Figure 22. *Front-panel control section of an oscilloscope.*

The Systems and Controls of an Oscilloscope

A basic oscilloscope consists of four different systems – the vertical system, horizontal system, trigger system, and display system. Understanding each of these systems will enable you to effectively apply the oscilloscope to tackle your specific measurement challenges. Recall that each system contributes to the oscilloscope's ability to accurately reconstruct a signal.

This section briefly describes the basic systems and controls found on analog and digital oscilloscopes. Some controls differ between analog and digital oscilloscopes; your oscilloscope probably has additional controls not discussed here.

The front panel of an oscilloscope is divided into three main sections labeled **vertical**, **horizontal**, and **trigger**. Your oscilloscope may have other sections, depending on the model and type – analog or digital – as shown in Figure 22. See if you can locate these front-panel sections in Figure 22, and on your oscilloscope, as you read through this section.

When using an oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

- The **attenuation** or **amplification** of the signal. Use the volts/div control to adjust the amplitude of the signal to the desired measurement range.
- The **time base**. Use the sec/div control to set the amount of time per division represented horizontally across the screen.
- The **triggering** of the oscilloscope. Use the **trigger level** to stabilize a repeating signal, or to trigger on a single event.

Vertical System and Controls

Vertical controls can be used to position and scale the waveform vertically. Vertical controls can also be used to set the input coupling and other signal conditioning, described later in this section. Common vertical controls include:

- Termination
  - 1M Ohm
  - 50 Ohm
- Coupling
  - DC
  - AC
  - GND
- Bandwidth Limit
  - 20 MHz
  - 250 MHz
  - Full
- Position
- Offset
- Invert – On/Off
- Scale
  - 1-2-5
  - Variable
- Zoom

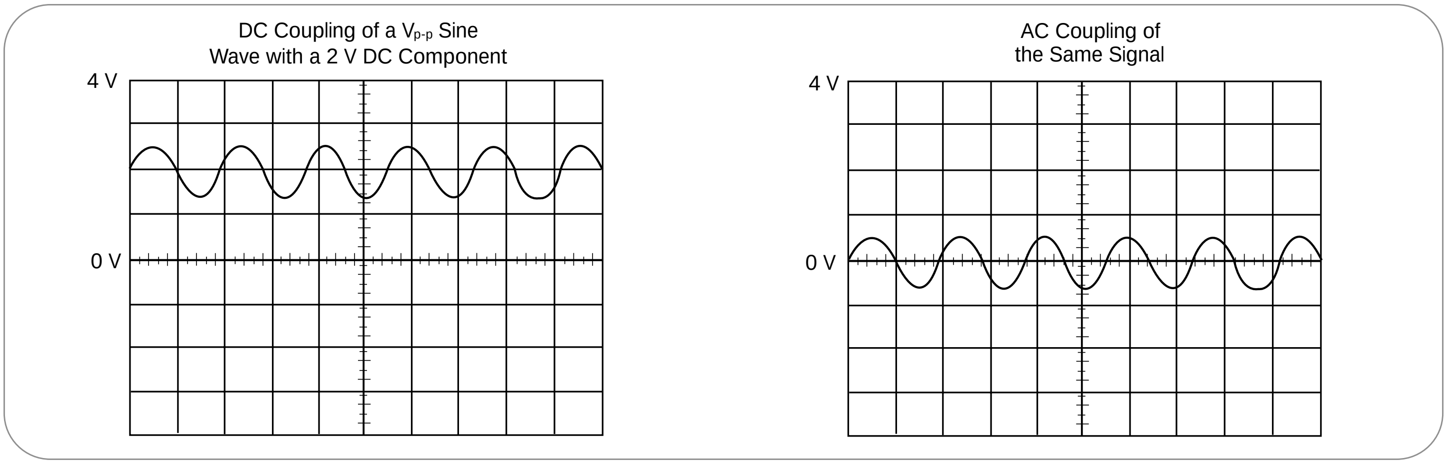


Figure 23. *AC and DC input coupling.*

Position and Volts per Division

The vertical position control allows you to move the waveform up and down exactly where you want it on the screen.

The volts-per-division setting (usually written as volts/div) varies the size of the waveform on the screen. A good general-purpose oscilloscope can accurately display signal levels from about 4 millivolts to 40 volts.

The volts/div setting is a scale factor. If the volts/div setting is 5 volts, then each of the eight vertical divisions represents 5 volts and the entire screen can display 40 volts from bottom to top, assuming a graticule with eight major divisions. If the setting is 0.5 volts/div, the screen can display 4 volts from bottom to top, and so on. The maximum voltage you can display on the screen is the volts/div setting multiplied by the number of vertical divisions. Note that the probe you use, 1X or 10X, also influences the scale factor. You must divide the volts/div scale by the attenuation factor of the probe if the oscilloscope does not do it for you.

Often the volts/div scale has either a variable gain or a fine gain control for scaling a displayed signal to a certain number of divisions. Use this control to assist in taking rise time measurements.

Input Coupling

Coupling refers to the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your test circuit to the oscilloscope. The coupling can be set to DC, AC, or ground. DC coupling shows all of an input signal. AC coupling blocks the DC component of a signal so that you see the waveform centered around zero volts. Figure 23 illustrates this difference. The AC coupling setting is useful when the entire signal (alternating current + direct current) is too large for the volts/div setting.

The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts is located on the screen. With grounded input coupling and auto trigger mode, you see a horizontal line on the screen that represents zero volts. Switching from DC to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

