

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ELEG 4101- Electronics Laboratory
FALL 2021**

I. COURSE DESCRIPTION IN ABET FORMAT

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in Course

Assessment Summary of Class Semester Averages for Outcomes

End of Semester Course Outcomes Assessment Reports

II. TESTS

Summary of Topics covered by Test

Original Test Questions & Master Solution/grading scheme used

(Summary of topics can be a separate page or include on the assignment itself)

Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

III. QUIZZES

Summary of Topics covered by Quiz

Original Quiz Questions & Master Solution/grading scheme used

Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

IV. HOMEWORK ASSIGNMENTS

Summary of Topics covered by Homework

Original Homework Questions & Master Solution/grading scheme used

Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

V. LABORATORY REPORTS

Summary of Topics covered by lab

Laboratory Handout/Instructions and Grading Scheme

Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

VI. PROJECT

Summary of Topics Covered by Project

Project Problem Statement and Grading Scheme

Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

[Include any other evaluation used and omit any method above method (Test, Quizzes, Homework, Laboratory and Project reports) that was not used]

Course Description

in ABET Format

1.	Course number and name:	ELEG 4011 ELECTRONICS LABORATORY
2.	Credits and contact hours:	1 credit hours; 3 contact hours * Subject Area: Engineering Topics
3.	Instructor's or course coordinator's name:	Dr. Mohan Ketkar
4.	Text book: Title:	Laboratory Explorations to accompany Microelectronics Circuits
	Author:	Sedra and Smith
	Publisher, Year & Edition:	Oxford University Press
	a. Other Supplemental material	J.O. Attia, "Circuits and Electronics: Hands-on learning with Analog Discovery"
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	ELEG 4011 Electronics Laboratory: 1 semester hour. Applications of semiconductors diodes. Operational characteristics of transistor amplifiers (inverters, emitter follower, difference, etc.) FET characteristics and applications. Operational amplifier characteristics and circuit implementation. Frequency response of amplifiers.
	b. Prerequisites or Co-requisites	ELEG 2011 ELEG 3043
	c. ** Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required
6.	a. Specific goals for the course specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.) <i>Students will be able to :</i>	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course. <i>The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:</i>

	Students will be able to 1.select electronic components appropriate for the design of electronic circuits 2. use modern engineering tools such as MATLAB, PSPICE/MultiSim. 3.design, construct, test electronic circuit that satisfies multiple design constraints 4.use modern laboratory equipment	
7	Brief list of topics to be covered	Operational Amplifiers Instrumentation Amplifier Diodes and applications MOSFETs at DC Bipolar Junction Transistors at DC Active bandpass Filter Amplifiers

* For all Engineering programs, indicate subject area from the following: **Math, Basic science, Engineering topic or Other**

** **Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group

Grade Sheet downloaded from canvas

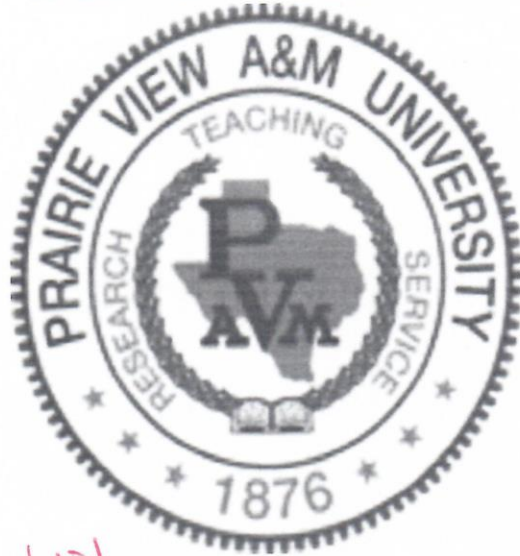
	Student	Attendance (195137)	Lab Report 1 (175166)	Lab Report 2 (175163)	Lab Report 3 (175170)	Lab Report 4 (175171)	Lab Report 5 (175172)	Lab Report 6 (175173)	Lab Report 7 (175174)	Participation & Attendance Current Score	Lab reports Current Score	Current Score	Current Grade
1		14.86	9	9	9	9	10	10	10	92.86	78.57	80.86	B
2		16	11	11	11	11	11	12	0	100	79.76	83	B
3		14.86	9	9	9	9	9	9	9	92.86	75	77.86	C
4		11.08	9	9	8	9	0	0	8	69.23	51.19	71.52	C
5		14.86	11	11	11	11	11	11	0	92.86	78.57	80.86	B
6		16	10	10	10	10	10	10	11	100	84.52	87	B
7		16	12	10	10	10	11	10	10	100	86.9	89	A
8		16	12	11	11	12	12	12	11	100	96.43	97	A
9		16	10	10	10	10	11	11	10	100	85.71	88	B
10		16	12	12	12	12	11	12	10	100	96.43	97	A
11		14.86	12	11	12	12	11	12	10	92.86	95.24	94.86	A

Lab I Report

ABOVE AVERAGE

(Note: All Pages shown in Light Blue should be printed on Light Blue Paper)

**ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



100

Excellent
Report

4101

ELEG 3304: Electronics I Lab
Fall 2021

Lab Report 1:
Op-amp Configuration

Ben Nguyen
Abel Mendoza

Submitted on:
September 14th

To:
Dr. Mohan Ketkar

Objective:

The lab was done in order to learn the LM741 operational amplifier. Specifically, the inverting, non-inverting, difference and gain features that the circuit offers.

Expectations:

Lab participants need to follow the procedure for each specified configuration, build a physical circuit on the bread boards, measure the input, output, and waveform, build a simulating circuit on a virtual software, comparing the results, and conduct a formal lab report.

Equipment:

- Breadboard (Model: NI-ELVIS)
- Color codes Jumper leads
- Multimeter
- Keysight Digital Storage Oscilloscope (Model: EDUX1052G)
- KeySight Waveform Generator (Model: EDU33212A)
- Resistors
- LM741 Chip

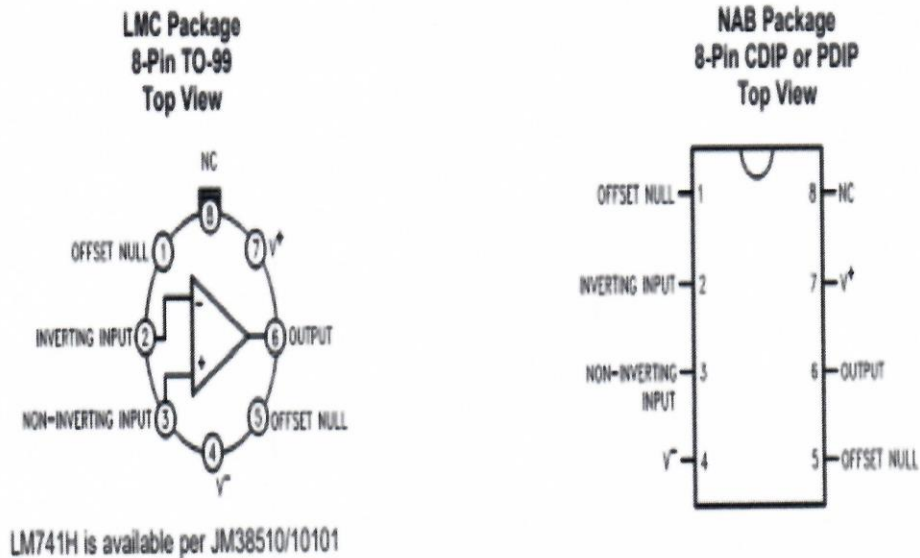


Figure 1: LM741 Operational Amplifier Pin Configuration

2.1 Inverting Op-amp Configuration

Procedures:

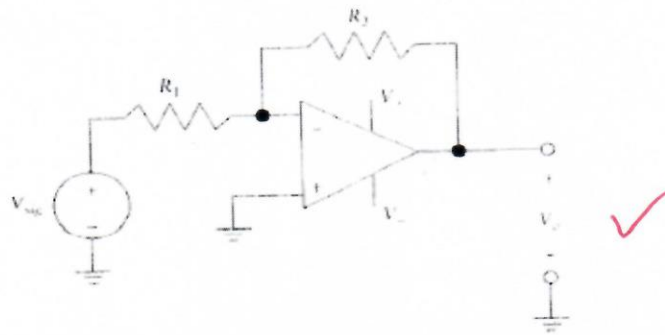


Figure 2: Inverting Op-amp Schematic

Based on the specified gain of 10 and 100 V/V, the hand calculations were done as below.

① $\frac{V_o}{V_{srg}} = -\frac{R_2}{R_1} \Rightarrow 10 \frac{V}{V}$
 $R_1 = 100 \Omega$
 $\Rightarrow R_2 = 1000 \Omega$

② $\frac{V_o}{V_{srg}} = -\frac{R_2}{R_1} = 100 \frac{V}{V}$
 $R_1 = 100 \Omega$
 $\Rightarrow R_2 = 10k \Omega$

Figure 3: Hand Calculations for Inverting Op-amp Configuration

A physical circuit was built on a provided breadboard, resistors, and color-coded jumpers. The input of the first resistor would be hooked to the positive terminal of the wave generator. The output of the first resistor would be connected to the second resistor's input at pin 2 of the Op-amp. The output of the second resistor would be connected to pin 6. Pin 3 would be

going to ground. +15 VDC would be connected to pin 7 and -15 VDC would be provided to pin 4. Channel 1 of the wave generator would be used as the input signal. A Peak-Peak AC voltage of 50 millivolts with the frequency of 1k Hz would be the signal source. Channel 1 and 2 of the oscilloscope would be used to view the input and output signals respectively. For the gain of 10 V/V, two resistors of 100 Ohm and 10k Ohm were used. To acquire the gain of 100 V/V, 100 Ohm and 10k Ohm would be utilized. The circuit would be shown in the figure below. ✓

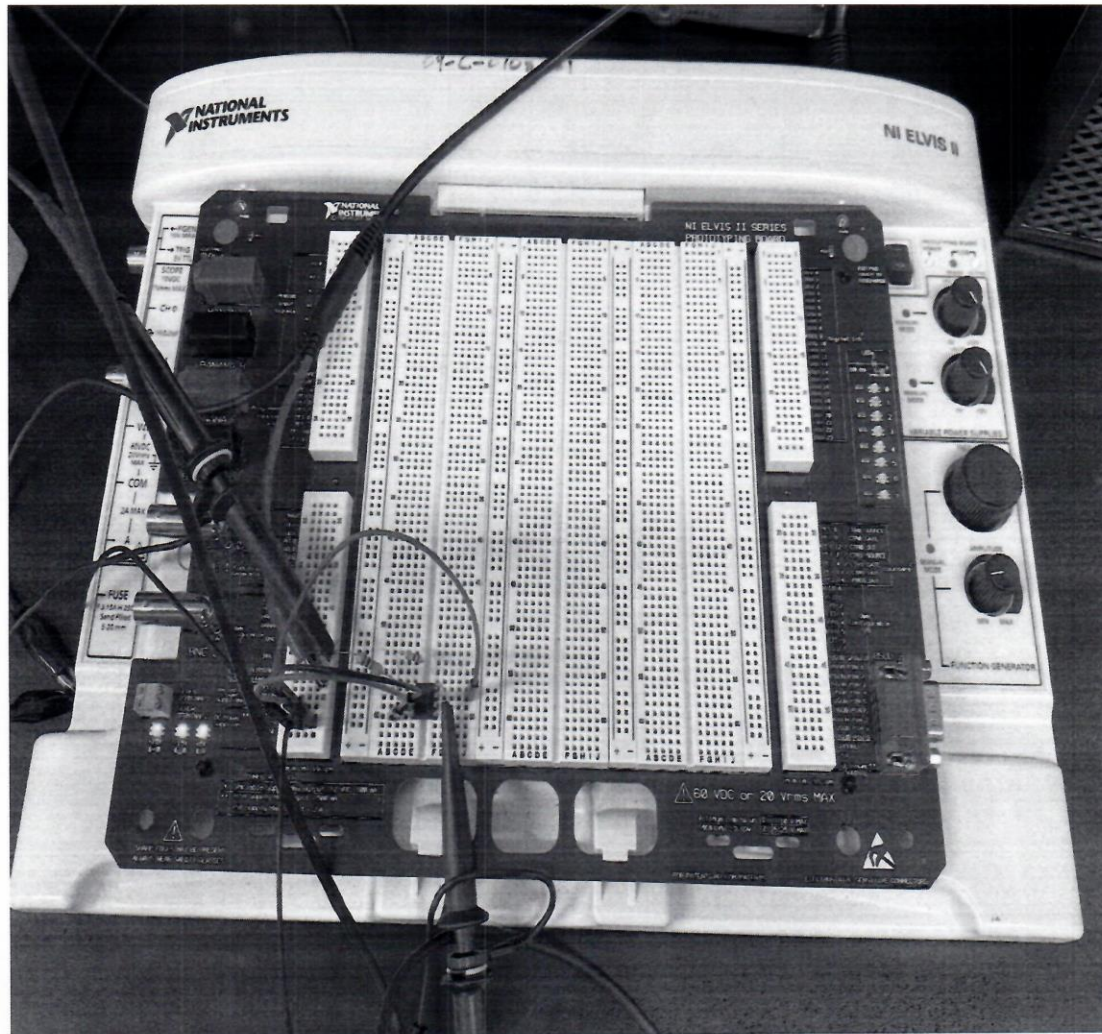


Figure 4: The Inverting Op-amp Physical Circuit

With the same schematic structure, a simulating circuit was constructed on Multisim. The circuits would be shown below. ✓

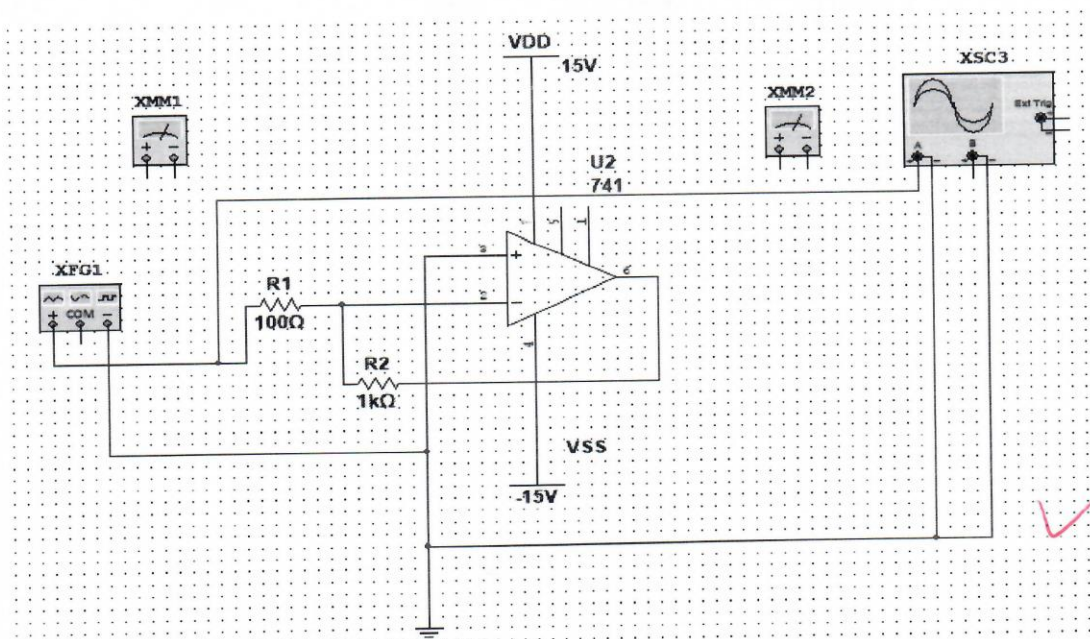


Figure 5: 10 V/V Gain Inverting Op-amp on Multisim

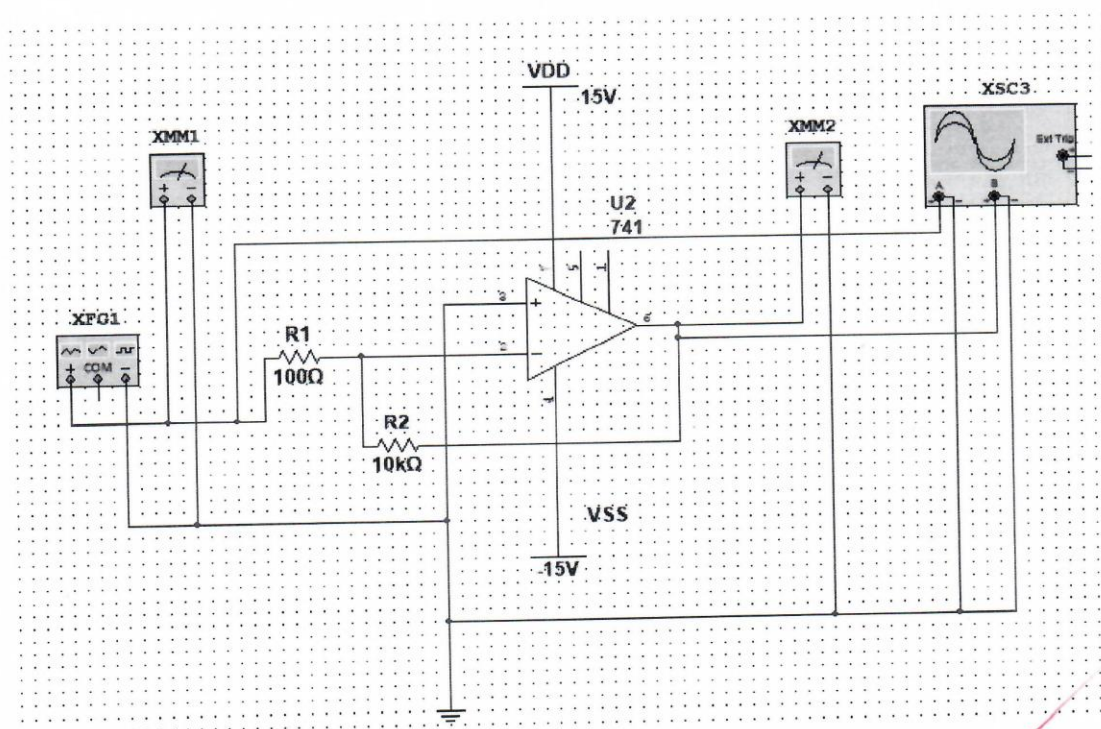


Figure 6: 100 V/V Gain Inverting Op-amp on Multisim

Results:

On the Keysight Digital Storage Oscilloscope's screen, the yellow wave represented the input signal. The green wave indicated the output.

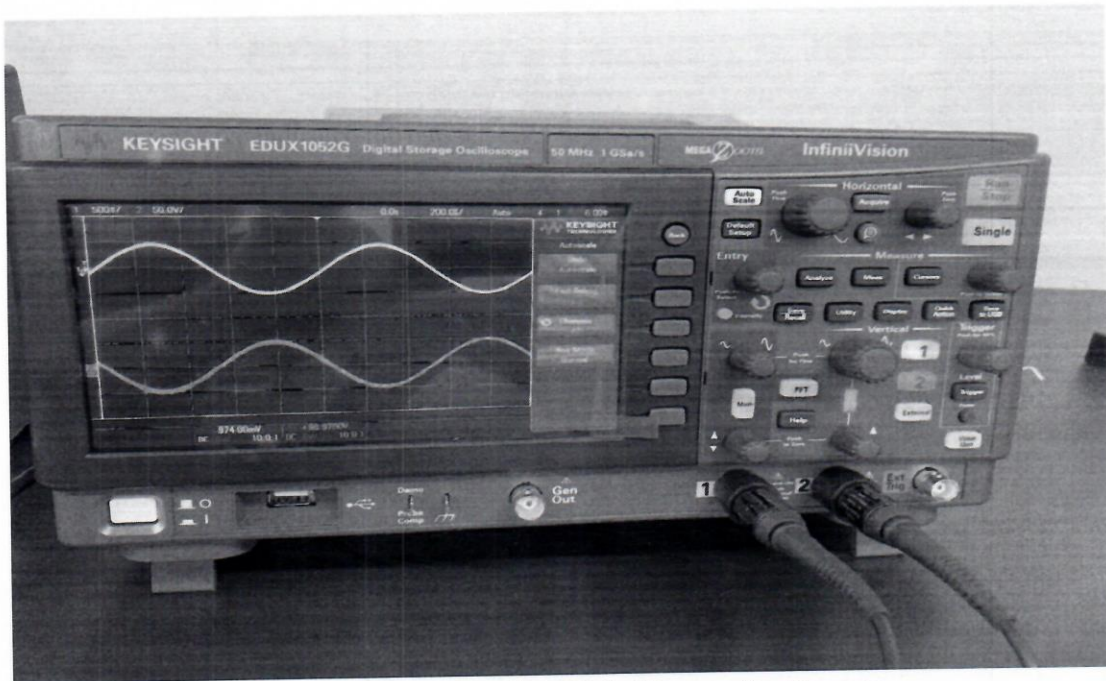


Figure 7: 10 V/V Gain on Keysight Digital Storage Oscilloscope

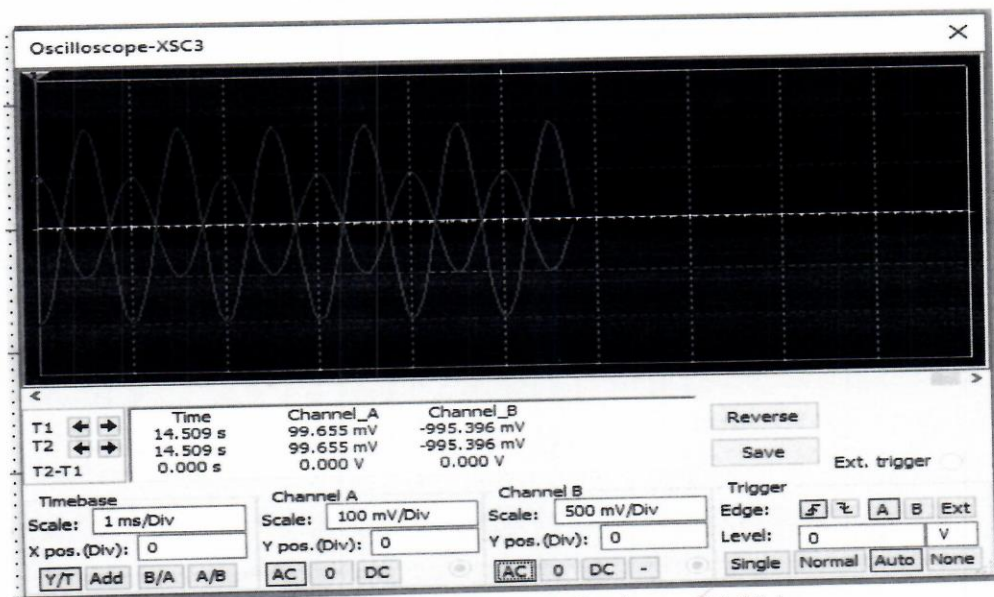


Figure 8: 10 V/V Gain Oscilloscope Indication on Multisim

For the gain of 10 V/V, we measured the input and output voltages as 0.7 mV and 7.2 mV respectively by using the multimeter. In Multisim, we collected the input of 70.71 mV and output of 707.01 mV as shown in the figure below.

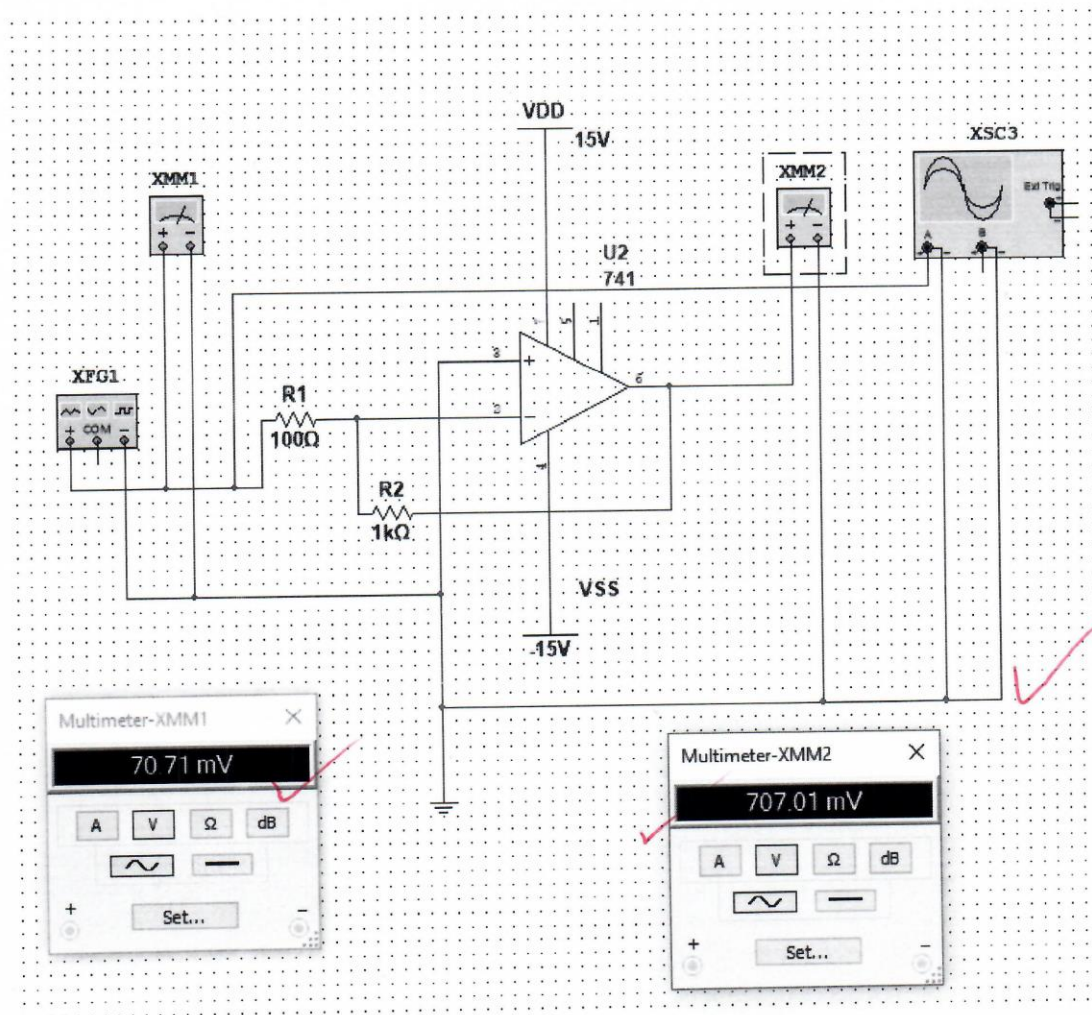


Figure 9: 10 V/V Gain Voltage Measuring on Multisim

For the gain of 100 V/V, we measured the input and output voltages as 0.7 mV and 92.6 mV respectively by using the multimeter. In Multisim, we collected the input of 70.71 mV and output of 7.03 V as shown in the figure below.

