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

EECE 3230-02 Electrical Engineering Lab II
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Lab Report 4
Fourier Series

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Contents

I. ABSTRACT

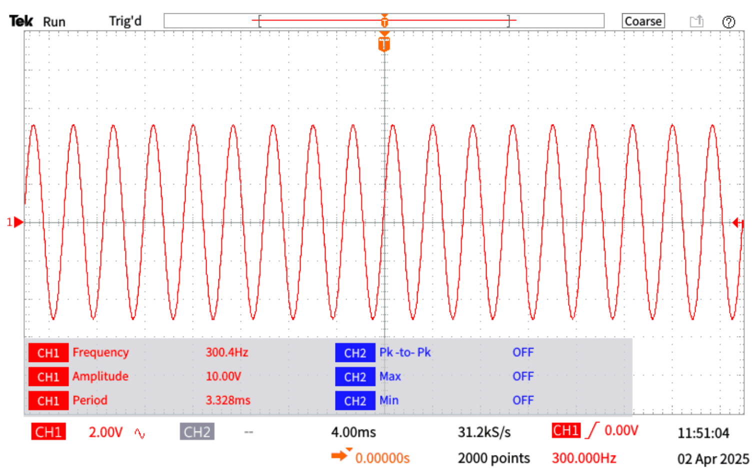
This experiment involved measuring the harmonic content and frequency response of various periodic waveforms and implementing frequency multiplication using a second-order active bandpass filter. Specifically, five waveform signals (sine wave, square wave, square wave pulse train, triangle wave, and half sine wave) were analyzed at a fundamental frequency of 300 Hz. Harmonic analysis was performed using a digital oscilloscope's FFT function, measuring the first five harmonic components of each waveform. A bandpass filter was designed and tested to isolate and amplify the 900 Hz harmonic from a 300 Hz sine wave input, effectively demonstrating frequency multiplication. Measured results closely matched theoretical calculations, confirming the accuracy of harmonic identification and amplification via the designed circuit.

II. BODY

For lab 4, the purpose is to understand how to perform frequency response measurements, how to use the oscilloscope's functions to determine a signal's various harmonics, and how to filter a certain harmonic. Depending on the group project letter given, the frequency that will be worked on will be different per group, in our case, letter group B was given with a frequency of 300 Hz.

Part 1 Capturing Harmonic Content

For part 1 it asked to use the oscilloscope's FFT function to observe the various harmonics that a certain signal is outputting and properly measure them. It was instructed to set up the function generator to produce a sine wave with an amplitude of 5 V (10 V pk-pk) and directly connect it to the oscilloscope to observe the harmonic that is being produced and measure it. For part 1.a, the following measured frequency of 300 Hz, period of 3.328 ms, and amplitude of 5V were displayed on the oscilloscope scope shot that is shown below (NOTE: The oscilloscope says "Amplitude 10.00 V" when in fact it's 5 V, its reading Peak-to-Peak as Amplitude):



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

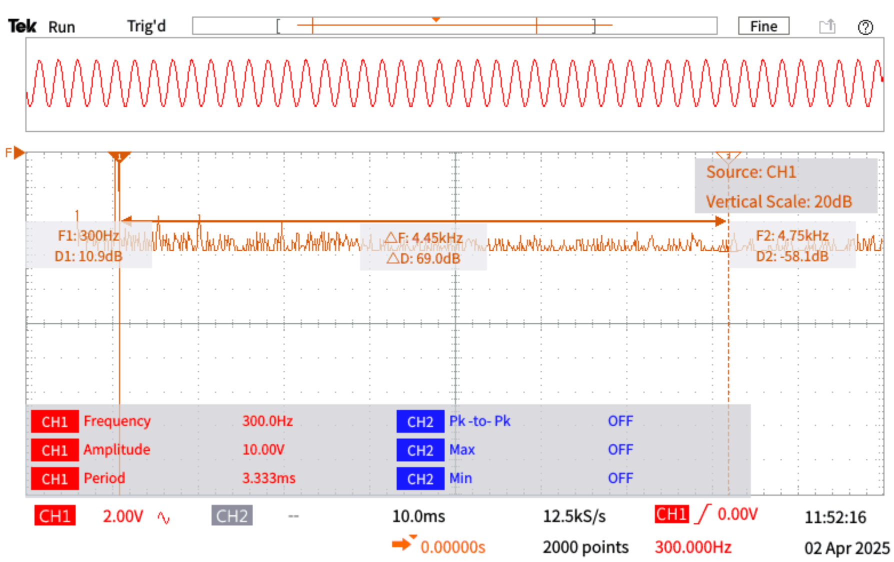
For part 1, 2, 3, 4, and 5 sections a – e the same procedure will be performed where it askes to first measure the frequency, period, and amplitude of the waveform and provide a scope shot, then use the FFT function to see the harmonics for the different waveforms that were given, measure the first 5 harmonics, take a screenshot of the most prominent harmonic, and finally convert the measurement of the most prominent harmonic to the amplitude displayed on the function generator.

