User Manual

Tektronix

TDS 620A, 640A & 644A
Digitizing Oscilloscopes

070-8715-04
WARRANTY

Tektronix warrants that the products that it manufactures and sells will be free from defects in materials and workmanship for a period of three (3) years from the date of shipment. If a product proves defective during this warranty period, Tektronix, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

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German Postal Information

Certificate of the Manufacturer/Importer

We hereby certify that the TDS 620A, TDS 640A, and TDS 644A Oscilloscopes and all factory-installed options complies with the RF Interference Suppression requirements of Postal Regulation Vfg. 243/1991, Amended per Vfg. 46/1992

The German Postal Service was notified that the equipment is being marketed.

The German Postal Service has the right to re-test the series and to verify that it complies.

TEKTRONIX

Bescheinigung des Herstellers/Importeurs


Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhalten der Bestimmungen eingeräumt.

TEKTRONIX

NOTICE to the user/operator:

The German Postal Service requires that Systems assembled by the operator/user of this instrument must also comply with Postal Regulation, Vfg. 243/1991, Par. 2, Sect. 1.

HINWEIS für den Benutzer/Betreiber:


NOTICE to the user/operator:

The German Postal Service requires that this equipment, when used in a test setup, may only be operated if the requirements of Postal Regulation, Vfg. 243/1991, Par. 2, Sect. 1.8.1 are complied with.

HINWEIS für den Benutzer/Betreiber:

EC Declaration of Conformity

We

Tektronix Holland N.V.
Marktweg 73A
8444 AB Heerenveen
The Netherlands

declare under sole responsibility that the

**TDS 620A, 640A, & 644A Digitizing Oscilloscopes**


Compliance was demonstrated to the following specifications as listed in the official Journal of the European Communities:

EN 50081—1 Emissions:

- EN 55022 Radiated
- EN 55022 Conducted
- EN 60555—2 Power Harmonics

EN 50082—1 Immunity:

- IEC 801—2 Electrostatic Discharge
- IEC 801—3 RF Radiated
- IEC 801—4 Fast Transients
- IEC 801—5 Surge
Welcome

This is the User Manual for the TDS Family Digitizing Oscilloscopes.

The Getting Started section familiarizes you with the operation of the digitizing oscilloscope.

Operating Basics covers basic principles of the operation of the oscilloscope. These articles help you understand why your instrument works the way it does.

The Reference section teaches you how to perform specific tasks. See page 3-1 for a complete list of tasks covered in that section.

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 digitizing oscilloscope:

- The TDS Family Digitizing Oscilloscopes Programmer Manual (Tektronix part number 070-8709-XX) describes using a computer to control the digitizing oscilloscope through the GPIB interface.

- The TDS Family Option 05 Video Trigger Instruction Manual (Tektronix part number 070-8748-XX) describes use of the video trigger option (for TDS oscilloscopes equipped with that option only).


- The TDS 620A, 640A, & 644A Performance Verification (Tektronix part number 070-8717-XX) tells how to verify the performance of the digitizing oscilloscope.

- The TDS 620A, 640A, & 644A Service Manual (Tektronix part number 070-8718-XX) provides information for maintaining and servicing the digitizing oscilloscope to the module level.
Conventions

In the Getting Started and Reference sections, 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.
- Front-panel and menu names also appear in the same upper and lower case as is used on the oscilloscope. Front panel names are all upper case letters, such as, 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) → 100 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 100 MHz.

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

Safety ................................................................. xi

Getting Started

Product Description .................................................. 1-1
Start Up ............................................................... 1-3
Setting Up for the Examples ....................................... 1-7
Example 1: Displaying a Waveform ............................... 1-8
Example 2: Multiple Waveforms ................................ 1-14
Example 3: Automated Measurements ........................... 1-18
Example 4: Saving Setups ......................................... 1-24

Operating Basics

Overview ............................................................... 2-1
At a Glance .......................................................... 2-3
Triggering ............................................................. 2-13
Acquisition ........................................................... 2-19
Scaling and Positioning Waveforms ............................... 2-22
Measurements ......................................................... 2-26

Reference

Overview ............................................................... 3-1
Acquisition Modes .................................................. 3-3
Autoset .................................................................... 3-8
Color (TDS 644A) ..................................................... 3-10
Cursor Measurements ............................................... 3-15
Delayed Triggering .................................................... 3-20
Display Modes ......................................................... 3-26
Edge Triggering ......................................................... 3-32
Fast Fourier Transforms ............................................. 3-36

