Faculty of Engineering, Alexandria University
Computer & Communications Program

EEC116
Analysis of Electrical Circuits

Final Project Report

Operational Amplifiers
Inverting, Non-Inverting & Buffer Applications

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***Abstract*—This lab report aims to study ideal operational amplifiers (otherwise known as *op-amps*) and three of their applications, by using the simulation software NI Multisim and comparing the simulated measurements of the voltage gain to the theoretical values. Op-amps offer significant voltage gain, which this project will demonstrate.**

1. The Inverting Closed Loop

1.1. The Circuit

The circuit in Figure 1 is a layout of the inverting closed loop op-amp circuit connected to an oscilloscope that measures the input and output voltage.

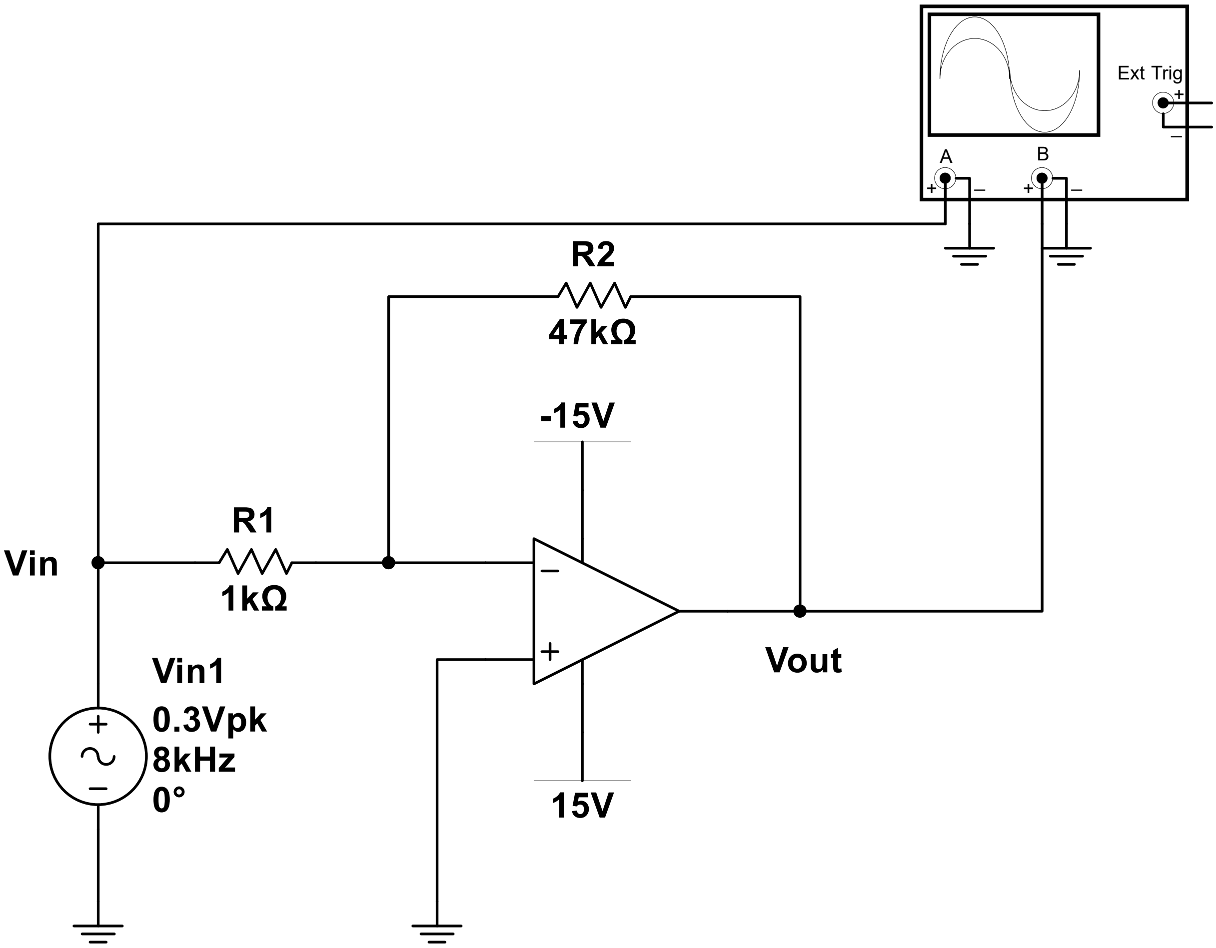

Figure 1: Circuit design in NI Multisim

1.2. Theoretical Gain

The theoretical formula for the voltage gain $G = \frac{V_o}{V_{in}}$ is $\frac{-R_2}{R_1}$. This evaluates to $\frac{-47{,}000}{1{,}000} = -47$.

