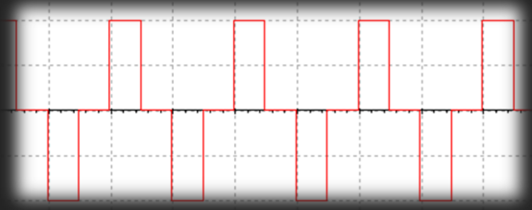
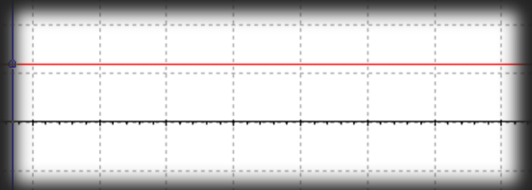
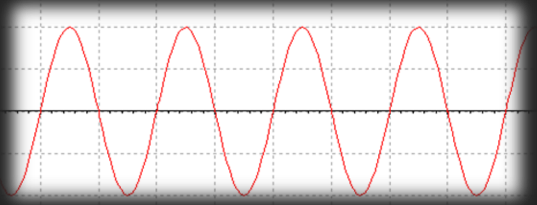
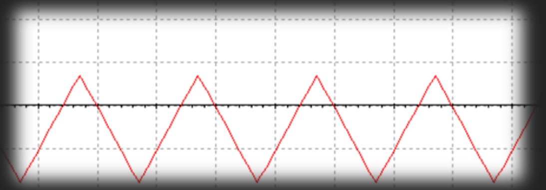
AC Fundamentals





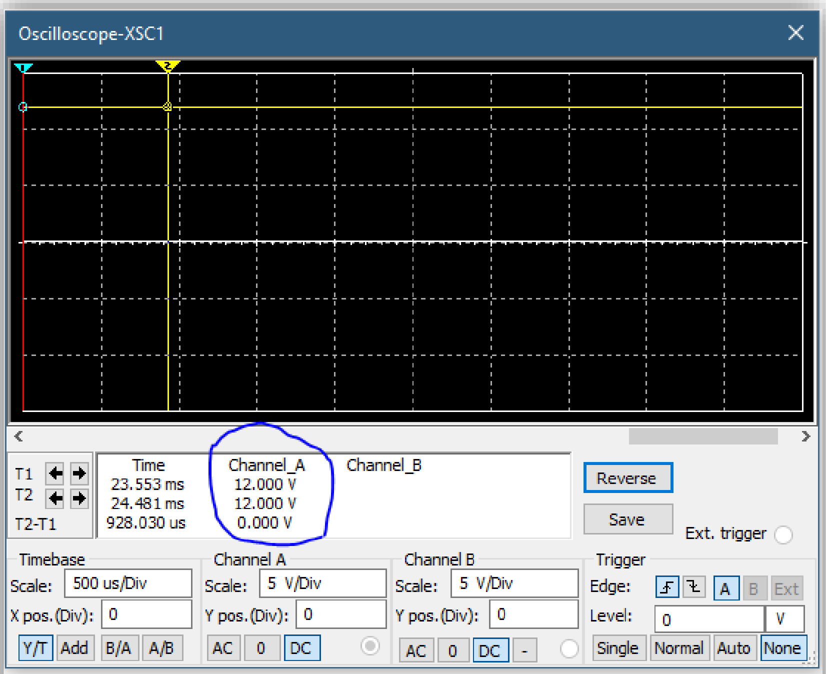




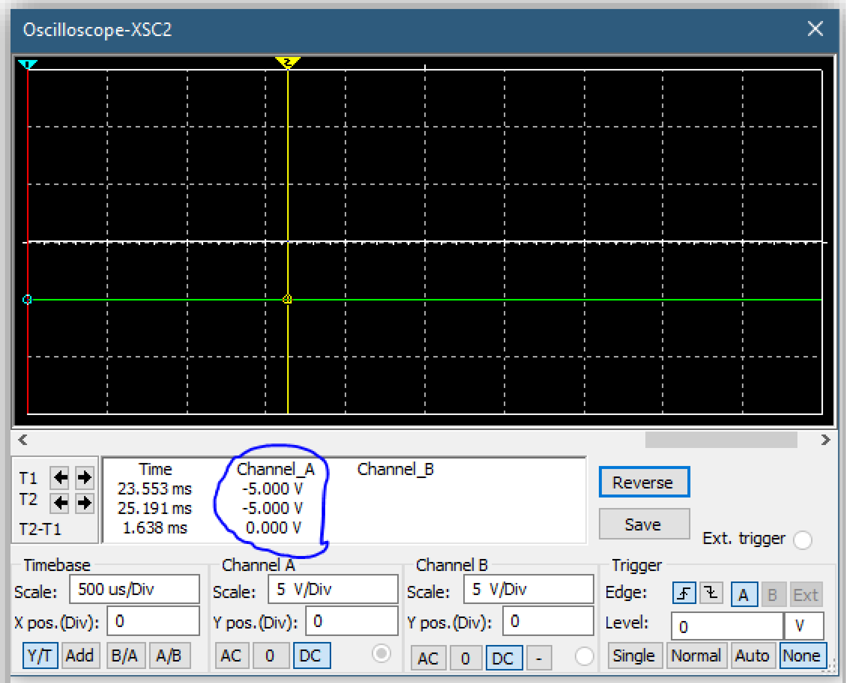
Paramount Electronics Services

Signal Fundamentals

- All time varying signals vary from t = - ∞ to t = +∞.
- Signals that stay constant over time are classified as DC signals and they can either positive or negative voltage or current values.



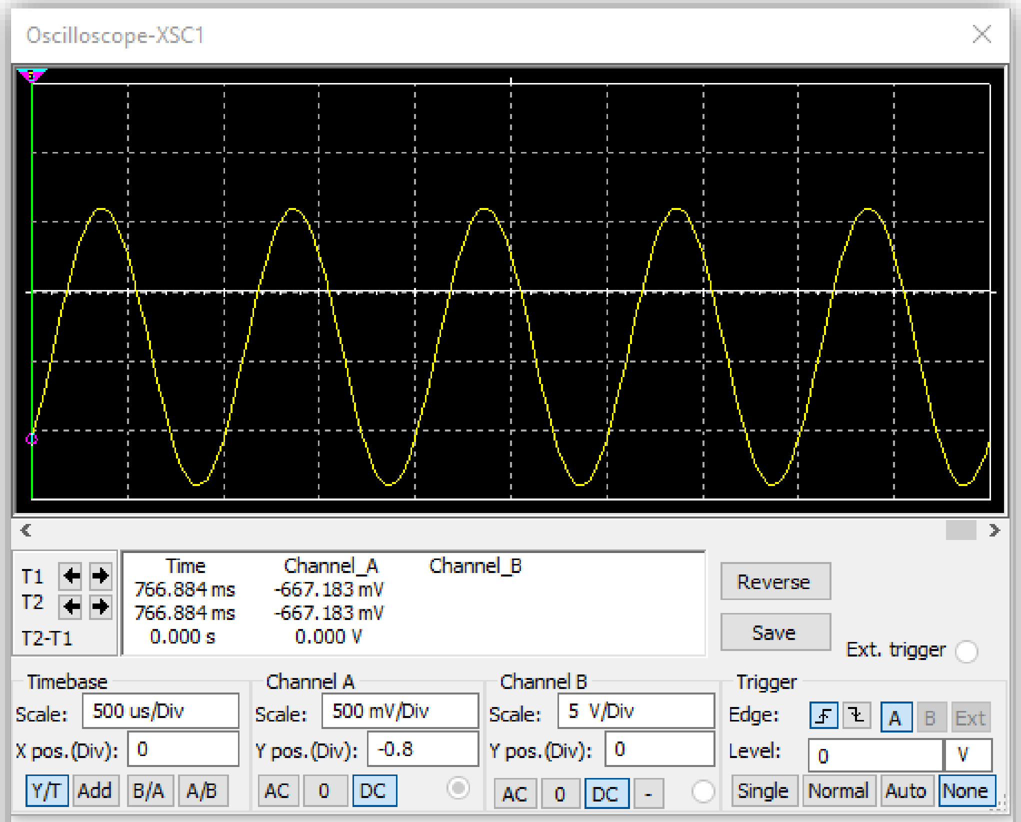
Scope cursur shows a DC voltage of 12 V



Scope cursur shows a DC voltage of -5 V

Signal Fundamentals

- Signals that are repetitive vs time, meaning they constantly repeat themselves are classified as periodic signals.



Periodic signal that repeats over time

Signal Fundamentals

- Theoretically all periodic signal are made up of two signal components:
  - A DC component
  - An AC component

- Either the DC or AC component can have any value including zero.