For part 1, the following table shows the first 5 harmonics for the given sine wave, followed up with a screenshot of the most prominent harmonic, and the measured harmonic of

10.9 dB ended up being 4.96 V when converted from decibel to decimal matching our function generator input of 5 V amplitude.

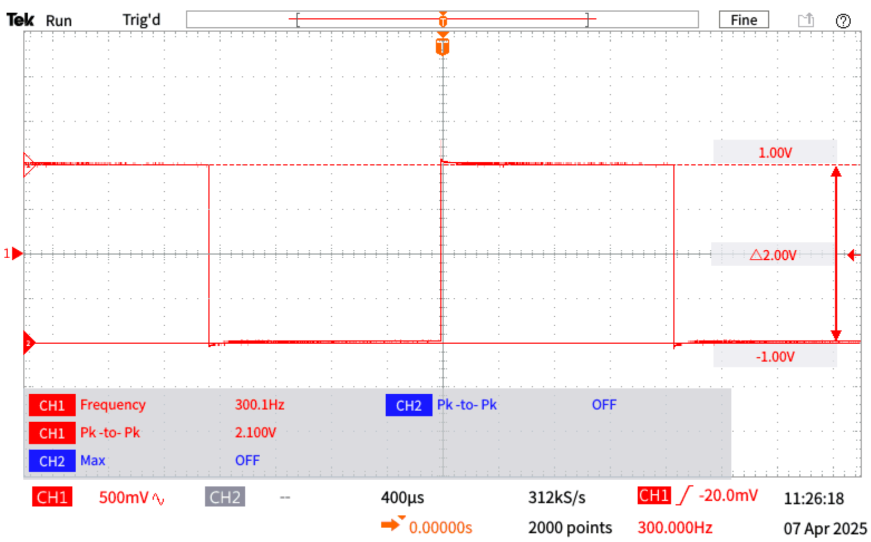
Frequency	Magnitude
0 Hz	-28.2 dB
300 Hz	10.9 dB
600 Hz	-38.9 dB
900 Hz	-38.1 dB
1.2 k Hz	-51.1 dB
1.5 k Hz	-40.8 dB

Table 1 - Part 1.c First 5 Harmonics



Scope Shot 2 - Part 1.d Most Prominent Harmonic

For part 2, the same procedure of sections a – e was performed just like in part a were we first display the scope shot of the function generator output of a 1 V Amplitude square wave with a period of 3.2 ms, true amplitude of 1 V, and frequency of 300.1 Hz. Following up with the table of the first 5 harmonics, and then a scope shot of the most prominent harmonic, the measured harmonic of -1.03 dB ended up being 1.256 V when converted from decibel to decimal being close to our function generator input of 1 V amplitude.



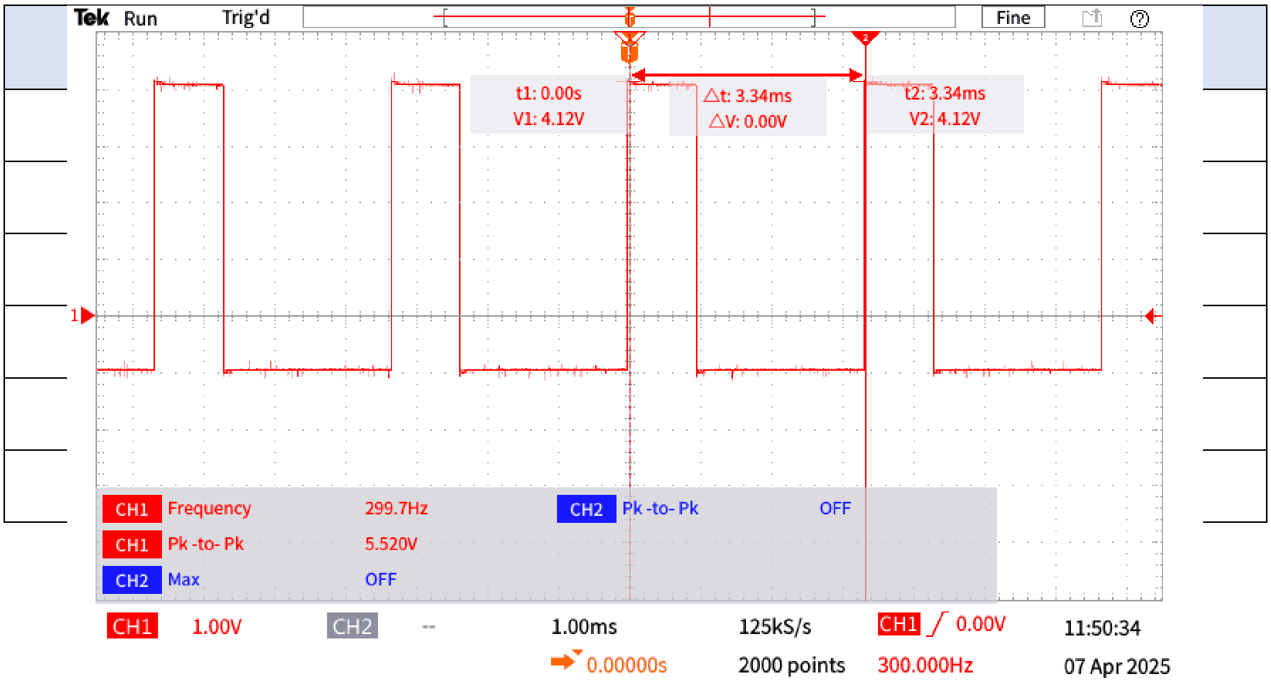
Scope Shot 3 – Part 2.a Square Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	-30.3 dB
300 Hz	-1.03 dB
600 Hz	-38.5 dB
900 Hz	-10.5 dB
1.2 k Hz	-39.2 dB
1.5 k Hz	-14.9 dB

