Diploma of Audio Production   Name________________

Analogue Fundamentals

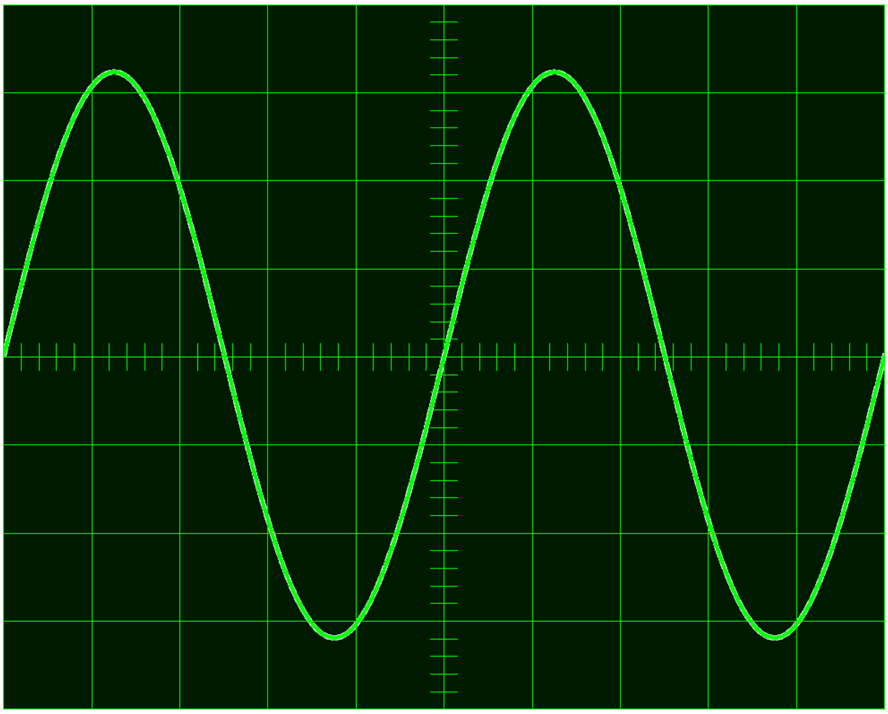
Module 4

AC/DC and the Sine Wave

Up to this point we have focused on DC (Direct Current). Apart from batteries as a source of power such as in a guitar FX pedal for instance in most cases we derive this source of EMF from a Power Supply. A typical power supply takes the mains power, which is Alternating Current (AC), and converts it to whatever useful Direct Current (DC) is required for the device. We also know that with DC the current only flows in one direction and that direction, in the case of "Electron Flow", is from **Negative** to **Positive.**

So in this session we are going to look at **AC** or **Alternating Current** where the current flows in 2 directions. The primary source of the EMF is a "Sine Wave" and in the case of the "mains" supply it has a frequency of 50 Hz.

Well what do we know about a Sine Wave? Well, on a Cathode Ray Oscilloscope, it looks like this:



