Work-Ready Electronics

Synchronizing Curriculum to the Rapidly Changing Workplace

Module: Frequency Domain View of Electronic Signals: Practical Application of the Fourier Theory

WORKREADY ELECTRONICS

Frequency Domain View of Electronic Signals:
Practical Applications of the Fourier Theory

Most circuit operation and analysis is explained in the time domain; that is, in terms of how the voltages change with time.

An alternative method of looking at electronics signals views electronic signals in the frequency domain or the variations of signal voltage or power over a frequency range. Even though such a view helps to better explain many electronic concepts than a time domain discussion, this method is often ignored in technology education because it is difficult mathematically.

This module introduces the Fourier theory to provide a way to analyze and understand electronic signals in the frequency domain. This mathematical technique is easy to learn and gives technicians another way to understand electronic applications.

What Technicians Need to Know

The relationship between the time and frequency domains

The Fourier theory in non-mathematical terms

The term harmonic and how to calculate harmonic frequencies

The Fourier expressions for square, sawtooth, triangle and rectified sine waves

The plot that defines the spectrum of a binary signal

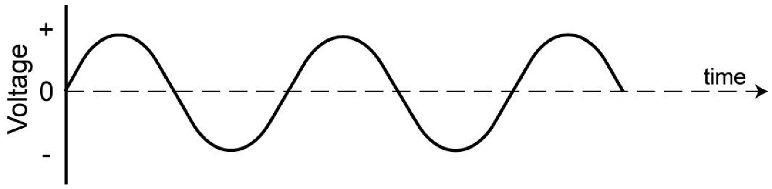
Bandwidth and how to calculate it for a rectangular pulse signal

