The University of Texas Rio Grande Valley
College of Engineering and Computer Science
Department of Electrical & Computer Engineering

EECE 3230-1ET Electrical Engineering Lab II
Summer 2025

Lab Report #3: Fourier Series

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I. ABSTRACT

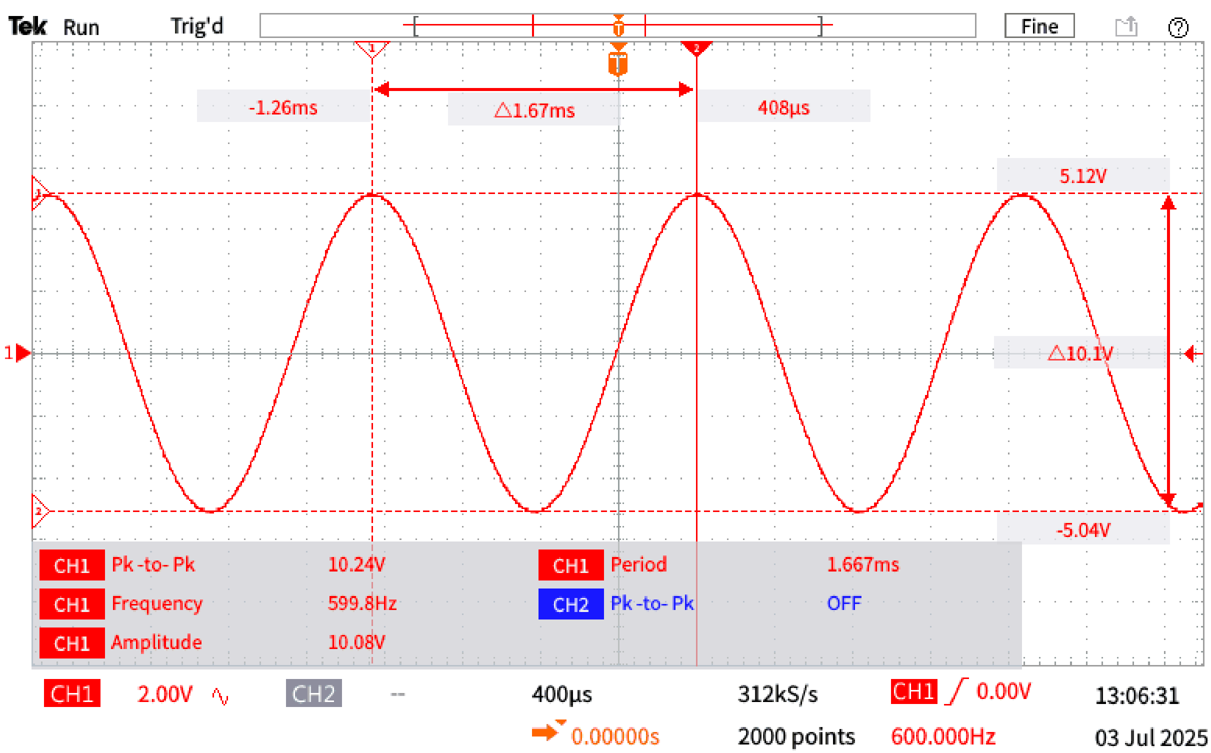
This experiment focused on measuring the harmonic content and frequency response of five periodic waveforms: sine, square, square pulse train, triangle, and half-sine, each at a fundamental frequency of 600Hz. A digital oscilloscope with an FFT feature quantified the first five harmonics for every waveform. To demonstrate frequency multiplication, a second-order active band-pass filter was designed to extract and amplify the 1200Hz harmonic produced by the 600Hz sine-wave input. The filter successfully isolated the target harmonic and increased its amplitude. Measured results aligned closely with Fourier-series predictions, confirming both the accuracy of the harmonic analysis and the effectiveness of the filter circuit.

II. BODY

Lab 3 centers on Fourier-series analysis. In this exercise we will measure a signal's frequency response with precision, use the oscilloscope's built-in tools to find and quantify each harmonic, and then design a filter that isolates one chosen harmonic for detailed evaluation. The test frequency is assigned according to project letter; our team received designation E/K, which corresponds to a fundamental frequency of 600 Hz.

Part 1 Capturing Harmonic Content

Part 1 required the use of the oscilloscope's FFT feature to identify and quantify the harmonics generated by a test signal. A function generator was configured to deliver a 5 V-amplitude sine wave (10V peak-to-peak) that was fed directly into the oscilloscope for analysis. The scope captured a fundamental frequency of 600Hz, corresponding to a period of 1.667ms, and reported a peak-to-peak voltage of 10.24V. Although the oscilloscope display labeled this value as "Amplitude 10.08V," the instrument was in fact showing the peak-to-peak level; the true amplitude remained 5V.



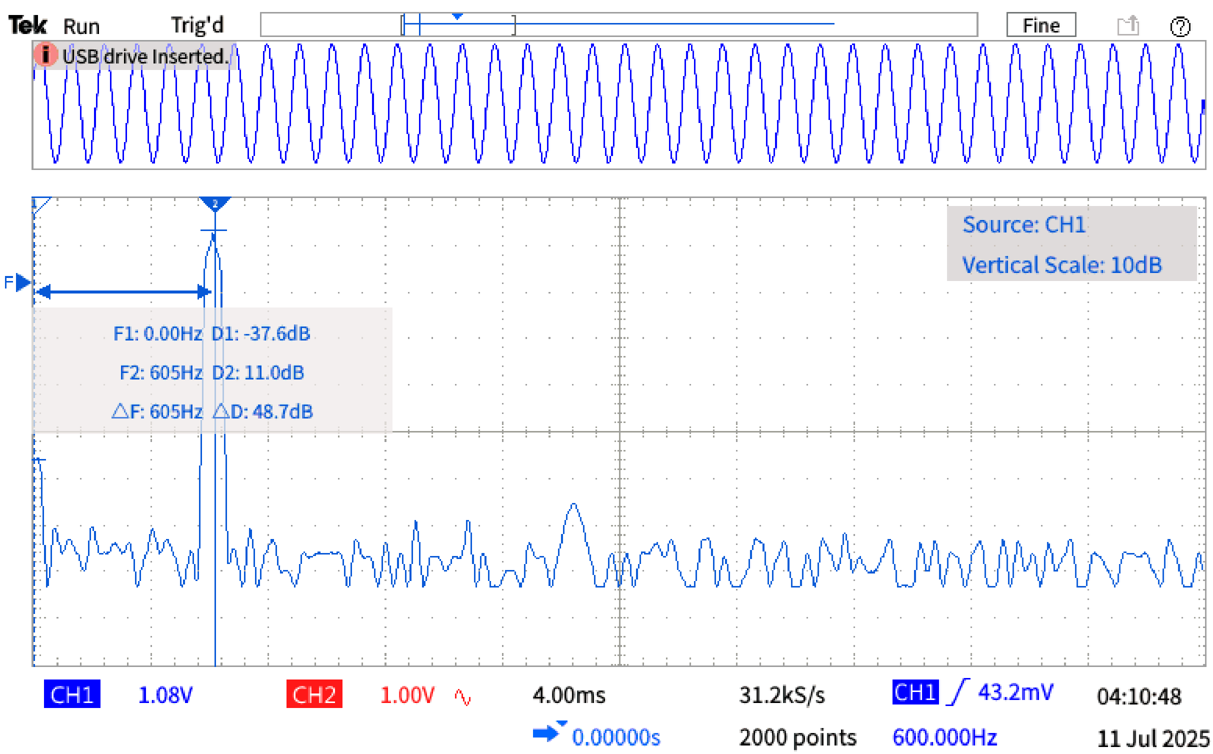
Scope Shot 1 – Part 1.a Sine Wave Amplitude, Period, and Frequency

For every subsection (Parts 1 through 5, items a–e) the same workflow is used. First, the oscilloscope is employed to measure and record the waveform's frequency, period, and peak-to-peak voltage, and a scope trace is saved for documentation. The instrument's FFT feature is then activated to display the spectrum, the first five harmonics are tabulated, and a screen capture of the strongest spectral component is taken. Finally, the magnitude of that dominant harmonic is converted from decibels to volts so it can be compared with the amplitude set on the function generator.

Applying this procedure in Part 1 produced the results listed in Table 1: the first five harmonics of the 600 Hz sine wave. The FFT reported a dominant spectral line at 11 dB, which converts to an amplitude of roughly 3.55 V. This value is consistent with the 5 V generator setting once normal line and loading losses are considered.

