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ECEN 325 Section 510

Lab date: 29 February 2024

Due date: 5 March 2024

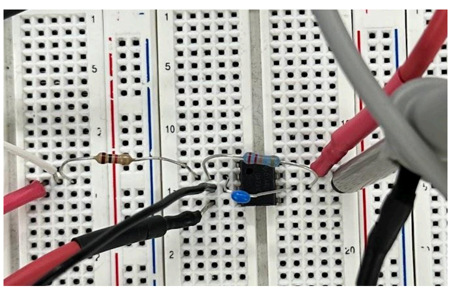
Lab 5: Operational Amplifiers – Part III

Objective & Procedure:

The purpose of the lab is to study some of the op amp configurations commonly found in practical applications and also investigate the non-idealities of the opamp such as finite Gain-Bandwidth product and slew rate limitations. The circuits studied will include an integrator, a differentiator, a non-inverting amplifier and a unity-gain buffer.
For the lab procedure, I started by building the lossy integrator circuit. I then obtained the bode plots and transient plots stated in the lab manual. Next, I built the pseudo differentiator and obtained the bode plots and transient plots stated in the lab manual. Next, I built the non-inverting amplifier to test the GBW limitations, and obtained the bode plots for the different resistor combinations. Finally, I built the buffer circuit to test the slew rate limitations, and obtained the bode plots and transient plots stated in the lab manual.

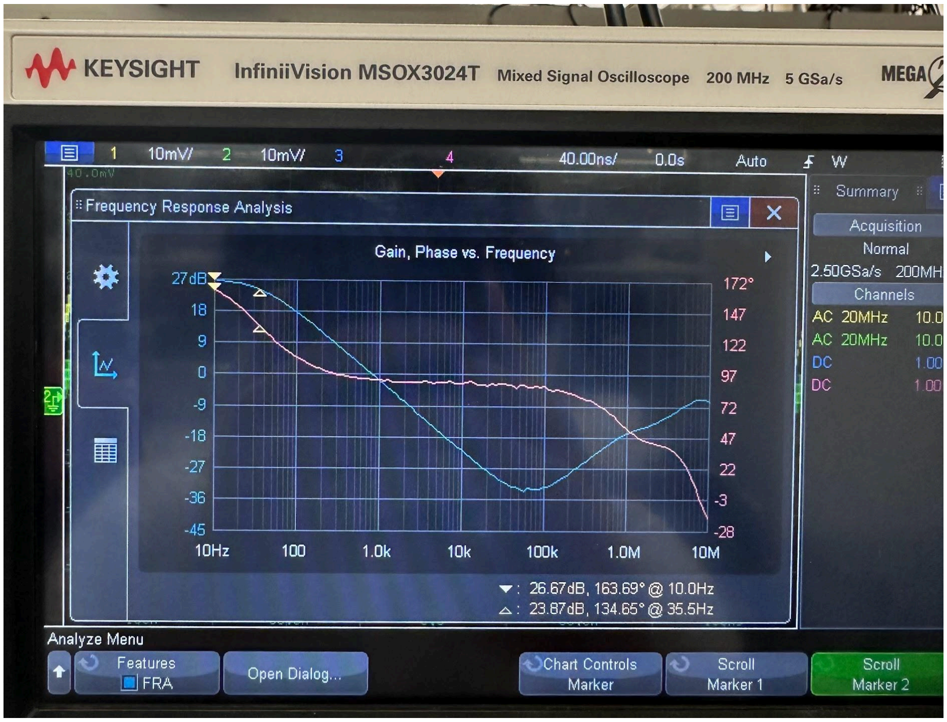
Lossy Integrator:

Breadboard

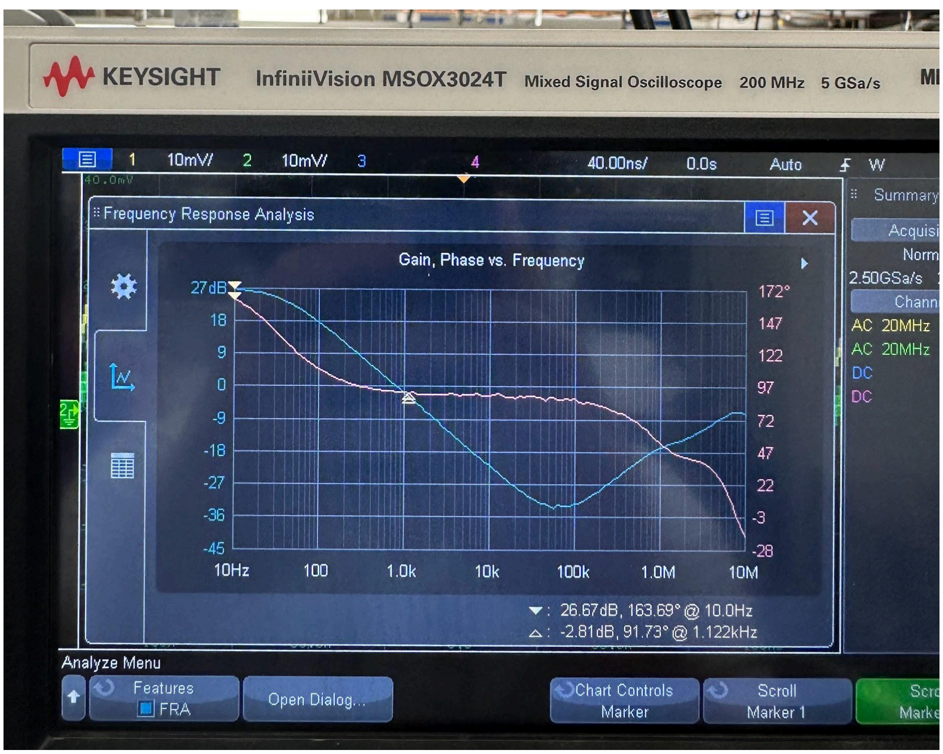


Bode Plots:

Low frequency gain and $f_{3\text{-dB}}$: 21.55 V/V, 35.5 Hz

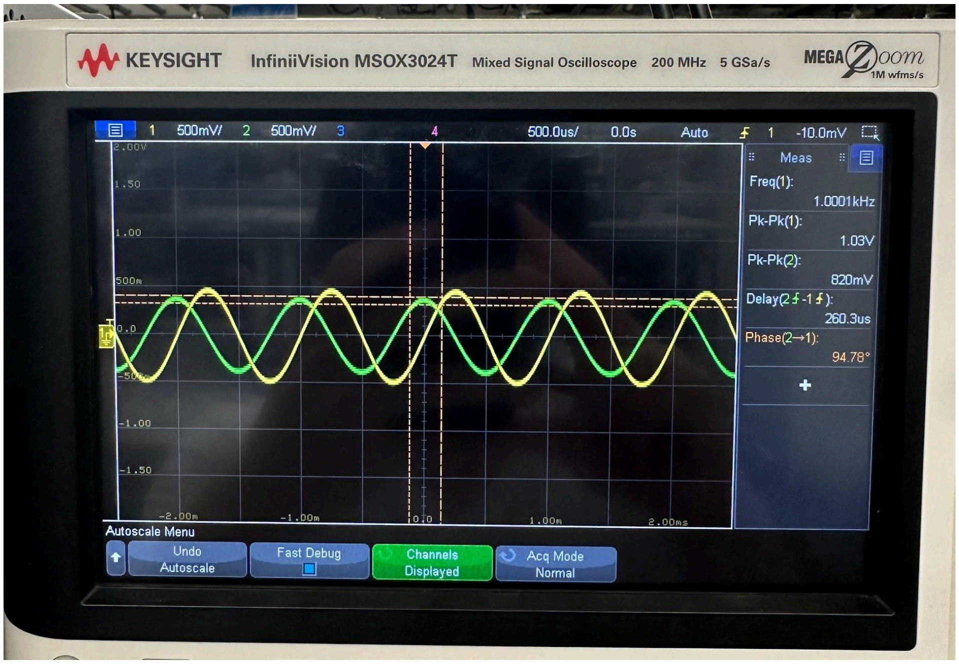


Magnitude and Phase @ 1kHz: -2.81 dB, 91.73 deg

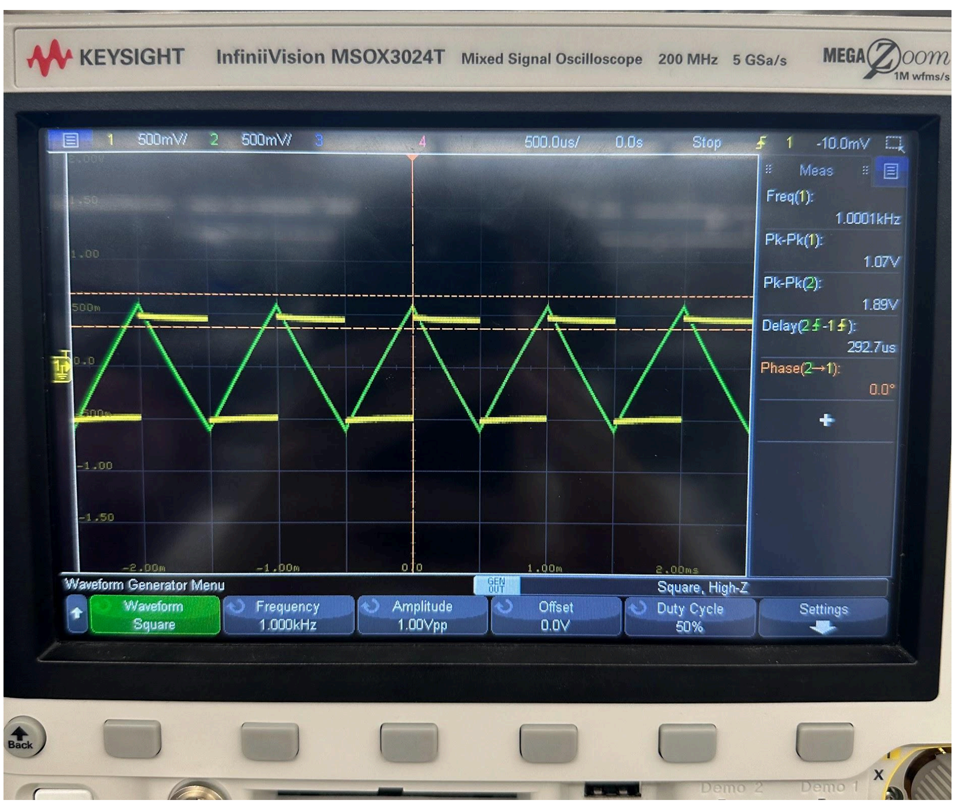


Time-domain Waveforms:

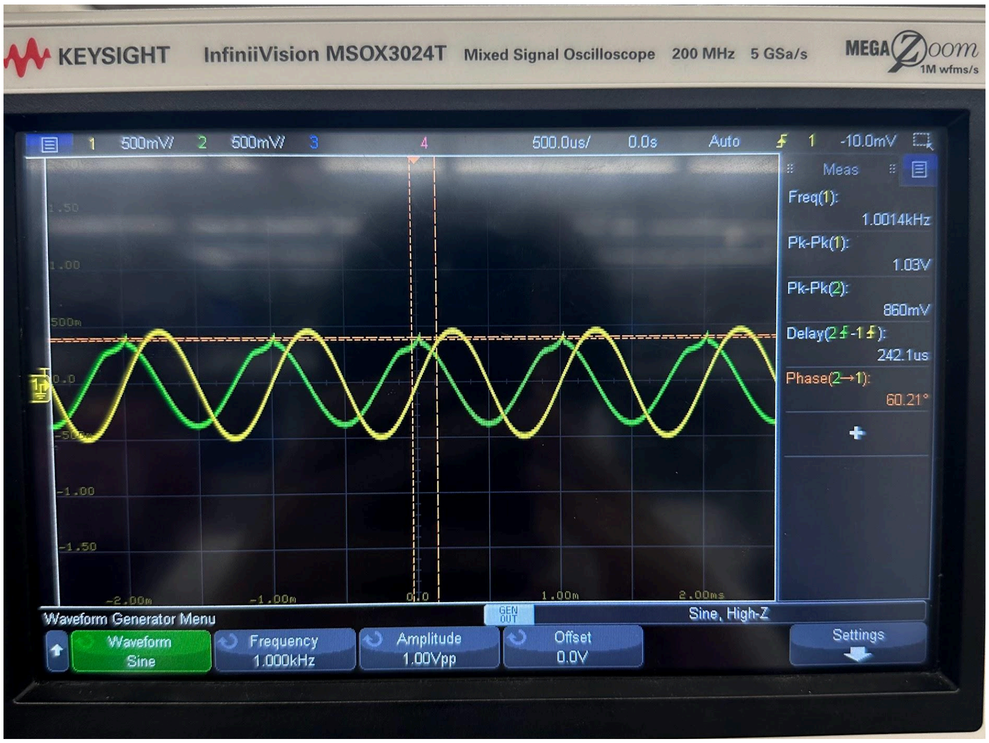
Sine wave input



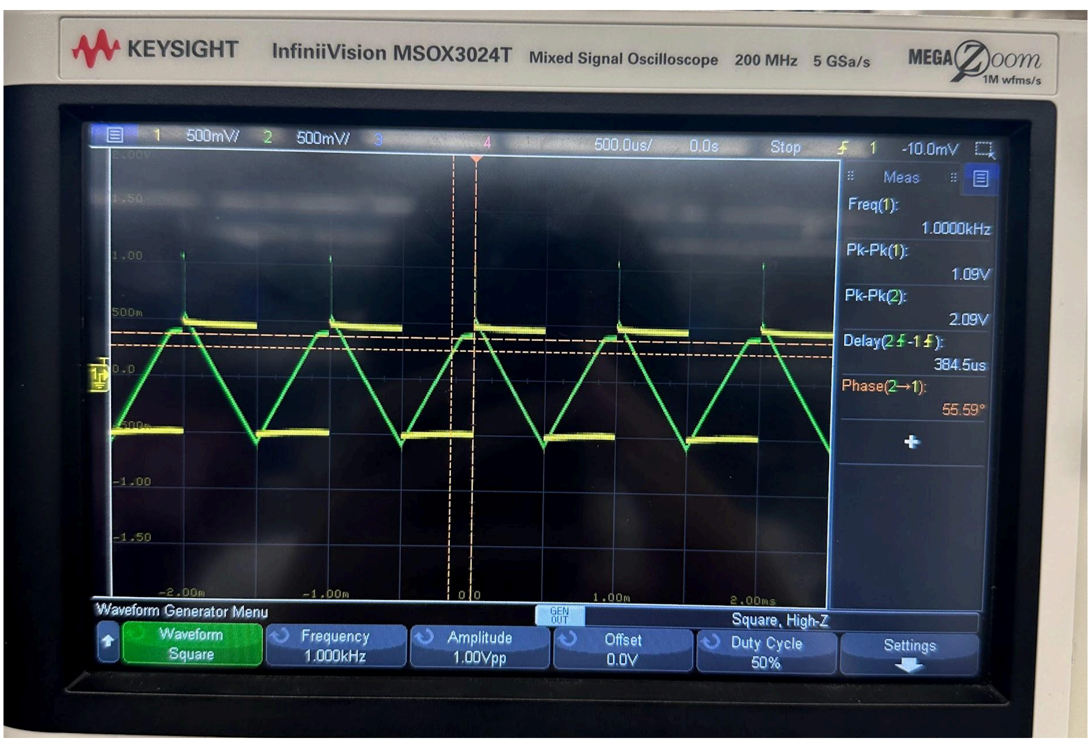
Square wave input



Sine wave input without R2



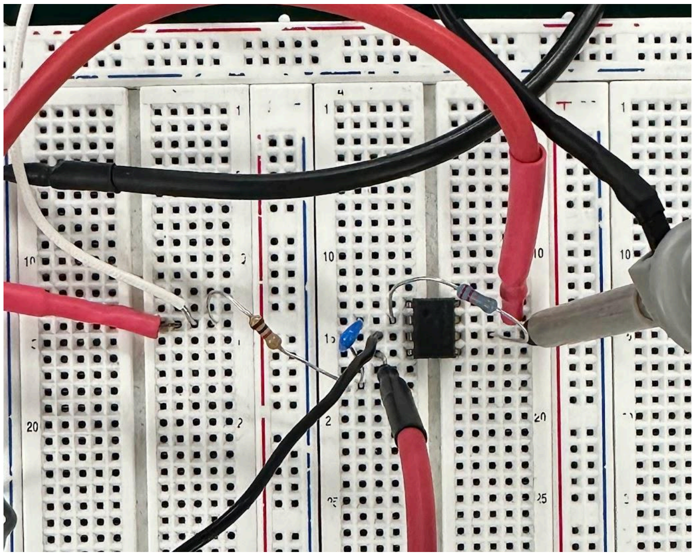
Square wave input without R2



There are spikes that occur at the peaks of the output signal for both plots without R2

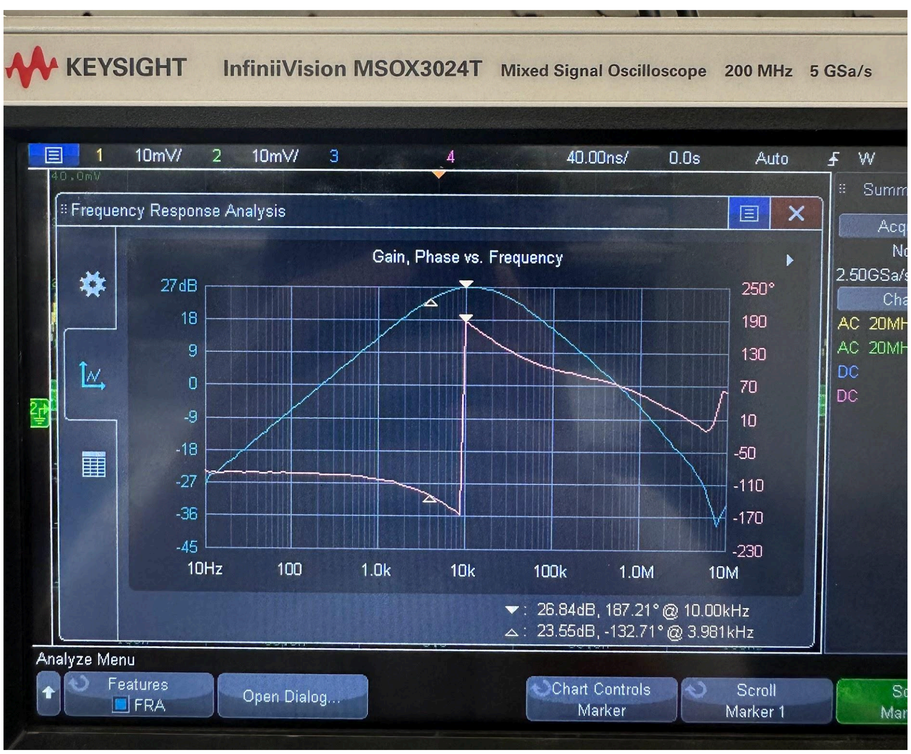
Pseudo Differentiator:

Breadboard

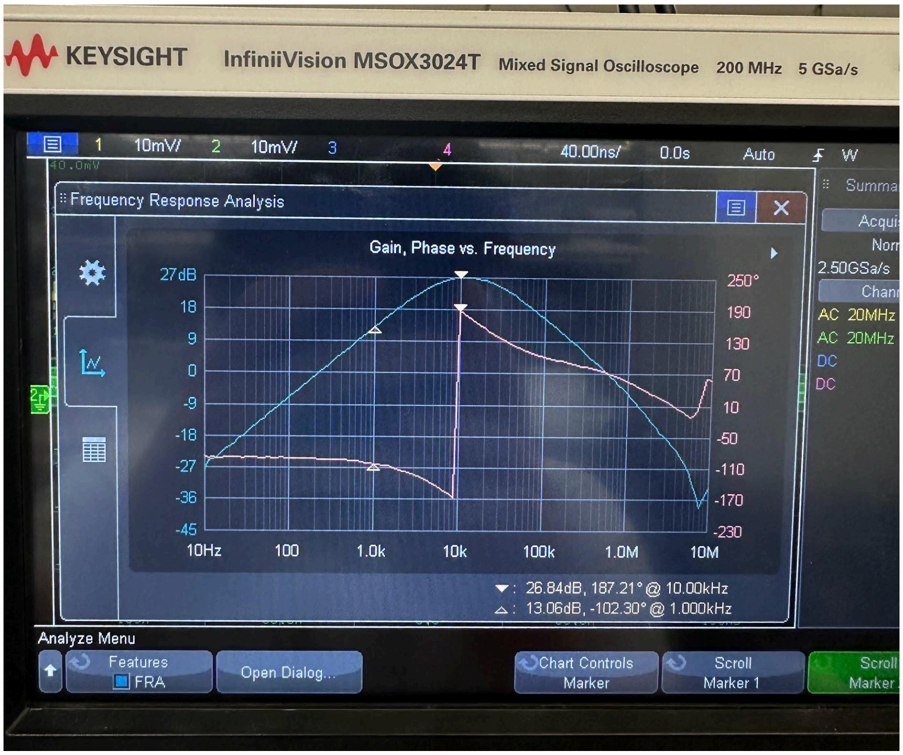


<u>Bode Plots:</u>

Low frequency gain and $f_{3\text{-dB}}$: 21.98, 3.981 kHz

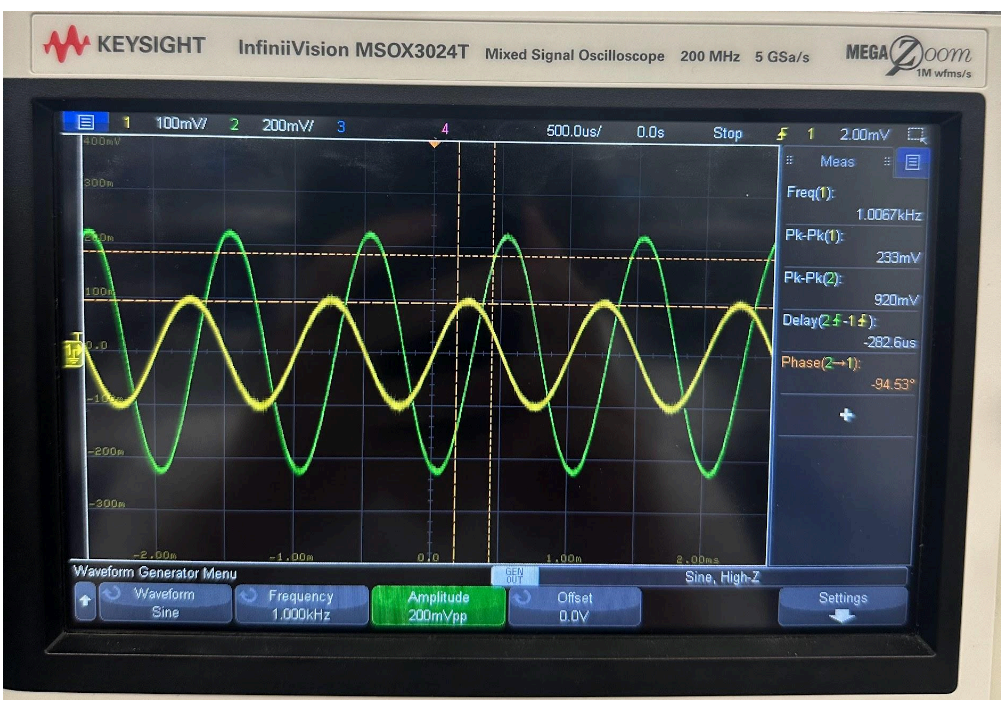


Magnitude and Phase at 1 kHz: 13.06 dB, -102.3 deg

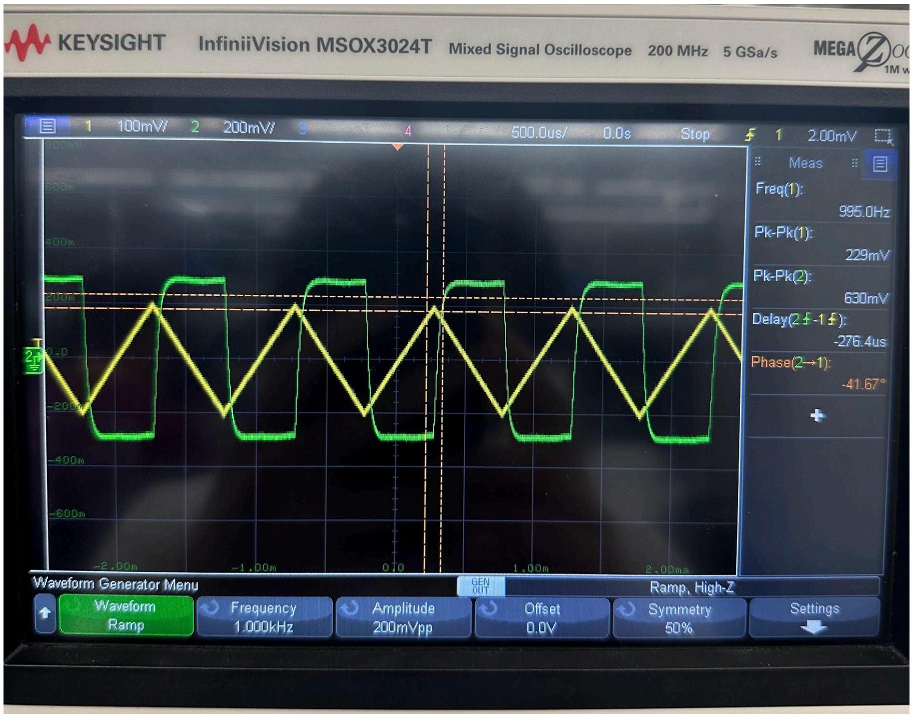


Time-domain waveforms:

Sine wave input



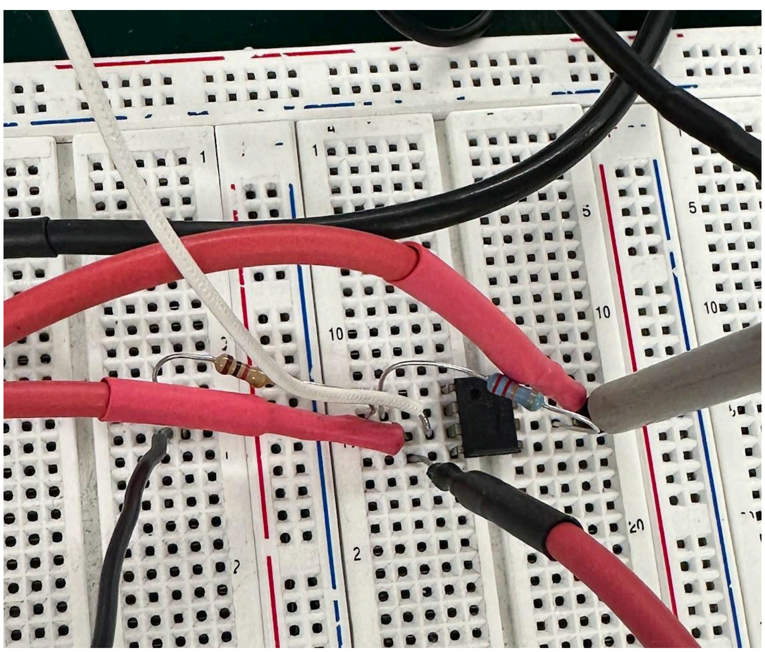
Triangle wave input



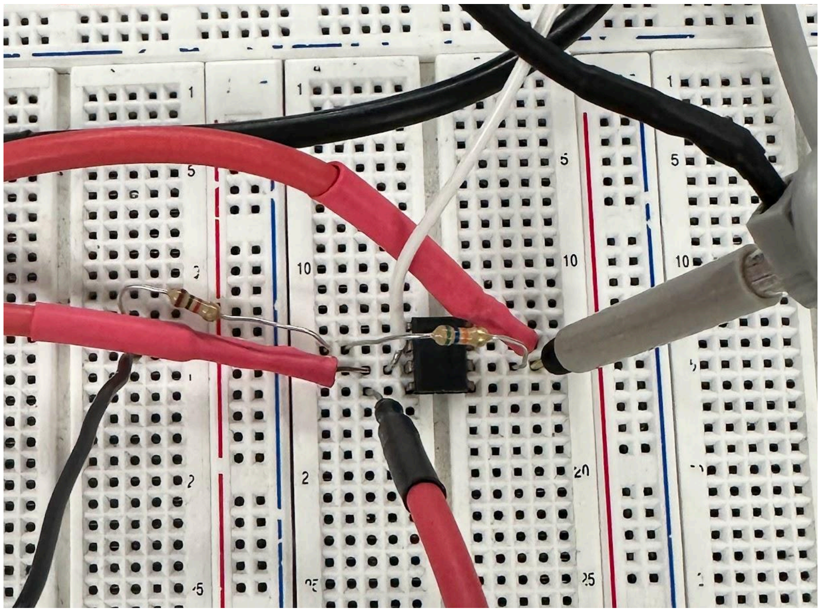
Finite GBW Limitations:

Non-inverting amplifier Breadboard

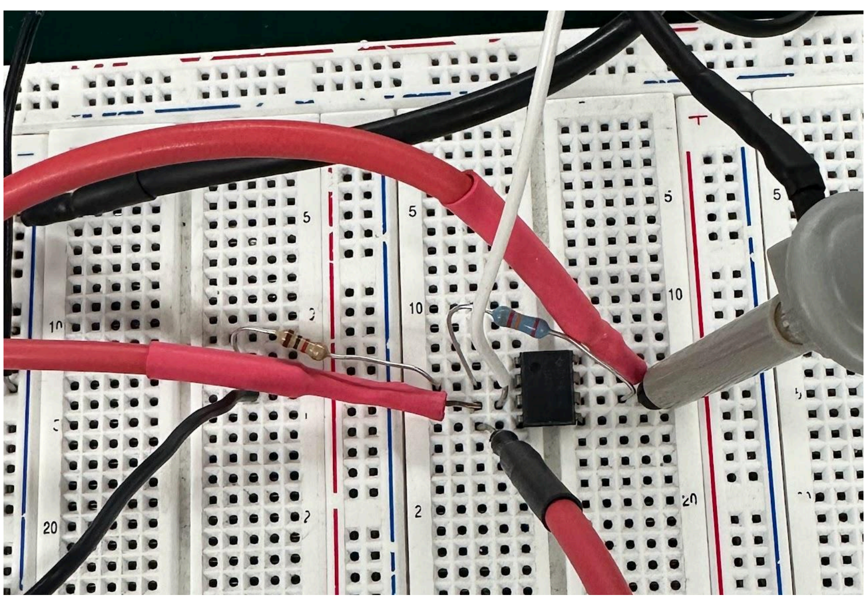
R2 = 22k



R2 = 56k

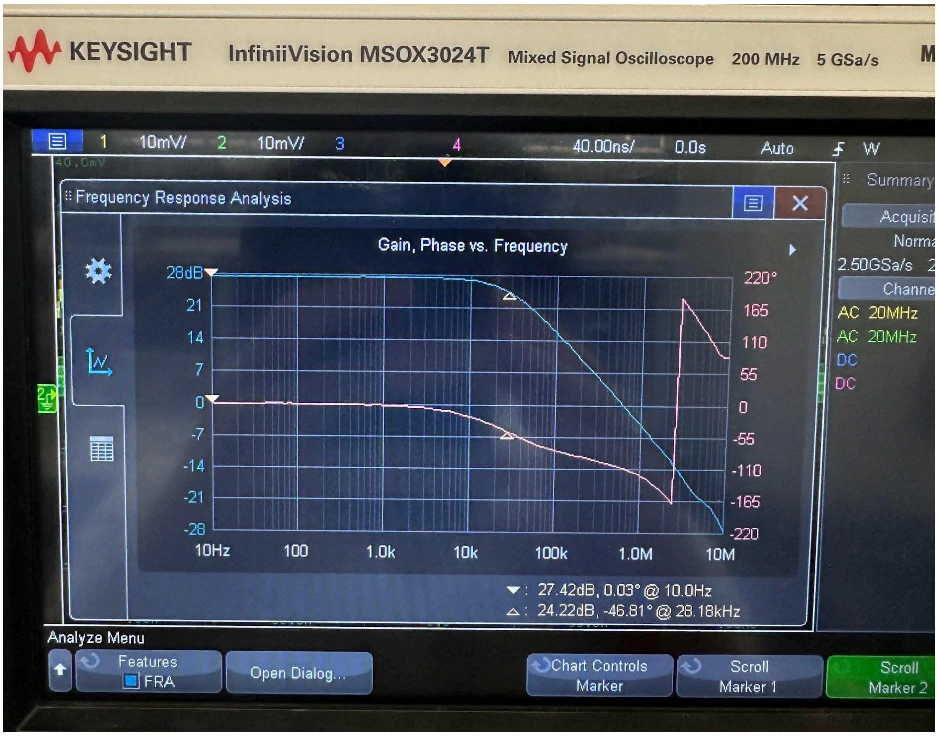


R2 = 82k

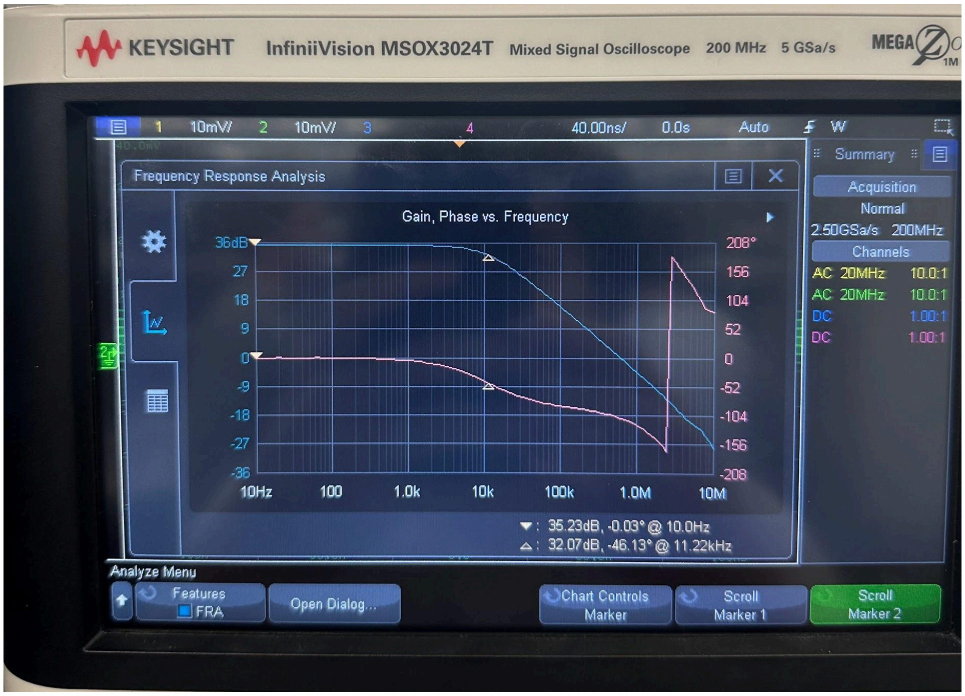


Bode Plots:

R2 = 22k. Low frequency gain and $f_{3\text{-dB}}$: 23.5, 28.18 kHz



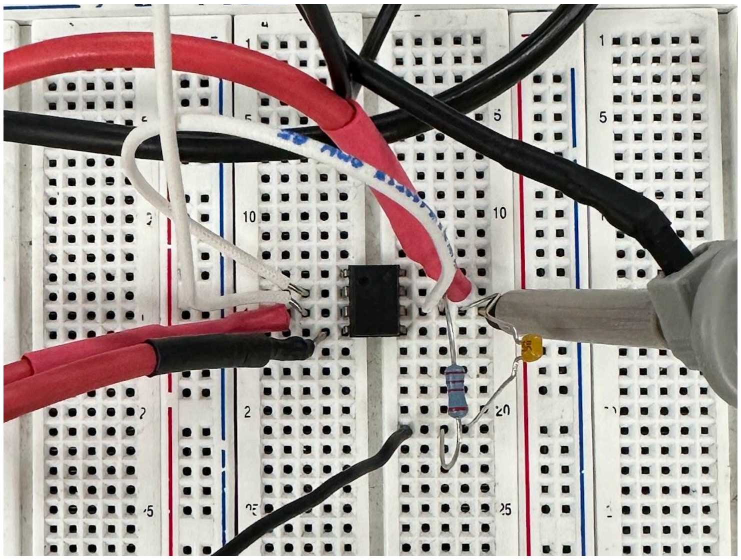
R2 = 56k. Low frequency gain and $f_{3\text{-dB}}$: 57.7, 11.22 kHz



