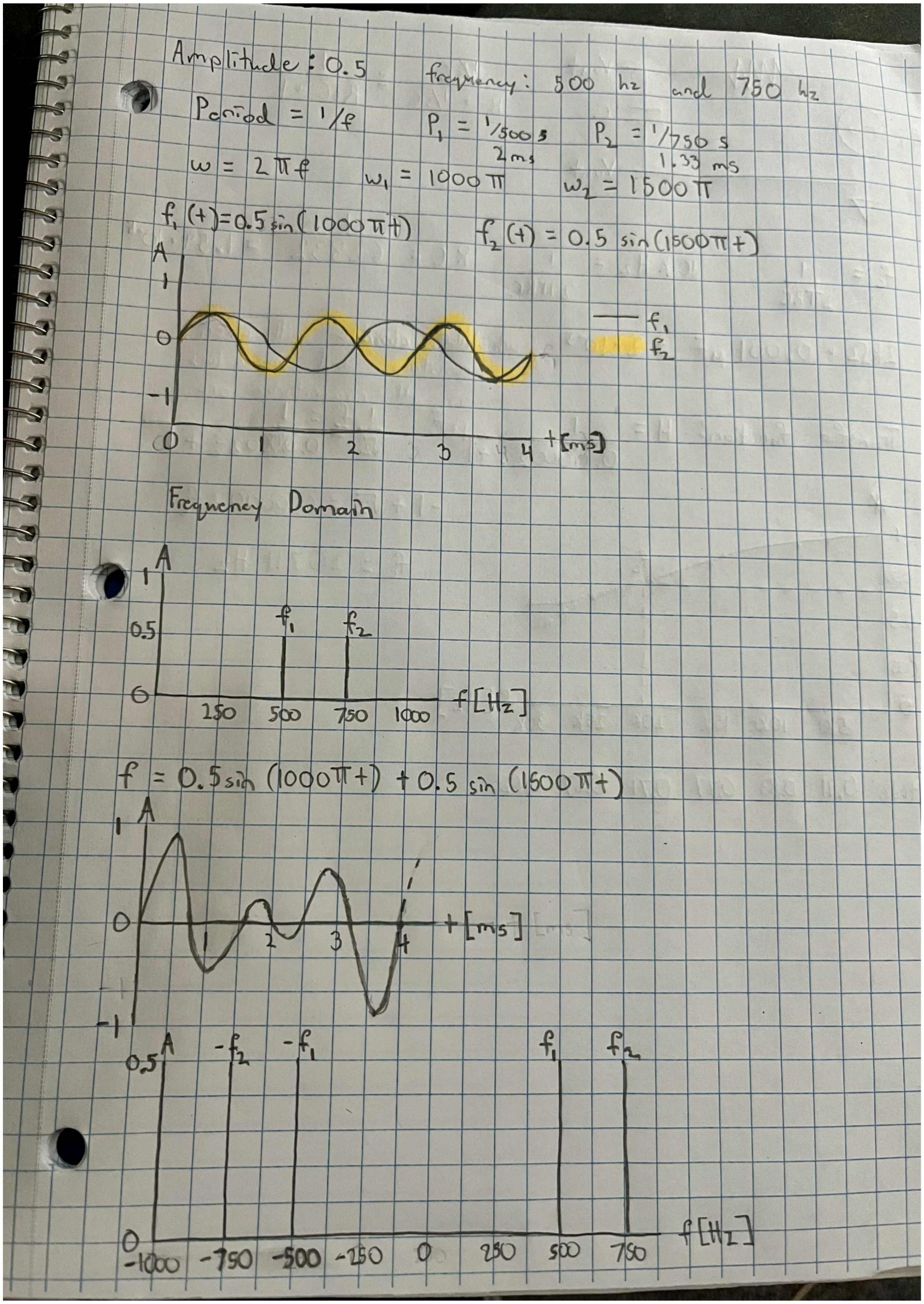
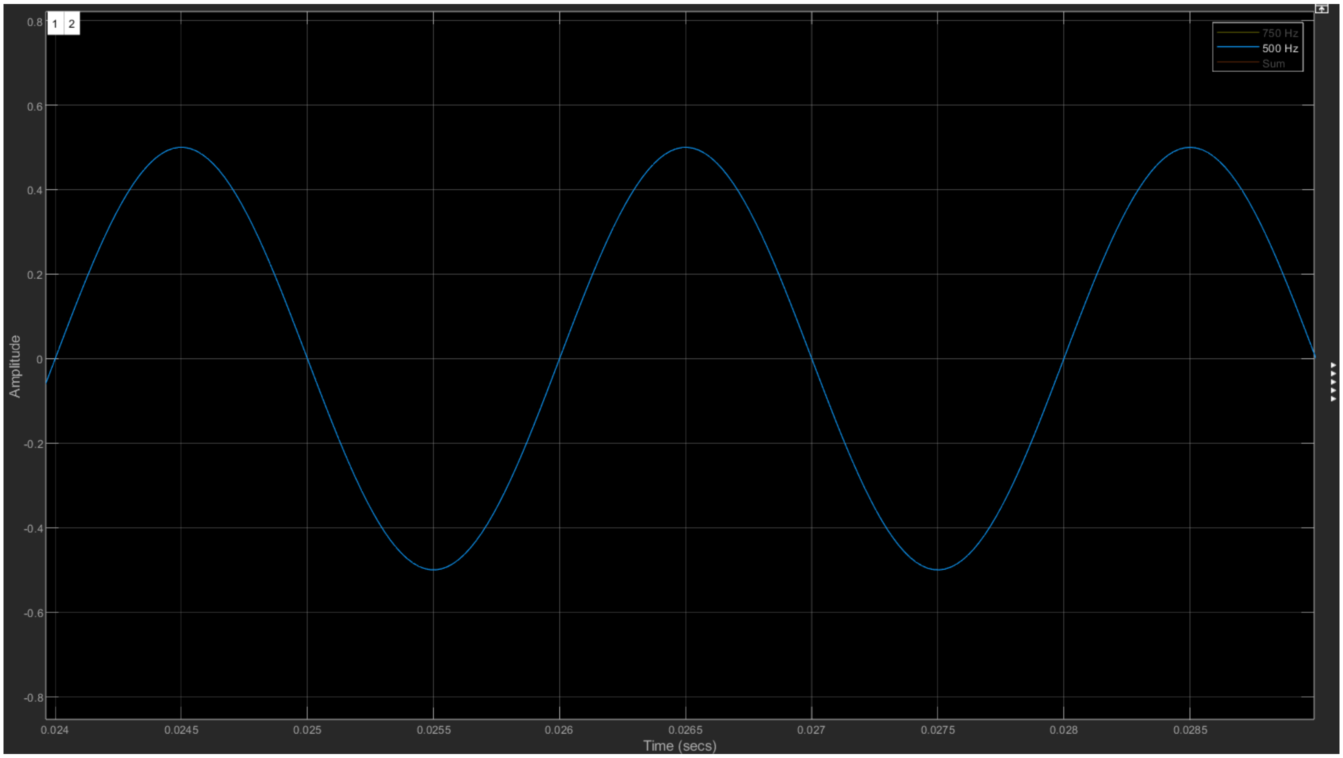
Andy Zheng

LABORATORY 3: The Signals and the Noise

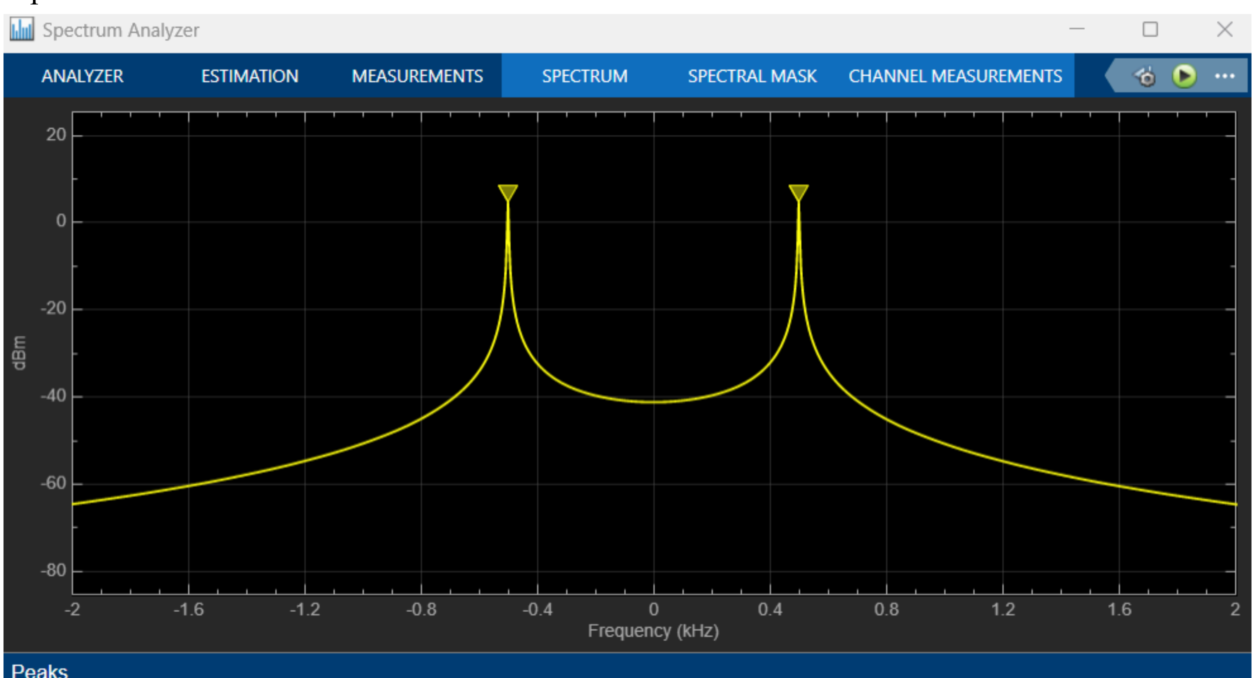
Part A:





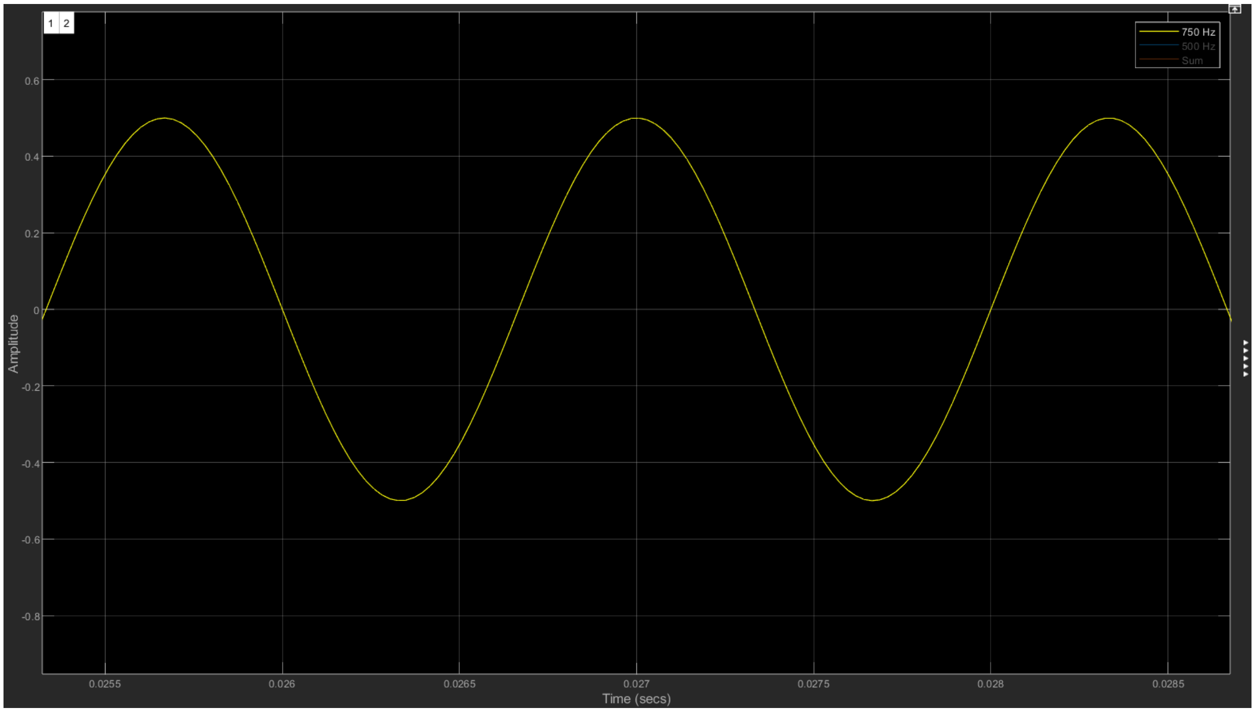
0.0285 - 0.0265 = 0.0265 - 0.0245 = 0.002s

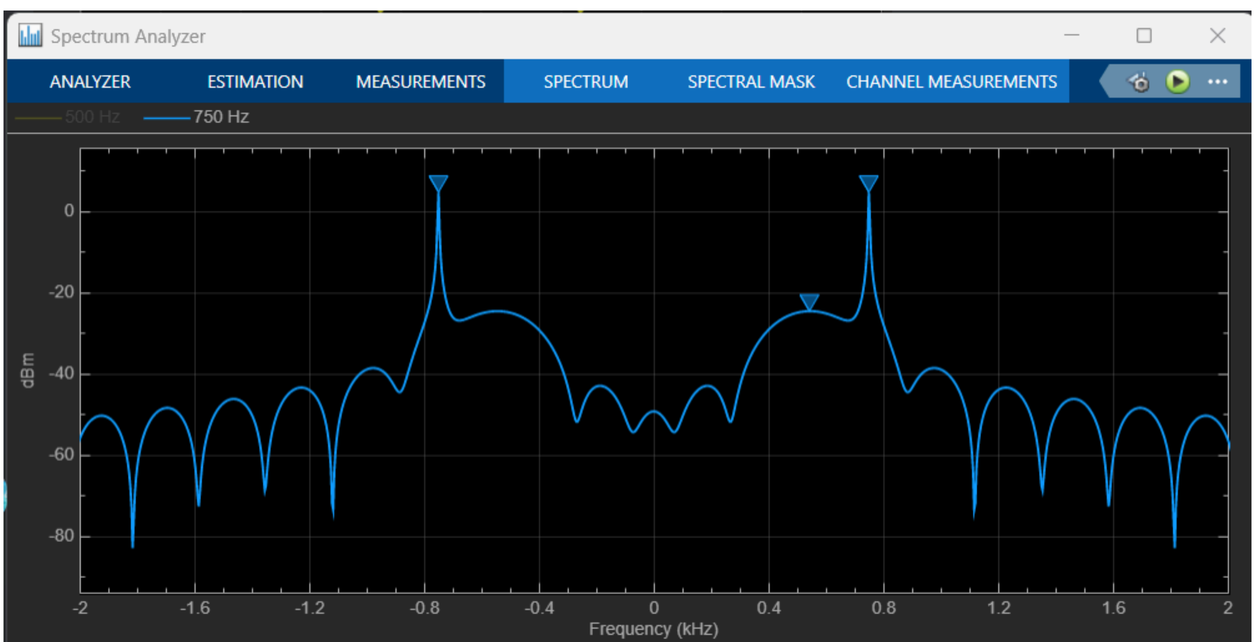
A period of 2ms matches what I calculated above.



