Lab 8: Fourier analysis

Goals: (A) The frequency components of a square wave are obtained by capturing the waveform and using the FFT (fast-Fourier transform) algorithm; both a low and 50% level duty cycle will be studied. They are compared with the frequency component of a sine wave of the same frequency. (B) Two sinusoidal waves with slightly different frequencies are added, and the frequency components observed, and compared with those obtained by passing the signal through a diode.

Sine and square waves:

For both the sine and square waves, connect the function generator directly to the oscilloscope. A frequency of 200 Hz is reasonable and capturing ~20 oscillations on the screen will give a good spectrum. For the square wave, capture a wave with 50% duty cycle, meaning half-on and half-off, as well as a wave with the smallest possible duty cycle permitted by the equipment. The Fourier transform of the latter will give a signal resembling that from a diffraction grating.

OpenChoice is used to read out the data from the oscilloscope and Matlab is used to take the Fourier transform of the data. The frequency decomposition algorithm, "fft(y)", produces a complex number. In this experiment, we are only interested in the magnitude and so the absolute value of the complex number is taken when plotting the Fourier transform. The FFT algorithm produces frequency components over a finite set of frequencies. The lowest one is zero, corresponding to a constant level. The highest one is: $f_{max} = 1 / (2\ t)$, where t is the time interval between samples. The frequency resolution is 1/(duration of the acquire window).

Make a graph of the FFT magnitude vs frequency for the sine and two different square waves. Compare the amplitude and frequency of the first few harmonic peaks to expectations for the sine and square waves. For the low-duty cycle square wave, find the missing harmonic and compare it to the theoretical prediction.

Beats and half-rectified beats:

Now take two waveform generators, and add their signals as shown in Figure 1 below. Make the generator amplitudes equal. On the scope, you should see the beats caused by the two signals. An example is given in Fig. 2. Set the time scale so that you can see at least 5 beats. Now repeat the capture and FFT analysis you did above. Is there a peak in the frequency spectrum corresponding to the "beat" frequency?

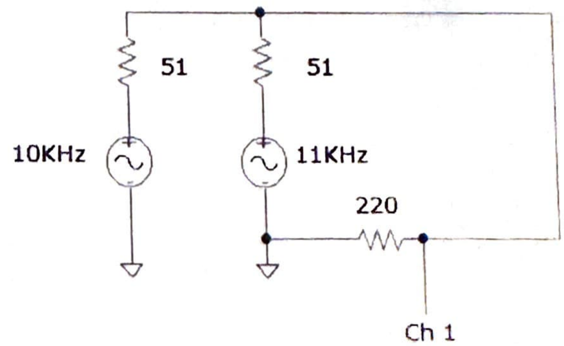


Figure 1. Setup for addition of sinusoidal signals using two function generators. Note the 51 Ω is external to the function generator.

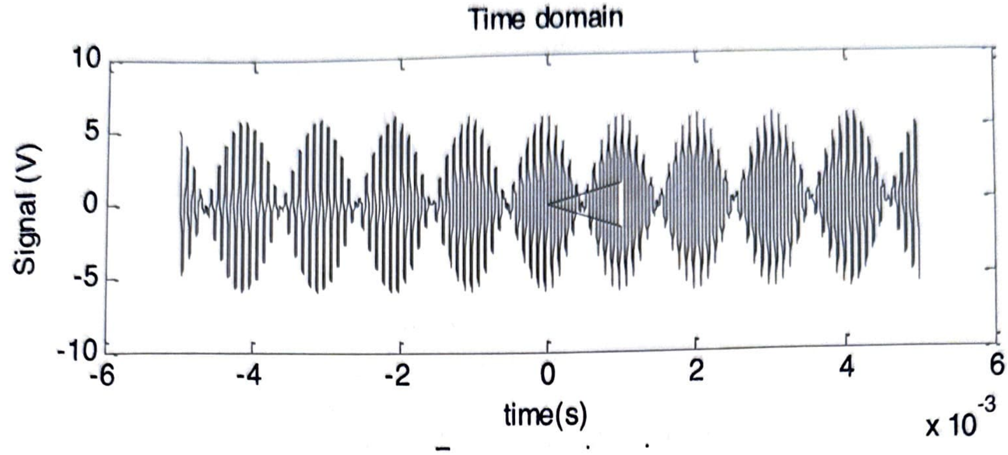
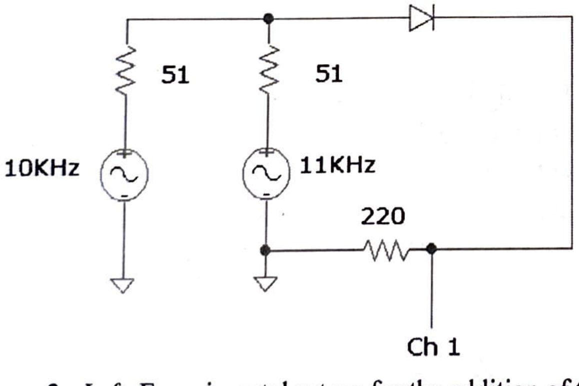


Figure 2. Example of beats.

A non-linear element (one for which the output current is not proportional to the voltage drop) has interesting effects on the frequency response. The simplest non-linear circuit element is a diode. Insert a diode in your circuit as shown in Fig. 3. A diode conducts in the forward direction. The result is half-rectification of the signal. Repeat the capture and FFT analysis. Make plots comparing the frequency spectrum with and without the diode. What additional frequencies does the diode produce? How are they related to the frequencies of the function generators?



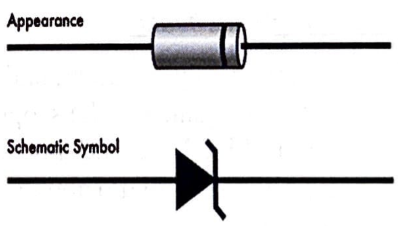


Figure 3. *Left:* Experimental set-up for the addition of two sine waves with a diode added to the system. *Right:* Appearance both physical (top) and schematic (bottom) of a diode. The diode allows current to only flow in one direction.