`ECE 65 – Components and Circuits Lab

Lab 2 Report – Circuit Simulations

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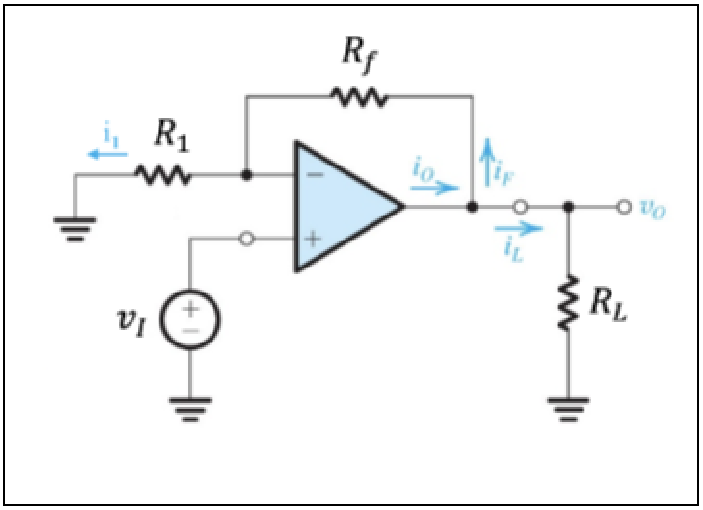
Abstract

The objective of this lab was to deepen our understanding of voltage amplification using operational amplifiers (op-amps). We conducted two experiments: the first involving a single op-amp and the second employing a two-op-amp configuration. For each experiment, we utilized circuit analysis and PSpice simulation techniques to calculate the expected input and output voltages of the circuits. These theoretical and simulated results were then tested through physical implementation on a breadboard. The experimental outcomes aligned closely with the predictions from our calculations and simulations, validating our initial hypotheses.

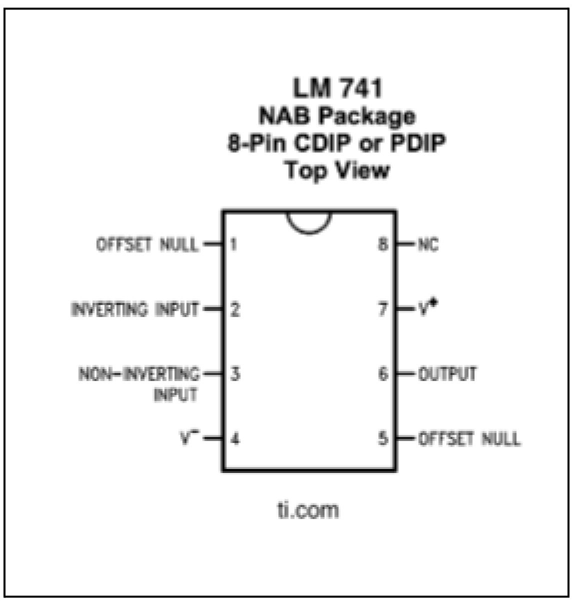
Experiment #1:

Build the circuit on the breadboard using an LM 741 chip.

The supply terminals, pin 4 and pin 7 must be connected to ±15V. The balance terminals and pin 8 can be left ”floating,” i.e., not connected. Connect the resistors in the appropriate fashion to form the non-inverting amplifier.



LM741 pinout:



Part 1:

Set the function generator to generate a sinusoidal waveform with a peak amplitude of VP= 1V and the frequency of 1kHz and use this waveform as the input voltage signal (vI). Use RL= 1kΩ in your circuit.

1. Measure the input and output waveform using the Oscilloscope.

In the waveform generator, we setted up the sinusoidal wave to have a 2.0 VPP and a frequency of 1kHz, with a 0 V offset.
The peak to peak of the input waveform is 2V.
The peak to peak of the output waveform is 20V.