Sine Wave	P1	P2	P3
Frequency (Hz)	4.9972e+2	-4.9972e+2	
Power (dBm)	4.5987e+0	4.5987e+0	

Frequencies Peak at 500 and -500 Hz.

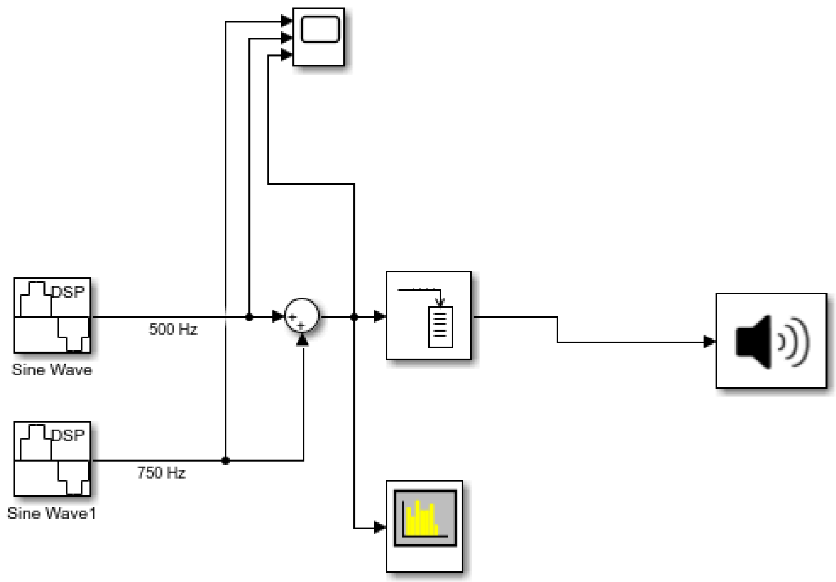


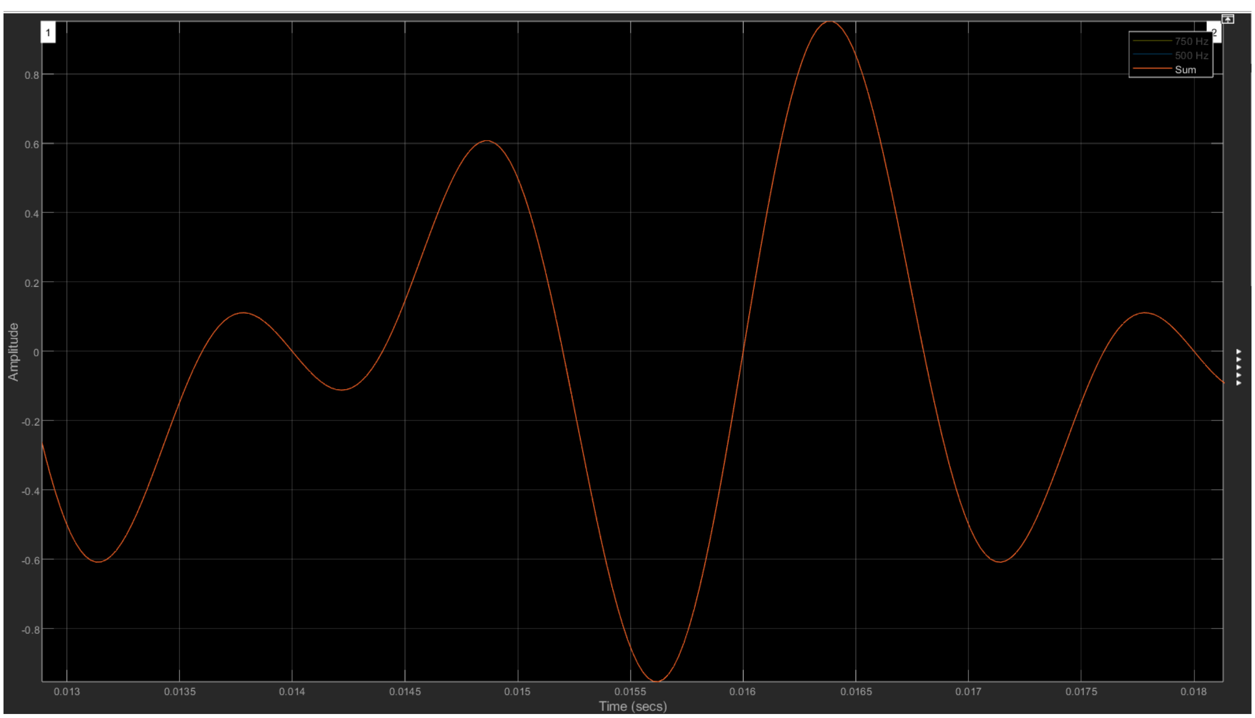


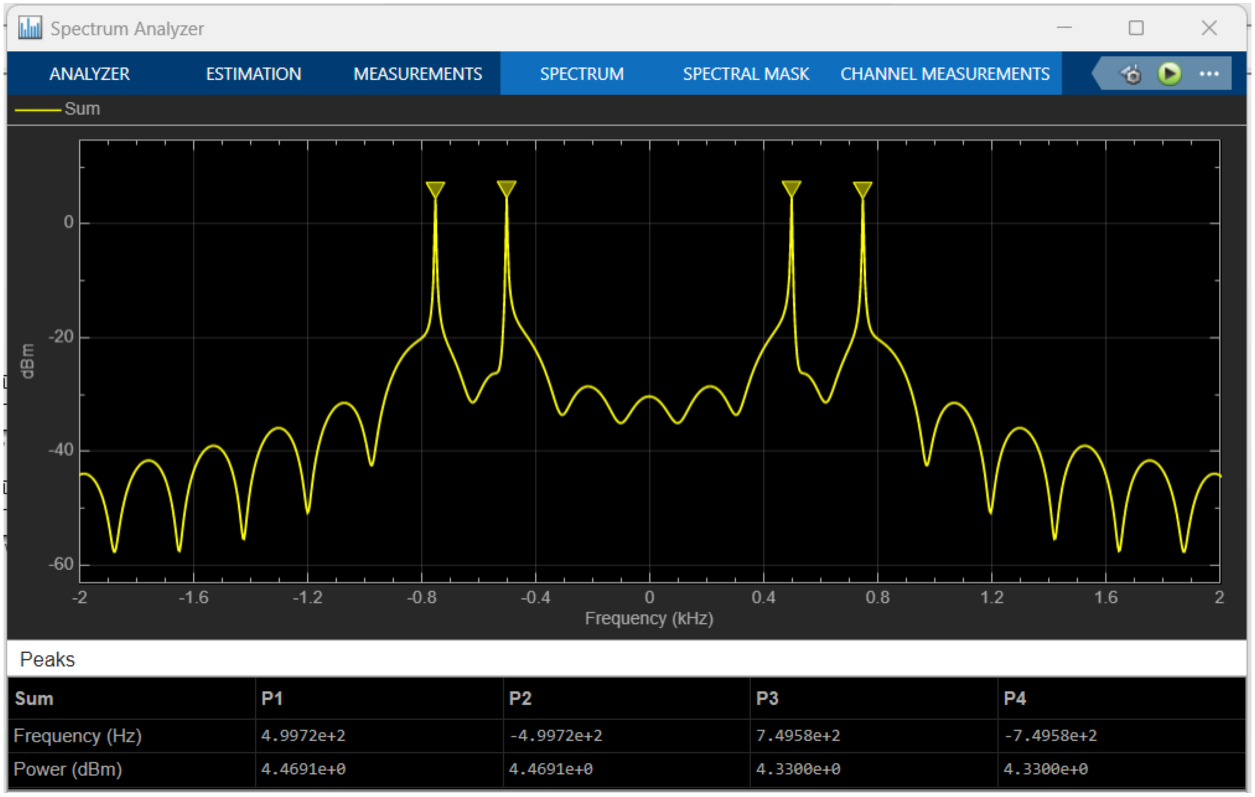
Peaks

750 Hz	P1	P2	P3
Frequency (Hz)	7.4958e+2	-7.4958e+2	5.4266e+2
Power (dBm)	4.6881e+0	4.6881e+0	-2.4650e+1

As frequency increases, pitch gets higher, periods on the time domain get shorter, and peaks are further from zero on freq domain and more noise is added.


DSP
Sine Wave
500 Hz
DSP
Sine Wave1
750 Hz


750 Hz
500 Hz
Sum
Amplitude
Time (secs)



The summed function sounds kind of like a phone dial. The graphs on both the time and freq domain added as I expected, with the amplitudes just being added together.

Proof of Concept:

Amplitude = 0.5

f_1 = 100 hz

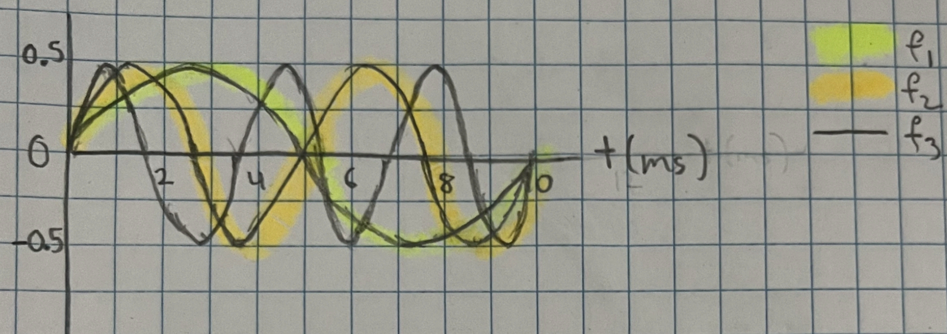
P_1 = 1/100 s
= 10 ms

f_2 = 200 hz

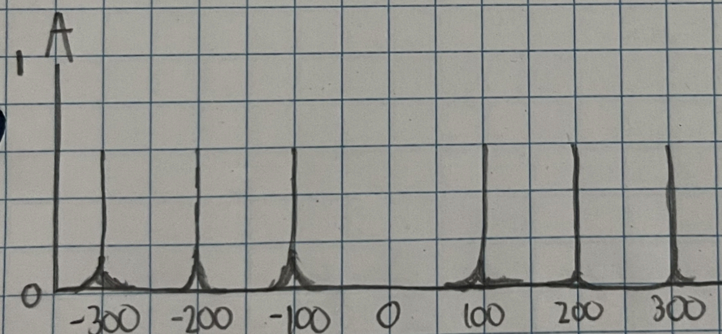
P_2 = 1/200 s
= 5 ms

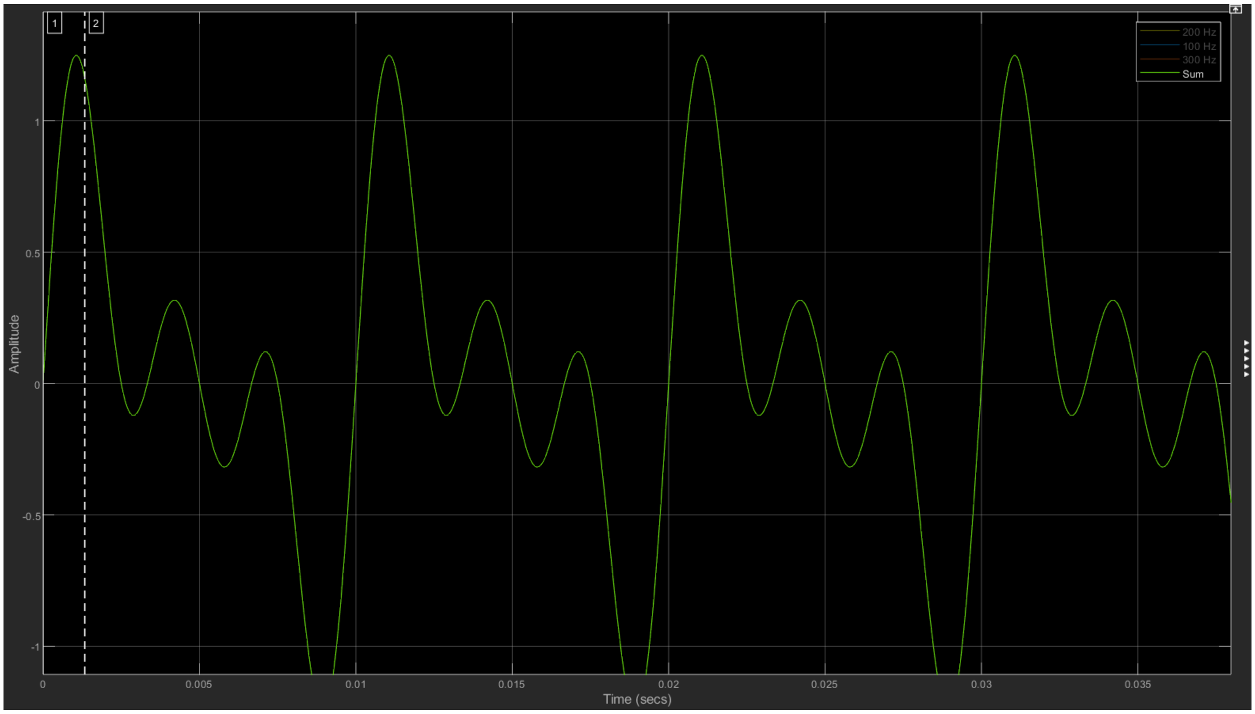
f_3 = 300 hz

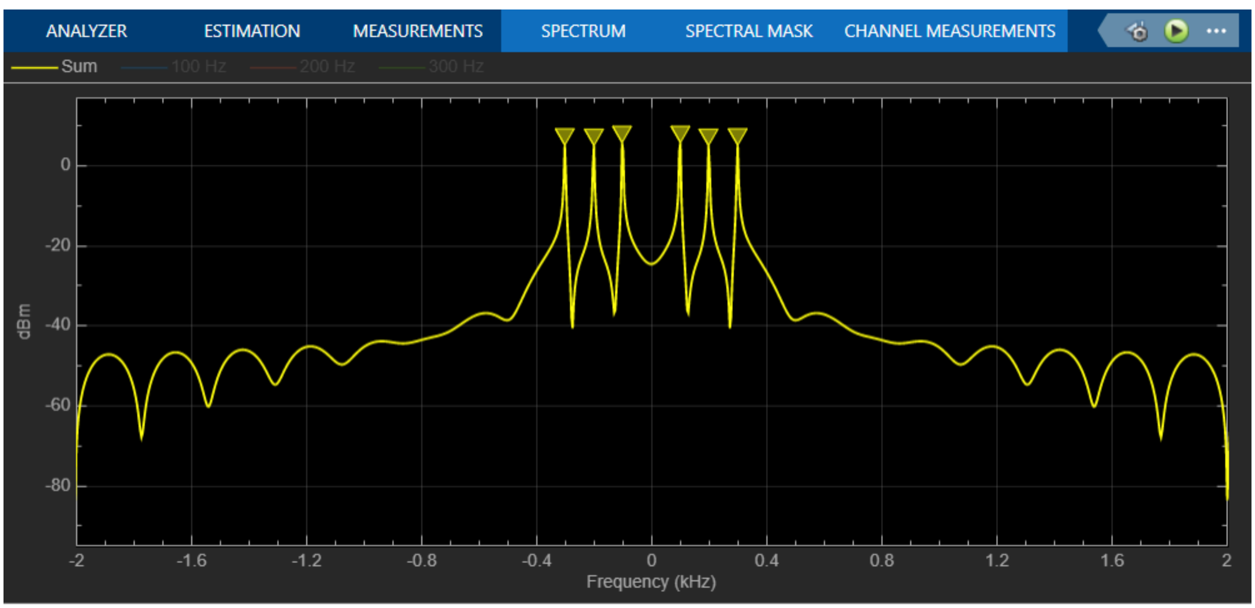
P_3 = 1/300 s
= 3.33 ms



Frequency Domain



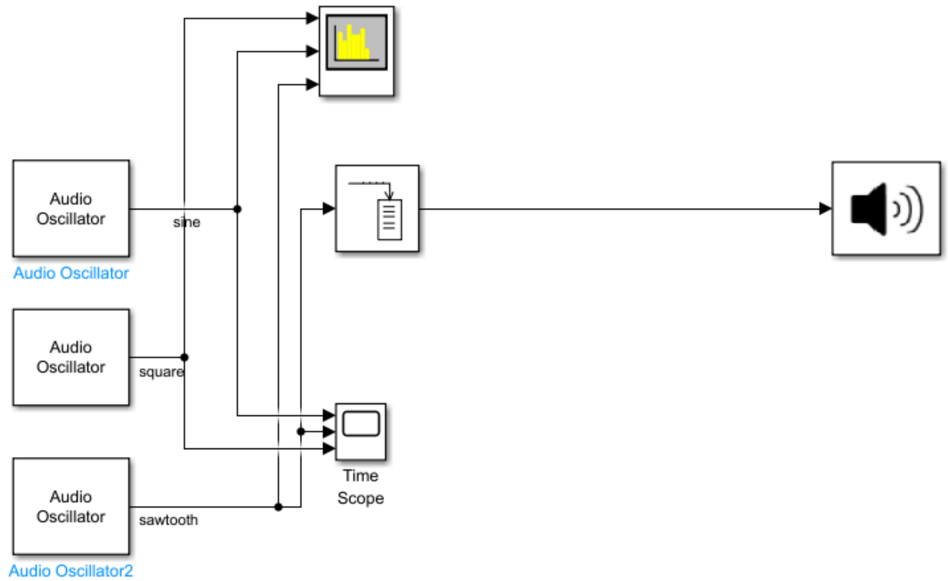




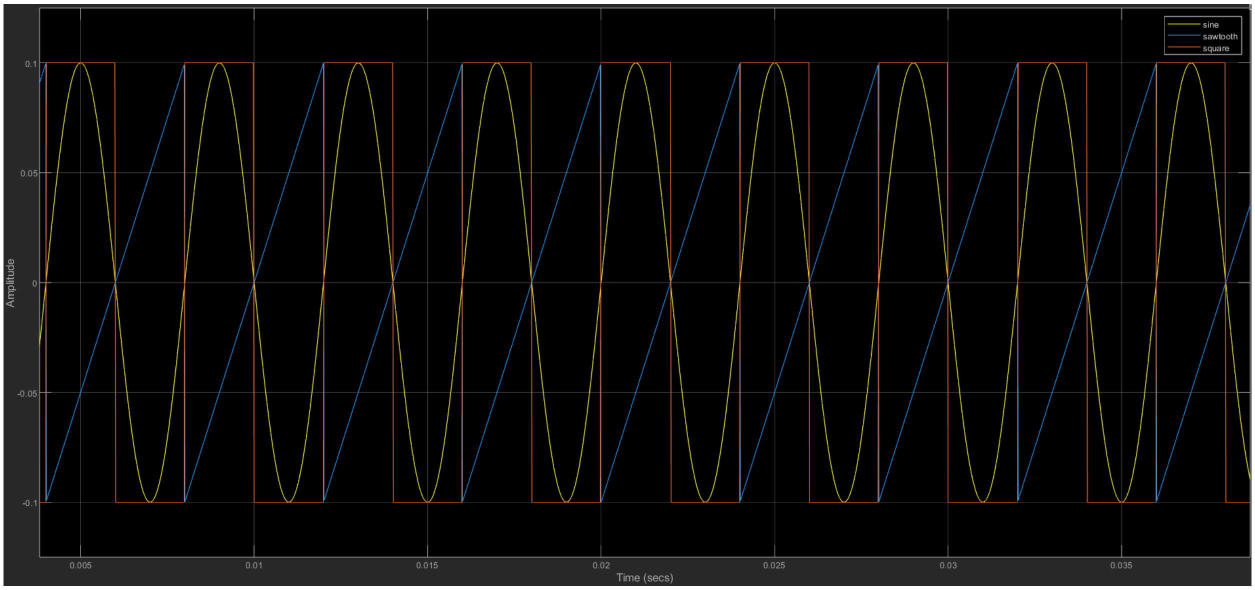
Peaks

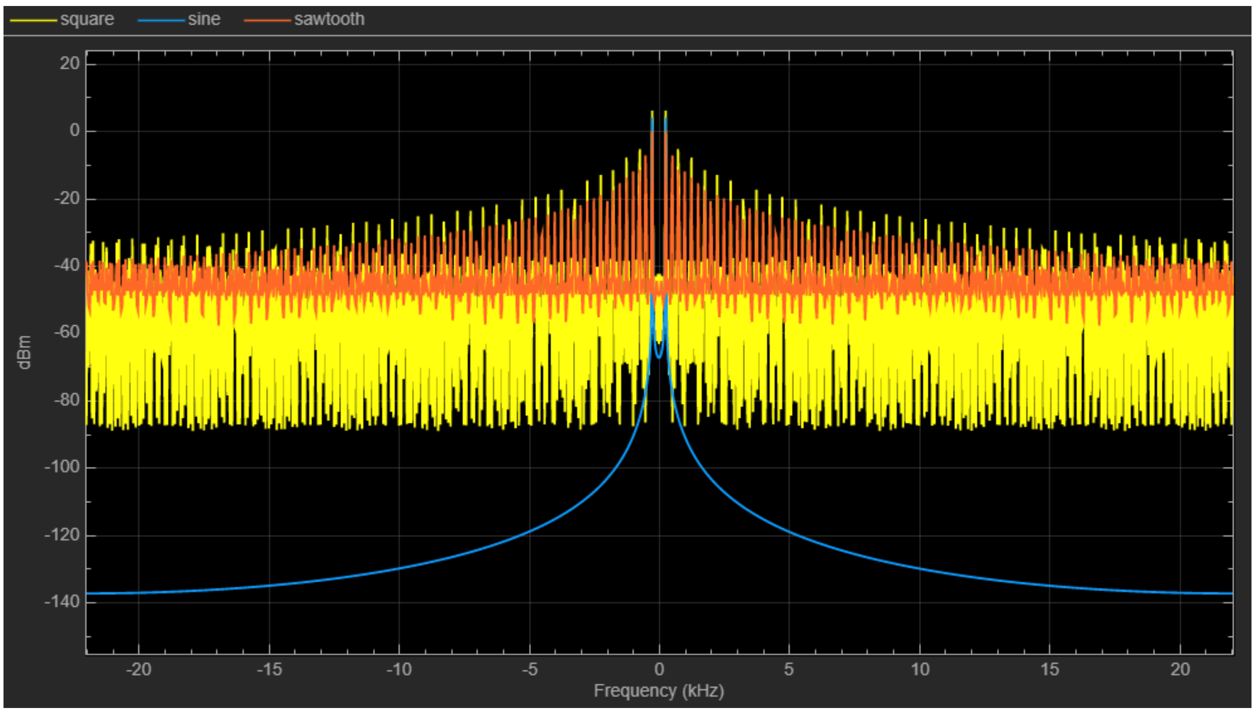
Sum	P1	P2	P3	P4	P5	P6
Frequency (Hz)	1.0150e+2	-1.0150e+2	3.0061e+2	-3.0061e+2	1.9911e+2	-1.9911e+2
Power (dBm)	5.6056e+0	5.6056e+0	4.9804e+0	4.9804e+0	4.8743e+0	4.8743e+0

Part B:



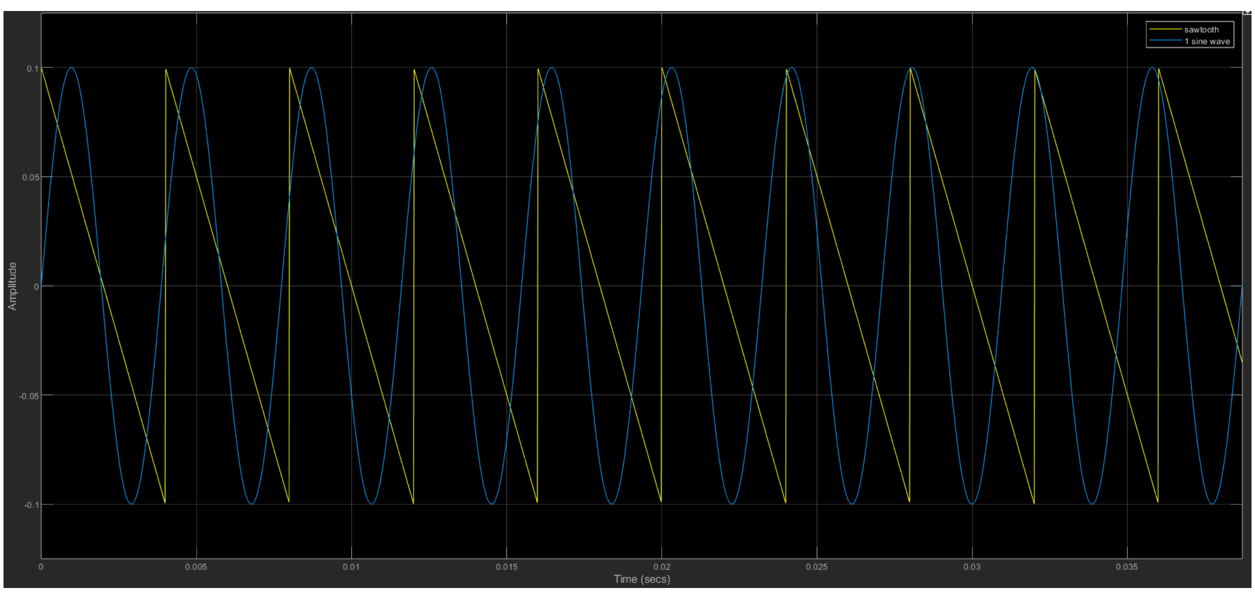
The square is louder and sharper than sine. It's like a blare while the sine is a smooth sound.
Time domain looks like squares rather than the sine waves
They have the same peaks on freq but the square has many smaller spikes that are noisy.
The sawtooth sounds like between the two, it's not completely smooth like sine, but not the horrendous blare that square is.
Freq is like the square but missing the lower dbs.
On time scale, saw has linear increasing amp but sharp falls. They have the same frequency but sound different because of their shapes on the time domain, they change amplitude in differing ways.


sine
sawtooth
square
0.1
0.05
0
-0.05
-0.1
Amplitude
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Time (secs)

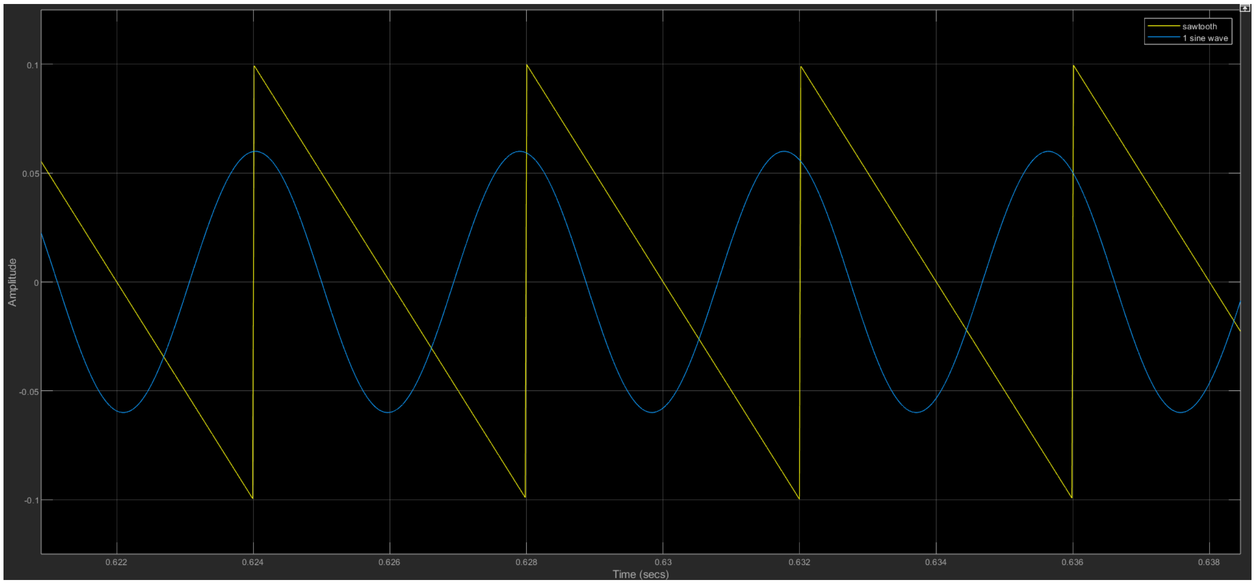

square
sine
sawtooth
20
0
-20
-40
-60
-80
-100
-120
-140
dBm
-20
-15
-10
-5
0
5
10
15
20
Frequency (kHz)

Peak Number	Frequency (Hz)	Magnitude (dBm)
1	260	0
2	520	-7
3	730	-11
4	990	-12
5	1250	-14
6	1510	-16
7	1770	-18
8	2240	-19
9	2500	-20
10	2760	-21

The frequencies are all around the multiples of the frequency of the sawtooth entered. The 260 hz is the highest peak and it is the closest to the original frequency entered.

