Alternating Current

A closer look at AC (3f.1)

THE FOUNDATION TRAINING introduced the idea that current does not always flow in a single direction; it can alternate in direction. It should be fairly obvious that as alternating current passes back and forth through a resistor, the potential difference across that resistor will rise and fall in accordance with Ohm's law.

Similarly, having grasped that energy is transferred as heat in resistors and bulbs when a direct current passes through them in worksheet 12, it will be no surprise to hear that energy is transferred as heat in much the same way when alternating current passes through the same components; in resistive circuits the direction of travel is immaterial.

This rise and fall of the current and potential difference is normally shown graphically as a sine wave curve, as shown in **Fig 24.** You saw a similar sine wave in the Foundation training to illustrate the varying values of potential difference and current over time. In electronics there are many other waveforms, such as 'square' and 'saw tooth', but in radio circuits we are normally dealing with sine waves. Two of the key features of the sine wave need to be specified for it to be meaningful; the amplitude and the frequency.

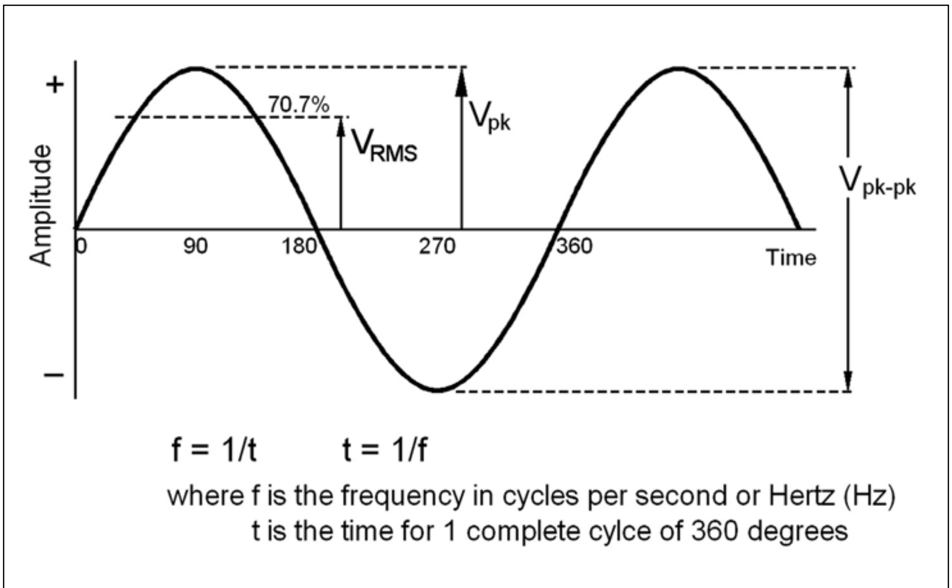


Fig 24. A Sine Waveform showing the relationships between Peak, Peak-to-Peak and RMS and between time and frequency. The numbers on the time line are degrees of the cycle; 360 degrees in one full cycle, just like a circle. Degrees are not used at Intermediate level but will be useful in later studies.

Amplitude

THE AMPLITUDE IS represented by the 'height' of the peaks or the 'depth' of the troughs in the sine wave; the difference between zero and the maximum value above, or below, zero. The vertical scale could show volts or amps, depending on which property is being described. The peak is more correctly referred to as a positive peak and the trough as a negative peak, which is usually a mirror image of the positive peak.

There are three values associated with the amplitude of the sine wave; peak, peak-to-peak and RMS. They are shown in **Fig 24** but let's look at what these terms actually mean.

The peak value $_{(pk)}$ is the difference between zero and a positive or negative peak. It matters not whether you are looking at the positive or the negative peak, the peak value of a sine wave does not normally have a +/- sign. A peak value for potential difference would be shown as $V_{(pk)}$.

The peak-to-peak value $_{(pk-pk)}$ is the difference between the positive and the negative peaks. It should not come as a shock to know that the peak-to-peak value is double the peak value. Again, there is no +/- sign. A peak-to-peak value for potential difference would be shown as $V_{(pk-pk)}$.

The RMS value is a kind of average, known as the Root Mean Square value. Because the instantaneous value of a sine wave signal is constantly changing the average is not simply half of the peak value and there is a formula that you will have to remember. The actual formula is RMS= pk/√2, which you may be asked to identify and/or use in the exam.

You may find it easier to remember that if you work the formula through you find that the RMS value is the peak value multiplied by 0.707. For most purposes you can use 0.7 to calculate the ballpark value. For example, if you have a sine wave with a peak value of 100 volts, the RMS 'average' would be about 70 volts (actually 70.7 volts but Intermediate exam questions are unlikely to require that degree of accuracy).