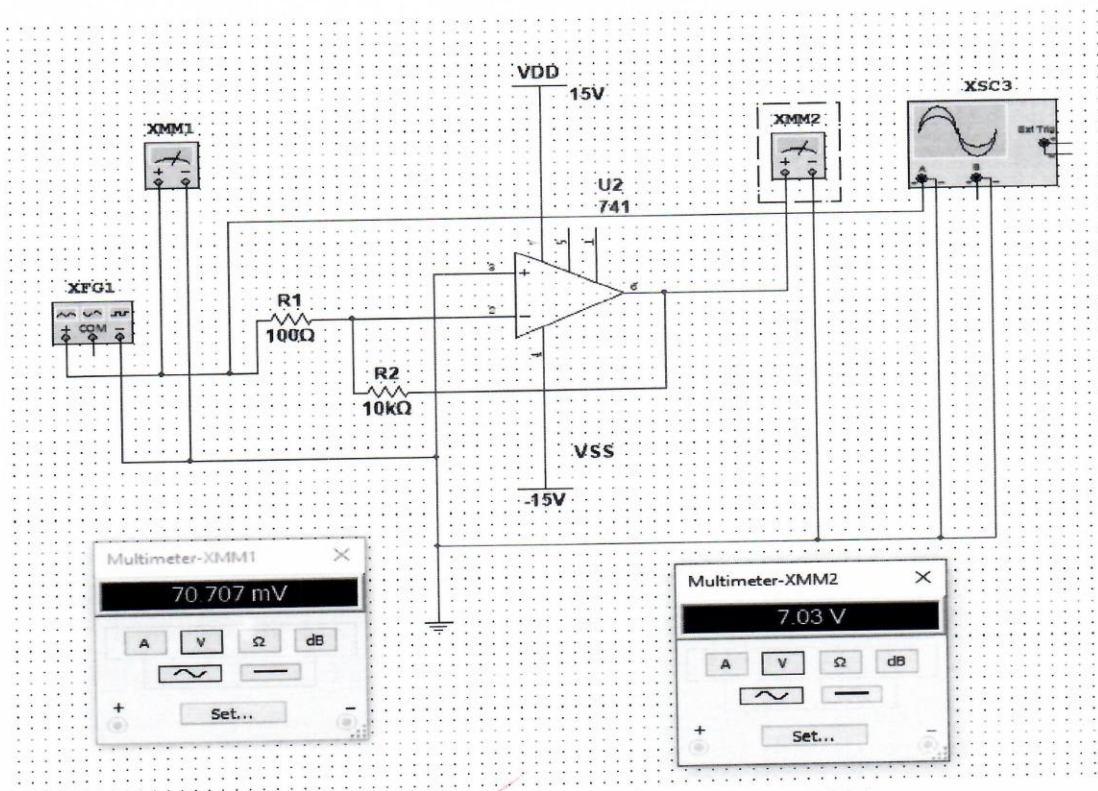


Figure 10: 100 V/V Gain Voltage Measuring on Multisim

$A = 10 \text{ V/V}$

INPUT	OUTPUT
-0.005 mV	5V
-0.7 mV	10.03V
0.005mV	-5V
1mV	-9.94v

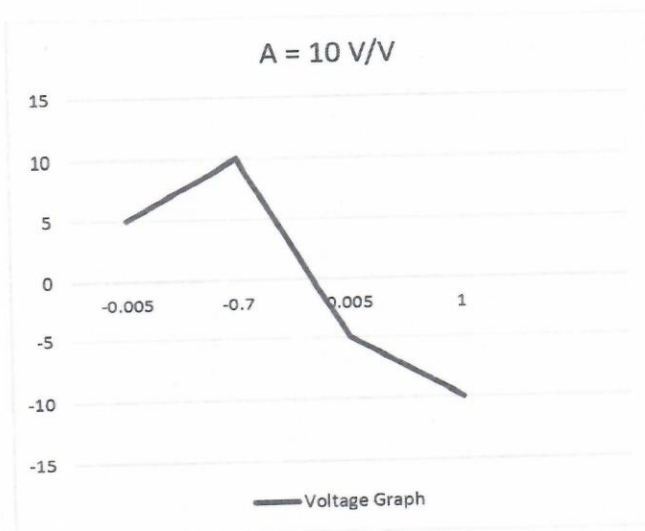


Figure 11: 10 V/V Gain Incrementing DC Voltage Table and Graph

$$A = 100 \text{ V/V}$$

INPUT	OUTPUT
-0.34	14.83V
-0.5	14.83V
-0.85	14.82V
0.35	-13.78V
0.65	-13.78V
0.85	-13.78V

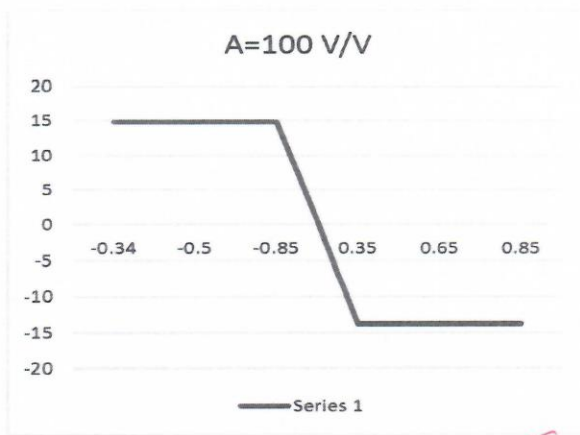


Figure 12: 100 V/V Gain Incrementing DC Voltage Table and Graph

Discussion and Conclusion:

In the lab, we collected 0.7 mV at the input and 7.2 mV at the output by using the multimeter. We divided the output to the input which resulted in 10.285 V/V gain. The collected voltages in Multisim were significantly larger at 70.71 mV for the input and 707.01 mV for the output. The gain was calculated to be 9.9887 V/V. We achieved the gain on our physical circuit with 2.85% of error.

For the 100 V/V gain, we measured the input voltage of 0.7 mV and the output voltage of 92.6 mV. The calculated gain was 132.285 V/V which was significantly larger than the desired value. The percentage of error was calculated to be 32.285%. On Multisim, the input voltage was 70.71 mV and the output was 7.03 V. The gain was calculated to be 100 V/V. With an extremely high percentage of error, our measurements were confirmed to be incorrect.

On the oscilloscope, the waves of both the input and output were in phase, but the output wave was inverted as we expected. That also means we connected the pins correctly.

The graph showed the result as we anticipated, a negative slope of $y = x$ function. The data make sense since the positive voltages would be inverted and amplified to the ratio of the gain. We would have collected better data points if we had a DC power supply that could be adjusted accurately to the hundredths.

The results indicated that Multisim provided more accurate values. The reasons could be, in the lab, the resistors were not as accurate as their designed values. Also, human error could have happened in the measuring process. We could have not connected the terminals correctly. The multimeter's cables could have been worn out due to excessive usage.

2.2 Non-inverting Op-amp Configuration

Procedure:

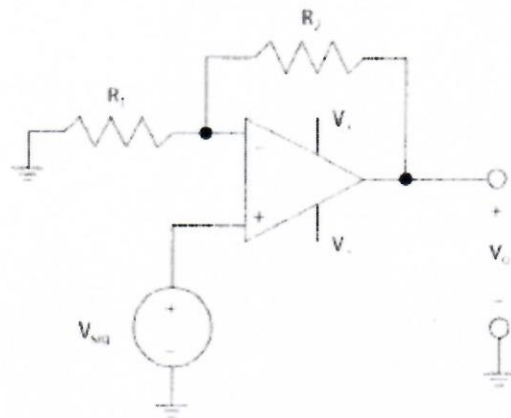


Figure 13: Non-inverting Circuit Schematic

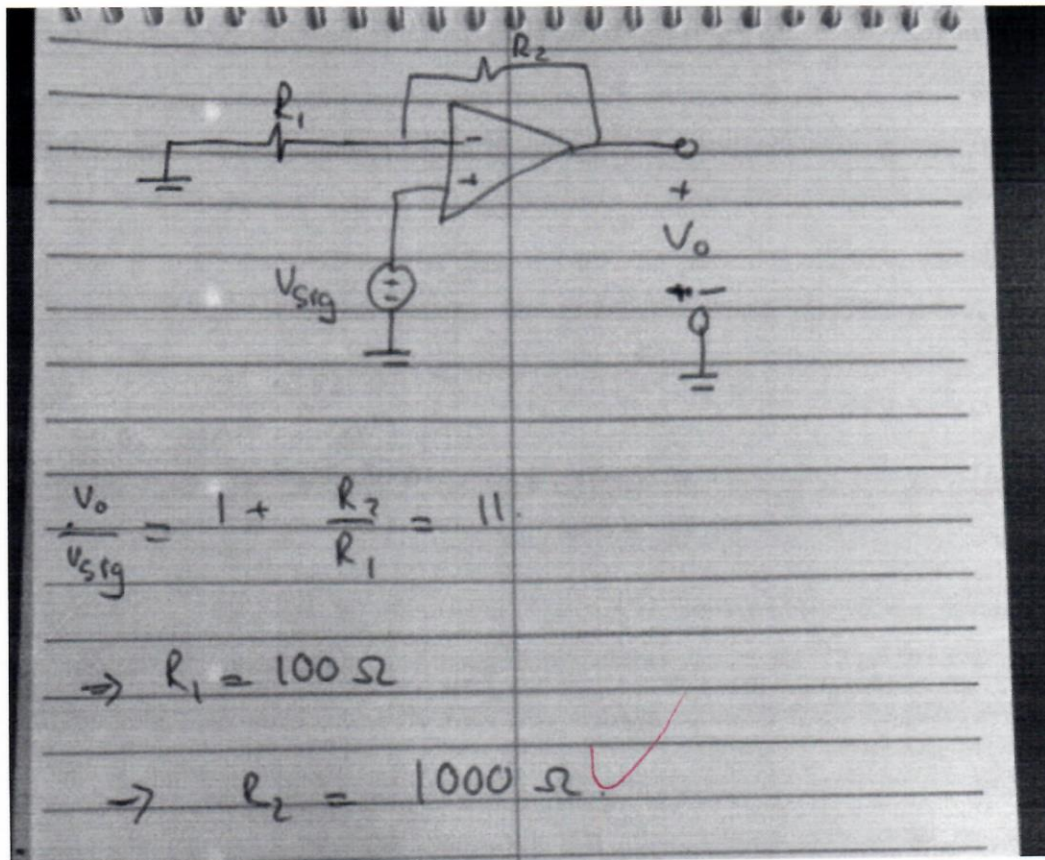


Figure 14: Hand Calculations for Non-inverting Op-amp Configuration

A physical circuit was built on a provided breadboard, resistors, and color-coded jumpers. The input of the first resistor would be connected to ground. The output of the first resistor would be connected to the second resistor's input at pin 2 of the Op-amp. The output of the second resistor would be connected to pin 6. +15 VDC would be connected to pin 7 and -15 VDC would be provided to pin 4. Channel 1 of the wave generator would be used as the input signal. A Peak-Peak AC voltage of 50 millivolts with the frequency of 1k Hz would be the signal source. Pin 3 would be connected to the input terminal of the wave generator Channel 1 and 2 of the oscilloscope would be used to view the input and output signals respectively. For the gain of 11 V/V, two resistors of 100 Ohm and 1k Ohm were used. The circuit would be shown in the figure below.

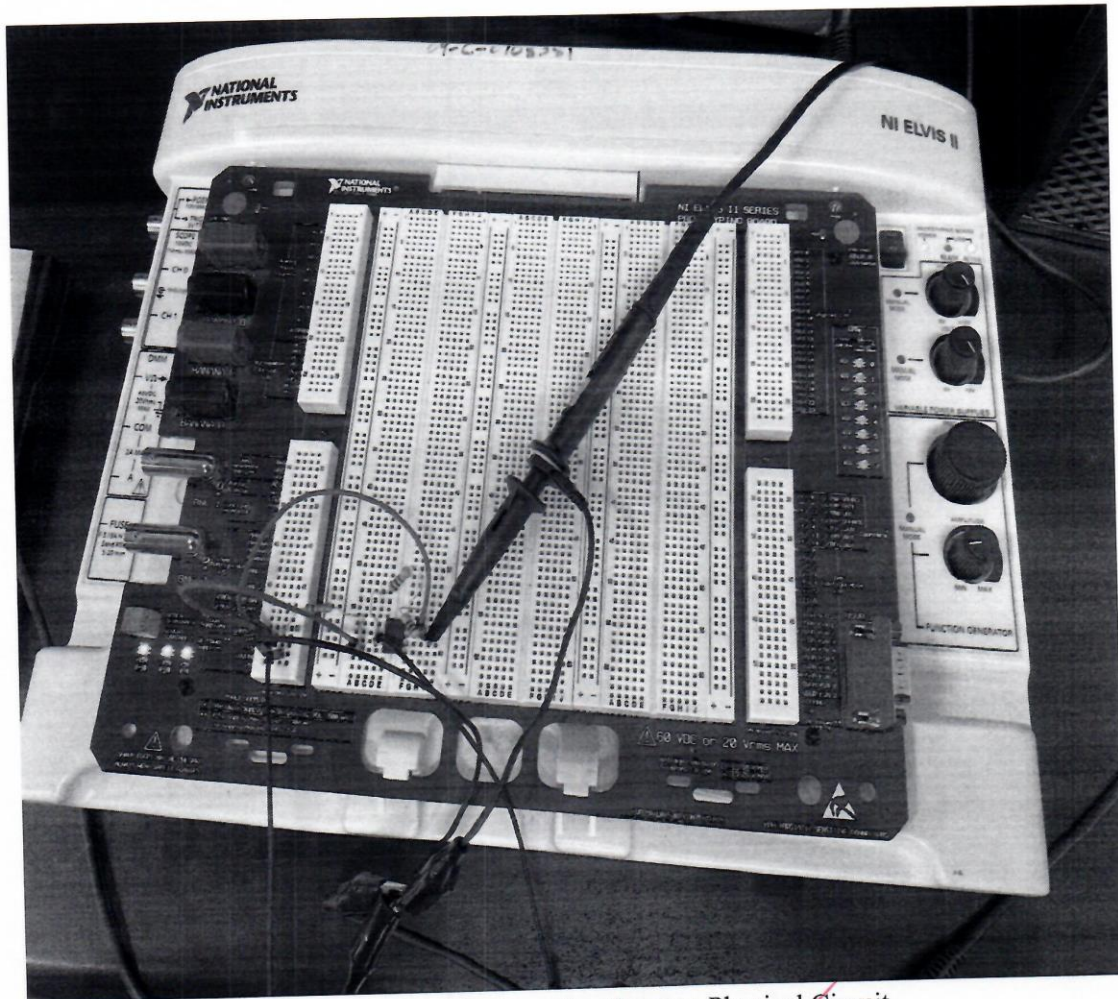


Figure 15: The Non-inverting Op-amp Physical Circuit

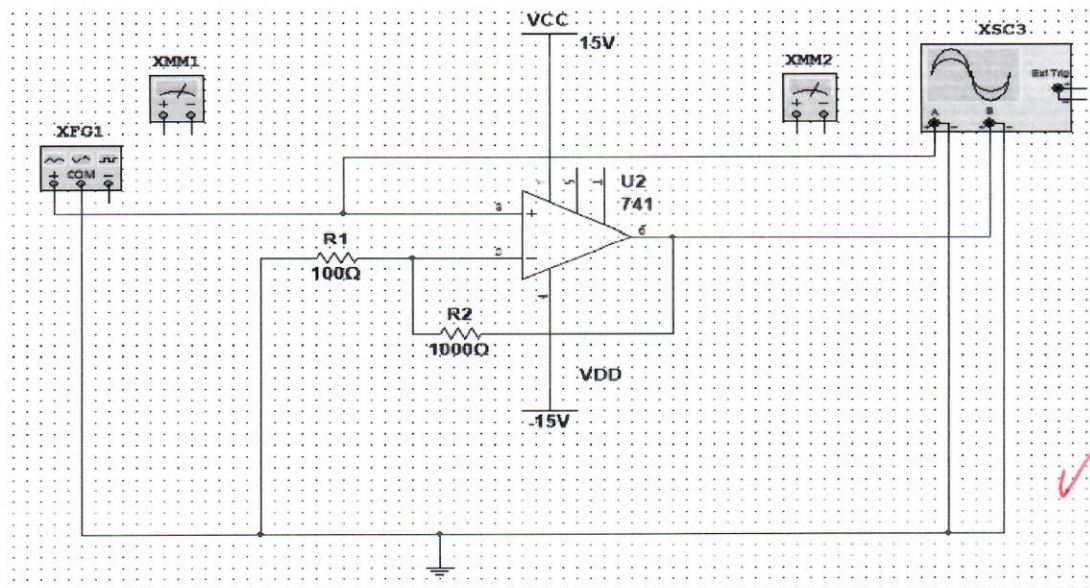


Figure 16: 11 V/V Gain Inverting Op-amp on Multisim

Results:

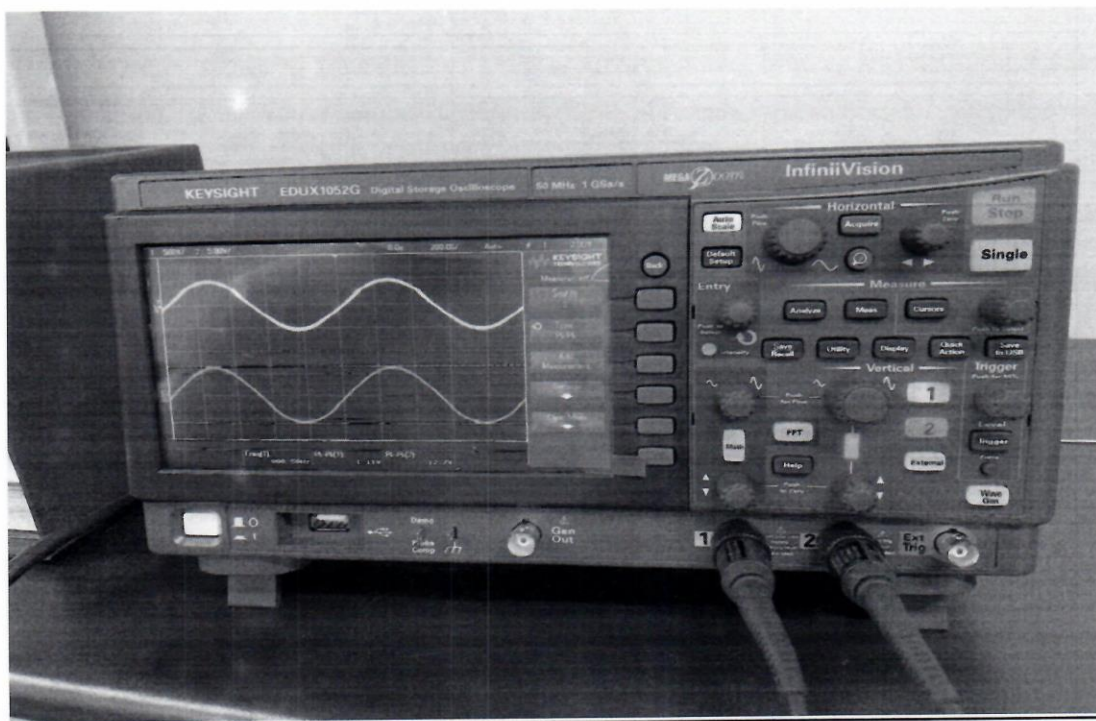


Figure 17: 10 V/V Gain on Keysight Digital Storage Oscilloscope

For the gain of 11 V/V, we measured the input and output voltages as 0.7 mV and 10.1 mV respectively by using the multimeter. In Multisim, we collected the input of 35.354 mV and output of 388.386 V as shown in the figure below.

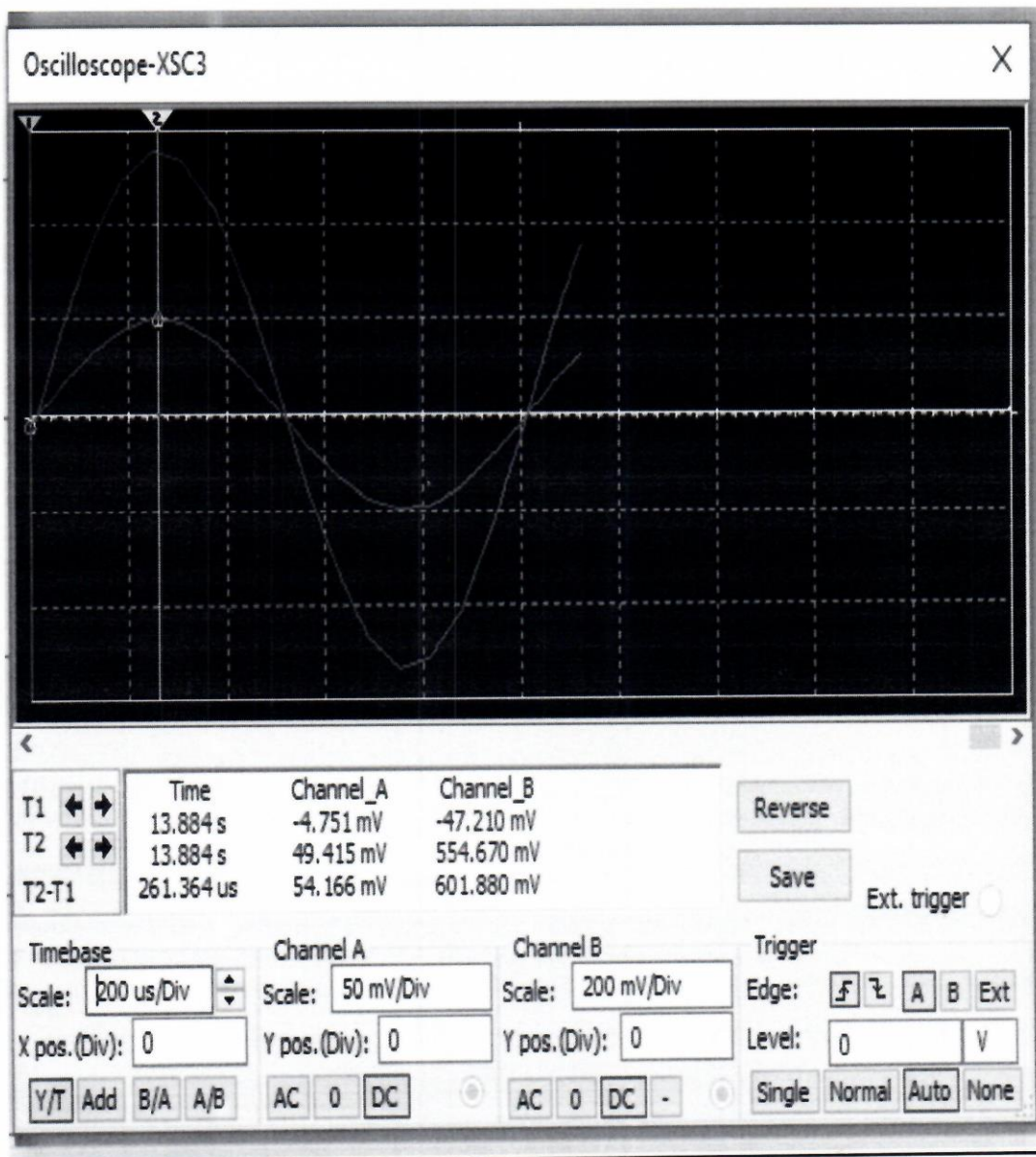


Figure 18: 11 V/V Gain Oscilloscope on Multisim

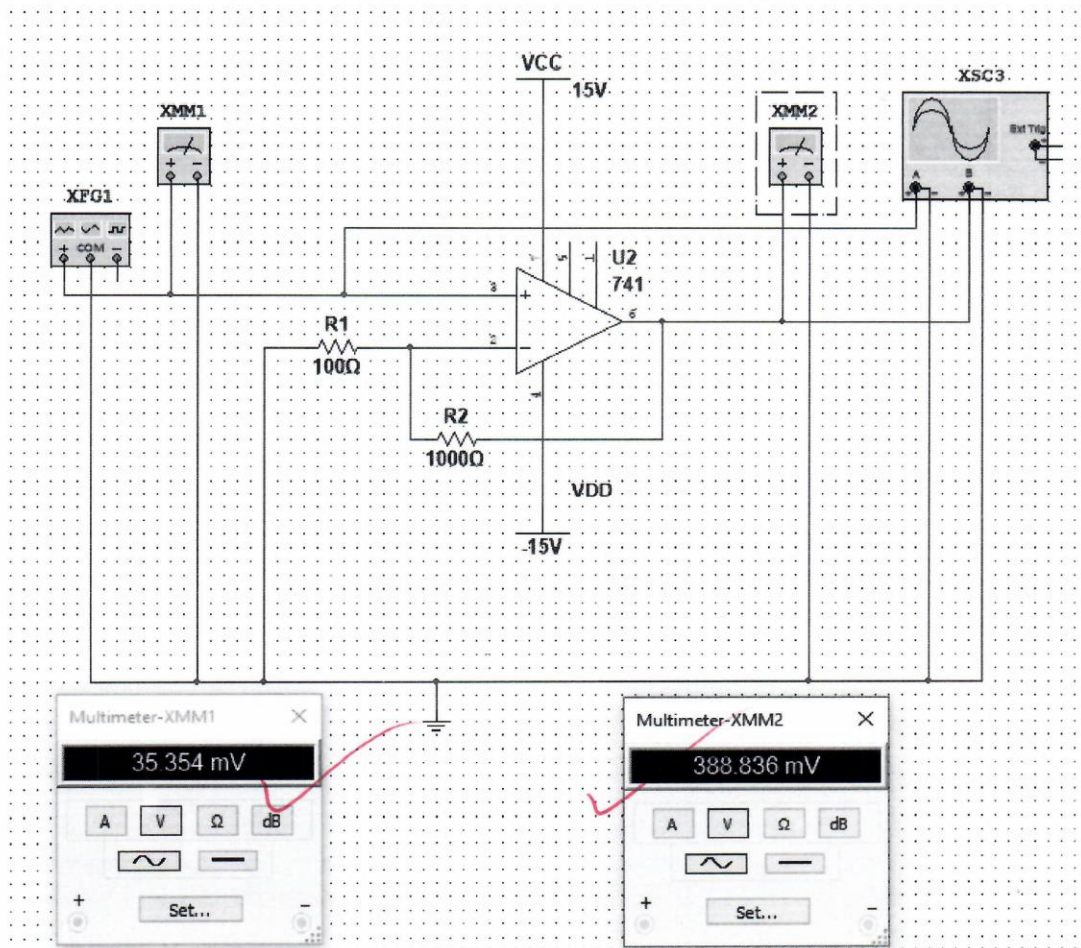


Figure 19: 11 V/V Gain Voltage Measuring on Multisim

Discussion and Conclusion:

In the lab, we collected 0.7 mV at the input and 10.1 mV at the output by using the multimeter. We divided the output to the input which resulted in 14.42 V/V gain. The collected voltages in Multisim were significantly larger at 35.354 mV for the input and 388.836 mV for the output. The gain was calculated to be 10.998 V/V. We achieved the gain on the physical circuit with 31.09% of error.

In conclusion, the collected data on our physical circuit was incorrect. After evaluating the procedure, we realized the problem was that we added an extra 100 ohm resistor to be R2 because we mistakenly thought the same ratio gain formula for the inverting and non-inverting op-amp would be the same. As a result, the gain ratio on our circuit was calculated to be 12 V/V. Also, human error could have occurred during the measuring process which brought our measured gain ratio to an even larger value. We could have selected the incorrect setting on our multimeter. Equipment malfunction could have happened on the multimeter's cables due to the

excessive usage in the lab. The issues could have been from the provided resistors. Their tolerance values could have been significantly different than their designed values.

However, we still achieved the anticipated data on the oscilloscope. The input and output signals were shown to be in phase, not being inverted and magnified roughly 14 times.

The measurement on Multisim was considered to be accurate. The gain ratio could be rounded up to be 11 V/V. The software indicated to provide correct measurements. Multisim had proven again to be an excellent tool for comparing data.

2.3 Difference Amplifier

Procedure:

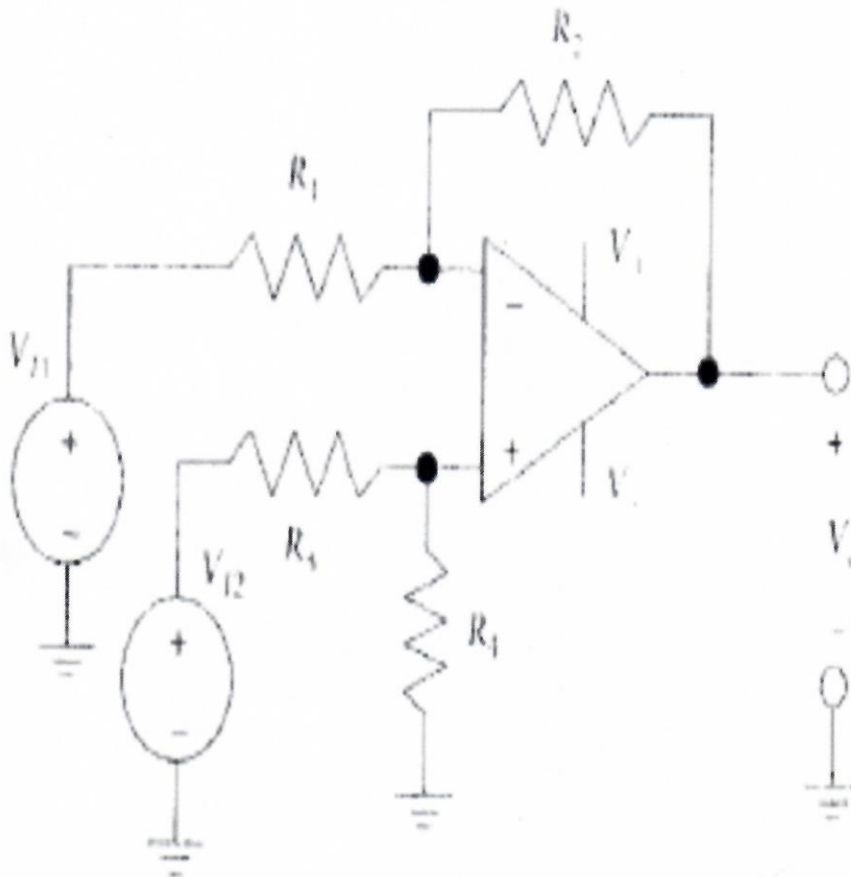


Figure 20: Non-inverting Circuit Schematic

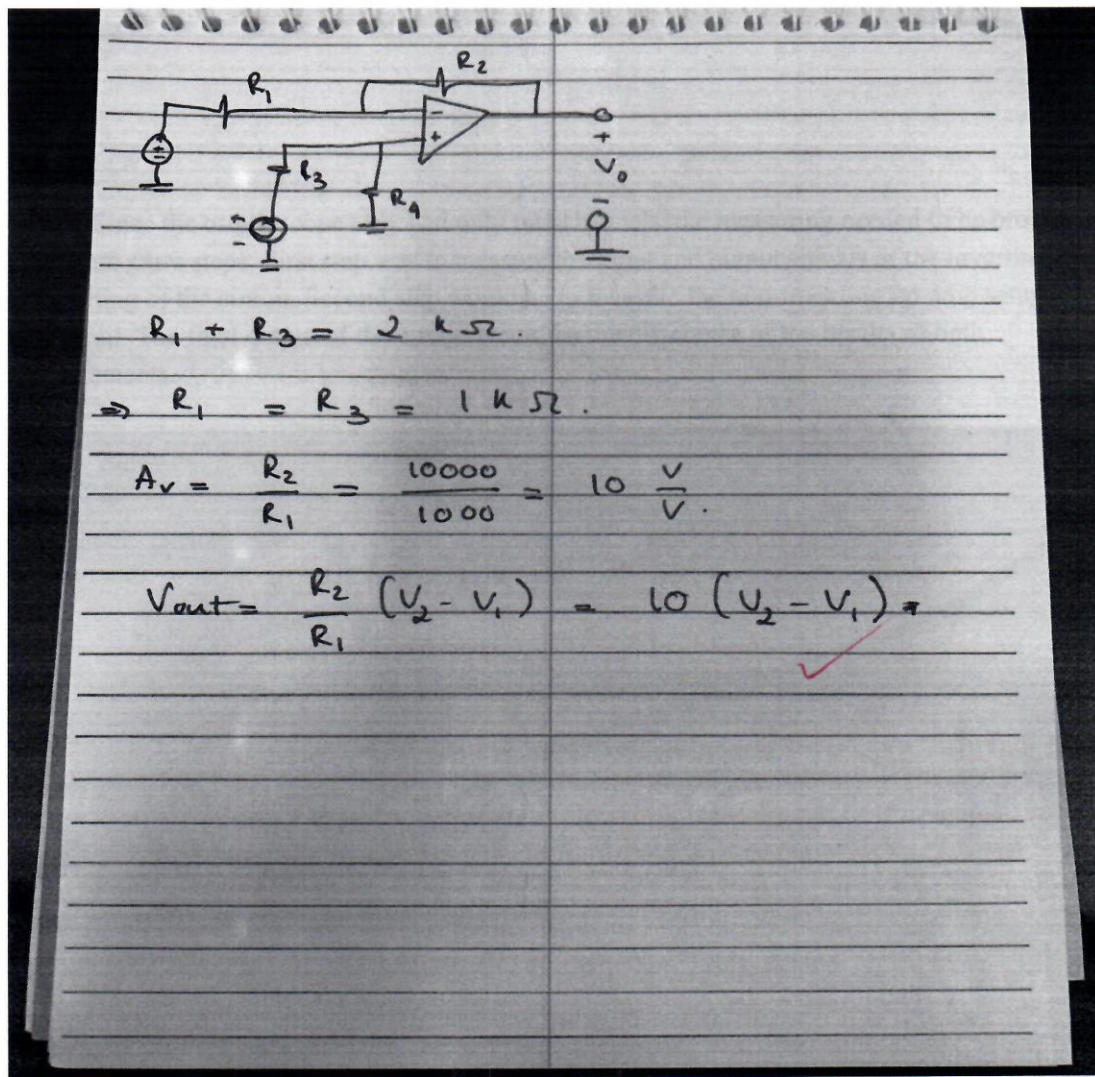


Figure 21: Hand Calculations for Non-inverting Op-amp Configuration

A physical circuit was built on a provided breadboard, resistors, and color-coded jumpers. +15 VDC would be connected to pin 7 and -15 VDC would be provided to pin 4. Channel 1 of the wave generator would be used as the input signal. A Peak-Peak AC voltage of 50 millivolts with the frequency of 1k Hz would be the signal source. R_1 was equal to R_3 as 1k Ohm. R_2 and R_4 would both have the value of 10k Ohm. Channel 1 of the wave generator would be connected to the input of R_1 . By following the schematic circuit above, the output of R_1 and the input of R_2 would be connected to pin 2. Channel 2 of the wave generator would be connected to the input of R_3 as a second signal source. The output of R_3 and the input of R_4 would be hooked to pin 3. Both output of R_2 and R_4 would be directed to common ground. The circuit would be shown in the figure below.

