User Manual

Tektronix

TDS 500D, TDS 600B & TDS 700D Digitizing Oscilloscopes

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General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use this product only as specified.

Only qualified personnel should perform service procedures.

To Avoid Fire or Personal Injury

Use Proper Power Cord. Use only the power cord specified for this product and certified for the country of use.

Connect and Disconnect Properly. Do not connect or disconnect probes or test leads while they are connected to a voltage source.

Ground the Product. This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminals of the product, ensure that the product is properly grounded.

Observe All Terminal Ratings. To avoid fire or shock hazard, observe all ratings and marking on the product. Consult the product manual for further ratings information before making connections to the product.

The common terminal is at ground potential. Do not connect the common terminal to elevated voltages.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

Do Not Operate Without Covers. Do not operate this product with covers or panels removed.

Use Proper Fuse. Use only the fuse type and rating specified for this product.

Avoid Exposed Circuitry. Do not touch exposed connections and components when power is present.

Do Not Operate With Suspected Failures. If you suspect there is damage to this product, have it inspected by qualified service personnel.

Do Not Operate in Wet/Damp Conditions.

Do Not Operate in an Explosive Atmosphere.

Keep Product Surfaces Clean and Dry.

Provide Proper Ventilation. Refer to the manual's installation instructions for details on installing the product so it has proper ventilation.

Symbols and Terms

Terms in this Manual. These terms may appear in this manual:

WARNING. *Warning statements identify conditions or practices that could result in injury or loss of life.*

CAUTION. *Caution statements identify conditions or practices that could result in damage to this product or other property.*

Terms on the Product. These terms may appear on the product:

DANGER indicates an injury hazard immediately accessible as you read the marking.

WARNING indicates an injury hazard not immediately accessible as you read the marking.

CAUTION indicates a hazard to property including the product.

Symbols on the Product. The following symbols may appear on the product:

WARNING
High Voltage

Protective Ground
(Earth) Terminal

CAUTION
Refer to Manual

Double
Insulated

Electrostatic Discharge

Acquisition circuitry in the TDS 794D is very susceptible to damage from electrostatic discharge and from overdrive signals.

To prevent electrostatic damage to the TDS 794D, be sure to operate the oscilloscope only in a static-controlled environment. Be sure to discharge to ground any electrostatic charge that may be present on cables and probes before attaching them to the oscilloscope.

To prevent damage from electrostatic discharge, install short-circuit terminations on unused input connectors. Always use a wrist strap with internal impedance (provided with your instrument) when handling your oscilloscope or making connections.

Preface

This is the User Manual for the TDS 500D, TDS 600B, & TDS 700D Digitizing Oscilloscopes.

The chapter *Getting Started* briefly describes the TDS Oscilloscope, prepares you to install it, and tells you how to put it into service.

The chapter *Operating Basics* covers basic principles of the operation of the oscilloscope. The operating interface illustrations and the tutorial examples rapidly help you understand how your oscilloscope operates.

The chapter *Reference* teaches you how to perform specific tasks. See page 3–1 for a complete list of operating tasks covered in that chapter.

The *Appendices* provide an options listing, an accessories listing, and other useful information.

Related Manuals

The following documents are related to the use or service of the oscilloscope.

- The *TDS Family Digitizing Oscilloscopes Programmer Manual* (a diskette that is included with the user manual) describes using a computer to control the oscilloscope through the GPIB interface.
- The *TDS 500D, TDS 600B, & TDS 700D Reference* gives you a quick overview of how to operate the oscilloscope.
- The *TDS 500D, TDS 600B, & TDS 700D Technical Reference (Performance Verification and Specifications)* tells how to verify the performance of the oscilloscope and lists its specifications.
- The *TDS Family Option 05 Video Trigger Instruction Manual* describes use of the video trigger option for TDS oscilloscopes equipped with that option only.
- The *TDS 500D, TDS 600B, & TDS 700D Service Manual* provides information for maintaining and servicing the oscilloscope to the module level.

Default Model

This manual documents the TDS 500D, TDS 600B, & TDS 700D Digitizing Oscilloscopes. Take special note of the following conventions:

- Some TDS models have two auxiliary channels called AUX 1 and AUX 2, instead of CH 3 and CH 4. References to these channels default to CH 3 and CH 4; if your oscilloscope is one of these models, read AUX 1 and AUX 2 respectively for all references to CH 3 and CH 4 in this manual.
- The TDS 684B display screen appears as the default screen wherever a display screen is illustrated in this manual.

Model References

This manual documents the TDS 500D, TDS 600B, & TDS 700D Digitizing Oscilloscopes. Take note of the following conventions used when referencing these oscilloscopes:

- The name “TDS 500D” is used when providing information common to the TDS 520D, TDS 540D, and TDS 580D model oscilloscopes.
- The name “TDS 600B” is used when providing information common to the TDS 620B, TDS 644B, TDS 680B, and TDS 684B model oscilloscopes.
- The name “TDS 700D” is used when providing information common to the TDS 724D, TDS 754D, TDS 784D, and TDS 794D model oscilloscopes.

Conventions

In this manual, you will find various procedures which contain steps of instructions for you to perform. To keep those instructions clear and consistent, this manual uses the following conventions:

- In procedures, names of front panel controls and menu labels appear in boldface print.

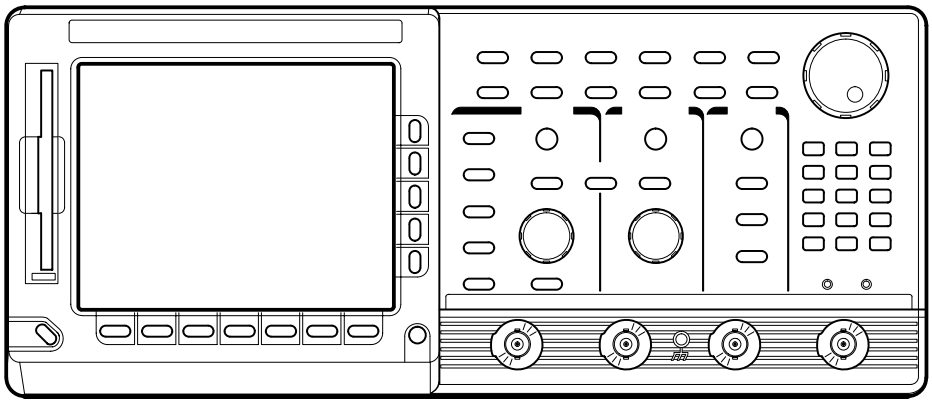
- Names also appear in the same case (initial capitals or all uppercase) in the manual as is used on the oscilloscope front panel and menus. Front panel names are all upper case letters, for example, **VERTICAL MENU** and **CH 1**.
- Instruction steps are numbered. The number is omitted if there is only one step.
- When steps require that you make a sequence of selections using front panel controls and menu buttons, an arrow (→) marks each transition between a front panel button and a menu, or between menus. Also, whether a name is a main menu or side menu item is clearly indicated: Press **VERTICAL MENU → Coupling** (main) → **DC** (side) → **Bandwidth** (main) → **250 MHz** (side).

Using the convention just described results in instructions that are graphically intuitive and simplifies procedures. For example, the instruction just given replaces these five steps:

1. Press the front-panel button **VERTICAL MENU**.
2. Press the main-menu button **Coupling**.
3. Press the side-menu button **DC**.
4. Press the main-menu button **Bandwidth**.
5. Press the side-menu button **250 MHz**.

Sometimes you may have to make a selection from a pop-up menu: Press **TRIGGER MENU → Type** (main) → **Edge** (pop-up). In this example, you repeatedly press the main menu button **Type** until **Edge** is highlighted in the pop-up menu.

Product Description



The Tektronix TDS Oscilloscope is a superb tool for acquiring, displaying, and measuring waveforms. Its performance addresses the needs of both benchtop lab and portable applications with the following key features:

- An analog bandwidth of up to 2 GHz, depending on the model (see Table 1–1 *Key Features and Differences of by Models* on page 1–3)
- A maximum sample rate of up to 5 GS/s per channel, depending on the model (see Table 1–1 on page 1–3)
- Records lengths up to 8 M, depending on the model and options (see Table 1–1 on page 1–3)
- Up to 29 automatic measurements and measurement statistics (see *Taking Automated Measurements* on page 3–126)
- 1% DC vertical gain accuracy (see *TDS 500D, TDS600B & TDS 700D Technical Reference* manual)
- DPO for high speed acquisition and analog oscilloscope emulation (see *Using DPO Acquisition Mode* on page 3–59)
- Internal floppy disk storage and compatible with Iomega 100 Mbyte Zip drive (see *Saving Waveforms and Setups* on page 3–165)
- Trigger modes include edge, logic, pulse, delay, communication, and video trigger modes (see *Triggering on Waveforms* on page 3–73)

- Advanced features include limit testing (see *Limit Testing* on page 3–201), FFT (see *Fast Fourier Transforms* on page 3–209), waveform differentiation and integrations (see *Waveform Differentiation* and *Waveform Integration* starting on page 3–228), mask testing (see *Mask Testing* on page 3–148), waveform histograms (see *Displaying Histograms* on page 3–145), and communications signal analysis (see *Communication Triggers* on page 3–113, *Mask Testing* on page 3–148, and options 2C, 3C, and 4C on page A–2)
- Adjustable channel deskew for increased measurement accuracy (see *Channel/Probe Deskew* on page 3–158)
- Full GPIB programmability (see *Communicating with Remote Instruments* on page 3–191 and the *TDS Family Programmer Manual* disk)
- Wide array of probing solutions (see *Accessory Probes* on page A–6 and *Probe Selection* on page D–1)
- CE, FCC, UL, and CAN/CSE compliant (see *TDS 500D, TDS600B & TDS 700D Technical Reference* manual)
- Four channel or 2 + 2 channel operation, depending on the model. All channels have 8-bit resolution. (See Table 1–1 on page 1–3.)
- Dual Window Zoom, which shows a waveform magnified and unmagnified on the same display (see *Using Dual Window Mode* on page 3–56)
- Sample, envelope, average, high res, peak-detect and DPO acquisition modes (see Table 1–1, on page 1–3, for models and modes available)

Differences by Model

Table 1–1 lists some key TDS features and relates them to the different TDS models that this manual covers.

Table 1–1: Key Features and differences of models

Feature	520D	540D	580D	620B	644B	680B	684B	724D	754D	784D	794D
No. of channels	2+2[1]	4	4	2 + 2[1]	4	2 + 2[1]	4	2+2[1]	4	4	4
Digitizing rate, max.	2 GS/s	2 GS/s	4 GS/s	2.5 GS/s		5 GS/s		2 GS/s	2 GS/s	4 GS/s	4 GS/s
No. of Channels. @ maximum rate	1	2	1	2	4	2	4	1	2	1	
Analog Bandwidth	500 MHz		1 GHz	500 MHz		1 GHz		500 MHz		1 GHz	2 GHz
Record Lengths, max.	To 50K/Channel[2]			To 15K/Channel				To 50K/Channel[2]			
DPO Acquisitions	Yes			No				Yes			
Hi Res Acquisitions	Yes			No				Yes			
Advanced DSP Math[3]	Opt. 2F			Std.[4]							
Communication Signal Analyzer	Opt. 2C			No				Opt. 2C			
Reference Receiver	Opt. 3C and 4C			No				Opt. 3C and 4C			No
Storage, Floppy Disk	Std.										
iomega Zip Drive support	Yes			No				Yes			
I/0 includes RS–232 and Centronics[5]	Opt. 13			Std.[4]							
Input Impedance	50 Ω and 1 MΩ										50 Ω only
Display	Mono				Color	Mono		Color			

1 **Two plus Two channel operation allows two of four channels to be displayed simultaneously. Channels not displayed can be used to couple a triggering signal to the oscilloscope.**

2 **These TDS models can be purchased with Option 1M or Option 2M, which add longer record length settings (up to 2 Mb/channel). See Option 1M and Option 2M on page A–2.**

3 **Advanced digital signal processing provides FFTs, integrals, and derivatives of waveforms. See Option 2F on page A–3.**

4 **Std. denotes a standard product feature as opposed to a feature included as part of an option.**

5 **GPIB I/O included with all models.**

Product Specification

The product specification is found in the technical reference *TDS 500D, TDS 600B, & TDS 700D Technical Reference (Performance Verification and Specifications)* that is shipped as a standard accessory with the TDS Oscilloscope.

Start Up

Before you use the TDS Oscilloscope, ensure that it is properly installed and powered on.

Preparation

To ensure maximum accuracy for your most critical measurements, you should know about signal path compensation and the proper use of the probe you choose to use with your oscilloscope.

Signal Path Compensation

Be sure you compensate your oscilloscope for the surrounding temperature. This action, called *Signal Path Compensation (SPC)*, ensures maximum possible accuracy for your most critical measurements. See *Signal Path Compensation* on page 3–156 for a description of and operating information on this feature.

Recommended Probes

The TDS 580D, TDS 680B, TDS 684B, TDS 784D, and TDS 794D oscilloscopes ship without probes. To take advantage of the higher bandwidth of these oscilloscopes, order the P6245, P6217, or P6158 probes.

The remaining TDS 500D, TDS 600B, and TDS 700D oscilloscopes ship with general-purpose probes. The probe model and quantities shipped are listed in *Standard Accessories* on page A–4.

For a list of recommended optional-accessory probes for all oscilloscope models, see *Accessory Probes* on page A–5.

Probe Usage

Be sure you use the appropriate probe for the measurement. For instance, do not use the P6245 Active Probe to measure signals greater than ±8 volts or with more than ±10 volts of offset, since errors in signal measurement will result. (See the User manual for the probe for more information.) Instead, use a passive probe, such as P6139A passive probe, that allows higher voltage measurements. The P6139A probe is for measurements up to ±500 volts.

Probes that require a 1 MΩ input, like the P6139A, will not work on the TDS 794D.

CAUTION. *Using the P6243 or P6245 Active Probe to measure signals greater than ±40 volts may damage the probe. Using the P6158 Voltage Divider Probe to measure signals greater than ±22 V_{RMS} may damage the probe.*

Input Coupling

Be sure to choose the proper input coupling and impedance for the probe or other cabling you use to couple signals to your oscilloscope. You should read *Input Impedance Considerations* on page 3–8 for information needed to ensure proper coupling of your input signals.

Putting into Service

To learn how to install, access the front panel, power on, do a self test, and power off the oscilloscope, do the following procedures:

Installation

To properly install and power on the oscilloscope, do the following steps:

1. Be sure you have the appropriate operating environment. Specifications for temperature, relative humidity, altitude, vibrations, and emissions are included in the *TDS 500D, TDS 600B, & TDS 700D Technical Reference (Performance Verification and Specifications)* manual (Tektronix part number 071-0135-xx).
2. Leave space for cooling. Do this by verifying that the air intake and exhaust holes on the sides and bottom of the cabinet are free of any airflow obstructions. Leave at least 5.1 cm (2 inches) free on each side.

WARNING. *To avoid electrical shock, be sure that the power cord is disconnected before checking the fuse.*

3. Check the fuse to be sure it is the proper type and rating (see Figure 1–1). You can use either of two fuses. Each fuse requires its own cap (see Table 1–2). The oscilloscope is shipped with the UL approved fuse installed.
4. Check that you have the proper electrical connections. The oscilloscope requires 100 to 240 VAC_{RMS}, continuous range, 45 Hz to 440 Hz, and may require up to 300 W.

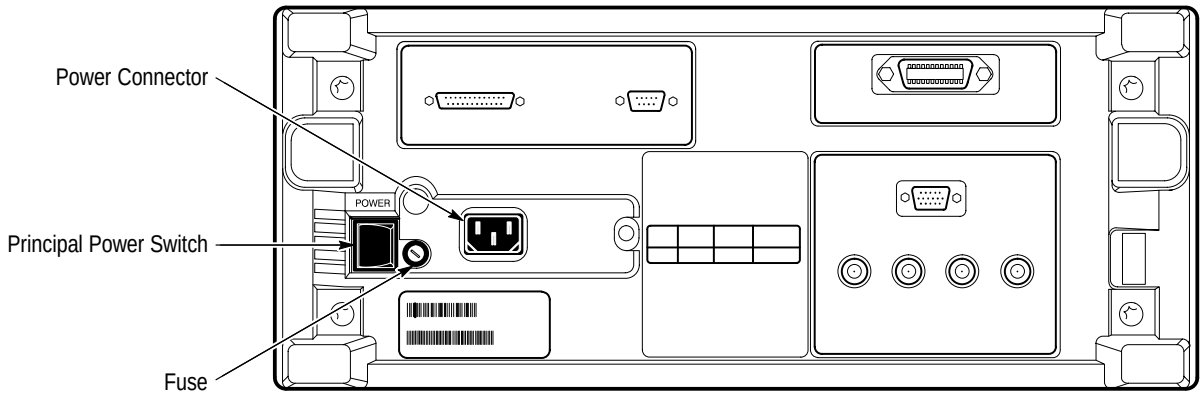


Figure 1–1: Rear Panel Controls Used in Start Up

5. Connect the proper power cord from the rear-panel power connector (see Figure 1–1) to the power system.

Table 1–2: Fuse and fuse cap part numbers

Fuse	Fuse part number	Fuse cap part number
0.25 inch × 1.25 inch (UL 198.6, 3AG): 6 A FAST, 250 V	159-0013-00	200-2264-00
5 mm × 20 mm (IEC 127): 5 A (T), 250 V	159-0210-00	200-2265-00

Front Cover Removal

To remove the front cover, grasp the left and right edges and snap the cover off of the front subpanel. (To reinstall the cover, align it to the front subpanel and snap it back on.)

Power On

To power on the oscilloscope, do the following steps:

1. Check that the rear-panel principal power switch is on (see Figure 1–1). The principal power switch controls all AC power to the instrument.
2. If the oscilloscope is not powered on (the screen is blank), push the front-panel **ON/STBY** button to toggle it on (see Figure 1–2).

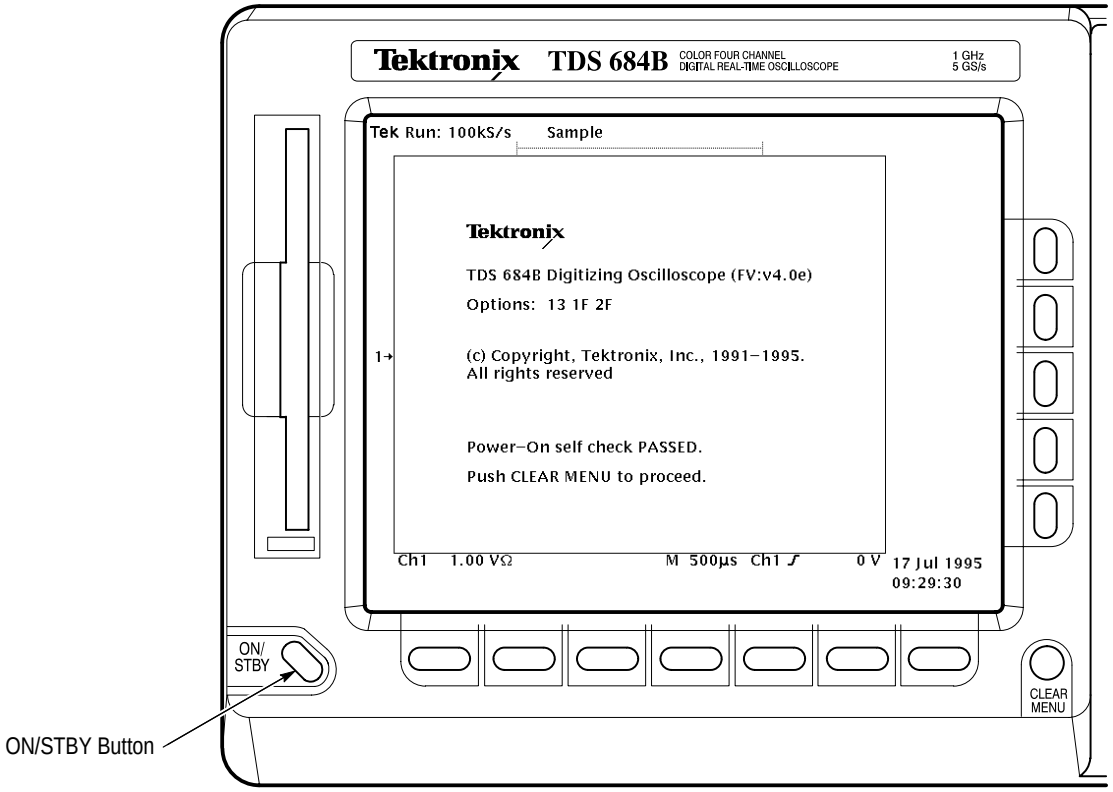


Figure 1–2: ON/STBY Button

The ON/STBY button controls power to most of the instrument circuits. Power continues to go to certain parts even when this switch is set to STBY.

Once the oscilloscope is installed, it is typical to leave the principal power switch on and use the ON/STBY button instead of the power switch.

Self Test

The oscilloscope automatically performs power-up tests each time it is turned on. It will come up with a display screen that states whether or not it passed the self test. To determine the self-test results, check the screen. (If the self test passed, the status display screen will be removed after a few seconds.)

If the self test fails, call your local Tektronix Service Center. Depending on the type of failure, you may still be able to use the oscilloscope before it is serviced.

Power Off

To power off the oscilloscope, toggle the **ON/STBY** switch.

Overview

This chapter describes the basic concepts of operating the TDS Oscilloscope. Understanding the basic concepts of your oscilloscope will help you use it much more effectively.

The first section, *Operating Interface Maps*, quickly shows you how the oscilloscope controls are organized and where you can read about them. It also illustrates the general procedures for operating the menu system. This section includes the titles:

- *Front Panel Map*
- *Rear Panel Map*
- *Display Map*
- *To Operate a Menu*
- *To Operate a Pop-Up Menu*

The second section, *Tutorial*, contains example procedures that lead you through the fundamental tasks needed to display a waveform measurement. It also includes an example procedure that teaches you how to store a setup of the oscilloscope controls for later use. This section includes the following tutorial examples:

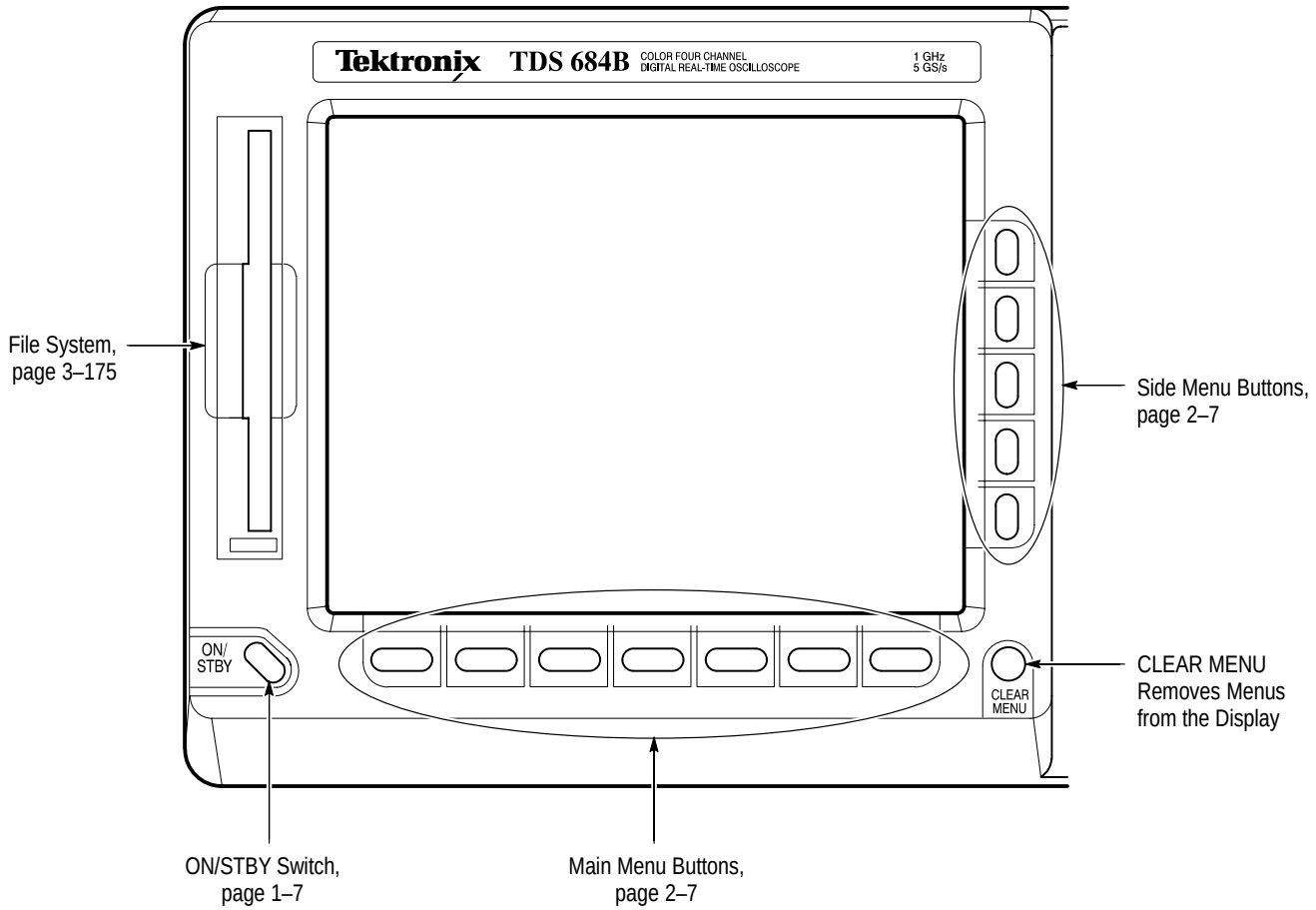
- *Setting Up for the Examples*
- *Example 1: Displaying a Waveform*
- *Example 2: Displaying Multiple Waveforms*
- *Example 3: Taking Automated Measurements*
- *Example 4: Saving Setups*

To explore these topics in more depth and to read about topics not covered in this section, see *Reference.* A list of the topics covered begins on Page 3–1.

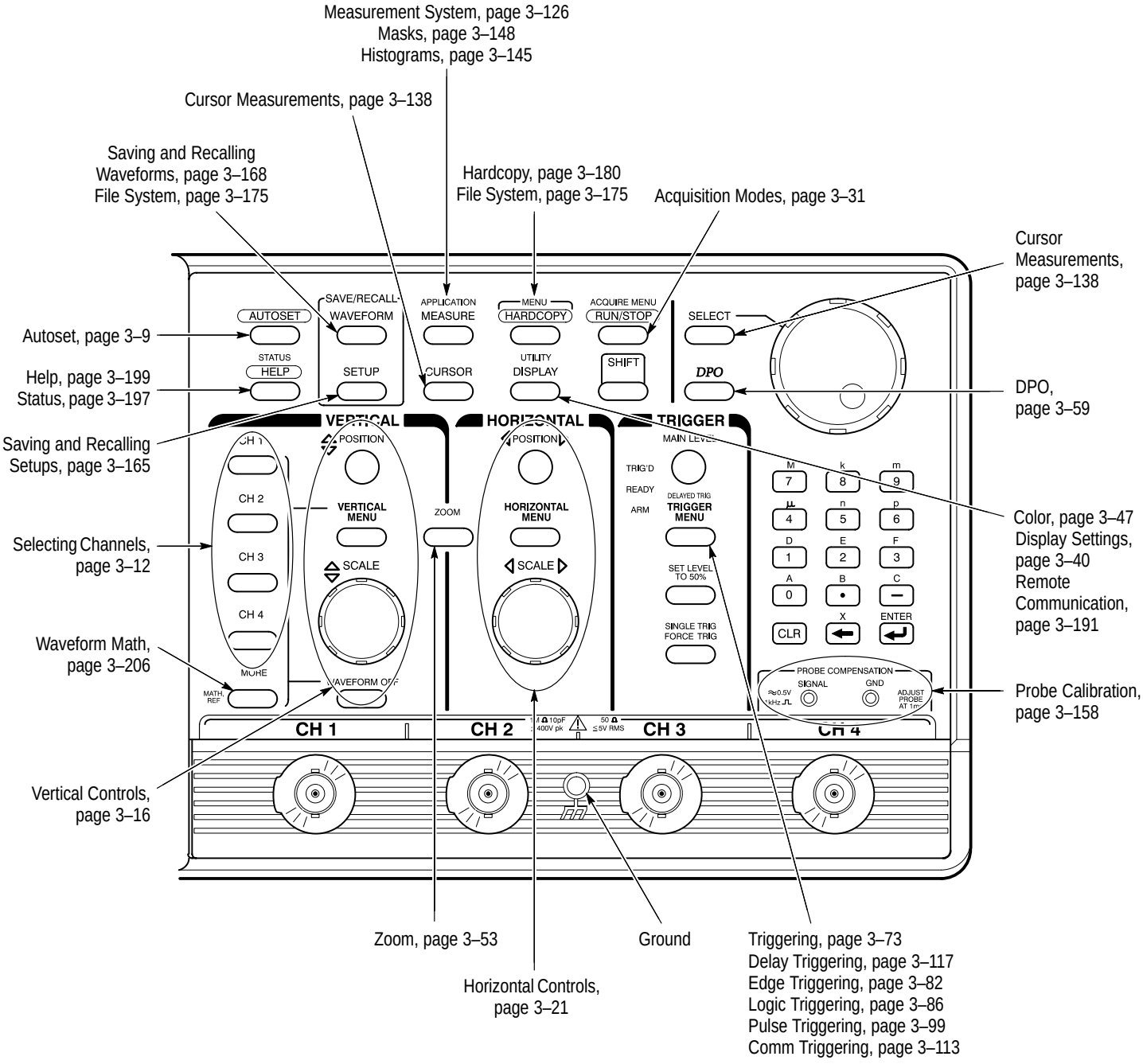
Operating Interface Maps

This section contains illustrations, or maps, of the display, the front and rear panels, and the menu system of the TDS Oscilloscope. These maps will help you understand and operate the oscilloscope. This section also contains a visual guide to using the menu system.

