California State University Sacramento
Electrical and Computer Science Department

EEE 108L Lab - Section 05
Laboratory Experiment Number 3: Lab Report

Operational Amplifiers

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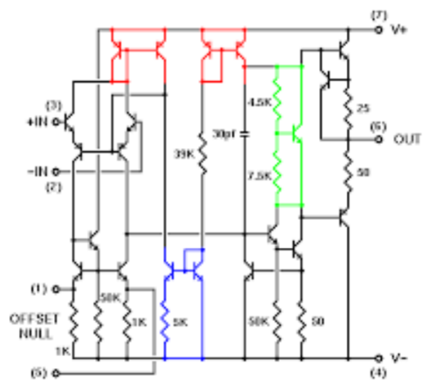
Abstract

For this laboratory experiment we will be testing operational amplifiers. The circuits we will be experimenting with contain inverting and non-inverting amplifiers. In this case we will be using the 741 OpAmp with + and - 10V power.

LM741 Internal Circuitry



Part 1: Preliminary Calculations

STEP 1: Calculating Voltage Gain

For this step we chose a resistor value of R_A. The value we chose was 3.3kΩ.

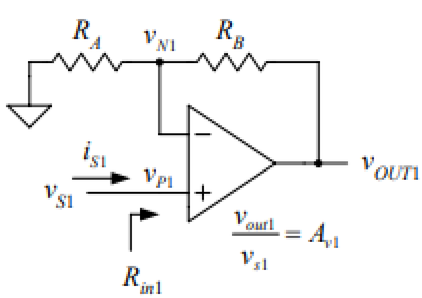


Figure 1. Non-Inverting Amplifier

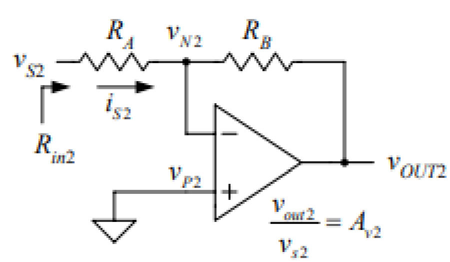


Figure 2. Inverting Amplifier

Now looking for R_B we did this by writing the voltage gain for Av1 in terms of R_A.

$A_{v1} = \frac{v_{out1}}{v_{s1}}$ in terms of R_A = $(R_A + R_B) / R_A$ => $(3.3k\Omega + R_B) / 3.3k\Omega = 3$

This shows that $\mathbf{R_B = 6.6k\Omega}$

STEP 2: Finding the Input Resistance for Non-Inverting Amplifier

For this step we are tasks to find the input resistance of the Non-Inverting circuit.

the input resistance $R_{in1} = \frac{v_{s1}}{i_{s1}}$ of the circuit of Figure 1'

We know that Rin is ∞ This means that the ideal operational amplifier does not draw a current.

Now time to find the fraction of the voltage at Vout in Vn1.

Vn1= Vout/ (1+ (R_B/R_A)

Vn1= Vout/ (1+ (6.6k /3.3k)

Vn1= ⅓ Vout

STEP 3: Calculating the Nominal Voltage Gain

For this step we will be focusing on figure 2 the Inverting Amplifier.
We start off by finding the voltage gain using the equation,

$A_{v2} = \frac{v_{out2}}{v_{s2}}$ in terms of R_A and R_B

Av2 = -R_B/R_A
Av2 = -6.6k/3.3k
Av2 = -2

STEP 4: Calculating the input resistance

For this step it is time to calculate the input resistance for the figure 2 circuit,

