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Section: 009

Lab: 06

AD2 #: 210321AA2E82

Date: 9/30/2024

Abstract

The purpose of this lab is to demonstrate the different parts within an op-amp, including a current mirror, differential amplifier, and a common source amplifier. The circuits used an ALD1105, ALD1106, and ALD1107 for the MOSFETs and an AD2 for measurements and supplies. The gain of each amplifier was found, and current was measured to predict current. Overall, the lab showed how an op-amp works step by step and how each part relies on the next.

Task 1

Objective

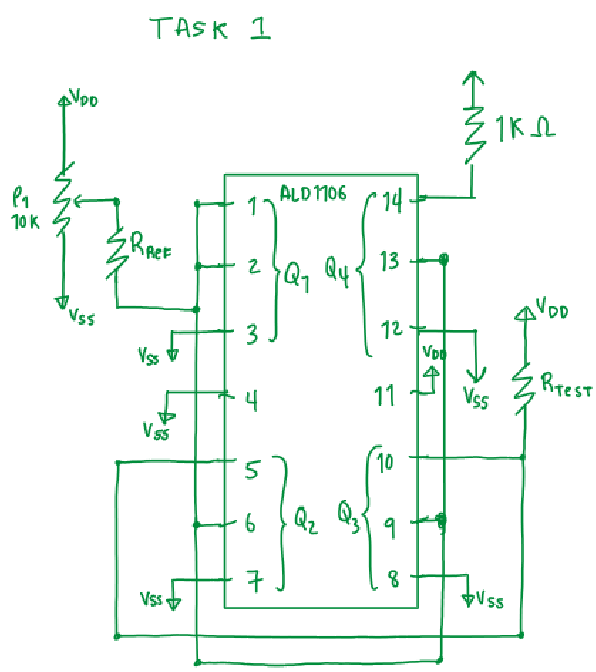
The objective of this task is to demonstrate a current mirror and doubler using an ALD1106 transistor. The current through the branches were measured to demonstrate the current mirror/doubler and predict gain in future sections.

Procedure

First, a current mirror was build using an ALD1106. The reference current was set to 200µA by measuring the voltage across R_{ref} and dividing it by R_{ref}. afterwards, the current through the 2 branches were found. Their percent error from the expected current was found.

Results

Circuit



I_{REF} = 204.5 µA

Current through the 2 branches found:

Pin 14 (to common source amplifier): 233.71µA (expected ~204.5µA)

Pin 10 (to differential amplifier): 461.7µA (expected ~409µA)

Percent error:

$$\%Error = \frac{|Actual - Expected|}{Expected} \times 100$$

Branch to CS Amp: 14.28%

Branch to Differential Amp: 12.89%

Possible sources of error:

- Imperfect resistors- the resistors are not the exact value that is expected in theory.
- Nonideal MOSFETs- no real MOSFETs are ideal.
- Resistance of wires- at this small of a measurement, the wires might have a resistance that matters.
- Limitations of equipment- this small of a measurement might be rounded since the AD2 can only be so precise.

Conclusions

Overall, this task was successful because the error was relatively low and the results matched what was expected. The error is above 10% because of the scale we were measuring at and imperfections in devices along the way.

Task 2

Objective

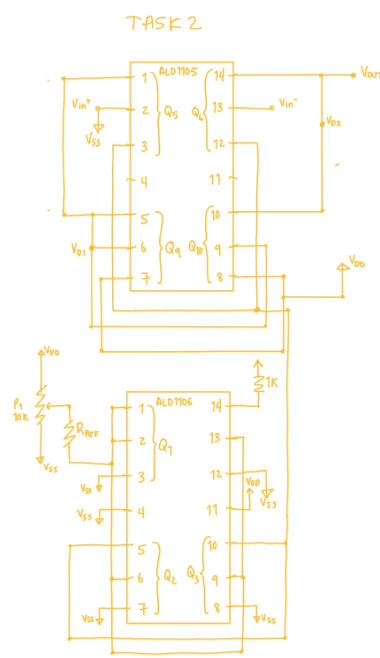
The objective of this task is to build a differential amplifier circuit using the ALD1105 transistor to demonstrate its use within an op-amp.

