# Chapter 4

# BASIC ALTERNATING CURRENT (AC) CIRCUITS

**OUTLINE**

- AC Waveforms
- AC Terms
- AC Calculations

**OBJECTIVES**

Given various electronic devices, symbols, and diagrams, you will be able to accomplish the following objectives:

- Identify various AC waveforms.
- Identify basic AC Terms.
- Calculate values for an AC circuit.

# AC Waveforms

## Alternating Current

- Alternating current is the term applied to current that constantly changes in amplitude and periodically reverses direction.

- Current supplied by a battery is direct current. This means that the current flows in one direction only. This current is unidirectional. Alternating current is bi-directional. The electrons flow first in one direction and they in the opposite direction. If it were possible to continuously reverse the polarity of a battery, alternating current would be the result.

Common AC Waveforms

- Graphic representations of how voltage and current changes in amplitude and direction over a period of time are called waveforms. Figure 4-1 shows various waveforms of AC. These AC waveforms are visible through the use of an oscilloscope.

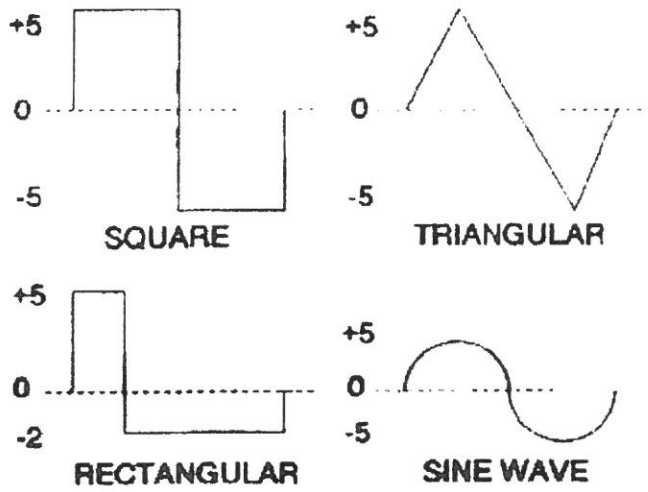



**Figure 4-1**

***Square Wave***

- Square waves are symmetrical (mirror) images of the first half of the waveform) however the second half of the waveform has reverse polarity. Used for digital operations and computers.

### ***Rectangular Wave***

- Rectangular waves have two alternations that are unequal in time. The rectangular waveform is non-symmetrical.

### ***Triangular Wave***

- Triangular waves are symmetrical. This means they have equal changes in voltage for equal changes in time.

### ***Sine Wave***

- The sine wave is the most common AC waveform. In fact, the sine wave is so widely used that most people automatically think of the sine wave when discussing AC.

- Like triangular waves, sine waves are also symmetrical.

- Household AC is a form of sine wave.

- The shape of the sine wave is a plot of points generated when a radius line of a circle rotates through 360° as shown in Figure 4-2. Starting at zero, the sine wave increases to maximum amplitude in one direction and then decreases to zero. It then increases to maximum amplitude in the opposite direction and again decreases to zero.

- The shape of the sine wave can represent either alternating voltage or alternating current values.

