Electronics Design Principles

Basic Op Amp

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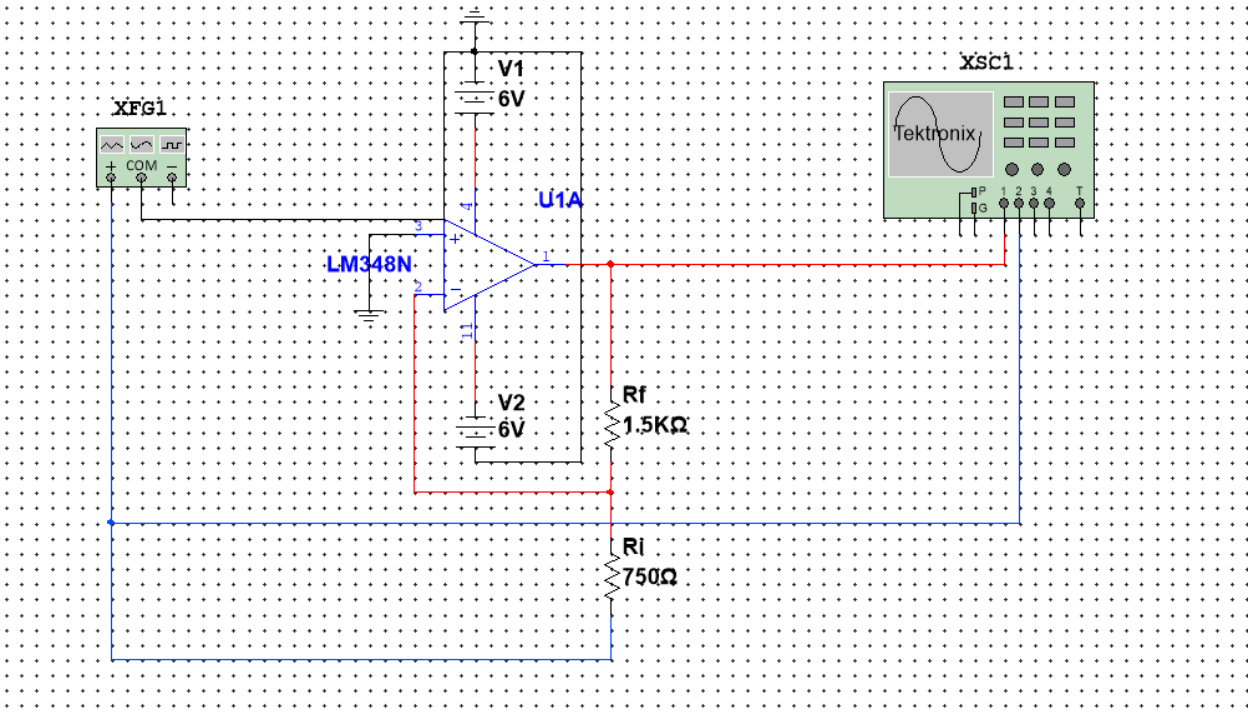
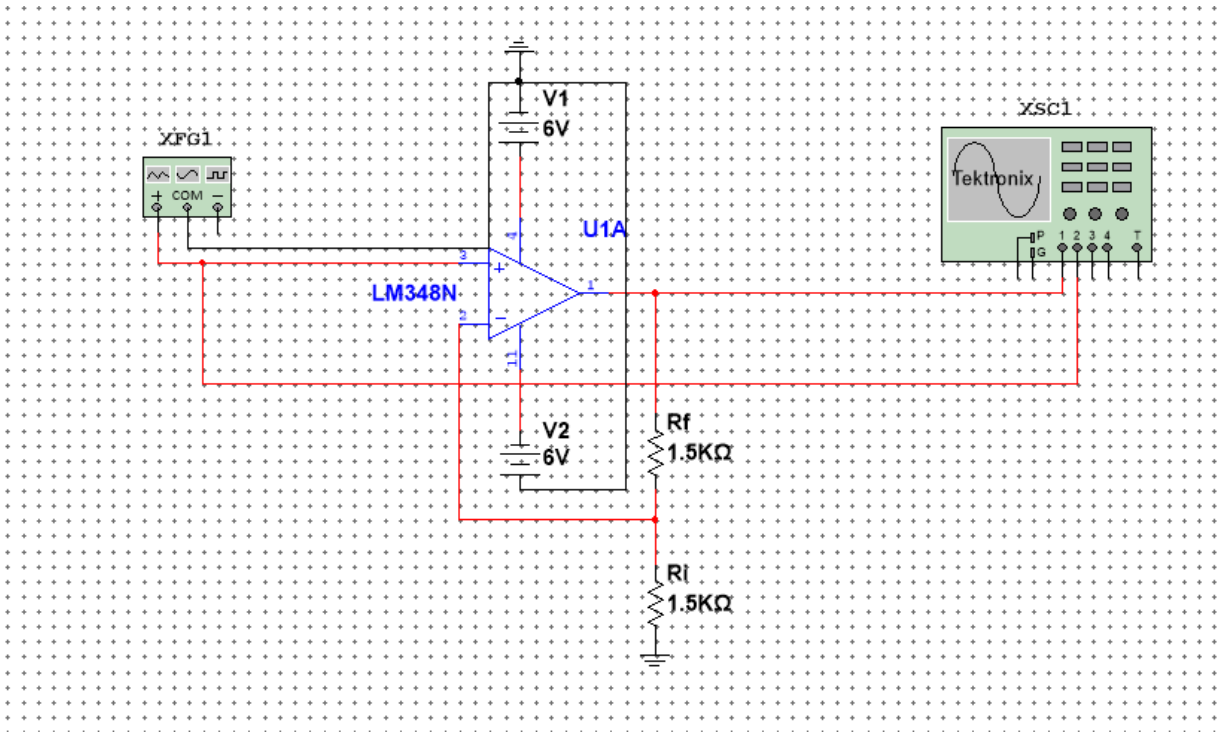
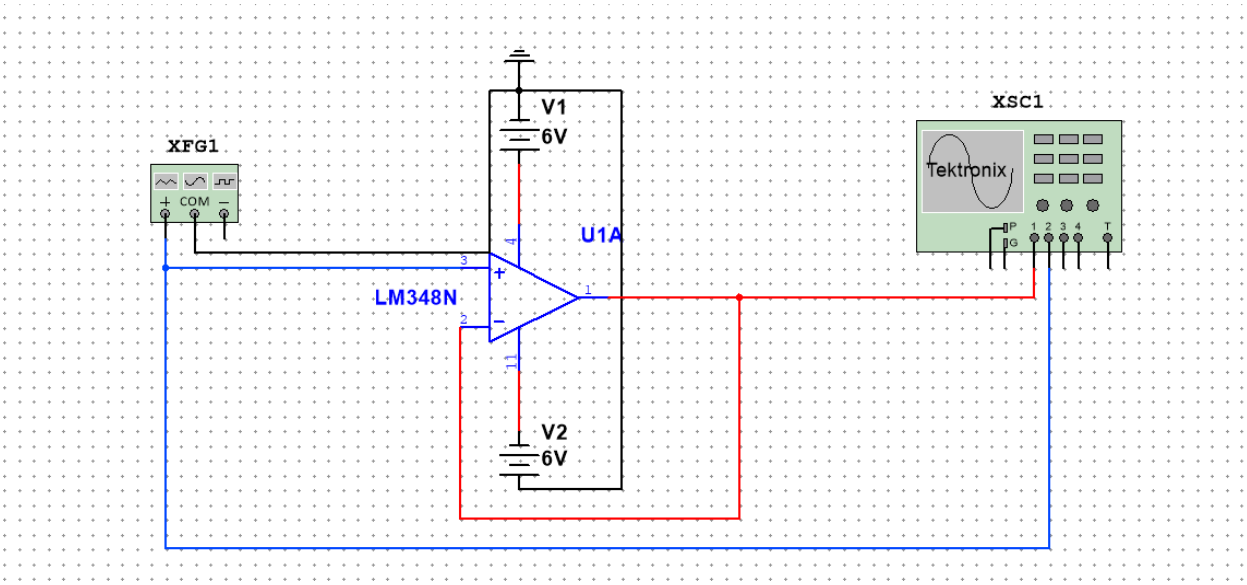
Object: Build an inverting amplifier, non-inverting amplifier, and voltage follower.
The amplification should be 2 for both amplifier.
Use a potentiometer (variable resister) to vary the input voltage.

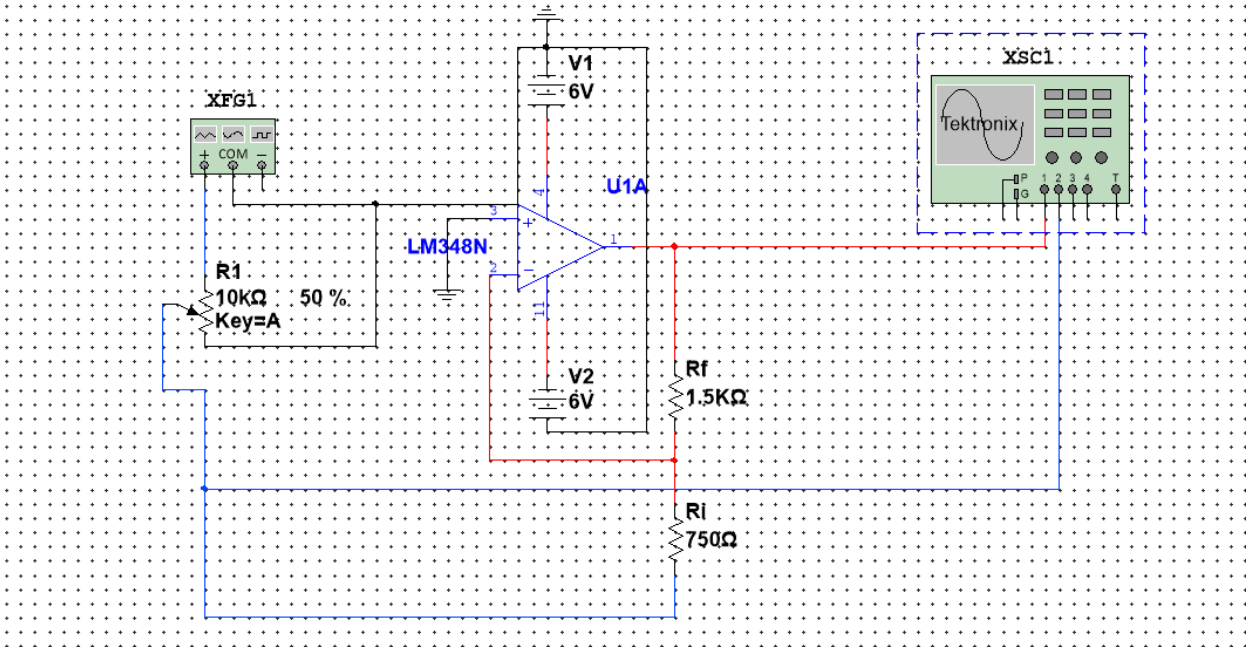
Equipment: Oscilloscope, power supply, function generator, resistors, potentiometer, LM348M op amp, wires, breadboard.

