# User and Service Guide

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# HP 54600-Series Oscilloscopes

# General-Purpose Oscilloscopes

The HP 54600-Series Oscilloscopes offer exceptional waveform viewing and measurements in a small, lightweight package. The two-channel HP 54600 is suited for production, field service, and education applications. The four-channel HP 54601 is best suited for research and design labs, and applications involving digital circuit test and troubleshooting. For higher frequency applications, the HP 54602 provides 150 MHz bandwidth and triggering up to 250 MHz. Each of these oscilloscopes gives you:

- 100-MHz bandwidth, 2 ns/div main and delayed time bases
- Automatic setup of the front panel
- Automatic and cursor measurements of frequency, time, and voltage
- Waveform storage
- Save and recall of 16 front-panel setups
- Peak detect

These oscilloscopes are easy to use with familiar controls and high display update rate, but with none of the viewing problems that are associated with analog oscilloscopes. A bright, crisp display is obtained at all sweep speeds and delayed sweep magnifications. Storage is as simple as pressing a button. Negative time allows the viewing of events that occur before the trigger event. Cursors and automatic measurements greatly simplify the analysis of these events. You can upgrade both of the oscilloscopes to print to a printer or to plot to a plotter, or remote control by either HP-IB or RS-232. The HP 54653A ScopeLink software simplifies the transfer of waveforms, data, and setups to a personal computer for analysis and documentation.



**Accessories supplied**

- Two 1.5 meter, 10:1 Probes (HP 10071A)
- Power cord for country of destination
- This *User and Service Guide*

**Accessories available**

- HP 54650A HP-IB Interface Module
- HP 54651A RS-232 Interface Module
- HP 54652A Parallel Interface Module
- HP 54653A ScopeLink Software
- HP 54654A Operator's Training Kit
- HP 54655A and HP 54656A Test Automation Modules
- HP 54657A and HP 54678A Measurement/Storage Modules
- HP 34810A BenchLink Software for Windows
- HP 5041-9409 Carrying Case
- HP 5062-7345 Rackmount Kit
- HP 10079A Camera
- HP 10070A 1.5 meter, 1:1 Probe
- HP 10100C 50 Ω Termination

**Options available**

- Option 001 RS-03 Magnetic Interference Shielding Added to CRT
- Option 002 RE-02 Display Shield Added to CRT
- Option 101 Accessory Pouch and Front-Panel Cover
- Option 102 Two Additional 10:1 Probes (HP 10071A)
- Option 103 Operator's Training Kit (HP 54654A)
- Option 104 Carrying Case (HP 5041-9409)
- Option 105 ScopeLink Software (HP 54653A)
- Option 106 BenchLink Software (HP 34810A)
- Option 908 Rackmount Kit (HP 5062-7345)
- Power Cords (see "Replaceable Parts," table 15 on page 115)

# In This Book

This book is the operating and service manual for the HP 54600-Series Oscilloscopes, and contains four chapters.

**Beginners** Chapter 1 is a quick start guide that gives you a brief overview of the oscilloscope.

**Advanced users** Chapter 2 is a series of exercises that guide you through the operation of the oscilloscope.

**Service technicians** Chapter 3 contains the service information for the oscilloscope. There are procedures for verifying performance, adjusting, troubleshooting, and replacing assemblies in the oscilloscope.

**Reference information** Chapter 4 lists the characteristics of the oscilloscope.



# Contents

1

# The Oscilloscope at a Glance

# The Oscilloscope at a Glance

One of the first things you will want to do with your new oscilloscope is to become acquainted with its front panel. Therefore, we have written the exercises in this chapter to familiarize you with some of its controls.

The front panel has knobs, grey keys, and white keys. The knobs are used most often and are similar to the knobs on other oscilloscopes. The grey keys bring up softkey menus on the display that allow you access to many of the oscilloscope features. The white keys are instant action keys and menus are not associated with them.

Throughout this book, the front-panel keys are denoted by a box around the name of the key, and softkeys are denoted by a change in the text type. For example, [Source] is the grey front-panel key labeled source under the trigger portion of the front panel, and `Line` is a softkey. The word `Line` is at the bottom of the display directly above an unlabeled softkey (which is also grey).

The rear cover of this book is a fold out reference guide. On this cover you will find a diagram of the front panel, and inside the cover is another diagram showing which grey keys to press to bring up the softkey menus.

The status line, located at the top of of the display, lets you quickly determine the setup of the oscilloscope. In this chapter you will learn to interpret the setup of the oscilloscope from the status line. An example of the status line is on the rear cover of this book.





## To connect a signal to the oscilloscope

The HP 54600 is a two-channel oscilloscope with an external trigger input, while the HP 54601 and HP 54602 are four-channel oscilloscopes. The four-channel oscilloscope replaces the external trigger input with channels 3 and 4. In this exercise you connect a signal to the channel 1 input.

To avoid damage to your new oscilloscope, make sure that the voltage level of the signal you are using is less than or equal to 400 V (dc plus the peak ac). For a complete list of the characteristics see chapter 4, "Performance Characteristics," on page 117.

- Use a cable or a probe to connect a signal to channel 1.

  If you are using a probe, the oscilloscope allows you to enter the attenuation factor for the probe. The attenuation factor changes the vertical scaling of the oscilloscope so that the measurement results reflect the actual voltage levels at the probe tip.

- To set the probe attenuation factor press [1]. Next toggle the `Probe` softkey to change the attenuation factor to match the probe you are using.

You should compensate 10:1 probes to match their characteristics to the oscilloscope. A poorly compensated probe can introduce measurement errors. To compensate a probe, follow these steps.

1 Connect the 10:1 probe from channel 1 to the front-panel probe adjust signal on the oscilloscope.

2 Press [Autoscale].

3 Use a nonmetallic tool to adjust the trimmer capacitor on the probe for the flattest pulse possible as displayed on the oscilloscope.

**Figure 1**

Overcompensation causes pulse peaking.

**Figure 2**

Correct compensation with a flat pulse top.

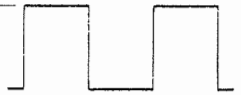


**Figure 3**

Undercompensation causes pulse rolloff.





## To display a signal automatically

The oscilloscope has an Autoscale feature that automatically sets up the oscilloscope to best display the input signal. Using Autoscale requires signals with a frequency greater than or equal to 50 Hz and a duty cycle greater than 1%.

When you press the Autoscale key, the oscilloscope turns on and scales all channels that have signals applied, and it selects a time base range based on the trigger source. The trigger source selected is the highest numbered input that has a signal applied. (If a signal is connected to the external trigger input on the HP 54600, then it is selected as the trigger source.)

1 Connect a signal to the oscilloscope.

2 Press [Autoscale].

When you press the Autoscale key, the oscilloscope changes the front-panel setup to display the signal. However, if you pressed the Autoscale key unintentionally, you can use the Undo Autoscale feature. To use this feature, perform the following step.

- Press [Setup]. Next, press the `Undo Autoscale` softkey.

  The oscilloscope returns to the configuration in effect before you pressed the Autoscale key.

## To set up the vertical window

The following exercise guides you through the vertical keys, knobs, and status line.

1 **Center the signal on the display with the Position knob.**

The Position knob moves the signal vertically, and it is calibrated. Notice that as you turn the Position knob, a voltage value is displayed for a short time indicating how far the ground reference is located from the center of the screen. Also notice that the ground symbol on the right side of the display moves in conjunction with the Position knob.

**Measurement hints**

If the channel is dc coupled, you can quickly measure the dc component of the signal by simply noting its distance from the ground symbol.

If the channel is ac coupled, the dc component of the signal is removed allowing you to use greater sensitivity to display the ac component of the signal.





2 **Change the vertical setup and notice that each change affects the status line differently.**

You can quickly determine the vertical setup from the status line in the display.

- Change the vertical sensitivity with the Volts/Div knob and notice that it causes the status line to change. For channels 3 and 4 on the HP 54601 and HP 54602, press [3] or [4]. Then use the softkeys to change the vertical sensitivity.
- Press [1].

  A softkey menu appears on the display, and the channel turns on (or remains on if it was already turned on).
- Toggle each of the softkeys and notice which keys cause the status line to change.