Frequency	Magnitude
0 Hz	-37.6 dB
600 Hz	11 dB
1200 Hz	-38.9 dB
1800 Hz	-38.1 dB
2.4 k Hz	-51.1 dB
3 k Hz	-40.8 dB

Table 1 - Part 1.c First 5 Harmonics

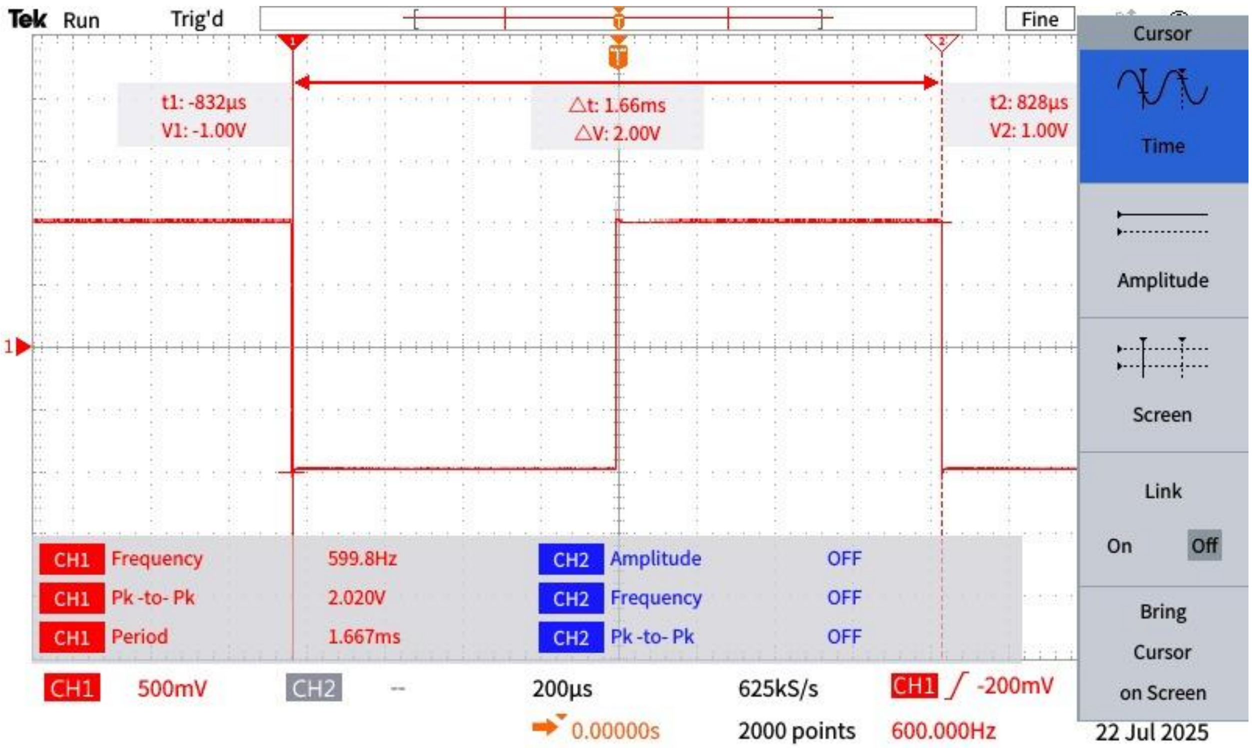


Scope Shot 2 - Part 1.d Most Prominent Harmonic

Magnitude(dB)	Magnitude(Vpk)
-37.6 dB	0.013183 V
11 dB	3.54813 V
-38.9 dB	0.01135 V
-38.1 dB	0.012445 V
-51.1 dB	0.002786 V
-40.8 dB	0.00912 V

Table 2 - Part 1.e Convert to peak volts

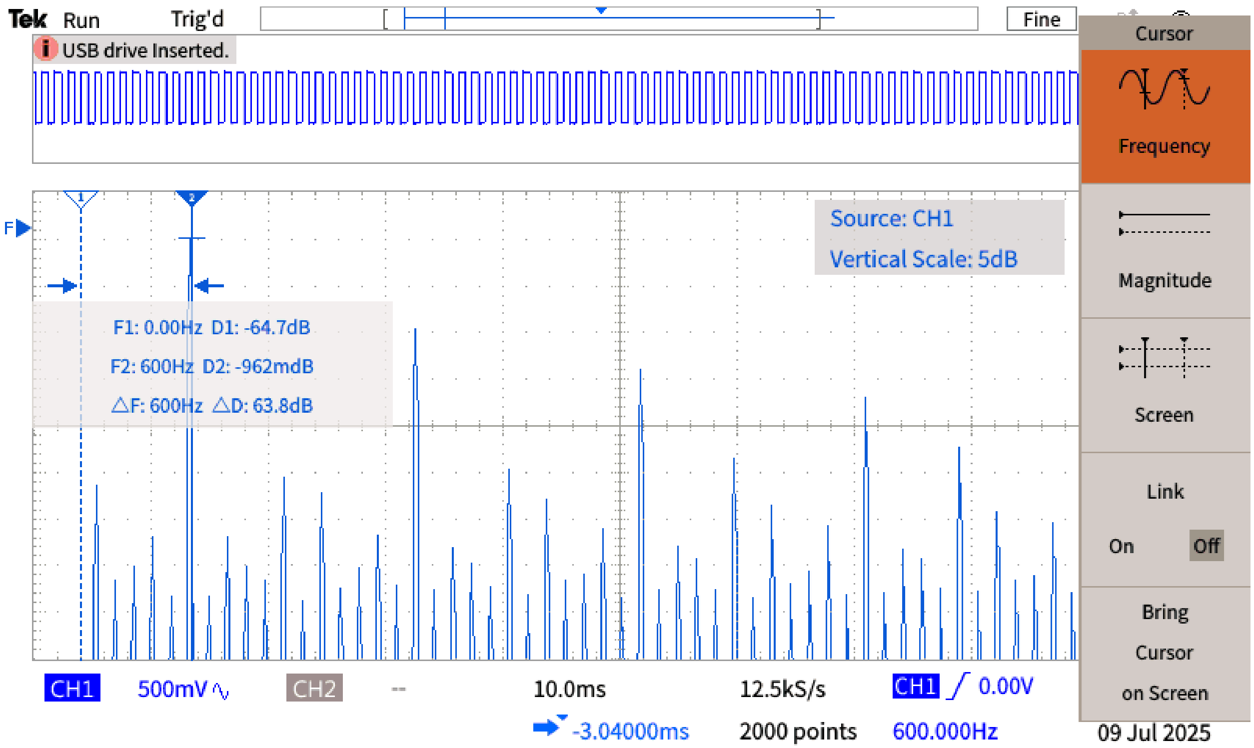
In Part 2 the same steps a through e were carried out. The function generator was programmed for a square wave with a 1V amplitude, a period of 1.6ms, and a frequency of 600Hz, and the resulting waveform was captured on the oscilloscope. The FFT display was then used to tabulate the first five harmonics, and a screenshot of the dominant spectral line was saved. That line registered -0.962 dB, which converts to approximately 0.9V, very close to the 1V set on the generator once minor transmission losses are considered.



Scope Shot 1 – Part 2.a Square Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	-64.7 dB
600 Hz	-0.962 dB
1200 Hz	-38.7 dB
1800 Hz	-10.4 dB
2.4 k Hz	-38.9 dB
3 k Hz	-14.8 dB

