Curtin University

ELECTRONICS (ETEN1000)

STUDENT NUMBER: **22663281**

NAME: Dhrubo Jouti das Troyee

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

LABORATORY: **04** Operational Amplifier circuits

LABORATORY SUPERVISOR: **: Dr King Sun Chan**

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.

Summery

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

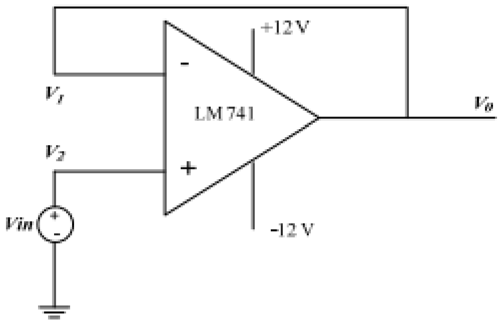

Figure 1: Buffer configuration

The circuit in figure 1 is a buffer configuration using an LM741 operational amplifier. The input voltages Vin is applied directly to the non- inverting input (pin3) while the output Vout (pin6) is connected back to the inverting input (pin2), creating a unity grain feedback loop. This setup makes the voltage Vout equal to the input voltage Vin, 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 positives and negative output voltages. This configuration is used to compare and separates resistance without inverting or increasing the signal

(ii) Opamp: Non-inverting Configuration

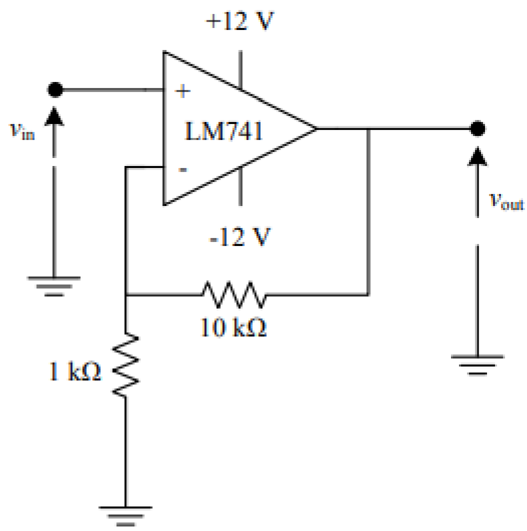

Figure 2: A non-inverting Opamp configuration

The circuit in figure 2 is a non -inverting amplifier configuration using an LM741 operational amplifier. The input voltage Vin is applied to the non-inverting input (pin3) while the inverting input(pin2) receives feedback from the output pin6) though a 1o k ohm resistor, with an additional 1 k ohm resistor connected fro m the inverting input to ground. This op -amp is powered by +12 V and – 12V , this configuration provides amplification without inverting the input signal , making it useful for application requiring a positive gain.

(iii) Opamp: Inverting Configuration

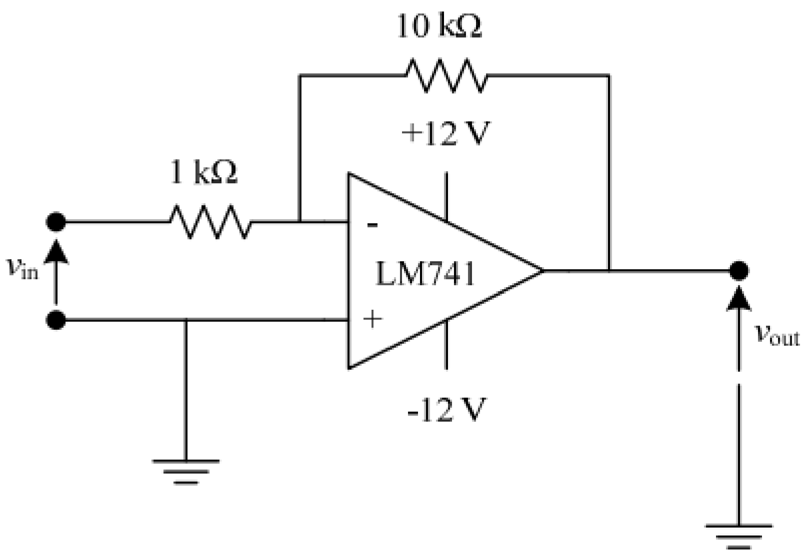

Figure 3: An inverting opamp configuration

The circuit in figure 3 is an inverting amplifier configuration using an LM741 operational amplifier. A 1 kΩ resistor connected to the inverting input (Pin 2) receives an input voltage ***Vin,*** 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 kΩ 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

