Lab 4: Operational Amplifiers Part 2

ECEN 325 - 511

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Date Performed: October 5, 2021

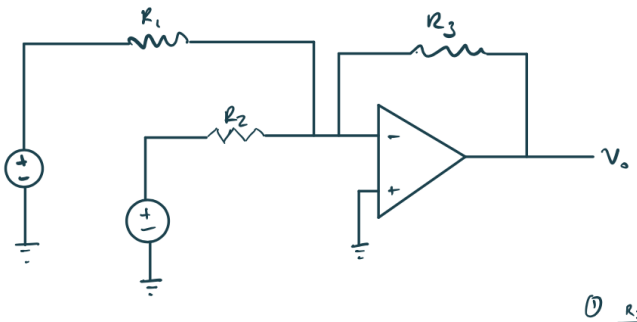
Due Date: October 12, 2021

Purpose

The purpose of this lab was to be able to learn the different types of advanced op-amp configurations. Students will learn about summing, differential, and instrumentation amplifiers through measurements, calculations, and simulations.

Calculations

1)



$R_3 = 15k\Omega$

$V_o = -\left(\frac{R_3}{R_1}V_{i1} + \frac{R_3}{R_2}V_{i2}\right)$

$V_o = -\left(V_{i1} + 2V_{i2}\right)$

① $\frac{R_3}{R_1} = 1$ ② $\frac{R_3}{R_2} = 2$

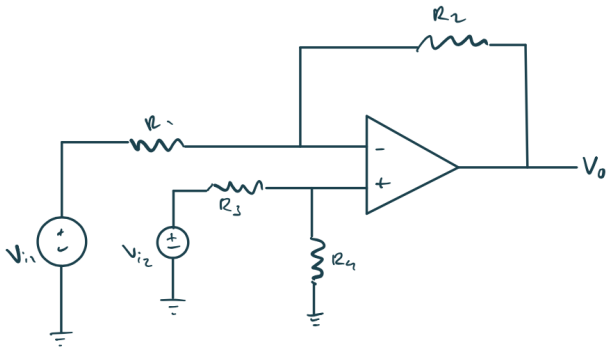
① $\frac{R_3}{R_2} = 1$ $\frac{15k\Omega}{R_1} = 1$

$R_1 = 15k\Omega$

$\frac{R_3}{R_2} = 2$ $\frac{15k\Omega}{R_2} = 2$

$R_2 = 7.5k\Omega$

2)



$\frac{R_2}{R_1} = \frac{R_4}{R_3}$

so $R_3 = R_4 = R_2 = 10k\Omega$

$V_o = \frac{R_2}{R_1}\left(V_{i2} - V_{i1}\right)$

to get $V_o = V_{i2} - V_{i1}$

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

$10k\Omega = R_1$

$R_1 = 10k\Omega$

3) for instrumental amplifier,

$$V_o = \left(1 + \frac{2R}{R_{gain}}\right)(V_{i2} - V_{i1})$$

$$V_o = 3(V_{i2} - V_{i1}), \quad R_{gain} = 1k\Omega$$

so $$3 = 1 + \frac{2R}{R_{gain}}$$

$$3 = 1 + \frac{2R}{1k\Omega}$$

$$2 = \frac{2R}{1k\Omega}$$

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

4) Here $V_{i1} = 0.2\sin(2\pi 1000t)$

$V_{i2} = 0.8V$

summing amplifier: $V_o = -(V_{i1} - 2V_{i2})$

$$V_o = -(0.2\sin(2\pi 1000t) + (2)(0.5))V$$

$$\boxed{V_o = -(0.2\sin(2\pi 1000t) + 0.6)V}$$

differential amplifier: $V_o = V_{i2} - V_{i1}$

$$\boxed{V_o = 0.3V - 0.2\sin(2\pi 1000t)V}$$

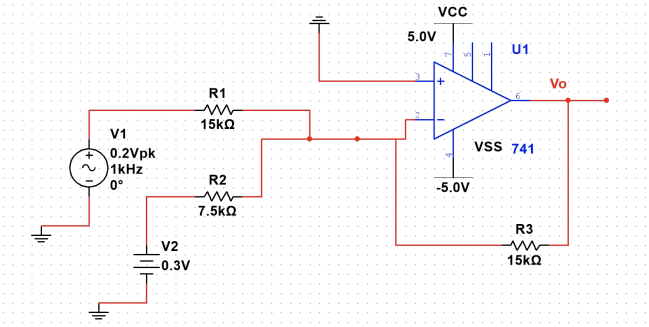
instrumentation amplifier: $V_o = 3(0.3V - 0.2\sin(2\pi 1000t))V$