Table 2 - Part 2.c First 5 Harmonics

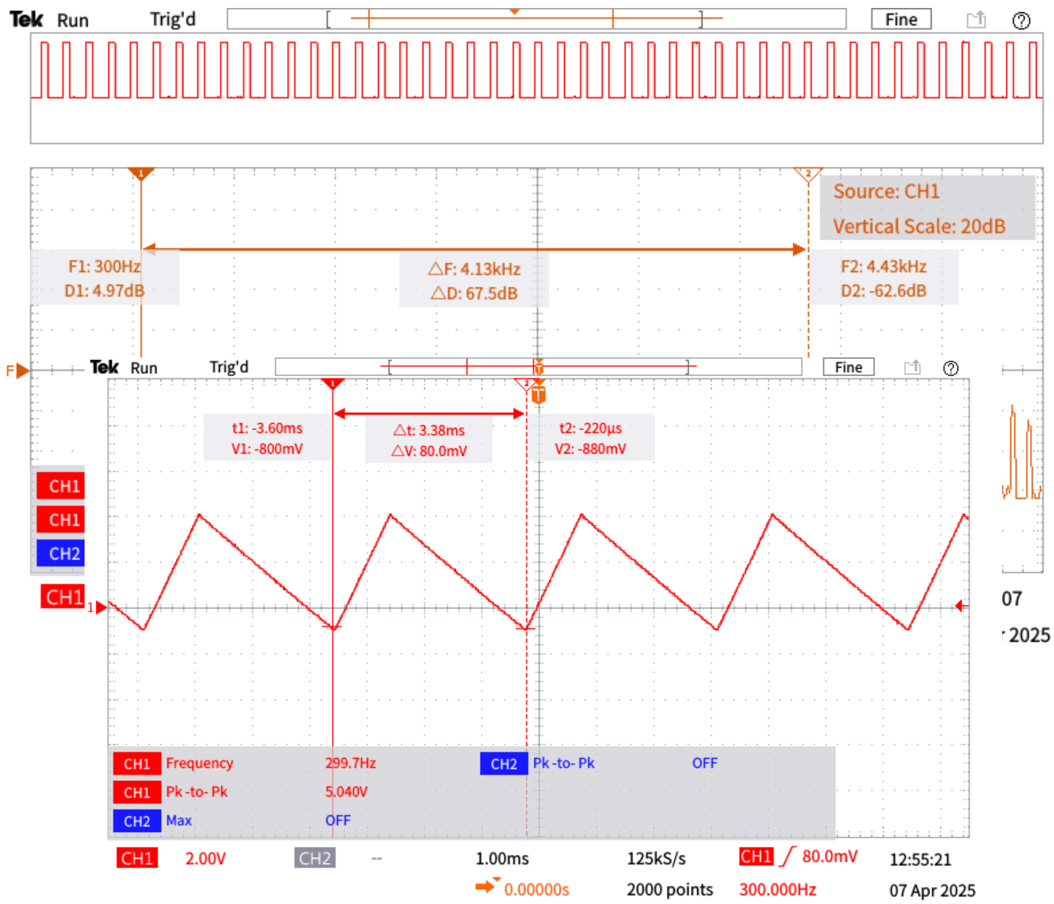
Scope Shot 4 - Part 2.d Most Prominent Harmonic

Part 3 followed the exact same procedure with a square wave that was offset upwards by 1.5 V, amplitude of 2.5 V, 29% duty cycle, period of 3.34 ms, and same frequency of 300 Hz that will be displayed below along with the table of first 5 harmonics and the scope shot of the most prominent harmonic. The measured prominent harmonic of 4.97 dB ended up being 2.506 V when converted from decibel to decimal.