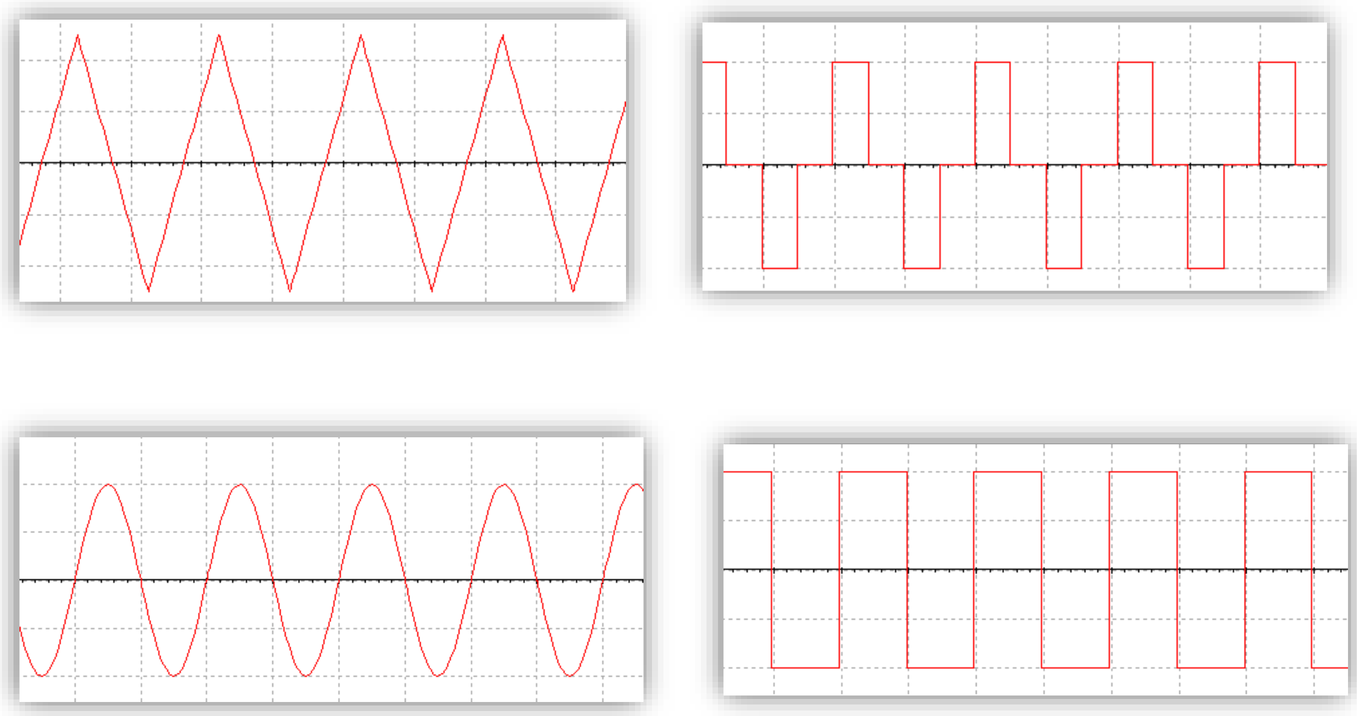
- For example, a signal can be a pure DC signal which means that its AC component is equal to zero.

- Also, a signal can be a pure AC signal which mean that its DC component is equal to zero.

- A pure AC signal is one that has an average value of 0 over a whole cycle period. In other words, for that signal and over a whole period, the signal enclosed area above the 0 level is equal to the signal enclosed area below the 0 level.

Signal Fundamentals

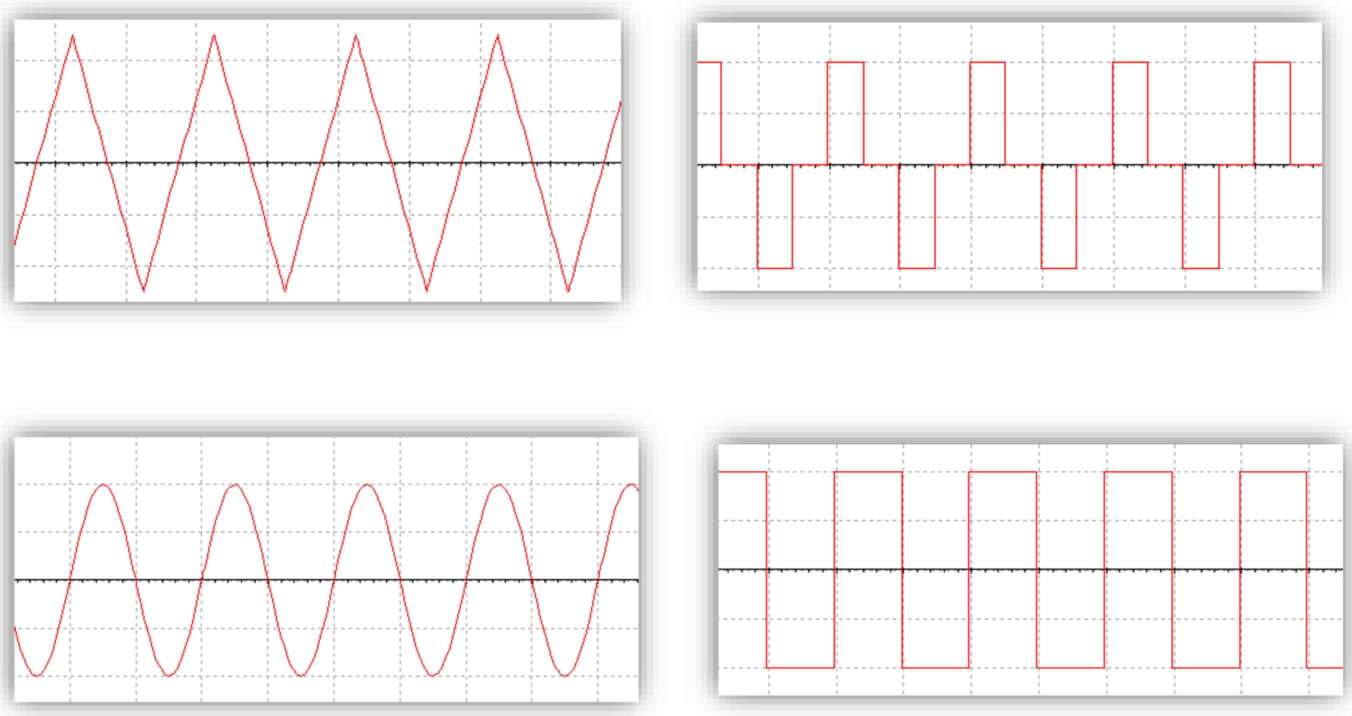
- For all the signals shown, when the multimeter is coupled to read DC voltages, it will read a zero voltage, but when it coupled to read AC voltages it will read the RMS value of the waveform. Those are pure AC signals.



Pure AC signals. Notice that for each cycle the area above the 0 is the same as the area below the 0 V.

Signal Fundamentals

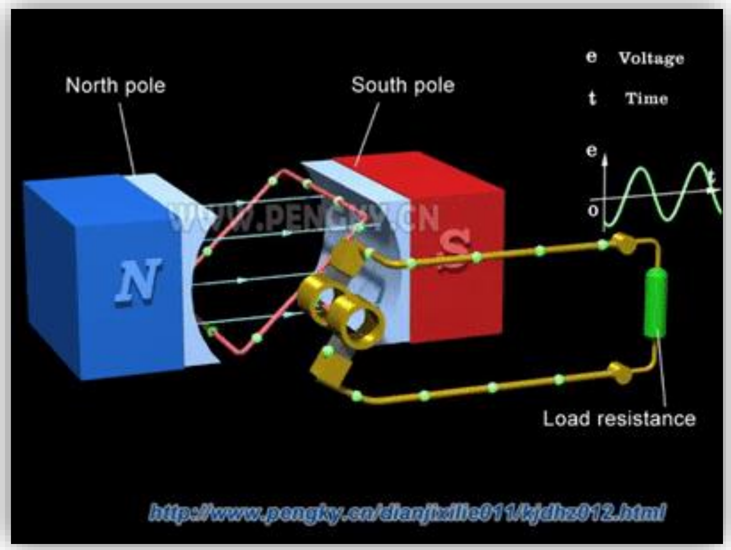
- For all the signals shown, when the multimeter is coupled to read DC voltages, it will read a zero voltage, but when it coupled to read AC voltages it will read the RMS value of the waveform. Those are pure AC signals.



Pure AC signals. Notice that for each cycle the area above the 0 is the same as the area below the 0 V.

The Sine Waveform

- The sinusoidal waveform or sine wave is the most fundamental pure AC waveform.
- The electrical service provided by the power companies is in the form of sinusoidal voltage and current.
- AC waveforms are produced by two types of sources:
  - ➢ Rotating electrical machines also known as generators.
  - ➢ Electronic oscillator circuits which are used in instruments known as electronic signal generators.