  Channels 1 and 2 have a vernier softkey that allows the Volt/Div knob to change the vertical step size in smaller increments. These smaller increments are calibrated, which results in accurate measurements even with the vernier turned on.
- To turn the channel off, either press [1] a second time or press the left-most softkey.

**Invert operating hint**

When you are triggered on the signal you are inverting, the inversion also applies to the trigger signal (what was a rising edge now is a falling edge). If the signal has a 50% duty cycle (square wave or sine wave), the displayed waveform appears not to invert. However, for signals with a duty cycle other than 50%, the displayed waveform does invert as you would expect.

## To set up the time base

The following exercise guides you through the time base keys, knobs, and status line.

1 **Turn the Time/Div knob and notice the change it makes to the status line.**

The Time/Div knob changes the sweep speed from 2 ns to 5 s in a 1-2-5 step sequence, and the value is displayed in the status line.

2 **Change the horizontal setup and notice that each change affects the status line differently.**

- Press Main/Delayed .

  A softkey menu appears on the display with six softkey choices.

- Toggle each of the softkeys and notice which keys cause the status line to change.





There is also a horizontal vernier softkey that allows the Time/Div knob to change the sweep speed in smaller increments. These smaller increments are calibrated, which results in accurate measurements even with the vernier turned on.

- Turn the Delay knob and notice that its value is displayed in the status line.

  The Delay knob moves the main sweep horizontally, and it pauses at 0.00 s, mimicking a mechanical detent. At the top of the graticule is a solid triangle ( ▼ ) symbol and an open triangle ( ∇ ) symbol. The ▼ symbol indicates the trigger point and it moves in conjunction with the Delay knob. The ∇ symbol indicates the time reference point. If the time reference softkey is set to left, the ∇ is located one graticule in from the left side of the display. If the time reference softkey is set to center, the ∇ is located at the center of the display. The delay number tells you how far the reference point ∇ is located from the trigger point ▼.

  All events displayed left of the trigger point ▼ happened before the trigger occurred, and these events are called pretrigger information. You will find this feature very useful because you can now see the events that led up to the trigger point. Everything to the right of the trigger point ▼ is called posttrigger information. The amount of delay range (pretrigger and posttrigger information) available is dependent on the sweep speed selected. See "Horizontal System," on page 120.

## To trigger the oscilloscope

The following exercise guides you through the trigger keys, knobs, and status line.

1 **Turn the trigger Level knob and notice the changes it makes to the display.**

On the HP 54601 and HP 54602 and on an internally triggered HP 54600, as you turn the Level knob or press a trigger menu key, for a short time two things happen on the display. First, the trigger level is displayed in inverse video. If the trigger is dc coupled, it is displayed as a voltage. If the trigger is ac coupled or if LF reject was selected, it is displayed as a percentage of the trigger range. Second, if the trigger source is turned on, a line is displayed showing the location of the trigger level (as long as ac coupling or low frequency reject are not selected).

2 **Change the trigger setup and notice that each change affects the status line differently.**

- Press [ Source ].

  A softkey menu appears on the display showing the trigger source choices.

- Toggle each of the softkeys and notice that each key causes the status line to change.





- Press [ Mode ].

  A softkey menu appears on the display with five trigger mode choices.

- Toggle the `Single` and `TV` softkeys and notice that they affect the status line differently. (You can only select TV if the trigger source is either channel 1 or 2.)

  When the oscilloscope is triggering properly, the trigger mode portion of the status line is blank.

**What happens if the oscilloscope loses trigger?**

If Auto Level is the trigger mode, Auto flashes in the status line. If dc coupled, the oscilloscope resets the trigger level to the center of the signal. If ac coupled, the oscilloscope resets the trigger level to the middle of the screen. (Every time you press the Auto Level softkey, the oscilloscope resets the trigger level.)

If Auto is the trigger mode, Auto flashes in the status line and the oscilloscope free runs.

If either Normal or TV is the trigger mode, the trigger setup flashes in the status line.

- Press [Slope/Coupling].

  A softkey menu appears on the display. If you selected Auto level, Auto, Normal, or Single as a trigger mode, six softkey choices are displayed. If you selected TV as a trigger source, five other softkey choices are available.

- Toggle each of the softkeys and notice which keys affect the status line.

  On the HP 54600, external trigger is always dc coupled. If you select ac coupling or low frequency reject, these functions do not occur until you change the trigger source to channel 1, channel 2, or line.

**3 Adjust the Holdoff knob and notice the change it makes to the display.**

Holdoff keeps the trigger from rearming for an amount of time that you set with the Holdoff knob. Holdoff is often used to stabilize the complex waveforms. The Holdoff range is from 200.0 ns to about 13.5 s. It is displayed, for a short time, in inverse video near the bottom of the display.





## To use roll mode

Roll mode continuously moves data across the display from right to left. It allows you to see dynamic changes (like adjusting a potentiometer) on low frequency signals. Two frequently used applications are transducer monitoring and power supply testing.

**1 Press [Mode]. Then press the `Auto Lvl`, `Auto`, or `Normal` softkey.**

**2 Press [Main/Delayed].**

**3 Press the `Roll` softkey.**

The oscilloscope is now untriggered and runs continuously. Also notice that the time reference softkey selection changes to center and right.

**4 Press [Mode]. Then press the `Single` softkey.**

The oscilloscope fills either $\frac{1}{2}$ or $\frac{9}{10}$ of the display (depending on the time reference selection), then it searches for a trigger. After a trigger is found, the remainder of the display is filled. Then, the oscilloscope stops acquiring data.

You can also make automatic measurements in the roll mode. Notice that the oscilloscope briefly interrupts the moving data while it makes the measurement. The acquisition system does not miss any data during the measurement. The slight shift in the display after the measurement is complete is that of the display catching up to the acquisition system.

**Roll mode operating hints**

Roll mode operates on channels 1 and 2 only.
Math functions, averaging, and peak detect are not available.
Holdoff and horizontal delay do not affect the signal.
Both a free running (nontriggered) display and a triggered display (available in the single mode only) are available.
It is available at sweep speeds up to 200 ms.





# Operating Your Oscilloscope

# Operating Your Oscilloscope

By now you are familiar with the VERTICAL, HORIZONTAL, and TRIGGER groups of the front-panel keys. You should also know how to determine the setup of the oscilloscope by looking at the status line. If you are unfamiliar with this information, we recommend you read chapter 1, "The Oscilloscope at a Glance," starting on page 7.

This chapter takes you through two new groups of front-panel keys: STORAGE, and the group of keys that contains the Measure, Save/Recall, and Display keys. You will also add to your knowledge of the HORIZONTAL keys by using delayed sweep.

We recommend you perform all of the following exercises so you become familiar with the powerful measurement capabilities of the oscilloscope.





## To use delayed sweep

Delayed sweep is a magnified portion of the main sweep. You can use delayed sweep to locate and horizontally expand part of the main sweep for a more detailed (high resolution) analysis of signals. The following steps show you how to use delayed sweep. Notice that the steps are very similar to operating the delayed sweep in analog oscilloscopes.

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Press [Main/Delayed].

3 Press the Delayed softkey.

The screen divides in half. The top half displays the main sweep, and the bottom half displays an expanded portion of the main sweep. This expanded portion of the main sweep is called the delayed sweep. The top half also has two solid vertical lines called markers. These markers show what portion of the main sweep is expanded in the lower half. The size and position of the delayed sweep are controlled by the Time/Div and Delay knobs. The Time/Div next to the  symbol is the delayed sweep sec/div. The delay value is displayed for a short time at the bottom of the display.

- To display the delay value of the delayed time base, either press [Main/Delayed] or turn the Delay knob.
- To change the main sweep Time/Div, you must turn off the delayed sweep.

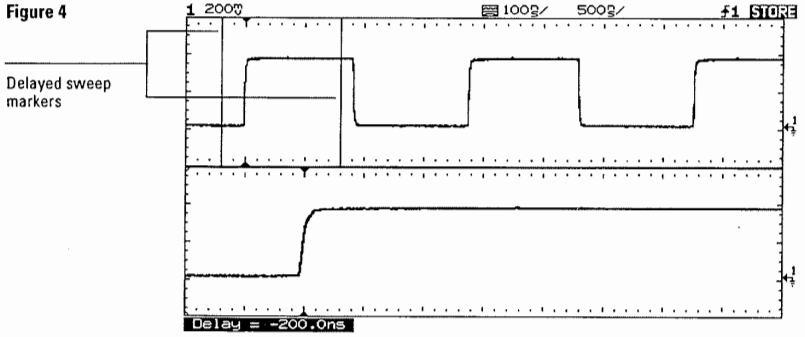
Since both the main and delayed sweeps are displayed, there are half as many vertical divisions so the vertical scaling is doubled. Notice the changes in the status line.