Figure 22: The Difference in Getting Physical Circuit

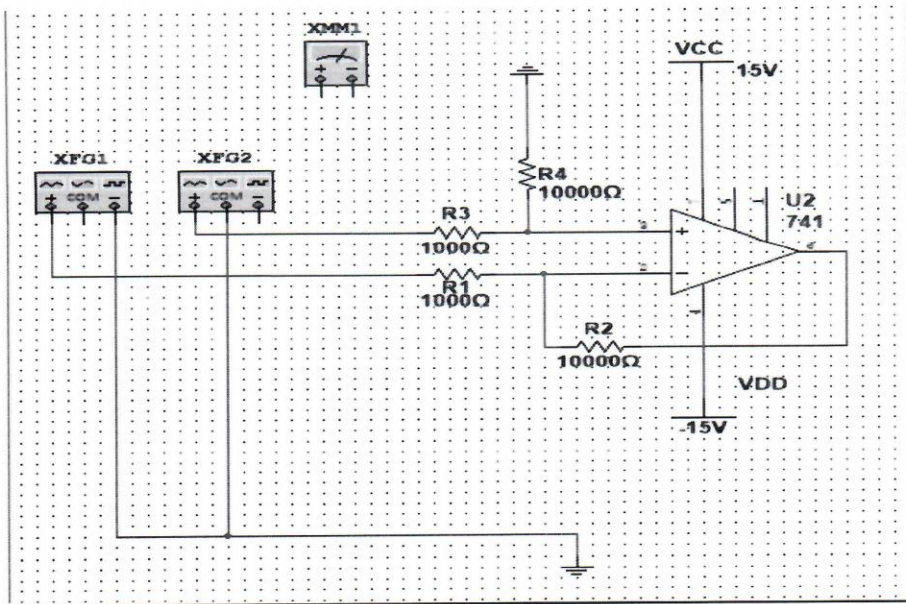


Figure 23: Difference Op-amp on Multisim

Results:

For the gain of 10 V/V, Multisim showed the V1 or the inverting op-amp as 35.355, V2 or non-inverting op-amp as 70.71 mV, and the final output voltage as 353.517 mV

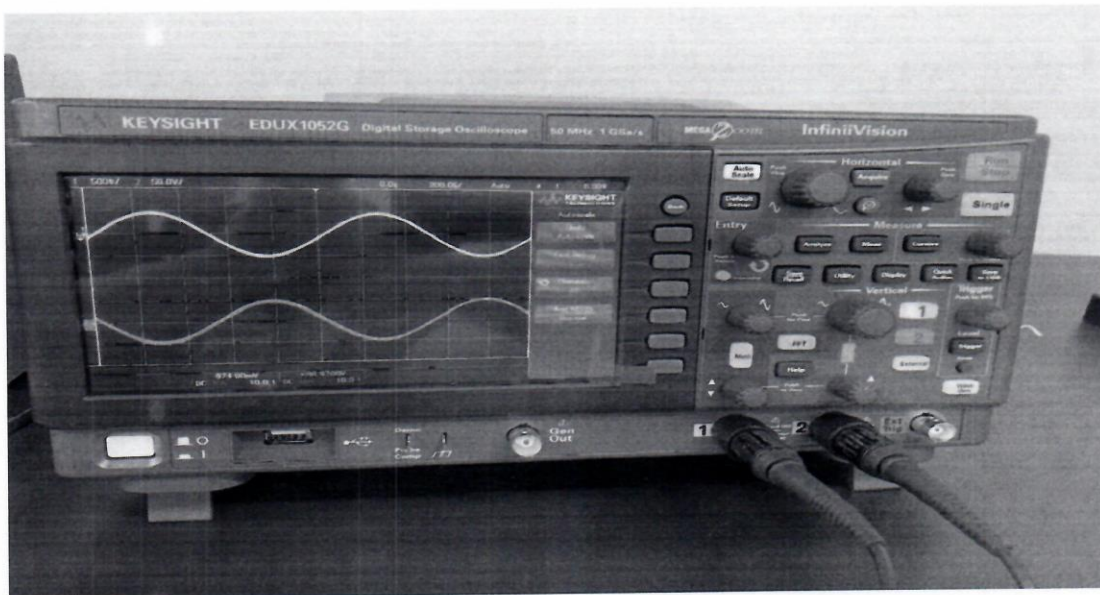


Figure 24: 10 V/V Gain Inverting Op-amp

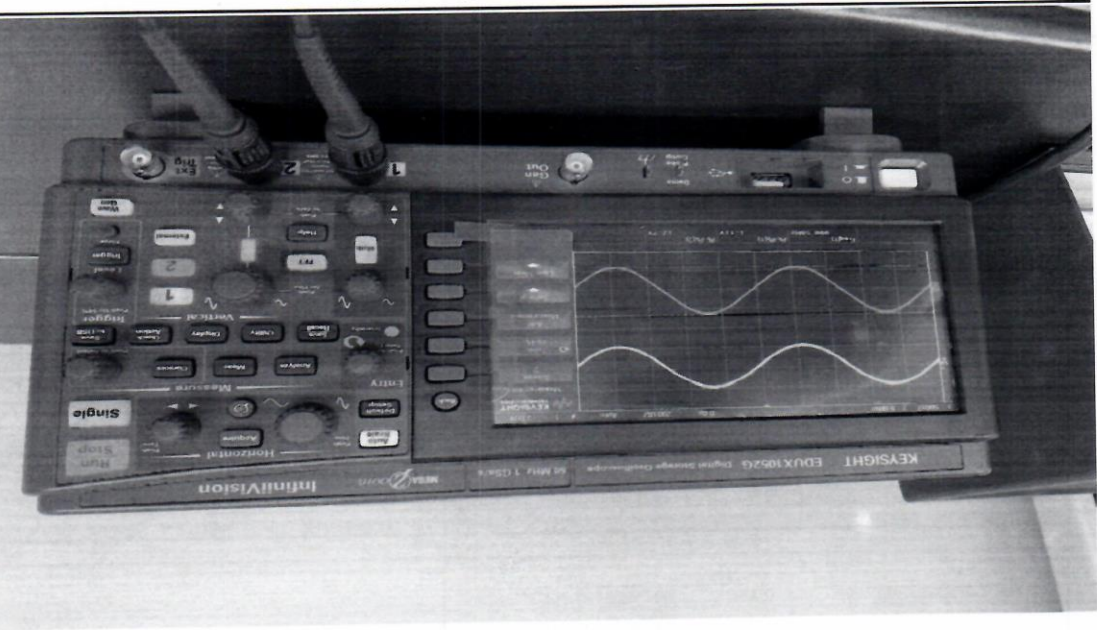


Figure 25: 10 V/V Gain Non-Inverting Op-amp

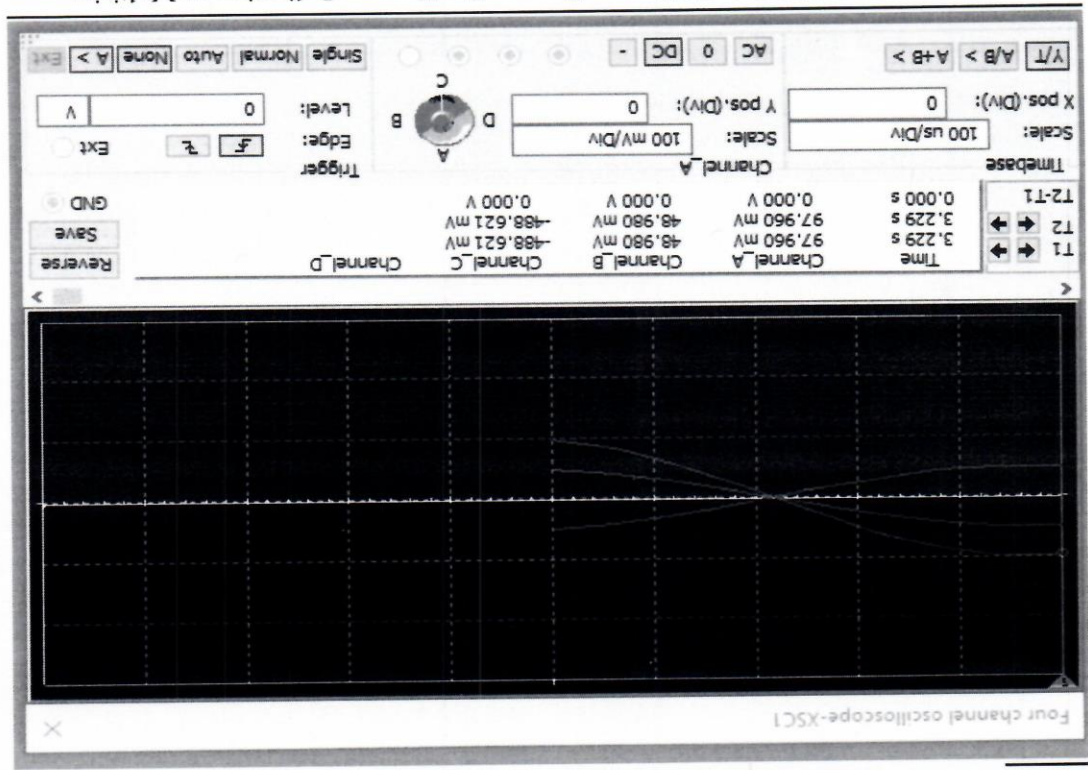


Figure 26: 10 V/V Gain Difference Op-amp Oscilloscope Indication on Multisim

AVERAGE

Electronics 1 Laboratory (2.1, 2.2, 2.3)

ELEG 4101

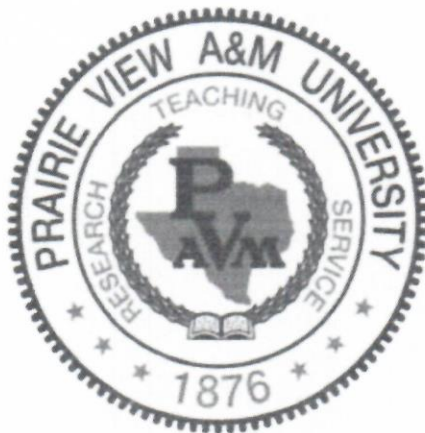
85

Names: Eric Anumnu, Teminioluwa Folorunso, Breon Holmes

Date of Submission: 09/21/2021

Date of Performance: 09/07/2021

Department of Electrical and Computer Engineering
Prairie View A&M University



Objectives:

2.1:

To study an Op-Amp and an inverting Op-Amp by:

- 1) Completing the analysis of the circuit and selecting resistors that satisfy design specifications for two values of voltage gain.
- 2) Simulating the circuits to compare the results with the paper analysis.
- 3) Implementing the circuits in an experimental setting, taking measurements, and comparing circuit performance to theoretical and simulated results.

2.2:

To study an Op-Amp and a non-inverting Op-Amp by:

- 1) Completing the analysis of the circuit and selecting resistors that satisfy design specifications for two values of voltage gain.
- 2) Simulating the circuits to compare the results with the paper analysis.
- 3) Implementing the circuits in an experimental setting, taking measurements, and comparing circuit performance to theoretical and simulated results.

2.3:

To study an Op-Amp and a difference amplifier by:

- 1) Completing the analysis of the circuit and selecting resistors that satisfy design specifications for two values of voltage gain.
- 2) Simulating the circuits to compare the results with the paper analysis.
- 3) Implementing the circuits in an experimental setting, taking measurements, and comparing circuit performance to theoretical and simulated results.

Equipment Used:

2.1:

- 1) Laboratory set up, including breadboard
- 2) 1 741-type operational amplifier (obtain its datasheet) ✓
- 3) Several wires and resistors of varying sizes ✓

2.2:

- 1) Laboratory set up, including breadboard
- 2) 1 741-type operational amplifier (obtain its datasheet) ✓
- 3) Several wires and resistors of varying sizes ✓

2.3:

- 1) Laboratory set up, including breadboard
- 2) 1 741-type operational amplifier (obtain its datasheet) ✓
- 3) Several wires and resistors of varying sizes

Procedure:

2.1:

- 1) Sketch the inverting Op-Amp circuit in lab notebook.
- 2) assemble circuit on breadboard and connect to waveform generator and oscilloscope.
- 3) Do hand Calculations for inverting Op-Amp.
- 4) Build inverting Op-Amp on multisim.
- 5) Power circuit and get results.
- 6) Run simulated circuit in multisim and get results.
- 7) Compare results from all three. ✓

2.2:

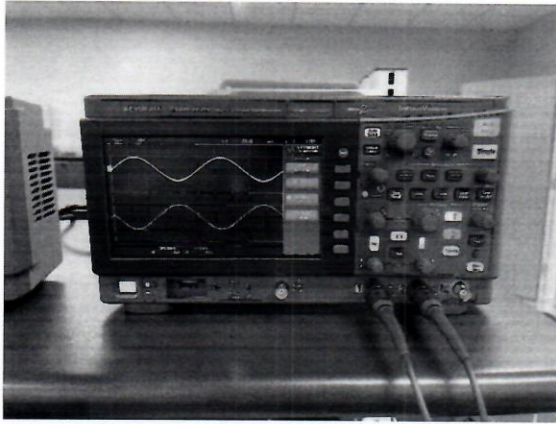
- 1) Sketch the non-inverting Op-Amp circuit in lab notebook.
- 2) assemble circuit on breadboard and connect to waveform generator and oscilloscope.
- 3) Do hand Calculations for non-inverting Op-Amp.
- 4) Build non-inverting Op-Amp on multisim.
- 5) Power circuit and get results.
- 6) Run simulated circuit in multisim and get results.
- 7) Compare results from all three.

2.3:

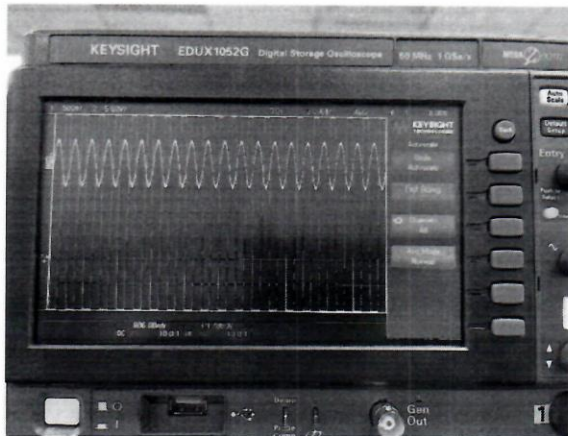
- 1) Sketch the difference amplifier circuit in lab notebook.
- 2) assemble circuit on breadboard and connect to waveform generator and oscilloscope.
- 3) Do hand Calculations for difference amplifier.
- 4) Build difference amplifier on multisim.
- 5) Power circuit and get results.
- 6) Run simulated circuit in multisim and get results.
- 7) Compare results from all three.

Results:

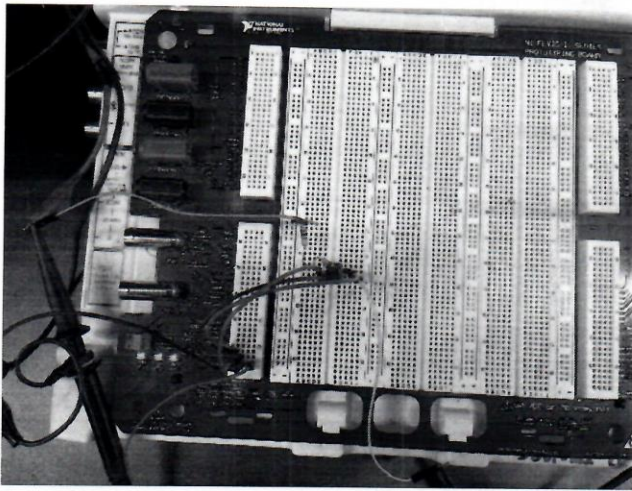
2.1:



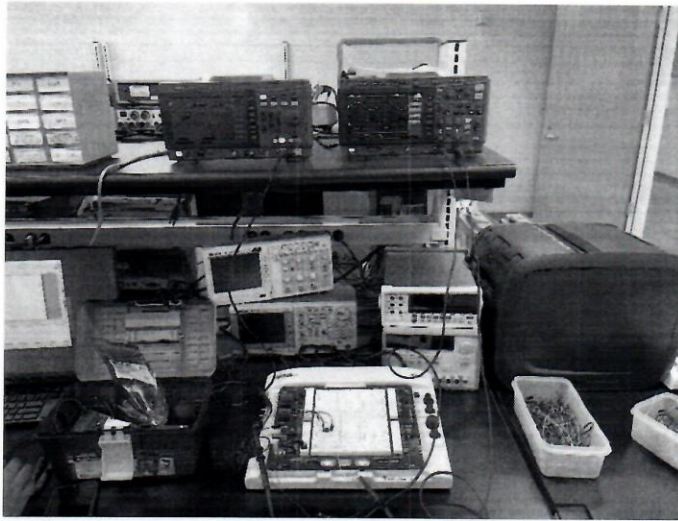
(1V-10V result on oscilloscope)



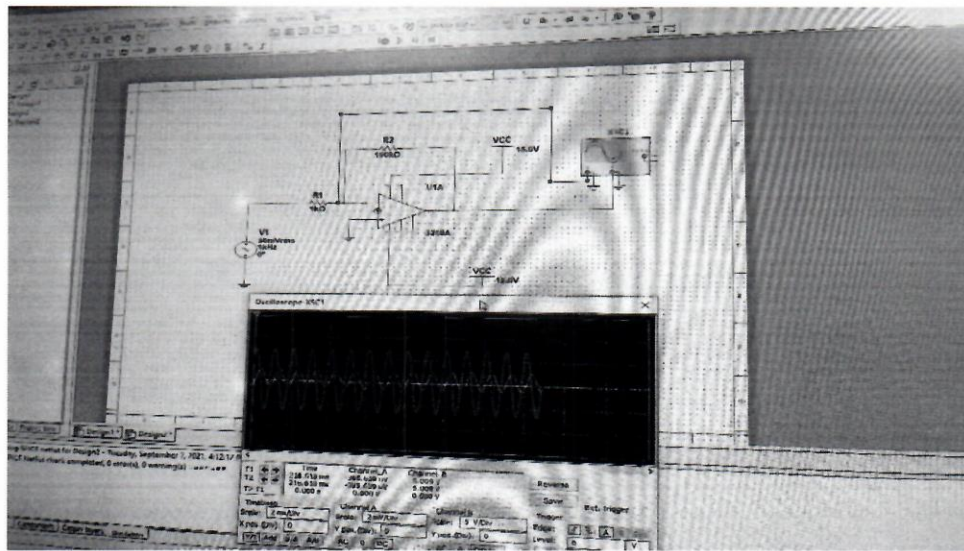
(1V-100V result on oscilloscope)



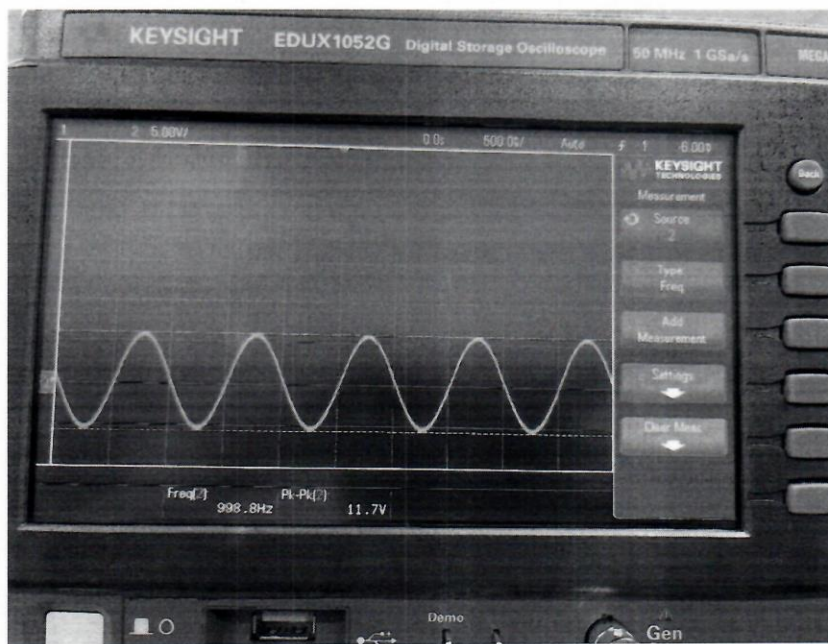
(Circuit on breadboard)



(Complete setup)

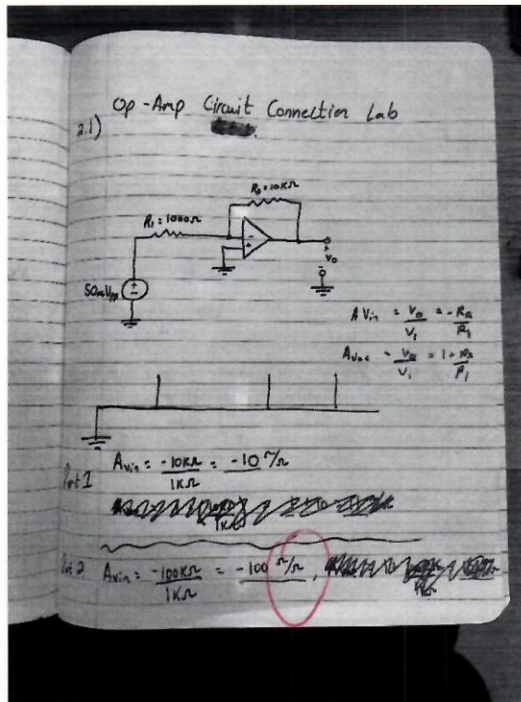


(Simulation of the circuit)



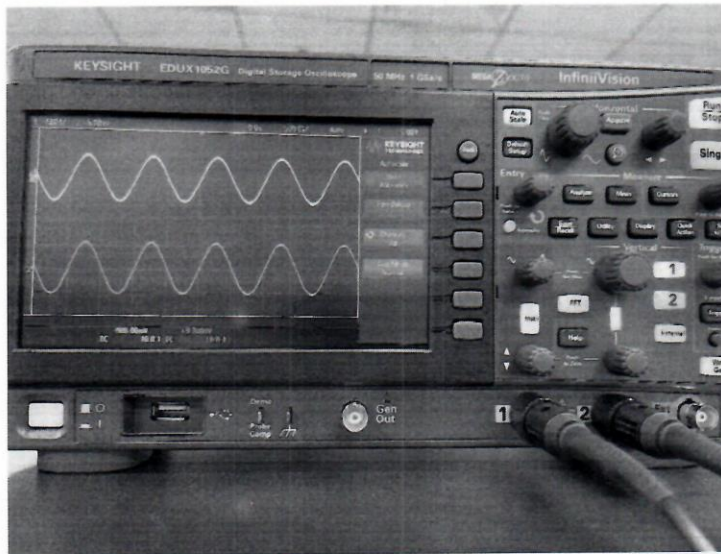
(Peak-to-Peak measure)

?

