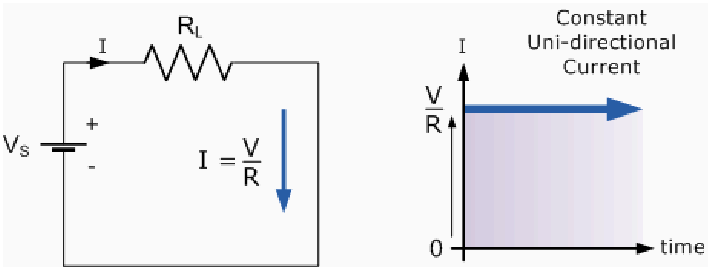
4. The AC Waveform

Direct Current or **D.C.** as it is more commonly called, is a form of current or voltage that flows around an electrical circuit in one direction only, making it a "Uni-directional" supply. Generally, both DC currents and voltages are produced by power supplies, batteries, generators or solar cells, etc. A DC voltage and current has a fixed magnitude (amplitude) and a definate direction associated with it. For example, +12V represents 12 volts in the positive direction, or -5V represents 5 volts in the negative direction. We also know that DC power supplies do not change their value with regards to time, they are a constant value flowing in a continuous steady state direction. In other words, DC maintains its value for all times. A uni-directional or DC supply never becomes negative unless its connections are physically reversed. An example of a simple DC or direct current circuit is shown below.

DC Circuit and Waveform



An alternating function or **AC Waveform** on the other hand is defined as one that varies in both magnitude and direction in more or less an even manner with respect to time making it a "Bi-directional" waveform. An AC function can represent either a power source or a signal source with the shape of an AC waveform generally following that of a mathematical sinusoid as defined by:- $A(t) = A_{max} \times \sin(2\pi f t)$.

The term AC or to give it its full description of Alternating Current, generally refers to a time-varying waveform with the most common of all being called a **Sinusoid** better known as a **Sinusoidal Waveform**. Sinusoidal waveforms are more generally called by their short description as **Sine Waves**. Sine waves are by far one of the most important types of AC waveform used in electrical engineering.

The shape obtained by plotting the instantaneous ordinate values of either voltage or current against time is called an **AC Waveform**. An AC waveform is constantly changing its polarity every half cycle alternating between a positive maximum value and a negative maximum value respectively with regards to time with a common example of this being the domestic mains voltage supply we use in our homes. This means then that AC waveforms are "time-dependent signals" with the most common type of time-dependant signal being that of the **Periodic Waveform**. The periodic or AC waveform is the resulting product of a rotating electrical generator. Generally, the shape of any periodic waveform can be generated using a fundamental frequency and superimposing it with harmonic signals of varying frequencies and amplitudes but thats for another tutorial.

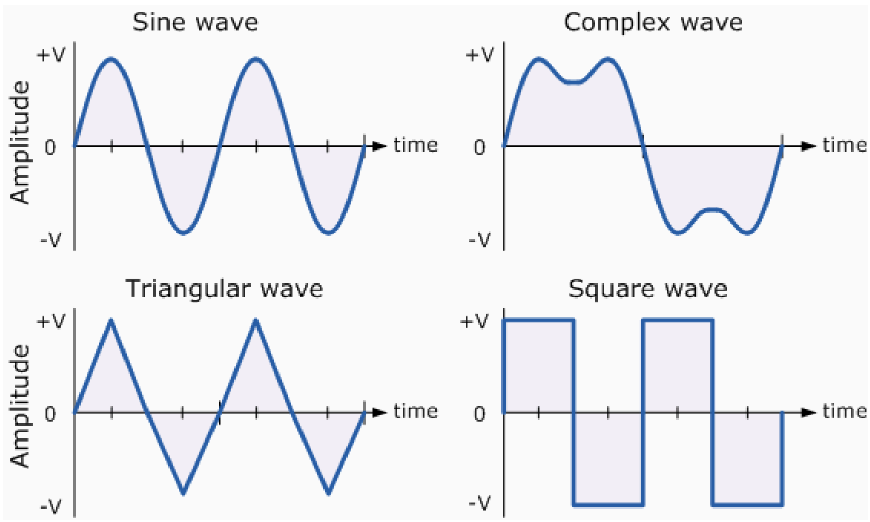
Alternating voltages and currents can not be stored in batteries or cells like direct current can, it is much easier and cheaper to generate them using alternators and waveform generators when needed. The type and shape of an AC waveform depends upon the generator or device producing them, but all AC waveforms consist of a zero voltage line that divides the waveform into two symmetrical halves. The main characteristics of an **AC Waveform** are defined as:

- The Period, (T) is the length of time in seconds that the waveform takes to repeat itself from start to finish. This can also be called the *Periodic Time* of the waveform for sine waves, or the *Pulse Width* for square waves.
- The Frequency, (f) is the number of times the waveform repeats itself within a one second time period. Frequency is the reciprocal of the time period, ($f = 1/T$) with the unit of frequency being the *Hertz*, (Hz).
- The Amplitude (A) is the magnitude or intensity of the signal waveform measured in volts or amps.

