Trenton Cathcart
October 27, 2022

FREQUENCY SPECTRUM CHARACTERISTICS

Objectives:
This lab will introduce the frequency spectrum characteristics of signals and how the amplitude of the signals directly relates to the power of the signals. Again, we are looking at Fourier domain analysis of signals, the frequency domain.

Preliminary Calculations: The preliminary calculations required us to refresh our memories on fourier domain analysis, and review class material about these subjects.

Results and Discussions:

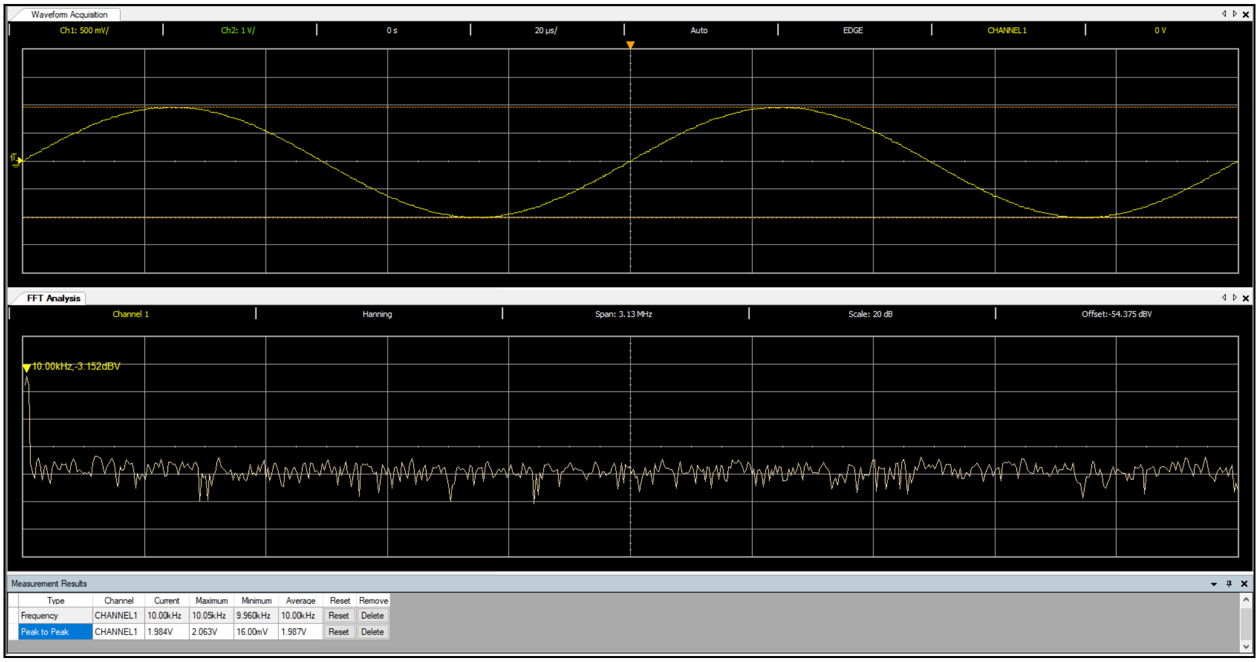
1. **SINE WAVE ANALYSIS**
    a. Use the function generator to produce a sine wave with a peak amplitude of 1 volt and a frequency of 10 kHz. Measure the amplitude and frequency of the signal on both the oscilloscope and frequency spectrum FFT, and see if all three devices (signal generator, oscilloscope and frequency spectrum FFT) agree on the amplitude and frequency of the wave. The amplitude is scaled in logarithms per decade, you will have to un-scale it to get better analysis of the signal compared to the other two devices.

