AC Peak, RMS, and Phase Measurement

Aims:

- To become familiar with the oscilloscope and what it does.
- To learn how to use the various controls on the oscilloscope.
- To identify the characteristics of basic non-sinusoidal waveforms.

Background & Theory:

The Oscilloscope is a device for observing and taking measurements of electrical signals and waveforms.

The analog oscilloscope consists of a cathode ray tube (CRT) which displays a graph, primarily voltage versus time. It also has one or more amplifiers to supply voltage signals to the CRT and a time base system for generating the time scale. Some of the modern digital oscilloscopes use a liquid crystal display screen for the same purpose.

Sine Wave

The sine wave is a common type of alternating current (ac) and alternating voltage.

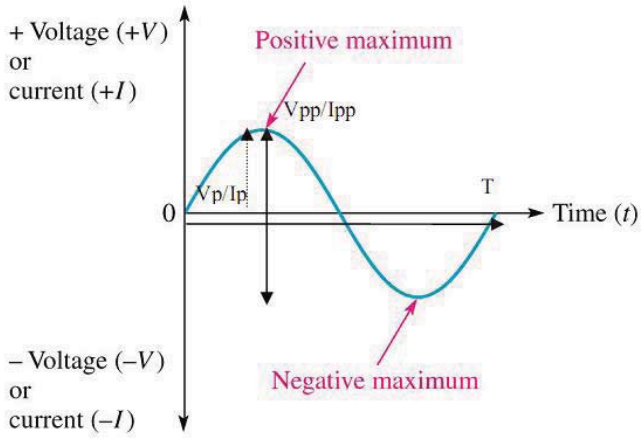


Fig 1: Graph of one cycle of a sine wave

For the wave in Figure 6-1:

- Time period = T
- Frequency f = 1/T
- $v = V \sin 2\pi ft = V \sin(2\pi / T)t$

Period of Sine Wave

The time required for a sine wave to complete one full cycle is called the period (T).

- A cycle consists of one complete positive, and one complete negative alternation.
- The period of a sine wave can be measured between any two corresponding points on the waveform by any of the three methods.
  i) The period can be measured from one zero crossing to the corresponding zero crossing in the next cycle.
  ii) The period can be measured from the positive peak in one cycle to the positive peak in the next cycle.
  iii) The period can be measured from the negative peak in one cycle to the negative peak in the next cycle.

Frequency of a Sine Wave

Frequency (*f*) is the number of cycles that a sine wave completes in one second.

- The more cycles completed in one second. The higher the frequency.
- Frequency is measured in **hertz** (Hz)Relationship between frequency (*f*) and period (T) is: ***f* = 1/T**

Electronic Signal / Frequency Generators

In the lab, we usually use a signal generator to produce a variety of waveforms at a wide range of frequencies.

- An oscillator in the signal generator produces the repetitive wave.
- We are able to set the frequency and amplitude of the signal from the signal generator.

Instantaneous Values of Sine Waves

The instantaneous values of a sine wave voltage (or current) are different at different points along the curve, having negative and positive values.

Instantaneous values are represented as:
v and ***I***

Peak Values of Sine Waves

The peak value of a sine wave is the value of voltage or current at the positive or negative maximum with respect to zero.

Peak values are represented as:
$\mathbf{V_P}$ and $\mathbf{I_p}$

Peak-to-Peak Values

The peak-to-peak value of a sine wave is the voltage or current from the positive peak to the negative peak.
The peak-to-peak values are represented as:

$\mathbf{V_{pp}}$ and $\mathbf{I_{pp}}$

Where:

$\mathbf{V_{pp} = 2V_p}$ **and** $\mathbf{I_{pp} = 2I_p}$

Effective Value

Effective (rms) values of ac waveforms are given as:

$$V = \sqrt{\frac{1}{T}\int_0^T v^2 dt} = \frac{V_m}{\sqrt{2}} \qquad \text{(For sinusoidal wave)}$$

$$I = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \frac{I_m}{\sqrt{2}} \qquad \text{(For sinusoidal wave)}$$

These values are directly measured in ac voltmeter / ammeter and can be used in **power calculation** as:

True /Average Power $P = VI.Cos\theta$ **W** or $P=I^2R$ **W**

Apparent Power $P_A = VI$ **VA**

Reactive Power $P_R = VI.Sin\theta$ **VAR**

where θ is phase difference between voltage and current.