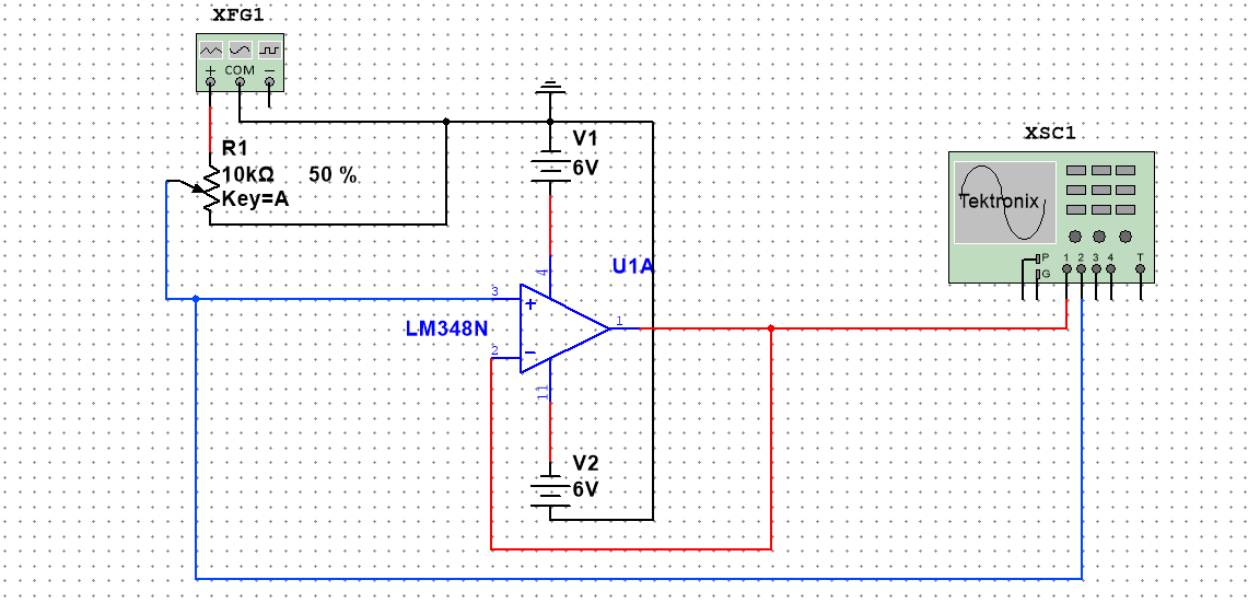
Schematic:




XFG1
COM
V1
6V
U1A
LM348N
V2
6V
Rf
1.5KΩ
Ri
1.5KΩ
XSC1
Tektronix


XFG1
COM
V1
6V
U1A
LM348N
V2
6V
XSC1
Tektronix


XFG1
COM
V1
6V
U1A
LM348N
XSC1
Tektronix
R1
10KΩ
50 %
Key=A
V2
6V
Rf
1.5KΩ
Ri
750Ω


XFG1
COM
R1
10kΩ
50 %
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V1
6V
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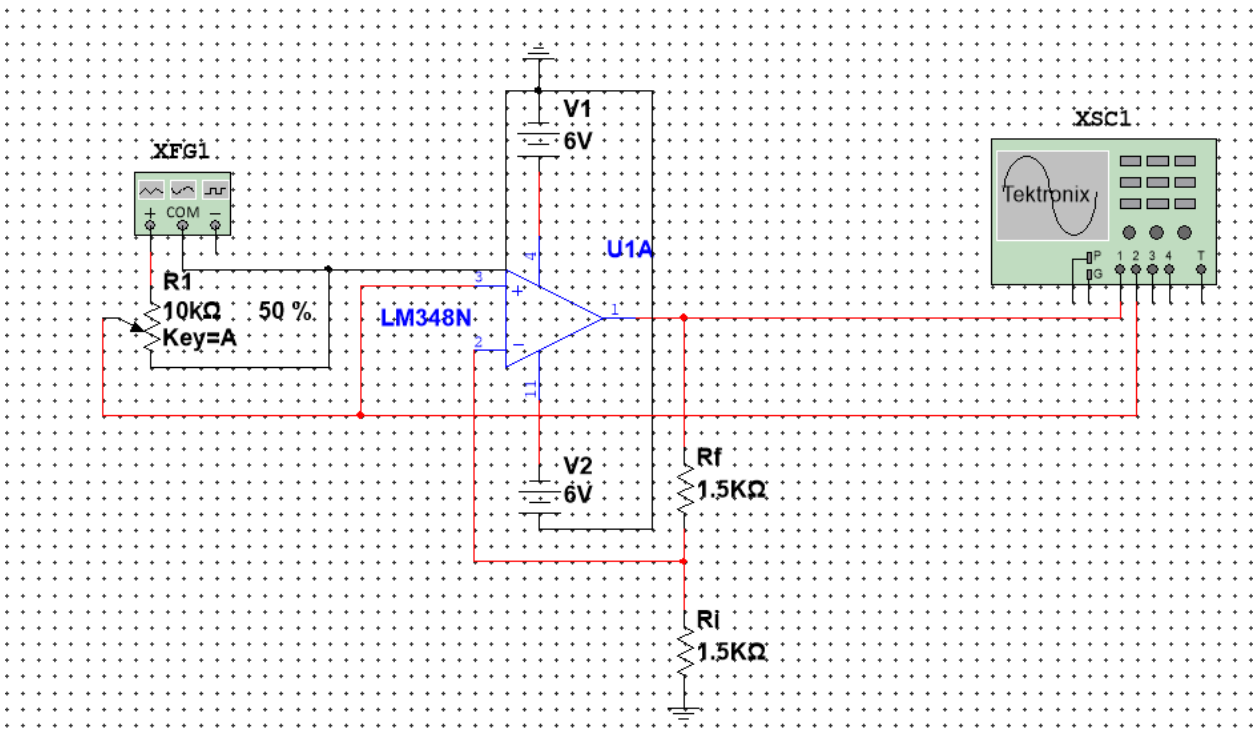
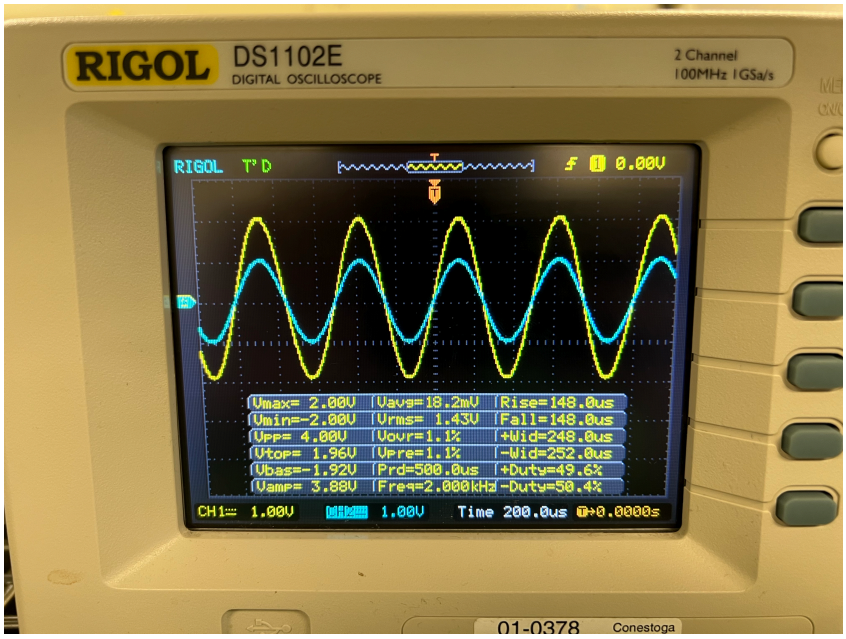
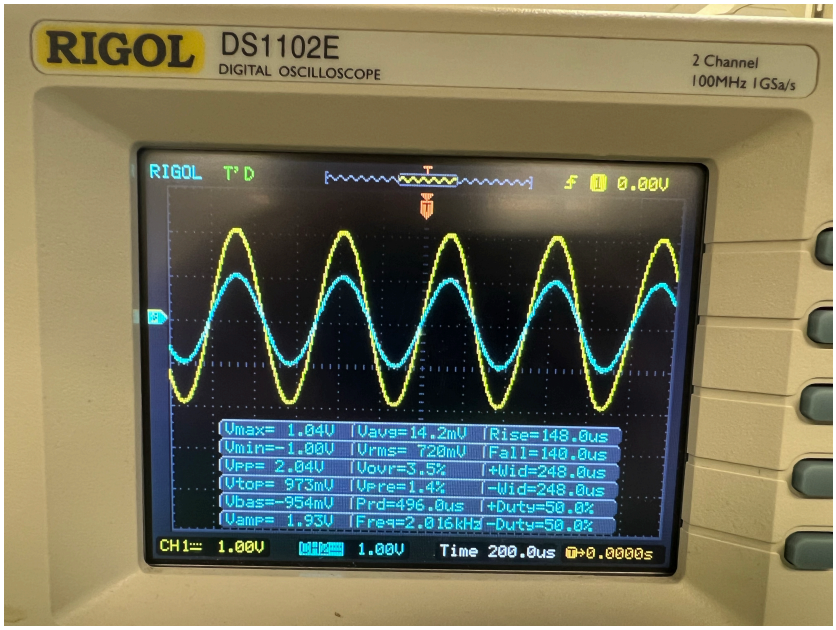
LM348N
XSC1
Tektronix
V2
6V



Output:

Case 1: Rf = 1.5K ohm Ri = 1.5K ohm





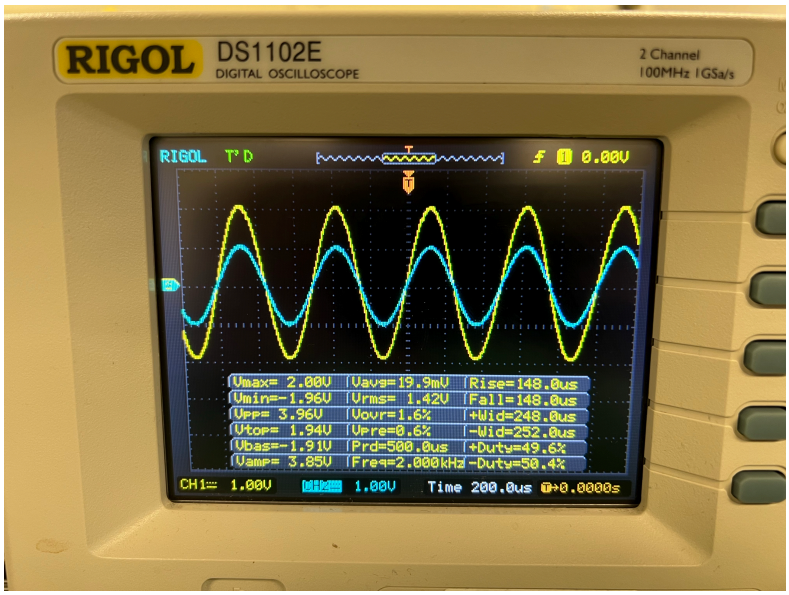
Real Values

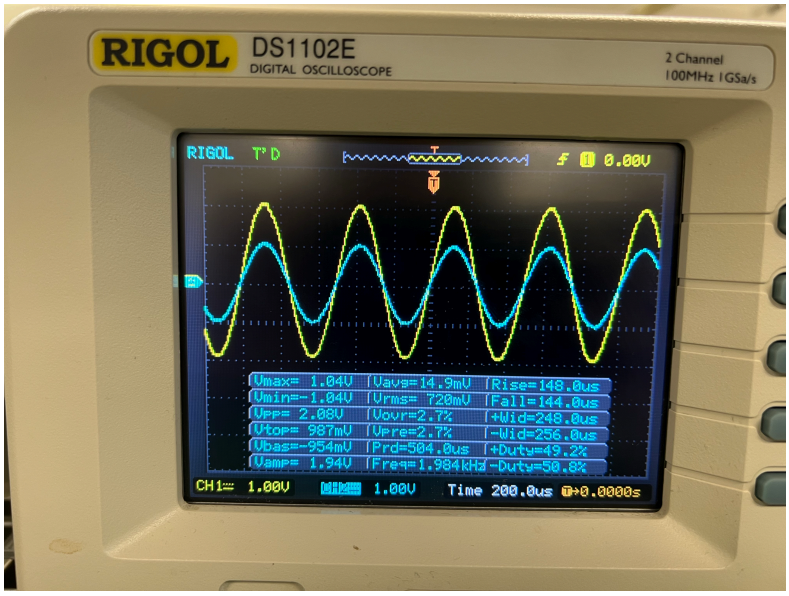
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	4V	2.04V
V_{top}	1.96V	973mV
V_{base}	-1.92V	-954mV
V_{avg}	18.2mV	14.2mV
V_{rms}	1.43V	720mV
Period	500.0us	500.0us
Frequency	2kHz	2.016kHz

