OPERATING AN OSCILLOSCOPE

BASIC ANALOG OSCILLOSCOPES

This chapter provides a complete step-by-step procedure on oscilloscope operation. It begins with basic scope operation and proceeds to more advanced features.

Initial Startup Procedure

The first step in using any oscilloscope, from a simple dual-trace unit to the most sophisticated DSO, is turning it on and obtaining a trace.

1. The following basic controls should be present in some form on any scope. Set them as follows:

    a. Channel 1 input coupling switch (AC-GND-DC switch): GND.

    b. Channel 1 vertical position control: centered.

    c. Horizontal position control: centered.

    d. Auto trigger control: auto triggering on.

    e. Vertical mode control: channel 1 (single trace).

    f. Intensity control: minimum intensity.

    g. TIMEJDIV control: 0.5 mS/Div.

These settings prepare the unit for a single-trace display of a zero-volt base line, centered vertically and horizontally. At this point, no signal needs to be connected.

Fig. 1 shows these control settings on a typical unit, a **B+K Precision** Model 2120B.

2. Plug the scope into ac power and turn the Power switch on. Allow the unit a few seconds to warm up.

3. Slowly bring the Intensity control up. You should see a horizontal trace somewhere near the center of the screen.

4. You can adjust the trace sharpness with the Focus control, and, if necessary, adjust the trace tilt with the Trace Rotation control.

Displaying a Signal

This procedure displays a waveform on channel 1. The exact same process can be used for a single-trace display on channel 2.

1. Connect a signal to the channel 1 input jack. This can be a point in a test circuit connected via a scope probe, or the output of a function generator, via a BNC-to-BNC cable. If probing in a test circuit, first connect the probe's ground clip to the chassis or common of the equipment under test. Then connect the probe tip to the point of interest.

Tips:

Always use the probe ground clips attached to a circuit ground point near the point of measurement. Do not rely solely on an external ground wire in lieu of the probe ground clips, as undesired signals may be induced.

The probes should be compensated. Compensation matches the probe to the input of the scope. It should be adjusted initially, and then the same probe always used with the same channel. The chapter on "Oscilloscope Probes" discusses compensation.

When using a signal generator whose output has fast edges such as square waves or pulses, terminate the output into its characteristic impedance to minimize ringing. For example, a 50-ohm generator output should be terminated into an external 50-ohm resistor and connected to the scope with 50-ohm coaxial cable.

2. Set the channel 1 input coupling switch to AC.

3. If no waveforms appear, increase the sensitivity by turning the channel 1 vertical attenuator (Volts/Div.) clockwise to a position that gives 2 to 6 divisions vertical deflection.

4. The display on the screen may be unsynchronized, that is, not locked in place. You should be able to steady it using the Trigger Level control. Use the sweep time control (Time/Div.) to display the desired number of cycles. The "Triggering" and "Time Base" sections of this chapter discuss these controls in more detail.

Dual-Trace Display

The capability of an oscilloscope to display two simultaneous waveforms, dual-trace mode, is a very useful feature. In observing simultaneous waveforms on channels 1 and 2, the waveforms are usually related in frequency, or one of the waveforms is synchronized to the other, although the basic frequencies are different. For example, Fig. 5 depicts the waveforms associated with a simple flip-flop circuit, wherein the first trace shows the clock waveform and the second the output waveform. The scope clearly shows that the output is a divide-by-two of the clock, and that output changes always take place on the negative-going edge of the clock.

To obtain a dual-trace display:

1. Connect probes to both the channel 1 and channel 2 input jacks of the oscilloscope.

2. Connect the ground clips of the probes to the chassis or common of the circuit under observation. Connect the tips of the probes to the two circuit points of interest.

3. Locate the control that activates dual-trace mode on your oscilloscope. Some scopes simply have a position in the "Vertical Mode" switch labeled "Dual". However, many units have two distinct positions called "Alt" and "Chop". These activate two different kinds of dual-trace sweep, as follows:

    a. "Alt" stands for "alternate" sweep. The oscilloscope first draws the complete sweep of the channel 1 signal, then draws the complete sweep of the channel 2 signal, then repeats in an alternating manner. When fast sweep speeds are selected, the two traces appear to the human eye as simultaneous. The fact that they really aren't becomes more and more evident as sweep rate is decreased.

    b. "Chop" stands for "chopped" sweep. The scope draws a small part of the channel 1 signal, then a small part of the channel 2 signal, and so on, continually switching back and forth until both sweeps are complete. When slow sweep speeds are

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selected, the chopping is much faster than the sweep and is unnoticeable. If chop mode is used at very high sweep rates, the chop rate becomes a significant portion of the sweep and may become visible in the displayed waveform. Chopping may also become noticeable if the input signal frequency is close to, or a sub-multiple of, the chop frequency.

Note:

Alternate and chop sweep techniques are actually used in all multi-trace oscilloscopes. However, many units automatically choose alt or chop depending on the time base setting you select. These are the units that have one single "Dual" switch instead of separate "Alt" and "Chop" facilities.

4. Adjust the channel 1 and 2 vertical position controls to position the two traces as desired. Channel 1 is usually positioned above channel 2, as in Fig. 5.

5. Set the channel 1 and channel 2 vertical attenuators (Volts/Div.) so that the wave forms are the desired height.

6. Set the time base (Time/Div.) control for the desired number of cycles of the waveforms. If the display is unsynchronized ("rolling"), attempt to lock it with the Trigger Level control. Consult the section on "Triggering" later in this chapter for more information on obtaining a stable waveform.