Table of Contents

File System (Optional on TDS 620A & TDS 640A) ............... 3-53
Hardcopy ....................................................... 3-57
Help ............................................................. 3-65
Horizontal Control ............................................. 3-66
Limit Testing .................................................... 3-70
Logic Triggering ............................................... 3-75
Measurement System ......................................... 3-83
Probe Cal ......................................................... 3-94
Probe Compensation .......................................... 3-100
Probe Selection ............................................... 3-102
Pulse Triggering .............................................. 3-109
Remote Communication ....................................... 3-116
Saving and Recalling Setups ................................... 3-120
Saving and Recalling Waveforms ............................... 3-123
Selecting Channels ............................................ 3-126
Signal Path Compensation ................................. 3-128
Status .......................................................... 3-130
Triggering ....................................................... 3-132
Vertical Control ............................................... 3-136
Waveform Differentiation .................................... 3-139
Waveform Integration ........................................ 3-143
Waveform Math ................................................ 3-148
Zoom ............................................................ 3-151

Appendices

Appendix A: Options and Accessories ..................... A-1
Appendix B: Algorithms ...................................... A-7
Appendix C: Packaging for Shipment ...................... A-21
Appendix D: Factory Initialization Settings .............. A-23

Glossary

Index
List of Figures

Figure 1-1: Rear Panel Controls Used in Start Up .................. 1-4
Figure 1-2: ON/STBY Button ...................................... 1-5
Figure 1-3: Connecting a Probe for the Examples .................. 1-7
Figure 1-4: SETUP Button Location ................................. 1-8
Figure 1-5: The Displayed Setup Menu .............................. 1-8
Figure 1-6: Trigger Controls ........................................ 1-9
Figure 1-7: The Display After Factory Initialization ............... 1-10
Figure 1-8: The VERTICAL and HORIZONTAL Controls .......... 1-11
Figure 1-9: TRIGGER Controls ...................................... 1-12
Figure 1-10: AUTOSET Button Location ............................. 1-12
Figure 1-11: The Display After Pressing Autoset ................. 1-13
Figure 1-12: Display Signals Requiring Probe Compensation ... 1-13
Figure 1-13: The Channel Buttons and Lights ..................... 1-14
Figure 1-14: The Vertical Main Menu and Coupling Side Menu .. 1-16
Figure 1-15: The Menus After Changing Channels ................. 1-17
Figure 1-16: Measure Main Menu and Select Measurement Side Menu ....................................................... 1-18
Figure 1-17: Four Simultaneous Measurement Readouts ........... 1-20
Figure 1-18: General Purpose Knob Indicators ...................... 1-21
Figure 1-19: Snapshot of Channel 1 ............................... 1-22
Figure 1-20: Save/Recall Setup Menu ................................. 1-25
Figure 2-1: Triggered Versus Untriggered Displays ............... 2-13
Figure 2-2: Trigger Holdoff Time Ensures Valid Triggering ...... 2-16
Figure 2-3: Slope and Level Controls Help Define the Trigger ... 2-17