1.3. Simulated Data

1.3.1. Oscilloscope Measurement

Figure 2 is a screenshot of the oscilloscope window, showing the sine wave of the output voltage (Channel B) in red (higher peaks) and the and the input voltage (Channel A) in black (lower peaks).

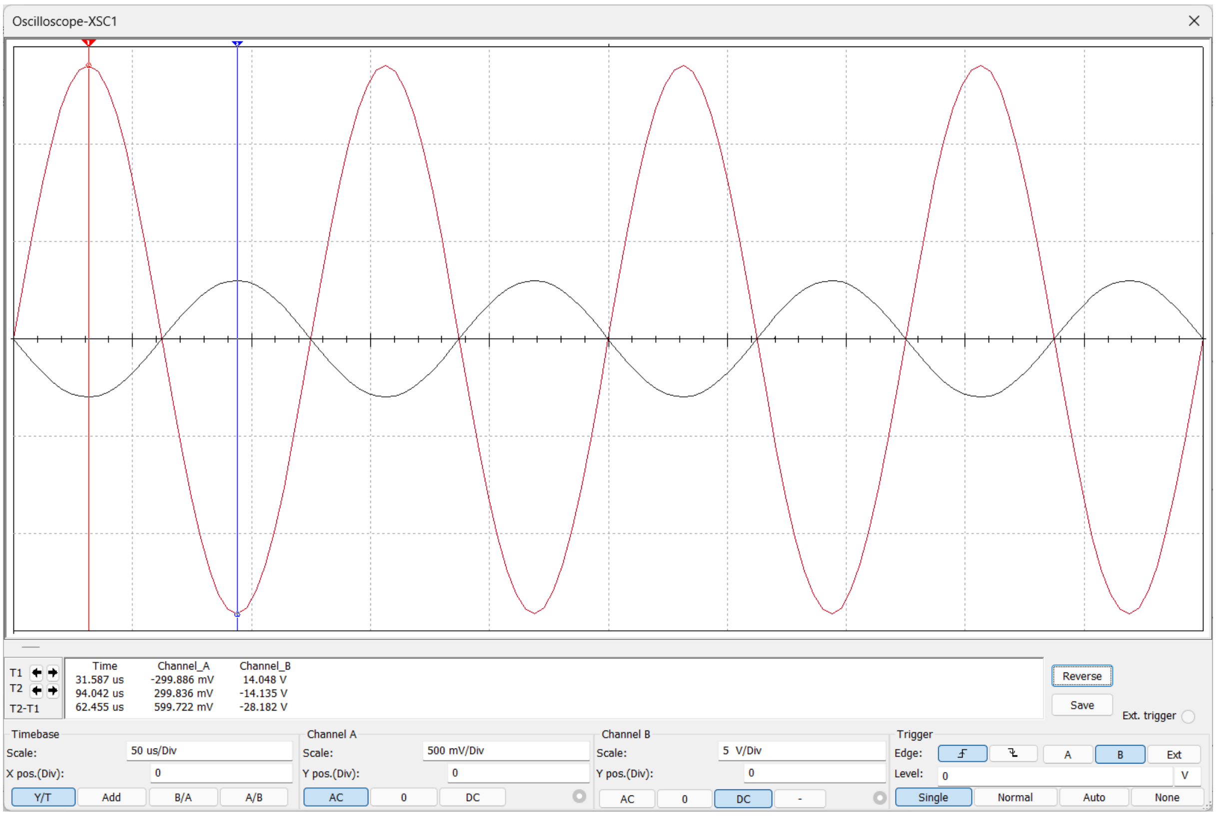

Figure 2: Oscilloscope readings window in NI Multisim

1.3.2. Calculation on Readings

$$G_{\text{experimental}} = \frac{-28.182}{0.599722} = -46.99 \approx -47$$

1.4. Conclusion

$$G_{\text{theoretical}} = -47$$
$$G_{\text{experimental}} = -47$$

The theoretical and simulated gain in voltage match together.

