EEE 117L Laboratory – Network Analysis
Lab #6: Operational Amplifiers (Week I)

Lab Day and Time: Wednesday 1:30 - 4:10

Group Number: # 03

Group Members: (Last Name, First Name)

Member #1: Algador, Vigomar Kim

Member #2: Chan, Casey

Member #3: Bon, Trinh

Total Score: /100

Work Breakdown Structure: It is important that every group member do their share of the work in these labs. Remember that you will receive no credit for the lab worksheet if you did not contribute. Write in the Table provided below, which group member(s) contributed to the solution of each problem on the lab worksheet. Also remember that only one lab worksheet per group will be turned in to Canvas. If there was any group member that did not contribute, then write their name in the space provided below.

Problem Number	Group member(s) that worked on the problem.
Part Ia	Algador, Vigomar Kim Chan, Casey Trinh, Bon
Part Ib	Algador, Vigomar Kim Chan, Casey Trinh, Bon
Part Ic	Algador, Vigomar Kim Chan, Casey Trinh, Bon
Part IIa	Algador, Vigomar Kim Chan, Casey Trinh, Bon
Part IIb	Algador, Vigomar Kim Chan, Casey Trinh, Bon
Part III	Algador, Vigomar Kim Chan, Casey Trinh, Bon

Absent member(s):____

General Instructions:

1) To work properly, operational amplifiers (op-amps) must be powered externally by both a positive and a negative voltage supply, typically labelled $+\ V_{CC}$ and $-\ V_{CC}$ respectively. When connecting the power supplies to the op-amp, DO NOT mix the two power sources up or it is almost guaranteed that you will irreversibly damage the op-amp and potentially other circuit components including the power supply.

2) If you ever smell something funny or burning, turn off the voltage sources from the AD2 immediately!

3) If the voltage source does not allow you to increase the voltage using the dial, then there is something wrong with your circuit and you have to go back and check your connections and components. This is usually an indication that too much current is flowing through your circuit and it could potentially damage it if it isn't fixed.

4) For all circuits that contain op-amps, it is usually a good idea to connect the external power supplies before connecting other components. After the power supplies, it's a good idea to then connect any ground wires. To connect the rest of the components (especially for the more complex circuits), it is usually a good idea to identify and label nodes in the original circuit rather than trying to link up components.

5) Remember that Ch1 and Ch2 refer to channels one and two of the oscilloscope, respectively.

6) A voltage gain, sometimes labelled A_V, is by definition the ratio of the voltage output to the voltage input $A_V = \frac{V_{out}}{V_{in}}$.

Part I. Inverting Amplifier   Total Score: ____/50

a) Preliminary Measurements: Score: ____/5

This section of the lab involves the circuit shown in Figure 1 below. This is the so-called inverting amplifier for reasons which will become apparent soon. Before simulating or building the circuit, the values of the resistors R_1 and R_2 must be measured using the DMM. Do so and record the values in Table 1.