$R_{in2} = \frac{v_{s2}}{i_{s2}}$

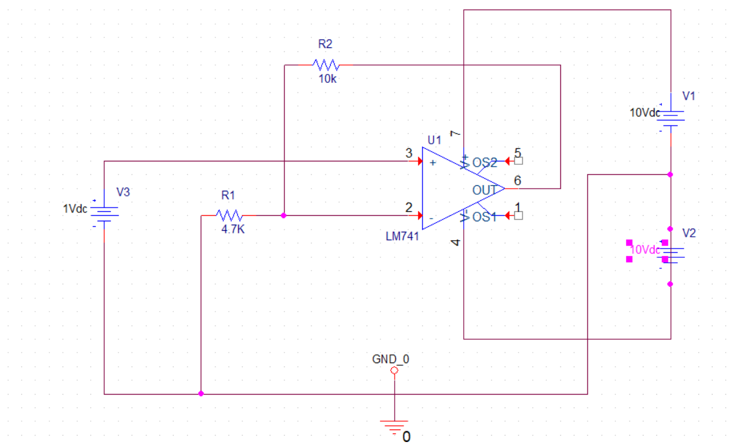
Rin2 = R_A

Rin2 = 3.3kΩ

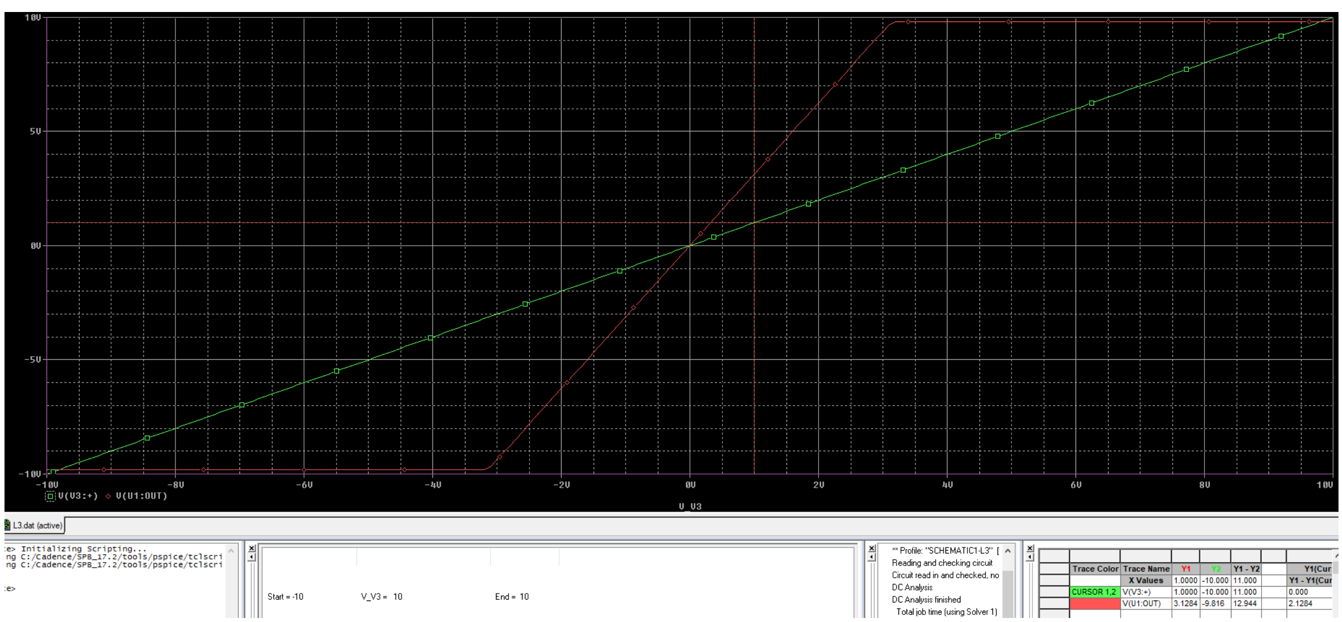
<u>Part 2: PSPICE Simulation</u>

STEP 5: Construct the circuit in Pspice

This step is to construct the Figure 1 Non-Inverting Circuit on pspice program. Also using a +-10V power supplies

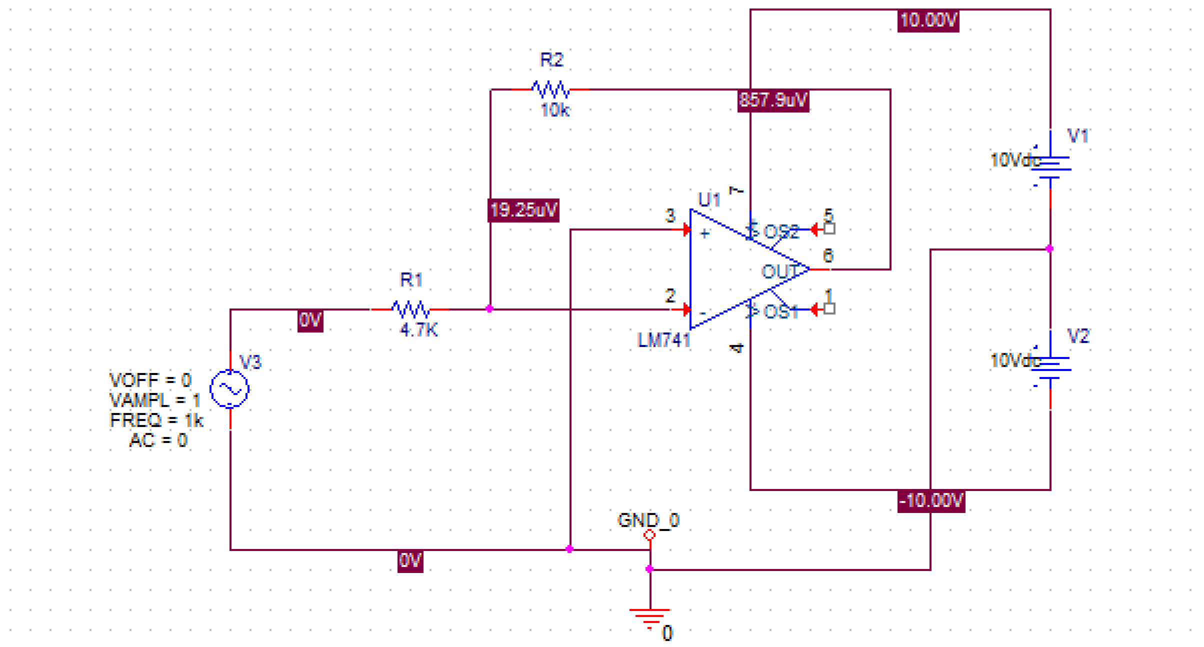


Next, we will be performing a DC Sweep simulation to show the Vout and the Vn1 seen in the trace below.

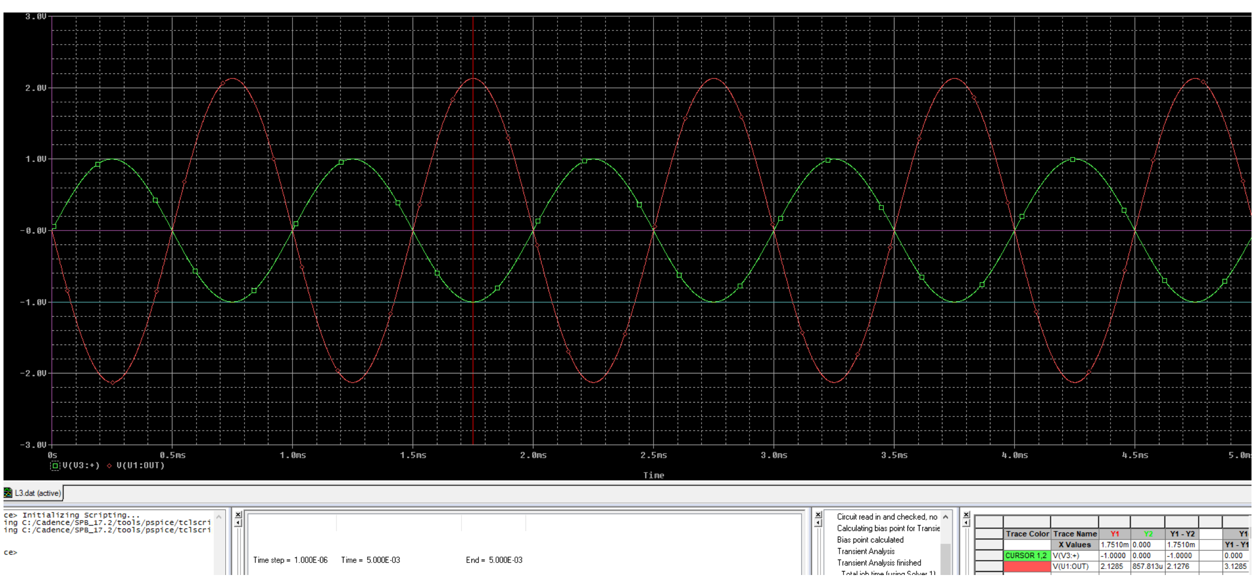


	Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cur
		X Values	1.0000	-10.000	11.000		Y1 - Y1(Cur
	CURSOR 1,2	V(V3:+)	1.0000	-10.000	11.000		0.000
		V(U1:OUT)	3.1284	-9.816	12.944		2.1284