2. The Non-Inverting Closed Loop

2.1. The Circuit

The circuit in Figure 3 is a layout of the non-inverting closed loop op-amp circuit connected to an oscilloscope that measures the input and output voltage.

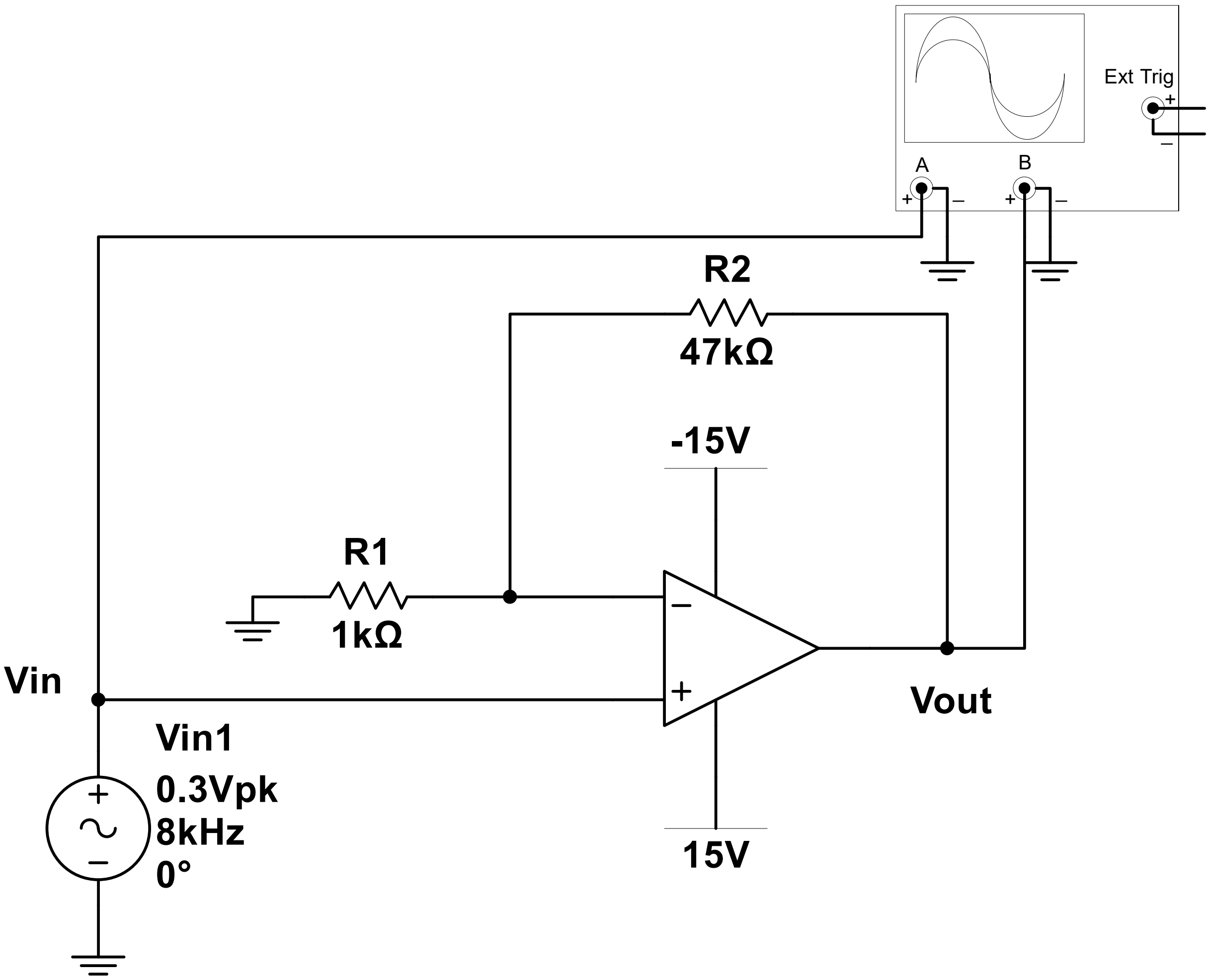

Figure 3: Circuit design in NI Multisim

2.2. Theoretical Gain

The theoretical formula for the voltage gain $G = \frac{V_o}{V_{in}}$ is $\frac{R_1 + R_2}{R_1}$. This evaluates to $\frac{48{,}000}{1{,}000} = 48$.