Figure 2-4: Acquisition: Input Analog Signal, Sample, and Digitize .......................................................... 2-19
Figure 2-5: Real-Time Sampling .................................... 2-20
Figure 2-6: Scaling and Positioning ................................ 2-22
Figure 2-7: Aliasing ................................................. 2-24
Figure 2-8: Graticule, Cursor and Automated Measurements .... 2-26
<table>
<thead>
<tr>
<th>Figure 2-9: Cursor Modes</th>
<th>2-27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 3-1: How the Acquisition Modes Work</td>
<td>3-4</td>
</tr>
<tr>
<td>Figure 3-2: Acquisition Menu and Readout</td>
<td>3-5</td>
</tr>
<tr>
<td>Figure 3-3: Acquire Menu — Stop After</td>
<td>3-6</td>
</tr>
<tr>
<td>Figure 3-4: Display Menu — Setting</td>
<td>3-10</td>
</tr>
<tr>
<td>Figure 3-5: Display Menu — Palette Colors</td>
<td>3-12</td>
</tr>
<tr>
<td>Figure 3-6: Display Menu — Map Reference Colors</td>
<td>3-13</td>
</tr>
<tr>
<td>Figure 3-7: Display Menu — Restore Colors</td>
<td>3-14</td>
</tr>
<tr>
<td>Figure 3-8: Cursor Types</td>
<td>3-15</td>
</tr>
<tr>
<td>Figure 3-9: Cursor Modes</td>
<td>3-16</td>
</tr>
<tr>
<td>Figure 3-10: H Bars Cursor Menu and Readouts</td>
<td>3-17</td>
</tr>
<tr>
<td>Figure 3-11: Paired Cursor Menu and Readouts</td>
<td>3-18</td>
</tr>
<tr>
<td>Figure 3-12: Delayed Runs After Main</td>
<td>3-20</td>
</tr>
<tr>
<td>Figure 3-13: Delayed Triggerable</td>
<td>3-20</td>
</tr>
<tr>
<td>Figure 3-14: How the Delayed Triggers Work</td>
<td>3-22</td>
</tr>
<tr>
<td>Figure 3-15: Delayed Trigger Menu</td>
<td>3-24</td>
</tr>
<tr>
<td>Figure 3-16: Display Menu — Style</td>
<td>3-26</td>
</tr>
<tr>
<td>Figure 3-17: Trigger Point and Level Indicators</td>
<td>3-28</td>
</tr>
<tr>
<td>Figure 3-18: Edge Trigger Readouts</td>
<td>3-32</td>
</tr>
<tr>
<td>Figure 3-19: Main Trigger Menu — Edge Type</td>
<td>3-33</td>
</tr>
<tr>
<td>Figure 3-20: System Response to an Impulse</td>
<td>3-37</td>
</tr>
<tr>
<td>Figure 3-21: Define FFT Waveform Menu</td>
<td>3-38</td>
</tr>
<tr>
<td>Figure 3-22: FFT Math Waveform in Math1</td>
<td>3-39</td>
</tr>
<tr>
<td>Figure 3-23: Cursor Measurement of an FFT Waveform</td>
<td>3-41</td>
</tr>
<tr>
<td>Figure 3-24: Waveform Record vs. FFT Time Domain Record</td>
<td>3-43</td>
</tr>
<tr>
<td>Figure 3-25: FFT Time Domain Record vs. FFT Frequency Domain Record</td>
<td>3-43</td>
</tr>
<tr>
<td>Figure 3-26: How Aliased Frequencies Appear in an FFT</td>
<td>3-47</td>
</tr>
<tr>
<td>Figure 3-27: Windowing the FFT Time Domain Record</td>
<td>3-50</td>
</tr>
<tr>
<td>Figure 3-28: FFT Windows and Bandpass Characteristics</td>
<td>3-52</td>
</tr>
<tr>
<td>Figure 3-29: File Utilities</td>
<td>3-53</td>
</tr>
<tr>
<td>Figure 3-30: File System — Labelling Menu</td>
<td>3-55</td>
</tr>
<tr>
<td>Figure 3-31: Utility Menu — System I/O</td>
<td>3-58</td>
</tr>
</tbody>
</table>
Figure 3-32: Hardcopy Formats ........................................ 3-59
Figure 3-33: Date and Time Display ............................... 3-61
Figure 3-34: Connecting the Digitizing Oscilloscope Directly to the
Hardcopy Device .................................................. 3-62
Figure 3-35: Connecting the Digitizing Oscilloscope and Hardcopy
Device Via a PC .................................................. 3-63
Figure 3-36: Initial Help Screen ..................................... 3-65
Figure 3-37: Horizontal Controls .................................... 3-66
Figure 3-38: Record View and Time Base Readouts .......... 3-67