Ways to use the Fourier theory in testing and troubleshooting

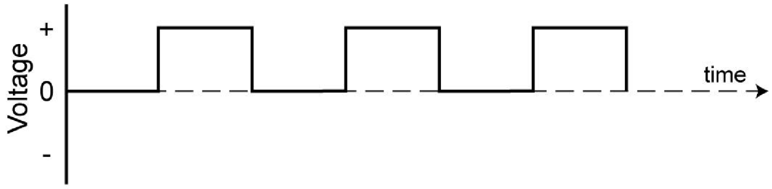
The Sine Wave and the Time Domain

A Review

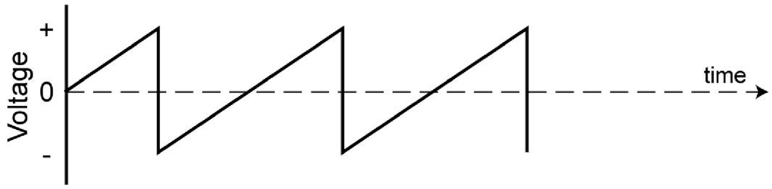
Common Waves in the Time Domain



a) Sine wave



b) Square wave



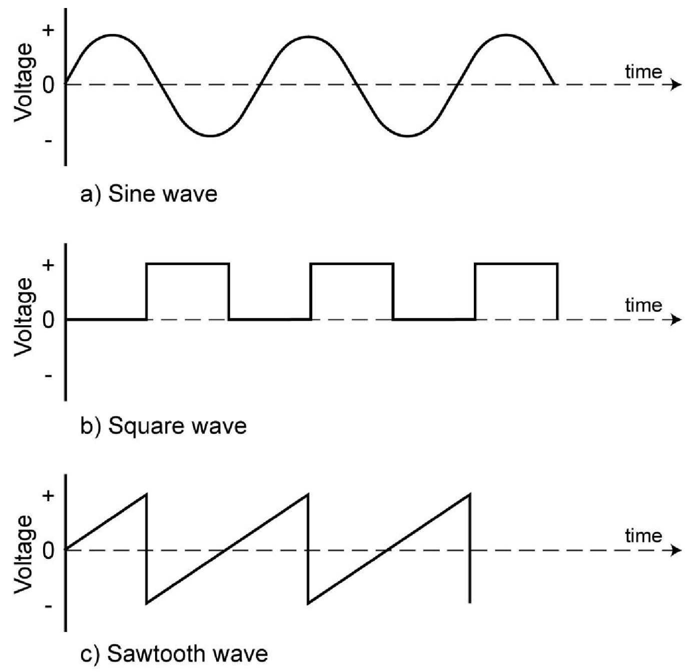
c) Sawtooth wave

A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

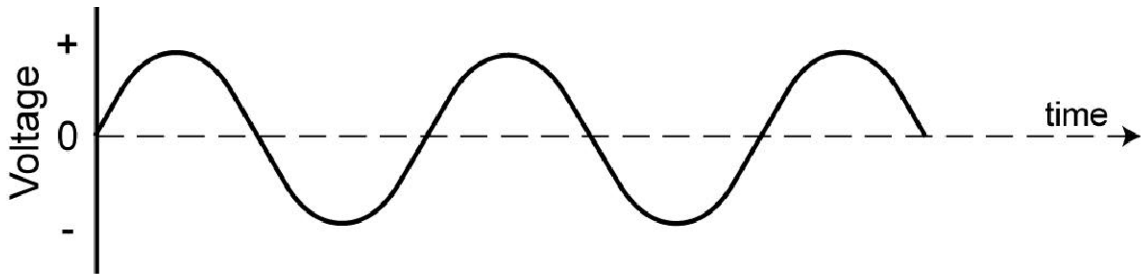
The Time Domain Defined

The term time domain as it applies to electronic signals refers to a way to show how a signal voltage varies over time. It is a plot of voltage variations on the vertical axis of a graph with time on the horizontal axis. A drawing of a sine wave, a square wave, or any other electronic signal is a time domain presentation.

One method of viewing a time domain signal is with an oscilloscope. The figure on the right shows several common electronic signals displayed in the time domain.



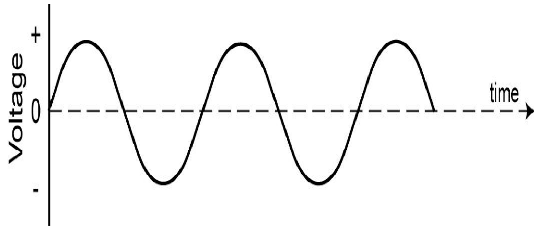
The Sine Wave



a) Sine wave

One of the most common and natural occurring electronic signals is the sine wave. Examples of sine waves include radio waves and AC power line voltage. Most sound waves are mixtures of sine waves.

The Sine Wave: Mathematical Expression



a) Sine wave

The trigonometric expression that represents a sine wave in the time domain is:

$$v = V_p \sin 2\pi ft$$

v = instantaneous voltage of the sine wave at some time t

V_p = peak voltage value

f = frequency of the sine wave in Hz

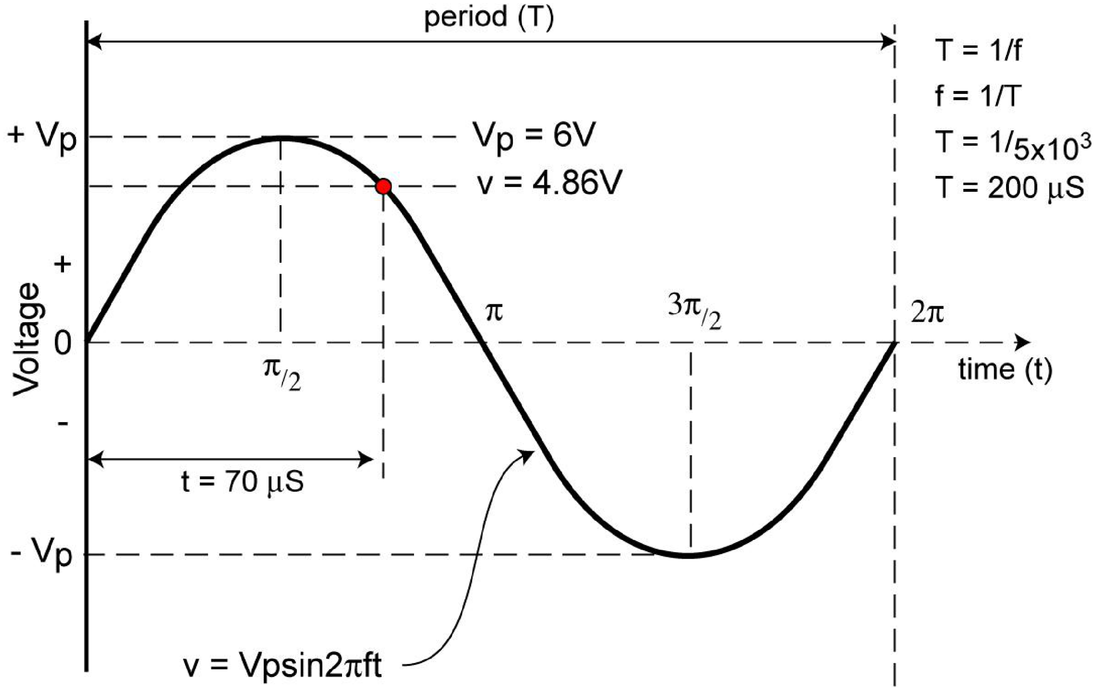
$2\pi f$ = the angular velocity (often stated as the Greek letter omega ω)

