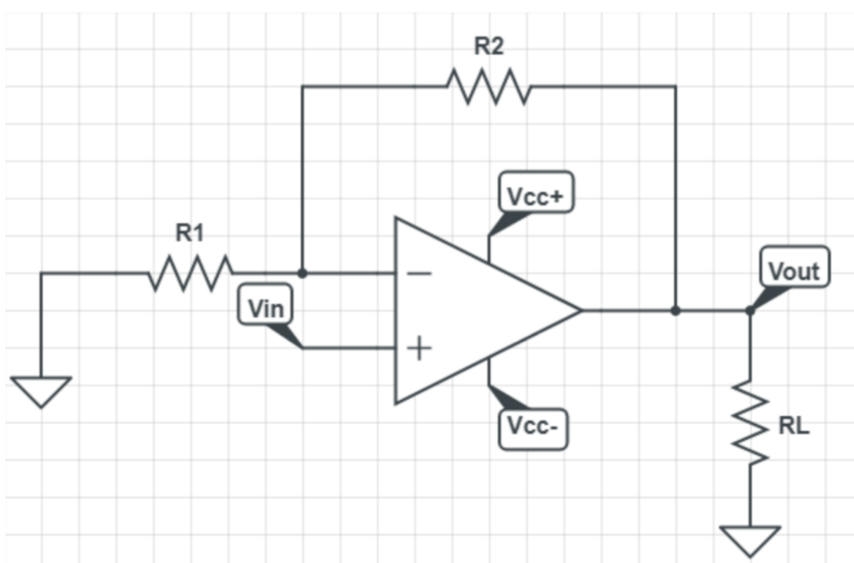

Figure 2: Schematic for Non-Inverting Op-Amp Circuit