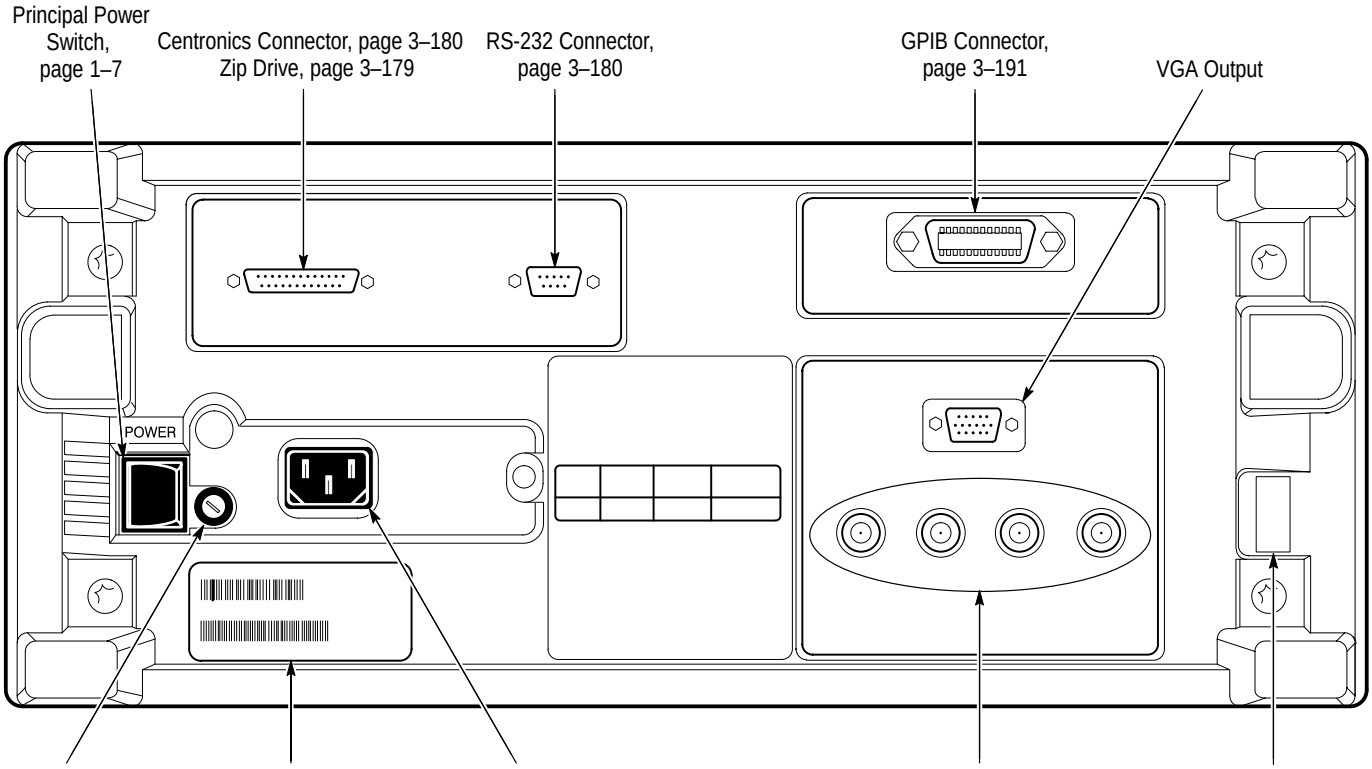
Front Panel Map — Left Side



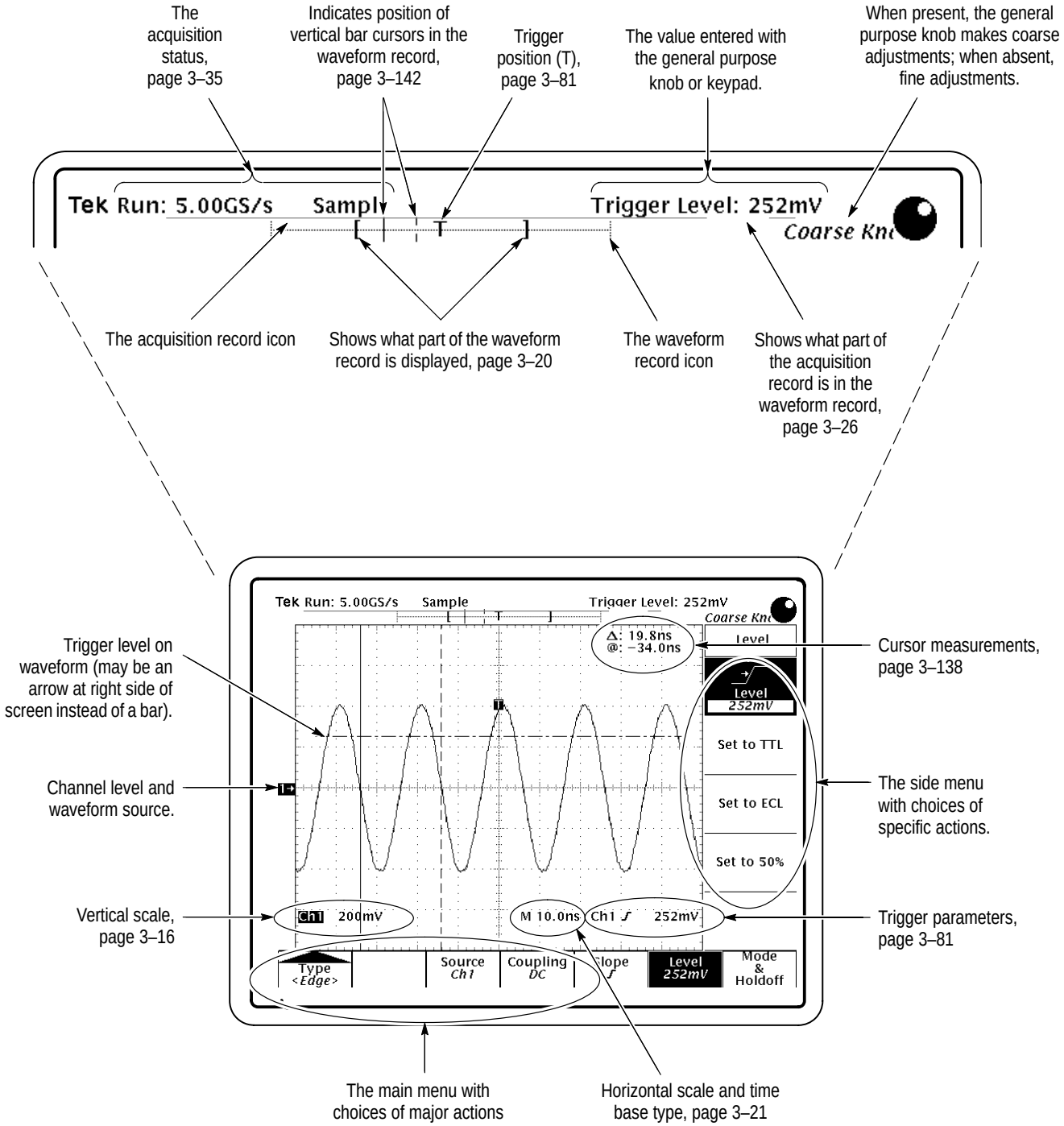
Front Panel Map — Right Side



Rear Panel Map

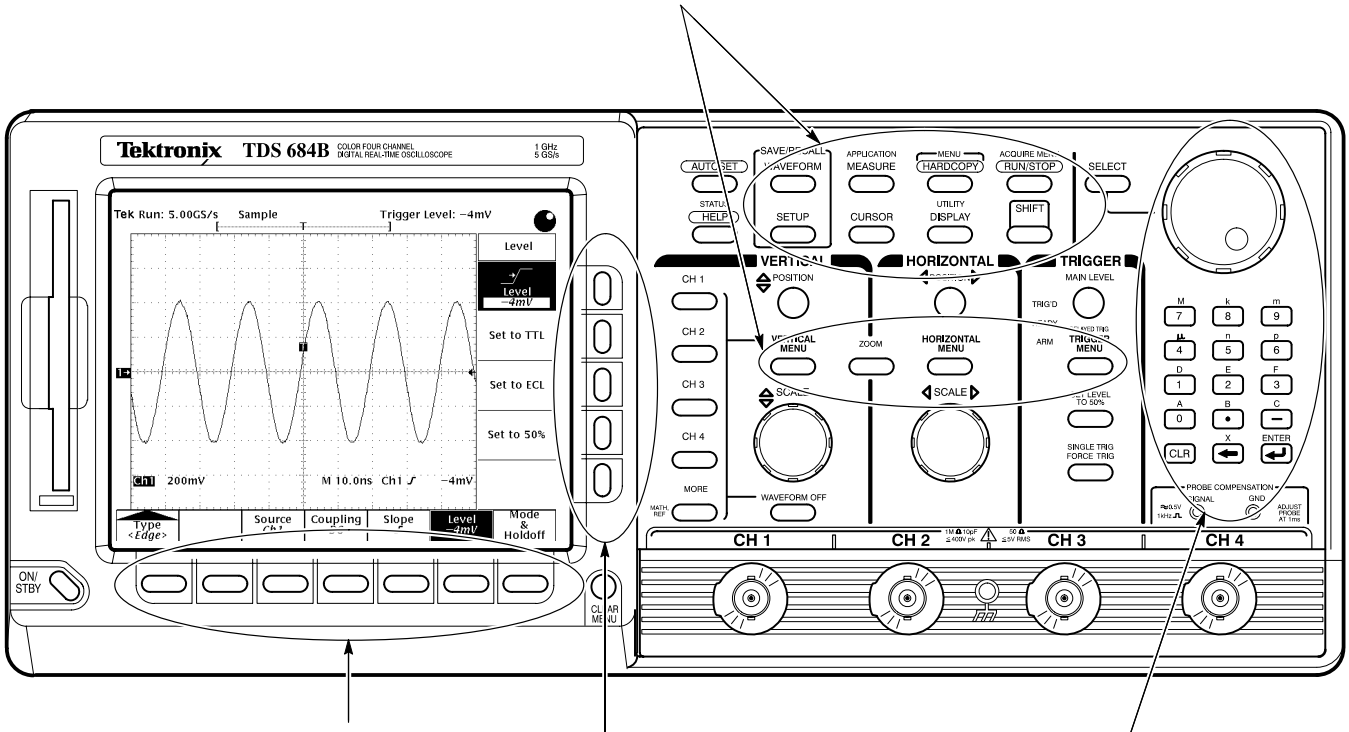


Display Map


The acquisition status, page 3–35
Indicates position of vertical bar cursors in the waveform record, page 3–142
Trigger position (T), page 3–81
The value entered with the general purpose knob or keypad.
When present, the general purpose knob makes coarse adjustments; when absent, fine adjustments.
Tek Run: 5.00GS/s Sampl
Trigger Level: 252mV
Coarse Kn
The acquisition record icon
Shows what part of the waveform record is displayed, page 3–20
The waveform record icon
Shows what part of the acquisition record is in the waveform record, page 3–26
Tek Run: 5.00GS/s Sample
Trigger Level: 252mV
Coarse Kn
Δ: 19.8ns
@: −34.0ns
Level
Level
252mV
Set to TTL
Set to ECL
Set to 50%
Ch1 200mV
M 10.0ns Ch1 ƒ 252mV
Type
<Edge>
Source
Ch1
Coupling
DC
Slope
Level
252mV
Mode
&
Holdoff
Trigger level on waveform (may be an arrow at right side of screen instead of a bar).
Channel level and waveform source.
Vertical scale, page 3–16
Cursor measurements, page 3–138
The side menu with choices of specific actions.
Trigger parameters, page 3–81
The main menu with choices of major actions
Horizontal scale and time base type, page 3–21

To Operate a Menu

1 Press front-panel menu button. (Press **SHIFT** first if button label is blue.)

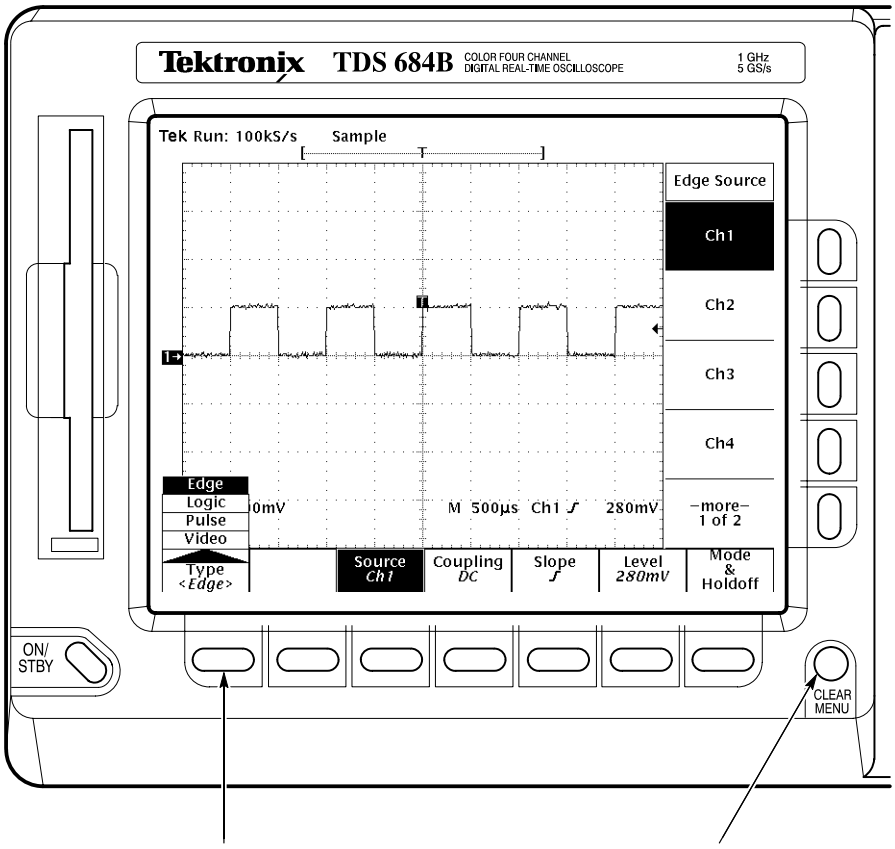


2 Press one of these buttons to select from main menu.

3 Press one of these buttons to select from side menu (if displayed).

4 If side menu item has an adjustable value (shown in reverse video), adjust it with the general purpose knob or keypad.

To Operate a Pop-Up Menu



Press to display pop-up menus.

Press it again to make selection.

Alternatively, press SHIFT first to make selection in the opposite direction.

A pop-up selection changes the other main menu titles.

Press here to remove menus from screen.

Tutorial

This section quickly makes you acquainted with some of the fundamental operations required to use the TDS Oscilloscope to take measurements. Start this tutorial by doing *Setting Up for the Examples* on this page.

Setting Up for the Examples

Perform the following tasks to connect input signals to the TDS Oscilloscope, to reset it, and to become acquainted with its display screen. Once completed, these tasks ready the oscilloscope for use in the examples that follow.

Connect the Input Signal

Remove all probes and signal inputs from the input BNC connectors along the lower right of the front panel. Then, using an appropriate probe (such as the P6245), connect from the **CH 1** connector of the oscilloscope to the **PROBE COMPENSATION** connectors. (See Figure 2–1.)

NOTE. *See* Appendix A: Options and Accessories *for optional probes you can order and use with this product.*

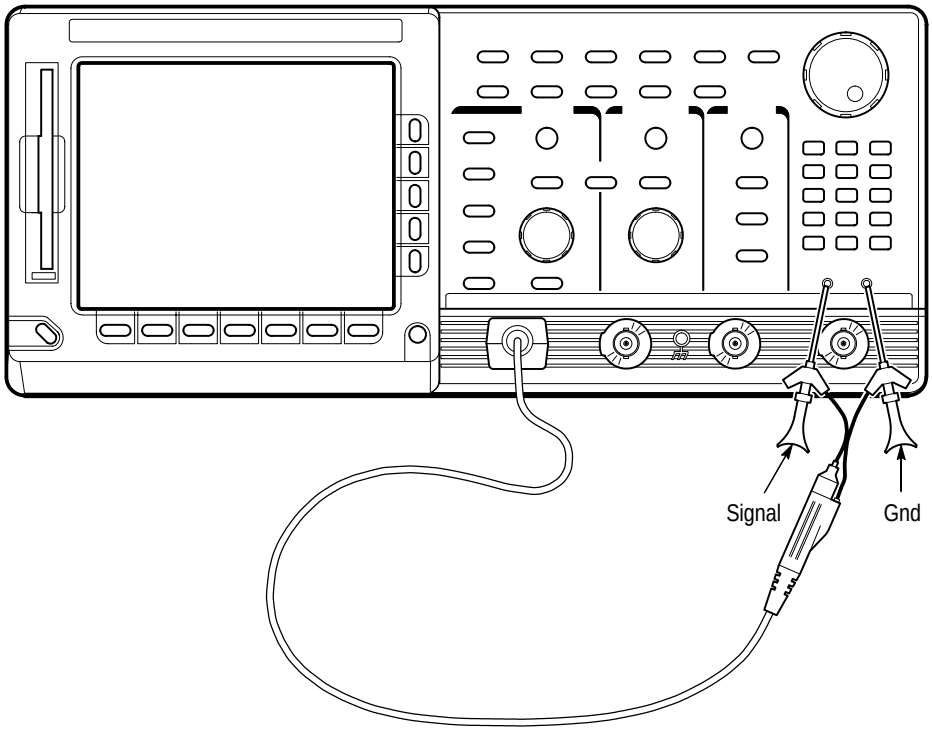


Figure 2–1: Connecting a Probe for the Examples (P6245 shown)

Reset the Oscilloscope

Do the following steps to reset the oscilloscope to a known factory default state before doing the examples. (You can reset the oscilloscope anytime you begin a new task and need to "start fresh" with known default settings.)

1. Press the save/recall **SETUP** button to display the Setup menu. (See Figure 2–2.)

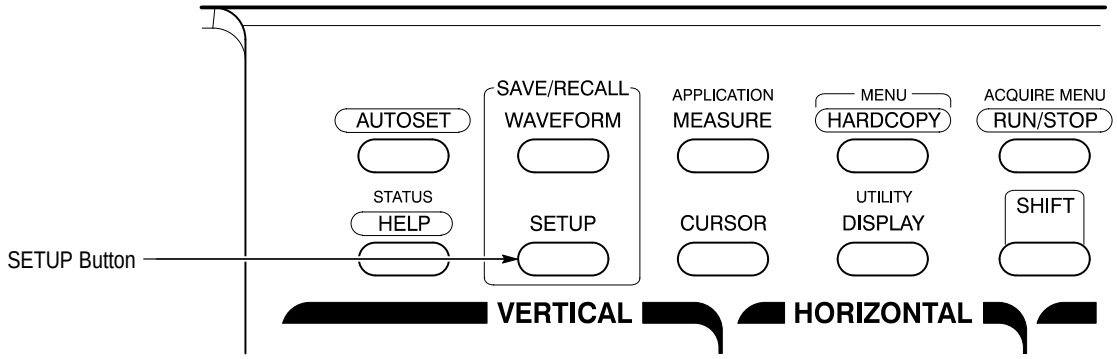


Figure 2–2: SETUP Button Location

The oscilloscope displays *main menus* along the bottom of the screen. Figure 2–3 shows the Setup main menu.

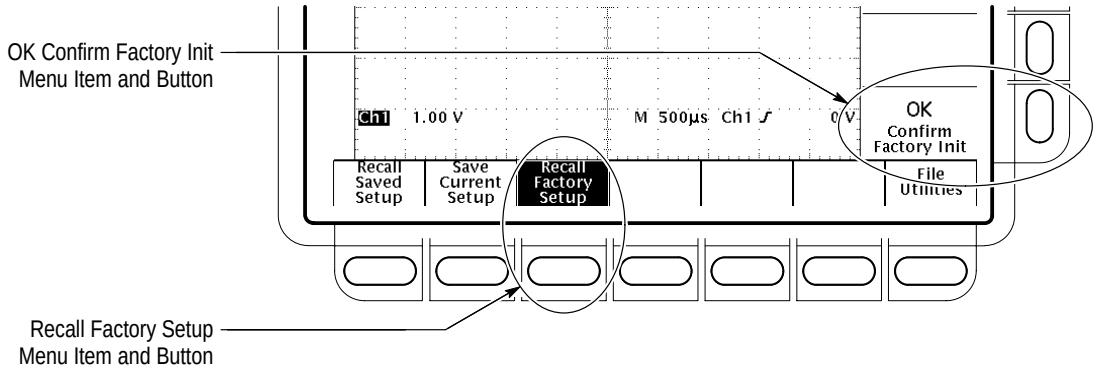


Figure 2–3: The Setup Menu

2. Press the button directly below the **Recall Factory Setup** menu item.

The display shows *side menus* along the right side of the screen. The buttons to select these side menu items are to the right of the side menu.

Because an accidental instrument reset could destroy a setup that took a long time to create, the oscilloscope asks you to verify the Recall Factory Setup selection. (See Figure 2–3.)

3. Press the button to the right of the **OK Confirm Factory Init** side menu item.

NOTE. *This manual uses the following notation to represent the sequence of selections you made in steps 1, 2 and 3:* Press save/recall **SETUP → Recall Factory Setup** (main) **→ OK Confirm Factory Init** (side).

Note that a clock icon appears on screen. The oscilloscope displays this icon when performing operations that take longer than several seconds.

4. Press **SET LEVEL TO 50%** (see Figure 2–4) to be sure the oscilloscope triggers on the input signal.

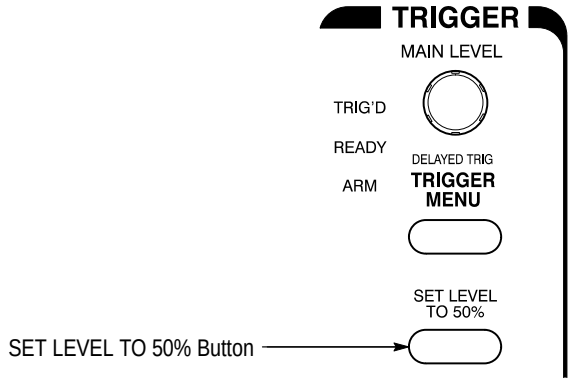


Figure 2–4: Trigger Controls

Examine the Display Elements

Read the following information to become familiar with the oscilloscope display before doing the examples.

Figure 2–5 shows the display that results from the oscilloscope reset. There are several important points to observe:

- The *trigger level bar* shows that the waveform is triggered at a level near 50% of its amplitude (from step 4).
- The *trigger position indicator* shows that the trigger position of the waveform is located at the horizontal center of the graticule.
- The *channel reference indicator* shows the vertical position of channel 1 with no input signal. This indicator points to the ground level for the channel when its vertical offset is set to 0 V in the vertical menu; when vertical offset is *not* set to 0 V, it points to the vertical offset level.

- The *trigger readout* shows that the oscilloscope is triggering on channel 1 (Ch1) on a rising edge, and that the trigger level is about 200–300 mV.
- The *time base readout* shows that the main time base is set to a horizontal scale of 500 μs/div.
- The *channel readout* indicates that channel 1 (Ch1) is displayed with DC coupling. (In AC coupling, ~ appears after the volts/div readout.) The oscilloscope always displays channel 1 at reset.

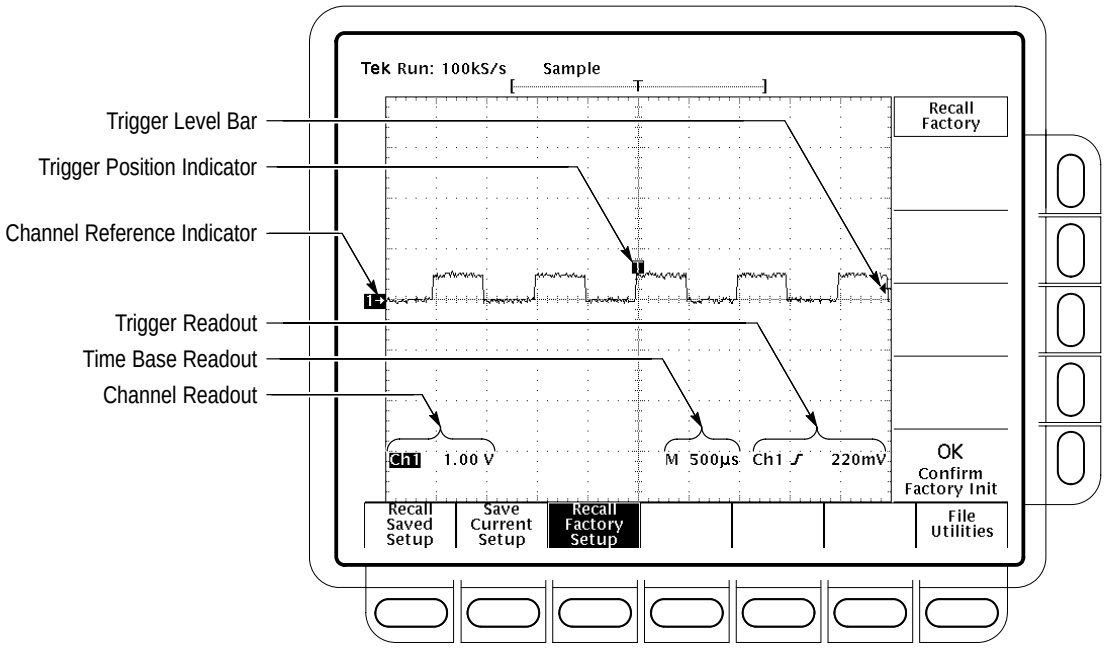


Figure 2–5: The Display After Factory Initialization

Right now, the channel, time base, and trigger readouts appear in the graticule area because a menu is displayed. You can press the CLEAR MENU button at any time to remove any menus and to move the readouts below the graticule.

Example 1: Displaying a Waveform

The TDS Oscilloscope provides front panel knobs for you to adjust a waveform, or it can automatically set up its controls to display a waveform. Do the following tasks to learn how to adjust a waveform and how to autoset the TDS Oscilloscope.

Adjust the Waveform Display

The display shows the probe compensation signal. It is a 1 kHz square wave of approximately 0.5 V amplitude.

Figure 2–6 shows the main VERTICAL and HORIZONTAL sections of the front panel. Each has SCALE and POSITION knobs. Do the following steps to adjust the size and placement of the waveform using the front-panel knobs:

1. Turn the vertical **SCALE** knob clockwise. Observe the change in the displayed waveform and the channel readout at the bottom of the display.

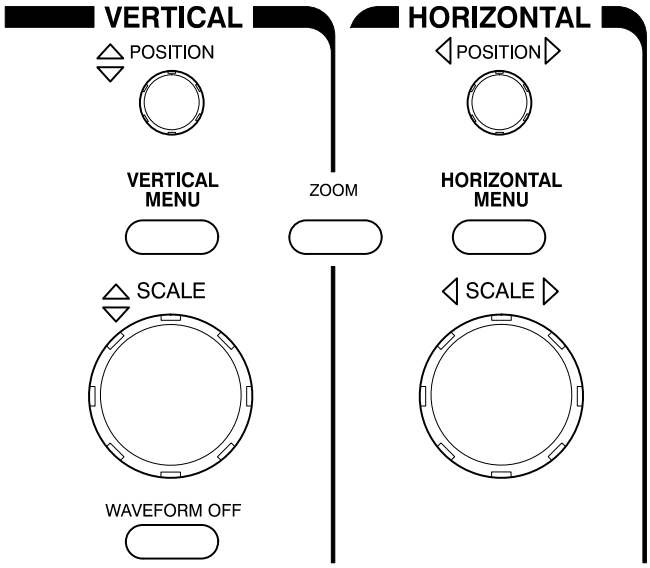


Figure 2–6: The VERTICAL and HORIZONTAL Controls

2. Turn the vertical **POSITION** knob first one direction, and then the other. Observe the change in the displayed waveform. Then return the waveform to the center of the graticule.

3. Turn the horizontal **SCALE** knob one click clockwise. Observe the time base readout at the bottom of the display. The time base should be set to 200 μs/div now, and you should see two complete waveform cycles on the display.

Autoset the Oscilloscope

When you first connect a signal to a channel and display it, the signal displayed may not be scaled and triggered correctly. Use the autoset function and you should quickly get a meaningful display.

You should have a stable display of the probe compensation waveform from the last step. Do the following steps to first create an unstable display and then to autoset the display:

1. To create an unstable display, slowly turn the trigger **MAIN LEVEL** knob (see Figure 2–7) first one direction, and then the other. Observe what happens when you move the trigger level above the highest part of the waveform. Leave the trigger level in that untriggered state.

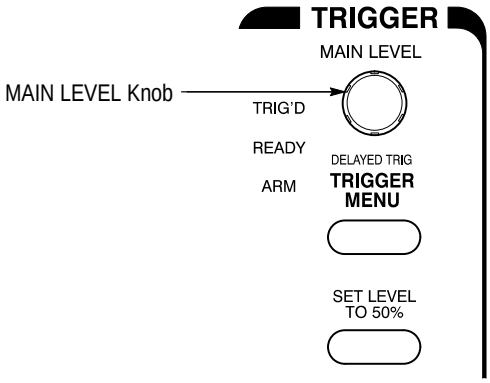


Figure 2–7: TRIGGER Controls

2. Press **AUTOSET** (see Figure 2–8) and observe the stable waveform display.

NOTE*. The oscilloscope triggers on the input signal. Sometimes the oscilloscope triggers on high frequency signal components that are not visible using the current setup. You may see these signal components at higher HORIZONTAL SCALE settings. You can eliminate these signal components using shorter probe ground and signal leads or by using bandwidth limiting.*

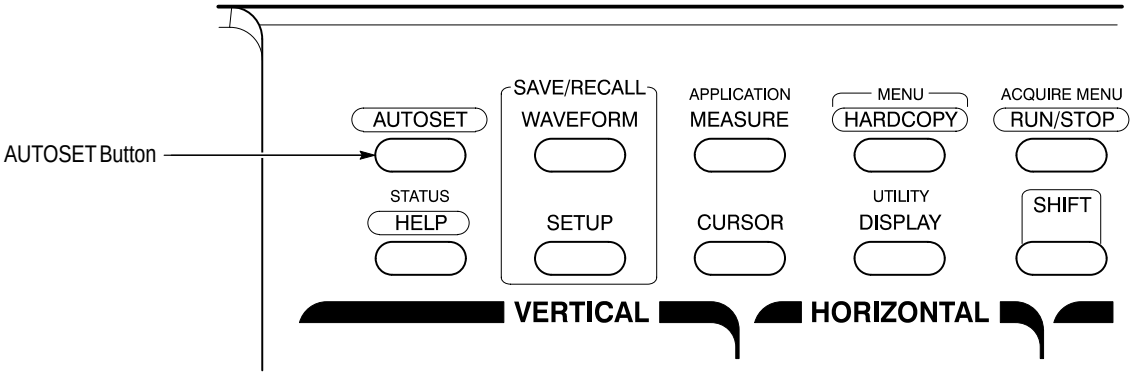


Figure 2–8: AUTOSET Button Location

Figure 2–9 shows the display after pressing AUTOSET. If necessary, you can adjust the waveform now by using the knobs discussed earlier in this example.

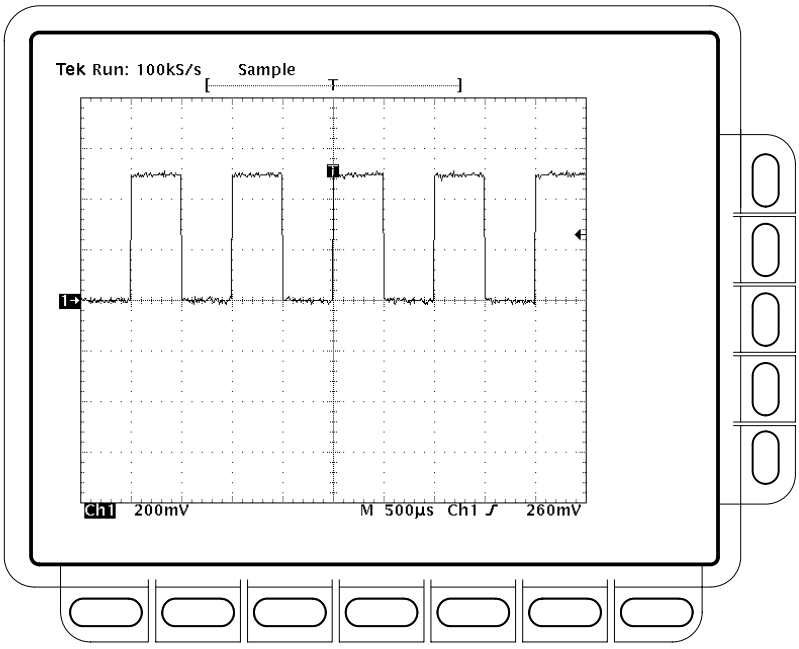


Figure 2–9: The Display After Pressing Autoset

***NOTE**. If you are using a passive probe, such as the P6139A probe, the corners on your displayed signal may look rounded or pointed. (See Figure 2–10.) If so, then you may need to compensate your probe. See* To Compensate Passive Probes *on page 3–6.*

Figure 2–10: Display Signals Requiring Probe Compensation

Example 2: Displaying Multiple Waveforms

The TDS Oscilloscope can display up to four channels, three math waveforms, and four reference waveforms at one time. Do the following tasks to learn how to display and control more than one waveform at a time.

Add a Waveform

The VERTICAL section of the front panel contains the channel selection buttons. These buttons are CH 1, CH 2, CH 3, CH 4, and MORE. (See Figure 2–11.) (CH 3 and CH 4 will be replaced by AUX1 and AUX2 on some models; see *Default Model* on page xii and *Differences by Model* on page 1–3.)

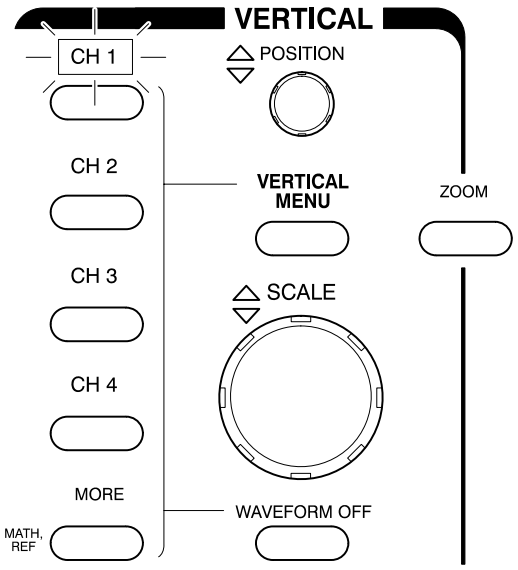


Figure 2–11: The Channel Buttons and Lights

Each of the channel (CH) buttons has a light behind its label. Right now, the CH 1 light is on. That light indicates that the vertical controls are set to adjust channel 1. Do the following steps to add a waveform to the display:

1. If you are not continuing from the previous example, follow the instructions on page 2–9 under the heading *Setting Up for the Examples*.
2. Press **SETUP → Recall Factory Setup** (main) **→ OK Confirm Factory Init** (side).
3. Press **AUTOSET**.
4. Press **CH 2**.

   The display shows a second waveform, which represents the signal on channel 2. Since there is nothing connected to the CH 2 input connector, this waveform is a flat line. There are several other important things to observe:

   - The channel readout on the display now shows the settings for both Ch1 and Ch2.

- There are two channel indicators at the left edge of the graticule. Right now, they overlap.
- The light above the CH 2 button is now on, and the CH 1 light is off. Because the knobs control only one channel at a time, the vertical controls are now set to adjust channel 2.
- The trigger readout still indicates that the trigger is detecting trigger events on channel one. The trigger source is not changed simply by adding a channel. (You can change the trigger source by using the TRIGGER MENU button to display the trigger menu.)

5. Turn the vertical **POSITION** knob clockwise to move the channel 2 waveform up on the graticule. You will notice that the channel reference indicator for channel 2 moves with the waveform.

6. Press **VERTICAL MENU → Coupling** (main).

   The VERTICAL MENU button displays a menu that gives you control over many vertical channel parameters. (See Figure 2–12.) Although there can be more than one channel displayed, the vertical menu and buttons only adjust the selected channel.