Transient response circuit for the Figure 1 Non-Inverting Amplifier

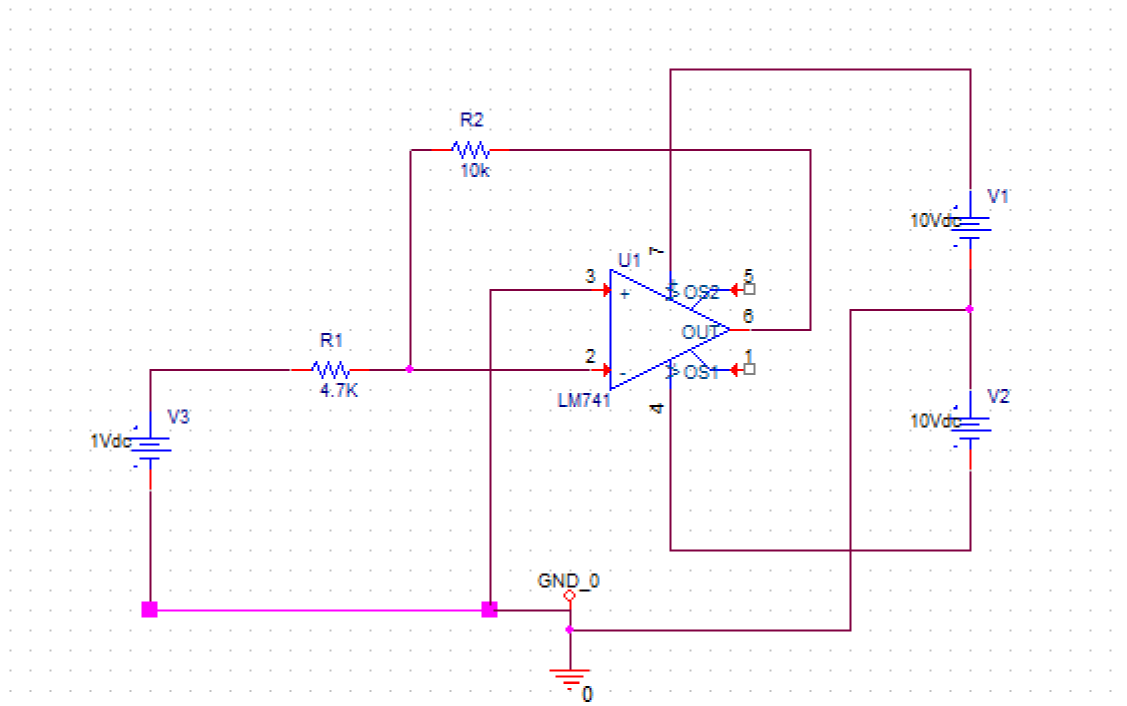


Transient Response frequency sweep

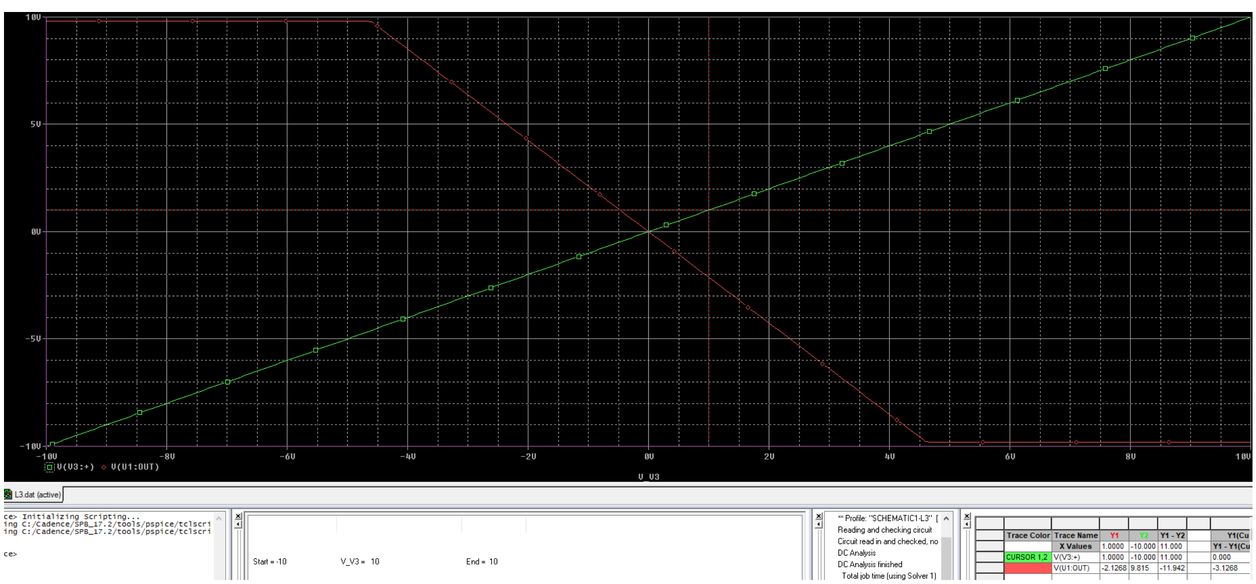


STEP 6: Plot of Vout max and min

For this step start off with the simulation for Figure 2 Inverting Amplifier..