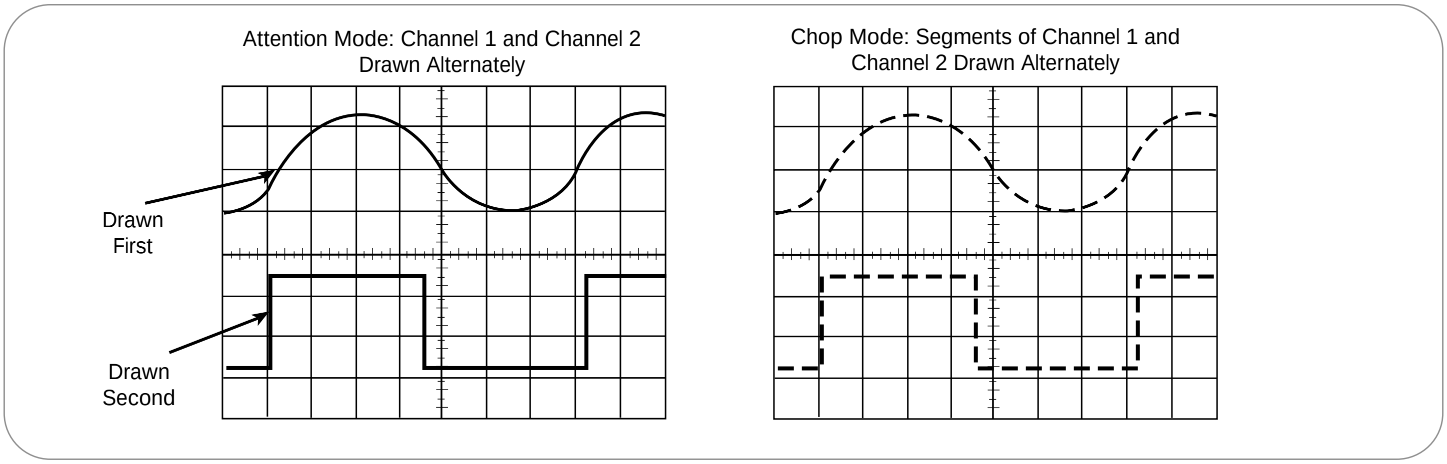


Figure 24. *Multi-channel display modes.*

Bandwidth Limit

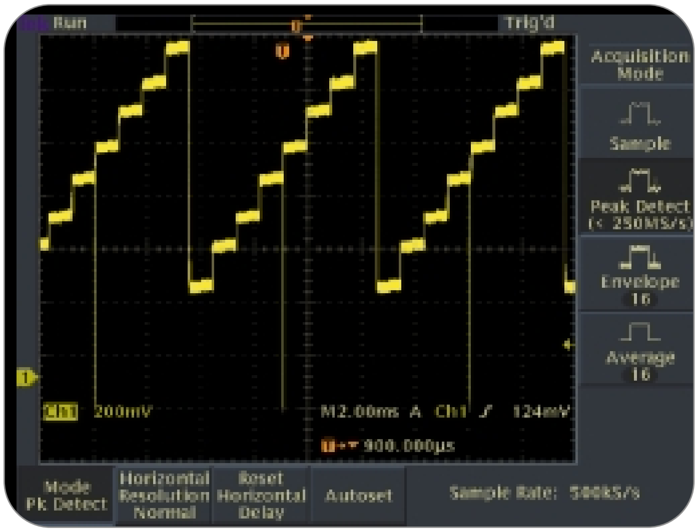
Most oscilloscopes have a circuit that limits the bandwidth of the oscilloscope. By limiting the bandwidth, you reduce the noise that sometimes appears on the displayed waveform, resulting in a cleaner signal display. Note that, while eliminating noise, the bandwidth limit can also reduce or eliminate high-frequency signal content.

Alternate and Chop Display Modes

Multiple channels on analog oscilloscopes are displayed using either an **alternate** or **chop mode**. (Many digital oscilloscopes can present multiple channels simultaneously without the need for chop or alternate modes.)

Alternate mode draws each channel alternately – the oscilloscope completes one sweep on channel 1, then another sweep on channel 2, then another sweep on channel 1, and so on. Use this mode with medium– to high–speed signals, when the sec/div scale is set to 0.5 ms or faster.

Chop mode causes the oscilloscope to draw small parts of each signal by switching back and forth between them. The switching rate is too fast for you to notice, so the waveform looks whole. You typically use this mode with slow signals requiring sweep speeds of 1 ms per division or less. Figure 24 shows the difference between the two modes. It is often useful to view the signal both ways, to make sure you have the best view.



▶ ***Figure 25.*** *Example of an acquisition menu.*

Horizontal System and Controls

An oscilloscope's horizontal system is most closely associated with its acquisition of an input signal – sample rate and record length are among the considerations here. Horizontal controls are used to position and scale the waveform horizontally. Common horizontal controls include:

- Main
- Delay
- XY
- Scale
  - 1-2-5
  - Variable
- Trace Separation
- Record Length
- Resolution
- Sample Rate
- Trigger Position
- Zoom

Acquisition Controls

Digital oscilloscopes have settings that let you control how the acquisition system processes a signal. Look over the acquisition options on your digital oscilloscope while you read this description. Figure 25 shows you an example of an acquisition menu.

Acquisition Modes

Acquisition modes control how waveform points are produced from sample points. Sample points are the digital values derived directly from the analog-to-digital converter (ADC). The **sample interval** refers to the time between these sample points. **Waveform points** are the digital values that are stored in memory and displayed to construct the waveform. The time value difference between waveform points is referred to as the **waveform interval**.

The sample interval and the waveform interval may, or may not, be the same. This fact leads to the existence of several different acquisition modes in which one waveform point is comprised of several sequentially acquired sample points. Additionally, waveform points can be created from a composite of sample points taken from multiple acquisitions, which provides another set of acquisition modes. A description of the most commonly used acquisition modes follows.

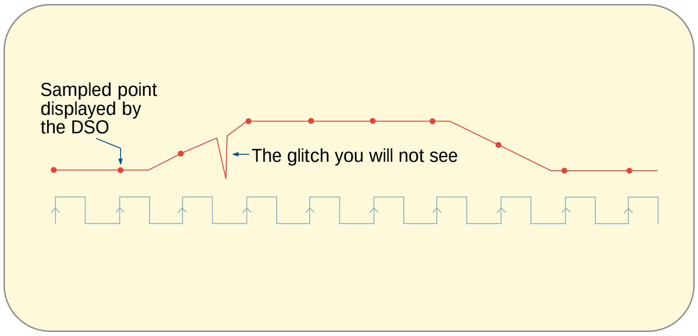


__Figure 26.__ Sample rate varies with time base settings – the slower the time base setting, the slower the sample rate. Some digital oscilloscopes provide peak detect mode to capture fast transients at slow sweep speeds.