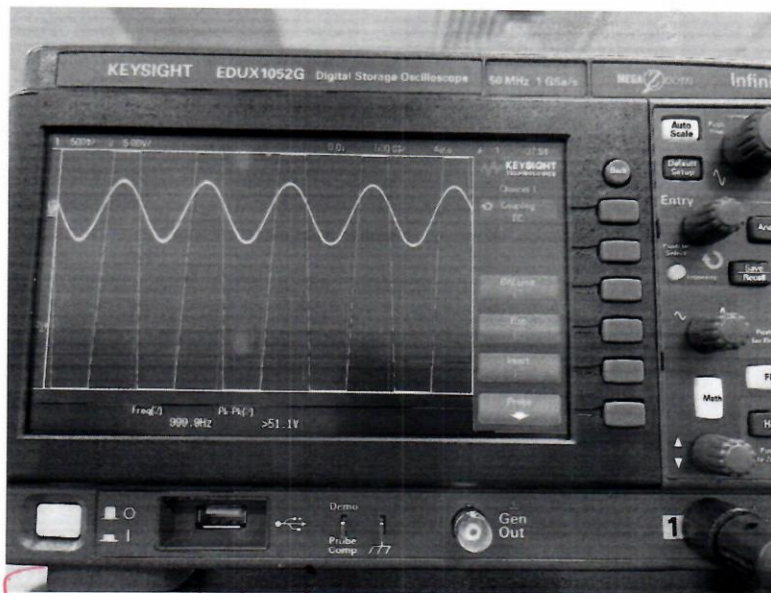


(Hand calculations)

2.2:

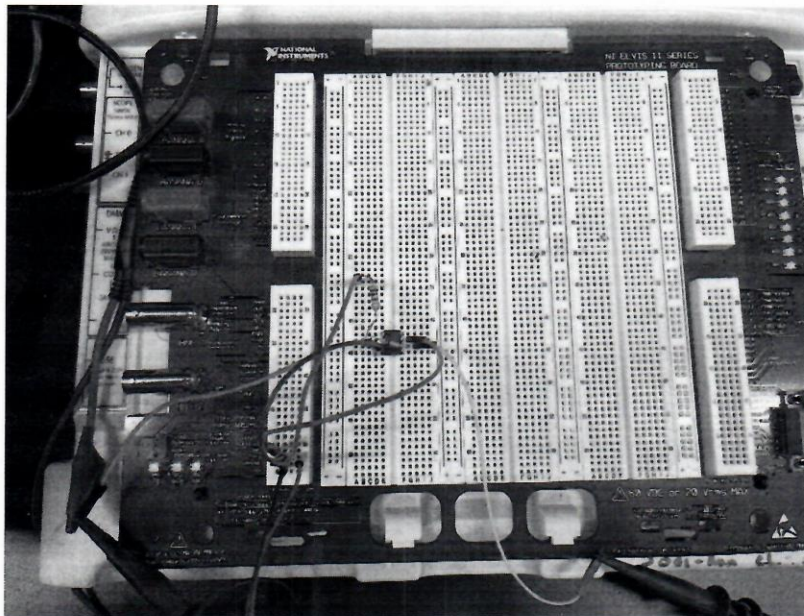


(1V-10V oscilloscope) ✓

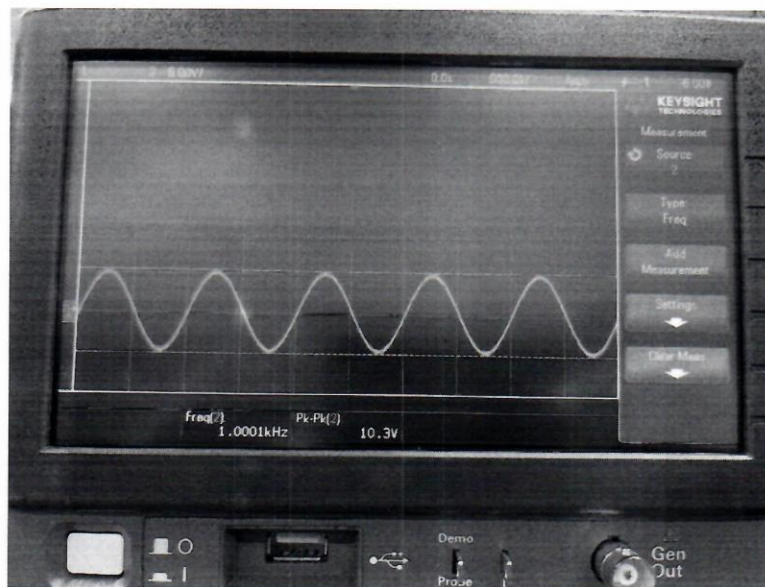


*Out of
Scale*

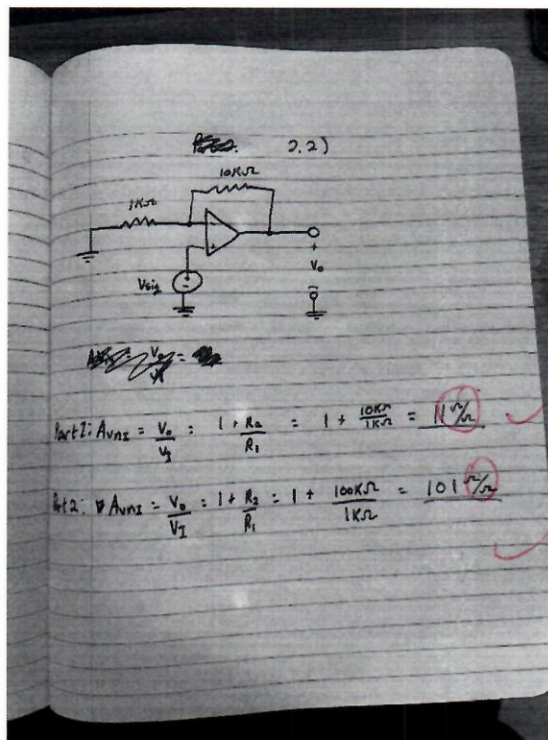
(1V-100V oscilloscope)



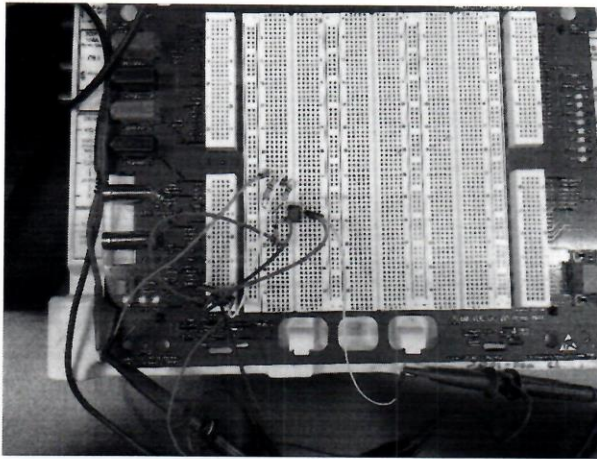
(Breadboard setup)



(Peak-to-peak measurement)



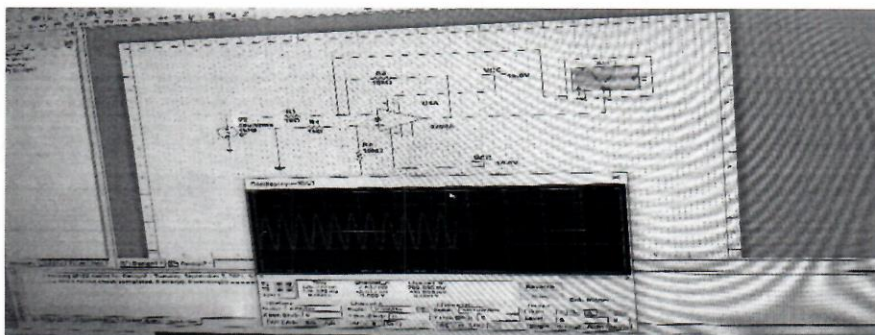
(Hand calculations)

2.3:

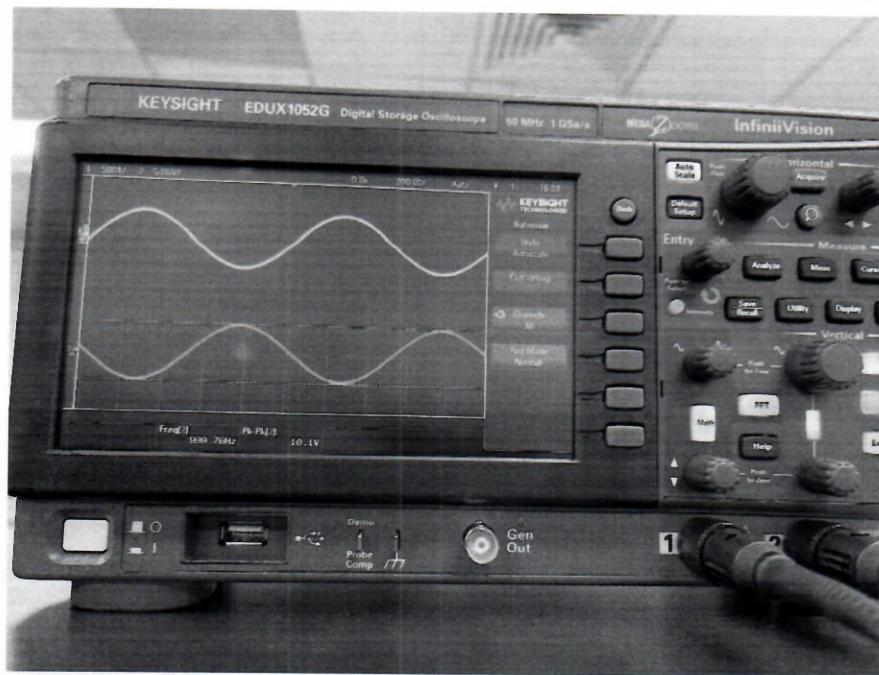
(Part 1 breadboard)



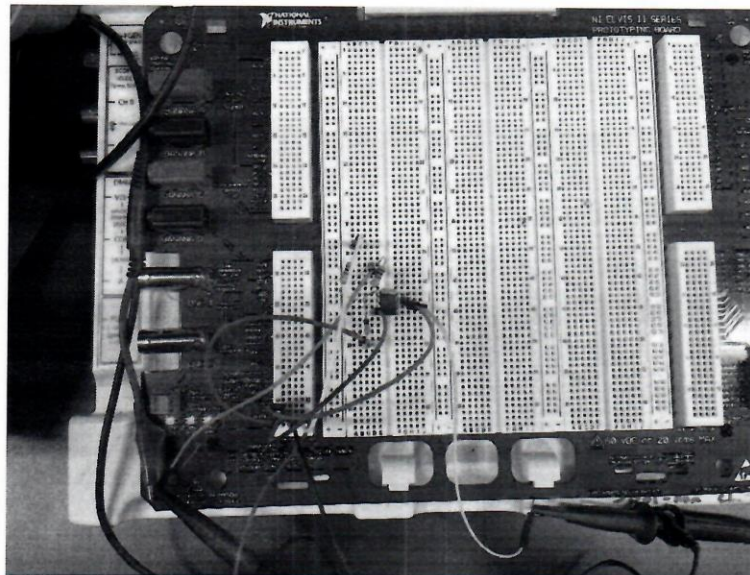
(Part 1 complete setup)



(Part 1 simulation)



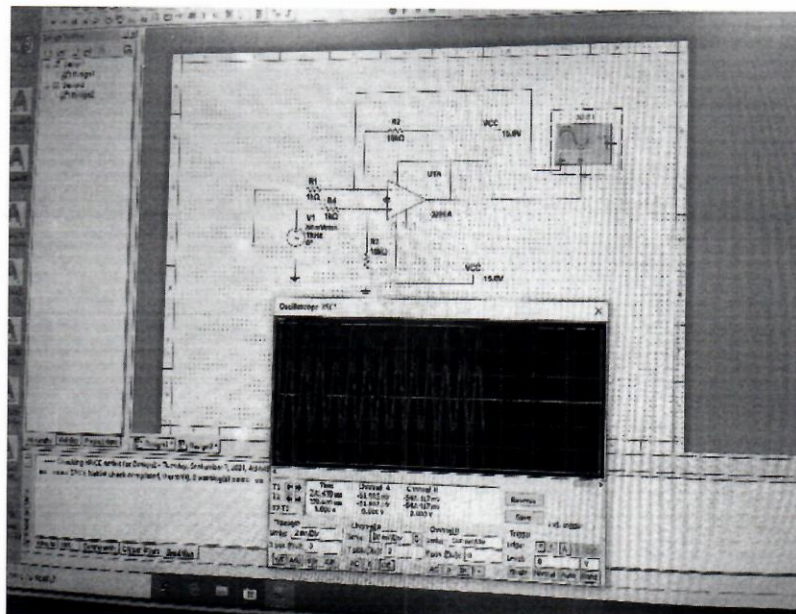
(Part 1 measure)



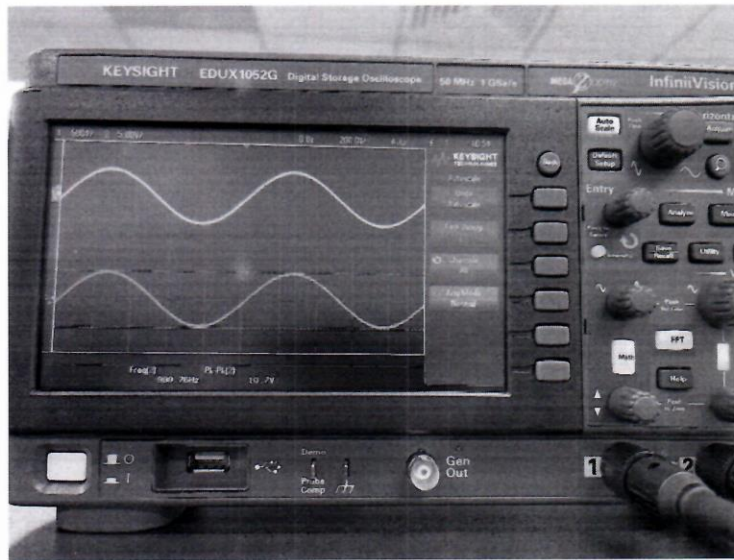
(Part 2 breadboard)



(Part 2 complete setup)



(Part 2 simulation)



(Part 2 measure)

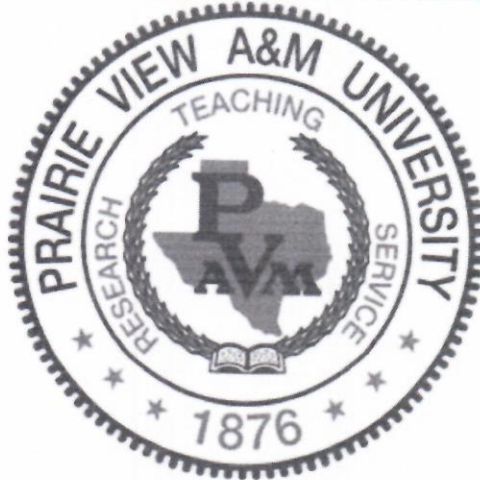
Conclusion:

In conclusion this lab was a very good learning experience with a lot of trial and error. The main problem our group had was connecting the chip correctly on the breadboard. We managed to solve this problem thanks to the professor in the lab. Another problem we had was finding the correct way to read the output signal, this was fixed by setting the scale to a different size. This lab was a good way to show how different amplifiers work in changing the voltage and fortunately our handwritten work matched with the oscilloscope.

Comparisons / Discussion

BELOW AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING



70

Electronics Laboratory

ELEG 4101

Lab 2.1: Inverting Op-Amp Configuration

Submitted by:

Trevor Johnson

Johnn Owens

Date of Submission: 9/14/2021

Date of Performance: 9/7/2021

Department of Electrical and Computer Engineering

Prairie View A&M University

Objective:

The main objective of Lab 1 is to enable students to gain a comprehensive knowledge of inverting Op-Amp configuration.

- Completing the analysis of the circuit and selecting resistors that satisfy design specifications for two values of voltage gain.
- Simulating the circuits to compare the results with the paper analysis.
- Implementing the circuits in an experimental setting, taking measurements, and comparing circuit performance to theoretical and simulated results.

Introduction/Theory:

In the lab we experimented with the inverting Op amp amplifier circuit, the circuit is based around an operational amplifier, which is a differential amplifier with two inputs: inverting and non-inverting. The circuit consists of a resistor from the input terminal to the inverting input of the circuit, and another resistor connected from the output to the inverting input of the op-amp. The non-inverting input is connected to ground. An operational amplifier circuit produces an output which is out of phase with respect to its input by 180° .

Equipment:

- Laboratory setup including breadboard
- 1 741-type operational amplifier
- Several wires and resistors of varying sizes
- Resistors: 100Ω , $1k\Omega$

Procedure:**Part 1: DESIGN AND ANALYSIS**

Design two versions of the circuits in Figure 1: one that achieves $A_V = -10$ V/V, and one that achieves $A_V = -100$ V/V. Assume a 1-k HZ input waveform V_{sig} of 50 mV_{pk-pk}. The circuit may only draw up to 50 μ A of current from V_{sig} (it will draw more from V_+ and V_- .) Use supplies of $V_+ = -V_- = 15$ V.

Hand calculation

- Sketch the circuit in your lab book. clearly labeling the op-amp terminals.
- What values of R_1 must you use to satisfy the current constraint? What is the input resistance of the circuit?
- What values of R_2 do you need to use to meet the two gain specifications? Is the problem completely specified?

Simulation

- Simulate both circuits using a transient simulation with a -50 -mV_{pk-pk} 1-k Hz input sine wave V_{sig} . In your simulations, assume that your input voltage source V_{sig} has an output resistance of 50Ω . Use values of R_1 and R_2 based on your preceding calculations.

- Plot the input and output waveforms. What is the DC voltage at the inverting terminal of the op-amp?
- What are the simulated voltage gains of your circuit?

Part 2: PROTOTYPING AND MEASUREMENT

- Assemble the circuit with $A_V = 10 \text{ V/V}$ onto a breadboard. Do not include the $50\text{-}\Omega$ output resistance of V_{sig} .
- Using a digital multimeter, measure the DC voltages at the input, output, and inverting terminal, while leaving the input tied to ground.
- Using a function generator, provide a 1-k Hz $50\text{-mV}_{\text{pk pk}}$ sine wave to the input. Using an oscilloscope, observe the output voltage waveform.
- Using a power supply, provide a DC input to the circuit in increments of 0.1 V , from -1 V to $+1 \text{ V}$. Record the values of v_o and plot your results.
- Repeat the measurements for the gain $A_V = -100\text{V/V}$, but this time sweeping the DC input to the circuit in increment of 0.01 V , from -0.1 V to $+0.1 \text{ V}$.
- Using a digital multimeter, measure all resistors to three significant digits.

Part 3: POST- MEASUREMENT EXERCISE

- For both circuits, calculate the voltage gain you obtained in your measurement. Explain any discrepancies between the experiments, simulations, and hand analysis.
- Recalculate the theoretical gain of the circuit using the measure resistor values. Is the recalculated value closer to the measured gain?

Circuit Diagram:

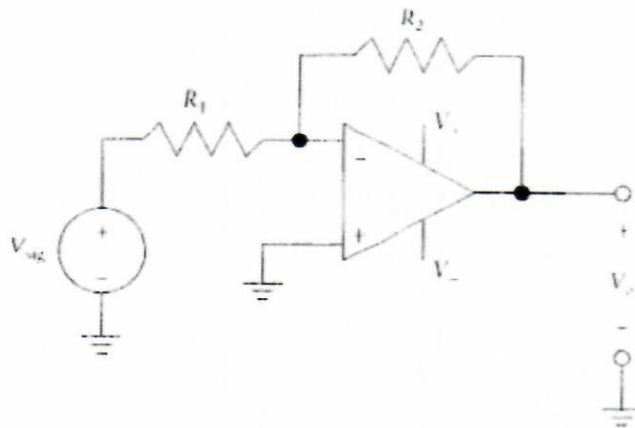


Figure 1: Inverting Op-Amp Configuration

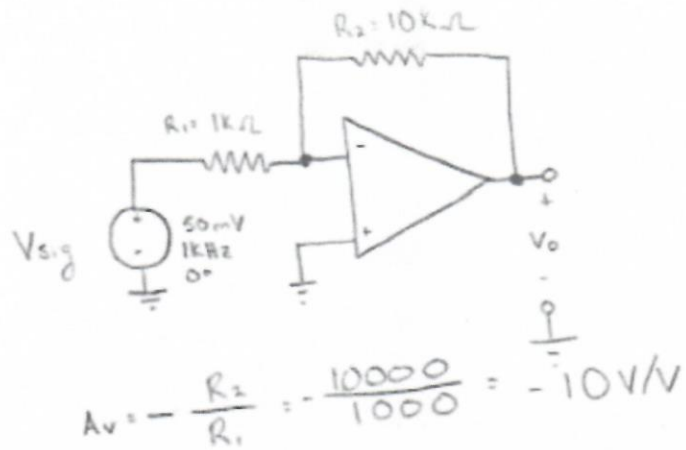


Figure 2: Circuit $A_v = -10V/V$

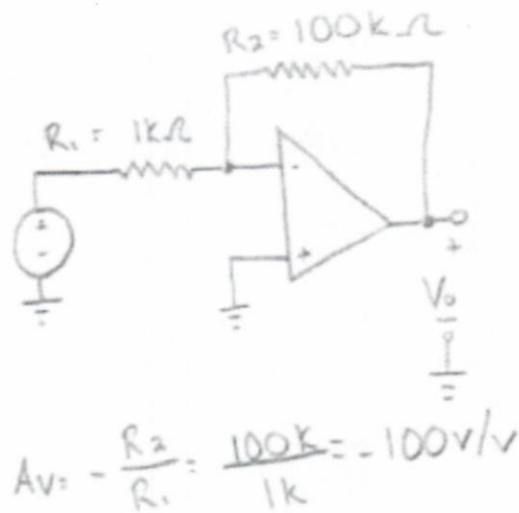


Figure 3: Circuit $A_v = -100V/V$

LM741 Pinout Diagram

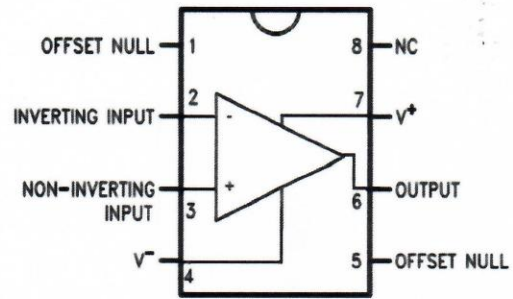


Figure 4: LM741 Pinout Diagram



Figure 5: 1K Resistor measured by Multimeter

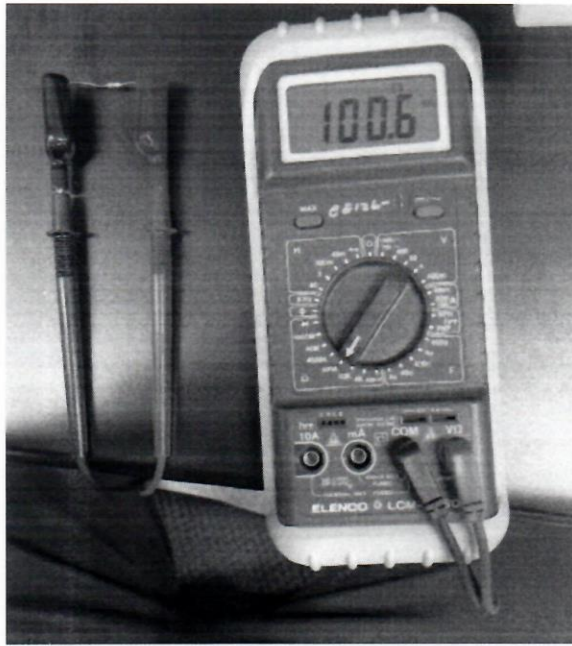


Figure 6: 10K Resistor measured by Multimeter

Solution:

A_v = Voltage Gain

$$A_v = \frac{V_{out}}{V_{in}} = - \frac{R_2}{R_1}$$

Find the value for R_1 and R_2 ?

Given: $A_v = -10 \text{ v/v}$

$$R_1 = 1000 = 1 \text{ k}\Omega$$

$$R_2 = 10 \text{ k}\Omega$$

$$A_v = - \frac{10 \text{ k}}{1 \text{ k}} = -10$$

$$A_v = -100 \text{ v/v}$$

$$R_1 = 1 \text{ k}\Omega$$

$$R_2 = 100 \text{ k}$$

$$A_v = - \frac{100 \text{ k}}{1 \text{ k}} = -100$$

Voltage Input

Based on Figure 9: Oscilloscope $1 \text{ k}\Omega + 10 \text{ k}\Omega$

$$\text{Pk-Pk (1)}: 37.24 \text{ mV}$$

Voltage Output

$$\text{Pk-Pk (2)}: -372.39 \text{ mV} = -0.37239 \text{ V}$$

Voltage Gain = V_{out}/V_{in}

$$A_v = -372.39 \text{ mV} / 37.24 \text{ mV} = \boxed{-9.998 \text{ v/v}}$$

Voltage Input

Based on Figure 10: Oscilloscope $1 \text{ k}\Omega + 100 \text{ k}\Omega$

$$\text{Pk-Pk (1)}: 49.890 \text{ mV}$$

Voltage Output

$$\text{Pk-Pk (2)}: -4986.1 \text{ mV} = -4.9861 \text{ V} = \boxed{-99.942 \text{ v/v}}$$

Figure 7: Hand calculations

Data and Results:

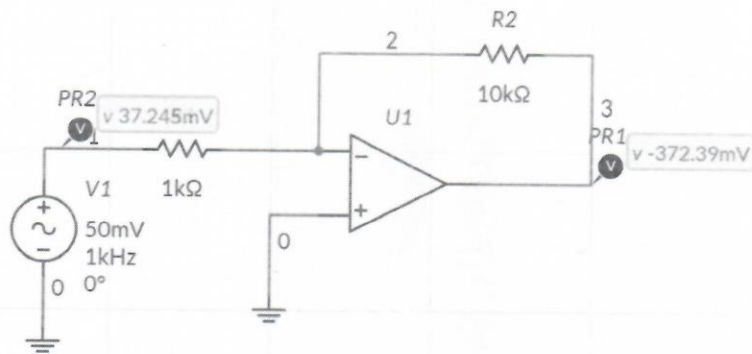


Figure 8: Circuit schematic from Multisim 1K Ω & 10K Ω

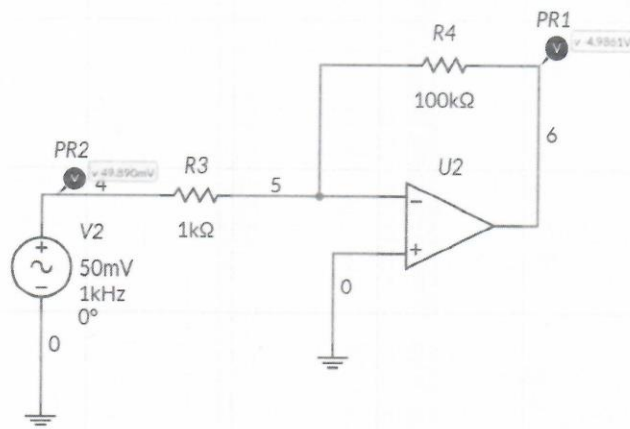


Figure 9: Circuit schematic from Multisim 1K Ω & 100K Ω

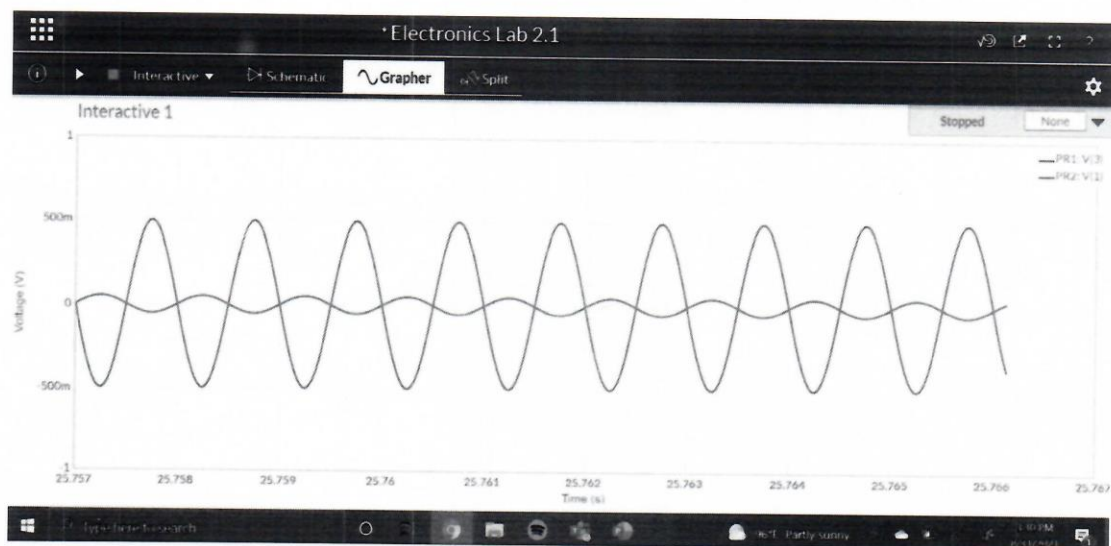


Figure 10: Waveform Screen

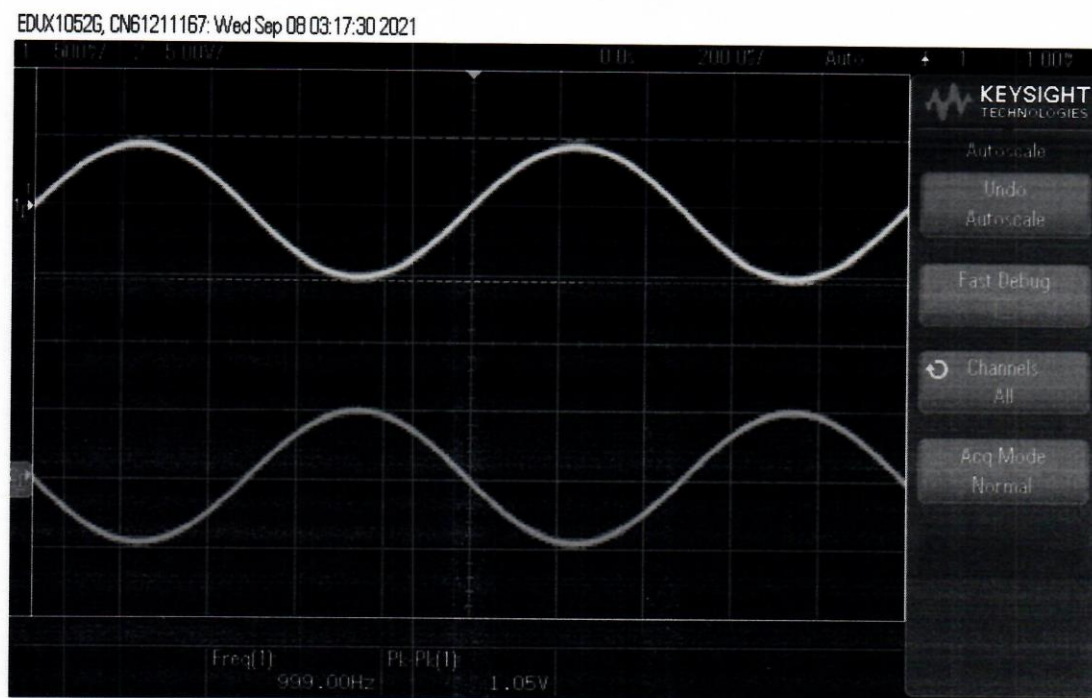


Figure 11: Oscilloscope 1k Ω & 10k Ω

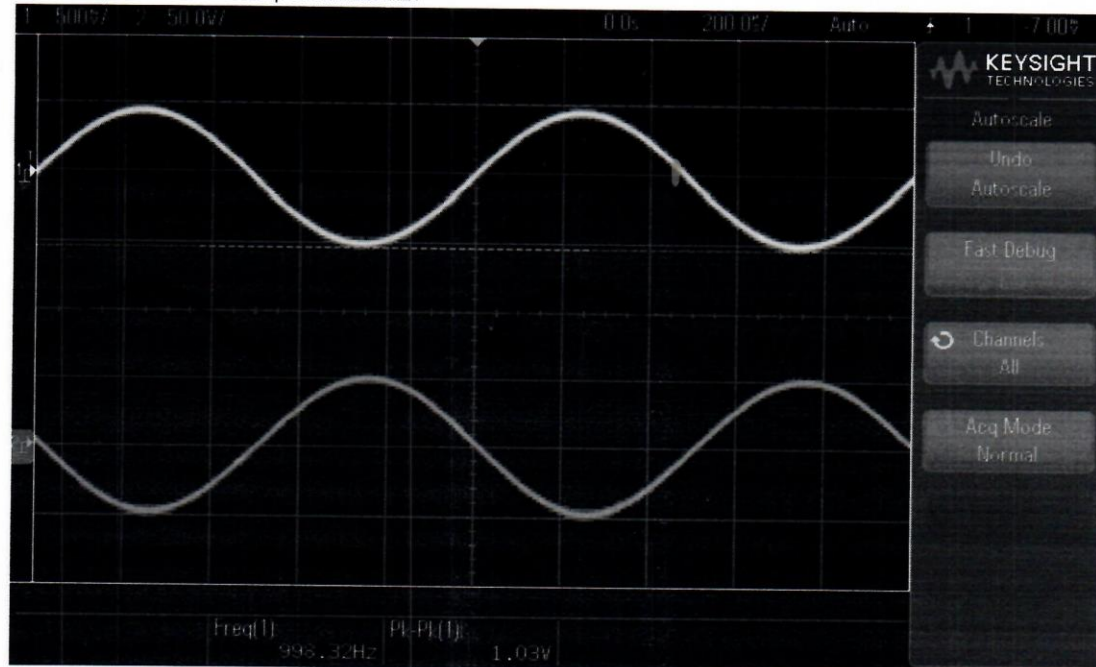


Figure 12: Oscilloscope 1k Ω & 100k Ω

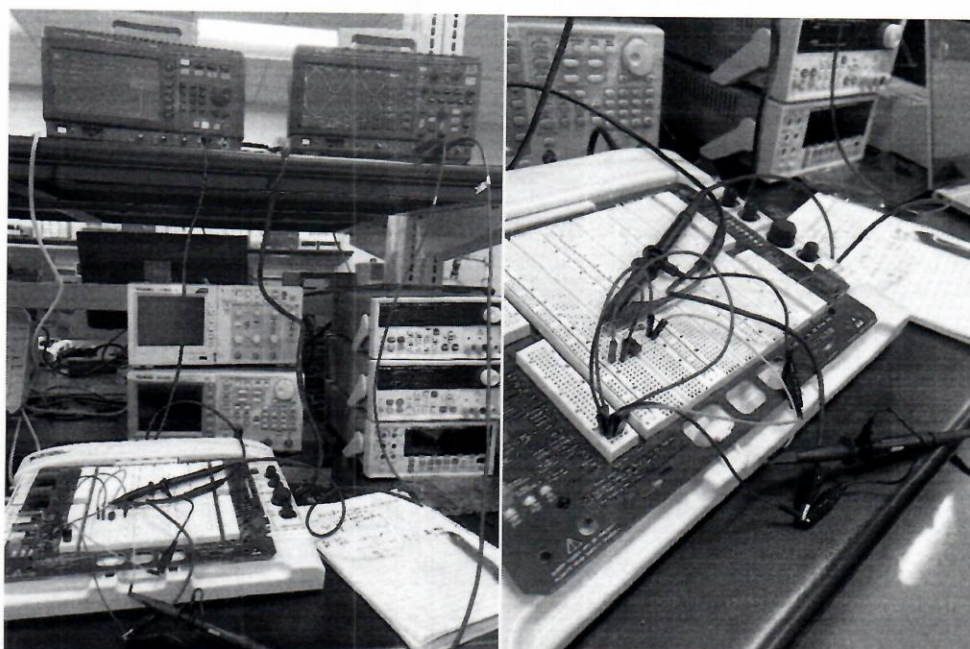
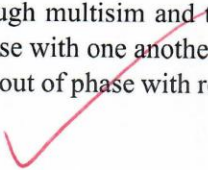


Figure 13: Oscilloscope/Generator overall set up

Conclusion:

In this experiment, we constructed two configurations for a 741 inverting operational amplifier. One configuration resulted in a voltage gain of -10 while the other resulted in -100. We were able to reach the desired output by implementing a 1:10 and then a 1:100 ratio of the input resistance to the output resistance. We successfully built both versions of the circuit physically as well as simulated them through multisim acquiring similar results thus confirming our calculations. Similar waveforms were achieved through multisim and the oscilloscope showing that both the input and output signals were not in phase with one another. The op-amp changes the phase angle of the output signal exactly 180 degrees out of phase with respect to input signal. This was true for both configurations of the op amp.