Figure 3-39: Comparing a Waveform to a Limit Template ...... 3-70
Figure 3-40: Acquire Menu — Create Limit Test Template ...... 3-71
Figure 3-41: Logic Trigger Readouts ............................. 3-76
Figure 3-42: Logic Trigger Menu ................................... 3-78
Figure 3-43: Logic Trigger Menu — Time Qualified TRUE ...... 3-81
Figure 3-44: Measurement Readouts .............................. 3-86
Figure 3-45: Measure Menu ........................................ 3-87
Figure 3-46: Measure Menu — Gating ............................. 3-88
Figure 3-47: Measure Menu — Reference Levels ............... 3-90
Figure 3-48: Measure Delay Menu — Delay To .................. 3-91
Figure 3-49: Snapshot Menu and Readout ....................... 3-92
Figure 3-50: Probe Cal Menu and Gain Compensation Display . 3-96
Figure 3-51: Re-use Probe Calibration Data Menu ............. 3-98
Figure 3-52: How Probe Compensation Affects Signals ........ 3-100
Figure 3-53: P6139A Probe Adjustment .......................... 3-101
Figure 3-54: The P6009 and P6015A High Voltage Probes ...... 3-103
Figure 3-55: A6303 Current Probe Used in the AM 503S Opt. 03 3-105
Figure 3-56: Pulse Trigger Readouts .............................. 3-109
Figure 3-57: Main Trigger Menu — Glitch Class ............... 3-111
Figure 3-58: Main Trigger Menu—Runt Class ..................... 3-114
Figure 3-59: Typical GPIB Network Configuration ............. 3-117
Figure 3-60: Stacking GPIB Connectors ........................... 3-117
Figure 3-61: Connecting the Digitizing Oscilloscope to a
Controller ...................................................... 3-118
Figure 3-62: Utility Menu .......................................... 3-119
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-63</td>
<td>Save/Recall Setup Menu</td>
<td>3-120</td>
</tr>
<tr>
<td>3-64</td>
<td>Save Waveform Menu</td>
<td>3-124</td>
</tr>
<tr>
<td>3-65</td>
<td>More Menu</td>
<td>3-125</td>
</tr>
<tr>
<td>3-66</td>
<td>The Channel Readout</td>
<td>3-126</td>
</tr>
<tr>
<td>3-67</td>
<td>Waveform Selection Priority</td>
<td>3-127</td>
</tr>
<tr>
<td>3-68</td>
<td>Performing a Signal Path Compensation</td>
<td>3-129</td>
</tr>
<tr>
<td>3-69</td>
<td>Status Menu — System</td>
<td>3-130</td>
</tr>
<tr>
<td>3-70</td>
<td>Banner Display</td>
<td>3-131</td>
</tr>
<tr>
<td>3-71</td>
<td>TRIGGER Controls and Status Lights</td>
<td>3-132</td>
</tr>
<tr>
<td>3-72</td>
<td>Example Trigger Readouts</td>
<td>3-134</td>
</tr>
<tr>
<td>3-73</td>
<td>Record View, Trigger Position, and Trigger Level Bar Readouts</td>
<td>3-135</td>
</tr>
<tr>
<td>3-74</td>
<td>Vertical Readouts and Channel Menu</td>
<td>3-137</td>
</tr>
<tr>
<td>3-75</td>
<td>Derivative Math Waveform</td>
<td>3-140</td>
</tr>
<tr>
<td>3-76</td>
<td>Peak-Peak Amplitude Measurement of a Derivative Waveform</td>
<td>3-141</td>
</tr>
<tr>
<td>3-77</td>
<td>Integral Math Waveform</td>
<td>3-144</td>
</tr>
<tr>
<td>3-78</td>
<td>H Bars Cursors Measure an Integral Math Waveform</td>
<td>3-145</td>
</tr>
<tr>
<td>3-79</td>
<td>More Menu</td>
<td>3-148</td>
</tr>
<tr>
<td>3-80</td>
<td>Dual Waveform Math Main and Side Menus</td>
<td>3-150</td>
</tr>
<tr>
<td>3-81</td>
<td>Zoom Mode with Horizontal Lock Set to None</td>
<td>3-152</td>
</tr>
<tr>
<td>A-1</td>
<td>MCross Calculations</td>
<td>A-10</td>
</tr>
<tr>
<td>A-2</td>
<td>Fall Time</td>
<td>A-13</td>
</tr>
<tr>
<td>A-3</td>
<td>Rise Time</td>
<td>A-17</td>
</tr>
<tr>
<td>A-4</td>
<td>Choosing Minima or Maxima to Use for Envelope Measurements</td>
<td>A-19</td>
</tr>
</tbody>
</table>
List of Tables