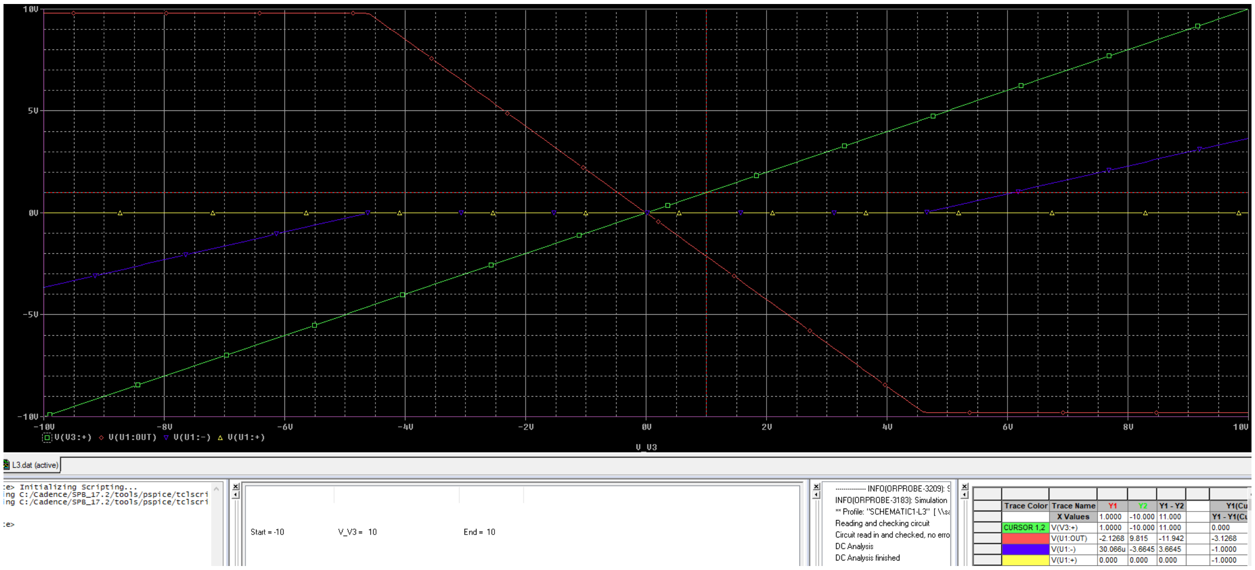


Finding a plot of Vn2 and Vout2



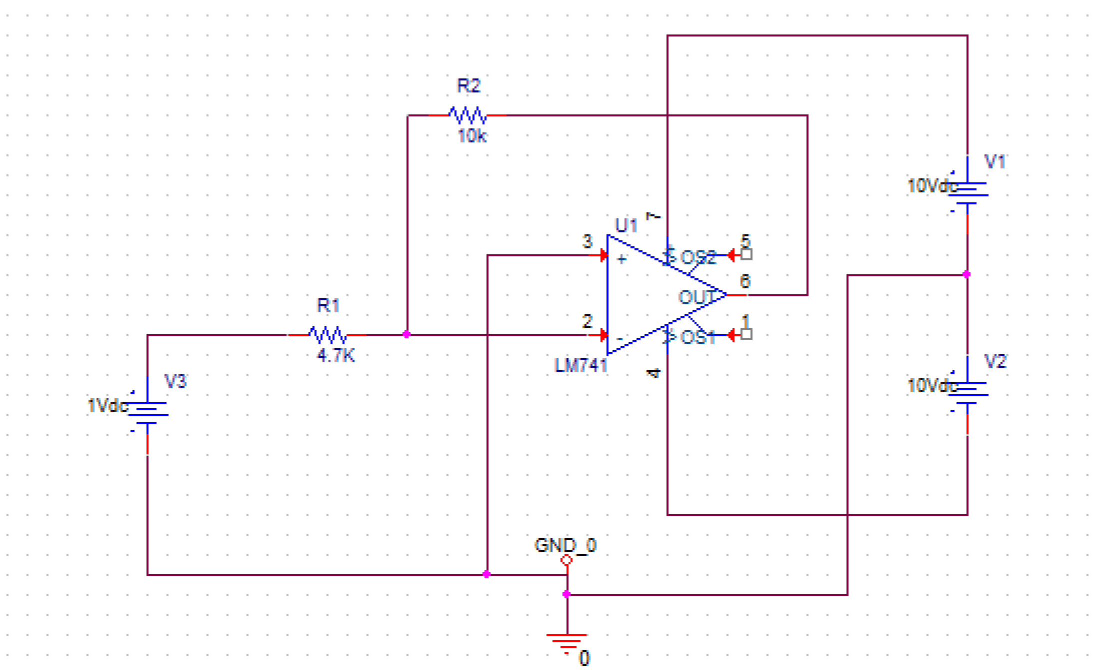
Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cu
	X Values	1.0000	-10.000	11.000		Y1 - Y1(Cu
CURSOR 1,2	V(V3:+)	1.0000	-10.000	11.000		0.000
	V(U1:OUT)	-2.1268	9.815	-11.942		-3.1268

Next we will Identify the Vout max and Vout min.

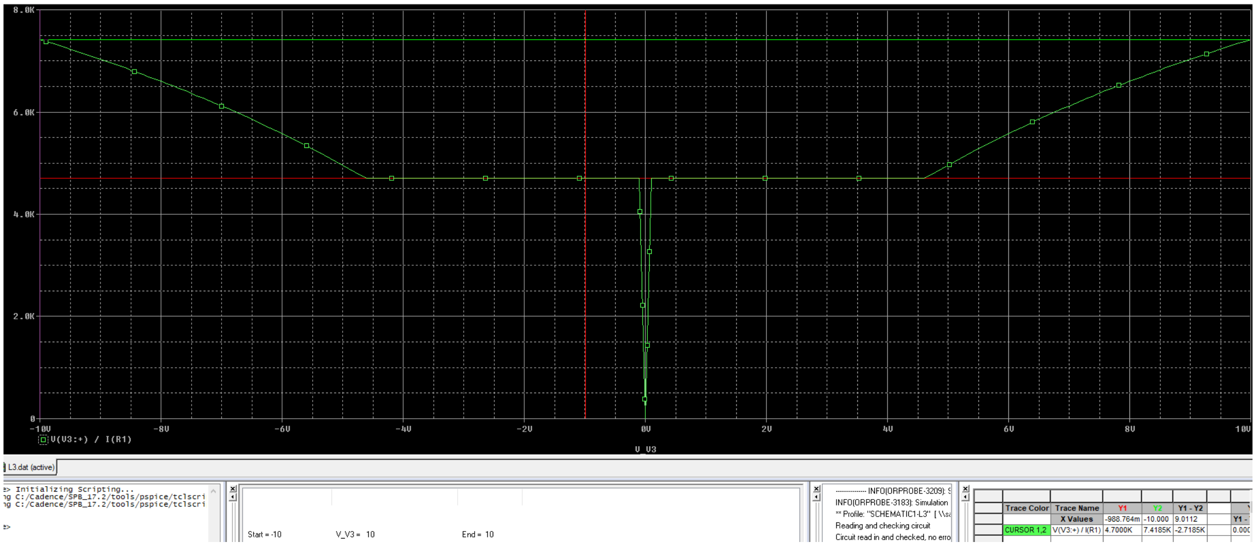


STEP 7: Simulate and Calculate value of Rin2

For this step using this circuit below, obtain the plot for i_{s2} then determine Vout/ Vs2



Using the circuit above we were able to trace this output which shows the range.



