Circuits and Systems 2CJ4

Lab 1

Jenisha Thevarajah – C01 – 400473218
Nandha Dileep – C01 – 400437930

Set 1 Laboratory Experiment

Given the circuit in Figure 8 with R_1 = 10kΩ, R_2 = 47kΩ, $+V_{CC}$ = 5V, and $-V_{CC}$ = -5V, express the gain $A = \frac{Vo}{Vi}$ as a function of R_1 and R_2 and determine the linear active region and saturation region.

I. Build the circuit with the values given and with % being a 1 kHz square wave with amplitudes of 200 mV, 2 V, and 5 V and an offset of 0V, where you should only observe the peak to peak magnitude. Plot V_i and V_o using the oscilloscope tool on the Analog Discovery 2 in the linear active region and saturation region.

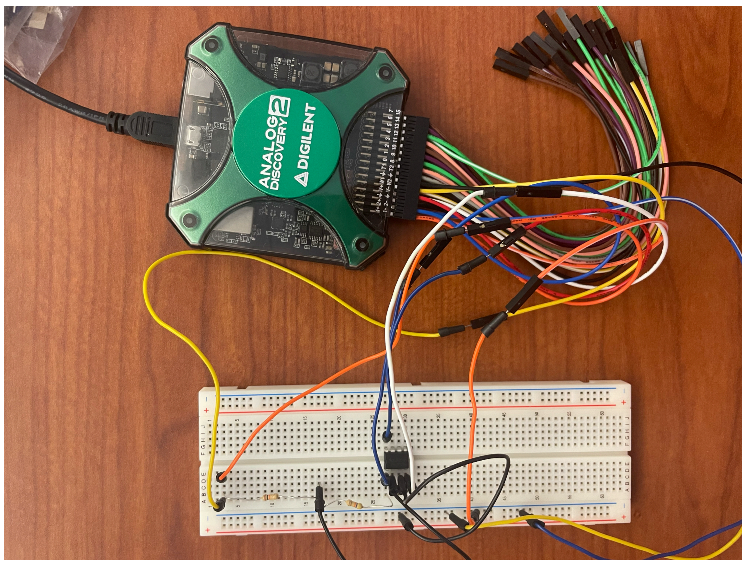

Figure 1: Set 1 Circuit

Analog Discovery 2 Plot Graphs for $+V_{CC}$ = 5V and $-V_{CC}$ = -5V

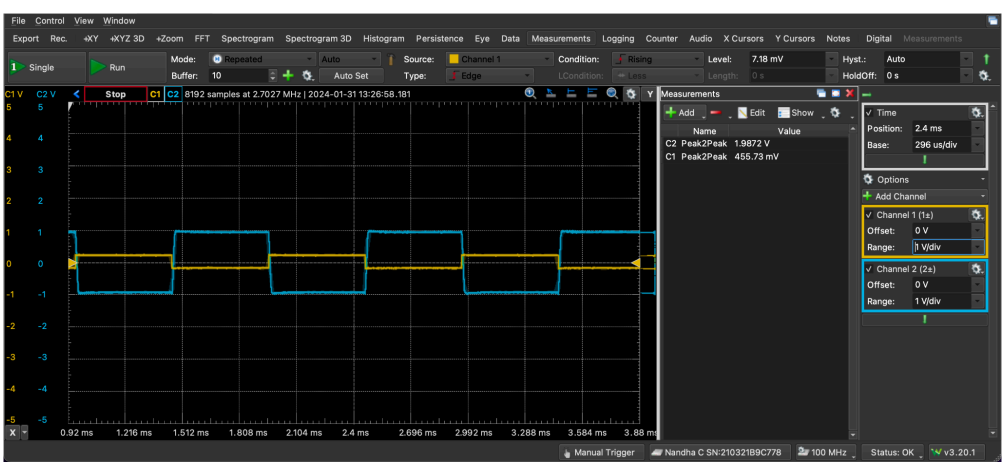

Figure 2: The V_i and V_o with Amplitude of 200mV (Linear Active Region)

