Using Oscilloscopes

Author	Message

mechie
Electronics Expert

Joined: 04 Sep 2002
Posts: 481
Location: Lincolnshire

Posted: Sun Nov 17, 2002 9:11 pm   Post subject: Using Oscilloscopes

Oscilloscope Application

OSCILLOSCOPE LEADS

Oscilloscope leads are available as simple screened cable with 'crocodile clip' terminations or as 'probes' switchable between 'Times One' (X1) and 'Times Ten' (X10), also fixed attenuating X10 probes may sometimes be seen. Other types are rare enough to ignore. When a probe is switched to X10 an internal attenuator reduces the signal seen by the 'scope to one tenth of that at the probe's tip - what you measure with the 'scope needs multiplying by ten to obtain the correct magnitude.
The reason for using a probe is this :-
An oscilloscope may have an input impedance of 1 Meg with 47pF in parallel; this may seem good enough but if you want to look at square waves or high frequencies this capacitance will act as a filter, rounding the corners of transients and reducing the apparent magnitude of high frequencies. If you start to probe around on high impedance circuits as are often used in CMOS logic then the 1 Meg resistance can start to affect the operation of the circuit you are trying to study.
A simple X10 probe could be just a 9 Meg resistor in series with the 'scope, this would work perfectly for DC but if a small adjustable capacitor is placed in parallel with this 9 Meg resistor it becomes possible to tune the circuit's AC response. An overall effective impedance of 10 Meg with a parallel capacitance of 5pF is easy to achieve. Setting this adjustable capacitor to match your 'scope is referred to as compensation and must be checked if a new probe/scope combination is used, every 'scope is different.

PROBE COMPENSATION

If accurate measurements are to be made, the effect of the probe being used must be properly adjusted to match the oscilloscope's input circuit using the internal calibration signal or some other square wave source.
1. Connect probe to INPUT jack. Connect ground clip of probe to oscilloscope ground terminal and touch tip of probe to CAL terminal (usually a small pad or pin in a corner of the front panel).
2. Select single trace operation on channel 1 then channel 2, perform steps 3 to 5 for each in turn.
3. Set the probe for 10:1 attenuation (X10 position) and VOLTS/DIV to 10mV/div.
4. Set oscilloscope controls to display 3 or 4 cycles of PROBE ADJ square wave at 5 or 6 divisions amplitude.
5. Adjust compensation trimmer on probe for optimum square wave shape (minimum overshoot, rounding off, and tilt).

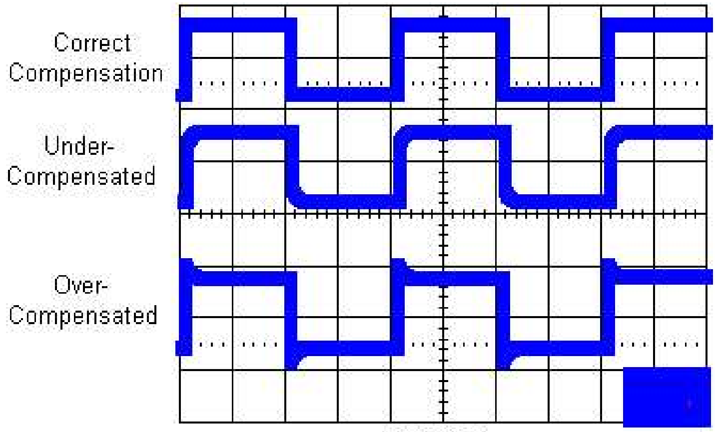

FIGURE 1
Probe Compensation

TRACE ROTATION COMPENSATION
Rotation from a horizontal trace position can be the cause of measurement errors.
Adjust the controls for a single display. Set the AC-GND-DC switch to GND and TRIG MODE to AUTO. Adjust the VERT POSITION control such that the trace is over the centre horizontal graticule line. If the trace appears to be rotated from horizontal, align it with the centre graticule line using the TRACE ROTATION control (could be on oscilloscope's rear panel).