    Results 1:
    1. Measure the amplitude and frequency of the signal on both the oscilloscope and frequency spectrum FFT, and see if all three devices (signal generator, oscilloscope and frequency spectrum FFT) agree on the amplitude and frequency of the wave.
        a. The measurements we recorded and are presented within **Table 1.** The measurements are very close, but off by plus or minus 0.02 V. The oscilloscope output can be observed within **Figure 1.**

Table 1: Measurements

Device	Measurement
Signal Generator	2 Vpp
Oscilloscope	1.984 Vpp
Fast Fourier Transform	1.96999 Vpp

Figure 1: Oscilloscope Output



2. SINE WAVE AVERAGE POWER

a. Calculate the average power of the sine wave from step 1 using the oscilloscope (not FFT), assuming it was put across a 1 ohm load. Don't actually put it across a 1 ohm resistor, just calculate the power if that voltage had been put across a 1 ohm resistor (hint: as in divided by one). For the rest of this lab, any time the power of a signal is mentioned, it will be assumed to be the power if the signal was put across a 1 ohm load.

Results 2:

1. Using equations to find Vpp the average power was calculated to be 1.414 W.

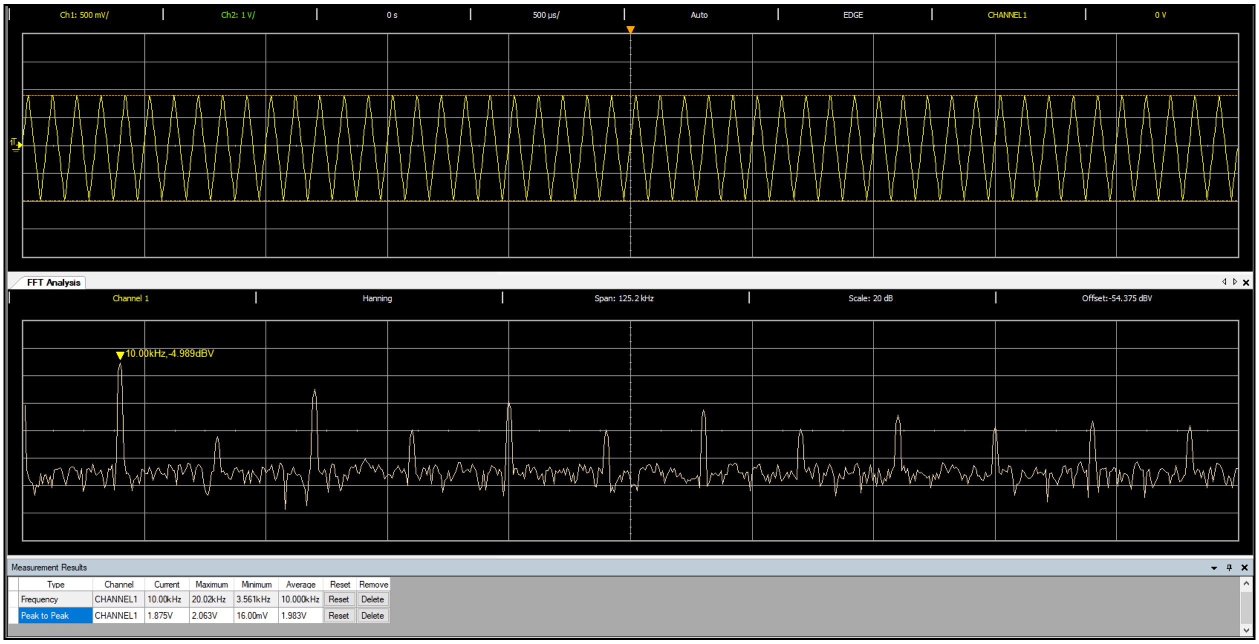
3. TRIANGLE WAVE AVERAGE POWER

a. Use the function generator to produce a triangle wave with a peak amplitude of 1 volt and a frequency of 10 kHz. Verify it is correct by displaying the signal on the oscilloscope. Calculate the average power of the triangle signal using the oscilloscope (not FFT).

Results 3:

1. Using equations to find Vpp the average power was calculated to be 2.5327 W. The signal output can be observed within **Figure 2.**

Figure 2: Oscilloscope Output



4. **TRIANGLE WAVE SIGNAL POWER**
    a. Measure the triangle wave from the previous step on the spectrum analyzer. Determine the power of the term at 10 kHz, 20 kHz, and the other multiples of 10 kHz (until you reach the ambient noise levels). The sum of all these powers should add to the same number you got in the previous step (Part 3).

