Reading 10

Ron Bertrand VK2DQ
http://www.radioelectronicschool.com

ALTERNATING CURRENT - PART 2

In the last reading we discussed how an alternating current, or voltage, can be produced using a generator,

We are now going to look more closely at the shape (waveform) of this AC voltage. Recall how we discussed that the voltage starts out at zero, builds up to a maximum, then falls to zero. The polarity of the voltage then reverses. It builds up to a maximum again and then falls back to zero. This is one cycle. How many cycles in a second we have, is called the frequency and is measured in Hertz.

Now the shape (waveform) of the wave from a generator is called a sine wave or sinusoidal wave. Most textbooks just flash this shape in front of you and say here it is. When I was learning I found the concept of a sine wave a little difficult, so I am going to assume the same for you.

A sine wave is the graphical representation of the alternating current or voltage plotted against time.

AN EXPERIMENT

Get your self a piece of paper, about A4. On the left hand side of the paper place a pen down and draw a vertical line about 50 mm long. Now continue to trace over the line going up and down, over and over. Consider the centre of this line to represent zero volts. Why aren't you doing it?

Continue to move your pen up and down, redrawing the line. I want you to think that the middle of the line represents zero volts. Your pen moving upwards toward the top of the line represents current or voltage increasing in one direction. When you get to the top move down again, and you eventually pass through the zero point. Once through zero your pen movement is now representing a change in the direction of the current and it begins to increase towards the bottom of the line, which represents maximum current in this direction. When you reach maximum at the bottom your pen now moves back toward the zero point and so on.

So you are sitting there copying over this vertical line. Do it reasonably quickly and get used to it.

Now without stopping your up and down motion, move your hand to the right without even thinking about the pen.

This is what I got, shown below in figure 1, though I have added a couple of notations.

Rough as guts but it does illustrate clearly the waveshape of an alternating current plotted against time. The waveshape is called a sine wave.

An AC voltage can be fed into an oscilloscope and its screen will display the waveform precisely. Refer to figure 1 below.

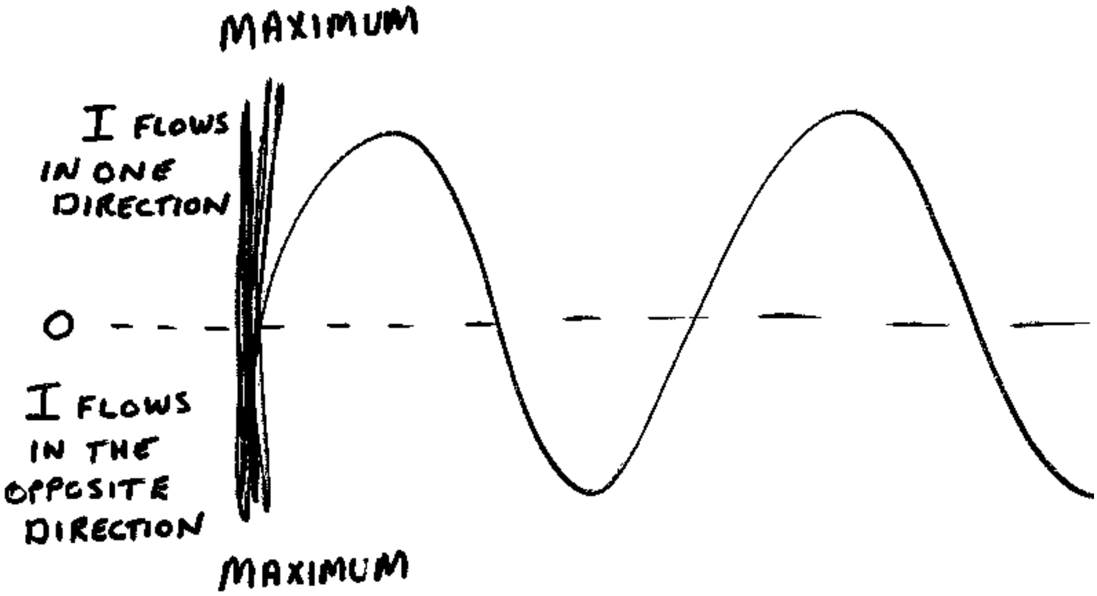

Figure 1 – Sketch showing alternating current plotted against time

This is how you will see the sine wave represented in most textbooks. The positive and negative symbols I find can be a little confusing. Just think of positive as being current flow in one direction and negative as current flow in the opposite direction. How many cycles you see will depend on the time scale on the horizontal axis. On an oscilloscope the horizontal and vertical axes are calibrated accurately in time and voltage. So we can actually read things like the maximum voltage, and we can work out the frequency in Hertz (number of cycles per second).

