General-Purpose Oscilloscopes

The HP 54600B-Series Oscilloscopes offer exceptional waveform viewing and measurements in a small, lightweight package. The two-channel HP 54600B and HP 54603B are suited for production, field service, and education applications. The four-channel HP 54601B is best suited for research and design labs, and applications involving digital circuit test and troubleshooting. For higher frequency applications, the HP 54602B provides 150 MHz bandwidth and triggering up to 250 MHz. Each of these oscilloscopes gives you:

- 60-MHz bandwidth (HP 54603B)
  100-MHz bandwidth (HP 54600B and HP 54601B)
  150-MHz bandwidth (HP 54602B)
- 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 this oscilloscope for hardcopy or remote control with the addition of an interface module. Unattended waveform monitoring and additional waveform math, such as FFT, can be added with the addition of one of the Measurement/Storage modules.

Bring your scope and PC together with BenchLink software. BenchLink, which runs under Windows, allows easy transfer of scope traces and waveform data to your PC for incorporation into documents or storage.

Accessories supplied

- Two 1.5 meter, 10:1 Probes (HP 10071A)
- Power cord for country of destination
- This *User and Service Guide*
- *Programmer's Guide* with Microsoft Windows Help file, ascii help file, and sample programs.

Accessories available

- HP 34810B BenchLink/Scope Software for Windows
- HP 54650A HP-IB Interface Module
- HP 54652A Parallel Interface Module
- HP 54654A Operator's Training Kit
- HP 54655A and HP 54656A Test Automation Modules
- HP 54657A HP-IB Measurement Storage Module
- HP 54659B Serial/Parallel Measurement/Storage Modules
- HP 5041-9409 Carrying Case
- HP 5062-7345 Rackmount Kit
- HP 10070A 1.5 meter, 1:1 Probe
- HP 10100C 50 Ω Termination

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.

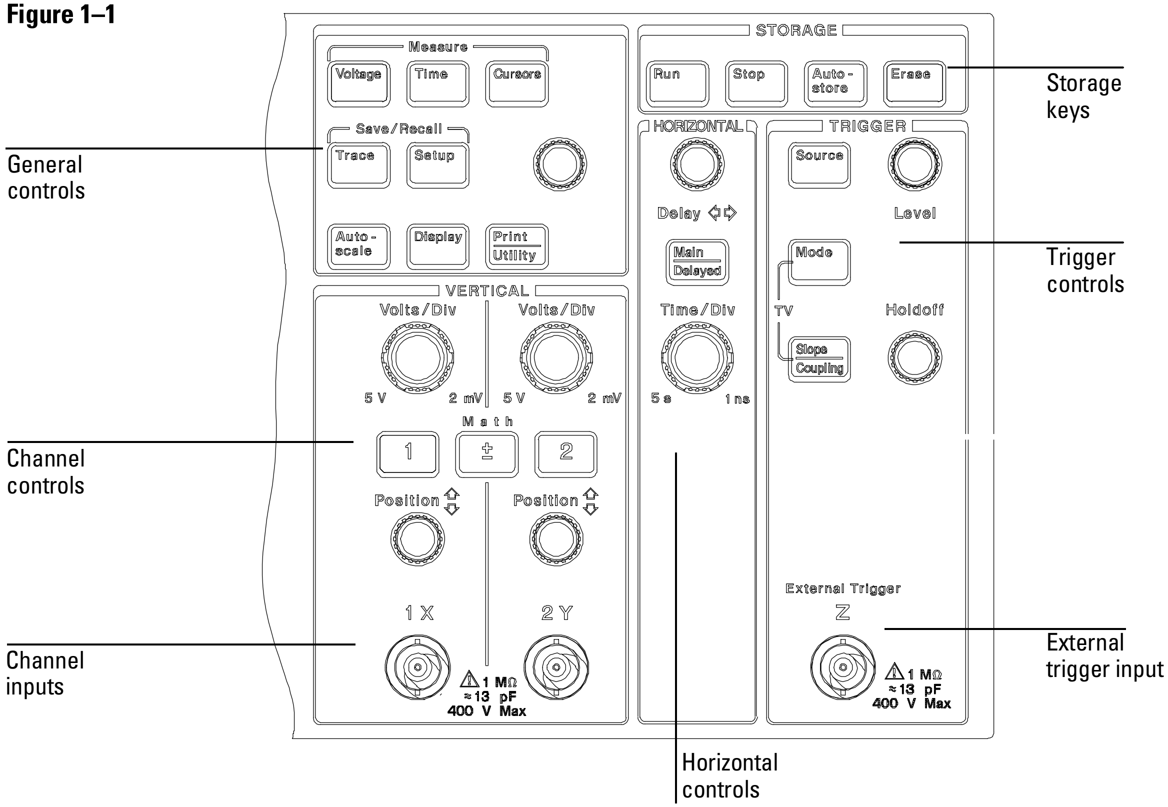
Throughout this book, the front-panel keys are denoted by a box around the name of the key, and softkeys are denoted by a change in the text type. For example, [**Source**] is the grey front-panel key labeled source under the trigger portion of the front panel, and **Line** is a softkey. The word **Line**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

Figure 1-1 is a diagram of the front-panel controls and input connectors of the HP 54600B and HP 54603B. Figure 1-2 is a diagram of the front-panel controls and input connectors of the HP 54601B and HP 54602B.

Figure 1-3 is a status line example on the HP 54602B. 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 read at a glance the setup of the oscilloscope from the status line.

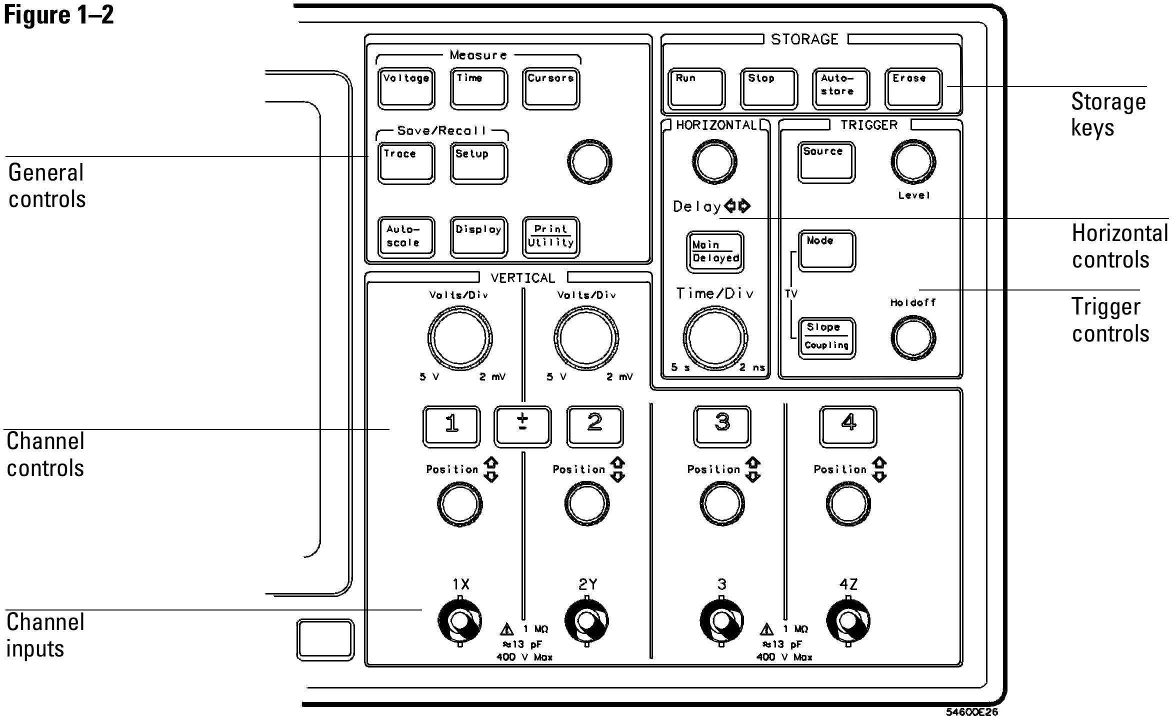
Figure 1-4 is a diagram showing which grey keys to press to bring up the various softkey menus.

Figure 1–1



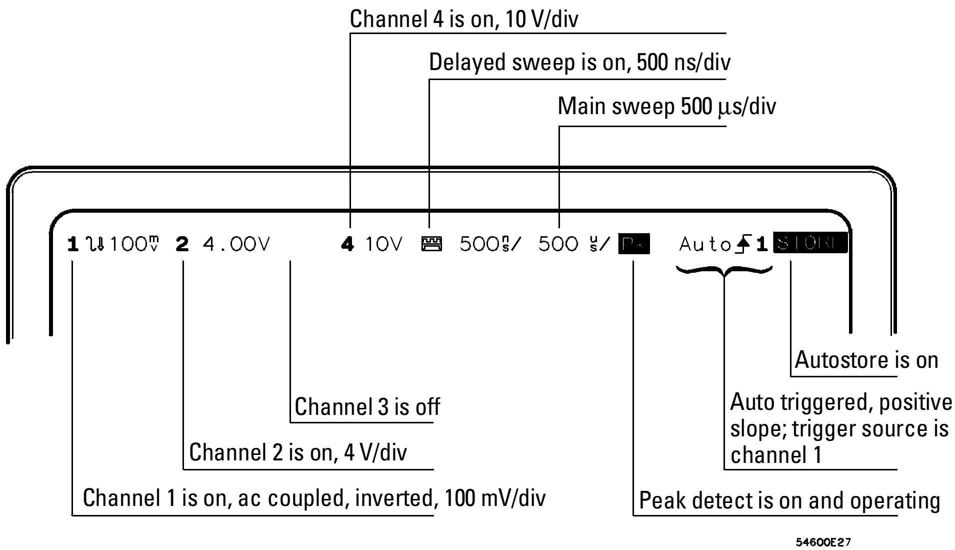
HP 54600B and HP 54603B Front Panel Controls

Figure 1–2



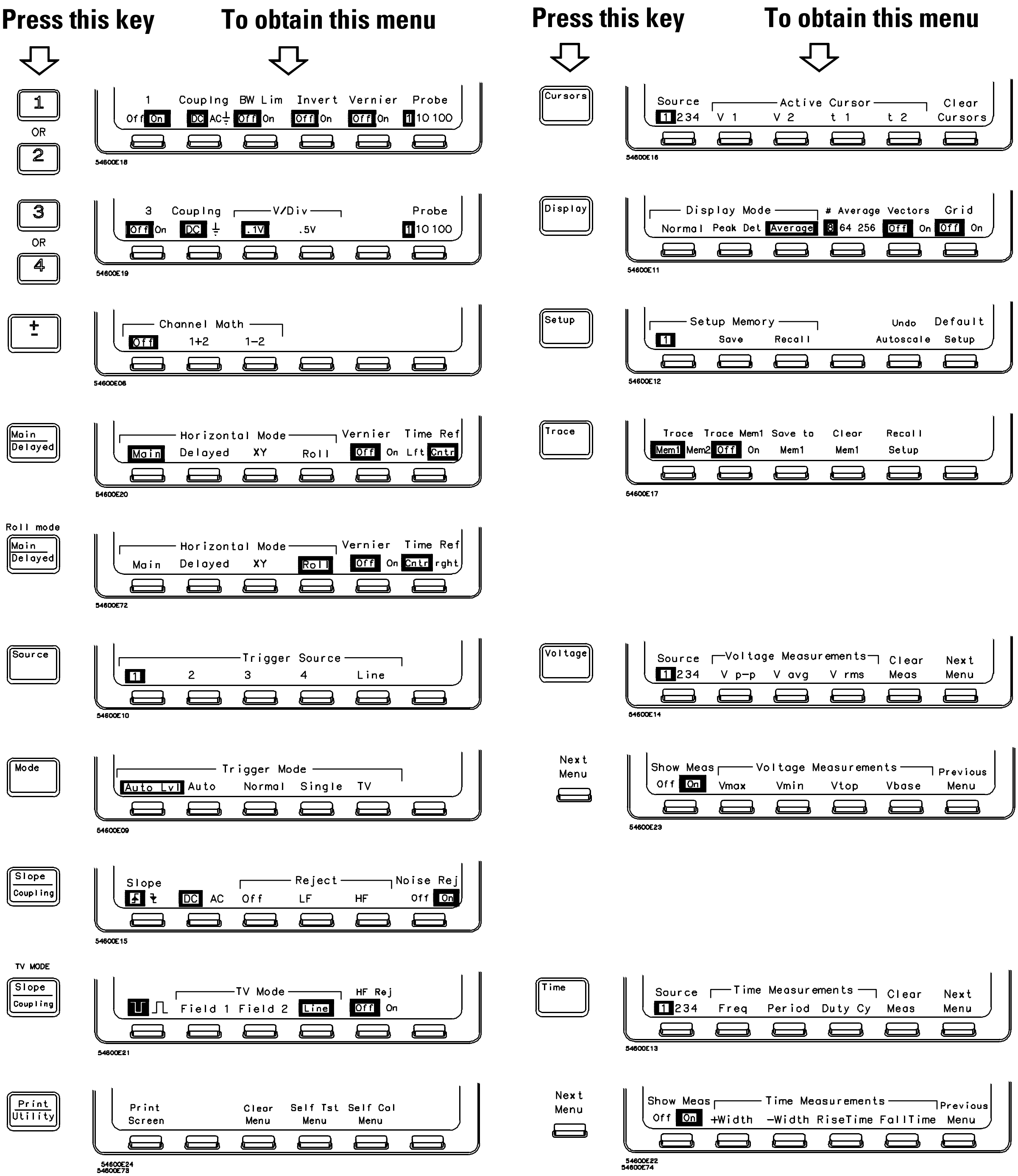
HP 54601B and HP 54602B Front Panel Controls

Figure 1–3



HP 54602B Display Status Line Indicators

Figure 1–4



Softkey Menu Reference

To inspect the instrument

☐ Inspect the shipping container for damage.

Keep a damaged shipping container or cushioning material until the contents of the shipment have been checked for completeness and the instrument has been checked mechanically and electrically.

☐ Check the accessories.

Accessories supplied with the instrument are listed in "Accessories Supplied" in the front of this manual.

- If the contents are incomplete or damaged notify your HP sales office.

☐ Inspect the instrument.

- If there is mechanical damage or defect, or if the instrument does not operate properly or pass performance tests, notify your HP sales office.
- If the shipping container is damaged, or the cushioning materials show signs of stress, notify the carrier as well as your HP sales office. Keep the shipping materials for the carrier's inspection. The HP office will arrange for repair or replacement at Hewlett-Packard's option without waiting for claim settlement.

To clean the instrument

If this instrument requires cleaning, disconnect it from all power sources and clean it with a mild detergent and water. Make sure the instrument is completely dry before reconnecting it to a power source.

To connect a signal to the oscilloscope

The HP 54600B and HP 54603B are a two-channel oscilloscopes with an external trigger input, while the HP 54601B and HP 54602B 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 5, "Performance Characteristics."

- **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 1–5

Overcompensation causes pulse peaking.

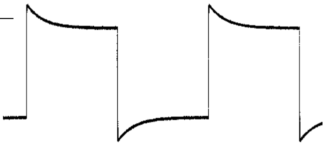


Figure 1–6

Correct compensation with a flat pulse top.