Procedure

First, the circuit was built using an ALD1105. It was connected to the current mirror and the resistive load was removed. A .01sin(2pi100t) input signal was connected to v_{in}^{+}, and v_{in}^{-} was grounded. The single ended gain was measured.

Results

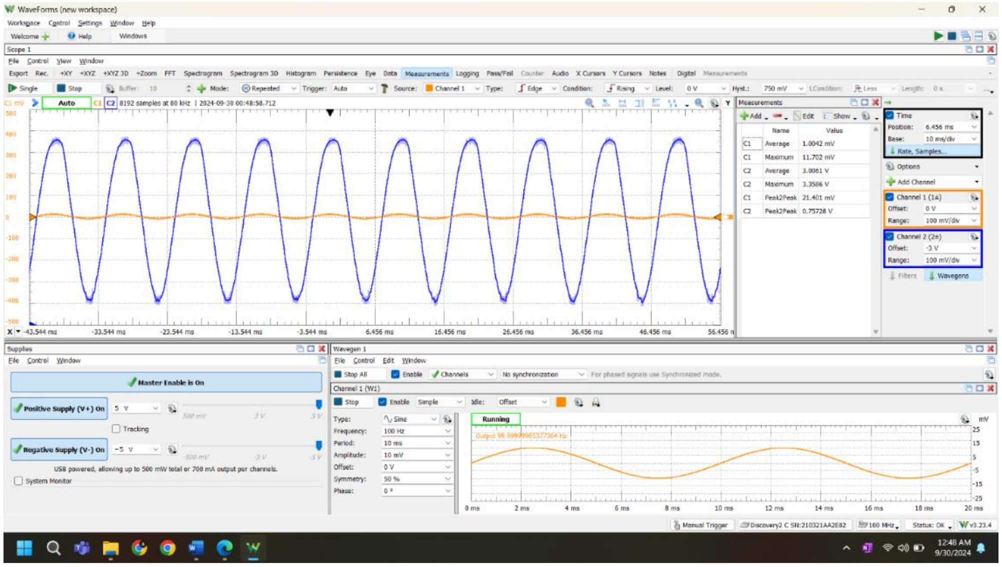
Circuit



Ch1 (input): 100mV_{pp}

Ch2(output): 3.4 V_{pp}

$$Gain = \frac{v_{out}}{v_{in}} = \frac{3.4}{.1} = 34$$



Conclusions

This task was successful because the expected gain was around 30 (from the prelab) and the gain that was found was 34.

Task 3

Objective

The objective of this task is to build a CS amplifier and demonstrate its application within an op-amp.

Procedure

First, the gain was estimated from the actual current found in task 1. Then, the overall open loop gain was estimated using the current found in task 2. Afterwards, the common source amplifier was built and attached to the previous circuit. v_{in}^{-} was grounded. v_{in}^{+} was varied between -2V and 2V DC, and the output was observed. The input and output for all voltages applied was recorded. Afterwards, the input voltage was changed to be a $2\sin(2\pi 100t)$ signal. The input and output were plotted and recorded.

Results

Gain formula:

$$A_v = g_{m8}(r_{op8}||r_{on4})$$

Finding internal resistances:

$$r_o = \frac{1}{\lambda I_D}$$

$$r_{on} = \frac{1}{.008 * .0002045} = 611k\Omega$$

$$r_{op} = \frac{1}{.009 * .0002045} = 543k\Omega$$

$$r_{op8}||r_{on4} = 288k\Omega$$

Finding g_m

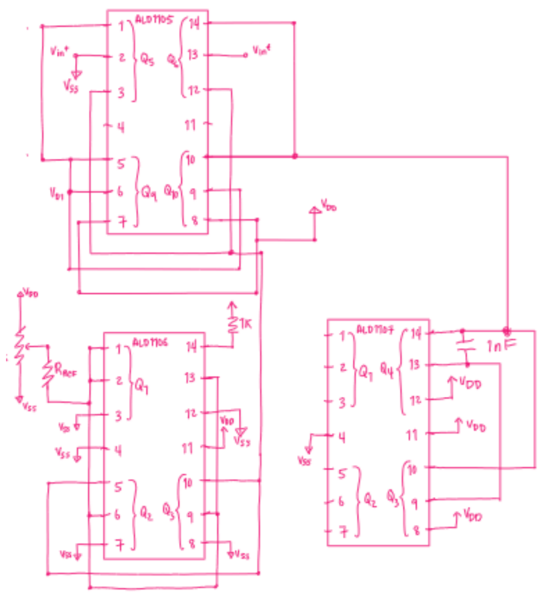
$$g_m = \sqrt{2k\frac{W}{L}I_D} = \sqrt{2 * .00011 * \frac{138}{7.8} * .0002054} = 0.00089413645$$