$$\boxed{V_o = 0.9V - 0.6\sin(2\pi 1000t))V}$$

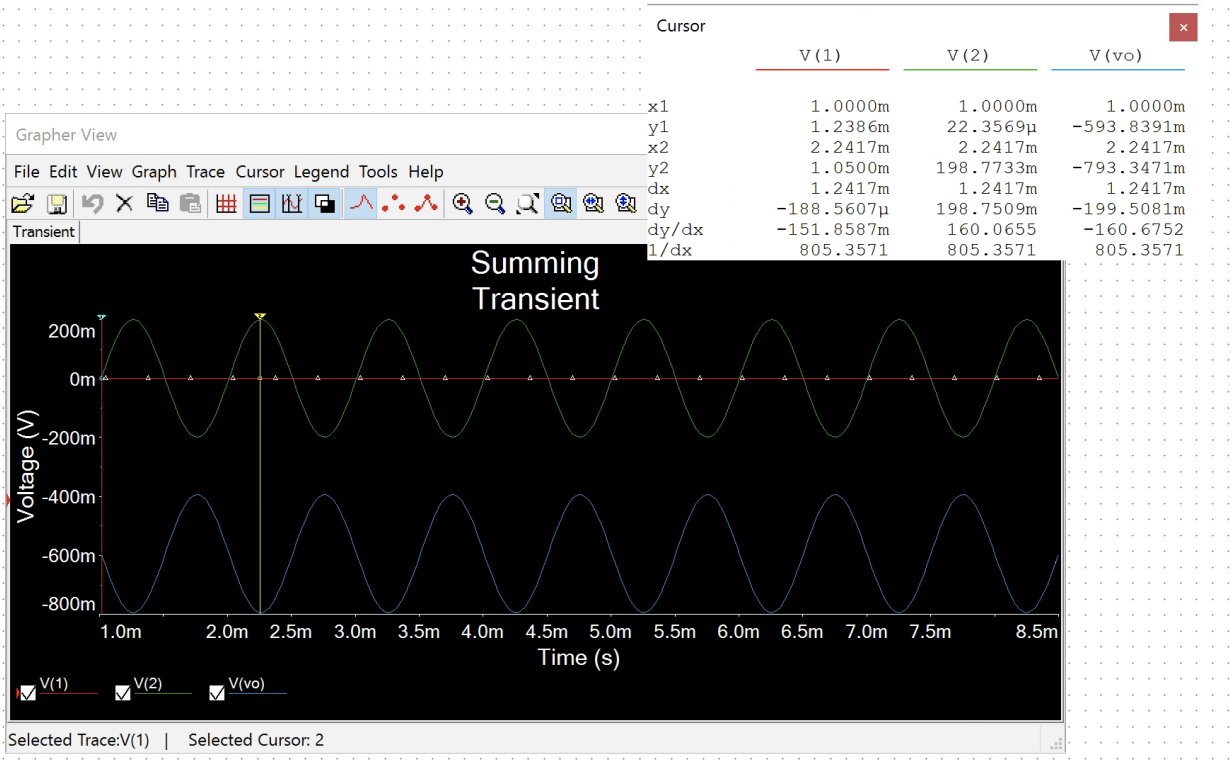
Simulations (on Multisim)