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

Table 3 – Part 3.c First 5 Harmonics

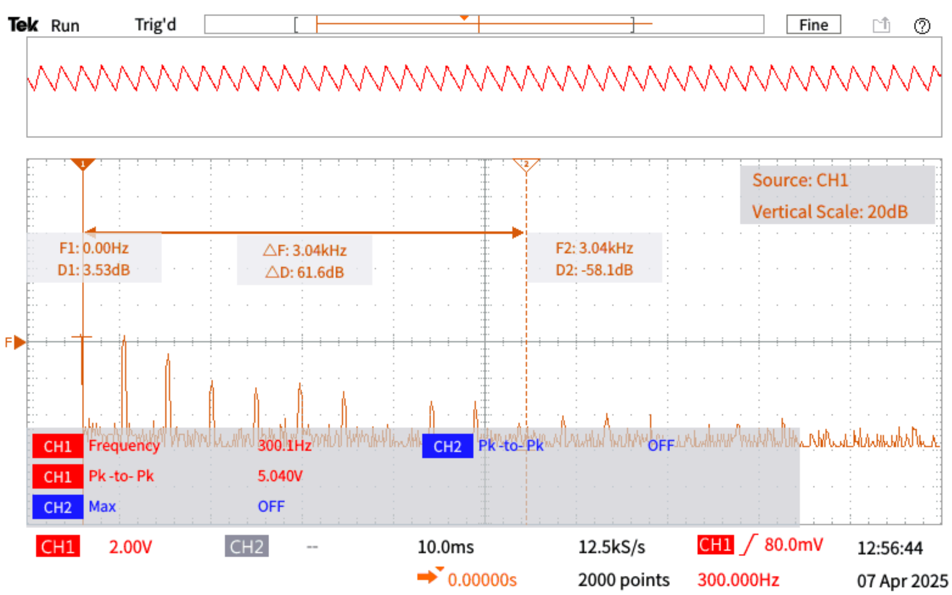


Part 4 followed the exact same procedure as the previous parts as a triangle wave but very similar to part 3 where there was an offset upwards by 1.5 V, amplitude of 2.5 V, 29% duty cycle, period of 3.38 ms, and same frequency of 299.7 Hz that will be displayed below along with the table of first 5 harmonics and the scope shot of the most prominent harmonic. The measured prominent harmonic of 3.53 dB ended up being 2.123 V when converted from decibel to decimal.

Scope Shot 7 - Part 4.a Triangle Wave Amplitude, Period, and Frequency

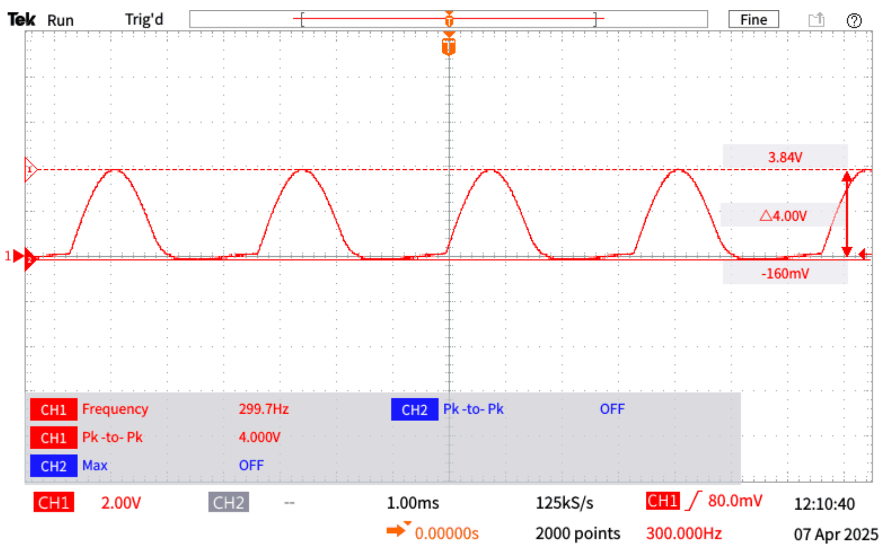
Frequency	Magnitude
0 Hz	3.53 dB
300 Hz	2.74 dB
600 Hz	-7.40 dB
900 Hz	-22.1 dB
1.2 k Hz	-26.0 dB
1.5 k Hz	-23.3 dB