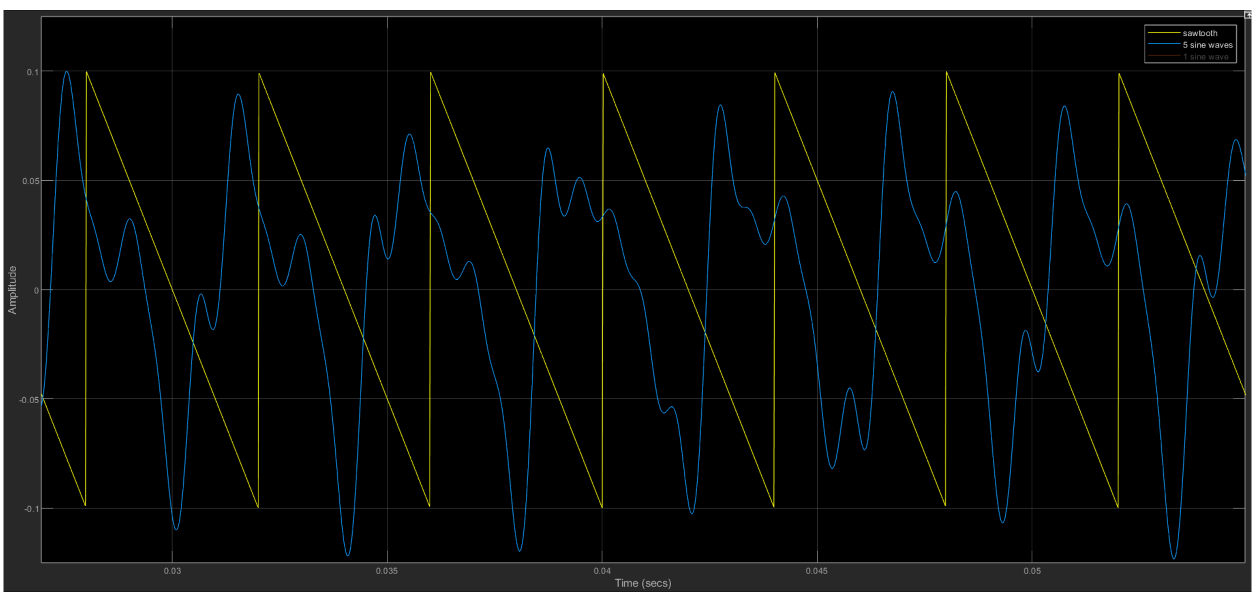


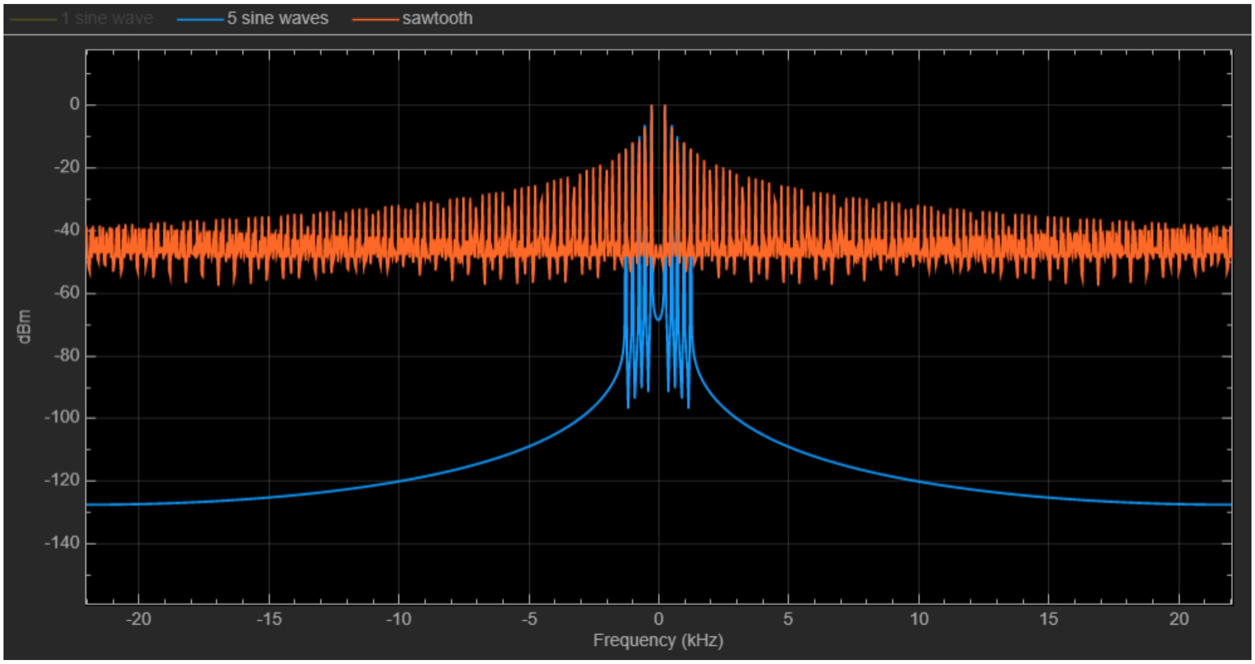
Amplitude on time domain matched, but freq differed and amplitude on freq domain didn't match. Had to drop amplitude to 0.06V. Now time domain looks like this:



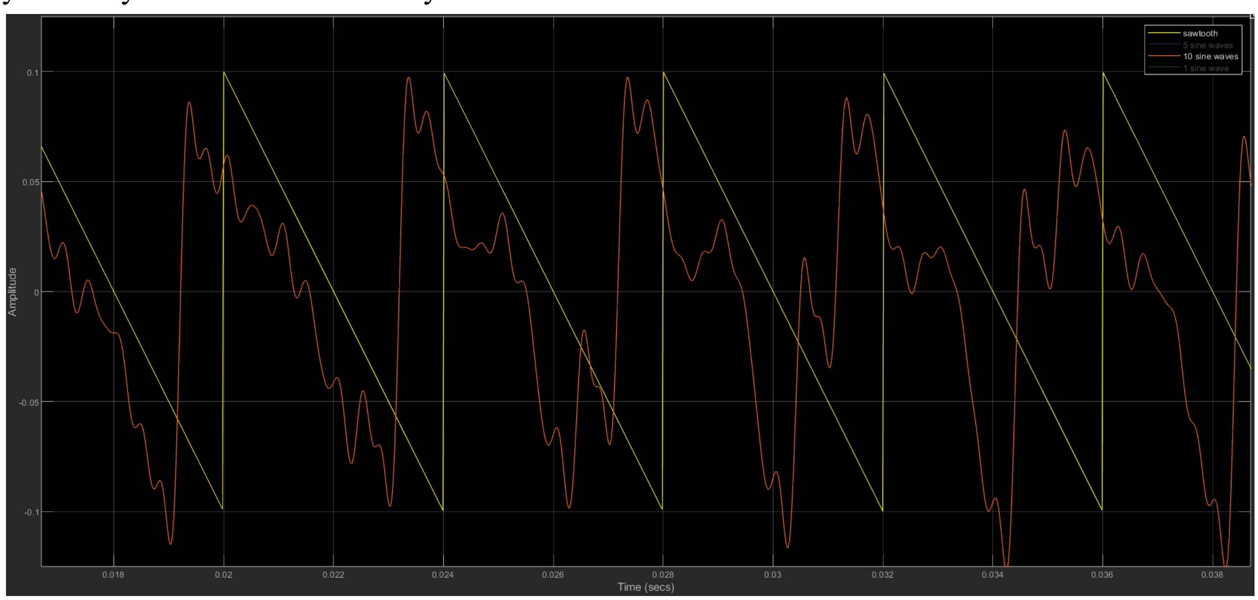
It seems a single sinusoid is a poor approximation of the sawtooth wave.
2nd sine wave just sounds like a second audio layer has been added
It is a better approximation of sawtooth.

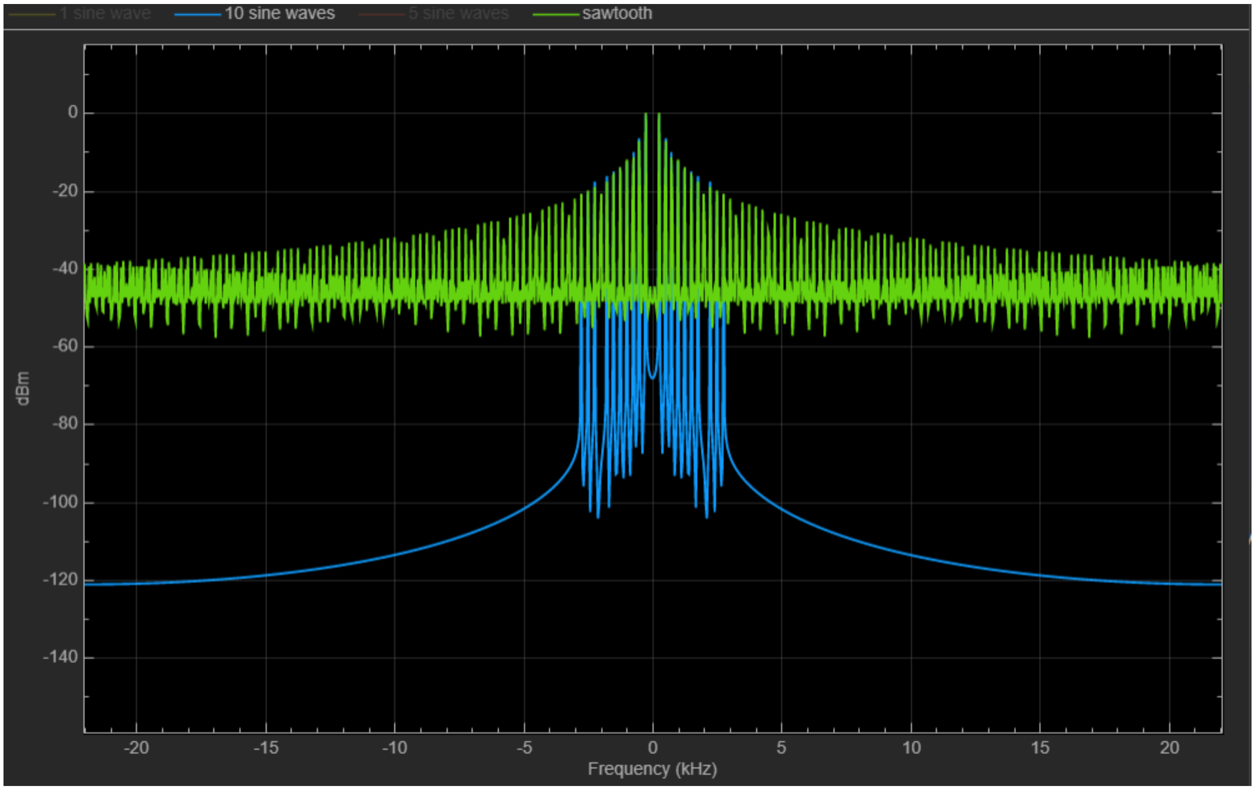
As more sinusoids are added, the time domain gets closer to sawtooth, sound becomes more layered, more like sawtooth but changes less pronounced as you add higher freq sinusoids. It is a better approximation.