2. Is the gain of the circuit as expected by the equations?

V_{in}= 2V

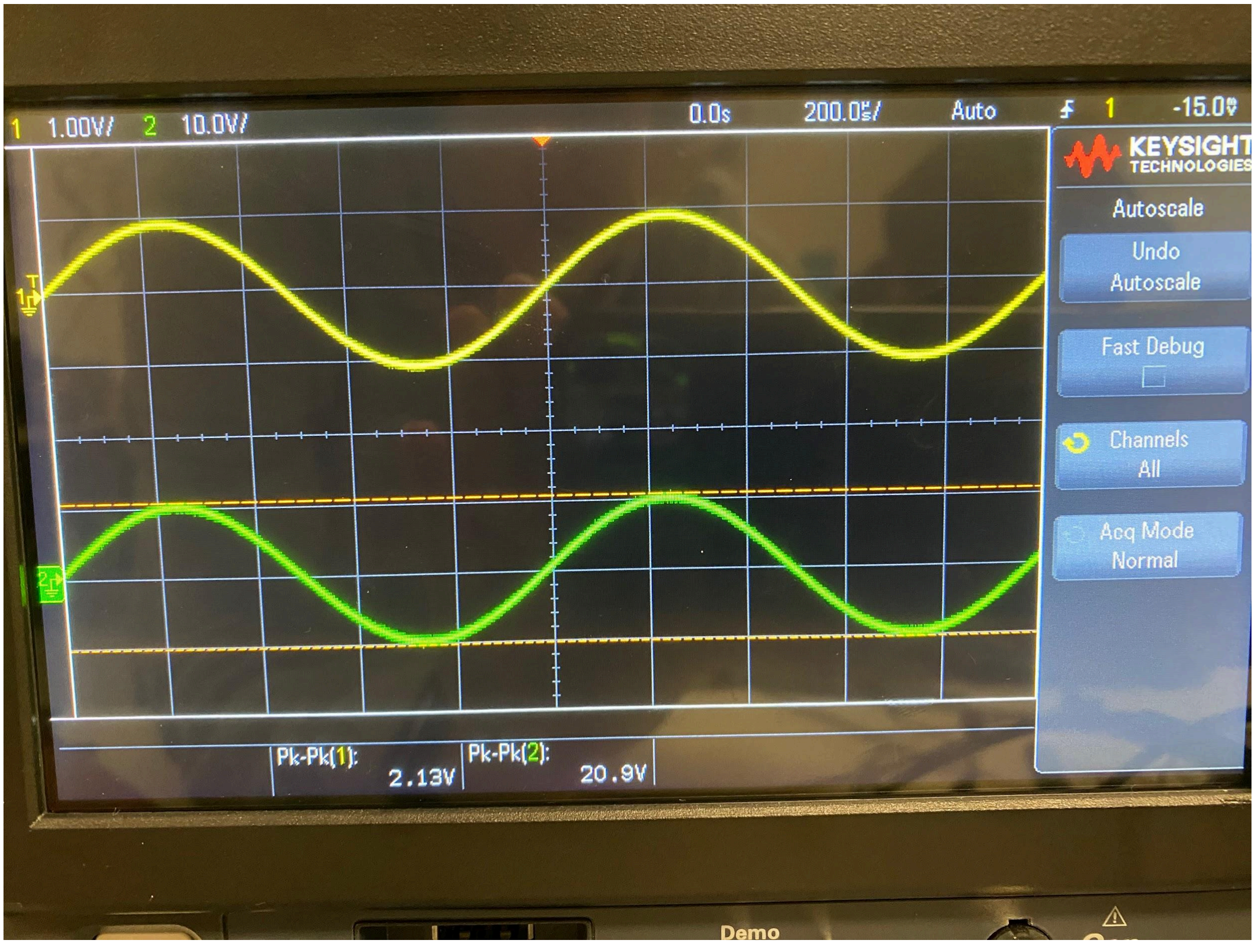
$A_V = 1 + \frac{R_f}{L} = 1 + \frac{9k\Omega}{1k\Omega} = 10V$