The Vertical Attenuator (Volts/Div) Controls

On dual-trace scopes, there are two of these, one each for channel 1 and channel 2. These controls adjust the vertical height of the wave-form on the screen. They do this by attenuating the input signal by a selected amount before it is applied to the scopes vertical amplifier. The amount of attenuation is always rendered on the dial in a 1-2-5 sequence, and is calibrated in volts/division. Here, "division" means the squares on the scope graticule, generally 1 cm in area. (It does not refer to the smaller subdivisions on the center graticule lines.) Therefore, for example, if the channel 1 vertical attenuator is set to 2 volts/division, and a sine wave is displayed which covers 4 divisions from top to bottom, then that sine wave has a peak-to-peak amplitude of 8 volts.

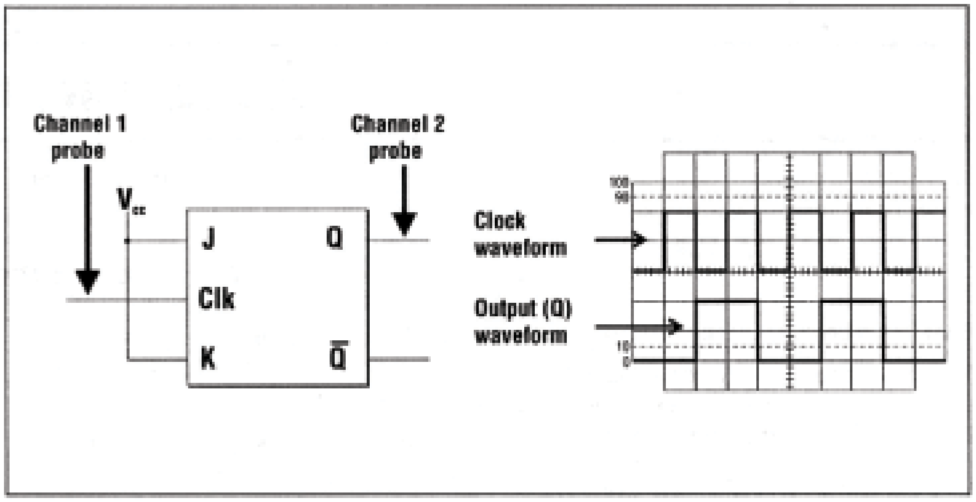

Fig. 5 A simple dual-trace display

Two things should be noted in this regard. First, there usually is a Variable control associated with the vertical attenuator. This must be set to the "Calibrated" position in order for measurements to be accurate. The Variable control allows you to smoothly vary the waveform height between calibrated settings of the attenuator. Some units have a built-in LED which lights to inform you that measurements are not calibrated because of this control's setting.

Second, the use of a 10:1 probe multiplies the vertical attenuator dial setting by 10. For example, if the attenuator is set to 0.2 volts/division, and a 10:1 probe is being used, the actual value being obtained from the screen is 2 volts/division. A detailed discussion of probes is given in the chapter on "Oscilloscope Probes".

The chapter on "Applications" gives more information about on-screen voltage measurements; see "Instantaneous DC Voltage Measurements" and "Peak-to-Peak Voltage Measurements", in that chapter.

The Time Base (Time/Div) Control

This control adjusts the sweep speed of the oscilloscope. Its settings are calibrated in a 1-2-5 sequence, in units of time per division. These indicate how long the dot takes to travel horizontally across one square division on the graticule. For example, if the time base control is set to 2 mS/division, and an event on the screen, say the positive half of a square wave, extends for 3 divisions, then that event is 6 milliseconds long. This is an example of determining a "time interval" with the scope. Frequency can also be determined. Both are discussed in more detail in the "Applications" chapter.

As with the vertical attenuators, there is usually a Variable control which must be set to "Calibrated" for horizontal measurements to be accurate.

Use the time base control to display the desired number of cycles of a waveform. If there are too many cycles displayed for good resolution, switch to a faster sweep time. If only a line is displayed, try a slower sweep time. When the sweep time is faster than the waveform being observed, only part of it will be displayed, which may appear as a straight line for a square wave or pulse waveform.

Some more advanced scopes have a second time base control; this is discussed in the section on "Delayed Sweep Operation", later in this chapter.

Triggering

The trigger is the event or signal that causes the oscilloscope CRT beam to begin its sweep across the display. Without an adequate trigger, the display starts at unrelated points on the waveform, and the result is a display that is unsynchronized, or "rolls". For the display to be synchronized, or stable, the trigger event should

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be related in some way to the displayed waveform. Many times it is the waveform itself. Modern oscilloscopes provide versatility in selection of trigger signal, method of coupling the trigger signal into the scope, and positioning of the actual trigger point on the trigger signal waveform.

Normal vs. Auto Triggering

Virtually all oscilloscopes provide these two triggering modes; each works as follows:

Normal: The sweep remains at rest until the trigger occurs. That trigger causes one sweep to be generated, after which the sweep again remains at rest until the next trigger. If an adequate trigger signal is not present, no trace is displayed.

Auto: The sweep generator continually gen erates a sweep even if no trigger signal is present. However, it automatically reverts to triggered sweep operation in the presence of a suitable trigger signal.

Auto triggering is handy when first setting up the scope to observe a waveform; it provides a sweep for waveform observation until other controls can be properly set. (Once the controls are set, the scope is often switched to normal triggering mode because that mode is generally more sensitive.) Auto triggering must be used for dc measurements and signals of such low magnitude that they will not trigger the sweep.

Typically, in the normal triggering mode, signals that produce even 1/2 division of vertical deflection are adequate to produce a display.