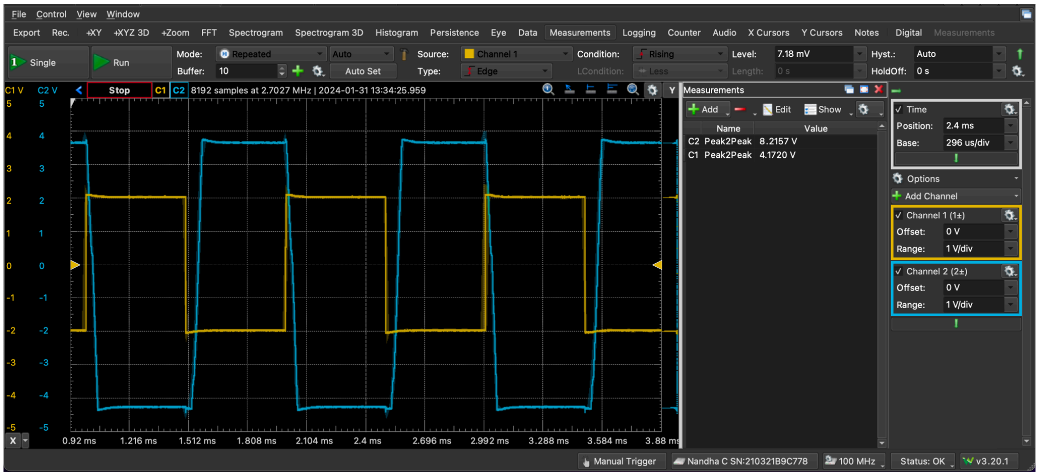

Figure 3: The V_i and V_o with Amplitude of 2V (Saturation Region)

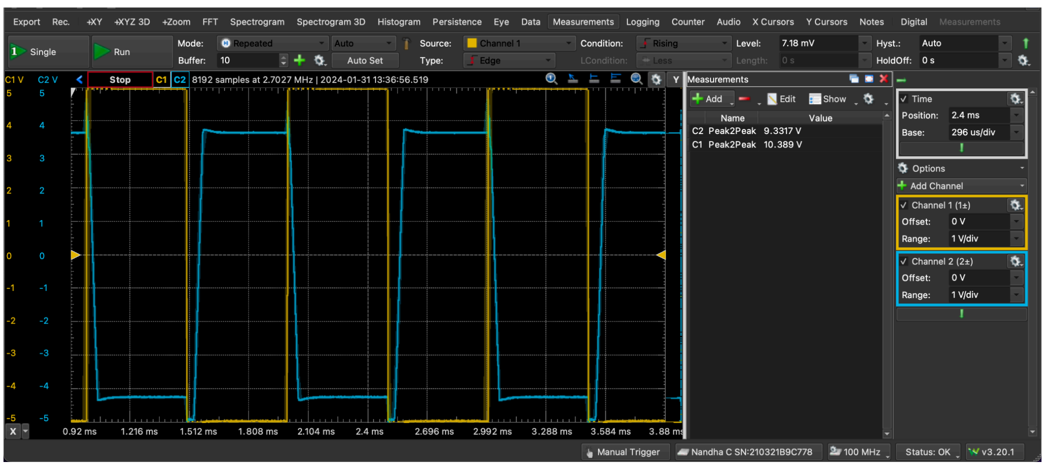

Figure 4: The V_i and V_o with Amplitude of 5V (Saturation Region)

II. Using the circuit from part i, estimate the gain using the Analog Discovery 2. Compare your analytical results with your experimental measures.

Gain Calculations using AD2

Note: V_o = Channel 1 and V_i = Channel 2

It is important to note that V_{out} was determined to be negative as it goes the opposite direction of V_{in}.

200mV Amplitude Graph:

$$A = \frac{Vo}{Vin} = \frac{-1.9872V}{0.45573V} = -4.36$$

Thus, the gain of the circuit with $+V_{CC}$ = 5V, $-V_{CC}$ = -5V and 200mV amplitude is -4.36

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Percent Error:
|((-4.36)- (-4.7))|/-4.7 =7.23%

2V Amplitude Graph:

$$A = \frac{Vo}{Vin} = \frac{-8.2157}{4.1720} = -1.969$$

Thus, the gain of the circuit with $+V_{CC}$ = 5V, $-V_{CC}$ = -5V and 2V amplitude is -1.67.