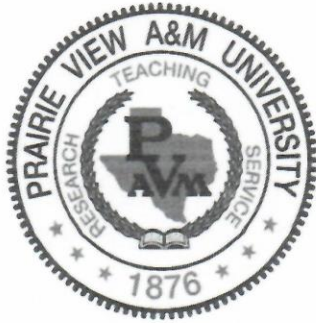


2.2 & 2.3
Comparisons
& Discrepancies!

Lab 2 Report

ABOVE AVERAGE

(Note: All Pages shown in Light Blue should be printed on Light Blue Paper)



ELECTRICAL & COMPUTER ENGINEERING

Course Name: ELEG 4101

✓ Electronics Laboratory

100

Lab Report

Excellent Report

Course Name: ~~Electronic~~ Laboratory

✓ **Lab 2: Operational Amplifiers**

Student Name

✓ Bob Patthammavong

✓ Jacqueline Torralba

Date of Submission: // 10/05/21

Date of Performance: //10/28/21

Department of Electrical and Computer Engineering

Prairie View A&M University

Objective

Study of (a) Instrumentation amplifier, (b) Lossy Integrator, and (c) Lossy Differentiator

(a)

- Completing the analysis of the circuit and selecting the right resistor for design specification of voltage gain.
- Simulating the circuit in Multisim to compare the results with hand calculate and circuit build in the breadboard
- Implementing the circuit in an experimental setting, taking measurements in the laboratory and comparing them to the theoretical and simulated results.

(b)

- Complete the analysis of the circuit using specific resistors and capacitors to study lossy differentiator and integrator behavior in its time domain and frequency domain.

Introduction/Theory

In this lab experiment we will be focusing on the instrumentation amplifier, the Lossy Integrator/Inverting Integrator, and the Lossy Differentiator/Op-Amp Differentiator.

An instrumentation amplifier is a type of op-amp that has input buffer amplifiers to eliminate the need for input impedance matching. This type of op-amp is best used for test equipment when accuracy and stability are needed. This circuit will have high input resistance and high differential gain. The instrumentation amplifier has two stages: the first one being op-amp 1 and 2 associated with their respective resistors, then the second stage of the 3rd op-amp associated with its 4 respective resistors.

The next op-amp that will be discussed is the Lossy Integrator or Inverting Integrator Op-Amp that is part of the op-amp RC circuits. The lossy integrator is an element whose output signal is the time integral of the input signal. The integrator will be in the form of a first order low pass filter.

While the Lossy Differentiator is an op amp whose output signal is the first derivative of the input signal. Meaning it will produce a voltage output directly proportional to the input voltage rate of change with respect to time. Thus, the faster the change of the input signal the greater the input current will cause a great output voltage creating a spike in change.

Equipment

In the simulation program Multisim

- Variable Power Supply in the Multisim
- Multimeter the Multisim
- Function generator, Oscilloscope.
- 7 resistors with nominal values: provided in the Multisim.
- 1 capacitor with nominal value: provided in Multisim.

In the Laboratory

- 3 Op Amp 741-type

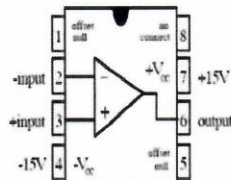


Figure 1. Pinout for the 741 op-amp

- 7 resistors with nominal values: provided in the Laboratory
- 1 capacitor with nominal value: provided in Multisim.
- Breadboard and several wires
- Function generator, Oscilloscope.
- Variable Power Supply on the breadboard + and – 15V
- Multimeter to check and measurement

Procedure

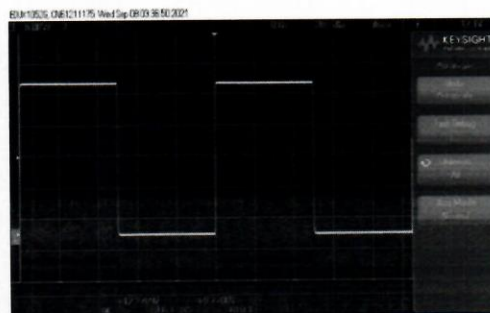
Operational amplifier and a difference amplifier circuit simulation Figure L2.3, L2.4, and L2.5

Plot the input and out put waveforms for all simulations.

Report the DC voltage at the inverting terminal and output of each op-amp.

Record the result value of differential and common-mode gain.

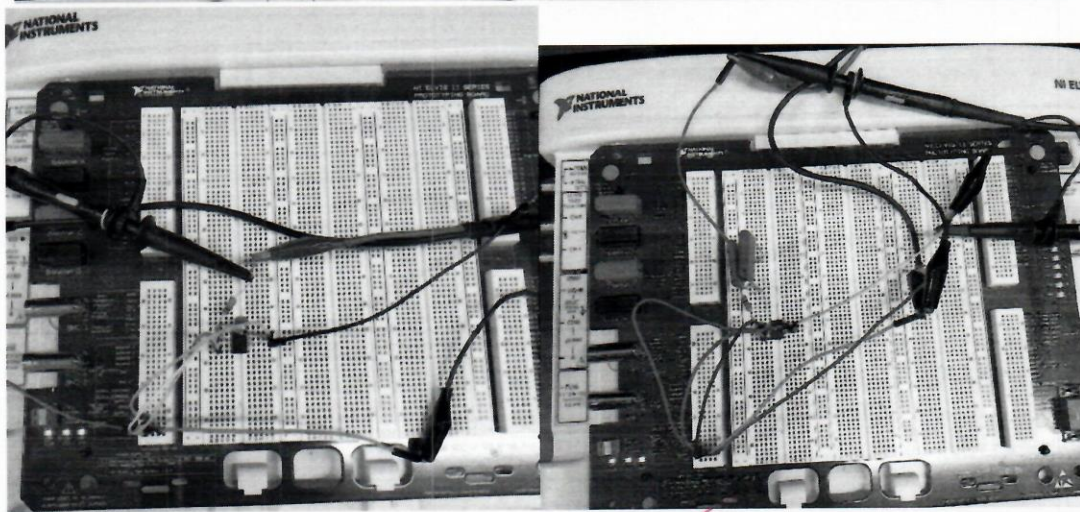
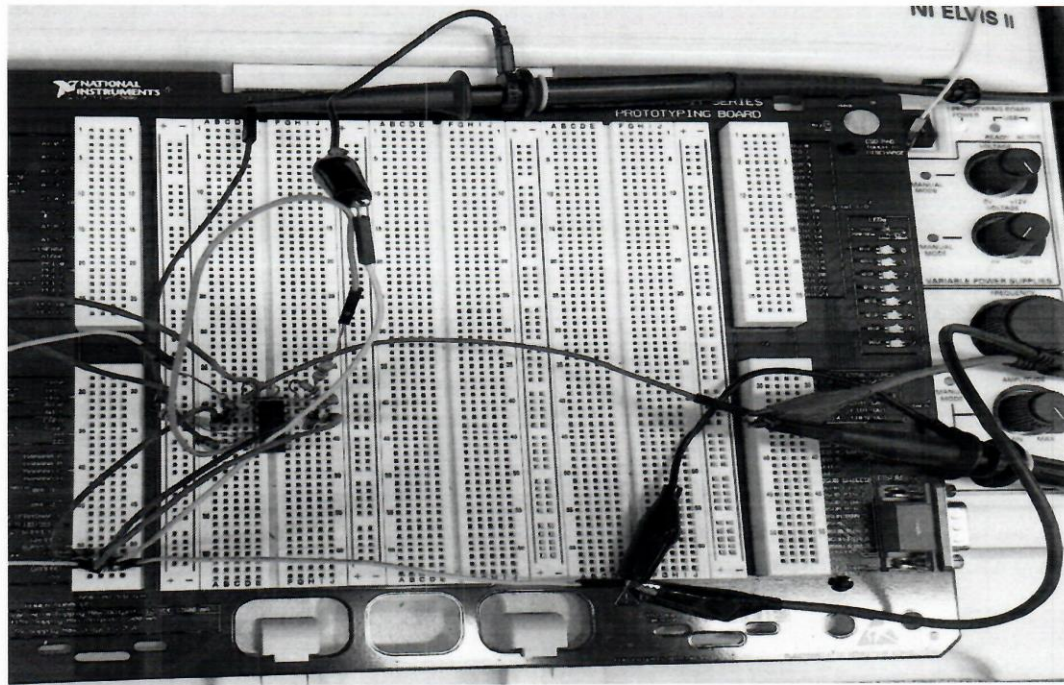
Testing Equipment



Lab 2.4			
	Expected Value	Actual Measurement	
R1	1k Ω	0.98k Ω	0.98k Ω
R2	10k Ω	9.95k Ω	9.86k Ω
R3	1k Ω	0.98k Ω	0.98k Ω
R4	1k Ω	9.82 k Ω	9.80k Ω
Lab 2.5			
R	1k	0.98k	
Rf	10k	9.86k	
C	0.15 μ F	0.15 μ F	
Lab 2.6			
R	1k	0.98 k Ω	
Rf	10k	9.95k Ω	
C	1.59 μ F	1.53 μ F	



2.4 Instrumentation Amplifier, 2.5 Lossy Integrator, and 2.6 Lossy Differentiator



Calculation Part

PART 1: DESIGN AND ANALYSIS

Consider the circuit shown in Figure L2.4:

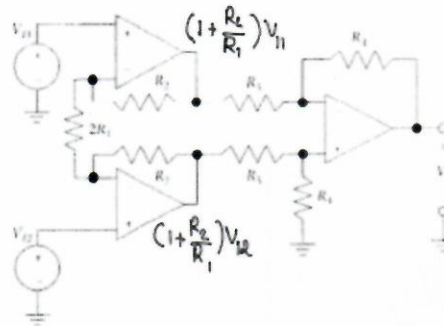
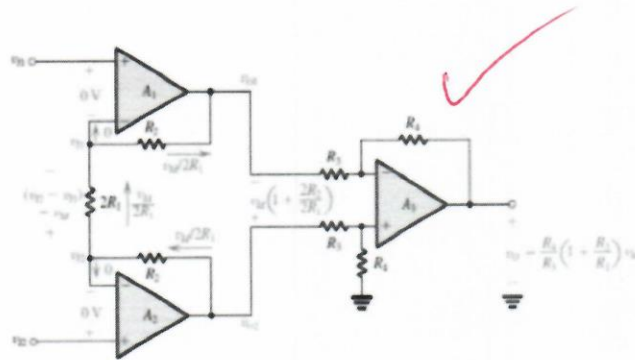


FIGURE L2.4:
Instrumentation amplifier.
Based on Fig. 2.20(b),
p. 83 S&S.



Find

$$R_1 = R_2 = 1\text{ k}\Omega$$

Find R_3 and R_4

$$A_{V_{A1}} = 11\text{ V/V}$$

$$A_{V_{A2}} = -10\text{ V/V}$$

From A_1

$$V_1 = 0.5\text{ V}$$

$$V_{O1} = 7\text{ V}$$

$$A_{V1} = 11\text{ V/V}$$

$$A_{V1} = \frac{V_{O1}}{V_1}$$

$$V_{O1} = A_{V1} \cdot V_1 = 11 \times 0.5$$

$$V_{O1} = 5.5\text{ V}$$

From A_2

$$V_{O2} = 7\text{ V}$$

$$V_2 = 0.5\text{ V}$$

$$A_{V2} = -10\text{ V/V}$$

$$V_{O2} = A_{V2} \cdot V_2$$

$$V_{O2} = -5\text{ V}$$

Find R_2

$$V_{O1} = \left(1 + \frac{R_2}{R_1}\right) V_1$$

$$\frac{V_{O1}}{V_1} = 1 + \frac{R_2}{R_1}$$

$$11 = 1 + \frac{R_2}{R_1}$$

$$10 \times R_1 = R_2$$

$$R_2 = 10\text{ k}\Omega$$

$$V_{Id} = V_2 - V_1$$

$$V_{Id} = -5 - 5.5 = -10.5V$$

$$R_3 = R_1 = 1k\Omega$$

$$R_2 = R_2 = 10k\Omega$$

PART 1: DESIGN AND ANALYSIS

Consider the circuit shown in Figure L2.5:

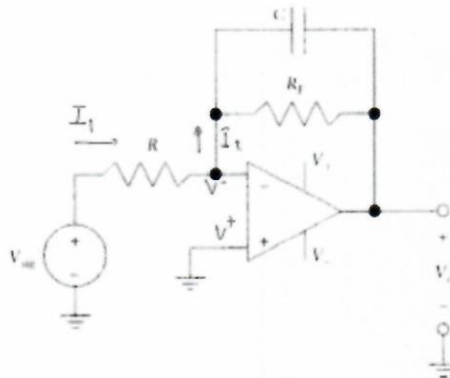


FIGURE L2.5: Lossy integrator.
See Fig. 2.25, p. 92 S&S.

Given

$$R = 1k\Omega$$

$$f_s = 1000Hz$$

$$A_v = -10V/V$$

$$V_s = 50mV$$

$$V_o = 0$$

Find V_o

$$A_v = \frac{V_o}{V_s}$$

$$V_o = A_v V_s = -10 \times 0.5$$

$$V_o = -5V$$

Find R_f

$$I_1 = I_2$$

$$I_1 = \frac{V_s}{R} = \frac{0.5}{1000} \approx 5 \times 10^{-4} A$$

$$R_f = \frac{V - V_o}{I_2}$$

$$R_f = \frac{0 - (-5)}{5 \times 10^{-4}} \approx 10k\Omega$$

Find C

$$f = \frac{1}{2\pi RC}$$

$$C = \frac{1}{2\pi R f} \approx \frac{1}{2 \times \pi \times 10 \times 10^3 \times 1000} = 0.0159 \mu F$$

PART 1: DESIGN AND ANALYSIS

Consider the circuit shown in Figure L2.6:

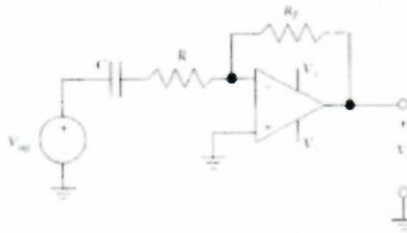


FIGURE L2.6: Lossy differentiator. Based on Fig. 2.27(a) on p. 95 S&S.

Design the circuit in Figure L2.6 such that its high-frequency gain is -10 V/V, and its -3 -dB frequency is 100 Hz. Select resistor values such that the input resistance

Given

$$R = 1 \text{ k}\Omega$$

$$f_c = 100 \text{ Hz}$$

$$A_v = -10 \text{ V/V}$$

$$V_s = 50 \text{ mV}$$

$$V_o = ?$$

Find V_o

$$A_v = \frac{V_o}{V_s}$$

$$V_o = A_v V_s = -10 \times 0.05$$

$$V_o = -0.5 \text{ V}$$

Find C

$$C = \frac{1}{2\pi f_c R} = \frac{1}{2\pi \times 100 \times 1000}$$

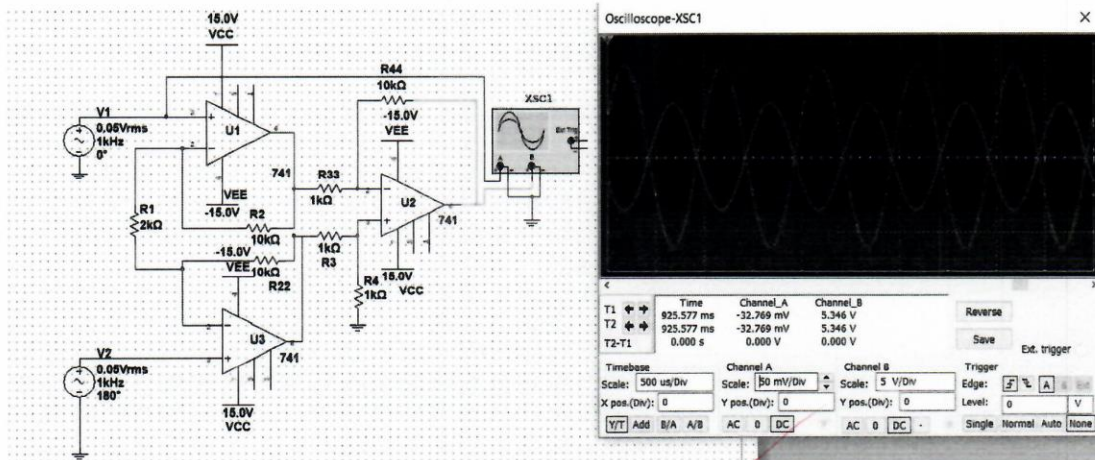
$$C = 1.59 \mu F$$

$$V_o = -\frac{R_f}{R} V_s$$

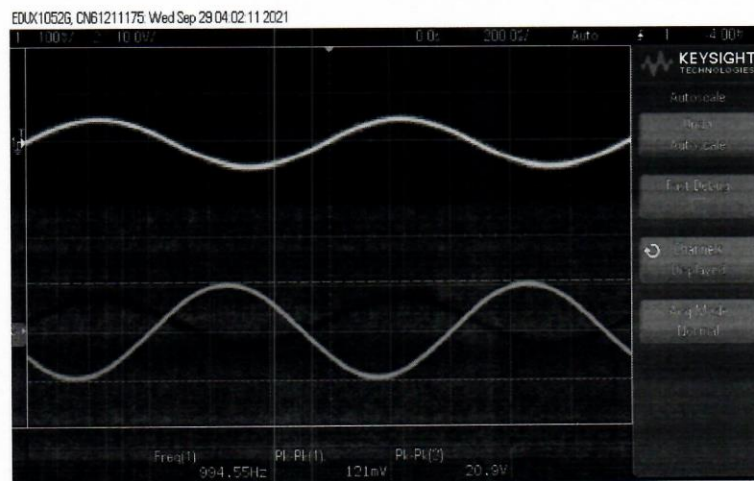
$$10 = \frac{R_f}{R}$$

$$R_f = 10 \text{ k}\Omega$$

Multisim Simulation 2.4 Instrumentation Amplifier



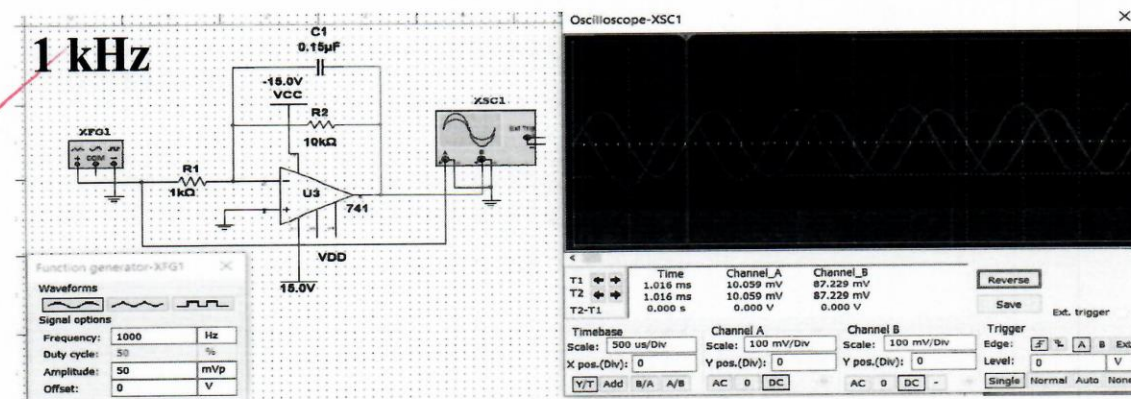
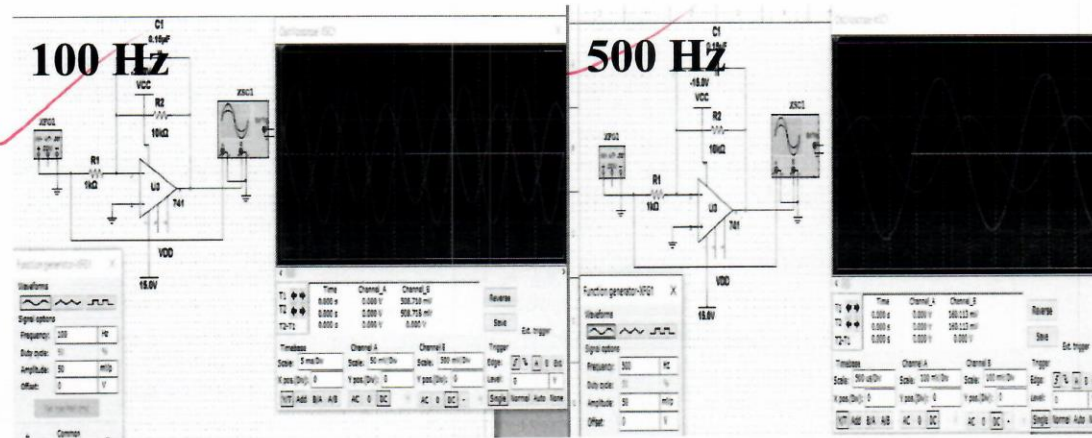
Laboratory Simulation 2.4 Instrumentation Amplifier



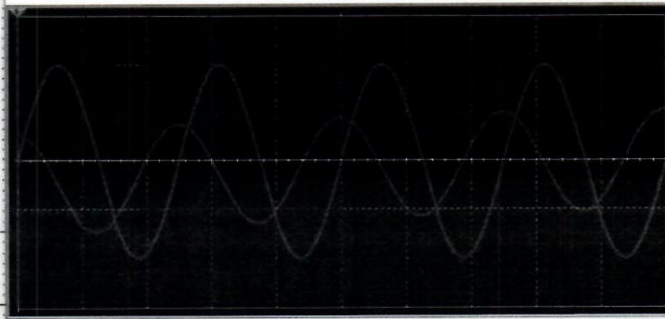
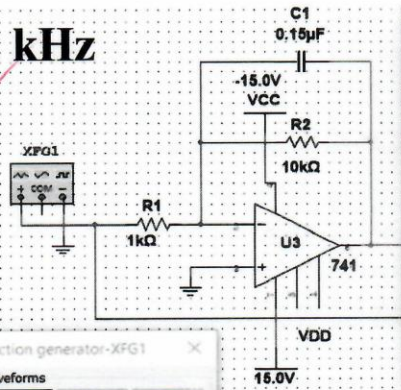
$$P_k - P_k = \frac{20.9}{2} = 10.45V/V$$

Frequency (f)	MULTISIM				Frequency (f)	HAND CALCULATE				Frequency (f)	SIMULATION IN LAB						
	Instrumentation Amplifier					Lossy Integrator					Lossy Differentiator						
	V _m	Resistor		V _{out}	A		V _m	Resistor		V _{out}	A		V _m	Resistor		V _{out}	A
	V	R1=R3 kΩ	R2=R4 kΩ	mV	V		V	R1=R3 kΩ	R2=R4 kΩ	mV	V		V	R1=R3 kΩ	R2=R4 kΩ	mV	V
1000Hz	0.5	1	10	5.346	10.692	1000Hz	0.5	1	10	10.5	10.5	1000Hz	0.5	0.98, 0.95	9.95, 9.82	-	10.45

2.5 Lossy Integrator



2 kHz



Function generator-XFG1

Waveforms

Signal options

Frequency: 2000 Hz

Duty cycle: 50 %

Amplitude: 50 mVp

Offset: 0 V

Timebase

Scale: 200 us/Div

Channel A

Scale: 50 mV/Div

Channel B

Scale: 50 mV/Div

Trigger

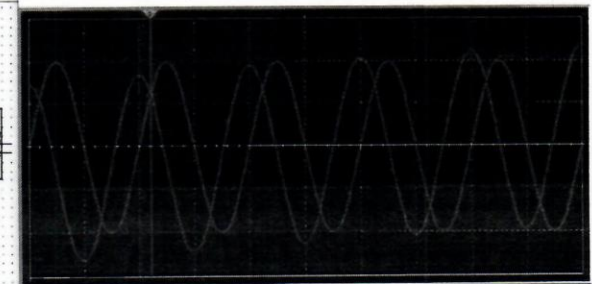
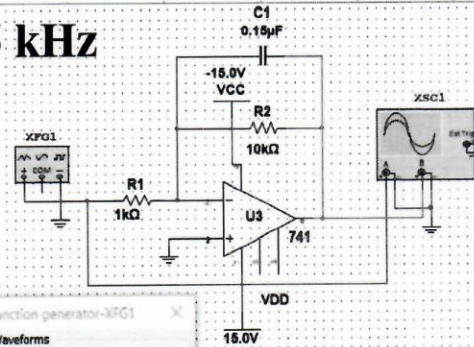
Edge: f A B Ext

Level: 0 V

Single Normal Auto None

	Time	Channel_A	Channel_B
T1	0.000 s	0.000 V	26.734 mV
T2	0.000 s	0.000 V	26.734 mV
T2-T1	0.000 s	0.000 V	0.000 V

5 kHz



Function generator-XFG1

Waveforms

Signal options

Frequency: 5000 Hz

Duty cycle: 50 %

Amplitude: 50 mVp

Offset: 0 V

Timebase

Scale: 100 us/Div

Channel A

Scale: 50 mV/Div

Channel B

Scale: 10 mV/Div

Trigger

Edge: f A B Ext

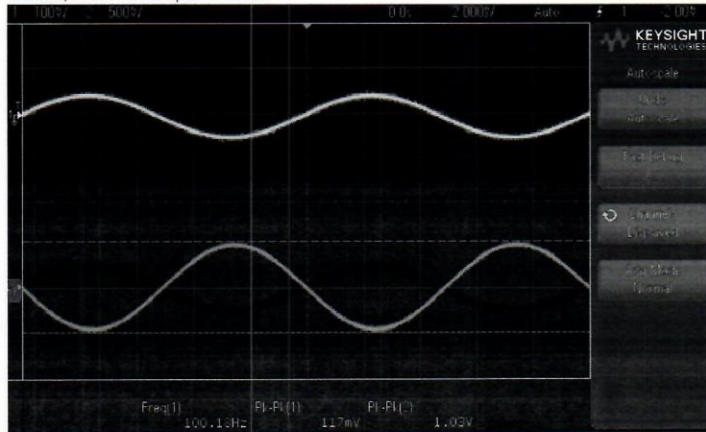
Level: 0 V

Single Normal Auto None

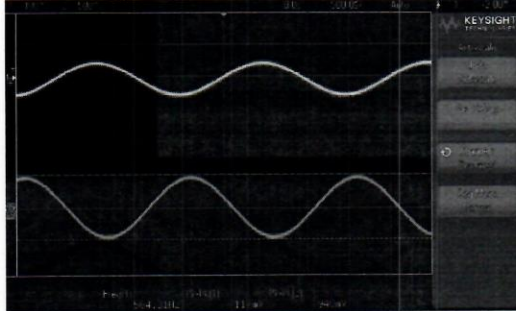
	Time	Channel_A	Channel_B
T1	220.968 us	61.115 mV	12.548 mV
T2	220.968 us	61.115 mV	12.548 mV
T2-T1	0.000 s	0.000 V	0.000 V