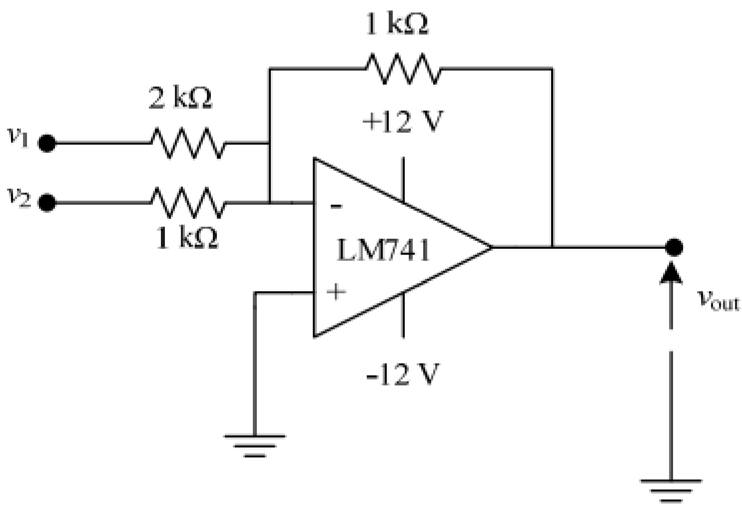

Figure 4: A weighted adder configuration

The circuit in figure 4 is a weighted adder or summing amplifier using an LM741 operational amplifier that combines two input voltages V1 and v2, into a single output.

More specifically, this is configured as an inverting summing amplifier where inverting input (pin2) is used to sum the weighted input signals. Two input voltages V1 and V2 are fed into inverting input of the op-amp through resisters. V1 is connected through a 2K Ω resister, while V2 is connected with 1K Ω resister. 1K Ω resister is connected from the output (pin 6) back to the inverting input(pin2) 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 V and -12 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

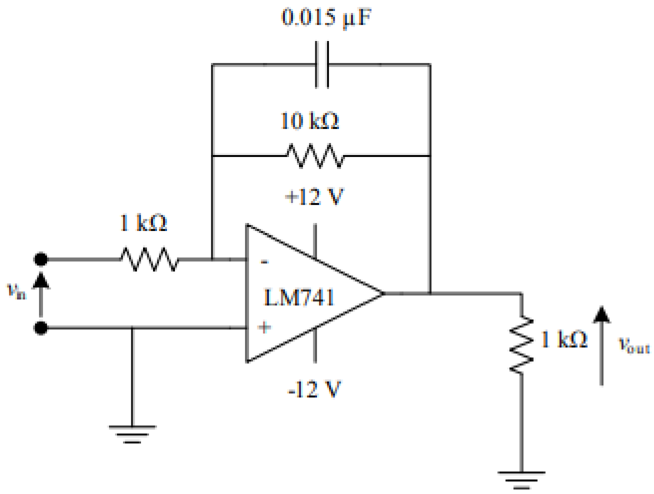

Figure 5: Effect of Non-linear Components

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 V and pin4 (negative supply) connected to -12 V. **Pin3** (non- inverting Input) connected to ground which sets a reference point for the input voltage. **Pin2** (Inverting input connected to the input voltage ***Vin*** through a 1K Ω resister. **Pin 6 this** is the output pin where ***Vout*** is measured. 1K Ω resister is connected from the output to ground which sets the output signal. The Feedback loop which is connected from pin6 to pin2 consists of a 10 K Ω resister and a 0.015 µF capacitor in series. This feedback loop controls the gain and the frequency response of the circuit.

