Fall 2018

California State University, Northridge
Department of Electrical & Computer Engineering

Experiment 8
Operational Amplifiers
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ECE 240L
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Group 2
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Introduction:

The purpose of this experiment is to understand how to analyze circuits that contain operational amplifiers, through modeling them as an ideal, using their properties to simplify a circuit, and determining their outputs. Through this experiment, the different types of output voltages possible from an operational amplifier will be observed.

Equipment used:

Type	Model	Serial No.	Calibration Date
Function Generator	Agilent 33220A	MY44017172	N/A
Oscilloscope	Tektronix 2213A	LR37158	N/A
Digital Multimeter	Tektronix CDM250	CDM-250TW5238 0	N/A
DC power supply	Agilent E3630	MY40004246	N/A

Parts Used:

QTY	Component	Value	Tolerance	Type
1	Resistor	3.3kΩ	+/- 5%	Carbon
1	Resistor	10kΩ	+/- 5%	Carbon
1	Resistor	6.2kΩ	+/- 5%	Carbon
1	Resistor	27kΩ	+/- 5%	Carbon
1	Resistor	4.7kΩ	+/- 5%	Carbon
1	Resistor	100kΩ	+/- 5%	Carbon

Software Used:

1. Google Docs
2. Krita
3. Snipping Tool
4. Pspice

Theory:

An Op. Amp. takes 2 input voltages and applies a gain A_V between the difference of inputs V_A and V_B as shown in figure 8.1

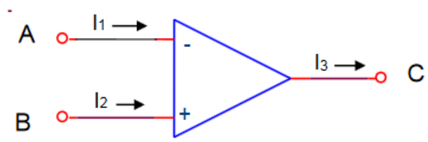


Figure 8.1

The important characteristics of an ideal op amp are that it has an infinite gain and infinite resistance which results in the following properties.

The difference in voltages between inputs A and B are 0.

$V_A - V_B = 0v$ or $V_A = V_B$

There is no current that travels through the inputs.

$I_1 = I_2 = 0A$

The output current is not 0.

Operational amplifiers come in the form of a DIP integrated circuit shown in Figure 8.5

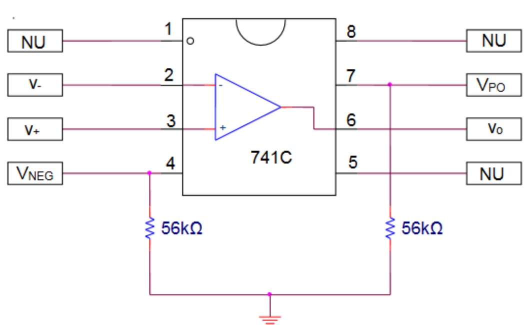


Figure 8.5

Pin 2 is the inverting input. Pin 3 is the non-inverting input. Pin 4 is the negative power. Pin 6 is the output of the Op amp, and Pin 7 is the positive power.

Procedure & Results:

1. The output voltage V_O of Figure 8.2 was found to be a function of R_F and V_I.

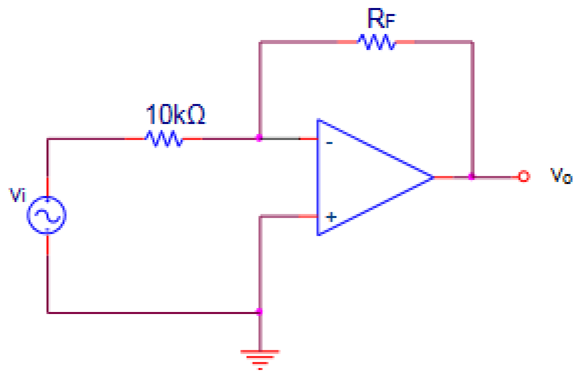


Figure 8.2

$$i = \frac{V_i}{10k\Omega} = \frac{0 - V_o}{R_F}$$

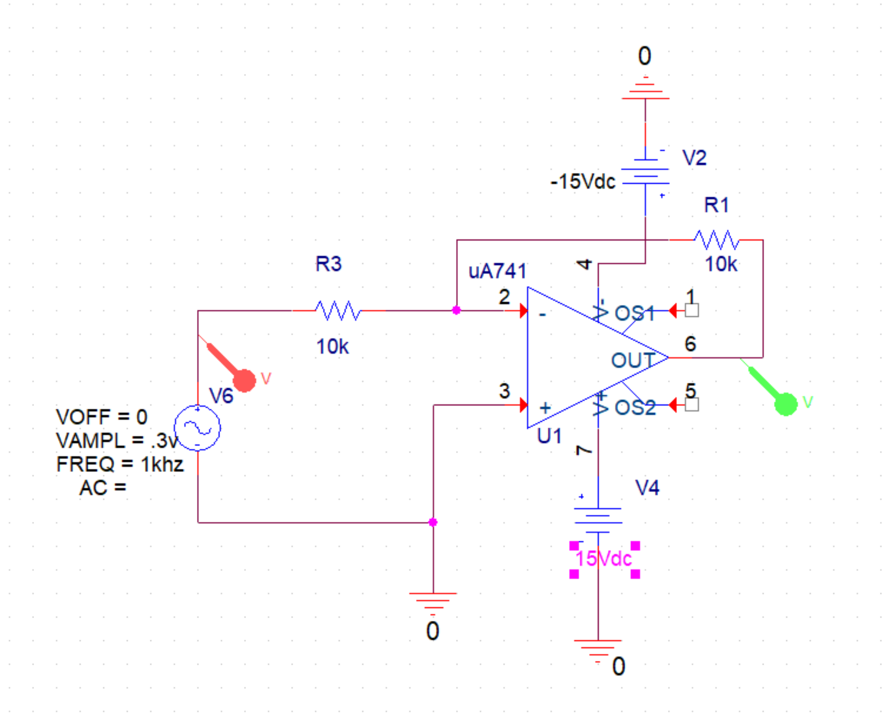
$$V_o = -I_1 R_F = -V_i\left(\frac{R_F}{10k\Omega}\right)$$

Figure 8.2 was constructed for values of R_F as 10kΩ, 27kΩ, 100kΩ

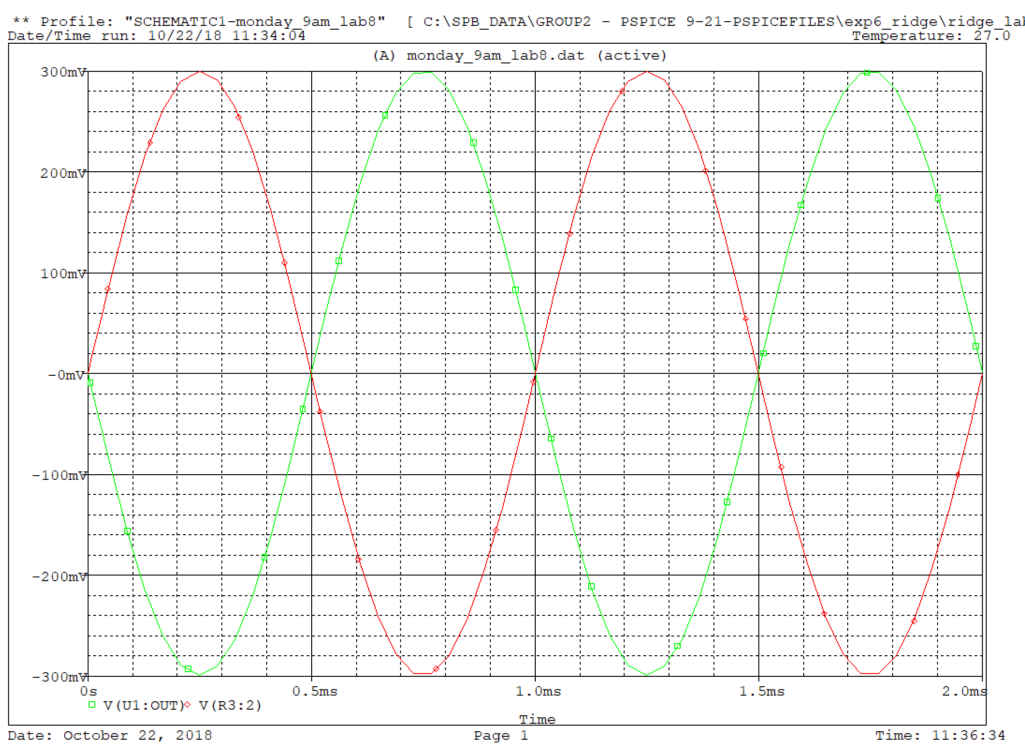
V_O, A_V, and % error of A_V were recorded with an for an amplitude of .3v in Table 8.1

Table 8.2	Measured			Calculated			
R_F	V_I	V_O	A_V	V_I	V_O	A_V	A_V%error
10kΩ	0.30 v	-0.29 v	-.984	0.30v	-.30 v	-1.0	1.6%
27kΩ	0.30 v	-0.80 v	-2.667	0.30v	-0.81	-2.7	1.2%
100kΩ	0.30	-2.91	--9.7	0.30v	-3.0v	-10.0	3%