2.3. Simulated Data

2.3.1. Oscilloscope Measurement

Figure 4 is a screenshot of the oscilloscope window, showing the sine wave of the output voltage (Channel B) in red (higher peaks) and the and the input voltage (Channel A) in black (lower peaks).

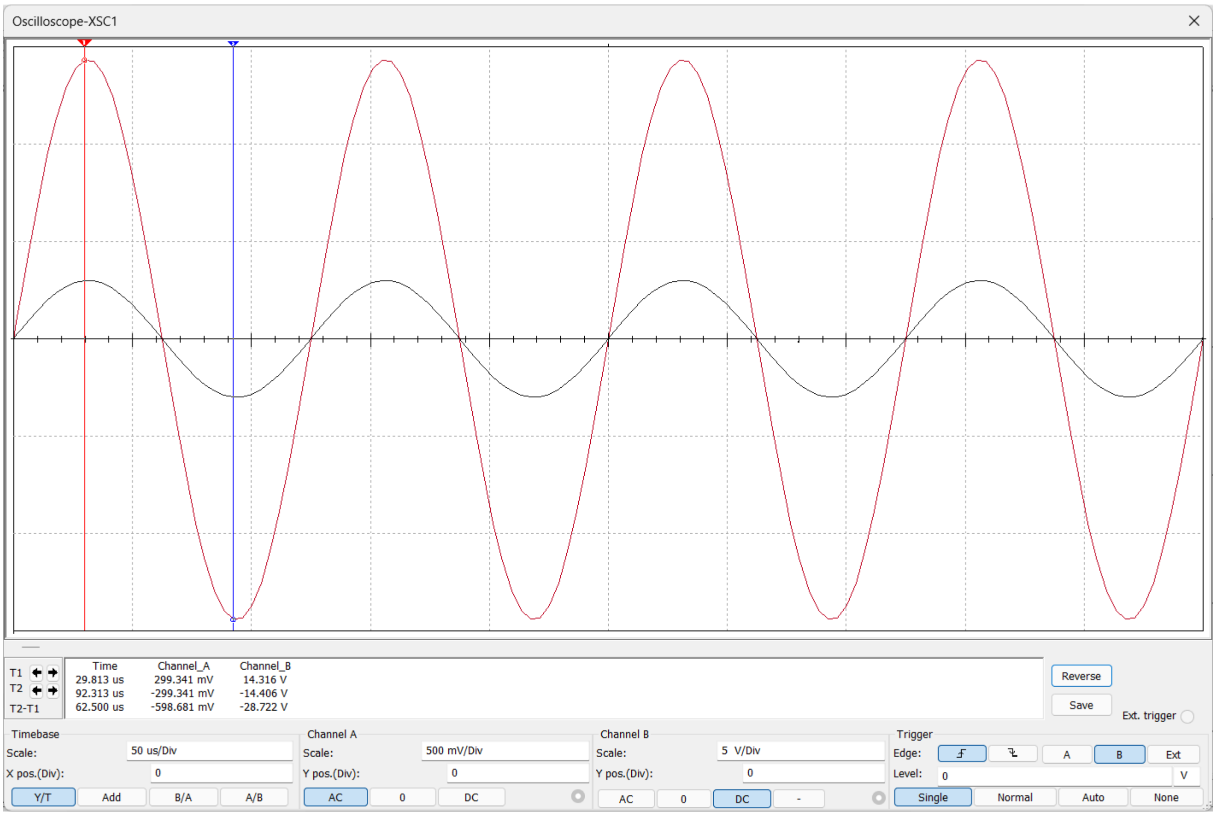

Figure 4: Oscilloscope readings window in NI Multisim

2.3.2. Calculation on Readings

$$G_{\text{experimental}} = \frac{-28.722}{-0.598681} = 47.97 \approx 48$$

2.4. Conclusion

$$G_{\text{theoretical}} = 48$$
$$G_{\text{experimental}} = 48$$

The theoretical and simulated gain in voltage match together.