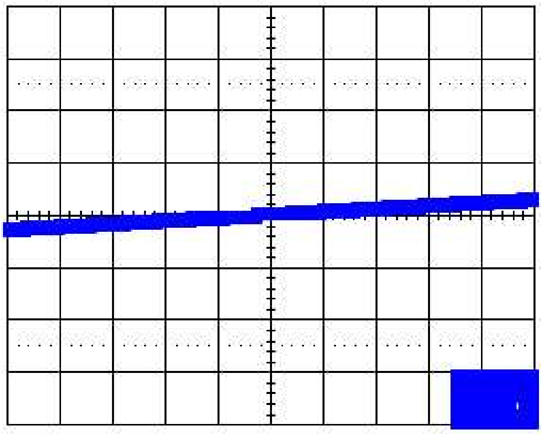

FIGURE 2
Trace Rotation Required

DC VOLTAGE MEASUREMENTS
This procedure describes the measurement procedure for DC waveforms.

Procedure:
1. Connect the signal to be measured to the INPUT jack. Set the vertical MODE for the channel to be used Set the VOLTS/DIV and SWEEP TIME/DIV switch to obtain a normal display of the waveform to be measured. Set the VARIABLE control to the CAL position.
2. Set the TRIG MODE to AUTO and AC-GND-DC to the GND position, which establishes the zero volt reference. Using the VERT POSITION control adjust the trace position to the desired reference level position, making sure not to disturb this setting once made.
3 Set the AC-GND-DC switch to the DC position to observe the input waveform including its DC component. If an appropriate reference level or VOLTS/DIV setting has not made the waveform may not be visible on the CRT screen at this point. If not, reset VOLTS/DIV and/or the VERT POSITION control.
4 Use the HORIZ POSITION control to bring the portion of the waveform to be measured to the centre vertical graduation line of the CRT screen.
5. Measure the vertical distance from the reference level to the point to be measured (the reference level can be rechecked by setting the AC.GND.DC switch again to GND).
Multiply the distance measured above by the VOLTS/DIV setting and the probe attenuation ratio as well. Voltages above and below the reference level are positive and negative values respectively.

Using the formula:
DC level =Vertical distance in divisions * (VOLTS/DIV setting * (probe attenuation ratio).

[EXAMPLE]

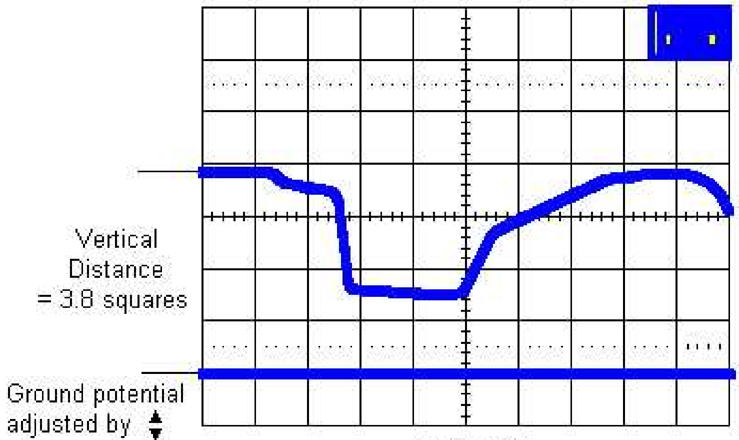

FIGURE 3
DC Voltage Measurement

For the example the point being measured is 3.8 divisions from the reference level ground potential.
If the VOLTS/DIV was set to O.2 V and a 10:1 probe was used.

Substituting the given values.
DC level = 3.8 (div) * 0.2(V) * 10 = 7.6 V

MEASUREMENT OF THE VOLTAGE BETWEEN TWO POINTS ON A WAVEFORM

This technique can be used to measure peak-to-peak voltages.

Procedure:
1 Apply the signal to be measured to the INPUT jack. Set the vertical MODE to the channel to be used
Set the AC-GND-DC to AC. adjusting VOLTS/DIV and SWEEP TIME/DIV for a normal display. Set the VARIABLE to CAL.
2 Using the VERT POSITION control, adjust the waveform position such that one of the two points falls on a CRT graduation line and that the other is visible on the display screen.
3 Using the HORIZ POSITION control, adjust the second point to coincide with the centre vertical graduation line.
4 Measure the vertical distance between the two points and multiply this by the setting of the VOLTS/DIV control.
If a probe is used, further multiply this by the attenuation ratio.