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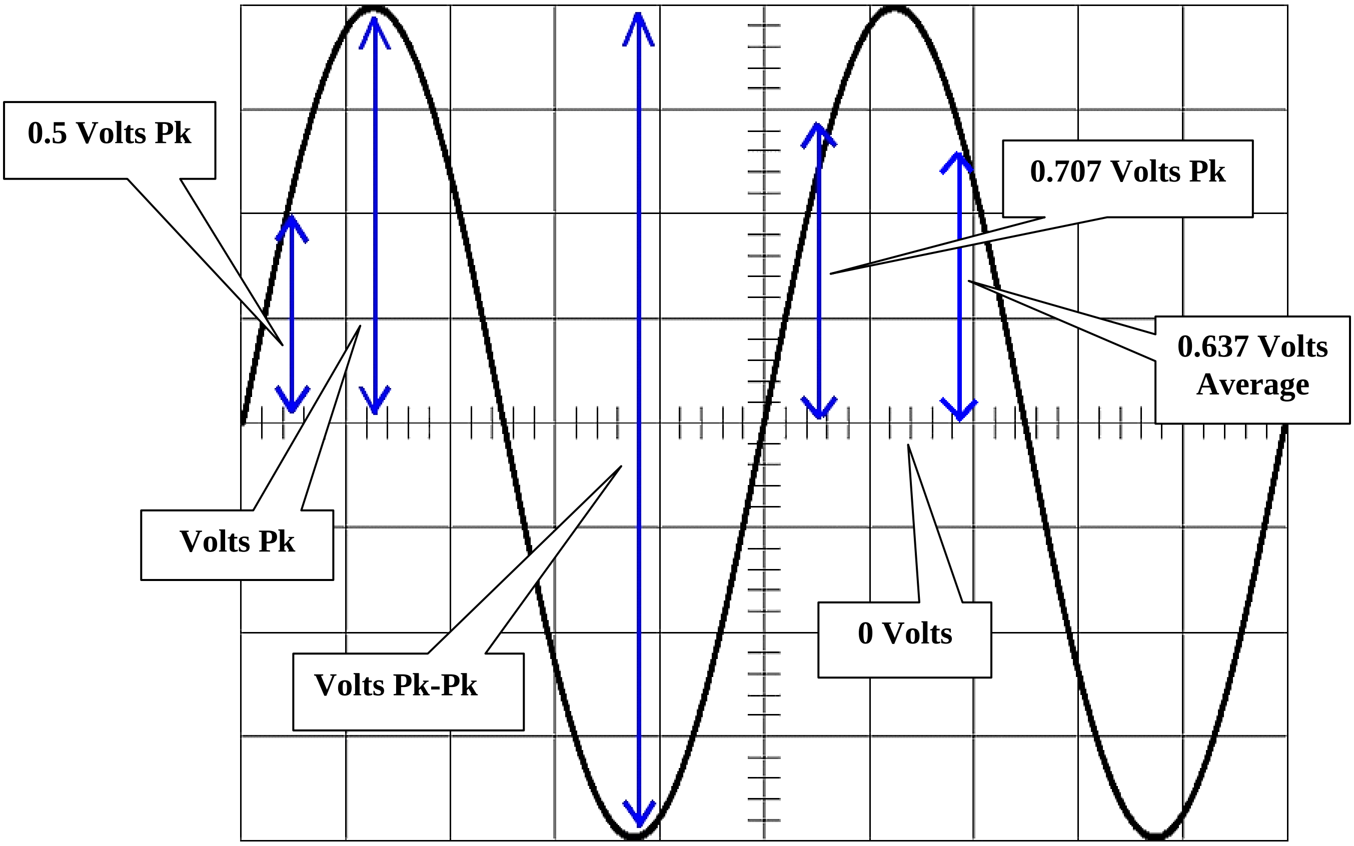
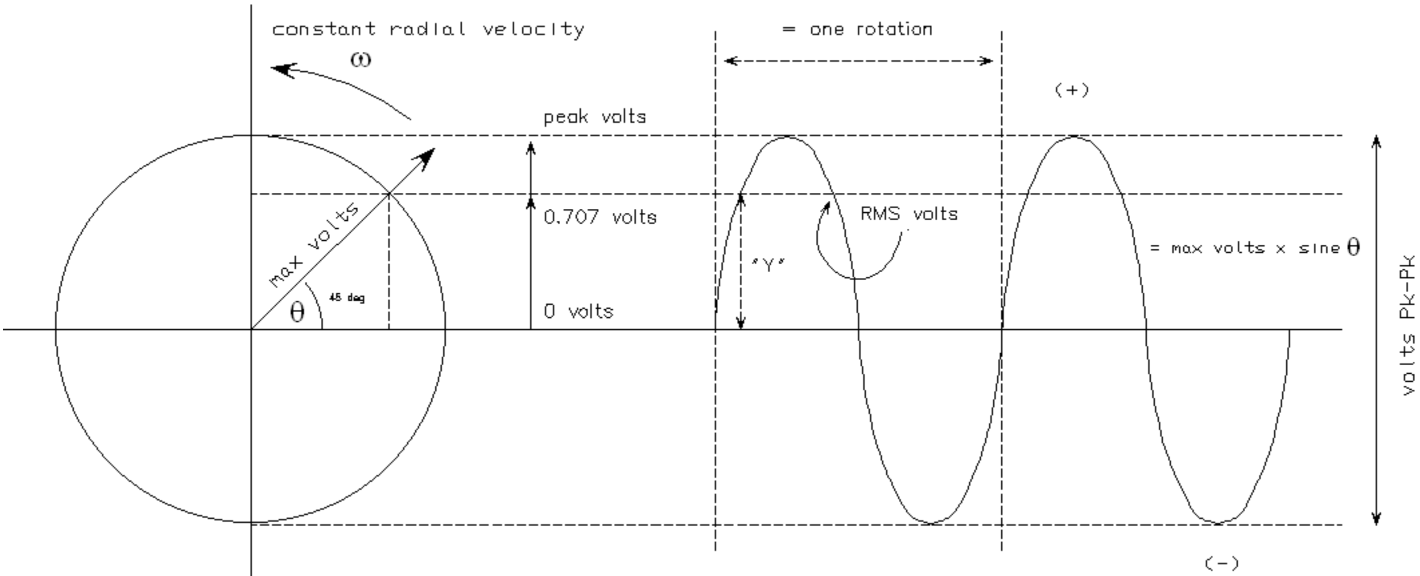
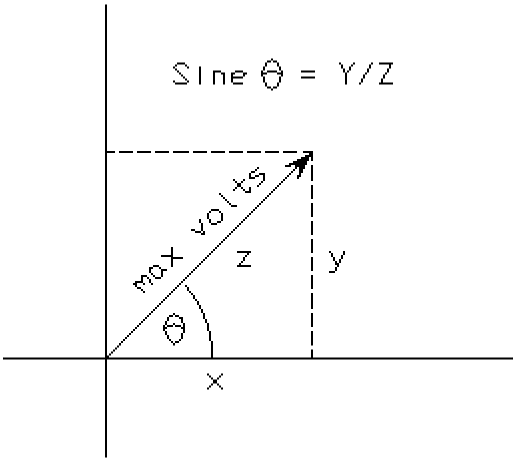
Here is a list of characteristics that can apply to this waveform but lets have a look at a drawing of one first up.