   Each menu item in the Vertical menu displays a side menu. Right now, the Coupling item in the main menu is highlighted, which means that the side menu shows the coupling choices. At the top of the side menu, the menu title shows the channel affected by the menu choices. That channel always matches the lighted channel button.

7. Press **GND** (side) to toggle the selection to ground (**GND**). That changes the input coupling of channel 2 from DC to GND. The channel readout for channel 2 (near the bottom of the graticule) now shows a ground indicator.

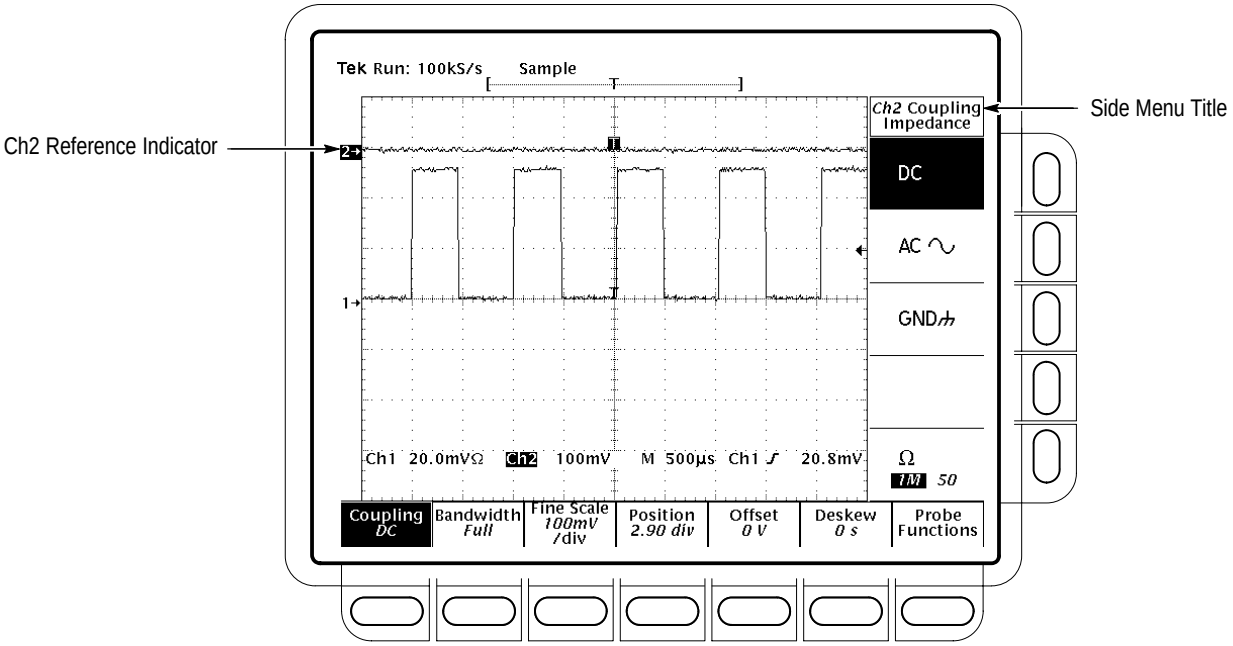


Figure 2–12: The Vertical Main Menu and Coupling Side Menu

Assign Controls to Another Channel

Pressing a channel (CH) button sets the vertical controls to that channel. It also adds the channel to the display if that waveform is not already displayed. To explore assigning controls to different channels, do the following steps:

1. Press **CH 1**.

   Observe that now the side menu title shows Ch1 (see Figure 2–13) and that the light above CH 1 is lighted. The highlighted menu item in the side menu has changed from the GND channel 2 setting to the DC coupling setting of channel 1.

2. Press **CH 2 → DC** (side) to toggle the selection to **DC**. That returns the input coupling of channel 2 to its initial state.

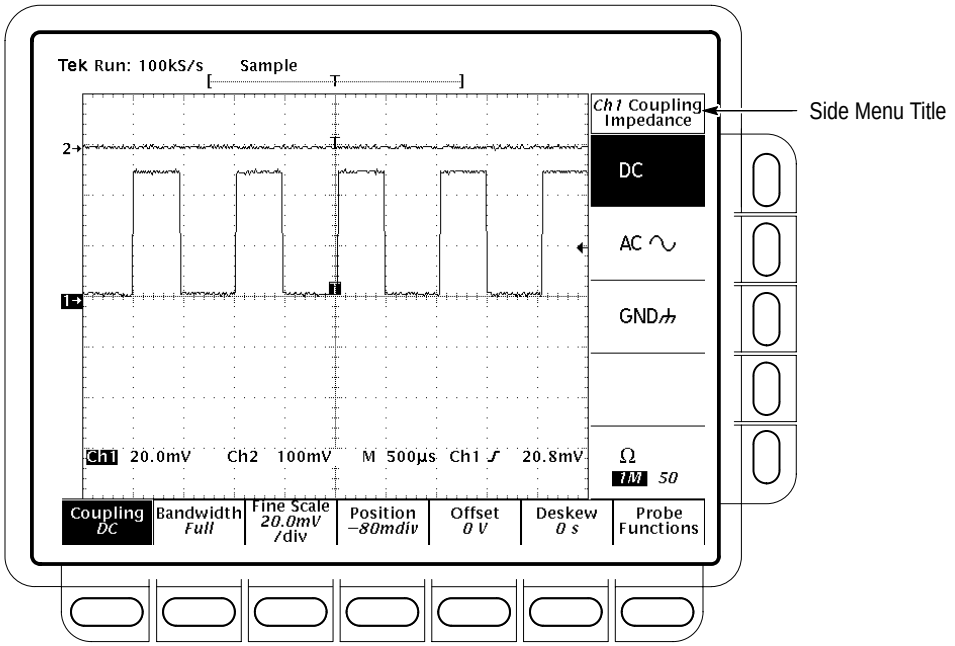


Figure 2–13: The Menus After Changing Channels

Remove a Waveform

Pressing the WAVEFORM OFF button removes the waveform for the currently selected channel. If the waveform you want to remove is not already selected, select that channel using the channel (CH) button.

1. Press **WAVEFORM OFF** (under the vertical **SCALE** knob).

   Since the CH 2 light was on when you pressed the WAVEFORM OFF button, the channel 2 waveform was removed.

   The channel (CH) lights now indicate channel 1. Channel 1 has become the selected channel. When you remove the last waveform, all the CH lights are turned off.

2. Press **WAVEFORM OFF** again to remove the channel 1 waveform.

Example 3: Taking Automated Measurements

The TDS Oscilloscope can measure many waveform parameters automatically and read out the results on screen. Do the following tasks to discover how to set up the oscilloscope to measure waveforms automatically. (For information on additional measurement features, see *Display Measurement Statistics* on page 3–137, *Displaying Histograms* on page 3–145, and *Mask Testing* on page 3–148.)

Display Measurements Automatically

To use the automated measurement system, you must have a stable display of your signal. Also, the waveform must have all the segments necessary for the measurement you want. For example, a rise time measurement requires at least one rising edge, and a frequency measurement needs at least one complete cycle. To take automated measurements, do the following steps:

1. If you are not continuing from the previous example, follow the instructions on page 2–9 under the heading *Setting Up for the Examples*.
2. Press **SETUP → Recall Factory Setup** (main) **→ OK Confirm Factory Init** (side).
3. Press **AUTOSET**.
4. Press **MEASURE** to display the Measure main menu. (See Figure 2–14.)
5. If it is not already selected, press **Select Measrmnt** (main). The readout for that menu item indicates which channel the measurement will be taken from. All automated measurements are made on the selected channel.

   The Select Measurement side menu lists some of the measurements that can be taken on waveforms. There are many different measurements available; up to four can be taken and displayed at any one time. Pressing the button next to the **–more–** menu item brings up the other measurement selections.

6. Press **Frequency** (side). If the **Frequency** menu item is not visible, press **–more–** (side) repeatedly until the **Frequency** item appears. Then press **Frequency** (side).

Observe that the frequency measurement appears within the right side of the graticule area. The measurement readout includes the notation **Ch1**, meaning that the measurement is taken on the channel 1 waveform. (To take a measurement on another channel, select that channel, and then select the measurement.)

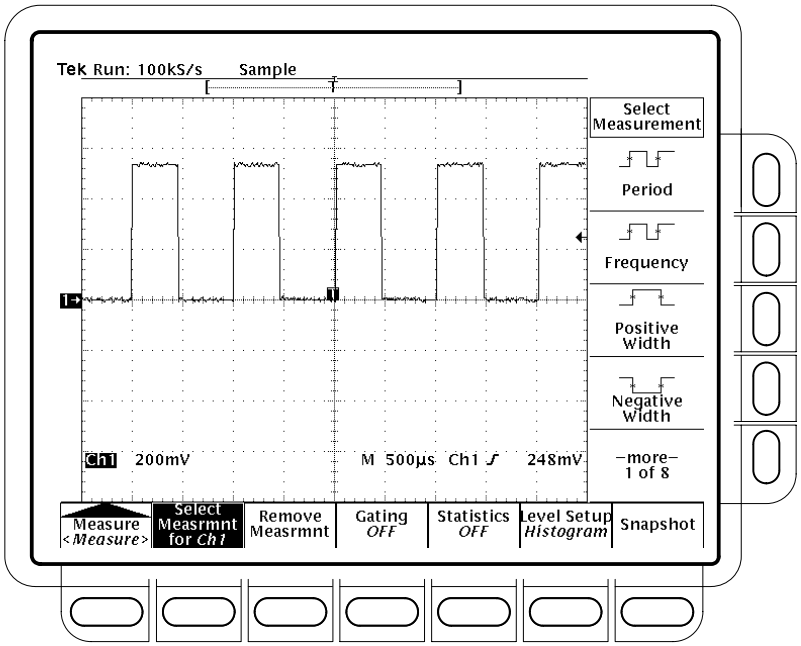
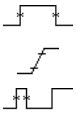


Figure 2–14: Measure Main Menu and Select Measurement Side Menu



7. Press **Positive Width** (side) → **–more–** (side) → **Rise Time** (side) → **Positive Duty Cycle** (side).

   All four measurements are displayed. Right now, they cover a part of the graticule area, including the displayed waveforms.

8. To move the measurement readouts outside the graticule area, press **CLEAR MENU**. (See Figure 2–15.)

Remove Measurement Readouts

Use the Measure menu to remove measurements you no longer want. To remove a measurement individually (you can also remove them, as a group), do the following step:

1. TDS 600B models: Press **MEASURE → Remove Measrmnt** (main) → **Measurement 1**, **Measurement 2**, and **Measurement 4** (side) to remove those measurements. Leave the rise time measurement displayed.
2. TDS 500D and TDS 700D models: Press **MEASURE → Measure** (pop-up) → **Remove Measrmnt** (main) → **Measurement 1**, **Measurement 2**, and **Measurement 4** (side) to remove those measurements. Leave the rise time measurement displayed.

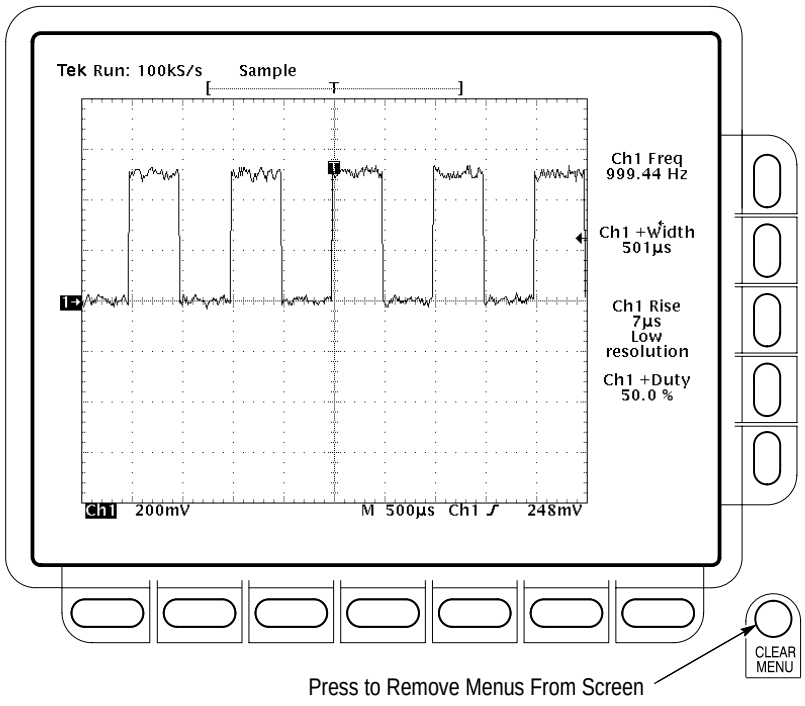


Figure 2–15: Four Simultaneous Measurement Readouts

Change the Measurement Reference Levels

By default, the measurement system will use the 10% and 90% levels of the waveform for taking the rise time measurement. You can change these values to other percentages or change them to absolute voltage levels.

To examine the current values, press **Level Setup** (main) → **High Ref** (side).

The General Purpose Knob. The general purpose knob, the large knob, is now set to adjust the high reference level (Figure 2–16.)

There are several important things to observe on the screen:

- The knob icon appears at the top of the screen. The knob icon indicates that the general purpose knob has just been set to adjust a parameter.
- The upper right corner of the screen shows the readout High Ref: 90%.
- The High Ref side menu item is highlighted, and a box appears around the 90% readout in the High Ref menu item. The box indicates that the general purpose knob is currently set to adjust that parameter.

Turn the general purpose knob left and right, and then use it to adjust the high level to 80%. That sets the high measurement reference to 80%.

Hint: To make large changes quickly with the general purpose knob, press the **SHIFT** button before turning the knob. When the light above the **SHIFT** button is on and the display says ***Coarse Knobs*** in the upper-right corner, the general purpose knob speeds up significantly.

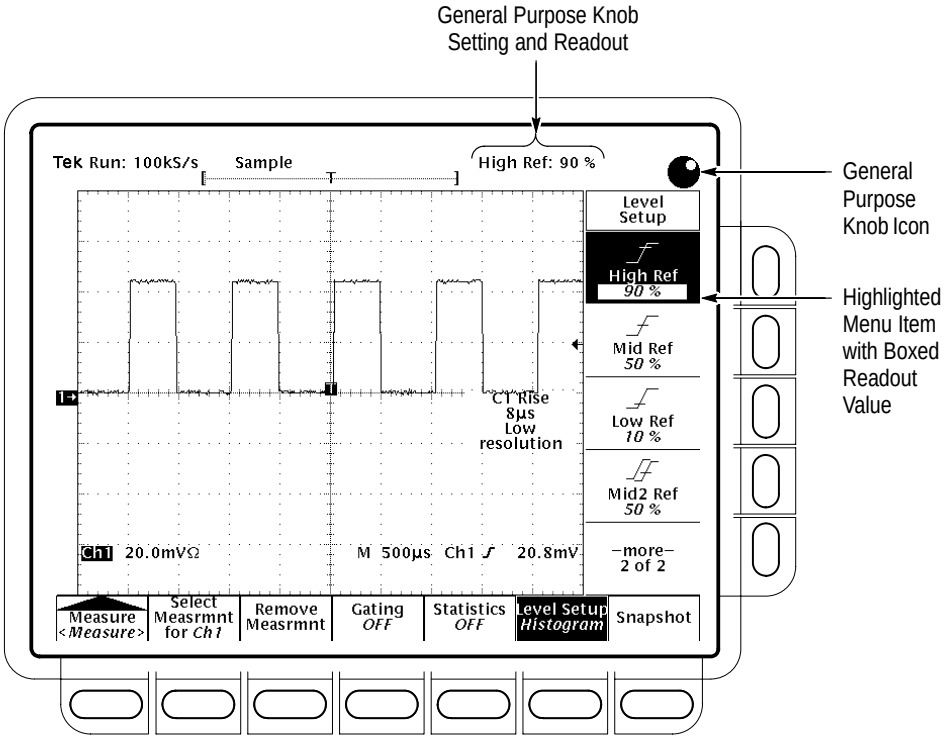


Figure 2–16: General Purpose Knob Indicators

The Numeric Keypad. Any time the general purpose knob is set to adjust a numeric parameter, you can enter the value as a number using the keypad instead of using the knob. Always end the entry of a number by pressing ENTER (↵).

The numeric keypad also provides multipliers for engineering exponents, such as m for milli, M for mega, and µ for micro. To enter these multiplier values, press the SHIFT button, and then press the multiplier.

1. Press **Low Ref** (side).
2. On the numeric keypad, press the **2**, the **0**, and the **ENTER** (↵) buttons, which sets the low measurement reference to 20%. Observe that the rise-time value has changed.
3. Press **Remove Measrmnt** (main) → **All Measurements** (side). That returns the display to its original state.

Displaying a Snapshot of Automated Measurements

You have seen how to display up to four individual automated measurements on screen. You can also pop up a display of almost all of the automated measurements available in the Select Measrmnts side menus. This snapshot of measurements is taken on the waveform currently selected using the channel selection buttons.

As when displaying individual measurements, you must have a stable display of your signal, and that signal must have all the segments necessary for the measurement you want.

1. Press **Snapshot** (main) to pop up a snapshot of all available single waveform measurements. (See Figure 2–17.)

   The snapshot display includes the label Ch 1, meaning that the measurements displayed are taken on the channel 1 waveform. You take a snapshot of a waveform in another channel by first selecting that channel using the channel selection buttons.

   The snapshot measurements do not continuously update. Snapshot executes a one-time capture of all measurements and does not update those measurements unless it is performed again.

2. Press **Again** (side) to do another snapshot and update the snapshot measurements.
3. Press **Remove Measrmnt** (main) to remove the snapshot display. (You can also press **CLEAR MENU**, but a new snapshot will be executed the next time you display the Measure menu.)

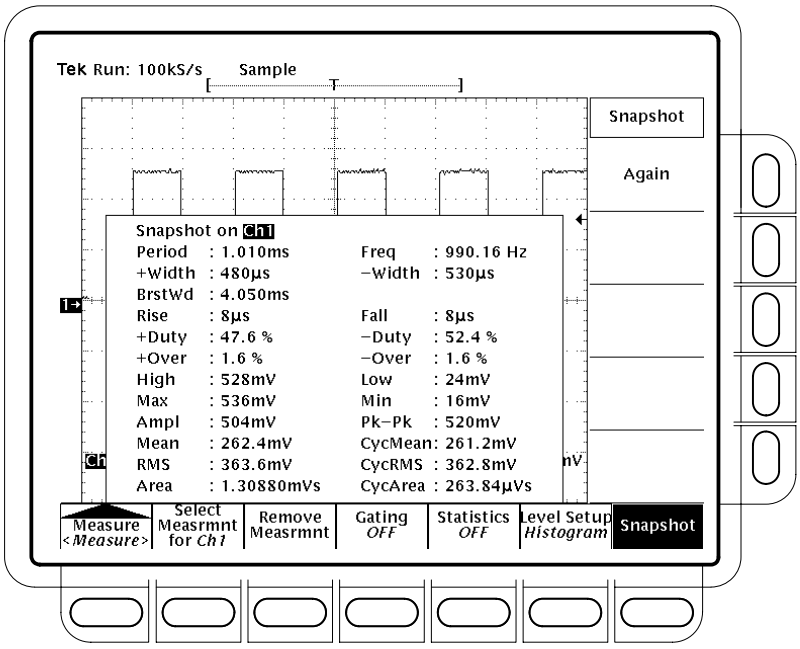


Figure 2–17: Snapshot of Channel 1

Example 4: Saving Setups

The TDS Oscilloscope can save its controls settings and recall them later to quickly re-establish a setup. It provides ten storage locations to store up to ten setups. It also provides a file system, so that you can also save setups to a floppy disk, an optional hard disk, or an external Zip drive. Do the following procedures to learn how to save, and then recall, a setup.

***NOTE**. Besides being able to save several complete setups, the oscilloscope remembers all the parameter settings when you power it off. That feature lets you power on and continue where you left off without having to reconstruct the setup in effect when you powered off the oscilloscope.*

Save a Setup

First, you need to create an instrument setup you want to save. Perform the following steps to create and save a setup that is complex enough that you might prefer not to go through all these steps each time you want that display:

1. If you are not continuing from the previous example, follow the instructions on page 2–9 under the heading *Setting Up for the Examples*.
2. Press **SETUP → Recall Factory Setup** (main) **→ OK Confirm Factory Init** (side).
3. Press **AUTOSET**.

4. Press **MEASURE → Select Measrmnt** (main) **→ Frequency** (side). (Press the **–more–** side menu item if the **Frequency** selection does not appear in the side menu.)
5. Press **CH 2 → CLEAR MENU**.
6. Press **SAVE/RECALL SETUP → Save Current Setup** (main) to display the Setup main menu. (See Figure 2–18.)

CAUTION. *Setup locations in the side menu appear with the label* user *if they contain a stored setup or with the label* factory *if they do not. To avoid overwriting (and losing forever) a saved setup, choose a setup location labeled* factory. *(Setup locations labeled* factory *have the factory setup stored as a default and can be used to store current setups without disturbing previously stored setups.)*

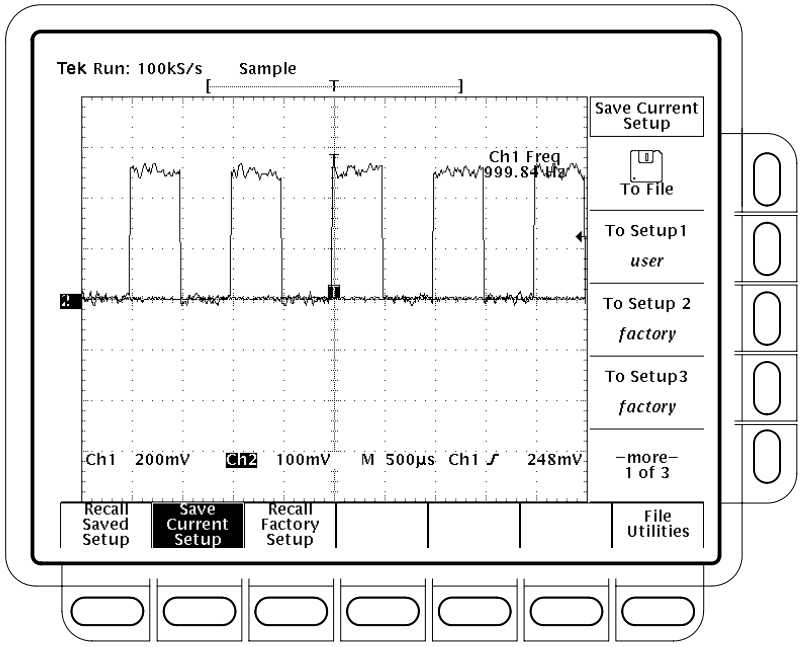


Figure 2–18: Save/Recall Setup Menu

7. Press one of the **To Setup** side menu buttons to store the current instrument settings into that setup location. Remember which setup location you selected for use later.

There are more setup locations than can be listed at one time in the side menu. The –more– side menu item gives you access to all the setup locations.

Once you have saved a particular setup, you can change the settings as you wish, knowing that you can come back to that setup at any time.

8. TDS 600B models: Press **MEASURE → Positive Width** (side) to add that measurement to the display.

9. TDS 500D and TDS 700D models: Press **MEASURE → Measure** (pop-up) **→ Positive Width** (side) to add that measurement to the display.

Recall a Setup

To recall the setup, press **SAVE/RECALL SETUP → Recall Saved Set-up** (main) → **Recall Setup** (side) for the setup location you used in the last exercise. The positive width measurement is now removed from the display because you selected it after you saved the setup.

The step just performed completes the examples. You can restore the default settings by pressing **SETUP → Recall Factory Setup** (main) → **OK Confirm Factory Init** (side).

Overview

This chapter describes in detail how to perform the operating tasks you must do to measure, test, process, or save and document your waveforms. It leads with three sections on the fundamental tasks of acquiring, stably displaying, and taking measurements on waveforms:

- *Acquiring and Displaying Waveforms*
- *Triggering on Waveforms*
- *Measuring Waveforms*

Once you have acquired and measured waveforms, you may want to save and restore them or the control setups used to acquire and measure them. Or you may want to save the display screen, complete with waveform and setup information, to include them with the documents you produce with your desk top publishing system. You may even want to digitally process them (add, multiply, or divide them; integrate, differentiate or take an FFT of them). The following two topics cover these tasks:

- *Saving Waveforms and Setups*
- *Using Features for Advanced Applications*

When performing any operation task, you might want to display a comprehensive listing of its current control settings on screen. Or you may find it handy to display operating information about front panel controls and menus instead of looking them up in this manual. The following topic tells you how to do both:

- *Determining Status and Accessing Help*

The topics just listed contain steps that you perform to accomplish the task that the topic defines. You should read *Conventions* on page xii of *Preface* before reading about these tasks.

Each topic just listed comprises more basic operation tasks and topics. A list of these tasks follows.

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Acquiring and Displaying Waveforms

To use the TDS Oscilloscope to measure or monitor waveforms, you need to know how to acquire, select, and display those waveforms properly. To help you do so, this section describes how to do the following tasks:

- How to couple waveforms to the oscilloscope channels
- How to select channels to turn on and off their display
- How to size and position the selected channel on screen
- How to use the menus to set vertical (coupling, offset, and bandwidth) and horizontal (time base, record length, and so on) parameters

This section also describes how to choose the appropriate acquisition mode for acquiring your waveform, how to customize the display (including selecting the color of the display elements), and how to use the *Zoom*, *FastFrame*, and DPO features.

Coupling Waveforms to the Oscilloscope

Tektronix produces a variety of probes and cables suitable for connecting various types of signals to the input channels of this product. This subsection covers two topics important to coupling: *Probe Compensation* and *Input Impedance Considerations*.

If your model oscilloscope ships with a probe, use it for general-purpose coupling of waveforms to the oscilloscope. For a list of other probes available for use, see *Accessory Probes* on page A–5.

The TDS 580D, TDS 680B, TDS 684B, TDS 784D, and TDS 794D oscilloscopes ship without probes. Tektronix recommends you order and use the P6245, P6217, or P6158 probes. These probes take advantage of the higher bandwidth of these models.

The remaining TDS 500D, TDS 600B, and TDS 700D oscilloscopes ship with general-purpose probes — either the P6139A or P6243, depending on the oscilloscope model. The standard-accessory probes and quantities shipped for these oscilloscopes are listed in *Standard Accessories* on page A–4.

Tektronix also offers a variety of optical probes, differential probes, adapters, and BNC cabling and connectors to couple a variety of signal sources to the input channels. See *Options and Accessories* on page A–1 or your Tektronix Sales representative for the specific items offered for signal coupling.

NOTE. *A buffered passive probe, such as the P6339A, does not require compensation.*

To Compensate Passive Probes

When using a *passive* probe with any product, compensate it to ensure maximum distortion-free input to the oscilloscope and to avoid high frequency amplitude errors (see Figure 3–1). To compensate your probe, do the following steps:

1. Connect the probe to the probe compensation signal on the front panel. Connect the probe ground lead to the ground terminal on the front panel.
2. Press **AUTOSET**.
3. Press **VERTICAL MENU → Bandwidth** (main) **→ 20 MHz** (side).

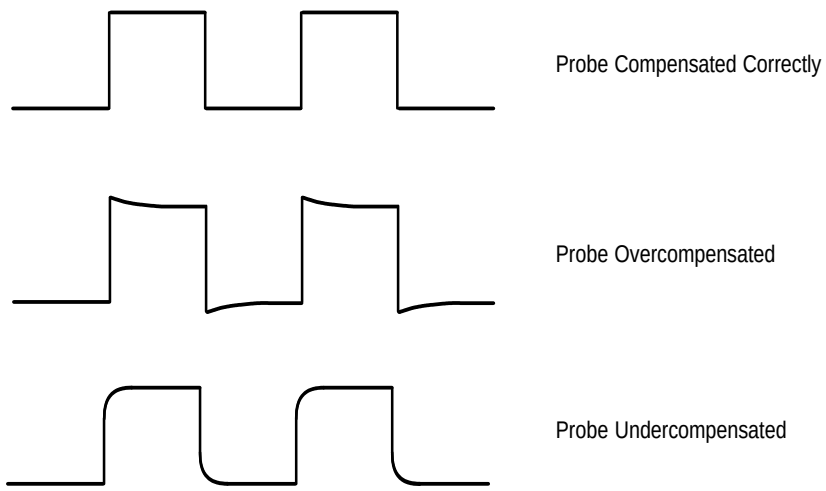


Figure 3–1: How Probe Compensation Affects Signals

4. If you need to change the input impedance, press **Coupling** (main). Then toggle the side menu selection Ω to get the correct impedance.
5. TDS 500D and 700D models only: Press **SHIFT ACQUIRE MENU** → **Mode** (main) → **Hi Res** (side).
6. TDS 600B models only: Press **SHIFT ACQUIRE MENU** → **Mode** (main) → **Average** (side). Use the keypad to set Averages to 5.
7. Adjust the probe until you see a square wave with a perfectly flat top on the display. Figure 3–2 shows where the adjustment is located.

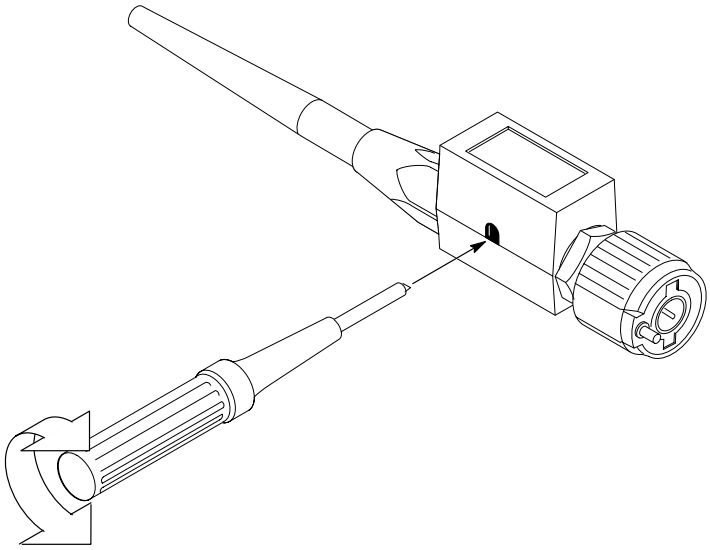


Figure 3–2: P6139A Probe Adjustment

NOTE. *The TDS 794D Oscilloscope requires a P6339A probe for AC, 10 MΩ, and bandwidth selections to appear in the menus.*

Input Impedance Considerations

To ensure proper coupling of your input signals to the oscilloscope, consider the following points when you use 50 Ω coupling with any channel:

- The oscilloscope does not accurately display frequencies under 200 kHz *if* AC coupling is selected.
- The oscilloscope reduces the maximum volts/division setting for the channel to 1 V from 10 V (to 10 V from 100 V with a X10 probe attached), since input amplitudes appropriate for the higher settings would overload the 50 Ω input.
- The oscilloscope switches to 50 Ω and disables AC coupling (and switches coupling to DC if AC is selected) if you connect an active probe, such as the P6245 probe. Such probes also reduce the maximum volts/div to 10 V as just described. This behavior results in 50 Ω, nonAC coupling, which is appropriate for active probes (probes with a level 2 or 3 interface do not display Ω in the readout).

NOTE. *If you remove an active probe, the oscilloscope does not switch coupling back to 1 MΩ (nor AC if it was previously selected). Nor does the oscilloscope, when you restore 1 MΩ coupling, return to a volts/division setting that was reduced due to the 50 Ω selection. You must set channel scale, input coupling, and impedance appropriate for your input coupling scheme. Be sure to switch to 1 MΩ for any input signal* not *from a 50 Ω system.*

To Find More Information

To find a procedure for changing the coupling and input impedance settings, see *To Change Vertical Parameters* on page 3–18.

To find a list of available probes, see *Accessory Probes* on page A–6.

To find a guide for selecting probes for a variety of applications, see *Appendix D: Probe Selection* on page D–1.

Setting up Automatically: Autoset and Reset

The TDS Oscilloscope can automatically obtain and display a stable waveform of usable size. It can also be reset to its factory default settings. This subsection describes how to execute Autoset and reset, and lists the default settings in effect after an Autoset.

Autoset automatically sets up the front panel controls based on the characteristics of the input signal. It is much faster and easier than a manual control-by-control setup. Autoset adjusts controls in these categories: *Acquisition, Display, Horizontal, Trigger, and Vertical.*

To Autoset the Oscilloscope

Do the following steps to automatically set up the oscilloscope:

1. Press the channel selection button (such as **CH 1**) corresponding to your input channel to make it active.
2. Press **AUTOSET**.

If you use Autoset when one or more channels are displayed, the oscilloscope selects the lowest numbered channel for horizontal scaling and triggering. Vertically, all channels in use are individually scaled. If you use Autoset when no channels are displayed, the oscilloscope will turn on channel one **(**CH 1) and scale it.

