MEEN 2210 Electromechanical Engineering Systems Spring 2011

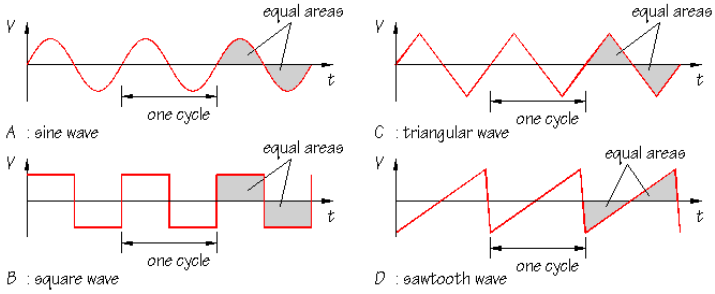
Studio Exercise # 1: Introduction to the Oscilloscope & Function Generator
Pre-Studio Reading

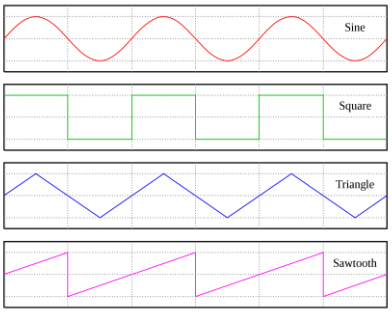
Analog Function Generator
INSTEK GFG-8215A

Digital Oscilloscope
HP 54602B 150MHz Oscilloscope

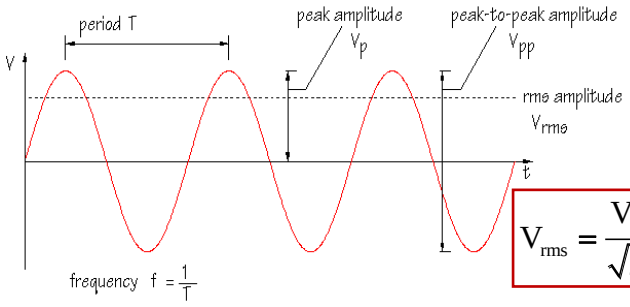
Waveform Graphs

- Typical voltage vs. time AC (alternating current, i.e., both positive and negative values, as opposed to DC, direct current, i.e., always positive or always negative) waveforms produced by a function generator are shown. The sine wave and square wave are the waveforms most often used.





- A **sine wave** has the same shape as the graph of the sine function used in trigonometry. Sine waves are produced by rotating electromechanical machines and electrical energy is transmitted to the consumer in this form. Sine waves are among the most useful of all signals in analyzing dynamic system performance.
  - Period T: The period is the time taken for one complete cycle of a repeating waveform. The period is often thought of as the time interval between peaks, but can be measured between any two corresponding points in successive cycles.
  - Frequency f: This is the number of cycles completed per second. The measurement unit for frequency is the hertz, Hz. 1 Hz = 1 cycle per second. f = 1/T. 1 kHz = 10^3 Hz and 1 MHz = 10^6 Hz.