$V_o = A_V(V_{in}) = 10(2V) = 20V$

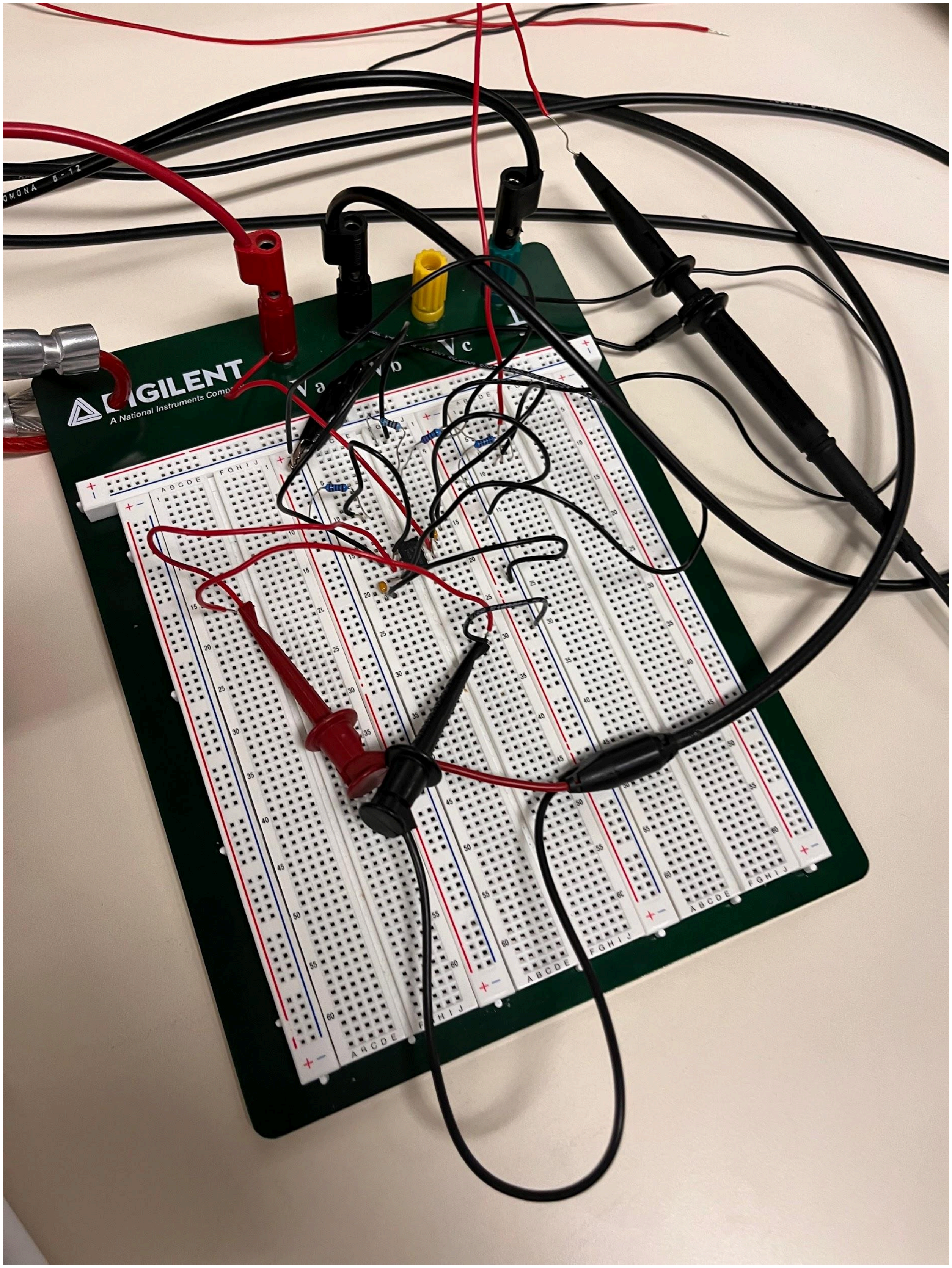
Based on the equation, we expect that the circuit will have a gain of 10V using the non-inverting formula.

Based on what we saw from the Oscilloscope device, when we compared the input vs. the output waveform, we noticed that the output waveform had a greater amplitude than the input waveform. The voltage out waveform had an amplitude 10 times greater than the input voltage waveform.

3. Include the graphs of the waveforms in your lab report.



4. Include a photo of your circuit setup in your lab report.



Part 2:

Repeat Part 1 for a sinusoidal waveform with the peak amplitude of VP= 1.5V and the frequency of 1kHz, and RL= 1kΩ

1. Measure the input and output waveform using the Oscilloscope.

V_{in} is 3.1V.

V_{out} is 27.3V.

2. Is the output waveform any different from the previous one? Explain your observation.

the output waveform is different from the previous one because the output voltage saturates (flattens) rather than peaking at the peak amplitude

3. Measure the total output current.

The total output current is 11mA.