Table 3 - Part 2.c First 5 Harmonics

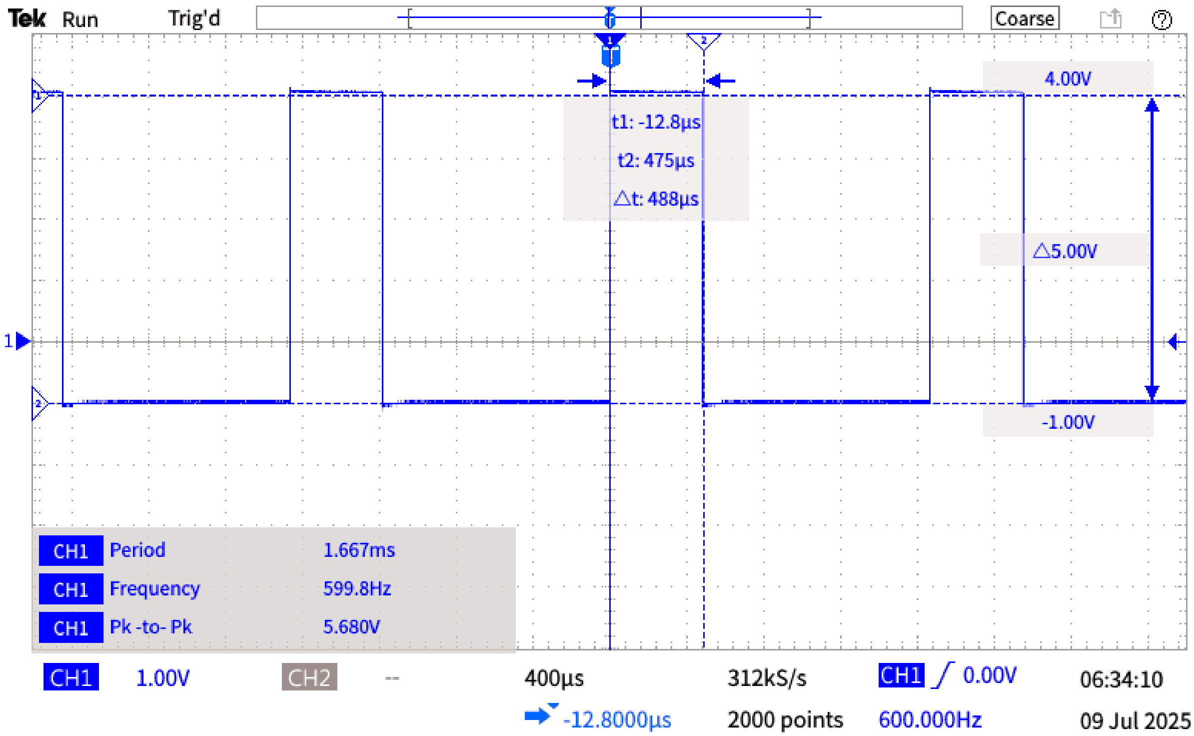


Scope Shot 4 - Part 2.d Most Prominent Harmonic

Magnitude(dB)	Magnitude(Vpk)
-64.7 dB	0.000582 V
-0.962 dB	0.895159 V
-38.7 dB	0.011614 V
-10.4 dB	0.301995 V
-38.9 dB	0.01135 V
-14.8 dB	0.18197 V

Table 4 - Part 2.e Convert to peak volts

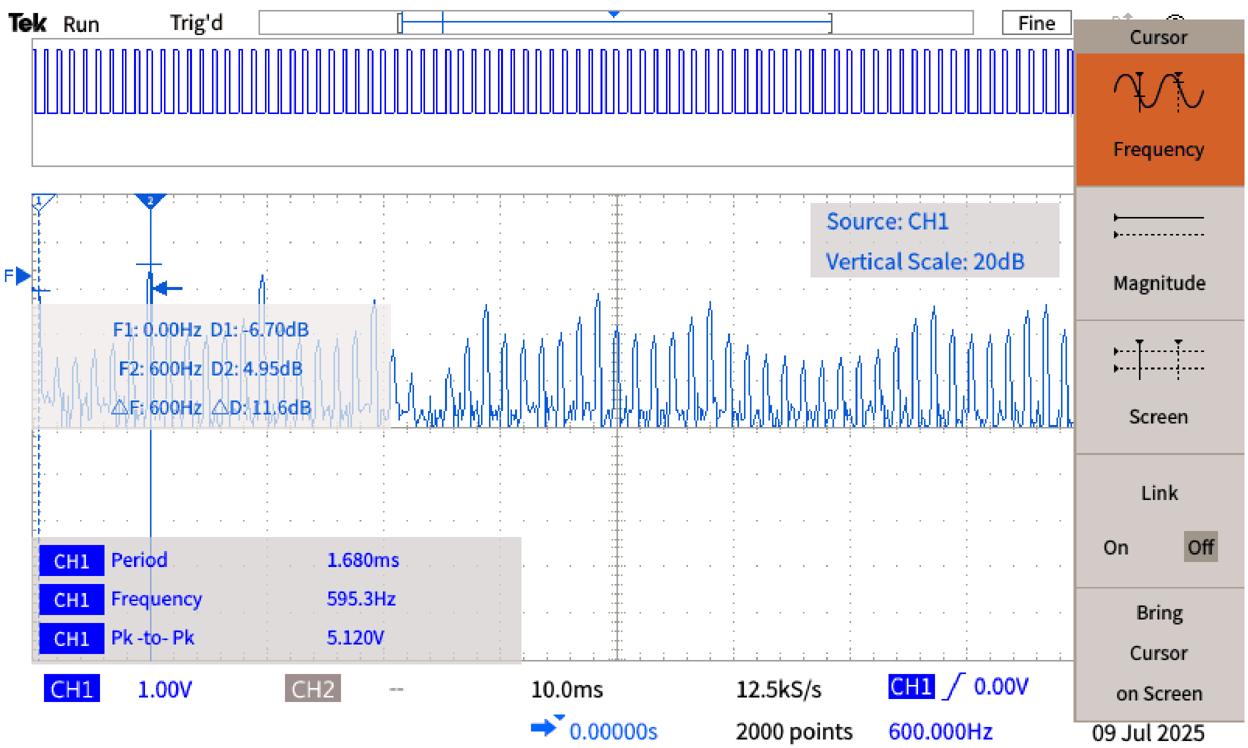
In Part 3 the procedure used previously was repeated with a square wave that included a 1.5V DC offset, an amplitude of 2.5V, a 29 percent duty cycle, a 1.6ms period, and a fundamental frequency of 600Hz. An oscilloscope capture of this waveform is shown below, followed by a table listing the first five harmonic magnitudes and a screenshot highlighting the strongest spectral component. The dominant harmonic was measured at 4.95dB, which converts to approximately 1.768V, in good agreement with the programmed generator settings once normal line losses are considered.



Scope Shot 5 – Part 3.a Square Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	-6.70 dB
600 Hz	4.95 dB
1200 Hz	0.681 dB
1800 Hz	-11.7 dB
2.4 k Hz	-11.6 dB
3 k Hz	-7.02 dB

Table 5 – Part 3.c First 5 Harmonics

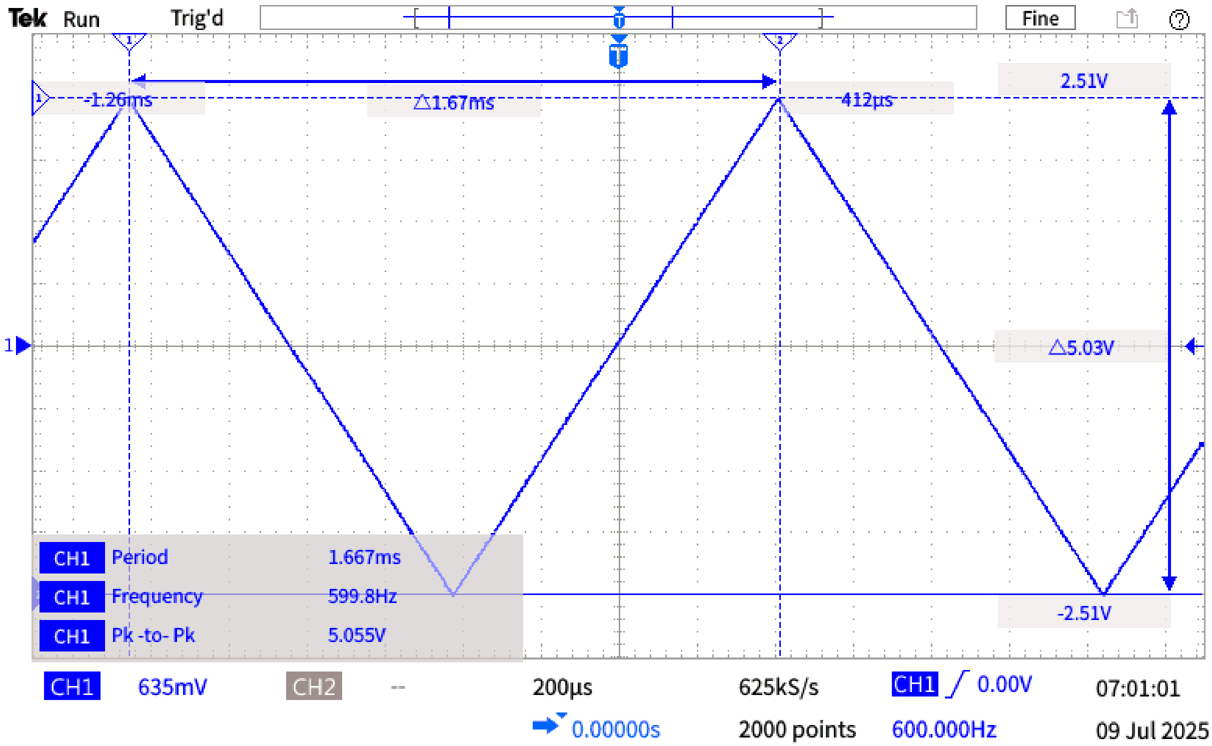


Scope Shot 6 - Part 3.d Most Prominent Harmonic

Magnitude(dB)	Magnitude(Vpk)
-6.70 dB	0.462381 V
4.95 dB	1.76807 V
0.681 dB	1.08156 V
-11.7 dB	0.260016 V
-11.6 dB	0.263027 V
-7.02 dB	0.445656 V