Types of Acquisition Modes

- Sample Mode: This is the simplest acquisition mode. The oscilloscope creates a waveform point by saving one sample point during each waveform interval.
- Peak Detect Mode: The oscilloscope saves the minimum and maximum value sample points taken during two waveform intervals and uses these samples as the two corresponding waveform points. Digital oscilloscopes with peak detect mode run the ADC at a fast sample rate, even at very slow time base settings (slow time base settings translate into long waveform intervals) and are able to capture fast signal changes that would occur between the waveform points if in sample mode (Figure 26). Peak detect mode is particularly useful for seeing narrow pulses spaced far apart in time (Figure 27).
- Hi Res Mode: Like peak detect, hi res mode is a way of getting more information in cases when the ADC can sample faster than the time base setting requires. In this case, multiple samples taken within one waveform interval are averaged together to produce one waveform point. The result is a decrease in noise and an improvement in resolution for low-speed signals.

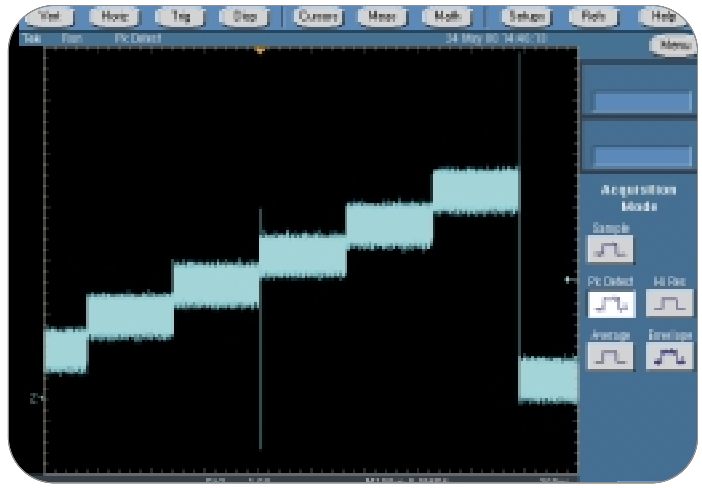


__Figure 27.__ Peak detect mode enables the TDS7000 Series oscilloscope to capture transient anomalies as narrow as 100 ps.

- Envelope Mode: Envelope mode is similar to peak detect mode. However, in envelope mode, the minimum and maximum waveform points from multiple acquisitions are combined to form a waveform that shows min/max accumulation over time. Peak detect mode is usually used to acquire the records that are combined to form the envelope waveform.
- Average Mode: In average mode, the oscilloscope saves one sample point during each waveform interval as in sample mode. However, waveform points from consecutive acquisitions are then averaged together to produce the final displayed waveform. Average mode reduces noise without loss of bandwidth, but requires a repeating signal.

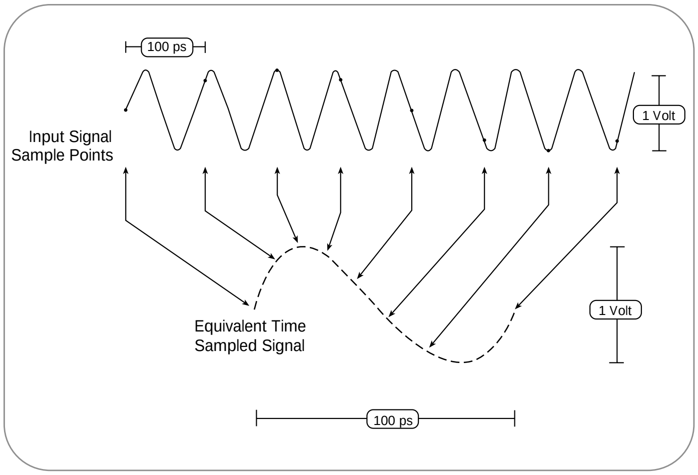


Figure 28. *Basic Sampling. Sampled points are connected by interpolation to produce a continuous waveform.*

Starting and Stopping the Acquisition System

One of the greatest advantages of digital oscilloscopes is their ability to store waveforms for later viewing. To this end, there are usually one or more buttons on the front panel that allow you to start and stop the acquisition system so you can analyze waveforms at your leisure. Additionally, you may want the oscilloscope to automatically stop acquiring after one acquisition is complete or after one set of records has been turned into an envelope or average waveform. This feature is commonly called single sweep or single sequence and its controls are usually found either with the other acquisition controls or with the trigger controls.

Sampling

Sampling is the process of converting a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and/or display. The magnitude of each sampled point is equal to the amplitude of the input signal at the instant in time in which the signal is sampled.

Sampling is like taking snapshots. Each snapshot corresponds to a specific point in time on the waveform. These snapshots can then be arranged in the appropriate order in time so as to reconstruct the input signal.

In a digital oscilloscope, an array of sampled points is reconstructed on a display with the measured amplitude on the vertical axis and time on the horizontal axis, as illustrated in Figure 28.

The input waveform in Figure 28 appears as a series of dots on the screen. If the dots are widely spaced and difficult to interpret as a waveform, the dots can be connected using a process called interpolation. Interpolation connects the dots with lines, or vectors. A number of interpolation methods are available that can be used to produce an accurate representation of a continuous input signal.

Sampling Controls

Some digital oscilloscopes provide you with a choice in sampling method – either real-time sampling or equivalent-time sampling. The acquisition controls available with these oscilloscopes will allow you to select a sample method to acquire signals. Note that this choice makes no difference for slow time base settings and only has an effect when the ADC cannot sample fast enough to fill the record with waveform points in one pass.

Sampling Methods

Although there are a number of different implementations of sampling technology, today's digital oscilloscopes utilize two basic sampling methods: real-time sampling and equivalent-time sampling. Equivalent-time sampling can be divided further, into two subcategories: random and sequential. Each method has distinct advantages, depending on the kind of measurements being made.