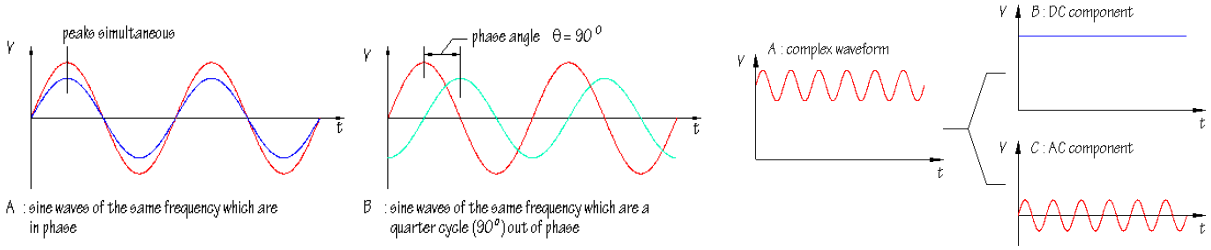
$$V_{rms} = \frac{V_p}{\sqrt{2}}$$

$$V(t) = V_p \sin(\omega t) = V_p \sin(2\pi f\, t)$$

$$\omega(\text{rad/s}) = 2\pi(\text{rad/cycle}) \times f(\text{cycles/s})$$

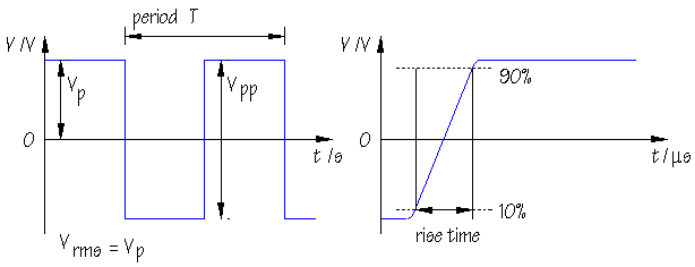
  - Amplitude: The amplitude, or height, of a sine wave is measured in three different ways. The peak amplitude, V_p, is measured from the t-axis, 0 V, to the top of a peak, or to the bottom of a trough. The peak-to-peak amplitude, V_{pp}, is measured between the maximum positive and negative values. In practical terms, this is often the easier measurement to make.
    - Although peak and peak-to-peak values are easily determined, it is often more useful to know the root mean square, or *rms* amplitude of the wave. The *rms* (root mean square) amplitude is the DC voltage which will deliver the same average power as the AC signal. For a sine wave, $V_{rms} = 0.707\ V_p$.
  - Phase: It is sometimes useful to divide a sine wave into degrees. Remember that sine waves are generated by rotating electromechanical machines. A complete 360° turn of the voltage generator corresponds to one cycle of the sine wave. Therefore 180° corresponds to a half turn, 90° to a quarter turn, and so on. Using this method, any point

on the sine wave graph can be identified by a particular number of degrees through the cycle. If two sine waves have the same frequency and occur at the same time, they are said to be <u>in phase</u>. On the other hand, if the two waves occur at different times, they are said to be <u>out of phase</u>. When this happens, the difference in phase can be measured in degrees, and is called the <u>phase angle</u>. As you can see, the two waves in part B are a quarter cycle out of phase, so the phase angle is 90°.



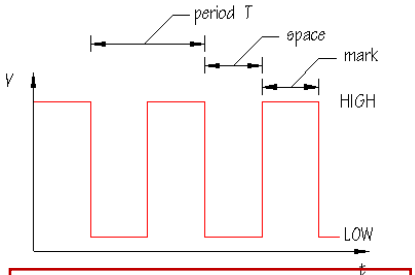
- Sine waves can be mixed with DC signals (a <u>DC offset</u>), or with other sine waves to produce new waveforms. Above is one example of a complex waveform.

- Like sine waves, **<u>square waves</u>** are described in terms of period, frequency and amplitude.
  - Peak amplitude, V_p, and peak-to-peak amplitude, V_{pp}, are measured as you might expect. However, the rms amplitude, V_{rms}, is greater than that of a sine wave. Remember that the *rms* amplitude is the DC voltage which will deliver the same power as the signal. If a square wave supply is connected across a lamp, the current flows first one way and then the other. The current switches direction but its magnitude remains the same. In other words, the square wave delivers its maximum power throughout the cycle so that V_{rms} is equal to V_p.



  - Although a square wave may change very rapidly from its minimum to maximum voltage, this change cannot be instantaneous. The rise time of the signal is defined as the time taken for the voltage to change from 10% to 90% of its maximum value. Rise times are usually very short, with durations measured in nanoseconds (1 ns = 10^{-9} s) or microseconds (1 μs = 10^{-6} s).

- **<u>Pulse waveforms</u>** look similar to square waves, except that all the action takes place above the time axis. At the beginning of a pulse, the voltage changes suddenly from a LOW level, close to the time axis, to a HIGH level, usually close to the power supply voltage. Sometimes, the frequency of a pulse waveform is referred to as its repetition rate. As you would expect, this means the number of cycles per second, measured in hertz. The HIGH time of the pulse waveform is called the mark, while the LOW time is called the space. The mark and space do not need to be of equal duration.



$$\text{duty cycle} = \frac{\text{High time}}{\text{period}} \times 100\%$$