    Results 4:

    1. Using **Equation 1,** we calculated the Vpp for 10, 20, 30Khz. The powers for each harmonic were calculated to be 1.565 V, 0.1744, 0.0304, and slowly descended for more harmonics. I'm sure if an infinite sum of these powers were taken for each harmonic, then the sum would approach the same number from the previous step.

Equation 1

$$\boxed{V_{pp} = 2\sqrt{2}10^{\frac{dbv}{20}}}$$

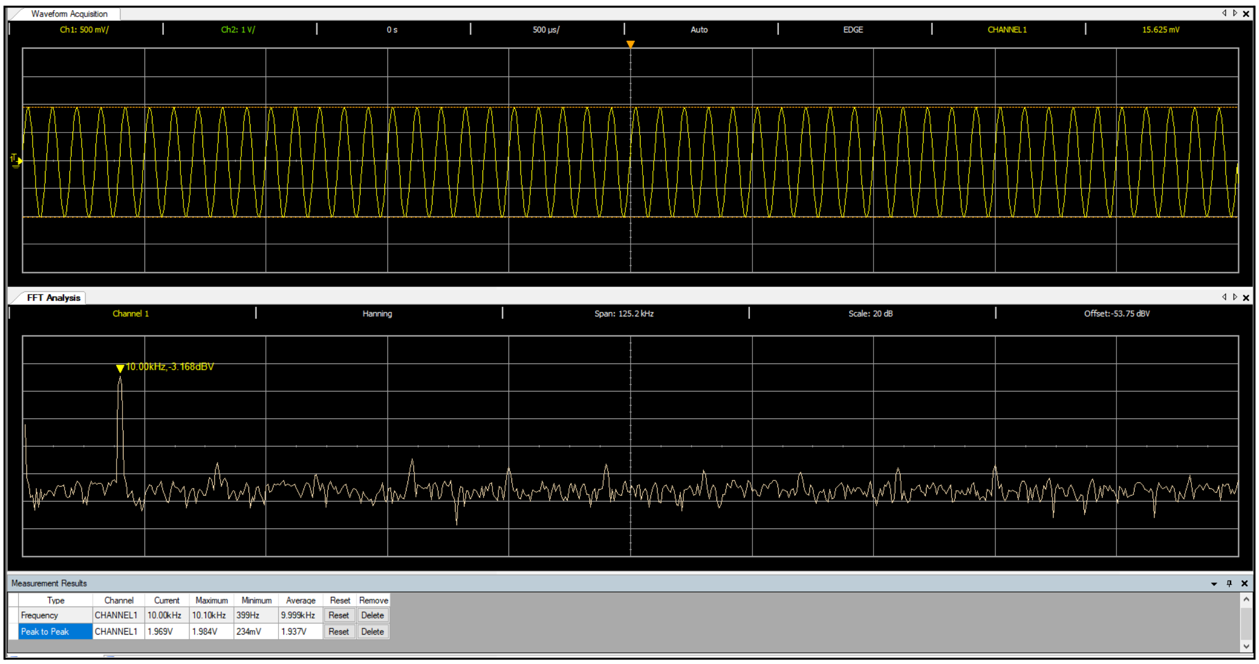
5. **SINE WAVE SIGNAL POWER**
    a. Repeat the previous step with a sine wave. But unlike in step 4, look at 10 kHz separately from any other multiples of 10 kHz (if they exist). Record

the total amount of the power that is at 10 kHz, how does this compare to the power calculated in Part 2? Is there any signal power not at 10 kHz?

Results 5:

1. Using equation 1, we were able to calculate the power at 10Khz to be 3.859 W. We also used equation 1 to decide if there was power anywhere other than 10Khz. We concluded that yes there was approximately 0.141 W at other harmonics.