AC Generator

Electronic Signal Generator

The Sine Waveform Characteristics (Instantaneous Value)

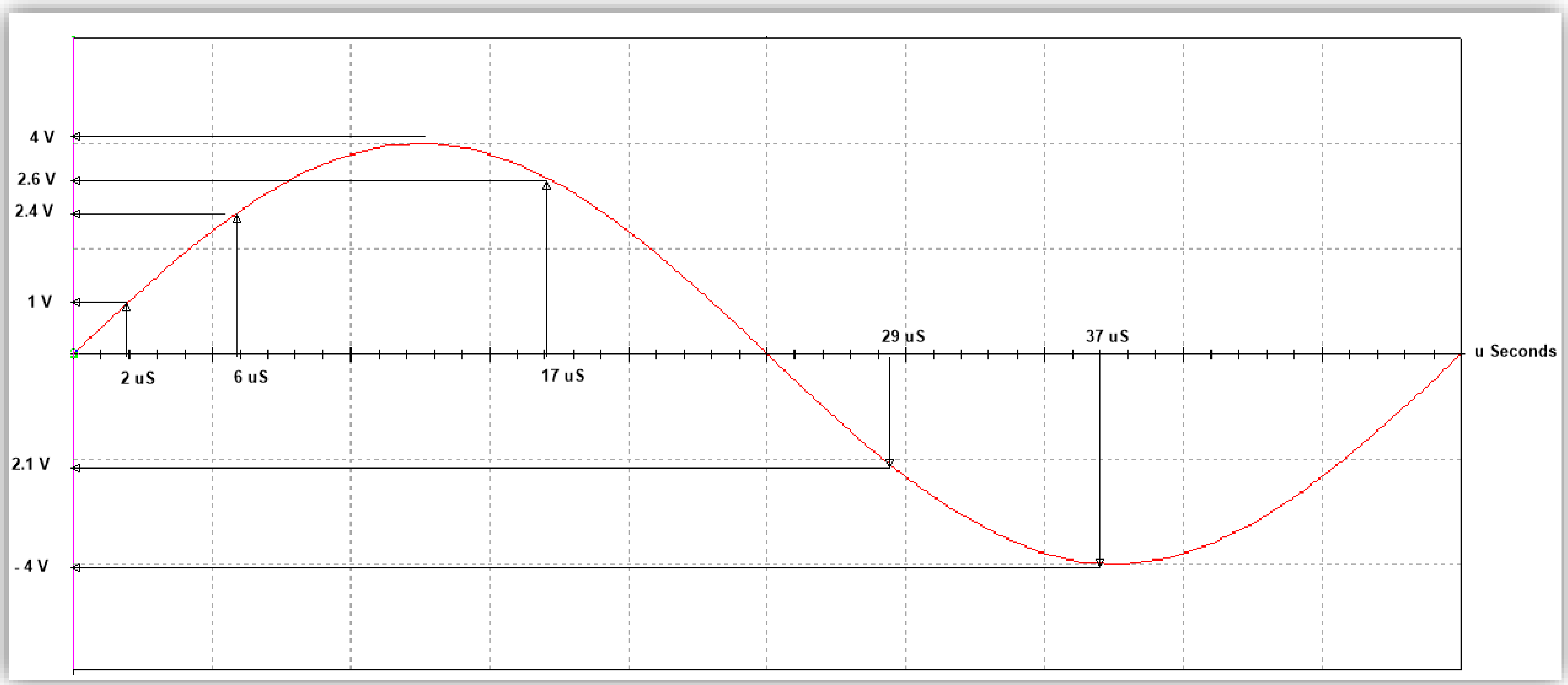
- Instantaneous Value: At any point in time on a sine wave, the voltage or current has a value which is called the instantaneous value.

- The instantaneous value is different at different points in time along the curve.

- They are positive during the positive alternation of the sine wave and negative during the negative alternation.

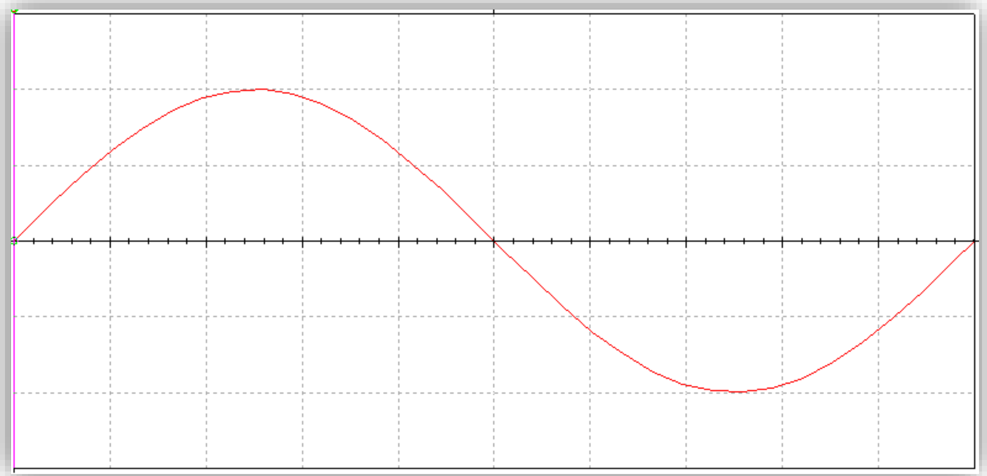
The Sine Waveform Characteristics (Instantaneous Value)

- The following graph shows instantaneous voltage values against time. The voltage values are expressed in Volts (V) and the time is expressed in microseconds (uS). Notice the positive values in the positive alternation and the negative values in the negative alternation.

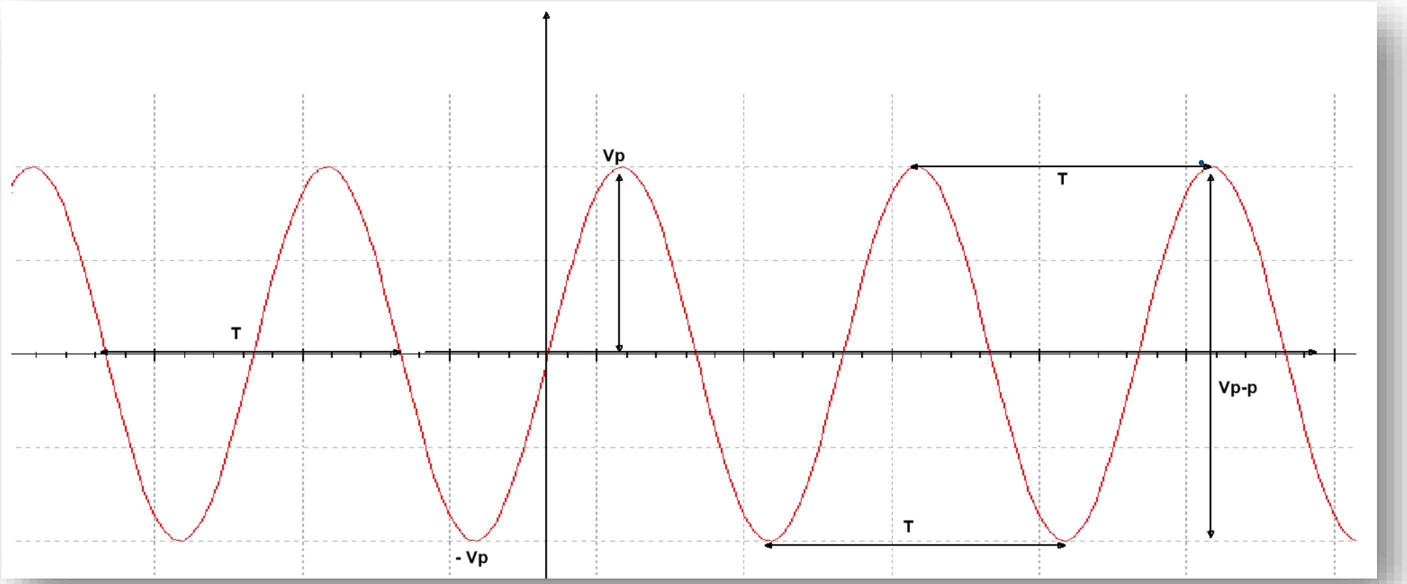


The Sine Waveform Characteristics (Period)

- *T*: The period of the sine wave (or any periodic waveform).
- It is defined as the time duration of one cycle.
- A cycle is defined as the portion of the waveform between any two identical points. The basic unit for the period T is the seconds.



One whole cycle of the sine wave: T



3 Periods T shown

The Sine Waveform Characteristics (Frequency)

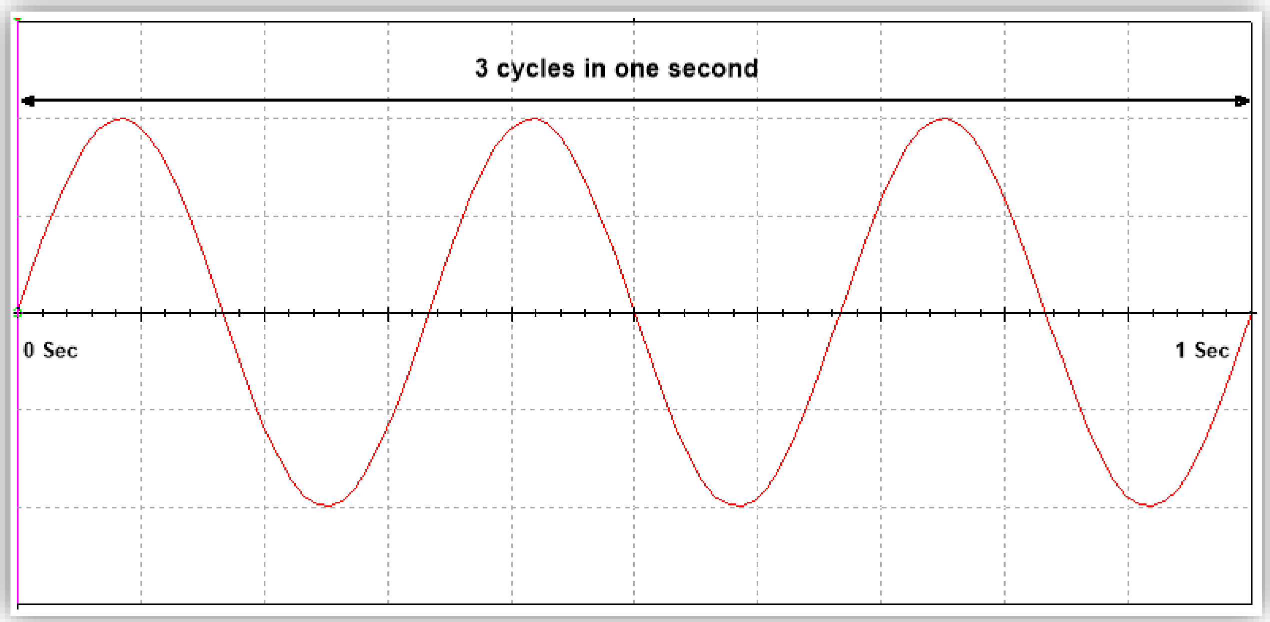
- Frequency: Is a measure of how often the sine wave or any periodic waveform repeats itself. It is denoted by F and its units are in Hertz (Hz).