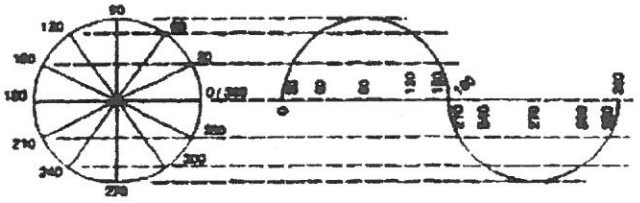


**Figure 4-2**

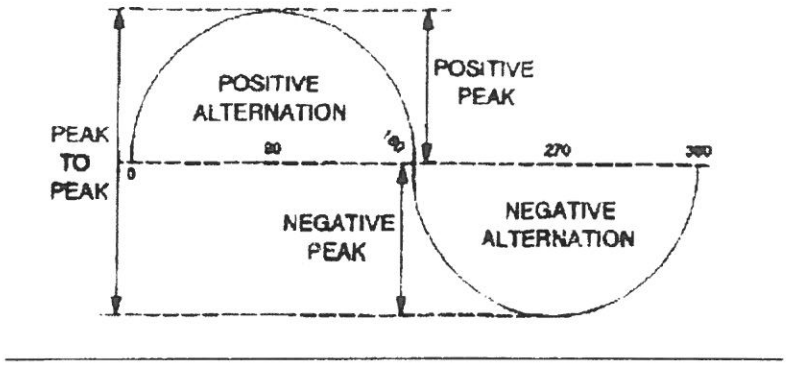



**Figure4-3**

### ***Alternation***

- An alternation is defined as the variations, either positive or negative, of a waveform from zero to maximum and back to zero.

- The horizontal line in Figure 4-3 divides the sine wave into two equal parts: one above the line and the other below it. The portion of the waveform above the line represents the positive alternation, and the portion of the waveform below the line represents the negative alternation.

### ***Amplitude***

- Take another look at Figure 4-3. Notice that the wave reaches its maximum swing from zero to 90° and 270°. Each of these points is called the peak of the sine wave. The peak amplitude of a sine wave refers to the maximum swing, or height of one of the alternations at its peak. The term peak-to-peak refers to the distance between the maximum positive and maximum negative peaks.

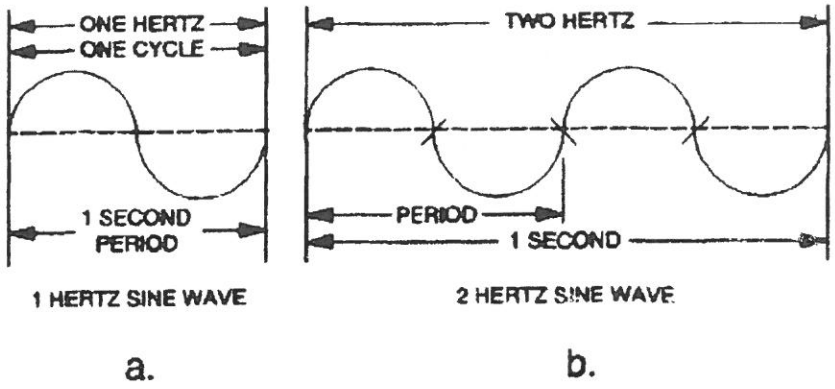


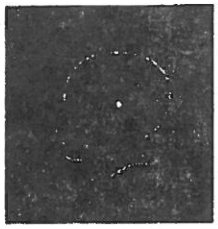

**Figure 4-4**

***Cycle***

- The cycle of a waveform refers to the part of the waveform that **does not** repeat itself.

- The cycle of a since wave can be divided into two equal parts. The positive alternation is the positive half cycle, and the negative alternation is the negative half cycle.

- The positive half cycle rises from zero to maximum positive value and then returns to zero. The negative half cycle drops from zero to maximum negative value and then returns to zero. One cycle of an AC waveform represents 360° of a sine wave.



## Activity 1

### *AC Voltage Calculations*

*Solve for the values below.*

1. Solve for Vpk when Vpk-pk is 20V. Vpk = _____

2. Solve for Vpk-pk when Vpk is 100. Vpk-pk = _____

***Frequency***

- It takes time to generate a sine wave. For example, household current takes 1/60 of a second for a single cycle. The term period is used to define the time of one cycle of alternating current.

- Another term having the same meaning as time and period is duration. The frequency of any AC waveform is defined as the number of cycles that occur in a given period of time. The unit of measure for frequency is hertz. Hertz is equal to one cycle per second.

***Time***

- Time is equal to one cycle of alternating current. Period, time and duration are synonymous. The unit of measure is seconds. The time of one cycle varies inversely with frequency. As the period of time for one cycle becomes shorter, the frequency increases, or as the frequency increases, the period of one cycle decreases.