The expression becomes

$$v = V_p \sin \omega t$$

ωt = an angle expressed in radians (rads) where 1 rad = 57.3°

Mathematical Expression Calculation



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An Example Calculation

Determine the instantaneous voltage (v) at 70 µS in a 5 kHz sine wave with a peak value (V_p) of 6 volts.

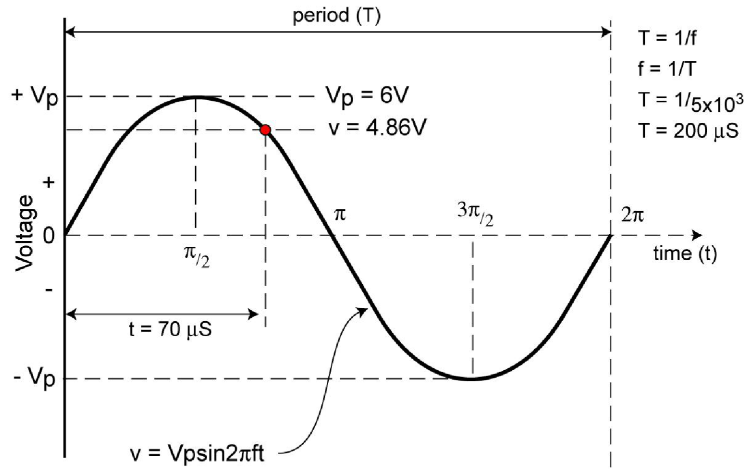
$v = V_p \sin(2\pi ft)$

$v = 6\sin(6.28)(5 \times 10^3)(70 \times 10^{-6})$

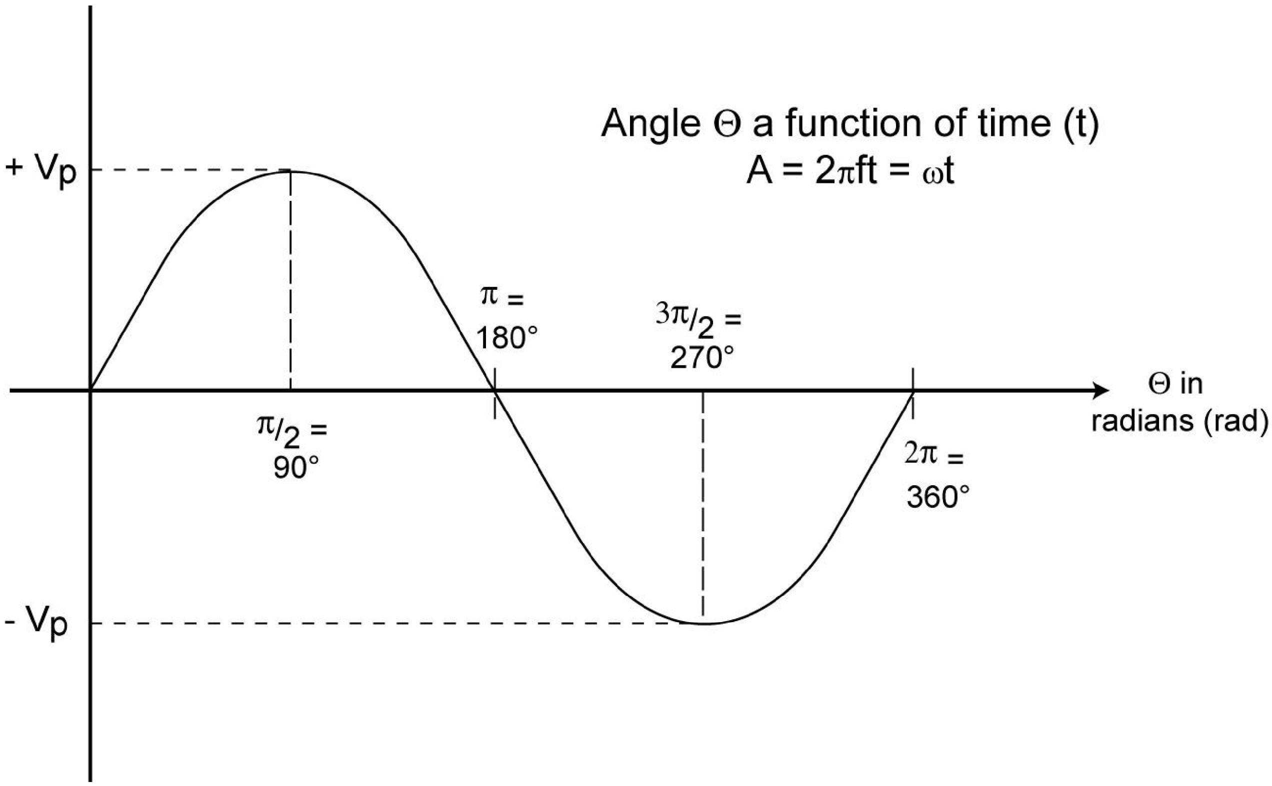
$v = 6\sin 2.198$ (2.198 is radians)

$v = 6(.8097) = 4.858$ volts

The figure shows the sine wave, its mathematical expression, and the instantaneous value.



Time Axis Converted to Angle



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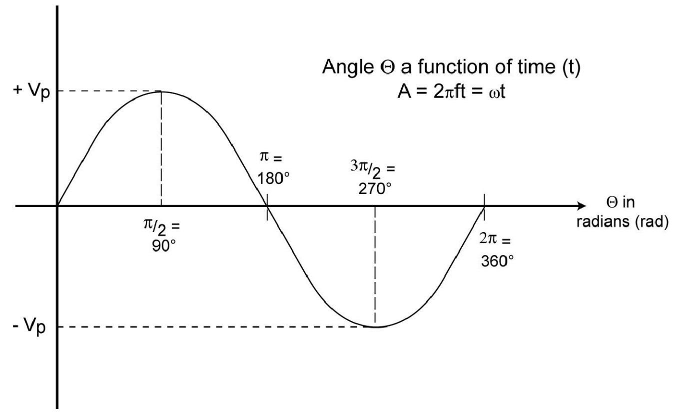