Percent Error:
|((-1.67)- (-4.7))|/-4.7 = 64.46%

5V Amplitude Graph:

$$A = \frac{Vo}{Vin} = \frac{-9.3317V}{10.389V} = -0.8982$$

Thus, the gain of the circuit with $+V_{CC}$ = 5V, $-V_{CC}$ = -5V and 5V amplitude is -0.90.

Percent Error:
|((-0.90)- (-4.7))|/4.7 = 80.85%

Theoretical Results

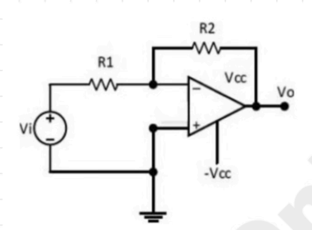
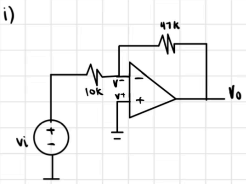


Figure 6

i)



$V^+ = 0V$

Apply Ground Circuit:

$V^+ = V^- = 0V$

Apply Nodal Analysis at the Node

$$\frac{V^- - V_i}{R_1} + \frac{V^- - V_o}{R_2} = 0$$

$$\frac{R_2(0 - V_i) + R_1(0 - V_o)}{R_1 R_2} = 0$$

$$\frac{V_o}{V_i} = -\frac{R_2}{R_1}$$

$$\frac{V_o}{V_i} = \frac{-47k}{10k}$$

$$\frac{V_o}{V_i} = -4.7 = A$$

For

$V_o = -V_{cc}$

$V_o = -5$

$-5 = -4.7V_i$

$V_i = 1.063V$

For

$V_o = +V_{cc}$

$V_o = 5$

$5 = -4.7V_i$

$V_i = -1.063V$

Transfer Characteristics

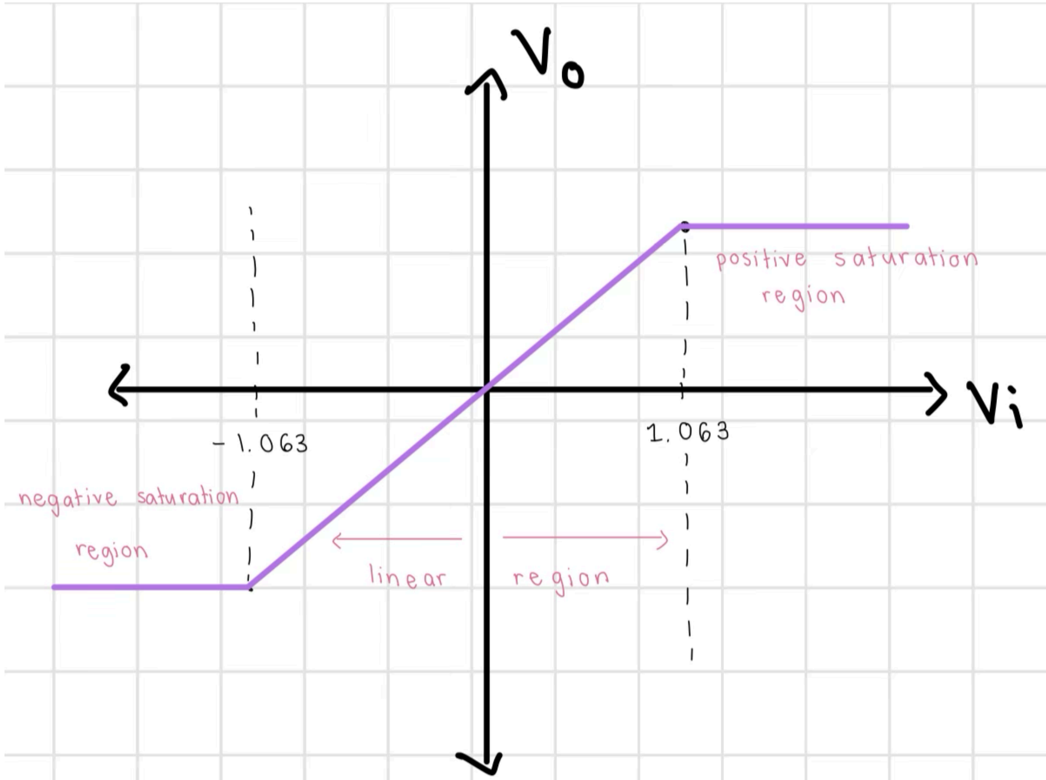


Figure 5: Transfer Characteristics of the circuit with $+V_{CC}$ = 5V and $-V_{CC}$ = -5V

Comparison Statement

The experimental measurements closely align with the theoretical predictions for the operational amplifier circuit. Our theoretical analysis indicated a gain of -4.7 within a V_{in} range of -1.063V to 1.063V, considering $+V_{cc}$ as 5V and $-V_{cc}$ as -5V.