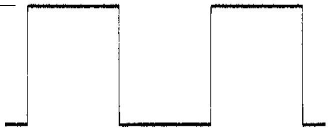
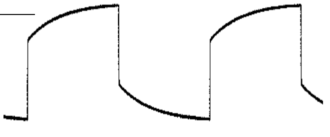


Figure 1–7

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 54600B and HP 54603B, 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 54601B and HP 54602B, 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" in chapter 5 for more details.

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 54601B and HP 54602B and on an internally triggered HP 54600B and HP 54603B, 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 54600B and HP 54603B, 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.
- Roll mode is available at sweep speeds up to 200 ms.

2

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."

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.

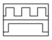
To use delayed sweep

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.

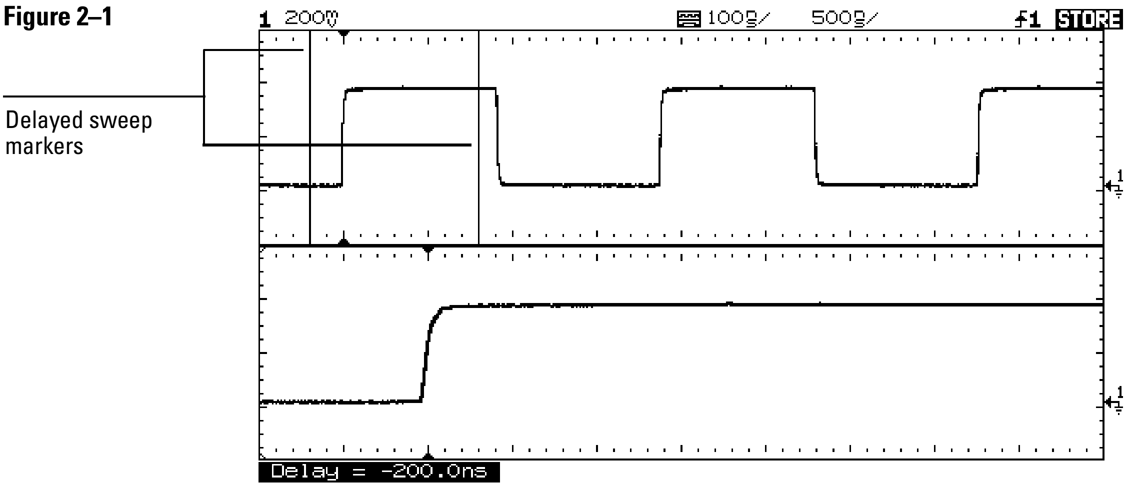
Since both the main and delayed sweeps are displayed, there are half as many vertical divisions so the vertical scaling is doubled. Notice the changes in the status line.

- 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 2-1 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.

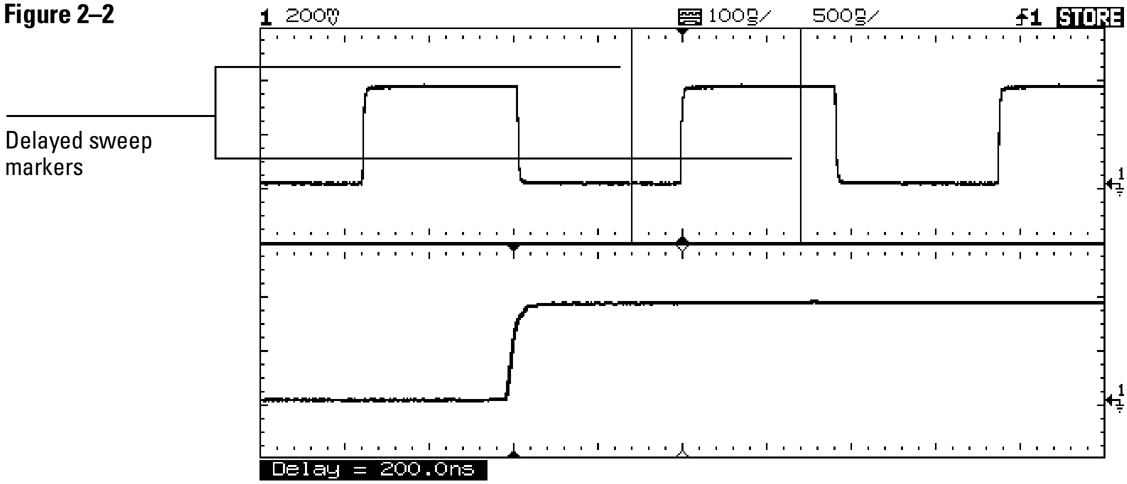
Figure 2–1



Time reference set to left

Figure 2-2 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 2–2



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 2–22.
- 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 `Run` 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, **Autostore** also arms the trigger circuit. When the trigger conditions are met, the oscilloscope triggers. Pressing **Autostore** 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 **Stop** , 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 54600B and HP 54603B, channels 1 and 2 are captured simultaneously. On the HP 54601B and HP 54602B 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 2-3 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 1–14. 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.

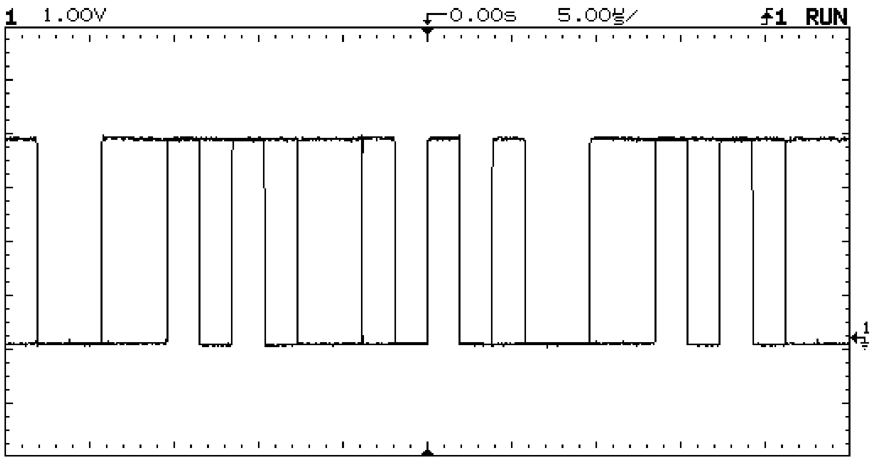
By setting the Holdoff to synchronize the trigger, the oscilloscope ignores the trigger that results in figure 2-3, and waits for the trigger that results in figure 2-4. Also notice in figure 2-3 that the trigger is stable, but the waveform is not synchronized with the trigger.

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.

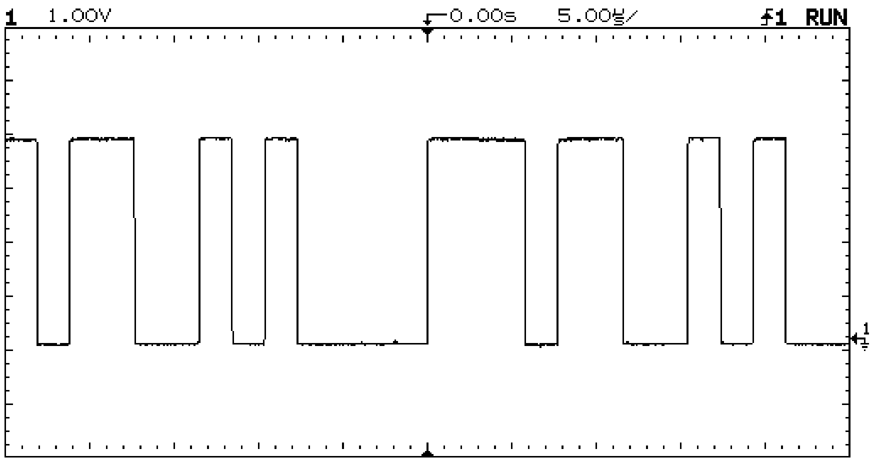
2 The rate of change of the holdoff adjustment knob depends on the time base setting you have selected. If you need a lengthy holdoff setting, increase the time/div setting on the time base, then make your coarse holdoff adjustment. Now switch back to the original time/div setting and make the fine adjustment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

Figure 2–3



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

Figure 2–4



Holdoff synchronizes the waveform with the trigger

In figure 2-4, the holdoff is set to about 25 µs (the duration of the pattern.)

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.

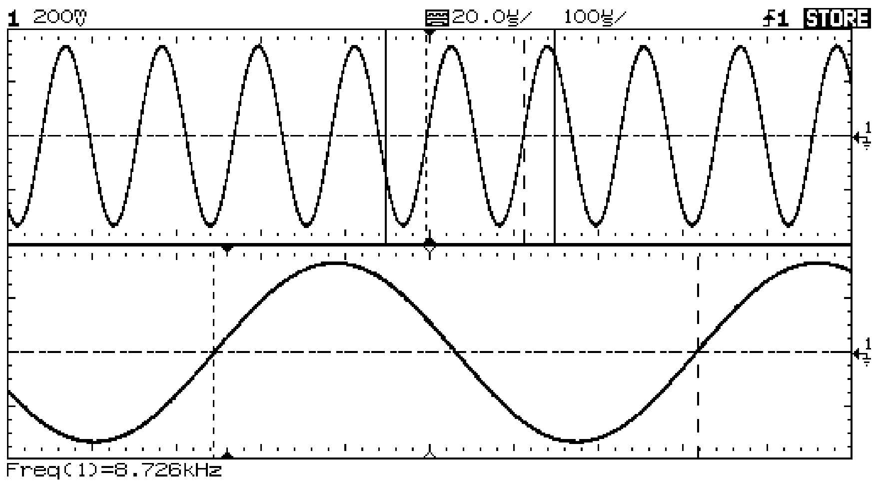
The oscilloscope automatically measures the frequency and displays the result on the lower line of the display. The number in parentheses after the word **Freq** is the number of the channel that the oscilloscope used for the measurement. The oscilloscope retains in memory and displays the three most 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 2-5 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 2–5



Delayed time base isolates an event for a frequency measurement

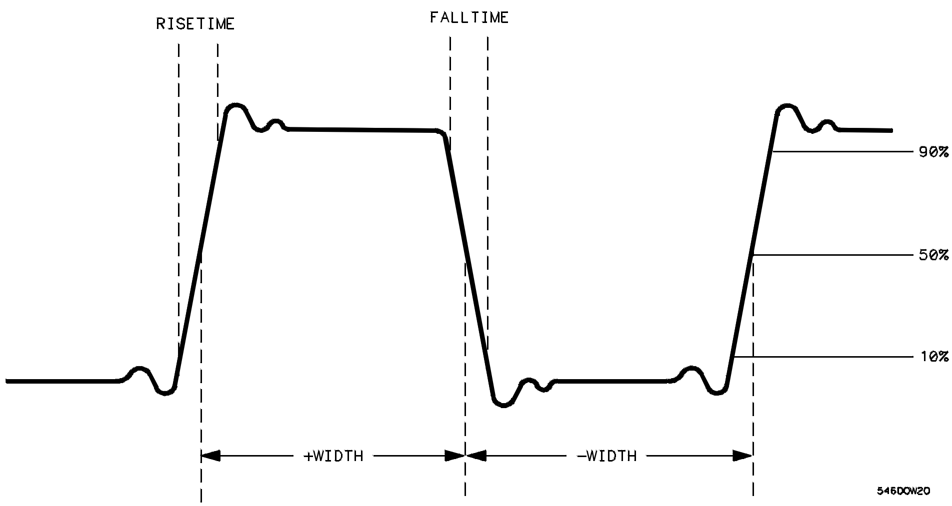
To make time measurements automatically

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 2-6 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 (see figure 2-8), 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 (see figure 2-9), the maximum and minimum levels are used to calculate the 10% and 90% points.

Figure 2–6



Time Measurement Points

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 2-6.

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, 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.

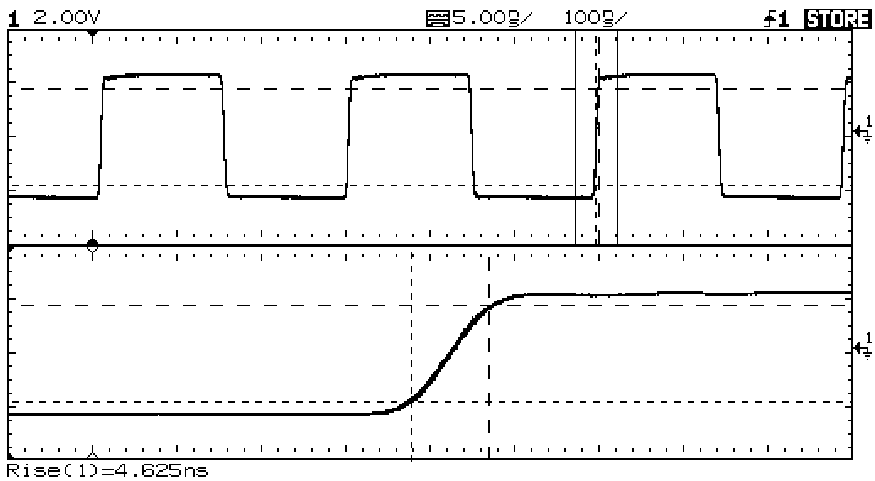
Previous Menu Returns to the previous softkey menu.

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 2-7 shows how to use delayed sweep to isolate an edge for a rise time measurement.

Figure 2–7

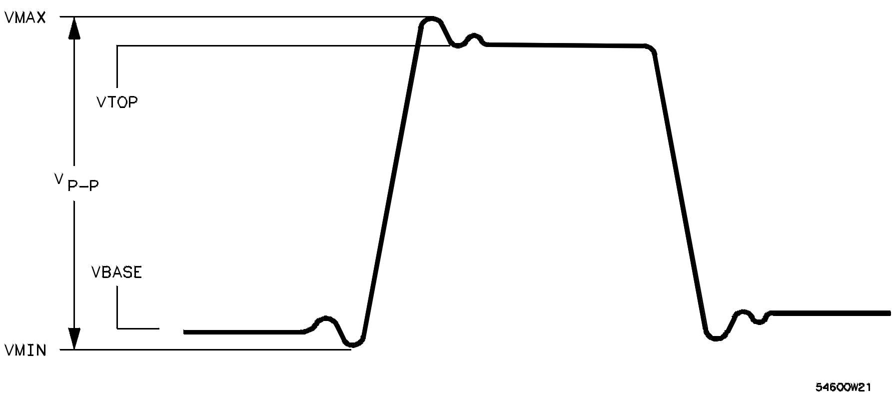


Delayed sweep isolates a leading edge for a rise time measurement

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 2-8 and 2-9 show pulses with some of the voltage measurement points.

Figure 2–8



Pulse where the top and bottom are well-defined

Figure 2–9

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.

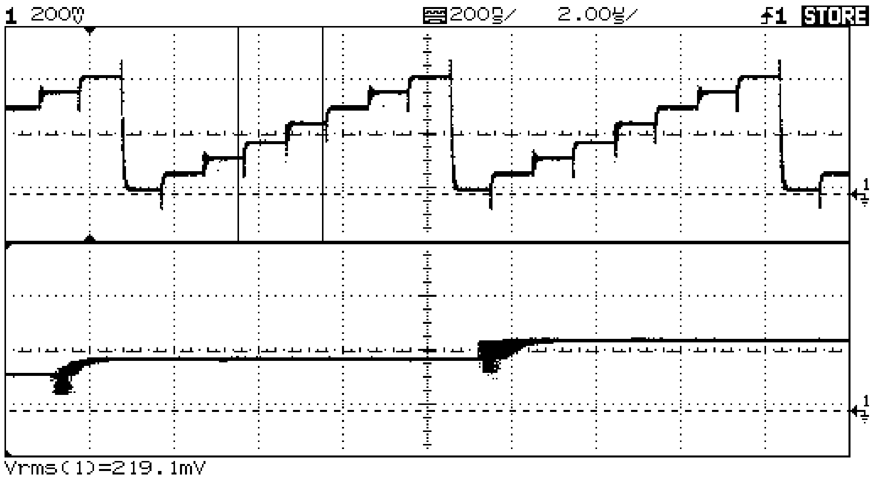
Next Menu Replaces the softkey menu with six additional softkey choices.