- To display the delay time of the delayed sweep, either press `Main/Delayed` or turn the delay knob. The delay value is displayed near the bottom of the display.

4 Set the `time reference` to either `left` or `center`.

Figure 4 shows the time reference set to left. The operation is like the delayed sweep of an analog oscilloscope, where the delay time defines the start of the delayed sweep.

**Figure 4**



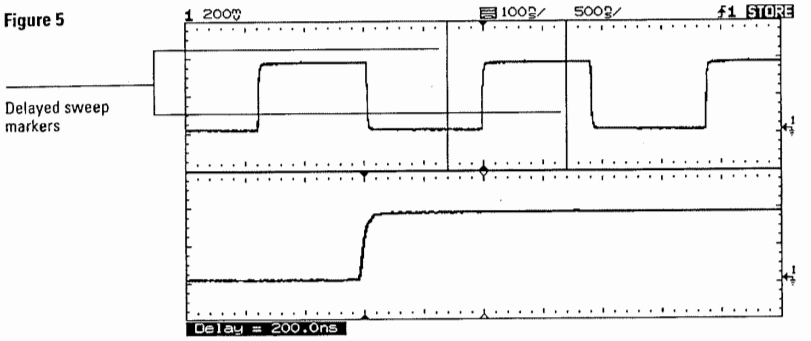

**Time reference set to left**





Figure 5 shows the time reference set to center. Notice that the markers expand around the area of interest. You can place the markers over the area of interest with the delay knob, then expand the delayed sweep with the time base knob to increase the resolution.

**Figure 5**




**Time reference set to center**

## To use storage oscilloscope operation

There are four front-panel storage keys. They are white instant action keys that change the operating mode of the oscilloscope. The following steps demonstrate how to use these storage keys.

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Press [Autostore].

Notice that STORE replaces RUN in the status line.

For easy viewing, the stored waveform is displayed in half bright and the most recent trace is displayed in full bright. Autostore is useful in a number of applications.

- Displaying the worst-case extremes of varying waveforms
- Capturing and storing a waveform
- Measuring noise and jitter
- Capturing events that occur infrequently





3 Using the position knob, move the trace up and down about one division.

Notice that the last acquired waveform is in full bright and the previously acquired waveforms are displayed in half bright.

- To characterize the waveforms, use the cursors. See "To make cursor measurements" on page 43.
- To clear the display, press [Erase].
- To exit the Autostore mode, press either [Run] or [Autostore].

**Summary of storage keys**

*Run* – The oscilloscope acquires data and displays the most recent trace.

Stop – The display is frozen.

*Autostore* – The oscilloscope acquires data, displaying the most recent trace in full bright and previously acquired waveforms in half bright.

*Erase* – Clears the display.

## To capture a single event

To capture a single event, you need some previous knowledge of the signal in order to set up the trigger level and slope. For example, if the event is derived from TTL logic, a trigger level of 2 volts should work on a rising edge. The following steps show you how to use the oscilloscope to capture a single event.

1 Connect a signal to the oscilloscope.

2 Set up the trigger.

- Press [Source]. Select a trigger source with the softkeys.
- Press [Slope/Coupling]. Select a trigger slope with the softkeys.
- Turn the Level knob to a point where you think the trigger should work.

3 Press [Mode], then press the `Single` softkey.

4 Press [Erase] to clear previous measurements from the display.

5 Press [Run].

Pressing the Run key arms the trigger circuit. When the trigger conditions are met, data appears on the display representing the data points that the oscilloscope obtained with one acquisition. Pressing the Run key again rearms the trigger circuit and erases the display.





6 If you need to compare several single-shot events, press [Autostore].

Like the Run key, the Autostore key also arms the trigger circuit. When the trigger conditions are met, the oscilloscope triggers. Pressing the Autostore key again rearms the trigger circuit, but this time the display is not erased. All the data points are retained on the display in half bright with each trigger allowing you to easily compare a series of single-shot events.

After you have acquired a single-shot event, pressing a front-panel key, softkey, or changing a knob can erase the event from the display. If you press the Stop key, the oscilloscope will recover the event and restore the oscilloscope settings.

- To clear the display, press [Erase].
- To exit the Autostore mode, press either [Run] or [Autostore]. Notice that RUN replaces STORE in the status line, indicating that the oscilloscope has exited the Autostore mode.

**Operating hint**

The single-shot bandwidth is 2 MHz for single-channel operation, and 1 MHz for two-channel operation. There are twice as many sample points per waveform on the one-channel acquisition than on the two-channel acquisition. On the HP 54600, channels 1 and 2 are captured simultaneously. On the HP 54601 and HP 54602 channels 1 and 2 are captured simultaneously, then on the next trigger channels 3 and 4 are captured simultaneously.

## To capture glitches or narrow pulses

A glitch is a rapid change in the waveform that is usually narrow as compared to the waveform. This oscilloscope has two modes of operation that you can use for glitch capture: peak detect and Autostore.

1 **Connect a signal to the oscilloscope and obtain a stable display.**

2 **Find the glitch.**

Use peak detect for narrow pulses or glitches that require sweep speeds slower than 50 µs/div.

- To select peak detect, press [ Display ]. Next, press the `Peak Det` softkey.

  Peak detect operates at sweep speeds from 5 s/div to 50 µs/div. When operating, the initials Pk are displayed in the status line in inverse video. At sweep speeds faster than 50 µs/div, the Pk initials are not displayed in inverse video, which indicates that peak detect is not operating.





Use Autostore for the following cases: waveforms that are changing, waveforms that you want to view and compare with stored waveforms, and narrow pulses or glitches that occur infrequently but require the use of sweep speeds outside the range of peak detect.

- Press [ Autostore ].

  You can use peak detect and Autostore together. Peak detect captures the glitch, while Autostore retains the glitch on the display in half bright video.

3 **Characterize the glitch with delayed sweep.**

Peak detect functions in the main sweep only, not in the delayed sweep. To characterize the glitch with delayed sweep follow these steps.

- Press [ Main/Delayed ]. Next press the `Delayed` softkey.
- To obtain a better resolution of the glitch, expand the time base.
- To set the expanded portion of the main sweep over the glitch, use the Delay knob.
- To characterize the glitch, use the cursors or the automatic measurement capabilities of the oscilloscope.

## To trigger on a complex waveform

The difficulty in viewing a complex waveform is triggering on the signal. Figure 6 shows a complex waveform that is not synchronized with the trigger.

The simplest trigger method is to trigger the oscilloscope on a sync pulse that is associated with the waveform. See "To trigger the oscilloscope" on page 16. If there is no sync pulse, use the following procedure to trigger on a periodic complex waveform.

1 Connect a signal to the oscilloscope.

2 Set the trigger level to the middle of the waveform.

3 Adjust the Holdoff knob to synchronize the trigger of the oscilloscope with the complex waveform.

By setting the Holdoff to synchronize the trigger, the oscilloscope ignores the trigger that results in figure 6, and waits for the trigger that results in figure 7. Also notice in figure 6 that the trigger is stable, but the waveform is not synchronized with the trigger.

**Holdoff operating hints**

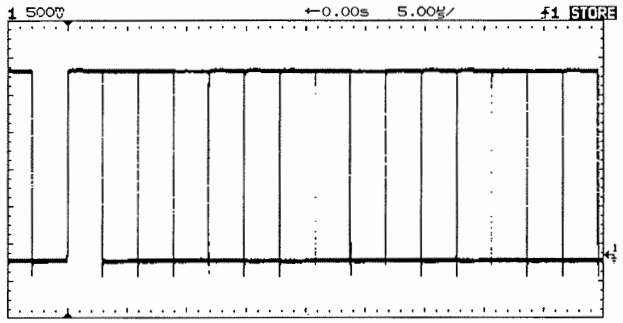
**1** The advantage of digital holdoff is that it is a fixed number. As a result, changing the time base settings does not affect the holdoff number; so, the oscilloscope remains triggered. In contrast, the holdoff in analog oscilloscopes is a function of the time base setting making it necessary to readjust the holdoff each time you change the time base setting.