The other important thing to remember about the RMS value is its technical definition; the RMS value is equal to the current or potential difference of a direct current supply that would result in the same power dissipation. In the example above, 70V DC would dissipate around the same power as $100V_{(pk)}$ of AC across the same resistor.

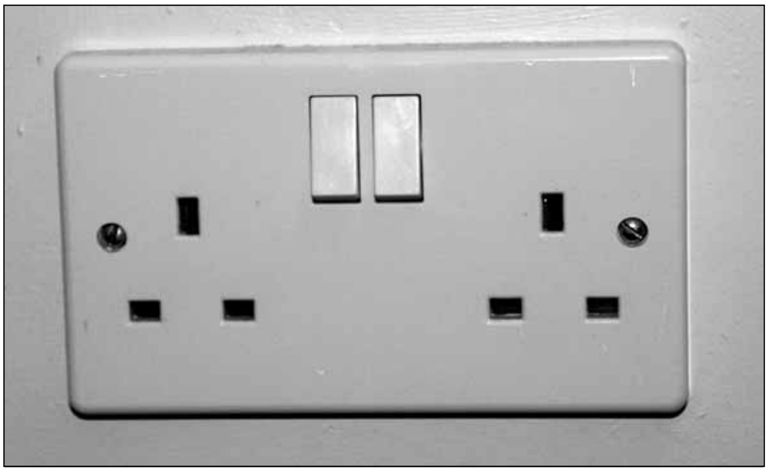
This is important to remember if you need to calculate the power being dissipated in an AC circuit; Ohm's law still applies, but you *must* use the RMS value, not the peak, or the peak-to-peak! For example, if the question asked how much power was dissipated in a transmitter when a $200V_{(pk)}$ AC power supply delivers a current of $1A_{(pk)}$ to it, it would be tempting to merely multiply the 200V by 1A and get 200W as the answer. However, we must use the RMS values, 140V ($200V_{(pk)}$ x 0.7) and 0.7A ($1A_{(pk)}$ x 0.7), which will give a power of around 98W, quite a difference from the 200W the peak values would give.

It is worth noting that some other books you might read may use slightly different notations for RMS, peak and peak-to-peak. Don't be confused by 'rms' or 'r.m.s', they mean the same as RMS. Similarly, if you see 'PK', it is the same as 'pk' in this book.

Frequency (3a.1 & 3f.1)

THE FREQUENCY OF an alternating current is the number of times the sine wave goes through its cycle in one second. A cycle is best visualised as one full transition from zero through a positive peak, back to zero, through a negative peak and ending back at zero, although the start point may not necessarily be zero in every case. See **Fig 24** on previous page. You should recall from your Foundation studies that the unit of measurement for frequency is ‘cycles per second’ or ‘Hertz’ (Hz). Radio frequencies are generally measured in kilohertz (kHz: thousands of cycles per second), megahertz (MHz: millions of cycles per second) and gigahertz (GHz: thousands of millions of cycles per second).

You are unlikely to be able to show the total number of cycles in one second on a sine wave diagram, and even if you could, counting the thousands, or millions, of cycles would be quite a challenge! However, if you have a sine wave curve showing a single cycle with the time marked along the horizontal scale it would be quite simple to read off the time taken for that single cycle to take place and from this you can work out the frequency; if you know the time for one cycle, dividing 1 second by the cycle time will tell you how many cycles will occur in that 1 second. Again, see **Fig 24** for a pictorial view.



Mains power is A.C.

Let’s try an example or two. If the cycle time was half a second (0.5s), you would get two cycles in one second and the frequency would be 2Hz. If the cycle time was one millionth of a second (0.000001s) you would have one million cycles in one second and the frequency would be 1MHz.

There is formula that makes it easy to work out frequency (f) if you know the cycle time (t): $f = 1/t$. You will need to commit this to memory as it could crop up in the exam. You may also be asked to work out the cycle time of a given frequency. In that case you can rearrange the formula so that $t = 1/f$. For example, the cycle time of a 3kHz audio tone would be 1 divided by 3000 = 0.000333s or 333µs.

You may be thinking ‘so what?’ or ‘How useful is this in real life?’ Well, there is a piece of test equipment known as an oscilloscope that displays alternating currents as sine waves and they are calibrated in fractions of a second. So knowing that $f = 1/t$ allows you to ‘measure’ the frequency of an AC signal, or at least confirm that a signal is at the frequency you are expecting. You will learn more about oscilloscopes if you move on to the Advanced training for the Full Licence.