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 2-10 shows how to use delayed sweep to isolate a pulse for an rms measurement.

Figure 2–10



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 2-11 through 2-16 for examples of custom measurements.

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

2 Press `Cursors` .

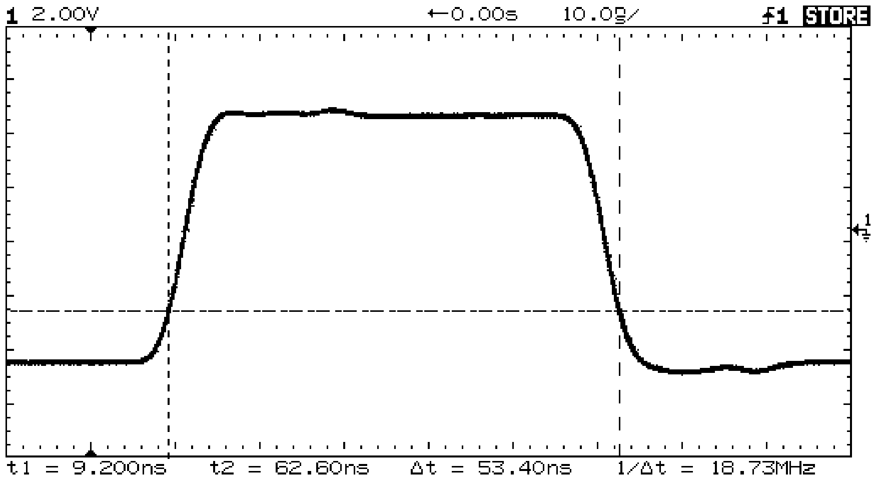
A softkey menu appears with six softkey choices. Four of the softkeys are cursor functions.

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.

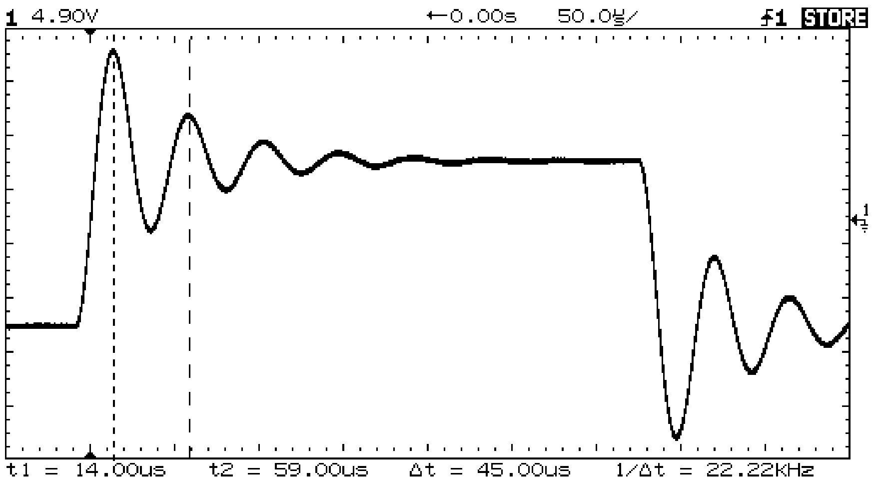
Clear Cursors Erases the cursor readings and removes the cursors from the display.

Figure 2–11



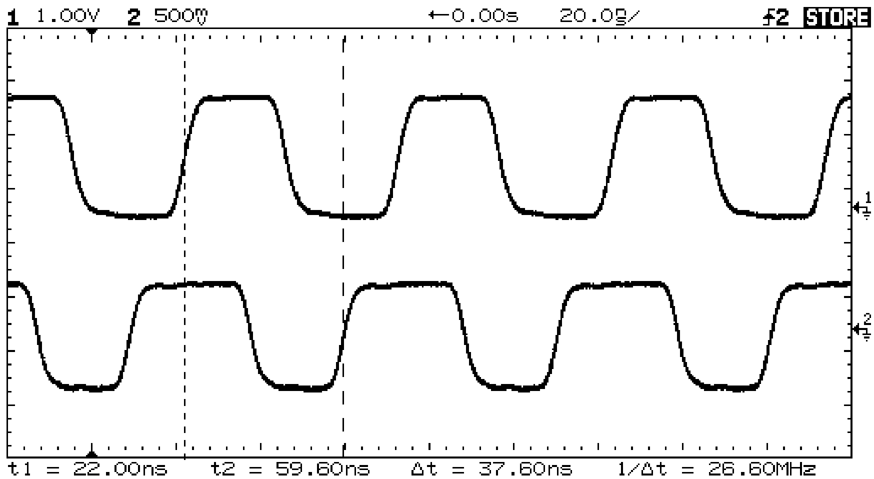
Cursors used to measure pulse width at levels other then the 50% points

Figure 2–12



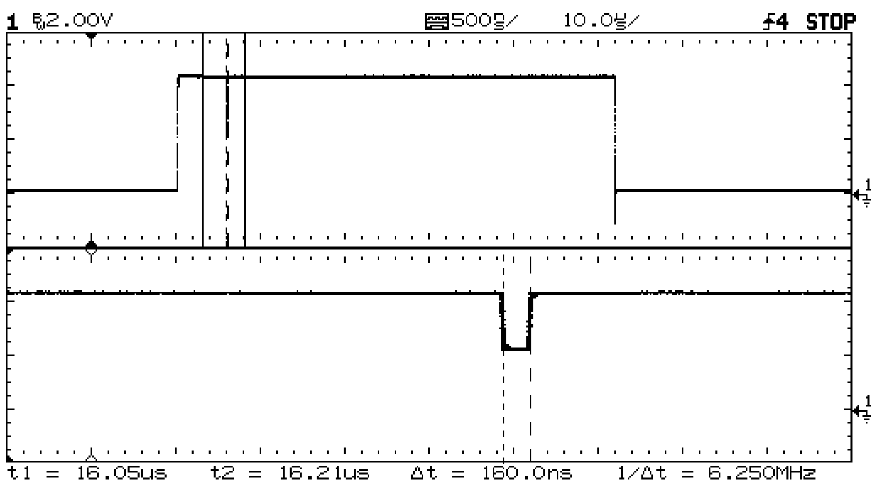
Cursors used to measure the frequency of the ringing on a pulse

Figure 2–13



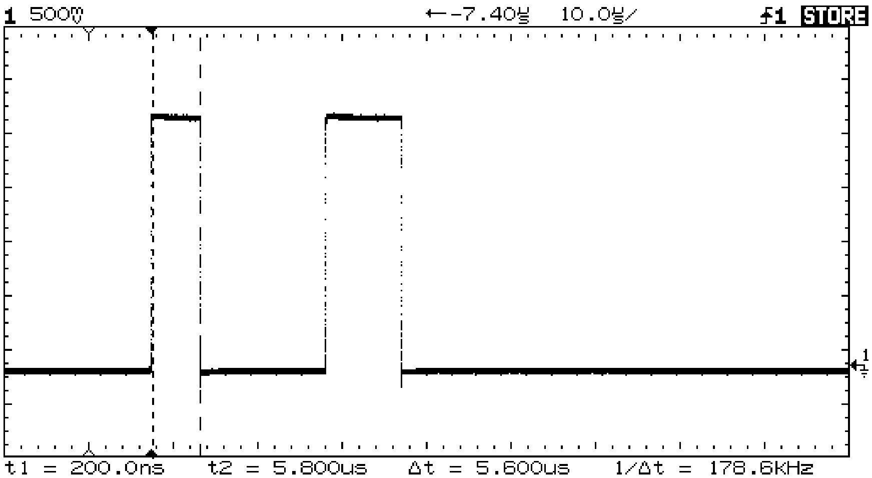
Cursors used to make channel-to-channel delay measurements

Figure 2–14



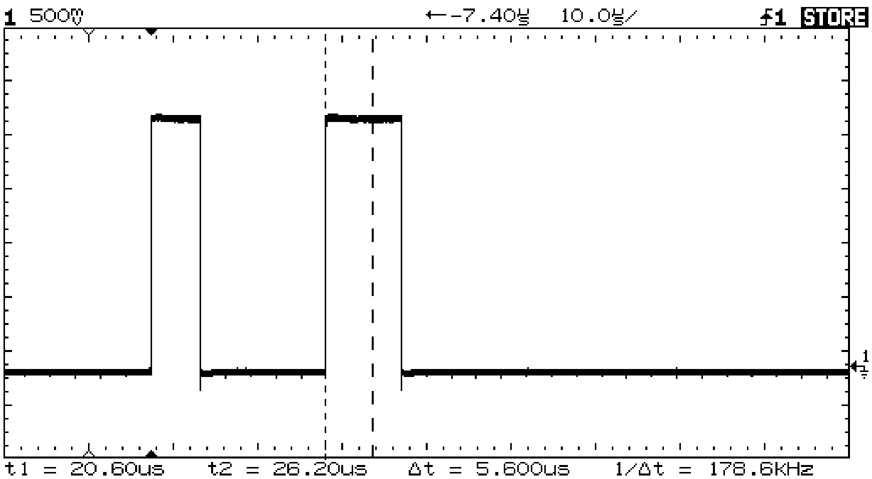
The cursors track delayed sweep. Expand the display with delayed sweep, then characterize the event of interest with the cursors.

Figure 2–15



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

Figure 2–16



By moving the cursors together, you can check for pulse width variations in a pulse train, as figures 2-15 and 2-16 show.

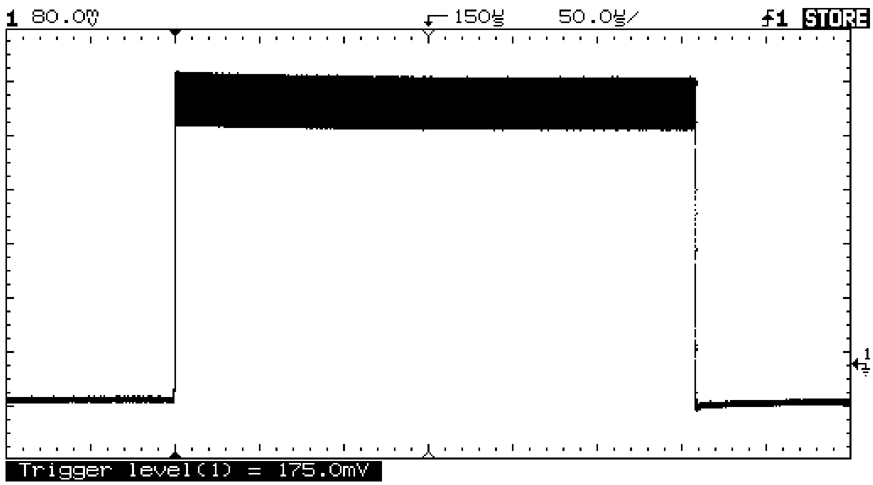
To view asynchronous noise on a signal

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 2-17 shows a waveform with asynchronous noise at the top of the pulse.

Figure 2–17



Asynchronous noise at the top of the pulse

2 Press `Autostore` .

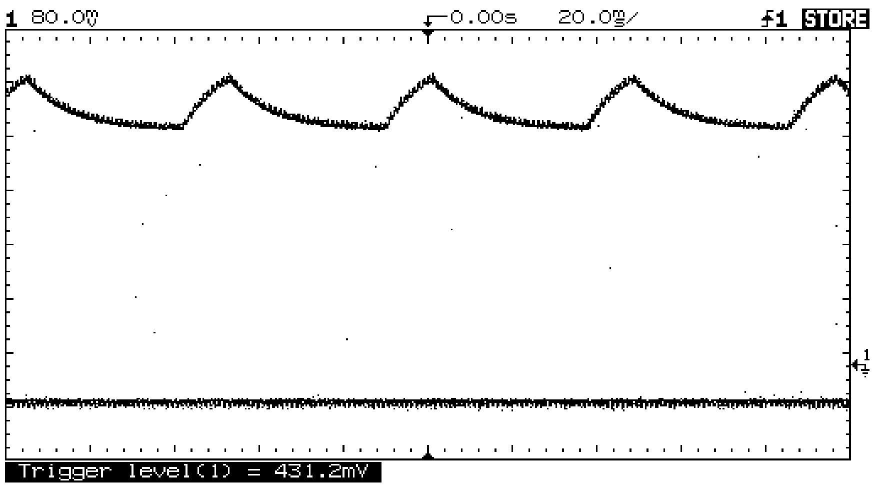
Notice that **STORE** is displayed in the status line.

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 2–18



This is a triggered view of the asynchronous noise shown in Figure 2-17

To reduce the random noise on a signal

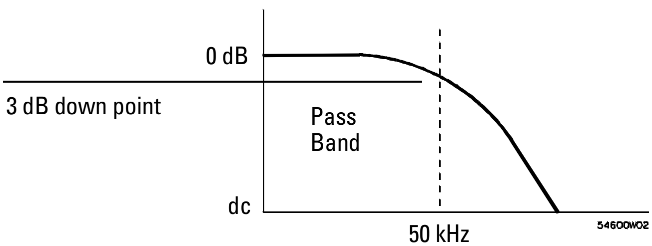
If the signal you are applying to the oscilloscope is noisy (figure 2-21), you can set up the oscilloscope to reduce the noise on the waveform (figure 2-22). First, you stabilize the displayed waveform by removing the noise from the trigger path. Second, you reduce the noise on the displayed waveform.

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 2-19). You use HF reject to remove high frequency noise such as AM or FM broadcast stations from the trigger path.

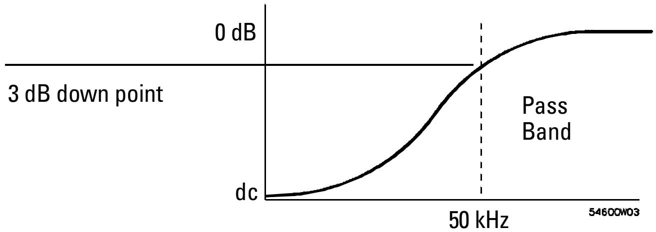
Figure 2–19



HF reject

Low frequency reject (LF reject) adds a high pass filter with the 3-dB point at 50 kHz (see figure 2-20). Use LF reject to remove low frequency signals such as power line noise from the trigger path.