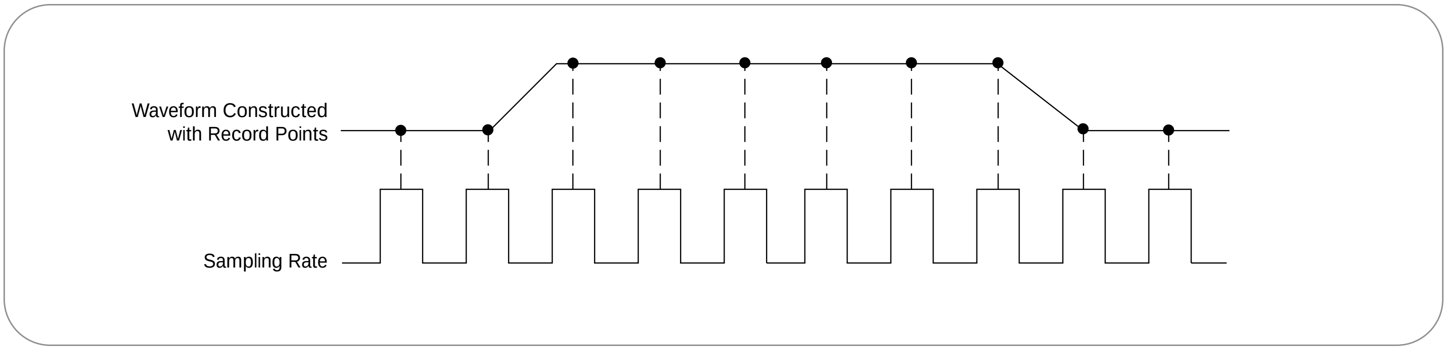


Figure 29. Real-time sampling method.

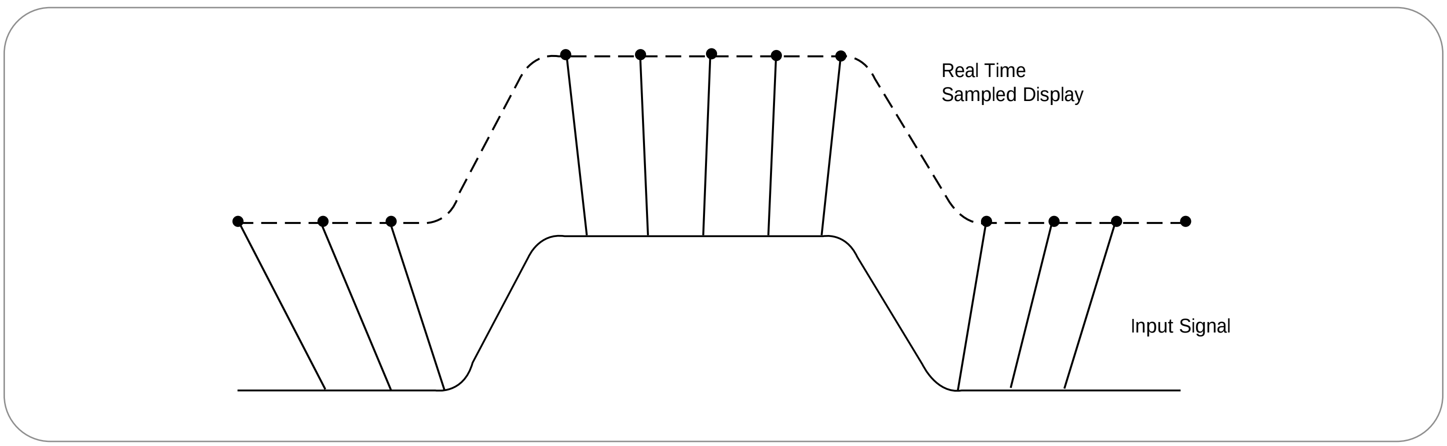


Figure 30. In order to capture this 10 ns pulse in real-time, the sample rate must be high enough to accurately define the edges.

Real-time Sampling

Real-time sampling is ideal for signals whose frequency range is less than half the oscilloscope's maximum sample rate. Here, the oscilloscope can acquire more than enough points in one "sweep" of the waveform to construct an accurate picture, as shown in Figure 29. Real-time sampling is the only way to capture fast, single-shot, transient signals with a digital oscilloscope.

Real-time sampling presents the greatest challenge for digital oscilloscopes because of the sample rate needed to accurately digitize high-frequency transient events, as shown in Figure 30. These events occur only once, and must be sampled in the same time frame that they occur. If the sample rate isn't fast enough, high-frequency components can "fold down" into a lower frequency, causing aliasing in the display. In addition, real-time sampling is further complicated by the high-speed memory required to store the waveform once it is digitized. Please refer to the **Sample Rate** and **Record Length** sections under **Performance Terms and Considerations** for additional detail regarding the sample rate and record length needed to accurately characterize high-frequency components.

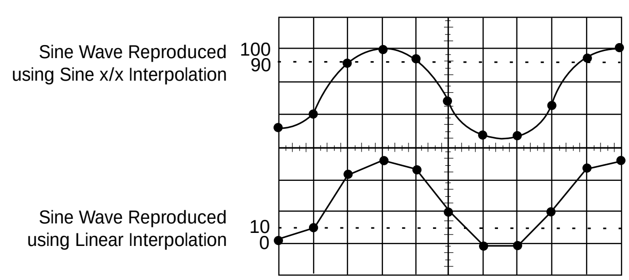


Figure 31. *Linear and sin x/x interpolation.*

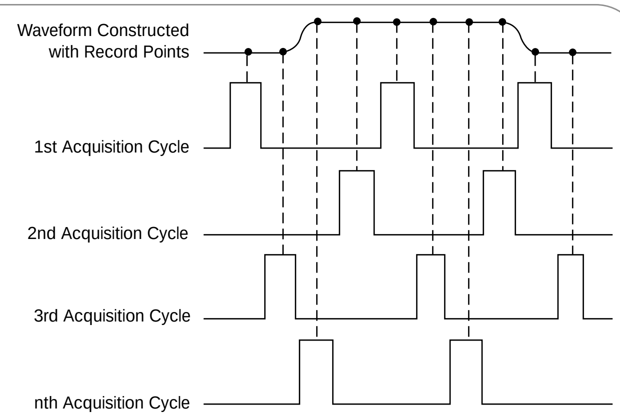


Figure 32. *Some oscilloscopes use equivalent-time sampling to capture and display very fast, repetitive signals.*

Real-time Sampling with Interpolation. Digital oscilloscopes take discrete samples of the signal that can be displayed. However, it can be difficult to visualize the signal represented as dots, especially because there can be only a few dots representing high-frequency portions of the signal. To aid in the visualization of signals, digital oscilloscopes typically have interpolation display modes.

In simple terms, **interpolation** "connects the dots" so that a signal that is sampled only a few times in each cycle can be accurately displayed. Using real-time sampling with interpolation, the oscilloscope collects a few sample points of the signal in a single pass in real-time mode and uses interpolation to fill in the gaps. Interpolation is a processing technique used to estimate what the waveform looks like based on a few points.