Table 6 - Part 3.e Convert to peak volts

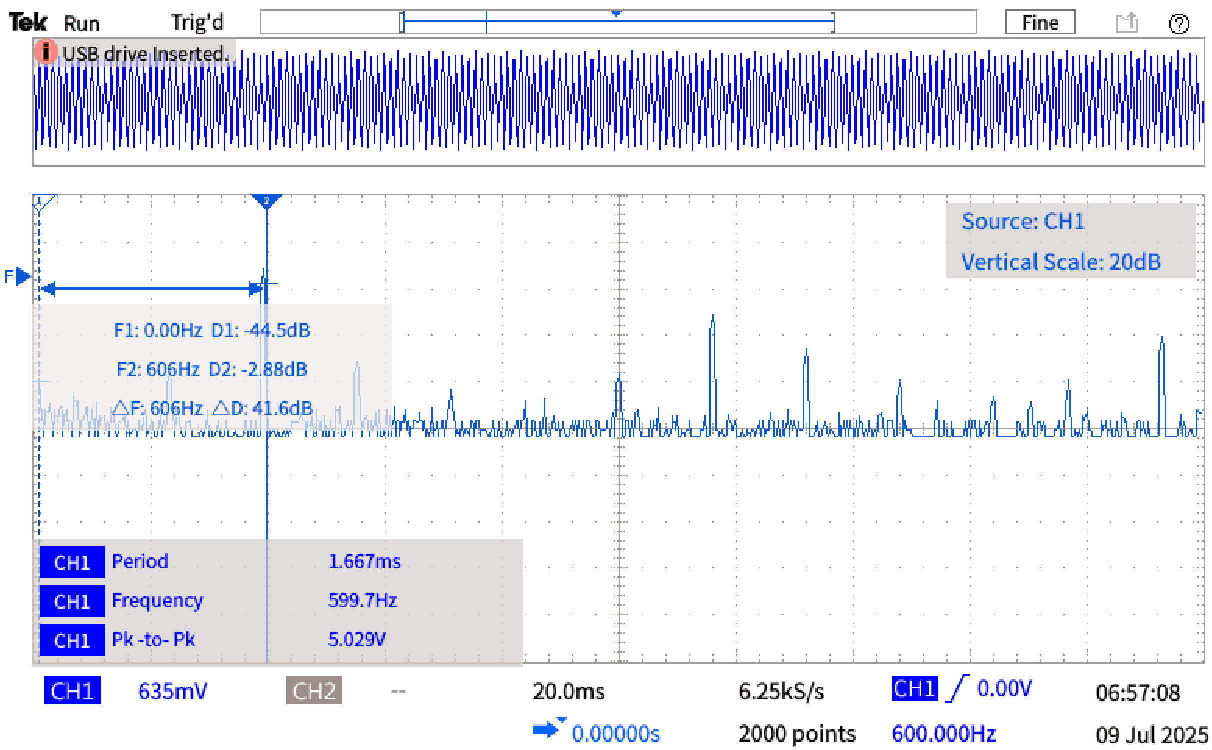
In Part 5 the procedure was repeated using a triangular waveform. The function generator delivered a 2.5V amplitude signal with a period of 1.67ms, corresponding to a fundamental frequency of 600Hz. An oscilloscope capture of the waveform, a table listing the first five harmonics from the FFT analysis, and a screenshot highlighting the strongest spectral line are presented below. The dominant harmonic measured −2.88dB, which converts to about 0.718V when expressed in linear units.



Scope Shot 7 - Part 5.a Triangle Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	-44.5 dB
600 Hz	-2.88 dB
1200 Hz	-59 dB
1800 Hz	-15.8 dB
2.4 k Hz	-55 dB
3 k Hz	-24.9 dB

Table 7 – Part 5.c First 5 Harmonics

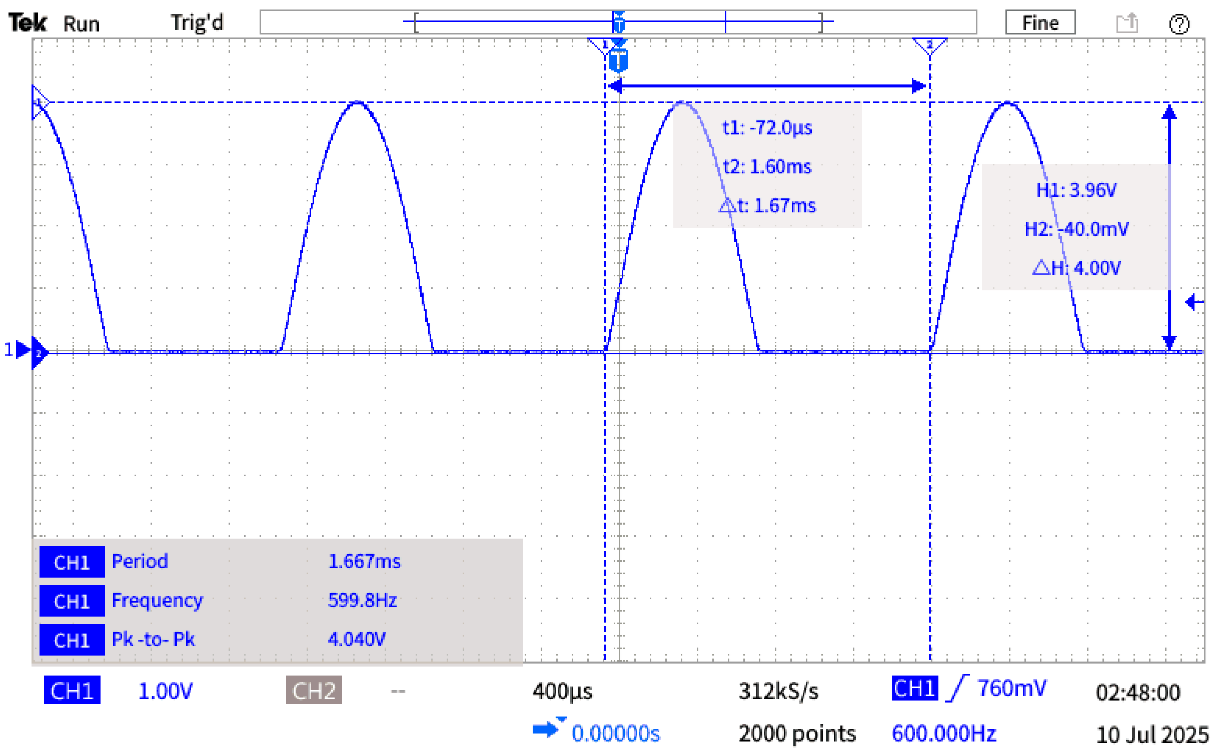


Scope Shot 8 - Part 5.d Most Prominent Harmonic

Magnitude(dB)	Magnitude(Vpk)
-44.5 dB	0.005957 V
-2.88 dB	0.717794 V
-59 dB	0.001122 V
-15.8 dB	0.162181 V
-55 dB	0.001778 V
-24.9 dB	0.056885 V