Multisim Value

Type	CH1	CH2
Pk-Pk	7.98V	4V
Min	-3.99V	-2V
Max	3.99V	2V

Case 2: Rf = 1.8K ohm Ri = 1.8K ohm





Real Value

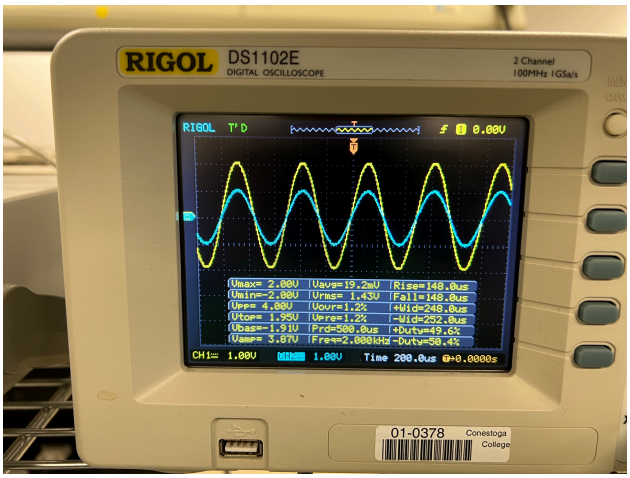
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-1.96V	-1.04V
V_{pp}	3.96V	2.08V
V_{top}	1.94V	987mV
V_{base}	-1.91V	-954mV

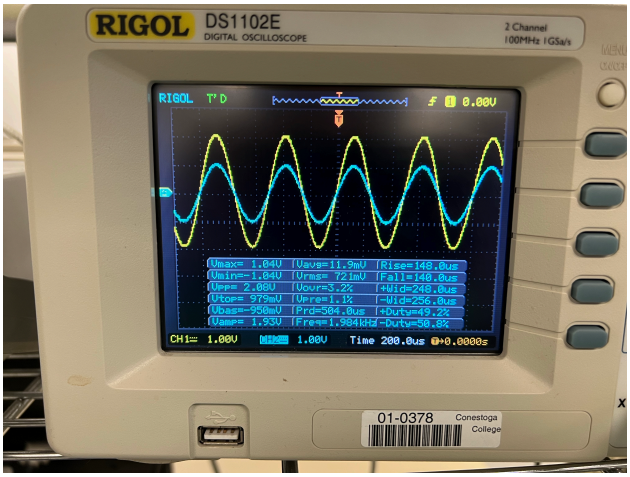
Type	CH1	CH2
V_{avg}	19.9mV	14.9mV
V_{rms}	1.42V	720mV
Period	500.0us	500.0us
Frequency	2kHz	2kHz

Multisim Value

Type	CH1	CH2
Pk-Pk	7.99V	4V
Min	-4V	-2V
Max	3.99V	2V

Case 3: Rf = 2.2K ohm Ri = 2.2K ohm





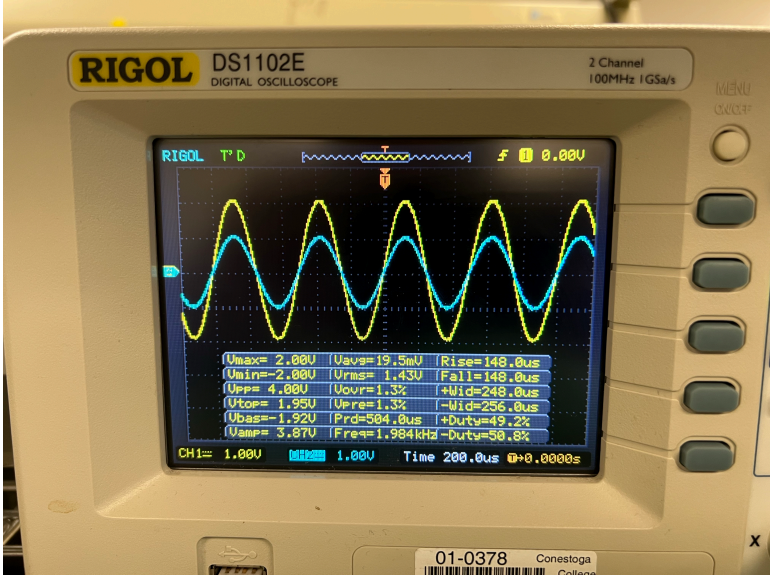
Real Value

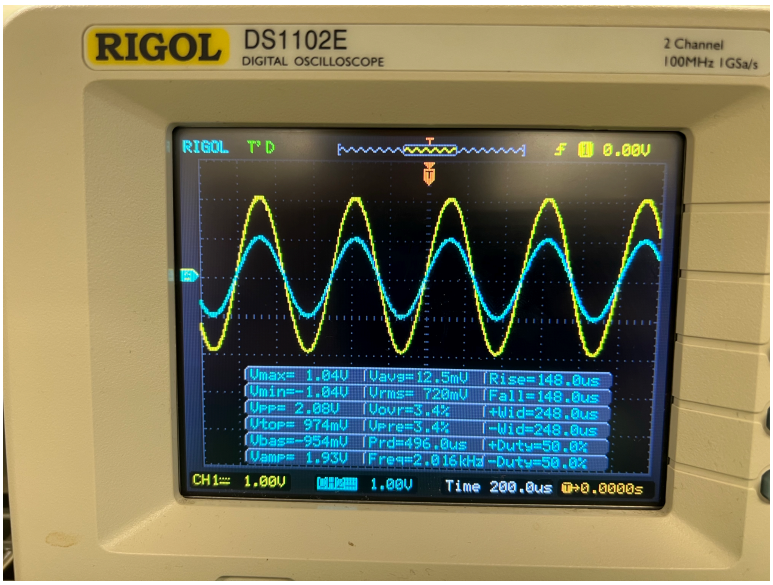
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	4V	2.08V
V_{top}	1.95V	979mV
V_{base}	-1.91V	-950mV

Multisim Value

Type	CH1	CH2
Pk-Pk	7.99V	3.99V
Min	-4V	-2V
Max	3.99V	2V

Case 4: Rf = 2.7K ohm Ri = 2.7K ohm





Real Value

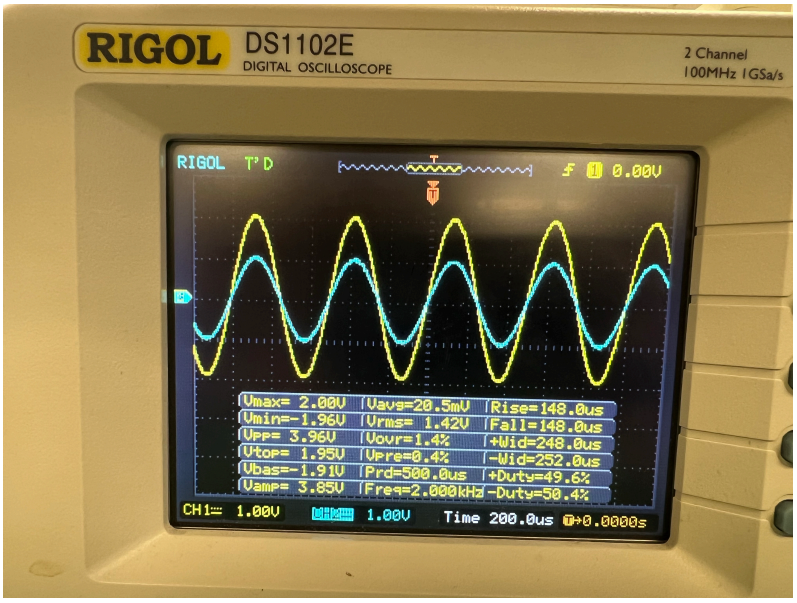
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	4V	2.08V
V_{top}	1.95V	974mV
V_{base}	-1.92V	-954mV

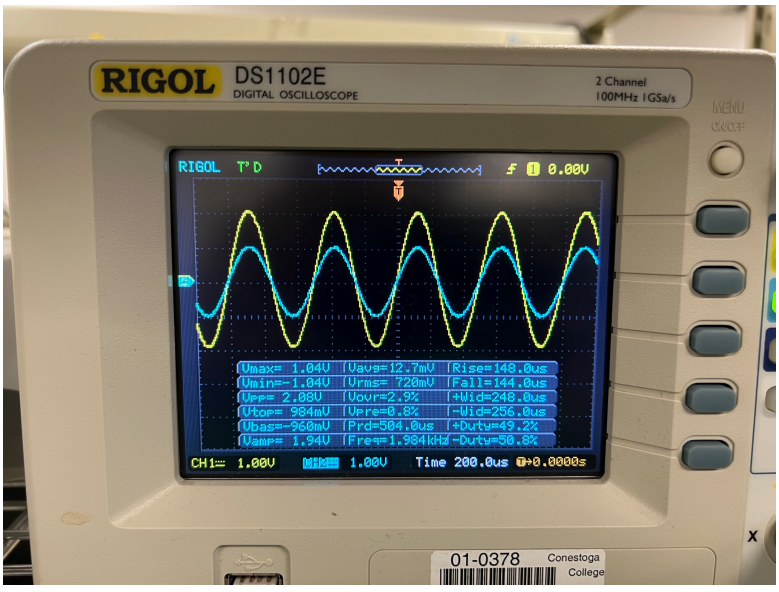
Multisim Value

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V

Type	CH1	CH2
Max	4V	2V

Case 5: Rf = 3.3K ohm Ri = 3.3K ohm





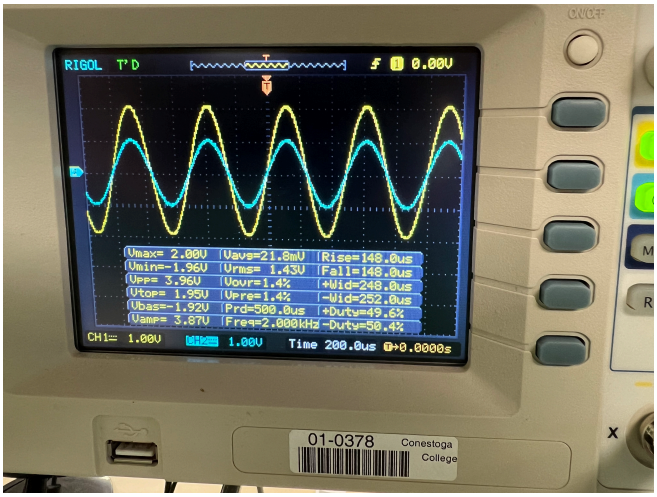
Real Value

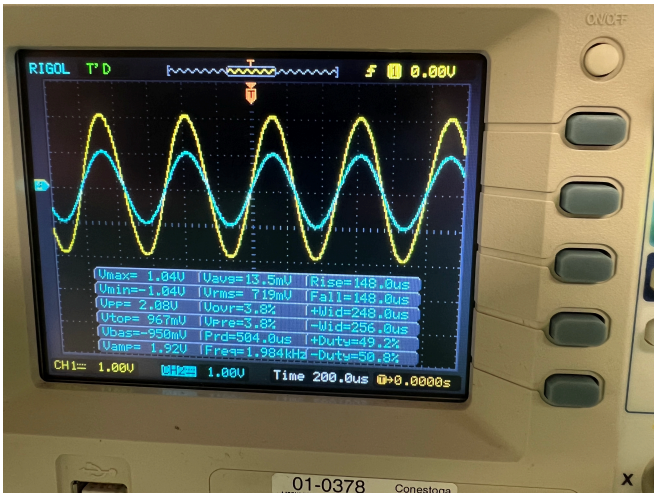
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-1.96V	-1.04V
V_{pp}	3.96V	2.08V
V_{top}	1.95V	984mV
V_{base}	-1.91V	-960mV