**2** The rate of change of the holdoff adjustment knob depends on the time base setting you have selected. If you need a lengthy holdoff setting, increase the time/div setting on the time base, then make your coarse holdoff adjustment. Now switch back to the original time/div setting and make the fine adjustment to reach the exact amount you want.



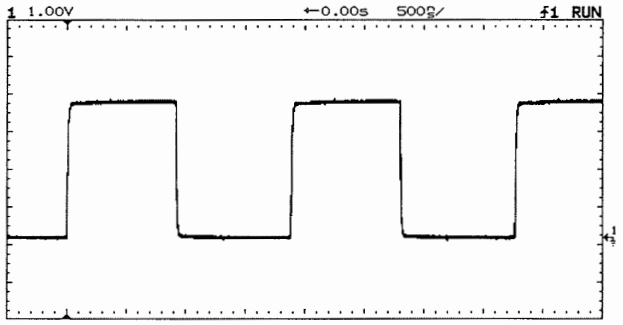


**Figure 6**




**Stable trigger, but the waveform is not synchronized with the trigger**

**Figure 7**




**Holdoff synchronizes the waveform with the trigger**

## To make frequency measurements automatically

The automatic measurement capability of the oscilloscope makes frequency measurements easy, as the following steps demonstrate.

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Press [Time].

A softkey menu appears with six softkey choices.

3 Toggle the `Source` softkey to select a channel for the frequency measurement.

4 Press the `Freq` softkey.

The oscilloscope automatically measures the frequency and displays the result on the lower line of the display. The number in parentheses after the word `Freq` is the number of the channel that the oscilloscope used for the measurement. The oscilloscope retains in memory and displays the three most current measurement results. If you make a fourth measurement, the left-most result is dropped



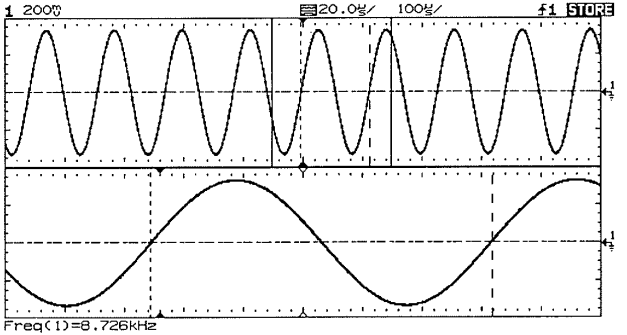


If the `Show Meas` softkey is turned on, cursors are displayed on the waveform that show the measurement points for the right-most measurement result. If you select more than one measurement, you can show a previous measurement by reselecting the measurement.

- To find the `Show Meas` softkey, press the `Next Menu` softkey key.

The oscilloscope makes automatic measurements on the first displayed event. Figure 8 shows how to use delayed sweep to isolate an event for a frequency measurement. If the measurement is not possible in the delayed time base mode, then the main time base is used. If the waveform is clipped, it may not be possible to make the measurement.

**Figure 8**




**Delayed time base isolates an event for a frequency measurement**

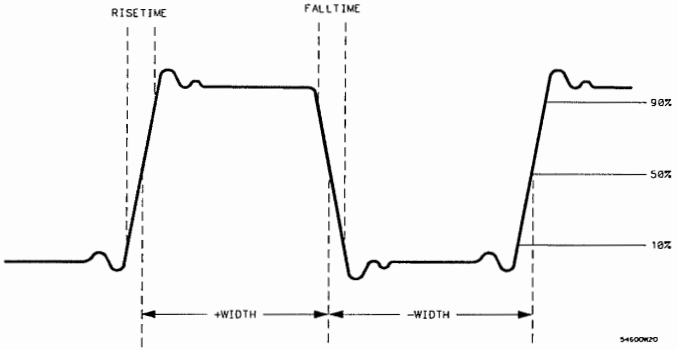
## To make time measurements automatically

You can measure the following time parameters with the oscilloscope: frequency, period, duty cycle, width, rise time, and fall time. The following exercise guides you through the Time keys by making a rise time measurement. Figure 9 shows a pulse with some of the time measurement points.

1 **Connect a signal to the oscilloscope and obtain a stable display.**

When the signal has a well-defined top and bottom, the rise time and fall time measurements are made at the 10% and 90% levels. If the oscilloscope cannot find a well-defined top or bottom, the maximum and minimum levels are used to calculate the 10% and 90% points from. These levels are shown on page 39 in figures 11 and 12.

**Figure 9**








2 Press `Time` .

A softkey menu appears with six softkey choices. Three of the softkeys are time measurement functions.

`Source` Selects a channel for the time measurement.

`Time Measurements` Three time measurement choices are available: Freq (frequency), Period, and Duty Cy (duty cycle). These measurements are made at the 50% levels. Refer to figure 9.

`Clear Meas` (clear measurement) Erases the measurement results and removes the cursors from the display.

`Next Menu` Replaces the softkey menu with six additional softkey choices.

3 Press the `Next Menu` softkey.

Another time measurement softkey menu appears with six additional choices. Four of the softkeys are time measurement functions.

`Show Meas` (show measurement) Displays the horizontal and vertical cursors where the measurement was taken.

`Time Measurements` Four additional time measurement choices are available; +Width, [Width]–Width, Rise time, and Fall time. Width measurements are made at the 50% levels, whereas rise time and fall time measurements are made at the 10% to 90% levels.

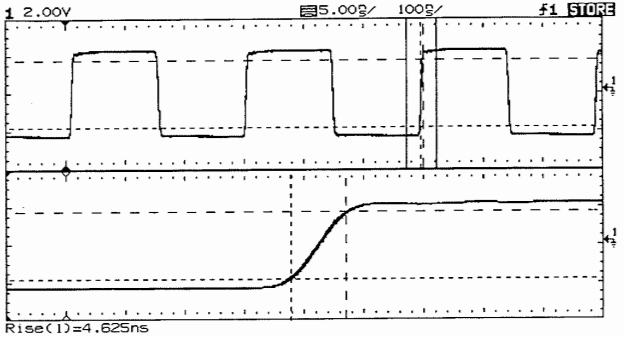
`Previous Menu` Returns to the previous softkey menu.

4 Press the `Rise Time` softkey.

The oscilloscope automatically measures the rise time of the signal and displays the result on the display.

The oscilloscope makes automatic measurements on the first displayed event. Figure 10 shows how to use delayed sweep to isolate an edge for a rise time measurement.

**Figure 10**




**Delayed sweep isolates a leading edge for a rise time measurement**

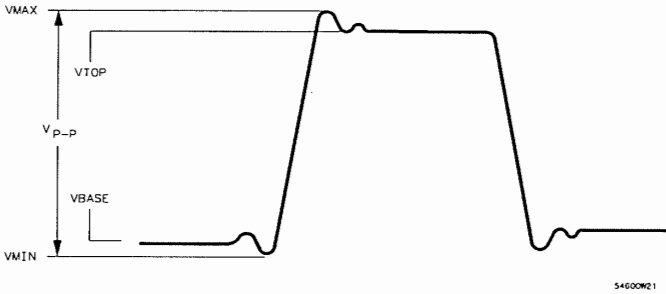




## To make voltage measurements automatically

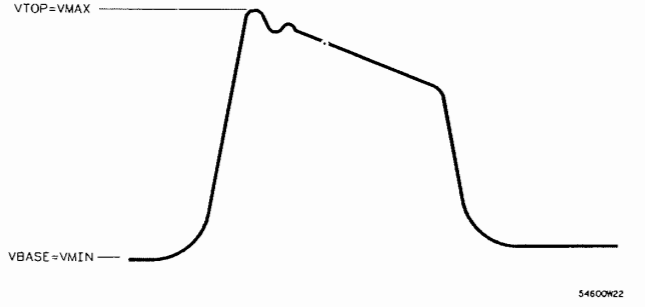
You can measure the following voltage parameters automatically with the oscilloscope: peak-to-peak, average, rms, maximum, minimum, top, and base. The following exercise guides you through the Voltage keys by making an rms voltage measurement. Figures 11 and 12 show pulses with some of the voltage measurement points.