Trace Color	Trace Name	Y1	Y2	Y1 - Y2
	X Values	-988.764m	-10.000	9.0112
CURSOR 1,2	V(V3:+) / I(R1)	4.7000K	7.4185K	-2.7185K

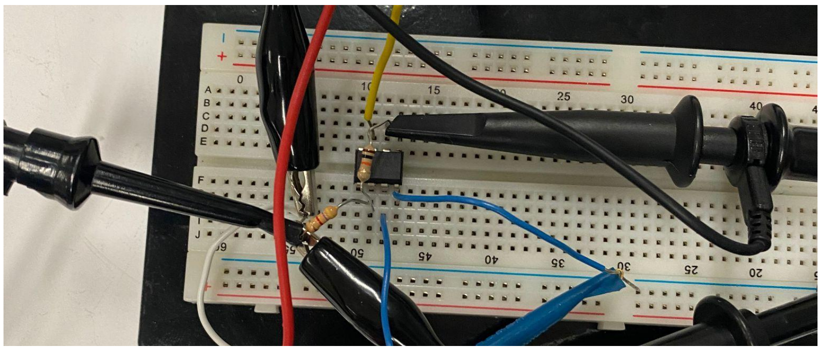
STEP 8: Results of the plots

As a result of the plots of step 5 and step 6. I can conclude that considering Vn = Vp, that **No,** the assumption does not hold when the output is saturated. As we see that they start to diverge in step 6.

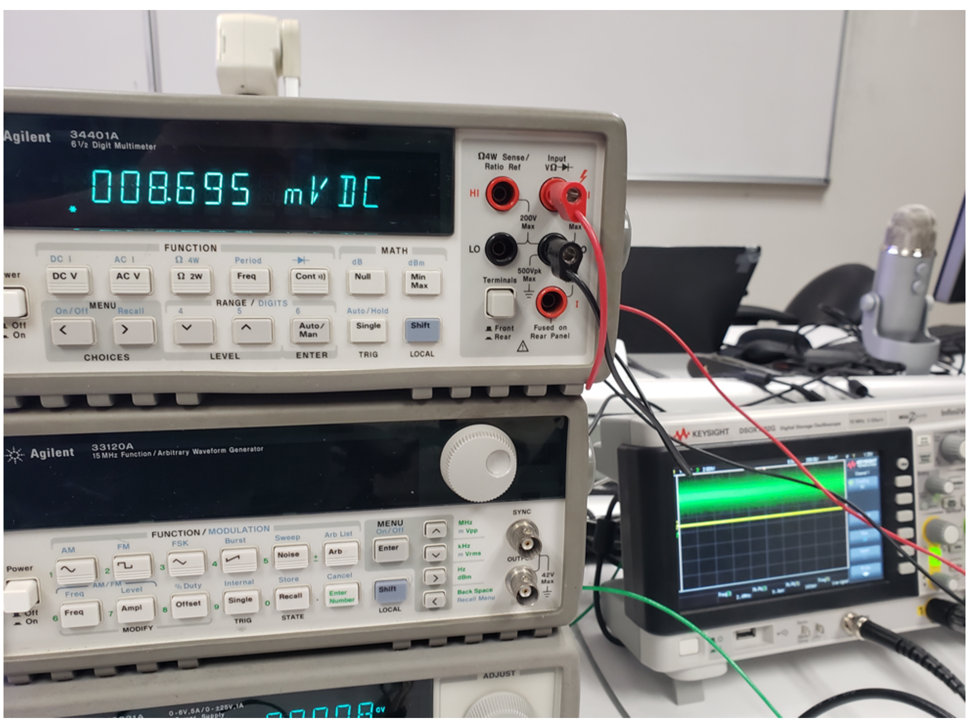
Part 3: Experiment Non-Inverting OpAMP

STEP 9: Construct the circuit on Breadboard

In this step it is time to build the Figure 1 Non - Inverting circuit on a live breadboard. Using +-10V power supply to measure the Vout and record the output voltages/ gain of the amplifier.



8.695 mVDC was the output and the waveform is seen on the right of the figure below.



STEP 10: Find Vout/Vs and Record Vout max and min

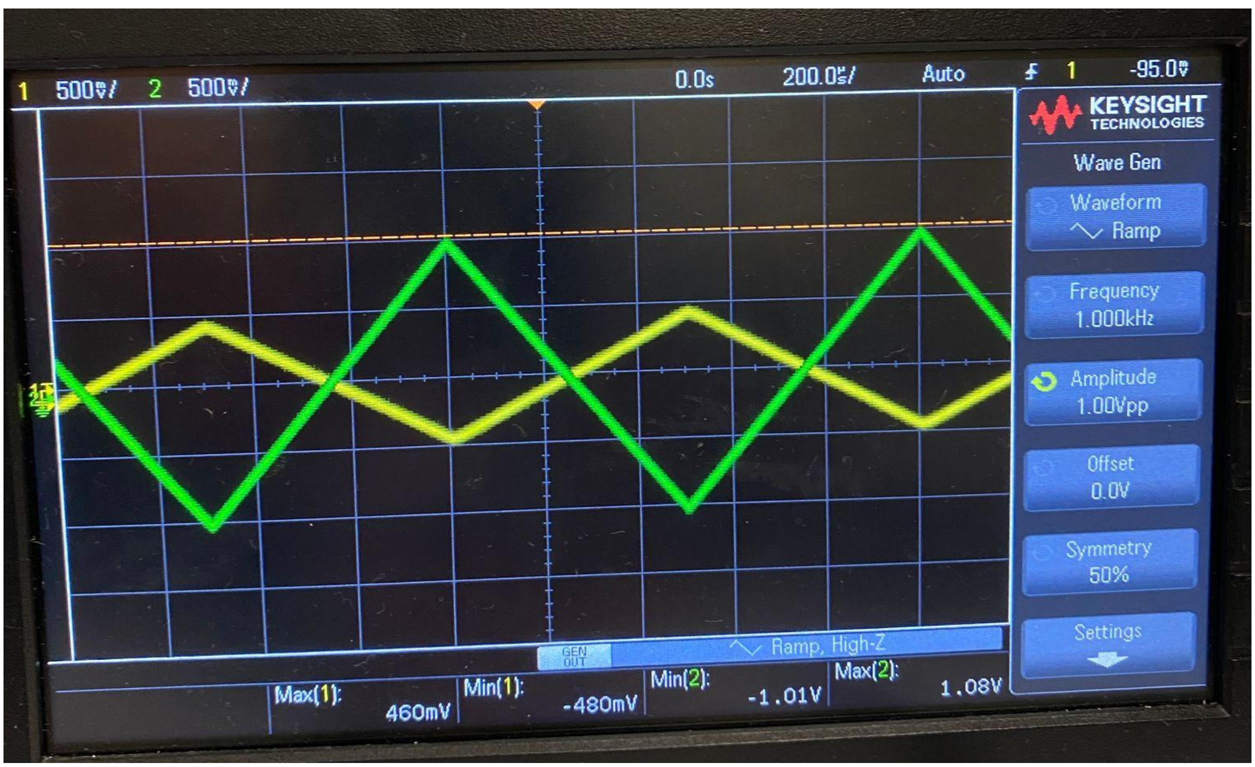
For this step we will be using a DC source with the range of +- 6V.