Table 8 - Part 5.e Convert to peak volts

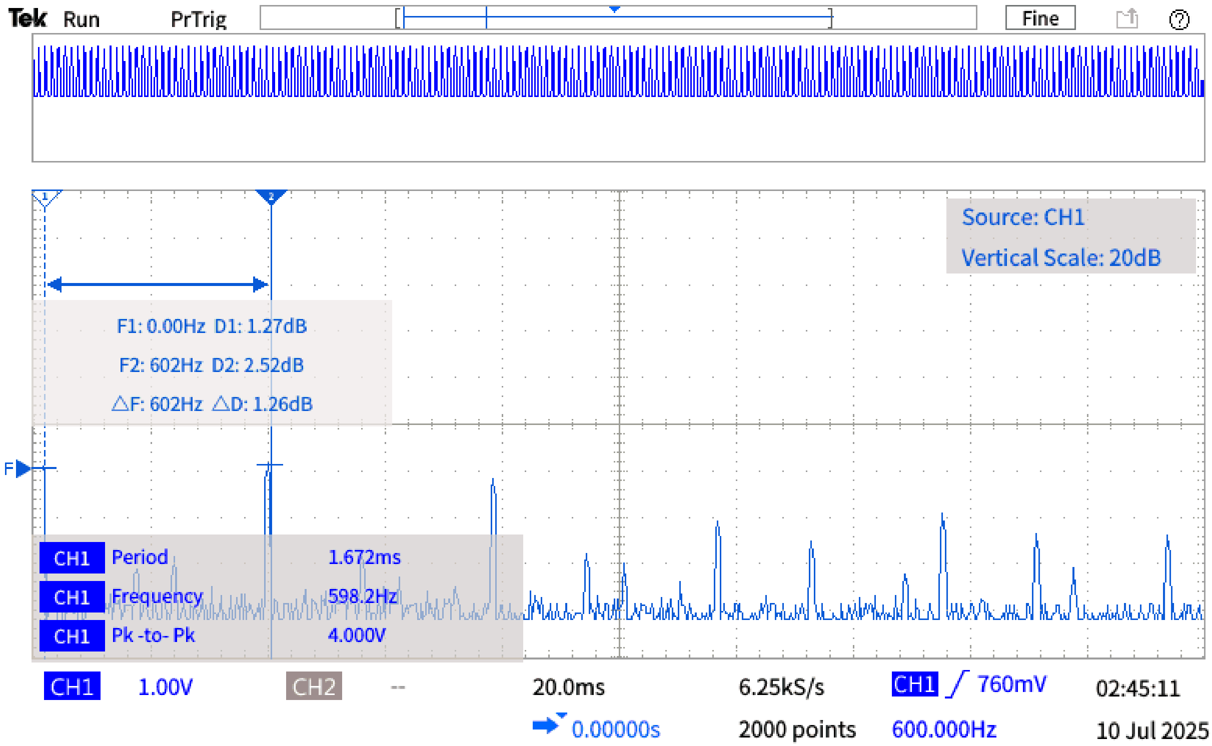
In Part 4 the standard measurement sequence was repeated for a half-sine waveform produced by the function generator. The signal had a 4 V amplitude, a period of 1.67 ms, and a fundamental frequency of 600 Hz. An oscilloscope captures the waveform appears below, followed by a table listing the first five harmonic magnitudes and a screenshot of the dominant spectral component. The largest harmonic measured 2.52 dB, which converts to approximately 1.337 V in linear terms.



Scope Shot 2 - Part 4.a Half Sine Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	1.27 dB
600 Hz	2.52 dB
1200 Hz	-3.66 dB
1800 Hz	-27.8 dB
2.4 k Hz	-18.8 dB
3 k Hz	-33.6 dB

Table 9 – Part 4.c First 5 Harmonics



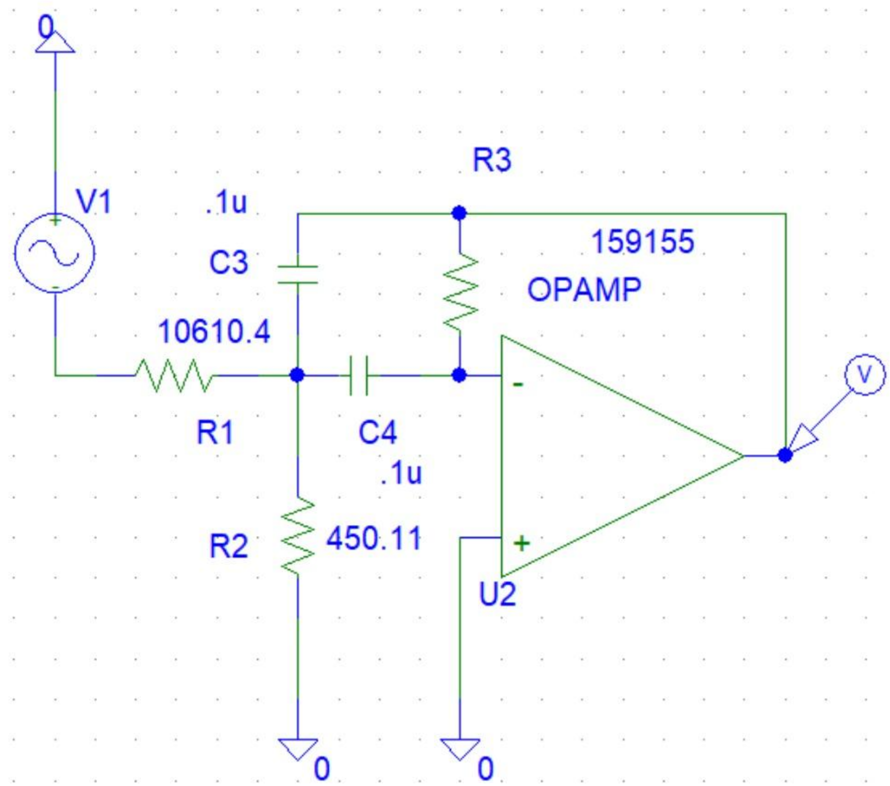
Scope Shot 10 - Part 4.d Most Prominent Harmonic

Magnitude(dB)	Magnitude(Vpk)
1.27 dB	1.15744 V
2.52 dB	1.3366 V
-3.66 dB	0.656145 V
-27.8 dB	0.040738 V
-18.8 dB	0.114815 V
-33.6 dB	0.020893 V

Table 10 - Part 4.e Convert to peak volts

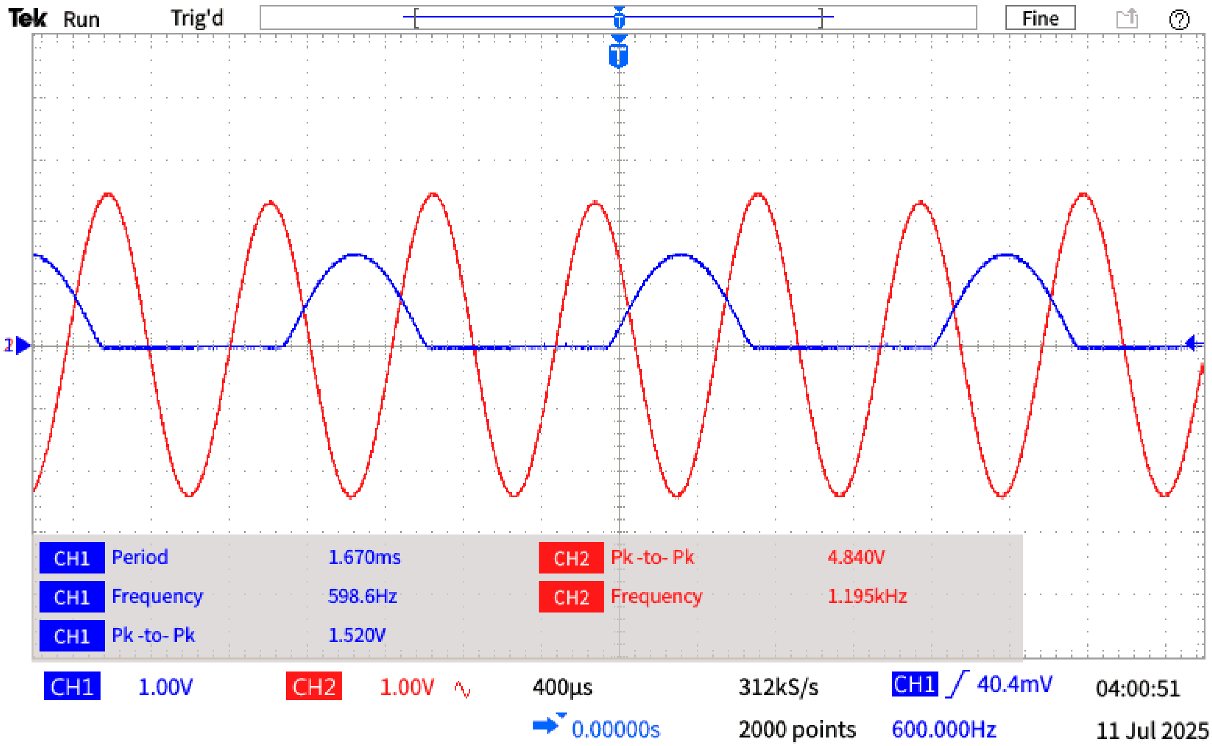
Part 2 Frequency Multiplication

In the second part of Lab 3 the function generator was adjusted to deliver a 600Hz sine wave with a 2V amplitude. The objective was then to construct a circuit that would accept this input and produce a 1200Hz sine wave with an amplitude of 5V. This result can be achieved by inserting a high-gain band-pass filter centered at 1200Hz. The filter isolates the second harmonic that appears at 1200Hz in the rectified waveform and amplifies it to the specified 5V output level.