Finding A_v

$$A_v = g_{m8}(r_{op8}||r_{on4}) = 257.5$$

$$A_{total} = A_{diff} * A_{CS} = 34 * 257.5 = 8738$$

Cs amp circuit



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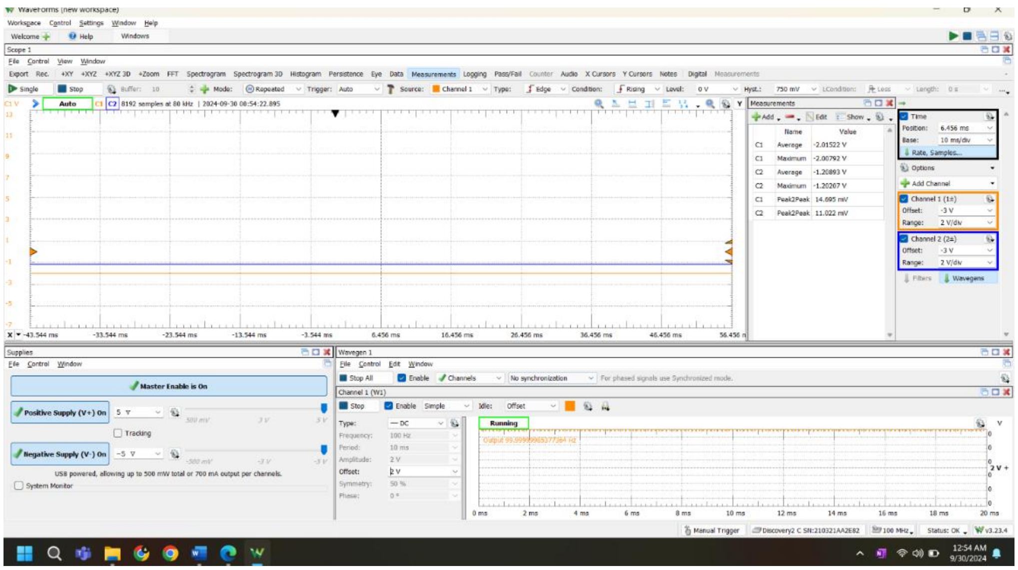
DC Open loop gain -2v -> 2v screenshots

- C_1 = input (orange)
- C_2 = output (blue)

2v:

C1	.98478 V
C2	1.79307 V
Gain	1.8207



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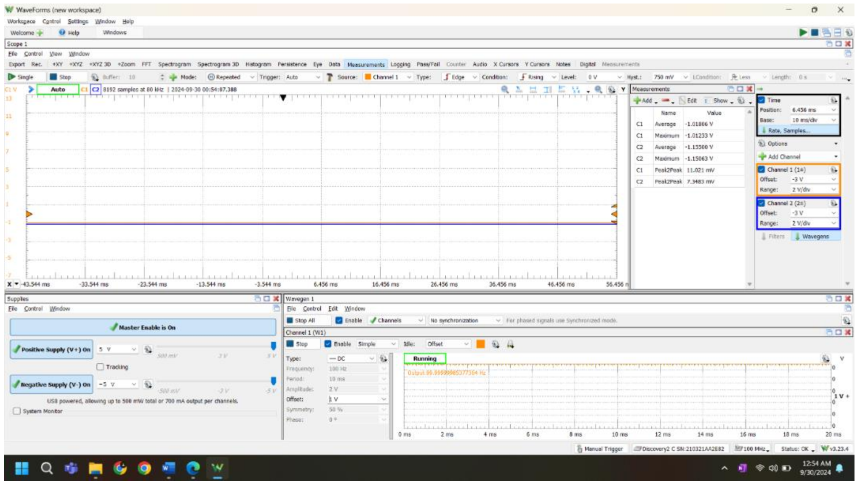
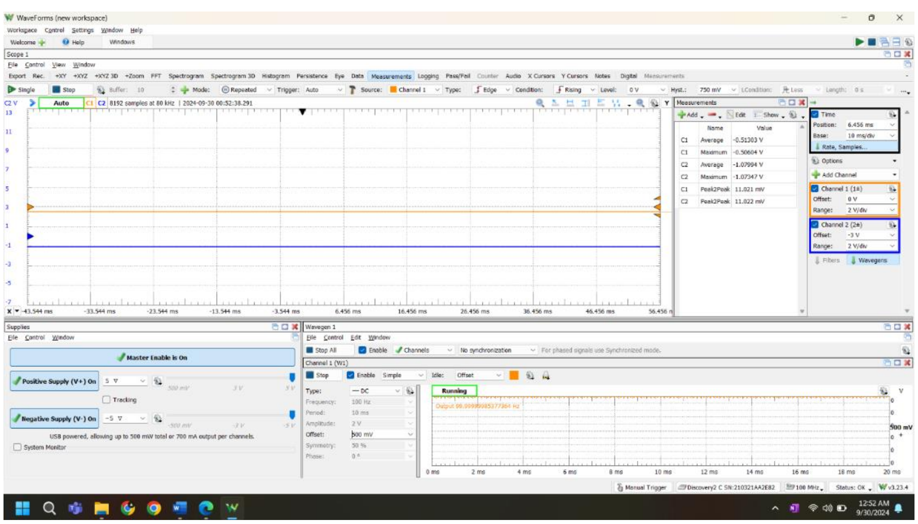
1v:

C1	1.98194 V
C2	1.845 V
Gain	.93141



5mV:

C1	-.51303 V
C2	1.92006 V
Gain	3.74258



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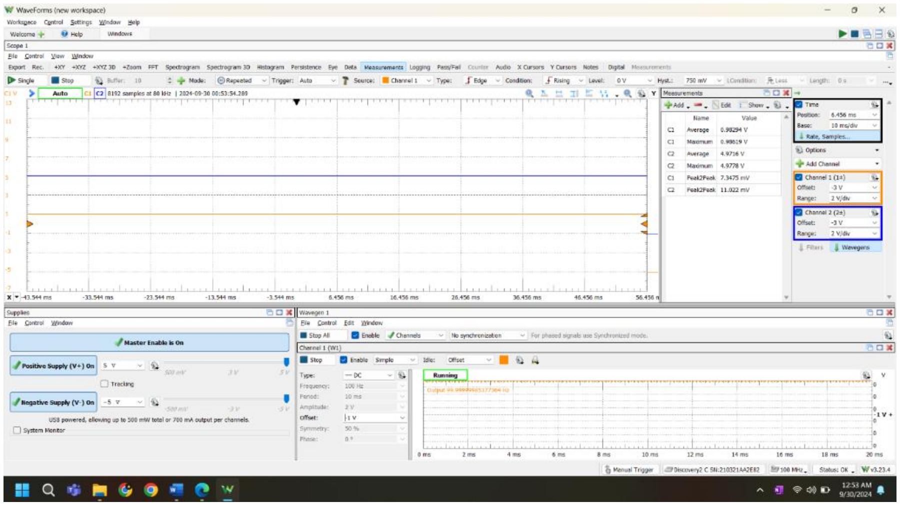
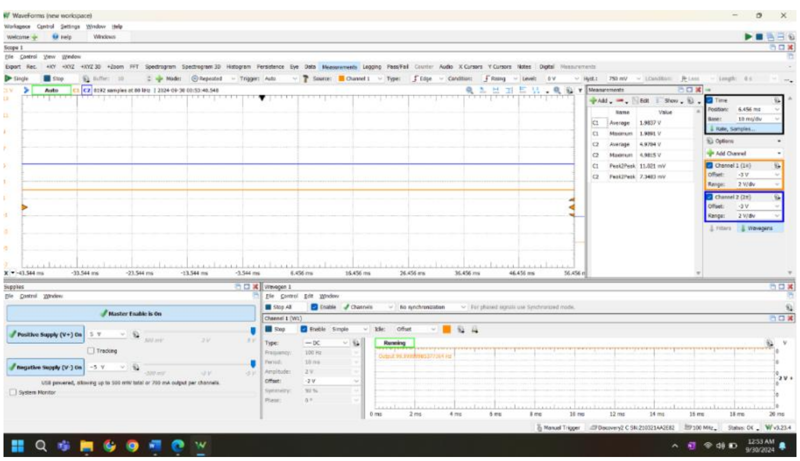
-1v:

C1	4.98294 V
C2	7.9716 V
Gain	1.5998



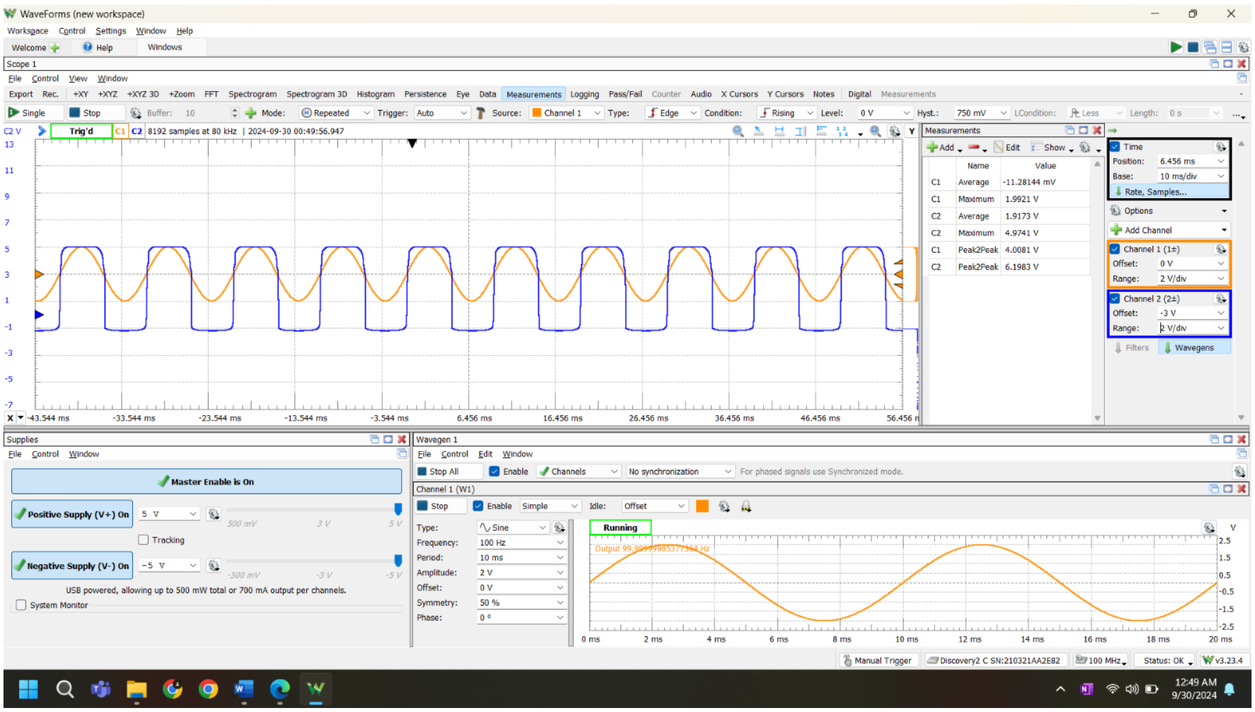
-2v:

C1	4.9337 V
C2	7.9784 V
Gain	1.61712



Sinusoidal signal screenshot

C1	4.0081 V_{pp}
C2	6.1983 V_{pp}
Gain	1.5464



The output (blue | channel 2) looks like this since it is comparing the voltage in to ground. If it is higher, it amplifies up and if it is negative, it amplifies down. It compares the values and outputs its results.

Conclusions

Overall, the lab itself was successful but my calculations seem incorrect. I have an incredibly powerful amplifier if I am actually getting 8k gain, which is definitely not true. After the horrendous gain result, the rest of the lab measurements made sense, so it was successful overall since I learned.

