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ELEN3081
Experiment 2
Nov 8, 2021

Verification against Manufacturer's Specifications

Using the LM741, we were able to first verify that the output of the opamp was as expected when a 2Vp-p, 1Hz triangle wave is connected to the non-inverting input of LM741. As seen in *Figure 1*, the output of the LM741 in this configuration produced a squarewave at the output terminal. There is visible noise that can be observed in the output.

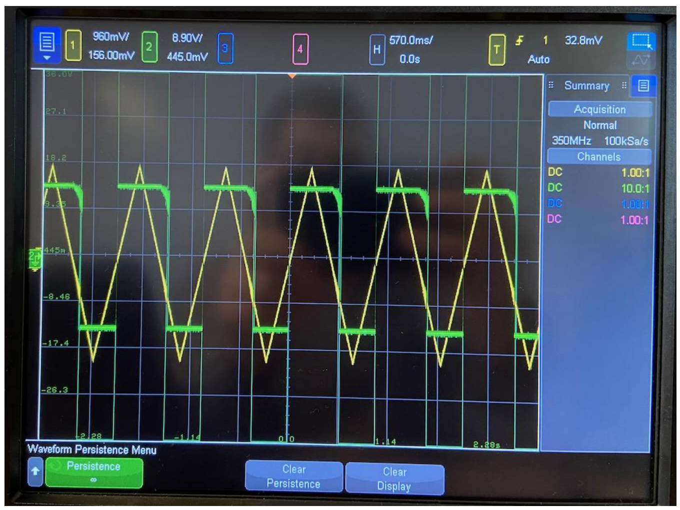

Figure 1: Despite visible noise, the expected output can be observed, demonstrating that the opamp performs as specified.

After loading the opamp with a 2kΩ resistor we are able to verify that the large signal voltage gain and output voltage swing are within spec. We can do this by analyzing the output seen in *Figure 2*.

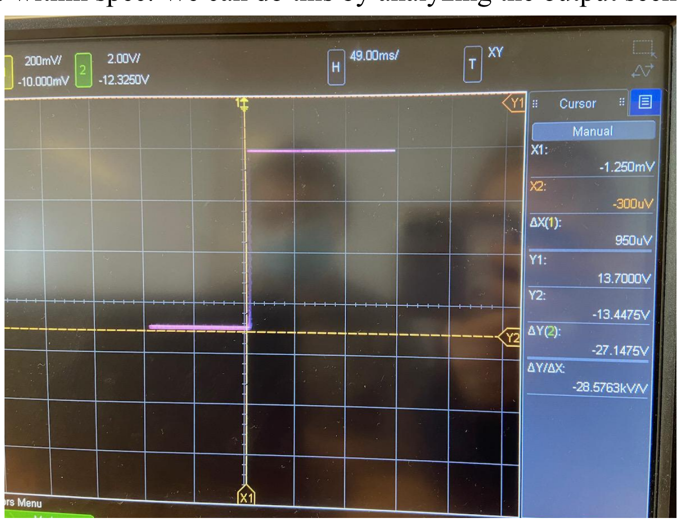

Figure 2: Voltage gain observed in the opamp.

We can see that there is a voltage gain from the opamp of $\frac{(13.700V)-(-13.4475V)}{(-1.250mV)-(-300\mu V)} =- 28.5763kV/V$. This is slightly under the large signal voltage gain given by the manufacturer, however it is still above the minimum gain of 25. Further, we can see that there is an output voltage swing of 13.7V. From the manufacturer, this is typically $\pm\ 13V$ for a load resistor greater than 2kΩ.

Finally, we can verify the output short circuit current for the opamp by shorting the opamp output to ground. From the manufacturer, we expect for there to be an output short circuit current of 25mA. When observed, we see an output short circuit current of 27.410mA. This can be seen in *Figure 4*. *Figure 3* shows a table with manufacturer and measured specifications.