**Figure 11**




**Pulse where the top and bottom are well-defined**

**Figure 12**




**Pulse where the top and bottom are not well-defined**

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Press [Voltage].

A softkey menu appears with six softkey choices. Three of the softkeys are voltage measurement functions.

`Source` Selects a channel for the voltage measurement.

`Voltage Measurements` Three voltage measurement choices are available: $V_{p\text{-}p}$, $V_{avg}$, and $V_{rms}$. The measurements are determined by voltage histograms of the signal.

`Clear Meas` (clear measurement) Erases any measurement results from the display, and removes the horizontal and vertical cursors from the display.

`Next Menu` Replaces the softkey menu with six additional softkey choices.



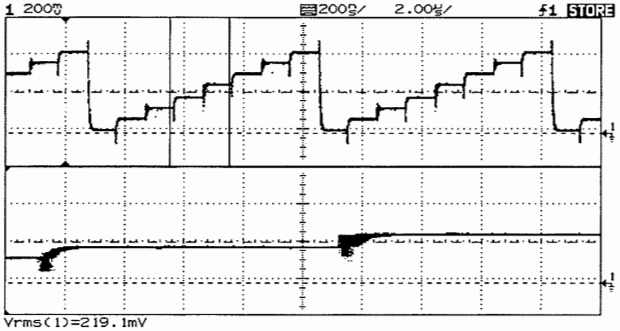


3 Press the $V_{rms}$ softkey.

The oscilloscope automatically measures the rms voltage and displays the result on the display.

The oscilloscope makes automatic measurements on the first pulse or period in the display. Figure 13 shows how to use delayed sweep to isolate a pulse for an rms measurement.

**Figure 13**




**Delayed sweep isolates an area of interest for an rms voltage measurement**

4 Press the `Next Menu` softkey.

Another voltage measurement softkey menu appears with six additional choices. Four of the softkeys are voltage measurement functions.

`Show Meas` (show measurement) Displays the horizontal and vertical cursors that show where the measurement was taken on the signal.

`Voltage Measurements` Four additional voltage measurement choices are available: $V_{max}$, $V_{min}$, $V_{top}$, $V_{base}$.

`Previous Menu` Returns to the previous softkey menu.





## To make cursor measurements

The following steps guide you through the front-panel Cursors key. You can use the cursors to make custom voltage or time measurements on the signal. Examples of custom measurements include rise time measurements from reference levels other than 10-90%, frequency and width measurements from levels other than 50%, channel-to-channel delay measurements, and voltage measurements. See figures 14 through19 for examples of custom measurements.

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Press [`Cursors`].

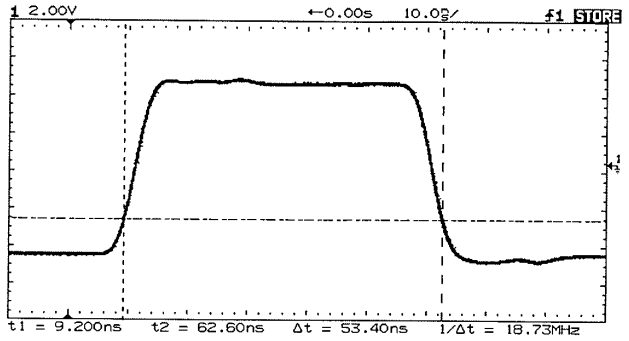
A softkey menu appears with six softkey choices. Four of the softkeys are cursor functions.

`Source` Selects a channel for the voltage cursor measurements.

`Active Cursor` There are four cursor choices: V1, and V2 are voltage cursors, while t1, and t2 are time cursors. Use the knob below the Cursors key to move the cursors. When you press the V1 and V2 softkeys simultaneously or the t1 and t2 softkeys simultaneously, the cursors move together.

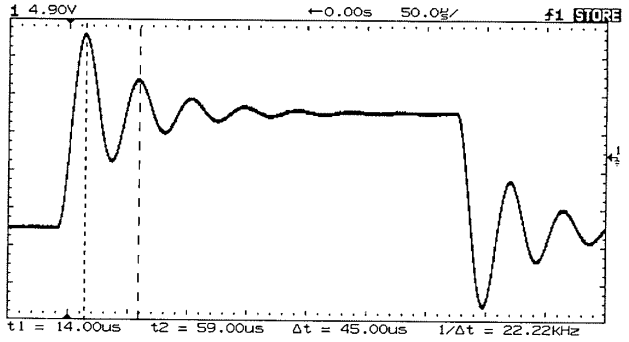
`Clear Cursors` Erases the cursor readings and removes the cursors from the display.

Figure 14




**Cursors used to measure pulse width at levels other then the 50% points**

Figure 15

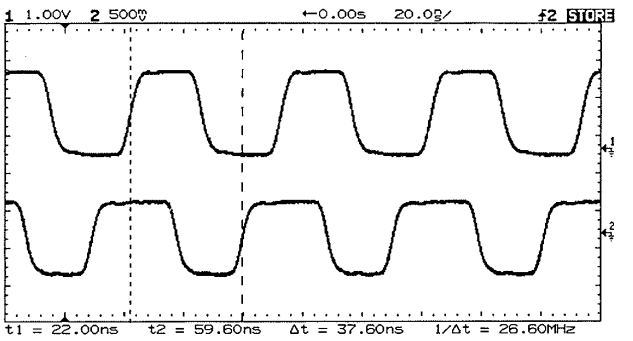



**Cursors used to measure the frequency of the ringing on a pulse**



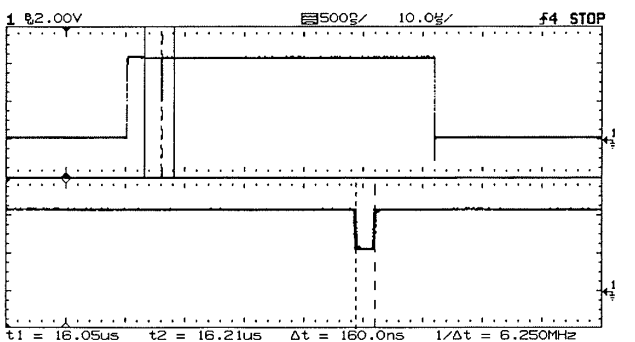


Figure 16



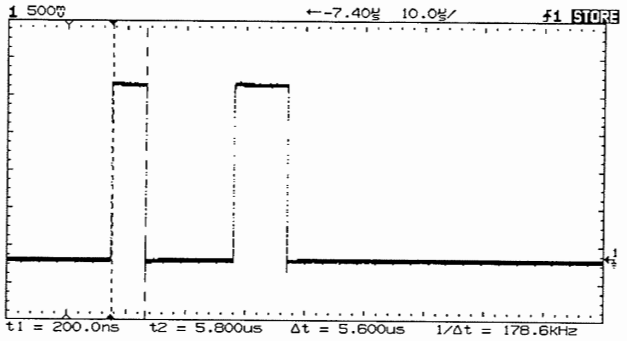

**Cursors used to make channel-to-channel delay measurements**

Figure 17



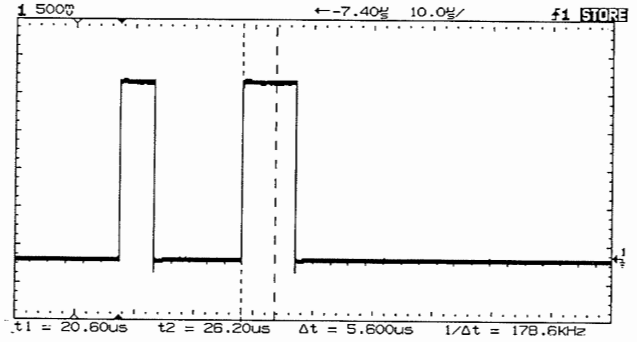

**The cursors track delayed sweep. Expand the display with delayed sweep, then characterize the event of interest with the cursors.**

**Figure 18**




**Pressing t1 and t2 softkeys simultaneously causes the cursors to move together when the cursor knob is adjusted.**

**Figure 19**




**By moving the cursors together, you can check for pulse width variations in a pulse train, as figures 18 and 19 show.**





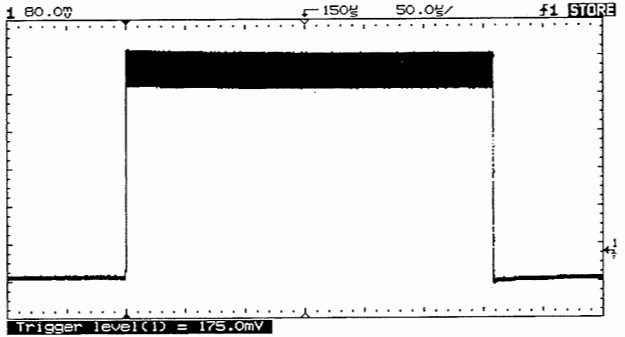
## To view asynchronous noise on a signal

The following exercise shows how to use the oscilloscope to view asynchronous noise on a signal that is not synchronous to the period of the waveform.