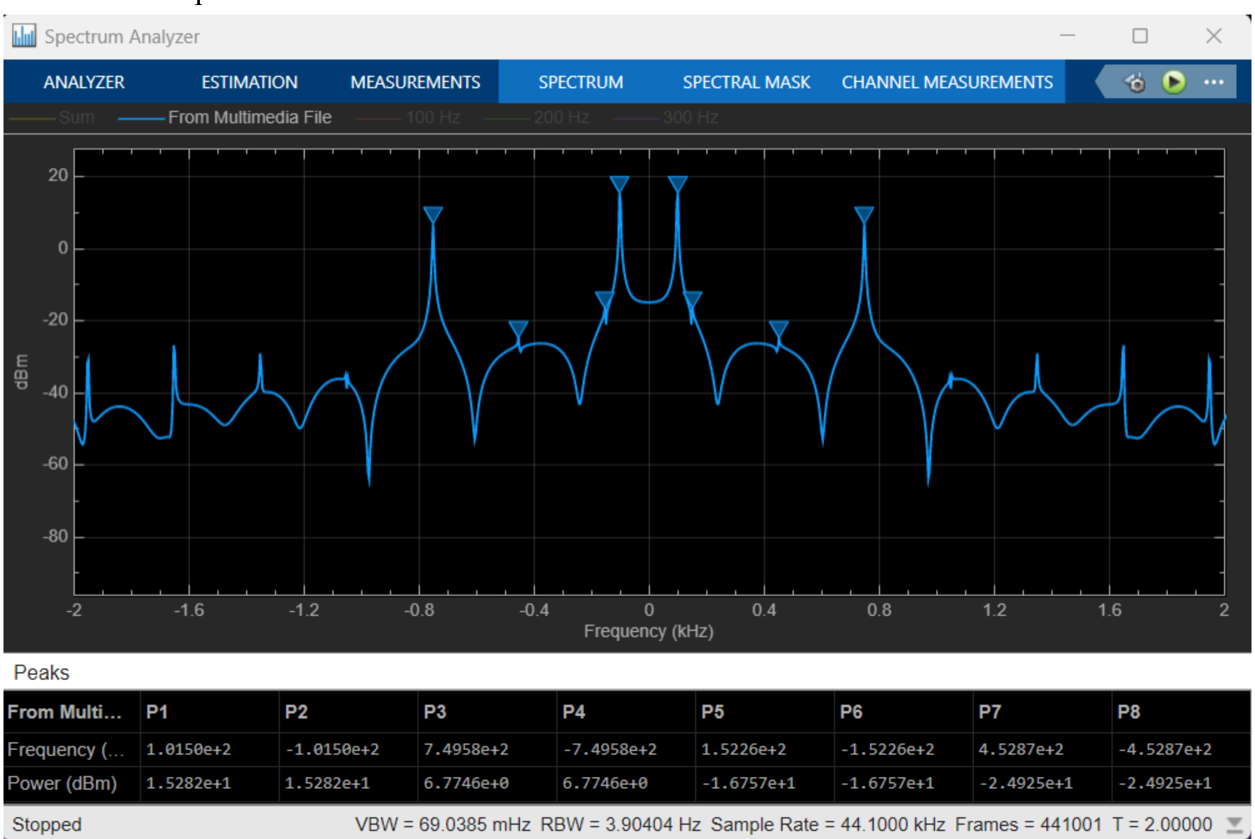


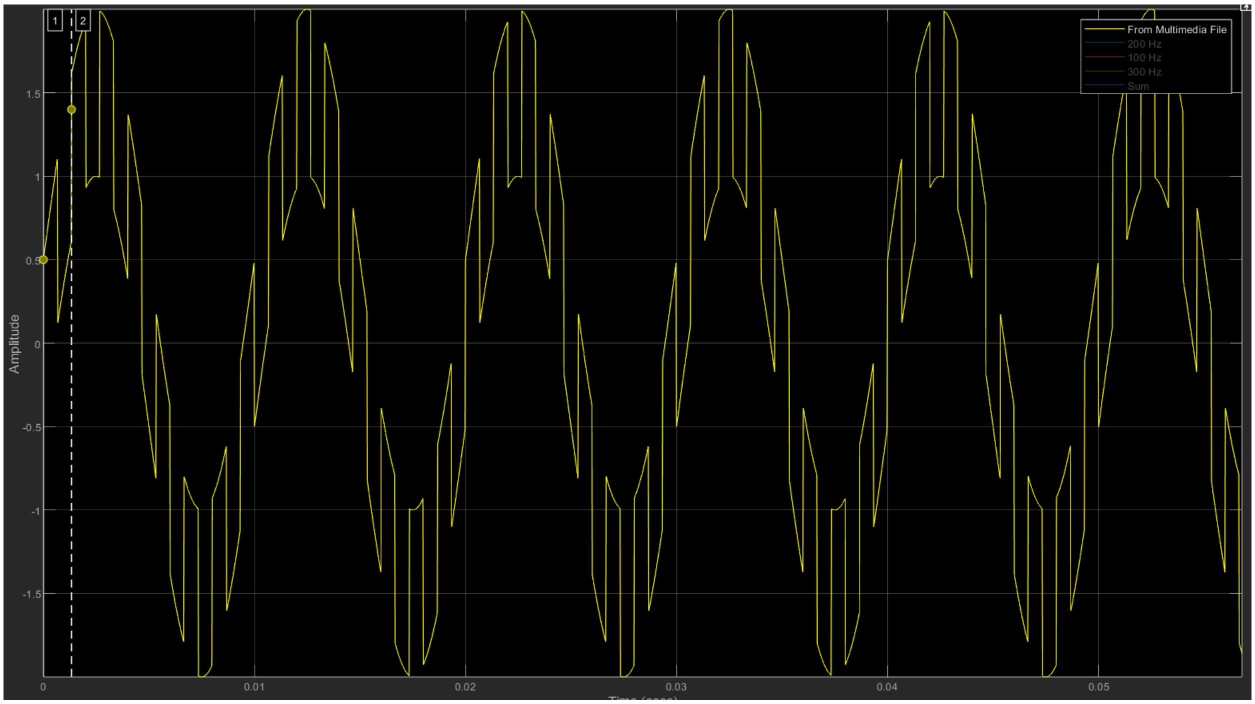
For 6-10 sinusoids:
Sound becomes more cluttered, more and more like the sawtooth. 10 sinusoids provide a better approximation than 5.
To perfectly recreate, you would need infinite sinusoids, but I would say around 50 would get you a very similar sound that very few humans could tell the difference



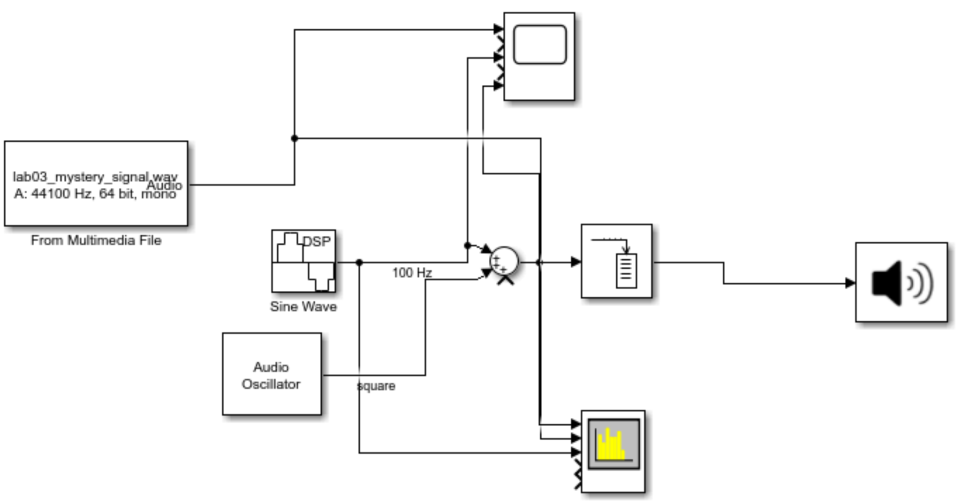


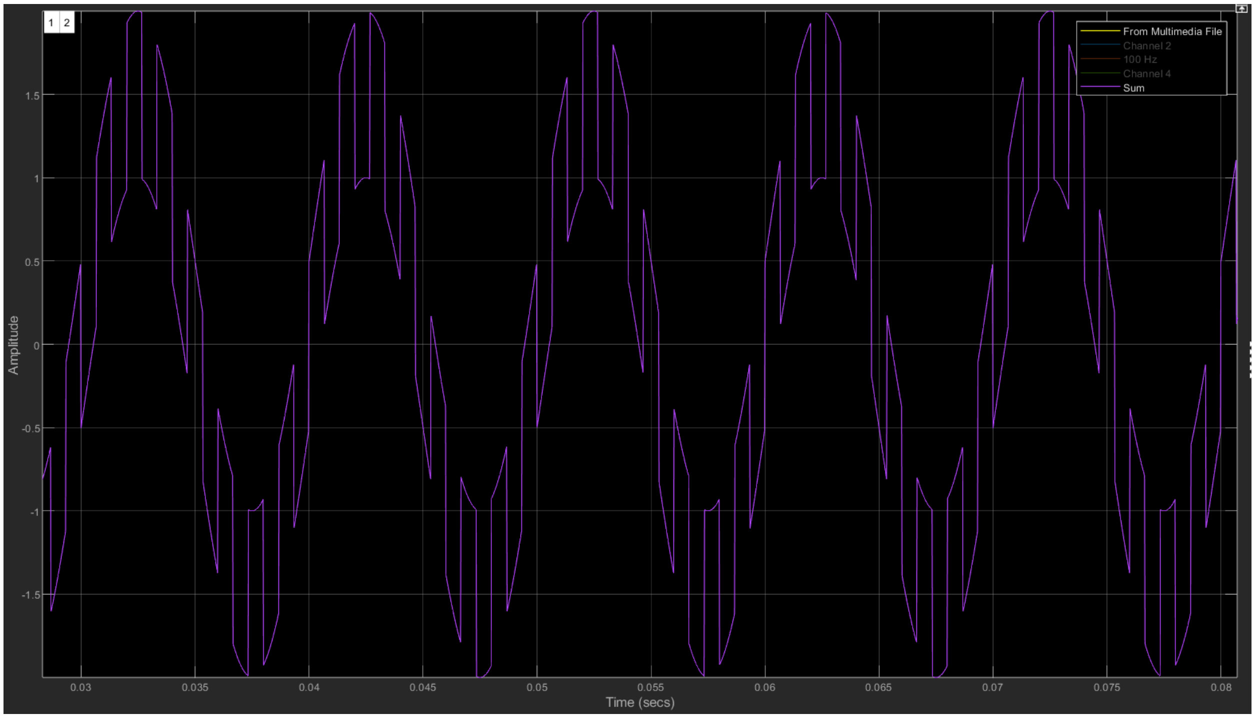
Proof of Concept:





The mystery signal is made up of 750 hz square wave with low amplitude and 100 hz sine wave with large amplitude.
I was able to recreate the signal with 1.5sin(200pi t) + 0.5square(1500pi t) sum.



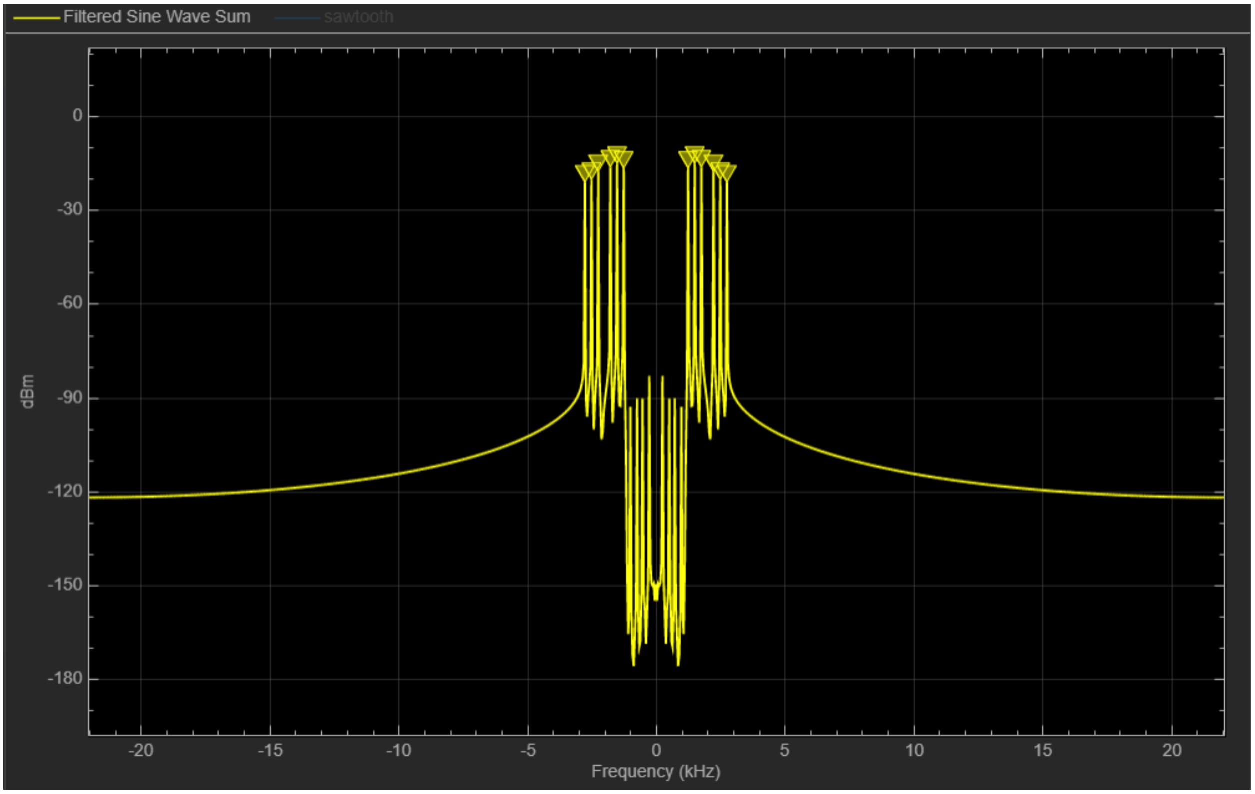


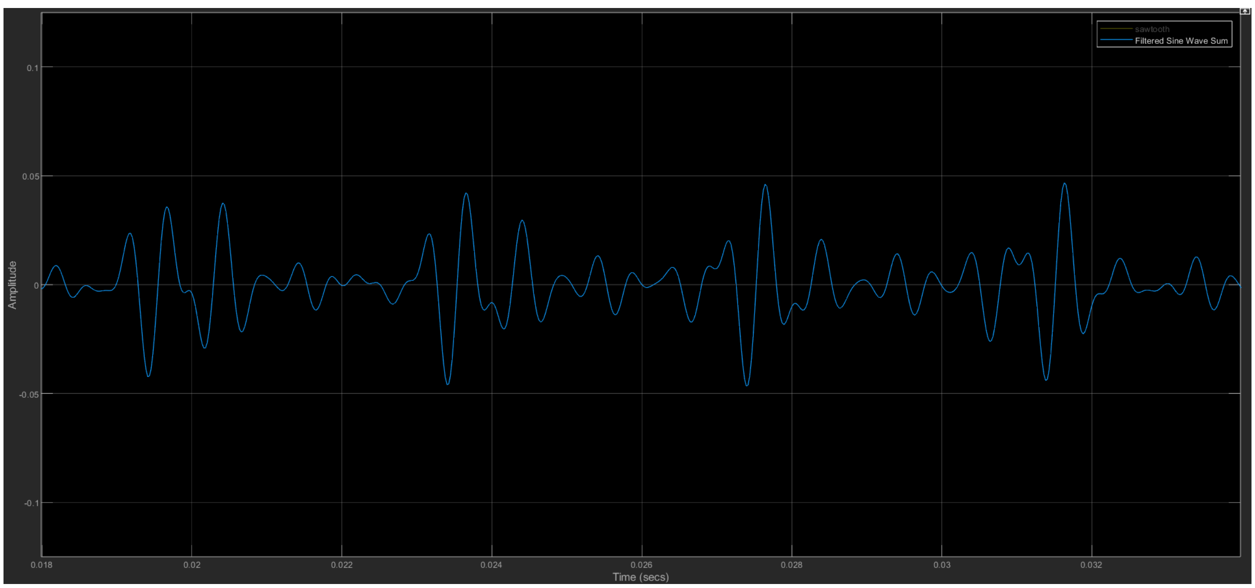
Part C:

The filter removes everything below 1100 hz and passes everything above 1300 hz but it looks a bit weird at 1250 hz which is between the two.