Figure 3:

	Manufacturer's Specifications	Measured Values
Large Signal Voltage Gain	MIN: 25 TYP: 200	28.5762
Output Voltage Swing	MIN: ±10V TYP: ±13V	13.7V
Output Short Circuit Current	TYP: 25mA	27.410mA

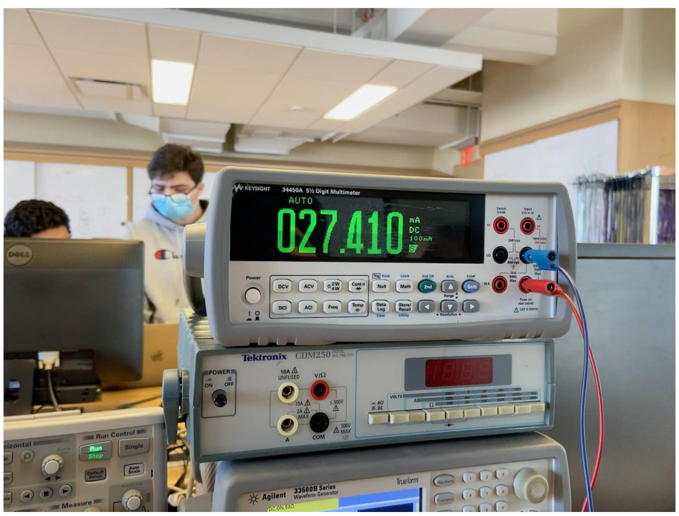

Figure 4: An output short circuit current of ~25mA can be observed.

Opamp with a Unity Gain Buffer

Through connecting the opamp as a unity gain buffer and by shorting the non-inverting input to ground we would expect to read an output voltage equal to that of the input voltage. An ammeter, through the grounded non-inverting input terminal reads a current of 77.5nA—this is the input bias current, with a typical value of 80nA, according to the manufacturer's specifications. *Figure 4* shows the reading of the input bias current through the ammeter. Then, connecting a 200mVp-p, 200 Hz sine wave to the non-inverting input through the ammeter reveals that the output voltage does, more or less, follow the input voltage. As with anything, we cannot expect for there to be no current at the input terminals of the opamps, however, this value is relatively small, so in most cases we should be able to make this approximation for most calculations. This same idea carries for the “virtual short” between the two input terminals—while we can approximate this to be true, it is not always perfect in the real world.

Figure 4: A measured output bias current of 77.5nA is observed.

Unity Gain Buffer with a 5KΩ resistor

By connecting a 5KΩ resistor to the input of the unity gain buffer, we can see how the opamp behaves when connected to a non-ideal source. *Figure 5* shows the opamp performing with the non-ideal source and it demonstrates that the unity gain buffer is extremely useful in preserving the input, since the input equals the output and there is minimal current drawn. *Figure 6* shows how the circuit behaves without the opamp.

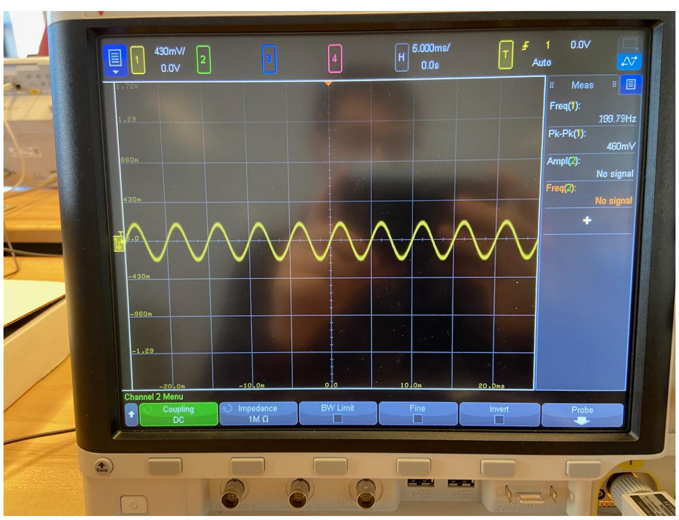

Figure 5: The unity gain buffer ensures that the input is equal to the output.