NOTE*. Autoset may change vertical position in order to position the waveform appropriately. It always sets vertical offset to 0 V.*

If a standard mask is active, Autoset adjusts the selected trace to match the mask, if possible. Vertical scale and offset, horizontal scale, trigger position, full bandwidth, average, and trigger parameters are set as required for the standard. If a calibrated optical probe is attached to Ch1 and an OC or FC standard is selected, Ch 1 is selected and other channels are turned off.

List of Autoset Defaults

Table 3–1 lists the autoset defaults.

Table 3–1: Autoset defaults

Control	Changed by autoset to
Selected channel	Numerically lowest of the displayed channels
Acquire Mode	Sample
Acquire Repetitive Signal (TDS 500D and 700D Models Only)	On
Acquire Stop After	RUN/STOP button only
Deskew, Channel/Probe	Unchanged
Display Style	Vectors
Display Intensity — Overall	If less than 50%, set to 75%
Display Format	YT
FastFrame (TDS 500D and 700D Models Only)	Off
Horizontal Position	Centered within the graticule window
Horizontal Scale	As determined by the signal frequency
Horizontal Time Base	Main Only
Horizontal Record Length	Unchanged
Horizontal Lock	Unchanged
Horizontal Fit-to-Screen	Unchanged
DPO Acquisitions (TDS 500D and 700D Models Only)	Unchanged
Limit Test	Off
Trigger Position	Unchanged
Trigger Type	Edge
Trigger Source	Numerically lowest of the displayed channels (the selected channel)

Table 3–1: Autoset defaults (cont.)

Control	Changed by autoset to
Trigger Level	Midpoint of data for the trigger source
Trigger Slope	Positive
Trigger Coupling	DC
Trigger Holdoff	Default Holdoff: Set equal to 5 horizontal divisions Adjustable Holdoff: 250 ns Selection in Mode and Holdoff menu determines whether the default holdoff value or the adjustable hold value is used.
Vertical Scale	As determined by the signal level
Vertical Coupling	DC unless AC was previously set. AC remains unchanged.
Vertical Bandwidth	Full
Vertical Offset	0 volts
Zoom	Off

To Reset the Oscilloscope

Do the following steps to reset the oscilloscope to its factory default settings:

1. Press the Save/Recall **SETUP** button to display the Setup menu (see Figure 3–3). Press the button directly below the **Recall Factory Setup** menu item.
2. Press the button to the right of the **OK Confirm Factory Init** side menu item.
3. Press the **SET LEVEL TO 50%** button (front panel) to be sure the oscilloscope triggers on the input signal.

Selecting Channels

The TDS Oscilloscope applies all actions based on a *specific* waveform, such as taking measurements or applying any changes it receives to the vertical control settings, to the *selected* waveform. You can select a *channel waveform*, a *math waveform*, or a *reference waveform.* This subsection describes how to select a waveform and how you can turn the display of a waveform off.

To Identify the Selected Channel

To determine which channel is currently selected, check the *channel readout*. It shows the selected channel in inverse video in the lower left corner of the display. The *channel reference indicator* for the selected channel also appears in reverse video along the left side of the display. (See Figure 3–3.)

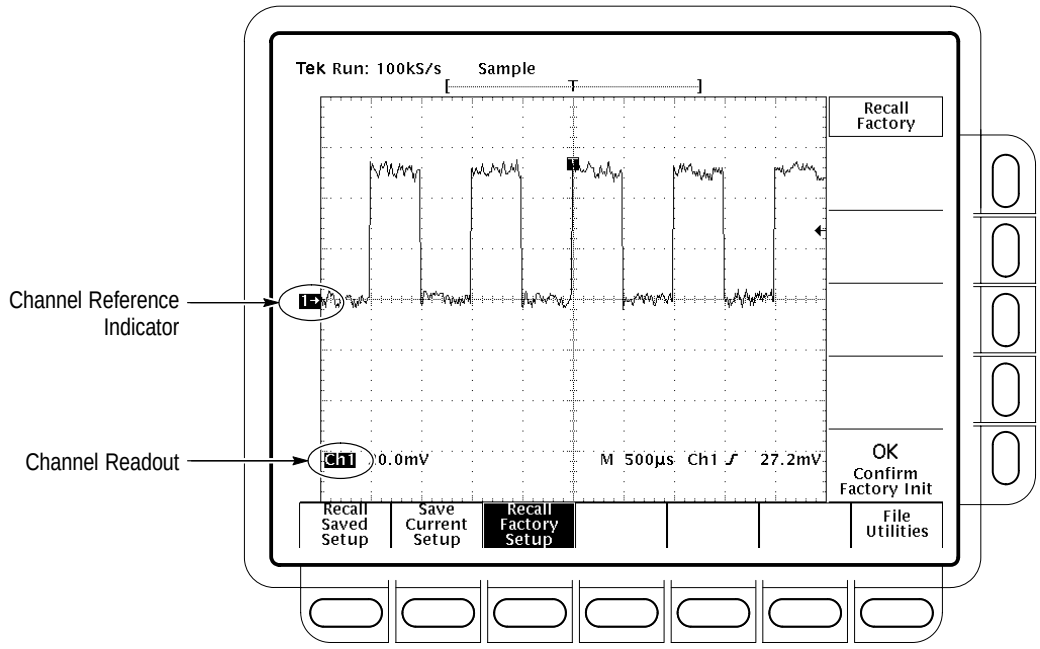


Figure 3–3: The Channel Readout

To Select and Remove Waveforms

To select a channel, use the *channel selection* buttons on the right of the display. These buttons labeled **CH 1**, **CH 2**, **CH 3**, **CH 4**, and **MORE** select a channel and display it if its off. (The **MORE** button allows you to select internally stored *Math* and *Ref* waveforms for display and manipulation.) The selected channel is indicated by the lighting the LED above the button of the selected channel.

Do the following steps to first display and then remove waveforms from the display:

1. Press **CH 1, CH 2, CH 3**, or **CH 4** to turn on as many of these channels as desired. The one you select last (or first if you only select one) becomes the selected channel. Selecting a channel turns it on if it is not already on.

   You do not use the channel selection buttons to select the trigger source. Instead you select the trigger source in the Main Trigger menu or Delayed Trigger menu.

2. Press **WAVEFORM OFF** to turn OFF the display of the selected channel waveform. It will also remove from the display any automated measurements being made on that waveform.

3. To select a math waveform you have created or a reference waveform you have stored, press **MORE** and select the waveform from the More menu. Press **WAVEFORM OFF** while the MORE button is lit to remove the display of the waveform selected in the More menu.

Waveform Priority

When you turn off a waveform, the oscilloscope automatically selects the next highest priority waveform. Figure 3–4 shows the order of priority.

1. CH1	1. MATH1
2. CH2	2. MATH2
3. CH3 or AX1	3. MATH3
4. CH4 or AX2	4. REF1
	5. REF2
	6. REF3
	7. REF4

Figure 3–4: Waveform Selection Priority

Note Figure 3–4 shows two orders of priority due to the following rules: If you are turning off more than one waveform and you start by turning off a channel waveform, all channels will be turned off before going to the MORE waveforms. If you start by turning off the MORE waveforms, all the MORE waveforms will be turned off before going to the channel waveforms.

If you turn off a channel that is a trigger source, it continues to be the trigger source even though the waveform is not displayed.

To Find More Information

To read about selecting reference waveforms, see *Saving and Recalling Waveforms* on page 3–168.

To read about selecting (and creating) math waveforms, see *Waveform Math* on page 3–206.

Scaling and Positioning Waveforms

The TDS Oscilloscope allows you to scale (change the vertical or horizontal size) and position (move up, down, left, or right) waveforms on screen for best display. (Figure 3–5 shows the results of both vertical and horizontal scaling and positioning.) This section first tells you how to quickly check and set vertical and horizontal scales, positions, and other parameters, such as vertical bandwidth and horizontal record length.

To Check Position

To quickly see the position of the waveform in the display, check the *Channel Reference*, *Record View*, and *Acquisition View* icons. (See figures 3–5, 3–9, and 3–10.)

The Channel Reference icon, at the left side of the display, points to ground on the waveform record when offset is set to 0 V. The oscilloscope contracts or expands the selected waveform around this point when you change the vertical scale.

The Record View, at the top of the display, indicates where the trigger occurs and what part of the waveform record is displayed. In extended acquisition mode, if the trigger is shown at 0% or 100% of the record view, see the acquisition view for the actual trigger location.

In extended acquisition mode (option 2M only), when a live channel is displayed, the acquisition view at the top of the display indicates where the trigger and waveform record occur in the extended acquisition.

To Check the Vertical Scale

Check the *Vertical Readout* at the bottom-left part of the display to read the volts/division setting for each displayed channel (the selected channel is in inverse video). (See Figure 3–6.)

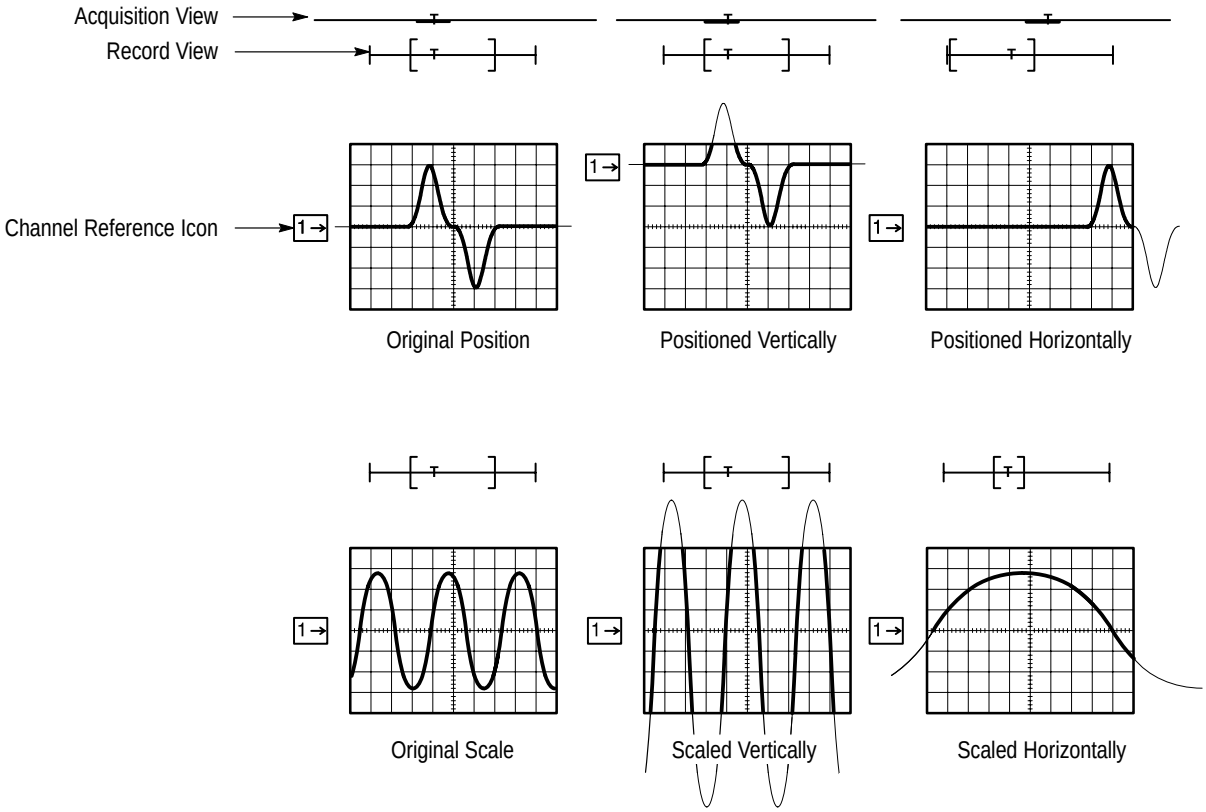


Figure 3–5: Scaling and Positioning

To Change Vertical Scale and Position

The TDS Oscilloscope permits you to change vertical scale and position quickly from the front panel using dedicated control knobs. To change the vertical scale and position:

1. Turn the vertical **SCALE** knob. Note only the scale of the selected waveform changes.

   As you turn the vertical SCALE knob clockwise, the value decreases resulting in higher resolution because you see a smaller part of the waveform. As you turn it counterclockwise, the scale increases allowing you to see more of the waveform but with lower resolution.

2. Turn the vertical **POSITION** knob. Again, note that only the selected waveform changes position.

3. To make positioning faster, press the **SHIFT** button. When the light above the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the **POSITION** knob positions waveforms more quickly.

   The POSITION knob simply adds screen divisions to the reference point of the selected waveform. Adding divisions moves the waveform up and subtracting them moves the waveform down. You also can adjust the waveform position using the offset option in the Vertical menu (discussed later in this section).

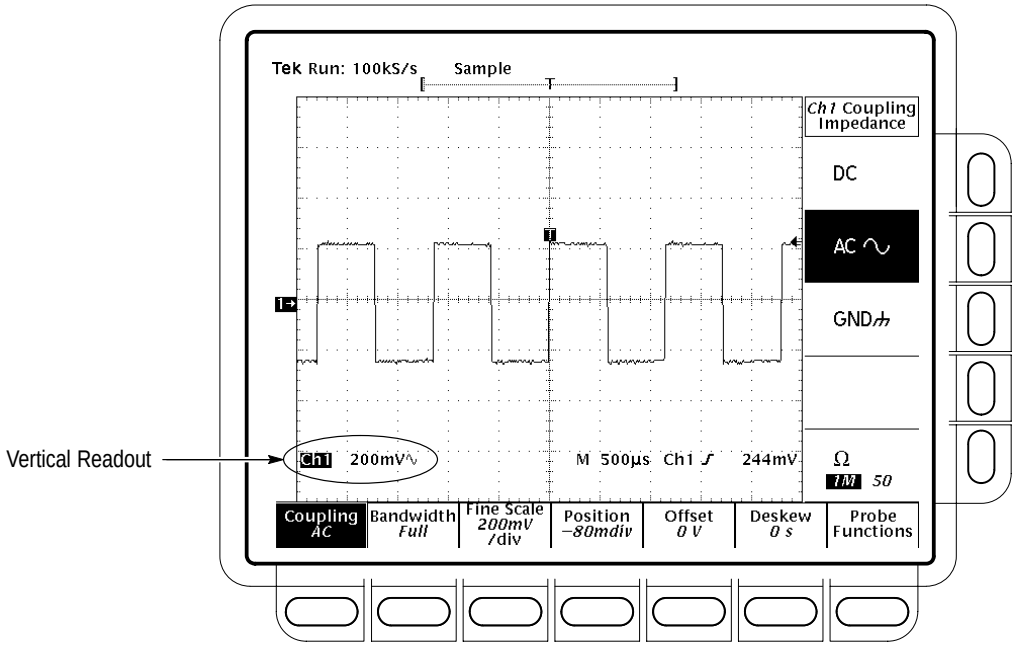


Figure 3–6: Vertical Readouts and Channel Menu

By changing the vertical scale, you can focus on a particular portion of a waveform. By adjusting the vertical position, you can move the waveform up or down on the display. Adjustment of vertical position is particularly useful when you are comparing two or more waveforms.

To Change Vertical Parameters

To select the coupling, bandwidth, and offset for the selected waveform, use the *Vertical menu* (Figure 3–6). This menu also lets you numerically change the position or scale instead of using the vertical knobs. To make such changes, do the following procedures:

NOTE*. The TDS 794D Oscilloscope requires a P6339 probe for AC coupling, 10 MΩ input impedance, and bandwidth selections to appear in the menus.*

Coupling. To choose the type of coupling for attaching the input signal to the vertical attenuator for the selected channel and to set its input impedance:

Press **VERTICAL MENU → Coupling** (main) → **DC**, **AC**, **GND**, or Ω (side).

DC
- **DC** coupling shows both the AC and DC components of an input signal.

AC ∿
- **AC** coupling shows only the alternating components of an input signal.

GND⏚
- Ground (**GND**) coupling disconnects the input signal from the acquisition.

Ω
- Input impedance lets you select either 1 M Ω or 50 Ω impedance.

NOTE*. If you select 50 Ω impedance with AC coupling, the digitizing oscilloscope will not accurately display frequencies under 200 kHz.*

Also, when you connect an active probe to the oscilloscope (such as the P6245), the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a passive probe (like the P6139A), you need to set the input impedance back to 1 MΩ.

The maximum volts/div setting is reduced from 10 V to 1 V when you select 50 Ω impedance. See the discussion Input Impedance Considerations *on page 3–8.*

Bandwidth. *Bandwidth* refers to the range of frequencies that an oscilloscope can acquire and display accurately (that is, with less than 3 dB attenuation). If you limit the upper limit for the higher frequency components by selecting **250 MHz** or **20 MHz**, a $^{B}_{W}$ symbol will appear in the lower part of the display. To change the bandwidth of the selected channel:

Press **VERTICAL MENU → Bandwidth** (main) **→ Full**, **250 MHz**, or **20 MHz** (side).

Fine Scale. To make fine adjustments to the vertical scale, press **VERTICAL MENU → Fine Scale** (main) and use the general purpose knob or the keypad.

Position. To adjust the vertical position to a specific number of divisions, press **VERTICAL MENU → Position** (main) and use the general purpose knob or the keypad to set the offset value. Press **Set to 0 divs** (side) if you want to reset the reference point of the selected waveform to the center of the display.

Offset. Use offset to subtract DC bias before examining a waveform. For example, you might want to display a small ripple (for example, 100 mV of ripple) on a power supply output (for example, a +5 V output). Adjust offset to keep the ripple on screen while setting the vertical scale sensitive enough to best display the ripple.

To adjust offset, press **VERTICAL MENU → Offset** (main). Then use the general purpose knob or keypad to set the vertical offset. Press **Set to 0 V** (side) if you want to reset the offset to zero.

To Set External Attenuation (TDS 500D and TDS 700D Only)

You can set an external attenuation (or gain) in addition to the attenuation specified by the probe.

To set external attenuation, press **VERTICAL MENU → Probe Functions** (main) **→ External Attenuation** or **External Attenuation in dB** (side).

External Attenuation — Use the general purpose knob or the keypad to set the external attenuation as a multiplier.

External Attenuation in dB — Use the general purpose knob or the keypad to set the external attenuation in dB.

To set the probe attenuation to its default value, press **VERTICAL MENU → Probe Functions** (main) **→ Set to Unity External Attenuation** (side). Attaching a probe also sets the probe attenuation to its default value.

To Check the Horizontal Status

Check the *Record View* to determine the size and location of the waveform record and the location of the trigger relative to the display. (See Figure 3–7.)

Check the *Time Base readout* at the lower right of the display to see the time/division settings and the time base (main or delayed) being referred to. (See Figure 3–7. Also see Figure 3–5 on page 3–16.) Since all live waveforms use the same time base, the oscilloscope only displays one time base and time/division setting for all the active channels.

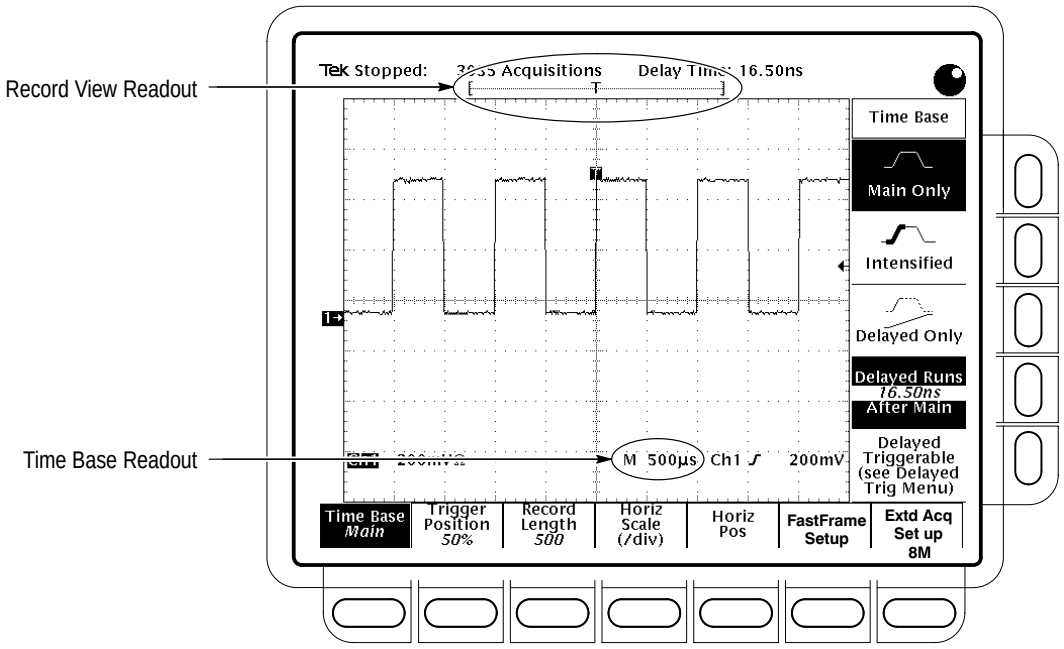


Figure 3–7: Record View and Time Base Readouts

To Change Horizontal Scale and Position

The TDS Oscilloscope provides control of horizontal position and scale using the horizontal front panel knobs.

By changing the horizontal position, you can move the waveform right or left to see different portions of the waveform. That is particularly useful when you are using larger record sizes and cannot view the entire waveform on one screen.

To change the horizontal scale and position:

1. Turn the horizontal **POSITION** and horizontal **SCALE** knobs. (See Figure 3–8.)
2. If you want the **POSITION** knob to move faster, press the **SHIFT** button. When the light above the shift button is on and the display says **Coarse Knobs** in the upper right corner, the **POSITION** knob positions waveforms more quickly.

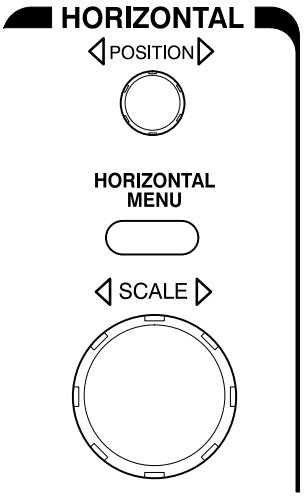


Figure 3–8: Horizontal Controls

When you select a channel, the horizontal **SCALE** knob scales all channel waveforms displayed at the same time. If you select a math or reference waveform, the knob scales only the selected waveform.

When you select a channel, the horizontal **POSITION** knob positions all channel, reference, and math waveforms displayed at the same time *when* Horizontal Lock is set to Lock in the Zoom menu. See *Zoom a Waveform* on page 3–54.

To Change Horizontal Parameters

To select the waveform record length and the trigger position, use the *Horizontal menu*. You can also use this menu to change the horizontal position or scale instead of using the horizontal knobs. You can select the delayed time base (see *Delayed Triggering* on page 3–117) or choose the *frames* on the waveform that you want to see (see *Using FastFrame* on page 3–67*)*.

Trigger Position. The trigger point marks time zero in a waveform or acquisition (in Extended Acquisition mode) record. All record points before the trigger event make up the pretrigger portion of the record. Every record point after the trigger event is part of the posttrigger portion. All timing measurements in the record are made relative to the trigger event. To define the trigger point position:

Press **HORIZONTAL MENU → Trigger Position** (main) **→ Set to 10%**, **Set to 50%**, or **Set to 90%** (side), or use the general purpose knob or the keypad to change the value.

Record Length. The number of points that make up the waveform record is defined by the record length. To set the waveform record length:

1. Press **HORIZONTAL MENU → Record Length** (main). Select the record length desired from the side menu. Press **–more–** to see additional choices:

   TDS 600B Oscilloscopes have standard record lengths up to 15,000 points. TDS 500D Oscilloscopes have standard record lengths up to 50,000 points. TDS 700D Oscilloscopes have standard record lengths up to 500,000 points. With Option 1M and Option 2M, TDS 500D and TDS 700D Oscilloscopes have record and acquisition lengths of up to 8,000,000 points depending on the model and option (see Table A–1 starting on page A–1 for more information). Option 2M is available only at the time of original purchase. Neither option is available for the TDS 600B models.

NOTE. *TDS 500D and TDS 700D Models: Hi Res acquisition mode requires twice the acquisition memory of other acquisition modes. Therefore, turning Hi Res on switches the setting for record length accordingly, thereby keeping the oscilloscope from running out of memory.*

2. To fit an acquired waveform (or with Extended Acquisition On, an acquisition) to the visible screen, regardless of record length, press **HORIZONTAL MENU → Record Length** (main). Then toggle **Fit to Screen** to **ON** from the side menu. This feature fits the waveform automatically much like you could do manually — by turning zoom mode on and changing the time/division until the waveform fits the screen. To turn off this feature, toggle **Fit to Screen** to **OFF**.

Horizontal Scale. To change the horizontal scale (time per division) numerically in the menu instead of using the Horizontal **SCALE** knob:

Press **HORIZONTAL MENU → Horiz Scale** (main) **→ Main Scale** or **Delayed Scale** (side), and use the keypad or the general purpose knob to change the scale values.

Horizontal Position. To set the horizontal position to specific values in the menu instead of using the Horizontal **POSITION** knob:

Press **HORIZONTAL MENU → Horiz Pos** (main) **→ Set to 10%**, **Set to 50%,** or **Set to 90%** (side) to choose how much of the waveform will be displayed to the left of the display center.

You can also control whether changing the horizontal position setting affects all displayed waveforms, just the live waveforms, or only the selected waveform. See *Zoom a Waveform*, on page 3–54 for the steps to set the horizontal lock feature.

To Select the Delayed Time Base

You also can select Delayed Runs After Main or Delayed Triggerable. Use the main time base for most applications. Use the delayed time base when you want to delay an acquisition so it captures and displays events that follow other events. See *To Find More Information* below.

Extended Acquisition Length (Option 2M Only)

Use Extended Acquisition mode to acquire an extended-length acquisition record. After the data is acquired, you can move to and display any portion of the data (see Figure 3–9).

NOTE. *To function properly, Extended acquisition mode forces some oscilloscope modes and settings to new values. Also, measurements, gating, and cursors are restricted to the current waveform record.*

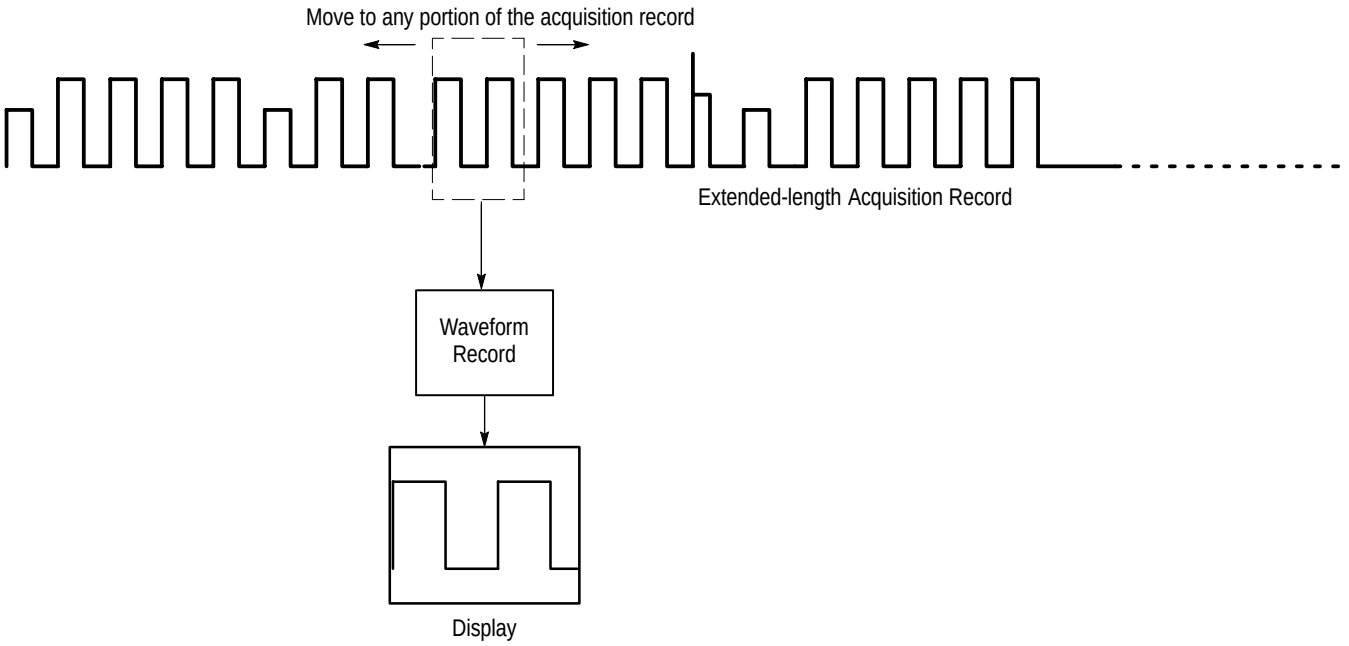


Figure 3–9: Displaying an Extended Acquisition Length Record

Extended acquisition mode is a single acquisition sequence mode allowing you time to examine the acquired data. To set Extended Acquisition mode:

Press **HORIZONTAL MENU → Extd Acq Setup** (main) **→ Extended Acquisition** (side) to toggle Extended Acquisition mode On (see Figure 3–10).

To acquire a new data record, press **Run/Stop**.

Read the side menus to determine the acquisition length, waveform record length, acquisition duration, and the record starting location:

- Acq Len displays the length of the acquisition record. The oscilloscope model and the number of channels in use determines the length.
- Wfm Len displays the length of the waveform record. The settings for Record Length in the Horizontal menu and for Extended Acquisition mode (on or off) determine the length.
- Acq Duration displays the time spanned by the acquisition data.
- Waveform Record Start displays/selects the percentage of the acquisition data that is before the waveform record of the selected channel and any locked live channels.
- Fit To Screen duplicates the function of Fit To Screen in the Record Length menu.

To set the starting position of the waveform record in the acquisition data, press **HORIZONTAL MENU → Extd Acq Setup** (main) **→ Waveform Record Start** (side). Then use the general purpose knob or keypad to set the percentage.

To view all acquisition data, use the Horizontal Position to pan the waveform record through the acquisition record. Or, use Zoom or Fit To Screen to compress the acquisition data into the waveform record.

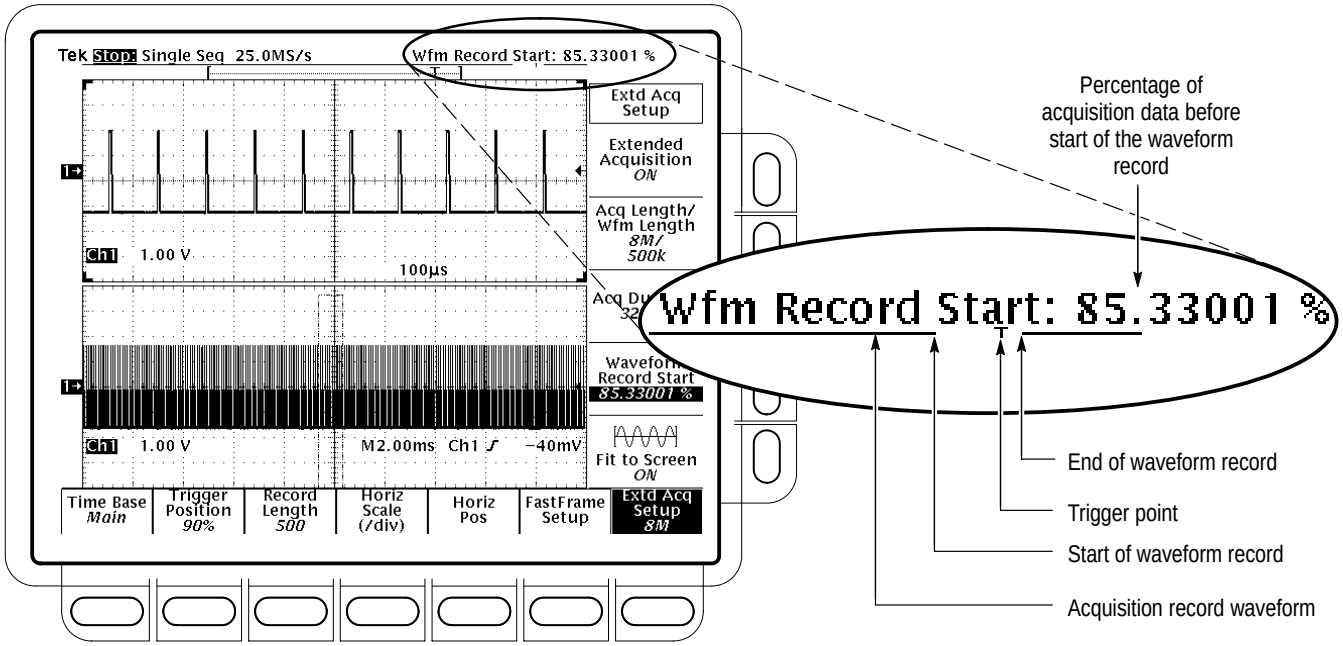


Figure 3–10: Extended Acquisition Length and Zoom

To Find More Information

To perform tutorials that teach selecting, scaling, and positioning of waveforms, see *Example 1: Displaying a Waveform* on page 2–13 and *Example 2: Displaying Multiple Waveforms* on page 2–17.

