



Curtin University

## ELECTRONICS (ETEN1000)

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**GROUP:** 12 pm to 2pm Thursday

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**LABORATORY:** 04 Operational Amplifier circuits

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**LABORATORY PARTNERS:** Tashi Lahdon 22155746

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*I hereby declare that the calculation, results, discussion and conclusions submitted in this report is entirely my own work and have not copied from any other student or past student.*

**Student Signature:** Troyee

## Operational Amplifier circuits

### Introduction

An essential part of analog electronics, operational amplifiers (op-amps) are often used in signal processing, filtering, and amplification applications. The purpose of this lab experiment is to examine the behaviour of several op-amp designs, particularly the weighted adder, buffer, non-inverting amplifier, and inverting amplifier circuits.

Every configuration shows unique features that offer significant knowledge into the operation and real-world uses of op-amps. To get a deeper knowledge of op-amp performance in different configurations, students will build these circuits, analyse input and output waveforms, and compare actual and theoretical values in this lab. Additionally, the lab aimed to examine the effects of non-linear components, such as capacitors and inductors, when used in conjunction with op-amps.

### Aim

The goal is to learn more about the various op-amp configurations, test their output, and compare the results with theoretical expectations in order to better understand how they are used in electronics.

### Summary

This experiment involved the setup and testing of various LM741 operational amplifier designs, such as buffer, non-inverting, inverting, and weighted adder circuits. The input and output signals were measured and examined for every setup. To identify any differences and determine their reasons, the measured values and theoretical values—such as output voltage and gain—were calculated and compared. All things considered, the experiment offered a useful comprehension of op-amp circuits, their configurations, and their importance in the design of electronic circuits.

## Circuit

### (i) Opamp: Buffer Configuration

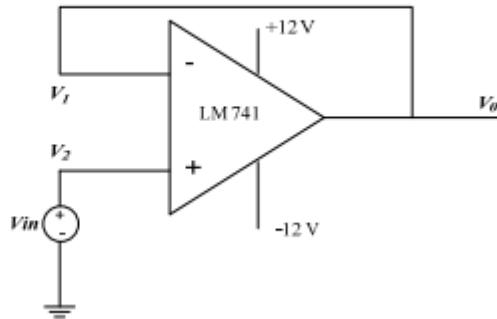


Figure 1: Buffer configuration

The circuit in figure 1 is a buffer configuration using an LM741 operational amplifier. The input voltage  $V_{in}$  is applied directly to the non-inverting input (pin 3) while the output  $V_{out}$  (pin 6) is connected back to the inverting input (pin 2), creating a unity gain feedback loop. This setup makes the voltage  $V_{out}$  equal to the input voltage  $V_{in}$ , providing a gain of 1.

The op-amp is powered by +12 V and -12 V on pin 7 and pin 4 respectively allowing it to produce both positive and negative output voltages. This configuration is used to compare and separate resistance without inverting or increasing the signal.

### (ii) Opamp: Non-inverting Configuration

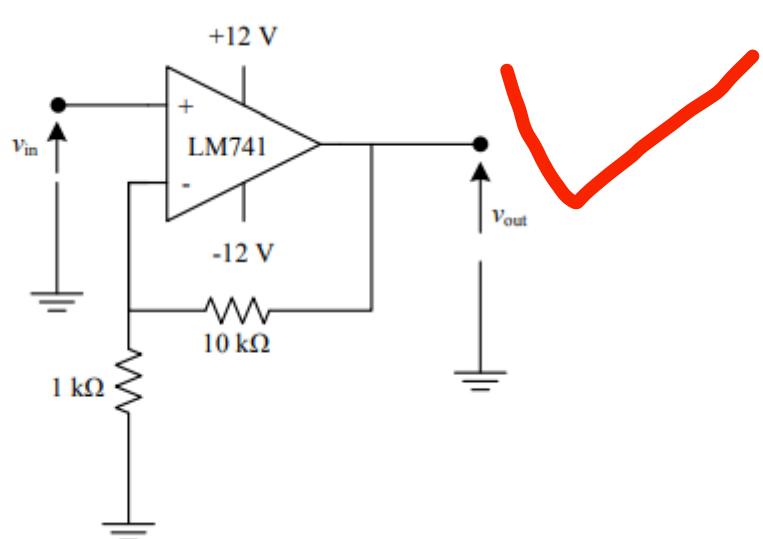
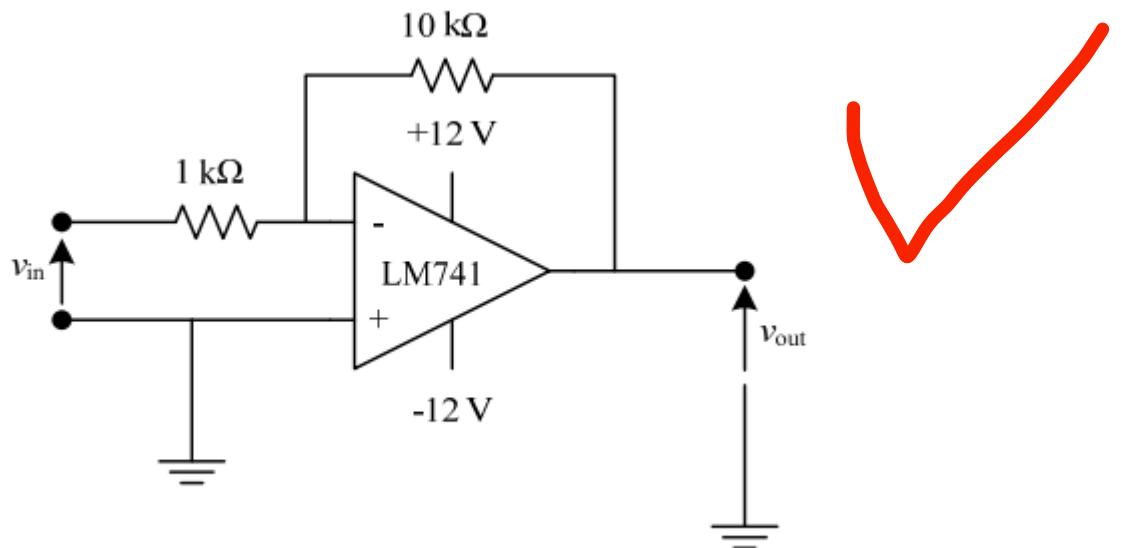