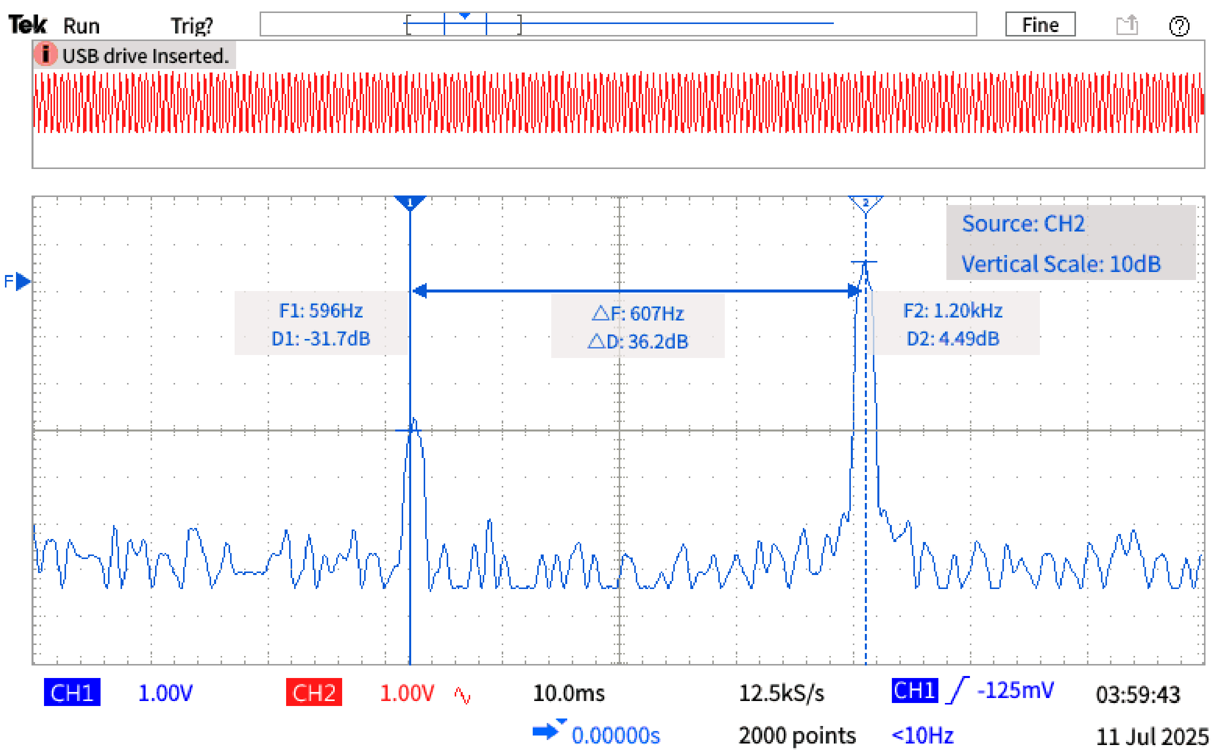


Schematic 1 - Bandpass Filter Isolating 1200 Hz Harmonic

After the bandpass filter had been designed to isolate the 1200Hz harmonic and raise it to roughly 5V, the circuit was assembled on a breadboard and examined with the oscilloscope's FFT function. The spectrum showed a peak at 1200Hz with a magnitude of 4.45dB, which converts to 1.677V in linear units. This result confirms that the filter successfully selected and amplified the target harmonic.



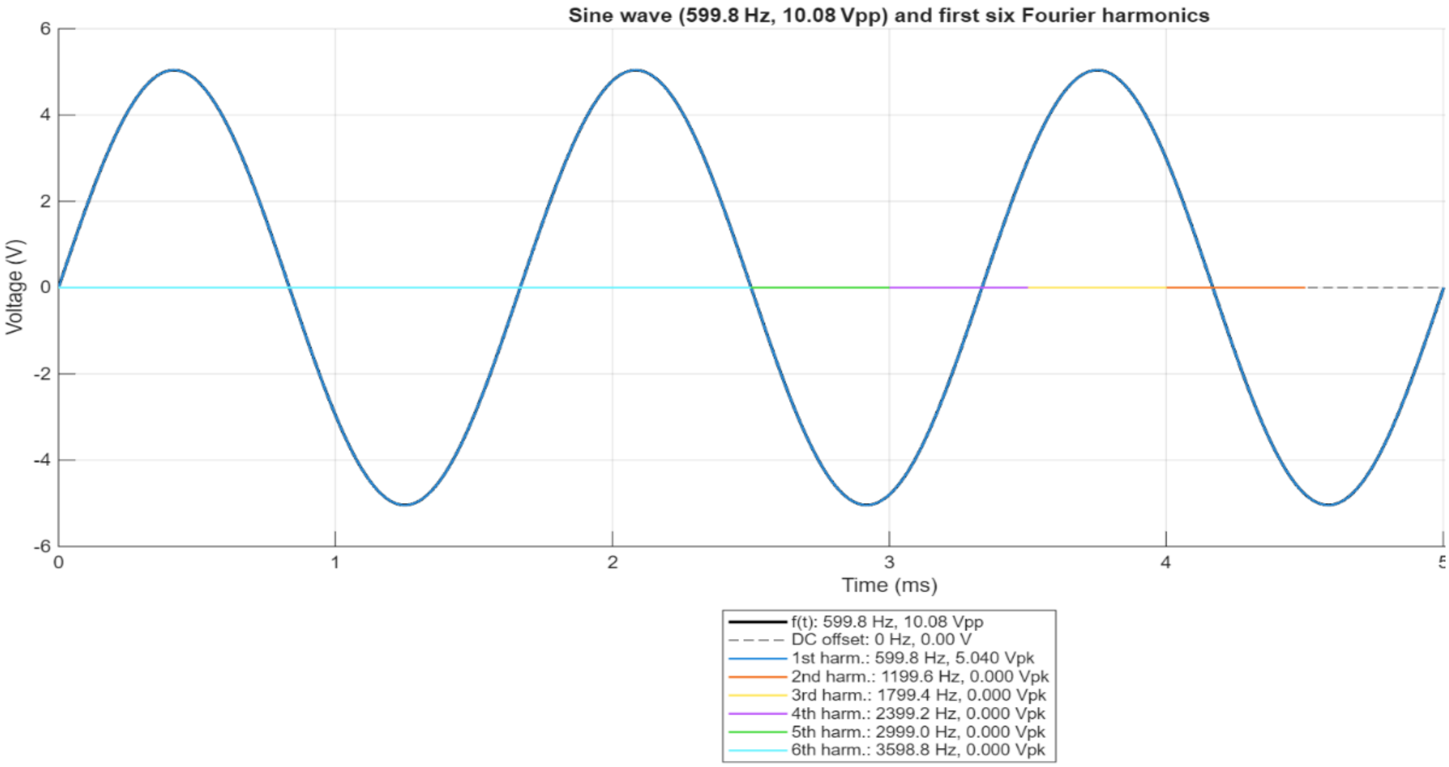
Scope Shot 11 – 600Hz input @≈2V & 1200 Hz output @≈5v



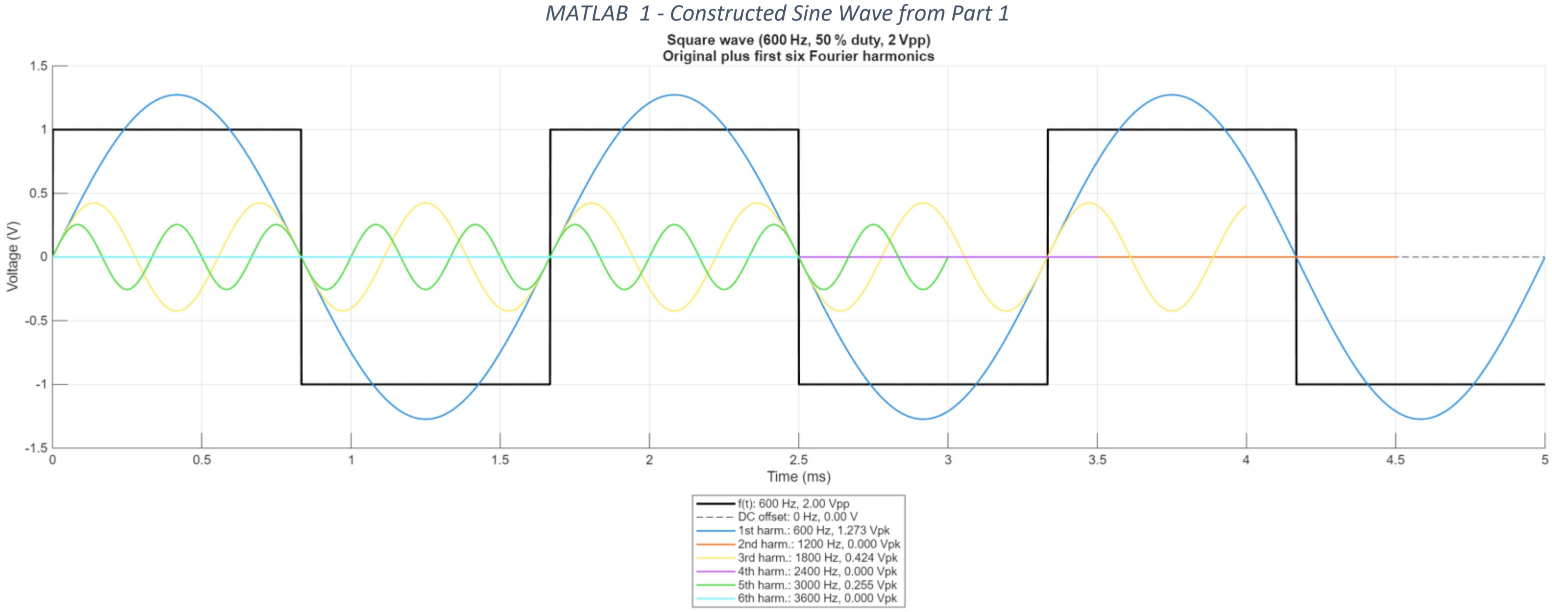
Scope Shot 11 - 1200 Hz Harmonic with a Magnitude of 4.49 dB & 30dB delta > 20dB