Summing Amplifier

1. ***Schematic***

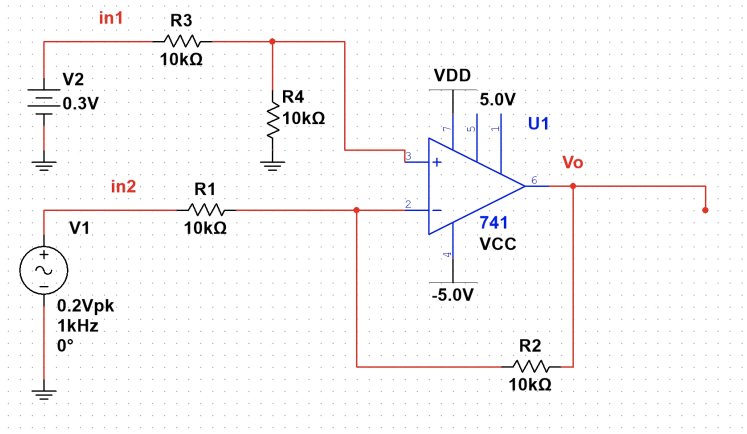


2. ***Transient***

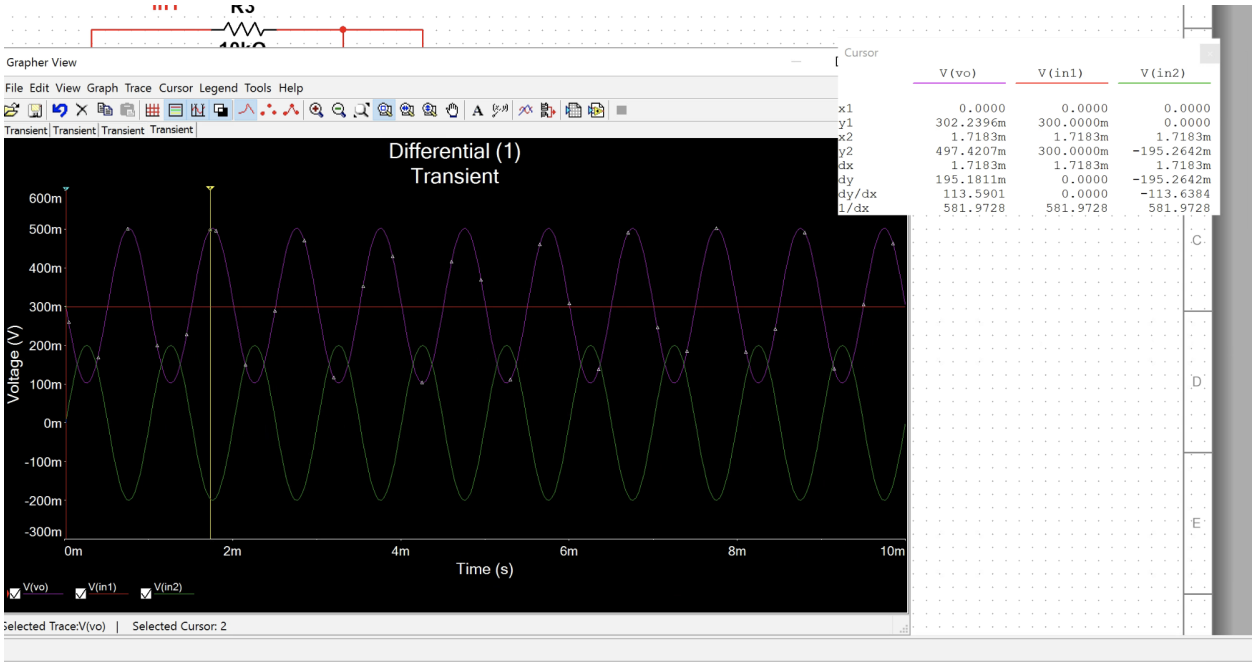


