Grade:___/20

Laboratory 3

Sinusoids in Engineering: Measurement and Analysis of Harmonic Signals

3.1 Laboratory Objective

The objective of this laboratory is to understand the basic properties of sinusoids and sinusoid measurements.

3.2 Educational Objectives

After performing this experiment, students should be able to:

1. Understand the properties of sinusoids.
2. Understand sinusoidal addition.
3. Obtain measurements using an oscilloscope.

3.3 Background

Sinusoids are sine or cosine waveforms that can describe many engineering phenomena. Any oscillatory motion can be described using sinusoids. Many types of electrical signals such as square, triangle, and saw-tooth waves are modeled using sinusoids. Their manipulation incurs the understanding of certain quantities that describe sinusoidal behavior. These quantities are described below.

3.3.1 Sinusoid Characteristics

Amplitude The amplitude A of a sine wave describes the height of the hills and valleys of a sinusoid. It carries the physical units of what the sinusoid is describing (volts, amps, meters, etc).

Frequency There are two types of frequencies that can describe a sinusoid. The normal frequency f is how many times the sinusoid repeats per unit time. It has units of cycles per second or Hertz (Hz). The angular frequency ω is how many radians pass per second. Consequently, ω has units of radians per second.

Period The period T is the time it takes a sinusoid takes to complete one cycle. The period is measured in seconds.

Phase The phase ϕ of a sinusoid causes a horizontal shift along the t-axis. The phase has units of radians.

Time Shift The time shift t_s of a sinusoid is a horizontal shift along the t-axis and is a time measurement of the phase. The time shift has units of seconds.

NOTE: A sine wave and cosine wave only differ by a phase shift of 90° or $\frac{\pi}{2}$ radians. In reality, they are the same waveform but with a different ϕ.

3.3.2 Sinusoidal Relationships

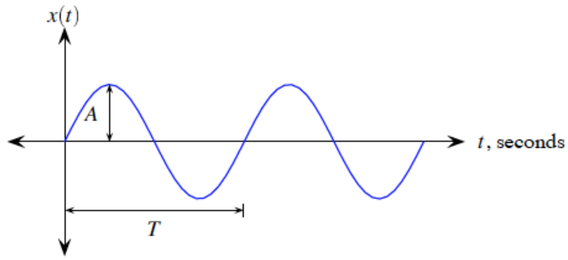

Figure 3.1: Sinusoid

The general equation of a sinusoid is given below and refers to Figure 3.1.

$$x(t) = Asin(\omega t + \phi) \tag{3.1}$$

The angular frequency is related to the normal frequency by Equation 3.2.

$$\omega = 2\pi f \tag{3.2}$$

The angular frequency is also related to the period by Equation 3.3.

$$\omega = \frac{2\pi}{T} \tag{3.3}$$

By inspection, the normal frequency is related to the period by Equation 3.4.

$$f = \frac{1}{T} \tag{3.4}$$

The time shift is related to the phase (radians) and the frequency by Equation 3.5.

$$t_s = -\frac{\phi}{\omega} \tag{3.5}$$

3.3.3 Sinusoidal Measurements

1. Connect the output channel of the Function Generator to channel one of the oscilloscope with a 50 Ω resistor bridging the positive and negative connectors as seen in Figure 3.2.

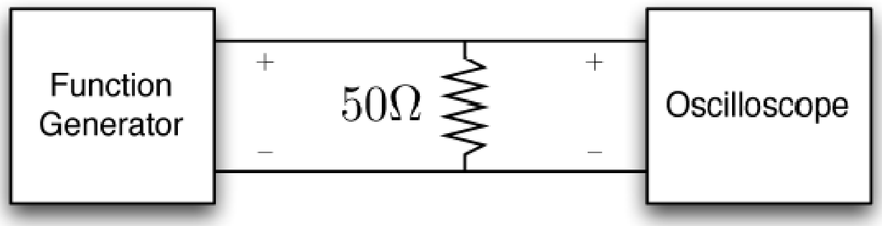

Figure 3.2: Measuring Sinusoids

2. Complete Table 3.1 using the given values for voltage and frequency.

3. Using an oscilloscope, make measurements across the two separate resistors and complete Table 3.2. Use $f = 2652.5$ Hz.
   a. Connect Channel 1 of the oscilloscope as shown in Fig. 3.3 and measure the amplitude, period, and frequency of the resistor signal that is in series with the capacitor. (NOTE: Polarity of the alligator clip connections is important. All the negative alligator clips should be hooked together when making measurements.)
   b. Move Channel 1 of the oscilloscope as shown in Fig. 3.3 and measure $V_{p\text{-}p}$ for each branch of the circuit.