1 Connect a noisy signal to the oscilloscope and obtain a stable display.

Figure 20 shows a waveform with asynchronous noise at the top of the pulse.

**Figure 20**




**Asynchronous noise at the top of the pulse**

2 Press Autostore .

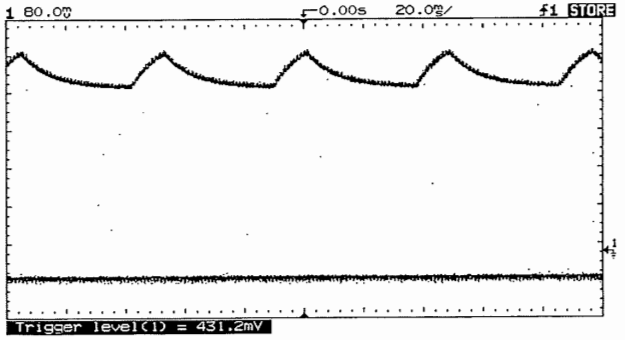
Notice that STORE is displayed in the status line.

3 Set the trigger mode to normal, then adjust the trigger level into the noise region of the signal.

4 Decrease the sweep speed for better resolution of the asynchronous noise.

- To characterize the asynchronous noise signal, use the cursors.

**Figure 21**




**This is a triggered view of the asynchronous noise shown in figure 20**





## To reduce the random noise on a signal

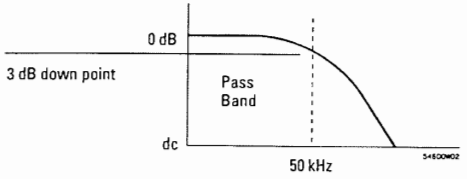
If the signal you are applying to the oscilloscope is noisy (figure 24), you can set up the oscilloscope to reduce the noise on the waveform (figure 25). First, you stabilize the displayed waveform by removing the noise from the trigger path. Second, you reduce the noise on the displayed waveform.

1 Connect a signal to the oscilloscope and obtain a stable display.

2 Remove the noise from the trigger path by turning on either high frequency reject or noise reject.

High frequency reject (HF reject) adds a low pass filter with the 3 dB point at 50 kHz (see figure 22). You use HF reject to remove high frequency noise such as AM or FM broadcast stations from the trigger path.

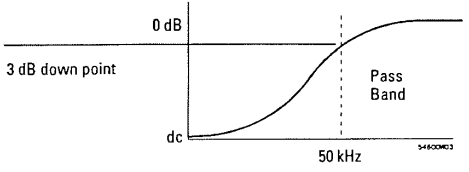
**Figure 22**




**HF reject**

Low frequency reject (LF reject) adds a high pass filter with the 3-dB point at 50 kHz (see figure 23). Use LF reject to remove low frequency signals such as power line noise from the trigger path.

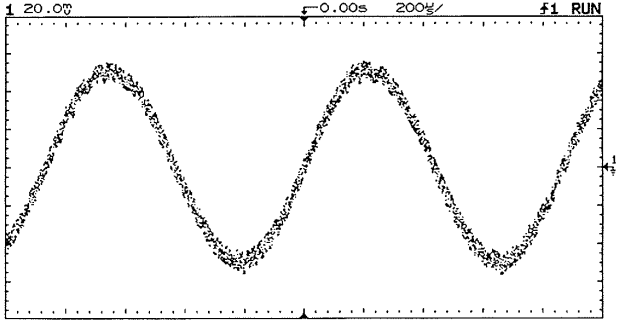
**Figure 23**




**LF reject**

Noise reject increases the trigger hysteresis band. By increasing the trigger hysteresis band you reduce the possibility of triggering on noise. However, this also decreases the trigger sensitivity so that a slightly larger signal is required to trigger the oscilloscope.

**Figure 24**




**Random noise on the displayed waveform**



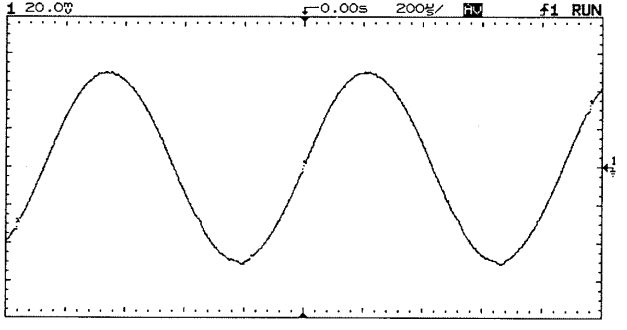


3 Use averaging to reduce noise on the displayed waveform.

To use averaging follow these steps.

- Press [Display], the press the `Average` softkey.
  Notice that `Av` appears in the status line.
- Toggle the `# Average` softkey to select the number of averages that best eliminates the noise from the displayed waveform.
  The `Av` initials in the status line indicates how much of the averaging process is finished, by turning to inverse video as the oscilloscope performs averaging. The higher the number of averages, the more noise that is removed from the display. However, the higher the number of averages, the slower the displayed waveform responds to waveform changes. You need to choose between how quickly the waveform responds to changes and how much noise there is on the signal.

**Figure 25**




**On this waveform, 256 averages were used to reduce the noise**

## To analyze video waveforms

The TV sync separator in the oscilloscope has an internal clamp circuit. This removes the need for external clamping when you are viewing unclamped video signals. TV triggering requires two vertical divisions of display, either channel 1 or channel 2 as the trigger source, and the selection of internal trigger. Turning the trigger level knob in TV trigger does not change the trigger level because the trigger level is automatically set to the sync pulse tips.

For this exercise we connected the oscilloscope to the video output terminals on a television. Then we set up the oscilloscope to view these parts of a TV signal: the second vertical interval with delayed sweep windowed on the vertical interval test signals (VITS) and the IRE displayed full screen.

1. Connect a TV signal to channel 1, then press [Autoscale].
2. Press [Display], then press the `Peak Det` softkey.
3. Press [Mode], then press the `TV` softkey.
4. Press [Slope/Coupling], then press the `Field 2` softkey.

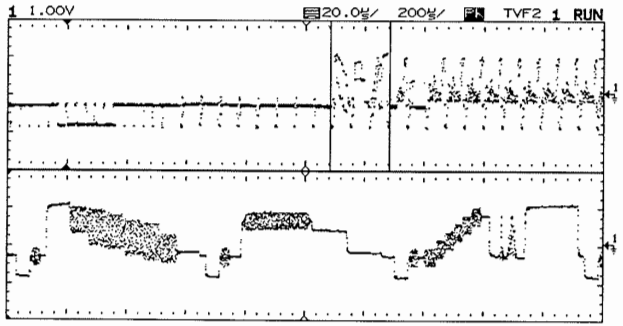




`Polarity` Selects either positive or negative sync pulses.
`Field 1` Triggers on the field 1 portion of the video signal.
`Field 2` Triggers on the field 2 portion of the video signal.
`Line` Triggers on all the TV line sync pulses.
`HF Rej` Controls a 500 kHz low pass filter in the trigger path.

5. Set the time base to 200 µs/div, then center the signal on the display with the delay knob (delay about 800 µs).
6. Press [Main/Delayed], then press the `Delayed` softkey.
7. Set the delayed sweep to 20 µs/div, then set the expanded portion over the VITS (delay about 988.8 µs).