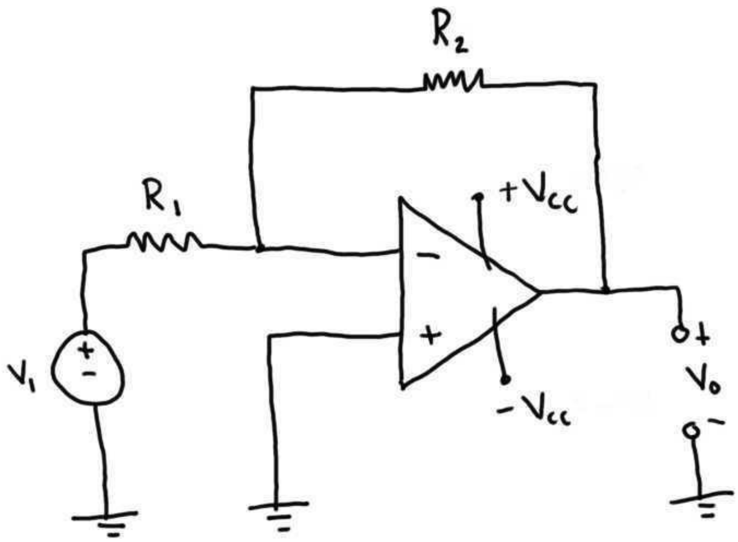


Figure 1. Inverting Amplifier Circuit

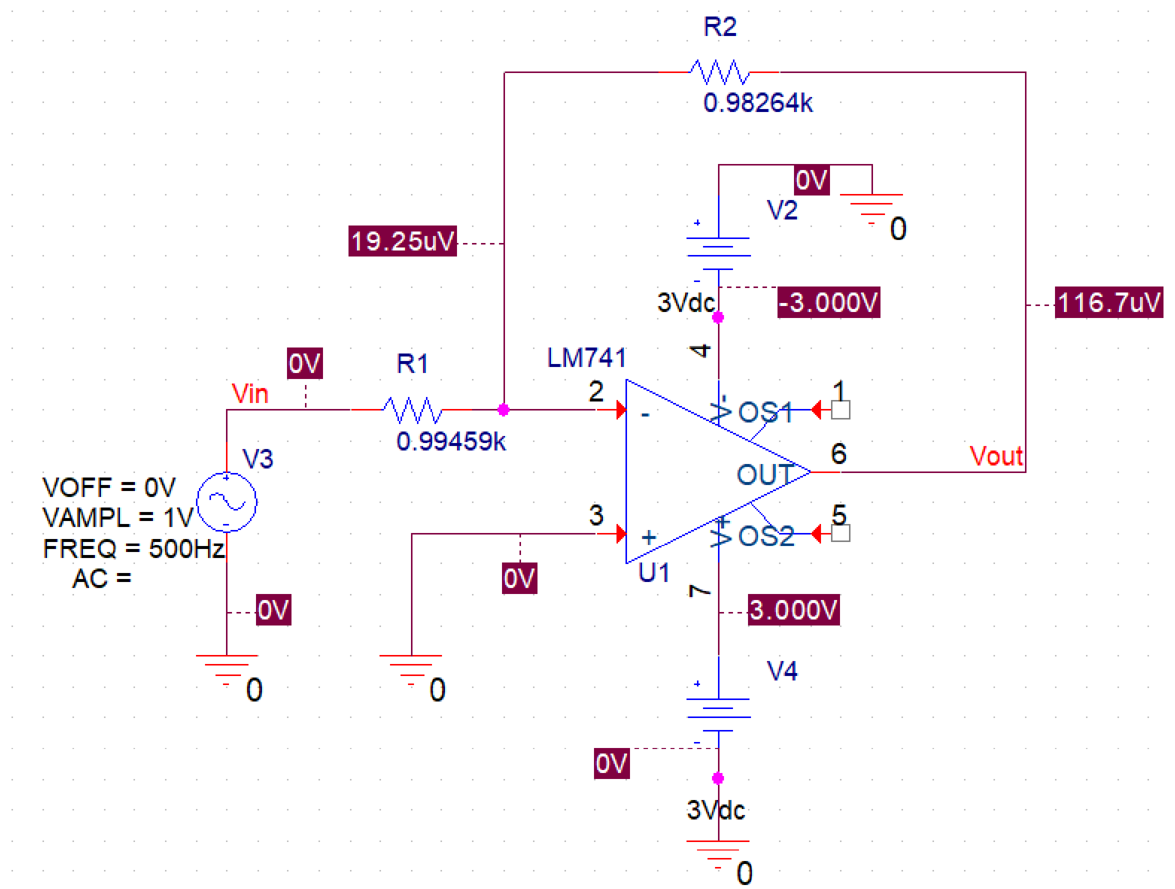
	Theoretical Value	Experimental Value
R_1	1000 Ω	0.99459 kΩ
R_2	1000 Ω	0.98264 kΩ