Laboratory Lossy Differentiator

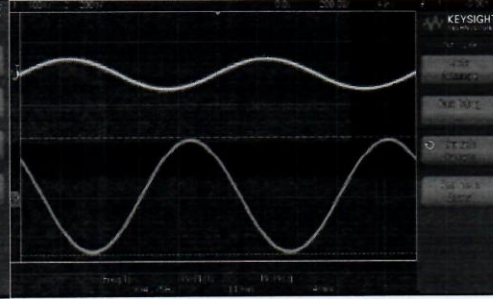
EDUX1062G, CN61211175 Wed Sep 29 04:15:20 2021



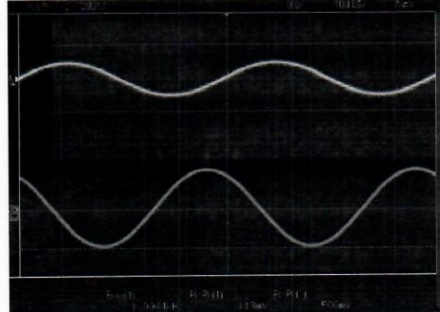
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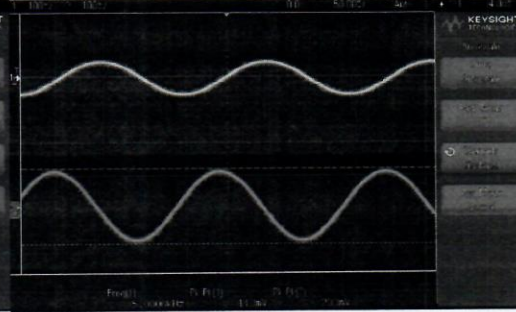
EDUX1062G, CN61211175 Wed Sep 29 04:18:49 2021



EDUX1062G, CN61211175 Wed Sep 29 04:19:42 2021



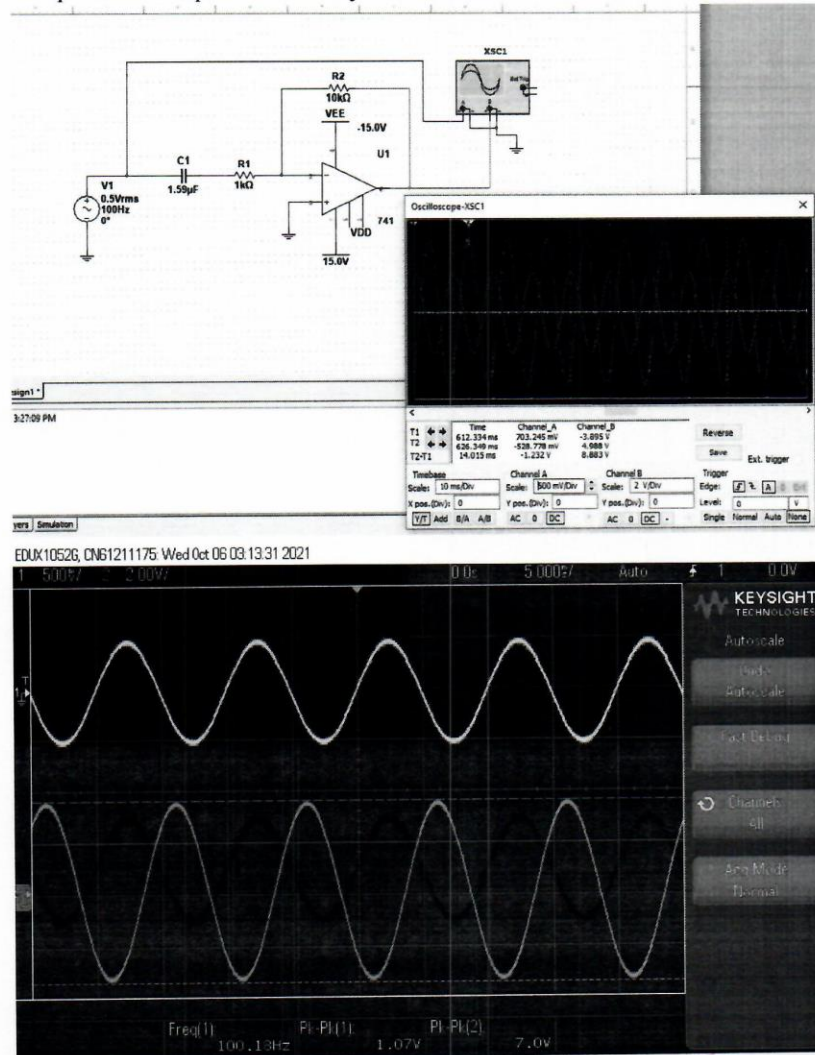
EDUX1062G, CN61211175 Wed Sep 29 04:21:08 2021



Frequency (f)	MULTISIM						Frequency (f)	HAND CALCULATE						Frequency (f)	SIMULATION IN LAB					
	Instrumentation Amplifier							Lossy Integrator							Lossy Differentiator					
	Capacitor	V _{in}	Resistor		V _{out}	A		Capacitor	V _{in}	Resistor		V _{out}	A		Capacitor	V _{in}	Resistor		V _{out}	A
	μF	mV	R1 kΩ	R2 kΩ	mV	V		μF	V	R1 kΩ	R2 kΩ	mV	V		μF	mV	R1 kΩ	R2 kΩ	mV	V
100Hz	0.0159	50	1	10	508.718	10.174	100Hz	0.0159	0.5	1	10	-5	-10	100Hz	0.0153	117	1	10	1030	8.8034
500Hz	0.0159	50	1	10	160.113	3.202	-	-	-	-	-	-	-	500Hz	0.0153	117	1	10	940	8.0342
1kHz	0.0159	50	1	10	87.229	1.745	-	-	-	-	-	-	-	1kHz	0.0153	113	1	10	740	6.5487
2kHz	0.0159	50	1	10	26.734	0.535	-	-	-	-	-	-	-	2kHz	0.0153	113	1	10	500	4.4248
5kHz	0.0159	50	1	10	12.549	0.251	-	-	-	-	-	-	-	5kHz	0.0153	113	1	10	233	2.0619

2.6 Lossy Differentiator

The picture we capture show only 100Hz on another that record on data sheet

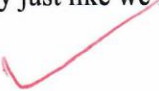


Frequency (f)	MULTISIM						Frequency (f)	HAND CALCULATE						Frequency (f)	SIMULATION IN LAB					
	Instrumentation Amplifier							Lossy Integrator							Lossy Differentiator					
	Capacitor μ F	V_{in} mV	Resistor R1 k Ω	Resistor R2 k Ω	V_{out} mV	A		Capacitor μ F	V_{in} V	Resistor R1 k Ω	Resistor R2 k Ω	V_{out} mV	A		Capacitor μ F	V_{in} V	Resistor R1 k Ω	Resistor R2 k Ω	V_{out} V	A
100Hz	1.59	50	1	10	-362.900	-7.258	100Hz	1.59	0.5	1	10	-5	-10	100Hz	1.59	0.5	1	10	7.01	14.0200
500Hz	1.59	50	1	10	-277.500	-5.550	-	-	-	-	-	-	-	500Hz	1.59	1.05	1	10	10.1	9.6190
1kHz	1.59	50	1	10	172.200	3.444	-	-	-	-	-	-	-	1kHz	1.59	1.05	1	10	10.1	9.6190
2kHz	1.59	50	1	10	172.200	3.444	-	-	-	-	-	-	-	2kHz	1.59	1.05	1	10	10.3	9.8095
5kHz	1.59	50	1	10	172.200	3.444	-	-	-	-	-	-	-	5kHz	1.59	1.05	1	10	10.1	9.6190

Conclusion

Conclusion

In the conclusion for 2.4 Instrumentation Amplifier, 2.5 Lossy Integrator, and 2.6 Lossy Differentiator. For all method that we use to record the data such as simulate in the laboratory, hand calculation, and simulate in the Multisim. The data show that all the method we use will get the data different from another that because of the environment in the lab, and the value of resistor we use to calculate is different by 1-5%. In the lab we use the real resistor that will not get 100% of the resistor's value. The same value of the capacitor that we use in the lab we cannot find the same value of our calculation and Simulation in Multisim. For example, when we pick 1kohm resistor we will get only 995 ohms and 985 ohms. For capacitor we need to use 0.159 μF and 1.59 μF , but in the lab we can obtain only 0.153 μF and 1.54 μF after using multimeter check real value. So, in all data of all method we use to simulate the circuits we can say that the result is close to each other but cannot get the same extract number. In additional for 2.5 and 2.6 cases, we change the frequency from 100Hz, 500Hz, 1kHz, 2kHz, and 5kHz, but the $V_{\text{out pk-pk}}$ does not change much however the cycle of the graph is changed to closes to each other when we increase the frequency just like we increase the frequency in the motor and the speed of cycle is also spin faster



References

Alexander, Charles K., and Matthew N. Sadiku. *Fundamentals of Electric Circuits*. Fifth ed., The McGraw-Hill Companies, 2004.

Sedra, Adel S., and Kenneth C. Smith. *Microelectronic Circuits Laboratory Exploration to Accompany*. Seventh edition., OXFORD UNIVERSITY PRESS.

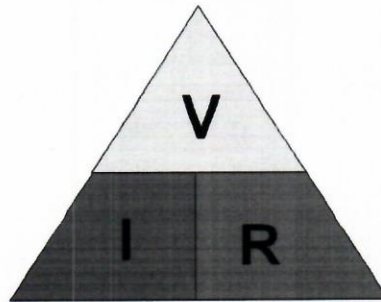


Appendix I

5% Standard Values											
Decade multiples are available from 10 Ω through 22 M Ω											
10	11	12	13	15	16	18	20	22	24	27	30
33	36	39	43	47	51	56	62	68	75	82	91

10% Standard Values											
Decade multiples are available from 10 Ω through 1 M Ω											
10	12	15	18	22	27	33	39	47	56	68	82

Ohm's Triangle



Cover the variable you want to find and perform the resulting calculation.

Attachment

Instructor signature on the record data lab sheet.

AVERAGE

Electronics 1 Laboratory (2.4, 2.5, 2.6)

ELEG 4101

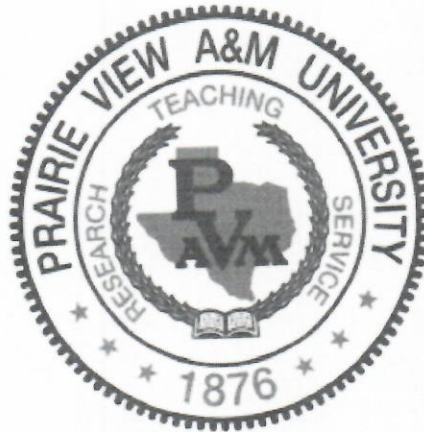
85

Names: Eric Anumnu, Teminioluwa Folorunso, Breon Holmes

Date of Submission: 10/04/2021

Date of Performance: 09/21/2021

Department of Electrical and Computer Engineering
Prairie View A&M University



Objectives:

2.4:

To study an instrumentation amplifier circuit by: ✓

- Completing the analysis of the circuit analysis selecting resistors that satisfy design specifications.
- Simulating the circuit to compare the results with the paper analysis.
- Implementing the circuit in an experimental setting, taking measurements and comparing its performance with theoretical and simulated results.

2.5:

To study lossy integrator and its time-domain and frequency-domain behavior by: ✓

- Completing the analysis of the circuit analysis selecting resistors that satisfy design specifications.
- Simulating the circuit to compare the results with the paper analysis.
- Implementing the circuit in an experimental setting, taking measurements and comparing its performance with theoretical and simulated results.

2.6:

To study a lossy differentiator and its time-domain and frequency-domain behavior by: ✓

- Completing the analysis of the circuit analysis selecting resistors that satisfy design specifications.
- Simulating the circuit to compare the results with the paper analysis.
- Implementing the circuit in an experimental setting, taking measurements and comparing its performance with theoretical and simulated results.

Equipment Used:

2.4, 2.5 & 2.6:

- Laboratory setup, including breadboard
- Three 741-type op amplifiers
- Several wires and resistors of varying sizes

Procedure:

2.4:

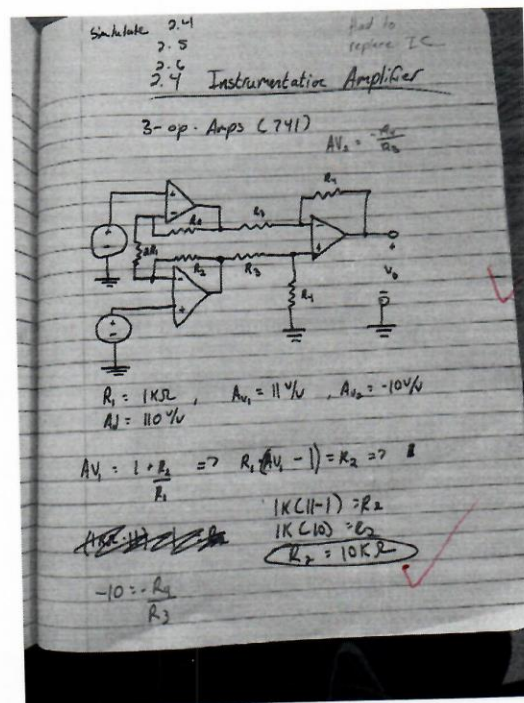
- Assemble the circuit onto a breadboard. Do not include the 50 ohm output resistance of your signal sources.
- While leaving V_{12} grounded, provide a DC input to V_1 in increments of 0.01V. from -0.1V to +0.1V. Record the values of V_o and plot your results.
- While leaving V_1 grounded, provide a DC input to V_{12} in increments of 0.01V. from -0.1V to +0.1V. Record the values of V_o and plot your results.
- Using a function generator, provide a 1kHz 50-mV_{pk pk} sine wave to input V_{11} and ground V_{12} . Using an oscilloscope, capture the output voltage waveform.
- Using a digital multimeter, measure all resistors to three sig. digits.

2.5:

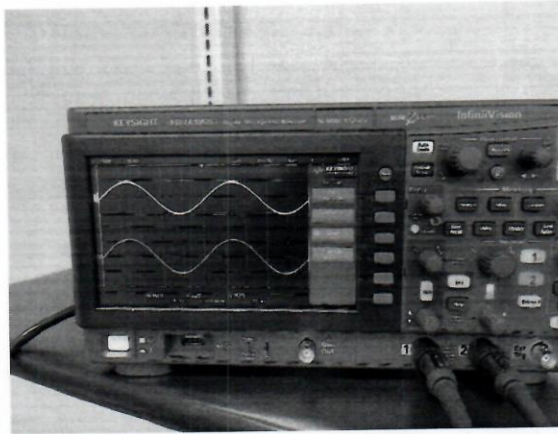
- Assemble the circuit onto a breadboard. Do not include the 50- ohm output resistance of your signal sources.
- Using a digital multimeter, measure the DC voltages at the input, output and inverting terminal, while leaving the input grounded.
- Using a function generator, provide a 50-mV_{pk pk} zero-DC sine wave to the input. Using an oscilloscope, capture the output reaches approximately 70% of it's low frequency magnitude. Record this as the 3-dB frequency.
- Using a digital multimeter, measure all resistors to three significant figs.

2.6:

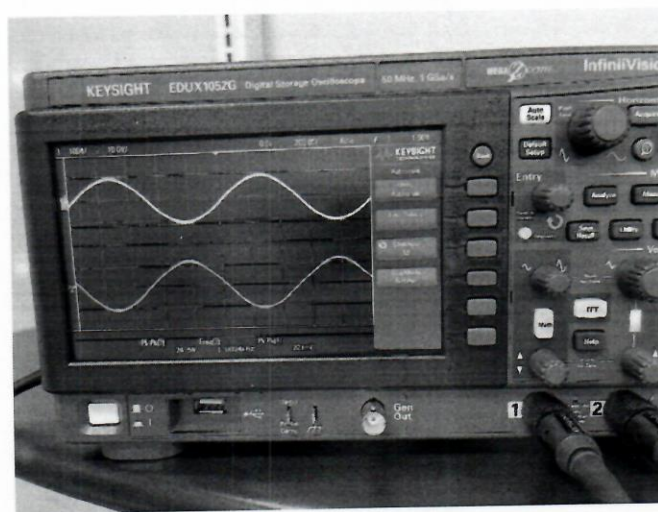
- Assemble the circuit onto a breadboard. Do not include the 50-ohm output resistance of your signal sources.
- Using a digital multimeter, measure the DC voltages at the input, output and inverting terminal, while leaving the input grounded.
- Using a function generator, provide a 50-mV_{pk pk} sine wave to the input. Using an oscilloscope, capture the output voltage waveform for input frequencies of 100Hz, 500Hz, 1kHz, 2kHz, 5kHz and 100kHz.
- Vary the input frequency until the output reaches approximately 70% of its high frequency magnitude. Record this as the 3-dB frequency.
- Using a digital multimeter, measure all resistors to three sig. figures.

Results:2.4:

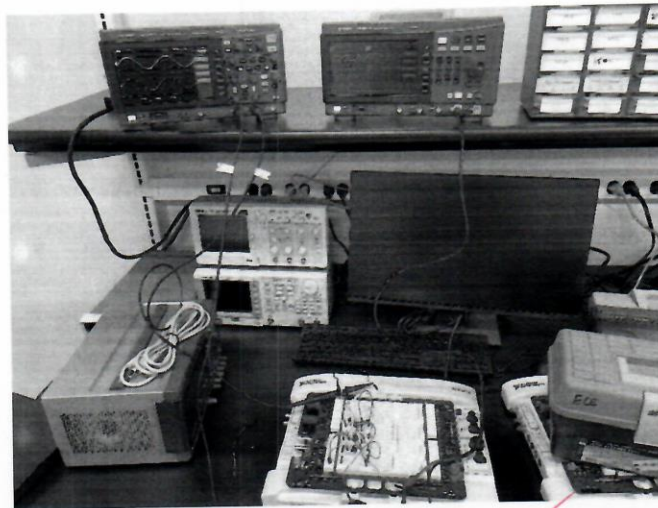
(Handwritten calculations)



(Waveform pt.1)

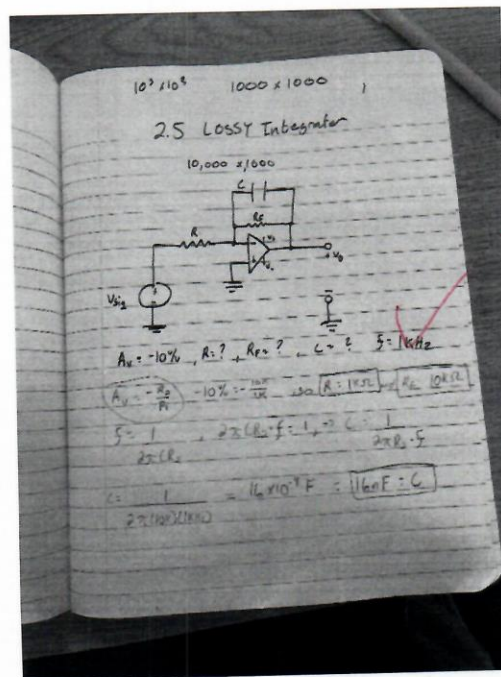


(Waveform pt. 2)

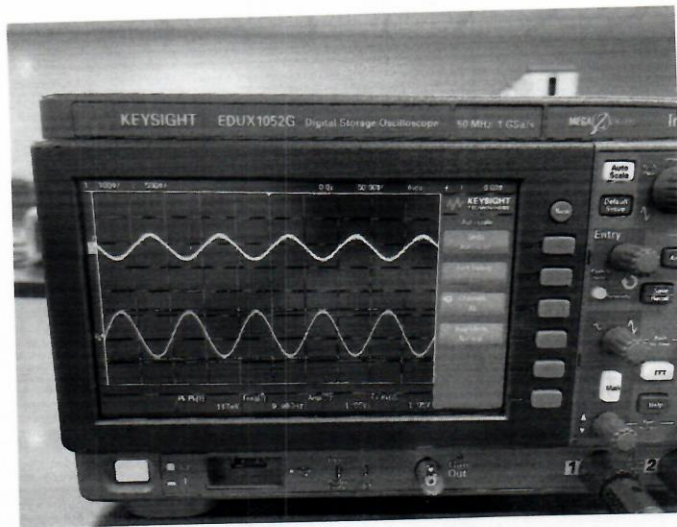


(Complete setup)

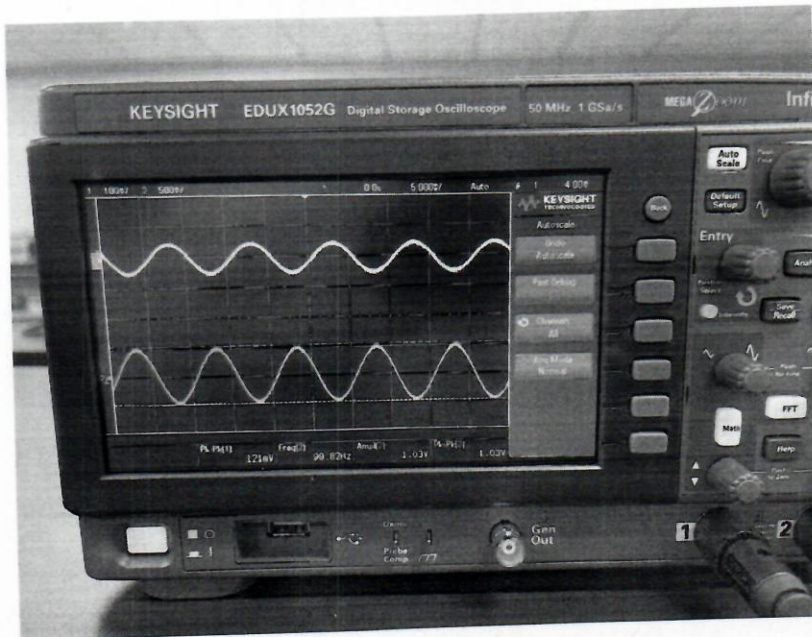
(Hand calculations)

2.5:

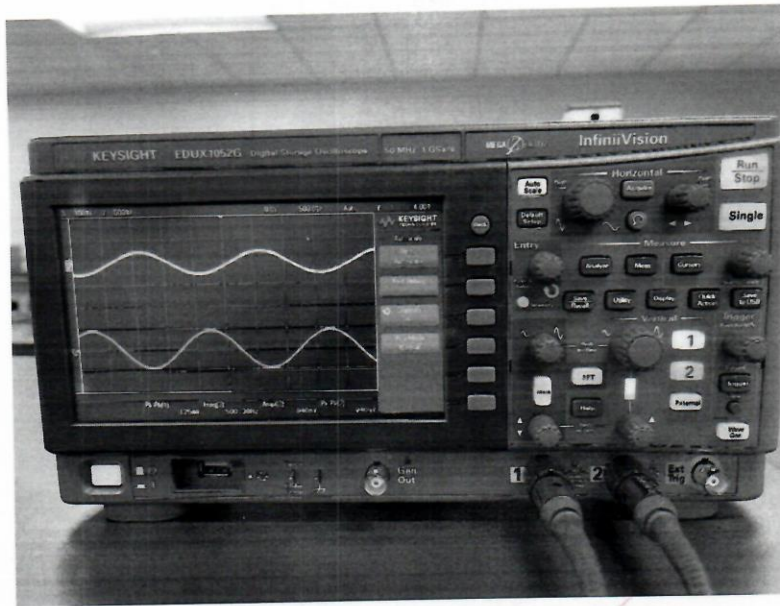
(Handwritten calculations)



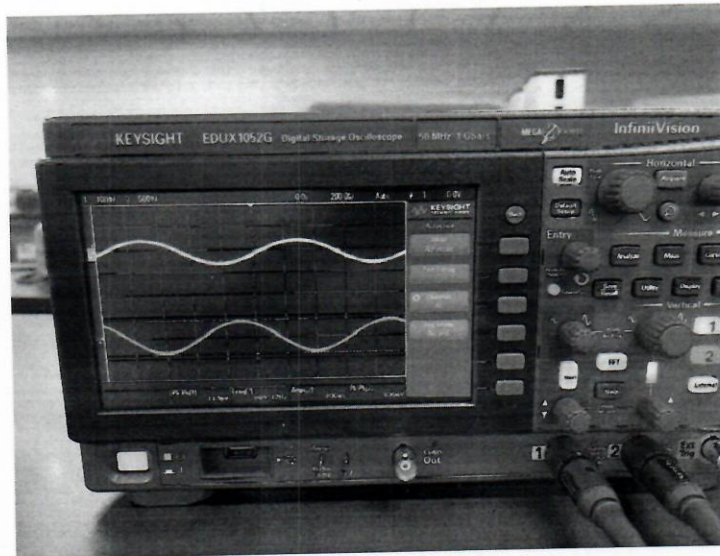
(Waveform at 10Hz)



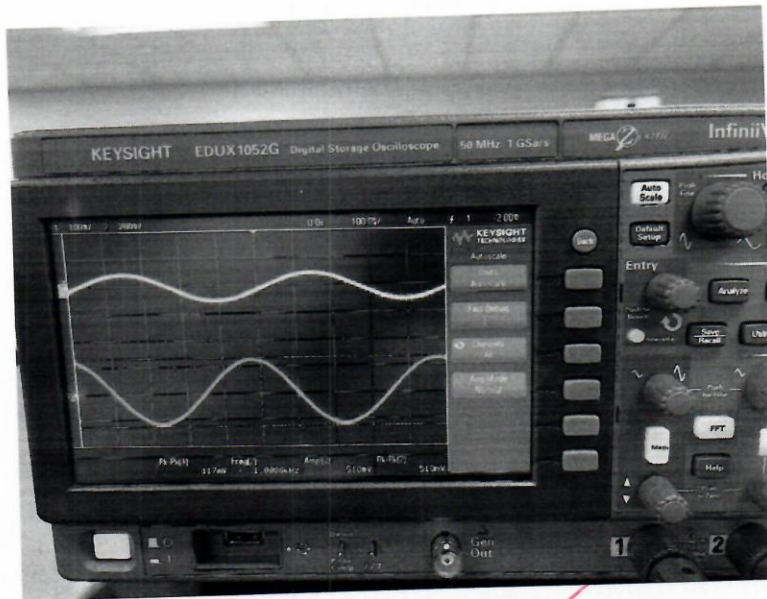
(Waveform at 100Hz)



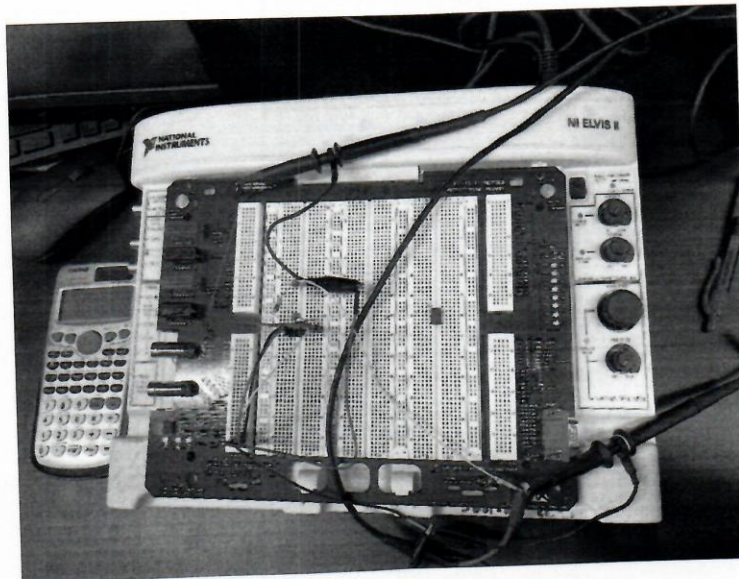
(Waveform at 500Hz)



(Waveform at 1kHz)



(Waveform at 2kHz)



(Circuit on breadboard)



(Complete setup)

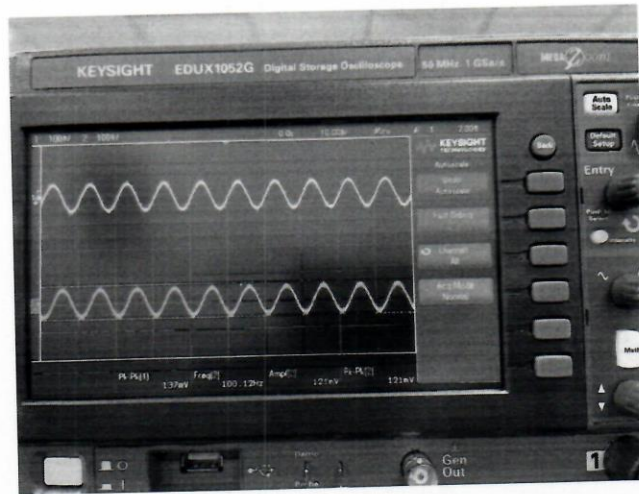
$1.03V \cdot 0.72 = 0.756$

3-10: 70% of V_{max}

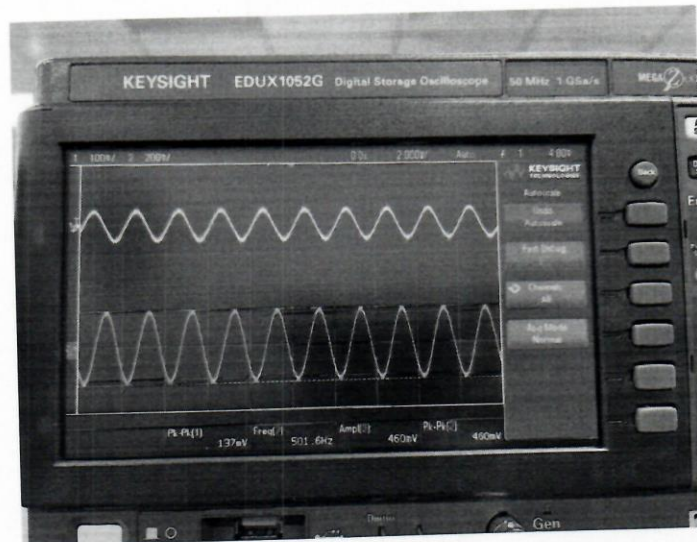
Frequency	Input	Output
10Hz	133mV	1.05V
100Hz	133mV	1.03V
1000Hz	133mV	960mV
1KHz	133mV	800mV
2KHz	133mV	550mV
5KHz	133mV	279mV
10.7KHz	133mV	750mV - 3dB