The shape of the AC voltage delivered to you home is a sine wave. A signal from a radio transmitter, without modulation, is also a sine wave.

Now one cycle, or if you like, revolution, is 360 degrees. Table 1 below shows the values of the voltage or current for any sine wave at different parts of the cycle. 'Sin' is a trigonometric function that you need not be concerned about. Though you will find the 'Sin' key on most calculators and if you enter say 30 into the calculator and press 'Sin' you will get 0.5.

This is why the waveform is called a sine wave.

Degrees	Sin (degrees)	Voltage
0	0	Zero
30	0.500	50% of maximum
45	0.707	70.7% of maximum
60	0.866	86.6% of maximum
90	1.000	Positive maximum
180	0	Zero
270	-1.000	Negative maximum
360	0	Zero

Table 1.

VOLTAGE AND CURRENT VALUES FOR A SINE WAVE

Suppose you were buying electricity from Edison or Tesla. They both have the same energy charge (kilowatt-hours). However, Edison says he will supply you with 100 volts direct current (DC), none of this sine wave stuff from him. He offers to provide 100 volts just like you would get from a battery. No current reversals. Tesla offers you 100 Volts AC. Who do you buy electricity from?

Well Edison's offer is very straightforward. Tesla on the other hand is offering a sinusoidal wave and you would have to ask more questions if his company said they were just going to supply you with 100 volts. When is it 100 Volts? At the peak value of each half cycle? Which would mean that you would only get 100 volts for a brief moment twice during each cycle. Does this matter? You bet it does. If you were in the middle of winter in front of the electric bar heater you would want 100 volts all the time not just for a brief period each half cycle.

100 volts peak AC will not produce the same heating effect as 100 volts DC. So there is a need to be able to compare the two, AC and DC that is, in terms of heating effect.

It can be found by math or by experiment that the equivalent heating effect of a sinusoidal waveform compared to DC is 0.707 of its peak value. This value is known as the root mean square or effective value and just written RMS.

So if Tesla was to supply 100 volts peak, the actual equivalent heating value would be:

0.707 x 100 = 70.7 volts RMS,

in which case you would go for Edison's deal.

The average value of a sine wave is:

Peak x 0.637

I have never found a use for this value myself.

Sometime an AC voltage is given as Peak to Peak. So if the maximum peak voltage was 100 volts, then the peak to peak value would be 200 volts - again a need to know, however I have never found any use in the peak to peak value.

Your household electricity supply is 240 Volts RMS. This means it provides the same heating value as 240 Volts DC. What is the peak value of the household power supply in Australia?

RMS = 0.707 x Peak

Transpose for Peak by dividing both sides by 0.707

Peak = RMS/0.707 = 240/0.707 = 339.46 Volts

So twice during each cycle the household mains voltage actually reaches 339 volts. The frequency of the household supply is 50 Hertz. How many times a second does the mains voltage reach 339 volts?

Since there are 50 cycles per second and two peaks during each cycle, the supply voltage will reach 339 volts 100 times each and every second.

Summary of equations

RMS = 0.707 x Peak
Peak = RMS / 0.707
Average = Peak x 0.637
Peak-to-Peak = Peak x 2 = 2.828 x RMS

Note: 1/0.707 is 1.414 and 1.414 is the square root of 2

The time taken for one cycle of AC is called the period.

What is the period of the household mains in Australia?
Since the frequency is 50Hz, there are 50 cycles in 1 second. Therefore 1 cycle has a period of 1/50th of a second or 20 milliseconds.

Period = 1 / frequency.

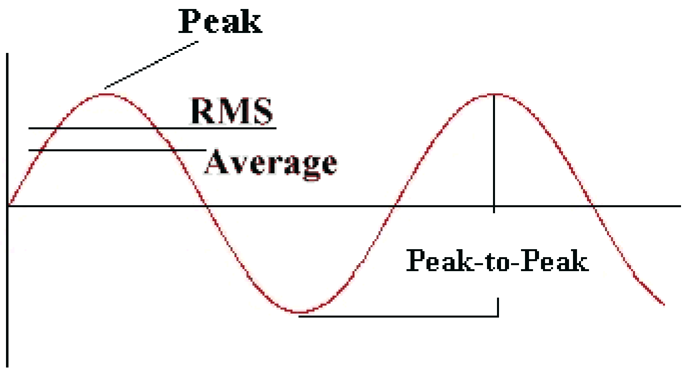

Figure 2.