Table 1-1: Fuse and Fuse Cap Part Numbers ...................... 1-4
Table 3-1: Autoset Defaults ...................................... 3-9
Table 3-2: XY Format Pairs ...................................... 3-30
Table 3-3: Logic Triggers ......................................... 3-77
Table 3-4: Measurement Definitions ............................... 3-83
Table 3-5: Probe Cal Status ...................................... 3-98
Table 3-6: TDS 600A Compatible Probes ........................... 3-107
Table 3-7: Probes by Application ................................. 3-108
Table 3-8: Pulse Trigger Definitions .............................. 3-110
Table 3-9: Zoom Defaults ......................................... 3-153
Table A-1: International Power Cords ............................ A-1
Table A-2: Standard Accessories ................................. A-3
Table A-3: Optional Accessories ................................. A-4
Table A-4: Accessory Software .................................. A-5
Table A-5: Factory Initialization Defaults ....................... A-23
Safety

Please take a moment to review these safety precautions. They are provided for your protection and to prevent damage to the digitizing oscilloscope. This safety information applies to all operators and service personnel.

Symbols and Terms

These two terms appear in manuals:

- **CAUTION** statements identify conditions or practices that could result in damage to the equipment or other property.
- **WARNING** statements identify conditions or practices that could result in personal injury or loss of life.

These two terms appear on equipment:

- **CAUTION** indicates a personal injury hazard not immediately accessible as one reads the marking or a hazard to property including the equipment itself.
- **DANGER** indicates a personal injury hazard immediately accessible as one reads the marking.

This symbol appears in manuals:

![Static-Sensitive Devices](image)

These symbols appear on equipment:

- **DANGER** High Voltage
- **Protective ground (earth) terminal**
- **ATTENTION** Refer to manual
Specific Precautions

Observe all of these precautions to ensure your personal safety and to prevent damage to either the digitizing oscilloscope or equipment connected to it.

Power Source

The digitizing oscilloscope is intended to operate from a power source that will not apply more than 250 V_{RMS} between the supply conductors or between either supply conductor and ground. A protective ground connection, through the grounding conductor in the power cord, is essential for safe system operation.

Grounding the Digitizing Oscilloscope

The digitizing oscilloscope is grounded through the power cord. To avoid electric shock, plug the power cord into a properly wired receptacle where earth ground has been verified by a qualified service person. Do this before making connections to the input or output terminals of the digitizing oscilloscope.

Without the protective ground connection, all parts of the digitizing oscilloscope are potential shock hazards. This includes knobs and controls that may appear to be insulators.

Use the Proper Power Cord

Use only the power cord and connector specified for your product. Use only a power cord that is in good condition.

Use the Proper Fuse

To avoid fire hazard, use only the fuse specified in the parts list for your product, matched by type, voltage rating, and current rating.

Do Not Remove Covers or Panels

To avoid personal injury, do not operate the digitizing oscilloscope without the panels or covers.

Electric Overload

Never apply a voltage to a connector on the digitizing oscilloscope that is outside the voltage range specified for that connector.

Do Not Operate in Explosive Atmospheres

The digitizing oscilloscope provides no explosion protection from static discharges or arcing components. Do not operate the digitizing oscilloscope in an atmosphere of explosive gases.
Product Description

Tektronix TDS 600A Digitizing Oscilloscopes are superb tools for acquiring, displaying, and measuring waveforms. Their performance addresses the needs of both benchtop lab and portable applications with the following features:

- 500 MHz maximum analog bandwidth.
- 2 Gigasamples/second maximum digitizing rate.
- Four channels for acquisition — the TDS 640A & 644A let you use and display all four channels simultaneously; the TDS 620A lets you use and display any two channels simultaneously. All channels can acquire at the maximum digitizing rate.
- Waveform Math — Invert a single waveform and add, subtract, multiply, and divide two waveforms. On instruments with Advanced DSP Math (standard on the TDS 644A), integrate or differentiate a single waveform or perform an FFT (fast fourier transform) on a waveform to display its magnitude or phase versus its frequency.
- Eight-bit digitizers.
- Up to 2,000-sample record length per channel.
- Full GPIB software programmability. Hardcopy output using RS-232 or Centronics ports (Optional on TDS 620A & 640A) and the GPIB.
- Complete measurement and documentation capability.
- Intuitive graphic icon operation blended with the familiarity of traditional horizontal and vertical knobs.
- On-line help at the touch of a button.
Start Up

Before you use the digitizing oscilloscope, ensure that it is properly installed and powered on.

Before You Begin

To ensure maximum accuracy for your most critical measurements, you should know about signal path compensation and the proper use of the P6139A probe shipped with your oscilloscope as a standard accessory.