Differential Amplifier

1. *Schematic*

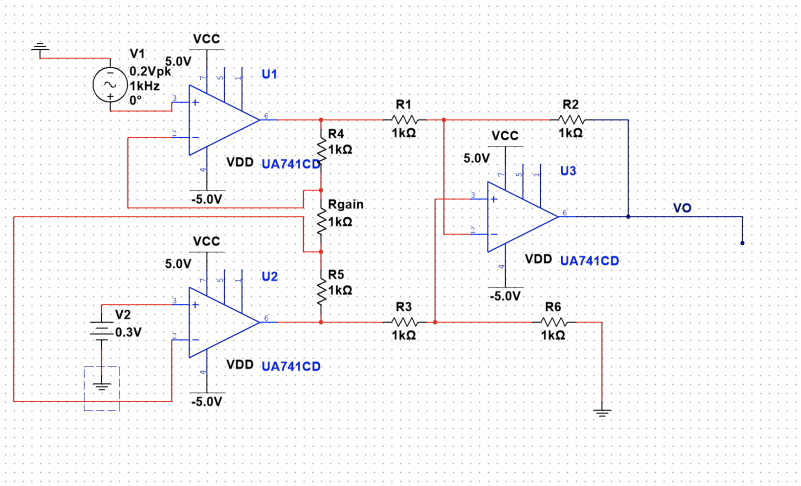


2. *Transient*

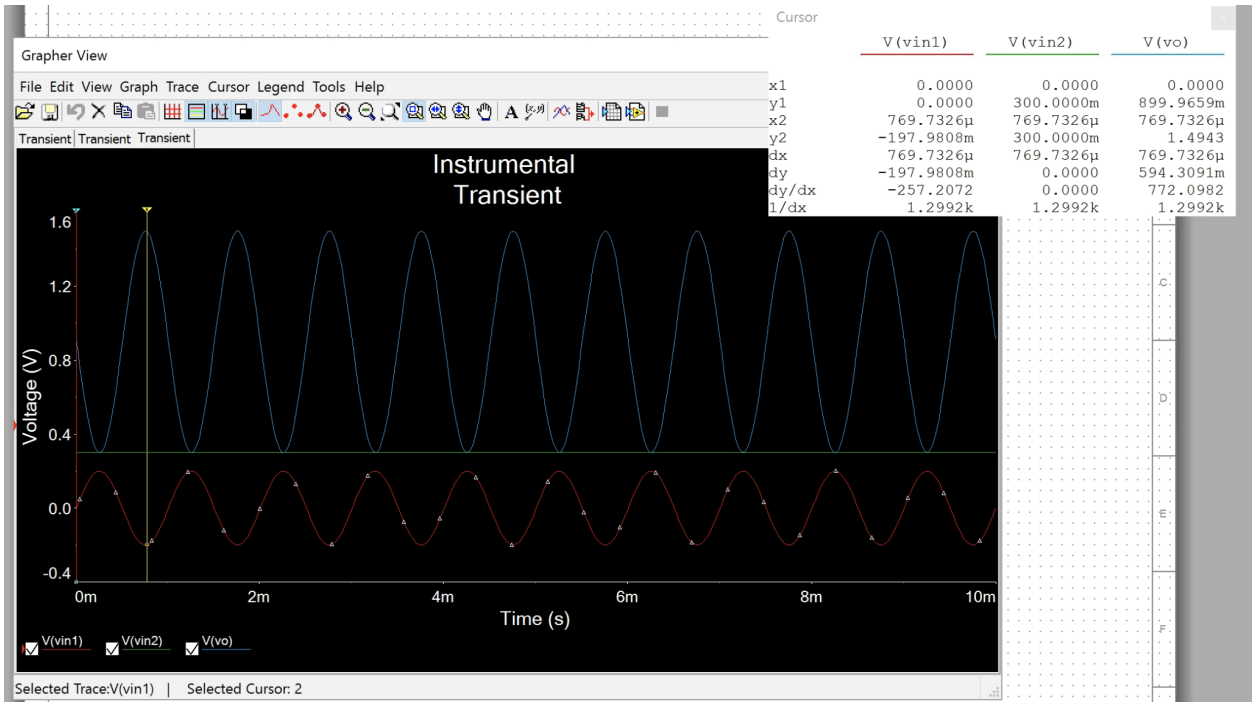