Using the formula:
Volts Peak-to-Peak
= Vertical distance (div) * (VOLTS/DIV setting) * (probe attenuation ratio)

[EXAMPLE]

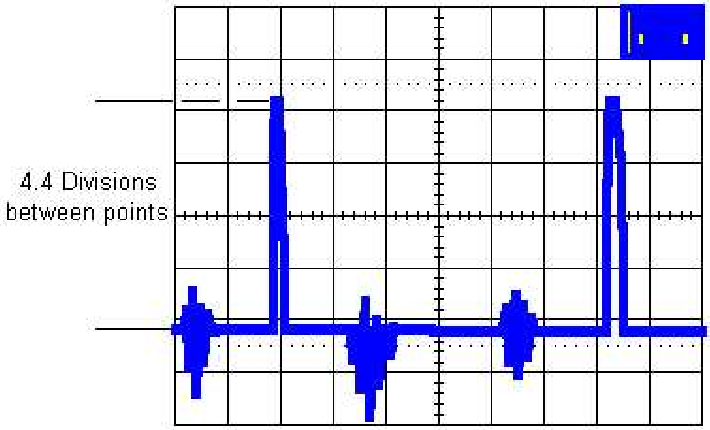

FIGURE 4
Measurement Between Two Points

For the example, 4.4 divisions separate the two points vertically. Let the VOLTS/DIV setting be 0.2 V/div and the probe attenuation be 10:1.

Substituting the given values:
Voltage between two points = 4.4 (div) * 0.2(v) * 10 = 8.8v

ELIMINATION OF UNDESIRED SIGNAL COMPONENTS
The ADD feature can be conveniently used to cancel out the effect of an undesired signal component that is superimposed on the signal you wish to observe.

Procedure:
1. Apply the signal containing an undesired component to the CH 1 INPUT jacks and the undesired signal to the CH 2 INPUT jack.
2 Set-the vertical MODE to CHOP and SOURCE to CH2 Verify that CH2 represents the unwanted signal, with an inverse polarity. The polarity can be reversed by setting CH2 to INV.
Set the VERTICAL MODE to ADD, SOURCE to VERT. MODE and CH2 VOLTS/DIV and VARIABLE so that the undesired signal component is cancelled as much as possible. The remaining signal should be the signal you wish to observe alone and free of the unwanted signal

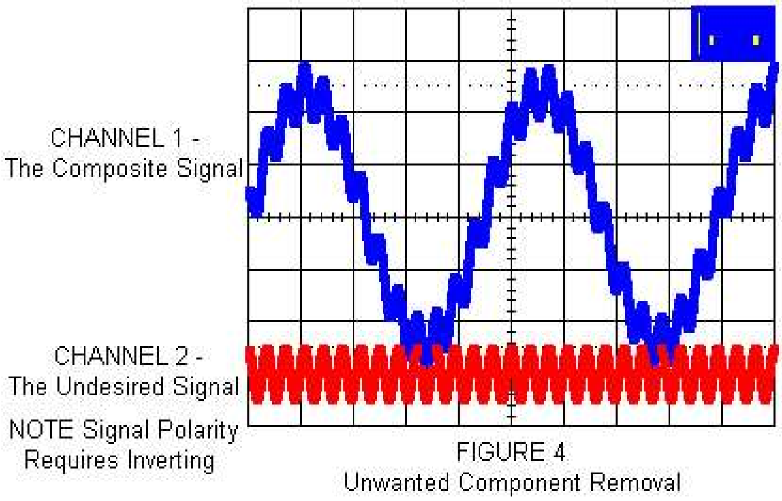

FIGURE 4
Unwanted Component Removal

TIME MEASUREMENTS
This is the procedure for making time measurements between two points on a waveform, the combination of the SWEEP TIME/DIV and the horizontal distance in divisions between the two points is used in the calculation.

Procedure:
1 Apply the signal to be measured to the INPUT jack. Set the vertical MODE to the channel to be used
Adjust the VOLTS/DIV and SWEEP TIME/DIV for a normal display. Se sure that the VARIABLE control is set to

CAL.
2 Using the VERT POSITION control set one of the points to be used as a reference to coincide with the horizontal centreline. Use the HORIZ POSITION control to set this point at the intersection of any vertical graduation line.
3 Measure the horizontal distance between the two points.
Multiply this by the setting on the SWEEP TIME/DIV control to obtain the time between the two points. If horizontal X 10 MAG is used, multiply this further by 1/10.

Using the formula:
Time = Horizontal distance (div) * (SWEEP TIME/DIV setting) * "X10 MAG" value (1/10)

[EXAMPLE]

For the example, the horizontal distance between the two points is 5.4 divisions.
It the SWEEP TIME/DIV is 0.2 ms/div we calculate.