Upon conducting experiments with input amplitudes of 200mV, the measured V_{out} was -1.9872V, resulting in a gain of approximately -4.36, which is in close agreement with our theoretical value. It is important to note that V_{out} was determined to be negative as it goes the opposite direction of V_{in}. Additionally, the V_{in} value of 0.45573V falls within the specified linear region, supporting the consistency between the experimental and theoretical outcomes. For an input amplitude of 2V, the measured V_{out} was -8.2157V, leading to a gain of -1.969. However, the V_{in} value of 4.1720V indicates that the circuit is in the positive saturation region, deviating from the theoretical expectations as the slope should now approach 0V. Similarly, with a 5V input amplitude, the measured V_{out} of -9.3317V resulted in a gain of -0.8982, closely resembling the theoretical expectation of 0V. This alignment is reasonable as V_{in} is further into the positive saturation region.

III. Repeat parts i-ii for the following values: $+V_{CC}$ = 2.5V, $-V_{CC}$ = -2.5V. Does the gain change? Explain?

Analog Discovery 2 Plot Graphs for $+V_{CC} = 2.5V$ and $-V_{CC} = -2.5V$

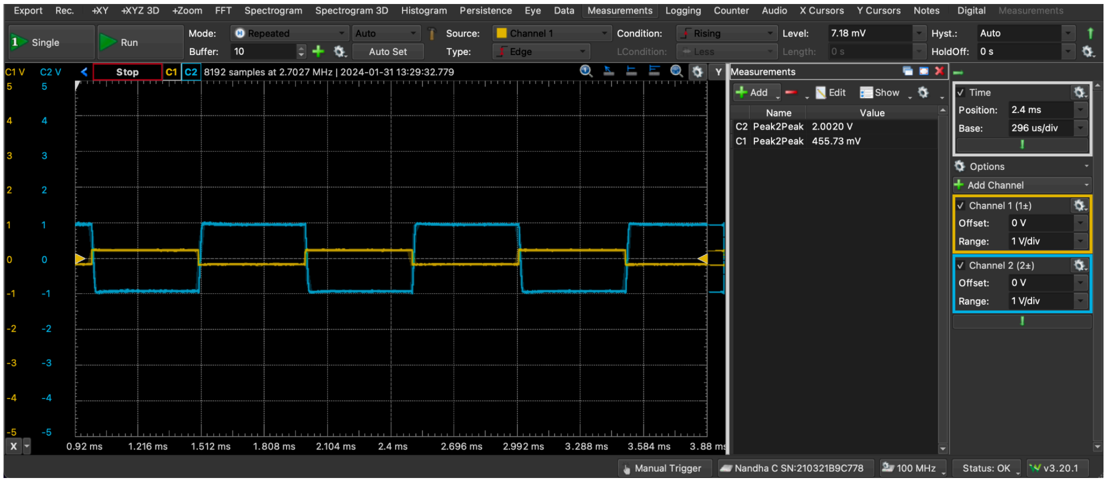


Figure 6: The V_i and V_o with Amplitude of 200mV (Linear Active Region)