Testing the Input VS from 1V-5V we got these results seen below

Input Voltage Vs	Output Voltage Vout
1V	3.1V
2V	6.2V
3V	9.2V
4V	9.2V
5V	9.2V

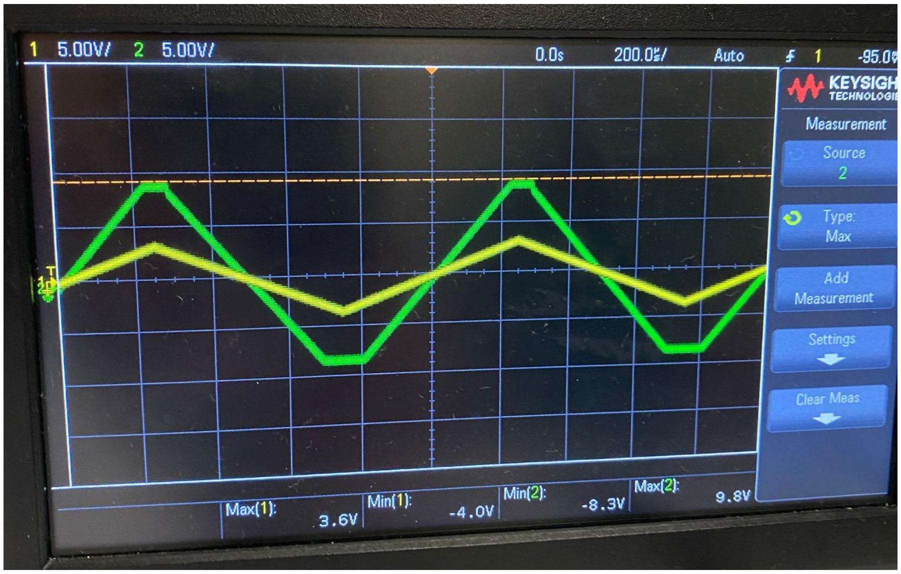
STEP 11: AC Signal Source

Now for this step instead of DC input use AC signal source. Using Vs1 with 1KHz triangle wave.



STEP 12: Oscilloscope Results

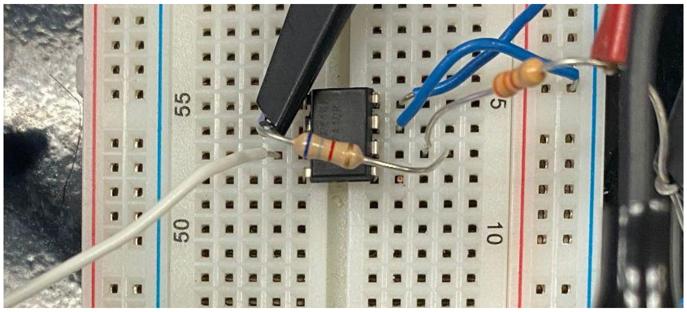
In this step the oscilloscope was set to 'DC' coupling which means that both the DC and the AC are both displayed. The waveform below shows what happens when we set it to DC coupling and it appears that there are signs of distortion.



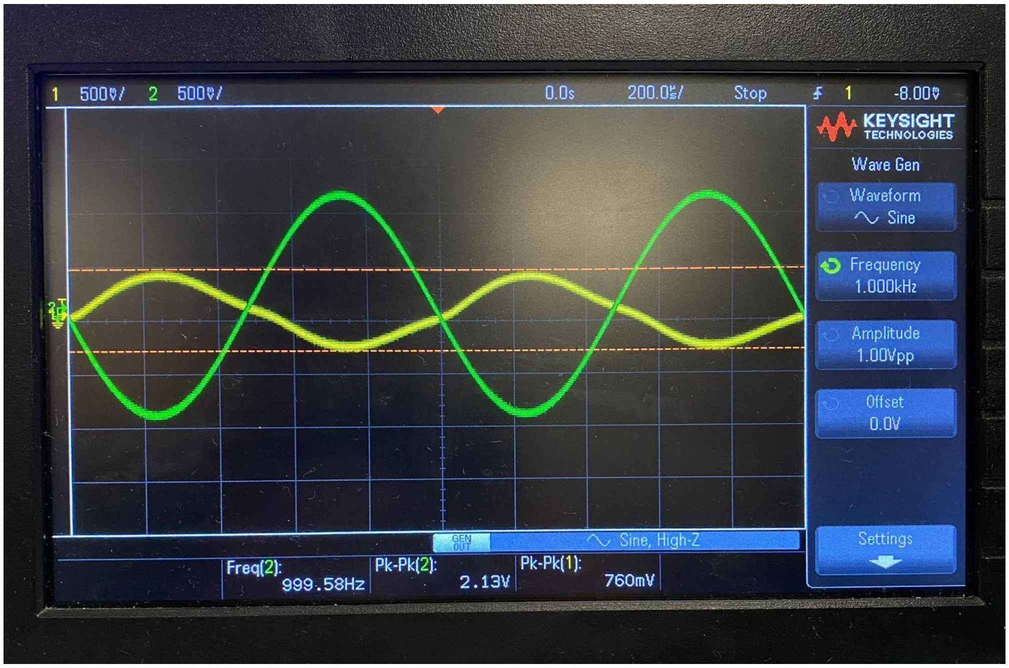
Part 4: Experiment Inverting OpAMP

STEP 13: Construct the circuit on breadboard

For this step we are constructing the circuit on Figure 2 the Inverting Amplifier.