Substituting the given values:
Time=5.4 (div) * O.2 (ms)= 1.08 ms

FREQUENCY MEASUREMENTS
Frequency measurements are made by measuring the period of one cycle of waveform and taking the reciprocal of this time value.

Procedure:
1 Set the oscilloscope up to display one cycle of waveform (one period).
2 The frequency is the reciprocal of the period measured.

Using the formula:

Freq = 1 / period

[EXAMPLE]

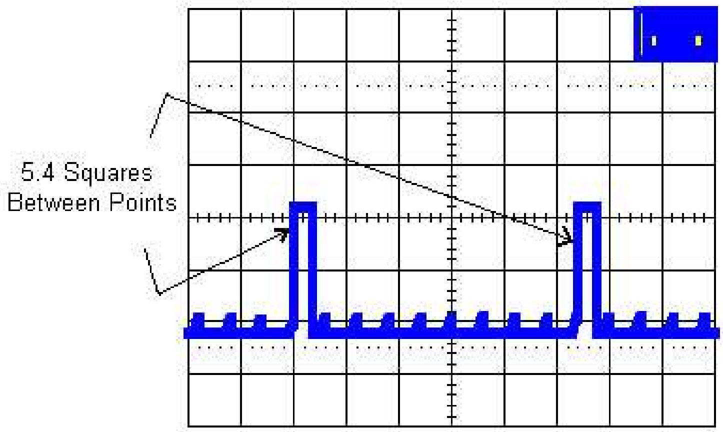

FIGURE 6
Time Measurement

A period of 1.08 ms is observed and measured.

Substituting the given values:
Freq=1/(1.08 * 10-3) = 925.926 Hz

The above method relies on measuring the period of exactly one cycle, any errors in this measurement will affect the accuracy of the result. The frequency may also be measured by counting any number of cycles present in a given time period, this effectively divides any measurement error by the number of cycles.
1. Apply the signal to the INPUT jack. Set the vertical MODE to the channel to be used and adjusting the various controls for a normal display. Set the VARIABLE to CAL.
2. Count the number of cycles of waveform between a chosen set of vertical graduation lines.

Using the horizontal distance between the vertical lines used above and the SWEEP TIME/Div. the time span may be calculated. Multiply the reciprocal of this value by the number of cycles present in the given time span. If "X 10 MAG" is used multiply this number by 10.
Note that errors will occur for displays having only a few cycles.

Using the formula:

Freq = ... # of cycles * "X 10 MAG" value . . . . .
. . . . . .Horizontal distance (div) x SWEEP TIME/DIV setting

[EXAMPLE]

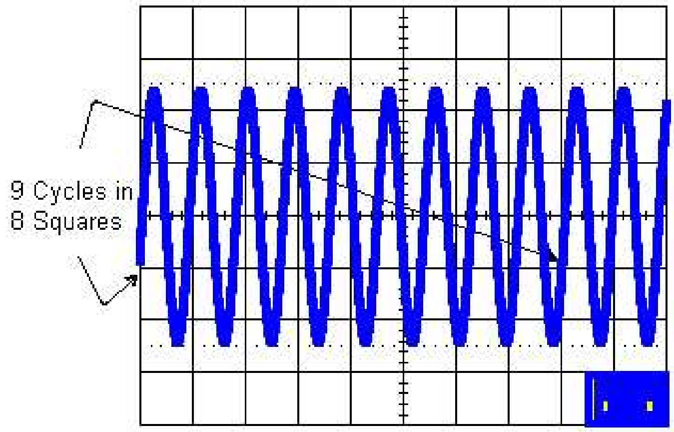

FIGURE 7
Frequency Measurement

For the example, within 8 divisions there are 9 cycles.
The SWEEP TIME/DIV is 5 us.

Substituting the given values:

Freq = 9 / (8 (div) * 5 (us))

= 9 / (8 * 5 *10-6)

= 225 kHz

PULSE WIDTH MEASUREMENTS
Procedure:
1. Apply the pulse signal to the INPUT jack. Set the vertical MODE to the channel to be used
2. Use the VOLTS/DIV, VARIABLE and VERT POSITION to adjust the waveform such that the pulse is easily observed and such that the centre pulse width coincides with the centre horizontal line on the CRT screen.
3. Measure the distance between the intersection of the pulse waveform and the centre horizontal line in divisions. Be sure that the VARIABLE is in the CAL. Multiply this distance by the SWEEP TIME/DIV and by 1/10 if "X 10 MAG" mode is being used.