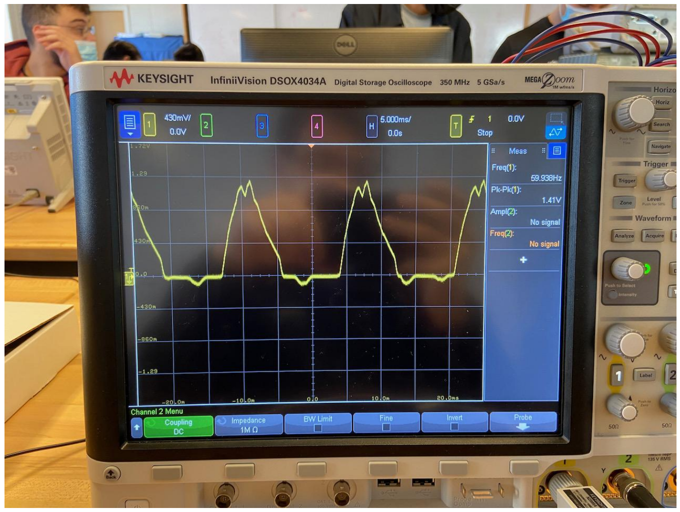

Figure 6: The output of the non-ideal source without the opamp.

Inverting Amplifier with a Set Gain Magnitude

To build an inverting amplifier with a set gain magnitude of 10, we can just the model of an inverting amplifier with the following relationship for the input resistor and the feedback resistor: $\frac{R_f}{R_1} = 10$. Given that, we decided to use a feedback resistor of 10KΩ and an input resistor of 1KΩ. The schematic for this circuit can be seen in *figure 7*, and the output seen in *figure 8* shows the output over a 2KΩ load resistor.

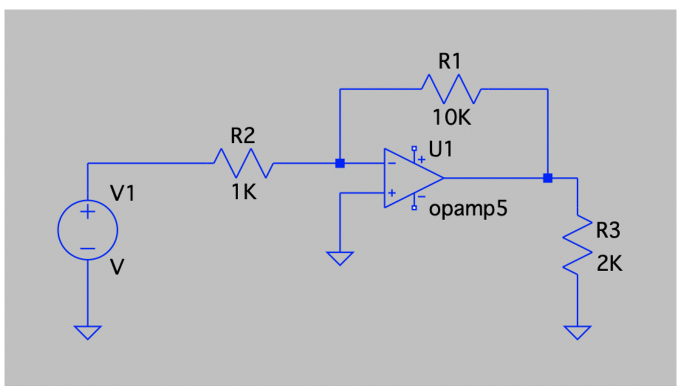

Figure 7: The schematic for an inverting amplifier with a gain of 10.

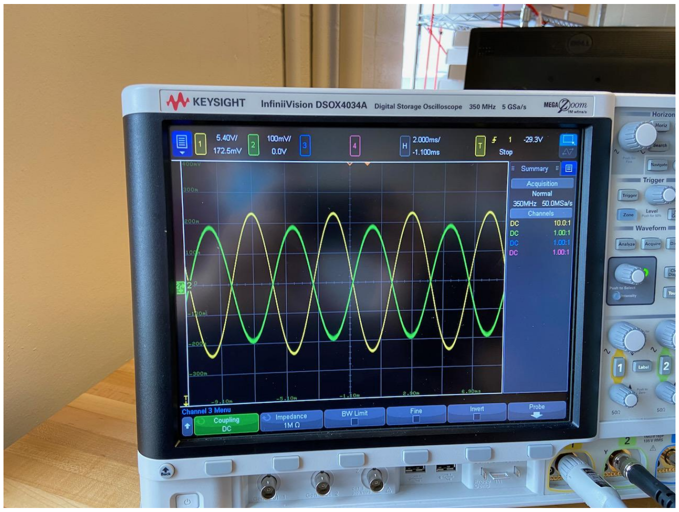

Figure 8: The inverting opamp with a gain of 10.