To learn how to use delay with waveforms, see *Delayed Triggering* on page 3–117. To learn how to magnify waveforms, see *Zooming on Waveforms*, on page 3–53.

Choosing an Acquisition Mode

The TDS Oscilloscopes are digital products that can acquire and process your input signal in a variety of modes. To help you choose the best mode to use for your signal measurement task, this section first describes:

- How the oscilloscope samples and digitizes an input signal
- How the different acquisition modes (such as *interpolation*) affect this process
- How to select among these modes

Following these descriptions are procedures for selecting the sampling and acquisition modes, beginning with *Checking the Acquisition Readout* on page 3–35.

Sampling and Digitizing

Acquisition is the process of sampling the analog input signal, digitizing it to convert it into digital data, and assembling it into a waveform record. (See Figure 3–11.) The oscilloscope creates a digital representation of the input signal by sampling the voltage level of the signal at regular time intervals. The sampled and digitized points are stored in memory along with corresponding timing information. You can use this digital representation of the signal for display, measurements, or further processing.

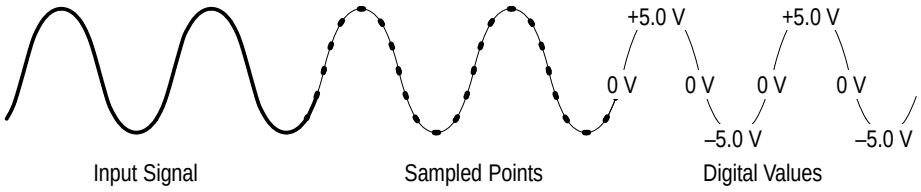


Figure 3–11: Acquisition: Input Analog Signal, Sample, and Digitize

The oscilloscope uses the samples it takes (see Figure 3–13) to create a waveform record containing a user-specified number of data or record points. Each record point represents a certain voltage level that occurs a determined amount of time from the trigger event.

The oscilloscope may take more samples than the number of points in your waveform record. In fact, the oscilloscope may take several samples for each record point (see Figure 3–12). The digitizer can use any extra samples to perform additional processing, such as averaging or looking for minimum and maximum values. The methods of sampling and acquisition modes you choose determine how the oscilloscope assembles the sample points it acquires into the waveform record.

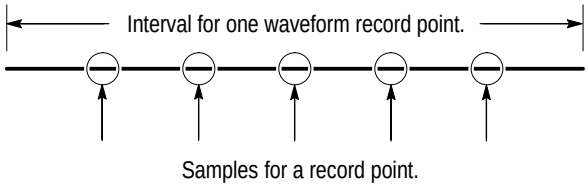


Figure 3–12: Several Points May be Acquired for Each Point Used

Real-time Sampling

The two general methods of sampling are *real-time* and *equivalent-time*. The TDS 600B Oscilloscopes use only real-time sampling; the TDS 500D and TDS 700D Oscilloscopes use both real- and equivalent-time sampling.

In real-time sampling, the oscilloscope digitizes all the points it acquires after *one* trigger event (see Figure 3–13). Always use real-time sampling to capture single-shot or transient events.

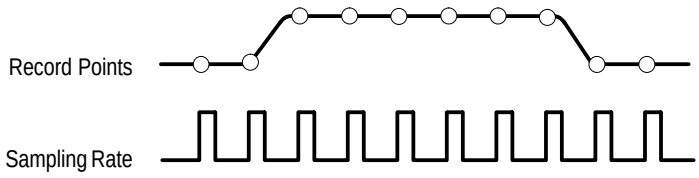


Figure 3–13: Real-Time Sampling

Equivalent-time Sampling

A TDS 500D or TDS 700D model oscilloscope (the TDS 600B models use only real time sampling) uses equivalent time sampling to extend its sample rate over its real-time maximum sampling rate, but only under two conditions:

- You must have turned equivalent-time on in the Acquisition menu.
- You must have set the oscilloscope to a sampling rate that is too fast to allow it to get enough samples with which to create a waveform record using real-time sampling.

If both conditions are the case, the oscilloscope takes a few samples with each trigger event and eventually obtains enough samples to construct a waveform record. In short, the oscilloscope makes *multiple* acquisitions of a *repetitive* waveform to obtain the sample density required for a waveform record. (See Figure 3–14.) By doing so, the oscilloscope lets you accurately acquire signals with frequencies much higher than its maximum real-time bandwidth would allow. Equivalent-time sampling should only be used on repetitive signals.

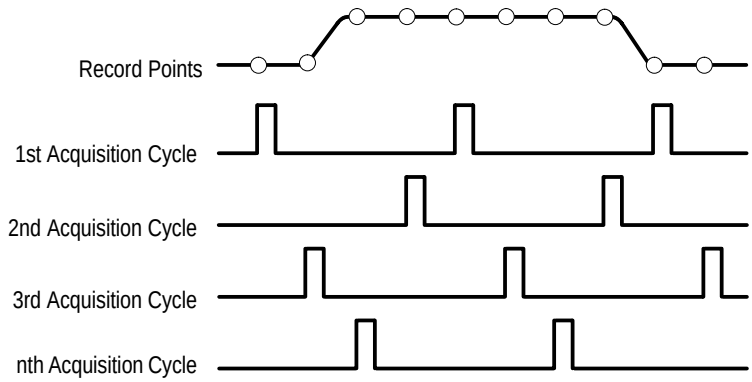


Figure 3–14: Equivalent-Time Sampling

The type of equivalent-time sampling the oscilloscope uses is called *random equivalent-time sampling*. Although it takes the samples sequentially in time, it takes them randomly with respect to the trigger. Random sampling occurs because the oscilloscope sample clock runs asynchronously with respect to the input signal and the signal trigger. The oscilloscope takes samples independently of the trigger position and displays them based on the time difference between the sample and the trigger.

Interpolation

Your oscilloscope can interpolate between the samples it acquires. Like for equivalent time sampling, it does so only when it cannot obtain all the *real* samples it needs to fill up its waveform record. For instance, setting the horizontal SCALE to progressively faster acquisition rates leaves progressively shorter time periods for the waveform record. Therefore, the oscilloscope must sample faster to acquire the samples (record points) needed to fill up the record. Eventually the time period established by scale setting does not allow enough time to get all the real samples needed to fill the record.

The situation just described occurs if you set the Horizontal SCALE knob to a time base setting that is faster than 10 ns (TDS 600B). (The setting varies with the number of channels for TDS 500D and TDS 700D models; see Table 3–4 on page 3–37.) The oscilloscope then interpolates to create the intervening points in the waveform record. There are two options for interpolation: linear or sin(x)/x. (TDS 500D and TDS 700D models can also equivalent-time sample to acquire more samples; see *Equivalent-Time Sampling* on page 3–29.)

Linear interpolation computes record points between actual acquired samples by using a straight line fit. It assumes all the interpolated points fall in their appropriate point in time on that straight line. Linear interpolation is useful for many waveforms such as pulse trains.

Sin(x)/x interpolation computes record points using a curve fit between the actual values acquired. It assumes all the interpolated points fall along that curve. That is particularly useful when acquiring more rounded waveforms such as sine waves. Actually, it is appropriate for general use, although it may introduce some overshoot or undershoot in signals with fast rise times.

NOTE. *When using either type of interpolation, you may want to set the display style so that the real samples are displayed intensified relative to the interpolated samples. The instructions under* Select the Display Style *on page 3–41 explain how to turn on intensified samples.*

Interleaving

A TDS 500D or TDS 700D Oscilloscope can interleave its channels to attain higher digitizing rates without equivalent time sampling or interpolating. The oscilloscope applies the digitizing resources of unused channels (that is, channels that are turned off) to sample those that are in use (turned on). Table 3–2 lists how interleaving more than one digitizer to sample a channel extends the maximum digitizing rate.

Once you set horizontal scale to exceed the maximum digitizing rate for the number of channels in use (see Table 3–2), the oscilloscope will not be able to get enough samples to create a waveform record. At that point, the oscilloscope will either *interpolate* to calculate additional samples or it will switch from real to equivalent time sampling to obtain additional samples. (See *Interpolation* on page 3–30 and *Equivalent-Time Sampling* on page 3–29.)

Table 3–2: How interleaving affects sample rate

No. of channels on	Maximum digitizing rate[1]			
	TDS 520D & TDS 724D	TDS 540D	TDS 754D	TDS 580D, TDS 784D, & TDS 794D
One	2 GS/sec	2 GS/sec	2 GS/sec	4 GS/sec
Two	1 GS/sec	2 GS/sec	2 GS/sec	2 GS/sec
Three or Four	Not Available	1 GS/sec	1 GS/sec	1 GS/sec

1 When real-time sampling. (GS = Gigasamples; MS = Megasamples.)

The Acquisition Modes

All oscilloscopes in this manual support the following four acquisition modes: *Sample, Envelope, Average, and Peak Detect.* TDS 500D and TDS 700D Oscilloscopes also support *Hi Res.* Keep in mind which modes apply to your model oscilloscope as you read the following descriptions.

Sample (the mode most commonly used), Peak Detect, and Hi Res modes operate in real time on a single trigger event, provided that the oscilloscope can acquire enough samples for each trigger event. Envelope and Average modes operate on multiple acquisitions; the oscilloscope averages or envelopes several waveforms on a point-by-point basis. (For TDS 500D and TDS 700D models only, Hi Res, Envelope, and Average modes are not available when in DPO mode; see *Incompatible Modes* on page 3–66.)

Figure 3–15 illustrates the different modes and lists the benefits of each. It will help you select the appropriate mode for your application. Refer to it as your read the following descriptions of each mode.

Sample Mode. In Sample mode, the oscilloscope creates a record point by saving the first sample (of perhaps many) during each acquisition interval. (An acquisition interval is the time covered by the waveform record divided by the record length.) Sample mode is the default mode.

Envelope Mode. In Envelope mode, the oscilloscope acquires and displays a waveform record that shows the extremes in variation over several acquisitions (you specify the number of acquisitions). The oscilloscope saves the highest and lowest values in two adjadcent intervals similar to the Peak Detect mode. But Envelope mode, unlike Peak Detect, gathers peaks over many trigger events.

After each trigger event, the oscilloscope acquires data and then compares the min/max values from the current acquisition with those stored from previous acquisitions. The final display shows the most extreme values for all the acquisitions for each point in the waveform record.

Average Mode. Average mode lets you acquire and display a waveform record that is the averaged result of several acquisitions. This mode reduces random noise. The oscilloscope acquires data after each trigger event using Sample mode. It then averages the record point from the current acquisition with those stored from previous acquisitions.

Peak Detect Mode. Peak Detect mode alternates between saving the highest sample in one acquisition interval and lowest sample in the next acquisition interval. Peak Detect mode only works with real-time, noninterpolated sampling.

If you set the time base so fast that it requires real-time interpolation or equivalent-time sampling, the mode automatically changes from Peak Detect to Sample, although the menu selection will not change.

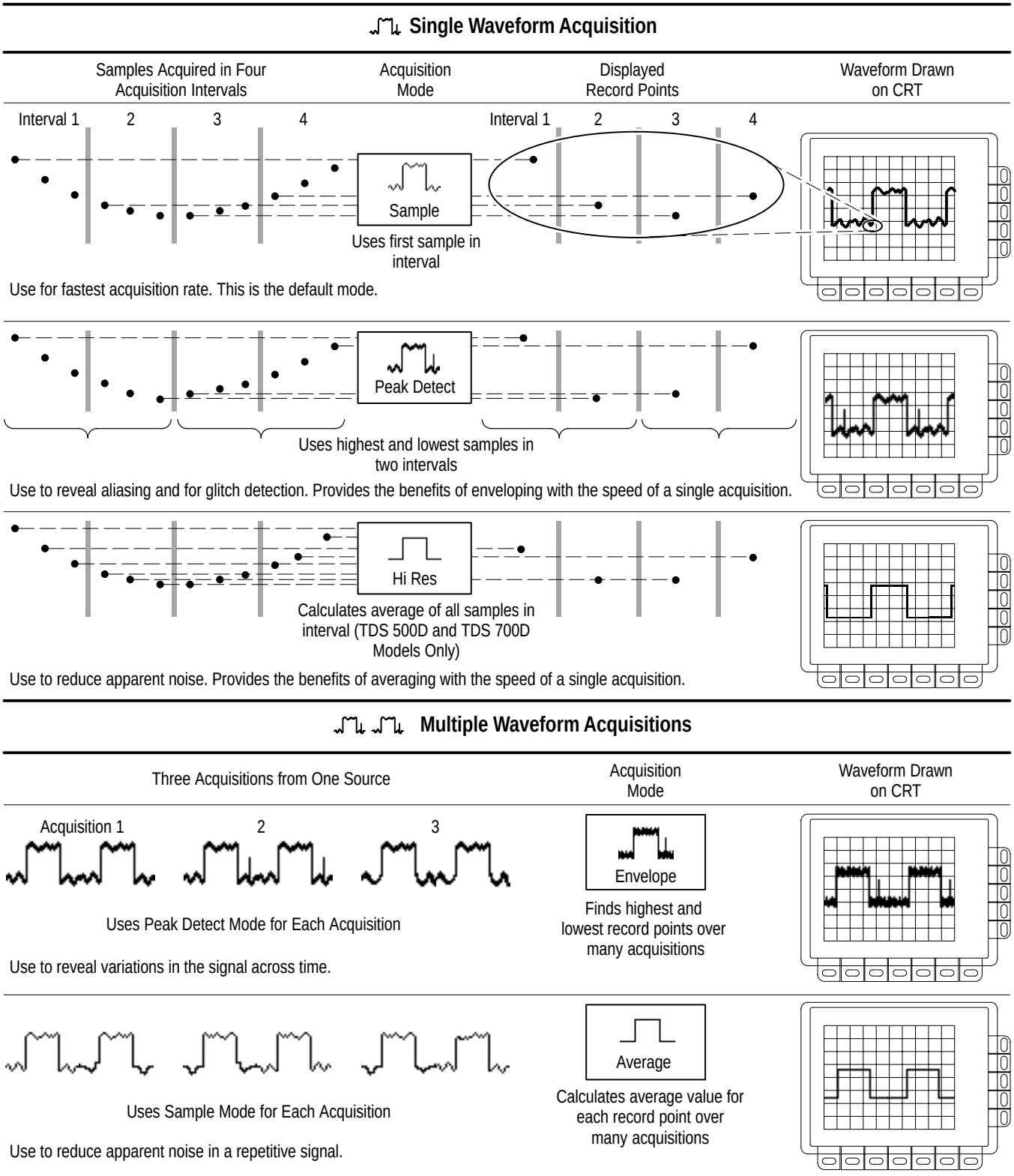


Figure 3–15: How the Acquisition Modes Work

Hi Res Mode. TDS 500D and 700D models only: Hi Res mode averages all samples taken during an acquisition interval to create a record point. The average results in a higher-resolution, lower-bandwidth waveform.

A key advantage of Hi Res is its potential for increasing resolution regardless of the input signal. Table 3–3 and the equations shown below illustrate how you can obtain up to 15 significant bits with Hi res mode. Note that the resolution improvements are limited to speeds slower than 100 ns/div. Also, resolutions above 15 bits are not allowed by internal hardware and computation limitations.

Si = *Sampling Interval for TDS 754D = 1 ns*

$$\Delta t = \text{Sample Interval} = \frac{\text{Time/Div}}{\text{Number Of Points/Div}} = \frac{5\ \mu s/\text{Div}}{50\ \text{Points/Div}} = 100\ ns$$

$$Nd = \text{Number of points per decimation interval} = \frac{\Delta t}{Si} = 100$$

$$\text{Resolution Enhancement (bits)} = 0.5 \times LOG_2(Nd) \approx 3\ \text{extra bits}$$

$$\text{Bits of Resolution} = \text{Resolution Enhancement (3 bits)} + 8\ \text{bits} \approx 11\ \text{bits}$$

Hi Res mode only works with real-time, noninterpolated sampling. If you set the time base so fast that it requires real-time interpolation or equivalent-time sampling, the mode automatically becomes Sample even though the menu selection will not change.

Table 3–3: Additional resolution bits

Time base speed	Bits of resolution
100 ns and faster	8 bits
200 ns to 500 ns	9 bits
1 µs to 2 µs	10 bits
5 µs to 10 µs	11 bits
20 µs to 50 µs	12 bits
100 µs to 200 µs	13 bits
500 µs	14 bits
1 ms and slower	15 bits

Checking the Acquisition Readout

To determine the acquisition sampling rate, the acquisition state (running or stopped), and the acquisition mode, check the Acquisition readout at the top of the display. (See Figure 3–16.) The state "Run:" shows the sample rate and acquisition mode. The state "Stop:"shows the number of acquisitions acquired since the last stop or major change.

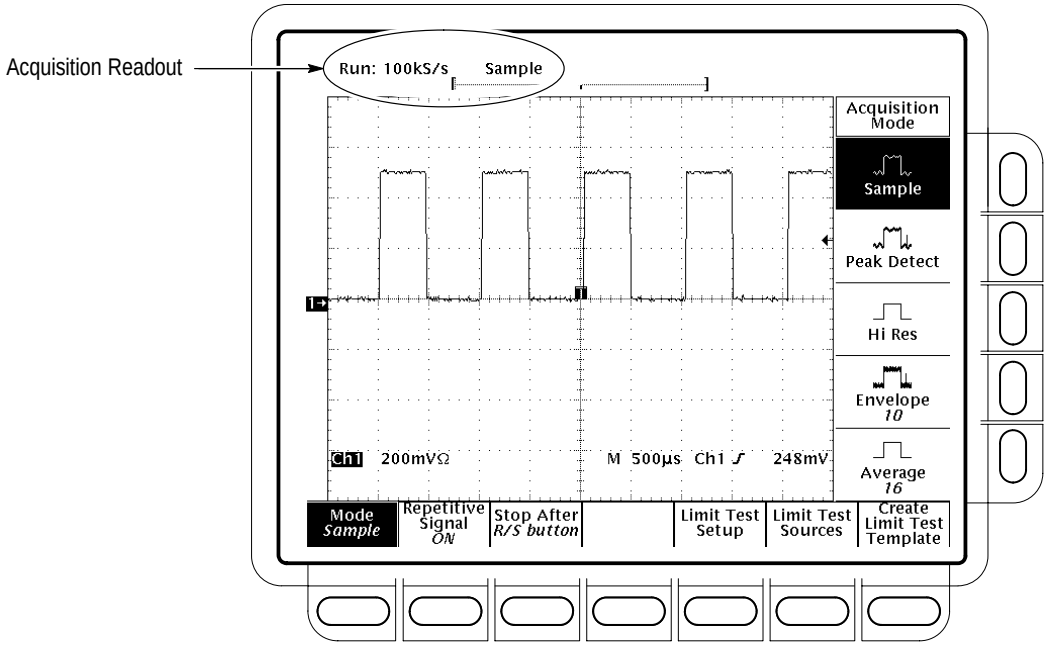


Figure 3–16: Acquisition Menu and Readout

Selecting an Acquisition Mode

The oscilloscope provides several modes (see *The Acquisition Modes* on page 3–31) for acquiring and converting analog data into digital form. To choose how the oscilloscope will create points in the waveform record:

1. Press **SHIFT ACQUIRE MENU → Mode** (main). (See Figure 3–16.)
2. TDS 600B: Press **Sample**, **Envelope**, **Average**, or **Peak Detect** (side) or ...

   TDS 500D and TDS 700D Models: Press **Sample**, **Peak Detect**, **Hi Res**, **Envelope,** or **Average** (side). (DPO mode must be off to use Hi Res, Envelope, or Average modes.)

3. If you selected Envelope or Average, enter the number of waveform records to be enveloped or averaged using the keypad or the general purpose knob.

NOTE. *TDS 500D and 700D models only: Selecting Hi Res mode in the Acquire menu automatically reduces long record-length settings to prevent overflow of acquisition memory. Because Hi Res mode uses twice the acquisition memory used by other acquisition modes, allowing selection of the longer horizontal record lengths with Hi Res mode would cause the oscilloscope to run out of memory.*

Selecting Repetitive Sampling

TDS 500D and TDS 700D models only: To limit the oscilloscope to real-time sampling or let it choose between real-time or equivalent-time sampling:

Press **SHIFT ACQUIRE MENU → Repetitive Signal** (main) → **ON** or **OFF** (side).

- **ON (Enable ET)** uses both the real-time and the equivalent-time sampling as appropriate (see Table 3–4).
- **OFF (Real Time Only)** limits the oscilloscope to real-time sampling. If the oscilloscope cannot accurately get enough samples for a complete waveform, it will interpolate.

NOTE. *The oscilloscope will use the interpolation method selected in the display menu to fill in the missing record points — either linear or sin(x)/x interpolation. See* Interpolation *on page 3–30 for a discussion of interpolation.*

The sampling speeds and the number of channels you choose affect the mode the oscilloscope uses to sample waveforms:

- The oscilloscope always real-time samples at slower time base settings; faster time settings force the oscilloscope to switch from real-time sampling to equivalent-time sampling or interpolation, depending on whether ET is on or off.

- The oscilloscope extends the limit at which it must switch from real-time sampling by using the digitizers of channels that are turned off to sample the channel or channels that are turned on.

Check Table 3–4 below to determine the time base setting(s) at which the switch from real-time sampling (RT) to equivalent time sampling or interpolation (ETI) occurs for your model.

Table 3–4: TDS 500D and TDS 700D Sampling mode selection (when fit to screen is off)

Model	TDS 520D & TDS 724D		TDS 754D & TDS 540D		TDS 580D, TDS 784D, & TDS794D		
Channels on[1]	1	2	1 or 2	3 or 4	1	2	3 or 4
Time base[2]							
> 50 ns	RT[3]	RT	RT	RT	RT	RT	RT
50 ns	RT	RT	RT	RT	RT	RT	RT
25 ns	RT	ETI[4]	RT	ETI	RT	RT	ETI
12.5 ns	ETI	ETI	ETI	ETI	RT	ETI	ETI
< 12.5 ns	ETI	ETI	ETI	ETI	ETI	ETI	ETI

1 **Note that the TDS 520D and TDS 724D can have no more that two channels on at a time.**

2 **"> " means "slower than"; "< " means "faster than."**

3 **"RT" abbreviates "Real-Time Sampling" throughout this table.**

4 **"ETI" abbreviates "Equivalent-Time Sampling or Interpolation" throughout this table.**

Stop After

To choose the event that stops the acquiring waveforms, do the following step:

Press **SHIFT ACQUIRE MENU → Stop After** (main) **→ RUN/STOP button only**, **Single Acquisition Sequence**, or **Limit Test Condition Met** (side). (See Figure 3–17.) (TDS 500D and TDS 700D models only: single acquisition and limit testing are ignored in DPO mode; see *Incompatible Modes* on page 3–66.)

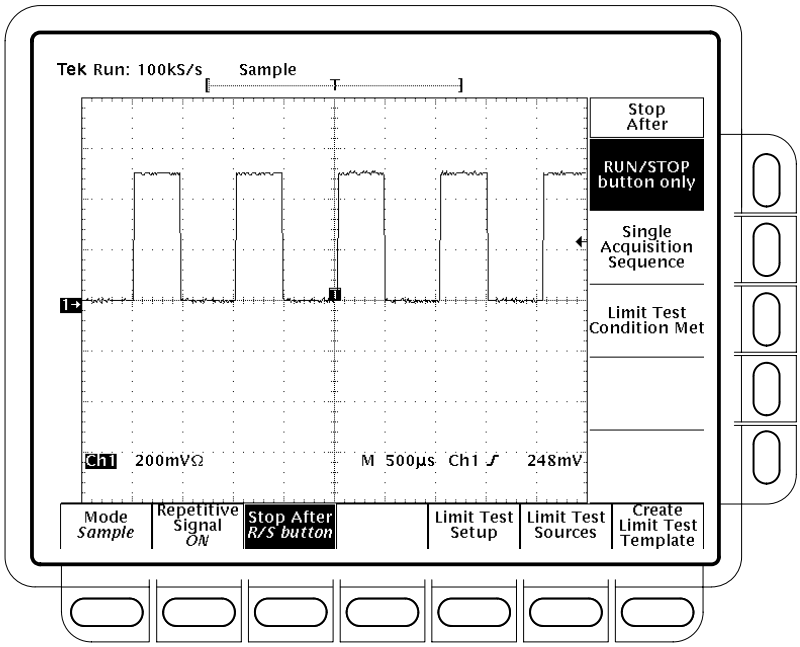


Figure 3–17: Acquire Menu — Stop After

- Press **RUN/STOP button only** (side) to use the **RUN/STOP** button to start or stop acquiring. Pressing the RUN/STOP button once will stop the acquisitions. The upper left hand corner in the display will say “Stop” and show the number of acquisitions. If you press the button again, the oscilloscope will resume taking acquisitions.
- Press **Single Acquisition Sequence** (side). That selection lets you run a single sequence of acquisitions by pressing the **RUN/STOP** button. In Sample, Peak Detect, or Hi Res mode, the oscilloscope will acquire a waveform record with the first valid trigger event and stop. (Hi Res is available only on TDS 500D and TDS 700D models.)

  In Envelope or Average mode, the oscilloscope will make the specified number of acquisitions to complete the averaging or enveloping task.

  TDS 500D and TDS 700D models only: If the oscilloscope is in equivalent-time mode and you press **Single Acquisition Sequence** (side), it will continue to recognize trigger events and acquire samples until the waveform record is filled.

NOTE. *To quickly select Single Acquisition Sequence without displaying the Acquire and Stop After menus, press SHIFT FORCE TRIG. Now the RUN/STOP button operates as just described. (You still must display the Acquire menu and then the Stop After menu to leave Single Acquisition Sequence operation.)*

- Press **Limit Test Condition Met** (side) to acquire waveforms until waveform data exceeds the limits specified in the limit test. Then acquisition stops. At that point, you can also specify other actions for the oscilloscope to take, using the selections available in the Limit Test Setup main menu.

NOTE. *For the oscilloscope to stop an acquisition when limit test conditions have been met, limit testing must be turned ON using the Limit Test Setup main menu.*

Setting up limit testing requires several more steps. See *Limit Testing* on page 3–201.

Preventing Aliasing

Under certain conditions, a waveform may be aliased on screen. Read the following description about aliasing and the suggestions for preventing it.

About Aliasing. When a waveform aliases, it appears on screen with a frequency lower than the actual waveform being input or it appears unstable even though the light next to **TRIG'D** is lighted. Aliasing occurs because the oscilloscope cannot sample the signal fast enough to construct an accurate waveform record. (See Figure 3–18.)

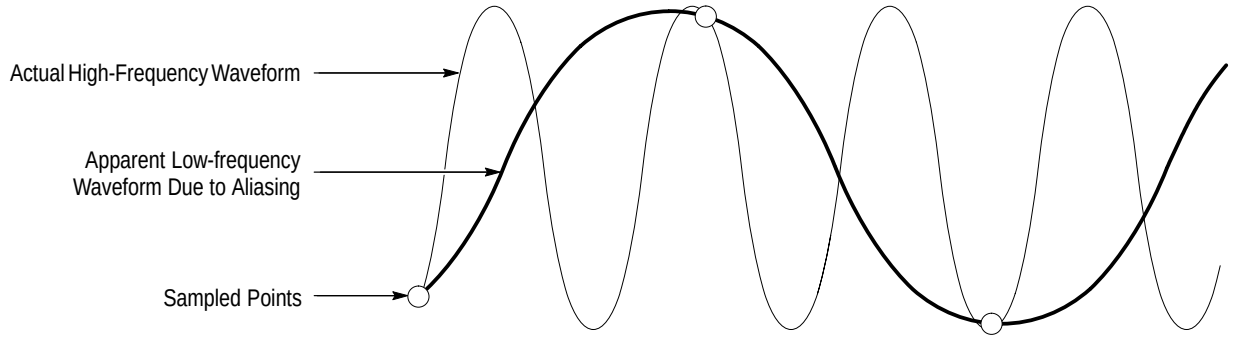


Figure 3–18: Aliasing

Methods to Check and Eliminate. To quickly check for aliasing, slowly increase the horizontal scale (time per division setting). If the shape of the displayed waveform changes drastically or becomes stable at a faster time base setting, your waveform was probably aliased.

To avoid aliasing, be sure to sample the input signal at a rate more than twice as fast as the highest frequency component. For example, a signal with frequency components of 500 MHz would need to be sampled at a rate faster than 1 Gigasamples/second to represent it accurately and to avoid aliasing. The following tips may help you eliminate aliasing on a signal:

- Try adjusting the horizontal scale.
- Try pressing the **AUTOSET** button.
- Try switching the acquisition mode (in the acquisition menu) to Envelope or Peak Detect. Envelope searches for samples with the highest and lowest values over multiple acquisitions; Peak Detect mode does the same but in a single acquisition. Either can detect faster signal components over time.
- Try pressing the **DPO** acquisition button (TDS 500D and TDS 700D models only). DPO mode results in waveform displays similar to those obtained using an analog oscilloscope.

Customizing the Display

The TDS Oscilloscope can display waveform records and other display elements in different ways. This section describes how to adjust the oscilloscope display style, intensity level, graticule, and format.

NOTE. *TDS 500D and 700D models only: This section assumes you are using Normal acquisition mode and gives display settings for this mode. If you select DPO acquisitions, procedures for making Style, Format, and Readout display settings differ and some selections are not permitted. See* Using DPO Acquisition Mode, *on page 3–59, for setup differences, and* Incompatible Modes *on page 3–66.*

Change Display Settings

To bring up the Display menu:

Press **DISPLAY → Settings** (main) **→ Display** (pop-up).

The **Display** menu allows you to adjust the style, intensity level, graticule, and format features described below. The **Color** menu allows you to alter color settings for various display components such as waveforms and text. To find more information on color, see *Customizing the Display Color* on page 3–47.

Select the Display Style

TDS 600B only: Press **DISPLAY → Settings** (main) **→ Display** (pop-up) **→ Style** (main) **→ Vectors**, **Dots, Intensified Samples**, **Infinite Persistence**, or **Variable Persistence** (side). (See Figure 3–19.)

TDS 500D and TDS 700D models only: Press **DISPLAY → Settings** (main) **→ Display** (pop-up) **→ Mode** (main) **→ Normal** (pop-up) **→ Style** (main) **→ Vectors**, **Dots**, **Intensified Samples**, **Infinite Persistence**, or **Variable Persistence** (side)

Vectors style displays vectors (lines) between the record points.

Dots style displays waveform record points as dots.

Intensified Samples style also displays waveform record points as dots. However, the points actually sampled are displayed in the color labeled “Zone” in the Display Colors menus.

In addition to choosing Intensified Samples in the side menu, the oscilloscope must be interpolating (equivalent time must be off for TDS 500D and TDS 700D models) or Zoom must be on with its horizontal expansion greater that 1X. See *Interpolation* on page 3–30; see *Zooming on Waveforms* on page 3–53.

Variable Persistence style accumulates the record points on screen and displays them only for a specific time interval. In that mode, the display behaves like that of an analog oscilloscope. You enter the time for that option with the keypad or the general purpose knob. Record points are also displayed with colors that vary depending on the persistence of the point. See *Choose a Palette* on page 3–48.

Infinite Persistence style accumulates the record points until you change some control (such as scale factor) causing the display to be erased.

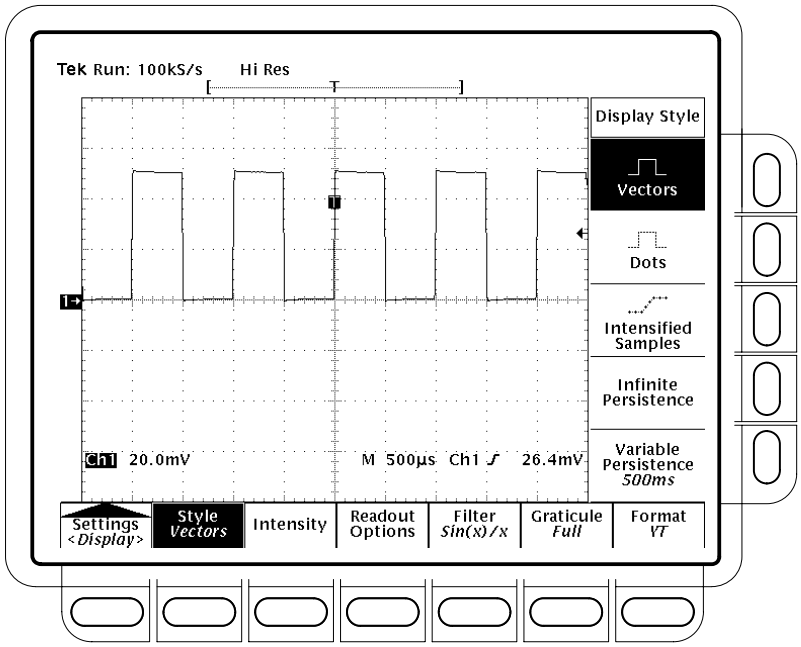


Figure 3–19: Display Menu — Style

NOTE. *TDS 500D and TDS 700D models only: See* Using DPO Acquisition Mode, *on page 3–59, to see how Style and Intensity setup differs for DPO mode.*

Adjust Intensity

Intensity lets you set text/graticule and waveform intensity (brightness) levels. To set the intensity:

Press **DISPLAY → Settings** (main) **→ Display** (pop-up) **→ Intensity** (main) **→ Text/Grat** or **Waveform** (side). Enter the intensity percentage values with the keypad or the general purpose knob.