Using the formula:
Pulse width = Horizontal distance (div) x SWEEP TIME/DIV setting) * "X 10 MAG" value (l/10)

[EXAMPLE]

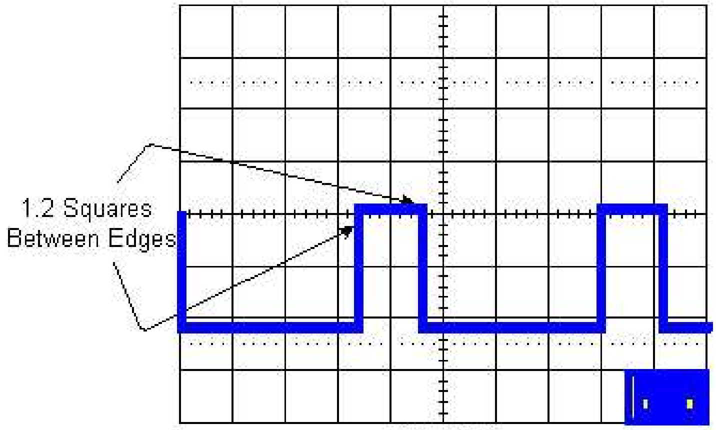

FIGURE 8
Pulse Width Measurement

For the example, the distance (width) at the centre horizontal line is 4.6 divisions and the SWEEP TIME/DIV is 0.2 ms

Substituting the given values:
Pulse width = 1.2 (div) * 0.2 ms = 0.24 ms

PULSE RISE TIME AND FALLTIME MEASUREMENTS
For rise time and fall time measurements the 10% and 90% amplitude points are used as starting and ending reference points.

Procedure:
1. Apply a signal to the INPUT jack. Set the vertical MODE to the channel to be used

Use the VOLTS/DIV and VARIABLE to adjust the waveform peak-to-peak height to six divisions.
2 Using the VERT POSITION control and the other controls, adjust the display such that the waveform is centred vertically in the display. Set the SWEEP TIME/DIV to as fast a setting as possible consistent with observation or both the 10% and 90% points. Set the VARIABLE to CAL
3. Use the HORIZ POSITION control to adjust the 10% point to coincide with a vertical graduation line and measure the distance in divisions between the 10% and 90% points on the waveform. Multiply this by the SWEEP TIME/DIV and also by 1/10, if "X 10 MAG" mode was used.

NOTE:
Be sure that the correct 10% and 90% lines are used. For such measurements the 0, 10, 90 and 100% points are marked on the CRT screen.

Using the formula:
Rise time = Horizontal distance (div) * (SWEEP TIME/DIV setting) * "X 10 MAG" value (1/10)

[EXAMPLE]

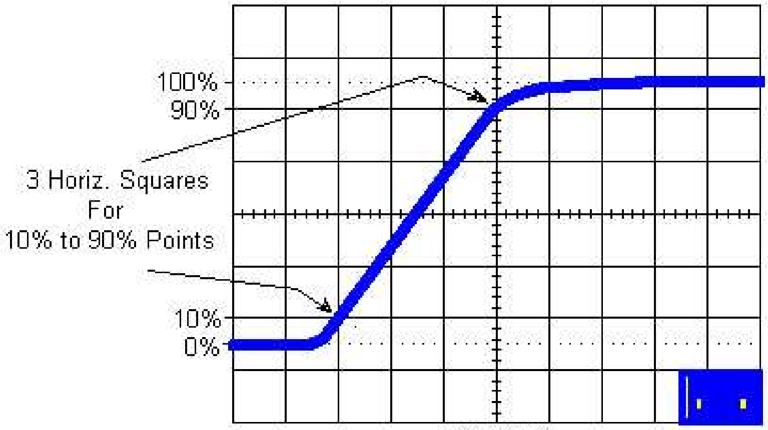

FIGURE 9
Rise Time Measurement

For the example, the horizontal distance is 4.0 divisions, The SWEEP TIME /DIV is 2 us.

Substituting the given values:
Rise time =3.0 (div) x 2 (us) = 6 us

TIME DIFFERENCE MEASUREMENTS

This procedure is useful in measurement of time differences between two signals that are synchronised to one another but skewed in time.

