



LAB 1 - Fourier Analysis

Signals in Time and Frequency Domains

By: Greg Swick
Niagara College
Welland, Ontario
Canada

Purpose:

1. To become familiar with the operation of a digital oscilloscope with FFT circuitry.
2. To verify the predictions of Fourier analysis by observing the frequency-domain representation of sine, triangle and square waves.
3. To observe the effect of filtering a complex waveform, in both time and frequency domains.

Equipment:

- Agilent 54622A or 54600A/B Digital Oscilloscope w/ FFT capability
- Agilent 33120A Function Generator
- Agilent Intuilink/Benchlink software
- Solderless Breadboard

Note: Oscilloscopes can be connected to a computer station and a printout of live data can be obtained using Agilent Intuilink/Benchlink software.

Materials:

- resistors: 1 k, 4.7 k
- capacitors: 1.5 nF, 330 pF

Procedure

1. Connect the function generator output to the Channel 1 input on the oscilloscope. Set the generator for a sine wave output with a frequency of 100 kHz and an amplitude of 4 V p-p. Use Auto-scale on the oscilloscope to display the waveform. Use the oscilloscope cursors to verify the frequency and amplitude of the signal.
2. Set up the oscilloscope to observe the signal in the frequency domain using the fast Fourier transform (FFT). Follow the steps below to do this:
 - Press the button labelled \pm located between the two channels on the vertical panel. This brings up the Function menu.
 - Press the softkey (under the screen) that turns on Function 2. You may have to select MENU and press the softkey under OPERATION in order to get FFT. You will see some dots on the screen (with the 54600A) in addition to the time-domain waveform. Note: the 54622A or 54600B will already have the dots connected. The extra dots represent the FFT sampled information.
 - Turn off the time-domain display by pressing the channel 1 button (above the channel 1 input), then pressing the left-hand softkey to turn channel 1 off. The frequency-domain representation will now be much clearer, with the dots connected. Note that the horizontal scale on the scope is now calibrated in frequency rather than voltage.



- Turn the Time/Div knob counterclockwise. As you do so, note that a message Effective FFT sample rate: (some number) MSa/s appears momentarily at the bottom of the screen each time you do this. This tells how many samples of the signal per second are used in the FFT computations. Fewer samples per second gives better frequency resolution, but the sampling rate must always be more than twice the highest frequency component of the signal, or serious frequency errors (called aliasing) result. Turn the Time/Div knob counterclockwise until you see the message:

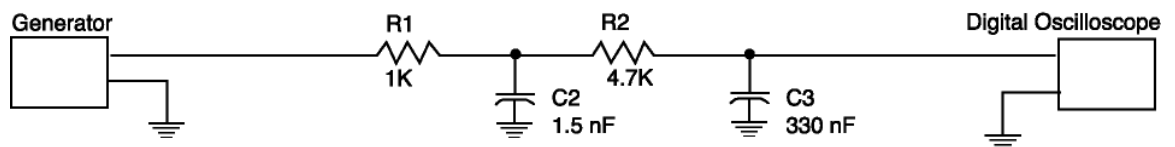
- Effective FFT sample rate: 2.000 MSa/s
- That is, 2 million samples per second are used.

You may wish to toggle above or below this value for results.

3. Measure the amplitude and frequency of the fundamental, second and third harmonic. To get the amplitude scale, go to the function 2 menu and note the reference level (at top of screen) and dB/div. Either of these can be changed by pressing the associated softkey, then turning the unmarked knob in the upper left area of the control panel. Use the cursors to find out how many dB down from the fundamental, the second and third harmonics are.

NOTE: You may want to engage FFT AUTOSCALE under FFT MENU in order to calibrate the screen. You will have to engage the CURSOR button in order to control the markers for reading amplitude and frequency. The rotary control offset from the cursor button will adjust the marker.

4. Change the generator output to square wave and note the effect. Find the amount in dB by which the third and fifth harmonics are below the fundamental. Compare with the values predicted by Fourier analysis. Change the frequency span to observe more harmonics, and verify using the cursors that they are odd harmonics.
5. Repeat step 5 for a triangle wave. What can you conclude about the relative harmonic content of sine, square and triangle waves?
6. Use the Agilent Intuilink or Benchlink software to capture the spectral response for the square wave signal. Obtain a printout of your results and include it in your lab with a brief commentary.
7. Build the circuit below. This is a second-order lowpass filter with a cutoff frequency of about 100 kHz. Observe the sine wave, square wave and triangle wave again, in both time and frequency domain, and compare with theory. Comment on your observations.



R1 = 1kilohm, R2 = 4.7 kilohm, C2 = 1.5 nf, C3 = 330 pf