

Chapter 8

Introduction to Alternating Current and Voltage

Objectives

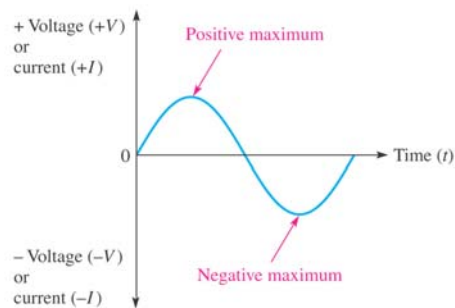
- Identify a sinusoidal waveform and measure its characteristics
- Describe how sine waves are generated
- Determine the various voltage and current values of sine waves
- Describe angular relationships of sine waves
- Mathematically analyze a sinusoidal waveform
- Apply the basic circuit laws to ac resistive circuits

Objectives

- Determine total voltages that have both ac and dc components
- Identify the characteristics of basic non-sinusoidal waveforms

Sine Wave

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



Period of a 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

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:

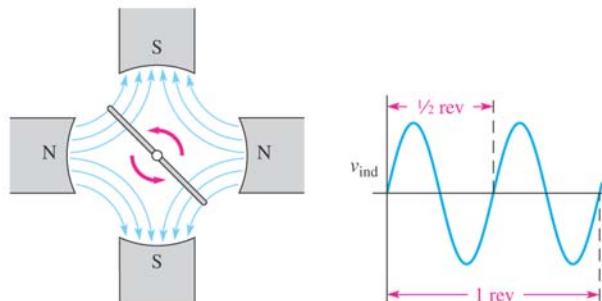
$$f = 1/T$$

AC Generator

- The ac generator has slip rings that pick up the induced voltage through a complete rotation cycle
- The induced voltage is related to the number of lines of flux being cut. When the loop is moving parallel with the lines of flux, no voltage is induced. When the loop is moving perpendicular to the lines of flux, the maximum voltage is induced

Multi-pole ac Generator

- By increasing the number of poles, the number of cycles per revolution can be increased



Electronic Signal 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:

$$V_p \text{ and } I_p$$

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:

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

where: $V_{pp} = 2V_p$ and $I_{pp} = 2I_p$

RMS Value of a Sine Wave

- The **rms** (root mean square) value, or **effective 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

$$V_{\text{rms}} = 0.707V_p$$

$$I_{\text{rms}} = 0.707I_p$$

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

$$V_{\text{avg}} = 0.637V_p$$

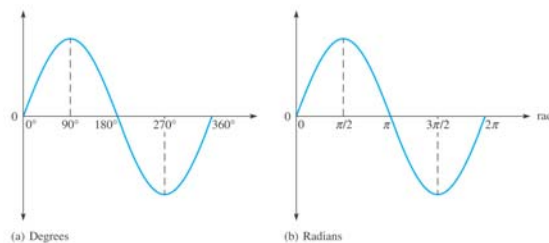
$$I_{\text{avg}} = 0.637I_p$$

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

Phase of a Sine Wave

- 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



Sine Wave Formula

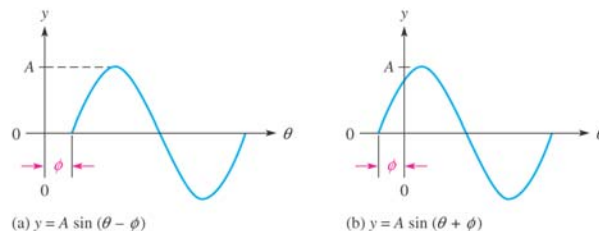
The general expression for a sine wave is:

$$y = A \sin \theta$$

Where: y = an instantaneous value (v or i)
 A = amplitude (maximum value)
 θ = angle along the horizontal axis

Expressions for Shifted Sine Waves

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

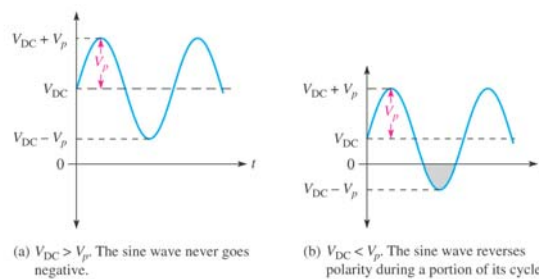


Ohm's Law and Kirchhoff's Laws in AC Circuits

- When time-varying ac voltages such as a sinusoidal voltage are applied to a circuit, the circuit laws that were studied earlier still apply
- Ohm's law and Kirchhoff's laws apply to ac circuits in the same way that they apply to dc circuits

