

Fourier Analysis

Purpose: Examine signals and circuits in the frequency domain.

Equipment Required:

- 1 – Components for LC circuit
- 1 – Agilent 6000 series oscilloscope
- 1 – 50 ohm terminator
- 1 – Function Generator

Prelab:

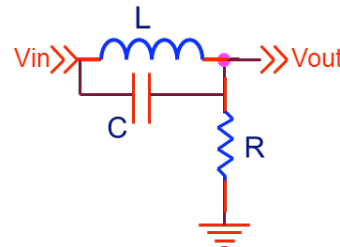
- 1) Read all of the lab.
- 2) Write expressions for the POWERS (for arbitrary load resistance R) of the harmonics of a sine wave, a triangle wave, a saw tooth wave, and a square wave in your lab book. Assume an peak to peak amplitude of all the functions to be $2A_0$. Note: 1st harmonic is the fundamental frequency ($f_1 = 1/T_0$) component. 2nd harmonic is $2f_1$ and so forth.
- 3) Set up an Excel spreadsheet as follows: Label seven columns “1”-“7” representing the first seven harmonics of the above functions (f_1 to $7f_1$). Label four rows ‘sin’, ‘tri’, ‘saw’, and ‘squ’. Assume all the functions are 1 Volt peak to peak (Vpp) into 50 ohms with no DC component, what are the expected powers (in Watts) of the first seven harmonics of each function? Enter the powers in the respective cells (i.e. enter a value in each of the 28 cells). Note some harmonics will have zero power. Hint on powers: if you sum the first seven harmonics of these functions, you should get respectively 2.5mW, 1.66mW, 1.53mW, 4.75mW.
- 4) Set up a second set of four rows in Excel (under the rows above) and again label ‘sin’, ‘tri’, ‘saw’, and ‘squ’. In these 28 cells, enter the dBVolts expected for the 1 Vpp functions. Note that dBV is a decibel based POWER measurement relative to the power of a 1 V rms signal into the scope, so 0dBV = 1V rms = 20mW into 50 ohms. A 1 Vpp sine wave is $1/8$ Vrms. dBV for nth harmonic is $10 \cdot \log_{10}((V_n)^2 / 2)$. Note $\log(0) = -\text{inf}$. A 0.1V rms is -20dBV. As a hint, the dBV of the sixth and seventh harmonic of these function are respectively:

6 th harmonic	-inf,	-inf,	-28.5dBV,	and	-inf.
7 th harmonic	-inf,	-44.7dBV,	-29.9dBV,	and	-23.8dBV.
- 5) Set up a third and fourth set of four rows and again label them ‘sin’, ‘tri’, ‘saw’, and ‘squ’. In these 28 cells, you will enter your experimental measurements and errors.
- 6) Set up on last row under above and label it “tri_filtered.”
- 7) Read the Fast Fourier Transform (FFT) section of the Agilent 6000 Series Oscilloscopes User’s Guide, pages 169 to 175. This section of the manual is on the class web site as a PDF. Note, there is no 50 ohm setting on inputs for scopes in lab. 50 ohms is on function generator and that is where the power will be dissipated.

Procedure:

1. Fast Fourier Transform
 - a. Set up your function generator and scope to look at the following signals on channel 1. All signals should be set to have 0 DC offset. To reasonably utilize vertical dynamic range of scope, set scale to 200 mV/div. Make sure signals aren’t clipping. Make sure 50ohm is on function generator and Vpp on scope is right.
 - i. 3.00 kHz sinusoid, 1 Vp-p
 - ii. 3.00 kHz triangular wave, 1 Vp-p
 - iii. 3.00 kHz sawtooth (Ramp) wave, 1 Vp-p
 - iv. 3.00 kHz square wave, 1 Vp-p

- b. Set MATH to FFT of channel 1. Set time scale to 1msec per division. Push preset to maximize span and center FFT. What is span setting after pushing preset? From the time scale, calculate what the span should be after pushing preset and verify that the span setting matches your calculation. (This is part of conclusion)
 - c. Under "More FFT", set scope for rectangular window. Set FFT vertical scale to 10dB/div and adjust offset so you see full FFT on screen. For each of the four functions, record in Excel the dBV for the first seven harmonics of each function.
 - d. For the ramp wave, save the trace and recall it (ask for instructions) so it is on screen as a reference. Set function to square wave. Capture scope screen with window on PC set to full size. Make sure FFT of both function are easily visible. Print and tape into lab book. Clear display when done.
2. Windows
 - a. View the 3kHz square wave with the window still set to Rectangle. Set window to Hanning. Flip back and forth between Hanning and Rectangle. What do you observe for each? Zoom in (by setting center and span) on 1st harmonic of FFT and measure and record the 3dB width of FFT peaks for both windows.
 3. Aliasing
 - a. Reset up for the 3.00 KHz square wave, as above in 1a. Make sure it is 10dB/div. Set frequency increment on function generator to 100Hz. Turn up frequency by pressing incremental advance button, scanning frequency from 3 KHz to 20 kHz. Notice how the different harmonic peaks in spectrum all move. Do you notice something strange about the direction of some peaks are moving? Capture a representative image that quantitatively shows aliasing. Note the frequency of the function generator was set to when you did your capture.
 4. Build the RLC notch filter shown to right experimentally. Pick out components $R=330\text{ ohm}$, $L=2.2\text{mH}$, and $C=0.1\mu\text{F}$. Measure the components and record. Calculate the notch frequency of the filter ($1/(2\pi\sqrt{LC})$). Set your function generator to a RAMP with 1/3 the notch frequency. Probe V_{in} and V_{out} . Set MATH to do FFT of V_{in} and then V_{out} . What is different between the two spectra? Adjust the frequency of the function generator measure the actual notch frequency of the RLC filter.



Data Analysis

1. In the last four rows in your Excel sheet compute the difference between the expected dBV and the measured dBV (for those that aren't "inf"). Then, compute the average dBV error for each waveform. What does the average tell you about the input waveform? What does the difference between the average of a function and the dBV error of a peak tell you about that peak? Compute the fractional error of the sawtooth peaks after taking into account the mean dBV difference between experiment and theory.

Conclusion and Questions

1. Verify the preset span in 1b is what you expect by showing a calculation of expected span.
2. Qualitatively explain the strange directional movement of the peaks in the alias section. Quantitatively explain your screen capture from aliasing section.
3. Calculate the magnitude of the transfer function for the notch filter and plot from 500 to 30KHz in 500Hz steps. Why is it called a notch filter?