Set 1 - Lab Report

Edison He (hee6)

ELECENG 2CJ4 - Circuits and Systems

February 10th, 2025

Introduction

The purpose of this lab is to explore the concepts and behaviors of operational amplifiers, specifically inverting operational amplifiers. This experiment aims to analyze the behaviors of inverting amplifiers in their natural configuration in addition to its limitations under saturation. Some objectives of this lab include to predict its voltage gain, analyzing the output based on different voltage inputs, and the event of saturation where the input voltage is bottlenecked by the supplied voltage. In addition, the lab aims to uncover the relationship between the supply voltage and the gain of the operational Amplifier.

Working Principle of the Circuit

As the name suggests, an inverting operational amplifier inverts the given input voltage. The input voltage is connected to the inverting or negative terminal of the operational amplifier through a resistor. The input voltage is also connected to the output voltage with a resistor which is called the negative feedback. This can be seen in Figure i. Like other operational amplifiers, there is virtually zero current and similar voltage values relative to the virtual ground in each terminal. With input voltage and the negative feedback, the operational amplifier is able to invert the input voltage with a gain of $A_o = -\frac{R_2}{R_1} = \frac{V_o}{V_i}$.

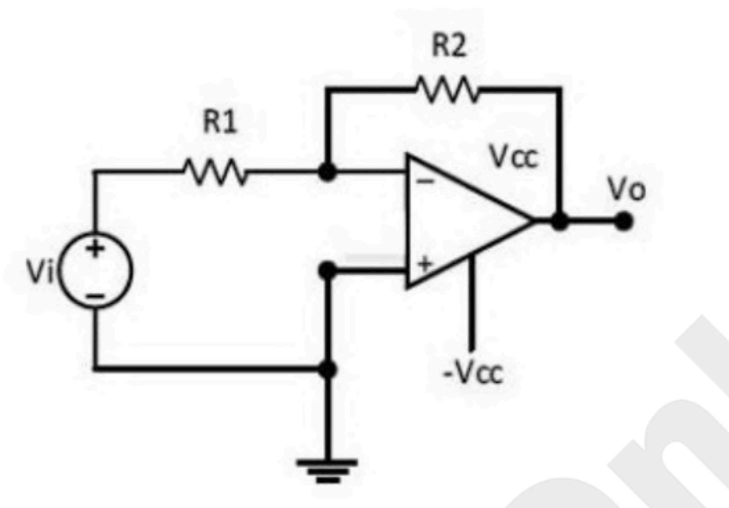

Figure i: Inverting Operational Amplifier Circuit Diagram

1. **Experiment Results**

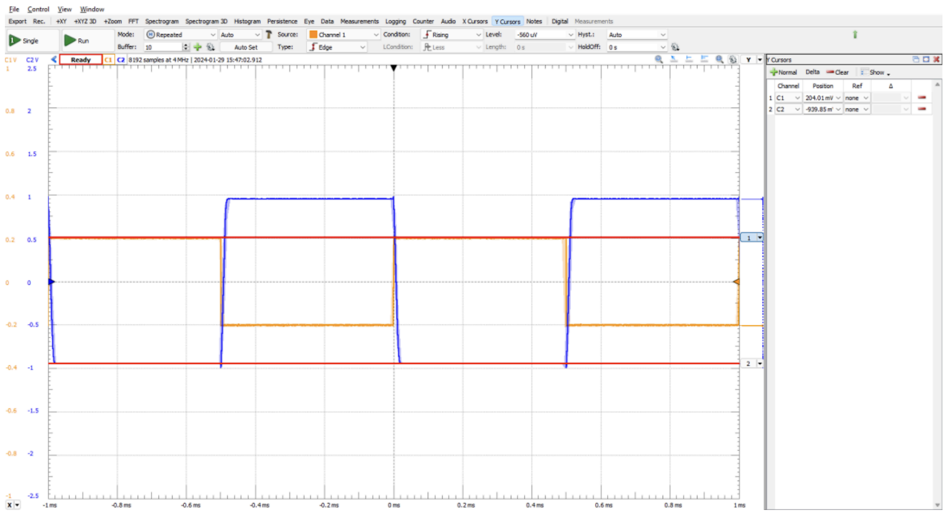

Figure 1: 200 mV Graph

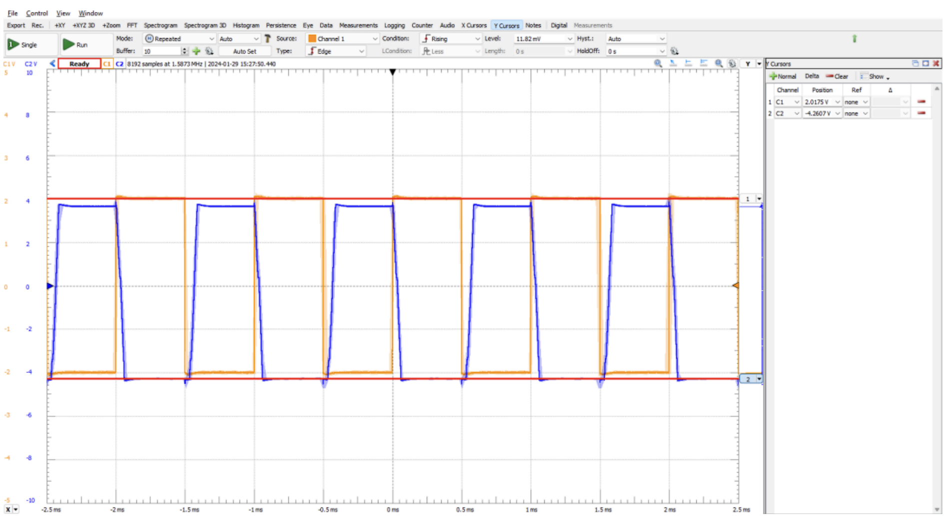

Figure 2: 2V Graph

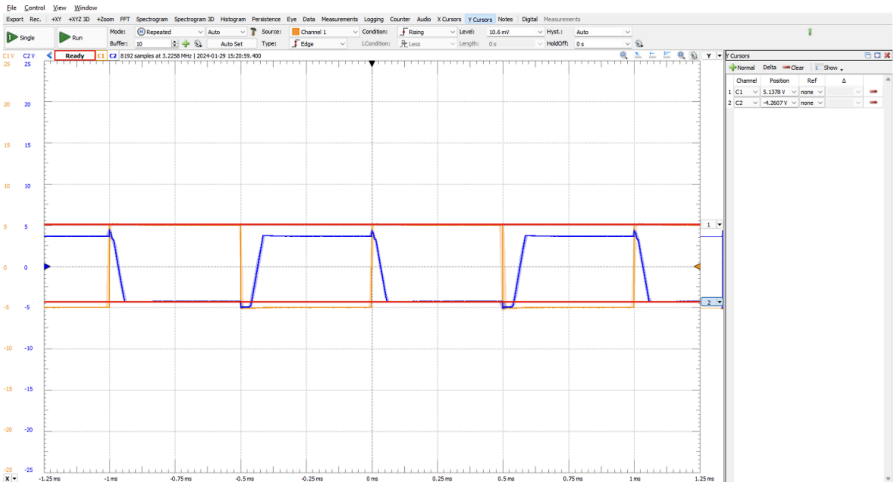

Figure 3: 5V Graph

2. Gain Estimation and Comparison:

a. Theoretical Gain:

$$Inverting\ Amplifier\ Gain\ =\ -\frac{R2}{R1}\ =\ \frac{-47k\Omega}{10k\Omega}\ =\ -4.7$$