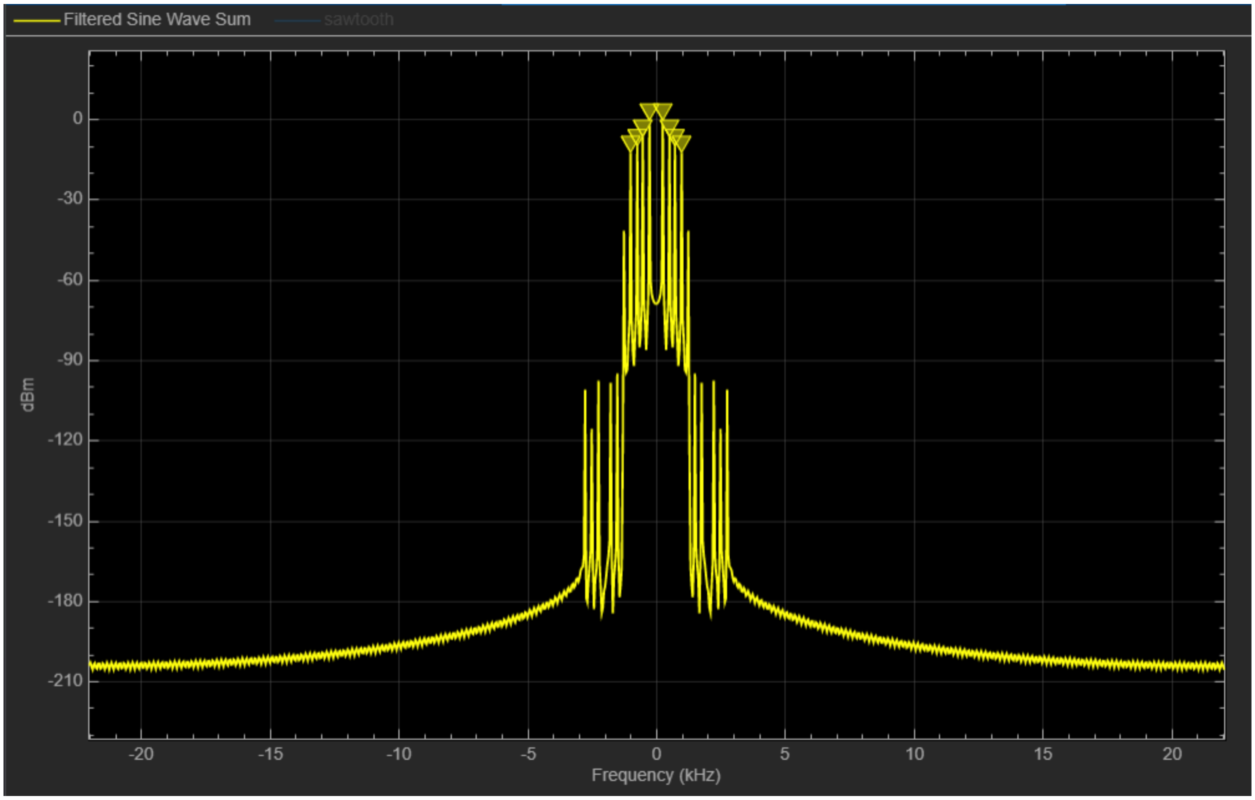
It sounds softer comparatively like it lost a lot of the noisy part.

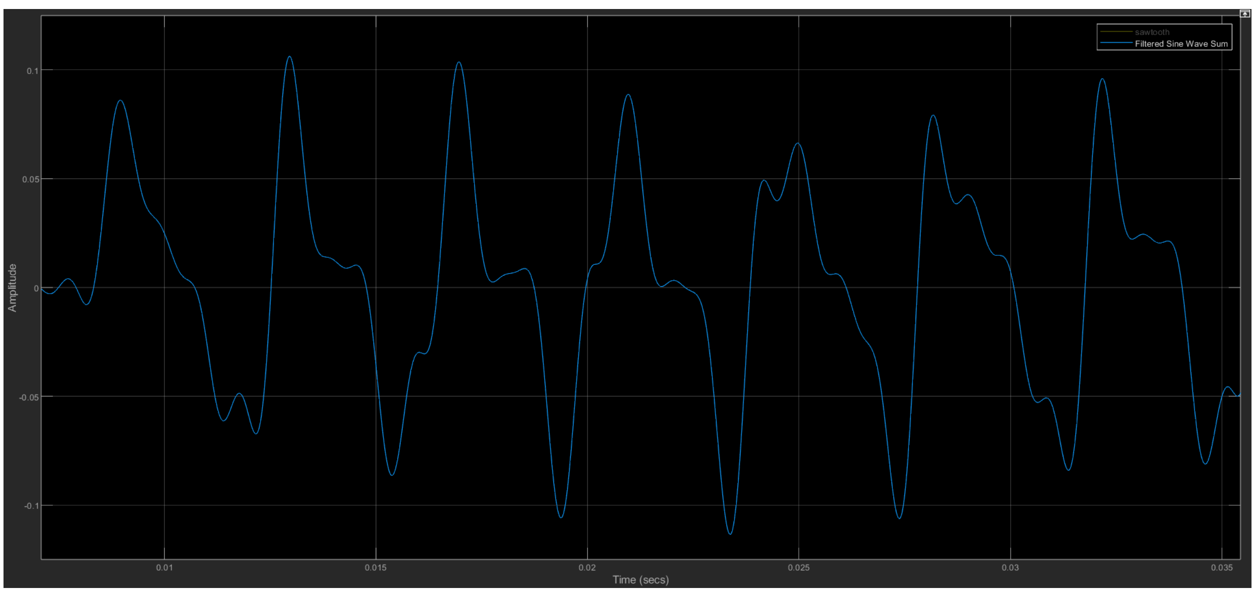
It removed the frequencies I expected and removed the larger amplitude sine waves from the time domain so the signal has way less change.



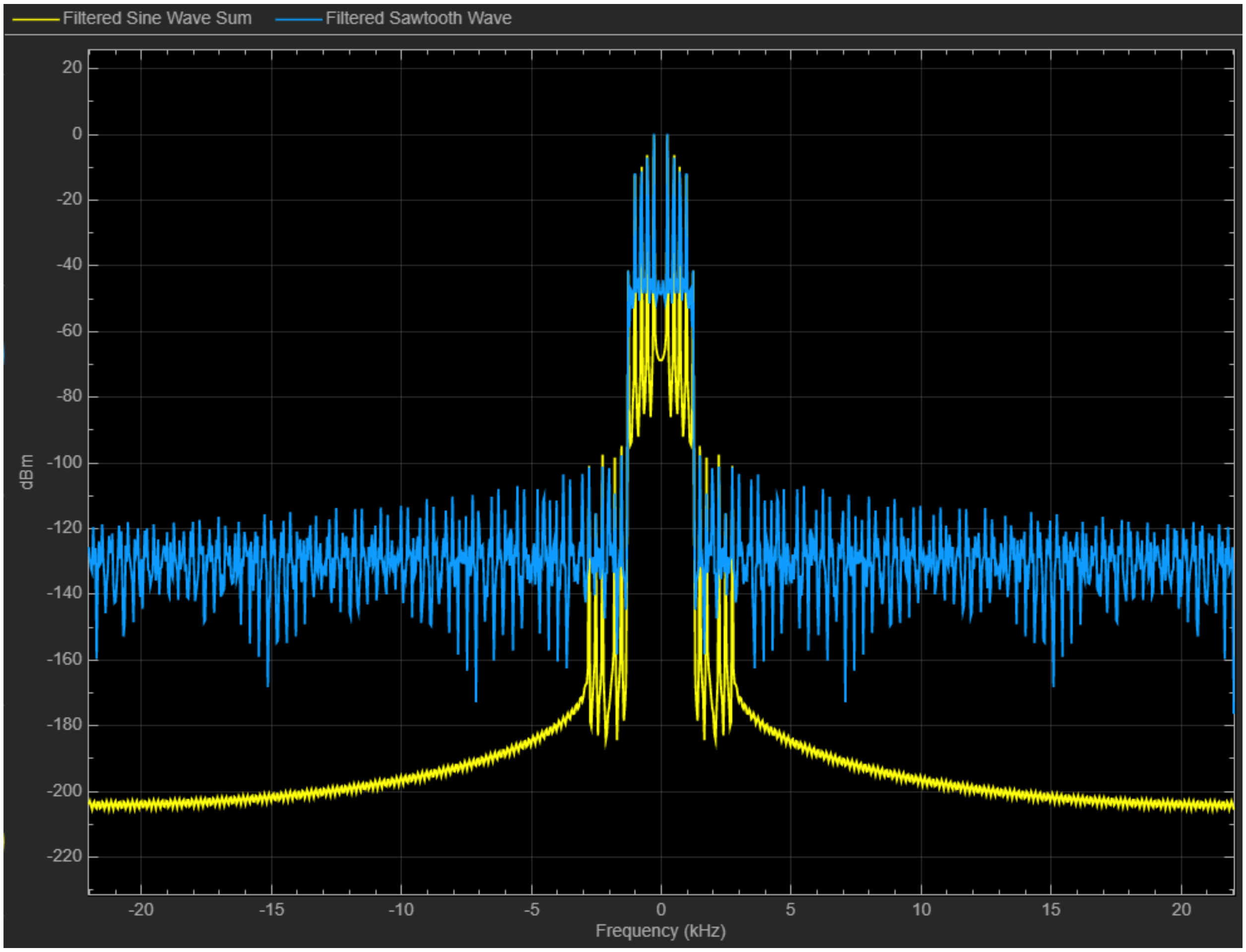


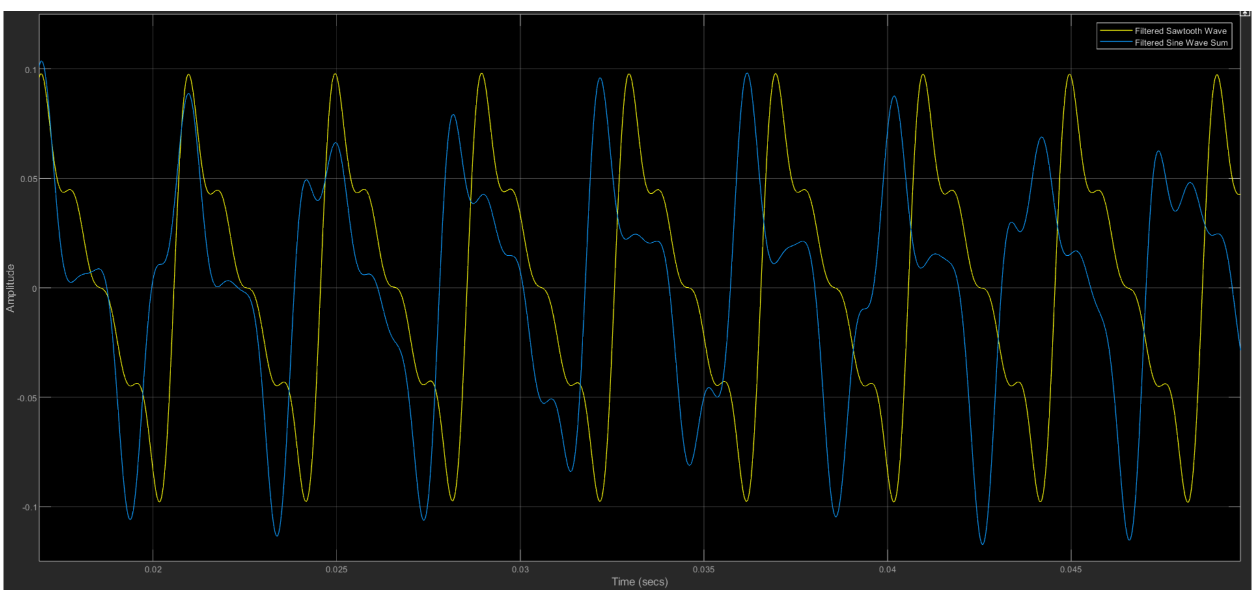
Lowpass felt a lot less refined, more noisy than the sum of 10, removed as I expected with everything above 1300 filtered and 1250 (in between 1100 and 1300) lowered slightly. On the time domain, we have the big amp spikes that are not smooth again, like that of the 5 sum.