Procedure:
1. Apply the two signals to CH1 and CH2 INPUT jacks. Set the vertical MODE to either ALT or CHOP mode. Generally for low frequency signals CHOP is chosen with ALT used for high frequency signals.
2. Select the faster of the two signals as the SOURCE and use the VOLTS/DIV and SWEEP TIME/DIV to obtain an easily observed delay.
Set the VARIABLE to CAL.
3. Using the VERT POSITION control to set the waveform to the centre of the CRT display, adjust the HORIZ POSITION control to make the reference signal coincident with a vertical graduation line.
4. Measure the horizontal distance between the two signals and multiply this distance in divisions by the SWEEP TIME/DIV setting.
If "X 10 MAG" is being used multiply this again by 1/10.

Using the formula:
Time = Horizontal distance (div) * (SWEEP TIME/DIV setting) * "X 10 MAG" value (1/10)

[EXAMPLE]

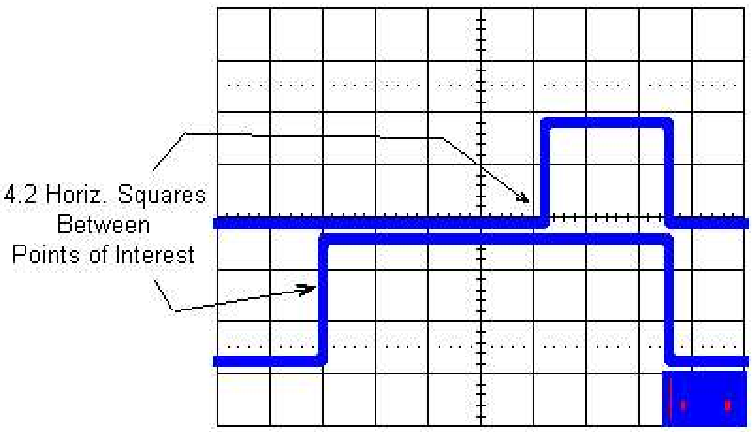

FIGURE 10
Time Difference

For the example, the horizontal distance measured is 4.2 divisions. The SWEEP TIME/DIV is 0.2 ms.

Substituting the given values:
Time = 4.2 (div) * 0.2 (ms) = 0.84 ms

PHASE DIFFERENCE MEASUREMENTS

This procedure is useful in measuring the phase difference of signals with the same frequency

Procedure;
1. Apply the two signals to the CH1 and CH2 INPUT jacks, setting the vertical MODE to either CHOP or ALT mode.
2. Set the SOURCE to the signal that leads in phase and use the VOLTS/DIV to adjust the signals such that they are equal in amplitude. Adjust the other controls for a normal display.
3. Use the SWEEP TIME/DIV and VARIABLE to adjust the display such that one cycle of the signals occupies 8 divisions of horizontal display
Use the VERT POSITION to bring the signals to the centre of the screen.
Having set up the display as above, one division now represents 45 degrees of phase.
4. Measure the horizontal distance between corresponding points on the two waveforms

Using the formula
Phase difference = Horizontal distance (div) * 45 degrees/div

[EXAMPLE]

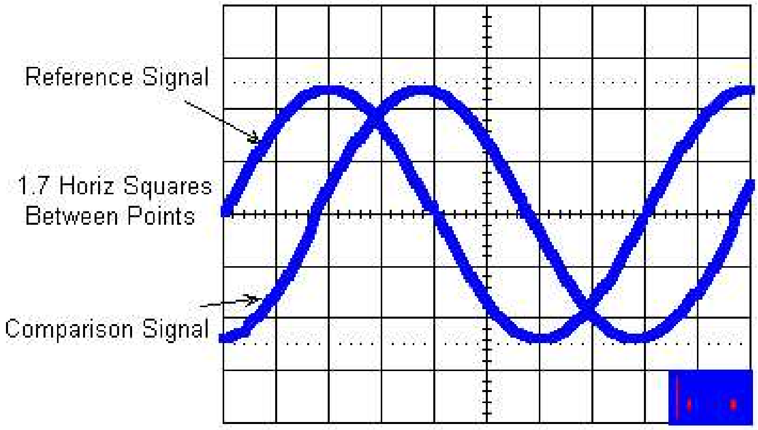

FIGURE 11
Phase Shift Measurement

For the example, the horizontal distance is 1.7 divisions.