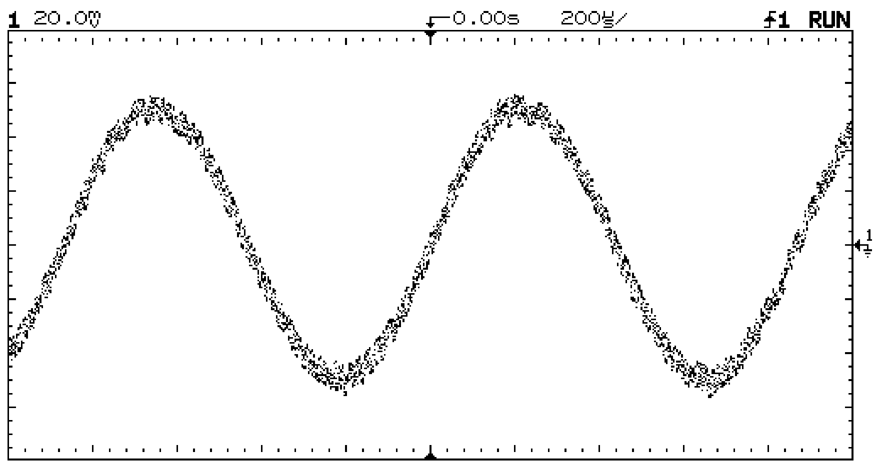
Figure 2–20



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 2–21



Random noise on the displayed waveform

3 Use averaging to reduce noise on the displayed waveform.

To use averaging follow these steps.

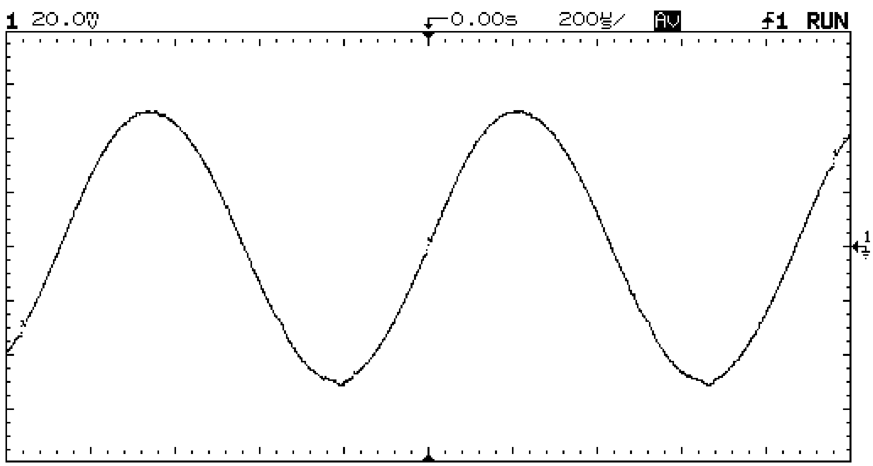
- Press `Display` , the press the **Average** softkey.

  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 2–22



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

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 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.

To reset the instrument setup

1 To reset the instrument to the default factory-preset configuration, press `Setup` .

2 Press the **Default Setup** softkey.

3 To reset the instrument to the configuration that was present before pressing **Autoscale**, press the **Undo Autoscale** softkey.

Table 2-1

Default Setup configuration settings

Configuration Item	Setting
Cursors	Cursors off; time readout is selected; all cursors are set to time/voltage zero.
Trace memories	Both trace memory 1 and 2 are off; trace 1 memory is selected.
Setup memories	Setup memories are off; setup memory 1 is selected.
Graticule	Grid set to Full
Autostore	Off
Time base	Time reference center; main, not delayed sweep; main and delay value 0; 100 µs/div main time base.
Display	Vectors On, Display Mode Normal.
Channels	Channel 1 on, Position 0 V, Volts/Div 100 mV.
Trigger Mode	Auto Level, Coupling DC, Reject Off, Noise Reject Off.
Trigger Condition	Rising edge of channel 1

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.

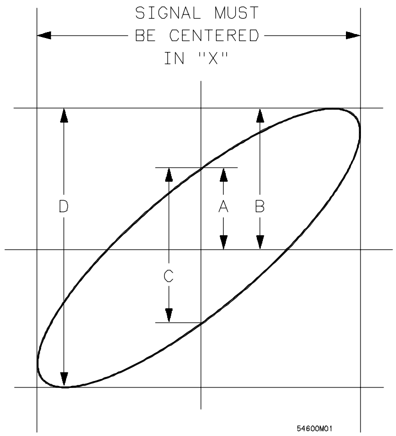
1 Connect a signal to channel 1, and a signal of the same frequency but out of phase to channel 2.

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.

$\sin\theta = \frac{A}{B}\ or\ \frac{C}{D}$, where θ = phase shift (in degrees) between the two signals.

Figure 2–23



Phase shift Parameters

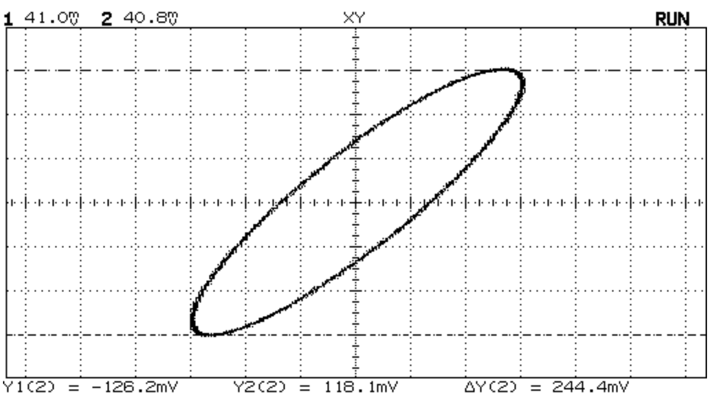
> XY display mode operating hint
>
> Before entering XY display mode, center both channels on screen in the main sweep and adjust sweep speed to obtain greater than or equal to 1 cycle of the lowest frequency input signal on screen.
>
> When you select the XY display mode, the time base is turned off. Channel 1 is the X-axis input, channel 2 is the Y-axis input, and channel 4 (external trigger in the HP 54600B and HP 54603B) 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.

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 2–24

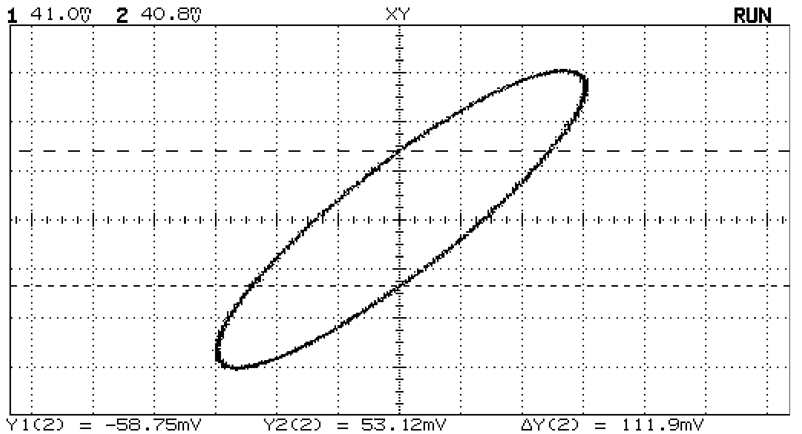


XY Display with Cursors On

6 Move the Y1 and Y2 cursors to the center of the signal.

Again, note the ΔY value.

Figure 2–25

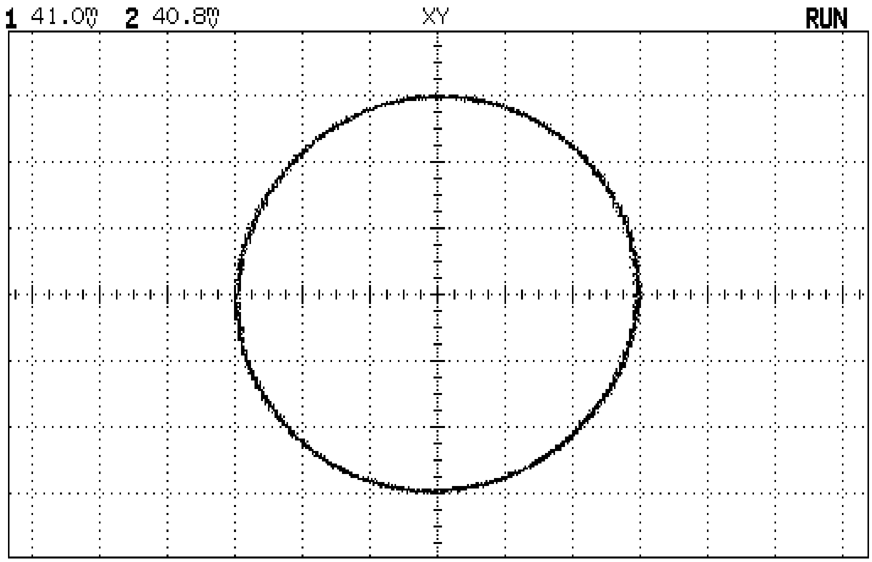


Y cursors centered

7 Calculate the phase difference using formula below.

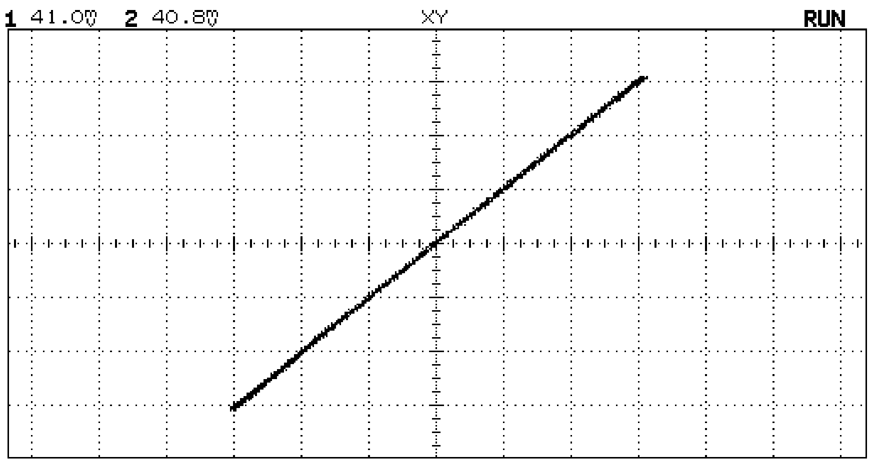
$$\sin\theta = \frac{second\ \Delta Y}{first\ \Delta Y} = \frac{111.9}{244.4} = 27.25 \text{ degrees of phase shift.}$$

Figure 2–26



Signals are 90° out of phase

Figure 2–27



Signals are in phase

5

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 4–5.

Vertical System

All channels

Bandwidth[1]

HP 54600B and HP 54601B

dc to 100 MHz –3 dB
ac coupled, 10 Hz to 100 MHz –3 dB

HP 54602B

dc to 100 MHz –3 dB (1, 2, & 5 mV/div)
dc to 150 MHz –3 dB (channels 1 & 2)
dc to 250 MHz –3 dB (channels 3 & 4)
ac coupled, 10 Hz to 150 MHz –3 dB (channels 1 & 2)

HP 54603B

dc to 60 MHz –3 dB
ac coupled, 10 Hz to 60 MHz

Rise time

3.5 ns (calculated, HP 54600B & HP 54601B)
<2.33 ns (calculated, channels 1 & 2, HP 54602B)
<1.4 ns (calculated, channels 3 & 4, HP 54602B)
5.8 ns (calculated, HP 54603B)

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 4–10.

Channels 1 and 2

Range 2 mV/div to 5 V/div (lower limit is 1 mV/div for the HP 54602B)

Accuracy[1] ±1.5% (HP 54600B, HP 54601B, and HP 54602B)
±2.0% (HP 54603B)

Verniers[1] Fully calibrated, accuracy about ±3.5%

Cursor accuracy[1, 2, 3]

Single cursor accuracy vertical accuracy ±1.2% of full scale ±0.5% of position value (HP 54602B at <10 mV/div: vertical accuracy ±2.4% 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 54601B & HP 54602B 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 16 mV for 1 mV/div range for HP 54602B.
Use a full scale of 80 mV for 2 mV/div and 5 mV/div ranges for all other scopes.
[3] Tested, see "To verify voltage measurement accuracy," on page 4–7.

Horizontal System

Sweep speeds

5 s/div to 2 ns/div main and delayed (HP 54600B, HP 54601B, HP 54602B
5 s/div to 5 ns/div main and delayed (HP 54603B)

Accuracy ±0.01% ±0.2% of full scale ±200 ps

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 4–16.

Trigger System

Internal trigger

Sensitivity[1]

HP 54600B	dc to 25 MHz	0.35 div or 3.5 mV
	dc to 100 MHz	1 div or 10 mV
HP 54601B	dc to 25 MHz	0.35 div or 3.5 mV
	dc to 100 MHz	1 div or 10 mV
HP 54602B	dc to 25 MHz	0.35 div or 3.5 mV (>5 mV/div)
		1.0 div or 2 mV (1, 2, or 5 mV/div)
	25 MHz to 100 MHz	1.5 div or 3 mV (1, 2, or 5 mV/div)
	dc to 150 MHz	1 div or 10 mV (chan 1&2)(>5 mV/div)
	dc to 250 MHz	1 div or 100 mV (chan 3&4)
HP 54603B	dc to 25 MHz	0.35 div or 3.5 mV
	dc to 60 MHz	1 div or 10 mV

Sources Channels 1, 2, 3, 4, and line on HP 54601B & HP 54602B
Channels 1, 2, line, and external on HP 54600B and HP 54603B

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

(HP 54600B and HP 54603B only)

Range ±18 V

Sensitivity[1]

HP 54600B	dc to 25 MHz	50 mV
	dc to 100 MHz	100 mV
HP 54603B	dc to 25 MHz	50 mV
	dc to 60 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 4–18.

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 forsignals 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 54600B and HP 54603B 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

2

Operating the Measurement/Storage Module

Operating the Measurement/Storage Module

This chapter provides you with the information necessary to use the additional, or enhanced features that the Measurement/Storage Module provides. Basic operation for the oscilloscope is covered in the *User and Service Guide* for your oscilloscope.

This chapter provides you with practical exercises and detailed information designed to guide you through operation of the following functions:

- Math Functions
- Automatic Measurements
- Cursor Measurements
- Mask generation and waveform monitoring
- Trace Storage

Math Functions

Without the Measurement/Storage module installed, addition and subtraction are the only math operations provided. In addition to the limited selections, the single function is performed on the pixel position of the data on the screen.

With the Measurement/Storage module installed, two functions define up to six operations that create mathematically altered waveforms (not pixel math.)

- Function 1 will add (+), subtract (–), or multiply (*) the signals acquired on vertical inputs 1 and 2, then it will display the result as F1.
- Function 2 will integrate, differentiate, or perform an FFT on the signal acquired on input 1, input 2, or the result in F1; then it will display the result in F2.

The vertical range and offset of each function can be adjusted for ease of viewing and measurement considerations. Each function can be displayed, measured (with cursors), stored in trace memory, or output over the interface.

Function 1

1 Press [±].

2 Toggle the **Function 1 On Off** softkey to enable math function number 1.

3 Press the **Function 1 Menu** softkey

A softkey menu with four softkey choices appears. Three of them are related to the math functions.

4 Toggle the **+ −*** softkey until the desired operation is selected. Results (F1) are displayed on the screen.

All operations are calculated on a point-by-point basis.

- **plus (+)** algebraically sum input 1 and input 2 (input 1 + input 2).
- **minus (−)** algebraically subtract input 2 from input 1 (input 1 – input 2).
- **multiply (*)** algebraically multiply input 1 with input 2 (input 1 * input 2).

5 Press the **Units/div** softkey and rotate the knob closest to the [Cursors] key to set the vertical sensitivity of the resulting waveform.

6 Press the **Offset** softkey and rotate the knob closest to the [Cursors] key to set the offset (from the center graticule) of the resulting waveform.

Function waveform (F1) is available for viewing, measurement, or storage.