- More precisely, the frequency F is defined as the number of cycles per one second or number of periods per one second.

- Therefore, the formula for F is given by:
  - $F = \frac{1}{T}$
- Inversely, the formula for the period T is given by:
  - $T = \frac{1}{F}$

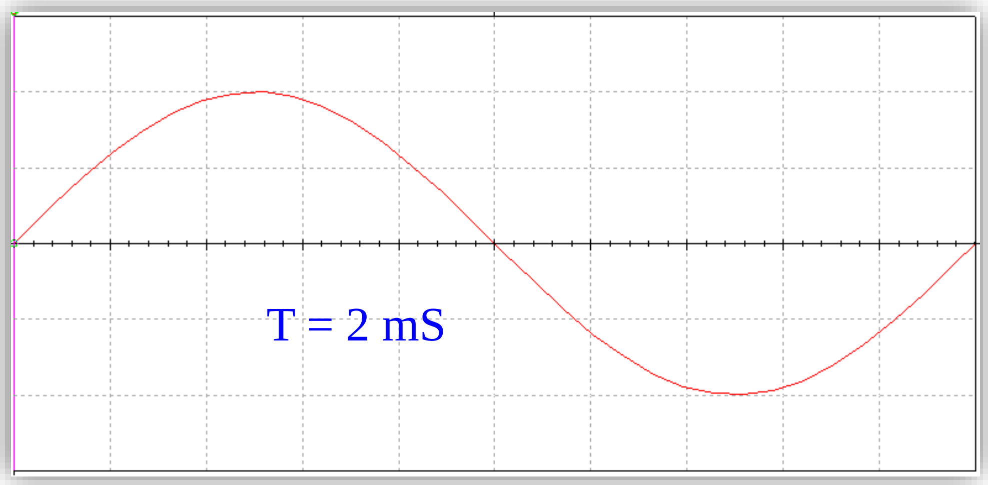
The Sine Waveform Characteristics (Frequency) Example

- For the following figure what is the frequency F of the sine wave.
- There are 3 cycles or periods in one second. Since the frequency is the number of cycles per one second, then: F = 3Hz



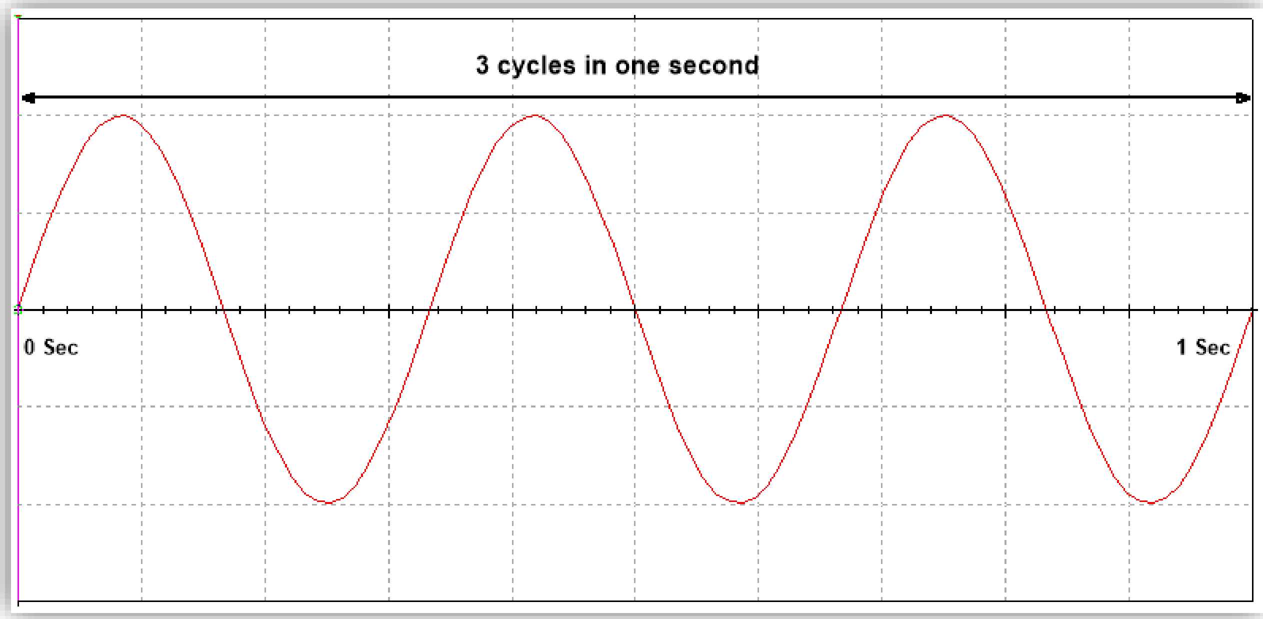
The Sine Waveform Characteristics (Frequency) Example

- If the following waveform shows a period (cycle time) of 2 mS, then what is its frequency?
- Given the period T of a periodic waveform, the frequency F is always given as the reciprocal of the period T. Therefore:
  - $F = \frac{1}{T} = \frac{1}{2\ mS} = 500\ Hz$



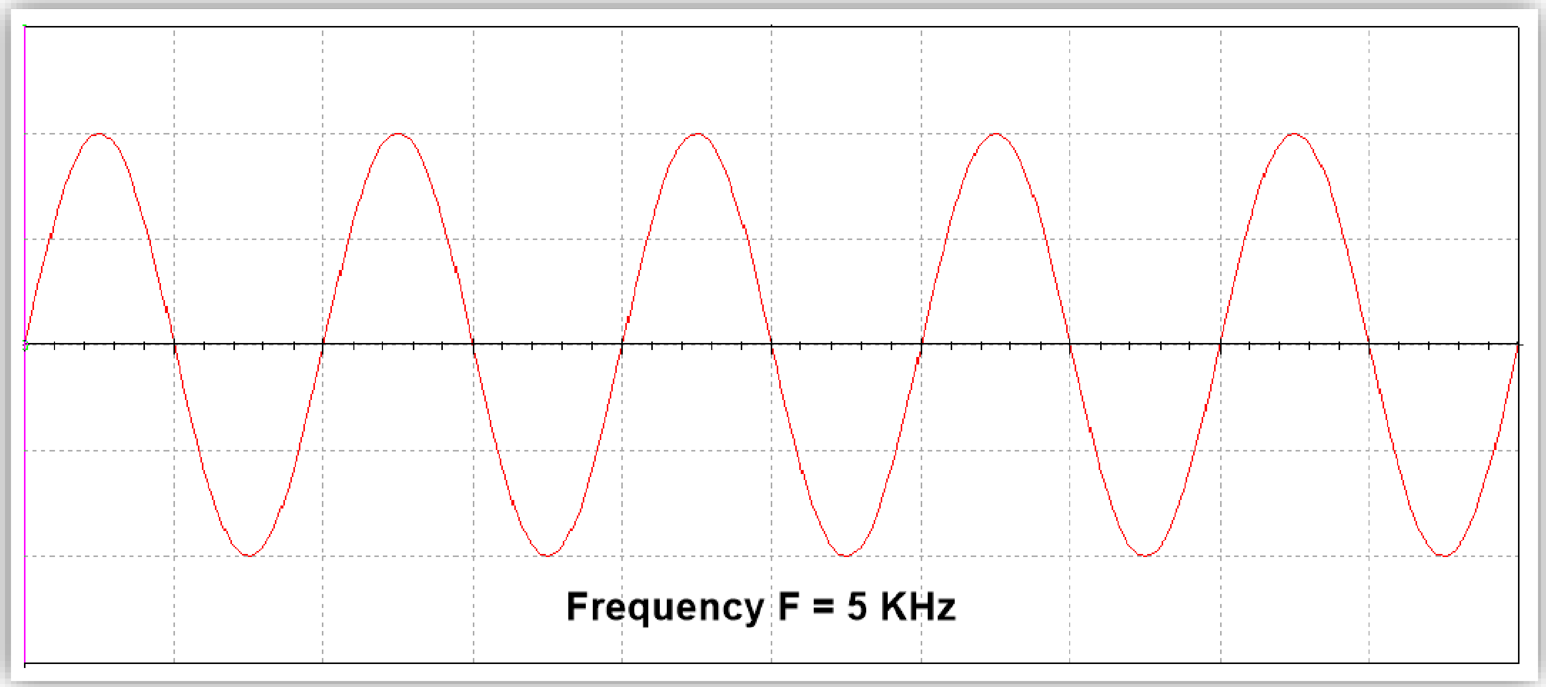
The Sine Waveform Characteristics (Period) Example