Average Value

Average values of ac waveforms are given as:

$$V = \frac{1}{T}\int_0^T v dt = 0 \qquad \text{(For sinusoidal wave)}$$

$$I = \frac{1}{T}\int_0^T i dt = 0 \qquad \text{(For sinusoidal wave)}$$

Phase Difference:

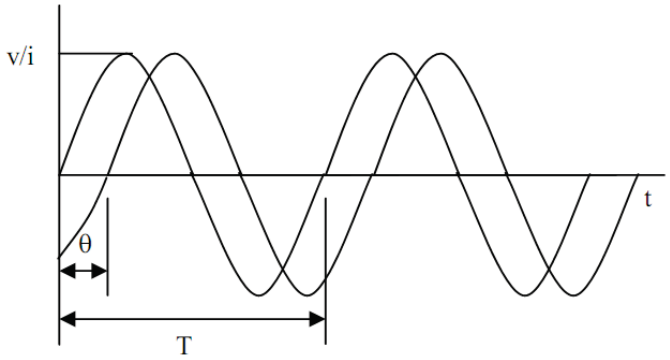


Figure 2. Two sinusoidal waves with phase difference

The phase of a sine wave is an angular measurement that specifies the position of a sine wave relative to a reference. When a sine wave is shifted left or right with respect to this reference, there is a phase shift or phase difference.

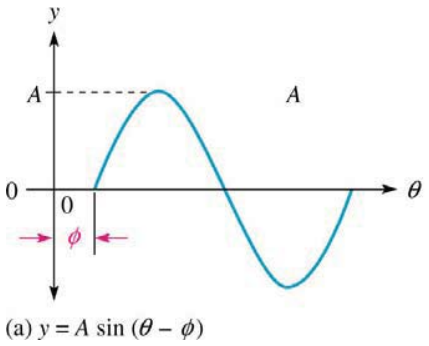
Phase difference between two ac sinusoidal waveforms is the difference in electrical angle between two identical points of the two waves. In **Figure 6-2**, the voltage and current equations are given as:

$$v = V_m Sin(2\pi/T)t$$

$$i = I_m Sin\left(\frac{2\pi}{T}\right)t - \theta$$

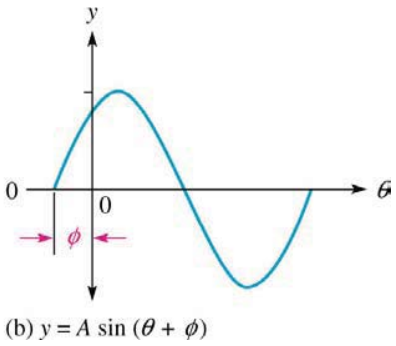
Expressions for Shifted Sine Waves

- When a sine wave is shifted to the right of the reference by an angle f, is is termed lagging.
- When a sine wave is shifted to the left of the reference by an angle f, is is termed leading.



(a) $y = A \sin(\theta - \phi)$

Figure 6-3(a)



(b) $y = A \sin(\theta + \phi)$

Figure 6-3(b)

Impedance:

Relation between the voltage across and the current through any component of an ac circuit is given by impedance. For the voltage and current waveforms in **Figure 6-2**, the corresponding impedance Z is given as:

$$Z = V_m / I_m \angle \theta) = V_{rms} / I_{rms} \angle \theta$$

RMS Value of a Sine Wave

The rms (root mean square) value of a sinusoidal voltage is equal to the dc voltage that produces the same amount of heat in a resistance as does the sinusoidal voltage.

V_{rms} = 0.707**V_p**

I_{rms} = 0.707**I_p**

Average Value of a Sine Wave

The average value is the total area under the half-cycle curve divided by the distance in radians of the curve along the horizontal axis.

V_{avg} = 0.637**V_p**

I_{avg} = 0.637**I_p**

Angular Measurement of a Sine Wave

A **degree** is an angular measurement corresponding to 1/360 of a circle or a complete revolution.
A radian (rad) is the angular measure along the circumference of a circle that is equal to the radius of the circle.
There are 2π radians or 360° in one complete cycle of a sine wave.