Linear interpolation connects sample points with straight lines. This approach is limited to reconstructing straight-edged signals like square waves, as illustrated in Figure 31.

The more versatile sin x/x interpolation connects sample points with curves, as shown in Figure 31. Sin x/x interpolation is a mathematical process in which points are calculated to fill in the time between the real samples. This form of interpolation lends itself to curved and irregular signal shapes, which are far more common in the real world than pure square waves and pulses. Consequently, sin x /x interpolation is the preferred method for applications where the sample rate is 3 to 5 times the system bandwidth.

Equivalent-time Sampling

When measuring high-frequency signals, the oscilloscope may not be able to collect enough samples in one sweep. Equivalent-time sampling can be used to accurately acquire signals whose frequency exceeds half the oscilloscope's sample rate, as illustrated in Figure 32. Equivalent time digitizers (samplers) take advantage of the fact that most naturally occurring and man-made events are repetitive. Equivalent-time sampling constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. The waveform slowly builds up like a string of lights, illuminating one-by-one. This allows the oscilloscope to accurately capture signals whose frequency components are much higher than the oscilloscope's sample rate.

There are two types of equivalent-time sampling methods: random and sequential. Each has its advantages. **Random equivalent-time sampling** allows display of the input signal prior to the trigger point, without the use of a delay line. **Sequential equivalent-time sampling** provides much greater time resolution and accuracy. Both require that the input signal be repetitive.

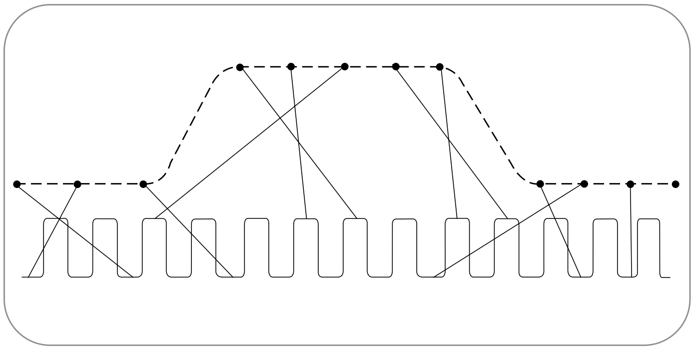


Figure 33. *In random equivalent-time sampling, the sampling clock runs asynchronously with the input signal and the trigger.*

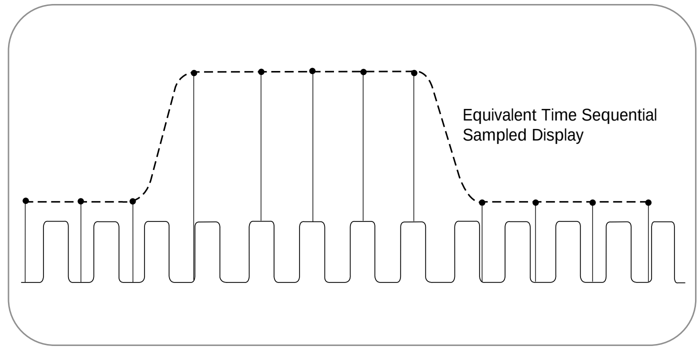


Figure 34. *In sequential equivalent-time sampling, a single sample is taken for each recognized trigger after a time delay which is incremented after each cycle.*

Random Equivalent-time Sampling. Random equivalent-time digitizers (samplers) utilize an internal clock that runs asynchronously with respect to the input signal and the signal trigger, as illustrated in Figure 33. Samples are taken continuously, independent of the trigger position, and are displayed based on the time difference between the sample and the trigger. Although samples are taken sequentially in time, they are random with respect to the trigger – hence the name “random” equivalent-time sampling. Sample points appear randomly along the waveform when displayed on the oscilloscope screen.

The ability to acquire and display samples prior to the trigger point is the key advantage of this sampling technique, eliminating the need for external pretrigger signals or delay lines. Depending on the sample rate and the time window of the display, random sampling may also allow more than one sample to be acquired per triggered event. However, at faster sweep speeds, the acquisition window narrows until the digitizer cannot sample on every trigger. It is at these faster sweep speeds that very precise timing measurements are often made, and where the extraordinary time resolution of the sequential equivalent-time sampler is most beneficial. The bandwidth limit for random equivalent-time sampling is less than for sequential-time sampling.

Sequential Equivalent-time Sampling. The sequential equivalent-time sampler acquires one sample per trigger, independent of the time/div setting, or sweep speed, as illustrated in Figure 34. When a trigger is detected, a sample is taken after a very short, but well-defined, delay. When the next trigger occurs, a small time increment – delta t – is added to this delay and the digitizer takes another sample. This process is repeated many times, with “delta t” added to each previous acquisition, until the time window is filled. Sample points appear from left to right in sequence along the waveform when displayed on the oscilloscope screen.

Technologically speaking, it is easier to generate a very short, very precise “delta t” than it is to accurately measure the vertical and horizontal positions of a sample relative to the trigger point, as required by random samplers. This precisely measured delay is what gives sequential samplers their unmatched time resolution. Since, with sequential sampling, the sample is taken after the trigger level is detected, the trigger point cannot be displayed without an analog delay line, which may, in turn, reduce the bandwidth of the instrument. If an external pretrigger can be supplied, bandwidth will not be affected.

Position and Seconds per Division

The horizontal position control moves the waveform left and right to exactly where you want it on the screen.

The seconds-per-division setting (usually written as sec/div) lets you select the rate at which the waveform is drawn across the screen (also known as the time base setting or sweep speed). This setting is a scale factor. If the setting is 1 ms, each horizontal division represents 1 ms and the total screen width represents 10 ms, or ten divisions. Changing the sec/div setting enables you to look at longer and shorter time intervals of the input signal.

As with the vertical volts/div scale, the horizontal sec/div scale may have variable timing, allowing you to set the horizontal time scale between the discrete settings.

Time Base Selections

Your oscilloscope has a time base, which is usually referred to as the main time base. Many oscilloscopes also have what is called a delayed time base – a time base with a sweep that can start (or be triggered to start) relative to a pre-determined time on the main time base sweep. Using a delayed time base sweep allows you to see events more clearly and to see events that are not visible solely with the main time base sweep.