For the inverting amplifier the waveform produced is the **input and output** V and is seen in the figure below.

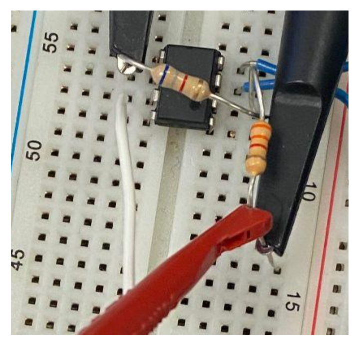


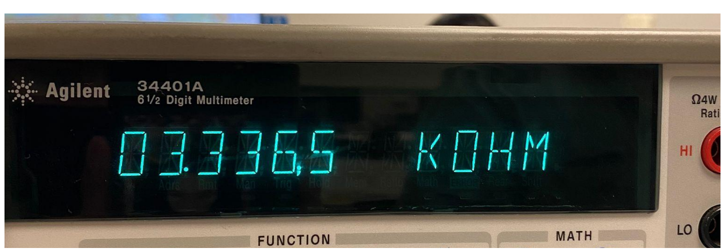
STEP 14: Measure small-signal input resistance

In this step I chose to use the method Rin=R_A to solve for the small signal input for the inverted circuit.

Rin2= 3.3kΩ

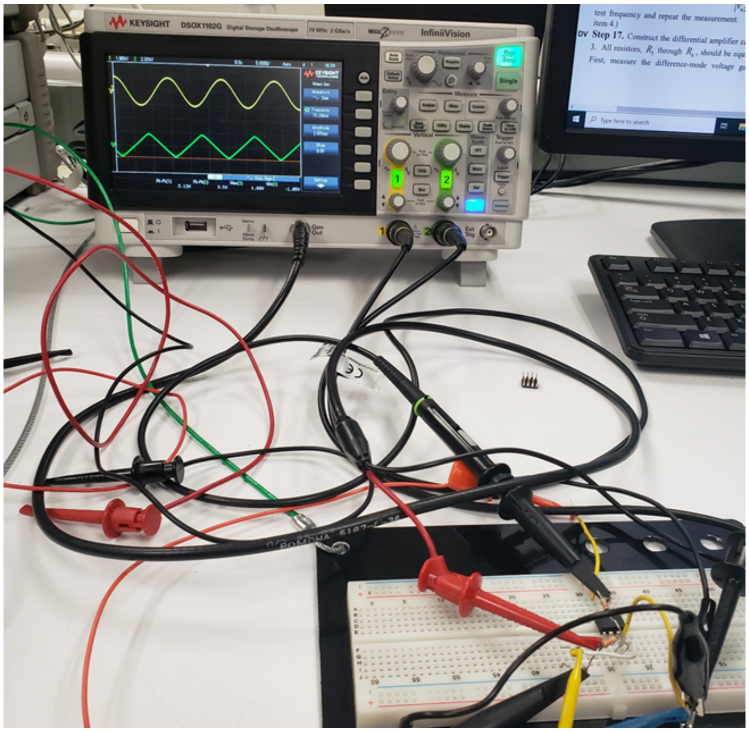
We also tested this theory when we did the test on the live circuit which received the results **3.336kΩ**



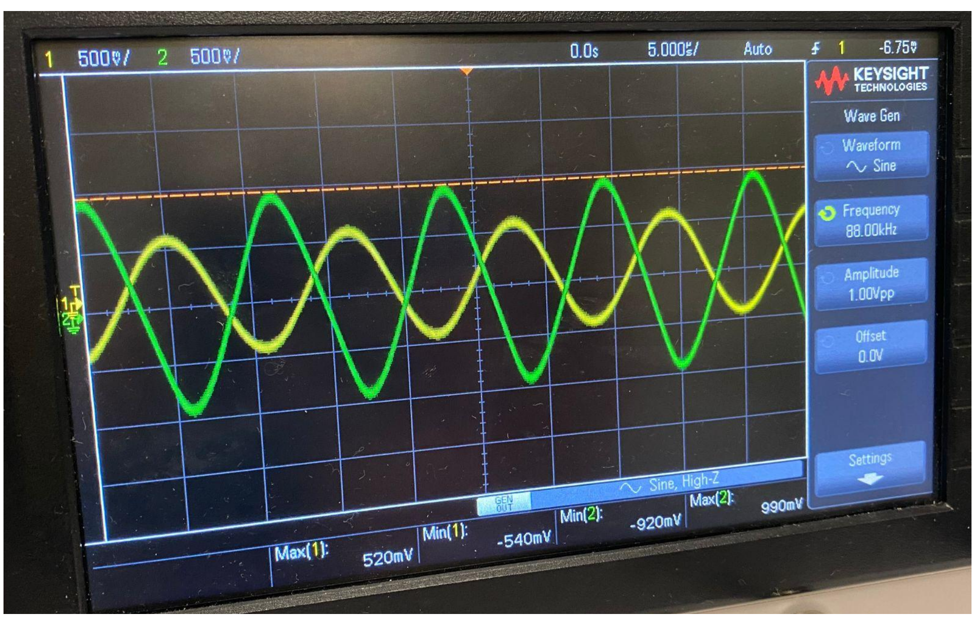


STEP 15: Observe the sine Waveform

Now for this step it is time to test the sine wave.