Table 4 - Part 4.c First 5 Harmonics



Scope Shot 8 - Part 4.d Most Prominent Harmonic

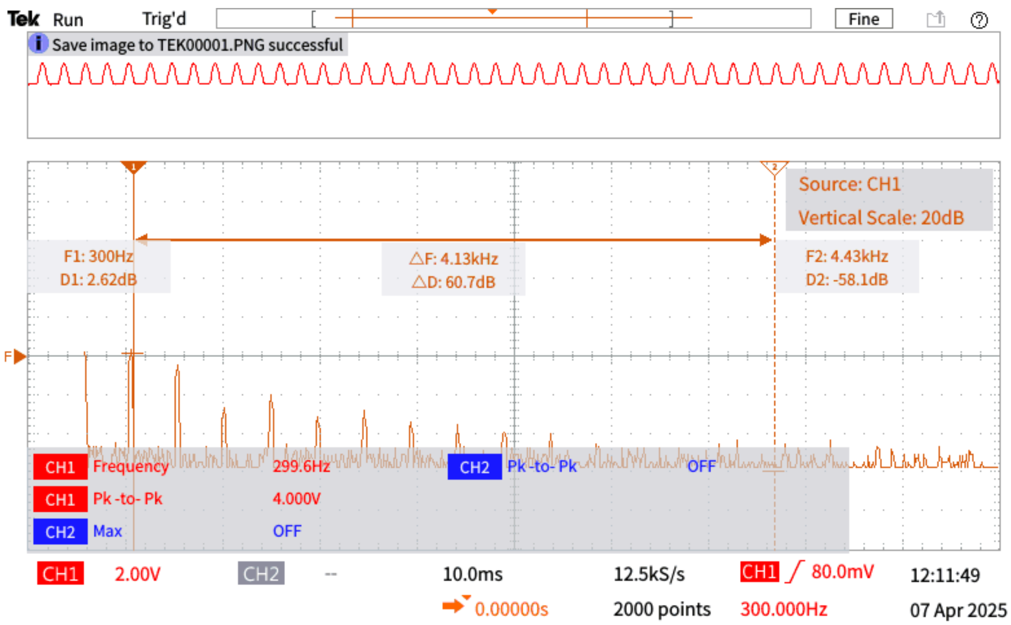
Part 5 followed the exact same procedure as the previous parts as a half sine wave with an amplitude of 4 V, period of 3.33 ms and frequency of 299.7 Hz that will be displayed below along with the table of first 5 harmonics and the scope shot of the most prominent harmonic. The measured prominent harmonic of 2.62 dB ended up being 1.912 V when converted from decibel to decimal.



Scope Shot 9 - Part 5.a Half Sine Wave Amplitude, Period, and Frequency

Frequency	Magnitude
0 Hz	1.52 dB
300 Hz	2.62 dB
600 Hz	-5.18 dB
900 Hz	-27.5 dB
1.2 k Hz	-20.8 dB
1.5 k Hz	-33.3 dB