(Table of different frequencies)

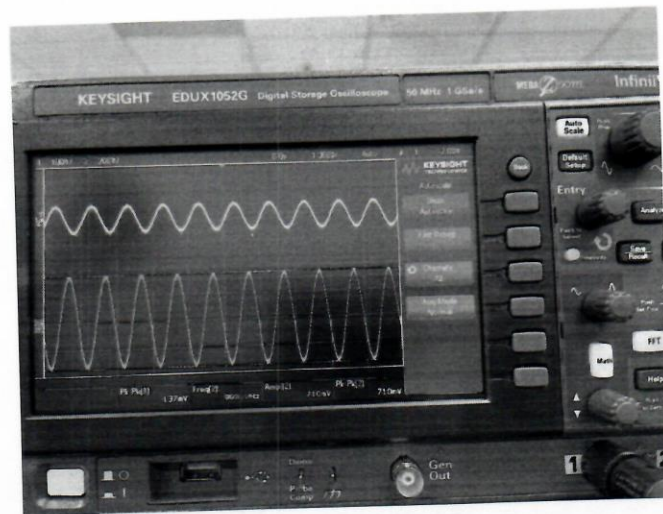
2.6:



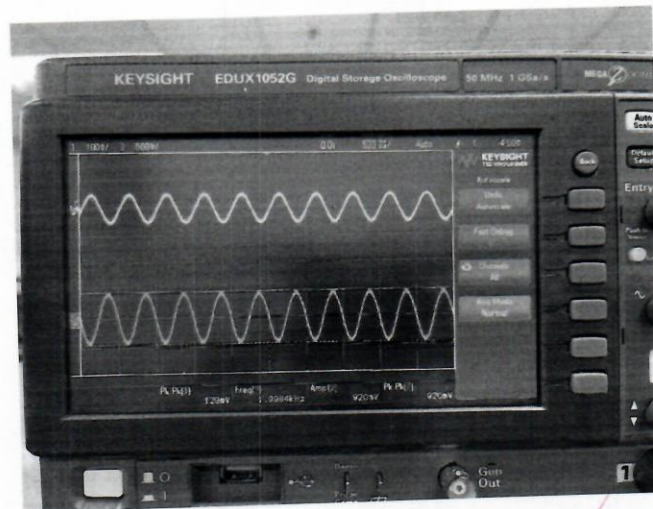
(Waveform at 100Hz)



(Waveform at 500Hz)

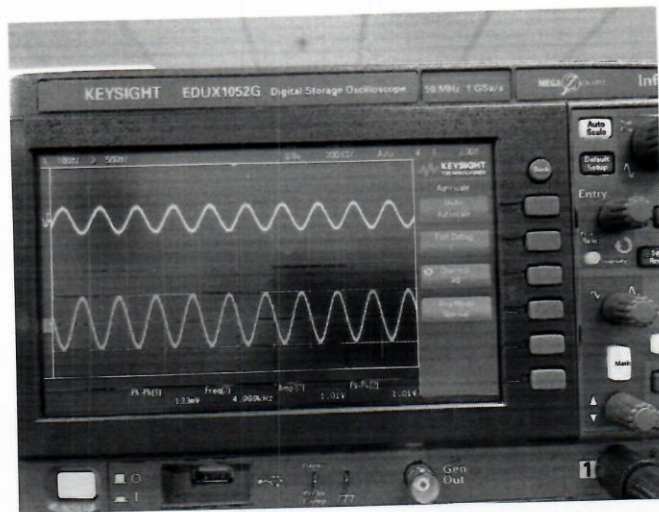


(Waveform at 1kHz)

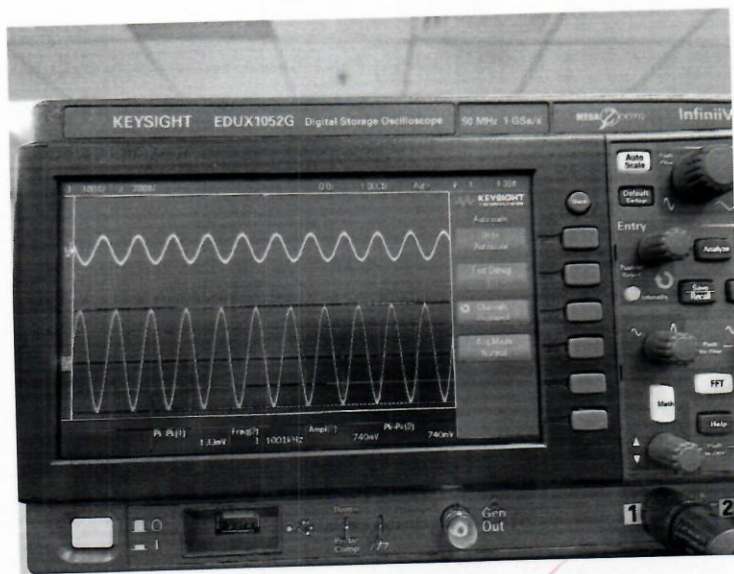


(Waveform at 2kHz)

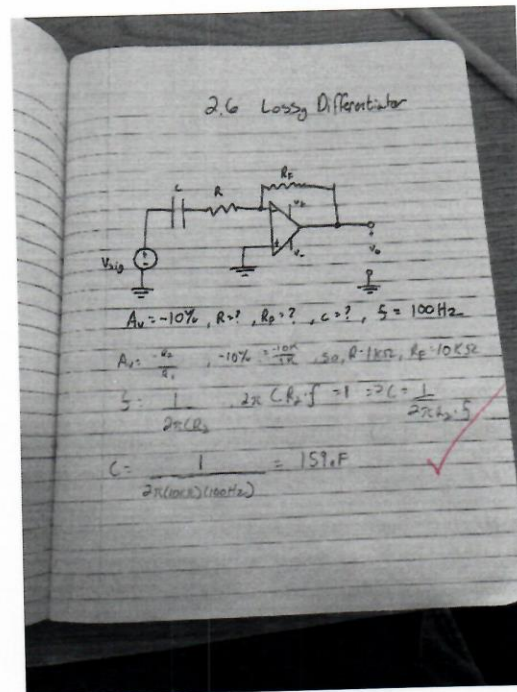




(Waveform at 5kHz)



(Waveform for 3dB)



(Handwritten calculations)

$f_{3dB} = 1.1\text{kHz}$

f_{input}	V_{in}	V_{out}
100Hz	137mV	117mV
500Hz	137mV	470mV
1kHz	137mV	710mV
2kHz	137mV	920mV
5kHz	137mV	1.01V
10kHz	137mV	1.03V
1.1kHz	137mV	740mV = 3dB

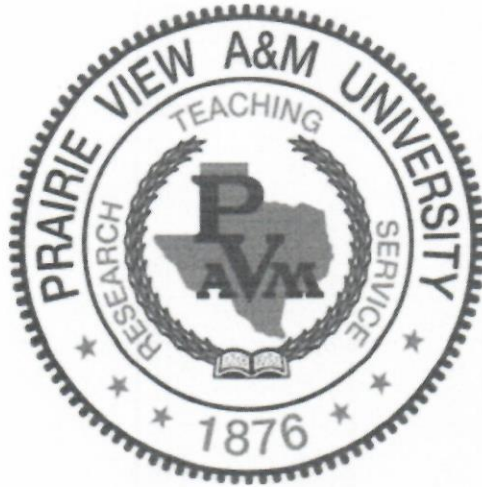
(Table of different frequencies)

Conclusion: In conclusion, we were able to complete these labs by using the equipment and following the procedures. We learned (state the objective again). While doing the experiment we had a problem with the IC. When trying to graph the circuit we saw that the output wasn't showing anything. After testing all our connections we decided to test the IC and found where the problem was. This was a learning lesson because it teaches you to test all your equipment before you start your lab.

*Comparison of simulation
& measurements!
Discussions*

BELOW AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING



75

Electronics Laboratory
ELEG 4101

Lab 2.4 Instrumentation Amplifier

Submitted by:

Trevor Johnson

Johnn Owens

Date of Submission: 10/6/2021

Date of Performance: 9/29/2021

Department of Electrical and Computer Engineering
Prairie View A&M University

Objective:

To study an instrumentation amplifier circuit by:

- Completing the analysis of the circuit and selecting resistors that satisfy design specifications.
- Simulating the circuit to compare the results with the paper analysis.
- Implementing the circuit in an experimental setting, taking measurements, and comparing its performance with theoretical and simulated results.

Introduction/Theory:

In this lab, we constructed an Instrumentation Amplifier circuit, which consists of three operational amplifiers and seven resistors. This circuit requires two AC voltage sources that are 180° out of phase with one another. The two sources feed into the non-inverting terminals of their respective op-amps. The two op-amps share a $2\text{ k}\Omega$ resistor, R_1 , that feeds into their inverting terminals. In Figure 1, it is shown that two resistors both labeled R_2 form a node at the inverting inputs of their respective op-amps and the output terminals of their op-amps. Another two resistors, labeled R_3 are connected to the output node of the two op-amps. One R_3 feeds into the inverting input of the third op-amp while the other R_3 feeds into the non-inverting input of the same op-amp. The final two resistors, labeled R_4 , have different connections. R_4 (top) forms a node at the inverting input terminal of op-amp 3 and connects to the output terminal of op-amp 3. R_4 (bottom) forms a node at the non-inverting input of op-amp 3 and is grounded.

Equipment:

- Laboratory setup, including breadboard
- Three 741-type operational amplifiers
- Several wires and resistors of varying sizes

Procedure:

Part 1: Design and Analysis

Design the circuit in Figure L2.4 such that $A_d = 110\text{ V/V}$. Select resistor values such that the first stage provides a gain of 11 V/V (magnitude) and $R_1 = 1\text{ k}\Omega$ and the second stage provides a gain of -10 V/V . Use supplies of $V_+ = -V = 15\text{ V}$.

Hand calculations

- Sketch the circuit in your lab book, clearly labeling the op-amp terminals.
- What values of R_1 , R_2 , R_3 , and R_4 do you need to use to meet the gain and input resistance specifications? Is the problem completely specified?

Simulation

- Use a $50\text{-mV}_{\text{pk-pk}}$ 1-k Hz input sine wave applied to v_{11} and another $50\text{-mV}_{\text{pk-pk}}$ 1-k Hz input sine wave applied to v_{12} that is 180° out of phase with v_{11} . In your simulation,

assume your input voltage sources have an output resistance of 50 Ω . What are V_{id} and V_{icm} ? What are V_{Od} and V_{Ocm} ?

- Plot the input and output waveforms for all simulations.
- For all simulations, report the DC voltage at the inverting terminal and output of each op-amp.
- What are the simulated values of differential and common-mode gain?

Part 2: Prototyping and Measurement

- Assemble the circuit onto a breadboard. Do not include the 50- Ω output resistance of your signal sources.
- While leaving v_{12} grounded, provide a DC input to v_{11} in increments of 0.01 V, from -0.1 V to +0.1 V. Record the values of v_0 and plot your results.
- While leaving v_{12} grounded, provide a DC input to v_{12} in increments of 0.01 V, from -0.1 V to +0.1 V. Record the values of v_0 and plot your results.
- Using a function generator, provide a 1-k Hz 50-mV_{pk-pk} sine wave to input v_{11} and ground to input v_{12} . Using an oscilloscope, capture the output voltage waveform.
- Using a function generator, provide a 1-k Hz 50-mV_{pk-pk} sine wave to input v_{12} and ground to input v_{11} . Using an oscilloscope, capture the output voltage waveform.
- Using a digital multimeter, measure all resistors to three significant digits.

Part 3: Post-Measurement Exercise

- Calculate the values of A_d and A_{cm} obtained in your measurement. What is the common-mode rejection ratio (CMRR) of the circuit? Express the CMRR in units of decibels. Explain any discrepancies between the experiments, simulations, and hand analysis.
- Recalculate the theoretical gains of the circuit, using the measured resistor values. Are the recalculated values closer to your measured gains?

Circuit Diagram:

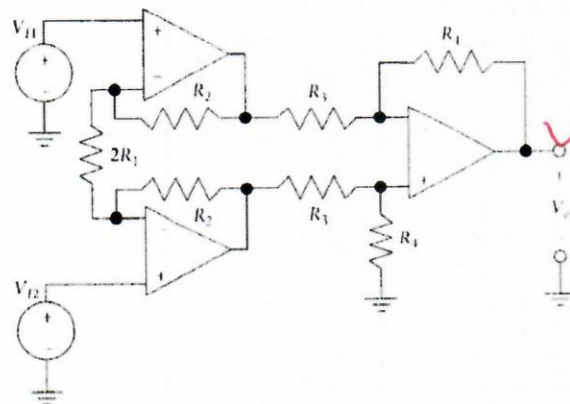


Figure 1: Circuit Diagram

Solution:

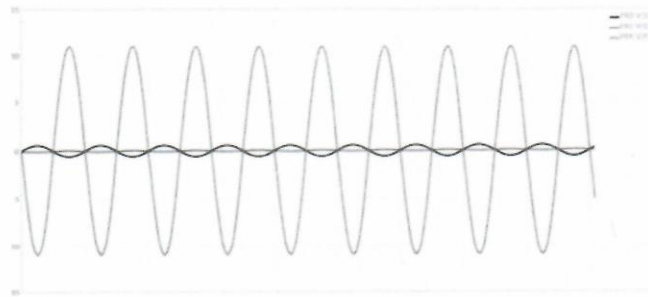


Figure 4: Multisim Waveform

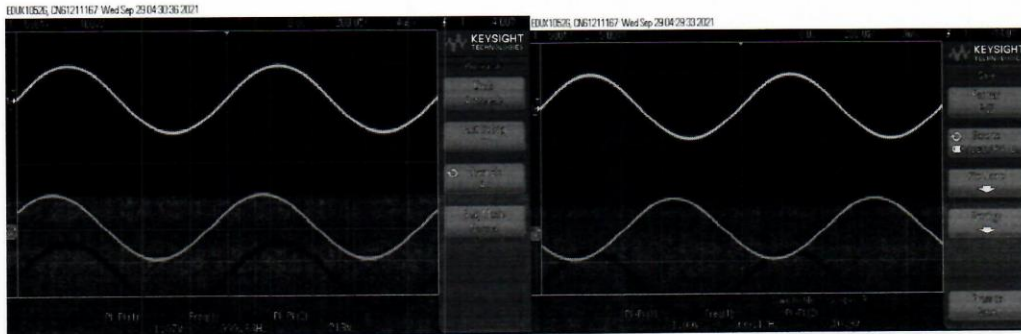


Figure 5: Waveforms for first and second gate

Conclusion:

In this lab, we constructed an Instrumentation Amplifier circuit. We successfully designed the circuit such that A_d was equal to 110 V/V and our resistor values were $R_1 = 2\text{ k}\Omega$, $R_2 = 10\text{ k}\Omega$, $R_3 = 1\text{ k}\Omega$, and $R_4 = 10\text{ k}\Omega$. These values aligned with our simulation as well as our breadboard measurements through the oscilloscope. The input and output signals were directly in phase with one another. By successfully implementing the instrumentation amplifier, we were able to complete all sections of the lab and learn another circuit configuration.

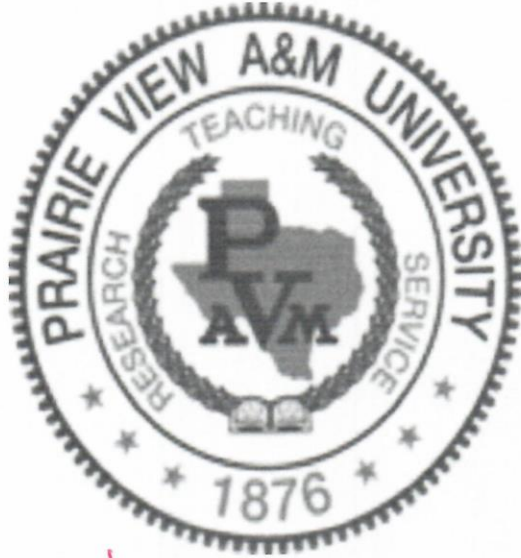
*Comparison
Discussion?*

Lab 3 Report

ABOVE AVERAGE

(Note: All Pages shown in Light Blue should be printed on Light Blue Paper)

**ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



95
Excellent

401

ELEG 3304: Electronics I Lab
Fall 2021

Lab Report 3:
Active Band-Pass Filter

Ben Nguyen ✓
Abel Mendoza ✓

Submitted on:
October 12th

To:
Dr. Mohan Ketkar

Objective

This lab was done in order to implement inverting op-amp, lossy integrator and differentiator circuits to form an active band-pass filter with the low cutoff frequency of 80 Hz and high cutoff frequency at 14k Hz.

Expectations

Lab participants need to follow the procedure for each specified configuration, calculate components values, build a physical circuit on the breadboard, perform measurement, build a simulating circuit on a virtual software, comparing the results, and conduct a formal lab report.

Equipment

- Breadboard (Model: NI-ELVIS)
- Color coded Jumper leads
- Multimeter
- Keysight Digital Storage Oscilloscope (Model: EDUX1052G)
- KeySight Waveform Generator (Model: EDU33212A)
- Resistors
- Capacitors
- LM741 Chip

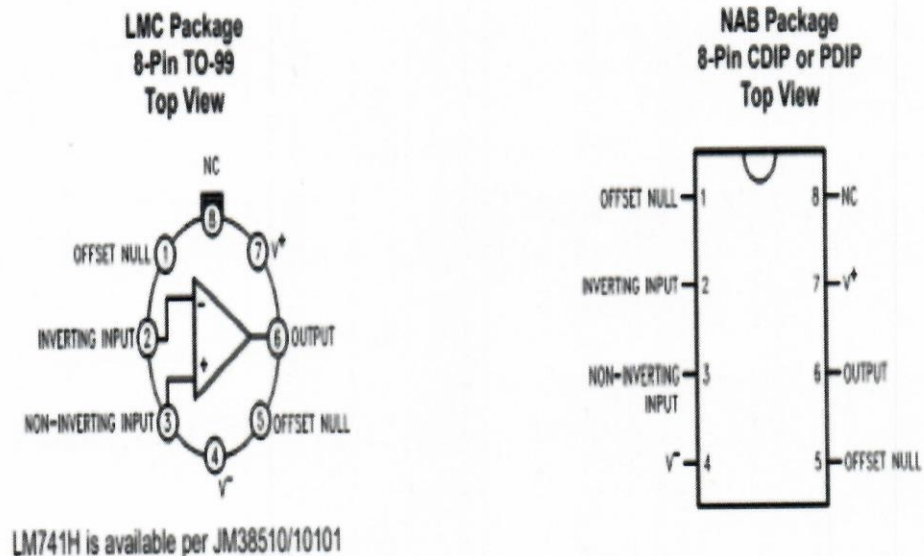


Figure 1: LM741 Operational Amplifier Pin Configuration

Procedure

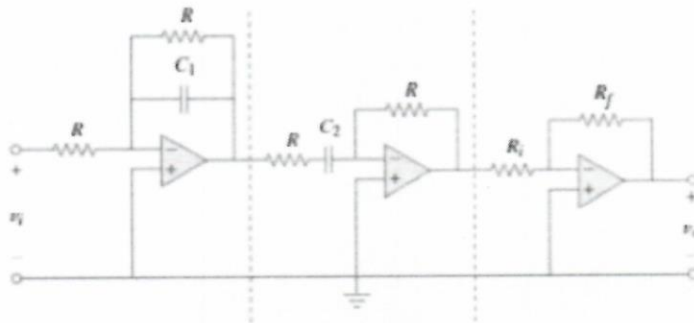


Figure 2: Active Band-pass Filter Schematic

Engineering Village
Band pass filter
R of value $10k\Omega$
gain of 10

80 Hz
14 kHz

Knovel

$$\omega_2 = \frac{1}{R \cdot C_1}$$

$$\omega_1 = \frac{1}{R \cdot C_2}$$

$$K = \frac{R_f}{R_i} \cdot \frac{\omega_2}{\omega_1 + \omega_2}$$

$$2\pi \cdot f = \frac{1}{R \cdot C_1}$$

$$f = \frac{1}{R \cdot C_1 \cdot 2\pi}$$

$$\omega_2 = \frac{1}{R \cdot C_1} = \frac{1}{10 \times 10^3 \cdot C_1} = 80 \times 2\pi$$

$$\Rightarrow C_1 = \frac{1}{10 \times 10^3 \cdot 80 \times 2\pi} = 198.94 \text{ nF}$$

$$\omega_1 = \frac{1}{R \cdot C_2} = \frac{1}{10 \times 10^3 \cdot C_2} = 14 \times 10^3$$

$$= C_2 = \frac{1}{10 \times 10^3 \cdot 14 \times 10^3 \cdot 2\pi} = 1.136 \text{ nF}$$

Figure 3: Hand Calculation to Size Capacitors

By following the schematic using (3) LM741 chips and calculated capacitors, lab participants would build a circuit on the breadboard. In order to obtain the gain ratio of 10 V/V , V_f and V_i would be 10k and 1k ohm respectively. The **Figure 4** below would show the completed circuit.

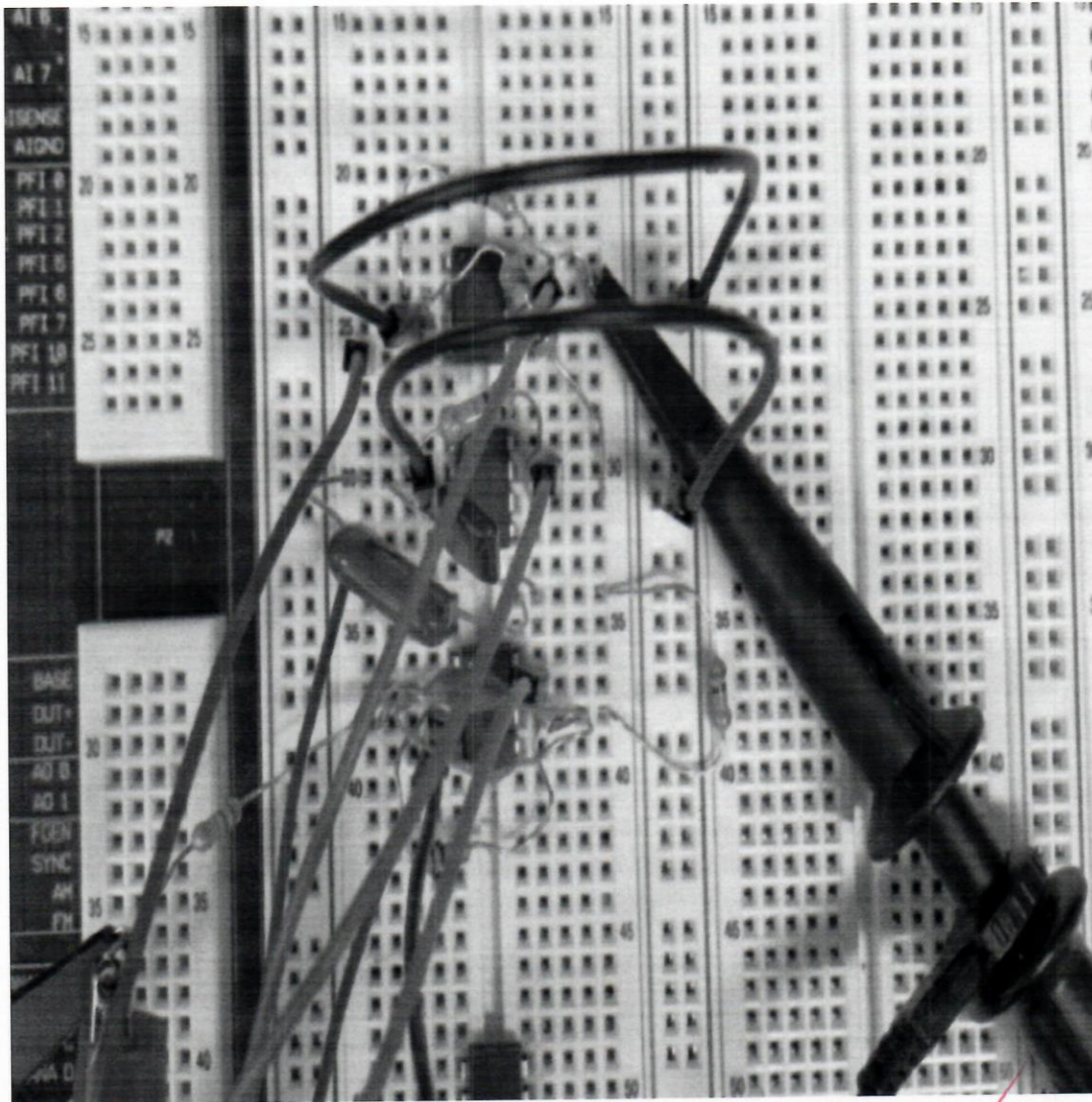


Figure 4: Physical Constructed Circuit

With the same schematic and components, lab participants would also need to construct a simulated circuit in Multisim to analyze and compare the data. **Figure 5** showed the circuit on Multisim.

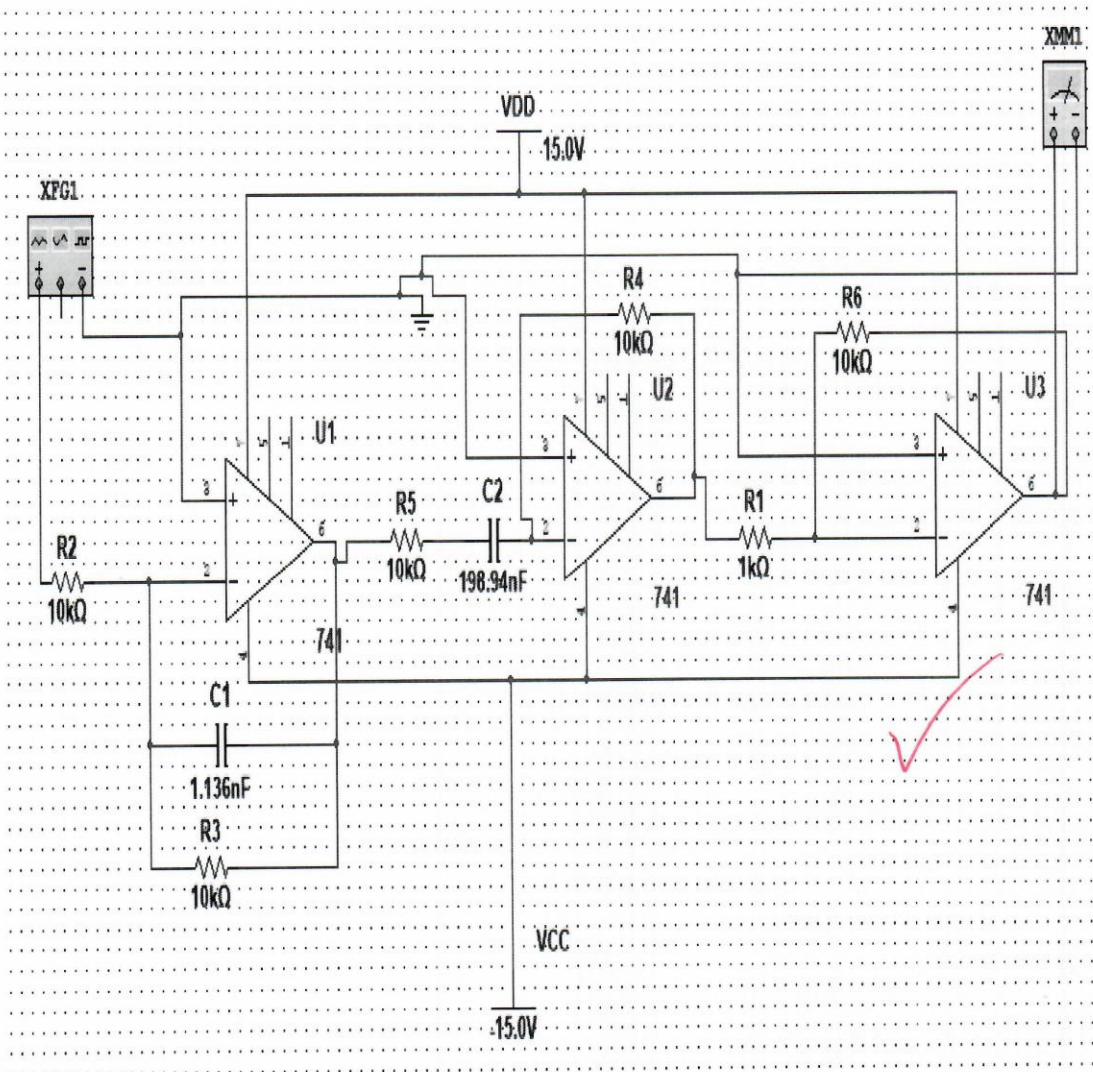


Figure 5: Circuit in Multisim

Experiment and Result

Since we did not have the exact capacitors' value, we used two different capacitors with the closest values that we could find in the lab. The first capacitor was measured to be 1.15 nF. The second capacitor was measured at 207.8 nF.