AFTER THE LAB

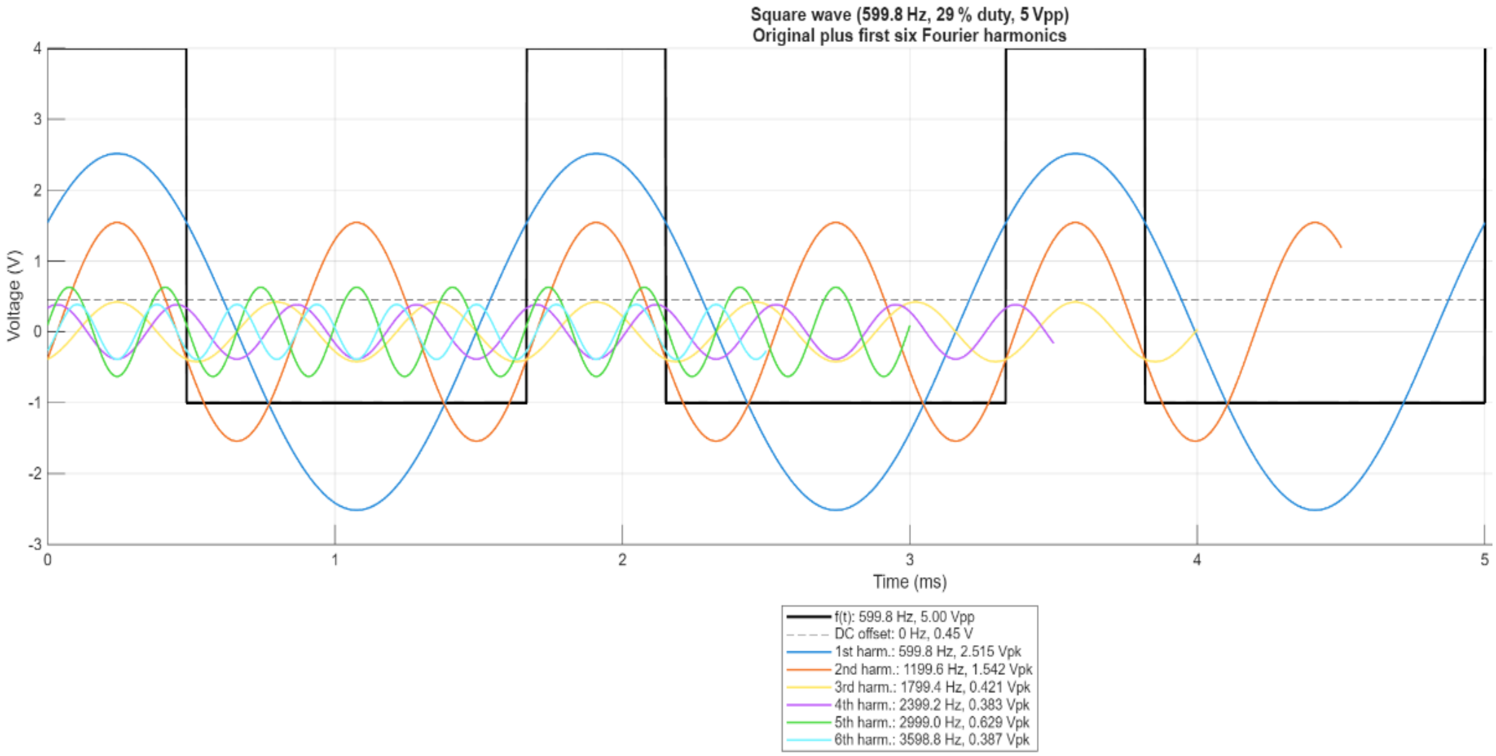
For the after the laboratory session we employed MATLAB to determine $a0$ and the first five Fourier coefficients for each of the five waveforms. The table below compares these calculated values with the corresponding experimental measurements.



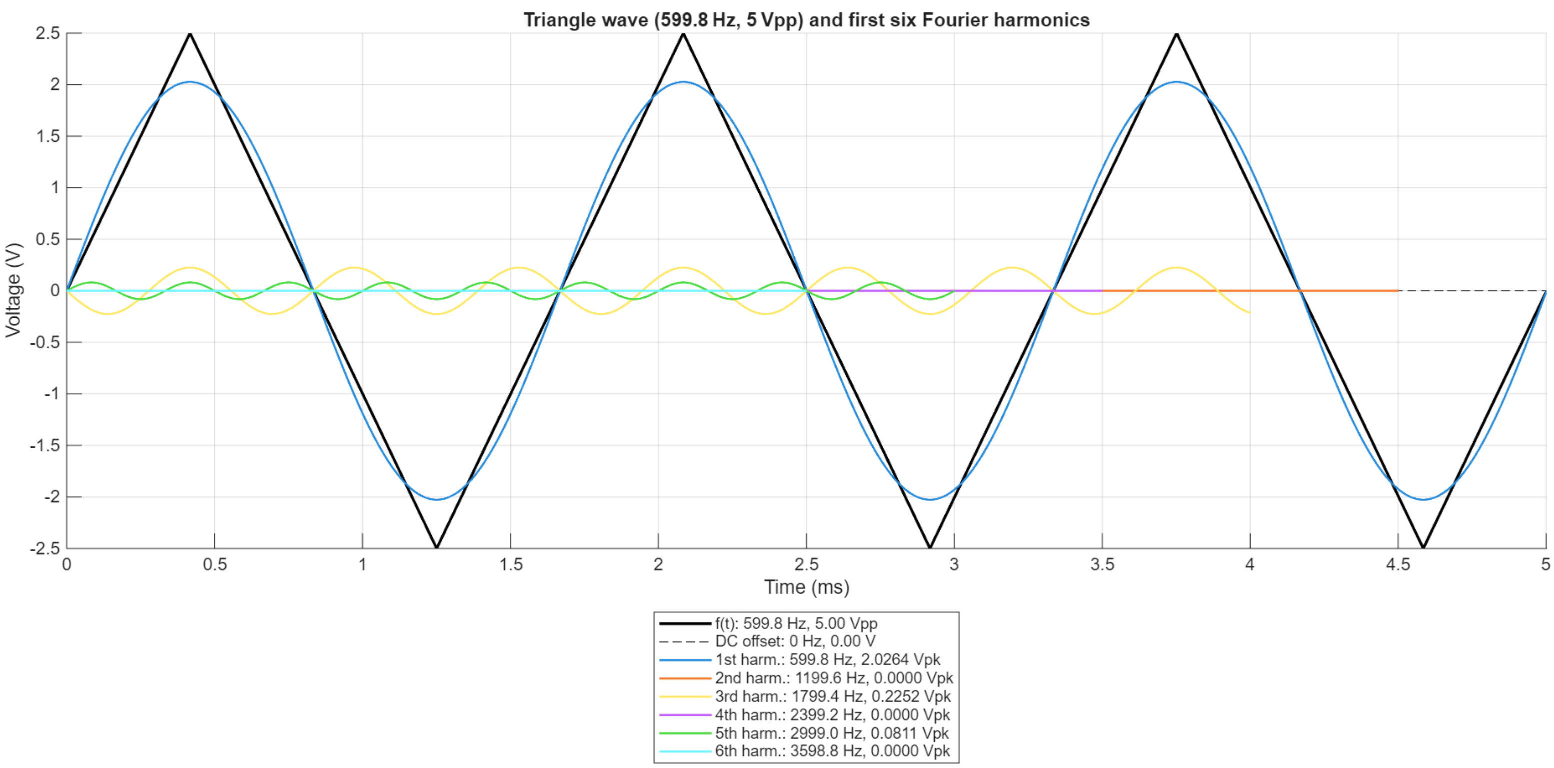
MATLAB 1 - Constructed Sine Wave from Part 1