But is *why* is a 'Sine Wave' called a sine wave?
Imagine a straight line representing a fixed voltage rotating in a circle at a constant rate (this is known as the radial velocity which = **2πƒ;** denoted by the symbol **ω**)



The Sine of the angle of the radian (θ), which equals the line opposite the angle divided by the line adjacent the angle on the diagram (Y/Z). Transposing this we get; any moment, **'Y' = Sine θ x Volts** $^{\textbf{Peak.}}$

<table>
<tr>
<td>
</td>
<td>When θ = 45 °, sine θ = $^{1}/\sqrt{2} \cong 0.707$

When θ = 30 °, sine θ = 0.5

When θ = 90 °, sine θ = 1

When θ = 0 °, sine θ = 0

One complete cycle of the wave goes through one revolution of the circle, or 360 ° of "phase".</td>
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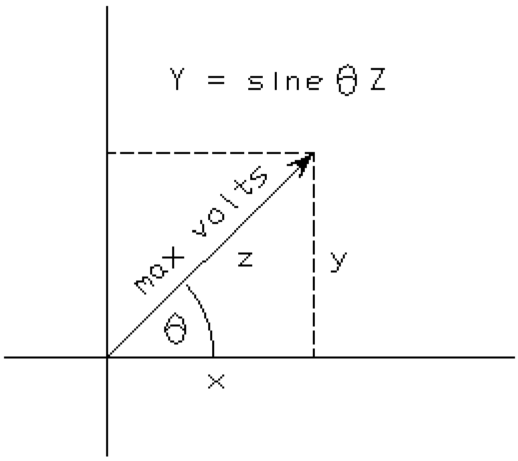
<tr>
<td>
</td>
<td>When θ = 45 °, sine θ = $^{1}/\sqrt{2} \cong 0.707$

∴ Y = RMS of Volts ^{Peak}

When θ = 90 °, sine θ = 1 ∴ V^{Pk} has been reached at the top (or the bottom) of the wave.