- For the following figure, what is the Period (cycle duration) of the sine wave?
- As seen from the figure, there are 3 cycles in 1 second which indicates that the frequency F = 3 Hz. Therefore, the period T is given by:
  - $T = \frac{1}{F}$
  - $T = \frac{1\ second}{3\ cycles} = 333.33$ mS



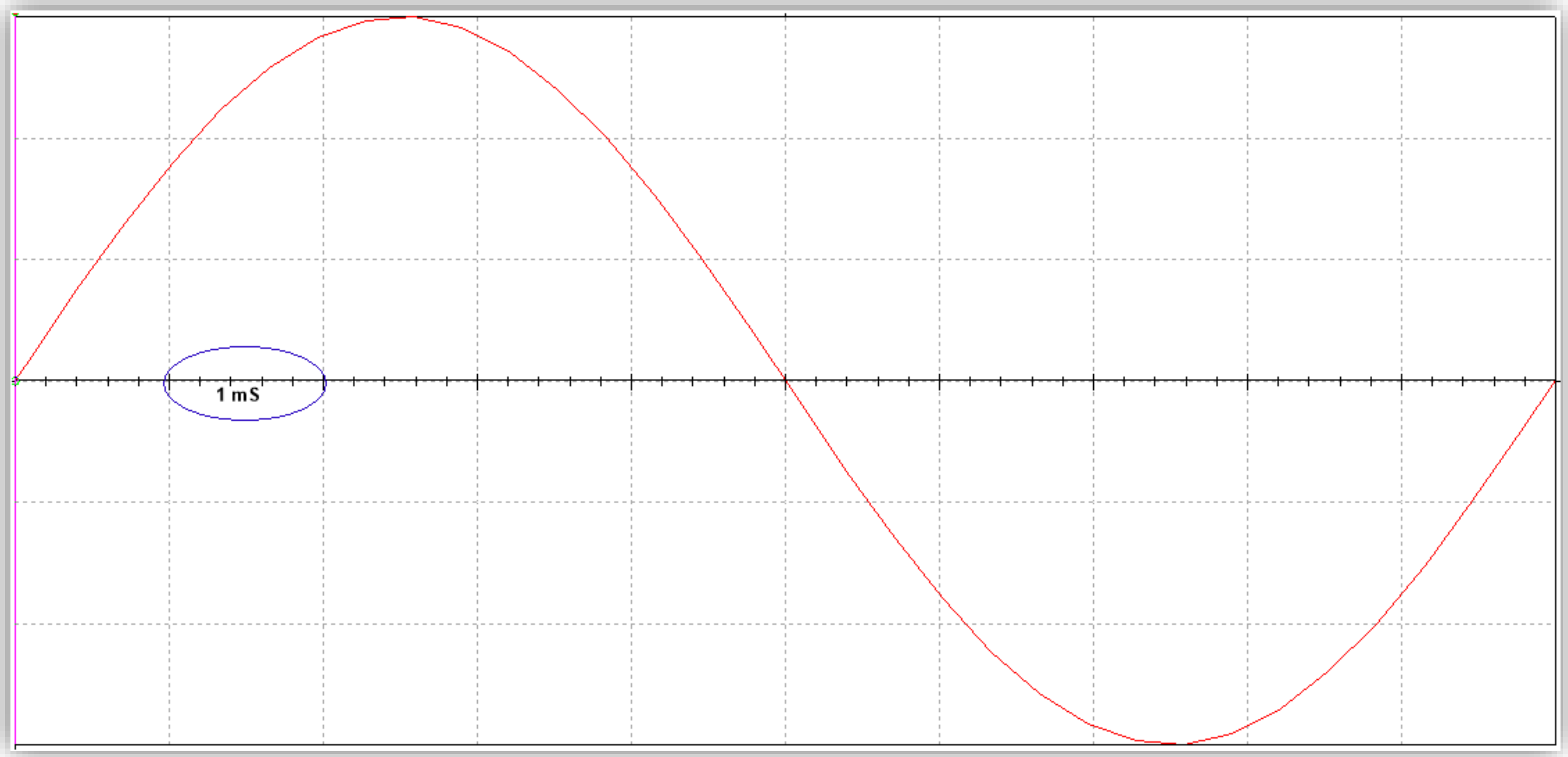
The Sine Waveform Characteristics (Period) Example

- For the following figure, what is the Period (cycle duration) of the sine wave?
- As seen from the figure, the frequency F of this sine wave is given as F = 5 KHz.
- Since: $T = \frac{1}{F}$,Then: $T = \frac{1}{F} = \frac{1}{5\ KHz}$ = 0.2 mS (milli Seconds)



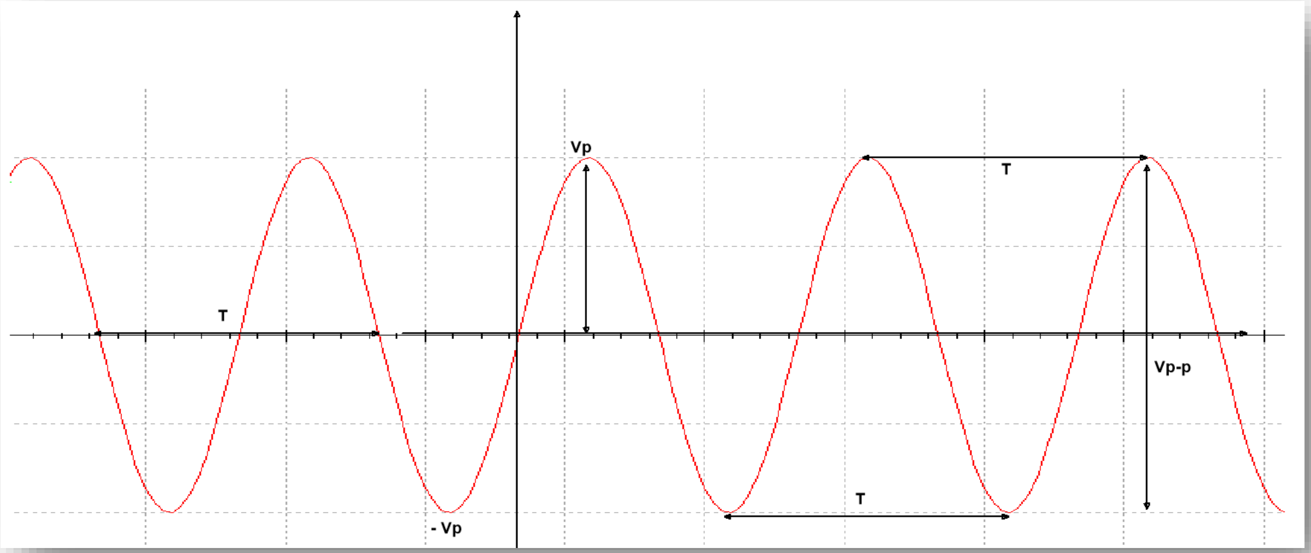
The Sine Waveform Characteristics (*Period T & Frequency F*) Example

- For the following figure, Determine the period T and frequency F.
- From the graph, the sine wave cycle spans ten whole division where each division corresponds to 1 mS. Therefore, the whole period T = 10 × 1 mS = 10 mS.
- Since $F = \frac{1}{T}$, then:
- $F = \frac{1}{10\ mS}$ = 100 Hz.



The Sine Waveform Characteristics (Peak Value, Peak-Peak Value)

- Peak Value: The peak value of a sine wave is the value of the voltage at the positive or the negative maximum (peaks) with respect to zero.
- Since the peaks are equal in magnitude, a sine wave is characterized by a single peak value.
- The peak value is constant, and it is represented by *Vp*.
- The basic unit of *Vp* is the voltage (V).
- *Peak to Peak value:* The lower peak to upper peak voltage. Its basic unit is the voltage (V). It is given by:
  - $Vp\text{-}p = 2 \times Vp$



Peak Value Vp, Peak to Peak Vp-p

The RMS value of a Periodic waveform

- RMS, stands for the **R**oot **M**ean **S**quare voltage. It is also called the effective voltage.

- It is a method of denoting an AC waveform as an equivalent voltage which represents a DC voltage value that will produce the same heating effect, or power dissipation, in a load, as this AC voltage.

- In other words, the waveform is an AC waveform, but the RMS value allows this waveform to be specified as if it is DC as far as power consumption is concerned.

- This is because it is the equivalent DC voltage that delivers the same amount of power to a load in a circuit as the AC signal does over its cycle.