Level and Slope Controls

A sweep trigger is developed when the trigger source signal crosses a preset threshold level. Every oscilloscope has a Trigger Level control which shifts the threshold level "up" or "down" (i.e. positive or negative) on the trigger waveform. Refer to Fig. 6. The Level control adjusts the start of the sweep to almost any desired point on the waveform. When the control is centered, the threshold level is set at the approximate average of the trigger signal. On sinewave signals, the phase at which sweep begins is variable in this fashion. Note that if the Trigger Level control is rotated toward its extreme (+) or (–) setting, no sweep will be developed in the normal trigger mode because the triggering threshold exceeds the peak amplitude of the trigger signal.

The Trigger Slope switch, also present on every scope, selects the slope of the trigger signal at the threshold. Refer again to Fig. 6. If Trigger Slope is set to the (+) position, sweep is developed from the trigger signal as it crosses the threshold level in a positive-going direction. In the (–) position, sweep is developed as the signal crosses the threshold in a negative-going direction.

On many units the Slope and Level functions are combined into one control, usually a push-pull action (Slope) on a rotary knob (Level).

Trigger Source Selection

Oscilloscopes generally permit you to choose which signal is to be used as the trigger signal.

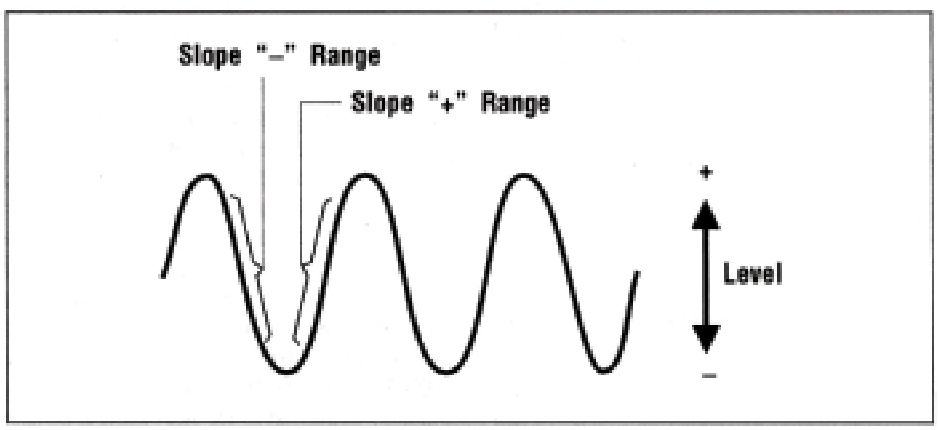

Fig. 6 Function of SLOPE and LEVEL controls

Oftentimes a scope's seeming inability to trigger is actually due to the operators having forgotten to select the appropriate signal as trigger.

The Trigger Source selector is usually a multi-position switch. Among modern scopes common offerings are:

Channel 1: The channel 1 signal is connected to the triggering circuits. In many units this can be so even if the channel 1 signal is not displayed. Thus, you could use channel 1 to trigger a channel 2 display. If they are related to each other in frequency, this will probably result in a stable display. Also, channel 1 could be used to trigger a dual-trace display of both channel 1 and channel 2. Again, if they are related, both traces will be stable.

Channel 2: Channel 2 is used for trigger, with the same considerations as channel 1 above.

Alternate: In dual-trace mode, the channel 1 trace is triggered by channel 1 and the chan nel 2 trace by channel 2. In this situation, you should realize that, although both waveforms are shown as stable traces, you cannot determine their phase or timing relationship to each other. This is because they are not triggering from a common source.

External: An external signal can be used as the trigger signal. This is usually applied to the "External Trigger" jack. This is useful when you wish to use a signal other than those displayed as the trigger, possibly because it may be a more suitable source (e.g. more amplitude, sharper edge).

Line: A signal internally developed from the input line voltage (50/60 Hz) becomes the trigger signal. This is useful when you are trying to observe power line "hum" on a signal with other components present. The "hum" component becomes more stable and hence, more clearly visible.

Trigger Coupling Selection

Besides being able to select which signal is to be trigger source, you are also able to choose the manner in which that signal is coupled to the trigger circuits. Modes commonly available are:

AC: This is used for viewing most types of waveforms. The trigger signal is capacitively coupled (dc component blocked) and may be used for all signals from below 30 Hz (depending on the unit) to the top frequency of the particular scope.

DC: Couples both the ac and dc component of the trigger signal. This is useful for viewing signals with frequency lower than the cutoff of the "AC" position above, or when you need to include the dc component for proper stabilization of the signal.

TV-H: Used for viewing horizontal sync pulses in composite video waveforms. A high-pass filter is employed, which couples through only higher-frequency components such as horizontal sync pulses. This position can also be used as a general high-pass (low-fre quency reject) position, and as such is sometimes labeled "HF".

TV-V: Used for viewing vertical sync pulses in composite video waveforms. A low-pass filter is employed, which couples through only lower-frequency components such as vertical sync pulses. This position can also be used as a general low-pass (high-frequency reject) position, and as such is sometimes labeled "LF".

Video: On some scopes, this general setting is provided instead of the two previous ones. Coupling is automatically switched between horizontal or vertical sync pulses depending on the setting of the main time base.

Vertical and Horizontal Magnifiers

Most scopes permit magnification of the on-screen waveform in both the vertical and horizontal direction.