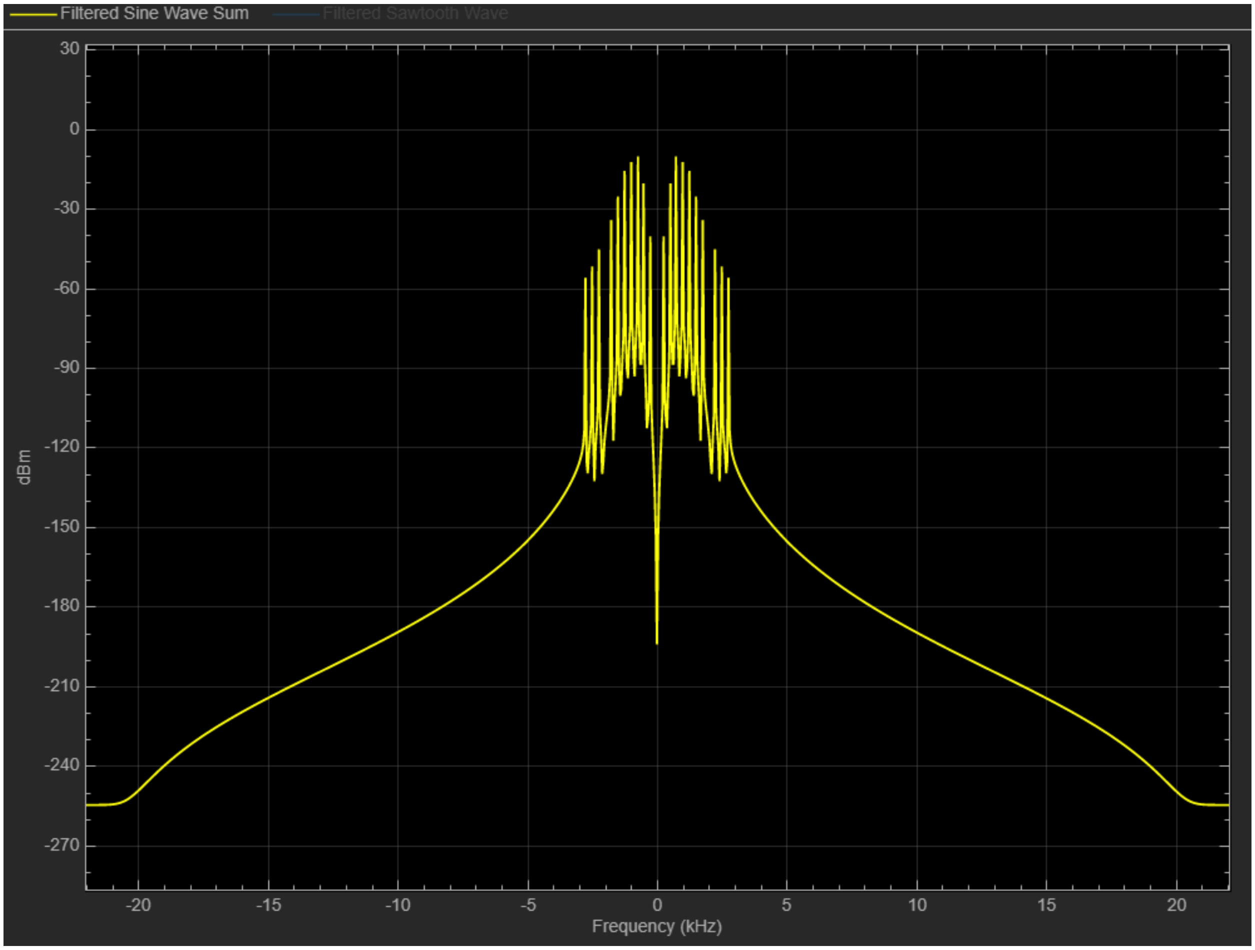


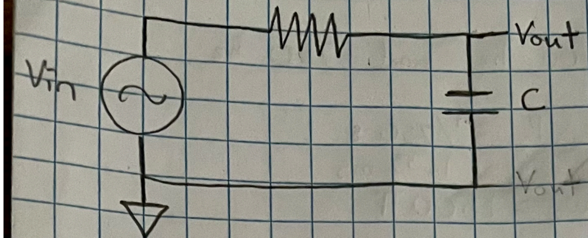
Sum of 5 sine waves is a very good approximation of the filtered sawtooth.





The octave filter seems to filter around the octave's frequency to form a triangle shape on the frequency domain around the octave's frequency.


Filtered Sine Wave Sum
Filtered Sawtooth Wave
30
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
dBm
-20
-15
-10
-5
0
5
10
15
20
Frequency (kHz)



$$\frac{1/sC}{R + 1/sC} = \frac{1}{RsC + 1}$$

$$f_c = \frac{1}{2\pi RC} \qquad 10\,kHz = \frac{1}{2\pi RC} \qquad RC = \frac{1}{62832} = 1.59 \cdot 10^{-5}$$

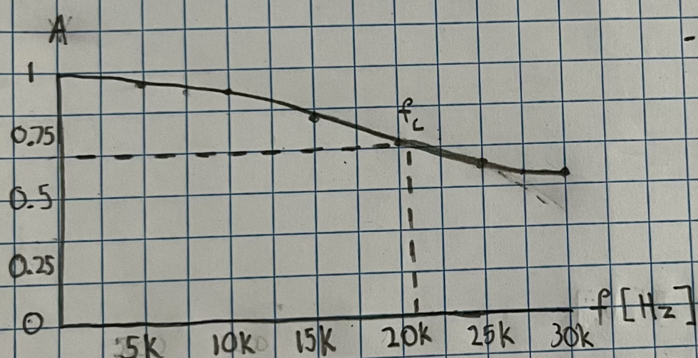
$2k\Omega \cdot 0.001\,\mu F = 2 \cdot 10^{-5}$ which is close.

Transfer function: $H = \dfrac{1}{0.00002s + 1}$

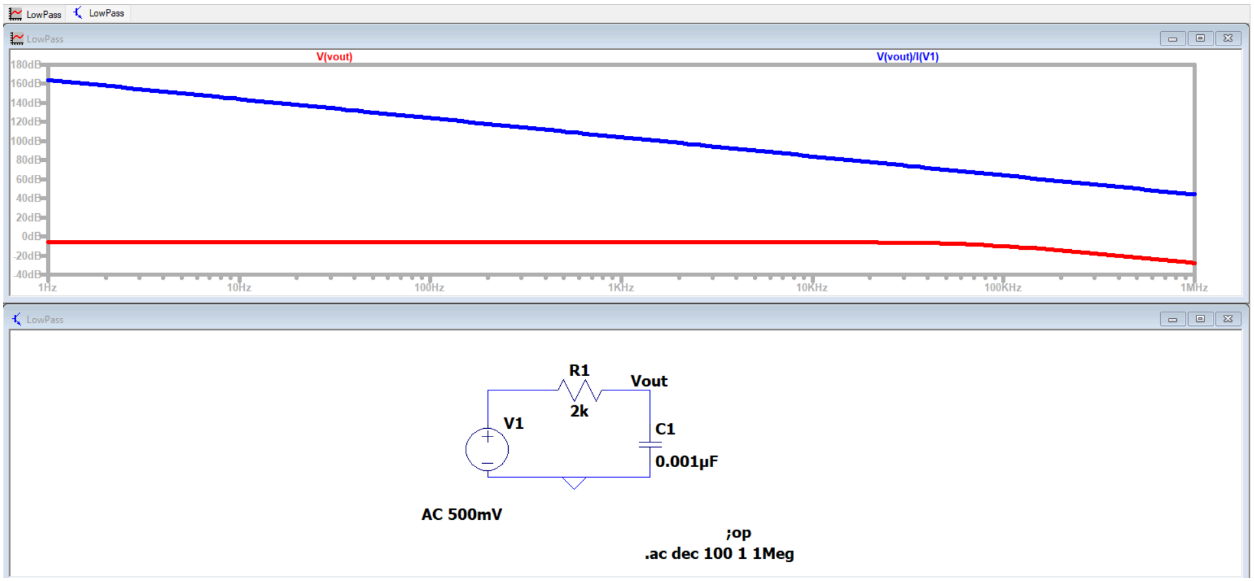
$$\frac{1}{\sqrt{2}} = \frac{1}{0.00002f_c + 1}$$

$$-1 + \sqrt{2} = 0.00002 f_c$$

$$f_c = 20711\ Hz$$

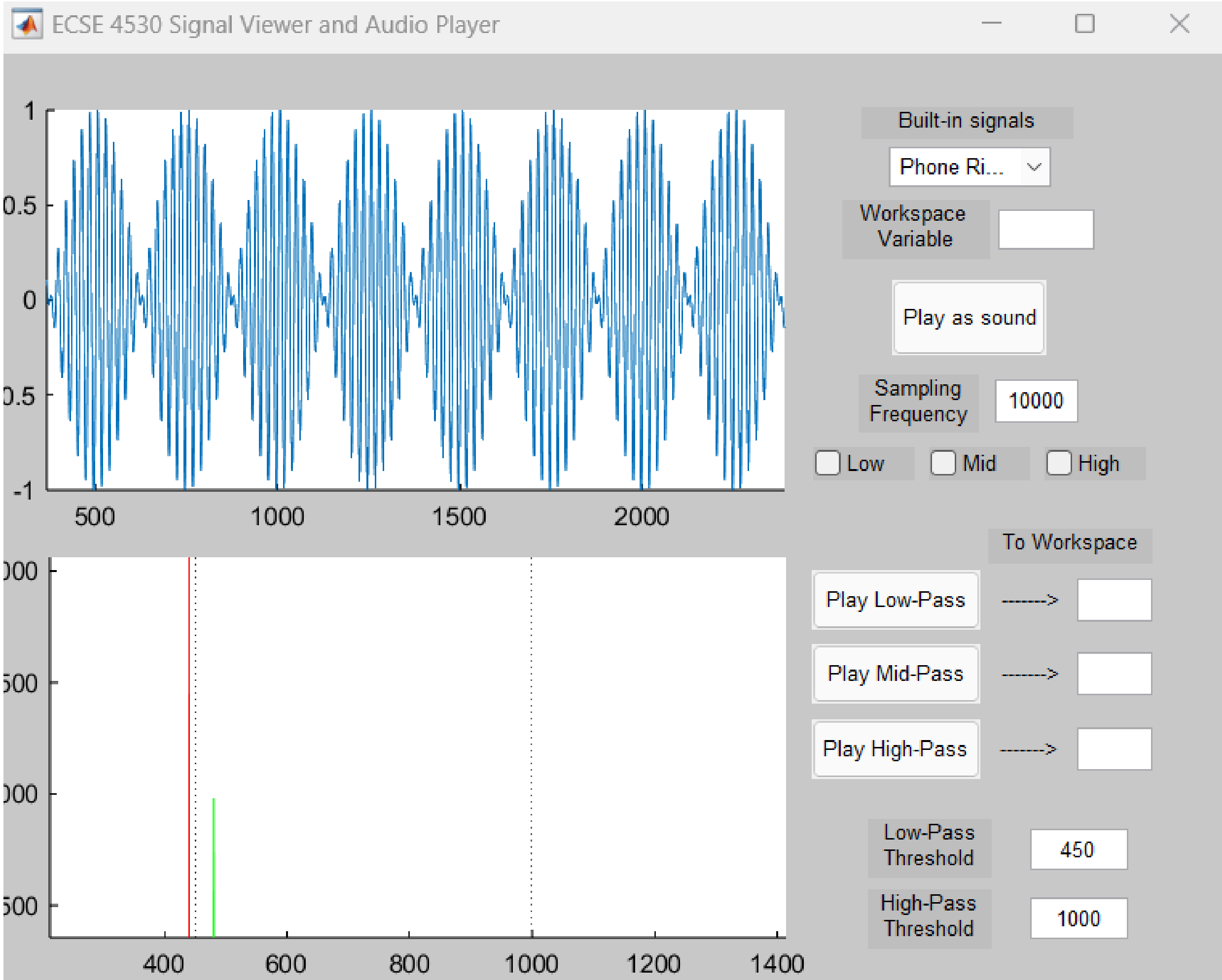


magnitude: 0.91 0.83 0.77 0.71 0.67 0.625



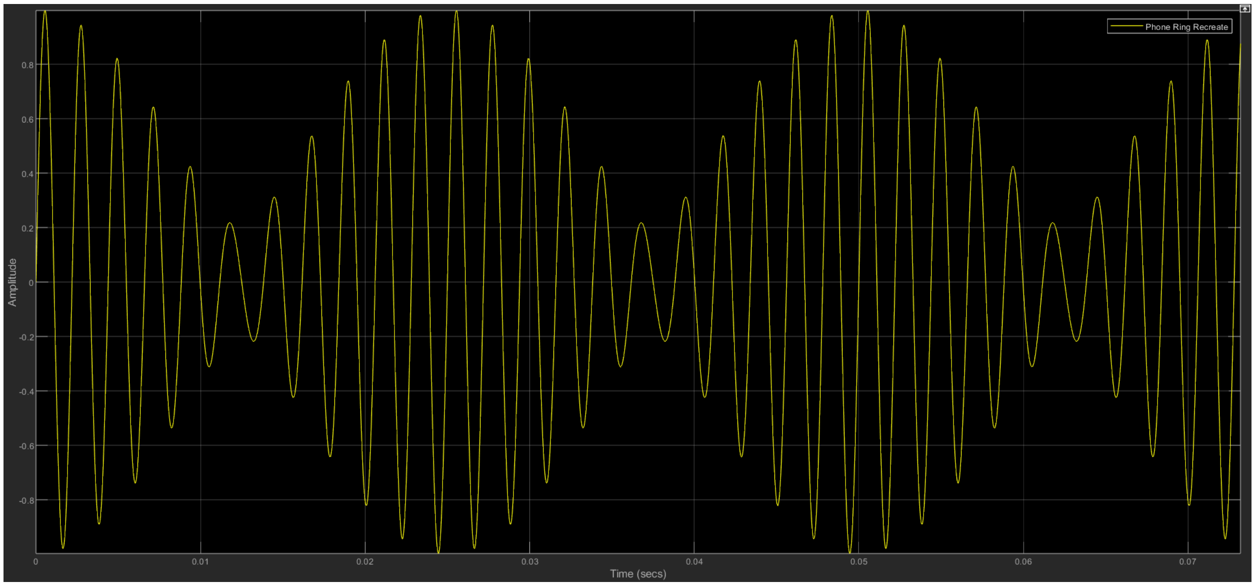
Proof of Concept: You could build a high pass filter with RL using the same block diagram but using an inductor instead of a capacitor. To make it low pass, just measure Vout across the inductor instead of at the node.