Figure 3: Oscilloscope Output



6. ATTENUATED SINE WAVE CHARACTERISTICS

a. Ideally, a sine wave on a spectrum analyzer should only have a peak at its frequency, its fundamental frequency. However, the spectrum analyzer will often find terms at high frequencies if the signal is distorted or attenuated, especially at odd multiples of its fundamental frequency. This is because the generator may not be producing an ideal sine wave, or the transmission cable or other element is attenuating the signal. To see this effect more clearly, assemble and connect the circuit shown below using a 1k resistor and two 1N4001 or 1N4002 diodes. Diodes start conducting around 700 mV. If the input sine wave is less than 700 mV, it should go through the circuit unchanged. However, once the peak voltage exceeds that level, the top of the sine wave will be attenuated, or clipped. Generate sine waves with amplitudes of 100 mV, 700 mV, 1.5 V and 3 V. Pass these signals through our circuit and measure the amplitude of the harmonics (as far the ambient noise levels will allow) on the spectrum analyzer (you can use cursors to determine the amplitudes if peak scan doesn't work), record these values for the next section. Also look at the signals on the oscilloscope and record the signal appearance.

Results 6:

1. The results for 3 V, 1.5 V, 700 mv, and 100 mv can be seen within **Figures 4-8,** Respectively. The results of whether or not the circuit clipped or not can be observed below within table 2.