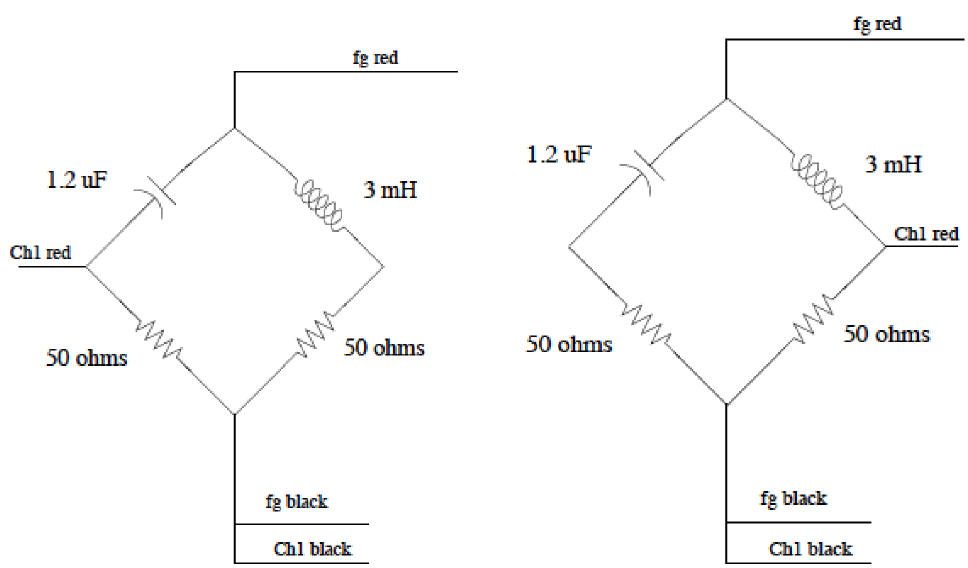

Figure 3.3: Voltage Measurements

4. Using an oscilloscope, make measurements across the two separate resistors relative to the function generator and complete Table 3.3.

   a. Leaving Channel 1 connected, connect Channel 2 of the oscilloscope across the voltage source (function generator) as shown in Fig. 3.4. Measure the time shift (t_s). Convert the time shift t_s with the following equation:

$$\phi = 2\pi f t_s \tag{3.5}$$

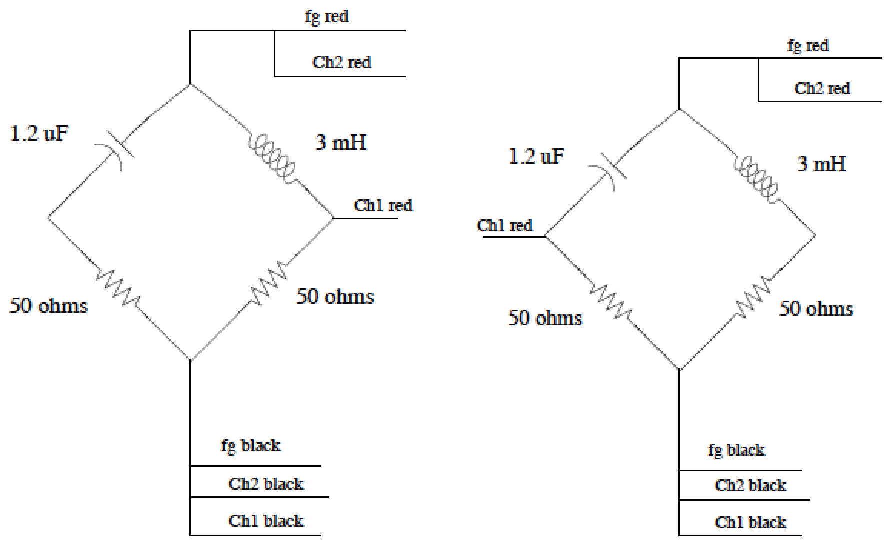

Figure 3.4: Signals Compared to the Function Generator

   b. Leaving Channel 2 connected, move Channel 1 of the oscilloscope across the resistor in series with the capacitor as shown in Fig. 3.4. Compare the two signals on the oscilloscope relative to the time scale and measure the time shift (t_s).

3.4 Lab Requirements

1. Write an abstract for this lab and submit it to the Lab 3 folder in your lab section's abstract folder found in the Pilot Dropbox. (Required to pass course.)

2. Complete Tables 3.1, 3.2, and 3.3 (2 points each, 6 total)

Table 3.1 Sinusoid Measurements

Function Generator		Oscilloscope (Measured)			Calculated	
Voltage (V)	Frequency (Hz)	$V_{p\text{-}p}$	*f (Hz)*	*T* (sec)	ω (rad/sec)	*T* (sec)
2.5	1000					
5	5000					

Table 3.2 Amplitude Measurements

Signal	$V_{p\text{-}p}$ (Volts)
V_S	
V_C	
V_L	

Table 3.3 Phase Angle Measurements

Signal	t_s (sec)	ϕ (rad)	ϕ (degrees)
V_C			
V_L			

3. Write out the equations of the sinusoids using Table 3.2 and 3.3. (2 points each, 4 total)

$$V_c(t) = \frac{V_c}{2}\cos(16666t + \phi_c) =$$

$$V_L(t) = \frac{V_L}{2}\cos(16666t + \phi_L) =$$

4. Generate a MATLAB plot with $V_C(t)$, $V_L(t)$, and $V_S(t)$ on the same plot using information from Tables 3.2 and 3.3. Publish and attach your code. (2 points each, 6 total)

5. Through circuit analysis, $V_s(t) = V_c(t) + V_L(t)$. Verify this by adding sinusoid equations together. Assume that $V_c = V_L = \sqrt{2}, \phi_C = 45°, \phi_L = -45°$, and $V_s(t) = \frac{V_{sp-p}}{2}\cos(\omega t + \phi) = 1.0\cos\,(16666t + 0\,°)$ V. (4 points)