b. Experimental Gain

$$Channel\ 1\ = V_o\ =\ 204.02\ mV$$

$$Channel\ 2\ = V_i\ =\ -939.85\ mV$$

$$Experimental\ Gain\ =\ \frac{V_0}{V_i}\ =\ \frac{=939.85\ mV}{204.02\ mV}\ =\ -4.602$$

c. $Percent\ Error\ =\ \frac{Experimental - Theoretical}{Theoretical} \times 100$

$$=\ abs(\frac{-4.602 - (-4.7)}{-4.7}) \times 100\ =\ 2.09\ percent\ error$$

3. $V_{CC} = +2.5V$, $V_{EE} = -2.5V$ Measurement Results

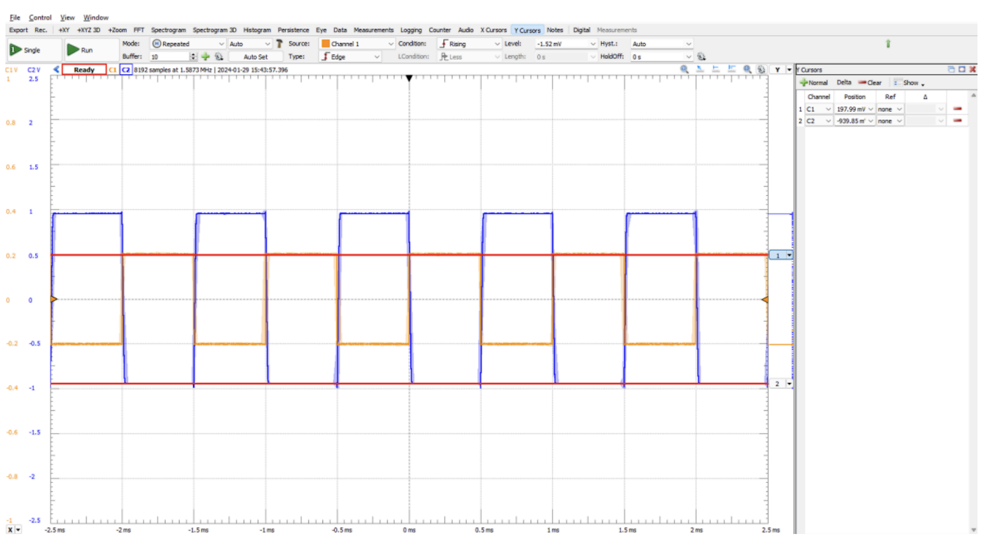

Figure 4: 200 mV Graph

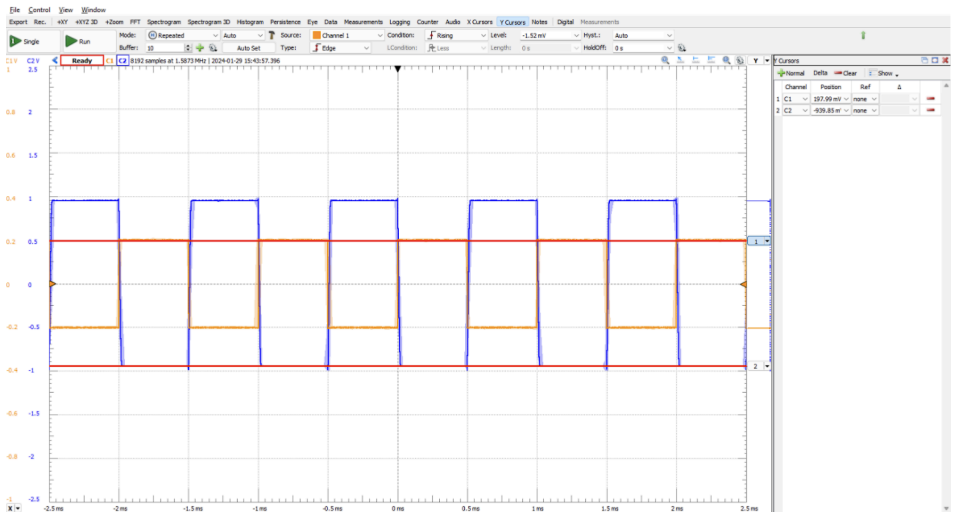

Figure 5: 2V Graph

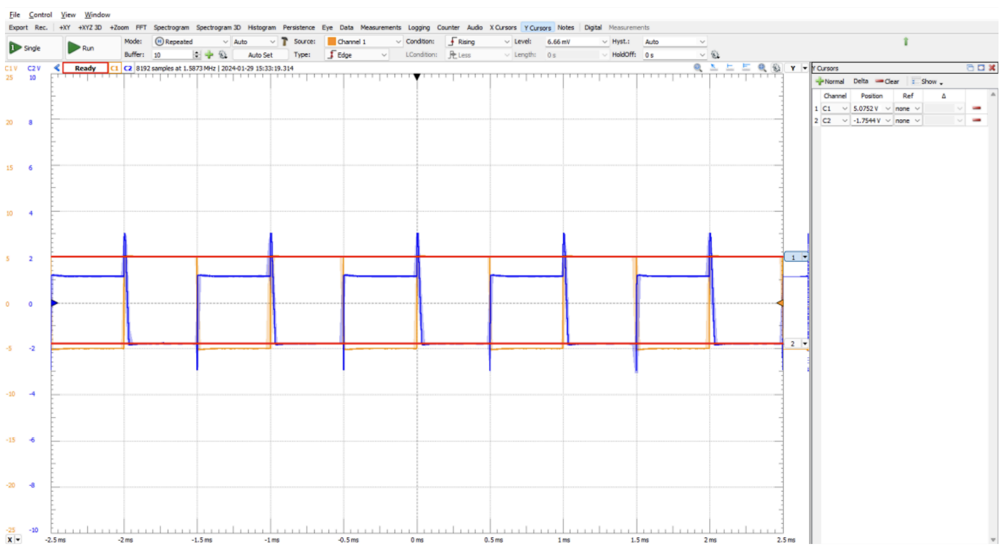

Figure 6: 5V Graph

Experimental Gain:

$$Channel\ 1 \ = V_o \ = \ 197.99\ mV$$

$$Channel\ 2 \ = V_i \ = \ -\ 939.85\ mV$$

$$Experimental\ Gain \ = \ \frac{V_0}{V_i} \ = \ \frac{-939.85\ mV}{197.99\ mV} \ = \ -4.75$$

$$Percent\ Error \ = \ \frac{Experimental - Theoretical}{Theoretical} \times\ 100$$

$$= \ abs(\ \frac{-4.75 - (-4.7)}{-4.7}) \ \times\ 100 \ = \ 1.064\ percent\ error$$

Discussion

In part 2, the theoretical gain and experimental gain for 200 mV is -4.7 and -4.602 respectively. Comparing the experimental value to the theoretical value results in a percent error in 2.09%. However, when the input voltage is increased to 2 and 5 volts, the gain is not similar to the original calculated gains. This is because the increasing voltages exceed V_{CC} and V_{EE}, saturating the operational amplifier. This can be seen in the voltage clips under 5V as the experimental operation amplifier is not ideal.

In part 3, when comparing the theoretical and experimental gains at V_{CC} = +2.5V and V_{EE} = -2.5V, it is seen that there is no change in gain at 200 mV. The percent error yields a small value once again at 1.064% further proving that changing supply voltage does not change the gain of the circuit. However, the decrease in voltage at the supply means the operational amplifier reaches saturation quicker, and the behavior of the gain changes.

In conclusion, the gain of operational amplifiers is not dependent on the supply voltage. This is seen in the inverting operational amplifier gain formula, where voltage is not present. In addition, the experiment yields similar gains for both 5V and 2.5V supplied when compared to the theoretical gain. However, the saturated regions do depend on the supplied voltage. There is only a noticeable change in gain between similar input voltages if the supply voltages are different.