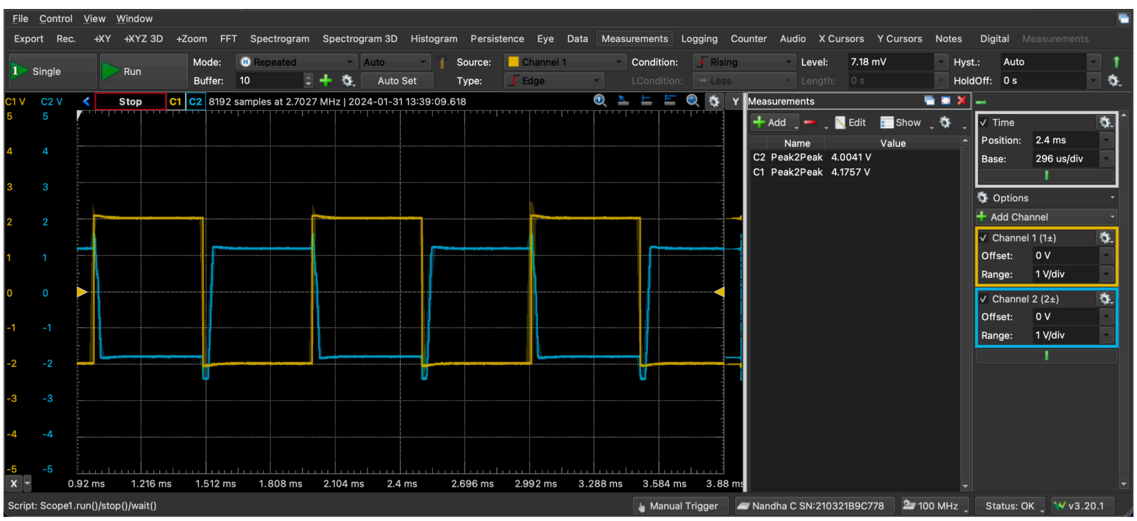


Figure 7: The V_i and V_o with Amplitude of 2V (Positive Saturation Region)

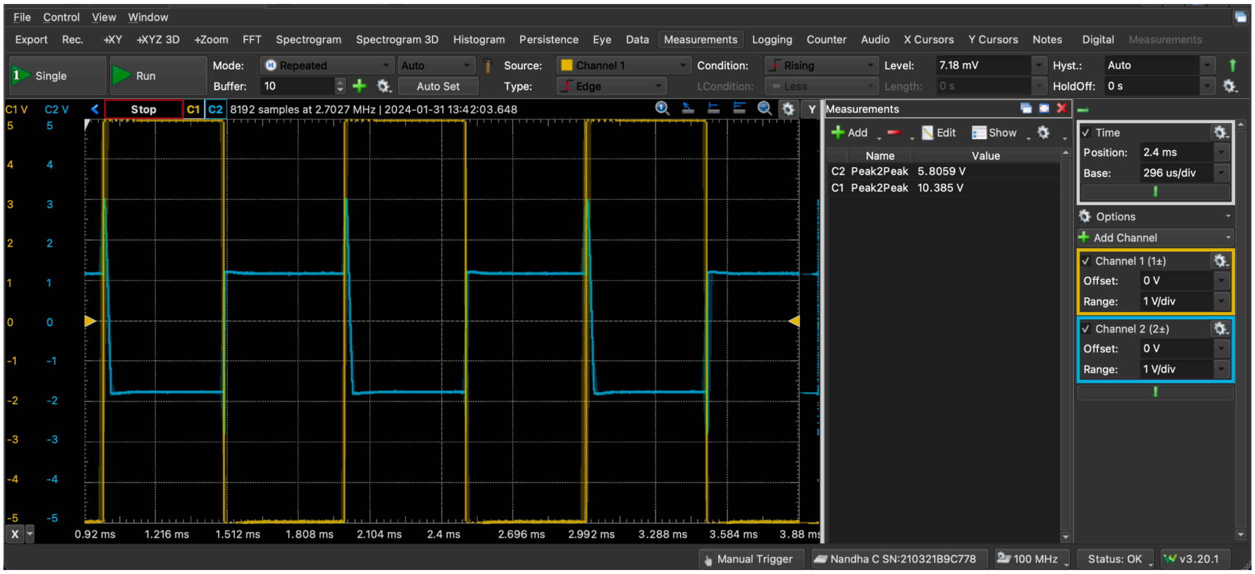


Figure 8: The V_i and V_o with Amplitude of 5V (Positive Saturation Region)

Gain Calculations using AD2

Note: V_o = Channel 1 and V_i = Channel 2

It is important to note that V_{out} was determined to be negative as it goes the opposite direction of V_{in}.