Task 4

Objective

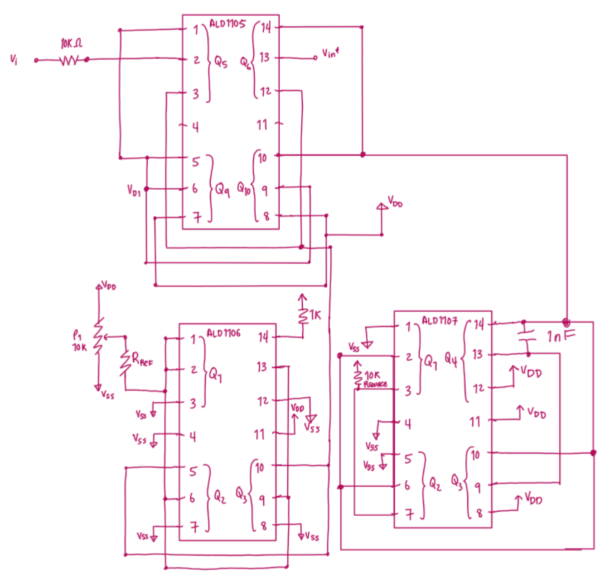
The objective of this task is to demonstrate the use of a common drain amplifier in an op-amp and how it is necessary to have.

Procedure

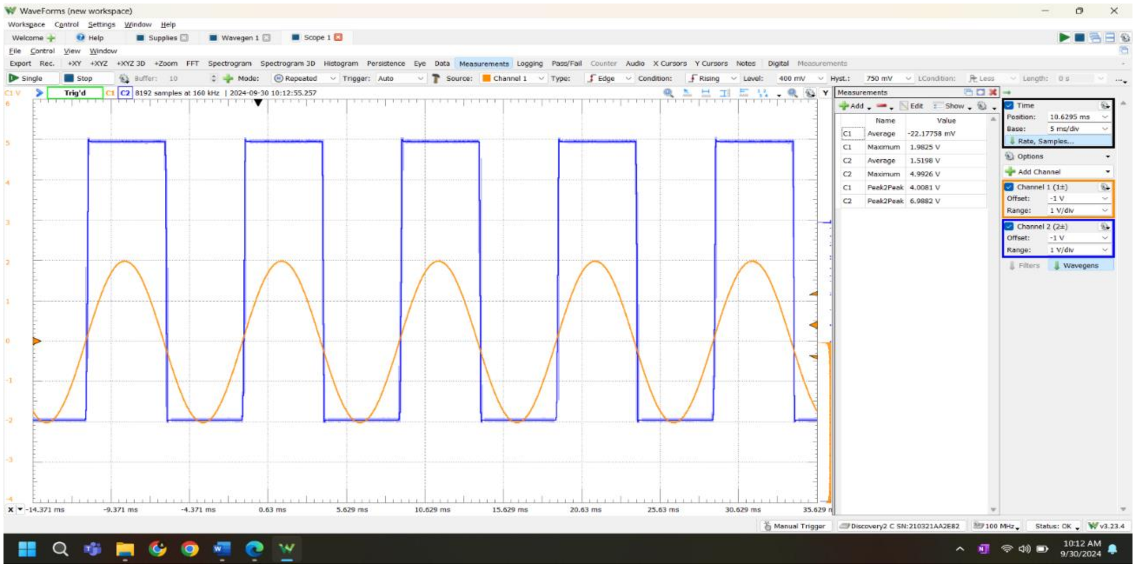
First, the common drain amplifier was built and attached to the rest of the circuit. Vin- was left grounded and vin+ was given a $2\sin(2\pi 100t)$ V signal. The input and output were plotted using the AD2 and compared to the plot from task 3.

Results

Circuit diagram



v_{in} (orange) and v_{out} (blue) plot



This output is sharper and more defined than the output in task 3. This graph looks different because the previous one had an offset on the display and this one does not. It would look slightly higher but not much.

Conclusions

This task was successful because the circuit was successfully completed and produced the expected output.