In our tutorial about **Waveforms** , we looked at different types of waveforms and said that "**Waveforms** are basically a visual representation of the variation of a voltage or current plotted to a base of time". Generally, for AC waveforms this horizontal base line represents a zero condition of either voltage or current. Any part of an AC type waveform which lies above the horizontal zero axis represents a voltage or current flowing in one direction. Likewise, any part of the waveform which lies below the horizontal zero axis represents a voltage or current flowing in the opposite direction to the first. Generally for sinusoidal AC waveforms the shape of the waveform above the zero axis is the same as the shape below it. However, for most non-power AC signals including audio waveforms this is not always the case.

The most common periodic signal waveforms that are used in Electrical and Electronic Engineering are the *Sinusoidal Waveforms*. However, an alternating AC waveform may not always take the shape of a smooth shape based around the trigonometric sine or cosine function. AC waveforms can also take the shape of either *Complex Waves*, *Square Waves* or *Triangular Waves* and these are shown below.

Types of Periodic Waveform



The time taken for an **AC Waveform** to complete one full pattern from its positive half to its negative half and back to its zero baseline again is called a **Cycle** and one complete cycle contains both a positive half-cycle and a negative half-cycle. The time taken by the waveform to complete one full cycle is called the **Periodic Time** of the waveform, and is given the symbol T. The number of complete cycles that are produced within one second (cycles/second) is called the **Frequency**, symbol f of the alternating waveform. Frequency is measured in **Hertz**, (Hz) named after the German physicist Heinrich Hertz.

Then we can see that a relationship exists between cycles (oscillations), periodic time and frequency (cycles per second), so if there are f number of cycles in one second, each individual cycle must take $1/f$ seconds to complete.

Relationship Between Frequency and Periodic Time

$$\text{Frequency}, (f) = \frac{1}{\text{Periodic Time}} = \frac{1}{T} \quad \text{Hertz}$$

or

$$\text{Periodic Time}, (T) = \frac{1}{\text{Frequency}} = \frac{1}{f} \quad \text{seconds}$$

Example No1

1. What will be the periodic time of a 50Hz waveform and 2. what is the frequency of an AC waveform that has a periodic time of 10mS.

1).

$$\text{Periodic Time, } (T) = \frac{1}{f} = \frac{1}{50} = 0.02\text{Secs or } 20\text{mS}$$

2).

$$\text{Frequency, } (f) = \frac{1}{T} = \frac{1}{10 \times 10^{-3}} = 100\text{Hz}$$

Frequency is specified in units called Hertz and for the domestic mains supply this will be either 50Hz or 60Hz depending upon the country and is fixed by the speed of rotation of the generator. But one hertz is a very small unit so prefixes are used that denote the order of magnitude of the waveform at higher frequencies such as **kHz**,**MHz** and even **GHz**.

Prefix	Definition	Written as	Periodic Time
Kilo	Thousand	kHz	1mS
Mega	Million	MHz	1uS
Giga	Billion	GHz	1nS
Terra	Trillion	THz	1pS

Amplitude of an AC Waveform

As well as knowing either the periodic time or the frequency of the alternating quantity, another important parameter of the AC waveform is **Amplitude**, better known as its Maximum or Peak value represented by the terms, V*max* for voltage or I*max* for current. The peak value is the greatest value of either voltage or current that the waveform reaches during each half cycle measured from the zero baseline. Unlike a DC voltage or current which has a steady state that can be measured or calculated using **Ohm's Law**, an alternating quantity is constantly changing its value over time. For pure sinusoidal waveforms this peak value will always be the same for both half cycles (+Vm = -Vm) but for non-sinusoidal or complex waveforms the maximum peak value can be very different for each half cycle. Sometimes, alternating waveforms are given a

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Formateret: Skrifttype: (Standard) Arial, 9 pkt, Skriftfarve: Brugerdefineret farve (RGB(0;0;64)) *peak-to-peak*, V*p-p* value and this is simply the distance or the sum in voltage between the maximum peak value, +V*max* and the minimum peak value, -V*max* during one complete cycle.

Ref: http://www.electronics-tutorials.ws/accircuits/AC-waveform.html

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