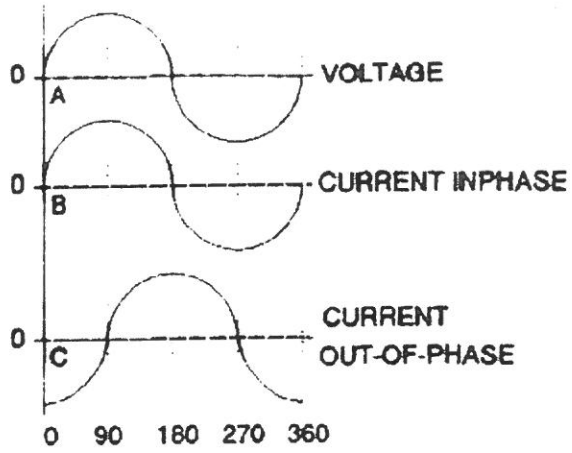



Figure 4-5

### ***Phase Relationship***

- ***In Phase.*** two waves of the same frequency pass through zero and reach their positive peaks and the same time.

- ***Out-of-phase.*** two waves of the same frequency which do not pass through zero at the same time.

### ***Peak Voltage***

- Peak voltage represents the maximum height of one alternation of a waveform (either positive or negative).

### ***Peak-to-Peak Voltage***

- As stated earlier, peak-to-peak voltage is the distance between the maximum positive and maximum negative peaks.

### ***Effective Value (Root-mean-square RMS)***

- Root-mean-square is defined as the amount of current or voltage that produces the same amount of work as an equal amount of direct current or voltage.

### ***Average Value***

- Average value is defined as the average instantaneous values of all points in a single alternation.

# AC Calculations

### ***Peak Value***

$V_{pk} = \frac{1}{2}V_{pk\text{-}pk}$

**Example:** $V_{pk} = \frac{1}{2} \times 20V$
$V_{pk} = 10V$

### ***Peak-to-Peak Value***

$V_{pk\text{-}pk} = 2V_{pk}$

**Example:** $V_{pk\text{-}pk} = 2 \times 25V$
$V_{pk\text{-}pk} = 50V$

### ***Effective Voltage (RMS)***

$V_{eff} = .707V_{pk}$

or

$V_{rms} = .707V_{pk}$

**Example:** $V_{eff} = .707 \times 30V$
$V_{eff} = 21.21V$

If $V_{rms}$ value is already known, use this formula

$$V_{pk} = 1.414 \times V_{rms}$$

**Example:** $V_{pk} = 1.414 \times 28V$
$V_{pk} = 39.59V$

***Average Voltage***

$V_{ave} = .636V_{pk}$

**Example:** $V_{ave} = .636 \times 40V$
$V_{ave} = 25.44V$

***Time to Frequency***

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

**Example:** $$T = \frac{1}{50kHz}$$
$T = 20\mu s$

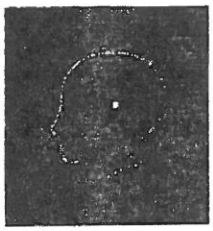
***Frequency to Time***

$$F = \frac{1}{t}$$

**Example:**

$$F = \frac{1}{40\mu s}$$

$F = 25kHz$



## Activity 2

***Time and Frequency***

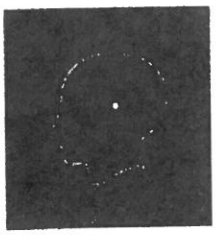
*Solve for the values below.*

1. What is the frequency of a waveform that requires .01 seconds to complete one cycle?

   F = _____

2. What is the period (T) of a 2-MHz sine wave?

   T = _____



## Activity 3

### *AC Calculations*

*Convert the following values*

1. Solve for $V_{pk}$ when $V_{pk-pk} = 80V$. $V_{pk}$ = _____
2. Solve for $V_{pk-pk}$ when $V_{pk}$ is 100. $V_{pk-pk}$ = _____
3. If a waveform requires 0.01 seconds to complete one cycle, what is its frequency ($V_{pk-pk}$?

   $f$ = _____

4. What is the period ($T$) of a 8kHz sine wave?

   $T$ = _____

5. Convert the following values

   **a.** $20V_{pk}$ = _____ $V_{pk-pk}$

   **b. If $f$ = 50kHz, then $T$ = _____**

   **c.** $110V_{pk-pk}$ = _____ $V_{pk}$

   **d. If $T$ = 25ms, then $f$ = _____**

The purpose of this chapter is to provide a general understanding of the subject areas addressed. For more information on the topics covered in this unit, refer to the reference books and other study materials listed in the Study Guide for the Basic Electricity Test.