4. What is the limiting factor of the amplitude of the input signal?

The limiting factor of the amplitude of the input signal is the voltage power supply.

Part 3:

Keeping RL= 1kΩ and using a sinusoidal input voltage, find the peak amplitude of the input voltage at which the output of the op-amp saturates.

1. What is the peak amplitude of the output current for this value of VP?

The peak amplitude of the output current for this value of VP
Find value of Vin toop

$$Peak\ Input\ Voltage\ =\ Saturation\ voltage/\ Circuit\ gain$$
$$Peak\ Input\ Voltage\ = \frac{15V}{10} = 1.5V$$

Finding peak amplitude of output current using Ohm's law, with the values of the peak input voltage

Peak amplitude of output current is 15mA.

Part 4:

Set the function generator to generate a sinusoidal waveform with the peak amplitude of Vp= 1V and the frequency of 1kHz and use this waveform as the input voltage signal (vI). Use a 10kΩ potentiometer as the load. Set the value of the potentiometer to its maximum 10kΩ and gradually decrease RL.

1. How does the output voltage waveform change when you reduce the value of RL?

As RL decreases, the output voltages decrease, and vice versa.

2. For what RL value will the output of the op-amp saturate?

The RL value will plateau at the value of
$V_{peak} = I_{peak}R$
Using the multimeter we found that the value of RL is 9komh's when the output of the op-amp saturates.

3. What is the maximum peak amplitude of the op-amp output current?

The max peak amplitude of the op-amp output current should 13.5mA.
V_{out} is 27.3V/2 = $\frac{13.5V}{R_L} = \frac{13.5}{1k\Omega} = 13.5mA$

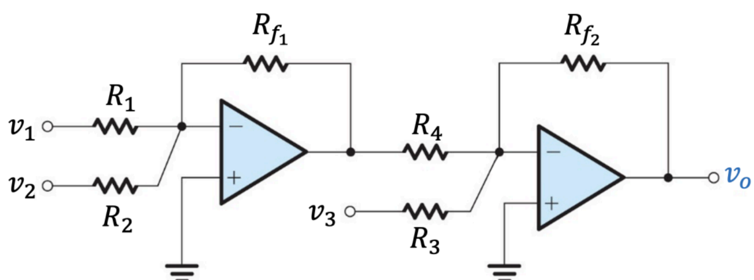
Experiment #2: Op-amp weighted summer

In this part of the experiment, we will design a summing amplifier in the inverting configuration. This circuit can be used to design and test standard mathematical linear equations and see the different results in terms of the output signals. The following diagram represents a summing amplifier.

Build the circuit on the breadboard using two LM741 op-amps.

$$v_o = 2v_1 + v_2 - 4v_3$$

Use resistor values between 500 Ω and 100 kΩ in your design.



1. Use two DC voltage sources as v1 and v3 and a sinusoidal signal with f= 1kHz from the function generator as source voltages. Use the voltage source amplitudes that you calculated in your prelab.