7 Press the **Previous Menu** softkey.

Function 1 Operating Hints
If channel 1 or 2 are clipped (not fully displayed on screen,) the resulting displayed function will also be clipped. Once the function is displayed, channel 1 and 2 may be turned off for better viewing.

When multiply is the operation selected, the value displayed for units per division and offset is (V^2).

Offset is the value (in V or V^2) assigned to the center graticule for function 1. Normal screen position is 0 V offset, or at the center graticule (until changed).

See "Making Cursor Measurements", and "Saving and Recalling Traces" in this chapter for more information.

Function 2

Function 2 will plot differential or integral waveforms, or perform an FFT using the input signals connected to the vertical inputs (1 and 2), or using the function 1 waveform.

1 Press [±].

2 Toggle the **Function 2 On Off** softkey to enable math function number 2.

3 Press the **Function 2 Menu** softkey.

4 Toggle the **Operand** softkey until the desired source is selected.

   F1 uses the result waveform in function 1.

5 Press the **Operation** softkey until the desired operation is selected. Results (F2) are displayed on the screen.

- **dV/dt** (differentiate) plots the derivative of the selected source using the "Central Difference" formula. Equation is as follows:

  $$d_{n+i} = \frac{c_n - c_{n+1+2i}}{\Delta t(2i+1)}$$

  Where

  d = differential waveform

  c = input 1, 2, or function 1

  i = data point step size

  Δt = point-to-point time difference

- **∫dt** (integrate) plots the integral of the source using the "Trapezoidal Rule". Equation is as follows:

  $$I_n = \frac{\Delta t}{2}\sum(c_n + c_{n+1})$$

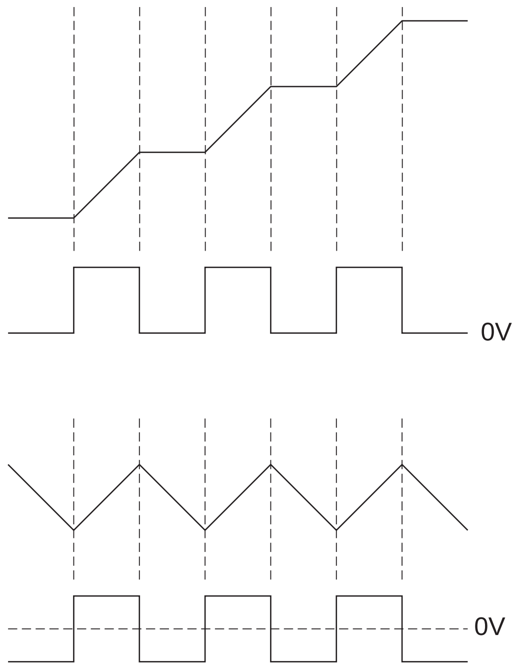
  Where

  Δt = point-to-point time difference

  c = input 1, 2, or function 1

The integrate calculation is relative to the currently selected source's input offset. The following examples illustrate any changes in offset level.

Figure 2–1



Integrate and Offset

- **FFT** (Fast Fourier Transform) inputs the digitized time record of the source and transforms it to the frequency domain. The FFT spectrum is plotted on the oscilloscope display as dBV (dBV or dBm for 54610 and 54615/54616) versus frequency. Selecting this function also adds the FFT Menu. See "FFT Measurement" later in this chapter for more information.

6 Press the **Units/div** softkey and rotate the knob closest to the `Cursors` key to set the vertical sensitivity of the resulting waveform.

Units per division changes from volts to dB when FFT is selected.

7 Press the **Offset** (differentiate and integrate) or **Ref Levl** (FFT) softkey and rotate the knob closest to the `Cursors` key to set the offset (from the center graticule) or reference level (top graticule) of the resulting waveform.

Function waveform (F2) is available for viewing, measurement, or storage.

8 Press the **Previous Menu** softkey.

For FFT functions, an additional menu is available to set additional parameters. See "FFT Measurement" later in this chapter for more information.

Function 2 Operating Hints

Timebase must be set to Main (and input channels 3 and 4 to Off on 4-channel oscilloscopes) when using function 2.

When differential is the operation selected, the value displayed for units per division and offset is volts per second (V/s). When integral is the operation selected, the value displayed for units per division and offset is volt seconds (Vs).

Offset is the value (in volts per second or volt seconds) assigned to the center graticule for function 2. Normal screen position is 0 offset, or at the center graticule (until changed).

See "Making Cursor Measurements", and "Saving and Recalling Traces" in this chapter for more information.

FFT Measurement

Operating System Requirements

Refer to "Oscilloscope Compatibility" on page 1-2 for operating system requirements for FFT operation.

FFT (Function 2) is used to compute the fast Fourier transform using vertical inputs (1 and 2), or the Function 1 waveform. This function takes the digitized time record of the specified source and transforms it to the frequency domain. When the function is selected, the FFT spectrum is plotted on the oscilloscope display as dBV (dBV or dBm for 54610 and 54615/54616) versus frequency. The readout for the horizontal axis changes from time to Hertz and the vertical readout changes from volts to dBV (dBV or dBm for 54610 and 54615/54616). For the 54610 and 54615/54616, when 50Ω input is selected, readout is in dBm; when 1MΩ input is selected, readout is in dBV. dBV is a unit of measure that is referenced to 1 Vrms. If the display of the 54600, 54601, 54602, 54603, or 54645 is needed to be in dBm, the operator must apply an external 50Ω load (10100C or equivalent), and then perform the following conversion:

$$dBm = dBV + 13.01$$

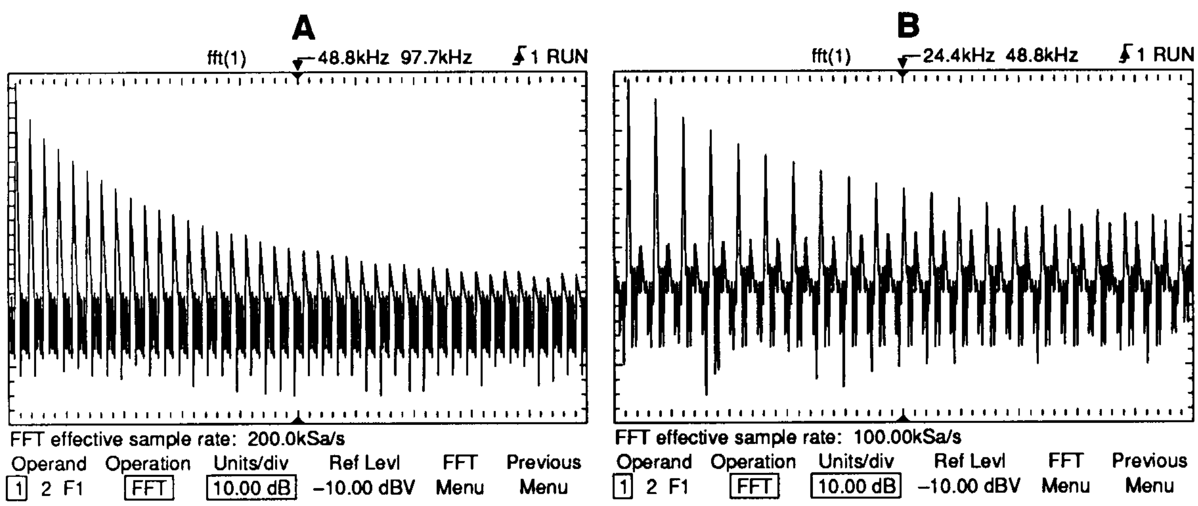
DC Value The FFT computation produces a DC value that is incorrect. It does not take the offset at center screen into account and is 1.41421 times greater than its actual value. The DC value is not corrected in order to accurately represent frequency components near DC. All DC measurements should be performed in normal oscilloscope mode.

Aliasing When using FFT's, it is important to be aware of aliasing. This requires that the operator have some knowledge as to what the frequency domain should contain, and also consider the effective sampling rate, frequency span, and oscilloscope vertical bandwidth when making FFT measurements. Effective sample rate is briefly displayed when the ± key is pressed.

Aliasing happens when there are insufficient samples acquired on each cycle of the input signal to recognize the signal. This occurs whenever the frequency of the input signal is greater than the Nyquist frequency (sample frequency divided by 2). When a signal is aliased, the higher frequency components show up in the FFT spectrum at a lower frequency.

The following figure illustrates aliasing. In waveform A, the sample rate is set to 200 kSa/s, and the oscilloscope displays the correct spectrum. In waveform B, the sample rate is reduced by one-half (100 kSa/s), causing the components of the input signal above the Nyquist frequency to be mirrored (aliased) on the display.

Figure 2–2



Aliasing

Since the frequency span goes from ≈ 0 to the Nyquist frequency, the best way to prevent aliasing is to make sure that the frequency span is greater than the frequencies present in the input signal.

Spectral Leakage The FFT operation assumes that the time record repeats. Unless there is an integral number of cycles of the sampled waveform in the record, a discontinuity is created at the end of the record. This is referred to as leakage. In order to minimize spectral leakage, windows that approach zero smoothly at the beginning and end of the signal are employed as filters to the FFT. The Measurement/Storage Module provides four windows: rectangular, exponential, hanning, and flattop. For more information on leakage, see Agilent Application Note 243, "The Fundamentals of Signal Analysis" (Agilent part number 5952-8898.)

FFT Operation

1 Press [±].

2 Toggle the **Function 2 On Off** softkey to enable math function number 2.

3 Press the **Function 2 Menu** softkey.

4 Toggle the **Operand** softkey until the desired source is selected.

F1 uses the result waveform in function 1.

5 Press the **Operation** softkey until FFT is selected. Results (F2) are displayed on the screen.

6 Press the **Units/div** softkey and rotate the knob closest to the [`Cursors`] key to set the vertical sensitivity of the resulting waveform.

7 Press the **Ref Levl** softkey and rotate the knob closest to the [`Cursors`] key to set the reference level (top graticule line) of the resulting waveform.

The **Autoscale FFT** softkey will automatically set Units/div and Ref Levl to bring the FFT data on screen. Frequency Span is set to maximum. Steps 6 and 7 could be replaced to say:
6 Press **FFT Menu** softkey.
7 Press **Autoscale FFT** softkey. Rotate Time/Div knob until freq span is around the frequencies of interest.

8 Press the **FFT Menu** softkey.

A softkey menu with six softkey choices appears. Five of them are related to FFT.

- **Cent Freq** Allows centering of the FFT spectrum to the desired frequency. Select and rotate the knob closest to the Cursors key to set the center frequency to the desired value.
- **Freq Span** Sets the overall width of the FFT spectrum (left graticule to right graticule). Select and rotate the knob closest to the Cursors key to set the center frequency to the desired value. See FFT Measurement Hints (next page) for information on using frequency span to magnify the display.
- **Move 0Hz To Left** Pressing this key changes the center frequency so that the left most graticule represents 0 Hz.
- **Autoscale FFT** The Autoscale FFT softkey will automatically set Units/div and Ref Levl to bring the FFT data on screen. Frequency Span is set to maximum.
- **Window** Allows one of four windows to be selected. Select and rotate the knob closest to the Cursors key to set the desired window. The rectangular window is useful for transients signals and signals where there are an integral number of cycles in the time record. The hanning window is useful for frequency resolution and general purpose use. It is good for resolving two frequencies that are close together or for making frequency measurements. The flattop window is the best window for making accurate amplitude measurements of frequency peaks. The exponential window is the best window for transients analysis.
- **Previous Menu** Returns you to the previous softkey menu.

FFT spectrum (F2) is available for viewing, measurement, or storage.

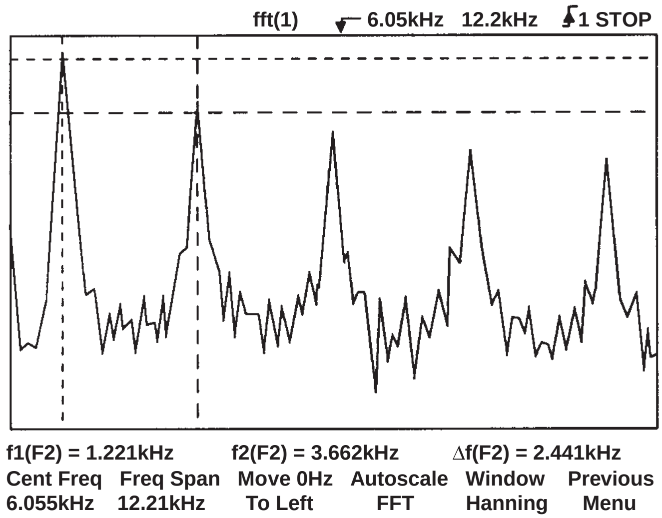
9 The Cursors key contains two additional selections that can be used to measure or move the FFT spectrum. Press Cursors , then set the **Source** softkey to **F2**.

Find Peaks Pressing this key sets Vmarker1 and the start marker (f1) on the peak with the highest amplitude and sets Vmarker2 and the stop marker (f2) on the peak with the next highest amplitude. Marker values in dBV/dBm or frequency (dependent on the active cursor)are automatically displayed at the bottom of the oscilloscope screen. The difference in dBV/dBm (ΔV) or frequency (Δf) between the two peaks is also displayed.

Move f1 To Center Pressing this key changes the center graticule (or center frequency) to the current f1 marker frequency. If f1 cannot be found, a message is displayed on the screen.

The following FFT spectrum was obtained by connecting the front panel probe adjustment signal to input 1. Set Time/Div to 500 s/div, Volts/Div to 100 mV/div, Units/div to 10.00 dB, Ref Level to –10.00 dBV, Center Freq to 6.055 kHz, Freq Span to 12.21 kHz, and window to Hanning.

Figure 2–3



FFT Measurements

FFT Measurement Hints

It is easiest to view FFT's with Vectors set to On. The Vector display mode is set in the Display menu. Note that on the 54615/54616, when Vectors is set from Off to On, the frequency span is halved, and when Vectors is set from On to Off, the frequency span is doubled.

The number of points acquired for the FFT record is normally 1024 (see FFT "Operating Characteristics" in Chapter 3 for specifics,) and when frequency span is at maximum, all points are displayed. Once the FFT spectrum is displayed, the frequency span and center frequency controls are used much like the controls of a spectrum analyzer to examine the frequency of interest in greater detail. Place the desired part of the waveform at the center of the screen and decrease frequency span to increase the display resolution. As frequency span is decreased, the number of points shown is reduced, and the display is magnified.

FFT Measurement Hints – Continued

While the FFT spectrum is displayed, use the and Cursor keys to switch between measurement functions and frequency domain controls in FFT menu. See the end of the manual for display menus.
Decreasing the effective sampling rate by selecting a slower sweep speed will increase the low frequency resolution of the FFT display and also increase the chance that an alias will be displayed. The resolution of the FFT is one-half of the effective sample rate divided by the number of points in the FFT. The actual resolution of the display will not be this fine as the shape of the window will be the actual limiting factor in the FFT's ability to resolve two closely space frequencies. A good way to test the ability of the FFT to resolve two closely spaced frequencies is to examine the sidebands of an amplitude modulated sine wave. For example, at 2 MSa/sec effective sampling rate, a 1 MHz AM signal can be resolved to 2 kHz. Increasing the effective sampling rate to 4 MSa/sec reduces the resolution to 5 kHz.

For the best vertical accuracy on peak measurements:

- Make sure the source impedance and probe attenuation is set correctly. The impedance and probe attenuation are set from the Channel menu if the operand is a channel.
- Set the source sensitivity so that the input signal is near full screen, but not clipped.
- Use the flattop window.
- Set the FFT sensitivity to a sensitive range, such as 2 dB/division.