Vertical magnifiers are usually implemented as a push-pull action on the Variable control for each vertical attenuator. Generally a factor of X5, this magnification can also be thought of as extending the sensitivity of the unit by one or two ranges. For example, if a scope has a minimum vertical attenuator setting of 5 mV/division, the X5 multiplier can provide two extra ranges: 2 mV/division (on the regular 10 mV/division setting) and 1 mV/division (on the regular 5 mV/division setting).

With this increase in ranges, however, come two performance degradations. First, the bandwidth of the scope is reduced when the magnifier is active. The reduction may he drastic; a 60 MHz unit may be limited to 10 MHz in this mode. (For a discussion of the bandwidth concept, see the "Bandwidth" section of this chapter.) Secondly, using the magnifier on the most sensitive settings results in increased noise on the waveform. The trace appears thicker and out-of-focus.

Horizontal magnification is usually achieved through a push-pull action on either the Variable Time Base control or the Horizontal Position control. Magnification factor is usually X 10. This feature is helpful in viewing a portion of a waveform that might disappear off the right of the screen if the Time Base setting is increased. Even though the waveform is magnified, rotating the Horizontal Position control can still enable you to observe every portion of it.

The Add and Invert Functions

A very common feature on modern oscilloscopes is the Add mode, which permits the channel 1 and channel 2 signals to be algebraically combined and displayed as one trace. This feature is particularly useful when used in conjunction with the "Invert" function. Invert takes one of the input channels and reverses its polarity on the display. For example, the highs of a sine wave are shown as lows, and vice versa. Any dc offset is also inverted (i.e. a positive dc offset becomes a negative one), assuming that the scope is set for dc coupling.

In effect, when an uninverted channel is added to an inverted one, the result is the algebraic difference. This is handy for differential measurements (when you wish to observe a signal not referenced to ground) and elimination of undesired signal components. Both uses are discussed in the "Applications" chapter of this manual.

The Add function is usually implemented on the same control that selects single-trace or dual-trace mode, i.e. the Vertical Mode control. The Invert function may be implemented on channel 1 or channel 2, depending on the particular scope, and may be a Vertical Mode control, a secondary function of the Variable attenuator, or a separate switch.

X-Y Operation

X-Y operation permits the oscilloscope to perform many measurements not possible with conventional sweep operation. The CRT display becomes an electronic graph of two instantaneous voltages. One voltage deflects the beam vertically (Y), and the other deflects it horizontally (X). The sweep aspects of the scope are disabled. Thus, with no signals connected, the display is merely a dot.

The signals being applied may be two voltages, such as stereoscope display of stereo signal outputs. However, the X-Y mode can be used to graph almost any dynamic characteristic if a transducer is used to change the characteristic (frequency, temperature, velocity, etc.) into a voltage. One common application is frequency response measurements, where the Y axis corresponds to signal amplitude and the X axis to frequency.

The controls used to implement X-Y mode vary among different scopes. However, the general procedure for using it is as follows:

1. Locate the switch that enables X-Y mode. This may be a separate switch, or the last position of the Time Base selector. On scopes with delayed sweep capability, it is usually one of the Sweep Mode selections. Turn on the X-Y mode. Make sure the trace intensity is not set too high; a bright stationary dot in one spot on the screen can be damaging if left there for a long time.

2. The channel 1 and channel 2 inputs now become X and Y inputs, though not necessarily in that order. Apply the desired signals to these channels.

3. The vertical attenuators now become the X and Y attenuators, i.e. one controls the height of the waveform, and the other its width. The Variable attenuator controls function similarly.

4. Positioning of the X-Y waveform is as follows:

a. Generally, the Vertical Position control of whichever channel is the Y-axis becomes the vertical positioning control for X-Y displays.
b. Horizontal positioning is accomplished by either the vertical control for the other channel, or the Horizontal Position control for the scope.

The "Applications" chapter discusses two common uses of X-Y mode, phase measurements and frequency response measurements.

Bandwidth

Bandwidth, or frequency response, is one of the most important characteristics of an oscilloscope. It is often the determining factor in preferring one unit over another.

By convention, bandwidth, which is measured in MHz, is the frequency at which signal amplitude "rolls off" by 3 dB from its value at 1 kHz. For example, assume that a 1 kHz signal produces a waveform six divisions high on a given Volts/Div setting. If that signal is increased in frequency (but input amplitude is kept constant), the frequency at which the display is reduced to 4.24 divisions (–3 dB, or 70.7%) is the bandwidth of the scope.

Bandwidth is important because it dictates the highest frequency at which accurate measurements can be made with a given oscilloscope. As might be expected, the scope buyer pays more for higher bandwidth. The range of applications and measurements goes up as the bandwidth does, and the availability of advanced features also increases. Basic oscilloscopes such as those discussed so far are generally 20 MHz or 30 MHz units. Higher bandwidths include 40 MHz, 60 MHz, 100 MHz, and beyond. The features discussed in the next section usually imply a minimum bandwidth of 40 MHz.

Using an Oscilloscope with 1 millivolt Sensitivity

Many oscilloscopes have a X5 MAG (5 times magnification of the vertical input signal) feature. With X5 magnification, the 10 mV/div attenuator setting becomes 2 mV/div sensitivity, and the 5 mV/div attenuator setting becomes 1 mV/div sensitivity. At these high sensitivity settings, special care must be taken for reliable low level measurements. Keep the following points in mind when measuring very low level signals.

- Placement of the ground clip may become critical if the signal ground circuitry carries appreciable current. Voltage differences of several millivolts are common from one side of a chassis to another. Attach the ground clip to a ground point nearest the point of signal measurement (the probe tip). This usually gives the smallest error. You may need to move the ground clip as you move the probe to other points of measurement.