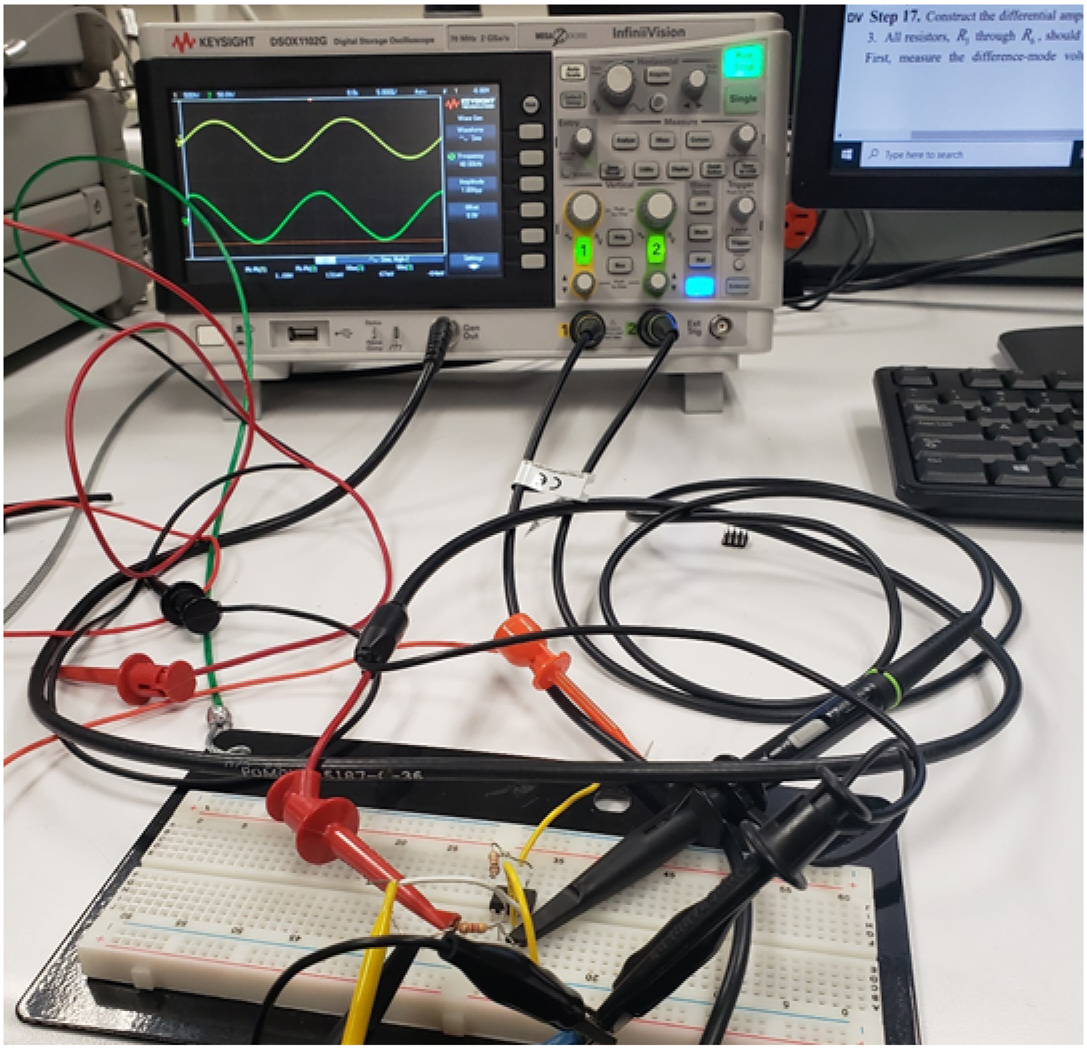


For this when we noticed the slew rate and distortion we increased the frequency and amplitude until we didn't see it as much seen in the figure below.



STEP 16: Calculate magnitude of the Open loop gain

This step is a continuation of the previous step but instead of increasing the frequency and amplitude, it is time to decrease it till the slew rate was not present on the output. At 1V we see a peak to peak sine wave signal into an Inverting Amplifier circuit at 40KHz.



STEP 17: Construct the differential amplifier circuit

In this step we constructed the differential amplifier circuit seen in Figure 3 below. With all the 4 resistors having 4.7kΩ values.

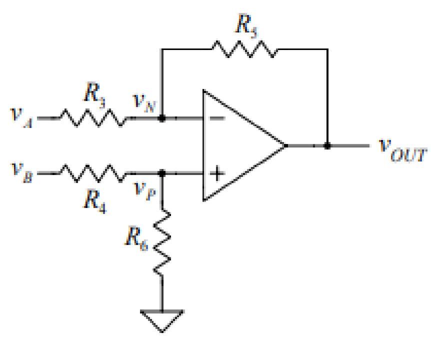


Figure 3

Now measuring the difference-mode voltage gain which is found by using the equation,

$$A_{dm} = \frac{v_{out}}{v_b - v_a}$$

In this case since V_A is linked to ground and V_B is set to the signal, $V_A = 0$, so we use this equation.

$$A_{dm} = \frac{v_{out}}{v_b}$$

The common mode gain = 10mV/1mV= 0.01mV

STEP 18: Construct the circuit with diodes

For this step we will be constructing the circuit seen below in Figure 4.
This circuit consists of two 1N4148 signal diodes.

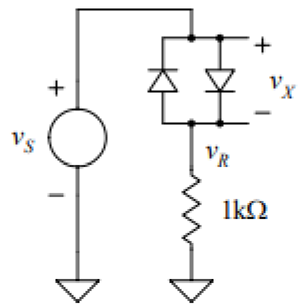


Figure 4

As a result of the circuit this was the waveform output.

CONCLUSION:

ITEM 1: Compare the SPICE simulation results to the laboratory measurements with regard to gain and output clipping levels. Suggest reasons for any differences.

As for the Pspice simulation results and the lab results I'd say both experiments had fairly similar results and as most of the waveforms turned out as expected. .

ITEM 2: Summarize the data and calculations you did to determine the input offset voltage (VOS) of your operational amplifier. Suppose that the amplifier circuit of Figure 1 is constructed with your operational amplifier with 100 RA = Ω and 100k RB = Ω. Assuming that VOS has not changed, what is the DC output voltage of the operational amplifier when the input is zero?

After all these tests we were able to conclude that the gain would be 1k

ITEM 3: Review your data of Steps 11 and 12 and make a general statement relating the output voltage swing of an operational amplifier to its power supply voltages.

In steps 11 before the clipping distortion occurs in step 12. We see that the clipping occurs in between -8.3V and 9.8V.

ITEM 4: Summarize the measurements of Step 16. Multiply each measured open-loop gain by the frequency at which it was measured. The result is called the gain-bandwidth product (GBP) of the operational amplifier. Does the GBP appear to be constant for the two cases?

We see in step 16 that the open loop gain is measured around 0.8V for the -1.4V. And the other case we see similar results for Vout min = Vpp+ 1.4V
Vout Max = Vcc - 0.8V

ITEM 5: Compare the voltage gain Adm found in Step 17 with theory. Does the voltage gain Acm found in Step 17 seem reasonable?

Yes, because it is less than what the theory from step 17 says. In this case the Acm = 1