For best frequency accuracy on peaks:

- Use the Hanning window.
- Use cursors to place f1 cursor on the frequency of interest.
- Press **Move f1 to Center** softkey.
- Adjust frequency span for better cursor placement.
- Return to the Cursors menu to fine tune the f1 cursor.

For more information on the use of window please refer to Agilent Application Note 243," The Fundamentals of Signal Analysis" Chapter III, Section 5 (Agilent part number 5952-8898.) Additional information can be obtained from "Spectrum and Network Measurements" by Robert A Witte, in Chapter 4 (Agilent part number 5960-5718.)

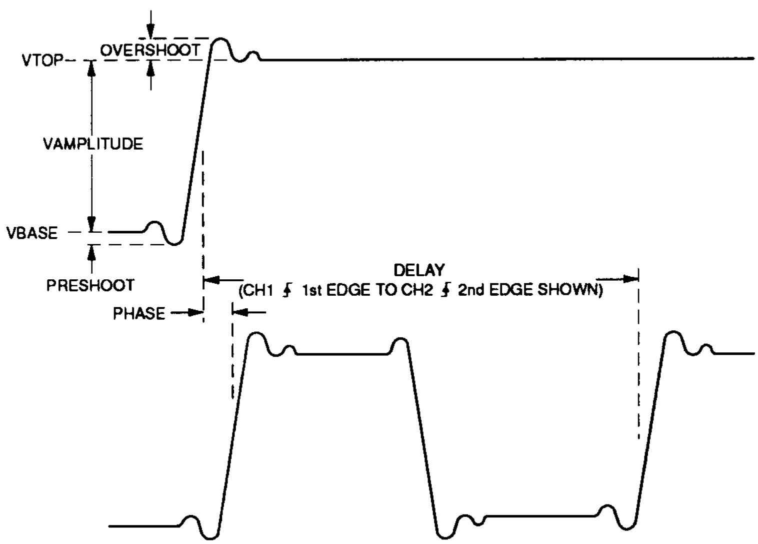
Automatic Measurements

With the Measurement/Storage Module installed, the oscilloscope is capable of making five additional automatic voltage and time measurements.

- Delay Measurements
- Phase Measurements
- Voltage Amplitude
- Voltage Overshoot
- Voltage Preshoot

In addition to the measurements, the thresholds used for automatic time measurements are user-selectable.

Figure 2–4



Automatic Measurements

Setting Thresholds

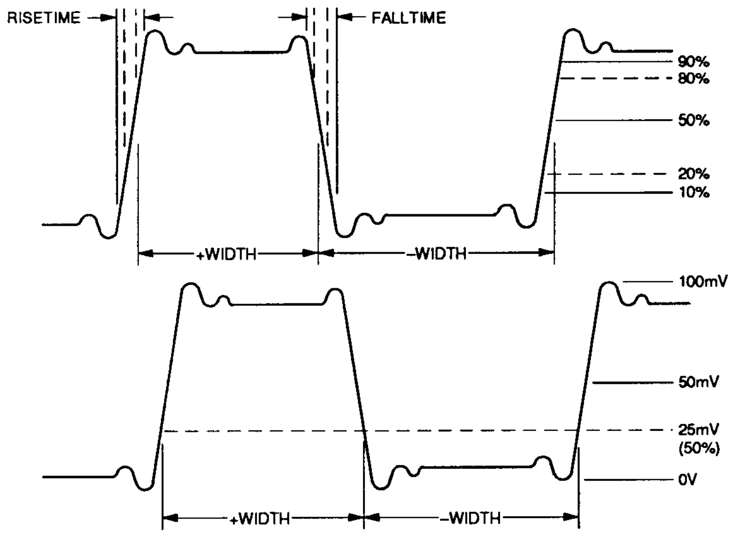
Without the Measurement/Storage module installed, rise time and fall time measurements are performed at the 10%/90% threshold levels. The remaining five time measurements (frequency, period, duty cycle, positive pulse width, and negative pulse width) are all performed at the 50% transition point. Refer to the *User and Service Guide* for your oscilloscope for more information.

With the Measurement/Storage module installed, the thresholds are user selectable. Rise time and fall time measurements are performed at 10%/90%, 20%/80%, or at a user defined threshold level. The remaining five time measurements are performed at the center point of the currently selected upper and lower threshold values.

- If 10%/90% is selected, the center is 50%.
- If 20%/80% is selected, the center is 50%.
- If voltage is selected, the center is dependent on the current lower and upper values.

As an example, if the lower value is set to 0 V, and the upper value is set to 50 mV, then the 50% level is 25 mV. 25 mV is the point that frequency, period, duty cycle, positive pulse width, and negative pulse width will be measured. The point of measurement is dependent on the amplitude of the input signal.

Figure 2–5



User Thresholds

1 Press `Time` .

2 Press the **Next Menu** softkey until the **Define Thresholds** softkey is displayed on the far left side.

3 Press the **Define Thresholds** softkey.

4 Press the desired **Thresholds** softkey.

A softkey menu with six softkey choices appears. Five of them are related to selecting thresholds.

- **10% 90%** Rise time/fall time measurements performed at the 10% (lower) and 90% (upper) levels. Frequency, period, duty cycle, positive pulse width, and negative pulse width measurements will be performed at the 50% level.
- **20% 80%** Rise time/fall time measurements performed at the 20% (lower) and 80% (upper) levels. Frequency, period, duty cycle, positive pulse width, and negative pulse width measurements will be performed at the 50% level.

- **Voltage** Rise time/fall time measurements performed at the lower and upper levels specified by you. Frequency, period, duty cycle, positive pulse width, and negative pulse width measurements will be performed at the center of both entered levels.
- **Lower** This softkey is displayed only when **Voltage** softkey is selected. Select and rotate the knob closest to the `Cursors` key to set the lower threshold to the desired value.
- **Upper** This softkey is displayed only when **Voltage** softkey is selected. Select and rotate the knob closest to the `Cursors` key to set the upper threshold to the desired value.
- **Previous Menu** Returns you to the previous softkey menu.

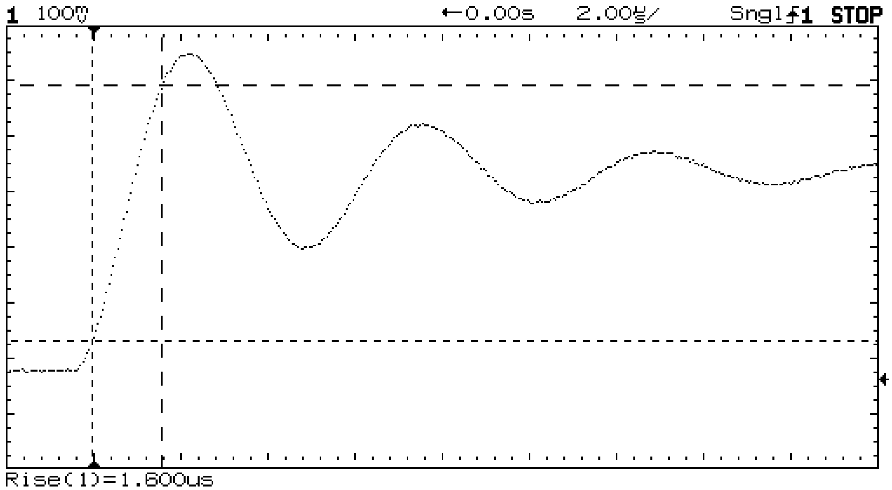
Selecting User Threshold Hints

Lower threshold level cannot be set to a value higher than the current upper threshold level.
Upper threshold level cannot be set to a value lower than the current lower threshold level.
If the upper and lower thresholds are set to levels greater to, or less than, the current displayed waveform, then the automatic rise time, fall time, frequency, period, duty cycle, positive pulse width, and negative pulse width measurements will not be performed. This is because the measurement point is not on the waveform.

Cursors can be used to set the threshold voltage levels as follows:

- Select an automatic time measurement with Show Meas set to On, and thresholds set to 10%/90%. Once initiated, the cursors will display on the waveform.
- Press Cursors key and record the current cursor voltage levels.
- Select Define Measurement Voltage, and adjust the upper and lower levels to the previously recorded values.
- Slowly rotate the knob closest to the Cursors key to fine tune the upper and lower threshold to the desired values. Cursor will track as long as the measurement is valid.

Figure 2–6



User Threshold Rise Time Measurement

To make delay measurements automatically

You can measure the delay of signals connected to the oscilloscope's input 1 and input 2 connectors when the Measurement/Storage Module is connected to the oscilloscope.
Delay is measured from the user-defined slope and edge count of the signal connected to input 1, to the defined slope and edge count of the signal connected to input 2.

1 Adjust controls so that a minimum of 6 full cycles of the signals connected to inputs 1 and 2 are displayed.

2 Press `Time`.

3 Press the **Next Menu** softkey until the **Define Thresholds** softkey is displayed on the far left side.

4 Press the **Define Delay** softkey.

A softkey menu with five softkey choices appears. Four of them are related to defining the delay measurement.

- **Chan 1** Selects the channel 1 slope (rising or falling) where the delay measurement will START. Threshold level is always 50%.
- **Edge** Selects the edge count (from 1 to 5) where the delay measurement will START.
- **Chan 2** Selects the channel 2 slope (rising or falling) where the delay measurement will STOP. Threshold level is always 50%.
- **Edge** Selects the edge (from 1 to 5) count where the delay measurement will STOP.
- **Previous Menu** Returns you to the previous softkey menu.

5 Use the displayed softkeys to specify the starting (from) and stopping (to) slope and edge count. Transition point (measurement threshold level) is fixed at 50%.

6 Press the **Previous Menu** softkey.

7 Press the **Measure Delay** softkey. Delay is measured and displayed on the screen.

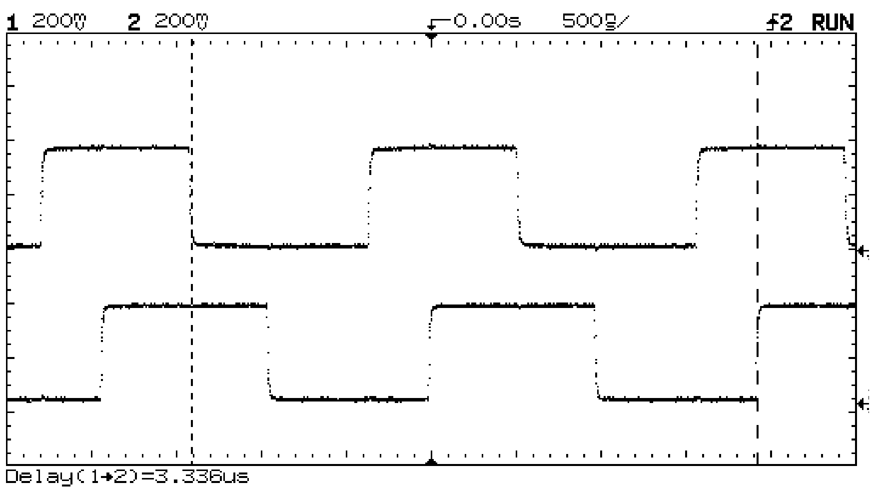
Negative delay values indicate the defined edge on channel 1 occurred after the defined edge on channel 2.

Automatic Delay Measurement Hints

If an edge is selected that is not displayed on the screen, delay will not be measured.

User thresholds have no effect on automatic delay measurements. Delay is always measured at the 50% transition point (measurement threshold level).

Figure 2–7



Automatic Delay Measurement

To make phase measurements automatically

Phase shift between two signals can be measured using the Lissajous method. Refer to the *User and Service Guide* for your oscilloscope for more information.

With the Measurement/Storage Module installed, phase is automatically measured and displayed. Measurement is made from the rising edge of the first full cycle on the input 1 signal, to the rising edge of the first full cycle on the input 2 signal. The method used to determine phase is to measure delay and period, then calculate phase as follows:

$$\text{Phase} = \frac{\text{delay}}{\text{period of input 1}} \times 360$$

1 Adjust controls so that a minimum of one full cycle of the signal connected to input 1 is displayed.

2 Press `Time` .

3 Press the **Next Menu** softkey until the **Define Thresholds** softkey is displayed on the far left side.

4 Press the **Measure Phase** softkey. Phase is measured and displayed on the screen.

Negative phase values indicate the displayed signal on channel 2 is leading the signal on channel 1.

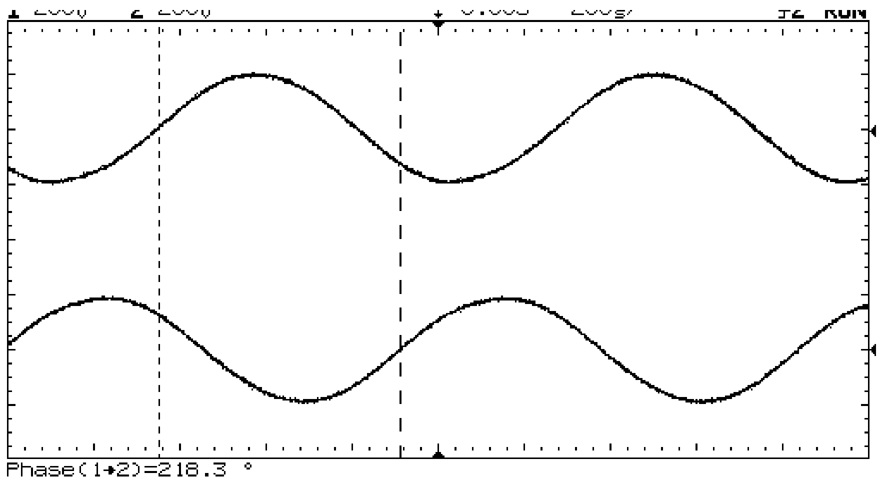
Automatic Phase Measurement Hints

If one full cycle of the signal connected to input 1 is not displayed, phase will not be measured.

User thresholds has no effect on automatic phase measurements. Phase is always measured at the 50% transition point (threshold level).

When using the delayed timebase, the instrument will attempt to perform the measurement using the delayed window. If the selected channel 1 edge, channel 2 edge, and channel 1 period cannot be found in the delayed window, the main window is used. See "Time Measurements" in the *User and Service Guide* for your oscilloscope for more information.

Figure 2–8



Automatic Phase Measurement

To make additional voltage measurements automatically

With the Measurement/Storage Module is installed, the following additional automatic voltage measurements can be performed.