Instrumentation Amplifier

1. *Schematic*



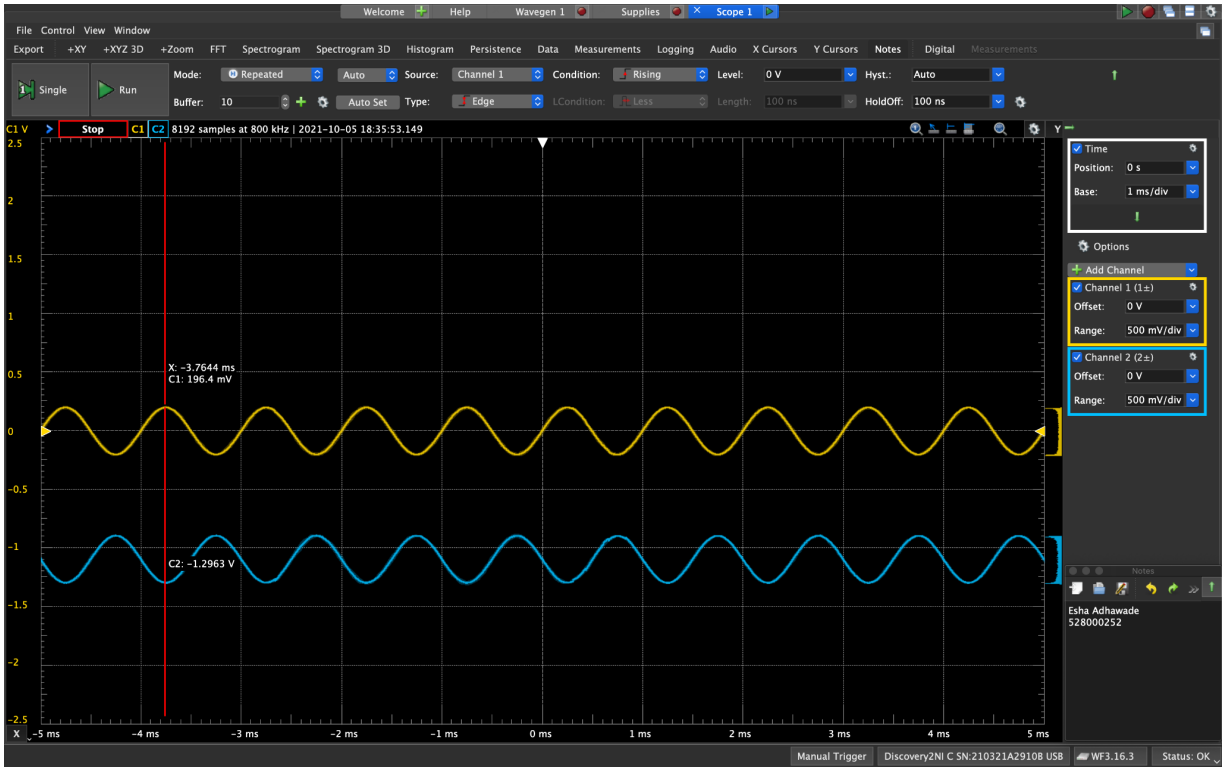
2. *Transient*



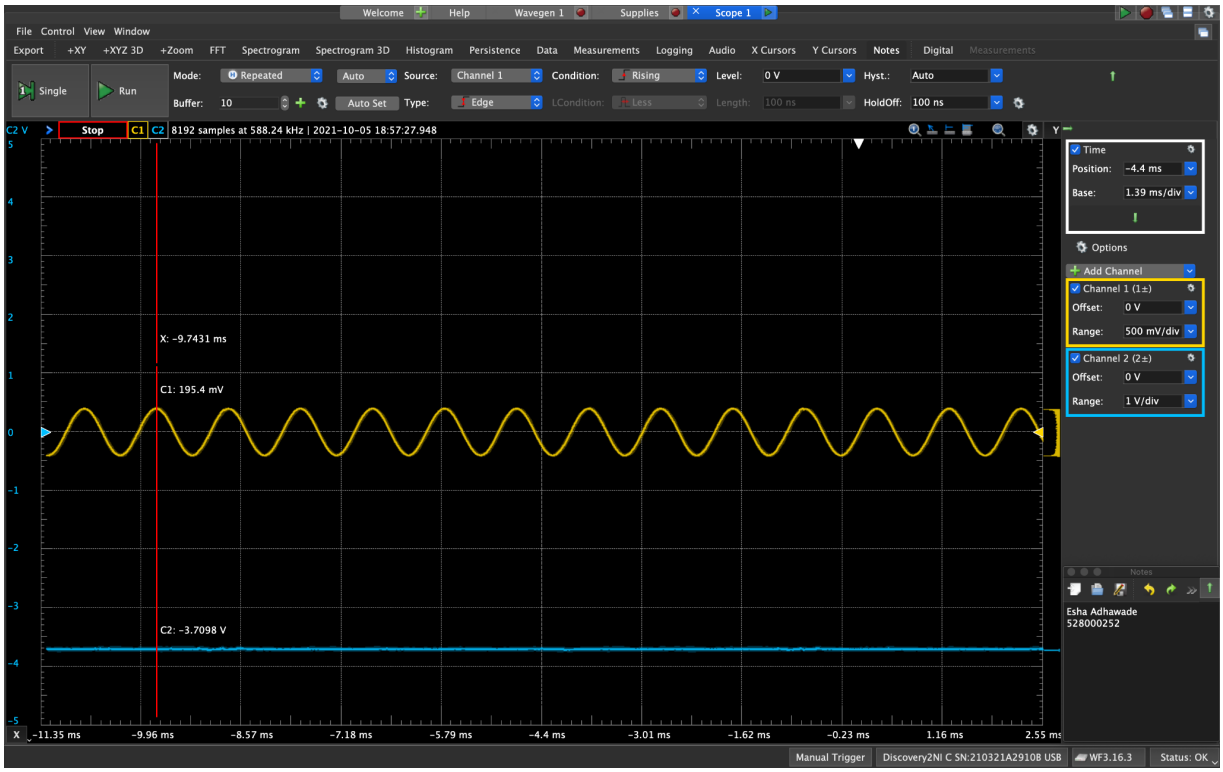
Measured Waveforms