The RMS value of a Sine waveform

- The RMS and peak voltage of a sine wave are related by:

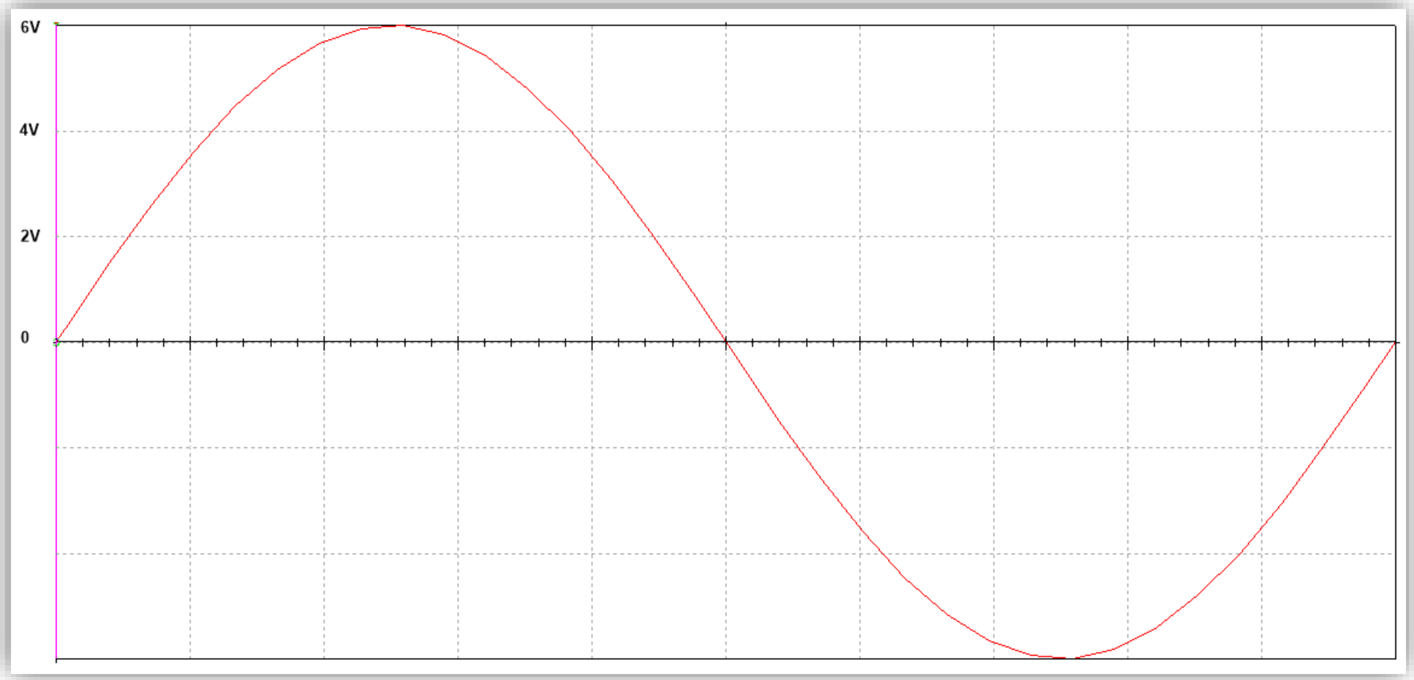
$$V_{RMS} = \frac{V_P}{\sqrt{2}} = 0.707 \times V_P$$

$$\&$$

$$V_P = \frac{V_{RMS}}{0.707} = \sqrt{2} \times V_{RMS}$$

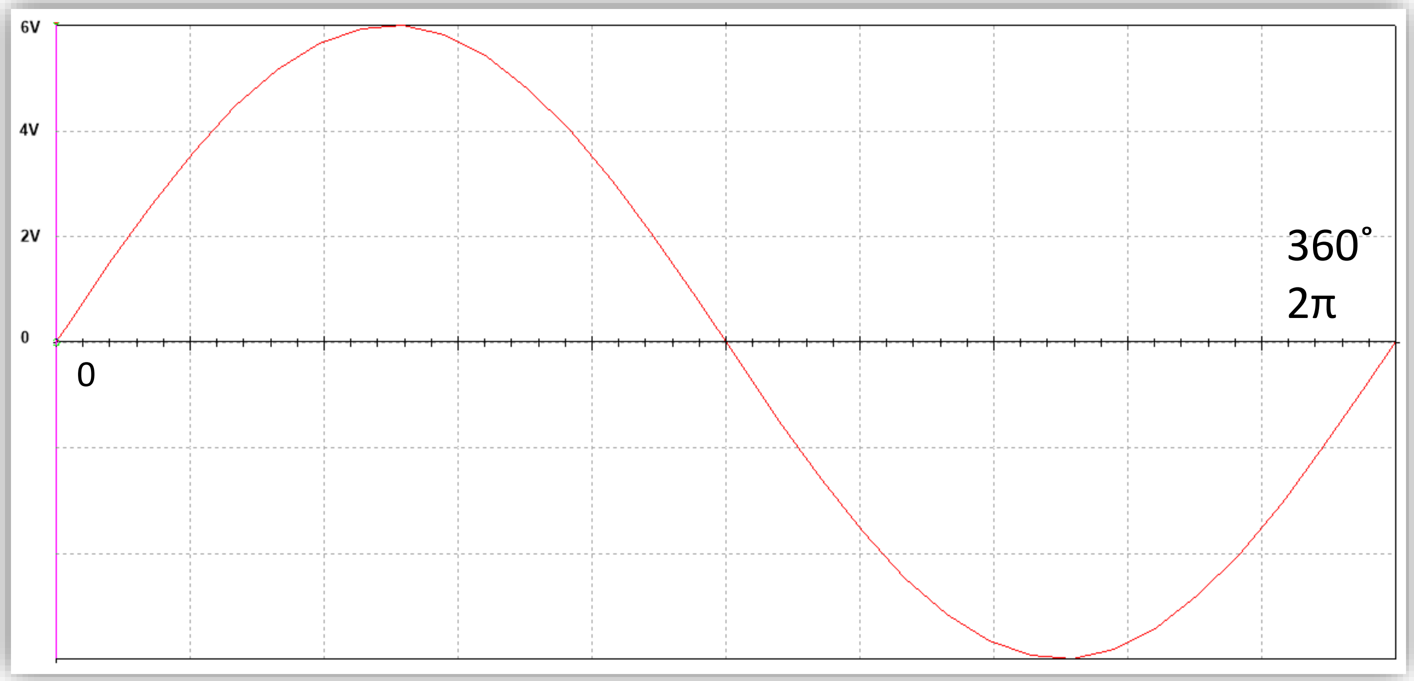
The Sine Waveform Characteristics (V_P, V_{P-P}, V_{RMS}) Example

- For the following figure, Determine V_P, V_{P-P} & V_{RMS}
- Taken directly from the graph, V_P = 6V. From this value, the other calculated values are given by:
- $V_{P-P} = 2 \times V_P = 2 \times 6V = 12V$
- $V_{RMS} = 0.707 \times V_P = 0.707 \times 6V = 4.242\ V$



Angular Measurement Of A Sine Wave

- The sine wave is a trigonometric function which means it takes an argument which is an angle measure.
- Angles can be represented either in degrees or radian.
- One whole cycle of a sine wave corresponds to 360˚ or 2π radians where π has a value of 3.141592654...



Radian/Degree Conversion

- If the angle is given in radians, it can be converted to degrees using the following formula:
  - $Degrees = \frac{180^{\circ}}{\pi} \times radians\ vlaue$

- Similarly, if the angle is given in degrees, it can be converted to radians using the following formula:
  - $Radians = \frac{\pi}{180^{\circ}} \times degrees\ vlaue$

- Represented in other words:
  - $1\ rad = 57.295^{\circ}$

Radian/Degree Conversion Example

- Convert the following:
  - a- 60° to radians.
  - b- $\frac{\pi}{6}$ rad to degrees.

- a- To convert from degrees to radians, use:
  - $Radians = \frac{\pi}{180^\circ} \times degrees\ vlaue = \frac{\pi}{180^\circ} \times 60^\circ = \frac{\pi}{3} = 1.047\ rad$

- To convert from radians to degrees:
  - $Degrees = \frac{180^\circ}{\pi} \times Radian\ Value = \frac{180^\circ}{\pi} \times \frac{\pi}{6} = 30^\circ$

The Sine Wave Equation As A Function Of Time

- In its most basic form, the equation for a sine wave voltage signal is given by:
  - $V(t) = V_p \times Sin\ (\omega t)$.

- The argument of the sine waveform is always an angle even though it appears that it is a function of time. See the following:

  - ω = 2 × π × f where ω is the angular frequency in radians/seconds.
  - f is the frequency which is given by: $f = \frac{1}{T\ in\ seconds}$. Therefore:
  - $\omega t = 2 \times \pi \times f \times t = 2 \times \pi \times \frac{1}{T\ in\ seconds} \times (t\ in\ seconds) = (\frac{2\pi}{T} \times t)\ rad$ **which is an angle measure.**