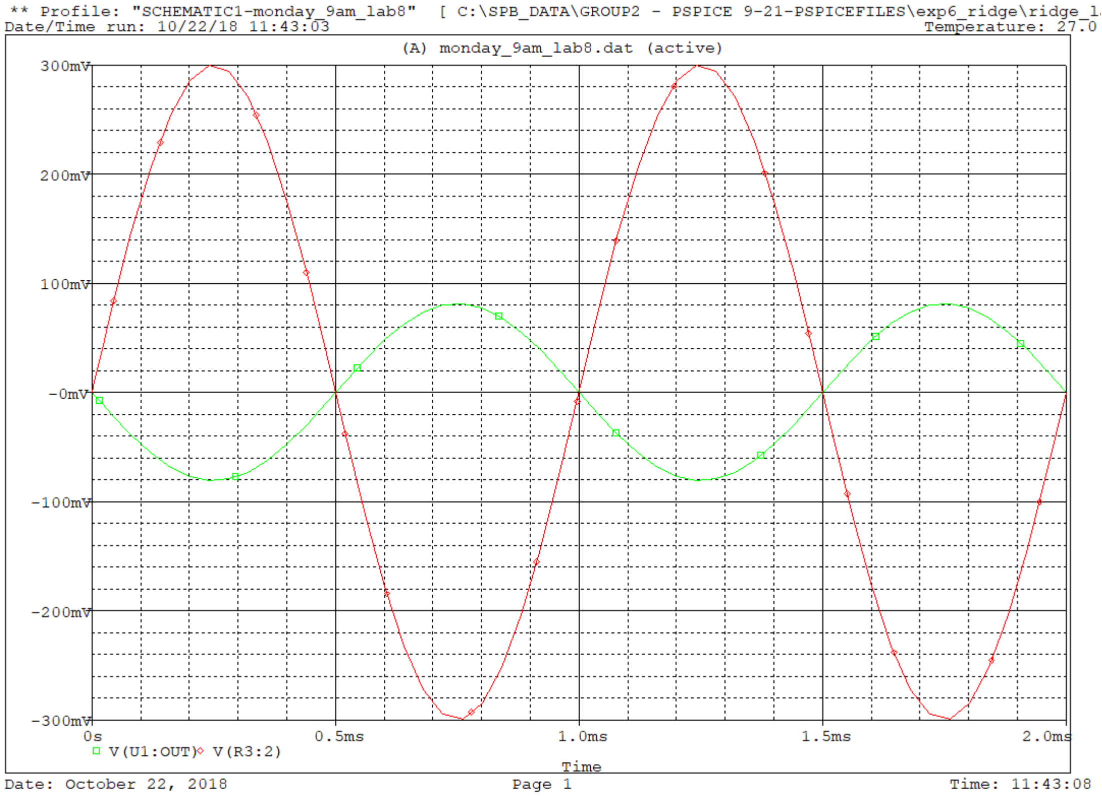
Figure 8.2 was simulated in Pspice 8.2 and the results were shown in graph 8.2a-c



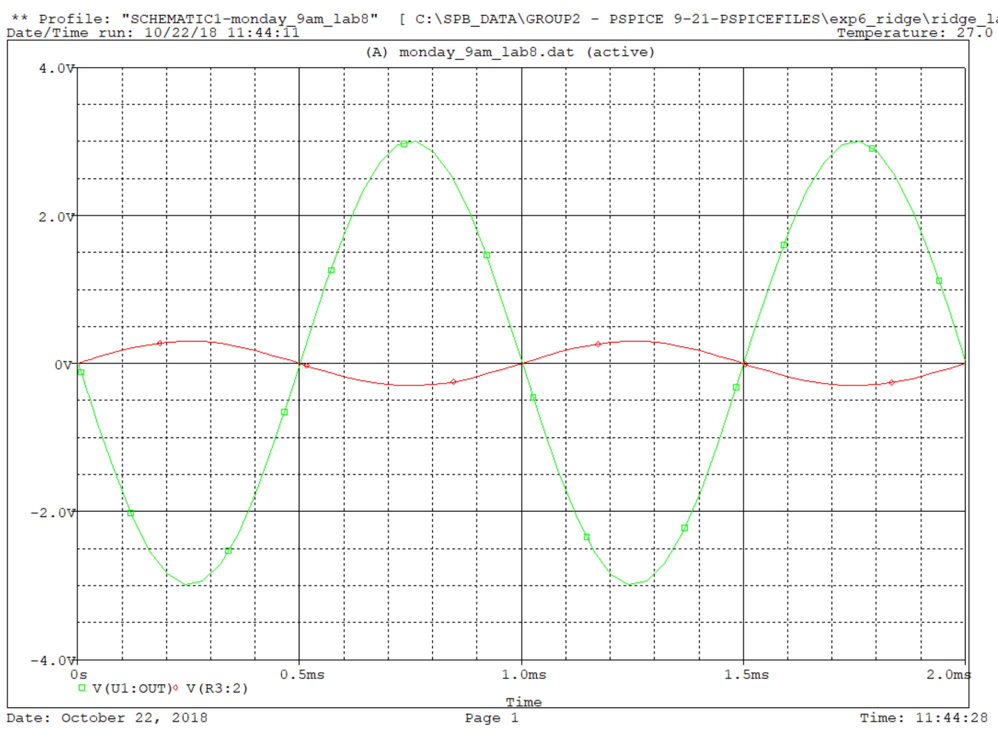
(Pspice 8.2)