When θ = 0 °, sine θ = 0. At this point the wave is crossing at the zero line.</td>
</tr>
</table>

Characteristics of a sine wave:

1. Average Voltage of a sine wave is "Zero" (0 volts)
2. Is the purest of waveforms and as such has no <u>Harmonics</u>
3. Its frequency or pitch can be determined if we know the time for one complete cycle.
4. The frequency is expressed in Hertz (Cycles per Second)

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5. Its amplitude (Voltage level) can be expressed in the following 3 ways;
   a) Peak to Peak (V $^{pk-pk}$)
   b) Peak (V ^{pk})
   c) RMS (Most Common) (V ^{RMS})

6. There are 360° in one complete cycle.

7. The shape of the waveform dictates that it reaches half the maximum peak amplitude at the 30° point. At the 45° degree point the amplitude is 0.707 of the Peak amplitude.

Getting technical:

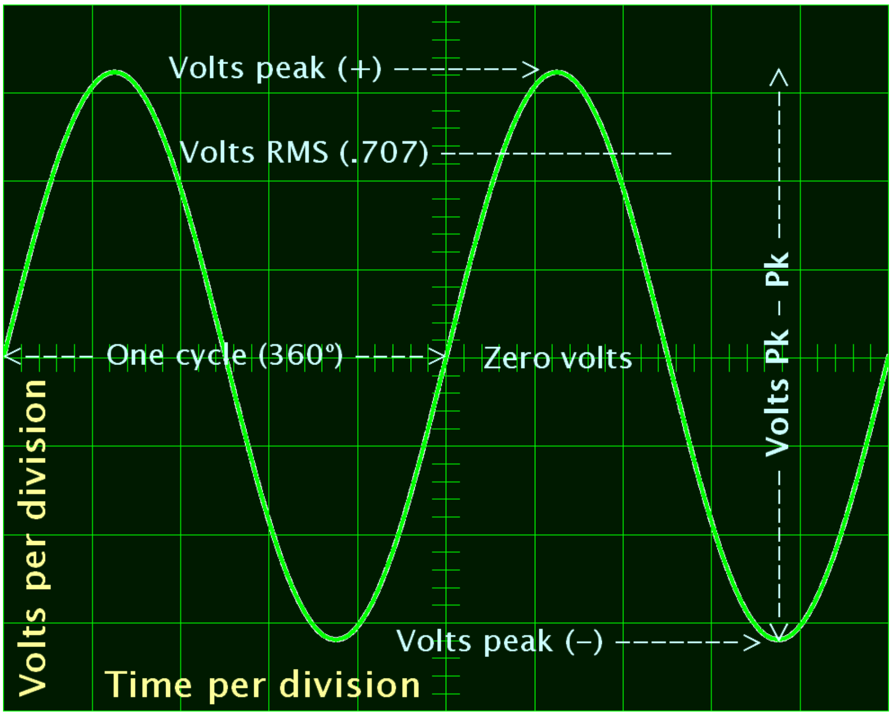
Volts RMS (Root Mean Square) of a sine wave $= \dfrac{\text{Volts Peak}}{\sqrt{2}}$

… or put more straight forwardly, Volts RMS = Volts ^{Peak} x .707

To convert Volts RMS to Volts Peak V ^{Peak} = V ^{RMS} x $\sqrt{2}$

… or more easily put: V ^{Peak} = V ^{RMS} x 1.414

… and Volts RMS $= \dfrac{\text{Volts}^{\text{Peak-Peak}}}{2} \times .707$



Expressing Amplitudes

It should be obvious that the peak-to-peak amplitude is twice the peak amplitude and therefore the peak is half the peak to peak.