Time Axis Converted to Angle

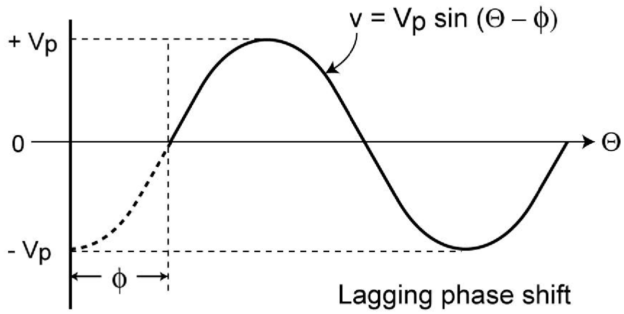


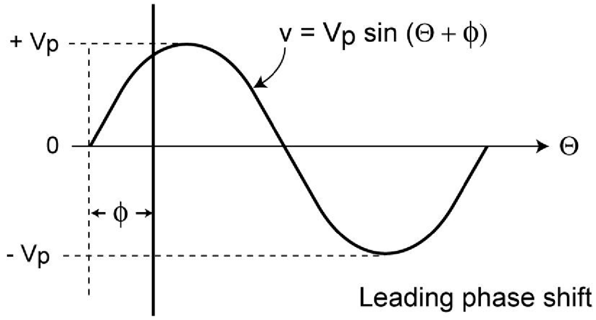
While the horizontal axis is time, you can convert time into an angle theta (θ). $\theta = \omega t$ and the unit is rads. It is common to express the angle using units of π where π = 180°, 2π = 360°, π/2 = 90°and so on.

$$2\pi \text{ rads} = 6.28 \text{ rads} = 6.28 \times 57.3° = 360°$$

By expressing the sine wave mathematically, you can use it to predict the operation and performance of electronic circuits. The sine wave input expression is multiplied by a mathematical equation expressing the operation of the electronic circuit. This produces a new expression for the output.