Table 1. Resistor Values for Inverting Amplifier

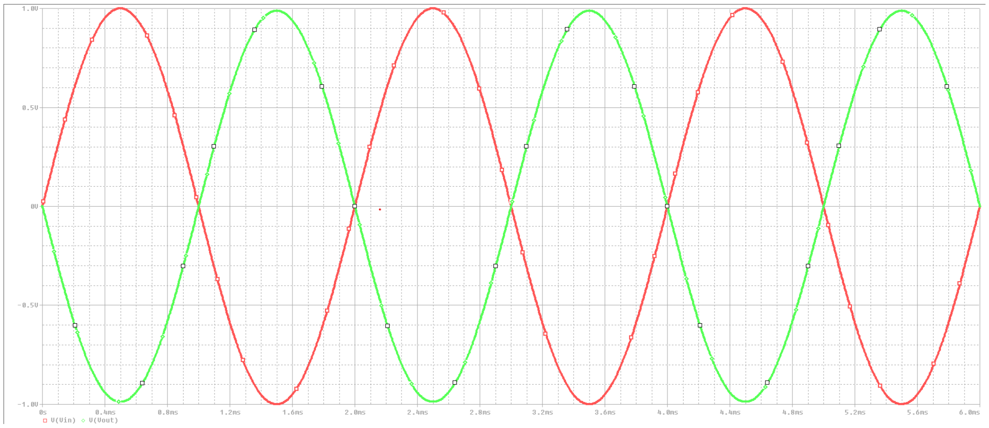
b) Prediction: Simulation Score: ____/15

Using PSpice, simulate the circuit shown in Figure 1 using a transient analysis from $0 \leq t \leq 3T$, where T is the period of the input voltage V_1. Choose the time step such that there are at least 500 data points in the simulation. In your simulation set the external power supplies to $+V_{CC} = 3\,V$ and $-V_{CC} = -3\,V$, while setting the input voltage V_1 to a sinusoidal signal with a frequency of 500 Hz and a peak-to-peak value of 2.0 V. Use the "Vsin" voltage source in PSpice to generate the sinusoidal voltage. Also use the experimental values of the resistors found in the previous section. For the output, on the same graph show the input voltage V_1 and the output voltage V_0. Include pictures of 1) the circuit schematic and 2) the output graph of the simulation below.

1) Circuit Schematic:



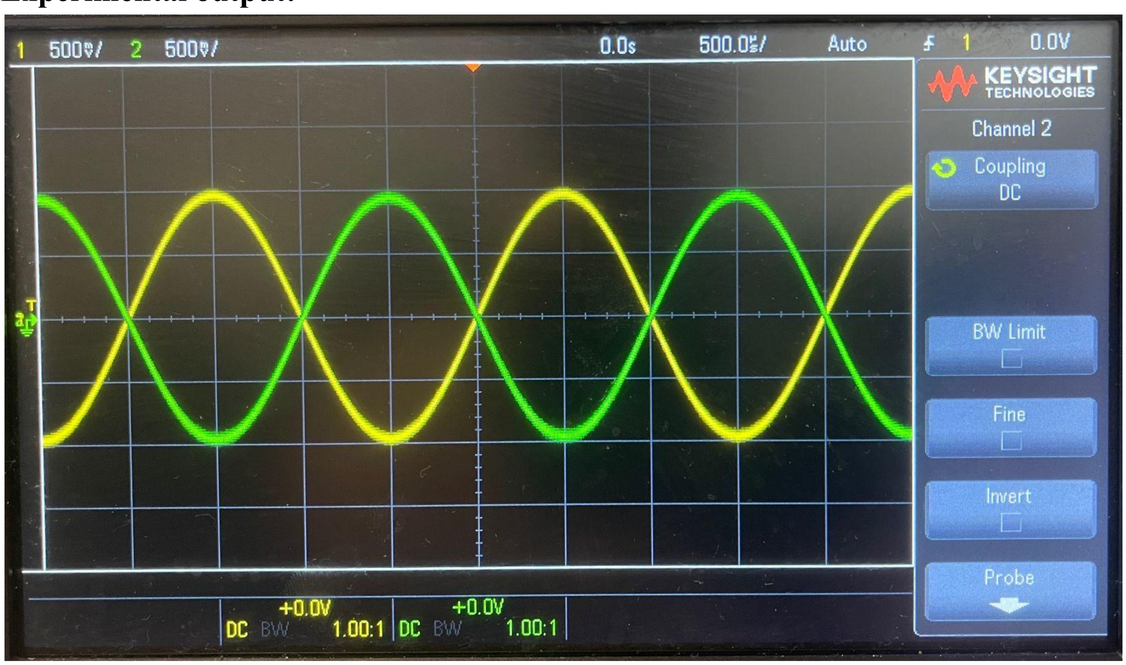
2) Output:



c) Data Collection and Analysis Score: ____/30

Assemble the circuit shown in Figure 1 on your breadboard. Use the function generator to generate the input voltage V_1 which is a sinusoidal signal with a frequency of 500 Hz and a peak-to-peak value of 2.0 V. Set the external power supplies to $V+ \;\; = +V_{CC} = 3\,V$ and $V- \;\; = -V_{CC} =- 3\,V$. Use Ch1 to monitor the input voltage V_1 and Ch2 to monitor the output voltage V_0. Set the time base on the oscilloscope so that **three full waveforms** are shown. Show the experimental output coming from the oscilloscope below.

Experimental output:



Question: How does this compare to the simulated results?

The oscilloscope and the simulated results were the same.

Using your results from the pre-lab, calculate the theoretical values of the missing parameters in Table 2. Using the oscilloscope and the DMM take the measurements missing from Table 2. Calculate the percent error for each parameter and enter it into the last column of Table 2. Show all your work. Include more pages if needed.

Inverting Amplifier Circuit	Theoretical Value	Experimental Value	Percent Error
f (Hz)	500	500	0%
V_1 pk-pk (V) - Scope	2.0	2.0	0%
V_0 pk-pk (V) - Scope	2.0	2.0	0%
V_1 RMS(V) - DMM	0.707	0.674	4.66%
V_0 RMS (V) - DMM	0.707	0.665	5.94%
Gain - Scope	-1	-0.996	0.4%
Gain - DMM	-1	-0.996	0.4%

Table 2. Comparison of theoretical results to experimental results

Calculations:

V_1pk-pk(V) = $\frac{|2.0-2.0|}{|2.0|} * 100 = 0\%$

V_0 pk-pk(V) = $\frac{|2.0-2.0|}{|2.0|} * 100 = 0\%$

V_1 RMS(V) = $\frac{|0.674-0.707|}{|0.707|} * 100 = 4.66\%$

V_0 RMS(V) = $\frac{|0.665-0.707|}{|0.707|} * 100 = 5.94\%$

Gain - Scope = $\frac{|-0.996-(-1)|}{|-0.996|} * 100 = 0.4\%$

Gain - DMM = $\frac{|-0.996-(-1)|}{|-0.996|} * 100 = 0.4\%$

Part II. Saturation in the Inverting Amplifier Total Score: ____/40

This is a continuation of Part 1. These experiments will be using the same circuit shown in Figure 1. We will be varying the input voltage V_1 and observing the effect on the output voltage V_0 when the output voltage goes beyond the voltages provided by the external power supplies. Set the external power supply voltages to $V+ \ = +V_{CC} = 3\,V$ and $V- \ = -V_{CC} =- 3\,V$. Use the function generator to generate a beginning input voltage V_1 which is a sinusoidal signal with a frequency of 500 Hz and a peak-to-peak value of 2.0 V. Set the time base so that **three complete waveforms** can be seen.

a) Symmetric external power supplies Score: ____/20

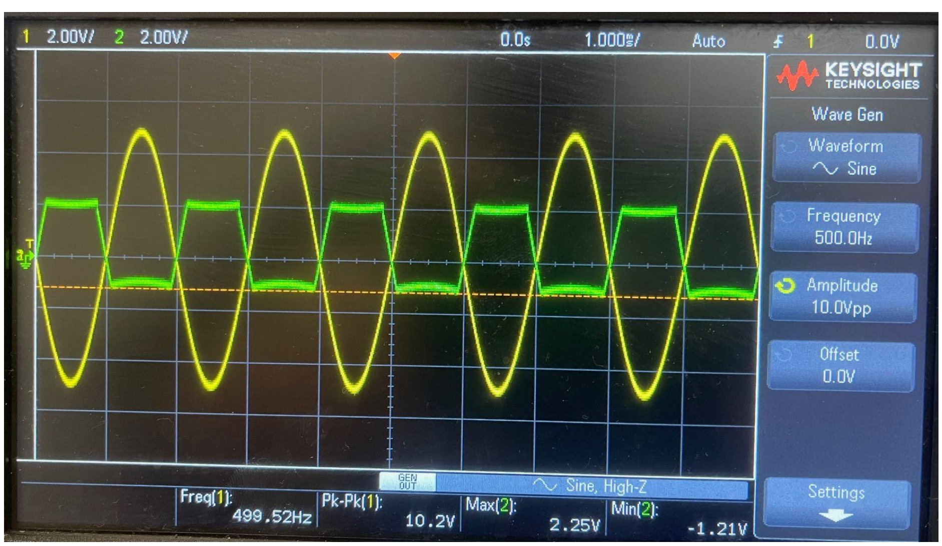
<u>Experimental:</u> Slowly increase the amplitude of the input voltage V_1 until it reaches a maximum value of 5 V. Observe any distortions in the voltage output. Record the maximum and minimum values of the output voltage V_0.