Result

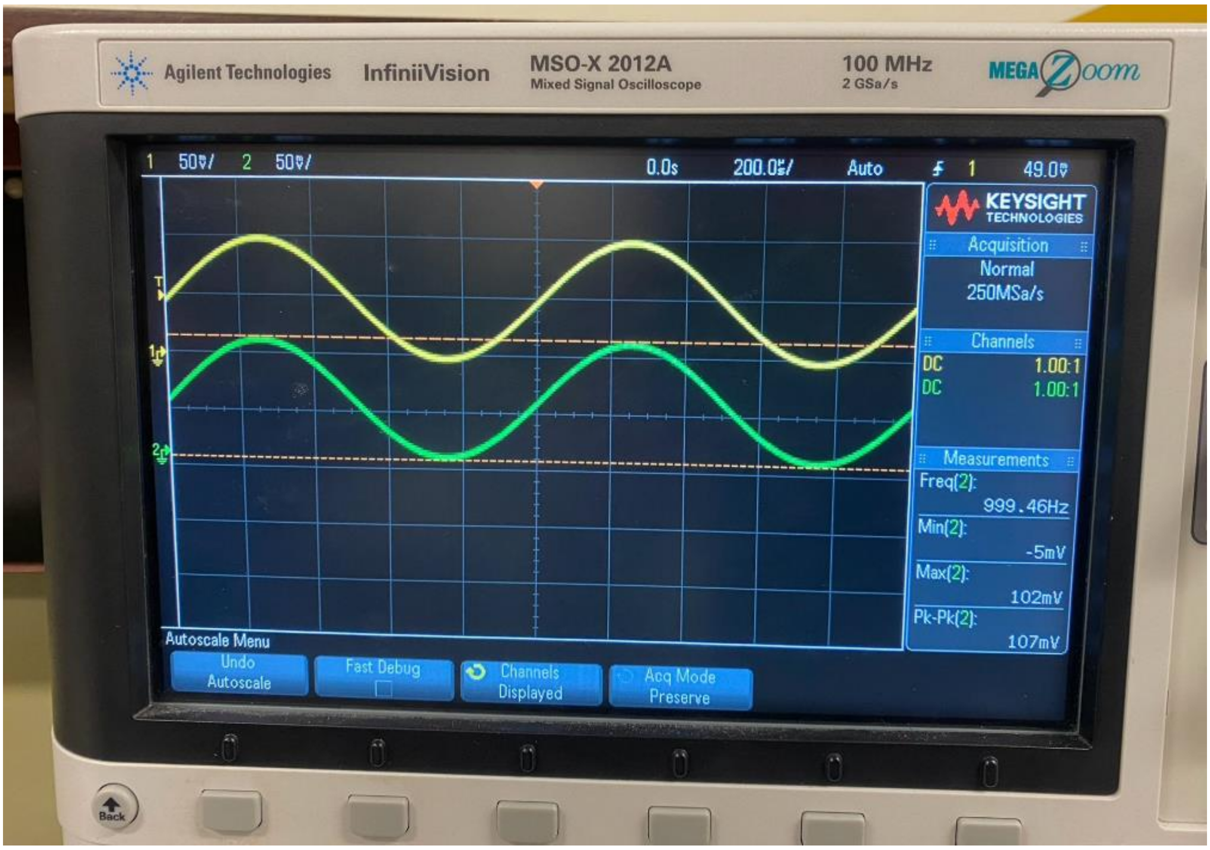

Figure 5 : Waveform of the Buffer Configuration

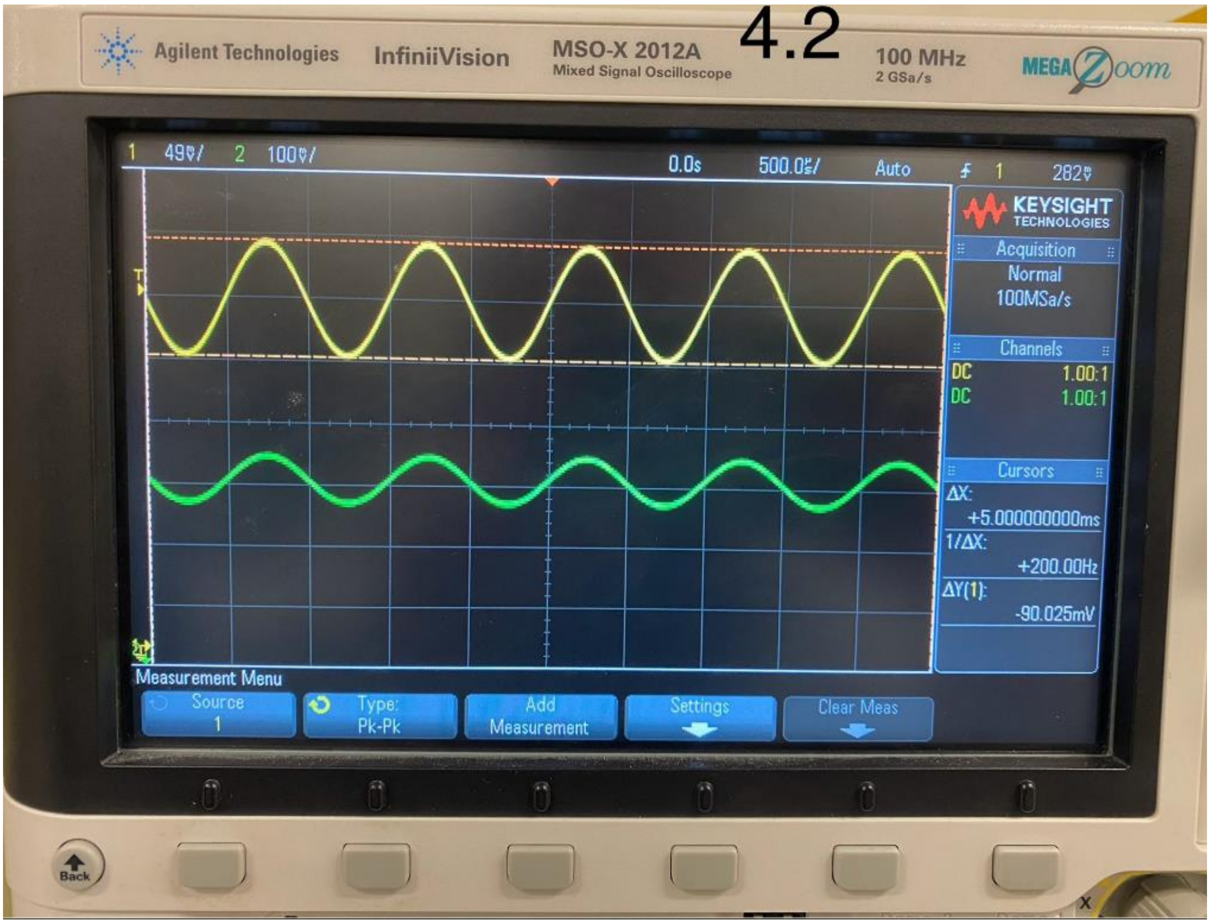

Figure 6: Waveform of the Non-inverting Amplifier

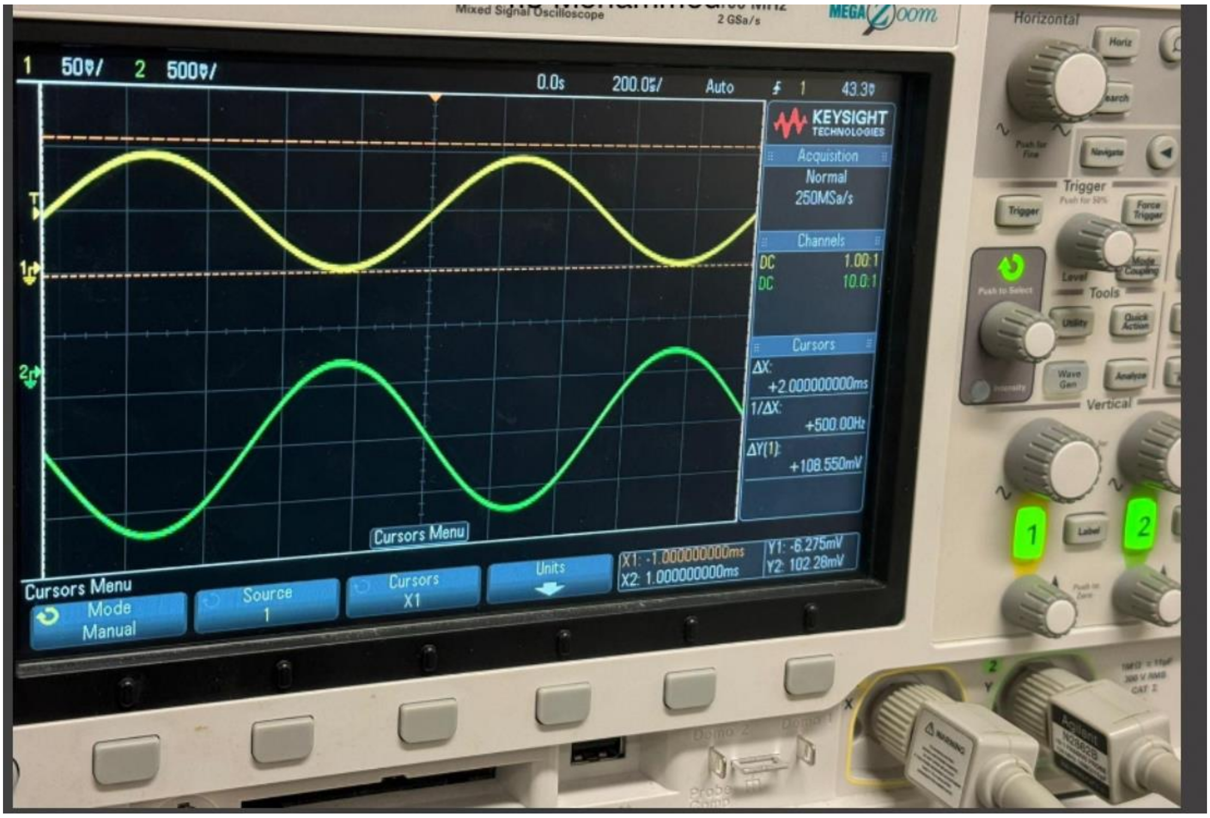

Figure 7 : Waveform of the Inverting Configuration 4.3

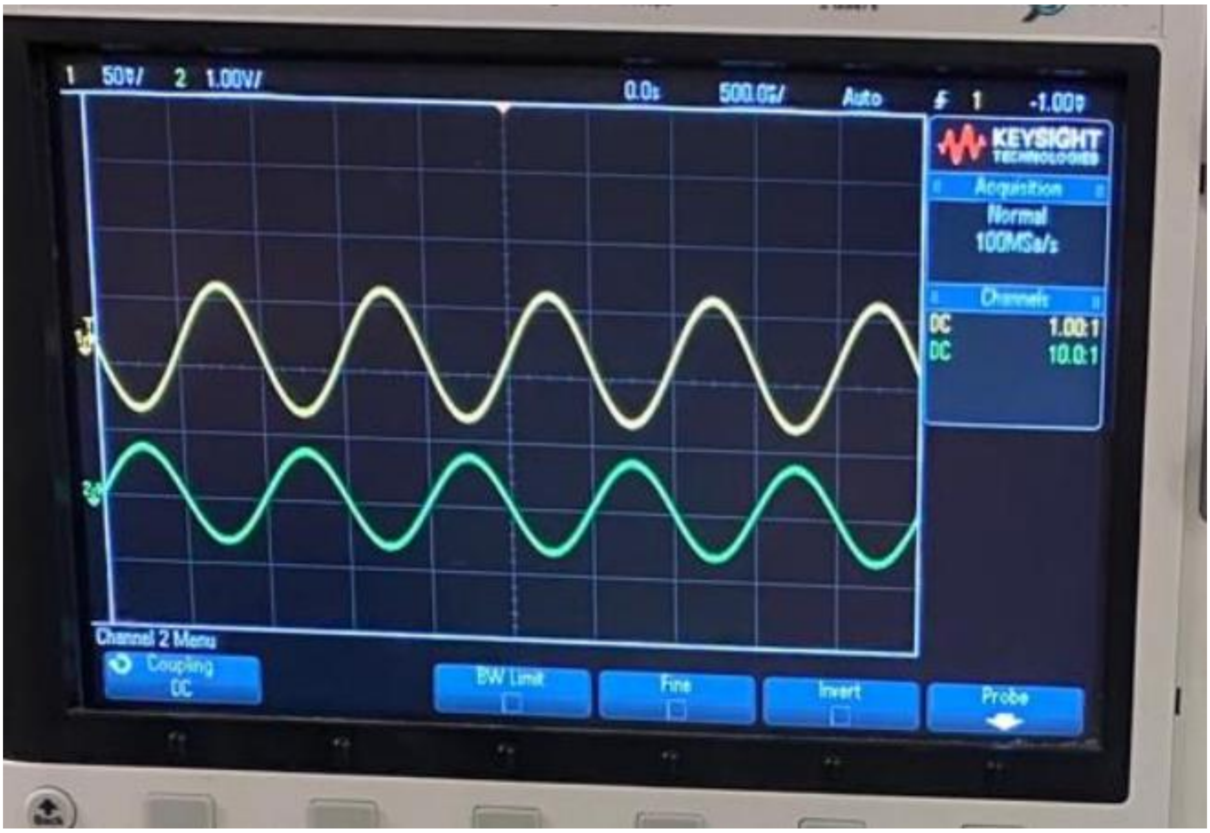

Figure 8: Waveform of the Weighted Adder Configuration 4.4

4.5 distortions because capacitor disturbs the resistors

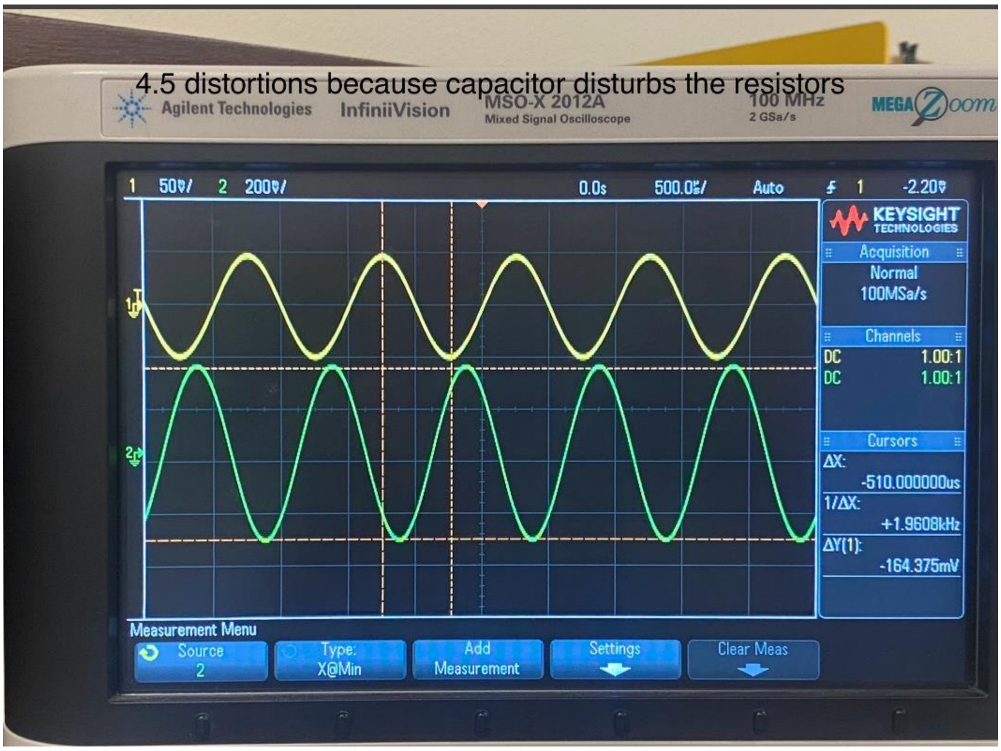