Variable-Gain Inverting Amplifier

By replacing the feedback resistor with a 10KΩ potentiometer, we were able to create a variable-gain inverting amplifier with a gain from 0 to 10. The schematic for this circuit is shown in *figure 9*. The outputs of this variable-gain inverting amplifier are shown in *figures 10, 11, 12*.

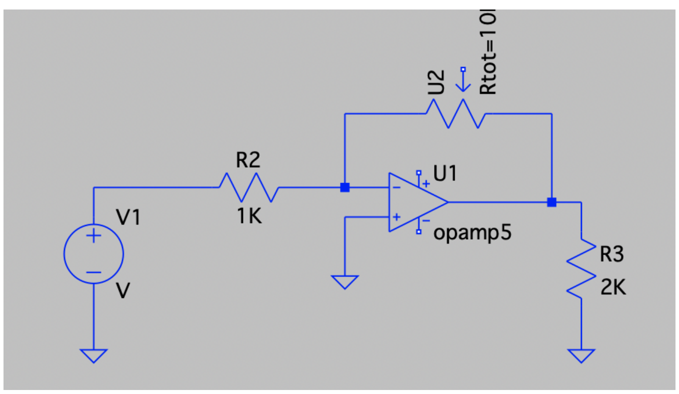

Figure 9: The schematic for a variable-gain inverting amplifier with a gain ranging from 0 to 10.

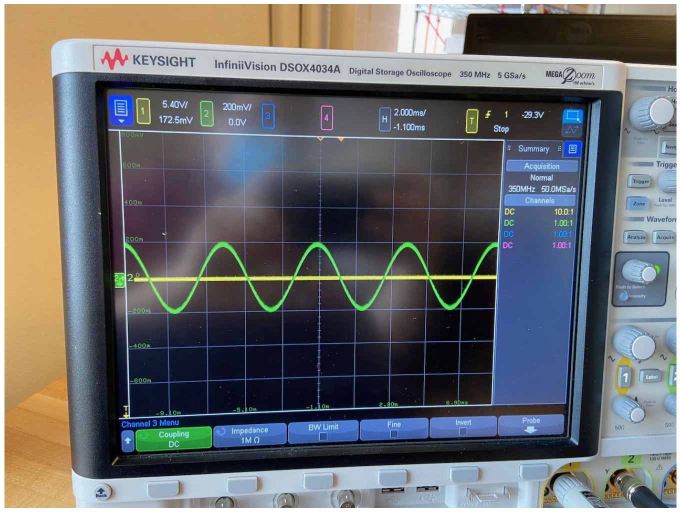

Figure 10: A gain of 0 seen by the inverting amplifier.

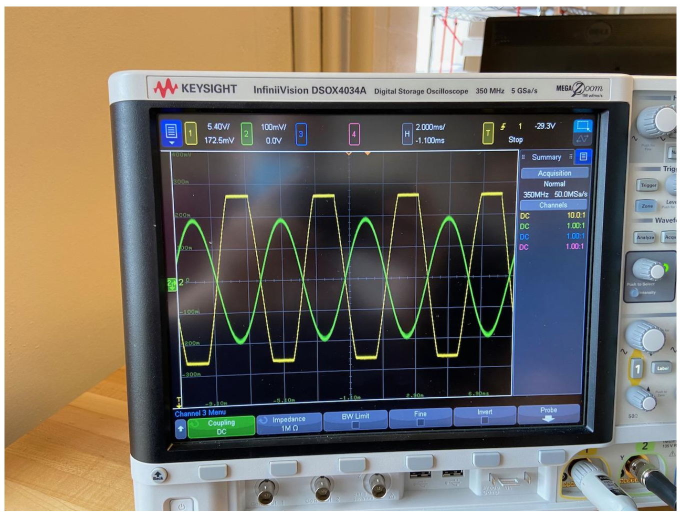

Figure 11: A gain of 5 seen by the inverting amplifier.