Output Voltage, V_0	Theoretical Value	Experimental Value
V_{max} (V)	3	2.25
V_{min} (V)	-3	-1.21

Table 3. Saturation for Symmetric External Power Supplies

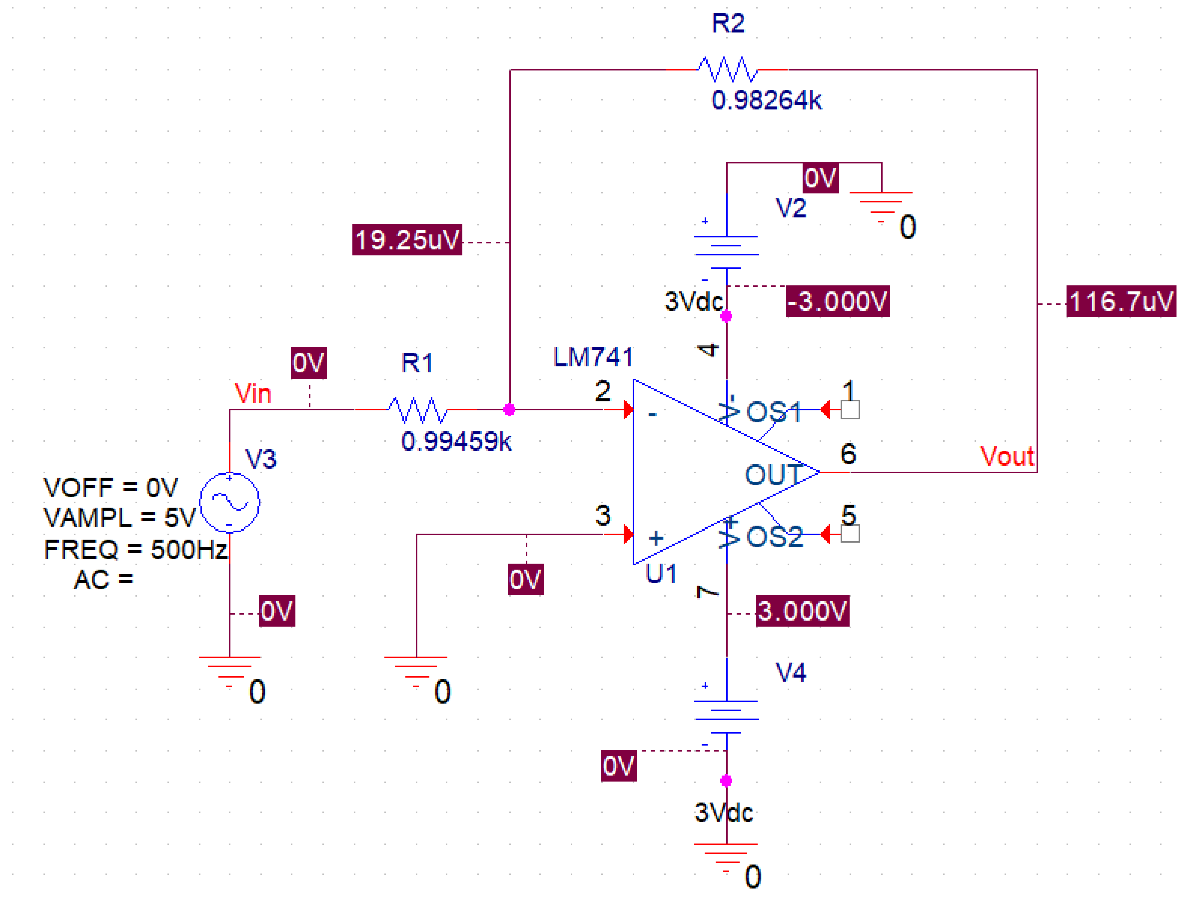
Show the experimental output coming from the oscilloscope below.