- It may be difficult to eliminate the pickup of stray 60 Hz signals, especially in high impedance circuits. Be sure to use shielded test cables. If necessary, shield the area around the probe tip.Wideband measurements become more difficult at 1 mV/div and 2 mV/div because of the inherent thermal noise of electronic components. The trace may appear "fuzzy" or wide and out of focus.

- Noise that appears as peaks or spikes may be caused by electromagnetic pickup of external interference, such as automotive ignition, computer clock pulses, etc. Such noise may also cause erratic triggering. If possible, shield the unit under test from external interference.

- Radio interference may be picked up in strong RF signal areas, such as a nearby AM broadcast station, CB radios, or other transmitting devices. Unshielded probes and test cables can act as antennas to magnify this type of interference.

- Use the lowest sensitivity possible for the measurement. Do not use 1 mV/div sensitivity if the measurement can be made at 5 mV/div sensitivity. Perhaps the probe can be switched to X1 instead of using X5 MAG, however, be aware that the probe's bandwidth is sharply reduced at X1 and its input impedance is much lower.

- Thermal drift may be apparent at high sensitivity if the test connections are across a semi-conductor junction or two dissimilar metals. The trace may drift as the junction temperature changes.

ADVANCED ANALOG OSCILLOSCOPES

This section discusses advanced features generally found on higher-bandwidth oscilloscopes, such as delayed sweep, variable holdoff, etc. However, B+K Precision offers a deluxe 30 MHz oscilloscope with many of the advanced features described here, including delayed sweep, component test, Y-axis output, and Z-axis input. This scope is Model 2125A.

Delayed Sweep

The delayed sweep feature permits the operator to magnify a portion of the trace for closer examination. While this can be done by using the horizontal magnifier as mentioned previously, delayed sweep provides higher orders of magnification, many more degrees of magnification, and the means to observe both the magnified and original waveforms simultaneously.

The feature is called "delayed sweep" because the magnification is achieved by delaying the beginning of the trace for a period determined by the operator. After this delay, the sweep then runs at a speed which the operator sets via a second Time Base control, separate from the main Time Base. By adjusting both the delay time and the sweep speed, the operator varies the position and the width of the magnified portion.

The delayed sweep (often referred to as the B sweep) begins immediately after the delay period selected by the operator is over. Adjustment range of the delay time is "continuous".

Note:

To obtain meaningful results with delayed sweep, the delayed sweep must be set to a faster sweep speed than the main sweep. This makes sense, since we are magnifying a portion of the original waveform.

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1. Initially set the unit for normal sweep operation. On most units this will be called "Main", and is most likely found as a position of a "Sweep" mode switch.

2. Connect a signal to one of the input channels. You may want to stay in single channel mode, to avoid clutter of too many waveforms on the screen. Set the oscilloscope as usual for a normal, stable display.

3. Turn on delayed sweep operation. On most units this is a position labeled "MIX" on the "Sweep" mode switch.

4. The display will show the main sweep on the left portion of the trace and the delayed sweep on the right portion of the trace, as shown in Fig. 7. The main sweep portion is usually brighter than the delayed sweep portion.

5. The beginning point of the delayed sweep can be adjusted using the "Delay Time" control.

6. The delayed sweep only may be viewed by switching the "Sweep" mode switch to the "Delay" position.

Variable Holdoff

A "holdoff" period occurs immediately after the completion of each sweep and is a period during which triggering of the next sweep is inhibited. The normal holdoff period varies with sweep rate, but is adequate to assure complete retrace and stabilization before the next sweep trigger is permitted. Some scopes provide a Holdoff control that allows this period to be extended by a variable amount, if desired.

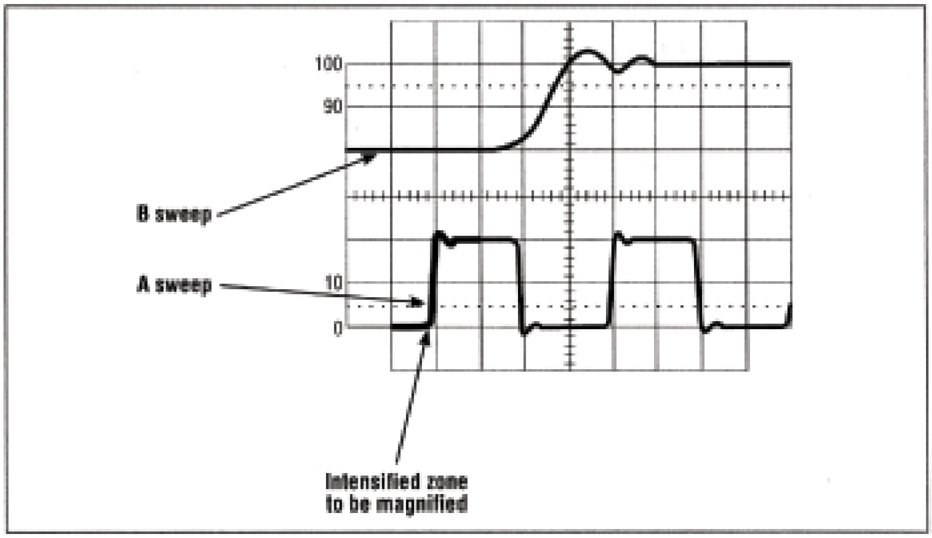

Fig. 7 Delayed sweep display.

The Holdoff control is used when a complex series of pulses appears periodically, such as in Fig. 8a. Improper sync may produce a double image, as in Fig. 8b. Such a display could be synchronized by adjusting the Variable Time Base control, but this is impractical because time measurements would then be uncalibrated. However, synchronization can be achieved with the Holdoff control. The sweep speed remains the same, but the triggering of the next sweep is "held off" for the duration selected by the Holdoff control.