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 3-128 for a description of and operating information on this feature.

P6205 Active Probe

Be sure you use the appropriate probe. Do not use the optional P6205 Active Probe to measure signals above ±10 volts since errors in signal measurement will result. Instead, use the standard accessory P6139A Passive Probe or one of the passive probes listed in Appendix A under Accessory Probes. The P6139A probe is for measurements up to ±500 volts.

CAUTION

Using the P6205 Active Probe to measure signals greater than ±40 volts may damage the probe.

Operation

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

Installation

1. Be sure you have the appropriate operating environment. Specifications for temperature, relative humidity, altitude, vibrations, and emissions are included in the TDS 620A, 640A, & 644A Performance Verification manual (Tektronix part number 070-8717-XX).
Start Up

2. Leave space for cooling. Do this by verifying that the air intake and exhaust holes on the sides of the cabinet (where the fan operates) 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 1-1). The digitizing oscilloscope is shipped with the UL approved fuse installed.

4. Check that you have the proper electrical connections. The digitizing oscilloscope requires 90 to 250 VAC RMS, continuous range, 47 Hz to 63 Hz, and may require up to 300 W.

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

![](image)

**Figure 1-1: Rear Panel Controls Used in Start Up**

### Table 1-1: Fuse and Fuse Cap Part Numbers

<table>
<thead>
<tr>
<th>Fuse Description</th>
<th>Fuse Part Number</th>
<th>Fuse Cap Part Number</th>
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<tbody>
<tr>
<td>.25 inch × 1.25 inch (UL 198.6, 3AG): 6 A FAST, 250 V.</td>
<td>159–0013–00</td>
<td>200–2264–00</td>
</tr>
<tr>
<td>5 mm × 20 mm (IEC 127): 5 A (T), 250 V.</td>
<td>159–0210–00</td>
<td>200–2265–00</td>
</tr>
</tbody>
</table>
Front Cover Removal

Remove the front cover by grasping its left and right edges and snapping it off of the front subpanel. (When reinstalling, align and snap back on.)

Power On

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).

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 digitizing oscilloscope is installed, it is typical to leave the principal power switch on and use the **ON/STBY** button as the power switch.
Start Up

Self Test
Check the self test results. The digitizing 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 self test. (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
Toggle the ON/STBY switch to turn off the oscilloscope.
Setting Up for the Examples

All the examples use the same setup. Once you perform this setup, you do not have to change the signal connections for any of the other examples.

Remove all probes and signal inputs from the input BNC connectors along the lower right of the front panel. Then, using one of the probes supplied with the digitizing oscilloscope, connect from the CH 1 connector to the PROBE COMPENSATION connectors (see Figure 1-3).

Figure 1-3: Connecting a Probe for the Examples
Example 1: Displaying a Waveform

In this first example you learn about resetting the digitizing oscilloscope, displaying and adjusting a waveform, and using the autoset function.

Resetting the Digitizing Oscilloscope

All examples in the tutorial begin by resetting the digitizing oscilloscope to a known factory default state. Reset the oscilloscope when 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 (Figure 1-4).

Figure 1-4: SETUP Button Location

The digitizing oscilloscope displays main menus along the bottom of the screen. Figure 1-5 shows the Setup main menu.

Figure 1-5: The Displayed 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 digitizing oscilloscope asks you to verify the Recall Factory Setup selection (see Figure 1-5).

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 1-6) to be sure the oscilloscope triggers on the input signal.

![Diagram of Trigger Controls]

Figure 1-6: Trigger Controls
Display Elements

Figure 1-7 shows the display that results from the instrument 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 digitizing 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 digitizing oscilloscope always displays channel 1 at reset.

Figure 1-7: 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.
Adjusting the Waveform Display

The display shows the probe compensation signal. It is a 1 kHz square wave of approximately 0.5 V amplitude. You can adjust the size and placement of the waveform using the front-panel knobs.

Figure 1-8 shows the main VERTICAL and HORIZONTAL sections of the front panel. Each has SCALE and POSITION 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.

![Vertical and Horizontal Controls]

**Figure 1-8: The VERTICAL and HORIZONTAL Controls**

2. Turn the vertical POSITION knob first one direction, 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 250 µs/div now, and you should see two complete waveform cycles on the display.

Using Autoset

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.