All intensity adjustments operate over a range from 20% (close to fully off) to 100% (fully bright).

Set Display Readout Options

Readout options control whether the trigger indicator, trigger level bar, and current date and time appear on the display. The options also control what style trigger level bar, long or short, is displayed.

1. TDS 600B: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Readout Options** (main).

   TDS 500D and TDS 700D Models: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **Normal** (pop-up) → **Format/ RO** (main).

2. Toggle **Display 'T' @ Trigger Point** (side) to select whether or not to display 'T' indicating the trigger point. You can select **ON** or **OFF**. (The trigger point indicates the position of the trigger in the waveform record.)

3. Press **Trigger Bar Style** (side) to select either the short or the long trigger bar or to turn the trigger bar off. (See Figure 3–20. Note that both styles are shown for illustrating purposes, but you can only display one style at a time.)

   The trigger bar is only displayed if the trigger source is an active, displayed waveform. Also, two trigger bars are displayed when delay triggerable acquisitions are displayed — one for the main and one for the delayed time base. The trigger bar is a visual indicator of the trigger level.

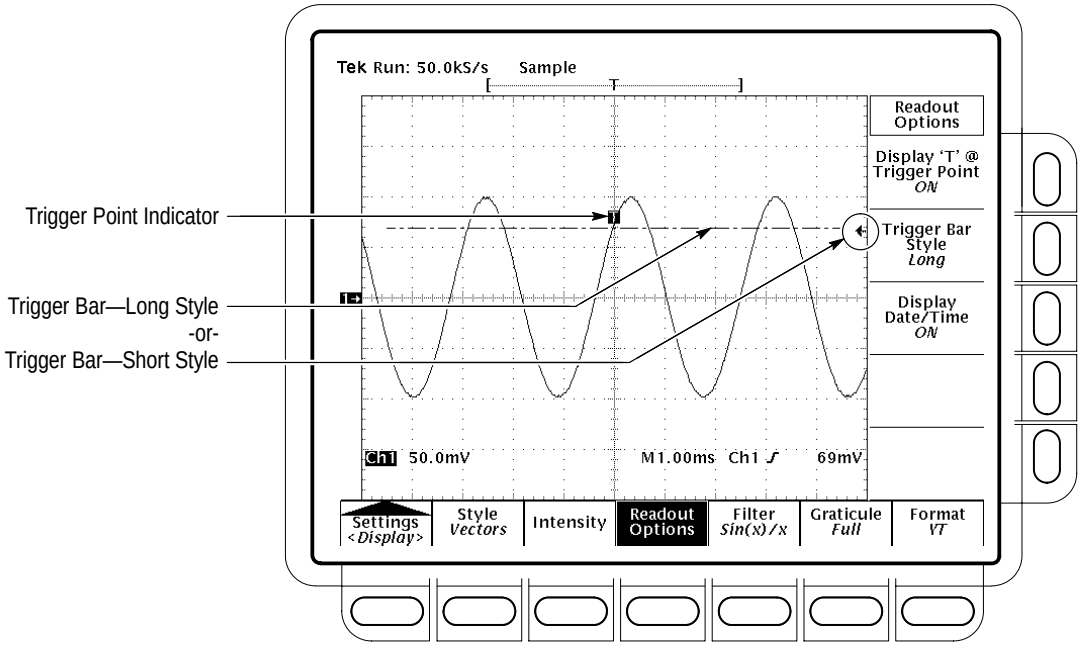


Figure 3–20: Trigger Point and Level Indicators

Sometimes, especially when using the hardcopy feature, you may want to display the current date and time on screen. (To find more information displaying and setting date and time, see *Date/Time Stamp the Hardcopy* on page 3–184.)

4. Press **Display Date/Time** (side) to turn it on or off. Push **Clear Menu** to see the current date and time.

Select Interpolation Filter

The display filter types are sin(x)/x interpolation and linear interpolation. To switch between interpolation filters:

TDS 600B: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Filter** (main) → **Sin(x)/x Interpolation** or **Linear Interpolation** (side).

TDS 500D and TDS 700D Models: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Normal** (pop-up) → **Filter** (main) → **Sin(x)/x Interpolation** or **Linear Interpolation** (side).

NOTE. *When the horizontal scale is set to the faster rates (10 ns/div for the TDS 600B; see Table 3–4 on page 3–37 for rates specific to the TDS 500D and TDS 700D models) or when using the ZOOM feature to expand waveforms horizontally, interpolation occurs. (The filter type, linear or sin(x)/(x), depends on which is set in the Display menu.) Otherwise, interpolation is not used. See* Interpolation *on page 3–30 for a discussion of interpolation.*

Select the Graticule Type

To change the graticule:

Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Graticule** (main) → **Full**, **Grid**, **Cross Hair**, **Frame**, **NTSC** or **PAL** (side).

Full provides a grid, cross hairs and a frame.

Grid displays a frame and a grid.

Cross Hair provides cross hairs, and a frame.

Frame displays just a frame.

NTSC provides a grid useful for measuring NTSC-class waveforms.

PAL provides a grid useful for measuring PAL-class waveforms.

NOTE. *Selecting either NTSC or PAL graticules automatically changes the vertical scale, position settings, coupling, and sets to zero any vertical offset of any channel displayed. These settings are not restored after switching to other graticule types. Therefore, you might want to recall the factory setup or other stored setup after selecting a different graticule.*

Select the Format

The oscilloscope displays waveforms in either of two formats: YT and XY. To set the display axis format:

TDS 600B: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Format** (main) → **XY** or **YT** (side).

TDS 500D and TDS 700D models: Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **Normal** (pop-up) → **Format/RO** (main) → **XY** or **YT** (side).

YT is the conventional oscilloscope display format. It shows a signal voltage (the vertical axis) as it varies over time (the horizontal axis).

XY format compares the voltage levels of two waveform records point by point. That is, the oscilloscope displays a graph of the voltage of one waveform record against the voltage of another waveform record. This mode is particularly useful for studying phase relationships.

When you choose the XY format, any channel or reference displayed is assigned to the axis indicated in Table 3–5 and displayed as part of an XY pair. If only one source in an XY pair is displayed, the oscilloscope automatically turns on the other source to complete the XY pair when you select XY. Moreover, once XY is on, selecting either source in a pair turns the pair on; pressing WAVEFORM OFF for either source in the pair removes both sources from the display.

Table 3–5: XY Format pairs

XY Pair	X-Axis source	Y-Axis source
Ch 1 and Ch 2	Ch 1	Ch 2
Ch 3 and Ch 4 (Ax1 and Ax2)	Ch 3 (Ax1)	Ch 4 (Ax2)
Ref 1 and Ref 2	Ref 1	Ref 2
Ref 3 and Ref 4	Ref 3	Ref 4

Since selecting YT or XY affects only the display, the horizontal and vertical scale and position knobs and menus control the same parameters regardless of the mode selected. Specifically, in XY mode, the horizontal scale will continue to control the time base and the horizontal position will continue to control which portion of the waveforms are displayed.

XY format is a dot-only display, although it can have persistence. The Vector style selection has no effect when you select XY format.

You cannot display Math waveforms in XY format. They will disappear from the display when you select XY.

NOTE. *Use of XY at higher room temperatures or with higher intensity display formats, such as the white fields in the Hardcopy palette, can temporarily degrade display quality.*

Customizing the Display Color

The TDS Oscilloscope can display information in different colors. This section describes how to use the Color menu to choose the colors in which the various display objects appear. Some items in the color menu are also available on the monochrome TDS 500D Oscilloscopes.

Change the Display Color

To bring up the Color menu:

1. Press **DISPLAY** to show the Display menu.
2. Press **Settings** in the main menu until you select **Color** from the pop-up menu. (See Figure 3–21.)

The Color menu allows you to alter color settings for various display components such as waveforms and text. The Display menu allows you to adjust the style, intensity level, graticule, and format features. To find more information on display, see *Change the Display Settings* on page 3–41.

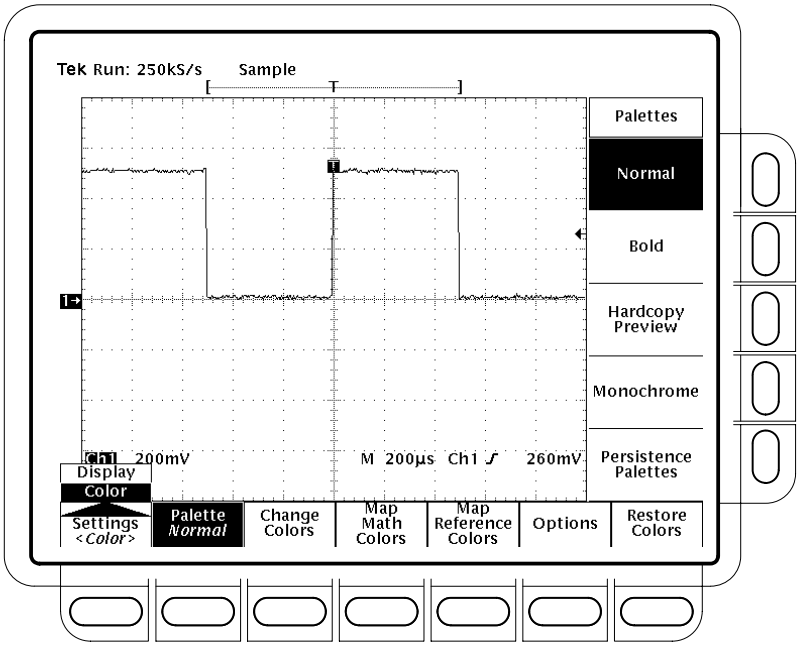


Figure 3–21: Display Menu — Setting

Choose a Palette

To choose a palette of 13 colors from a menu of preset palettes:

1. Choose the starting palette by selecting **Palette** from the main menu.
2. Select one of the available palettes in the side menu. Choose from **Normal**, **Bold**, **Hardcopy Preview** or **Monochrome**.
3. If you are using a persistence display and want to vary the color of each point depending on its persistence, choose **Persistence Palettes**. Then choose **Temperature**, **Spectral**, or **Gray Scale** from the resulting side menu. Choose **View Palette** to preview your selection on the display. Press **Persistence Palette** to quit preview mode. Press **Clear Menu** to return to the Palette menu.

***NOTE**. Use at higher room temperatures or with higher intensity display formats, such as the white fields in the Hardcopy Preview palette, can temporarily degrade display quality.*

You can select the Hardcopy Preview palette when using certain color hardcopy formats. The default colors in the this palette comprise a white background and fully saturated primary colors which generally produce the best result.

Change the Palette Colors

To change the color of the current palette, select a color and vary these attributes:

Hue, which is the wavelength of light reflected from the surface. It varies continuously along the color spectrum as produced by a rainbow. Hue is not available on monochrome oscilloscopes.

Lightness, which is the amount of light reflected from the surface. It varies from black, to the nominal color, to white.

Saturation, which is the intensity of color. Completely desaturated color is gray. Completely saturated color of any hue is that color at its most intense level. Saturation is not available on monochrome oscilloscopes.

1. Color oscilloscopes: Select the main menu **Change Colors** item. (See Figure 3–22.)

   If changing the colors of a persistence palette: press **Palette** (main) → **Persistence Palettes** (side) → **View Palette** (main). Then select the palette you want to change from the side menu and select the main menu **Change Colors for** item.

Monochrome oscilloscopes: Select the main menu **Change Persistence Colors** item.

2. Select one of the colors by pressing (repeatedly) **Color** (**Color Index** if changing a persistence palette) in the side menu.
3. If you want to use the factory default for this color or color index, press the side menu **Reset to Factory Color**.
4. Choose **Hue** from the side menu and use the general purpose knob or keypad to select the desired hue. Values range from 0 to 359. Sample values are: 0 = blue, 60 = magenta, 120 = red, 180 = yellow, 240 = green, and 300 = cyan.
5. Choose **Lightness** from the side menu and use the general purpose knob or keypad to select the lightness you desire. A value of 0 results in black. A value of 50 provides the nominal color. A value of 100 results in white.
6. Choose **Saturation** from the side menu and use the general purpose knob or keypad to select the saturation you desire. A value of 100 provides a pure color. A value of 0 provides gray.

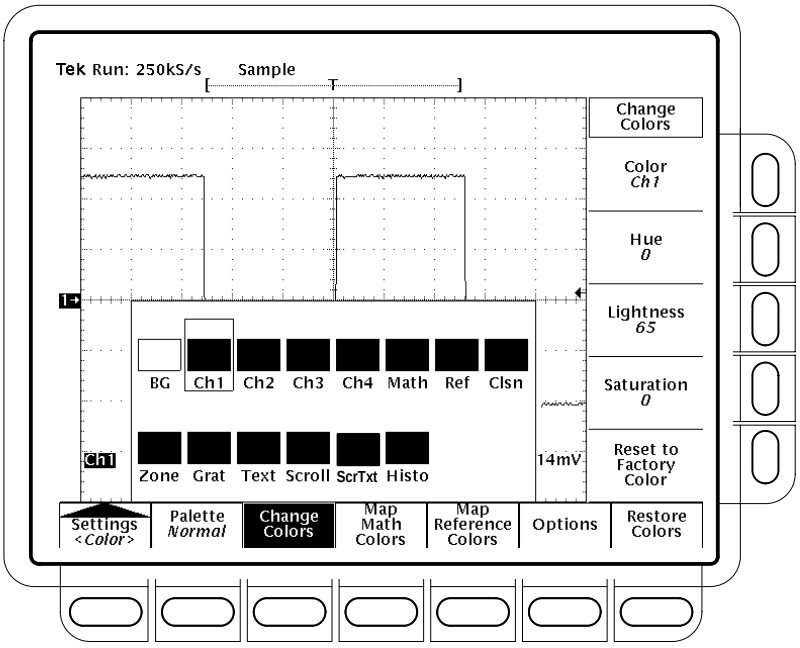


Figure 3–22: Display Menu — Palette Colors

Set Math Waveform Color

To define math waveform colors:

1. Choose to define math waveform colors by selecting the main menu **Map Math** item.
2. Select one of the three math waveforms by pressing **Math** in the side menu.
3. If you want to assign the selected math waveform to a specific color, press **Color** and cycle through the choices.
4. If you want the selected math waveform to be the same color as the waveform it is based on, select **Color Matches Contents**. If the math waveform is based on dual waveforms, the math waveform will use the color of the first constituent waveform.

To return to the factory defaults, select **Reset to Factory Color**.

Set Reference Waveform Color

To define reference waveform colors:

1. Press **Map Reference** in the main menu. (See Figure 3–23.)
2. Select one of the four reference waveforms by pressing **Ref** in the side menu.
3. To assign the selected reference waveform to a specific color, press (repeatedly) **Color** and choose the value.
4. To make the selected reference waveform the same color as the waveform it is based on, select **Color Matches Contents**.

To return to the factory defaults, select **Reset to Factory Color**.

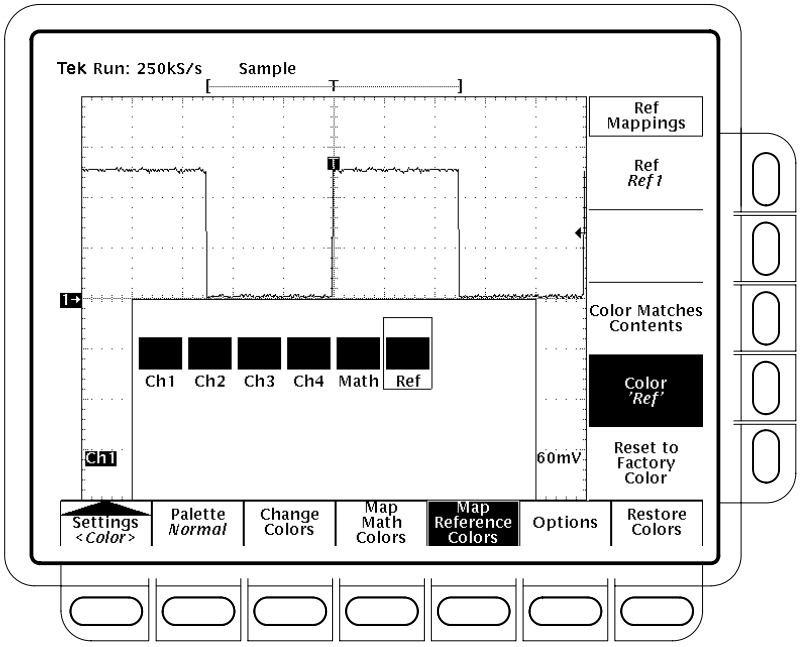


Figure 3–23: Display Menu — Map Reference Colors

Select Options

To define what color to show where a waveform crosses another waveform:

1. TDS 600B models: Press the **Options** main menu item.

   TDS 500D and TDS 700D models: Press the **Options Restore** main menu item.

2. Toggle **Collision Contrast** to **ON** in the side menu to mark collision zones with a special color.

Restore Colors

To restore colors to their factory default settings:

1. TDS 600B models: Press the main menu **Restore Colors** item. (See Figure 3–24.)

   TDS 500D and TDS 700D models: Press the main menu **Options Restore** item.

2. Select the object(s) you want to restore by pressing **Reset Current Palette To Factory**, **Reset All Palettes To Factory** (**Reset Palette** on monochrome oscilloscopes), or **Reset All Mappings To Factory** in the side menu.

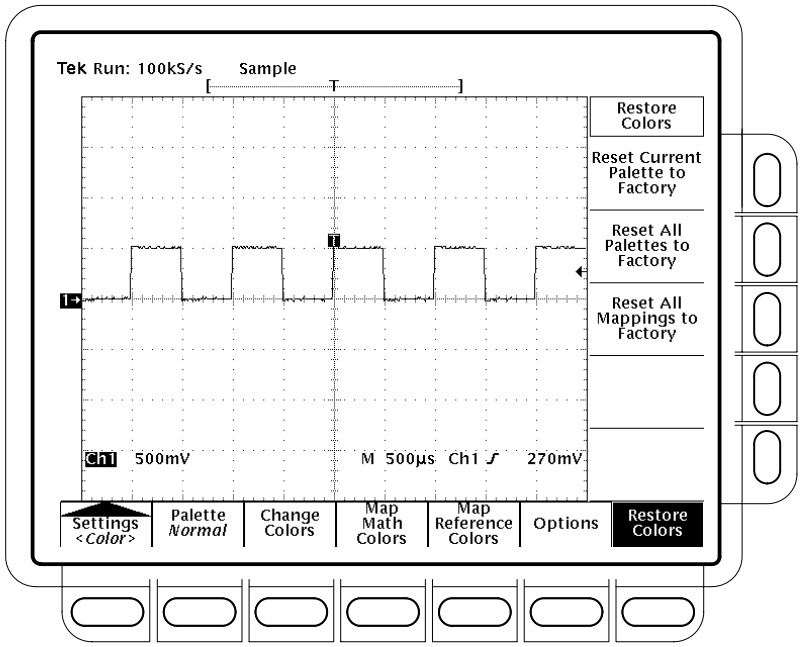


Figure 3–24: Display Menu — Restore Colors

Select Color Mapping

To define the method to map acquisition-database values to display indices (TDS 500D and 700D models only) do the following steps:

1. Press the **Options Restore** main menu item.
2. Toggle **Color Mapping** to **Intensity** or **Percentages** in the side menu to map values in intensity or percentage values.

   Intensity allows you to control the intensity using the DPO Brightness menu item (see page 3–63). Percentages allows you to set the Color Mapping percentages in the Map Colors menu.

Percentage Color Mapping

To set the percentages that map the acquisition-database values to display indices (TDS 500D and 700D models only), do the following steps:

1. Press the **Percentage Color Mapping** main menu item.
2. Toggle **Color Index** (side) to the color index range to be adjusted.
3. Press **Min Percentage** (side). Then use the general purpose knob or keypad to set the lower limit percentage of the selected color index.

To return to the factory defaults, select **Reset to Factory**.

Zooming on Waveforms

The TDS Oscilloscope can expand or compress (zoom in or out) on a waveform without changing the acquisition parameters (sample rate, record length, and so on). This section describes how to use Zoom and how it interacts with the selected waveform. It also describes how interpolation can affect Zoom.

Use Zoom (press the ZOOM button) when you want to temporarily expand a waveform to inspect small feature(s) on that waveform. For example, to temporarily expand the front corner of a pulse to inspect its aberrations, use Zoom to expand it horizontally and vertically. After you are finished, you can return to your original horizontal scale setting by pressing one menu button. (Zoom is also handy if you have acquired a waveform at the fastest time per division and want to further expand the waveform horizontally.)

Using with Waveforms

To help you use zoom effectively, consider how it operates on waveforms. When zooming vertically, the oscilloscope expands or contracts the *selected* waveform only. Also, the oscilloscope only positions the selected waveform when in Zoom.

When zooming horizontally, Zoom expands either the selected waveform, all live waveforms, or all live and reference waveforms, depending on the setting for Horizontal Lock in the Zoom menu.

When zooming horizontally or vertically, Zoom expands or contracts the waveform by the zoom factor.

Interpolation and Zoom

To help you use Zoom effectively, consider how it is affected by interpolation. When you zoom on a waveform, you expand a portion of it. If the expansion requires the oscilloscope to show more points for that portion than it has acquired, it interpolates.

The method the oscilloscope uses to interpolate, linear or sin(x)/x, can affect the way Zoom displays your waveform. If you selected sin(x)/x (the default), it may introduce some overshoot or undershoot to the waveform edges. If such is the case, change the interpolation method to linear, following the instructions on page 3–56.

To read about the two interpolation methods, see *Interpolation* on page 3–30. To differentiate between the real and interpolated samples, set the display style to **Intensified Samples**. (See *Select the Display Style* on page 3–41.)

Checking the Zoom Factor

To quickly determine the zoom factor of a zoomed waveform, select it and check the Zoom readout. It shows the selected waveform by number, along with the horizontal and vertical expansion factors.

The Zoom readout appears at the top of the display when zoom is on. (See Figure 3–25 on page 3–56.) Dual-window (preview) mode does not display the Zoom readout.

Zoom a Waveform

To use Zoom, select a waveform, turn Zoom on, and magnify that waveform using the vertical and horizontal scale knobs:

1. Press any of waveform selection buttons **CH 1** through **CH 4** on the right side of the display. Or press **MORE** and select a math or reference waveform from the More menu.
2. Press **ZOOM**.

   Press **ZOOM → Mode** (main) **→ ON** (side). The ZOOM front-panel button should light up. Toggle **Dual Zoom** to **OFF** in the side menu.
3. Adjust the vertical zoom factor for the selected waveform using the vertical **SCALE** knob. Adjust the vertical position of the zoomed waveform using the vertical **POSITION** knob.
4. Adjust the horizontal zoom factor using the horizontal **SCALE** knob. Adjust the horizontal position of the zoomed waveform using the horizontal **POSITION** knob.

Depending on the selection for Horizontal Lock in the side menu, Zoom affects the displayed waveforms as follows:

None — only the waveform currently selected can be magnified and positioned horizontally (Figure 3–25).

Live — all "live" (as opposed to reference) waveforms can be magnified and positioned horizontally at the same time. If a *reference* or *math* waveform is selected and Horizontal Lock set to Live, only the selected reference or math waveform is magnified and positioned.

All — all waveforms displayed (live, math, and reference) can be magnified and positioned horizontally at the same time.

5. Press **ZOOM → Lock** (main) **→ All**, **Live**, or **None** (side).

NOTE*. Although Zoom must be turned on to control which waveforms Zoom affects, the setting for Horizontal Lock affects which waveforms the horizontal control positions whether Zoom is on or off. The rules for the three settings are listed in step 4 on page 3–54.*

Only the selected waveform (the top one) changes size.

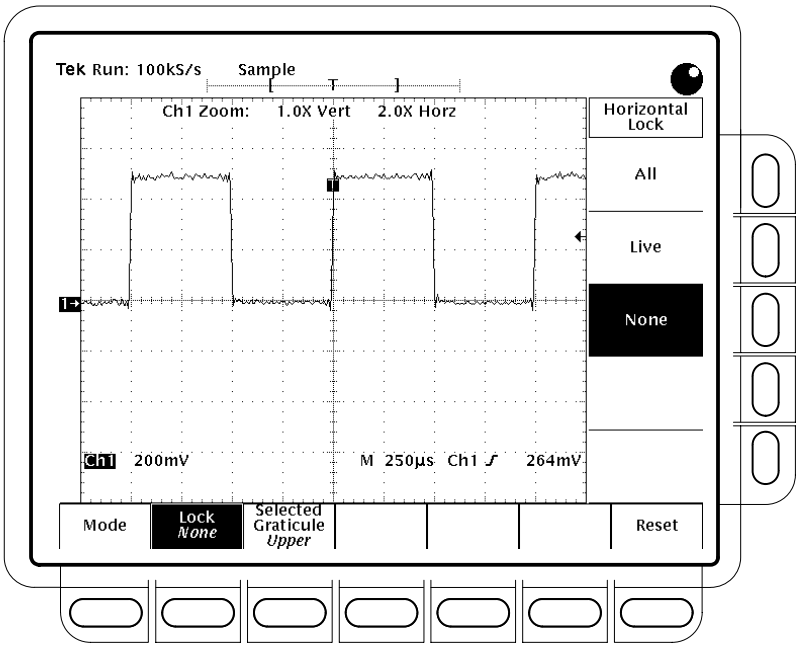


Figure 3–25: Zoom Mode with Horizontal Lock Set to None

Set Interpolation

To change the interpolation method used, press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Filter** (main) → **Sin(x)/x Interpolation** or **Linear Interpolation** (side).

Reset Zoom

To reset all zoom factors to their defaults, do the following step:

Press **ZOOM → Reset** (main) → **Reset Live Factors** or **Reset All Factors** (side). Reset Live Factors resets only for live waveforms, as opposed to reference waveforms; Reset All Factors resets for all waveforms.

Using Dual Window Mode

The oscilloscope can display and control a waveform that is both zoomed and unzoomed (magnified and unmagnified). To do so, it creates two 1/2 height graticules, or windows, and displays the magnified waveform in the upper, and the unmagnified waveform in the lower graticule. To use Dual Window Zoom (also called zoom preview mode), do the following steps:

1. Press **Zoom → Mode** (main) → **Preview** (side). Note that the oscilloscope displays the box-enclosed area on the waveform as magnified in the top graticule. (See Figure 3–26.)

2. To scale or position the *unmagnified* waveform, press **Selected Graticule** (main) → **Lower** (side). Use the vertical and horizontal knobs to scale and position the unmagnified waveform in the box.

   Note that as you scale or move the unmagnified waveform relative to the box, the oscilloscope alters the magnified display accordingly to include only the waveform portion within the box.

3. To scale or position the *magnified* waveform, press **Selected Graticule** (main) → **Upper** (side). Use the vertical and horizontal knobs to scale and position the magnified waveform.

   Note that as you scale or move the magnified waveform, the oscilloscope scales or moves the box relative to the unmagnified waveform, so the box encloses only the waveform portion magnified in the upper graticule.

   In Dual Window Zoom mode, the oscilloscope does not display the zoom magnification factors; however, it does display the scale factors (volts/division and time/division) for the zoomed waveform.

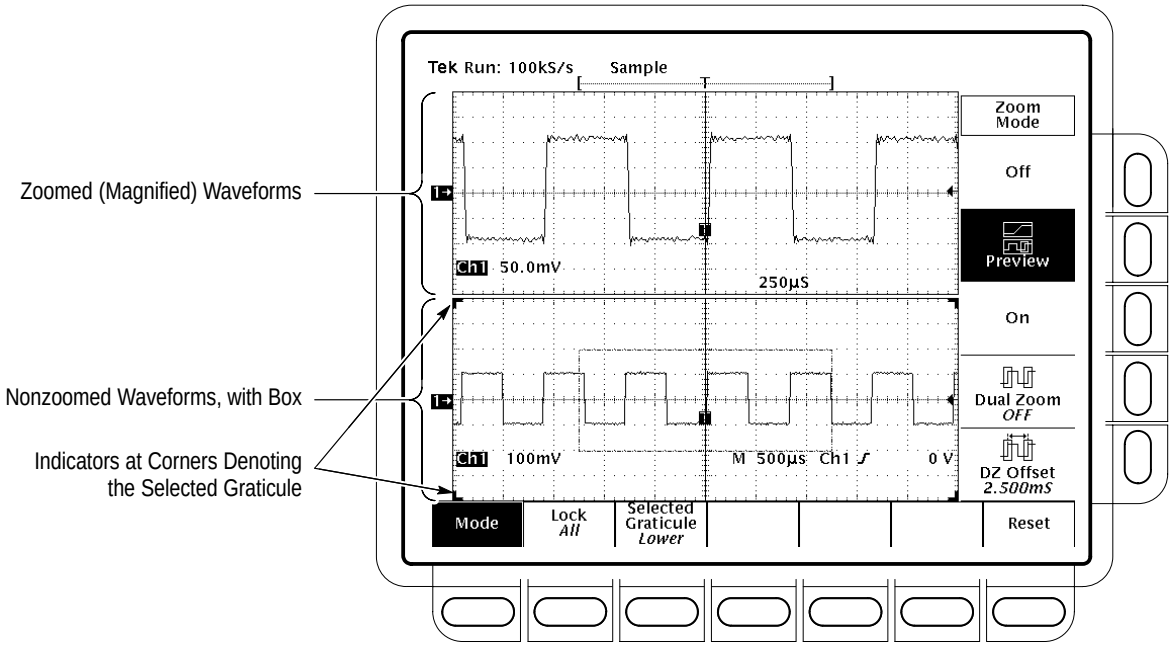


Figure 3–26: Dual Window (Preview) Mode

Dual Zoom a Waveform

To select Dual Zoom, press **ZOOM → Mode** (main) **→ Dual Zoom** (side) to toggle it to **ON**. (See Figure 3–27.)

Dual zoom displays a second zoomed view of the selected unzoomed waveform. The second zoomed view is offset in time from the first zoomed view. Also, zoom must be enabled (side menu set to On or Preview) to see the Dual Zoom displays.

To Set Dual Zoom Offset

To set the offset in time of the second zoomed waveform from the first, press **ZOOM → Mode** (main) **→ Dual Zoom Offset** (side). Then turn the general purpose knob or use the keypad to set the offset.

Dual Zoom offset is always positive. The oscilloscope sets the offset as close to the requested value as possible. An offset request of 0.0 insures that the zoom boxes are butted up against each other, regardless of the zoom factor.

The horizontal zoom and scale factors determine the minimum offset time available. Both zoom boxes always enclose equal amounts of time with the second box always offset from the first by a time equal to one box. Doubling the zoom factor halves the time enclosed by either box and, therefore, halves the minimum offset time.

The oscilloscope retains any value input that is less than the minimum time available as a "request" *if you enter that value using the keypad.* Increasing the zoom factor or decreasing the horizontal scale to a setting that allows the requested value sets offset time to that value. You cannot set offset to less than the minimum offset time available when using the general purpose knob.

NOTE. *To make setting up Dual Zoom easier, turn on Preview in the side menu. In this dual-window mode, the zoomed display appears in the top graticule, while the lower graticule shows the two zoomed portions enclosed in two boxes on the unzoomed waveform. Adjusting offset moves the right box relative to the left box, which remains stationary. The associated zoomed waveform in the upper graticule moves to track the offset changes. You can also adjust the waveform relative to the zoom boxes by selecting the lower graticule and adjusting the vertical and horizontal control knobs. See* Using Dual Window Mode *on page 3–56.*

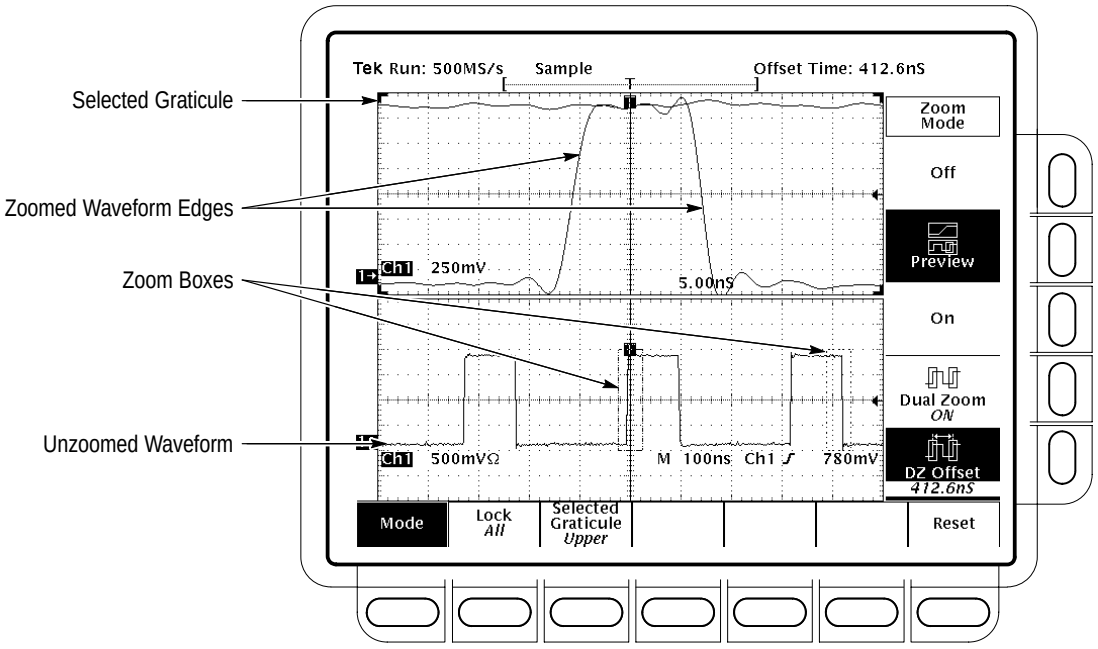


Figure 3–27: Dual Zoom — Shown Dual Window (Preview) Mode

Using DPO Acquisition Mode

The TDS 500D and 700D Oscilloscopes can use DPO acquisition mode to produce a display that provides intensity information. DPO acquisition mode reduces the dead time between waveform acquisitions that normally occur when digitizing storage oscilloscopes (DSOs) acquire waveforms. This dead-time reduction enables DPO mode to capture and display transient deviations, such as glitches or runt pulses, often missed during longer dead times that accompany normal DSO operation. DPO mode can also display waveform phenomena at an intensity that reflects their rate-of-occurrence.