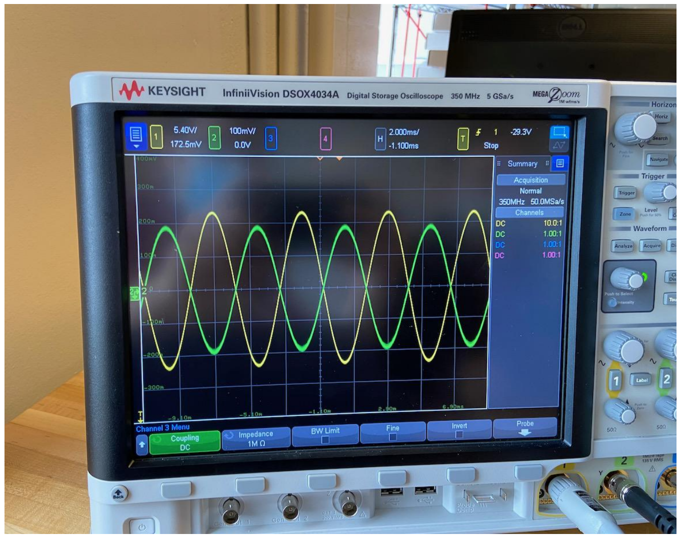

Figure 12: A gain of 10 seen by the inverting amplifier.

Non-Inverting Amplifier with a Set Gain Magnitude

Similarly to the inverting amplifier with a set gain magnitude, we can build a non-inverting amplifier with a set gain magnitude. We do this by creating a circuit much like that seen in *figure 7* with the only difference being that the input must be placed on the non-inverting input. Additionally, we must change the input resistors so that they follow the form $A = 1 + \frac{R_f}{R_1}$ where A is the gain of the opamp. To achieve a gain of 10, we used a feedback resistor with a value of 9KΩ and an input resistor with a value of 1KΩ. The output of this circuit can be seen in *figure 14*.

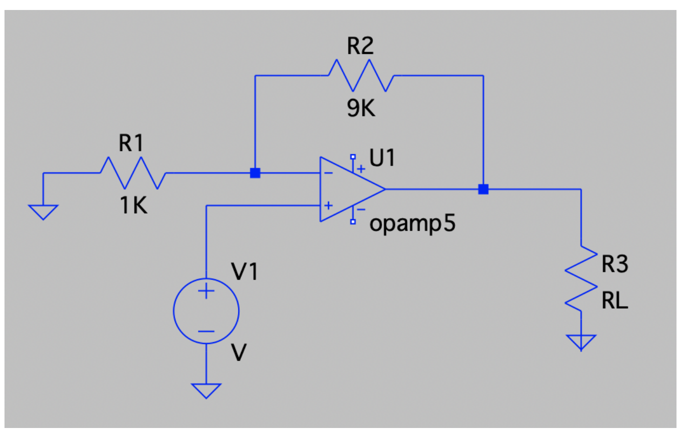

Figure 13: A non-inverting amplifier with a gain of 10.