200mV Amplitude Graph:

$$A = \frac{Vo}{Vin} = \frac{-2.0020V}{0.45573V} = -4.475$$

Thus, the gain of the circuit with $+V_{CC} = 2.5V$, $-V_{CC} = -2.5V$ and 200mV amplitude is -4.48.

Percent Error:

|((-4.48)- (-4.7))|/-4.7 = 4.61%

2V Amplitude Graph:

$$A = \frac{Vo}{Vin} = \frac{-4.0041V}{4.1757V} = -0.9589$$

Thus, the gain of the circuit with $+V_{CC} = 2.5V$, $-V_{CC} = -2.5V$ and 2V amplitude is -0.96.

Percent Error:

|((-0.96)-(- 4.7))/-4.7 = 79.61%

5V Amplitude Graph:

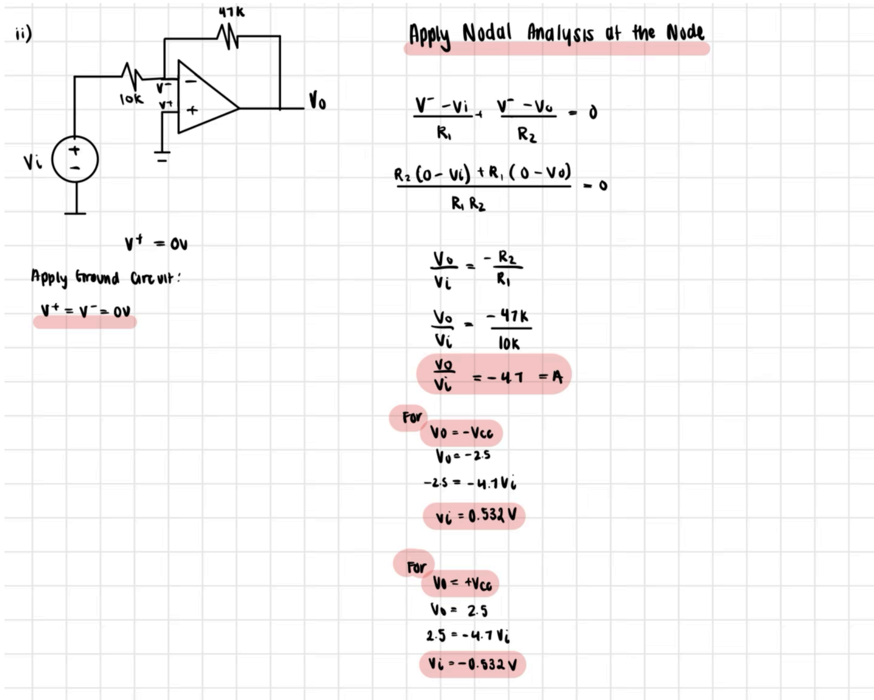
$$A = \frac{Vo}{Vin} = \frac{-5.8059V}{10.385V} = -0.5590$$

Thus, the gain of the circuit with $+V_{CC} = 2.5V$, $-V_{CC} = -2.5V$ and 5V amplitude is -0.56.