Graph 8.2a



Graph 8.2b



Graph 8.2c

2. The output voltage V_O of Figure 8.3 was found to be a function of R_F and V_I.

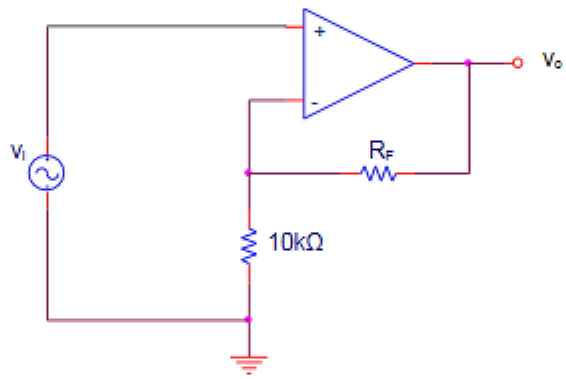


Figure 8.3

$$I = \frac{V_i}{10k\Omega} \qquad V_o = V_i - (-R_F)$$

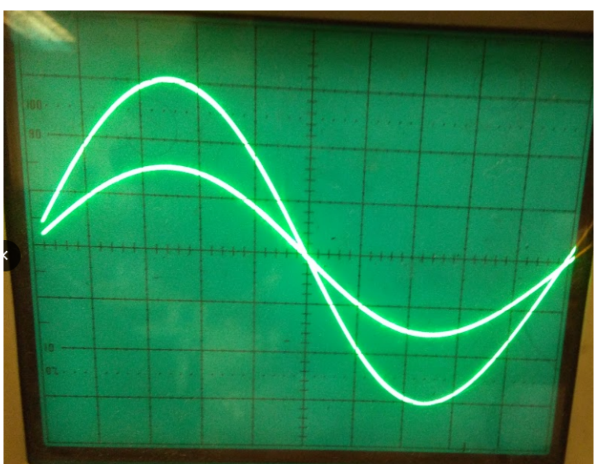
$$V_o = V_i + V_i\left(\frac{R_F}{10k\Omega}\right)$$

$$V_o = V_i\left(1 + \frac{R_F}{10k\Omega}\right)$$

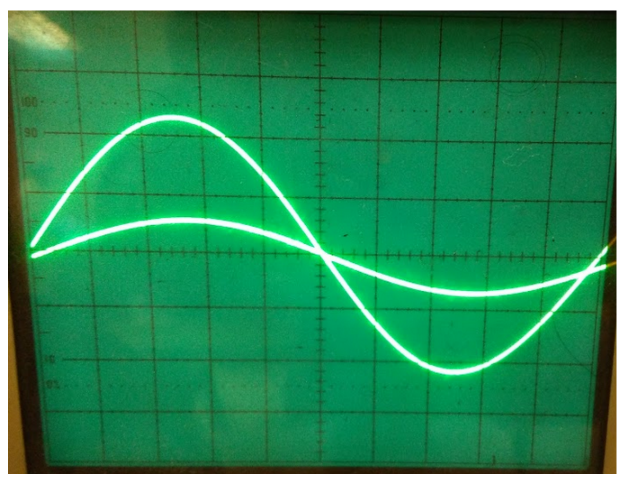
Figure 8.3 was constructed with values of R_F as 10kΩ, 27kΩ, and 100kΩ.