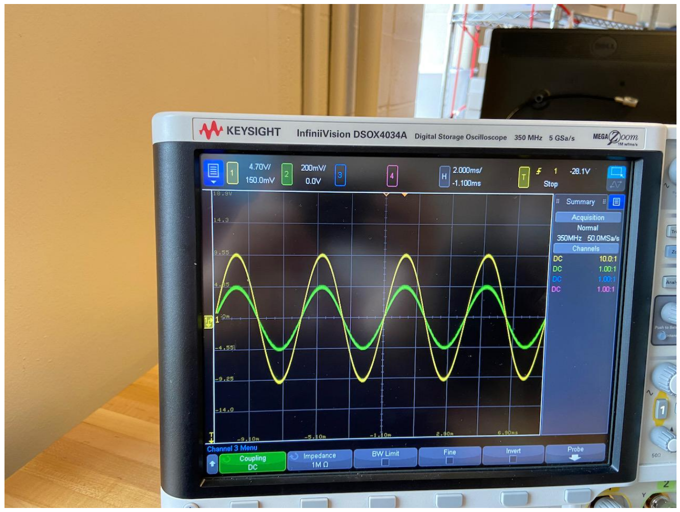

Figure 14: The output of the non-inverting amplifier with a gain of 10.

Variable-Gain Non-Inverting Amplifier

Similarly to the inverting amplifier with a variable gain, we can build a non-inverting amplifier with a variable gain using a 10KΩ potentiometer. We do this by creating a circuit much like that seen in *figure 13* with the only difference being that the feedback resistor is replaced with a 10KΩ potentiometer. This means that we will have a gain ranging from 1 to 11. The output of this circuit can be seen in *figures 16, 17, 18*.

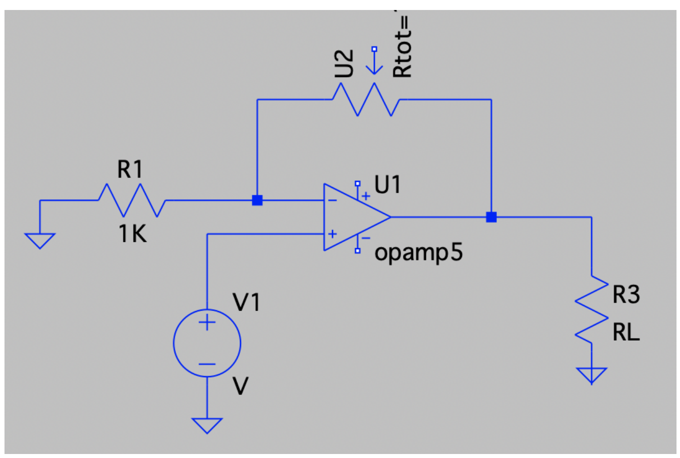

Figure 15: A non-inverting amplifier with a variable gain ranging from 1 to 11.

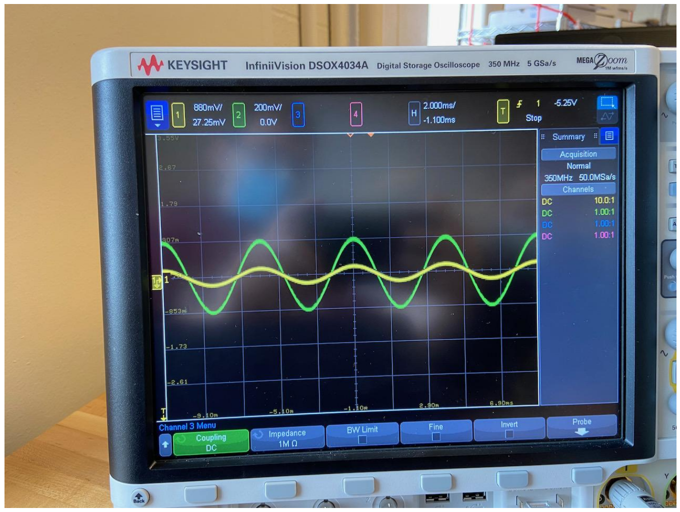

Figure 16: A non-inverting amplifier with a gain of 1.