Substituting the given values:
The phase difference = 1.7 (div) * 45 degrees/div = 76.5 degrees

The above set-up allows 45 degrees per division but if more accuracy is required the SWEEP TME/DIV may be changed and magnified without touching the VARIABLE control and if necessary the trigger level can be readjusted.

For this type of operation, the relationship of one division to 45 degrees no longer holds. Phase difference is defined by the formula as follows.

Phase difference = Horizontal distance of new sweep range (div) * 45 degrees/div * (New SWEEP TIME/DIV setting / Original SWEEP TIME/DIV setting)

Another simple method of obtaining more accuracy quickly is to simply use "X 10 MAG" for a scale of 4.5 degrees/div.

RELATIVE MEASUREMENT
If the frequency and amplitude of some reference signal is known, an unknown waveform's level and frequency may be measured without use of the VOLTS/DIV or SWEEP TIME/DIV for calibration.
The measurement is made in units relative to the reference signal.

* Vertical Sensitivity
Setting the relative vertical sensitivity using a reference signal

Procedure
1. Apply the reference signal to the INPUT jack and adjust the display for a normal waveform display. Adjust the VOLTS/DIV and VARIABLE so that the signal coincides with the CRT face's graduation lines. After adjusting, be sure not to disturb the setting of the VARIABLE control.

2. The vertical calibration coefficient is now the reference signal's amplitude in volts divided by the product of the vertical amplitude set in step 1 and the VOLTS/DIV setting.

Using the formula:
Vertical coefficient

* Voltage of the reference signal (V) .
Vertical amplitude (div) * VOLTS/DIV setting

Remove the reference signal and apply the unknown signal to the INPUT jack, using the VOLTS/DIV control to adjust the display for easy observation. Measure the amplitude of the displayed waveform and use the following relationship to calculate the actual amplitude of the unknown waveform.

Using the formula:
Amplitude of the unknown signal (V)
= Vertical distance (div) * Vertical coefficient * VOLTS/DIV setting

[EXAMPE]
For the example, the VOLTS/DIV is 1 V.
The reference signal is 2 Vrms. Using the VARIABLE, adjust so that the amplitude of the reference signal is 4 divisions.

Substituting the given values:
Vertical coefficient = 2 Vrms . =0.5
4 (div) * 1 (V)

Then measure the unknown signal. The VOLTS/DIV is 5 V and vertical amplitude is 3 divisions.

Substituting the given values:
Effective value of unknown signal = 3 (div) * 0.5 * 5(V)
= 7.5 V rms

* Period
Setting the relative sweep coefficient with respect to a reference frequency signal.

Procedure:
1. Apply the reference signal to the INPUT jack, using the VOLTS/DIV and VARIABLE to obtain an easily observed waveform display.
Using the SWEEP TIME/DIV and VARIABLE adjust one cycle of the reference signal to occupy a fixed number of screen divisions accurately. After this is done be sure not to disturb the setting of the VARIABLE control.
2. The Sweep (horizontal) calibration coefficient is then the period of the reference signal divided by the product of the number of divisions used in step 1 for set-up of the reference and the setting of the SWEEP

TIME/DIV control.

Using the formula:
Sweep coefficient

= Period of the reference signal (sec) .
horizontal width (div) * SWEEP TIME/DIV setting

3. Remove the reference signal and input the unknown signal, adjusting the SWEEP TIME/DIV control for easy observation.
Measure the width of one cycle in divisions and use the following relationship to calculate the actual period.

Using the formula:
Period of unknown signal = Width of 1 cycle (div) * sweep coefficient * SWEEP TIME/DIV setting

[EXAMPLE]
SWEEP TIME/DIV is 0.1 ms and apply 1.75kHz reference signal. Adjust the VARIABLE so that the distance of one cycle is 5 divisions.

Substituting the given values:

Horizontal coefficient = 1.75 (kHz)
5 * 0.1 (ms) = 1.142

The SWEEP TIME/DIV is 0.2 ms and horizontal amplitude is 7 divisions.