Figure 2: A non-inverting Opamp configuration

The circuit in figure 2 is a non-inverting amplifier configuration using an LM741 operational amplifier. The input voltage  $V_{in}$  is applied to the non-inverting input (pin3) while the inverting input (pin2) receives feedback from the output pin6 through a  $10\text{ k}\Omega$  resistor, with an additional  $1\text{ k}\Omega$  resistor connected from the inverting input to ground. This op-amp is powered by +12 V and -12 V, this configuration provides amplification without inverting the input signal, making it useful for applications requiring a positive gain.

### (iii) Opamp: Inverting Configuration



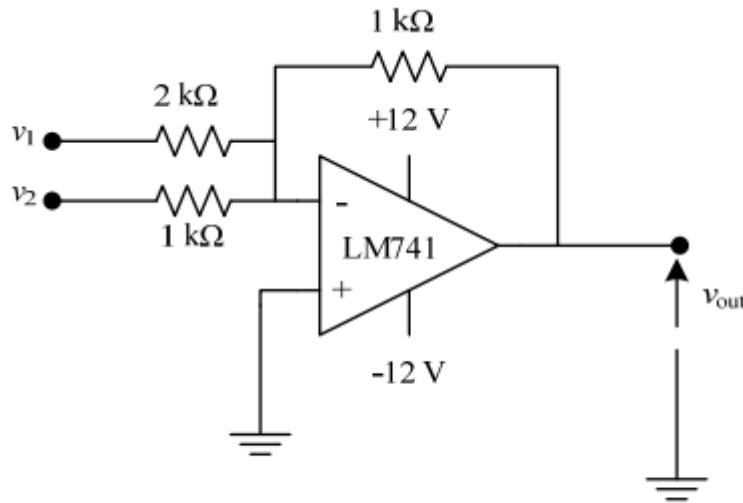
*Figure 3: An inverting opamp configuration*

The circuit in figure 3 is an inverting amplifier configuration using an LM741 operational amplifier. A  $1\text{ k}\Omega$  resistor connected to the inverting input (Pin 2) receives an input voltage  $V_{in}$ , while the non-inverting input (Pin 3) is grounded to create a zero-reference point. The amplifier's gain is adjusted by connecting the output (Pin 6) back to the inverting input via a  $10\text{ k}\Omega$  feedback resistor.

The op-amp is powered by +12 V and -12 V on pin 7 and pin 4 respectively

allowing it to produce both positives and negative output voltages. This configuration is suitable for applications requiring phase-inverted signal amplification.

#### (iv) Opamp: Weighted Adder



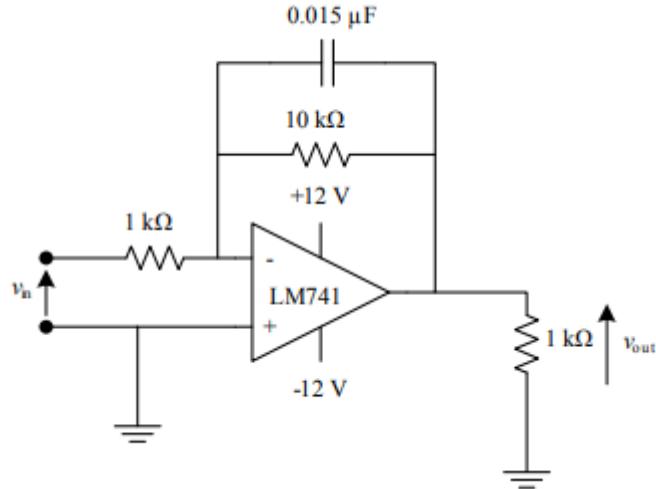
*Figure 4: A weighted adder configuration*

The circuit in figure 4 is a weighted adder or summing amplifier using an LM741 operational amplifier that combines two input voltages  $V_1$  and  $v_2$ , into a single output.