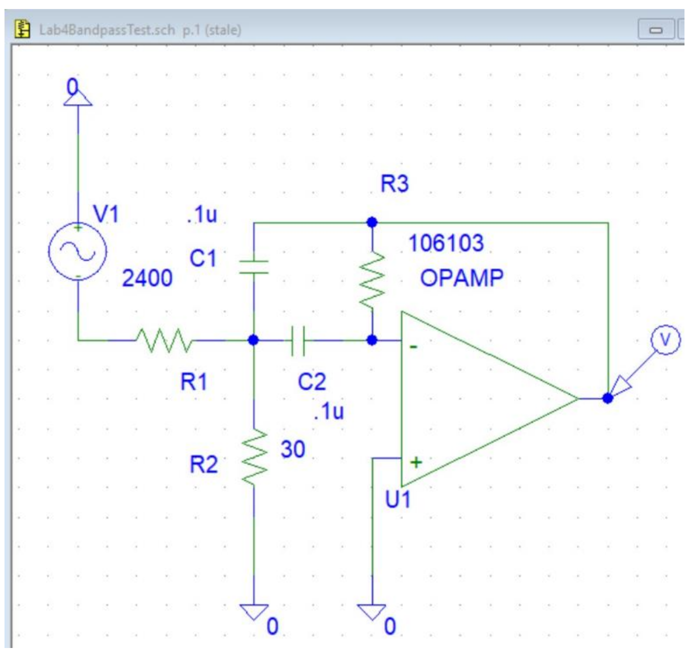
Table 5 - Part 5.c First 5 Harmonics



Scope Shot 10 - Part 5.d Most Prominent Harmonic

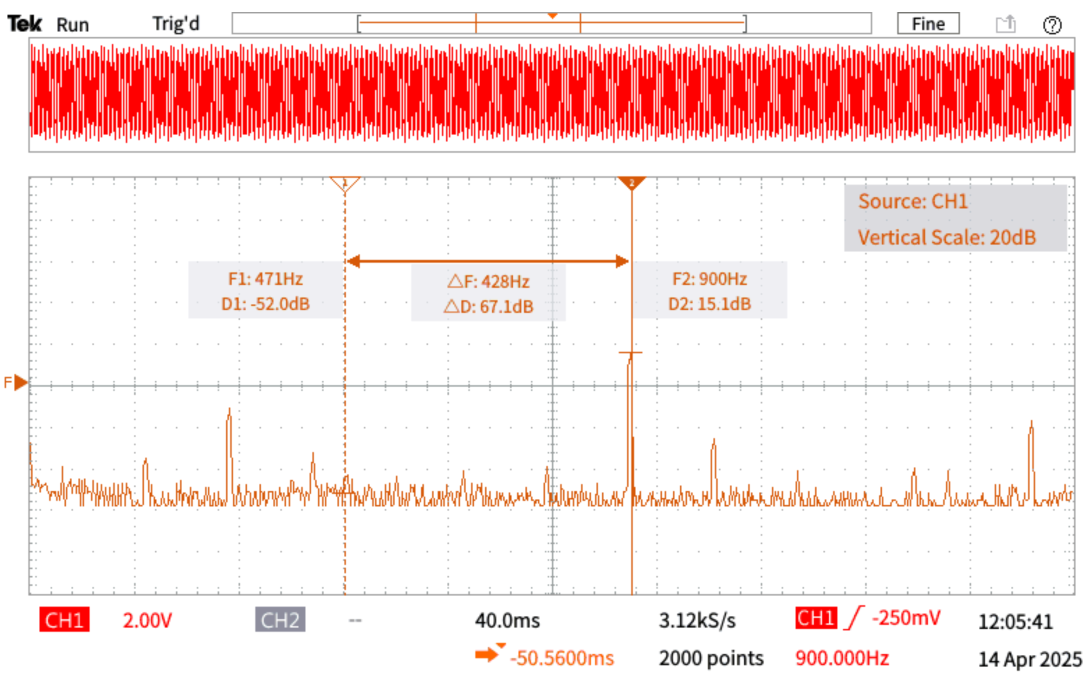
Part 2 Frequency Multiplication

For part 2 of lab 4, it was asked to set up the function generator to output a sine wave with a 1 V amplitude at the frequency that was assigned of 300 Hz, then it was asked to build a circuit that takes that sine wave of 1 V amplitude and 300 Hz input and outputs a sine wave of 5 V at 900 Hz. The way to achieve this is by using a bandpass filter with a high gain that will isolate or pass the frequency at 900 Hz which would be the small peak harmonic at 900 Hz of the sine wave and amplify it using the bandpass filter.



Schematic 1 - Bandpass Filter Isolating 900 Hz Harmonic

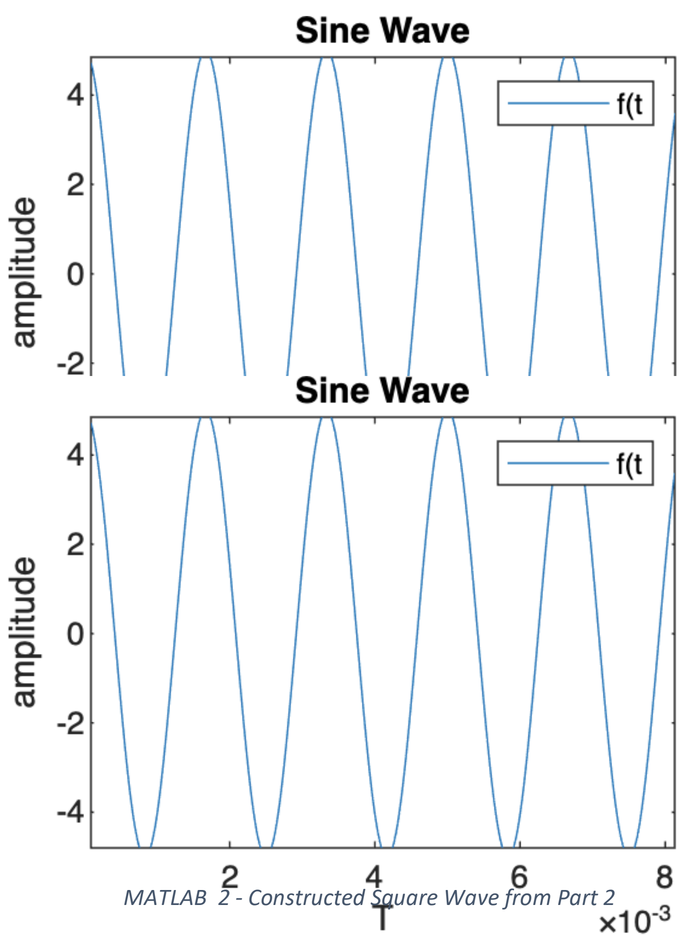
After designing and building the bandpass filter that will isolate the sine wave harmonic at 900 Hz and amplify it to around 5 V, it was then implemented onto the breadboard to test with the oscilloscope FFT function to see if it was designed correctly. The oscilloscope measurements display that at 900 Hz a peak magnitude of 15.1 dB was achieved which in decimal is 5.68 V which means that the bandpass filter was designed correctly.