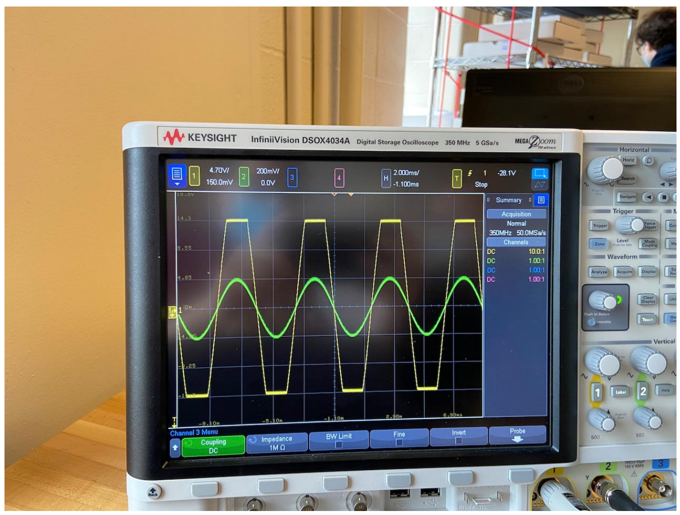

Figure 17: A non-inverting amplifier with a gain of 5.

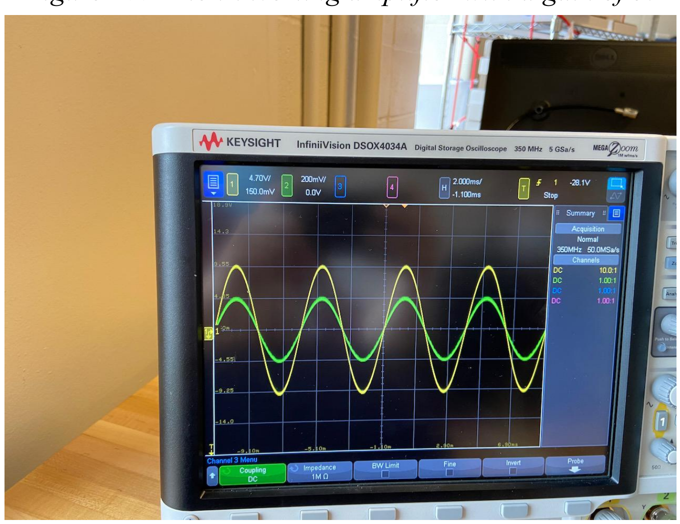

Figure 18: A non-inverting amplifier with a gain of 10.

Dual-Input Summing Inverting Amplifier

With the challenge of designing a dual-input summing Amplifier with the output $-\ (2V_1(t)\ +V_2(t))$, we can use the standard model for a multiple-input summing inverting amplifier with input resistances equal to $\frac{R_f}{A}$ where A is the leading coefficient seen in the output for each source—in our case these are 2, 1. To build this circuit, we chose to use a 2KΩ feedback resistor with a 1KΩ input resistor for the first signal and a 2KΩ resistor for the second signal. Then, we were able to test this dual-input summing inverting amplifier by testing a sinusoidal wave for the first signal and a square wave for the second signal.

The output seen in *figure 19* demonstrates that the desired output can be obtained from this circuit. A model of this circuit is shown in *figure 20*.

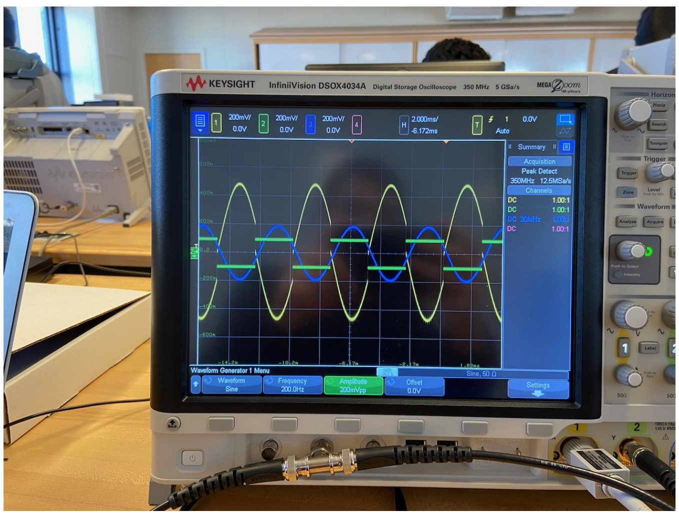

Figure 19: The desired output, seen in yellow, can be observed from both individual inputs.