Figure 4: Oscilloscope Output

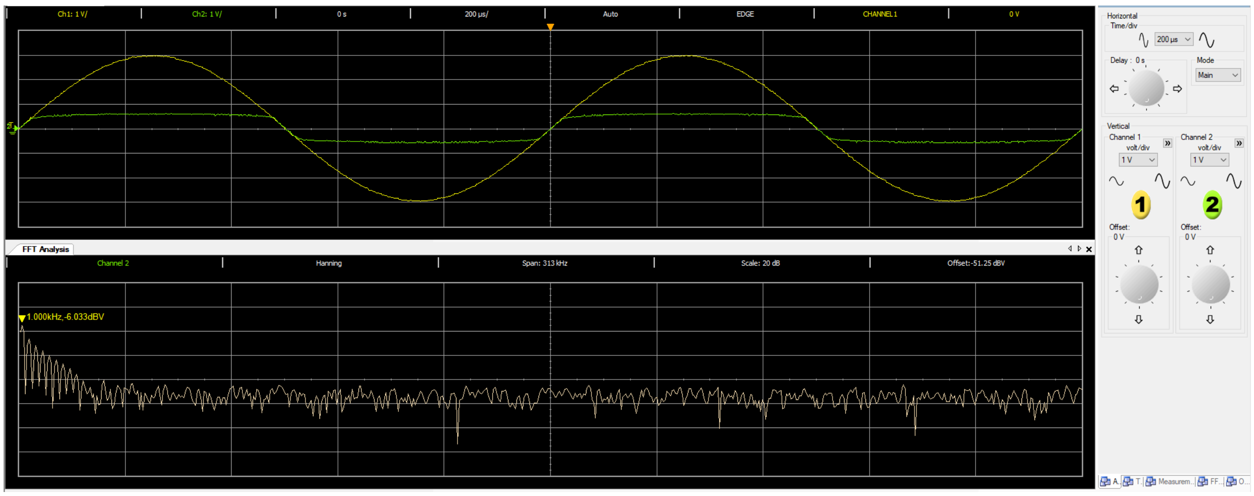


Figure 5: Oscilloscope Output

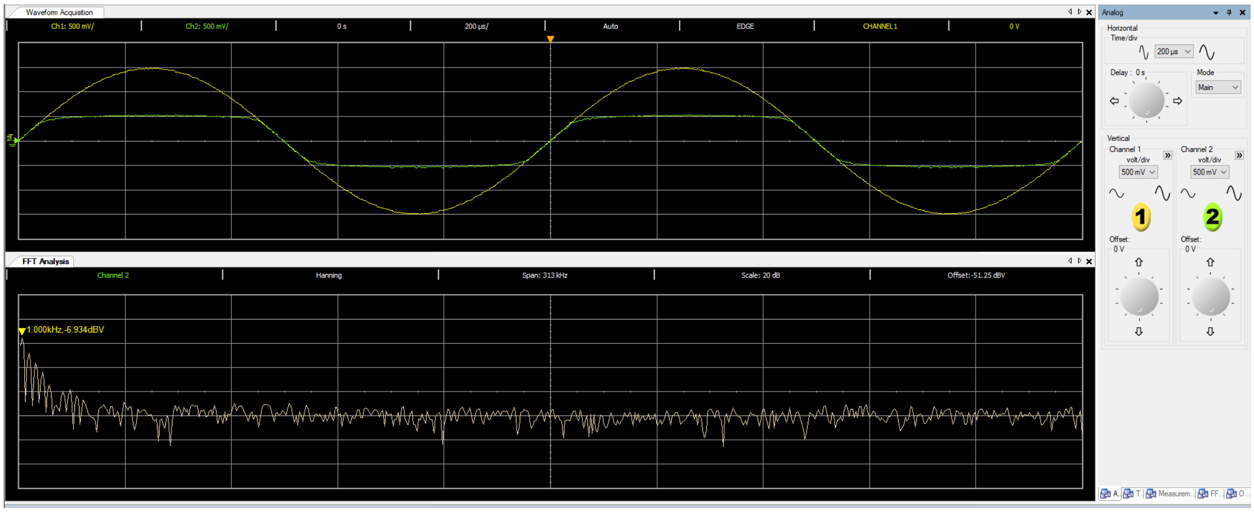


Figure 6: Oscilloscope Output

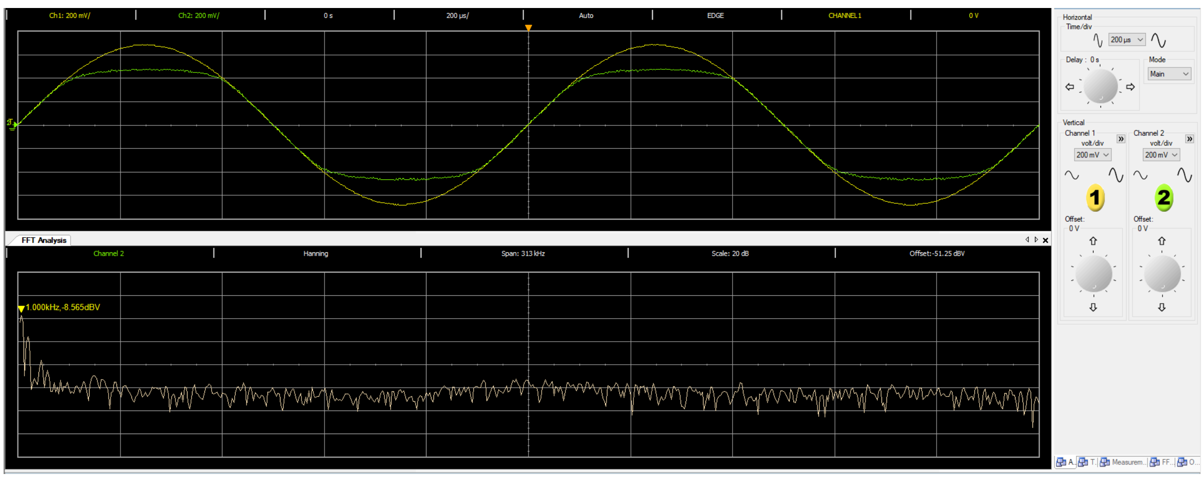


Figure 7: Oscilloscope Output

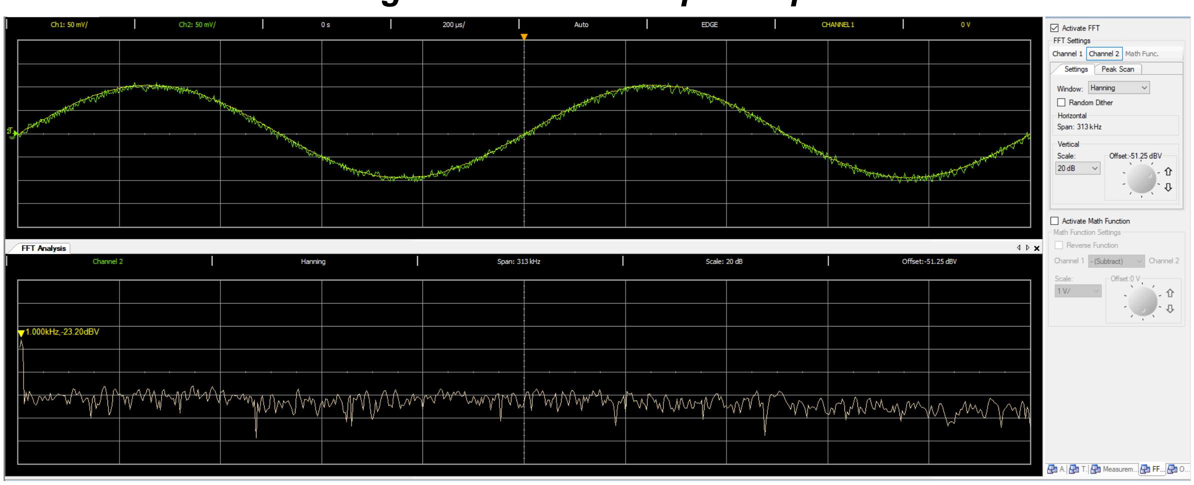


Table 2: Clipping

Voltage	Clipping
3 V	Yes Alot
1.5 V	Yes
700 mV	Yes
100 mV	No

7. **TOTAL HARMONIC DISTORTION**
    a. Each frequency you measured in the previous step represents a sinusoidal wave at that frequency. Each of these sine waves has some power associated by their peak amplitude. Calculate the sum of the power in all the sine waves that are not at the fundamental frequency (as far the ambient noise levels will allow). The ratio of this power to the total power of the signal is called the total harmonic distortion (THD). Find the THD, in percentage, for the four signals used in the previous step. That is the percentage of total power taken away from the signal's overall power (the harmonics power divided by the fundamentals power plus harmonics power).

    Results 7:
    1. The Vpp for each odd harmonic was calculated for each section. The voltage inputs that were investigated were 3V, 1.5V, 0.7V, and 0.1V. The results can be observed within **Tables 3-5** respectively. The 0.1 V results were negligible because there were no harmonics, therefore no THD. Using **Equation 2,** we were able to calculate the THD percentage. with respect to the tables, the percentages were 9.5%, 6.19%, 1.5%, and 0.001%.