R2 = 82k. Low frequency gain and $f_{3\text{-dB}}$: 85 V/V, 12.59 kHz

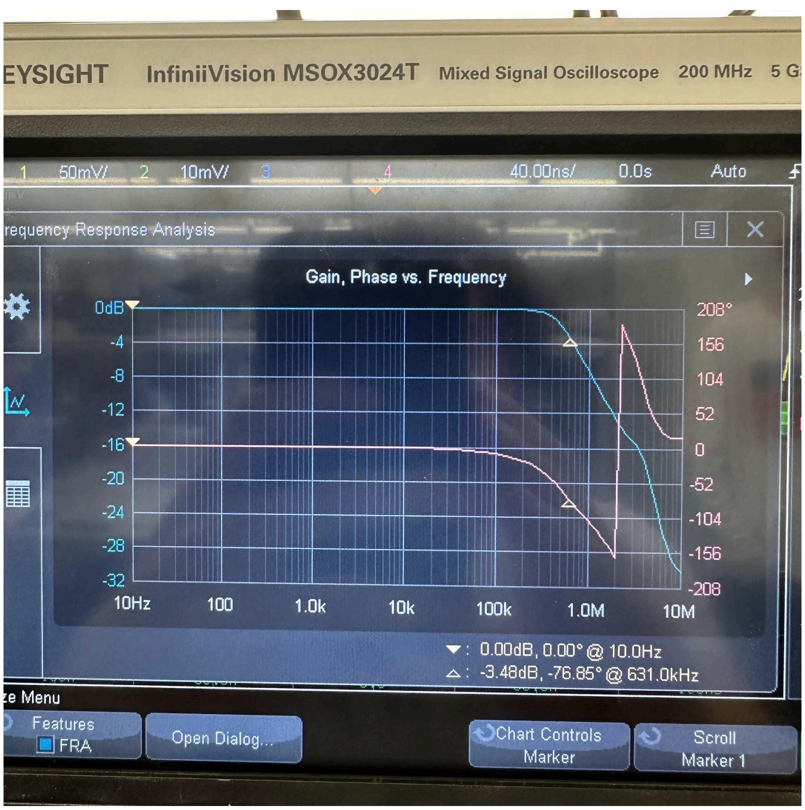
Slew Rate Limitations:

Unity Gain Buffer Breadboard



<u>Bode Plots:</u>

Low frequency gain and $f_{3\text{-dB}}$: 0 V/V, 631 kHz

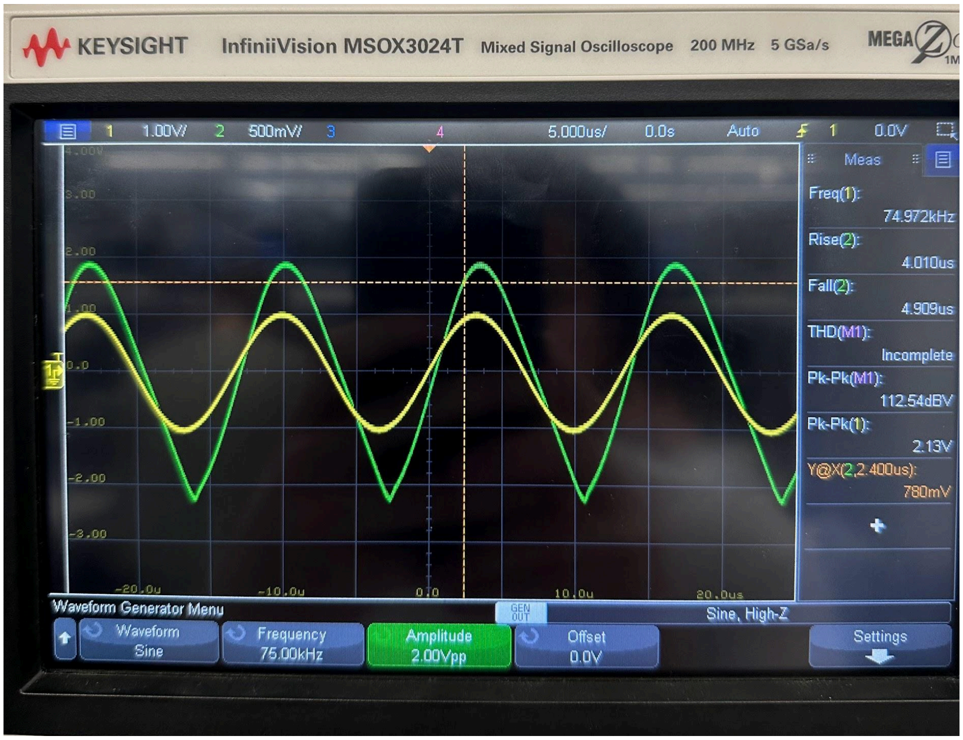


Magnitude @ 75 kHz

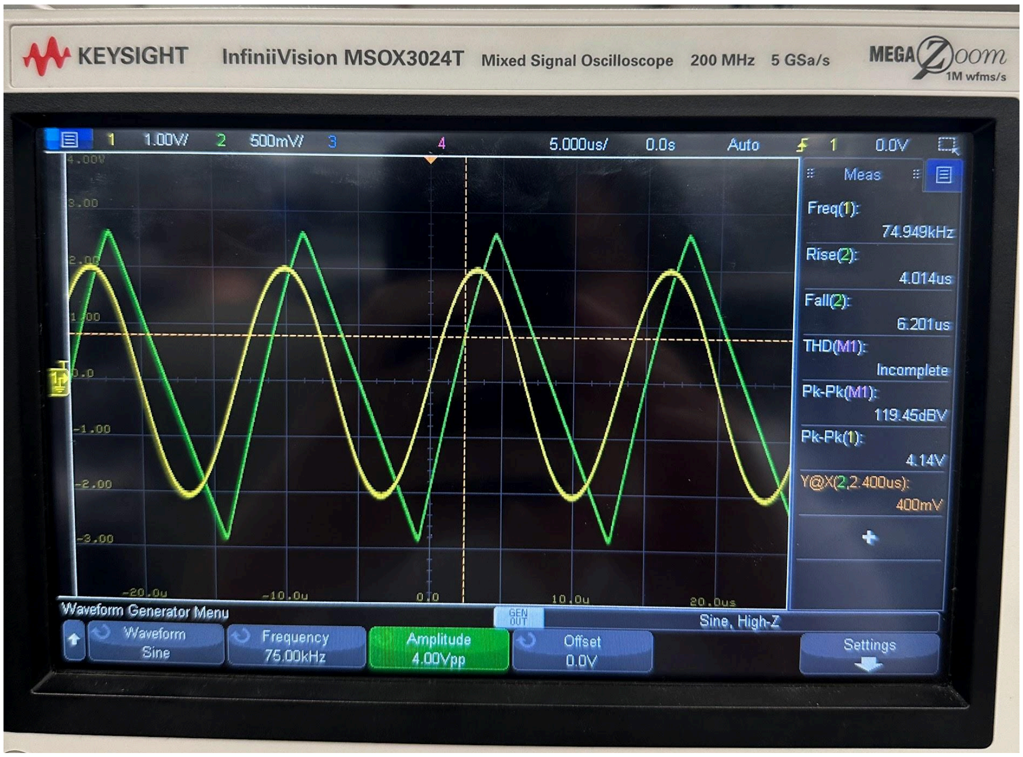
Magnitude @ 150 kHz

Time-domain Waveforms and THD:

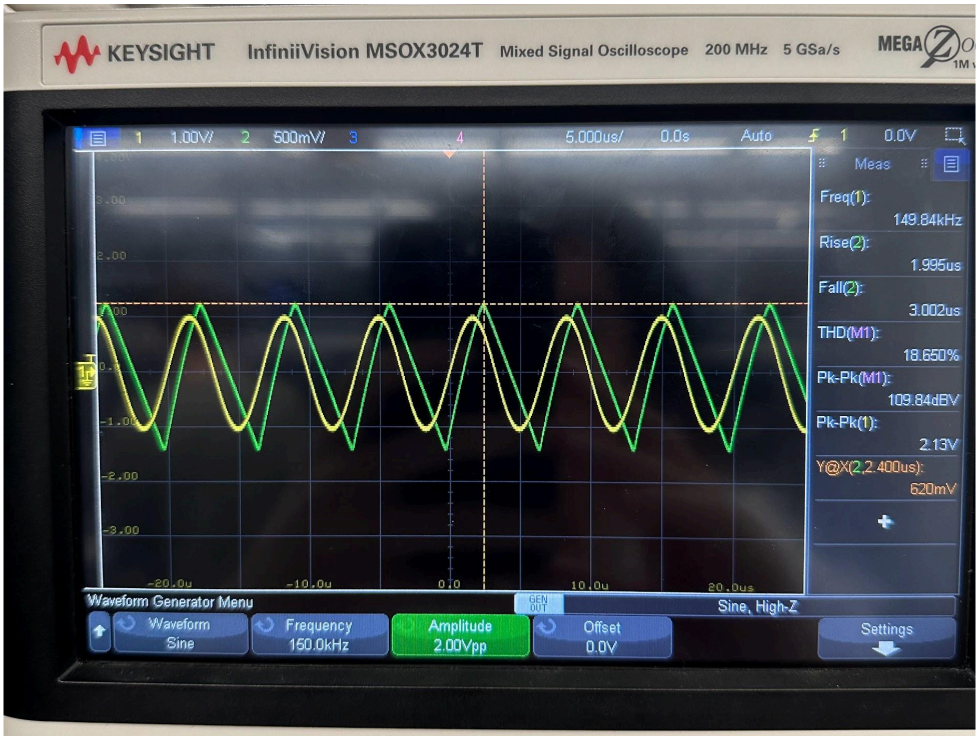
1 V, 75 kHz sine wave input



2 V, 75 kHz sine wave input



1 V, 150 kHz sine wave input



Calculated and Measured Component Values:

Table 1:

Here is a table containing the calculated and measured values used for the components in the lab.

Calculated Circuit	**R1 (kΩ)**	**R2 (kΩ)**	**C (nF)**
Lossy	1	22	220
Pseudo	1	22	33
Non-inverting	1	22, 56, 82	0
Measured Circuit	**R1 (kΩ)**	**R2 (kΩ)**	**C (nF)**
Lossy	1	22	220
Pseudo	1	22	33
Non-inverting	1	22, 56, 82	0

Data and Results:

Table 2:

Here is a table comparing calculated, simulated, and measured results for the Lossy Integrator

Lossy Integrator	Calculated	Simulated	Measured
Low Freq Gain (V/V)	-22	-10.99	-21.55
$f_{3\text{-dB}}$ (Hz)	32.9	32.86	35.5
Magnitude V_{in} sine (V)	0.5	0.5	0.5015
Magnitude V_{in} square (V)	N/A	0.5	0.5035
Magnitude V_{out} sine (V)	0.362	0.344	0.410
Magnitude V_{out} square (V)	N/A	0.447	0.945
Phase Diff sine (deg)	91.88	88.96	94.78
Mag (dB) & Phase (deg) @ 1kHz	N/A	8.9, 91.8	-2.81, 91.73

Some major differences from the table include the gain, the magnitude of Vout for the square input, and the magnitude of H(s) at 1 kHz from the simulation. The gain seems to be off by a factor of ½ which could be due to an error within the circuit or the op-amp that was chosen for the schematic.

Table 3:

Here is a table comparing calculated, simulated, and measured results for the Pseudo Differentiator

Pseudo	Calculated	Simulated	Measured
Low Freq Gain (V/V)	-22	-10.99	-21.98
$f_{3\text{-dB}}$ (kHz)	4.823	4.725	3.981
Magnitude V_{in} sine (V)	0.1	0.1	0.1175
Magnitude V_{in} triangle (V)	N/A	0.1	0.1145
Magnitude V_{out} sine (V)	0.447	0.4466	0.460
Magnitude V_{out} triangle (V)	N/A	0.2903	0.315
Phase Diff (deg)	-101.99	-104.78	-94.53
Mag (dB) & Phase (deg) @ 1kHz	N/A	7.04, -101.87	13.06, -102.30

Here we can see that the only major difference in the table is the gain from the simulation, and the $f_{3\text{-dB}}$ from the measurement. Similarly to the Lossy integrator, the simulated value is off by a factor of ½ which again could be due to the same reasons previously stated. As for the measured $f_{3\text{-dB}}$ this could be due to uncontrollable factors such as tolerances of the lab components, noise from the oscilloscope, or other unknown factors. The rest of the values seem to be quite similar to one another with very small differences

Table 3:

Here is a table comparing calculated, simulated, and measured results for the GBW limitations

Non-inverting	Calculated	Simulated	Measured
R2 = 22k Low Freq Gain (V/V)	23	23	23.5
R2 = 22k $f_{3\text{-dB}}$ (kHz)	52.174	48.111	28.42
R2 = 56k Low Freq Gain (V/V)	57	56.98	57.7
R2 = 56k $f_{3\text{-dB}}$ (kHz)	21.053	19.124	11.22
R2 = 82k Low Freq Gain (V/V)	83	82.96	85
R2 = 82k $f_{3\text{-dB}}$ (kHz)	14.458	13.273	12.59

Here we can see for the GBW limitations, the most notable differences in the table are the $f_{3\text{-dB}}$ for the measured values with R2 being at 22k and 56k. From the table it seems that the differences between the $f_{3\text{-dB}}$ values seem to decrease exponentially as R2 goes from 22k to 82k.

Table 4:

Here is a table comparing simulated and measured results for the slew rate limitations

	Simulated	**Measured**
1 V, 75 kHz sine input THD (%)	0.93953	10.290
2 V, 75 kHz sine input THD (%)	11.793	18.911
1 V, 150 kHz sine input THD (%)	11.236	18.375

Here we can see some notable differences in the THD values. This could be due to the noise affected by the oscilloscope.