Component Test

Some oscilloscopes include a component test function. In this mode, normal sweep is disabled and a component test pattern is displayed. A sine wave test signal is available at a pair of test jacks on the oscilloscope. Using test leads, this sine wave signal is applied to the component under test. The component may be out-of-circuit or in-circuit on a non-powered chassis. The displayed pattern (signature) is a dynamic plot of the impedance of the component with a sine wave signal applied. This test technique is very effective at locating defective components. The preferred method of testing is to use patterns from a known-good chassis for reference. Shorted, open, and leaky components produce patterns very dissimilar from reference patterns. Good components produce patterns identical or very similar to the reference patterns. Fig. 9 shows some typical patterns using component test.

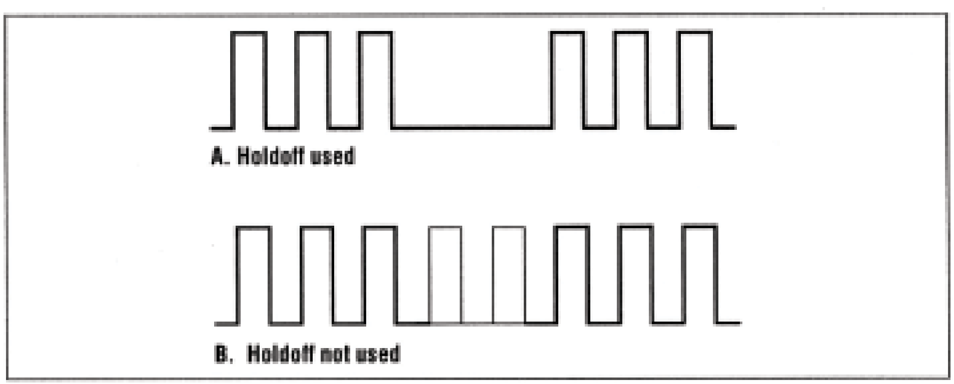

Fig. 8b Use of HOLDOFF control.

Other Advanced Features

Y-Axis Output
This feature allows a sample of the vertical signal (usually channel 2, but may be channel 1 on some oscilloscopes) to be used externally. The output signal is buffered from a low impedance source, usually 50 ohms. The amplitude of the Y-axis output is usually 50 millivolts per division of the vertical deflection seen on the screen of the CRT when terminated into 50 ohms. When unterminated (or terminated into a high impedance), the output is 100 mV/div. The Y-axis output allows the oscilloscope to be used as a wideband preamplifier. One typical application is to amplify a low level signal adequately to drive a frequency counter. A 10 mV peak-to-peak signal (about 3.6 mV rms) is not adequate to drive most frequency counters, however, it is enough to give two vertical divisions amplitude on an

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oscilloscope set at 5 mV/div sensitivity. With two divisions deflection on the CRT, the output of the Y-axis output (terminated into 1 megohm input impedance of most counters) is 200 millivolts peak-to-peak or 71 millivolts rms. This is plenty to drive the frequency counter solidly.

Z-Axis Input

This feature is sometimes called intensity modulation. When a signal is applied to the rear-panel Z-Axis input jack, the electron beam (which produces the scope display) varies in intensity according to the amplitude of that input. Thus, the display can be intensity modulated in a manner similar to a video or television display. Usually, the front panel Intensity control can be adjusted so that TTLlevels at the Z-Axis jack turn the beam on and off completely. The polarity of the modulation depends on the particular model of scope. Some displays grow brighter with a more positive voltage; others require a more negative voltage for a brighter display.

Beam Finder

This convenience feature helps you to find a trace that may be off the area of the screen. Beam Finder compresses the trace and "pulls" it into the CRT area, so that you may know in which direction the trace is off screen, Don't keep this momentary function on for too long, however; it also puts the trace at full intensity to help you locate it..

Bandwidth Limiter

On higher-frequency scopes, this switch allows the bandwidth to be scaled down. For example, a 100 MHz unit might offer a limiter that reduces it to 20 MHz. This feature is useful for filtering out higher-frequency noise, such as radio frequency interference, when using the scope for lower-frequency measurements.

Scale Illumination

This is a control, placed near the scope display, which causes the graticule to be illuminated for visibility in dark environments. This is usually done with small light bulbs placed around the perimeter of the display. The control varies the intensity of the illumination. The graticule is composed of a reflective substance that evens out the illumination over the total area of the grid

DIGITAL STORAGE OSCILLOSCOPES (DSO)

Description

The digital storage oscilloscope, or DSO, is a recent major development in the oscilloscope field. Instead of merely displaying a waveform on the CRT as it occurs, as does a standard analog oscilloscope, the DSO digitizes the incoming signal, stores it in memory, then continuously displays the contents of the memory on the screen. This enables the operator to capture and view one-time events, including activity immediately before the event itself (pre-trigger capture). DSOs are also excellent for displaying slow events that are difficult or impossible to view on standard analog oscilloscopes. DSOs can also store repetitive waveforms in memory, as well as one-time or slow waveforms, and transfer them to a plotter for future reference.

Although DSOs vary widely in features and operation, most DSOs include the basic features described in the following discussion, which is based on B+K Precision Model 2522B. The Model 2522B is a "hybrid" unit that can operate in conventional analog mode or in digital storage mode. The hybrid approach is often an advantage over full digital models in simplifying setup. The hybrid models can be adjusted in the familiar analog mode, then switched to digital storage operation for the actual waveform capture.