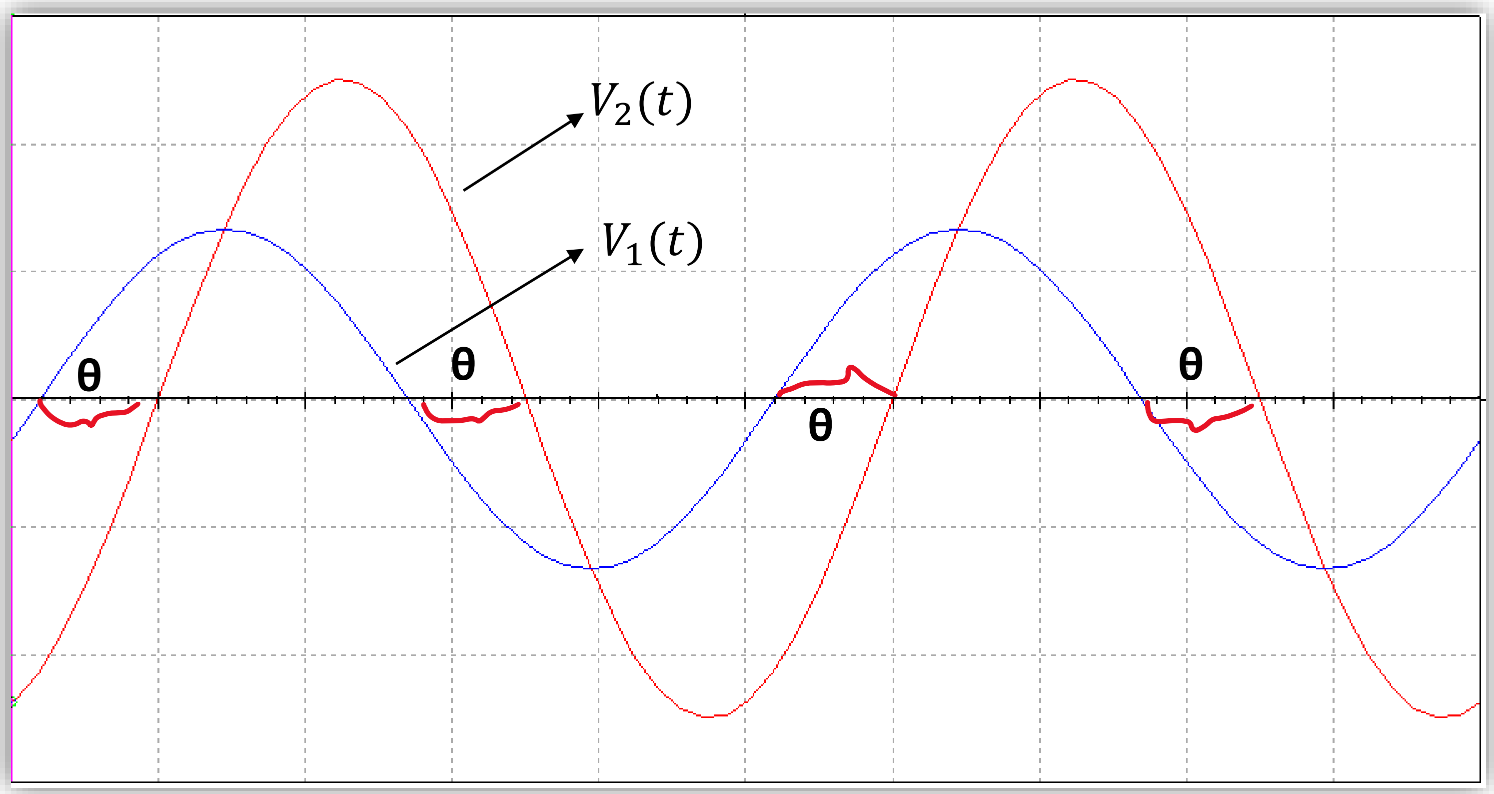
Phase Shifted Expressions of a Sine Wave

- In electronics circuitry under AC voltages, more than likely the sine wave voltages across circuit elements will be shifted either to the right or the left especially if there are capacitors or inductors in the circuit.

- For a sine wave shifted to the right (lagging the $Sin\ (\omega t)$ waveform in time) , the equation for the sine wave voltage signal is given by:
  - $V(t) = V_p \times Sin\ (\omega t - \theta)$.

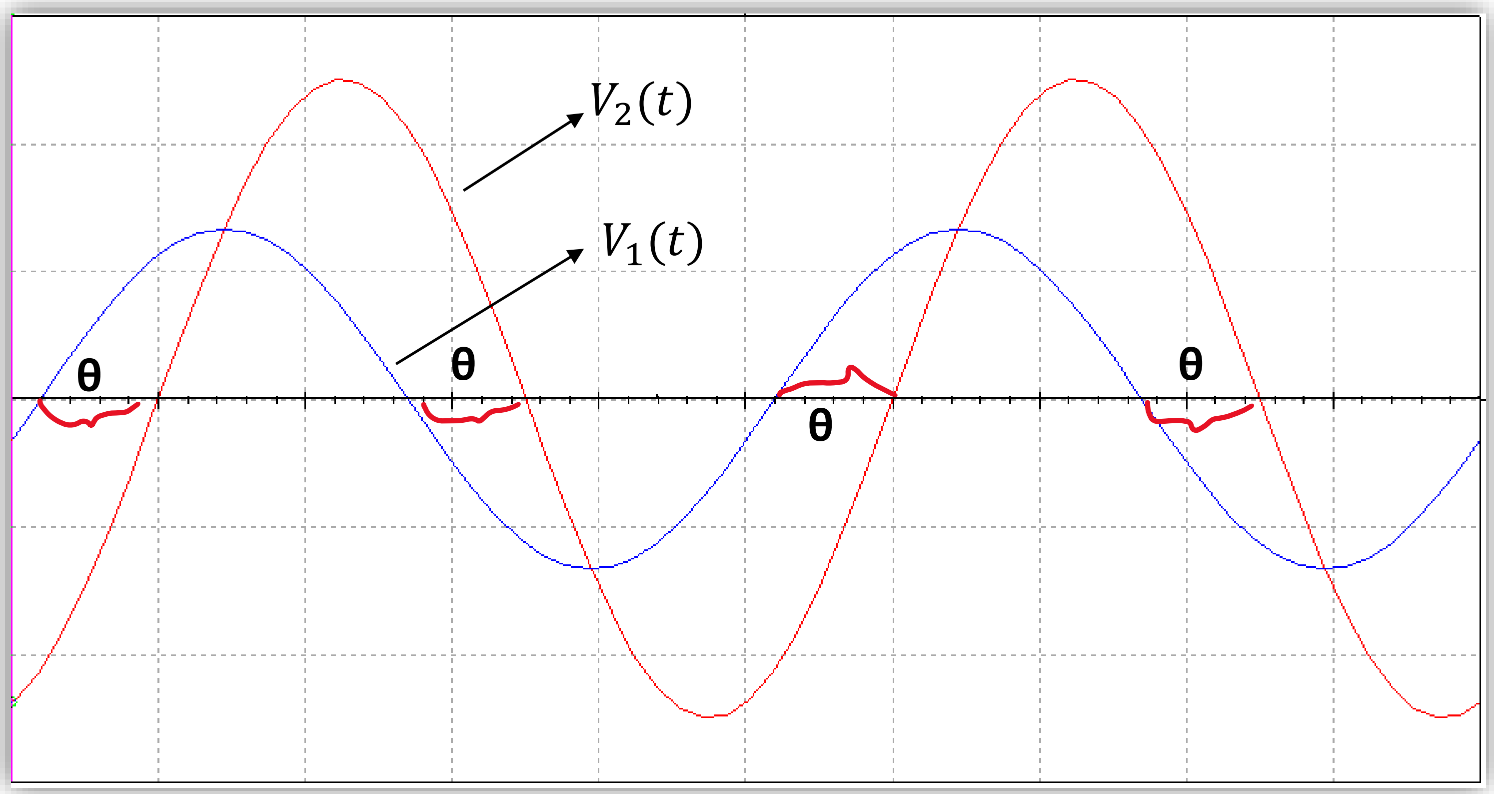
- For a sine wave shifted to the left, (leading the $Sin\ (\omega t)$ waveform in time) the equation for the sine wave voltage signal is given by:
  - $V(t) = V_p \times Sin\ (\omega t + \theta)$.

Phase-Shifted Expression1 of a Sine Wave



- $V_1(t) = V_{p1}(\omega t)$.
- $V_2(t) = V_{p2}(\omega t - \theta)$.
- Signal $V_1(t)$ leads $V_2(t)$ signal by an angle of θ. Stated otherwise signal $V_2(t)$ lags $V_1(t)$ signal by an angle of θ.

Phase-Shifted Expression2 of a Sine Wave



- $V_1(t) = V_{p1}(\omega t + \theta)$.
- $V_2(t) = V_{p2}(\omega t)$.
- Signal $V_1(t)$ leads $V_2(t)$ signal by an angle of θ. Stated otherwise signal $V_2(t)$ lags $V_1(t)$ signal by an angle of θ.