## SUMMARY

1. *Alternating current is current that changes in amplitude (voltage/height) and periodically reverses direction.*
2. *The four most common waveforms are the square, triangular (saw tooth), rectangular, and sine waveforms. Waveforms are graphic representations of how voltage and current changes in amplitude over a period of time.*
3. *Frequency is the number of cycles that occur in a given period of time. The unit of measure is the hertz.*
4. *Time is the period of one cycle of alternating current. Period, time and duration are synonymous. The unit of measure is seconds.*
5. *The effective value or the root-mean-square (RMS) is the amount of current or voltage that produces the same amount of work as an equal amount of direct current or voltage.*

# Chapter 4 Self Test

*Answer the following questions.*

1. Alternating current

   a. must always be a sine wave of current.
   b. may be periodically reversing direction.
   c. is current which periodically reverses its direction.
   d. must always have a frequency of 40 cycles per second.

2. The term "hertz" means

   a. time.
   b. cycles.
   c. duration.
   d. Cycle per second.

3. The peak amplitude of an AC sine wave refers to the

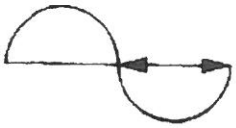
   a. duration of one cycle.
   b. time of one alternation.
   c. frequency of one alternation.
   d. maximum height of one alternation.

4. Effective voltage or current will do the same amount of work as

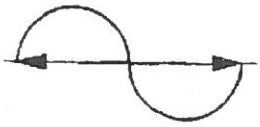
   a. an equal peak value of AC voltage or current.
   b. either alternation of AC voltage or current.
   c. an equal amount of DC voltage or current.
   d. the average voltage or current.

*Match the designated portion of the sine wave on the left with the appropriate term on the left.*

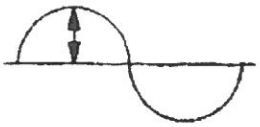
a.



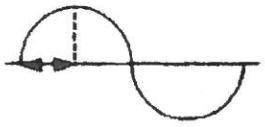
b.



c.



d.



| | |
|---|---|
| 5. _____ | Positive Peak |
| 6. _____. | Negative alternation |
| 7. _____. | 90 Degrees |
| 8._____. | One cycle |

*Convert the following values*

9. $30V_{pk}$ = _____ $V_{pk\text{-}pk}$

10. $11.5V_{pk}$ = _____ $V_{pk\text{-}pk}$

11. $200V_{pk}$ = _____ $V_{pk\text{-}pk}$

12. $5_{pk\text{-}pk}$ = _____ $V_{pk}$

13. $13V_{pk\text{-}pk}$ = _____ $V_{pk}$

14. $120V_{pk\text{-}pk}$ = _____ $V_{pk}$

15. $200V_{pk\text{-}pk}$ = _____ $V_{pk}$

16. $50V_{p}$ = _____ $V_{rms}$

17. $170V_{p}$ = _____ $V_{rms}$

18. f = 12.5kHz t = _____

19. f = 1MHz t = _____

20. f = 200Hz t = _____

21. f = 40kHz t = _____

22. t = 500µs f = _____

23. t = 12.5ms f = _____

24. t = .2s f = _____

25. t = 10µs f = _____

# Chapter 4- Activity-Answer Key

Activity 1

1. 10V
2. 200V

Activity 2

1. 100 Hz
2. .5µs

Activity 3

1. 40V
2. 200V
3. 100Hz
4. 125µs
5. 
    a. $40V_{pk-pk}$
    b. 20µs
    c. $55V_{pk}$
    d. 40Hz

# Chapter 4-Self Test-Answer Key

1. c
2. d
3. d
4. c
5. c
6. a
7. d
8. b
9. 60
10. 23
11. 400
12. 2.5
13. 6.5
14. 60
15. 100
16. 35
17. 120
18. 80µs
19. 1µs

20. 5ms
21. 25μs
22. 2kHz
23. 80Hz
24. 5Hz
25. 100kHz