Digitizing One-time Events

One of the most powerful features of a digital storage oscilloscope is its ability to capture one-time events. To do this, single-sweep operation is employed, using the Single and Reset (or Arm) button. When the Reset button is pressed, it readies the digital storage circuit to receive a trigger signal—presumably the event to be captured or some other time-related occurrence. When the event arrives, it is stored in memory and displayed.

Capture of one-time events is an ideal use for a hybrid DSO. The triggering adjustments can be made in analog mode, and then the actual capture done in digital. The procedure is as follows:

1. Set the scope to analog mode. Set the Trigger Level control for normal (not auto) triggering, and adjust the level so that the unit triggers on the event to be captured. This usually involves making the event occur a few times with the scope in analog mode. Using normal triggering is important because even though the event may be too brief to readily observe in analog mode, it will cause one sweep to cross the screen in normal triggering mode. This is helpful in getting the Trigger Level set correctly.
2. Press the Storage switch to enter the storage mode.
3. Press the Single button, then the Reset (or Arm) button. The Ready indicator (or Armed indicator) lights while waiting for the trigger signal and goes off when the trigger of the one-time event occurs.
4. The one-time event that has been captured in memory is displayed continuously until Reset is pressed again to capture another one-time event or until the mode is changed.

Pre-trigger and Post-trigger View

One of the big advantages of a DSO is its ability to view occurrences before the trigger, or pre-trigger view, as well as occurrences after the trigger, or post-trigger view. For example, not only can a voltage spike be observed, but perhaps the activity that caused it. In a conventional analog oscilloscope, the sweep begins at the trigger. Thus, only post-trigger events can be viewed. In DSOs, waveform recording does not begin with the occurrence of a trigger, it is continuous. Rather, the trigger determines where the waveform recording stops. The operator can set the trigger to occur at the beginning of the memory (0% pre-trigger), at the middle of the memory (50% pre-trigger), or at other points in the memory (25% and 75% pre-trigger with Model 2522B). Fig. 10a shows a waveform with 0% pre-trigger, and Fig. 10b shows the same waveform with 50% pre-trigger. Note that in Fig. 10b, observance of the time period immediately before the trigger is possible.

Digitizing Repetitive Events

Though the capture of one-time events is probably the most powerful aspect of a DSO, many units can also digitize conventional repetitive waveforms, such as those observed on a standard analog scope. To do this, a DSO

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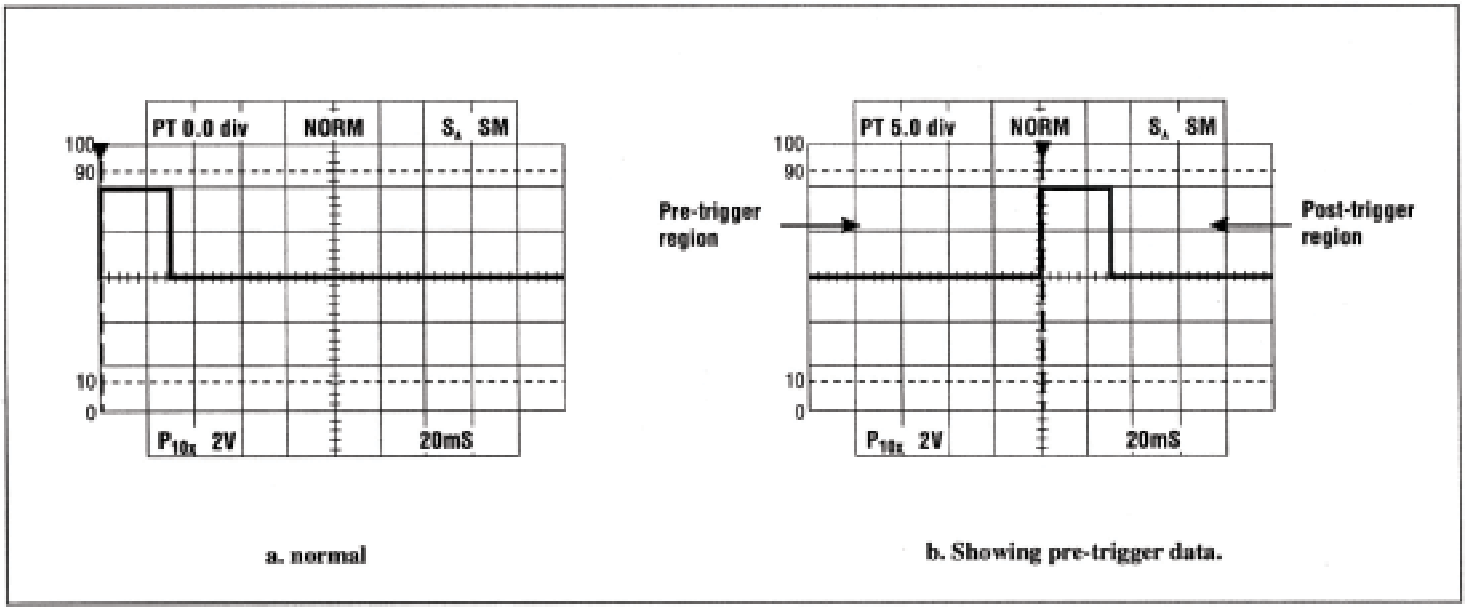

Fig. 10 Capture of a cone-time event.

uses what is commonly referred to as a "Refresh" mode, wherein the waveform is stored anew as each trigger signal arrives.
Although analog scopes are usually adequate to view repetitive events, some such signals can be viewed and measured much more effectively on a DSO. For example, a slow signal below 60 Hz may appear as a flickering waveform or just a moving dot on an analog scope. This same signal would be rendered as a bright, non-flickering, easily-viewed waveform on a DSO. Or again, a signal with a low repetition rate relative to the sweep rate may be too taint for viewing on an analog unit. On a DSO, the display is equivalent to a CRT with infinite persistence; the waveform may be easily viewed.