More specifically, this is configured as an inverting summing amplifier where inverting input (pin 2) is used to sum the weighted input signals. Two input voltages  $V_1$  and  $V_2$  are fed into inverting input of the op-amp through resistors.  $V_1$  is connected through a  $2\text{ k}\Omega$  resistor, while  $V_2$  is connected with  $1\text{ k}\Omega$  resistor.  $1\text{ k}\Omega$  resistor is connected from the output (pin 6) back to the inverting input(pin 2) which works to control the gain and sum the inputs according their weights.

The non- inverting input is grounded to establish a reference voltage of zero for the inverting input. The op-amp is powered by  $+12\text{ V}$  and  $-12\text{ V}$  on pin 7 and pin 4 respectively which allows to operate with both positives and negative output voltages.

## (v) Effect of Non-linear Components



*Figure 5: Effect of Non-linear Components*

Using an LM741 operational amplifier, the design in Figure 5 is an op-amp circuit with a capacitor and feedback resistors that most likely works as a high-pass or band-pass filter.

Here op-amp pin 7 (positive supply connected to  $+12\text{ V}$  and pin 4 (negative supply) connected to  $-12\text{ V}$ ). **Pin 3** (non-inverting Input) connected to ground which sets a reference point for the input voltage. **Pin 2** (Inverting input connected to the input voltage  $V_{in}$  through a  $1\text{ K }\Omega$  resistor). **Pin 6** this is the output pin where  $V_{out}$  is measured.  $1\text{ K }\Omega$  resistor is connected from the output to ground which sets the output signal. The Feedback loop which is connected from pin 6 to pin 2 consists of a  $10\text{ K }\Omega$  resistor and a  $0.015\text{ }\mu\text{F}$  capacitor in series. This feedback loop controls the gain and the frequency response of the circuit.