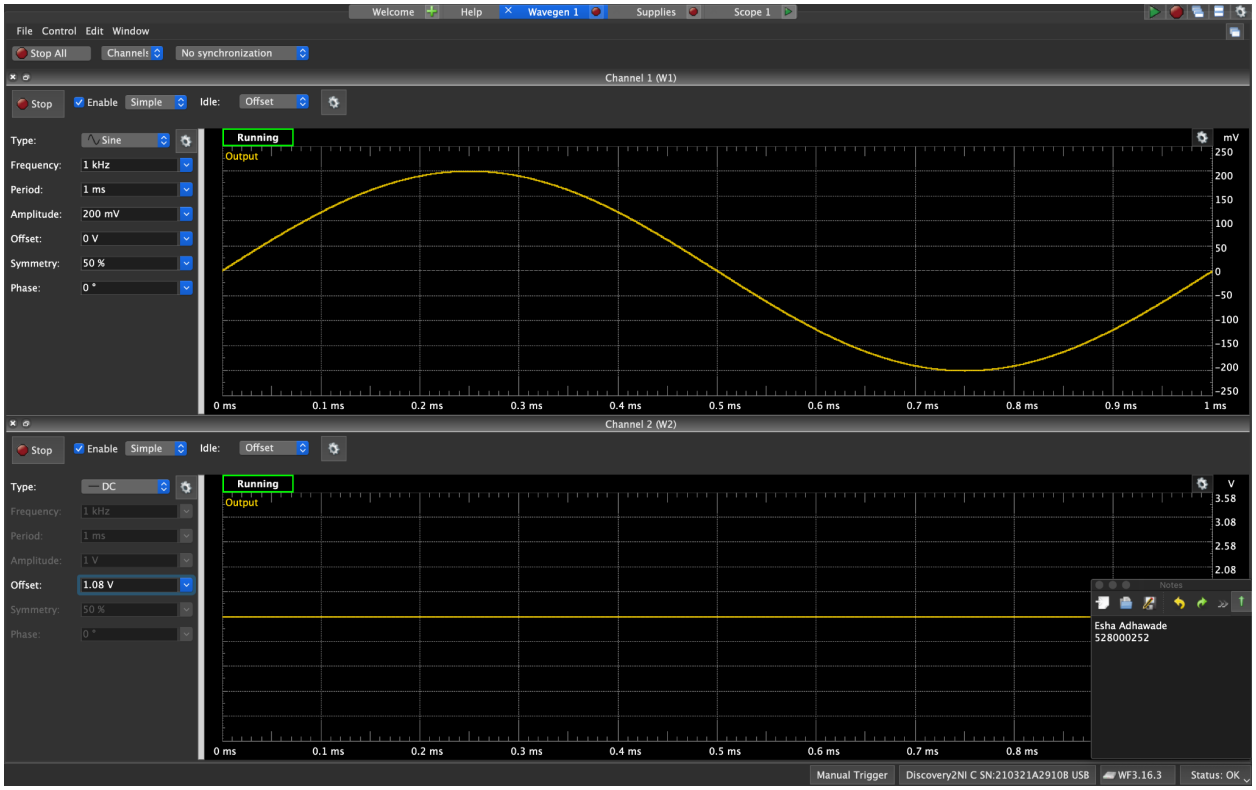
Summing Amplifier

Time Domain



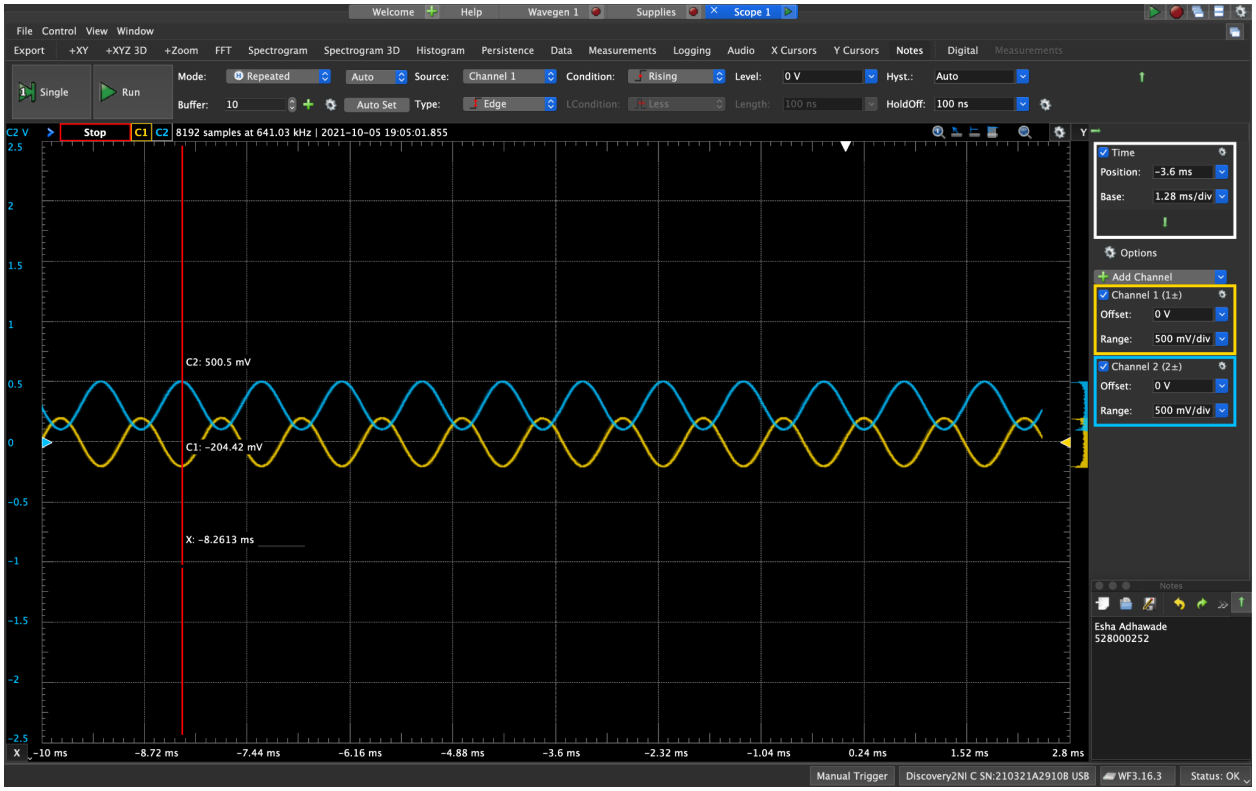
Clipping - (1.08V)