But what's this Root Mean Square (RMS) all about? This enables us to calculate the ***power*** coming from an AC waveform.. **The RMS voltage gives us the information we need to calculate the power being dissipated in an AC circuit.**

In real terms the RMS voltage of a sine wave will do the same "Work" as the same DC voltage. It is said to have the same "heating" effect as the equivalent DC Voltage.
So any time we are working out RMS currents in a circuit or RMS power dissipated in a circuit we **must** use the **RMS voltage**..

To calculate the RMS voltage from the Peak-to-Peak voltage we must first divide by 2 and then multiply by 0.707.

Formula wise

$$\textbf{RMS} = \frac{\textbf{peak to peak}}{\textbf{2}} \times \textbf{0.707}$$

Lets have a look at some example calculations.

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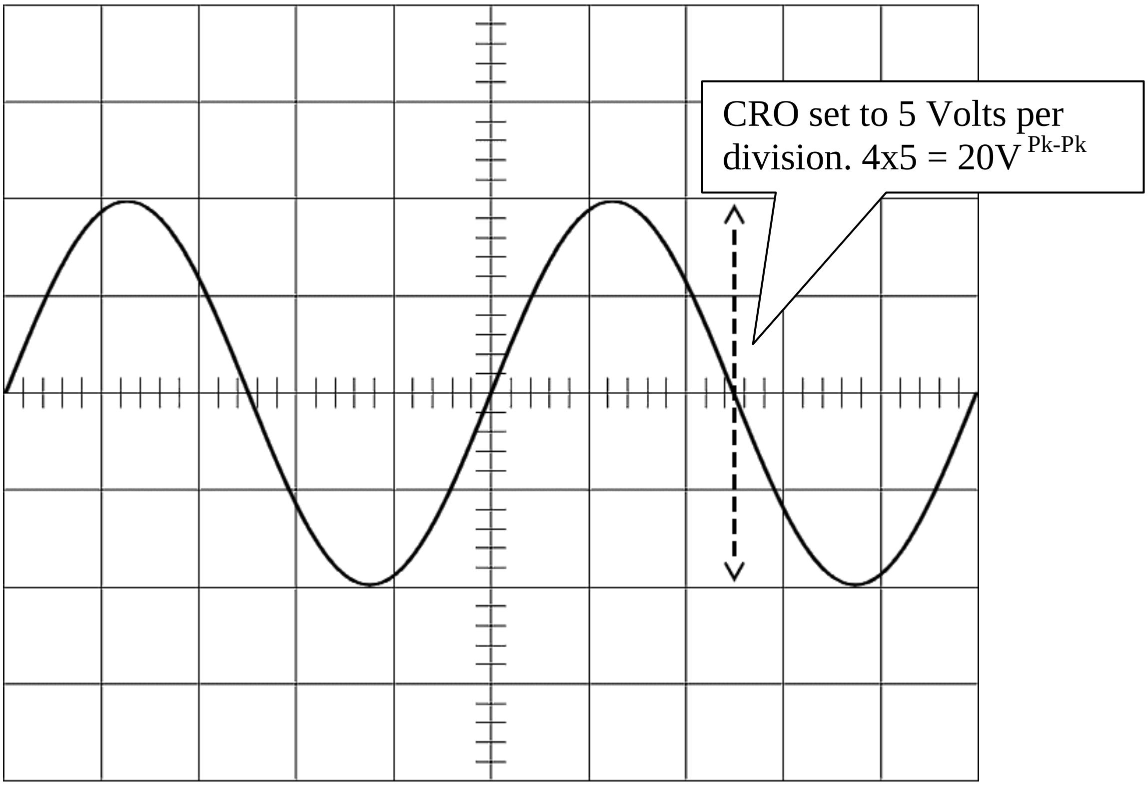

Given the sine wave shown above has an amplitude of 20 volts peak to peak calculate its RMS value.

$$\textbf{RMS} = \frac{\textbf{Pk – Pk}}{2} \times 0.707$$

$$= \frac{\textbf{20 Volts}}{2} \times 0.707$$

= 10 Volts x 0.707

= 7.07 Volts RMS

OK here are some problems for you to work out.