## Result

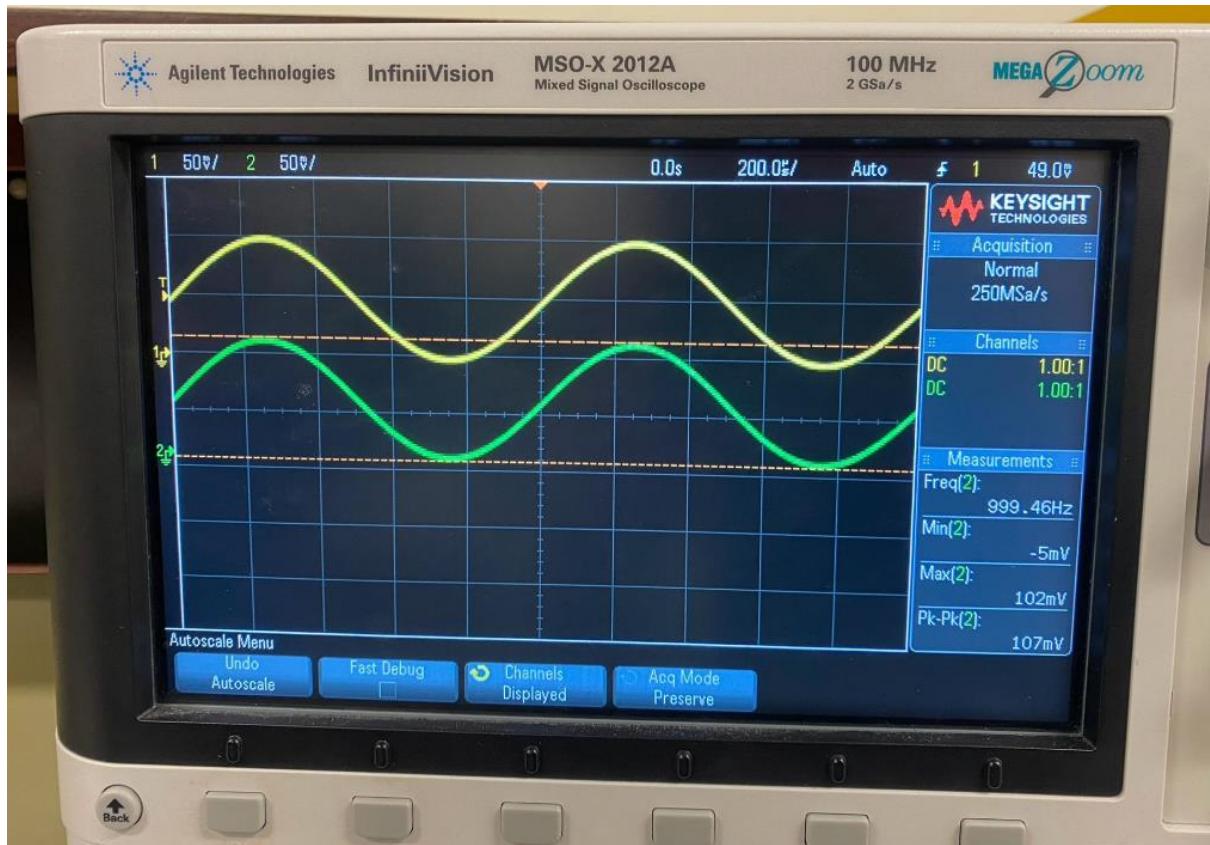


Figure 5 : Waveform of the Buffer Configuration



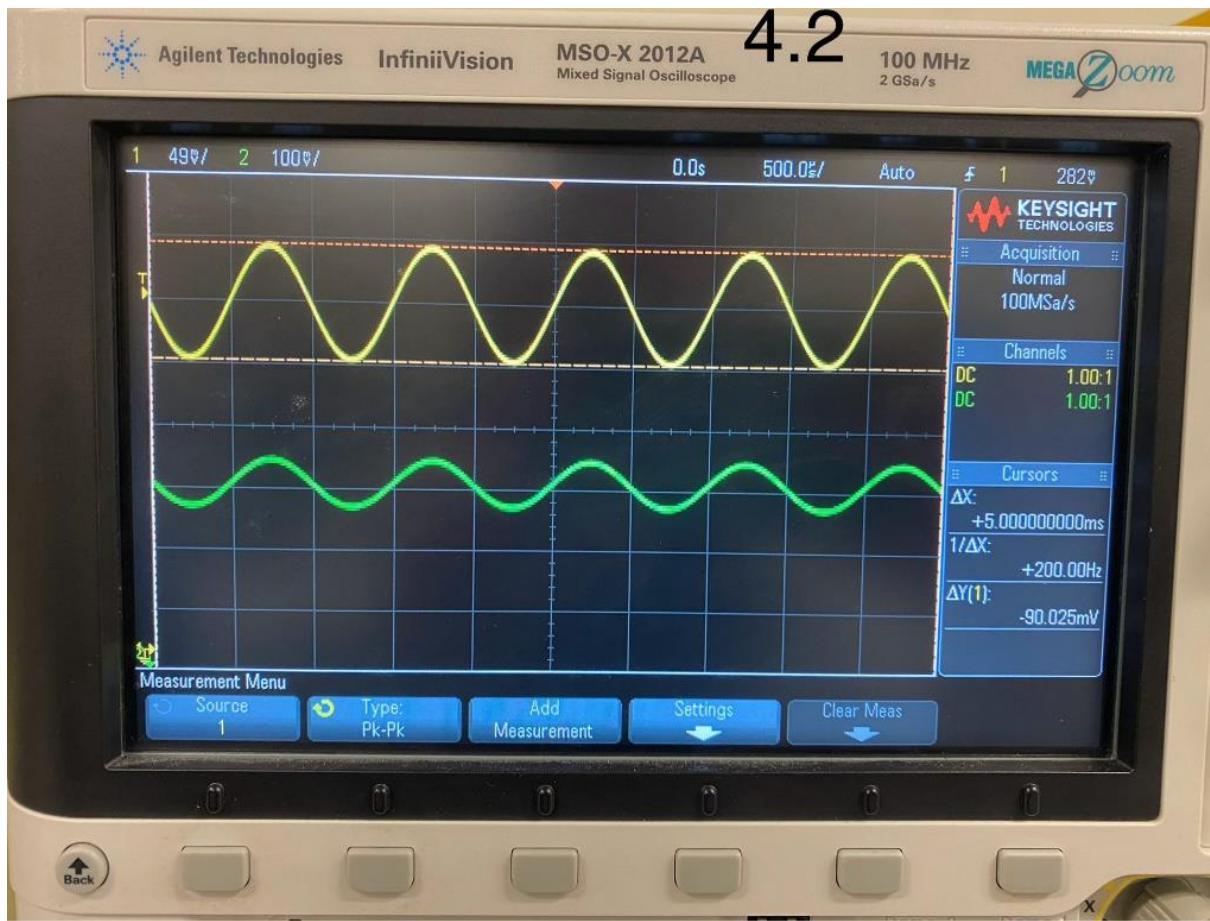


Figure 6: Waveform of the Non-inverting Amplifier

label -3 ✓

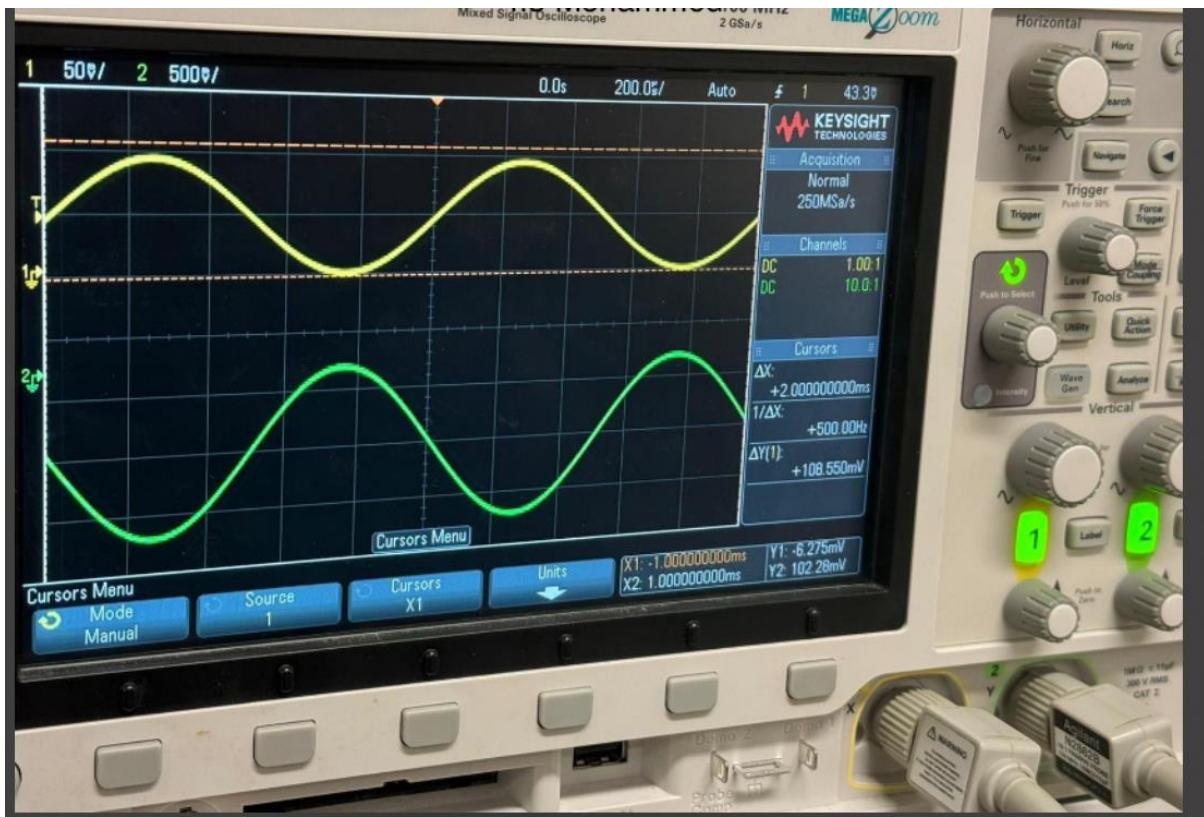


Figure 7 : Waveform of the Inverting Configuration 4.3



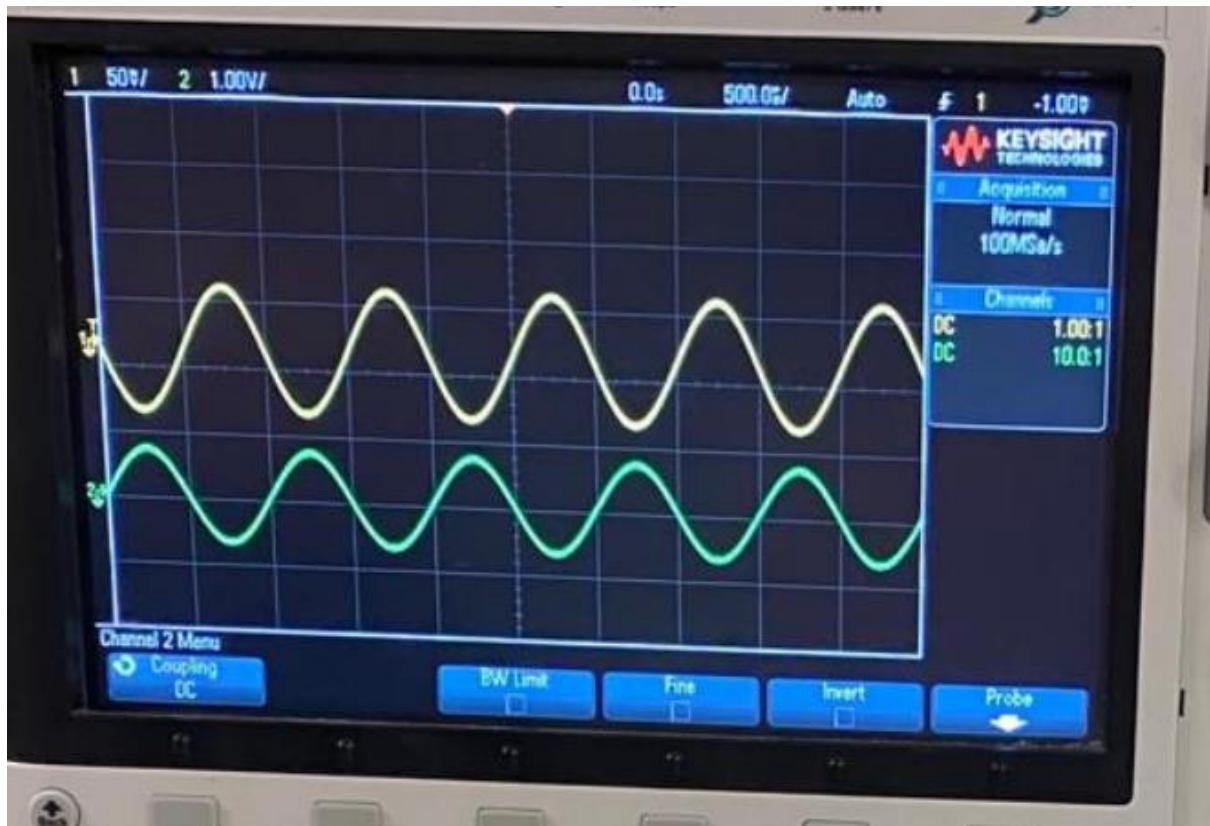


Figure 8: Waveform of the Weighted Adder Configuration 4.4

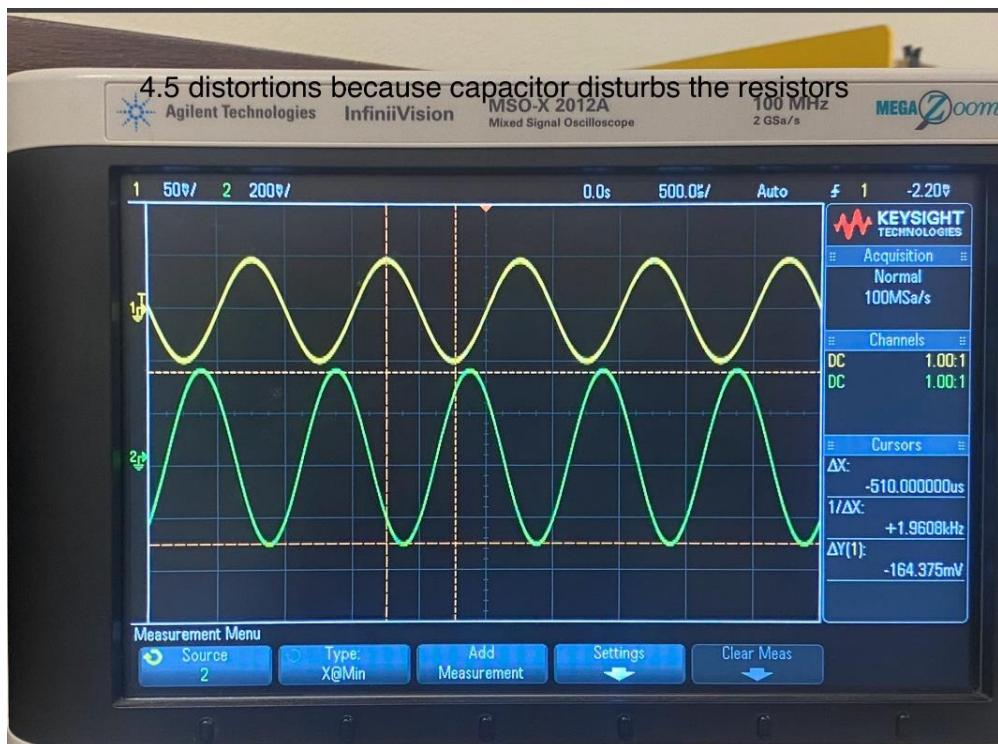


Figure 9: Waveform of the Effect non-linear Configuration

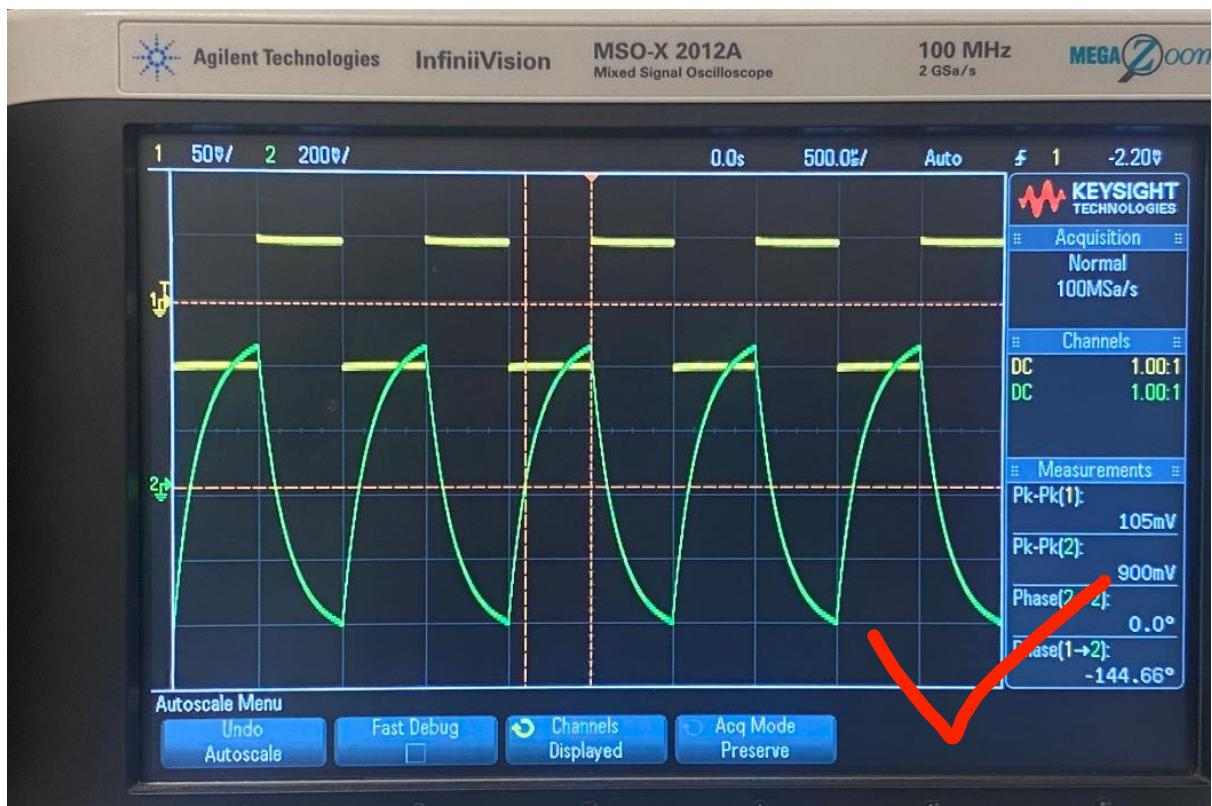