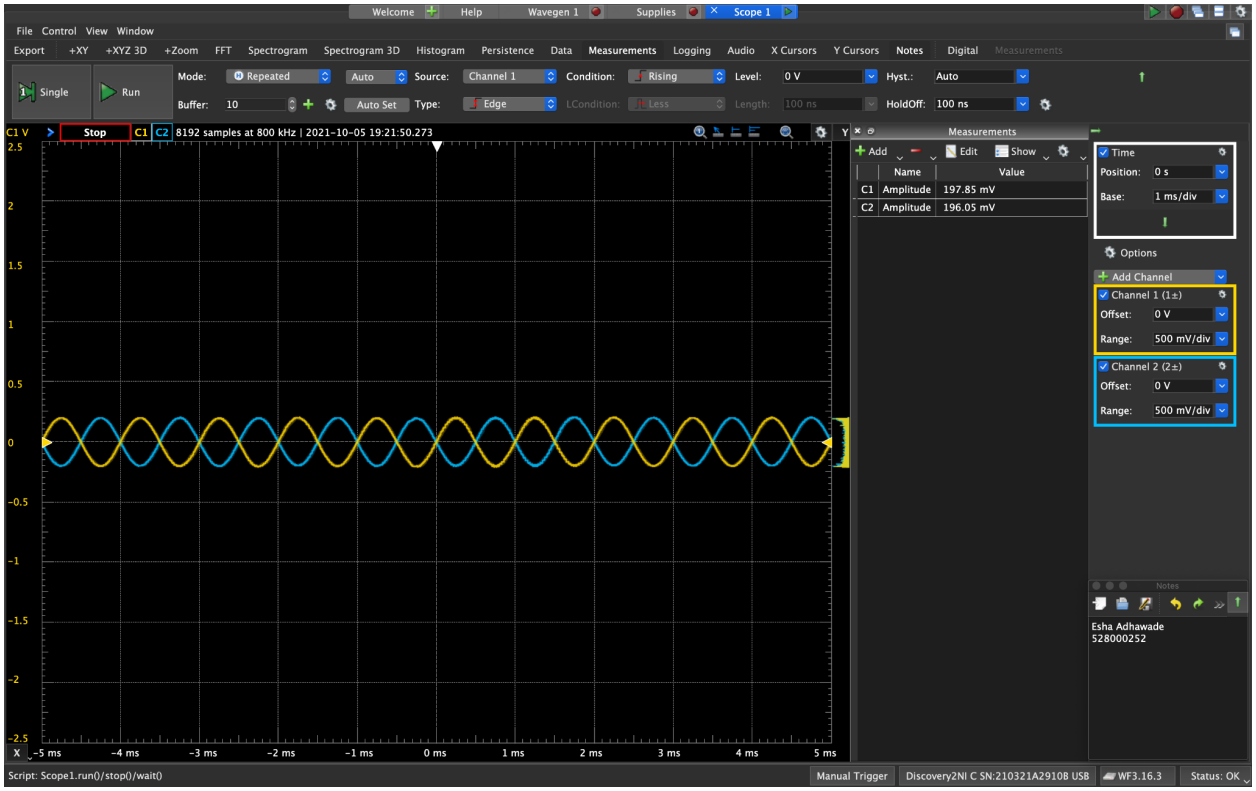


Differential Amplifier

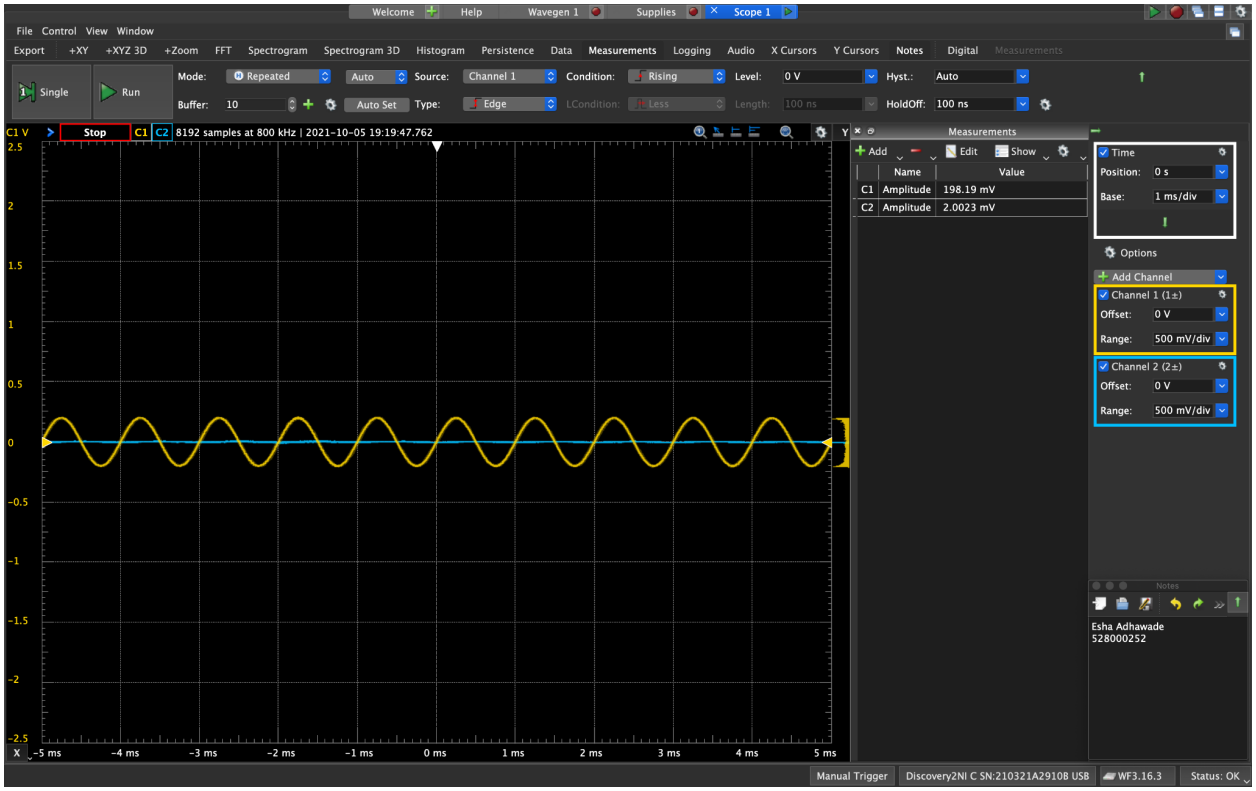
Time Domain



ADM

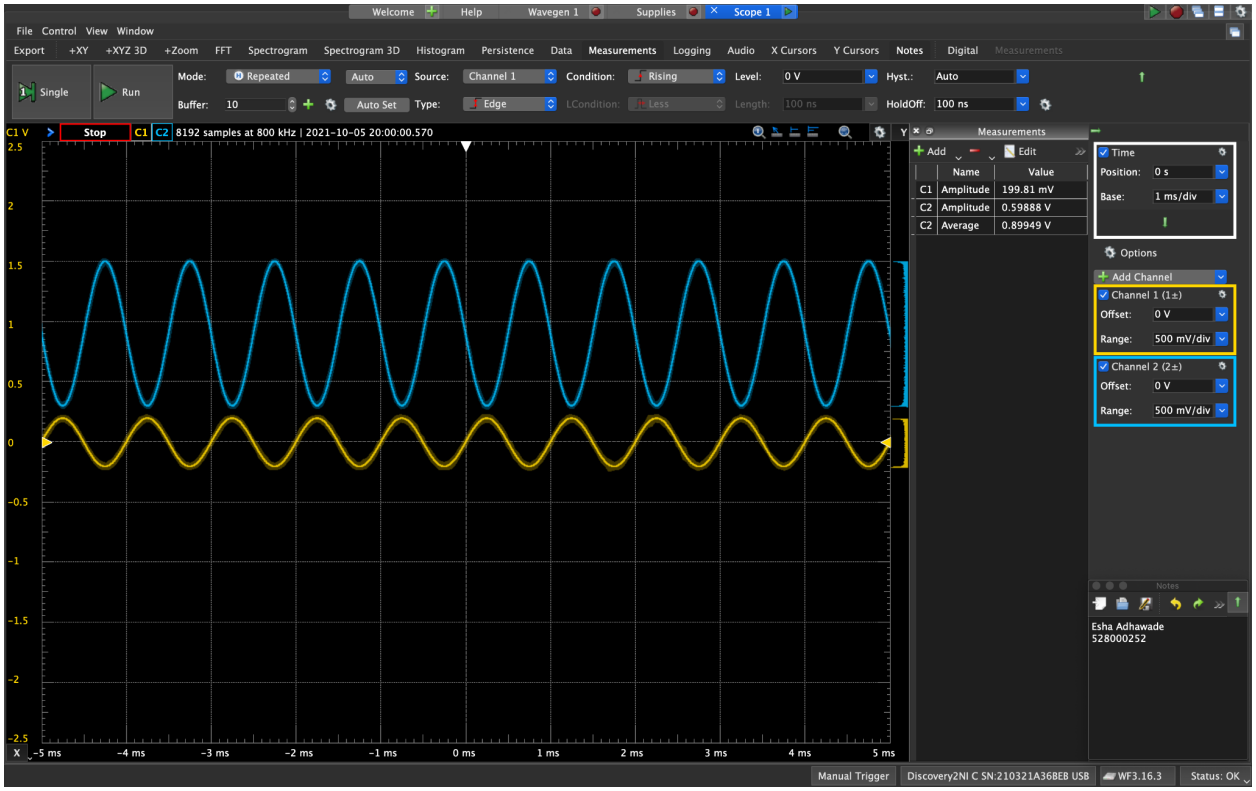

Welcome
Help
Wavegen 1
Supplies
Scope 1
File Control View Window
Export +XY +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Data Measurements Logging Audio X Cursors Y Cursors Notes Digital Measurements
Single
Run
Mode: Repeated
Auto
Source: Channel 1
Condition: Rising
Level: 0 V
Hyst.: Auto
Buffer: 10
Auto Set
Type: Edge
LCondition: Less
Length: 100 ns
HoldOff: 100 ns
C1 V
Stop
C1 C2 8192 samples at 800 kHz | 2021-10-05 19:21:50.273
Measurements
Add Edit Show
Name Value
C1 Amplitude 197.85 mV
C2 Amplitude 196.05 mV
Time
Position: 0 s
Base: 1 ms/div
Options
Add Channel
Channel 1 (1±)
Offset: 0 V
Range: 500 mV/div
Channel 2 (2±)
Offset: 0 V
Range: 500 mV/div
Notes
Esha Adhawade
528000252
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
X -5 ms -4 ms -3 ms -2 ms -1 ms 0 ms 1 ms 2 ms 3 ms 4 ms 5 ms
Script: Scope1.run()/stop()/wait()
Manual Trigger
Discovery2NI C SN:210321A2910B USB
WF3.16.3
Status: OK

ACM


Welcome
Help
Wavegen 1
Supplies
Scope 1
File Control View Window
Export +XY +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Data Measurements Logging Audio X Cursors Y Cursors Notes Digital Measurements
Single
Run
Mode: Repeated
Auto
Source: Channel 1
Condition: Rising
Level: 0 V
Hyst.: Auto
Buffer: 10
Auto Set
Type: Edge
LCondition: Less
Length: 100 ns
HoldOff: 100 ns
C1 V
Stop
C1 C2 8192 samples at 800 kHz | 2021-10-05 19:19:47.762
Measurements
Add Edit Show