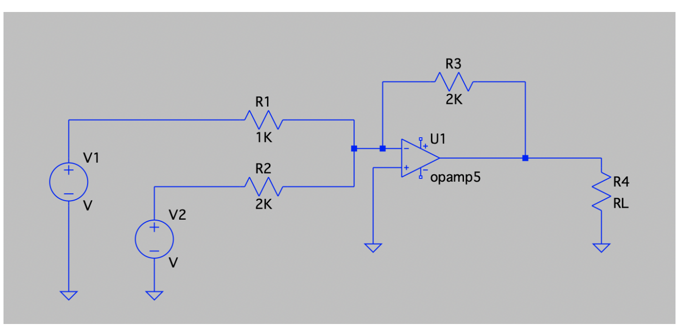

Figure 20: The schematic for the circuit we designed.

Dual-Input Differential Amplifier

With the challenge of designing a dual-input differential Amplifier with the output $V_1(t)\ - V_2(t)$, we can use the standard model for the dual-input differential amplifier where each input resistance is equal to each of the feedback resistances. Then, the voltage source at the inverting input is subtracted from the voltage source at the non-inverting input. The output seen in *figure 21* demonstrates that the desired output can be obtained from this circuit. A model of this circuit is shown in *figure 22*.

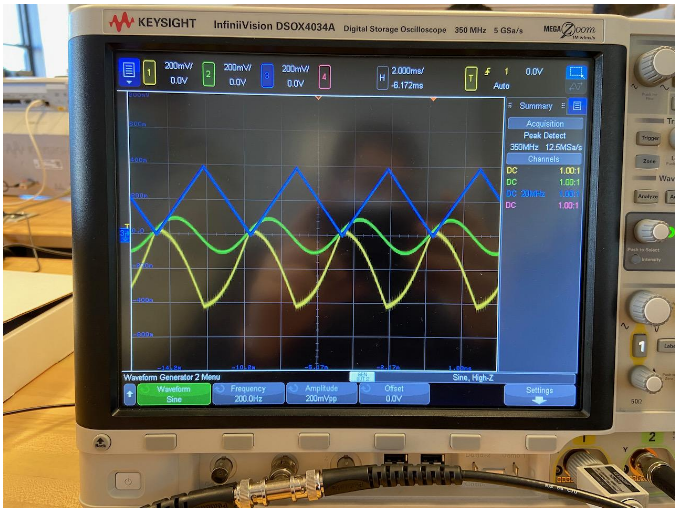

Figure 21: The desired output, seen in yellow, can be observed from both individual inputs.

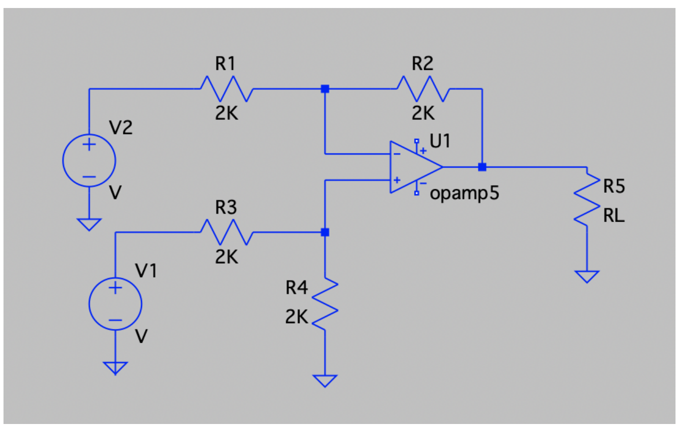

Figure 22: The schematic for the circuit we designed.