The delayed time base requires the setting of a time delay and the possible use of delayed trigger modes and other settings not described in this primer. Refer to the manual supplied with your oscilloscope for information on how to use these features.

Zoom

Your oscilloscope may have special horizontal magnification settings that let you display a magnified section of the waveform on-screen. The operation in a digital storage oscilloscope (DSO) is performed on stored digitized data.

XY Mode

Most analog oscilloscopes have an XY mode that lets you display an input signal, rather than the time base, on the horizontal axis. This mode of operation opens up a whole new area of phase shift measurement techniques, explained in the Measurement Techniques section of this primer.

Z Axis

A digital phosphor oscilloscope (DPO) has a high display sample density and an innate ability to capture intensity information. With its intensity axis (Z axis), the DPO is able to provide a three-dimensional, real-time display similar to that of an analog oscilloscope. As you look at the waveform trace on a DPO, you can see brightened areas – the areas where a signal occurs most often. This display makes it easy to distinguish the basic signal shape from a transient that occurs only once in a while – the basic signal would appear much brighter. One application of the Z axis is to feed special timed signals into the separate Z input to create highlighted “marker” dots at known intervals in the waveform.

XYZ Mode

Some DPOs can use the Z input to create an XY display with intensity grading. In this case, the DPO samples the instantaneous data value at the Z input and uses that value to qualify a specific part of the waveform. Once you have qualified samples, these samples can accumulate, resulting in an intensity-graded XYZ display. XYZ mode is especially useful for displaying the polar patterns commonly used in testing wireless communication devices – a constellation diagram, for example.

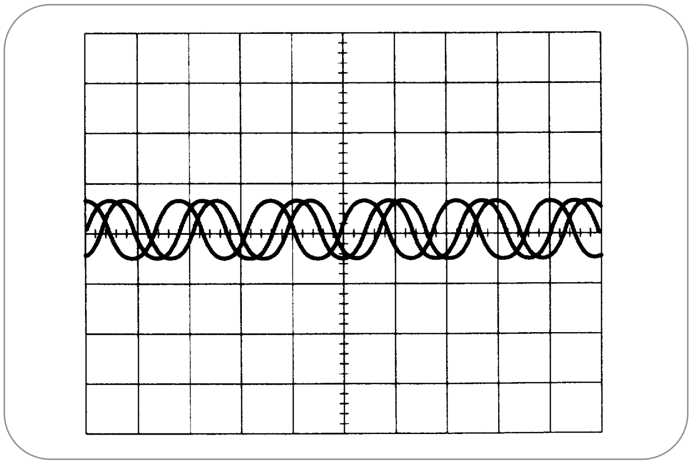


Figure 35. *Untriggered display.*

Trigger System and Controls

An oscilloscope's **trigger** function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms.

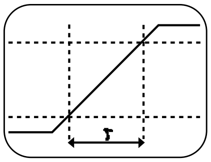
The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as illustrated in Figure 35.

Edge triggering, available in analog and digital oscilloscopes, is the basic and most common type. In addition to threshold triggering offered by both analog and digital oscilloscopes, many digital oscilloscopes offer a host of specialized trigger settings not offered by analog instruments. These triggers respond to specific conditions in the incoming signal, making it easy to detect, for example, a pulse that is narrower than it should be. Such a condition would be impossible to detect with a voltage threshold trigger alone.

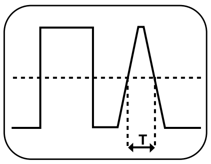
Advanced trigger controls enable you to isolate specific events of interest to optimize the oscilloscope's sample rate and record length. Advanced triggering capabilities in some oscilloscopes give you highly selective control. You can trigger on pulses defined by amplitude (such as runt pulses), qualified by time (pulse width, glitch, slew rate, setup-and-hold, and time-out), and delineated by logic state or pattern (logic triggering).

Optional trigger controls in some oscilloscopes are designed specifically to examine communications signals. The intuitive user interface available in some oscilloscopes also allows rapid setup of trigger parameters with wide flexibility in the test setup to maximize your productivity.

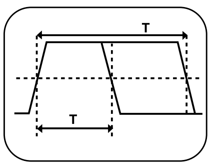
When you are using more than four channels to trigger on signals, a logic analyzer is the ideal tool. Please refer to Tektronix' *XYZs of Logic Analyzers* primer for more information about these valuable test and measurement instruments.



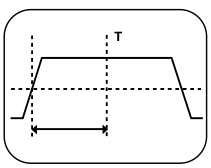
Slew Rate Triggering. High frequency signals with slew rates faster than expected or needed can radiate troublesome energy. Slew rate triggering surpasses conventional edge triggering by adding the element of time and allowing you to selectively trigger on fast or slow edges.



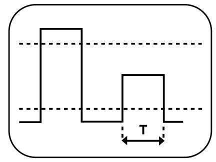
Glitch Triggering. Glitch triggering allows you to trigger on digital pulses when they are shorter or longer than a user-defined time limit. This trigger control enables you to examine the causes of even rare glitches and their effects on other signals



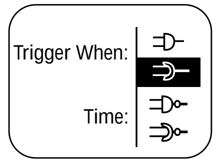
Pulse Width Triggering. Using pulse width triggering, you can monitor a signal indefinitely and trigger on the first occurrence of a pulse whose duration (pulse width) is outside the allowable limits.



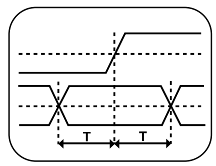
Time-out Triggering. Time-out triggering lets you trigger on an event without waiting for the trigger pulse to end, by triggering based on a specified time lapse.



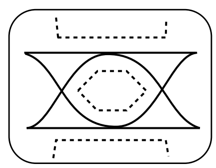
Runt Pulse Triggering. Runt triggering allows you to capture and examine pulses that cross one logic threshold, but not both.



Logic Triggering. Logic triggering allows you to trigger on any logical combination of available input channels – especially useful in verifying the operation of digital logic.



Setup-and-Hold Triggering. Only setup-and-hold triggering lets you deterministically trap a single violation of setup-and-hold time that would almost certainly be missed by using other trigger modes. This trigger mode makes it easy to capture specific signal quality and timing details when a synchronous data signal fails to meet setup-and-hold specifications.