DPO XY and XYZ modes also provide intensity information by accepting continuous, non-triggered data from the input channels. This section describes how to use DPO mode and how it differs from normal acquisition mode.

DPO automatically selects record length and sample rate to optimize the displayed image. DPO selects sample rates up to 1 GS/s and record lengths up to 500 K and compresses them to 500 pixels to produce the maximum display content.

Waveform Capture Rate

Figures 3–28, 3–29, and 3–30 illustrate how DPO acquisition mode differs from the normal acquisition mode used by digital storage oscilloscopes. Note that normal mode follows a "capture waveform–digitize waveform–update waveform memory–display waveform" cycle. Normal mode misses short term deviations occurring during the long dead times. Typical waveform capture rates are 50 waveforms per second.

DPO mode increases the waveform capture rate to up to 200,000 waveforms per second (maximum waveform rate depends on oscilloscope model), updating the waveform array many times between displays. This very fast capture rate greatly increases the probability that runts, glitches, and other infrequent events will accumulate in waveform memory. The oscilloscope then displays the waveform at the normal display rate using variable or infinite persistence and adjustable or automatic brightness. You can control how long the waveform persists on screen by selecting variable persistence and setting a decay constant. To display only the most recent acquisition, select No Persistence.

DPO adds intensity or gray scale information, like an analog oscilloscope, to each point in the waveform array. The waveform array is a two dimensional array of display pixels. Display pixel values are incremented each time they are written by a waveform acquisition. Pixels may saturate or overflow if the database is not reset soon enough. When saturation occurs is a function of the depth of the array for each pixel, the trigger rate, and how stable or consistent the acquisition data is. The more consistent the data, the more often a given data location will be incremented and the sooner it will saturate. To set the depth of the waveform array, see *To Set the Accumulation Depth* on page 3–64.

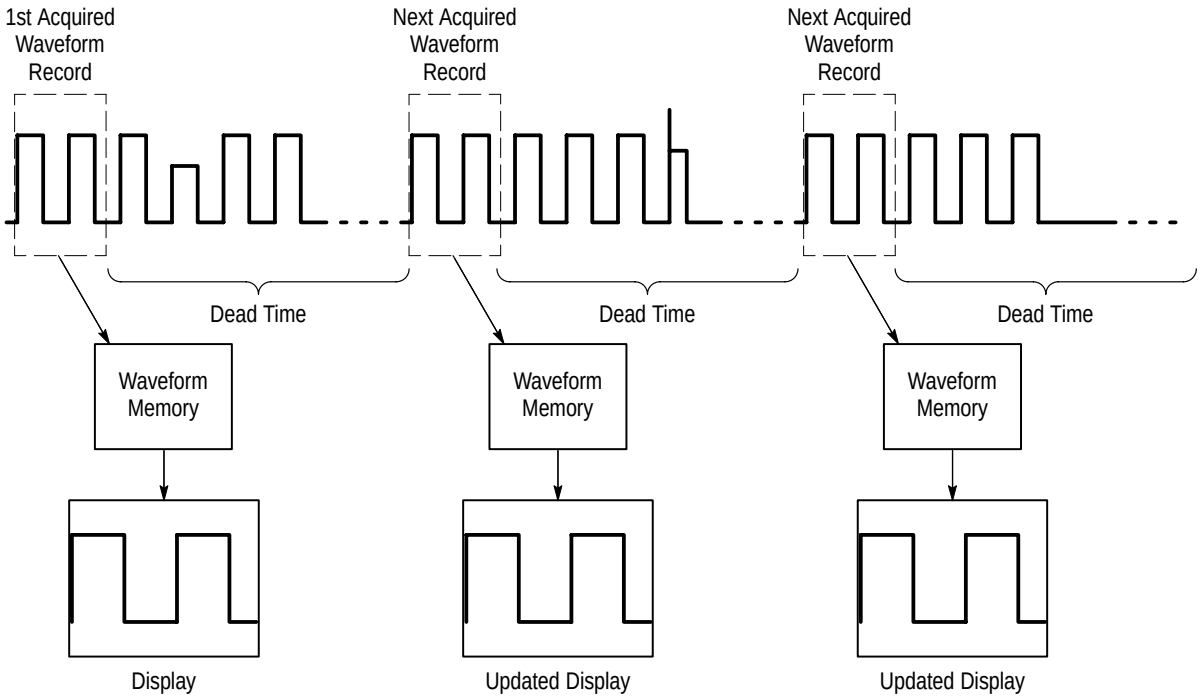
To Use DPO Mode

To turn on DPO mode, do *one* of the following steps:

1. Press the front-panel button **DPO**.
2. Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main). Push **Mode** again to toggle to DPO mode.
3. Press **SAVE/RECALL SETUP → Recall Factory With DPO** (main) → **OK Confirm DPO Init** (side) to recall the DPO factory setup.

To turn DPO off, press **DPO**. Alternatively, press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main), and then press **Mode** again to toggle to Normal mode.

Normal DSO Mode



DPO Mode

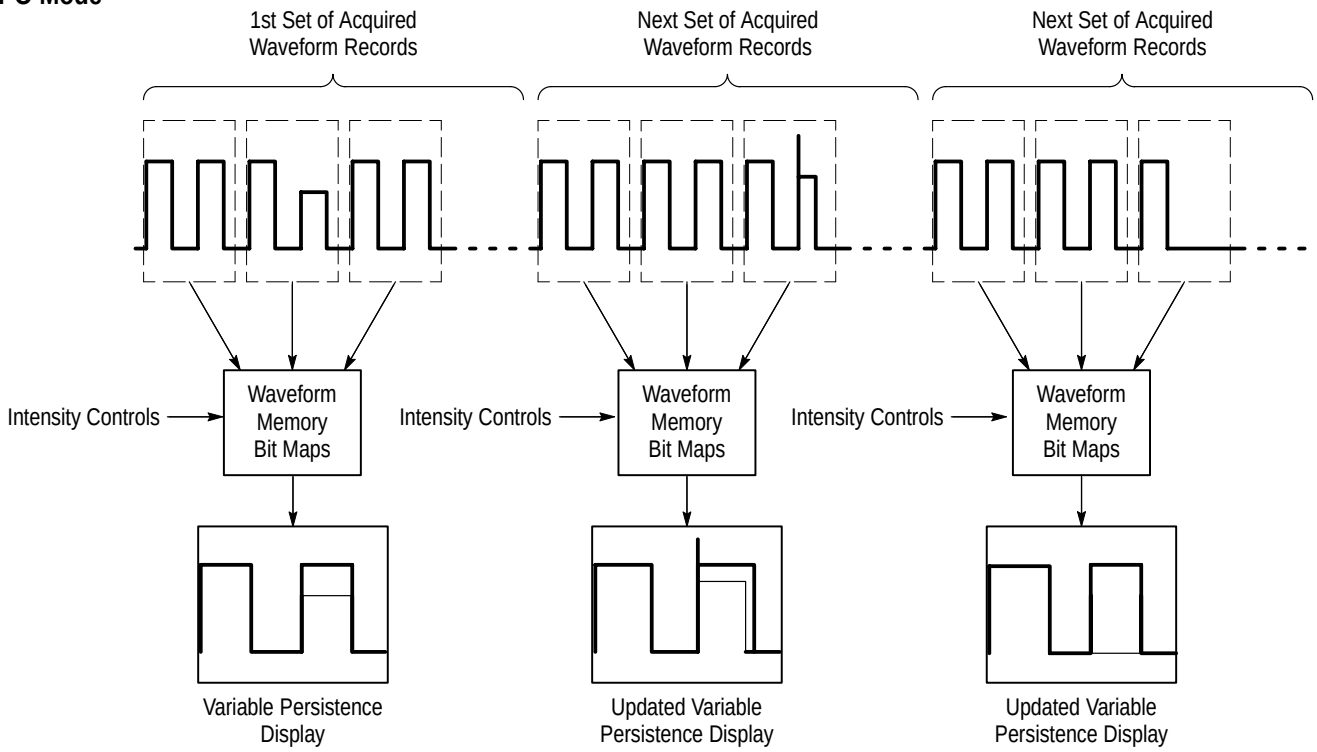


Figure 3–28: Normal DSO Acquisition and Display Mode Versus DPO Mode

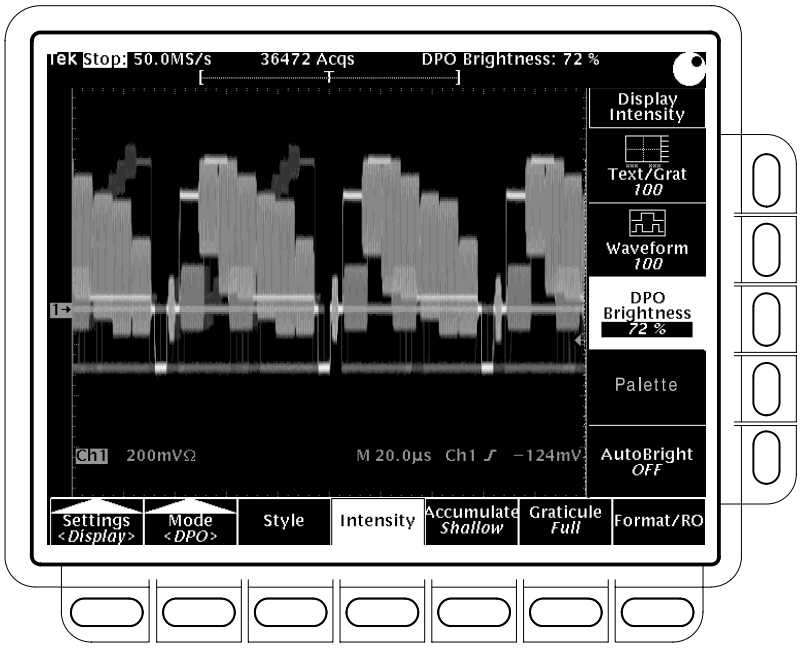


Figure 3–29: DPO Display

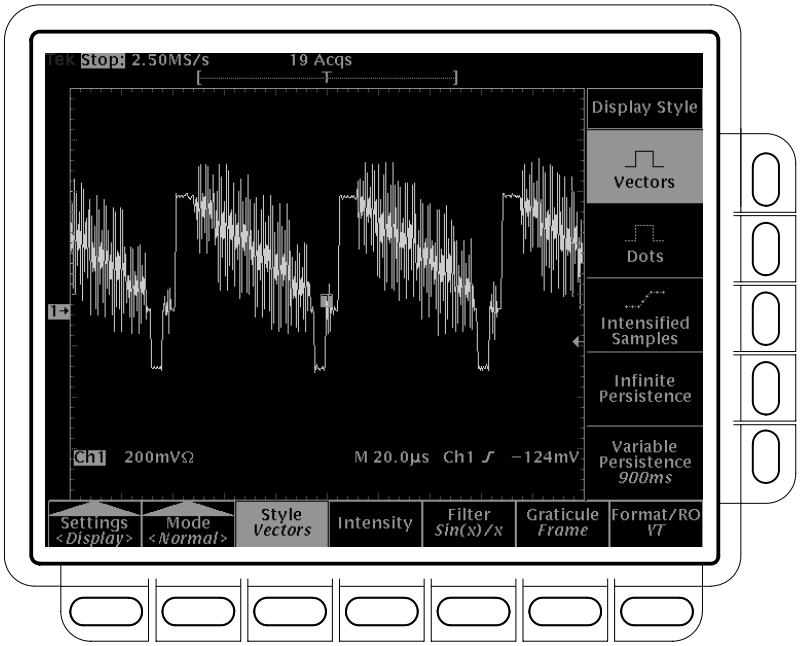


Figure 3–30: Normal DSO Display

To Set the DPO Style

To change the DPO display style, do the following steps:

1. Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **DPO** (pop-up) → **Style** (main).
2. Select between **Vectors** and **Dots** in the side menu. (Dots display is the factory default setting.)
3. Select between **Infinite Persistence**, **Variable Persistence**, and **No Persistence** in the side menu. (Variable Persistence is the factory default setting.)

   Infinite and variable persistence are explained on page 3–41. The No Persistence setting is available only in DPO mode. No Persistence erases the display each time a new waveform array is displayed.
4. If you select **Variable Persistence**, use the general purpose knob or keypad to adjust the persistence time (decay rate).

To Set the DPO Readout Options

To change the DPO readout options, do the following steps:

1. Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **DPO** (pop-up) → **Format/RO** (main).
2. Toggle **Display T @ Trigger Point**, **Trigger Bar Style** and **Display Date/Time** in the side menu to the settings desired.

To Adjust the Intensity

DPO adds two intensity settings that set the brightness of displayed images. To set the intensity do the following steps:

1. Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Intensity** (main) → **DPO Brightness** (side). Enter the intensity value with the keypad or the general purpose knob. The control is ignored if Color Mapping is set to Percentages. Higher brightness settings result in less frequent events being more easily seen.
2. To automatically set the brightness maximum to the value of the most frequent event, press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Intensity** (main). Then toggle **AutoBright** (side) to **ON**. Off lets the displayed brightness depend on the trigger rate, creating a display like an analog oscilloscope.

To Set the Accumulation Depth

Accumulation Depth determines the length of counters in the waveform array that record the number of times acquisition signals occur at a display pixel. DPO, Mask Counting, and Histogram modes use the counters. In DPO mode, the accumulated numbers and the intensity controls determine the gray-scale information for each displayed pixel.

To set the accumulation depth, do the following steps:

1. Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **DPO** (pop-up) → **Accumulate** (main).
2. Select between **Shallow** and **Deep** in the side menu. (Shallow is the default setting.)

Selecting shallow allows the image to saturate faster. Shallow sets the accumulation depth to 21 bits or, if histograms or mask counting is active, 32 bits. Deep sets the accumulation depth to 64 bits. Accumulation depths greater than 21 bits reduce the screen update rate, disable Variable Persistence and No Persistence, and enable Save/Recall of the Image Array.

Select the Format

The oscilloscope displays DPO waveforms in one of three formats: YT, XY, or XYZ. To set the display axis format:

Press **DISPLAY → Settings** (main) → **Display** (pop-up) → **Mode** (main) → **DPO** (pop-up) → **Format/RO** (main) → **XY**, **YT**, or **XYZ** (side).

YT is the conventional oscilloscope display format. It shows a signal voltage (the vertical axis) as it varies over time (the horizontal axis).

XY format compares the voltage levels of two waveform records point by point (see Figure 3–31). That is, the oscilloscope displays a graph of the voltage of one waveform record against the voltage of another waveform record. This mode is particularly useful for studying phase relationships. XY format is not triggered. When you set the VERTICAL POSITION and Vertical Offset to center the display in YT mode, the XY display is at center screen, and each division of display in YT mode produces a division of display in XY mode.

When you choose the XY format, any channel or reference displayed is assigned to the axis indicated in Table 3–6 and displayed as part of an XY pair. If only one source in an XY pair is displayed, the oscilloscope automatically turns on the other source to complete the XY pair. Moreover, once XY is on, selecting either source in a pair turns the pair on; pressing WAVEFORM OFF for either source in the pair removes both sources from the display.

If in DPO and XY or XYZ, masks and histograms are allowed.

Table 3–6: DPO XY Format pairs

XY Pair	X-Axis source	Y-Axis source
Ch 1 and Ch 2	Ch 1	Ch 2
Ch 3 and Ch 4 (Ax1 and Ax2)	Ch 3 (Ax1)	Ch 4 (Ax2)
Ref 1 and Ref 2	Ref 1	Ref 2
Ref 3 and Ref 4	Ref 3	Ref 4

XYZ format compares the voltage levels of the CH 1 (X) and CH 2 (Y) waveform records point by point as in XY format. The displayed waveform intensity is modulated by the CH 3 (Z) waveform record. XYZ format is not triggered. XYZ format is not available on 2+2 channel oscilloscopes. A –5 division signal (including position and offset) on CH 3 produces a blank screen; a +5 division signal produces full intensity.

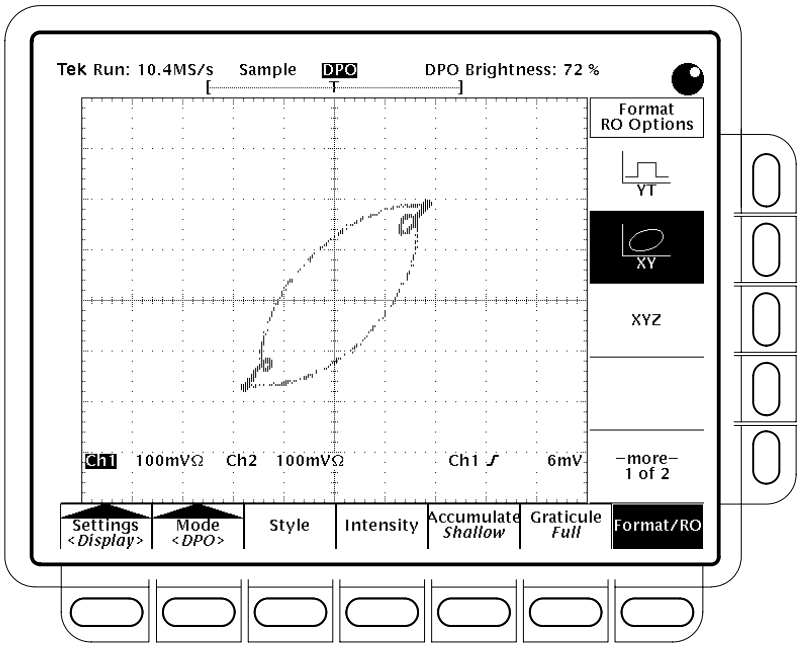


Figure 3–31: DPO XY Display

HORIZONTAL controls are ignored in DPO XY and XYZ.

XY format is a dot-only display, although it can have persistence. The Vector style selection has no effect when you select XY format.

Incompatible Modes

Several modes/features are unavailable when DPO mode is selected:

- FastFrame, Limit Testing, Extended Acquisition, and Zoom modes
- Envelope, Average, Hi Res, and Single Acquisition Sequence acquisition modes and Autosave mode
- Intensified time base
- Record lengths longer than 500 samples
- Interpolation (equivalent time sampling is used instead)
- Vectors when in equivalent time mode (waveforms are displayed as Dots instead). (To determine under what conditions the oscilloscope normally interpolates or uses equivalent time, see *Selecting Repetitive Sampling* on page 3–36.)
- Math waveforms
- Measurements on channels when in DPO XY or XYZ
- AMI triggers are allowed, but display invalid isolated one trailing edges
- Plot hardcopy formats
- Horizontal positioning is ignored

If you select any of these modes before or while DPO is on, they will remain selected in their respective menus, but the oscilloscope will ignore them. It will put the modes into effect when you turn DPO off. If the oscilloscope setup is not as you expect when you turn DPO off, this may be because the oscilloscope quit ignoring these DPO incompatible modes.

DPO mode disallows selection of Math waveforms. If you attempt to select a math waveform from the MORE menu, the oscilloscope will display an error message. Either switch DPO off and create the math waveform, or select a channel waveform and continue using DPO mode.

DPO displays using a persistence display style (see display menu). If you select Intensified time base, the intensified zone is controlled by Horizontal Scale and Delay time settings as when DPO is off, but the zone is masked by the persistence display mode and cannot be seen. Turn off DPO to display the intensified zone.

Using FastFrame™

You can define and enable FastFrame (TDS 500D and 700D models only). This feature lets you capture multiple acquisitions in the acquisition memory of a single channel. Figure 3–32 shows how FastFrame combines the desired captured records into one larger record. For example, FastFrame would let you store 10 records of 500 samples each into one record with a 5000 sample length.

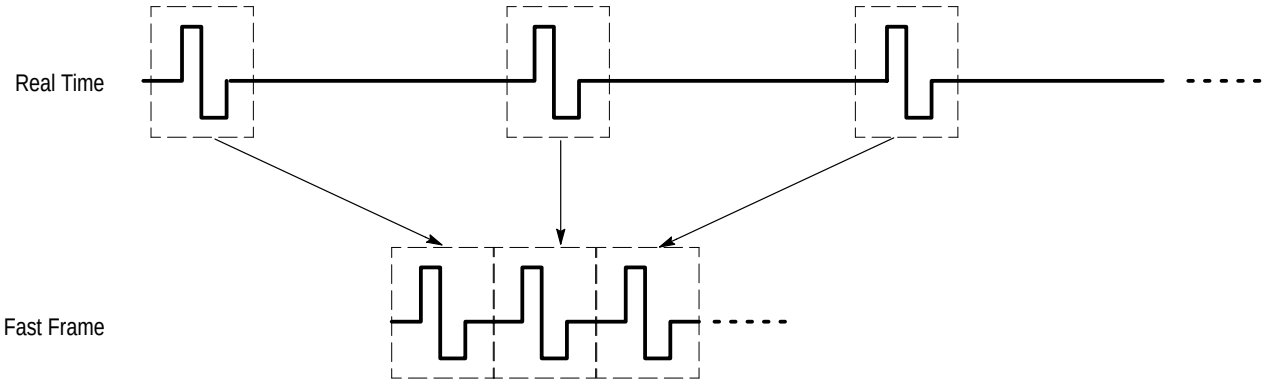


Figure 3–32: Fast Frame

If you are using the FastFrame mode, you can jump to the desired frame. To use FastFrame, do the following steps:

1. Press **HORIZONTAL MENU → FastFrame Setup** (main) **→ FastFrame** (side) to toggle on or off the use of FastFrame (see Figure 3–33).

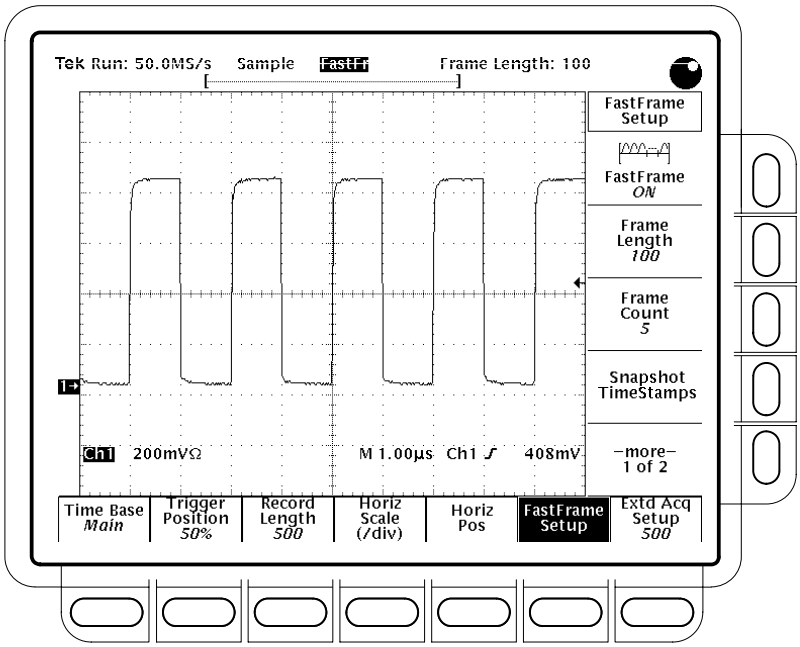


Figure 3–33: Horizontal Menu — FastFrame Setup

2. Press **Frame Length** or **Frame Count** (side) and use the general purpose knob to enter FastFrame parameters.

- Frame Length refers to the number of samples in each acquisition.
- Frame count refers to the number of acquisitions to store in the acquisition memory of the channel. The oscilloscope will set the record length to a value greater than or equal to the product of the frame count and the frame length. If the product exceeds the maximum available record length, the oscilloscope will reduce the frame length or frame count in size such that the product will fit the record length.

3. Press **Horiz Pos** (main), then **Frame** (side), and use the general purpose knob to enter the number of a specific frame to view. After you press **Enter**, that frame should appear on the display.

If you shift the waveform right or left with the front-panel **HORIZONTAL POSITION** knob, the window next to the side-menu **Frame** button will indicate the frame number of the waveform at the center of the screen.

Time Stamping Frames

Use TimeStamp to display the absolute trigger time for a specific frame and the relative time between triggers of two specified frames. To start FastFrame TimeStamp, do the following steps:

1. Turn on FastFrame as described starting on page 3–68.
2. To select the Reference Frame, press **HORIZONTAL → FastFrame Setup** (main) **→ Reference Frame** (side). Then use the general purpose knob or the keypad to select the reference frame. This value sets the starting frame when measuring the relative time between two frames.
3. To select the Position Frame, press **HORIZONTAL → FastFrame Setup** (main) **→ Position Frame** (side). Then use the general purpose knob or the keypad to select the position frame. This value sets the ending frame when measuring the relative time between two frames.
4. To lock the reference and position frames together, press **HORIZONTAL → FastFrame Setup** (main). Then toggle **Lock Frames** (side) to **ON**. If ON, they maintain the same relative distance from each other when either frame is adjusted.
5. To turn TimeStamp on, press **HORIZONTAL → FastFrame Setup** (main). Then toggle **TimeStamp** (side) to **ON** (see Figure 3–35).

The displayed time uses the following format:

@Pos: xxx	Position (or reference) frame number
DD MMM YYYY	Date (day, month, and year)
HH:MM:SS.mmm,	Clock time (hours, minutes, seconds, and milliseconds)
μμμ,nnn,ppp	Fraction of a second (to picoseconds)

View all Time Stamps

To display a list of all time stamps in the current acquisition relative to the reference frame time stamp (see Figure 3–34), press **HORIZONTAL → FastFrame Setup** (main) **→ Snapshot** (side).

The first column shows the delta time between the reference frame (frame 6 in the figure) and every other frame. The second column shows the delta time between each frame and its predecessor. To take another measurement, press **Again** (side). As you scroll the list, the position frame will track the scroll bar location.

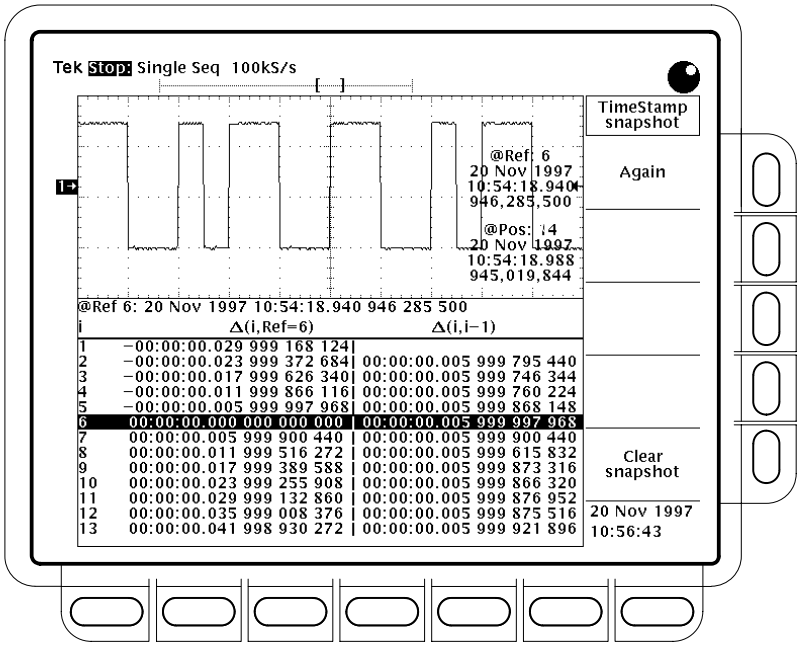


Figure 3–34: Horizontal Menu — FastFrame Snapshot

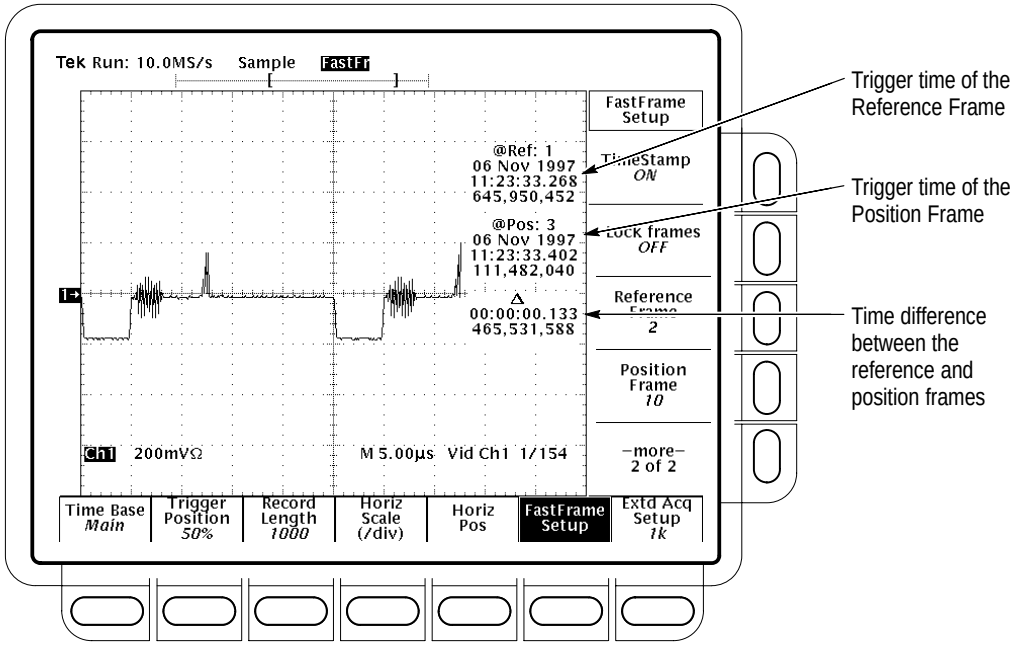


Figure 3–35: FastFrame TimeStamp

FastFrame Operating Characteristics

Consider the following operating characteristics when using FastFrame:

- Envelope, Average, and Hi Res form the envelope or average following the last frame of the concatenated record. For example, if Average or Hi Res acquisition modes are selected and the frame count is 10, segments 1 through 10 will show Sample or Hi Res frames, and frame 11 will show the average of frames 1 through 10. If there is not room for one additional frame, the envelope or average of the frames replaces the display of the last acquired frame. Average and envelope counts have no affect in FastFrame.
- You can press **RUN/STOP** to terminate a FastFrame sequence. If any frames were acquired, they are displayed. If no frames were acquired, the previous FastFrame waveform is displayed.
- Because FastFrame waveforms contain many triggers, trigger position indicators are removed from both the waveform and the record view when the selected channel, reference, or math waveform is a FastFrame waveform.
- In Equivalent Time, the oscilloscope ignores FastFrame mode.

- Because FastFrame introduces additional processing time into the operation cycle of acquire, process, and display, its best to use Single Sequence Acquisition (see Acquire menu, Stop After menu). With Single Sequence selected, you will see the current acquisition sequence; otherwise, the display lags the current sequence by one sequence. You can also see the current sequence by pressing the RUN/STOP button to stop the acquisition.
- TimeStamp uses the measurement readouts; therefore, turning on FastFrame TimeStamp turns off Measurements and vice versa.

Triggering on Waveforms

To use the TDS Oscilloscope to measure or monitor waveforms, you need to know how to trigger a stable display of those waveforms. Toward that end, this section first covers the following topics:

- *Trigger Concepts* which details some basic principles of triggering and describes triggering elements: *type*, *source*, *coupling*, *holdoff*, *mode*, and so on
- *Triggering from the Front Panel* which describes how to use the front-panel triggering controls each of which is common to most, if not all, the trigger types the oscilloscope provides

Once these basics are covered, this section describes how to trigger using the various trigger types provided by the Main trigger system: *edge, logic,* and *pulse.*

- To use the "general purpose" trigger type, edge, see *Triggering on a Waveform Edge* on page 3–82.
- To logic trigger based on an input pattern, state, or setup/hold violation, see *Triggering Based on Logic* on page 3–86.
- To pulse trigger based on various pulse types (glitch, runt) or their parameters (width, slew rate) see *Triggering on Pulses* on page 3–99.
- To trigger on communication signals (TDS 500D and 700D Option 2C models only) see *Communications Triggering* on page 3–113.