Phase Shift Representation In Time

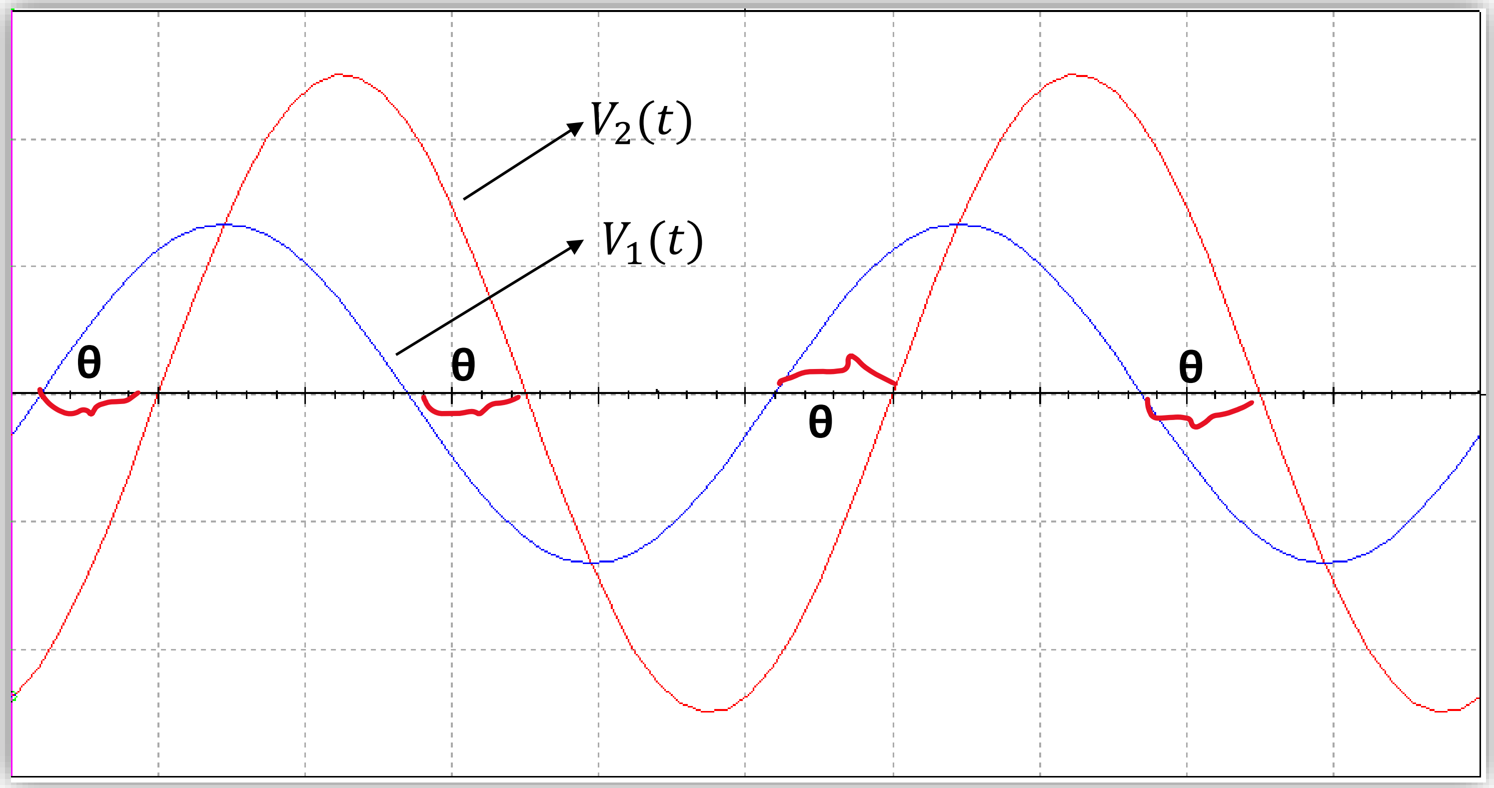
- Just as the lead or lag amount is expressed in degrees or radians, it can also be represented in time. In other words, it can be said that $V_1(t)$ occurs in time t seconds before $V_2(t)$. Or $V_2(t)$ occurs in time t seconds after $V_1(t)$.
- Since both signals are in the same circuit, then they have the same period T. The time t that corresponds to a phase angle of θ can be determined as:

  - $t = \dfrac{\theta\ in\ degrees}{360^\circ} \times T$ or
  - $\theta\ in\ degrees = \dfrac{t \times 360^\circ}{T}$

  - $t = \dfrac{\theta\ in\ radians}{2\pi} \times T$ or
  - $\theta\ in\ radians = \dfrac{t \times 2\pi}{T}$

Phase Shift Example of a Sine Wave

- For the following waveforms if the period T of the waveforms is 200 mS, then what is the time difference between the two waveforms $V_1(t)$ and $V_2(t)$ for:
- a- $\theta = 45^\circ$
- b- $\theta = \frac{\pi}{8}$



Phase Shift Example Solution of a Sine Wave

- For the following waveforms if the period T of the waveforms is 200 mS and the value of θ is 45°, then what is the time difference between the two waveforms $V_1(t)$ and $V_2(t)$?
- a- θ = 45°

- Since the phase shift is given in degrees, then the time difference between the two waveforms is given by:

$$t = \frac{\theta\ in\ degrees}{360^\circ} \times T = \frac{45^\circ}{360^\circ} \times 200\ mS = 25\ mS.$$

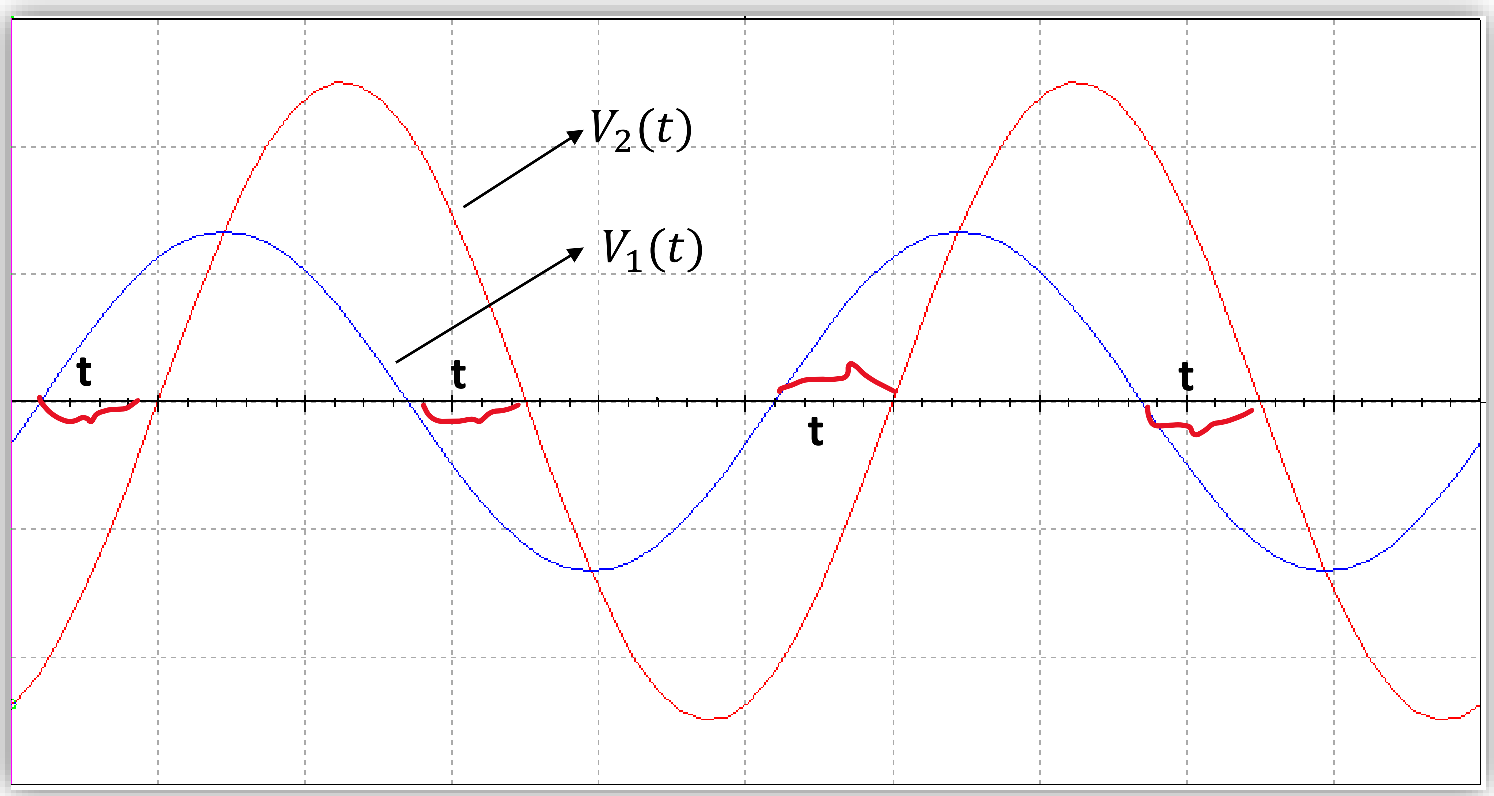
Phase Shift Example Solution of a Sine Wave

- For the following waveforms if the period T of the waveforms is 200 mS, then what is the time difference between the two waveforms $V_1(t)$ and $V_2(t)$?
- b- $\theta = \frac{\pi}{8}$
- Since the phase shift is given in radians, then the time difference between the two waveforms is given by:

$$t = \frac{\theta\ in\ radians}{2\pi} \times T = \frac{(\frac{\pi}{8})}{2\pi} \times 200\ mS = 12.5\ mS.$$

Phase Shift Example of a Sine Wave

- For the following waveforms if the period T of the waveforms is 200 mS, then what is the phase difference in degrees if the time difference between the two waveforms $V_1(t)$ and $V_2(t)$ is t = 35 mS?



Phase Shift Example of a Sine Wave

- For the following waveforms if the period T of the waveforms is 200 mS, then what is the phase difference in degrees if the time difference between the two waveforms $V_1(t)$ and $V_2(t)$ is t = 35 mS?

- Use the formula that converts time difference between the 2 signals to degrees:

$$\theta \; in \; degrees = \frac{t \times 360^\circ}{T} = \frac{35 \, mS \times 360^\circ}{200 \, mS} = 63^\circ$$

This Concludes the AC fundamentals Slides