An oscilloscope was used to measure V_I and V_O. The results were displayed in Pictures 8.3a-d

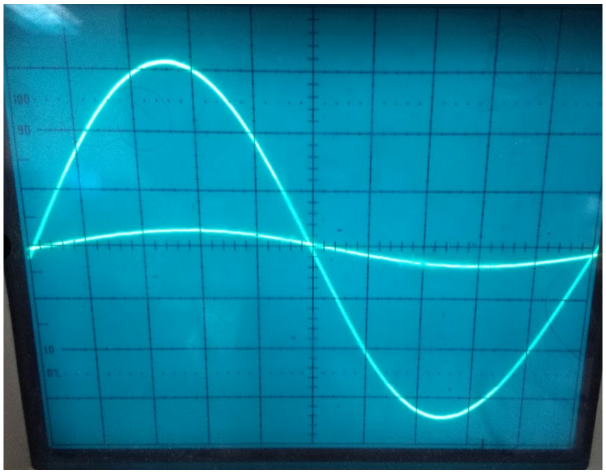
(Picture 8.3a)

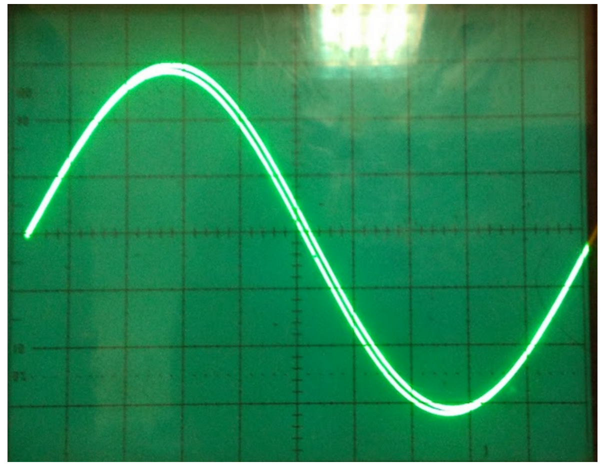


(Picture 8.3b)



(Picture 8.3c) (Picture 8.3d)

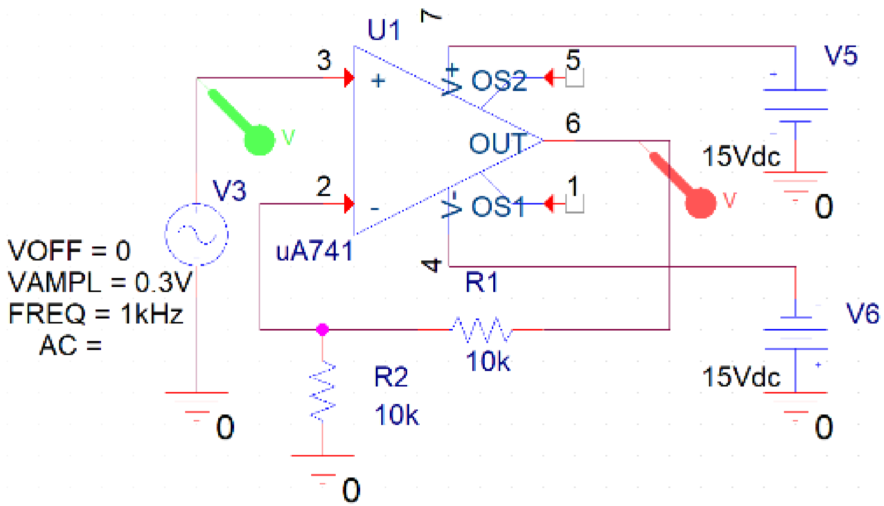




V_O, A_V, and A_V % error were recorded with in Table 8.3

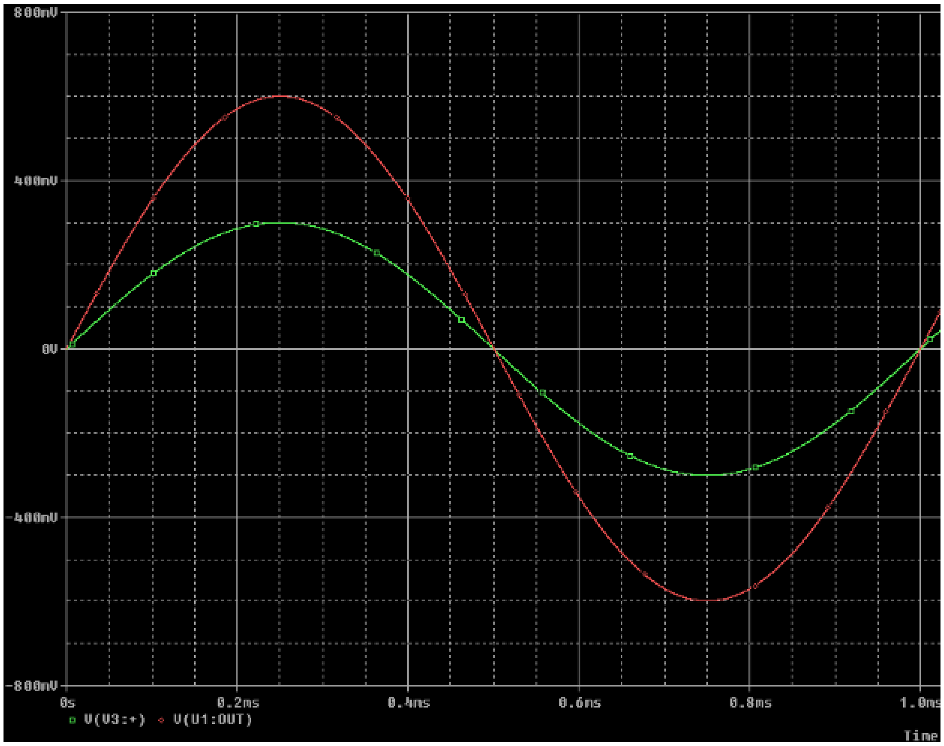
Table 8.3	Measured			Calculated			
R_F	V_I	V_O	A_V	V_I	V_O	A_V	A_V%error
10kΩ	0.30v	0.605 v	2.017	0.30v	.60v	2.0	.85%
27kΩ	0.30v	1.150 v	3.83	0.30v	1.11v	3.7	3.5%
100kΩ	0.30v	3.250 v	10.8	0.30v	3.3v	11.0	1.82%
Shorted	.30v	0.295 v	1.02	0.30v	.30v	1.0	2.0%