This section concludes with details about and instructions for using the *Delayed time base* and *Delayed trigger system* to delay the acquisition of a waveform relative to a trigger event. (See *Delayed Triggering* on page 3–117.)

Triggering Concepts

Triggers determine when the oscilloscope stops acquiring and displays a waveform. They help create meaningful waveforms from unstable jumbles or blank screens. (See Figure 3–36.) The oscilloscope has five types of triggers: edge, logic, pulse, and with option 2C, comm, and, with option 05, video.

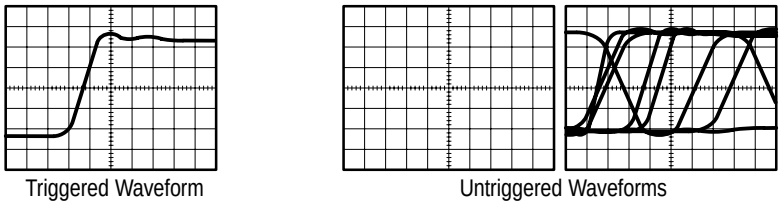


Figure 3–36: Triggered Versus Untriggered Displays

The Trigger Event

The trigger event establishes the time-zero point in the waveform record. All points in the record are located in time with respect to that point. The oscilloscope continuously acquires and retains enough sample points to fill the pretrigger portion of the waveform record (that part of the waveform that is displayed *before*, or to the left of, the triggering event on screen). When a trigger event occurs, the oscilloscope starts acquiring samples to build the posttrigger portion of the waveform record (displayed *after*, or to the right of, the trigger event). Once a trigger is recognized, the digitizing oscilloscope will not accept another trigger until the acquisition is complete.

Trigger Sources

You can derive your trigger from the following sources:

Input channels provide the most commonly used trigger source. You can select any one of the four input channels. The channel you select as a trigger source will function whether it is displayed or not.

AC ∿

AC Line Voltage is the trigger source most often used when you are looking at signals related to the power line frequency. Examples include devices such as lighting equipment and power supplies. Because the oscilloscope generates the trigger, you do not have to input a signal to create the trigger.

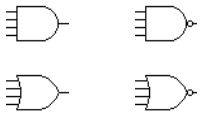
Auxiliary Trigger is the trigger source most often used in doing digital design and repair. For example, you might want to trigger with an external clock or with a signal from another part of the circuit. To use the auxiliary trigger, connect the external triggering signal to the Auxiliary Trigger input connector on the oscilloscope rear panel.

Trigger Types

The digitizing oscilloscope provides three standard triggers for the main trigger system: edge, pulse, and logic. Option 05 provides a video trigger. The standard triggers are described individually starting on page 3–82. A brief definition of each type follows:

Edge is the "basic" trigger. You can use it with both analog and digital test circuits. An edge trigger event occurs when the trigger *source* (the signal the trigger circuit is monitoring) passes through a specified voltage level in the specified direction (the trigger slope).

Pulse is a special-purpose trigger primarily used on digital circuits. The five classes of pulse triggers are *glitch, runt, width, slew rate* and *timeout*. Pulse triggering is available on the main trigger only.



Logic is a special-purpose trigger primarily used on digital logic circuits. Two of the classes, *pattern* and *state,* trigger based on the Boolean operator you select for the trigger sources. Triggering occurs when the Boolean conditions are satisfied. A third class, *setup/hold,* triggers when data in one trigger source changes state within the setup and hold times that you specify relative to a clock in another trigger source. Logic triggers are available on the main trigger system only.

Comm (available as option 2C) is a special trigger used on communication signals. See tables 3–9 and 3–10, starting on page 3–113, for a list of supported codes, standards and pulse forms.

Video (available as option 05) is a special trigger used on video circuits. It helps you investigate events that occur when a video signal generates a horizontal or vertical sync pulse. Supported classes of video triggers include *NTSC*, *PAL*, *SECAM*, and high definition TV signals.

Trigger Modes

The trigger mode determines how the oscilloscope behaves in the absence of a trigger event. The oscilloscope provides two trigger modes, *normal* and *automatic*.

Normal trigger mode enables the oscilloscope to acquire a waveform only when it is triggered. If no trigger occurs, the oscilloscope will not acquire a waveform. (You can push FORCE TRIGGER to force the oscilloscope to make a single acquisition.)

Automatic trigger mode (auto mode) enables the oscilloscope to acquire a waveform even if a trigger does not occur. Auto mode uses a timer that starts after a trigger event occurs. If another trigger event is not detected before the timer times out, the oscilloscope forces a trigger anyway. The length of time it waits for a trigger event depends on the time base setting.

Be aware that auto mode, when forcing triggers in the absence of valid triggering events, does not sync the waveform on the display. In other words, successive acquisitions will not be triggered at the same point on the waveform; therefore, the waveform will appear to roll across the screen. Of course, if valid triggers occur the display will become stable on screen.

Since auto mode will force a trigger in the absence of one, auto mode is useful in observing signals where you are only concerned with monitoring amplitude level. Although the unsynced waveform may "roll" across the display, it will not freeze as it would in normal trigger mode. Monitoring of a power supply output is an example of such an application.

Trigger Holdoff

When the oscilloscope recognizes a trigger event, it disables the trigger system until acquisition is complete. In addition, the trigger system remains disabled during the holdoff period that follows each acquisition. You can set holdoff time to help ensure a stable display.

For example, the trigger signal can be a complex waveform with many possible trigger points on it. Though the waveform is repetitive, a simple trigger might get you a series of patterns on the screen instead of the same pattern each time.

A digital pulse train is a good example of a complex waveform. (See Figure 3–37.) Each pulse looks like any other, so many possible trigger points exist. Not all of these will result in the same display. The holdoff period allows the oscilloscope to trigger on the correct edge, resulting in a stable display.

Holdoff is settable from 250 ns (minimum holdoff available) to 12 seconds (maximum holdoff available). To see how to set holdoff, see *To Set Mode & Holdoff* on page 3–85.

You can also set a default holdoff. The default hold is the "general purpose" holdoff for most triggering signals and varies with the horizontal scale. It is equal to 5 divisions times the current time/division settings.

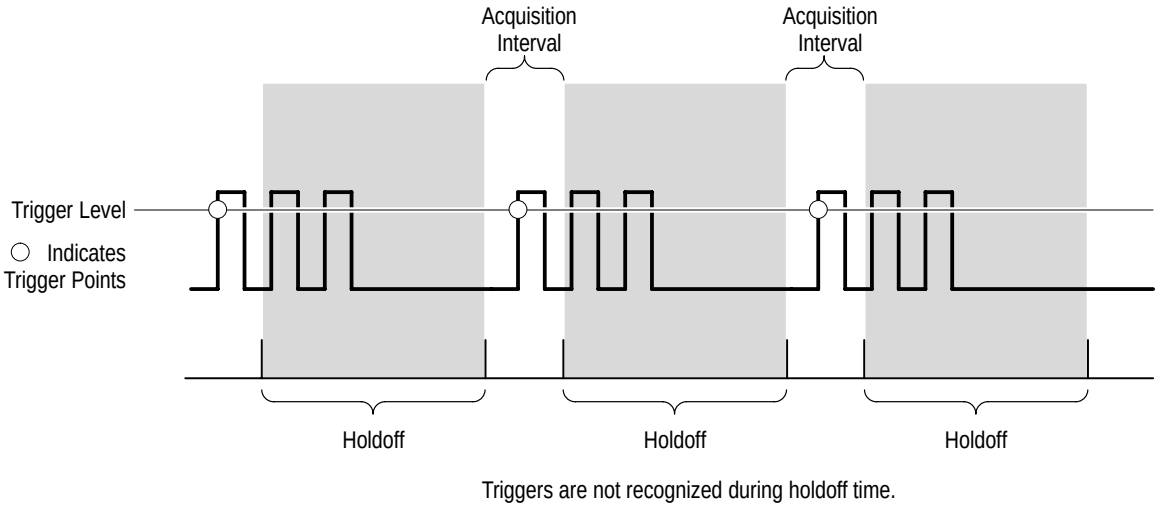


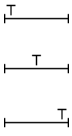
Figure 3–37: Trigger Holdoff Time Ensures Valid Triggering

Trigger Coupling

Trigger coupling determines what part of the signal is passed to the trigger circuit. All trigger types except edge triggering use only DC coupling; edge triggering can use all available coupling types: AC, DC, Low Frequency Rejection, High Frequency Rejection, and Noise Rejection: See *To Specify Coupling* on page 3–84 for a description of each coupling mode.

Trigger Position

The adjustable feature *trigger position* defines where on the waveform record the trigger occurs. It lets you properly align and measure data within records. The part of the record that occurs *before* the trigger is the pretrigger portion. The part that occurs *after* the trigger is the posttrigger portion.



To help you visualize the trigger position setting, the top part of the display has an icon indicating where the trigger occurs in the waveform record. You select in the Horizontal menu what percentage of the waveform record will contain pretrigger information.

Displaying pretrigger information can be valuable when troubleshooting. For example, if you are trying to find the cause of an unwanted glitch in your test circuit, it might trigger on the glitch and make the pretrigger period large enough to capture data before the glitch. By analyzing what happened before the glitch, you may uncover clues about its source.

Slope and Level

The slope control determines whether the oscilloscope finds the trigger point on the rising or the falling edge of a signal. (See Figure 3–38.)

You set trigger slope by first selecting Slope in the Main Trigger menu and then selecting between the rising or falling slope icons in the side menu that appears.

The level control determines where on that edge the trigger point occurs. (See Figure 3–38.) The oscilloscope lets you set the main trigger level with the trigger MAIN LEVEL knob.

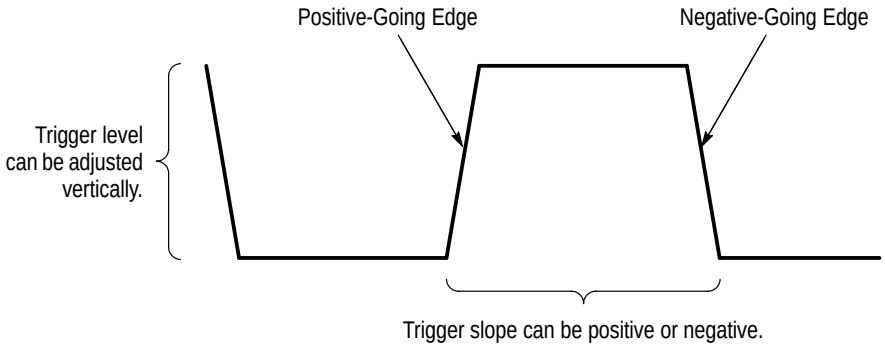


Figure 3–38: Slope and Level Controls Help Define the Trigger

Delayed Trigger System

The oscilloscope also has a delayed trigger system that provides an edge trigger (no pulse or logic triggers). When using the delayed time base, you can also delay the acquisition of a waveform for a user-specified time or a user-specified number of delayed trigger events (or both) after a main trigger event. See *Delayed Triggering* on page 3–117 to learn how to use delay.

Triggering from the Front Panel

The trigger buttons and knob let you quickly adjust the trigger level or force a trigger. (See Figure 3–39.) The trigger readout and status screen lets you quickly determine the state of the trigger system. You use the following trigger controls and readouts for all trigger types except where noted.

To set MAIN LEVEL

To manually change the trigger level when edge triggering (or certain threshold levels when logic or pulse triggering), turn the **MAIN LEVEL** knob. It adjusts the trigger level (or threshold level) instantaneously no matter what menu, if any, is displayed.

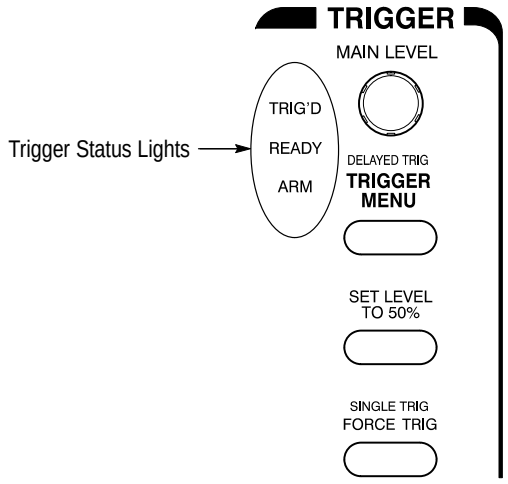


Figure 3–39: TRIGGER Controls and Status Lights

To Set to 50%

To quickly obtain an edge trigger or a glitch or width pulse trigger, press **SET LEVEL TO 50%**. The oscilloscope sets the trigger level to the halfway point between the peaks of the trigger signal. Set Level to 50% has no effect when trigger type is logic or video.

You can also set the level to 50% in the Trigger menu under the main menu item Level if edge trigger or glitch or width pulse trigger is selected.

Note that the MAIN LEVEL knob and menu items apply only to the main trigger level. To modify the delayed trigger level, use the Level item in the Delayed Trigger menu.

To Force a Trigger

To force the oscilloscope to immediately start acquiring a waveform record even without a trigger event, press the **FORCE TRIG** front panel button.

Forcing a trigger is useful when in normal trigger mode and the input signal is not supplying a valid trigger. By pressing FORCE TRIG, you can quickly confirm that there is a signal present for the oscilloscope to acquire. Once that is established, you can determine how to trigger on it (press **SET LEVEL TO 50%**, check trigger source setting, and so on).

The oscilloscope recognizes and acts upon FORCE TRIG even when you press it before the end of pretrigger holdoff. However, the button has no effect if the acquisition system is stopped.

To Single Trigger

To trigger on the next valid trigger event and then stop, press **SHIFT FORCE TRIG**. Now press the **RUN/STOP** button each time you want to initiate the single sequence of acquisitions.

To leave Single Trig mode, press **SHIFT ACQUIRE MENU → Stop After** (main) **→ RUN/STOP Button Only** (side).

See the description under *Stop After* on page 3–37 for further discussion of single sequence acquisitions.

(Single sequence triggering is not available in DPO mode; see *Incompatible Modes* on page 3–66.)

To Check Trigger Status

To ascertain the state and setup of the triggering circuit, use the *trigger status lights, readout,* and *screen.*

Trigger Status Lights. To quickly determine trigger status, check the three status lights **TRIG'D**, **READY**, and **ARM** in the Trigger control area. (See Figure 3–39.)

- When TRIG'D is lighted, it means the oscilloscope has recognized a valid trigger and is filling the posttrigger portion of the waveform.
- When READY is lighted, it means the oscilloscope can accept a valid trigger event and the oscilloscope is waiting for that event to occur.
- When ARM is lighted, it means the trigger circuitry is filling the pretrigger portion of the waveform record.
- When both TRIG'D and READY are lighted, it means the oscilloscope has recognized a valid main trigger and is waiting for a delayed trigger. When the oscilloscope recognizes a delayed trigger, it will fill in the posttrigger portion of the delayed waveform.
- When ARM, TRIG'D, and READY are all off, the digitizer is stopped.
- When ARM, TRIG'D, and READY are all lighted (TDS 500D and TDS 700D models only), FastFrame mode is in effect. No trigger status monitoring is taking place.

Trigger Readout. To quickly determine the settings of some key trigger parameters, check the Trigger readout at the bottom of the display. (See Figure 3–40.) The readouts differ for edge, logic, and pulse triggers.

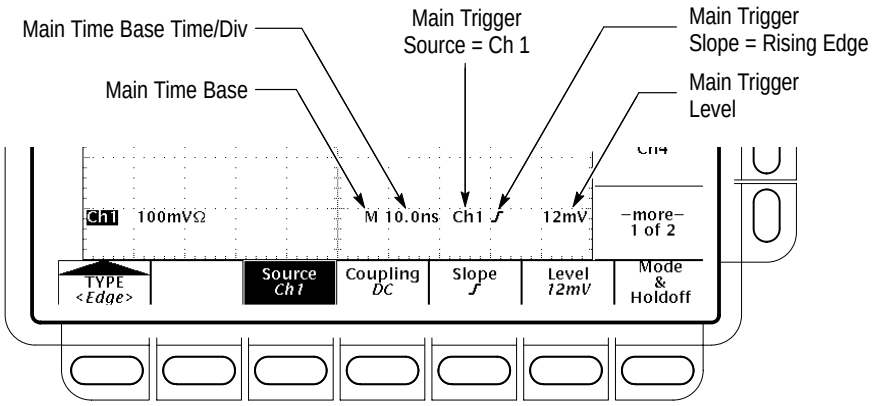


Figure 3–40: Example Trigger Readouts — Edge Trigger Selected

Record View. To determine where the trigger point is located in the waveform record and with respect to the display, check the record view at the top of the display. (See Figure 3–41.)

Trigger Position and Level Indicators. To see the trigger point and level on the waveform display, check the graphic indicators *Trigger Position* and *Trigger Bar.* Figure 3–41 shows the trigger point indicator and trigger level bar.

Both the trigger point indicator and level bar are displayed from the Display menu. See *Set Display Readout Options* on page 3–42 for more information.

The trigger point indicator shows position. It can be positioned horizontally off screen, especially with long record length settings. The trigger level bar shows only the trigger level. It remains on screen, regardless of the horizontal position, as long as the channel providing the trigger source is displayed.

Trigger Status Screen. To see a more comprehensive status listing of the settings for the main and delayed trigger systems, press **SHIFT STATUS → STATUS** (main) **→ Trigger** (side).

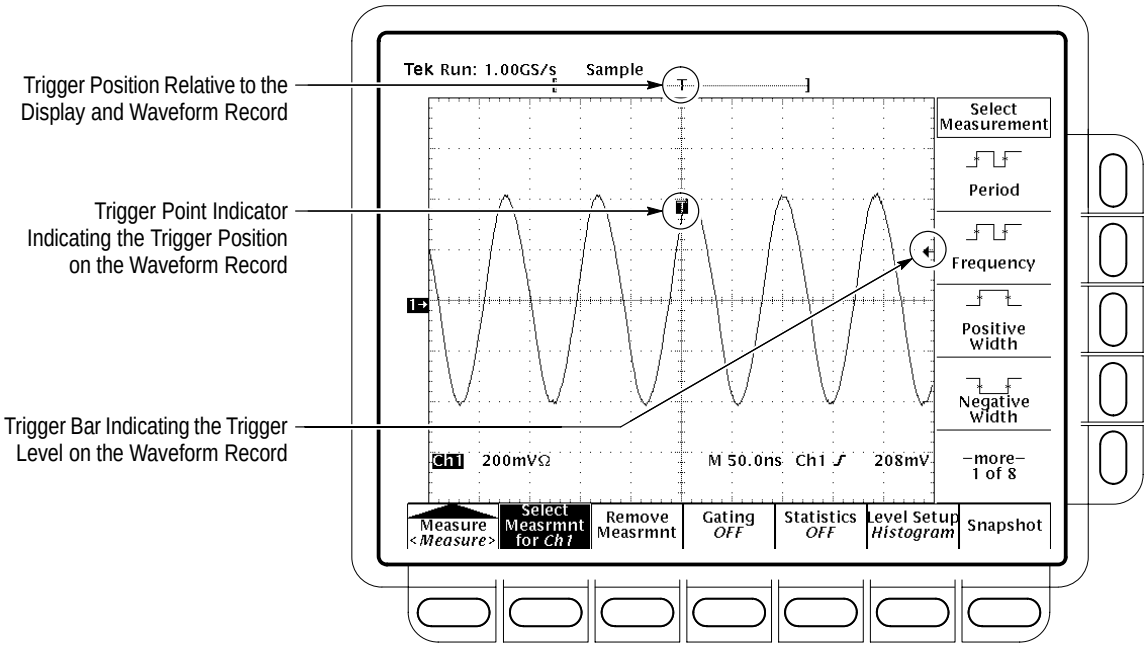


Figure 3–41: Record View, Trigger Position, and Trigger Level Bar Readouts

Trigger Menu

Each trigger type (edge, logic, and pulse) has its own main trigger menu, which is described as each type is discussed in this section. To select the trigger type, press **TRIGGER MENU → Type** (main) **→ Edge**, **Logic**, or **Pulse** (pop-up).

Triggering on a Waveform Edge

The TDS Oscilloscope can trigger on an edge of a waveform. An *edge trigger* event occurs when the trigger source passes through a specified voltage level in a specified direction (the trigger slope). You will likely use edge triggering for most of your measurements. This subsection describes how to use edge triggering — how to select edge type, source, coupling, slope, and level. It also details how to select trigger mode, auto or normal, for *all* trigger types.

To Check Edge Trigger Status

To quickly check if edge triggers are selected, check the Trigger readout. When edge triggers are selected, the trigger readout displays the trigger source, as well as the trigger slope and level. (See Figure 3–42.)

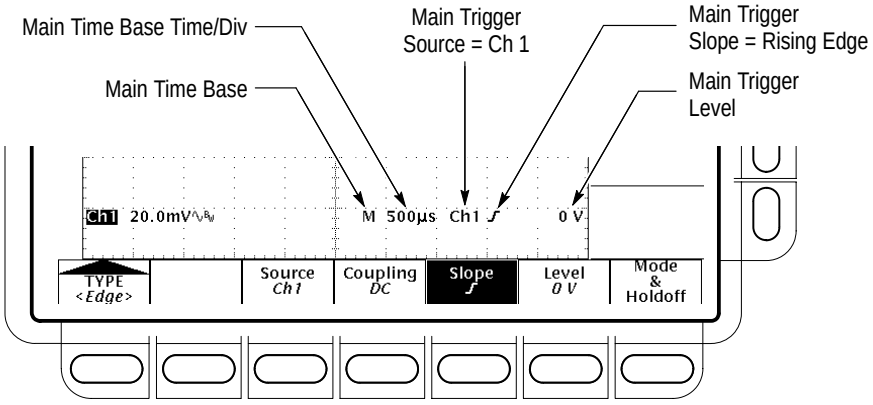


Figure 3–42: Edge Trigger Readouts

To Select Edge Triggering

Use the edge trigger menu to select edge triggering and to perform the procedures for source, coupling, slope, trigger level, mode, and holdoff that follow.

To bring up the Edge Trigger menu, press **TRIGGER MENU** → **Type** (main) → **Edge** (pop-up). (See Figure 3–43.)

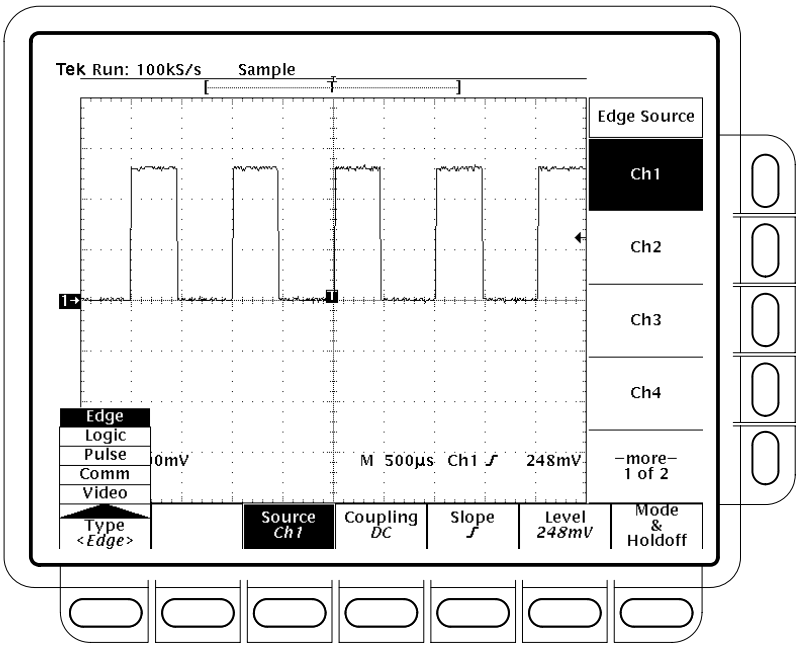


Figure 3–43: Main Trigger Menu — Edge Type

To Select a Source

To select which source you want for the trigger:

Press **TRIGGER MENU** → **Type** (main) → **Edge** (pop-up) → **Source** (main) → **Ch1**, **Ch2**, **Ch3**, **Ch4**, **AC Line**, or **DC Aux** (side).

To Specify Coupling

To select the coupling you want, press **TRIGGER MENU** → **Type** (main) → **Edge** (pop-up) → **Coupling** (main) → **DC**, **AC**, **HF Rej**, **LF Rej**, or **Noise Rej** (side).

DC passes all of the input signal. In other words, it passes both AC and DC components to the trigger circuit.

AC passes only the alternating components of an input signal. It removes the DC component from the trigger signal.

HF Rej removes the high frequency portion of the triggering signal. That allows only the low frequency components to pass on to the triggering system to start an acquisition. High frequency rejection attenuates signals above 30 kHz.

LF Rej removes the low frequency portion of the triggering signal. Low frequency rejection attenuates signals below 80 kHz.

Noise Rej provides lower sensitivity. Noise Rej requires additional signal amplitude for stable triggering, reducing the chance of falsely triggering on noise.

NOTE. *When you select Line as the trigger source, the oscilloscope uses AC coupling to couple a sample of the AC line voltage to the trigger circuits. Although trigger coupling can be set to other than AC when in Line, the oscilloscope ignores the setting until another source (one of Ch1 through Ch4) is selected.*

In similar fashion, when you select DC Aux (Rear Panel) as the trigger source, the oscilloscope uses DC coupling to couple an auxiliary signal to the trigger circuits. Although trigger coupling can be set to other than DC when in DC Aux, the oscilloscope ignores the setting until one of Ch1 through Ch4 is selected.

To Set Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu item. See *Trigger Modes* and *Trigger Holdoff* beginning on page 3–75 for a description of these features. To set mode and holdoff, do the following steps:

1. Press the **TRIGGER MENU → Mode & Holdoff** (main) → **Auto** or **Normal** (side). The modes operate as follows:

- In Auto mode the oscilloscope acquires a waveform after a specific time has elapsed even if a trigger does not occur. The amount of time the oscilloscope waits depends on the time base setting.
- In Normal mode the oscilloscope acquires a waveform only if there is a valid trigger.

2. To change the holdoff time, press **Holdoff** (side). Enter the value in time using the general purpose knob or the keypad.

If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light above the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the general purpose knob speeds up significantly.

You can set holdoff from 250 ns (minimum holdoff available) to 12 seconds (maximum available). See *Holdoff, Variable, Main Trigger* in the *TDS 500D, TDS 600B, & TDS 700D Oscilloscopes Performance Verification and Specifications* manual for typical minimum and maximum values.

3. To change to the factory default holdoff setting for the current horizontal scale setting, press **Default Holdoff** (side).

NOTE. *If you select Default Holdoff, the default holdoff time will vary with the horizontal scale setting to maintain a good value for general purpose triggering at that scale. However, if you select Holdoff (as opposed to Default Holdoff), the time set in the Holdoff menu item is used at all horizontal scale settings.*

To Set Slope

To select the slope that the edge trigger will occur on:

1. Press the **TRIGGER MENU → Type** (main) → **Edge** (pop-up) → **Slope** (main).

2. Select the rising or falling edge from the side menu.

To Set Level Press the **TRIGGER MENU → Type** (main) **→ Edge** (pop-up) **→ Level** (main) **→ Level**, **Set to TTL**, **Set to ECL**, or **Set to 50%** (side).

Level lets you enter the trigger level using the general purpose knob or the keypad.

Set to TTL fixes the trigger level at +1.4 V.

Set to ECL fixes the trigger level at –1.3 V.

NOTE*. When you set the volts/div smaller than 200 mV, the oscilloscope reduces the* ***Set to TTL*** *or* ***Set to ECL*** *trigger levels below standard TTL and ECL levels. This reduction occurs because the trigger level range is fixed at ±12 divisions from the center. At 100 mV (the next smaller setting after 200 mV) the trigger range is ±1.2 V, which is smaller than the typical TTL (+1.4 V) or ECL (–1.3 V) level.*

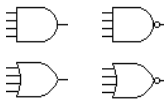
Set to 50% fixes the trigger level to approximately 50% of the peak-to-peak value of the trigger source signal.

Triggering Based on Logic

The TDS Oscilloscope can trigger on a logic or binary pattern and on the state of a logic pattern at the time it is clocked. It can also trigger on data that violates setup and hold times relative to a clock. This subsection describes how to use these three classes of logic triggering: *pattern, state,* and *setup/hold*.

A *pattern* trigger occurs when the logic inputs to the logic function you select cause the function to become TRUE (or at your option FALSE). When you use a pattern trigger, you define:

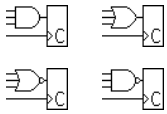
- The precondition for each logic input — logic high, low, or do not care (the logic inputs are channels 1, 2, 3, and 4)



- The Boolean logic function — select from AND, NAND, OR, and NOR
- The condition for triggering — whether the trigger occurs when the Boolean function becomes TRUE (logic high) or FALSE (logic low), and whether the TRUE condition is time qualified

A *state* trigger occurs when the logic inputs to the logic function cause the function to be TRUE (or at your option FALSE) *at the time* the clock input changes state. When you use a state trigger, you define:

- The precondition for each logic input, channels 1, 2, and 3
- The direction of the state change for the clock input, channel 4



- The Boolean logic function — select from clocked AND, NAND, OR, and NOR
- The condition for triggering — whether the trigger occurs when the Boolean function becomes TRUE (logic high) or FALSE (logic low)

A *setup/hold* trigger occurs when a logic input changes state inside of the setup and hold times relative to the clock. When you use setup/hold triggering, you define:

- The channel containing the logic input (the data source) and the channel containing the clock (the clock source)
- The direction of the clock edge to use
- The clocking level and data level that the oscilloscope uses to determine if a clock or data transition has occurred
- The setup and hold times that together define a time range relative to the clock

Pattern and State Classes

Pattern and state triggers apply boolean logic functions to the logic inputs. Table 3–7 defines these four logic functions.

For *pattern* triggering, the oscilloscope waits until the end of trigger holdoff and then samples the inputs from all the channels. The oscilloscope then triggers if the conditions defined in Table 3–7 are met. (Goes TRUE or Goes FALSE must be set in the Trigger When menu. The other settings in that menu are described in *To Define a Time Qualified Pattern Trigger* on page 3–93.)

For *state* triggering, the oscilloscope waits until the end of trigger holdoff and then waits until the edge of channel 4 transitions in the specified direction. At that point, the oscilloscope samples the inputs from the other channels and triggers if the conditions defined in Table 3–7 are met.

Table 3–7: Pattern and State Logic

Pattern	State	Definition[1, 2]
AND	**Clocked AND**	If *all* the preconditions selected for the logic inputs[3] are TRUE, then the oscilloscope triggers.
NAND	**Clocked NAND**	If *not all* of the preconditions selected for the logic inputs[3] are TRUE, then the oscilloscope triggers.
OR	**Clocked OR**	If *any* of the preconditions selected for the logic inputs[3] are TRUE, then the oscilloscope triggers.
NOR	**Clocked NOR**	If *none* of the preconditions selected for the logic inputs[3] are TRUE, then the oscilloscope triggers.

1 Note that for state class triggers, the definition must be met at the time the clock input changes state.

2 The definitions given here are correct for the Goes TRUE setting in the Trigger When menu. If that menu is set to Goes False, swap the definition for AND with that for NAND and for OR with NOR for both pattern and state classes.

3 The logic inputs are channels 1, 2, 3, and 4 when using pattern logic triggers. For State Logic Triggers, channel 4 becomes the clock input, leaving the remaining channels as logic inputs.

Setup and Hold Class

Setup/hold triggering uses the setup and hold times to define a "setup/hold violation zone" relative to the clock. Data that changes state within this zone triggers the oscilloscope. Figure 3–44 shows how the setup and hold times you choose positions this zone relative to the clock.

S*etup/hold* triggering uses the setup/hold violation zone to detect when data is unstable too near the time it is clocked. Each time trigger holdoff ends, the oscilloscope monitors the data and clock sources. When a clock edge occurs, the oscilloscope checks the data stream it is processing (from the data source) for transitions occurring within the setup/hold violation zone. If any occur, the oscilloscope triggers *with the trigger point located at the clock edge*.

Positive settings for both setup and hold times (the most common application) locate the setup/hold violation zone so it *spans* the clocking edge. (See the top waveform in Figure 3–44.) The oscilloscope detects and triggers on data that does not become stable long enough before the clock (setup time violation) or that does not stay stable long enough after the clock (hold time violation).

Negative settings for setup or hold times skew the setup/hold violation zone to locate it before or after the clocking edge. (See the bottom and center waveforms of Figure 3–44.) The oscilloscope can then detect and trigger on violations of a time *range* that occurs *before* or one that occurs *after* the clock.

***NOTE**. Keep the hold-time setting to no more than 2.5 ns less than one-half the clock period (hold time ≤ (period/2) – 2.5 ns) or the oscilloscope cannot trigger (this assumes a 50% duty cycle clock).*

To Check Logic Trigger Status

To quickly check if logic triggers are selected and if so, what class, check the Trigger readout. When logic triggers are selected, the trigger readout displays the selected logic trigger class: *Pattern, State,* or *StHld* (Setup/Hold). (See Figure 3–45.)