Equation 2

$$\boxed{\frac{Vpp_{All}}{Vpp_{All\,+\,Fundamental}}}$$

Table 3: 3V

Frequency	Vpp
1 Khz	1.409 V
3 Khz	0.389 V
5 Khz	0.19569 V
7 Khz	0.12346 V
9 Khz	0.0844 V
11 Khz	0.0533 V

Table 4: 1.5 V

Frequency	Vpp
1 Khz	1.27 V
3 Khz	0.3031 V
5 Khz	0.1207 V
7 Khz	0.048 V
9 Khz	0.0142 V
11 Khz	0.008 V

Table 5: 0.7V

Frequency	Vpp
1 Khz	1.05 V
3 Khz	0.132 V
5 Khz	0.052 V
7 Khz	0.011 V
9 Khz	0.0093 V
11 Khz	0.002 V

8. SPECTRUM OF A PULSED WAVE

a. Generate a RZ pulsed wave at a frequency of 1 Hz with 50% duty cycle. Theoretically calculate its Fourier Transform. Calculate the magnitude at 0 Hz, and the magnitude at the first 3 harmonics. Observe the spectrum of this pulsed wave on the spectrum analyzer. Verify the above calculated magnitudes with the observed magnitudes, using cursors, on the spectrum analyzer. Comment on any observed discrepancy.

Results 8:

1. Using the definition of a fourier transform, we were able to determine that the fourier transform of the RZ pulse was the Sinc(f)

function. Using **Equation 3,** we were able to determine that the magnitude at the first three harmonics was equal to 1.

Equation 3: L'Hopital's Rule

$$\boxed{\frac{d}{df}\left(\lim_{f \Rightarrow 0} \frac{\sin(pi \cdot f)}{pi \cdot f}\right)}$$

Conclusion: In this lab we were introduced to the use of the frequency domain of signal analysis. This lab showed how the uses of the fourier transform, and how to apply them to real world scenarios.