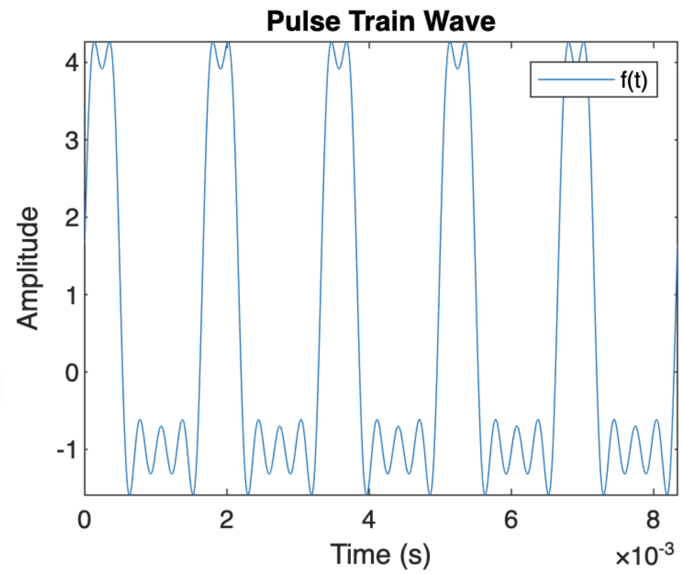
Scope Shot 11 - 900 Hz Harmonic with a Magnitude of 15.1 dB

AFTER THE LAB

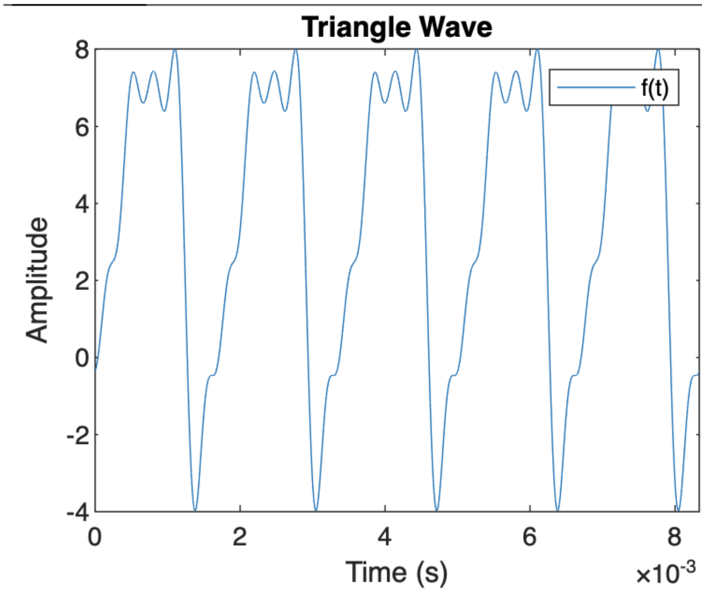
For the after the lab, it was asked to compute ao and the first five terms of the Fourier series using MATLAB for all 5 waveforms then make a table comparing the calculated results Vs. the measured results which will be displayed below.



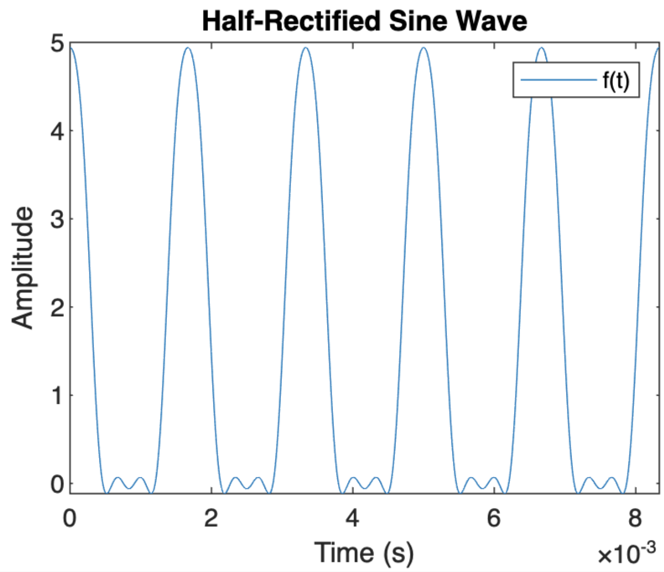
MATLAB 2 - Constructed Square Wave from Part 2