- **Vamplitude** Amplitude Voltage measurement is made using the entire waveform. When performing a measurement on a particular cycle, set the controls to display only that cycle is displayed. The method used to determine voltage amplitude is to measure Vtop and Vbase, then calculate voltage amplitude as follows:

  voltage amplitude = Vtop – Vbase

- **Vovershoot** A minimum of one edge must be displayed in order to perform an Overshoot measurement. If more than one waveform, edge, or pulse is present, the measurement is made on the first edge acquired. The method used to determine overshoot is to make three different voltage measurements, then calculate overshoot as follows:

  $$\text{percent overshoot} = \frac{\text{Vmax} - \text{Vtop}}{\text{Vtop} - \text{Vbase}} \times 100$$

- **Vpreshoot** A minimum of one edge must be displayed in order to perform a Preshoot measurement. If more than one waveform, edge, or pulse is present, the measurement is made on the first edge acquired. The method used to determine preshoot is to make three different voltage measurements, then calculate preshoot as follows:

  $$\text{percent preshoot} = \frac{\text{Vmin} - \text{Vbase}}{\text{Vbase} - \text{Vtop}} \times 100$$

1 Adjust controls until the desired signal is displayed.

2 Press `Voltage` .

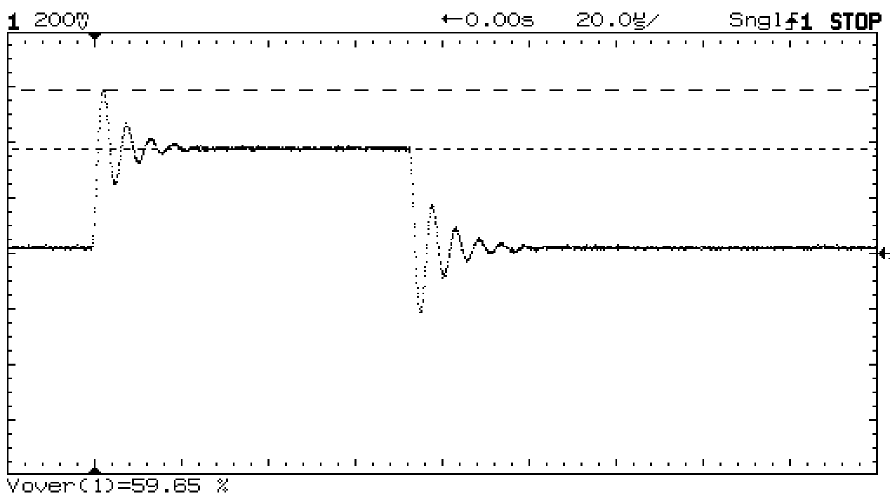
3 Press the **Source** softkey until the desired source is selected.

4 Press the **Next Menu** softkey until the **Vamp** softkey is displayed on the far left side.

5 Press the desired **Voltage Measurement** softkey.

- **Vamp** Select to perform a voltage amplitude measurement.
- **Vover** Select to perform an overshoot measurement.
- **Vpre** Select to perform a preshoot measurement.

Figure 2–9



Automatic Overshoot Measurement

To make additional cursor measurements

Without the Measurement/Storage Module installed, cursor measurements can be performed on channels 1 through 4, and are displayed in volts (V1/V2) and time (t1/t2). Refer to the *User and Service Guide* for your oscilloscope for more information.

With the Measurement/Storage Module installed, additional cursor measurement features include:

- Measurements can now be performed on functions 1 and 2.
- You can define voltage marker units as either volts or relative percent.
- You can define the time units as either seconds or relative degrees.

1 **Adjust controls until the desired signal is displayed.**

2 **Press `Cursors` .**

3 **Toggle the Source softkey until the desired source is selected (channels 1 through 4, functions 1 and 2).**

4 **Press the Active Cursor V1 V2 softkey.**

5 **Toggle the Readout softkey to select voltage markers in percent.**

If Readout Volts is selected, cursor measurements are displayed in volts (V1, V2, and ΔV), and operation is identical as when the module is not installed. Refer to the *User and Service Guide* for your oscilloscope for more information.

6 **Toggle the Active Cursor V1 V2 softkey until the desired marker(s) (V1, V2, or both) are selected, and rotate the knob closest to the `Cursors` key to set the marker(s) to the desired position.**

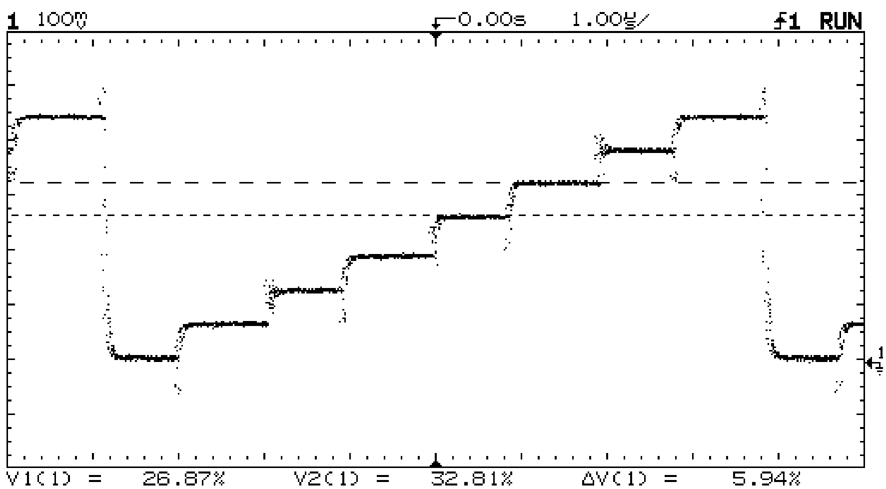
When both V1/V2 markers are selected, rotating the knob closest to the `Cursors` key moves both markers.

7 **Press the Set 100% softkey to set the V1 marker to 0% and the V2 marker to 100%. All readings are now relative to the established V1/V2 marker positions.**

- V1 reads the percentage the V1 marker has moved from the established 0% position. Negative readings indicate marker has moved away from the V2 marker.

- V2 reads the percentage the V2 marker has moved from the established 100% position. Negative readings indicate marker has moved through the established V1 marker position.
- ΔV reads the percentage difference between the V1 and V2 marker repetitive to the established positions. Negative readings indicate markers have crossed.

Figure 2–10



Voltage Cursor Measurements in Percent

8 Press the **Active Cursor t1 t2** softkey.

9 Toggle the **Readout** softkey to select time markers in degrees.

If Readout Time is selected, cursor measurements are displayed in seconds (t1, t2, and Δt), and Hz (1/Δt). Operation is identical as when the module is not installed. Refer to the *User and Service Guide* for your oscillosocpe for more information.

10 Toggle the **Active Cursor t1 t2** softkey until the desired marker(s) (t1, t2, or both) are selected, and rotate the knob closest to the `Cursors` key to set the marker(s) to the desired position.

When both t1/t2 markers are selected, rotating the knob closest to the `Cursors` key moves both markers.

11 Press the **Set 100%** softkey to set the t1 marker to 0° and the t2 marker to 360°. All readings (except second Δt display in seconds) are now relative to the established t1/t2 marker positions.

- t1 reads the phase the t1 marker has moved from established 0° position. Negative readings indicate marker has moved away from the t2 marker.
- t2 reads the phase the t2 marker has moved from established 360° position. Negative readings indicate marker has moved through the established t1 marker position.
- Δt in degrees reads the phase difference between the t1 and t2 marker repetitive to the established positions. Negative readings indicate markers have crossed.
- Δt in seconds reads the time difference between the t1 and t2 marker positions. Negative readings indicate markers have crossed.

Additional FFT Function Keys

When the FFT function is selected (refer to Math Functions), two additional keys are available as follows:

Find Peaks Pressing this key sets Vmarker1 and the start marker (f1) on the FFT trace peak with the highest amplitude and sets Vmarker2 and the stop marker (f2) on the peak with the next highest amplitude. Marker values in dBV or frequency (dependent on the active cursor)are automatically displayed at the bottom of the oscilloscope screen. The difference in dBV (ΔV) or frequency (Δf) between the two peaks is also displayed.

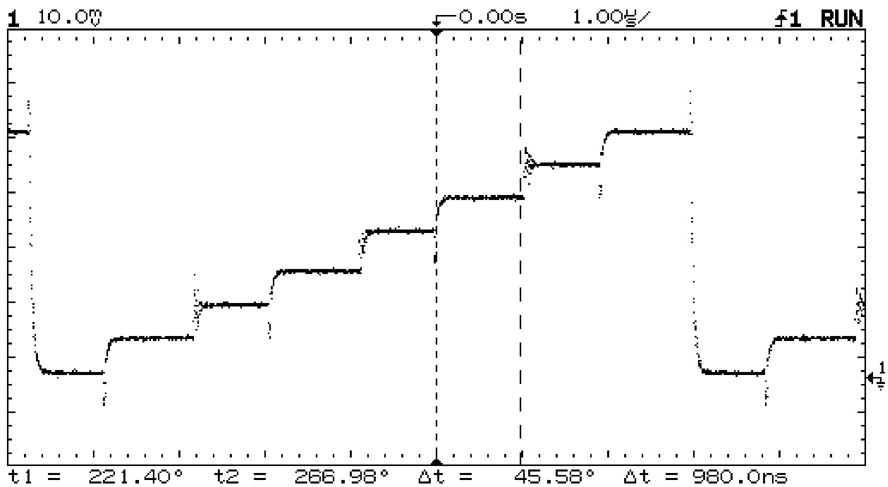
Move f1 To Center Pressing this key changes the center graticule (or center frequency) to the current f1 marker frequency. If f1 cannot be found, a message is displayed on the screen.

Cursor Measurement Hints

If cursors are positioned too closely together, an error will be displayed when the **SET** softkey is selected.

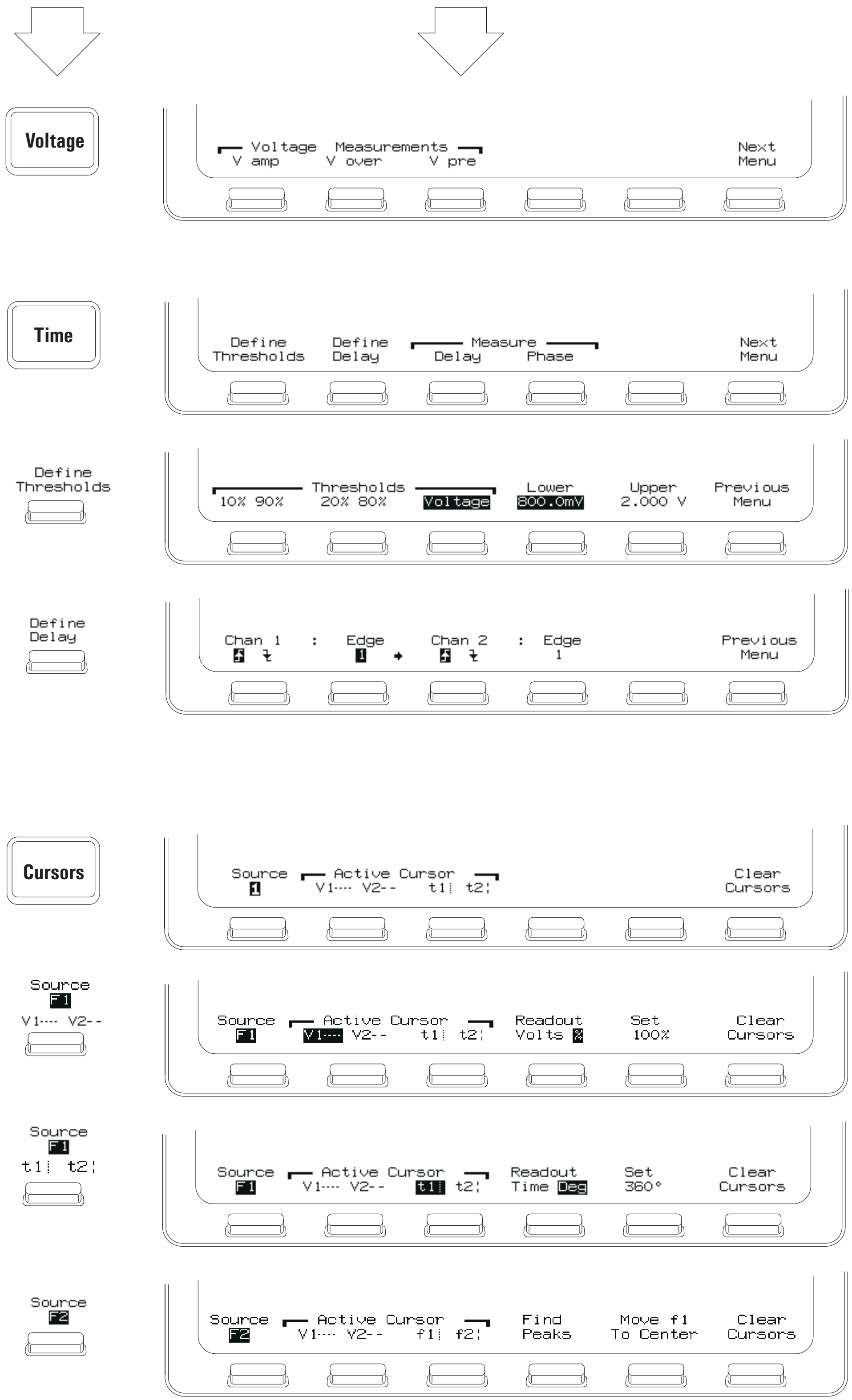
Displayed marker readings in percent (%) and degrees (°) are always relative measurements, with the current reading dependent on the previously established 100% or 360 reference setting.

Figure 2–11

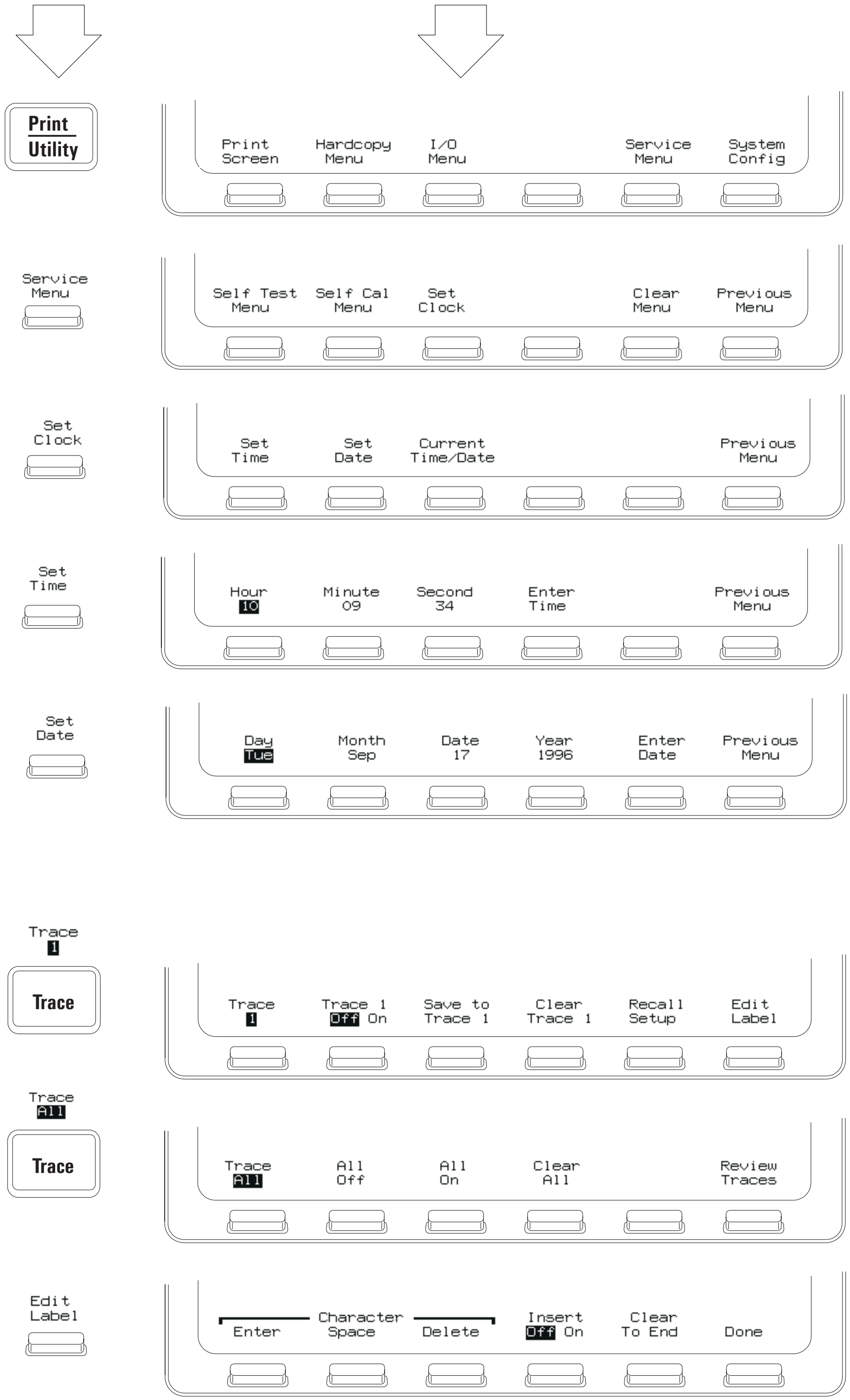


Time Cursor Measurements in Degrees

Press this key . . . **. . . to obtain this menu**



Press this key . . . **. . . to obtain this menu**



Press this key . . .	. . . to obtain this menu
±	Function 1: Off On, Menu · Function 2: Off On, Menu · Mask Test
Mask Test	Mask Test Off On · Use Mask 1 2 · Define Mask: Editor, AutoMask · Test Options · Previous Menu
AutoMask	Tolerance +/- 0.0 · Create Mask · Previous Menu
Test Options	Fail When In Out · On Fail Stop Run · Auto Save Off On · Save to Trace · Increment Off On · Previous Menu
Function 1 Menu	1 + 2: + - * · Units/div 5.000 V · Offset 0.000 V · Previous Menu
Function 2 Menu	Operand 1 2 F1 · Operation FFT · Units/div 10.00 dB · Ref Levl -10.00 dBV · FFT Menu · Previous Menu
FFT Menu	Cent Freq 244.1kHz · Freq Span 488.3kHz · Move 0Hz To Left · Autoscale FFT · Window Hanning · Previous Menu
Setup	Setup Memory: 1, Save, Recall · Recover Screen · Undo Autoscale · Default Setup