**Figure 26**

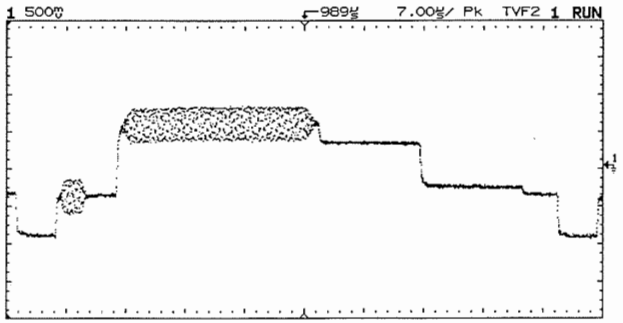



**Second vertical interval windowed on the VITS**

8 Press [Main/Delayed], then press the Main softkey.

9 Use the horizontal vernier to change the time base to 7 µs/div, then center the signal on the display with the delay knob (delay about 989 µs).

**Figure 27**




**Full screen display of the IRE**





**Delay in TV line units hint**

HP 54600-series oscilloscopes with system ROM versions 2.1 and greater have the ability to display delay in TV-line units. Using the TV field trigger mode activates this line-counting feature. When Field 1 or Field 2 is selected as the trigger source, delay can be set in terms of time or line number.

**Both-fields triggering hint**

The HP 54600 series oscilloscopes can trigger on the vertical sync pulse in both TV fields at the same time. This allows you to view noninterlaced video signals which are common in today's computer monitors. To trigger on both sync pulses, press Field 1 and Field 2 at the same time.

**TV trigger operating hints**

The color burst never really changes phase, it just looks doubled triggered because its frequency is an odd multiple of one half the line frequency.

When looking at live video (usually a field), use peak detect to improve the appearance of the display.

When making cursor measurements, use Autostore since you are usually looking for pulse flatness and extremes.

When using line trigger, use minimum holdoff to display all the lines. Due to the relationship between the horizontal and vertical sync frequencies the display looks like it is untriggered, but it is very useful for TV waveform analysis and adjustment because all of the lines are displayed.

## To save or recall traces

The oscilloscope has two pixel memories for storing waveforms. The following exercise guides you through how to store and recall waveforms from pixel memories.

1 **Connect a signal to the oscilloscope and obtain a stable display.**

2 **Press** `Trace` .

A softkey menu appears with five softkey selections. Four of the softkeys are trace memory functions.

`Trace` Selects memory 1 or memory 2.

`Trace Mem` Turns on or off the selected memory.

`Save to` Saves the waveform to the selected memory. The front-panel setup is saved to a separate memory location.

`Clear` Erases the selected memory.

`Recall Setup` Recalls the front-panel setup that was saved with the waveform.





3 **Toggle the** `Trace` **softkey to select memory 1 or memory 2.**

4 **Press the** `Save to` **softkey.**

The current display is copied to the selected memory.

5 **Turn on the** `Trace Mem` **softkey to view the stored waveform.**

The trace is copied from the selected trace memory and is displayed in half bright video.

The automatic measurement functions do not operate on stored traces. Remember, the stored waveforms are pictorial information rather than stored data.

- If you have not changed the oscilloscope setup, use the cursors to make the measurements.
- If you have changed the oscilloscope setup, press the `Recall Setup` softkey. Then,use the cursors to make the measurements.

**Trace memory operating hint**

The standard oscilloscope has volatile trace memories. When you add an interface module to the oscilloscope, the trace memories become nonvolatile.

## To use the XY display mode

The XY display mode converts the oscilloscope from a volts versus time display to a volts versus volts display. You can use various transducers so the display could show strain versus displacement, flow versus pressure, volts versus current, or voltage versus frequency. This exercise shows a common use of the XY display mode by measuring the phase shift between two signals of the same frequency with the Lissajous method.

1 Connect a signal to channel 1, and a signal of the same frequency but out of phase to channel 2.

2 Press [Autoscale], press [Main/Delayed], then press the XY softkey.

3 Center the signal on the display with the Position knobs, and use the Volts/Div knobs and the vertical Vernier softkeys to expand the signal for convenient viewing.

$$\sin\theta = \frac{A}{B} \text{ or } \frac{C}{D}$$

**Figure 28**

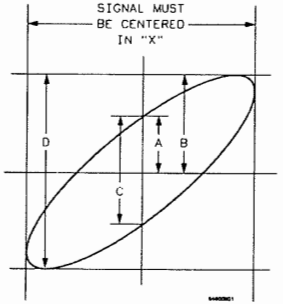
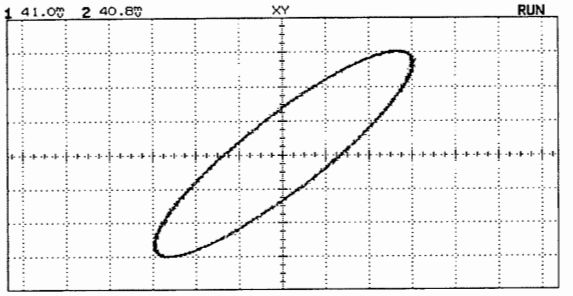







**Figure 29**

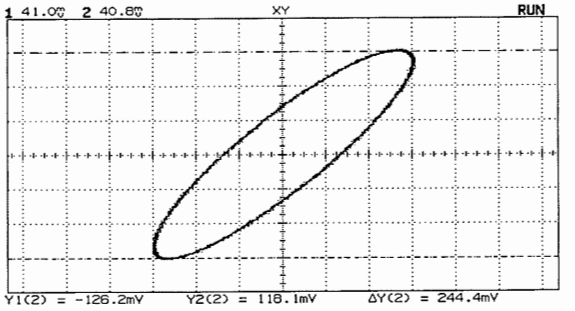



4 Press [Cursors].

5 Set the Y2 cursor to the top of the signal, and set Y1 to the bottom of the signal.

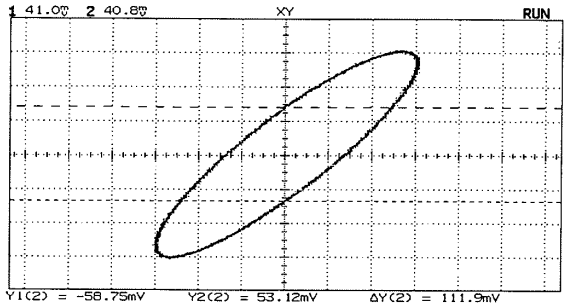
Note the ΔY value at the bottom of the display. In this example we are using the Y cursors, but you could have used the X cursors instead. If you use the X cursors, make sure you center the signal in the Y axis.

**Figure 30**



6 Move the Y1 and Y2 cursors to the center of the signal.
Again, note the ΔY value.

Figure 31



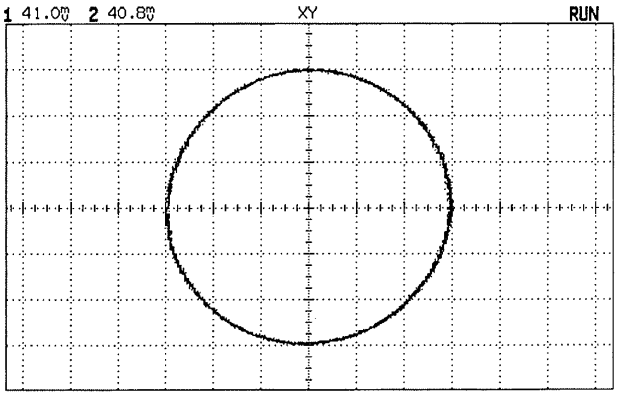

7 Calculate the phase difference using formula below.

$$\sin\theta = \frac{second\ \Delta Y}{first\ \Delta Y} = \frac{111.9}{244.4} = 27.25 \text{ degrees of phase shift.}$$



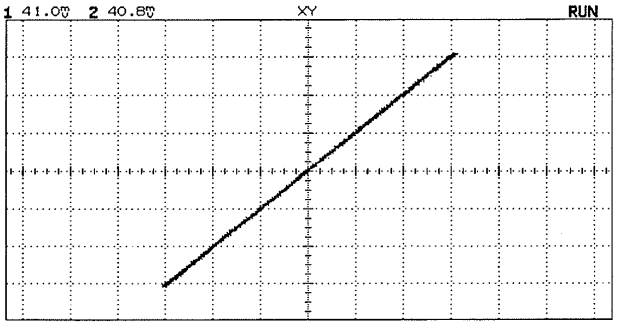


Figure 32




**Signals are 90° out of phase**

Figure 33




**Signals are in phase**

**XY display mode operating hint**

When you select the XY display mode, the time base is turned off. Channel 1 is the X-axis input, channel 2 is the Y-axis input, and channel 4 (external trigger in the HP 54600) is the Z-axis input. If you only want to see portions of the Y versus X display, use the Z-axis input. Z-axis turns on and off the trace (analog oscilloscopes called this Z-blanking because it turned the beam on and off). When Z is low (<1.3 V), Y versus X is displayed; when Z is high (>1.3 V), the trace is turned off.