Communication Triggering. Optionally available on certain oscilloscope models, these trigger modes address the need to acquire a wide variety of Alternate-Mark Inversion (AMI), Code-Mark Inversion (CMI), and Non-Return to Zero (NRZ) communication signals.

Trigger Position

Horizontal trigger position control is only available on digital oscilloscopes. The trigger position control may be located in the horizontal control section of your oscilloscope. It actually represents the horizontal position of the trigger in the waveform record.

Varying the horizontal trigger position allows you to capture what a signal did **before** a trigger event, known as **pre-trigger viewing**. Thus, it determines the length of viewable signal both preceding and following a trigger point.

Digital oscilloscopes can provide pre-trigger viewing because they constantly process the input signal, whether or not a trigger has been received. A steady stream of data flows through the oscilloscope; the trigger merely tells the oscilloscope to save the present data in memory. In contrast, analog oscilloscopes only display the signal – that is, write it on the CRT – after receiving the trigger. Thus, pre-trigger viewing is not available in analog oscilloscopes, with the exception of a small amount of pre-trigger provided by a delay line in the vertical system.

Pre-trigger viewing is a valuable troubleshooting aid. If a problem occurs intermittently, you can trigger on the problem, record the events that led up to it and, possibly, find the cause.

Trigger Level and Slope

The **trigger level** and **slope** controls provide the basic trigger point definition and determine how a waveform is displayed, as illustrated in Figure 36.

The trigger circuit acts as a comparator. You select the slope and voltage level on one input of the comparator. When the trigger signal on the other comparator input matches your settings, the oscilloscope generates a trigger.

- The slope control determines whether the trigger point is on the rising or the falling edge of a signal. A rising edge is a positive slope and a falling edge is a negative slope
- The level control determines where on the edge the trigger point occurs

Trigger Sources

The oscilloscope does not necessarily need to trigger on the signal being displayed. Several sources can trigger the sweep:

- Any input channel
- An external source other than the signal applied to an input channel
- The power source signal
- A signal internally defined by the oscilloscope, from one or more input channels

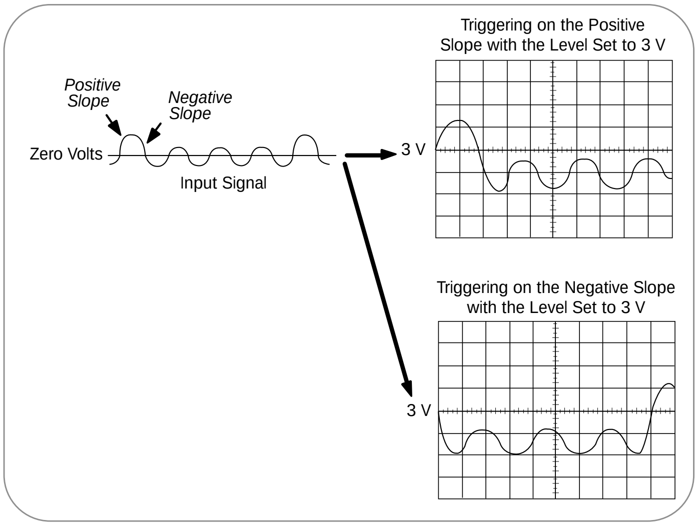
Most of the time, you can leave the oscilloscope set to trigger on the channel displayed. Some oscilloscopes provide a trigger output that delivers the trigger signal to another instrument.

The oscilloscope can use an alternate trigger source, whether or not it is displayed, so you should be careful not to unwittingly trigger on channel 1 while displaying channel 2, for example.

Trigger Modes

The **trigger mode** determines whether or not the oscilloscope draws a waveform based on a signal condition. Common trigger modes include **normal** and **auto**.

In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger point; otherwise (on an analog oscilloscope) the screen is blank or (on a digital oscilloscope) frozen on the last acquired waveform. Normal mode can be disorienting since you may not see the signal at first if the level control is not adjusted correctly.



▶ ***Figure 36.*** *Positive and negative slope triggering.*

Auto mode causes the oscilloscope to sweep, even without a trigger. If no signal is present, a timer in the oscilloscope triggers the sweep. This ensures that the display will not disappear if the signal does not cause a trigger.

In practice, you will probably use both modes: normal mode because it lets you see just the signal of interest, even when triggers occur at a slow rate, and auto mode because it requires less adjustment.

Many oscilloscopes also include special modes for single sweeps, triggering on video signals, or automatically setting the trigger level.

Trigger Coupling

Just as you can select either AC or DC coupling for the vertical system, you can choose the kind of coupling for the trigger signal.

Besides AC and DC coupling, your oscilloscope may also have high frequency rejection, low frequency rejection, and noise rejection trigger coupling. These special settings are useful for eliminating noise from the trigger signal to prevent false triggering.

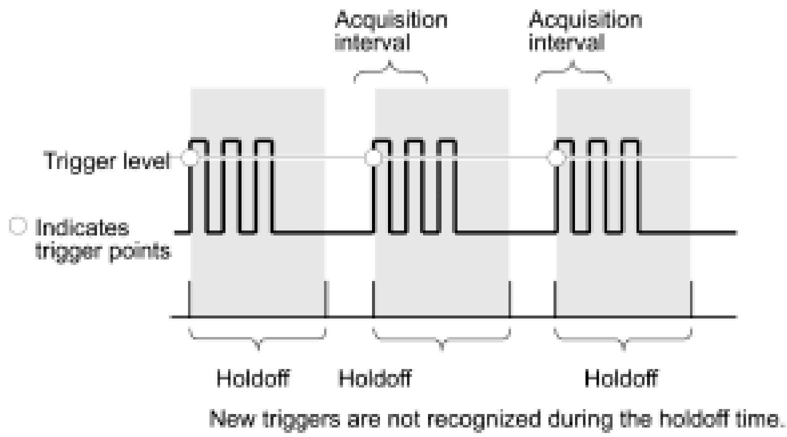


Figure 37. *Trigger holdoff.*

Trigger Holdoff

Sometimes getting an oscilloscope to trigger on the correct part of a signal requires great skill. Many oscilloscopes have special features to make this task easier.

Trigger **holdoff** is an adjustable period of time after a valid trigger during which the oscilloscope cannot trigger. This feature is useful when you are triggering on complex waveform shapes, so that the oscilloscope only triggers on an eligible trigger point. Figure 37 shows how using trigger holdoff helps create a usable display.