Name Value
C1 Amplitude 198.19 mV
C2 Amplitude 2.0023 mV
Time
Position: 0 s
Base: 1 ms/div
Options
Add Channel
Channel 1 (1±)
Offset: 0 V
Range: 500 mV/div
Channel 2 (2±)
Offset: 0 V
Range: 500 mV/div
Notes
Esha Adhawade
528000252
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
X -5 ms -4 ms -3 ms -2 ms -1 ms 0 ms 1 ms 2 ms 3 ms 4 ms 5 ms
Manual Trigger
Discovery2NI C SN:210321A2910B USB
WF3.16.3
Status: OK

Instrumentation Amplifier

Time Domain



Data Tables

Differential Amplifier

A_{DM} = 0.990902

A_{CM} = 0.010103

CMRR = 0.990902/0.010103 = 98.0807

Table for all Amplifiers

	V_{i1}	V_{i2}	V_{out}
Calculation Circuit Summing Amplifier	0.2sin(2π1000t)	0.3	-0.2sin(2π1000t)-0.6
Calculation Circuit Differential Amplifier	0.2sin(2π1000t)	0.3	0.3-0.2sin(2π1000t)
Calculation Circuit Instrumentation Amplifier	0.2sin(2π1000t)	0.3	0.9-0.2sin(2π1000t)

Simulation Circuit Summing Amplifier	0.2sin(2π1000t)	0.3	-0.7933
Simulation Circuit Differential Amplifier	0.2sin(2π1000t)	0.3	0.4974
Simulation Circuit Instrumentation Amplifier	0.2sin(2π1000t)	0.3	1.4943
Measurements Summing Amplifier	0.2sin(2π1000t)	0.3	-1.4927
Measurements Differential Amplifier	0.2sin(2π1000t)	0.3	0.70492
Measurements Instrumentation Amplifier	0.2sin(2π1000t)	0.3	0.39907

Discussion

For lab 4, students learned about the different configurations for opamps. Most of the values between the simulations and measurements were somewhat consistent for the circuits. If there were any minor differences, that's probably because of component differences, old breadboards, or loose wires.