WHAT DOES ROOT MEAN SQUARE REALLY MEAN?

This information is given for interest.

We have learnt what the RMS value of an AC voltage means. We also know the RMS value is 0.707 of the peak. However, what is the term 'root mean square'?

The factor 0.707 for RMS is derived as the square root of the average (mean) of all the squares of a sine wave. Now, if that stills sounds like gobbledygook, let me show you how it is done and at least we will take away the mystery of the term RMS.

Interval	Angles	Sin(angle)	Sin(angle)^2
1	15	0.26	0.07
2	30	0.50	0.25
3	45	0.71	0.50
4	60	0.87	0.75
5	75	0.97	0.93
6	90	1.00	1.00
7	105	0.97	0.93
8	120	0.87	0.75
9	135	0.71	0.50
10	150	0.50	0.25
11	165	0.26	0.07
12	180	0	0.00
	Total	7.62	6.00
	Average	7.62/12 = 0.635	SQRT(6/12) = 0.707

Table 2.

The average value is a little out due to there not being a sufficient number of intervals. The RMS value is spot on. So now you know how RMS is derived using math.

WHAT'S IN A NAME?

Michael Faraday, who became one of the greatest scientists of the 19th century, began his career as a chemist. He wrote a manual of practical chemistry that reveals his mastery of the technical aspects of his art. He discovered a number of new organic compounds, among them benzene, and was the first to liquefy a "permanent" gas (ie., one that was believed to be incapable of liquefaction). His major contribution, however, was in the field of electricity and magnetism. He was the first to produce an electric current from a magnetic field; invented the first electric motor and dynamo; demonstrated the relationship between electricity and chemical bonding; discovered the effects of magnetism on light; and discovered and named diamagnetism, the peculiar behaviour of certain substances in strong magnetic fields. He provided the experimental, and a good deal of the theoretical, foundation upon which James Clerk Maxwell erected classical electromagnetic field theory.

Nikola Tesla (b. July 9/10, 1856, Smilijan, Croatia. d. Jan. 7, 1943, New York City), Serbian-American inventor and researcher who discovered the rotating magnetic field, the basis of most alternating-current machinery. He immigrated to the United States in 1884 and sold the patent rights to his system of alternating-current dynamos, transformers, and motors to George Westinghouse the following year. In 1891 he invented the **Tesla** coil, an induction coil widely used in radio technology. **Tesla** was from a family of Serbian origin. His father was an Orthodox priest; his mother was unschooled but highly intelligent. A dreamer with a poetic touch, as he matured **Tesla** added to these earlier qualities those of self-discipline and a desire for precision.

Thomas Alva Edison was the quintessential American inventor in the era of Yankee ingenuity. He began his career in 1863, in the adolescence of the telegraph industry, when virtually the only source of electricity was primitive batteries putting out a low-voltage current. Before he died in 1931, he had played a critical role in introducing the modern age of electricity. From his laboratories and workshops emanated the phonograph, the carbon-button transmitter for the telephone speaker and microphone, the incandescent lamp, a revolutionary generator of unprecedented efficiency, the first commercial electric light and power system, an experimental electric railroad, and key elements of motion-picture apparatus, as well as a host of other inventions. Singly or jointly he held a world-record 1,093 patents. In addition, he created the world's first industrial-research laboratory. Born in Milan, Ohio, on Feb. 11, 1847, **Edison** was the seventh and last of four surviving children of Samuel **Edison** Jr. and Nancy Elliott **Edison**. At an early age he developed hearing problems, which have been variously attributed, but were most likely due to a family tendency to mastoiditis. Whatever the cause, **Edison**'s deafness strongly influenced his behaviour and career, providing the motivation for many of his inventions.

End of Reading 10.
Last revision: November 2001
Copyright © 1999-2001 Ron Bertrand
E-mail: manager@radioelectronicschool.com
http://www.radioelectronicschool.com
Free for non-commercial use with permission