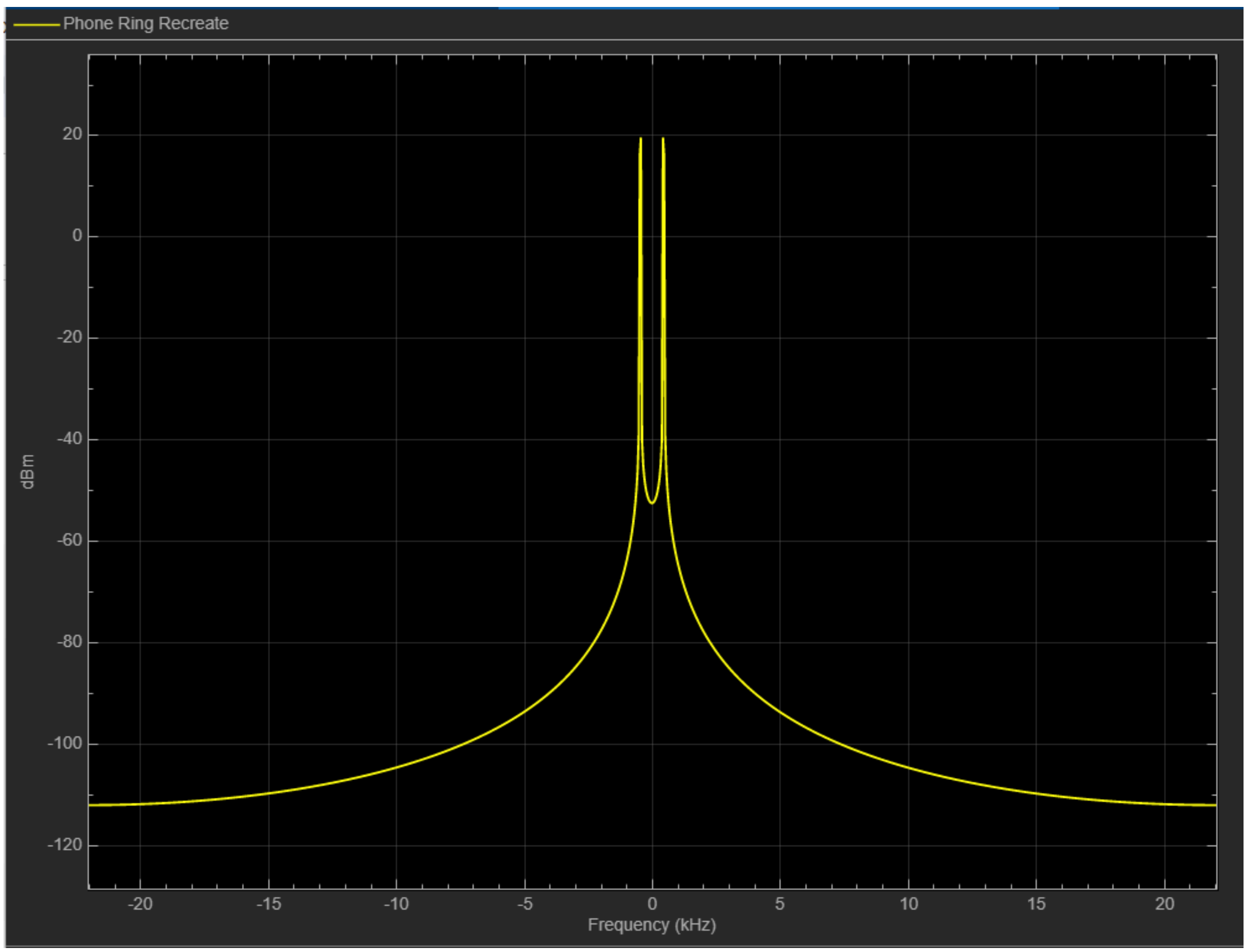
Part 4:



Trying to recreate the phone ring which has 2 sine waves, 440 hz and 480 hz.

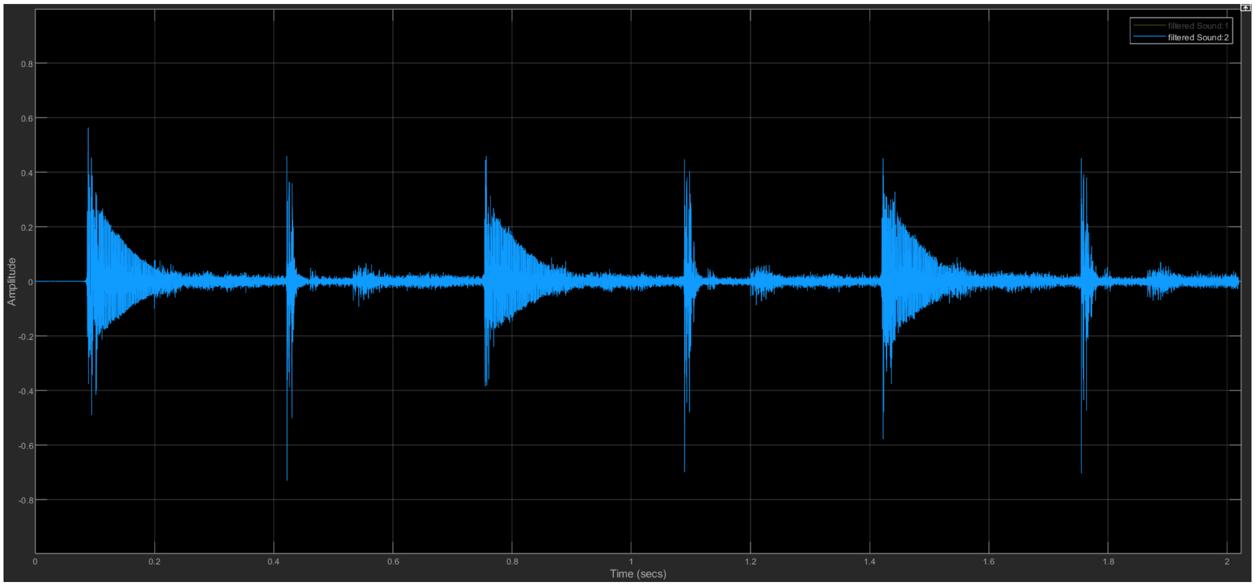
My attempt:

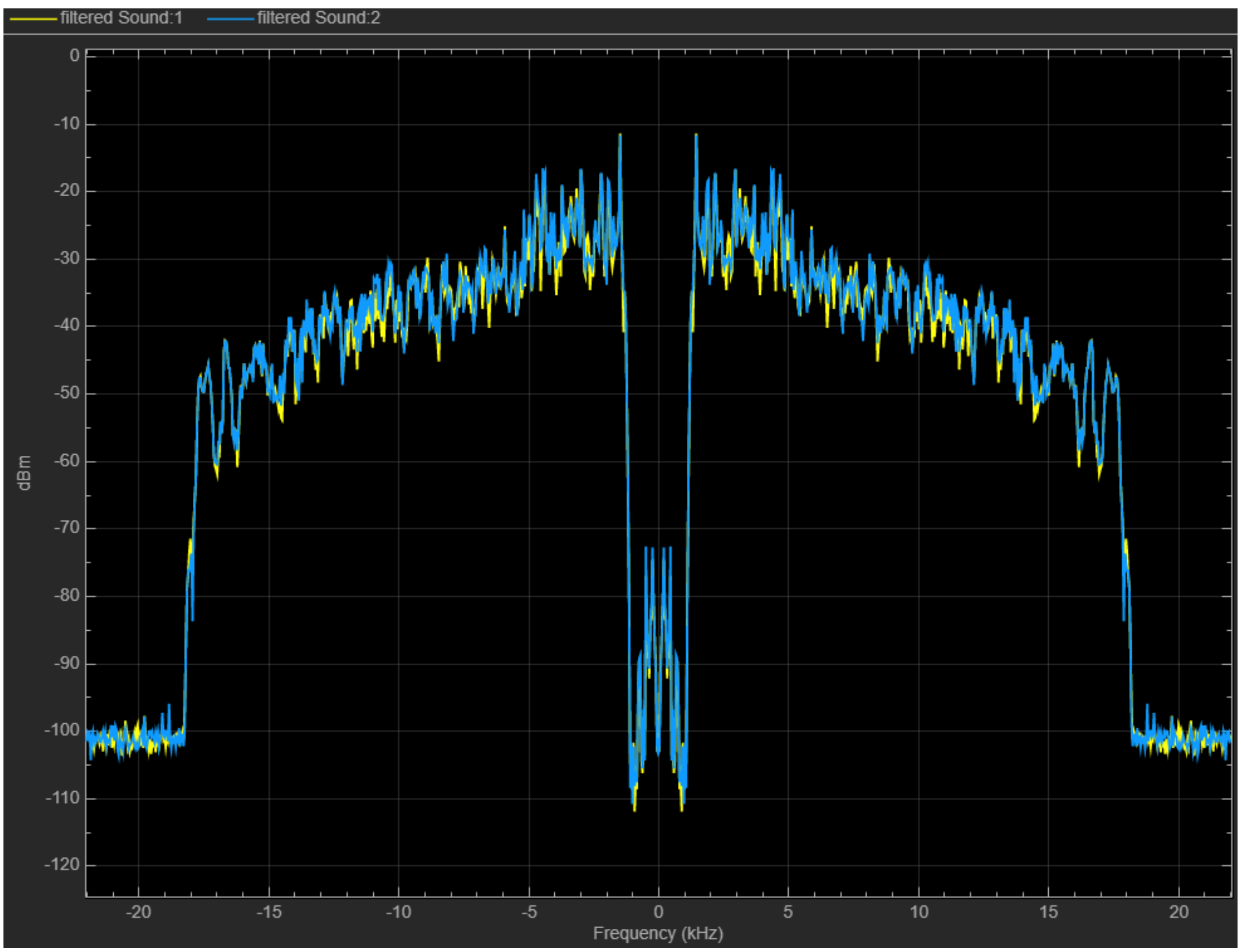




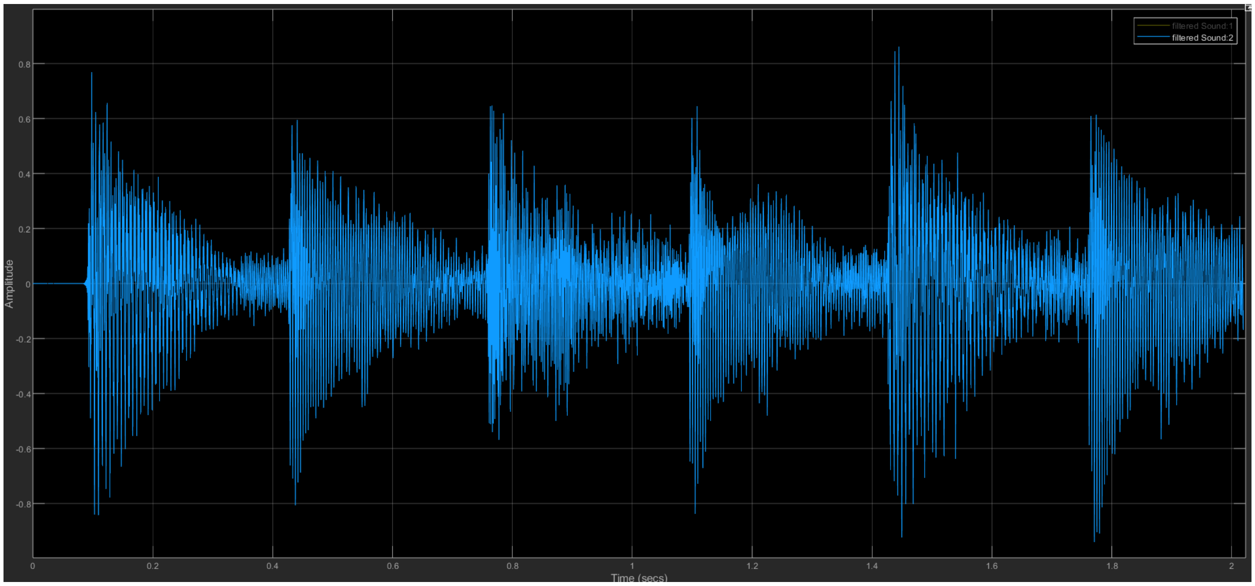
Filtering Alan Walker Fade:

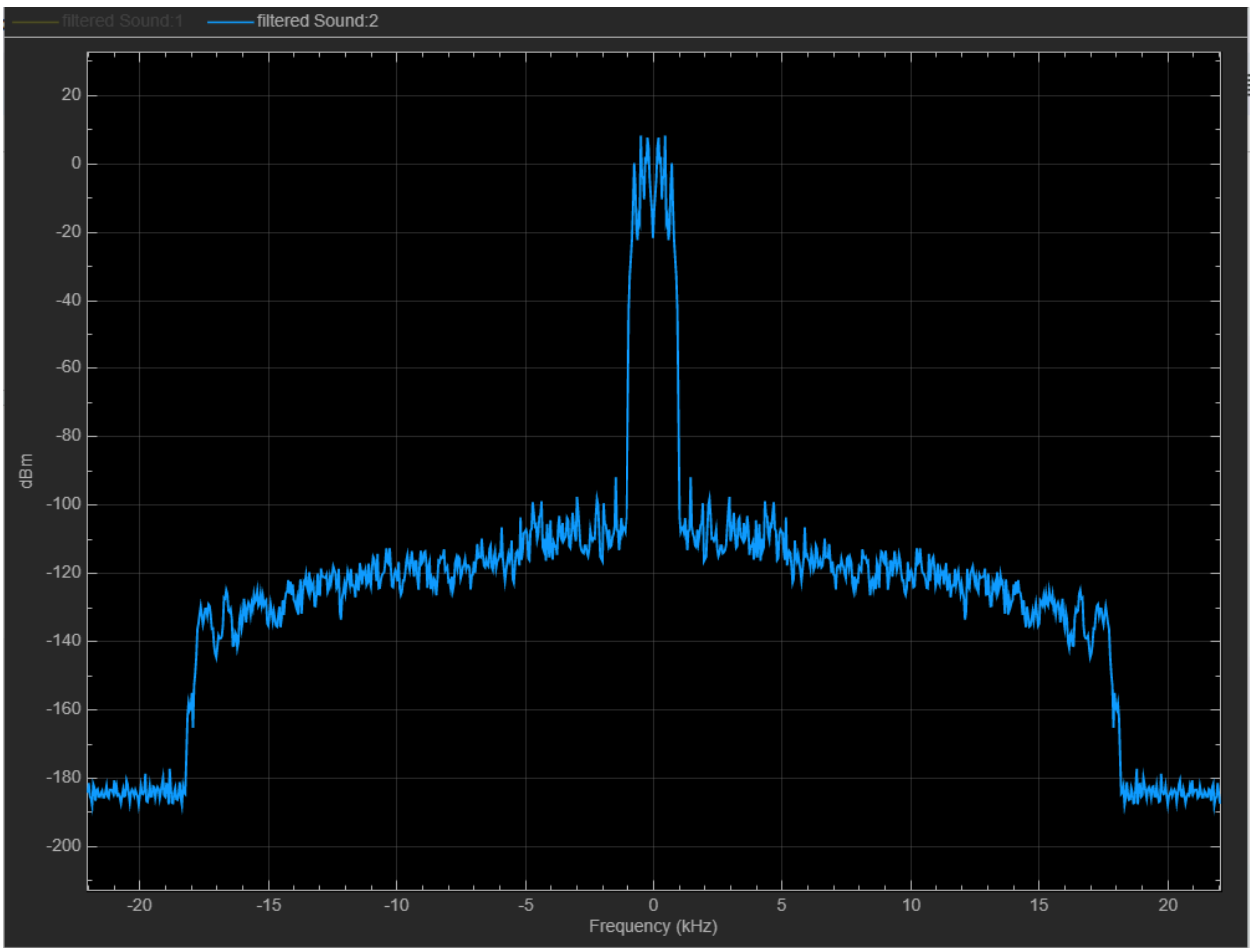
Highpass Filter





Lowpass:





In the low pass, I could only hear the bass and some piano, while the high pass I heard snare drums and higher piano.