Substituting the given values:
Pulse width=7 (div) * 1.142 * 0.2 (ms) = 1.6 ms

APPLICATION OF X-Y OPERATION

PHASE SHIFT MEASUREMENT
A method of phase measurement requires calculations based on the Lissajous patterns obtained using X-Y operations. Distortion due to non-linear amplification also can be displayed

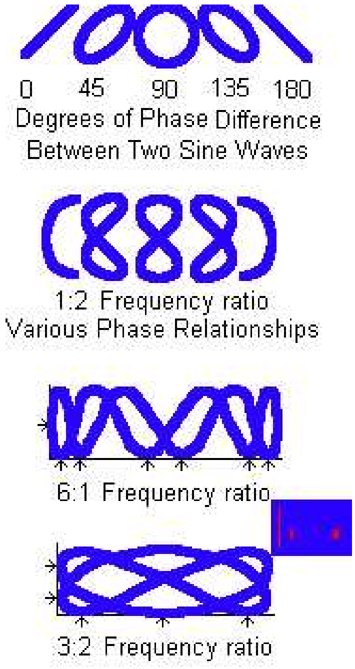

FIGURE 12
Lissajous Figures

A sine wave input is applied to the audio circuit being tested. The same sine wave input is applied to the vertical input of the oscilloscope, and the output of the tested circuit is applied to the horizontal input of the oscilloscope. The amount of phase difference between the two signals can be calculated from the resulting display.

To make phase measurements, use the following procedure.

1. Using an audio signal generator with a pure sinusoidal signal, apply a sine wave signal of the desired frequency to the audio network being tested.
2. Set the signal generator output for the normal operating level of the circuit being tested. If desired, the circuit’s output may be observed on the oscilloscope (if the test circuit is overdriven then the sine wave display on the oscilloscope is clipped and the signal level must be reduced).
3. Connect the channel 2 probe to the output of the test circuit.
4. Select X-Y operation by placing the TRIG MODE switch in the X-Y position.
5. Connect the channel 1 probe to the input of the test Circuit.

(The input and output test connections to the vertical and horizontal oscilloscope inputs may be reversed.)

6. Adjust the channel 1 and 2 gain controls for a suitable image size.

Some typical results are shown in Fig 12.

If the two signals are in phase, the oscilloscope trace is a straight diagonal line. If the vertical and horizontal gains are properly adjusted, this line is at an angle of 45 degrees. A 90-degree phase shift produces a circular oscilloscope pattern.

Phase shift of less or more than 90 degrees produces an elliptical oscilloscope pattern. The amount of phase shift can be calculated from the oscilloscope trace as shown in Fig 13

[EXAMPLE]

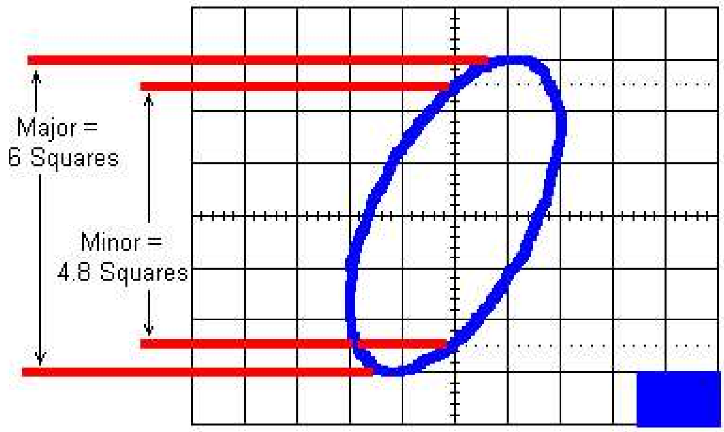

FIGURE 13
Measurement of Phase Difference

One of the sine waves (the Major) has an amplitude of 6 divisions, the other (the Minor) is measured as 4.8 squares.

Substituting the given values:

Sin Theta = Minor
. . . . Major

Therefore Theta = Asn Minor
_ _ _ _ _ _ _ _ _ _ _ _ _ Major

= ArcSin 4.8
_ _ _ _ _ _ 6

= 53.1 Degrees

Where Theta is phase angle in degrees.

FREQUENCY MEASUREMENT
1 Connect the sine wave of known frequency to the channel 2 INPUT jack of the oscilloscope and select X-Y operation. This provides external horizontal input.
2. Connect the vertical input probe (CH1 INPUT) to the unknown frequency.
3. Adjust the channel 1 and 2 size controls for convenient, easy-to-read size of display.
4. The resulting pattern, a Lissajous figure, shows the ratio between the two frequencies.
Some typical results are shown in Fig 12.

E&OE. The list of methods goes on but this should be more than enough for most users. Experimentation is the best way to learn.