The circuit was then simulated in pspice 8.3 and results shown in graph 8.3a -d

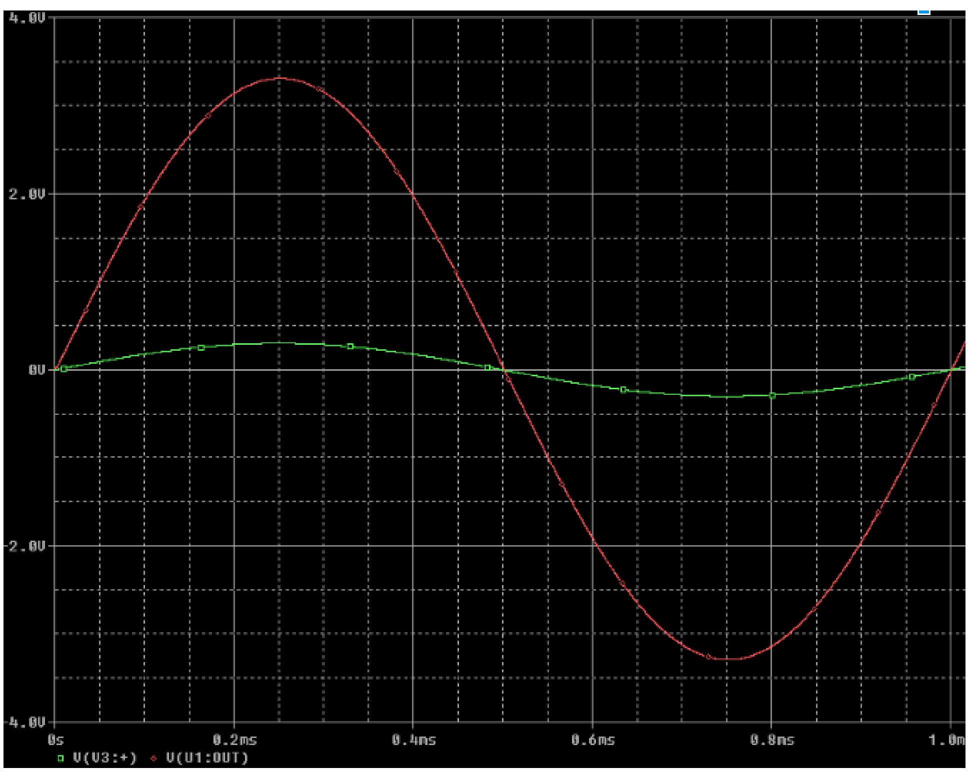


(Pspice 8.3)