Display System and Controls

An oscilloscope's front panel includes a display screen and the knobs, buttons, switches, and indicators used to control signal acquisition and display. As mentioned at the front of this section, front-panel controls are usually divided into **vertical**, **horizontal** and **trigger** sections. The front panel also includes input connectors.

Take a look at the oscilloscope display. Notice the grid markings on the screen – these markings create the **graticule**. Each vertical and horizontal line constitutes a **major division**. The graticule is usually laid out in an 8-by-10 division pattern. Labeling on the oscilloscope controls (such as volts/div and sec/div) always refers to major divisions. The tick marks on the center horizontal and vertical graticule lines, as shown in Figure 38 (see next page), are called minor divisions. Many oscilloscopes display on the screen how many volts each vertical division represents and how many seconds each horizontal division represents.

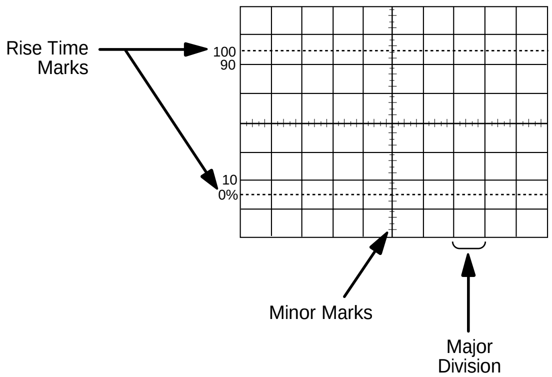


Figure 38. *An oscilloscope graticule.*

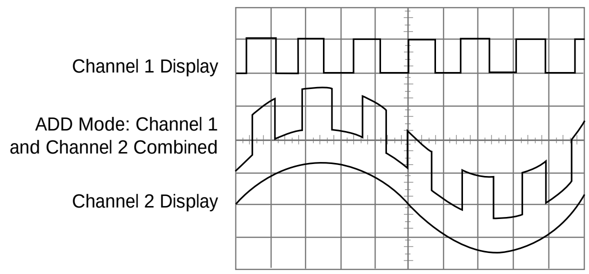


Figure 39. *Adding channels.*

Display systems vary between analog oscilloscopes and digital oscilloscopes. Common controls include:

- An intensity control to adjust the brightness of the waveform. As you increase the sweep speed of an analog oscilloscope, you need to increase the intensity level.
- A focus control to adjust the sharpness of the waveform, and a trace rotation control to align the waveform trace with the screen's horizontal axis. The position of your oscilloscope in the earth's magnetic field affects waveform alignment. Digital oscilloscopes, which employ raster- and LCD-based displays, may not have these controls because, in the case of these displays, the total display is pre-determined, as in a personal computer display. In contrast, analog oscilloscopes utilize a directed beam or vector display.
- On many DSOs and on DPOs, a color palette control to select trace colors and intensity grading color levels
- Other display controls may allow you to adjust the intensity of the graticule lights and turn on or off any on-screen information, such as menus

Other Oscilloscope Controls

Math and Measurement Operations

Your oscilloscope may also have operations that allow you to add waveforms together, creating a new waveform display. Analog oscilloscopes combine the signals while digital oscilloscopes create new waveforms mathematically. Subtracting waveforms is another math operation. Subtraction with analog oscilloscopes is possible by using the channel invert function on one signal and then using the add operation. Digital oscilloscopes typically have a subtraction operation available. Figure 39 illustrates a third waveform created by combining two different signals.

Using the power of their internal processors, digital oscilloscopes offer many advanced math operations: multiplication, division, integration, Fast Fourier Transform, and more.

We have described the basic oscilloscope controls that a beginner needs to know about. Your oscilloscope may have other controls for various functions. Some of these may include:

- Automatic parametric measurements
- Measurement cursors
- Keypads for mathematical operations or data entry
- Printing capabilities
- Interfaces for connecting your oscilloscope to a computer or directly to the Internet

Look over the other options available to you and read your oscilloscope's manual to find out more about these other controls.

The Complete Measurement System

Probes

Even the most advanced instrument can only be as precise as the data that goes into it. A probe functions in conjunction with an oscilloscope as part of the measurement system. Precision measurements start at the probe tip. The right probes matched to the oscilloscope and the device-under-test (DUT) not only allow the signal to be brought to the oscilloscope cleanly, they also amplify and preserve the signal for the greatest signal integrity and measurement accuracy.

To ensure accurate reconstruction of your signal, try to choose a probe that, when paired with your oscilloscope, exceeds the signal bandwidth by 5 times.

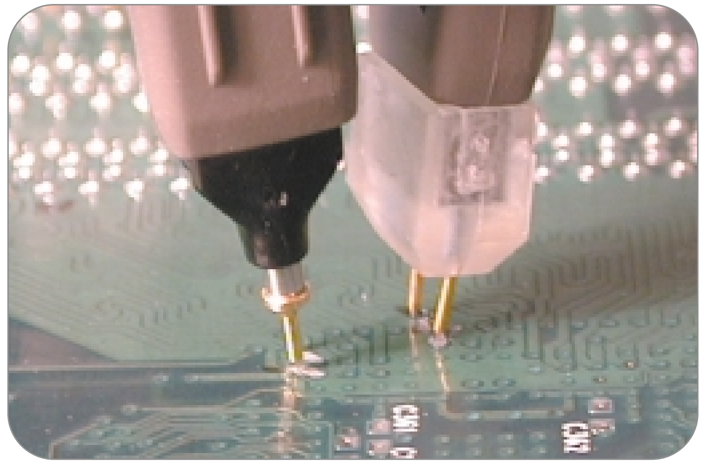


Figure 40. *Dense devices and systems require small form factor probes.*

Probes actually become part of the circuit, introducing resistive, capacitive and inductive loading that inevitably alters the measurement. For the most accurate results, the goal is to select a probe with minimal loading. An ideal pairing of the probe with the oscilloscope will minimize this loading, and enable you to access all of the power, features and capabilities of your oscilloscope.

Another consideration in the selection of the all-important connection to your DUT is the probe's form factor. Small form factor probes provide easier access to today's densely packed circuitry (see Figure 40).

A description of the types of probes follows. Please refer to Tektronix' *ABCs of Probes* primer for more information about this essential component of the overall measurement system.