Typical use of Refresh mode is as follows:

1. Set up the oscilloscope to view a periodic waveform in the analog operating mode. Adjust the controls for a stable waveform.

2. Press the Storage button. The waveform appears on the display, relatively unchanged from the previously displayed analog version.In this mode the display is continually updated as long as a suitable trigger signal remains present.

3. Pressing the Save All button at any time "freezes" the current waveform on the screen for further observation.

Roll Mode

In this mode of operation, the waveform rolls across the screen from right to left (as opposed to the standard left to right trace) in the same manner as most strip chart recorders. It is most commonly used for viewing very slow events. Typical operation is as follows:

1. Set up the oscilloscope in analog mode so that the event to be observed is properly positioned on the display. You may wish to use Auto triggering so that the scope continues to draw a trace even if the event is especially slow.

2. Press the Storage button to enter the storage mode.

3. Press the Roll button.

4. Select a Time/Div setting that produces a roll at the desired speed. As the sweep speed is decreased, the waveform will move across the screen more slowly and the Roll feature will become more apparent. In the Roll mode, the Time/Div setting is typically slowed by a factor of 100 by using the slow X100 button.

5. The rolling display can be frozen at any time by pressing the Save All button.

Other DSO Modes

Other features which may be found on digital storage oscilloscopes are briefly discussed here.

Save Operation
When waveforms are acquired, they are stored in memory, which is revised at each trigger occurrence in Refresh mode, or at each arming in Single mode.

Pressing the Save All button will save the waveform in memory. It remains there, regardless of operating mode, until the scope is shut off or the user purposely overwrites it with another waveform.

The Save CH2 button can be used to capture a waveform for reference. For example, a waveform from a known-good piece of equipment can be applied to channel 2 and captured in the Refresh mode. Then, the Save CH2 button can be pressed to freeze the waveform on the screen. Next, a waveform from the same point in the equipment under test can be captured on channel 1. The waveforms can be compared to determine whether the waveform on channel 1 is normal.

Plot output
The captured waveforms from a DSO can be permanently recorded for future reference by transferring the memory output to an analog

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plotter. First, the waveforms are frozen by pressing the Save All button. Then, an analog plotter can be connected to the channel 1 output, channel 2 output, and Pen Down output jacks on the rear panel of the DSO. When interconnected, plotting can begin by pressing the Plot button. The plot cycle is one screenful on (pen down) and the next screenful off (pen up). The Pen Down indicator lights for the entire pen-down period of the plot cycle.

Unique Characteristics of DSOs

Digital storage oscilloscopes use a digital sampling technique to convert analog signals to a series of digital words that can be stored in memory. Digital sampling has disadvantages as well as advantages, and it is important to be aware of these unique characteristics of DSOs.
Real Time Sampling and Aliasing

The DSO uses a technique called Real Time Sampling at sweep speeds slower than about 20 ms/div. Real Time Sampling simply means that samples of the input signal are taken at equal spaces (e.g., every 0.25 mS when the 50 mS/div range is selected). With Real Time Sampling, a phenomenon called "aliasing" can occur when the input signal is not sampled often enough. This causes the digitized signal to appear to be of a lower frequency than that of the input signal. Unless you have an idea what the input signal is supposed to look like, you will usually be unaware that aliasing is occurring.

To see an example of aliasing, connect a 10 kHz signal to a DSO, set the Time/Div setting to 50 mS/div, and put the scope in Refresh mode. You should see about five divisions displayed. Now change the Time/Div setting to 20 mS/div, and slightly alter the frequency of the input signal. If you do this carefully, you should be able to obtain a display that shows just a few cycles at this low sweep speed. If you calculate the frequency now, it appears to be something like 50 Hz or below, which is obviously incorrect.

This occurs because the DSO is taking samples too slowly to accurately render the waveform on the CRT, possibly one sample per cycle of the input signal. If the input frequency is set just right, the samples come at a slightly different point on each cycle, resulting in a waveform that appears to be valid but in fact is not.

Aliasing can occur whenever at least two samples per cycle are not taken (whenever the Time/Div setting is much too slow for the input signal). Whenever the frequency of the input signal is unknown, always begin with the fastest sweep speed, or view the waveform in analog mode first.
Viewing of one-time events poses no problem with aliasing because aliasing can occur only with repetitive waveforms.

Equivalent Time Sampling
On sweep speeds of 10 mS/div or greater, many DSOs use a sampling method known as Equivalent Time Sampling. This method permits viewing of repetitive waveforms of frequencies higher than the scope's sampling rate. When Equivalent Time Sampling is active, one sample is taken during each cycle. Of course, if that one sample is taken right at the trigger point on each cycle, a flat trace would be produced. Therefore, it is necessary to take each sample further (in time) from the trigger point than the last sample. This incremental delay is determined by the sweep Time/Div setting. To construct a complete waveform on the screen, the scope must sample as many cycles of the input signal as there are bytes in its memory.

Only repetitive waveforms should be observed in this mode. Irregularities that are present on an otherwise repetitive waveform are not likely to show up; with only one sample per cycle, glitches and other irregularities will most likely be skipped over.