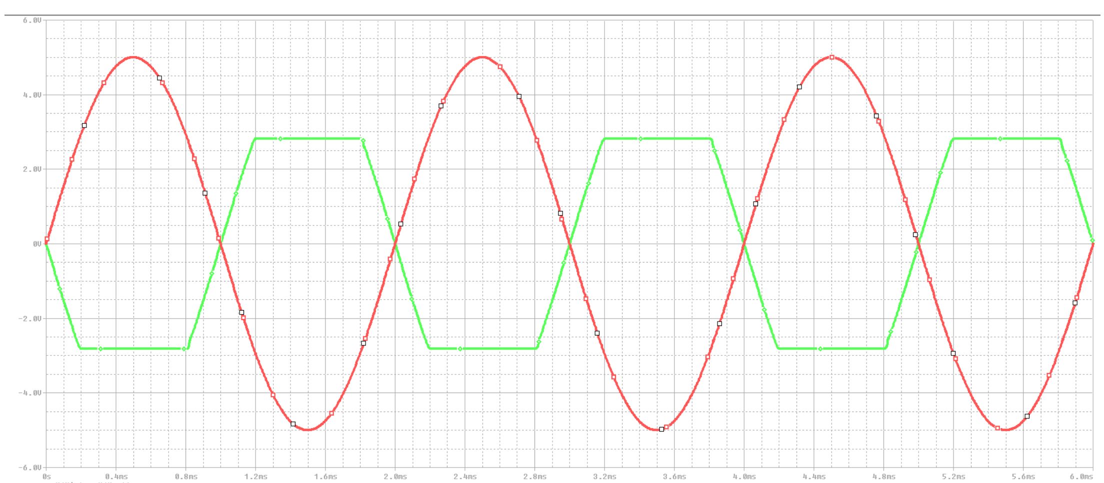
Experimental output:



Simulation: Use PSpice to simulate the circuit with the final value of the input voltage described in part a) above. Perform a transient analysis and plot both the voltage input V_1 and voltage output V_0 on the same graph for three periods. Use the “Vsin” voltage source in PSpice to generate the sinusoidal voltage.

Simulation output:





b) Asymmetric external power supplies Score: ____/20

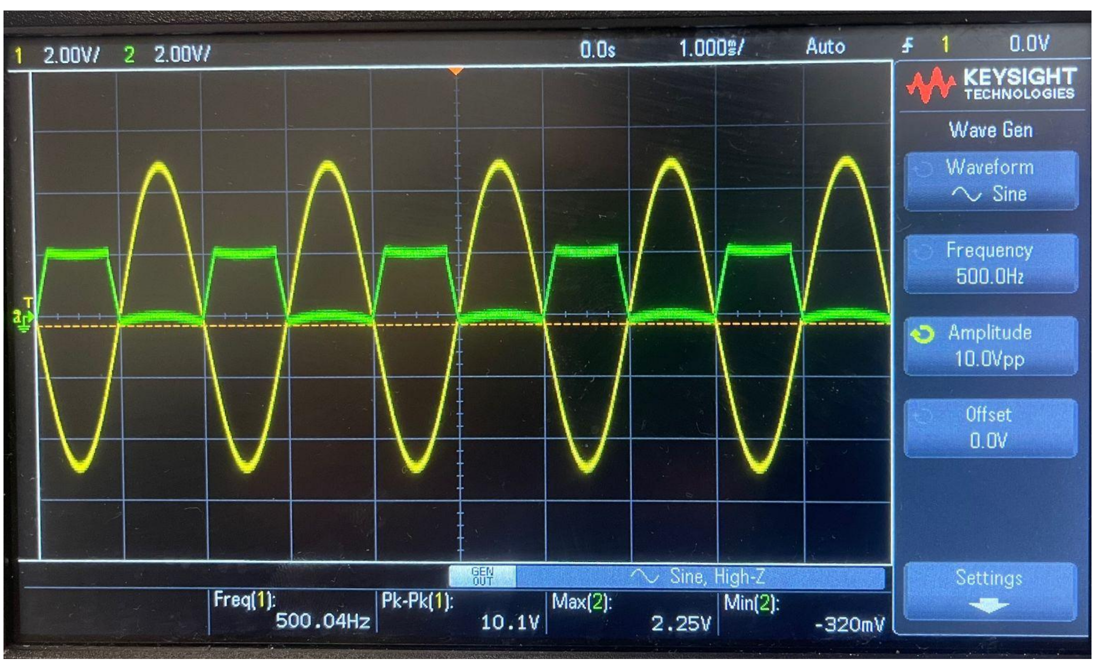
Experimental: Change the external power supply voltages to $V + \;\; = + V_{CC} = 4\,V$ and $V - \;\; = - V_{CC} =- 2\,V$. Use the function generator to generate a beginning input voltage V_1 which is a sinusoidal signal with a frequency of 500 Hz and a peak-to-peak value of
2.0 V. Slowly increase the amplitude of the input voltage V_1 until it reaches a maximum value of 5 V. Observe any distortions in the voltage output. Record the maximum and minimum values of the output voltage V_0.

Output Voltage, V_0	Theoretical Value	Experimental Value
V_{max} (V)	4	2.25
V_{min} (V)	-2	-0.320

Table 4. Saturation for Asymmetric External Power Supplies

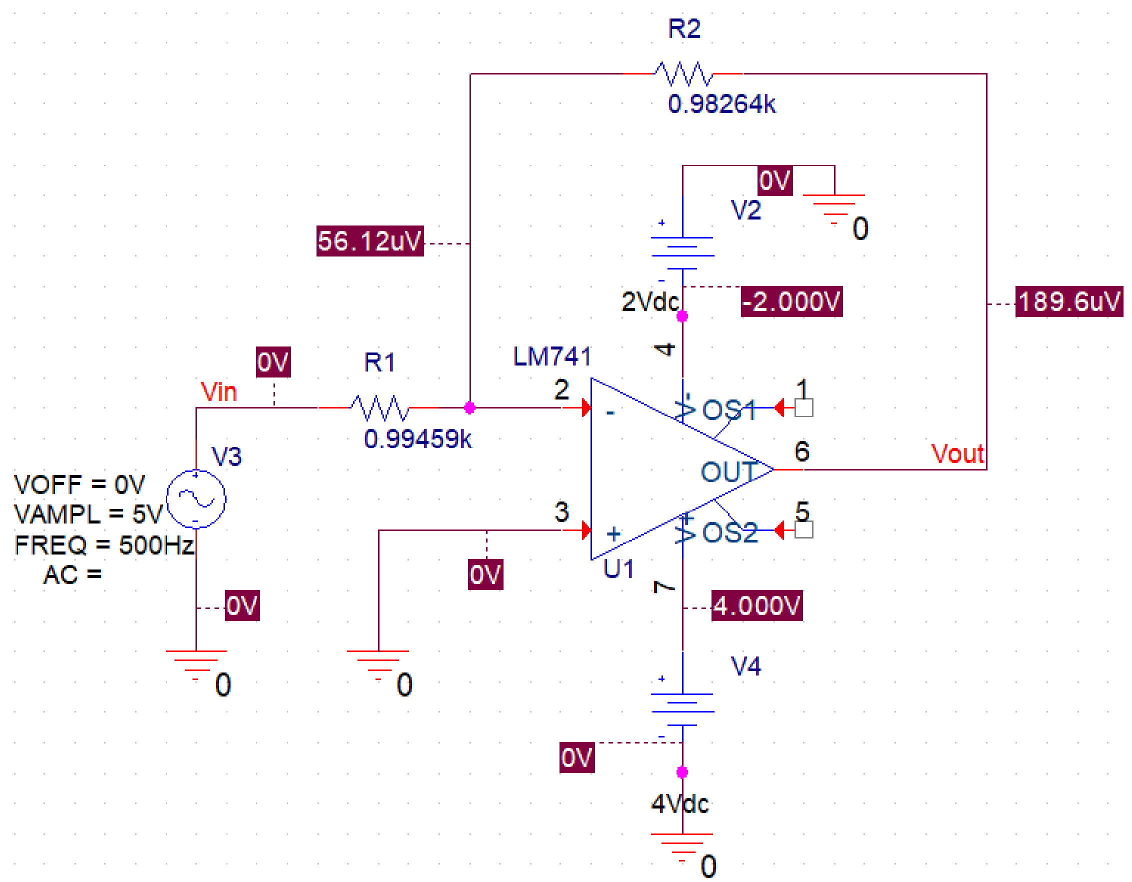
Show the experimental output coming from the oscilloscope below.