Figure 10: triangular Waveform of the Effect non- linear Configuration

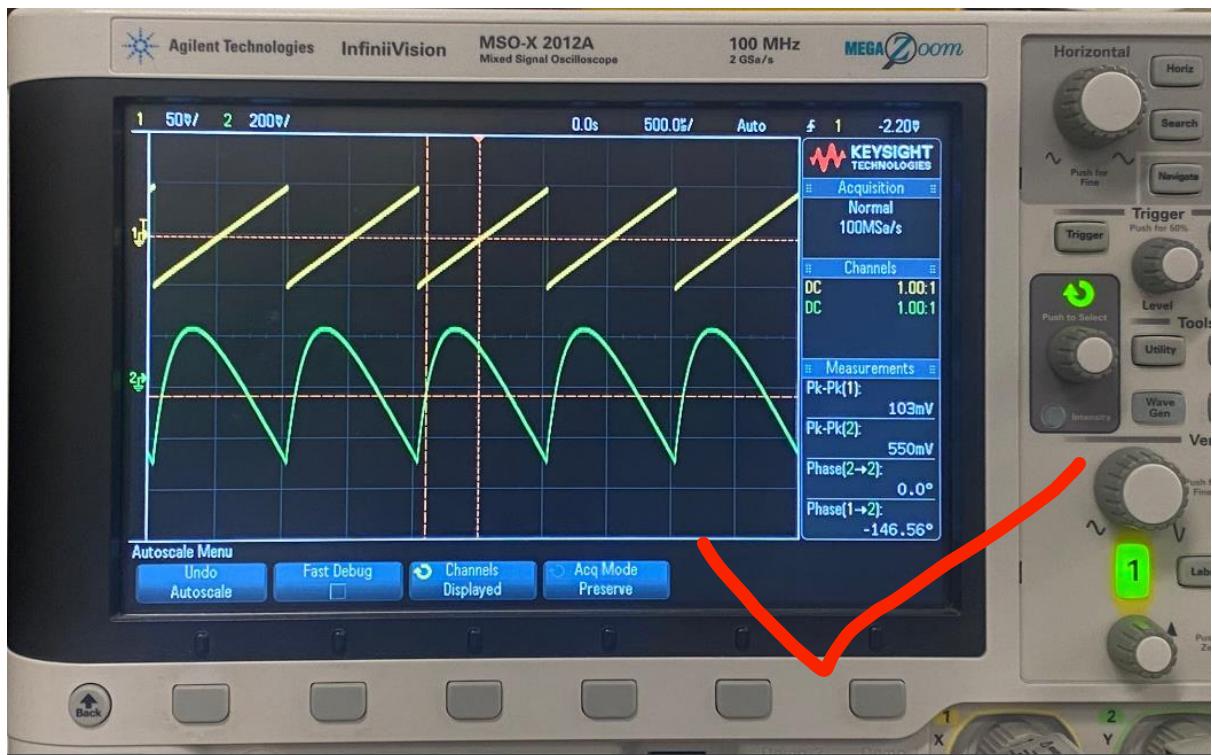


Figure 11: square Waveform of the Effect non- linear Configuration

## Discussion

For every setup, the measured values recorded in the lab closely matched the theoretical gains and output voltages. With only slight variations allocated to real-world variables like component tolerances and equipment practical mistakes, the measured gains for the buffer, non-inverting, and inverting configurations were almost exactly the same as the theoretical predictions.

Similar to this, the weighted sum configuration's output voltage was within theoretical bounds, with a few minor deviations that might be connected to the fundamental restrictions of the laboratory's measurement equipment and hardware.

Using the collected data, the closed loop gains of the buffer configuration (**Q6.1**) was calculated and compared with the theoretical calculations made during the prelab. Since the buffer circuit's theoretical gain is 1, the output voltage supposed to match the input voltage. This was confirmed by the experiment's measured input and output waveforms, which were shown on the oscilloscope. The output signal closely matched the input signal, giving a gain of approximately 1. The buffer setup performed according to plan since there were little variations between the measured and predicted findings. Because of its high input and low output resistance, which help avoid loading effects and enable signal isolation without compromising the signal's amplitude, the buffer is commonly used in real-world applications.