$R_{f1} = 2k\Omega$

$R_{f2} = 2k\Omega$

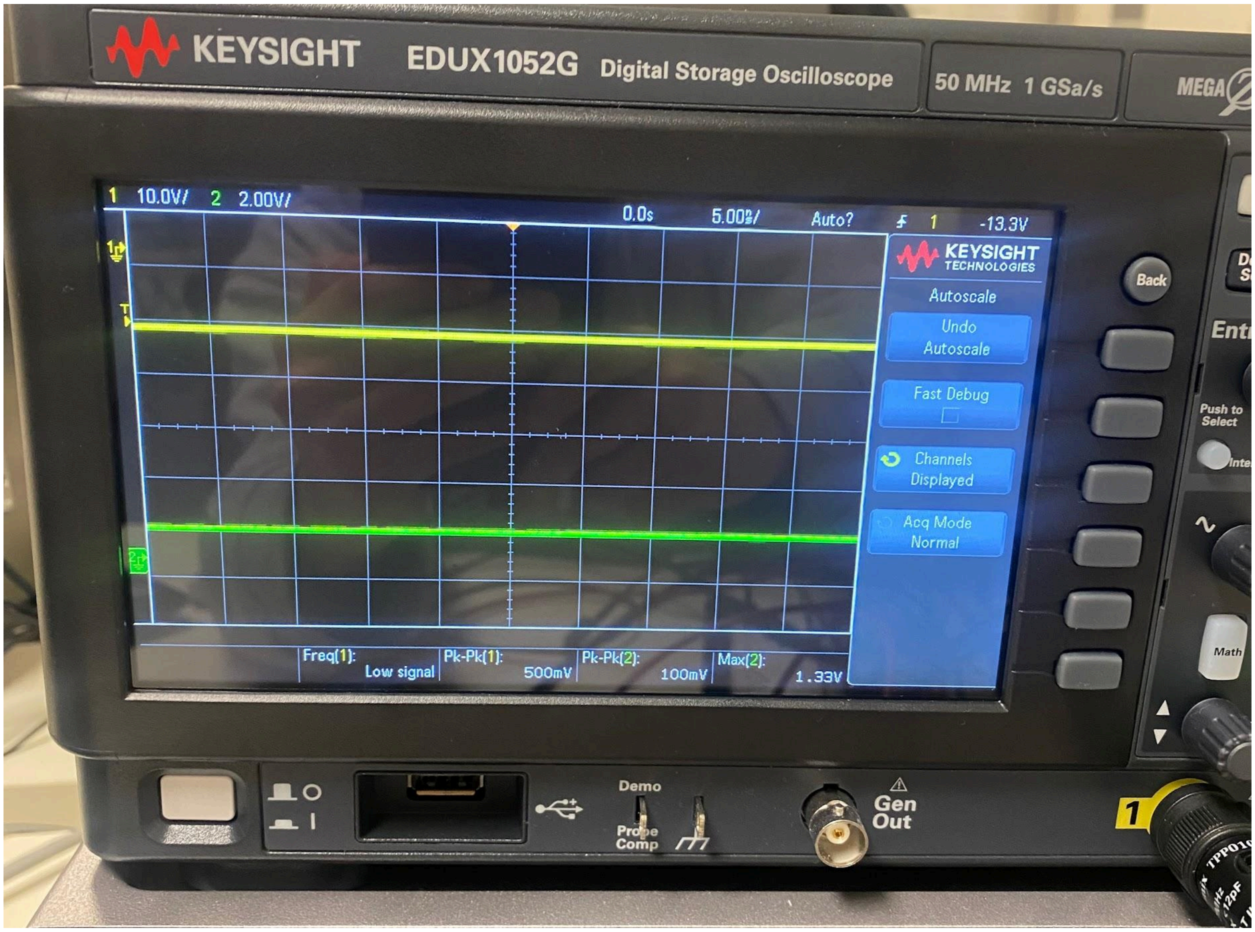
$R_1 = 1k\Omega$

$R_2 = 2k\Omega$

$R_3 = 500\Omega$

$R_4 = 2k\Omega$

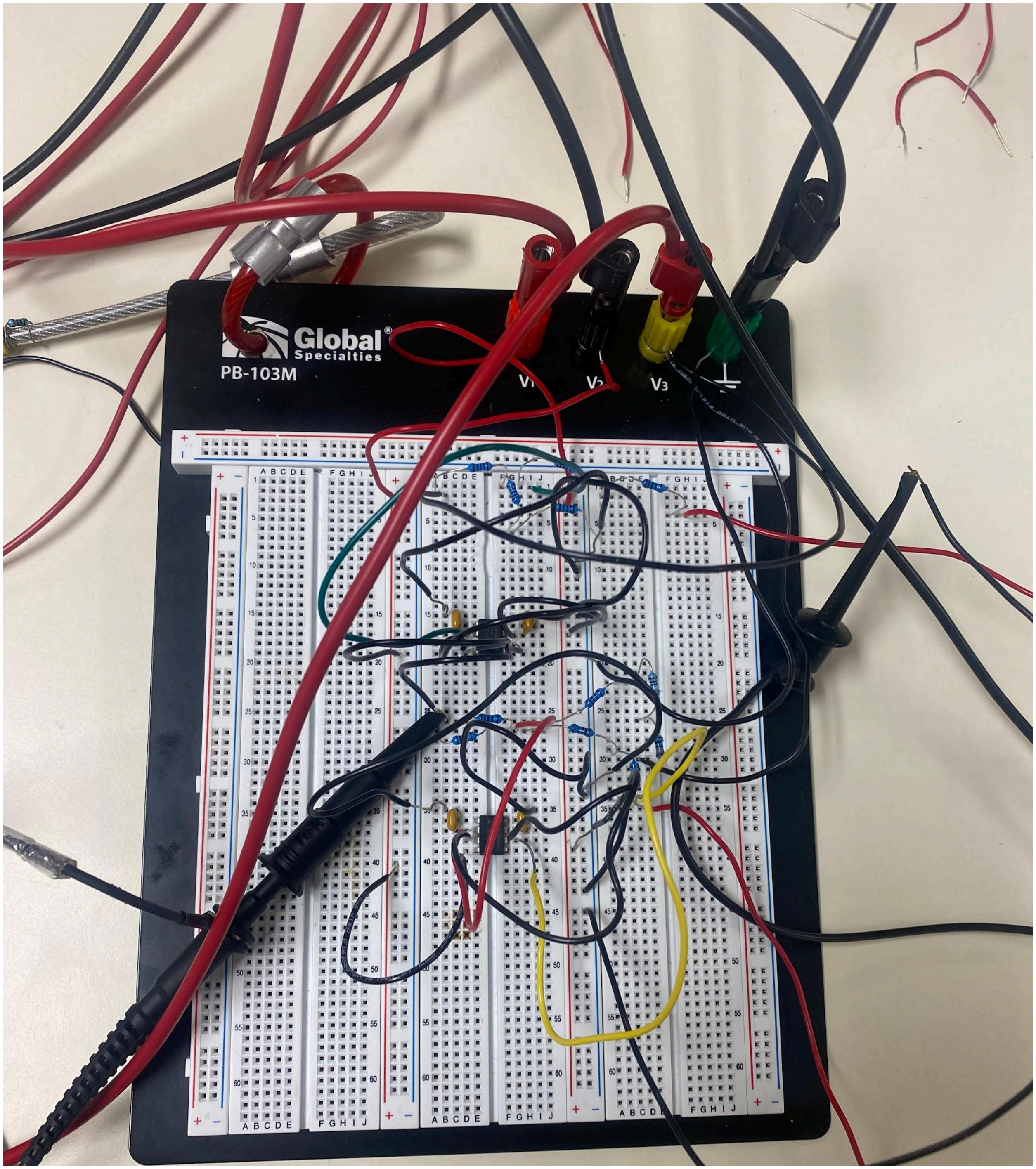
2. Measure the voltage waveforms at the output of each op-amp using the oscilloscope and include a photo of these waveforms in your report.



3. Do the results match your expectation?

Similar to the first experiment, in the second experiment we added another op-amp to the circuit. Unfortunately, the results did not match our expectations because we went into a few challenges in the lab and what we expected was two sine waves that represented the abilities of this circuit's summing amplification.

4. Include a photo of your circuit setup in your lab report.



Conclusion

In this lab, we analyzed and experimented with two distinct circuits containing operational amplifiers (op-amps).

In the first experiment, we implemented a single-op-amp circuit using the resistor values calculated during the pre-lab. Using an oscilloscope, we measured various voltage waveforms and compared them to our theoretical predictions under different input conditions, such as varying the peak voltage of a sinusoidal source. These measurements allowed us to observe the saturation behavior of the op-amp, evident when the output voltage plateaued in the graphs. Additionally, we analyzed the impact of changing the load resistor, noting that a decrease in the load resistance led to a corresponding decrease in output voltage. We also calculated the output current for different cases, enhancing our understanding of the relationship between the physical circuit and the theoretical concepts of op-amp operation.

In the second experiment, we implemented a more complex two-op-amp circuit comprising six resistors, two DC inputs, and one AC input. Using the derived relationship between Vo, V1, V2, and V3 from the pre-lab, we determined the required resistor values, simulated the circuit to verify input voltages, and then constructed it on a breadboard. Measurements of the output voltages from both op-amps confirmed our expectations, with the second op-amp exhibiting a higher output voltage than the first. This experiment expanded our understanding of op-amps, demonstrating their capabilities in more intricate circuit configurations.

Overall, this lab reinforced our theoretical knowledge of op-amps through practical application, simulations, and hands-on circuit implementation.