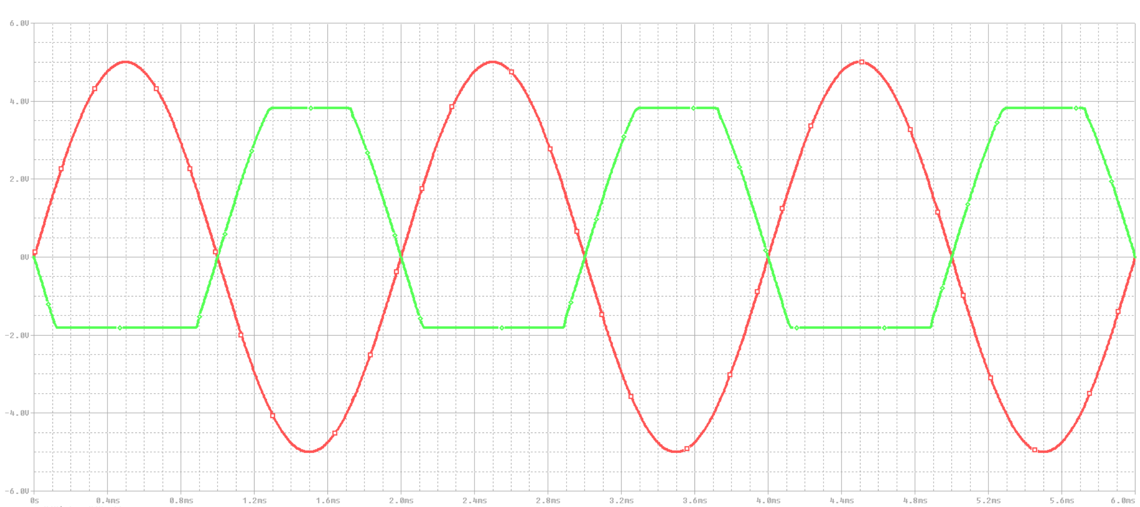
Experimental output:



Simulation: Use PSpice to simulate the circuit with the final value of the input voltage described in part b) above. Perform a transient analysis and plot both the voltage input V_1 and voltage output V_0 on the same graph for three periods. Use the “Vsin” voltage source in PSpice to generate the sinusoidal voltage.

Simulation output





Part III: Conclusions Total Score: /10

Explain in a few paragraphs the purpose of the lab, the experimental set up and methodology, and central results of the lab and these experiments. **You should be quantitative** in this summary. Include any important equations used and explain their significance. Write the conclusion as if you were writing an English essay. This is an important portion of the lab, so make sure to do a good and thorough job.

In this lab, we got to work with inverting operational amplifiers. Part one is working with an inverted op amp. The output of the circuit and the simulation showed v_{in} and v_{out} as a sinusoidal wave. Our prediction with the simulation matched with the analysis on the function generator. Part two is using the same circuit from part one. This time the input voltage V_1 will be changing. The changes occur on the output voltage, V_0.

When building the circuits, one thing to be careful of is to not mix the positives and negatives of the external power supply voltages or the circuit would start to burn. The positive should go to positive and negative go to negative. When we first simulated the circuit on PSpice, we made that exact mistake. This caused v_{out} to just output a straight horizontal line. Luckily, we only made this mistake on PSpice and not on the breadboard.