Using both theoretical and experimental data, the closed-loop gain of the non-inverting amplifier design (**Q6.2**) was calculated. Using the formula

$$Av = 1 + \frac{R_f}{R_{in}} \text{ where } R_f \text{ is } 10\text{k}\Omega, \quad R_{in} = 1\text{k}\Omega$$

$$Av = 1 + \frac{10}{1} = 11$$

which makes **Vout** equal to 11 times **Vin**.

So, the theoretical gain was found to be 11. There were very few differences between the measured input and output signals in the lab experiment and this theoretical gain. Overall, the circuit operated as expected, with any small variations due to practical issues like resistor tolerances or component flaws.

gain? -10

The closed-loop gain of the inverting configuration (Q6.3) was calculated using the formula  $A_v = - \frac{R_f}{R_{in}}$

$$= - \frac{10}{1}$$

$= - 10$ , resulting in a theoretical gain of -10.

The experimental measurements confirmed this, with the output waveform inverted and consistent with the expected value of -10, as shown by the oscilloscope. Minor discrepancies were attributed to real-world factors such as resistor tolerances and operational amplifier non-idealities, but these were minimal, confirming that the inverting amplifier operated as expected.

Finally, the output voltage of the weighted summer configuration (Q6.4) was calculated using the provided resistor values and input voltages V1 and V2. The theoretical expression for the output voltage was given by

$R_f$  is the feedback resistor ( $1k\Omega$ )

$R_1$  is the resistor for V1 ( $2k\Omega$ ),

$R_2$  is the resistor for V2 ( $1k\Omega$ ),

$$V_{out} = - \left( \frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} \cdot V_2 \right)$$

$$V_{out} = - \left( \frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} \cdot V_2 \right)$$

$$V_{out} = - \left( \frac{1k\Omega}{2k\Omega} \cdot V_1 + \frac{1k\Omega}{1k\Omega} \cdot V_2 \right)$$

$$V_{out} = - (0.5V_1 + 1V_2)$$

The measured results closely matched the theoretical predictions, with any discrepancies attributed to component tolerances and practical imperfections. Overall, the weighted summer configuration performed as expected, with the output signal reflecting the weighted contribution of the input signals.

## Conclusion

In conclusion, there were very few differences between the theoretical calculations and the lab measurements for the buffer, non-inverting, inverting, and weighted summer setups. The buffer and non-inverting designs showed a difference of less than 1%, while the inverting configuration and weighted summer circuit showed a similarly small percentage differences between the theoretical and lab results. Practical considerations like component tolerances, actual flaws in operating amplifiers, and the constraints of the testing tool are all responsible for these small variances. Overall, results validated the expected performance of the circuits and confirmed the accuracy of the theoretical predictions.

## Appendix

### Theoretical Measurements:

Pre-laboratory - 4

① Op-Amp Buffer Configuration:-

Considering an ideal op-amp

$$V_2 - V_1 = 0$$

Input (Non-inverting) which is  $V_{in}$

Output (inverting) which is  $V_{out}$

$$V_2 = V_{in} \text{ and } V_1 = V_{in}$$
$$V_1 = V_{in}$$
$$\boxed{V_o = V_{in}}$$

ii

### Op-Amp Non-inverting configuration:-

$V_{in}$  is given to the non-inverting (+) input.

$$V_2 = V_1 = 0$$

$$V_2 = V_{in}$$

$$V_1 = V_{in}$$

Current going to the op-amp is 0.

$$I R_1 = I R_2$$

$$\frac{O - V_1}{R_1} = \frac{V_1 - V_0}{R_L}$$

$$\frac{O - V_{in}}{R_1} = \frac{V_{in} - V_0}{V_{in}}$$

$$A_V = -\frac{R_2}{R_1} = \frac{V_{in} - V_0}{V_{in}}$$

$$\Rightarrow -\frac{R_2}{R_1} = \frac{1 - V_1}{V_{in}}$$

$$= \frac{V_0}{V_{in}} = 1 + \frac{R_L}{R_1}$$

$$\approx 1 + 10k\Omega$$

$\therefore A_V = 11$   
 $\therefore$  close loop gain is 11.

(ii) OP-Amp Inverting Configuration:-

Considering the ideal OP-Amp

$$V_2 = V_1 = 0$$

$$V_o = 0, V_i = 0$$

Current passing through OP-Amp is 0

$$I_{R1} = I_{R2}$$

using KCL,

$$\frac{V_{in} - V_1}{R_1} = \frac{V_1 - V_o}{R_2}$$

$$\therefore \frac{V_{in}}{R_1} = \frac{-V_o}{R_2} \quad [ \because V_1 = 0 ]$$

$$\frac{V_o}{V_{in}} = -\frac{R_2}{R_1} = -\frac{10k\Omega}{1k\Omega} = -10.$$

(iv) OP-Amp weighted Adder.

$$V_{out} = -\left( \frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} \cdot V_2 \right)$$

$$= \left( \frac{1k\Omega}{2k\Omega} \cdot V_1 + \frac{1k\Omega}{1k\Omega} \cdot V_2 \right)$$

$$= -\left( \frac{1}{2} V_1 + V_2 \right)$$

## References

Nil