3. Voltage Follower (Buffer)

3.1. The Circuit

The circuit in Figure 5 is a layout of the buffer op-amp circuit connected to an oscilloscope that measures the input and output voltage.

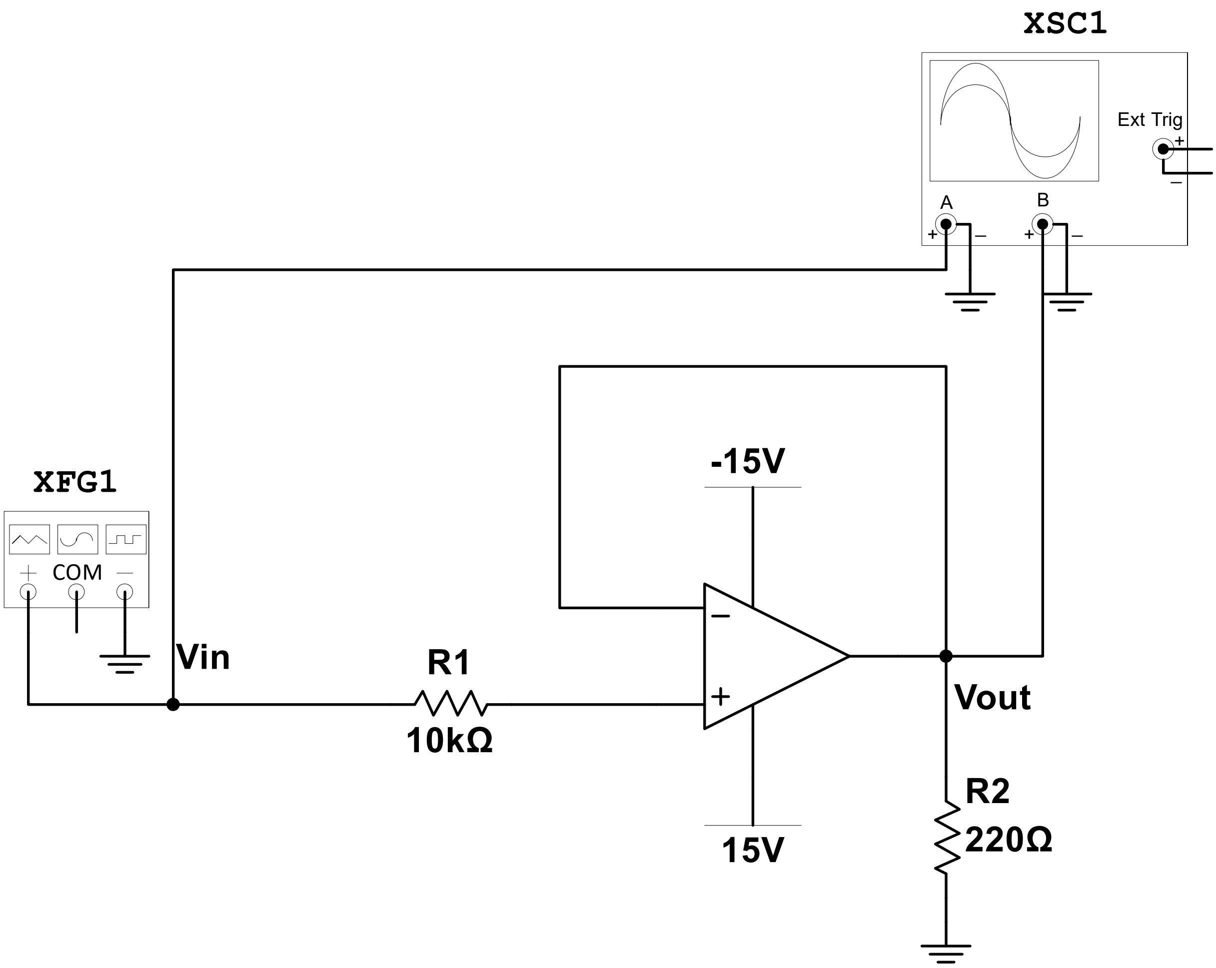

Figure 5: Circuit design in NI Multisim

3.2. Theoretical Gain

Theoretically, the output voltage is the same as the input voltage. Here the input voltage is set to $0.6V_{\text{p-p}}$.