Multisim Value

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 6: Rf = 3.9K ohm Ri = 3.9K ohm





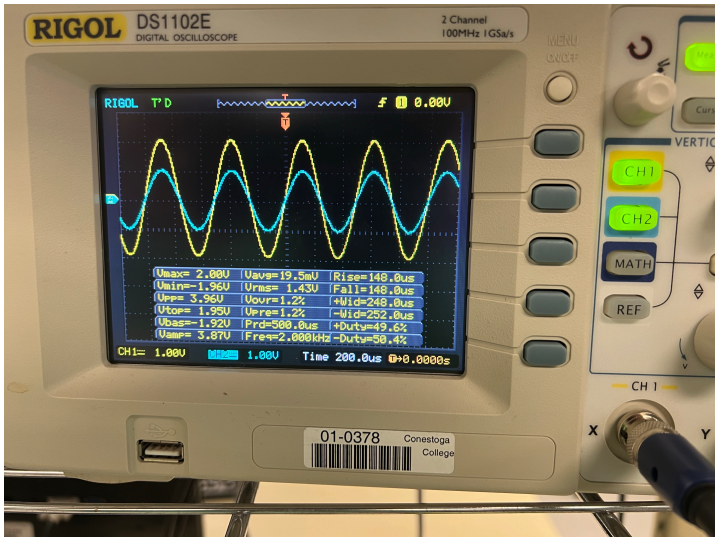
Real Value

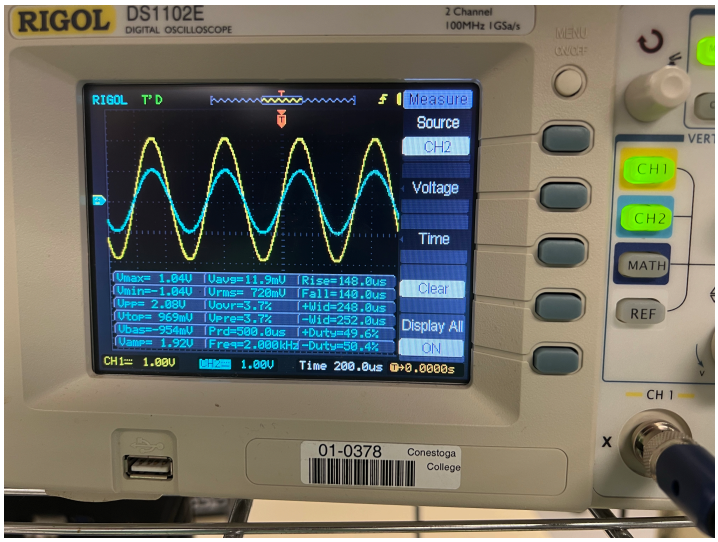
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	3.96V	2.08V
V_{top}	1.95V	967mV
V_{base}	-1.92V	-950mV

Multisim Value

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 7: Rf = 4.7K ohm Ri = 4.7K ohm





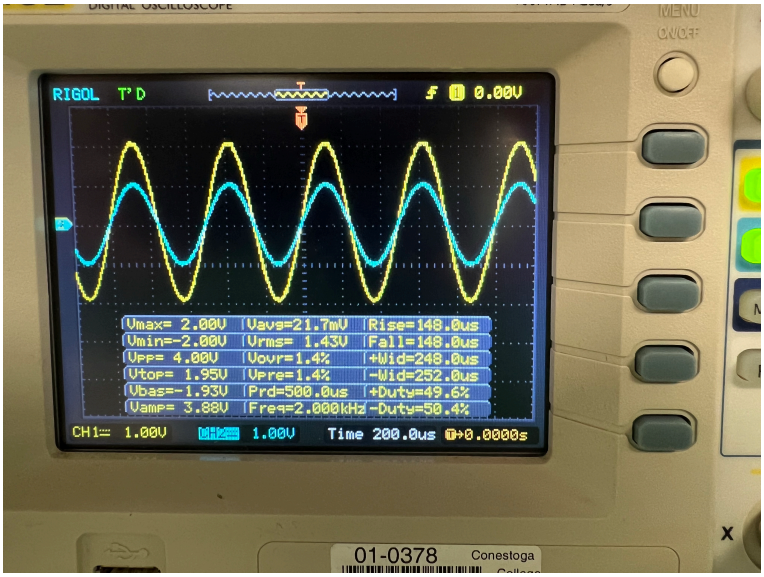
Real Value

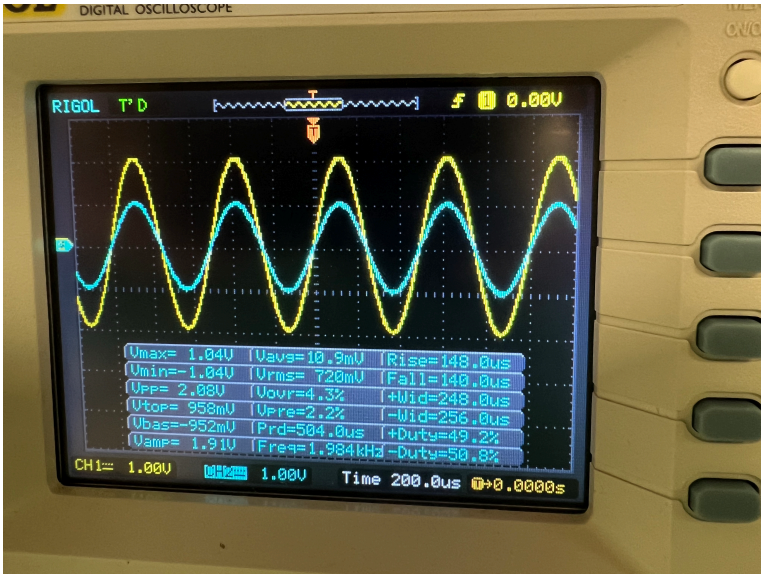
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-1.96V	-1.04V
V_{pp}	3.96V	2.08V
V_{top}	1.95V	969mV
V_{base}	-1.92V	-954mV

Multisim Value

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 8: Rf = 5.6K ohm Ri = 5.6K ohm





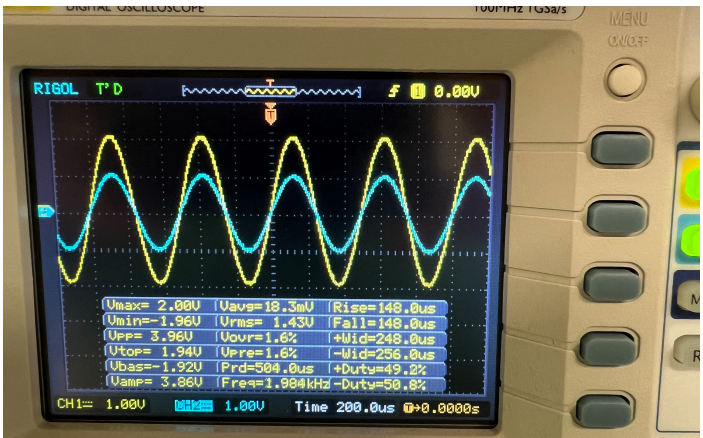
Real Value

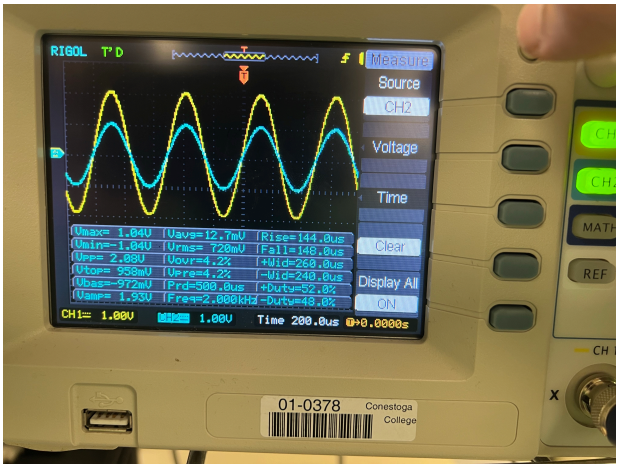
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	4V	2.08V
V_{top}	1.95V	958mV
V_{base}	-1.93V	-952mV

Multisim Value

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 9: Rf = 6.8K ohm Ri = 6.8K ohm





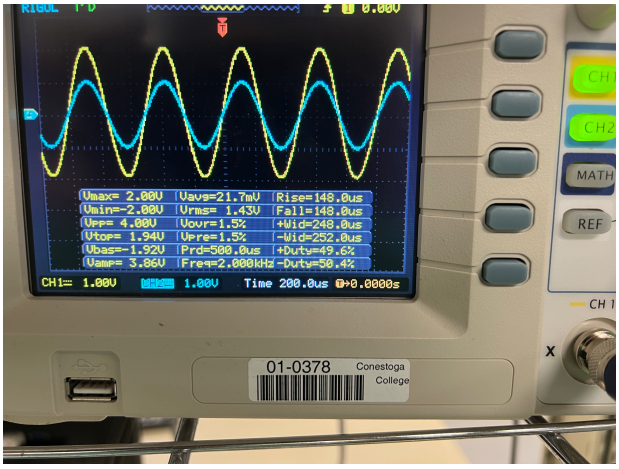
Real Value:

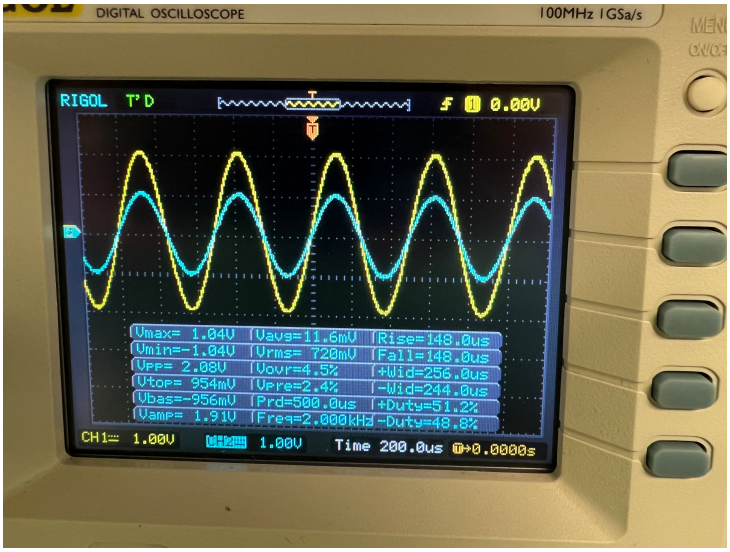
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-1.96V	-1.04V
V_{pp}	3.96V	2.08V
V_{top}	1.94V	954mV
V_{base}	-1.92V	-956mV