Graph 8.3a



Graph 8.3b



Graph 8.3c

3. The output voltage V_O of Figure 8.4 was found to be a function of R_F and V_I.

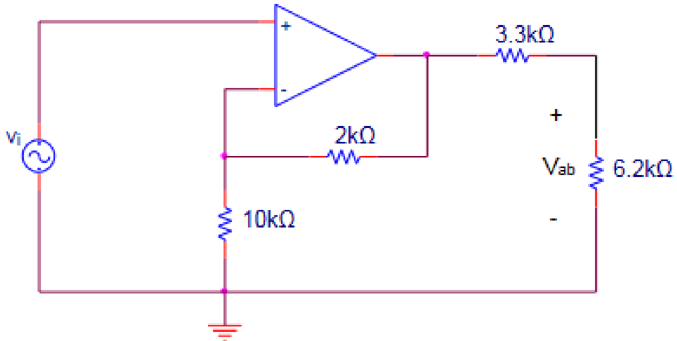


Figure 8.4

$$I_1 = \frac{V_i}{10K\Omega}$$

$$V_o = V_i\left(1 + \frac{2k}{10k}\right) \quad \boxed{V_o = 1.2V_i}$$

$$I_2 = \frac{V_o}{3.3K + 6.2k}$$

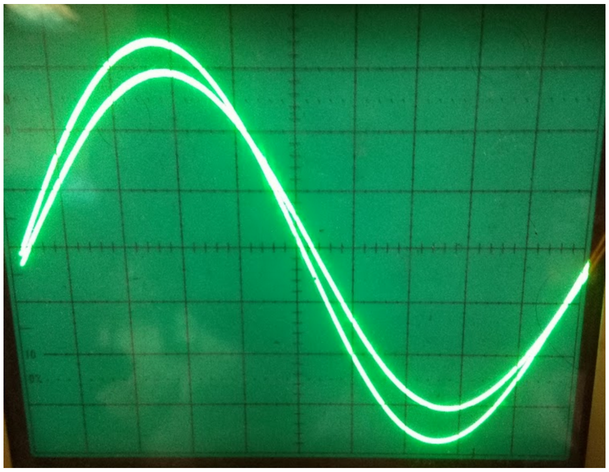
$$V_{ab} = V_o\left(\frac{6.2}{6.2+3.3}\right) = (.6526)\,V_o$$

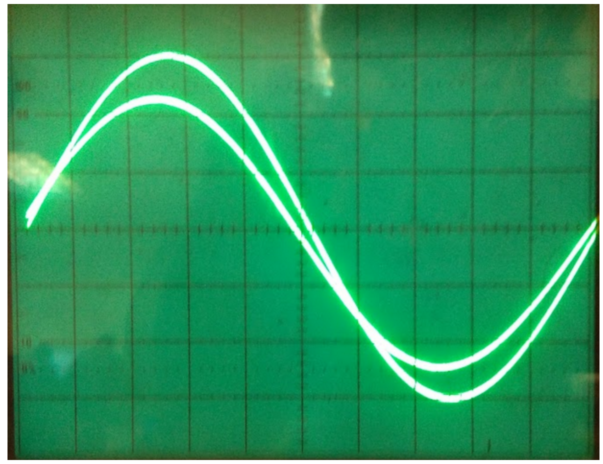
Figure 8.4 was constructed.

An oscilloscope was used to measure V_I,V_O, anb $V_{ab.}$

The results were displayed in Pictures 8.4a-b(Picture 8.4a)

(Picture 8.4b)