The Effect of Phase Shift





Θ is a function of time(t)

$\Theta = 2\pi f t = \omega t$

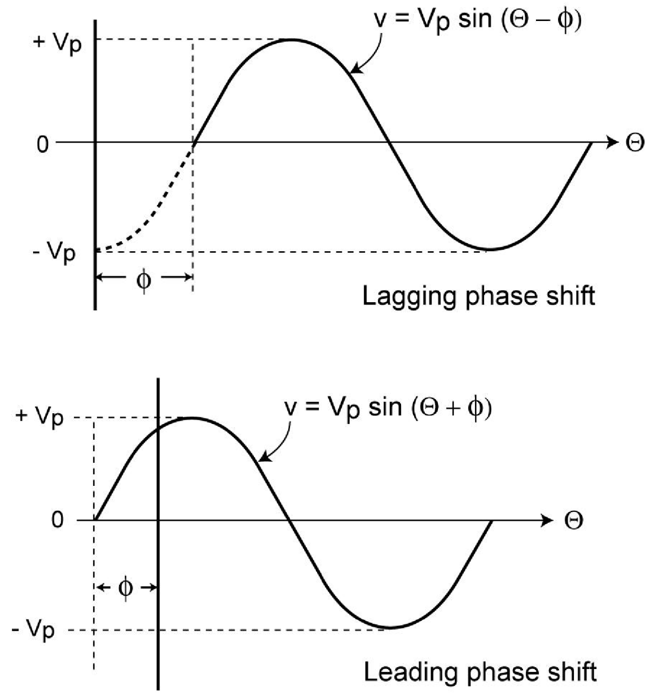
A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

The Effect of Phase Shift

Phase shift is a time difference between two sine waves of the same frequency. All sine waves do not start at zero going positive as a sine plot usually shows. They can start and stop at any time. For that reason, in some applications, the phase of the sine wave must be considered. This figure shows how a sine wave can lead or lag by some phase angle φ. This is expressed mathematically as:

$v = V_p \sin(\theta \pm \varphi) = V_p \sin(\theta \pm \varphi)$

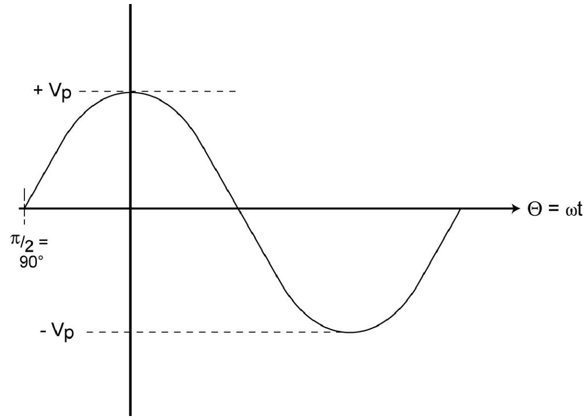
Here $\theta = \omega t$.



Θ is a function of time(t)

$\Theta = 2\pi ft = \omega t$

Cosine Waves



A cosine wave has exactly the same shape as a sine wave and is offset by one quarter of a cycle (90°). A cosine wave is said to lead a sine wave in phase.

The mathematical expression for a cosine wave is:

$$v = V_p \cos(\omega t \pm \varphi)$$

It is not necessary to know if an electronic signal is a sine wave, a cosine wave, or a phase shifted version because it does not matter in most applications. What does matter is the relationship between multiple sinusoidal waves of the same frequency.

Test your knowledge

Fourier Theory Knowledge Probe 1

The Sine Wave and the Time Domain

Click on Course Materials at the top of the page.

Then choose **Knowledge Probe 1**.