Percent Error:

|((-0.559)- (-4.7))/-4.7 = 88.1%

Theoretical Results



Transfer Characteristics

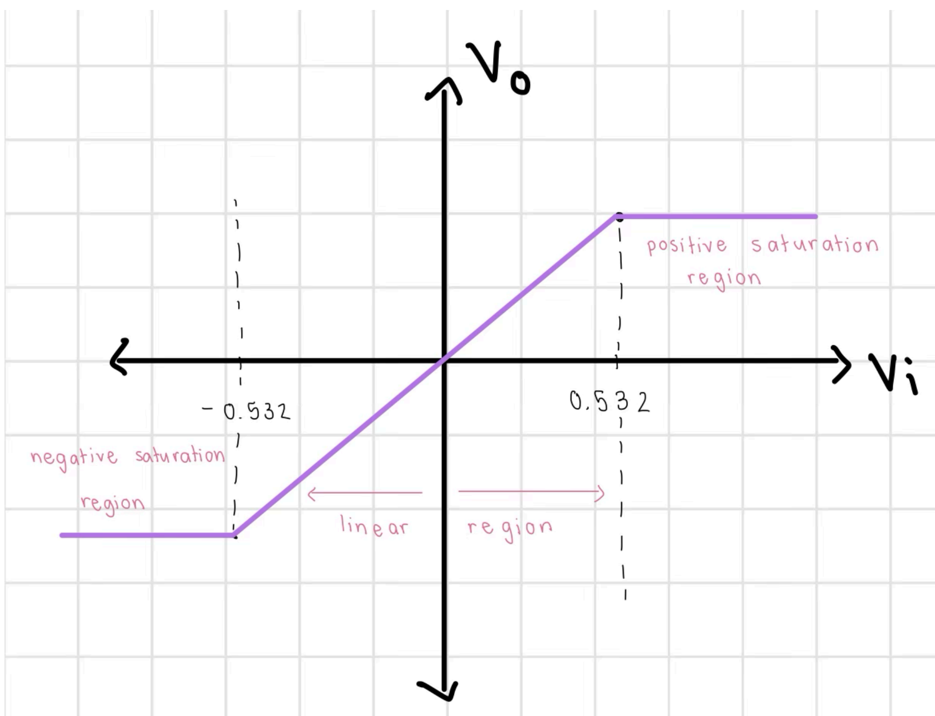


Figure 9: Transfer Characteristics of the circuit with $+V_{CC} = 2.5V$ and $-V_{CC} = -2.5V$

Comparison Statement
The experimental measurements closely align with the theoretical predictions for the operational amplifier circuit. Our theoretical analysis indicated a gain of -4.7 again within a V_{in} range of -0.532V to 0.532V, considering $+V_{cc}$ as 2.5V and $-V_{cc}$ as -2.5V.
Upon conducting experiments with input amplitudes of 200mV, the measured V_{out} was -2.002V, resulting in a gain of approximately -4.48, which is in close agreement with our theoretical value. Additionally, the V_{in} value of 0.45573V falls within the specified linear region, supporting the consistency between the experimental and theoretical outcomes.
For an input amplitude of 2V, the measured V_{out} was -4.0041V, leading to a gain of -0.9589. However, the V_{in} value of 4.1720V indicates that the circuit is in the positive saturation region, deviating from the theoretical expectations as the slope should now approach 0V. Similarly, with a 5V input amplitude, the measured V_{out} of -5.8059V resulted in a gain of -0.5590, closely resembling the theoretical expectation of 0V. This alignment is reasonable as V_{in} is further into the positive saturation region.

Does the Gain Change?
The gain does not change as the gain of an amplifier circuit is determined by its internal components and configuration, and it is generally independent of the power supply voltages $+V_{cc}$ and $-V_{cc}$ as long as the amplifier operates within its specified voltage range. In the case of this lab, when deriving the formula for gain it can be seen that an amplifier's gain is mostly dictated by the resistor values used in its circuit configuration. The gain for multiple amplifier circuits is usually represented with the following formula: $A = -R_o/R_i$. In this lab, the resistor values did not change, thus the gain remains -4.7.

The voltage supply range is essential to prevent clipping and guarantee the amplifier operates as intended. When the input signal is greater than the amplifier's capacity to produce the matching output within the specified voltage range, clipping takes place. It is possible to avoid distortion and non-linear behavior in the amplifier output by keeping the voltage range within a suitable range. This can be clearly seen in this lab, as the input of 2V and 5V amplitude did not give an input voltage within the linear region which can be determined with $+V_{CC}$ and $+V_{CC}$.