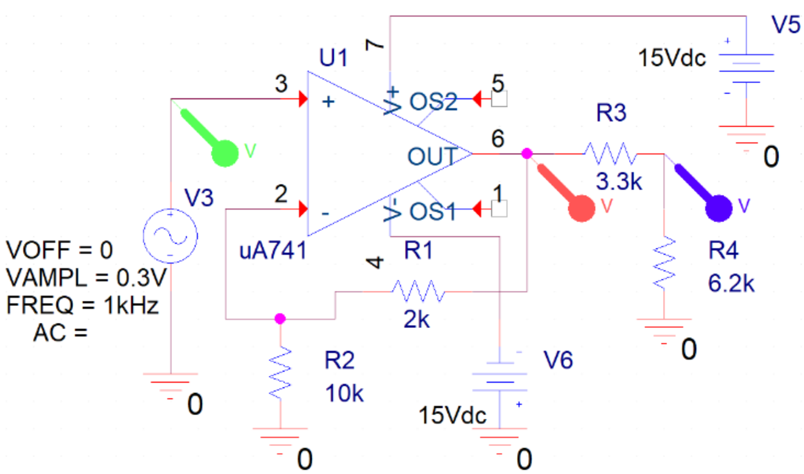




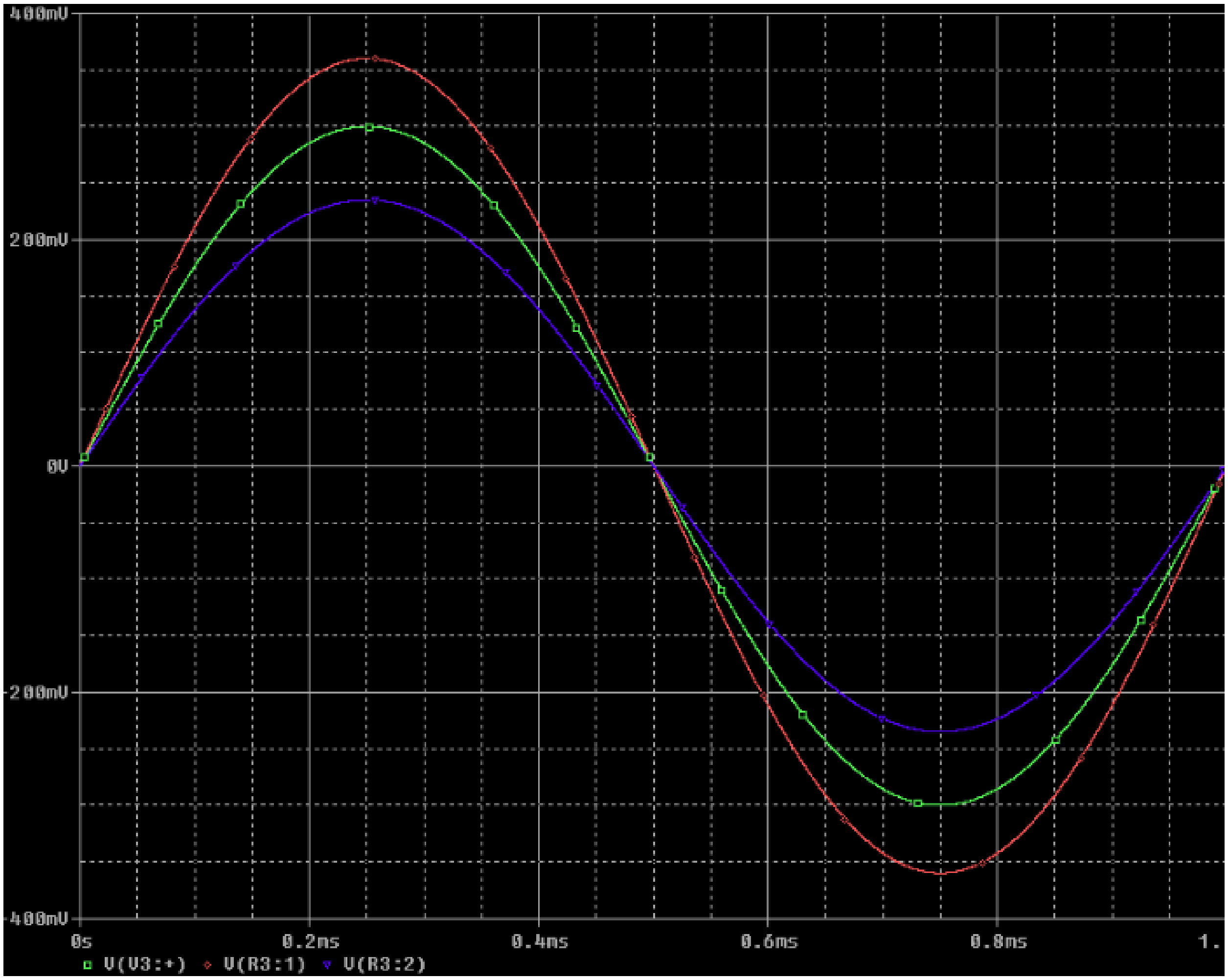
The output voltage, V_{ab}, and their gains were recorded in Table 8.4

Table 8.4	V_O	A_{V1}	V_{ab}	A_{V2}	A_V
Measured	0.355 v	1.18	0.230 v	0.648	0.767
Calculated	0.360 v	1.20	0.235 v	0.653	0.783
% error	1.39%	1.67%	2.12%	0.76%	2.04%

Figure 8.4 was simulated in Pspice 8.4 and the results in Graph 8.4



(Pspice 8.4)


400mV
200mV
0V
-200mV
-400mV
0s
0.2ms
0.4ms
0.6ms
0.8ms
1.
V(V3:+)
V(R3:1)
V(R3:2)

graph 8.4

Conclusion:

The experiment was a success in the demonstration and analysis of operational amplifiers in AC circuits. In part 1 of the procedure, the inverting amplifier was successfully analyzed and built. The measured results showed minimal % error between measured and calculated gain. In part 2, the circuit was identified as a non-inverting amplifier and again the % errors were less than 5% error between the measured and calculated results. In part 3, the attenuating circuit was correctly built and analysed. In Pspice, figures 8.2, 8.3, and 8.4 were all successfully simulated and the graphs produced the exact same results as seen on the analog oscilloscope. The experiment was a success in the demonstration in the inversion , non-inversion, and attenuation of input voltages.