3.3. Simulated Data

3.3.1. Oscilloscope Measurement

Figure 6 is a screenshot of the oscilloscope window, showing the square wave of the output voltage (Channel B) in red (higher peaks) and the and the input voltage (Channel A) in black (lower peaks). The scaling does not represent the actual magnitude.

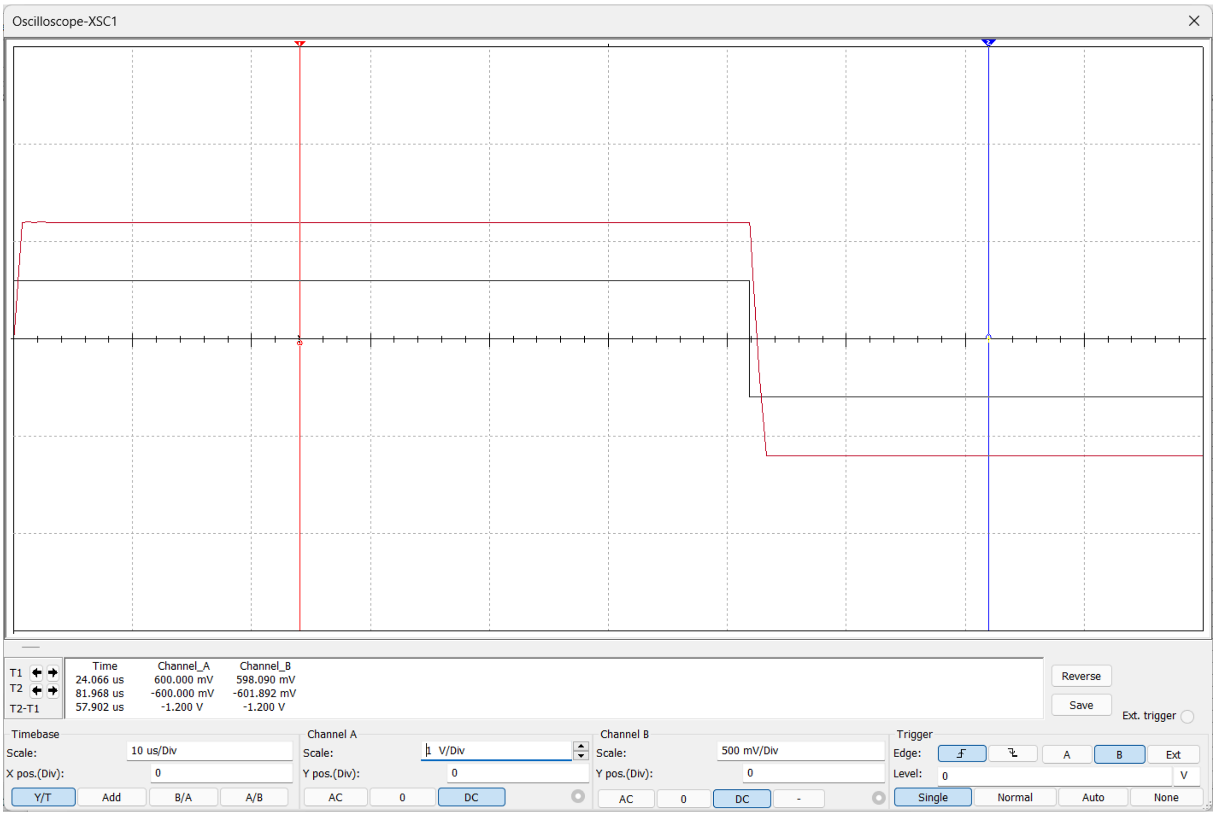

Figure 6: Oscilloscope readings window in NI Multisim

3.3.2. Calculation on Readings

$$G_{\text{experimental}} = \frac{0.601}{600} = 1.001 \approx 1$$

3.4. Conclusion

$$G_{\text{experimental}} = 1$$

$$A_{\text{p-p}} = \frac{V}{R} = \frac{0.6}{220} = 2.72 \text{ mA}$$