Multisim Value:

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 10: Rf = 8.2K ohm Ri = 8.2K ohm





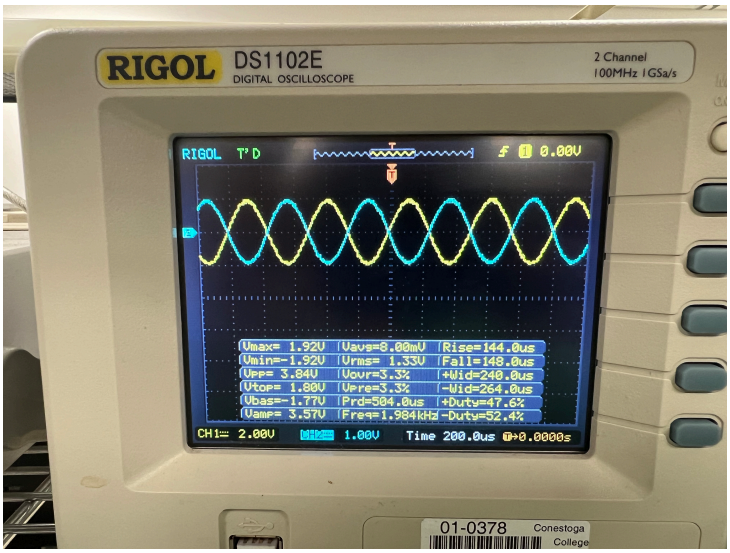
Real Value:

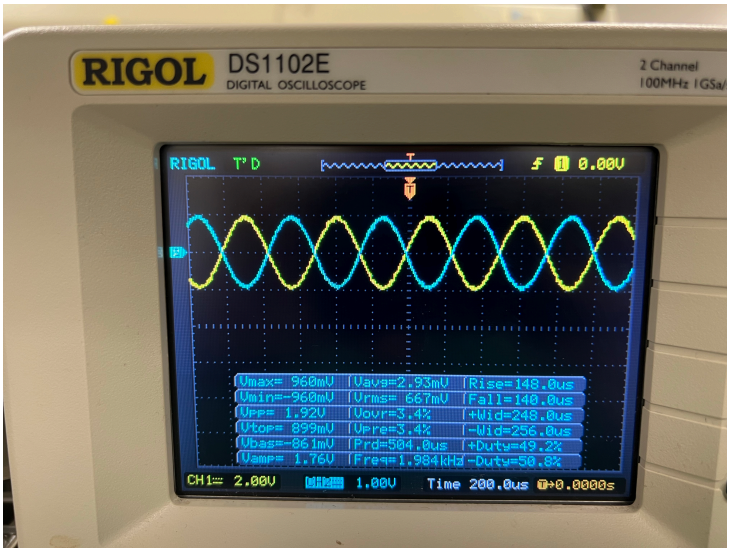
Type	CH1	CH2
V_{max}	2V	1.04V
V_{min}	-2V	-1.04V
V_{pp}	4V	2.08V
V_{top}	1.94V	958mV
V_{base}	-1.92V	-972mV

Multisim Value:

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 11: Rf = 1.5K ohm Ri = 750 ohm



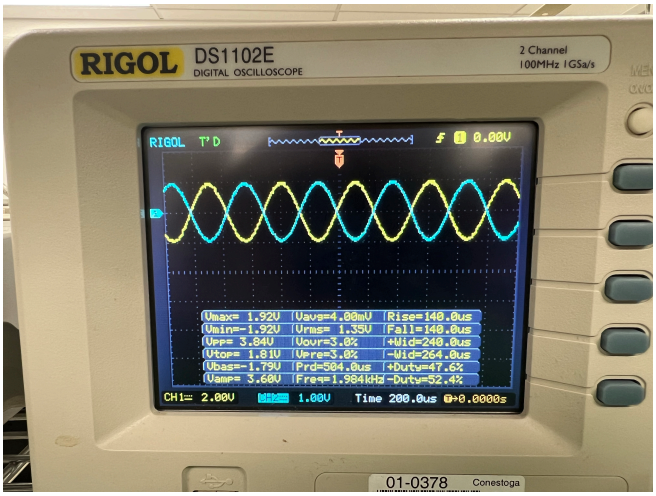


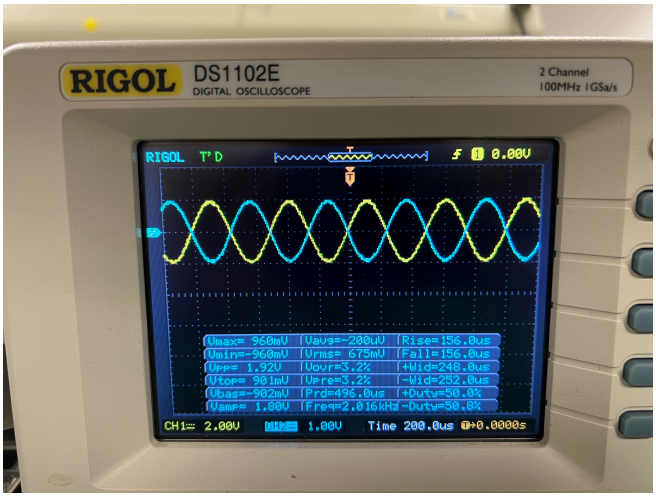
Type	CH1	CH2
V_{max}	1.92V	960mV
V_{min}	-1.92V	-960mV
V_{pp}	3.84V	1.92V
V_{top}	1.80V	899mV
V_{base}	-1.77V	-861mV

Multisim

Type	CH1	CH2
Pk-Pk	7.59V	4V
Min	-3.8V	-2V
Max	3.8V	2V

Case 12: Rf = 1.8K ohm Ri = 900 ohm





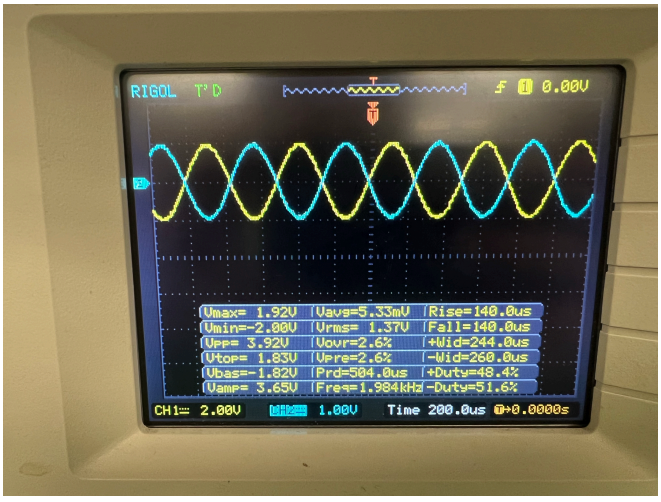
Real Value:

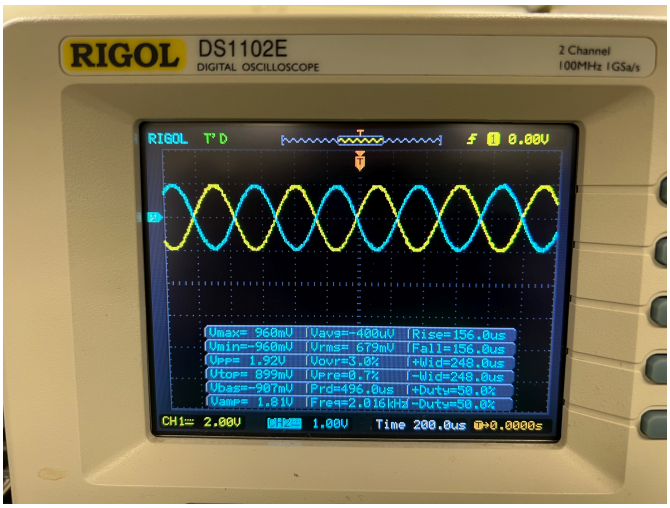
Type	CH1	CH2
V_{max}	1.92V	960mV
V_{min}	-1.92V	-960mV
V_{pp}	3.84V	1.92V
V_{top}	1.81V	901mV
V_{base}	-1.79V	-902mV

Multisim:

Type	CH1	CH2
Pk-Pk	7.74V	4V
Min	-3.87V	-2V
Max	3.87V	2V

Case 13: Rf = 2.2K ohm Ri = 1.1K ohm





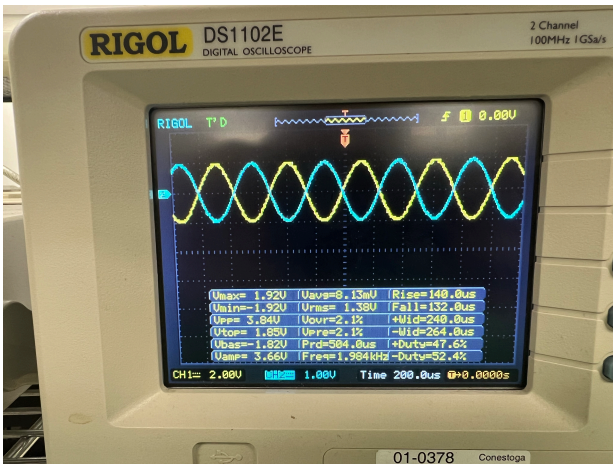
Real Value:

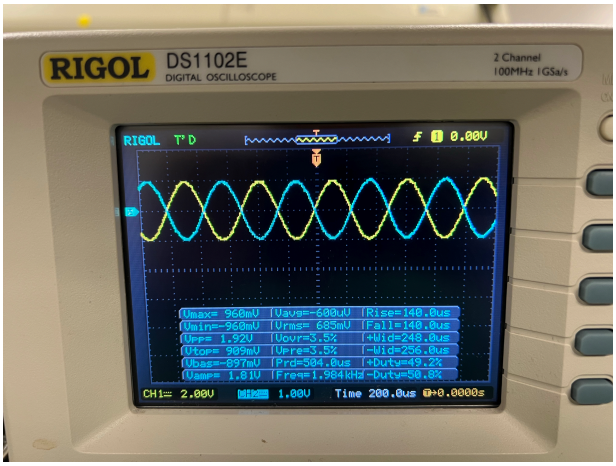
Type	CH1	CH2
V_{max}	1.92V	960mV
V_{min}	-2V	-960mV
V_{pp}	3.92V	1.92V
V_{top}	1.83V	899mV
V_{base}	-1.82V	-907mV

Multisim:

Type	CH1	CH2
Pk-Pk	7.86V	4V
Min	-3.93V	-2V
Max	3.93V	2V

Case 14: Rf = 2.7K ohm Ri = 1.35K ohm





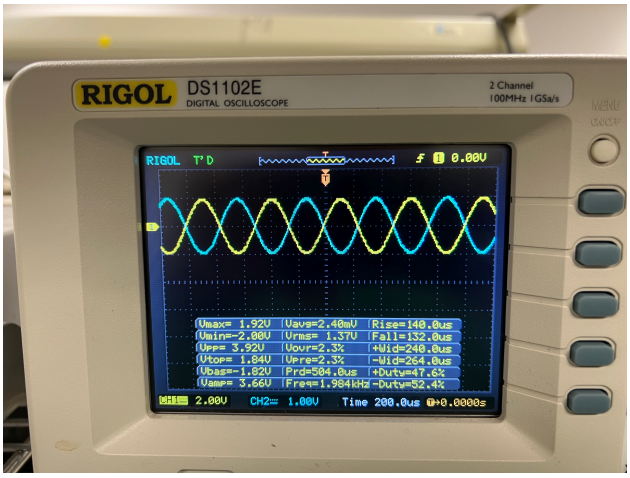
Real Value:

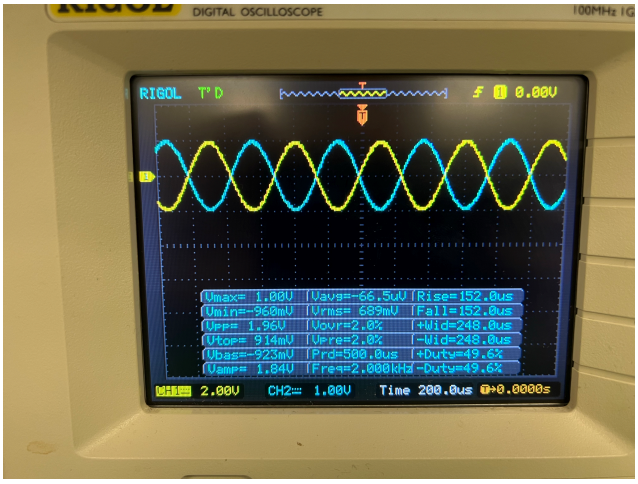
Type	CH1	CH2
V_{max}	1.92V	960mV
V_{min}	-1.92V	-960V
V_{pp}	3.84V	1.92V
V_{top}	1.85V	909mV
V_{base}	-1.82V	-897mV

Multisim:

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 15: Rf = 3.3K ohm Ri = 1.65K ohm





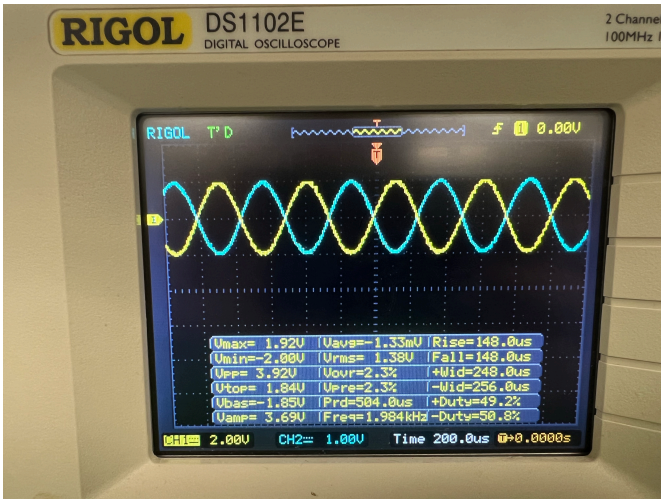
Real Value:

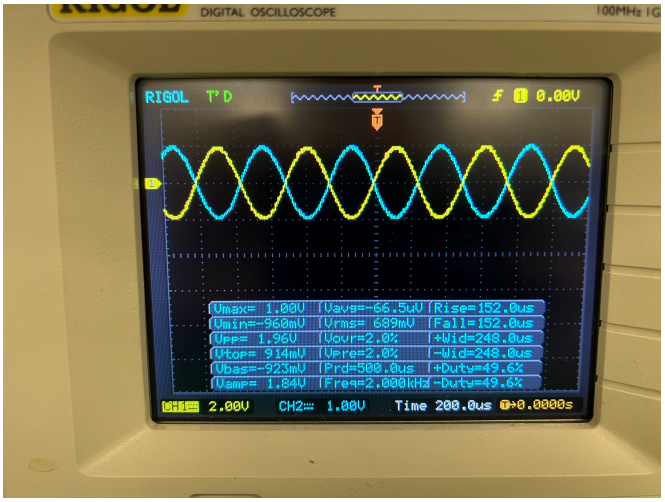
Type	CH1	CH2
V_{max}	1.92V	1V
V_{min}	-2V	-960mV
V_{pp}	3.92V	1.96V
V_{top}	1.84V	914mV
V_{base}	-1.82V	-923mV

Multisim:

Type	CH1	CH2
Pk-Pk	7.98V	4V
Min	-3.99V	-2V
Max	3.99V	2V

Case 16: Rf = 3.9K ohm Ri = 1.95K ohm





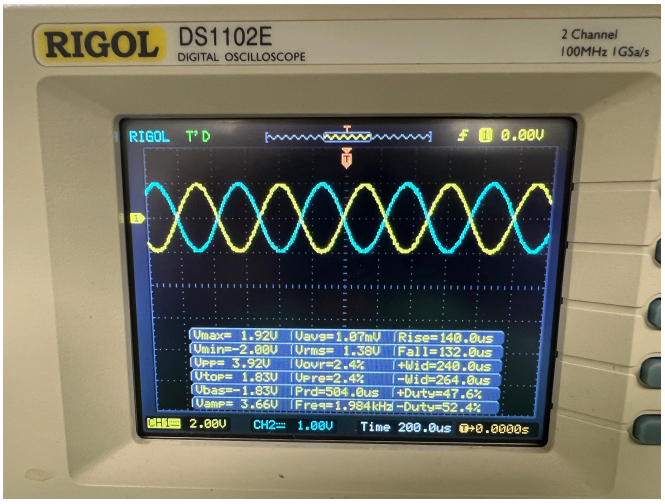
Real Value:

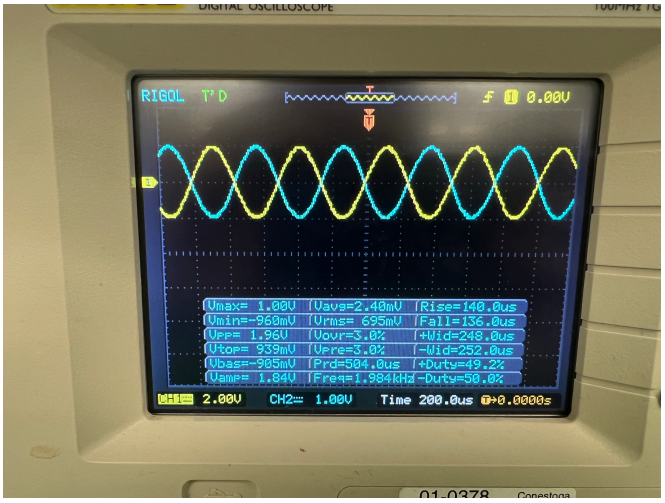
Type	CH1	CH2
V_{max}	1.92V	1V
V_{min}	-2V	-960mV
V_{pp}	3.92V	1.96V
V_{top}	1.84V	914mV
V_{base}	-1.85V	-923mV

Multisim:

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 17: Rf = 4.7K ohm Ri = 2.35K ohm





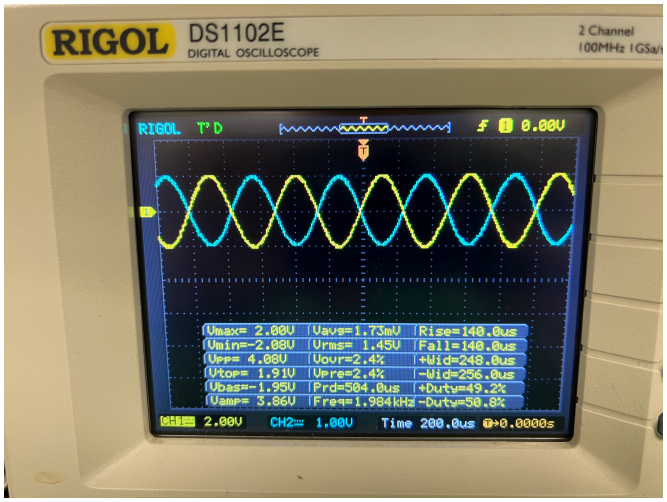
Real Value:

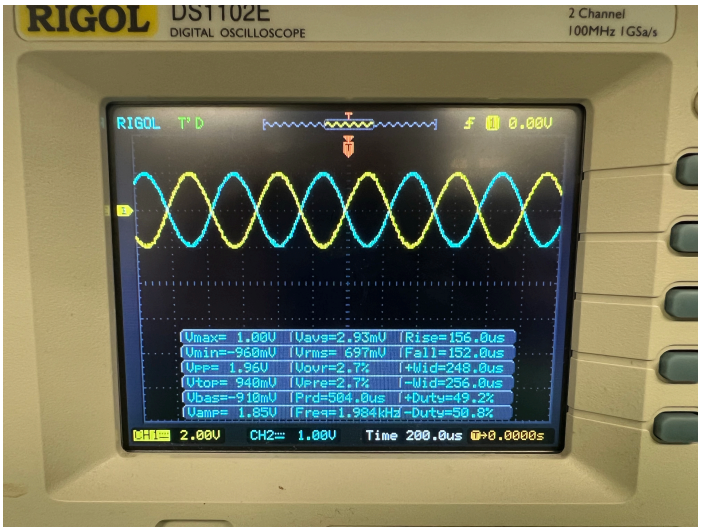
Type	CH1	CH2
V_{max}	1.92V	1V
V_{min}	-2V	-960mV
V_{pp}	3.92V	1.96V
V_{top}	1.83V	939mV
V_{base}	-1.83V	-905mV

Multisim:

Type	CH1	CH2
Pk-Pk	8V	4V
Min	-4V	-2V
Max	4V	2V

Case 18: Rf = 5.6K ohm Ri = 2.7K ohm





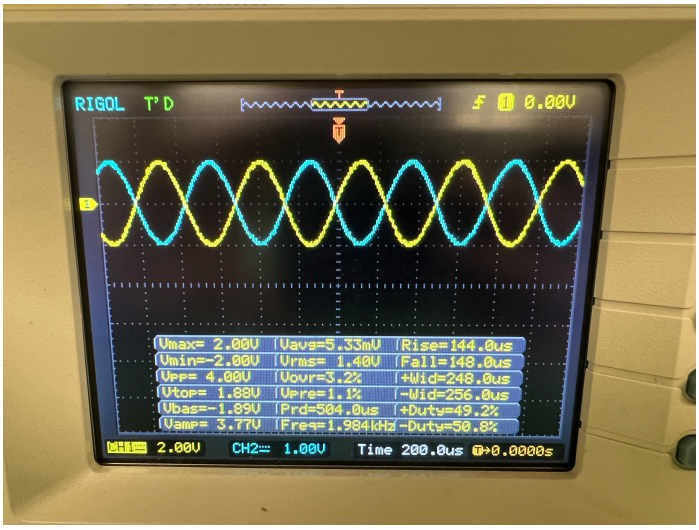
Real Value:

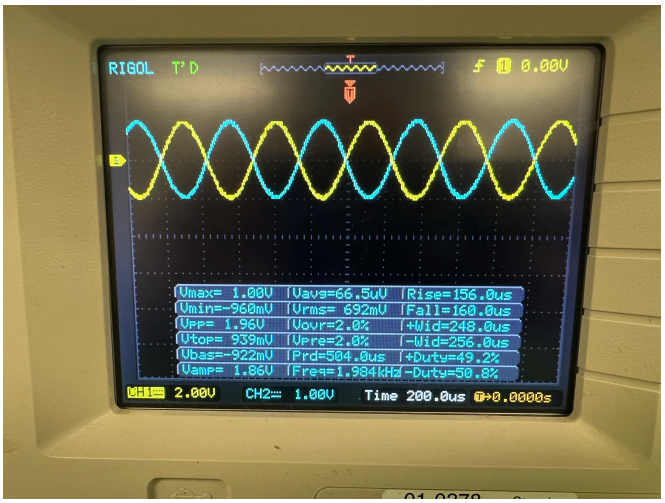
Type	CH1	CH2
V_{max}	2V	1V
V_{min}	-2.08V	-960mV
V_{pp}	4.08V	1.96V
V_{top}	1.91V	939mV
V_{base}	-1.95V	-922mV

Multisim:

Type	CH1	CH2
Pk-Pk	8.24V	4V
Min	-4.12V	-2V
Max	4.12V	2V

Case 19: Rf = 6.8K ohm Ri = 3.4K ohm





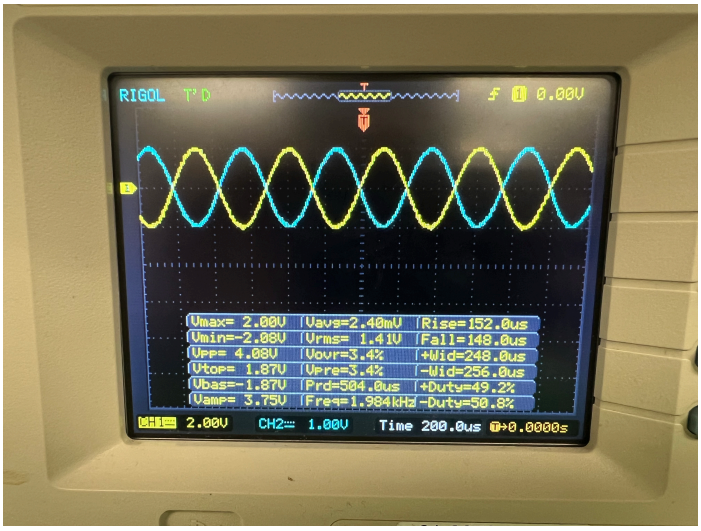
Real Value:

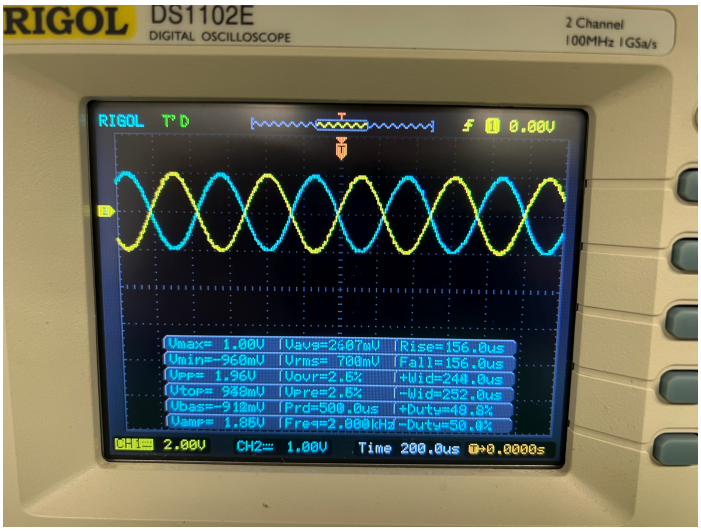
Type	CH1	CH2
V_{max}	2V	1V
V_{min}	-2V	-960mV
V_{pp}	4V	1.96V
V_{top}	1.88V	940mV
V_{base}	-1.89V	-941mV

Multisim:

Type	CH1	CH2
Pk-Pk	7.96V	3.98V
Min	-3.98V	-1.99V
Max	3.98V	1.99V

Case 20: Rf = 8.2K ohm Ri = 4.1K ohm





Real Value:

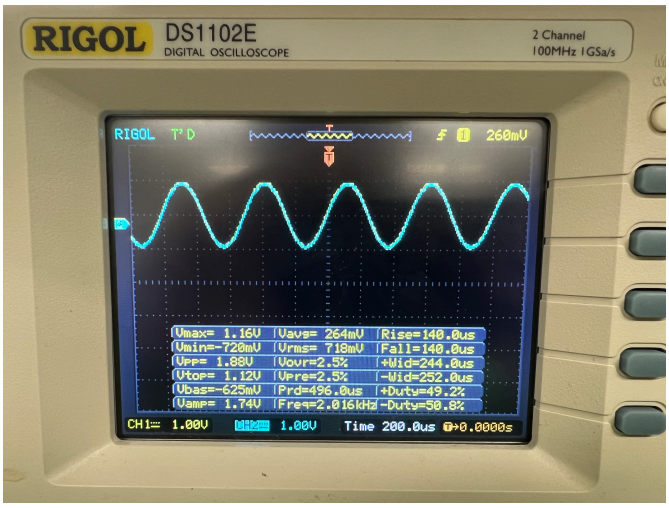
Type	CH1	CH2
V_{max}	2V	1V
V_{min}	-2.08V	-960mV
V_{pp}	4.08V	1.96V
V_{top}	1.87V	938mV
V_{base}	-1.87V	-912mV

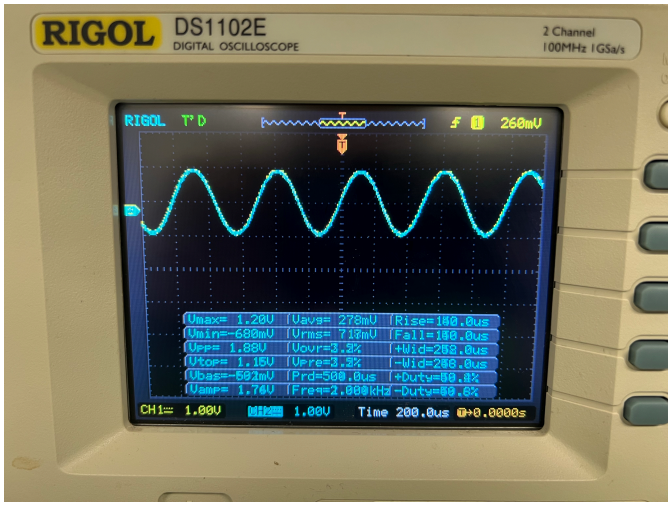
Multisim:

Type	CH1	CH2
Pk-Pk	7.99V	4V

Type	CH1	CH2
Min	-4V	-2V
Max	4V	2V

Case 21: Voltage Follower





Real Value:

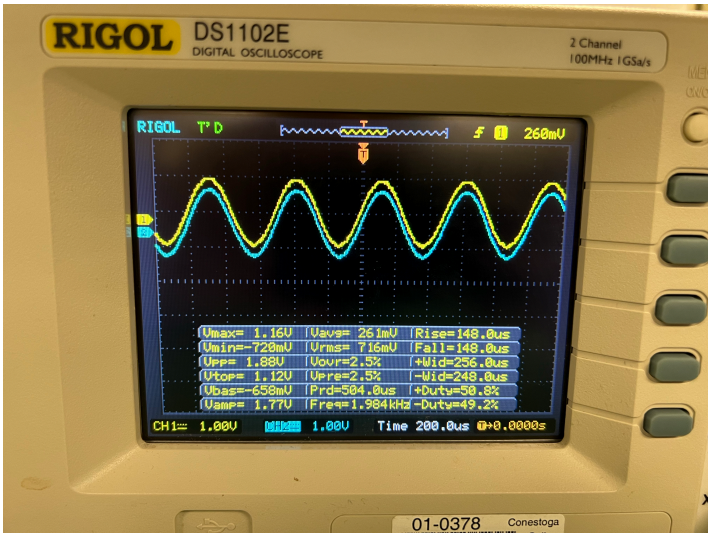
Type	CH1	CH2
V_{max}	1.16V	1.20V
V_{min}	-720mV	-680mV

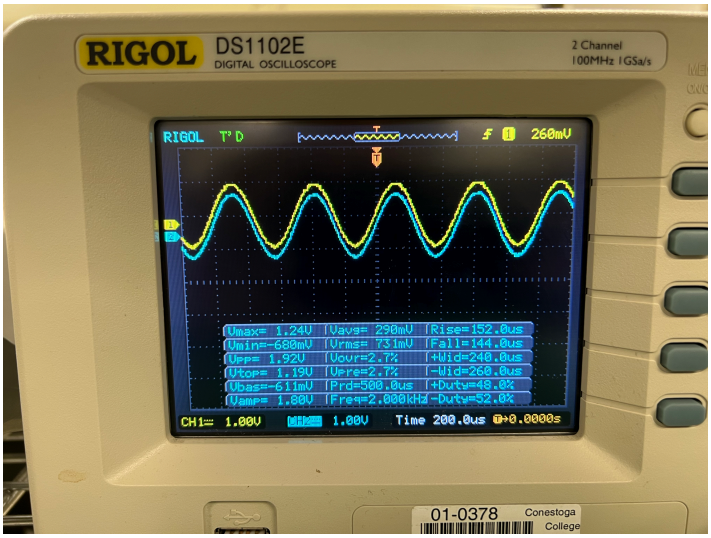
Type	CH1	CH2
V_{pp}	1.88V	1.88V
V_{top}	1.12V	1.15V
V_{base}	-625mV	-592mV

Multisim:

Type	CH1	CH2
Pk-Pk	4V	4V
Min	-2V	-2V
Max	2V	2V

Case 22: potentiometer 44%, Rf = 1.5k, Ri = 1.5k





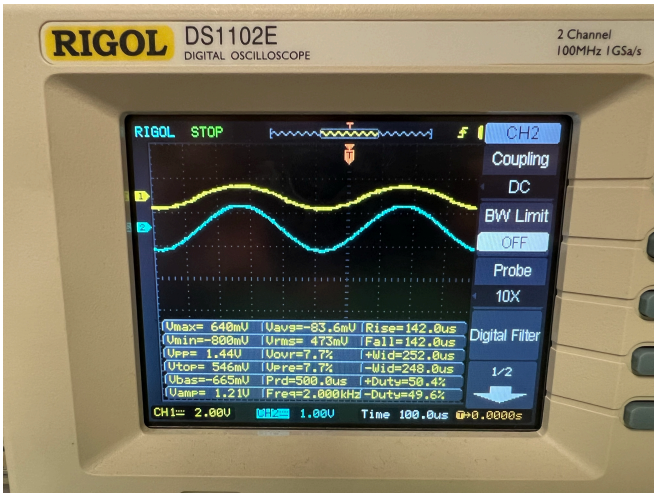
Real Value:

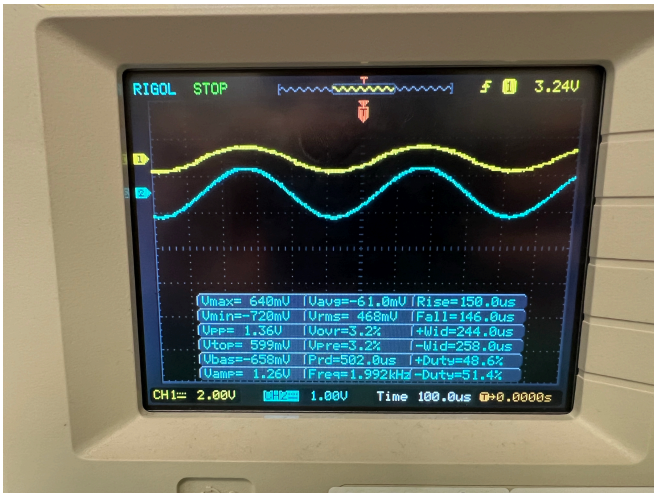
Type	CH1	CH2
V_{max}	1.16V	1.24V
V_{min}	-720mV	-680mV
V_{pp}	1.88V	1.92V
V_{top}	1.12V	1.19V
V_{base}	-658mV	-611mV

Multisim:

Type	CH1	CH2
Pk-Pk	3.52V	1.76V
Min	-1.76V	-880mV
Max	1.76V	879mV

Case 23: potentiometer 44%, voltage follower





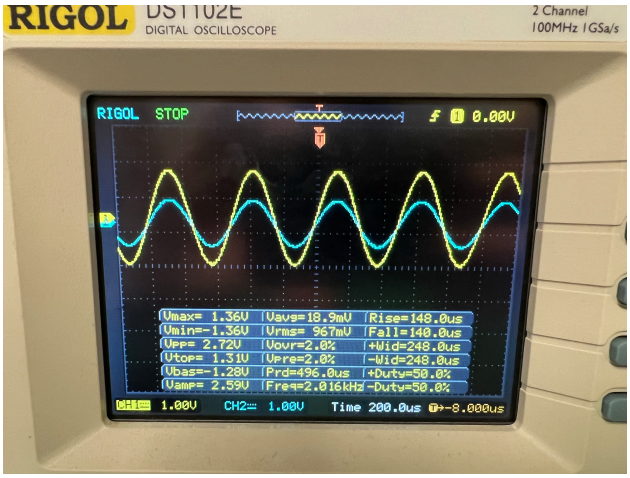
Real Value:

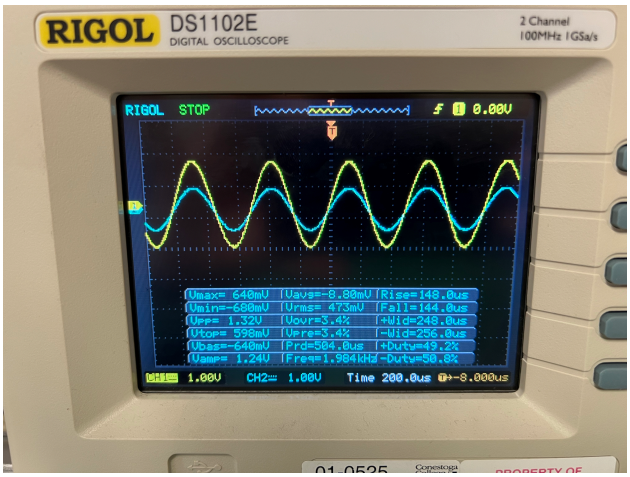
Type	CH1	CH2
V_{max}	640mV	640mV
V_{min}	-800mV	-720mV
V_{pp}	1.44V	1.36V
V_{top}	546mV	599mV
V_{base}	-665mV	-658mV

Multisim:

Type	CH1	CH2
Pk-Pk	3.44V	1.72V
Min	-1.72V	-880mV
Max	1.72V	880mV

Case 24: potentiometer 44%, Rf = 1.5k, Ri = 1.5k





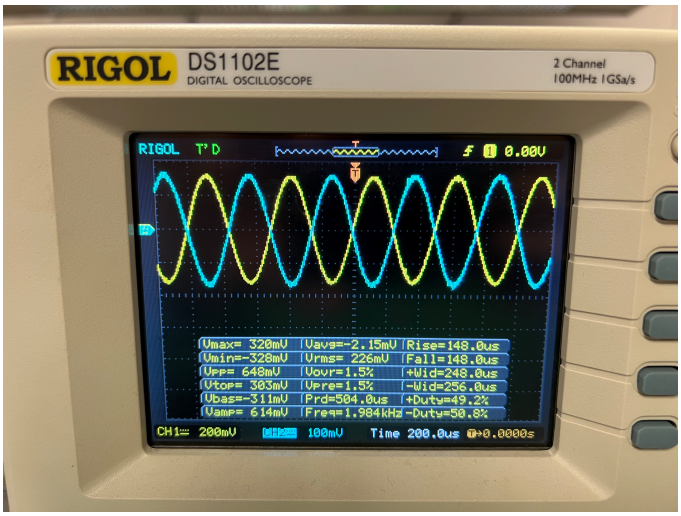
Real Value:

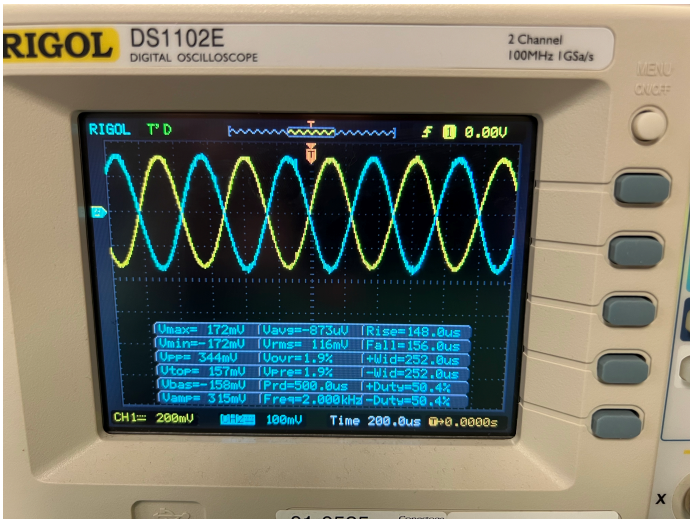
Type	CH1	CH2
V_{max}	1.36V	640mV
V_{min}	-1.36V	-680mV
V_{pp}	2.72V	1.32V
V_{top}	1.31V	598mV
V_{base}	-1.28V	-640mV

Multisim:

Type	CH1	CH2
Pk-Pk	923mV	461mV
Min	-461mV	-230mV
Max	461V	230mV

Case 25: potentiometer 44%, Rf = 1.5k, Ri = 750





Real Value:

Type	CH1	CH2
V_{max}	320mV	172mV
V_{min}	-328mV	-172mV
V_{pp}	648mV	344mV
V_{top}	303mV	157mV
V_{base}	-311mV	-158mV

Multisim:

Type	CH1	CH2
Pk-Pk	1.76V	1.76V
Min	-880mV	-880mV

Type	CH1	CH2
Max	879mV	880mV

Input:

Case 1: Rf = 1.5Kohm, Ri = 1.5Kohm
Case 2: Rf = 1.8Kohm, Ri = 1.8Kohm
Case 3: Rf = 2.2Kohm, Ri = 2.2Kohm
Case 4: Rf = 2.7Kohm, Ri = 2.7Kohm
Case 5: Rf = 3.3Kohm, Ri = 3.3Kohm
Case 6: Rf = 3.9Kohm, Ri = 3.9Kohm
Case 7: Rf = 4.7Kohm, Ri = 4.7Kohm
Case 8: Rf = 5.6Kohm, Ri = 5.6Kohm
Case 9: Rf = 6.8Kohm, Ri = 6.8Kohm
Case 10: Rf = 8.2Kohm, Ri = 8.2Kohm
Case 11: Rf = 1.5Kohm, Ri = 750ohm
Case 12: Rf = 1.8Kohm, Ri = 900ohm
Case 13: Rf = 2.2Kohm, Ri = 1.1Kohm
Case 14: Rf = 2.7Kohm, Ri = 1.35Kohm
Case 15: Rf = 3.3Kohm, Ri = 1.65Kohm
Case 16: Rf = 3.9Kohm, Ri = 1.95Kohm
Case 17: Rf = 4.7Kohm, Ri = 2.35Kohm
Case 18: Rf = 5.6Kohm, Ri = 2.7Kohm
Case 19: Rf = 6.8Kohm, Ri = 3.4Kohm
Case 20: Rf = 8.2Kohm, Ri = 4.1Kohm
Case 21: voltage follower
Case 22: potentiometer 44%, Rf = 1.5k, Ri = 1.5k
Case 23: potentiometer 44%, Rf = 1.5k, Ri = 1.5k
Case 24: potentiometer 44%, Rf = 1.5k, Ri = 750
Case 25: potentiometer 44%, voltage follower

Observations:

From the observation we can see that with the Rf and Ri being same we can get double the amplification in non-inverting op amp, and if the Rf is double the Ri than the amplification is double in inverting op amp. While the voltage follower just keeps the same amplitude has the input.

Calculations:

$A_{cl(NI)} = 1 + R_f/R_i$
$A_{cl(I)} = - R_f/R_i$

Case 1:

$A_{cl(NI)} = 1 + R_f/R_i$
$A_{cl(NI)} = 1 + 1.5K/1.5K$
$A_{cl(NI)} = 1 + 1 = 2$

Case 2:

$A_{cl(NI)} = 1 + R_f/R_i$
$A_{cl(NI)} = 1 + 1.8K/1.8K$
$A_{cl(NI)} = 1 + 1 = 2$

Case 3:

$A_{cl(NI)} = 1 + R_f/R_i$
$A_{cl(NI)} = 1 + 2.2K/2.2K$
$A_{cl(NI)} = 1 + 1 = 2$

Case 4:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 2.7K/2.7K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 5:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 3.3K/3.3K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 6:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 3.9K/3.9K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 7:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 4.7K/4.7K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 8:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 5.6K/5.6K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 9:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 6.8K/6.8K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 10:

$A_{cl(NI)} = 1 + R_f/R_i$

$A_{cl(NI)} = 1 + 8.2K/8.2K$

$A_{cl(NI)} = 1 + 1 = 2$

Case 11:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 1.5K/750$

$A_{cl(I)} = - 2$

Case 12:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 1.8K/900$

$A_{cl(I)} = - 2$

Case 13:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 2.2K/1.1K$

$A_{cl(I)} = - 2$

Case 14:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 2.7K/1.35K$

$A_{cl(I)} = - 2$

Case 15:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 3.3K/1.65K$

$A_{cl(I)} = - 2$

Case 16:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 3.9K/1.95K$

$A_{cl(I)} = - 2$

Case 17:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 4.7K/2.35K$

$A_{cl(I)} = - 2$

Case 18:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 5.6K/2.7K$

$A_{cl(I)} = - 2$

Case 19:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 6.8K/3.4K$

$A_{cl(I)} = - 2$

Case 20:

$A_{cl(I)} = - R_f/R_i$

$A_{cl(I)} = - 8.2K/4.1K$

$A_{cl(I)} = - 2$

Theory Vs Practical:

If we look at the values from our calculations and the real values we get from the oscilloscope than we can see the amplitude done on the input voltage is double like the calculations however it is not perfectly double as there is to believe some resistance in the wire or loss of energy in the practical cases.

Also when we look at the potentiometer cases there are a difference in values from the input has the function generator used as a internal resistance. This causes the actual input voltage to vary according to the multisim one.

Conclusions:

We can conclude that to the double the voltage or buffer the voltage we can follow the formula given in the above calculations as we can see that by following the above calculations to double the amplification we get that by the 10 cases we did for non-inverting, inverting. Or if we want to buffer the voltage we could use a voltage follower as we see in the example that the input voltage is the same as the output voltage.