Figure 9: Waveform of the Effect non- linear Configuration

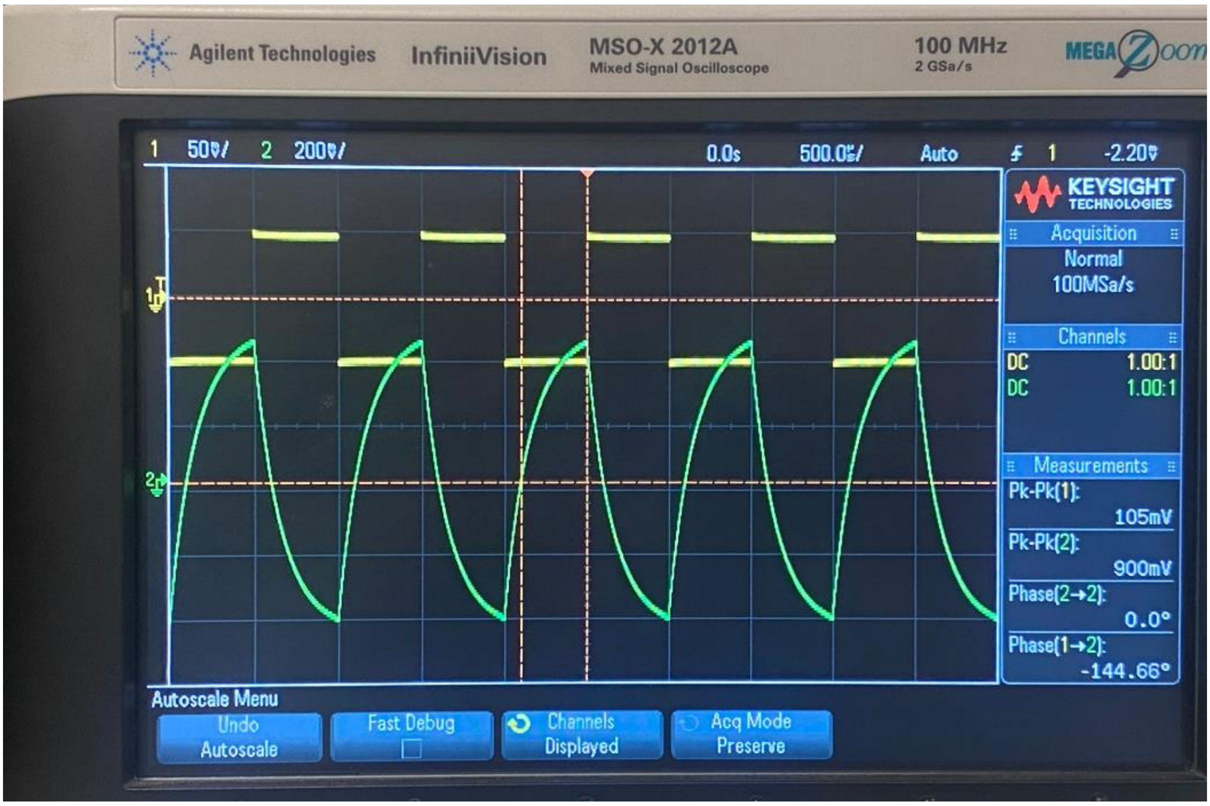

Figure 10: triangular Waveform of the Effect non- linear Configuration

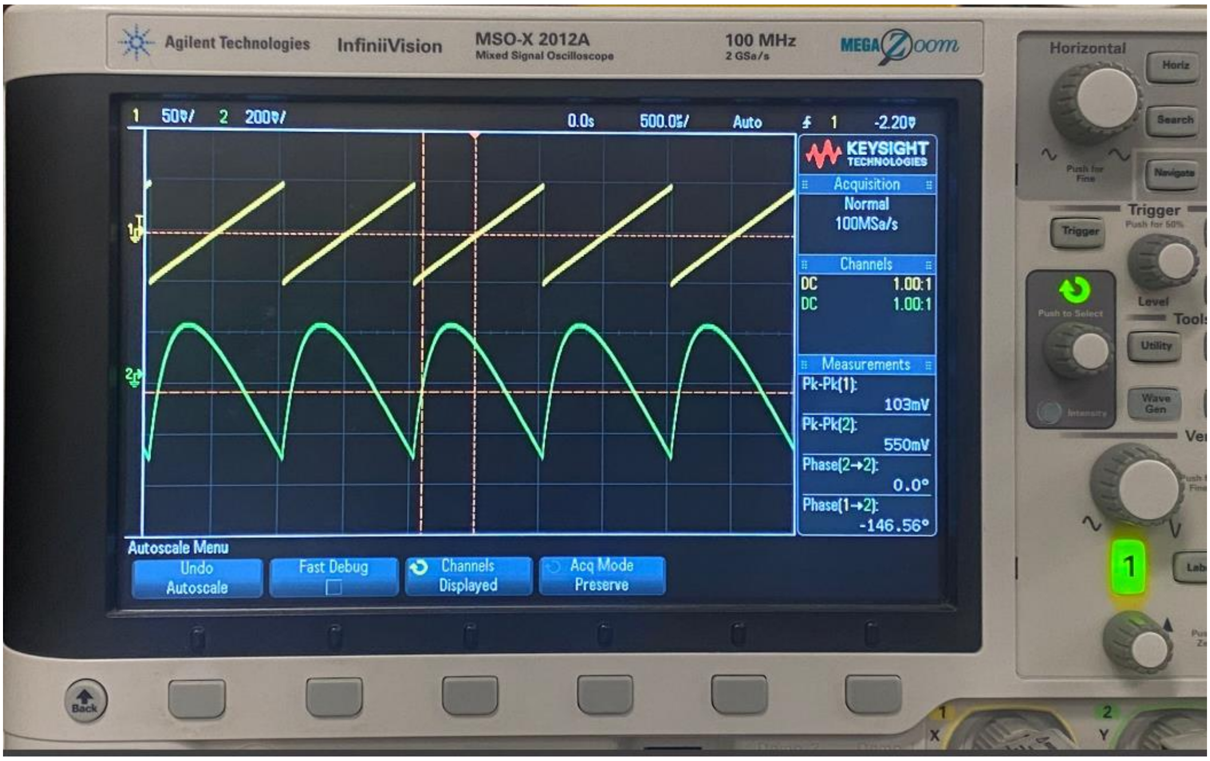

Figure 11: square Waveform of the Effect non- linear Configuration

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

$Av = 1 + \frac{Rf}{Rin}$ where Rf is =10kΩ , Rin = 1kΩ

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