Superimposed dc and ac Voltages

- DC and ac voltages will add algebraically, to produce an ac voltage "riding" on a dc level

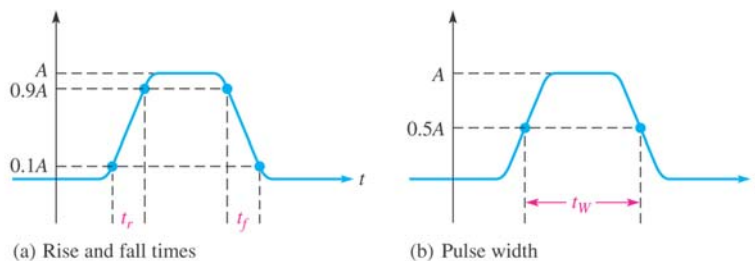


Pulse Waveforms

- A pulse has a rapid transition (**leading** or **rising edge**) from a baseline to an amplitude level, then, after a period of time, a rapid transition (**trailing** or **falling edge**) back to the baseline level
- Pulses can be positive-going, or negative-going, depending upon where the baseline is
- The distance between rising and falling edge is termed the **pulse width**

Non-ideal Pulse

- A non-ideal pulse has a rising and falling time interval, measured between 10% and 90% of its Amplitude
- Pulse width is taken at the half-way point



Repetitive Pulses

- Any waveform that repeats itself at fixed intervals is **periodic**
- The time from one pulse to the corresponding point on the next pulse is the period, T ($f=1/T$)
- The **duty cycle** is the ratio of the pulse width (t_w) to the period (T), and is usually expressed as %

$$\text{Duty cycle} = (t_w/T)100\%$$

- Square waves have a 50% duty cycle

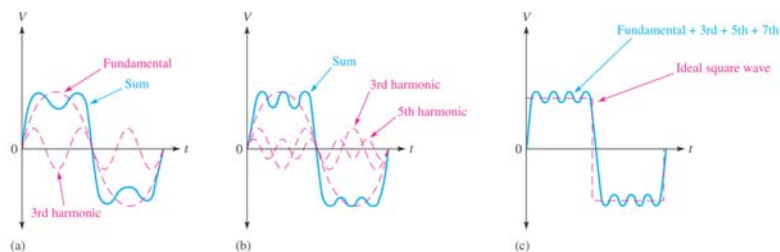
Triangular and Sawtooth Waveforms

- Triangular and sawtooth waveforms are formed by voltage or current ramps (linear increase/decrease)
- **Triangular waveforms** have positive-going and negative-going ramps of equal slope
- The **sawtooth waveform** is a special case of the triangular wave consisting of two ramps, one of much longer duration than the other. A sawtooth voltage is sometimes called a *sweep voltage*

Harmonics

- A repetitive non-sinusoidal waveform is composed of a **fundamental frequency** (repetition rate of the waveform) and **harmonic frequencies**
- **Odd harmonics** are frequencies that are odd multiples of the fundamental frequency
- **Even harmonics** are frequencies that are even multiples of the fundamental frequency
- **Composite waveforms** vary from a pure sine wave, they may contain only even harmonics, only odd harmonics or both

Odd Harmonics Produce a Square Wave



Summary

- The sine wave is a time-varying, periodic waveform
- Alternating current changes direction in response to changes in the polarity of the source voltage
- One cycle of an alternating sine wave consists of a positive alternation and a negative alternation
- Two common sources of sine waves are the electromagnetic ac generator and the electronic oscillator circuit

Summary

- A sinusoidal voltage can be generated by a conductor rotating in a magnetic field
- A full cycle of a sine wave is 360° , or 2π radians. A half-cycle is 180° , or π radians. A quarter cycle is 90° or $\pi/2$ radians
- Phase angle is the difference in degrees or radians between a given sine wave and a reference sine wave

Summary

- A pulse consists of a transition from a baseline level to an amplitude level, followed by a transition back to the baseline level
- A triangle or sawtooth wave consists of positive-going and negative-going ramps
- Harmonic frequencies are odd or even multiples of the repetition rate of a non-sinusoidal wave-form

Summary

- Conversions of sine wave values are:

TO CHANGE FROM	TO	MULTIPLY BY
Peak	rms	0.707
Peak	Peak-to-peak	2
Peak	Average	0.637
rms	Peak	1.414
Peak-to-peak	Peak	0.5
Average	Peak	1.57