We then set the input signal with a magnitude of 50 mVpp into the circuit with 2 kHz. The maximum peak-peak voltage was read at 10.7 V. Thus, the cutoff voltages would be 0.7 of 10.7 Vpp at 7.5 Vpp. **Figure 6** and **Figure 7** below showed that 7.5 V peak-peak, we were at 78.235 Hz and 14k Hz respectively. We also tested the circuit with different frequencies, measured the peak to peak output voltages and came up with a table and graph. They would be shown below in **Table 1** and **Figure 8**.

Table 1: Frequency and Peak-peak Output Voltages

Frequency (Hz)	Measured Peak-Peak Output Voltage (V)
50	5.8
78	7.5
500	10.7
1000	10.7
3000	10.4
5000	9.9
10000	8.4
12000	8
14000	7.4
16000	6.9
20000	6

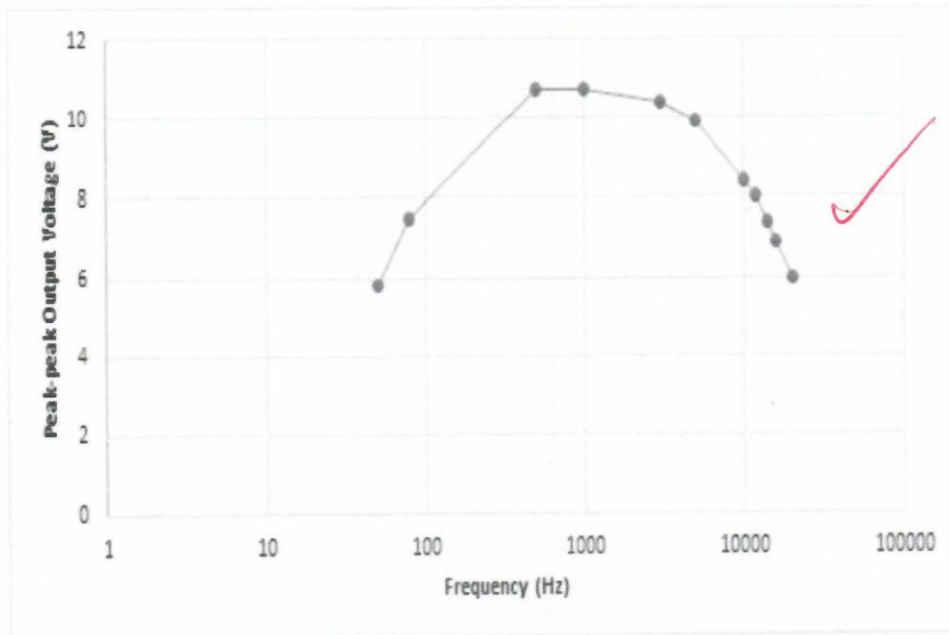


Figure 8: Frequency and Peak-peak Output Voltage Graph

In Multisim, we constructed a circuit with the same components values that we had in the lab. The magnitude of the input signal was set at 35 mV. We then measured the input voltage and output voltage. The maximum input voltage was read at 49.496 mV. The inverting op-amp would amplify the voltage to 496.96 mV. We would take 0.7×496.96 mV. As a result, the voltage at the cutoff frequencies would be expected to be at approximately 346.472 mV. On Multisim, the first cutoff frequency was estimated to be 72.15 Hz. The second cutoff frequency was approximated to be around 13810 Hz.

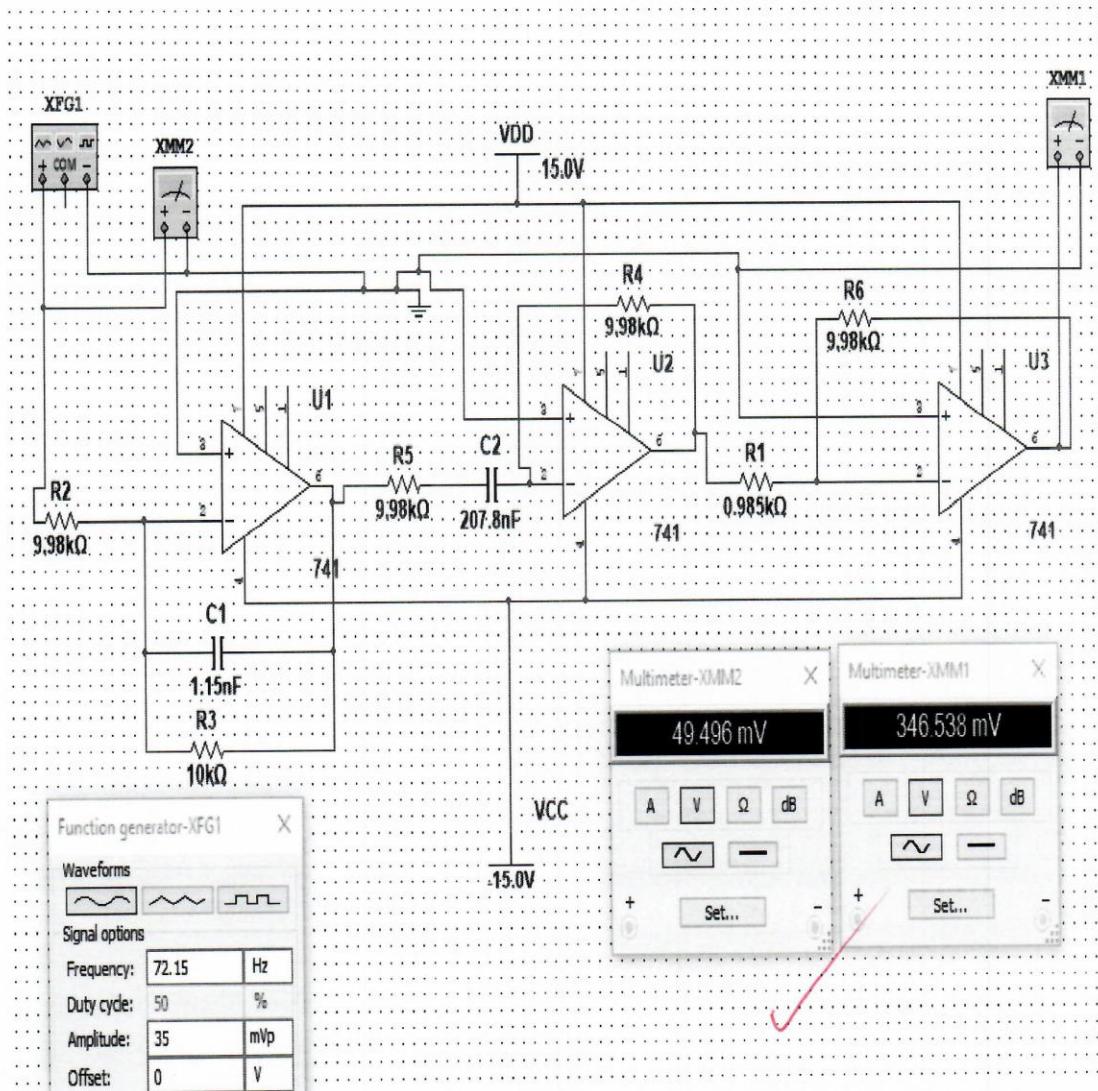


Figure 9: Measured Output Voltage at 72.15 Hz

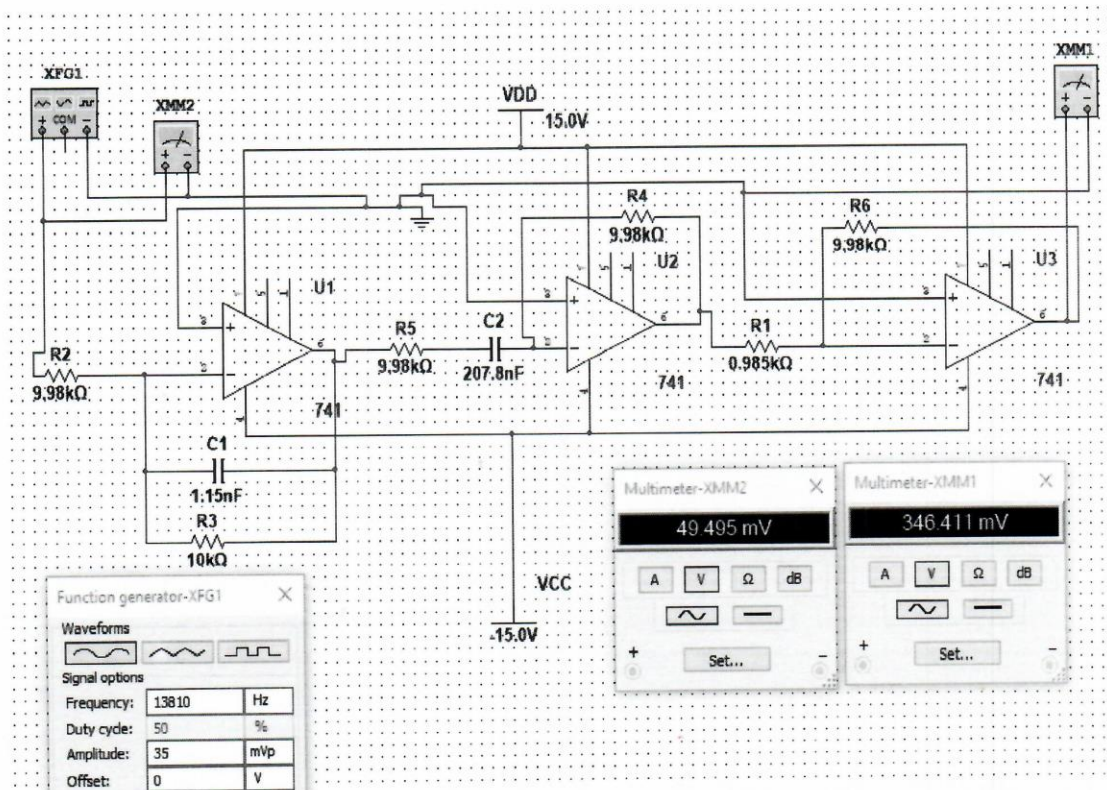


Figure 9: Measured Output Voltage at 13810 Hz

Discussion and Conclusion

Table 2: Actual and Theoretical Values

	Actual	Theoretical	Percent of Error
Ri	.985k ohm	1k ohm	1.5%
Rf	9.98k ohm	10k ohm	2%
C1	207.8 nF	198.9 nF	4.5%
C2	1.15 nF	1.136 nF	1.23%
1st Cutoff Frequency	78 Hz	80 Hz	2.5%
2nd Cutoff Frequency	14000 Hz	14000 Hz	0%

Since we did not obtain exact values for the capacitors. We had to find the closest values that we could get in the lab. As a result, it created some percentage of error. We also re-measured

the resistors. They also produced a small difference with the theoretical values. We would have gotten more accurate results if the components were at their actual values. With a small percent of error, our data would be within the acceptable range.

The circuit operated as we intended. A band-pass filter was created with two cutoff frequencies. As **Table 1** had shown, the peak to peak voltage was increasing as the frequency got larger. However, the voltage hit its maximum at a range of frequencies. Then, it started decreasing at certain larger frequencies. Thus, the circuit created a band of frequencies that it allowed to have the maximum output voltages.

At the cutoff frequencies, we expected to get 70% of the maximum voltage. In our case, the maximum voltage was recorded to be 10.7 V peak to peak. Thus, the output voltage would be roughly at 7.49 V peak to peak. As **Figure 6** and **Figure 7** indicated, 78 Hz and 14k Hz were to be the cutoff frequencies.

Table 3: Actual and Multisim Values

	Actual	Multisim	Percent of Difference
Ri	.985k ohm	0.985k ohm	0%
Rf	9.98k ohm	9.98k ohm	0%
C1	207.8 nF	207.8 nF	0%
C2	1.15 nF	1.15 nF	0%
1st Cutoff Frequency	78 Hz	72.15 Hz	8.1%
2nd Cutoff Frequency	14000 Hz	13810 Hz	1.36%

In conclusion, in Multisim the maximum input voltage was recorded at 49.496 mV since we set our input signal of 35 mVp. The circuit would amplify the input voltage to 494.96 mV. Therefore, the voltages at the cutoff frequencies would be approximately at 346.472 mV. We tried to estimate the frequencies on Multisim. It turned out to be 72.15 Hz and 13810 Hz where we would get approximately 346.4 mV. In the past experiment, Multisim usually provided more accurate values. We got relatively low percentages of difference between actual and Multisim. The reason was that we were trying to estimate the frequencies on Multisim. We could not zero into the exact frequencies. Therefore, the values could have been closer to the values that we had on our physical circuit. It could have been the components value on our physical circuit that were not measured correctly. As a result, it led to the difference of the data.

AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
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Electronics Laboratory
ELEG 4101

Lab 3 ACTIVE BAND-PASS FILTER

Submitted by:
Trevor Johnson
Johnn Owens

Date of Submission: 10/12/2021
Date of Performance: 10/5/2021

Department of Electrical and Computer Engineering
Prairie View A&M University

Objective:

In this lab the students will design, build, and test an active band-pass filter circuit that will meet design specifications. Your design should be based on an active filter with a gain of 10. You will use following specifications assigned for each student. Use all R of value 10 k Ω . Band-pass filter for frequencies between 60Hz and 16kHz.

Introduction/Theory:

Band-pass filter, arrangement of electronic components that allows only those electric waves lying within a certain range, or band, of frequencies to pass and blocks all others. The circuit in Fig. 14.42 may be combined with that in Fig. 14.43 to form a bandpass filter that will have a gain K over the required range of frequencies. By cascading a unity-gain lowpass filter, a unity-gain high-pass filter, and an inverter with gain as shown in the block diagram of Fig. 14.44(a), we can construct a bandpass filter whose frequency response is that in Fig. 14.44(b). The actual construction of the bandpass filter is shown in Fig. 14.45

Equipment:

- Laboratory setup, including breadboard
- 1 741-type operational amplifier
- Several wires
- Resistors and capacitors of varying sizes

Procedure:

Steps:

1. Design the circuit and specify the components values.
2. Verify your design using Multisim.
3. Build the circuit using available components closest to design values.
4. Measure and record the gain-frequency response.
5. Your Lab Report #3 should have following sections: a. Introduction b. Circuit Design c. Develop Experiment to Test Designed circuit d. Conduct Experiment e. Analysis and interpretation of Experimental Results f. Discussion of Results g. Conclusions
6. Upload your lab report on canvas individually.

Circuit Diagram:

Figure 14.44

Active bandpass filter: (a) block diagram, (b) frequency response.

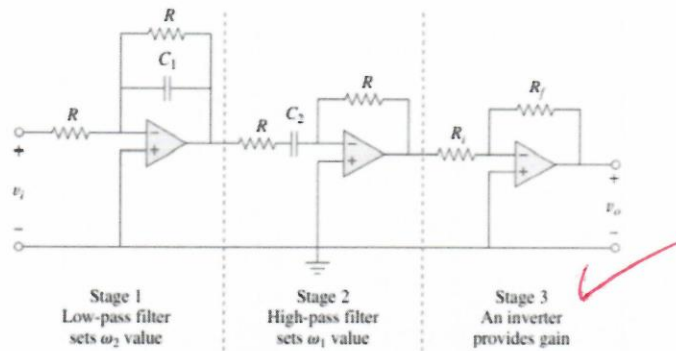


Figure 14.45

Active bandpass filter.

Solution:

Given: Active filter with a gain of 10
All resistors (R) of value 10 k Ω
Band-Pass Filter for frequencies between 60 Hz and 16 kHz
 $f_c = 60 \text{ Hz} = 0.06 \text{ kHz}$, $f_u = 16 \text{ kHz}$ and $R = 10 \text{ k}\Omega$

Bandwidth (B) = $\omega_u - \omega_c$

$$B = 2\pi (f_u - f_c)$$

$$B = 2\pi (16 \times 10^3 - 0.06 \times 10^3)$$

$$B = 2\pi (1.5940 \times 10^4)$$

$$B = 2\pi \times 15940 = 100.15397 \text{ krad/sec}$$

$$\text{Band width (B)} = \frac{f}{L} \Rightarrow L = \frac{f}{B}$$

$$L = \frac{10 \times 10^3}{100.15397} = 0.09985 \text{ H}$$

$$\text{Resonant frequency } (\omega_0) = \sqrt{\omega_c \omega_u}$$

$$\omega_0 = \sqrt{2\pi f_c \times 2\pi f_u}$$

$$= \sqrt{(2\pi \times 0.06 \times 10^3) \times (2\pi \times 16 \times 10^3)}$$

$$= 456.239 \text{ k rad/sec}$$

$$C_1 = \frac{1}{2\pi f_c L} = \frac{1}{2\pi (60)(10)} = 265 \text{ nF}$$

$$C_2 = \frac{1}{2\pi f_u L} = \frac{1}{2\pi (16 \times 10^3)(10)} = 994 \text{ pF}$$

Figure 1: Hand Calculations

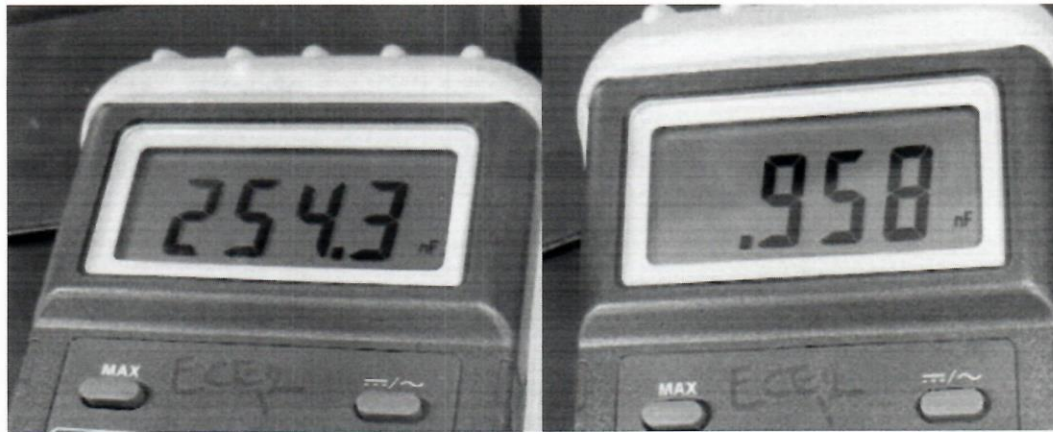


Figure 2: Capacitor Values on Multimeter

Data and Result:

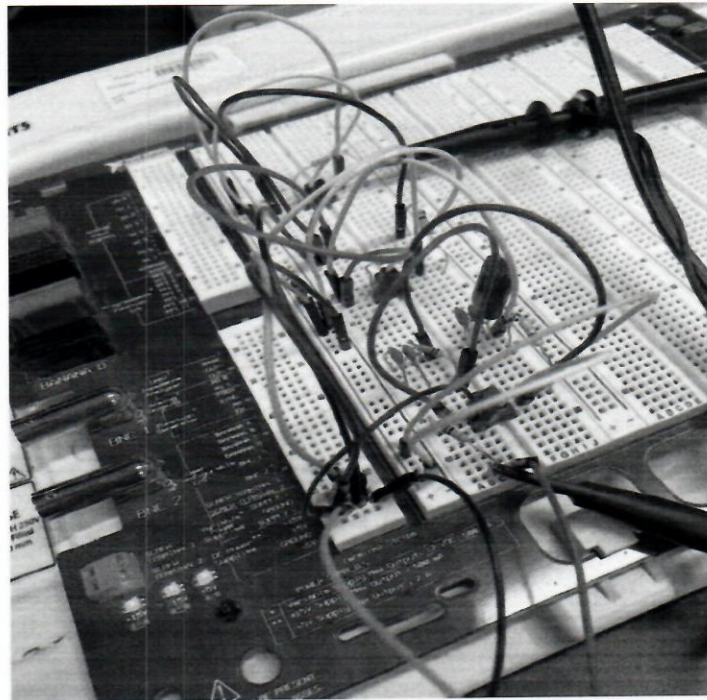


Figure 3: Completed Circuit Borad

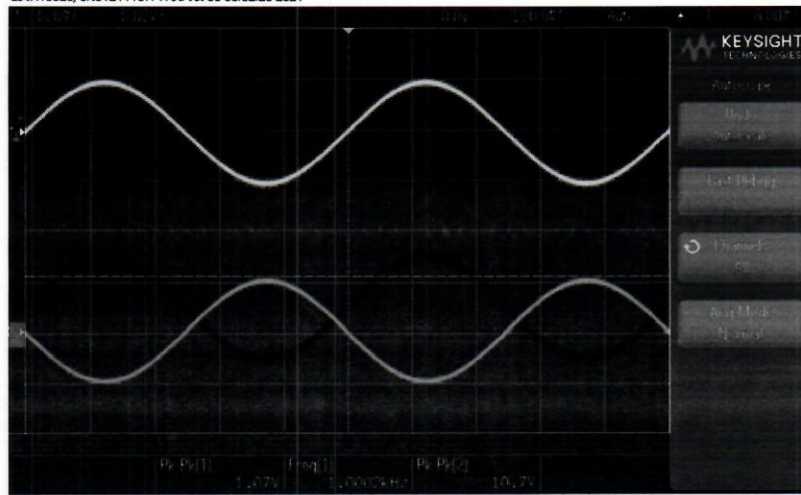


Figure 4: Oscilloscope Measurements

Conculsion:

In this lab we were able to successfully run our circuit, constructing Lab #3 Active Band- Pass Filter. We were able to calculate the two resistors and capacitor that needed to have a voltage gain of 10 V/V. We reached our desired results by assigning values as such: R_1 , R_2 , R_3 , and $R_4 = 10 \text{ k}\Omega$ and our Band-pass filter for frequencies between 60 Hz and 16 kHz. We then had to figure out what exact capacitor we need to complete the circuit board. We searched through many capacitors that the instructor offered and measured them on the multimeter until we found are calculated measurements shown in Figure 2. Once the hardware circuit was complete, we were able to measure it with the oscilloscope shown in Figure 4. The input and output signals were not in phase with one another. In the experiment, we were able to complete the lab and familiarize ourselves with active band-pass filters. Overall, we successfully finished the lab and gain valuable knowledge.

*Detailed
Measurements
& freq plots?*

BELOW AVERAGE

Electronics 1 Laboratory 3
ELEG 4101

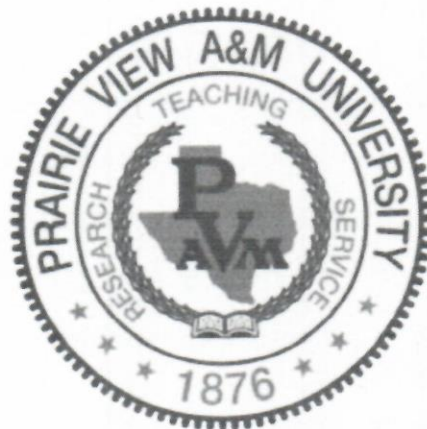
Names: Eric Anumnu, Teminioluwa Folorunso, Breon Holmes

Date of Submission: 10/12/2021

Date of Performance: 10/05/2021

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Department of Electrical and Computer Engineering
Prairie View A&M University



Objectives:

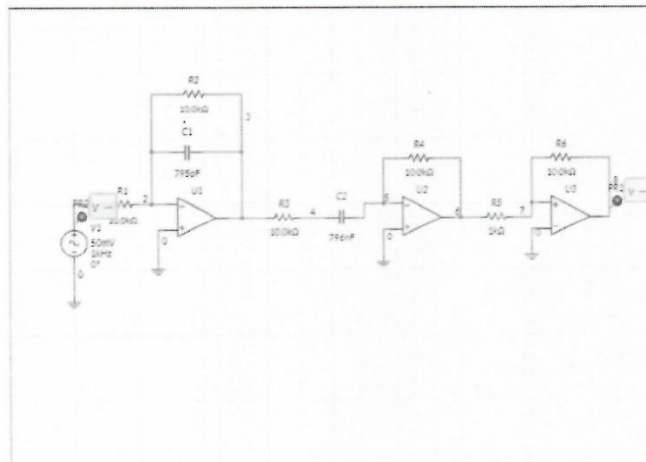
In this lab we designed, built and tested an active band-pass filter circuit. The design should be based on an active filter with a gain of 10. Our design specifications were a band pass filter for frequencies between 20Hz and 20kHz.

**Equipment Used:**

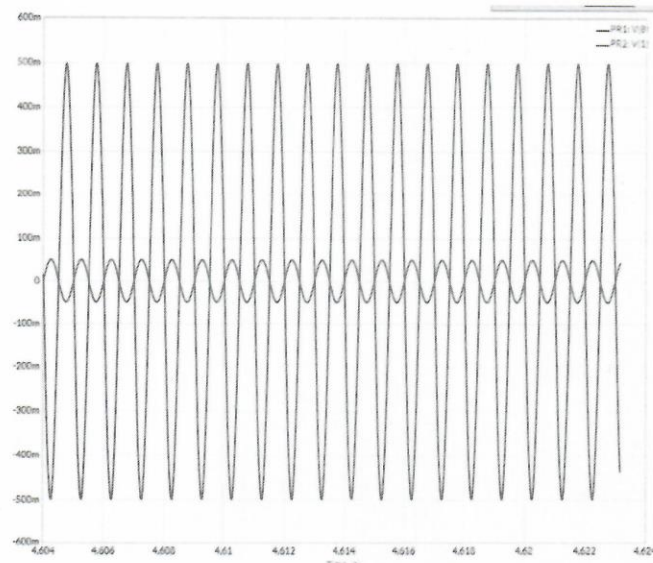
- 1) Laboratory set up, including breadboard
- 2) 1 482-type operational amplifier
- 3) Several wires and resistors of various sizes
- 4) Capacitors of various sizes

Procedure:

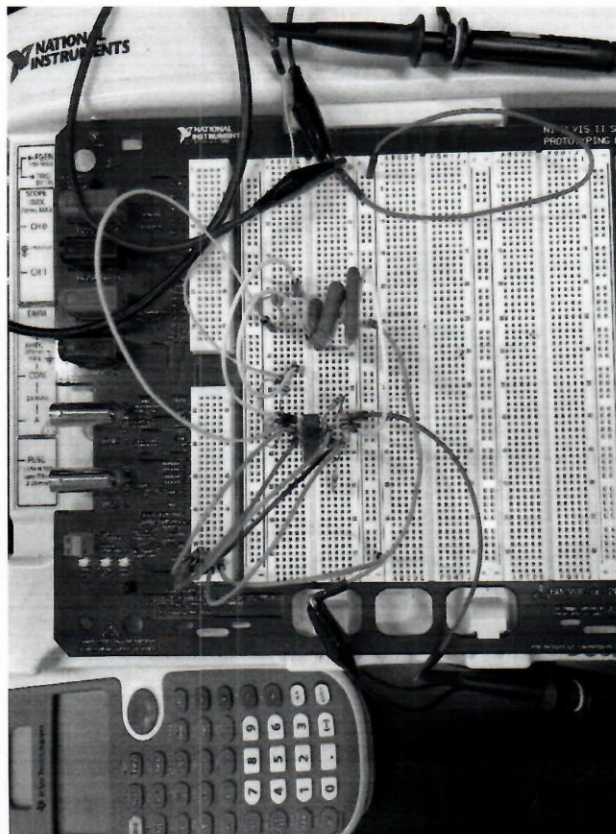
- 1) Complete pre-lab by finding the values of the capacitors to be used.
- 2) Simulate circuit on multisim.
- 3) Build the circuit on the bread board.
- 4) Measure and record the gain-frequency response.

Results:

(Circuit Built in simulation)



(Waveform Generated in simulation)



(Circuit as built on breadboard)

Lab #3

Band-pass Filter for frequencies between 20Hz and 20KHz
 $R = 10K\Omega$

$$S_1 = 20Hz, S_2 = 20KHz, R = 10K\Omega$$

$$B = \omega_H - \omega_L$$

$$B = 2\pi(S_H - S_L)$$

$$= 2\pi(20 \times 10^3 - 20) = 125.538 \text{ Krad/sec}$$

$$\omega_0 = \sqrt{2\pi S_L \times 2\pi S_H} = \sqrt{2\pi(20) \times 2\pi(20 \times 10^3)} = 3.973 \text{ Krad/sec}$$

$$B = \frac{R}{L} \Rightarrow L = \frac{R}{B} = \frac{10 \times 10^3}{125.538 \times 10^3} = 0.0796 \text{ H}$$

$$\frac{(\omega_0)^2}{LC} = 1 \Rightarrow C = \frac{1}{\omega_0^2 L} = \frac{1}{(3.973 \times 10^3)^2 (0.0796)} = 796 \text{ nF}$$

$$C_1 = \frac{1}{2\pi f_1 R_1} = \frac{1}{2\pi(20Hz)(10K)} = 796 \text{ nF} \quad (\text{Practical } 795 \text{ nF})$$

$$C_2 = \frac{1}{2\pi f_2 R_2} = \frac{1}{2\pi(20K)(10K)} = 795 \text{ pF} \quad (\text{Practical } 79 \text{ pF})$$

* Had to use multiple capacitors

(Pre-lab hand calculations)

Conclusion:

In conclusion we were not able to complete the lab this week. We followed the procedure and were able to simulate it on multism. We followed the procedure and was verified by the professor saying our circuit was correct. Our hypothesis was either our chip was dysfunctional, or our resistors and capacitors were too close together thus creating a short in the circuit. This lab was a learning experience in working fast in lab to come up with a concrete solution.

No actual measurements