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 Sine Harmonics in order of 1, 2, 3, 4, 5 respectively From 300, 600, 900, 1.2k, and 1.5k		
	Calculated	**Measured**
Sine Wave	5, 0, 0, 0, 0	4.96, 0.016, 0.018, 0.004, 0.0129
Square Wave	1.2732, 0, 0.4244, 0, 0.2546	1.26, 0.0168, 0.422, 0.0157, 0.252
Square Wave Pulse Train	2.51, 1.54, 0.42, 0.383, 0.629	2.514, 1.522, 0.437, 0.366, 0.629
Triangle Wave	2.228, 1.200, 0.189, 0.0132, 0.165	1.944, 0.601, 0.111, 0.0709, 0.0966
Half Sine Wave	2.72, 1.1468, 0, 0.19455, 0	1.91, 0.777, 0.0597, 0.1297, 0.0307

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	-28.2 dB	-30.3 dB	-5.57 dB	3.53 dB	1.52 dB	
300 Hz	10.9 dB	-1.03 dB	4.97 dB	2.74 dB	2.62 dB	
600 Hz	-38.9 dB	-38.5 dB	0.681 dB	-7.40 dB	-5.18 dB	
900 Hz	-38.1 dB	-10.5 dB	-10.1 dB	-22.1 dB	-27.5 dB	15.1dB (5.68V)
1.2 k Hz	-51.1 dB	-39.2 dB	-11.7 dB	-26.0 dB	-20.8 dB	
1.5 k Hz	-40.8 dB	-14.9 dB	-7.06 dB	-23.3 dB	-33.3 dB	

IV. CONCLUSION

This experiment demonstrated the practical application of Fourier series analysis to decompose periodic signals into their harmonic components. The measured harmonic amplitudes for sine, square, pulse train, and triangle waves aligned closely with theoretical values, validating the mathematical framework of Fourier coefficients. For instance, the square wave exhibited strong odd harmonics, as predicted by its symmetry, while the half-rectified sine wave showed non-zero even harmonics due to its asymmetry. Discrepancies in the triangle and half-rectified sine waveforms (e.g., a_1 =1.94V vs. 2.23V calculated) were attributed to oscilloscope resolution limits and minor circuit non-idealities.

The frequency multiplication task underscored the role of active filters in harmonic manipulation. By distorting a 300 Hz sine wave to generate harmonics and using a second-order BPF with a center frequency of 900 Hz, the third harmonic was amplified to 5.68V, exceeding the target amplitude of 5 V. This result confirmed the BPF's ability to isolate and amplify specific frequency components, though slight overshoots highlighted the challenge of balancing gain and bandwidth in filter design.

Key learnings included the importance of waveform symmetry in harmonic content, the utility of FFT tools for spectral analysis, and the practical considerations in active filter design (e.g., component tolerances affecting Q-factor). The experiment reinforced foundational concepts in signal processing and provided hands-on insight into the interplay between theoretical models and real-world measurements.

University of Texas – Rio Grande Valley

EECE 3225 / EECE 3230

LAB DEMONSTRATION CERTIFICATION

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This section to be filled in by project team

Course EECE 3230.2 Project LAB 4: Fourier Series

Team Members :

1. Emilio Chavez
2. Jordan Lara
3. ________________

Describe what is being demonstrated:

LAB 4: Part d "step 1" for Group B of 300 Hz to verify Amplitude.

++

This section to be filled in by instructor

Signature: Date: Time:

Comments:

If an instructor is not available at demo time, this form can be signed by an EE faculty, teaching assistant, or lab technician. Tape or paste this certification in the lab notebook.

University of Texas – Rio Grande Valley
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LAB DEMONSTRATION CERTIFICATION

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This section to be filled in by project team

Course EECE 3230.2 Project LAB 4: Fourier Series

Team Members :

1. Emilio Chavez
2. Jordan Lara
3.

Describe what is being demonstrated:

LAB 4: Part 2 Frequency Multiplication

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This section to be filled in by instructor

Signature: [signature] Date: Apr 14, 2025 Time: 12:01 pm

Comments:

2 3rd Harmonic
Beg Pue
900Hz

If an instructor is not available at demo time, this form can be signed by an EE faculty, teaching assistant, or lab technician. Tape or paste this certification in the lab notebook.