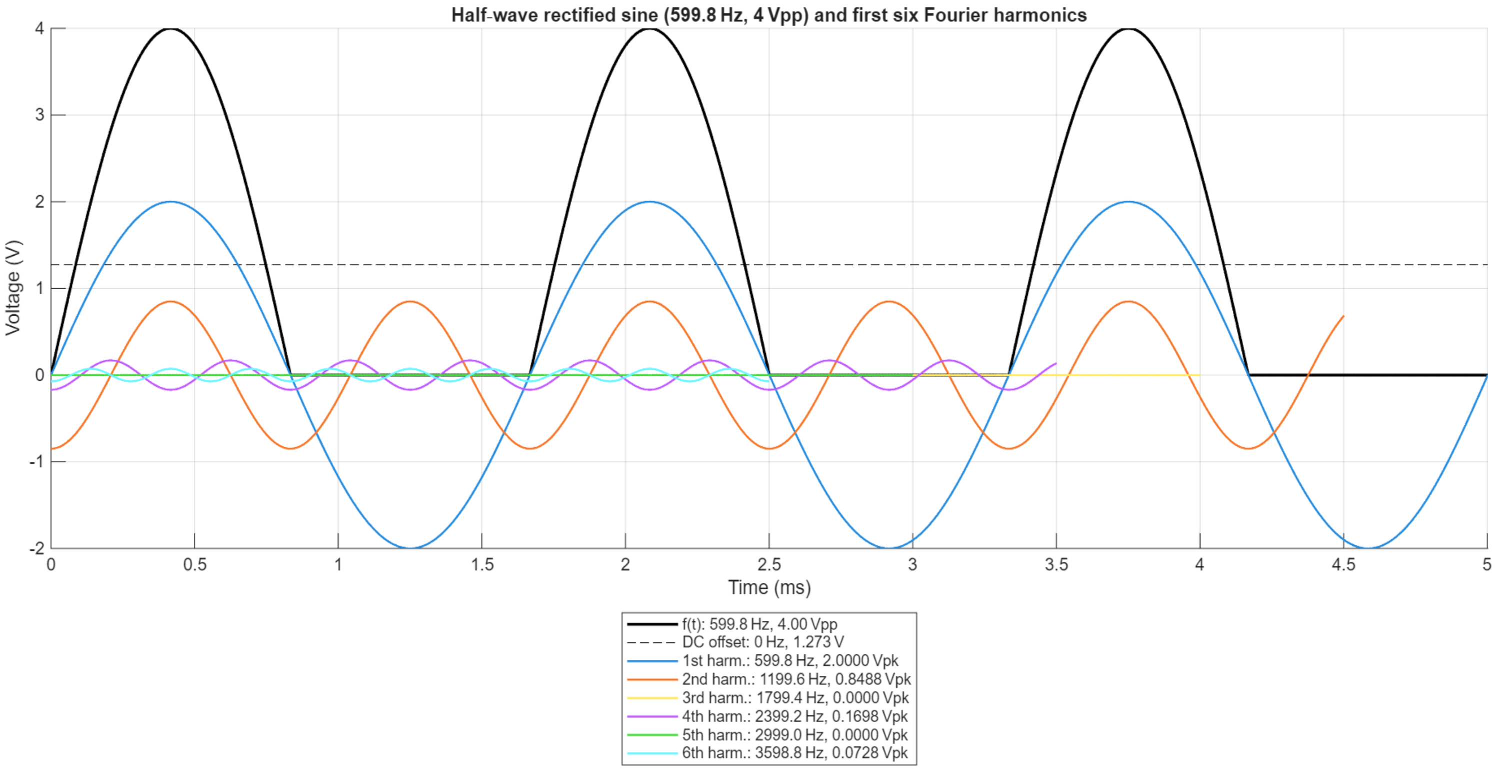
MATLAB 2 - Square Wave from Part 2



MATLAB 3 - Constructed Square Wave Pulse Train from Part 3



MATLAB 4 - Constructed Triangle Wave from Part 4



MATLAB 5 - Constructed Half Sine Wave from Part 5

Comparing Harmonics in order of 1, 2, 3, 4, 5 respectively From 600, 1200, 1800, 2.4k, and 3k		
	Calculated(Vpk)	**Measured(Vpk)**
Sine Wave	5.04, 0, 0, 0, 0	3.54813, 0.01135, 0.012445, 0.002786, 0.00912
Square Wave	1.273, 0, 0.424, 0, 0.255	0.895159, 0.011614, 0.301995, 0.01135, 0.18197
Square Wave Pulse Train	2.515, 1.542, 0.421, 0.383, 0.629	1.76807, 1.08156, 0.260016, 0.263027, 0.445656
Triangle Wave	2.0264, 0, 0.2252, 0, 0.0811	0.717794, 0.001122, 0.162181, 0.001778. 0.056885
Half Sine Wave	2, 0.8488, 0, 0.1698, 0	1.3366, 0.656145, 0.040738, 0.114815, 0.020893

Table 11 – Comparing Harmonics

III. SUMMARY OF RESULTS

	Sine Wave	Square Wave	Pulse Train	Triangle Wave	Half-Rectified Sine	Frequency Multiplier
Frequency	Magnitude	Magnitude	Magnitude	Magnitude	Magnitude	Amplified harmonic
0 Hz	-37.6 dB	-64.7 dB	-6.70 dB	-44.5 dB	1.27 dB	
600 Hz	11 dB	-0.962 dB	4.95 dB	-2.88 dB	2.52 dB	
1200 Hz	-38.9 dB	-38.7 dB	0.681 dB	-59 dB	-3.66 dB	
1800 Hz	-38.1 dB	-10.4 dB	-11.7 dB	-15.8 dB	-27.8 dB	4.49dB (1.677V)
2.4k Hz	-51.1 dB	-38.9 dB	-11.6 dB	-55 dB	-18.8 dB	
3k Hz	-40.8 dB	-14.8 dB	-7.02 dB	-24.9 dB	-33.6 dB	

Table 12 – Result Summary

IV. CONCLUSION

This experiment showed how Fourier-series theory translates to practical measurements of periodic signals. Using the oscilloscope's FFT, the harmonic amplitudes of sine, square, pulse-train, triangle, and half-rectified sine waves were measured and then compared with MATLAB calculations of $a0$ and the first five Fourier coefficients. Agreement was strong: the square wave displayed pronounced odd harmonics as expected from its symmetry, while the half-rectified sine wave produced non-zero even harmonics because of its DC offset. Small differences observed for the triangle and half-rectified waveforms were attributed to oscilloscope resolution limits and minor component tolerances.

The frequency-multiplication task illustrated harmonic manipulation with active filtering. A 600Hz sine wave was intentionally distorted to generate higher-order harmonics, then a second-order band-pass filter centered at 1200Hz isolated and boosted the third harmonic. The filter produced a peak of 4.49dB (about 1.677V), exceeding the design target with a harmonic delta of more than 30dB relative to the input wave, which confirms effective harmonic selection. Remaining discrepancies highlight the familiar trade-off between gain and bandwidth when selecting filter component values and Q-factor.

Overall, the work reinforced three core ideas: waveform symmetry governs harmonic content, FFT tools provide rapid spectral insight, and active filter performance is constrained by real-world tolerances. These findings bridge theoretical signal processing with hands-on circuit design and measurement.

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LAB DEMONSTRATION CERTIFICATION

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This section to be filled in by project team

Course________ Project Lab 3

Team Members:

1. Jordan lara
2.
3. GABRIEL VARGAS

Describe what is being demonstrated:

PART 1 Sine wave

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This section to be filled in by instructor

Signature: Date: Time:

Comments:

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LAB DEMONSTRATION CERTIFICATION

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This section to be filled in by project team

Course________ Project Lab 3

Team Members:

1. Jordan Lara
2. GABRIEL VARGAS
3. ______

Describe what is being demonstrated:

Frequency Multiplication

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This section to be filled in by instructor

Signature: Date: Time:

Comments:

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Lab 3