Task 5

Objective

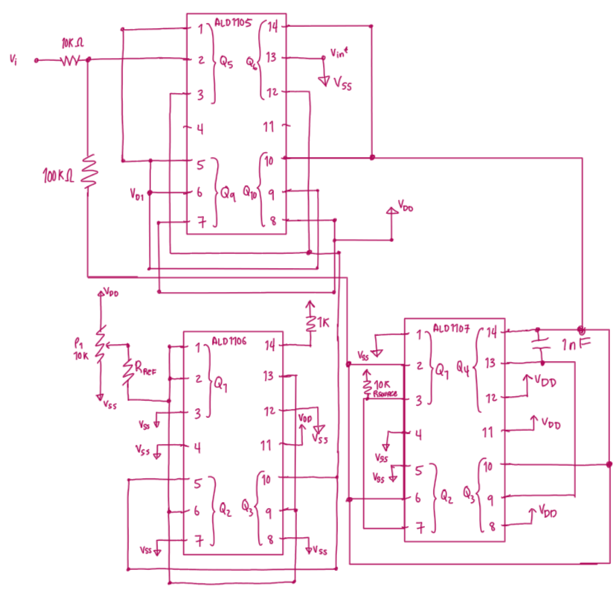
The objective of this task is to test and verify the overall op-amp circuit works. This is important to make sure that all of the inner pieces are working correctly and it demonstrates what is on the inside of an op-amp.

Procedure

With the overall circuit done, the only thing left to change is the circuit outside connecting to v_{in}^{-}, v_{in}^{+}, and the output. These inputs and outputs were traced over across the breadboard so that they were easier to find. An inverting amplifier with gain 10 was built using the op-amp built through the previous 4 tasks. A sinusoidal input was applied to vin- through a 10kΩ resistor. Vin+ was grounded. A 100kΩ resistor was placed between vin- and v_{out}. Afterwards, the gain was measured, and the percent error was found.

Results

Circuit diagram



Gain

v_{in} = .40411 V_{pp}

v_{out} = 3.8836 V_{pp}

$$Gain = \frac{v_{out}}{v_{in}} = \frac{3.8836}{.40411} = 9.61287, (Expected: 10)$$