which makes **Vout** qual 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.

The closed-loop gain of the inverting configuration (Q6.3) was calculated using the formula $Av = -\frac{Rf}{Rin}$

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

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

The experimental measurements confirmed his, 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

Rf is the feedback resister (1kΩ)

$R1$ is the resister for V1 (2kΩ),

$R2$ is the resister for V2 (1kΩ),

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

$$\boldsymbol{V}\text{out} = -\left(\frac{Rf}{R1}.V1 + \frac{Rf}{R2}.V2\right)$$

$$\boldsymbol{V}\text{out} = -\left(\frac{1k\Omega}{2k\Omega}.V1 + \frac{1k\Omega}{1k\Omega}.V2\right)$$

$$\text{Vout} = -(0.5\text{V1} + 1\text{V2})$$

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 as ideal op-amp [input (Non inverting) which is V_2

Output (inverting) which is V

$$V_2 - V_1 = 0$$

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

$$V_1 = V_{in}$$

$$\boxed{V_0 = V_{in}}$$

(ii) Op-Amp Non-inverting configuration:-

Vin 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.

$I_{R_1} = I_{R_2}$

$\frac{0 - V_1}{R_1} = \frac{V_1 - V_0}{R_2}$

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

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

$= \frac{-R_2}{R_1} = 1 - \frac{V_0}{V_{in}}$

$= \frac{V_0}{V_{in}} = 1 + \frac{R_2}{R_1}$

$= 1 + \frac{10k\Omega}{1k\Omega}$

$\therefore A_v = 11$

$\therefore$ close loop gain is 11.

(iii) Op-Amp Inverting configuration:-

Considering the ideal Op-Amp

$V_2 - V_1 = 0$

$V_2 = 0, \; V_1 = 0$

Current passing through Op Amp is 0

$I_{R1} = I_{R2}$

Using KCL,

$$\frac{V_{in} - V_1}{R_1} = \frac{V_1 - V_0}{R_2}$$

$$\therefore \frac{V_{in}}{R_1} = \frac{-V_0}{R_2} \qquad [\because V_1 = 0]$$

$$\frac{V_0}{V_{in}} = \frac{-R_2}{R_1} = \frac{-10k\Omega}{1k\Omega} = -10.$$

(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