Operating Characteristics

Operating Characteristics are specified with the Measurement/Storage Module installed on an Agilent 54600–Series Oscilloscope.

Measurements

Voltage	Vamp, Vavg, Vrms, Vpp, Vpre, Vovr, Vtop, Vbase, Vmin & Vmax
Time	Delay, Duty Cycle, Frequency, Period, Phase Angle, Rise Time, Fall Time, +Width, & –Width
Thresholds	User-selectable among, 10%/90%, 20%/80% or voltage levels
Cursor Readout	Voltage, time, percentage, and phase angle.
Waveform Math Functions	Addition, subtraction, multiplication, differentiation, integration, and FFT.

Fast Fourier Transforms

Test Region	Each pixel is selectable to be tested or not.
Inputs	On either ch1, ch2, or F1
Freq Cursor Resolution	From 1.22 mHz (milliHz) to 9.766 MHz (1.22 mHz to 48.828 MHz for 54615/54616)
Points	Fixed at 1024 for all models except 54615/54616 Fixed at 1024 for 54615/54616 with vectors off Fixed at 512 for 54615/54616 with vectors on
Peak Find:	Find Peak automatically snaps cursor to the two largest peaks located anywhere in the displayed frequency span. Measurement information is automatically displayed at the bottom of the screen together with the difference in frequency between the two selected peaks.
Variable Sensitivity and Offset	Sensitivity and vertical offset (position) are controlled from the front panel to display an optimum view of the spectrum. Sensitivity is calibrated in dB per divisions; vertical offset is calibrated in dBV.
Time Record Length	10x main sweep speed.
Horizontal Magnification and Center Frequency Control	As the frequency span is changed, the display is magnified about center frequency so that you get a closer view.

Selectable Windows Four windows are selectable: Hanning, for best frequency resolution and general purpose use; flattop, for best amplitude accuracy; rectangular, for single-shot signals such as transients and signals where there are an integral number of cycles in the time record, and exponential for best transient analysis.

Window Characteristics

Window	Highest Side Lobe (dB)	3dB Bandwidth(bins)	6dB Bandwidth(bins)	Scallop Loss (dB)
Rectangular	–13	0.89	1.21	3.92
Hanning	–32	1.44	2.00	1.42
Flattop	–70	3.38	4.17	0.005

FFT Freq Range dc to 100 MHz (54600/54601/54645)
dc to 150 MHz (54602)
dc to 60 MHz (54603)
dc to 500 MHz (54610/54615/54616)

Freq Span Control This control allows you to specify the frequency span of the FFT display. When the Span is adjusted the display will expand or contract about the center frequency as set by the Center Frequency control. Refer to Figure 3-1 for the limits of the Frequency Span control.

Center Freq Control This control allows you to specify the frequency at the center of the FFT display. When the Frequency Span is changed, the FFT display will expand or contract about the frequency at the center of the display. Refer to Figure 3-1 for the limits of this control.

Move 0 Hz to Left Pressing this soft key will move the FFT display so that the left hand edge of the display will be 0Hz.

FFT Vector display When the time domain display is turned off the FFT display will be displayed in vector drawing mode. The time domain display can be turned off by pressing the Channel # key twice

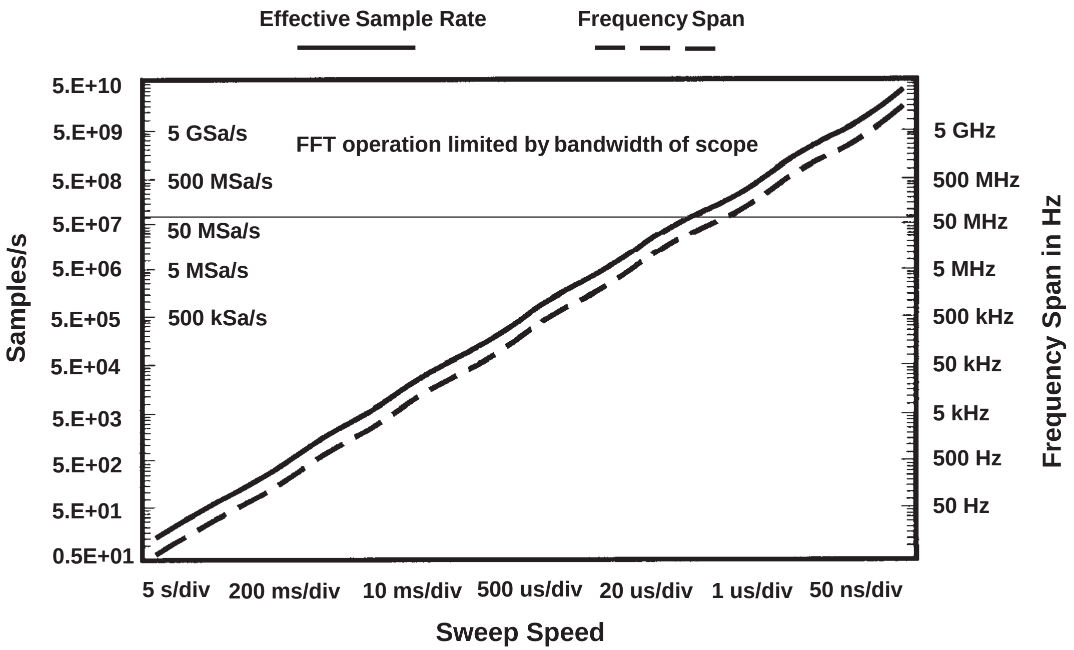
Display FFT vertical units in dB.

Units/Div This control allows you to adjust the vertical scaling of the FFT display in a 1-2-5 sequence from 1 dB/div to 50 dB/div.

Reference Level This control allows adjustment of the reference level of the FFT display across a range of 400 dBV. The minimum setting is -196 dB at 1 dBV/div decreasing to 0 dBV at 50 dBV/div. The maximum setting is 400 dBV at 50 dB/div, decreasing to 204 dB at 1 dBV/div.

Programmability All front-panel controls are fully programmable over GPIB (54657A) or RS-232 (54658A and 54659B)

Figure 3-1



Sweep Speed	Effective Sample Rate	Maximum Frequency Span	Sweep Speed	Effective Sample Rate	Maximum Frequency Span
5 s/div	20 Hz	9.75 Hz	50 µs/div	2 MHz	975k kHz
2 s/div	50 Hz	24.4 Hz	20 µs/div	5 MHz	2.44 MHz
1 s/div	100 Hz	48.85 Hz	10 µs/div	10 MHz	4.885 MHz
500 ms/div	200 Hz	97.5 Hz	5 µs/div	20 MHz	9.75 MHz
200 ms/div	500 Hz	244 Hz	2 µs/div	50 MHz	24.4 MHz
100 ms/div	1 kHz	488.5 Hz	1 µs/div	100 MHz	48.85 MHz
50 ms/div	2 kHz	975 Hz	500 ns/div	200 MHz	97.5 MHz
20 ms/div	5 kHz	2.44 kHz	200 ns/div	500 MHz	244 MHz
10 ms/div	10 kHz	4.885 kHz	100 ns/div	1 GHz	488.5 MHz
5 ms/div	20 kHz	9.75k Hz	50 ns/div	2 GHz	975 MHz
2 ms/div	50 kHz	24.4 kHz	20 ns/div	5 GHz	2.44 GHz
1 ms/div	100 kHz	48.85 kHz	10 ns/div	10 GHz	4.885 GHz
500 µs/div	200 kHz	97.5 kHz	5 ns/div	20 GHz	9.75 GHz
200 µs/div	500 kHz	244 kHz	2 ns/div*	50 GHz	24.41 GHz
100 µs/div	1 MHz	488.5 kHz			

* 2 ns/div FFT valid only on 54615/54616

FFT Operation
Frequency Span and Effective Sampling Rate vs Sweep Speed

This glossary is organized into two parts: oscilloscope ~~and TV/video trigger terms. The TV/video trigger terms apply to the HP 54602B with Option 005 installed.~~

Oscilloscope Terms

Auto A trigger mode that produces a baseline display if the trigger conditions are not met. If the trigger frequency is less than 25 Hz, even if the level and slope conditions are met, a free running display will result.

Auto Level The oscilloscope sets the trigger point to the 50% amplitude point on the displayed waveform. If there is no signal present, a baseline is displayed.

Autoscale Front-panel key that automatically sets up the oscilloscope to display a signal.

Autostore displays the stored waveforms in half bright, and the most recent trace is displayed in full bright.

Baseline Free running trace on the display when no signal is applied and the trigger mode is set to auto or auto level.

BW Lim (Bandwidth Limit) Limits the displayed bandwidth of the selected channel to 20 MHz, and is available for channels 1 and 2 only. This feature is useful for viewing noisy signals

Couplng (Coupling) For the channels, it changes the input coupling. Channels 1 and 2 allow dc, ac, or ground, while channels 3 and 4 allow dc or ground. In the trigger menu, it toggles between dc and ac for trigger coupling.

Cursors Horizontal and vertical markers used for making custom voltage and time measurements.

Delay In main sweep, the delay knob moves the sweep horizontally, and indicates how far the time reference is from the trigger point. In delayed sweep the delay knob moves the starting point of the portion of the main sweep to be expanded by the delayed sweep.

Delayed Gives an expanded view of the main sweep.

Display Allows selection of either normal, peak detect, or averaged display modes.

Erase Clears the display.

External Trigger Is available only on the two channel oscilloscope. Nonviewable input that is usable as a trigger source only.

Field 1 Triggers on the field 1 portion of the video signal.

Field 2 Triggers on the field 2 portion of the video signal.

HF Reject (high frequency reject) Adds a low pass filter with a 3 dB point at 50 KHz to the trigger path.

Holdoff Keeps the trigger from rearming for an amount of time set by the holdoff knob.

Internal Trigger The oscilloscope triggers from a channel input that you choose.

Invert Invert shifts the displayed waveform 180 degree, and is available for channels 1 and 2 only. When the oscilloscope is triggered on the signal to be inverted, the trigger is also inverted.

Level Front-panel knob that changes the trigger level.

LF Reject (low frequency reject) Adds a high pass filter with a 3 dB point at 50 KHz to the trigger path.

Line In TV trigger mode, the oscilloscope triggers on the TV line sync pulses. As a trigger source, the oscilloscope triggers off of the power line frequency.

Main Sets the oscilloscope to a volts vs time display that displays the main time base sweep.

Mode Allows you to select one of five trigger modes, Auto level, Auto, Normal, Single, TV.

Noise Rej (noise reject) Decreases the trigger sensitivity to reduce the triggering on signal noise.

Normal If a trigger signal is present and the trigger conditions are met, a waveform is displayed. If there is no trigger signal, the oscilloscope does not trigger and the display is not updated.

Peak Det (peak detect) Allows detection of signal extremes as the sample rate is decreased in the 5 s to 50 ms/div time base settings.

Polarity Selects either positive or negative TV sync pulses.

Position Knob that moves the signal vertically on the display.

Print/Utility Allows access to the module menus and service menus.

Probe Allows selection of 1, 10, or 100 to match a probe's division ratio so that the vertical scaling and voltage measurements reflect the actual voltage levels at the tip of the probe.

Recall Recalls a selected front-panel setup that you saved to one of 16 memory location. Memory selection is with either a softkey or the knob closest to the Cursors front-panel key.

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

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

Save Saves the current front-panel setup to one of the possible 16 memory locations. Memory selection is with either a softkey or the knob closest to the Cursors front-panel key.

Setup Allows access to front-panel setup keys.

Single (single shot) The oscilloscope triggers once when the trigger conditions are met. The oscilloscope must be rearmed before the oscilloscope retriggers by pressing either the Run or Autostore front-panel keys.

Slope/Coupling Allows access to the trigger slope and input coupling menus.

Slope Selects either the rising or falling edge of the signal to trigger the oscilloscope.

Source Allows you to select a trigger source.

Stop Freezes the display.

Time Allows access to the automatic time measurement keys.

Time/Div Changes the time base in a 1-2-5 step sequence from 2 ns to 5 s.

Time Ref Lft Cntr (time reference left or center) Sets the time reference to either one graticule in from the left edge of the display or to center of the display.

Trace Allows access to the trace storage keys.

Trace Mem (trace memory) One of two pixel memory locations used for storing traces.

TV Allows access to the TV slope and trigger coupling keys.

Vernier Vernier allows a calibrated fine adjustment with the channel 1 and 2 Volts/Div knob, and the time base Time/Div knob.

Voltage Allows access to the automatic voltage measurement keys.

Volts/Div Changes the vertical scaling in a 1-2-5 step sequence from 2 mV to 5 V.

XY Changes the display to a volts versus volts display.

TV/Video Trigger Terms

Blanking Level The level of the composite picture signal that separates the range containing picture information from the range containing synchronizing information. (IEEE Definition)

Chrominance That property of light which produces a sensation of color in the human eye apart from any variation in luminance that may be present.

Chrominance Signal That portion of the color television signal which contains the color information. (STOC Definition)

Color Burst In color systems, this normally refers to a burst of subcarrier frequency (8 to 10 cycles of 3.579545 MHz in NTSC systems) on the back porch of the composite video signal used to establish a frequency and phase reference for the chrominance signal.

Composite Sync The line and field rate synchronizing pulses (including the field equalizing pulses), when combined together, form the composite sync signal.