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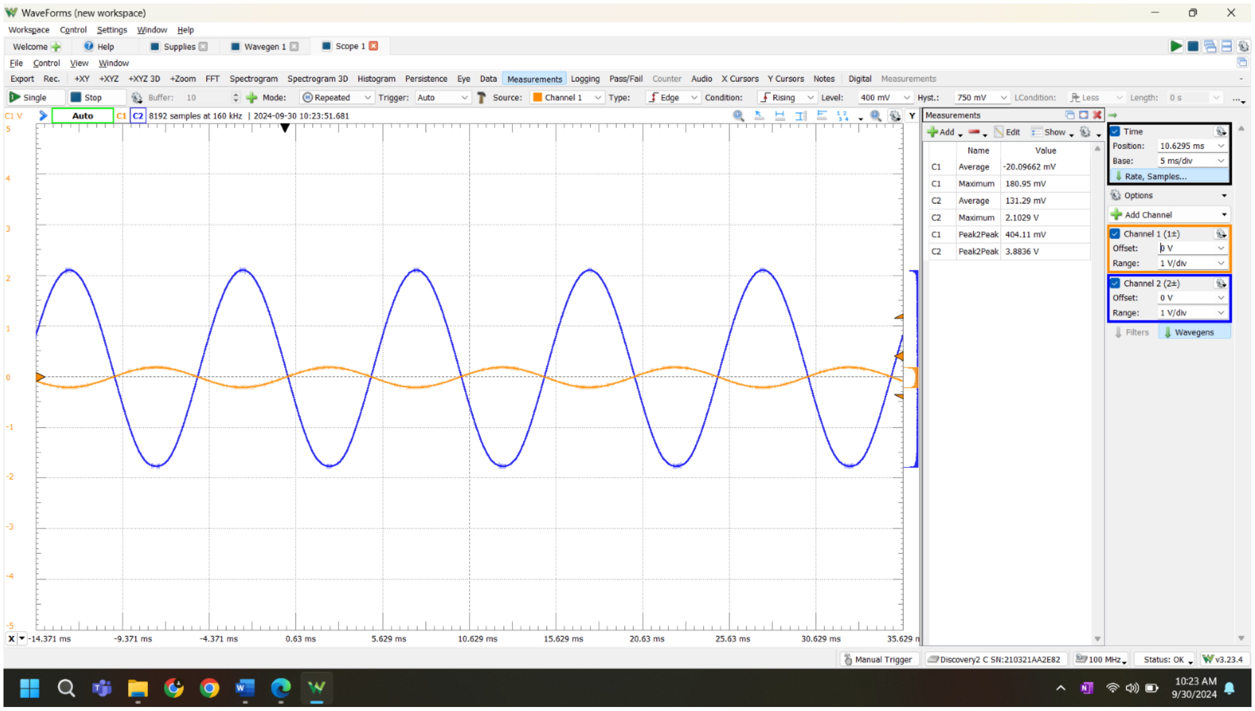
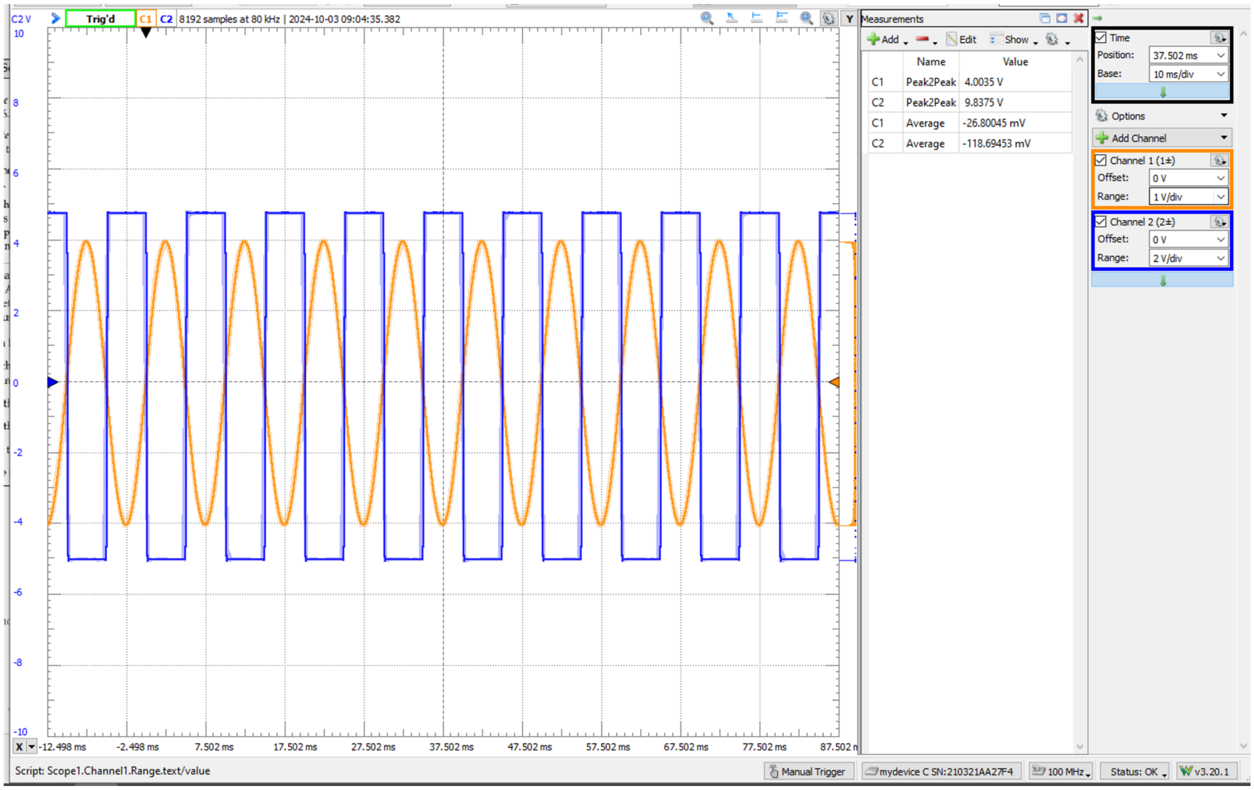
$$\%Error = \frac{|Actual - Expected|}{Expected} \times 100$$

%Error = 3.8713%

Wavegen : input set at 200mV amplitude



This input is reasonable since we want to limit to 2V output and .2V input is good for our -10 gain.



This plot is an example of clipping at large voltage inputs.

Conclusions

This task was a success because the op-amp circuit was successfully built and tested. Each of these labs make me more and more grateful for modern electronics because wow I cant believe this is all shoved into such a small space.