## To save or recall front-panel setups

There are 16 memories for storing front-panel setups. Saving front-panel setups can save you time in situations where several setups are repeated many times.

1 Press [Setup].

2 To change the selected memory location, press either the left-most softkey or turn the knob closest to the Cursors key.

3 Press the `Save` softkey to save a front-panel setup, then press the `Recall` softkey to recall a front-panel setup.



# 3



# Service

# 4

# Performance Characteristics

# Performance Characteristics

The performance characteristics describe the typical performance of the oscilloscope. You will notice that some of the characteristics are marked as tested, these are values that you can verify with the performance tests under "Verifying Oscilloscope Performance," on page 67.

## Vertical System

**All channels**

Bandwidth[1]:
- dc to 100 MHz –3 dB (HP 54600 & HP 54601)
- dc to 100 MHz –3 dB (HP 54602 at 1, 2, & 5 mV/div)
- dc to 150 MHz –3 dB (channels 1 & 2, HP 54602)
- dc to 250 MHz –3 dB (channels 3 & 4, HP 54602)
- ac coupled, 10 Hz to 100 MHz –3 dB (HP 54600 & HP 54601)
- ac coupled, 10 Hz to 150 MHz –3 dB (channels 1 & 2, HP 54602)

Rise time:
- 3.5 ns (calculated, HP 54600 & HP 54601)
- <2.33 ns (calculated, channels 1 & 2, HP 54602)
- <1.4 ns (calculated, channels 3 & 4, HP 54602)

Dynamic range: ±32 V or ±8 divisions, whichever is less
Math functions: Channel 1 + or – channel 2
Input resistance: 1 MΩ
⚠ Input capacitance: ≈13 pf
Maximum input voltage: 400 V (dc + peak ac)

1 Tested, see "To verify bandwidth," on page 72.





**Channels 1 and 2**

Range: 2 mV/div to 5 V/div (lower limit is 1 mV/div for the HP 54602)
Accuracy[1]: ±1.5%
Verniers[1]: Fully calibrated, accuracy about ±3%
Cursor accuracy[1, 2, 3]:
Single cursor accuracy: vertical accuracy ±1.2% of full scale ±0.5% of position value
Dual cursor accuracy: vertical accuracy ±0.4% of full scale
Bandwidth limit: ≈20 MHz
Coupling: Ground, ac, and dc
Inversion: Channel 1 and channel 2
CMRR (common mode rejection ratio): ≈ 20 dB at 50 MHz

**Channels 3 and 4 (HP 54601 & HP 54602 only)**

Range: 0.1 V/div and 0.5 V/div ranges
Accuracy[1]: ±1.5%
Coupling: Ground and dc

1 When the temperature is within ±10 °C from the calibration temperature.
2 Use a full scale of 80 mV for 2 mV/div and 5 mV/div ranges.
3 Tested, see "To verify voltage measurement accuracy," on page 69.

# Horizontal System

Sweep speeds: 5 s/div to 2 ns/div main and delayed
Accuracy: ±0.01%
Vernier: Accuracy ±0.05%
Horizontal resolution: 100 ps
Cursor accuracy[1,2]: (Δt and 1/Δt) ±0.01% ±0.2% of full scale ±200 ps
Delay jitter: 10 ppm
Pretrigger delay (negative time): ≥10 divisions
Posttrigger delay (from trigger point to start of sweep): at least 2560 divisions or 50 ms. Not to exceed 100 s.
Delayed sweep operation

| Main sweep | Delayed sweep |
|---|---|
| 5 s/div to 10 ms/div | up to 200 times main sweep |
| 5 ms/div and faster | up to 2 ns/div |

1 Use full scale of 50 ns on 2 ns/div range.
2 Tested, see "To verify horizontal Δt and 1/Δt accuracy," on page 78.





# Trigger System

**Internal trigger**

Sensitivity[1]:
dc to 25 MHz 0.35 div or 3.5 mV (all channels on all models)
dc to 100 MHz 1 div or 10 mV (all channels on HP 54600 & HP 54601)
dc to 150 MHz 1 div or 10 mV (channels 1 & 2 on HP 54602)
dc to 250 MHz 1 div or 10 mV (channels 3 & 4 on HP 54602)
54602 @ 1, 2, or 5 mV/div
dc to 25 MHz 1.0 div or 2 mV
dc to 100 MHz 1.5 div or 3 mV
Sources:
Channels 1 to 4 and line on HP 54601 & HP 54602,
Channels 1, 2, line, and external on HP 54600
Coupling: ac, dc, LF reject, HF reject, and noise reject
LF reject and HF reject –3 dB at ≈50 kHz
Modes: Auto, Autolevel, Normal, Single, and TV
TV triggering: Available on channels 1 and 2 only
TV line and field: 0.5 division of composite sync for stable display
Holdoff: Adjustable from 200 ns to ≈13 s

**External trigger (available on HP 54600 only)**

Range: ±18 V
Sensitivity[1]:
dc to 25 MHz 50 mV
dc to 100 MHz 100 mV
⚠ Coupling: dc, HF reject, and noise reject
Input resistance: 1 MΩ
Input capacitance: ≈13 pf
Maximum input voltage: 400 V (dc + peak ac)

1 Tested, see "To verify trigger sensitivity," on page 81.

## XY Operation

Z Blanking: TTL high blanks trace
Bandwidths: X and Y same as vertical system
Phase difference: ±3 degrees at 100 kHz

## Display System

Display: 7-inch raster CRT
Resolution: 255 vertical by 500 horizontal points
Controls: Front-panel intensity control
Graticule: 8 × 10 grid or frame
Autostore: Autostore saves previous sweeps in half bright display and the most recent sweep in full bright display.

## Acquisition System

Maximum sample rate: 20 MSa/s
Resolution: 8 bits
Simultaneous channels: Channels 1 and 2 or channels 3 and 4
Record length:
    Vectors off: 4,000 points
    Vectors on and/or single shot: 2,000 points
Maximum update rate:
    Vectors off: 1,500,000 points/sec
    Vectors on: 60 full screens/sec, independent of the number of waveforms being displayed
Single-shot bandwidth: 2 MHz single channel, 1 MHz dual channel
Peak detect: 50 ns glitch capture (100 ns dual channel) from 5 s/div to 50 µs/div
Average: Number of averages selectable at 8, 64, and 256
Roll Mode: At sweep speeds of 200 ms/div and slower, waveform data moves across the display from right to left with no dead time. Display can be either free-running (non-triggered) or triggered to stop on a trigger event.





## Advanced Functions

Automatic measurements: (measurements are continuously updated)
    Voltage: Vavg, Vrms, Vp-p, Vtop, Vbase, Vmin, Vmax
    Time: Frequency, period, + width, – width, duty cycle, rise time, and fall time
Cursors: Manually or automatically placed
Setup functions:
    Autoscale: Sets vertical and horizontal deflections and trigger level for signals with a frequency ≥50 Hz, duty cycle >1% and voltage level
        channels 1 and 2 >20 mVp-p
        channels 3 and 4 >100 mVp-p
        external trigger (HP 54600 only) >100 mVp-p
    Save/Recall: 16 front-panel setups
    Trace memory: Two volatile pixel memories

## Power Requirements

Line voltage range: 100 Vac to 240 Vac
Line voltage selection: Automatic
Line frequency: 45 Hz to 440 Hz
Maximum power consumption: 220 VA