Convert all the following to RMS

1. 10 Volts P-P
2. 100 Volts P-P
3. 2 Volts P-P
4. 50 Volts P-P
5. 8 Volts P-P

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6. 10 Volts Peak

If we know the RMS can we work out the Peak, Peak to Peak or both?

I think we should be able to by changing the formula around.

So given $$\mathbf{RMS = \frac{V^{pk-pk}}{2} \times 0.707}$$

$$\mathbf{Volts\ RMS \times 2 = V^{pk-pk} \times 0.707}$$

$$\mathbf{\frac{Volts\ RMS \times 2}{0.707} = V^{pk-pk}}$$

And to convert the answer to Peak, simply divide the answer by 2

Problem.

Convert 7.07 volts RMS to Peak to Peak. (It was one we looked at earlier)

Also we should note that if we divide 0.707 into 1 the answer would be 1.414. So dividing by 0.707 will give us the same result as multiplying by 1.414.

You should try this to prove this is correct.

Here are some other short cuts when converting RMS to Peak and Peak to Peak.

Where would we see this “alternating” voltage sine wave as a peak-to-peak waveform? If you said the CRO or scope you are dead right ..

But if we measure this voltage with a DMM (Digital Multi-Meter) it will give us the RMS value direct.

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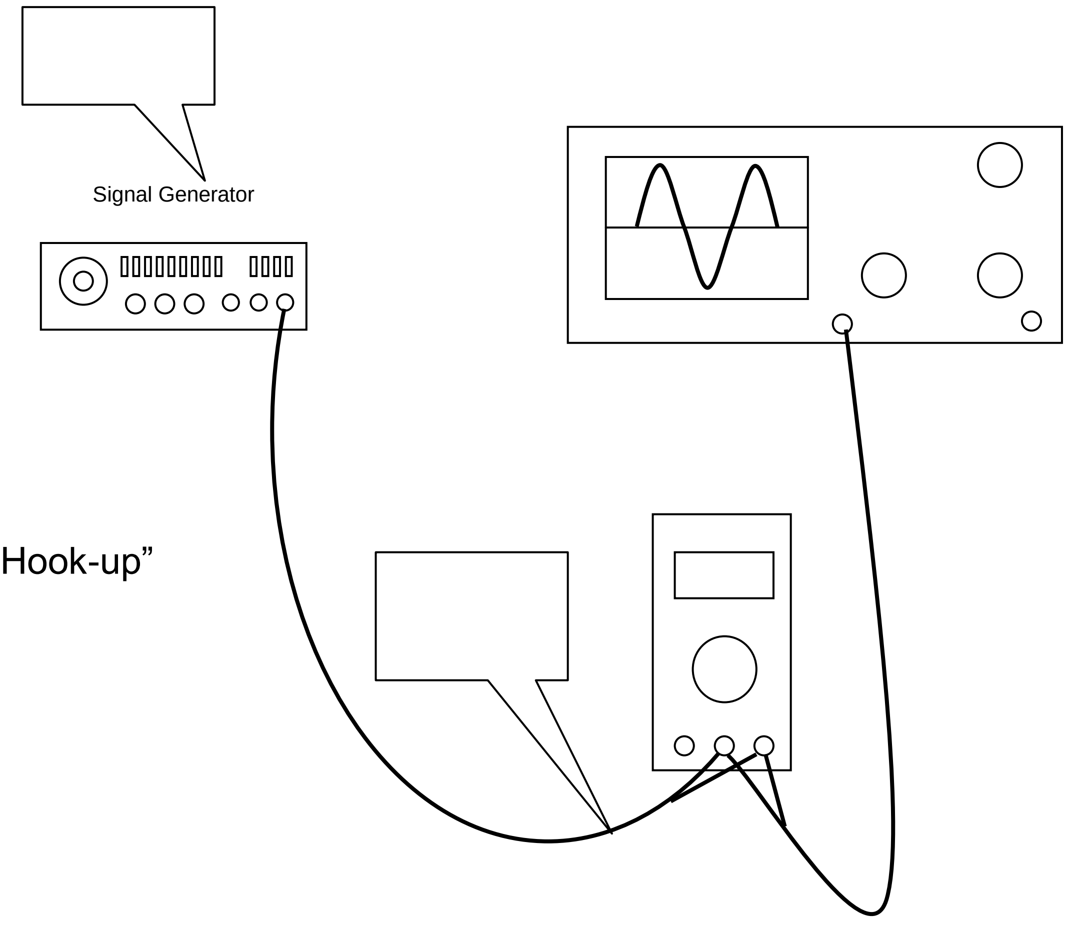
Prac exercise:

Aim to measure the RMS value of a Peak-to-Peak sine wave as viewed on the CRO.

Set up a 10 volts peak–peak (10 V $^{pk\text{-}pk}$) 1 Kilo Hertz waveform on the CRO using the signal generator. (Make sure the CRO's input is calibrated; remember the small knob in the centre of the volts per division switch. It has to be turned fully clockwise – gently)
Once you have done this check the reading with the DMM. It should give a reading around 3.5 Volts approximately.

Do the same for 8 Volts P – P and 1 volts $^{Pk-Pk}$.



Basic "Hook-up"

Using the Scope to measure period of the waveform. (Remember the period is the time taken for the waveform to complete one cycle and is usually measured in Seconds)

Looking at the waveform the period can be determined by measuring the time taken between to identical points on the waveform.

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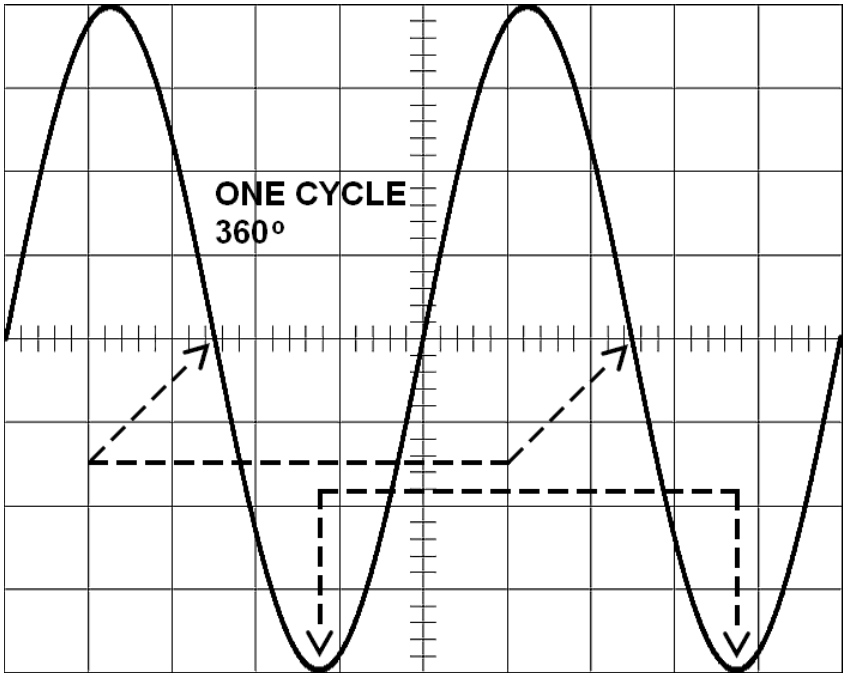

More on waveforms and audio next session.

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