When you reset the digitizing oscilloscope, you see a clear, stable display of the probe compensation waveform. That is because the probe compensation signal happens to display well at the default settings of the digitizing oscilloscope.
Example 1: Displaying a Waveform

1. To create an unstable display, slowly turn the trigger **MAIN LEVEL** knob (see Figure 1-9) first one direction, then the other. Observe what happens when you move the trigger level above the highest part of the displayed waveform. Leave the trigger level in that untriggered state.

2. Press **AUTOSET** (see Figure 1-10) and observe the stable waveform display.

![TRIGGER Controls](image)

**Figure 1-9: TRIGGER Controls**

![AUTOSET Button Location](image)

**Figure 1-10: AUTOSET Button Location**

Figure 1-11 shows the display after pressing **AUTOSET**. If necessary, you can adjust the waveform now by using the knobs discussed earlier in this example.
Example 1: Displaying a Waveform

Figure 1-11: The Display After Pressing Autoset

NOTE

If you are using a passive probe, such as the standard P6139A probe, the corners on your displayed signal may look rounded or pointed (see Figure 1-12). If so, then you may need to compensate your probe. The documentation included with such probes explains how to compensate your probe.

Figure 1-12: Display Signals Requiring Probe Compensation
Example 2: Multiple Waveforms

In this example you learn how to display and control more than one waveform at a time.

Adding a Waveform

The VERTICAL section of the front panel contains the channel selection buttons. These are CH 1, CH 2, CH 3, CH 4, and MORE (Figure 1-13); on the TDS 620A, they are CH 1, CH 2, AUX 1, AUX 2, and MORE.

![Diagram of channel buttons and lights](image)

Figure 1-13: The Channel Buttons and Lights

Each of the channel (CH) buttons has a light above its label. Right now, the CH 1 light is on. That light indicates that the vertical controls are set to adjust channel 1.

The following steps add a waveform to the display.

1. If you are not continuing from the previous example, follow the instructions on page 1-7 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 next to 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 **Ch1**. 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 (Figure 1-14). 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 always matches the lighted channel button.

7. Press **Ω (side)** to toggle the selection to **50 Ω**. That changes the input coupling of channel 2 from 1 MΩ to 50 Ω. The channel readout for channel 2 (near the bottom of the graticule) now shows an **Ω** indicator.
Example 2: Multiple Waveforms

![Diagram of a waveform display with labels for Ch2 Reference Indicator and Side Menu Title]

Figure 1-14: The Vertical Main Menu and Coupling Side Menu

**Changing 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.

1. Press **CH 1**.

Observe that now the side menu title shows **Ch1** (Figure 1-15), and that the light above **CH 1** is lighted. The highlighted menu item in the side menu has changed from the 50 Ω channel 2 setting to the 1 MΩ impedance setting of channel 1.

2. Press **CH 2 → Ω** (side) to toggle the selection to 1 MΩ. That returns the coupling impedance of channel 2 to its initial state.
Removing 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: Automated Measurements

In this example you learn how to use the automated measurement system to get numeric readouts of important waveform characteristics.

Displaying Automated Measurements

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.

1. If you are not continuing from the previous example, follow the instructions on page 1-7 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 1-16).

Figure 1-16: Measure Main Menu and Select Measurement Side Menu
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 that measurement is taken on the channel 1 waveform. (To take a measurement on another channel, select that channel, and then select the measurement.)

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 1-17).
Removing Measurement Readouts

The Measure menu lets you remove measurements you no longer want displayed. You can remove any one measurement, or you can remove them all with a single menu item.

Press MEASURE → Remove Measrmnt (main) → Measurement 1, Measurement 2, and Measurement 4 (side) to remove those measurements. Leave the rise time measurement displayed.

Changing 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 Reference Levels (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 1-18).
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.

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 the 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, then press the multiplier.
Example 3: Automated Measurements

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 Measrmt** (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 Measrmts** 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 1-19).

![Figure 1-19: Snapshot of Channel 1](image)

The snapshot display includes the notation **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.
Example 3: Automated Measurements

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 Measmnt** (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.)
Example 4: Saving Setups

This example shows you how to save all the settings of the digitizing oscilloscope and how to recall the setup later to quickly re-establish the previously saved state. The oscilloscope provides several storage locations where you can save the setups. With the file system (optional on the TDS 620A & TDS 640A), you can also save setups to a floppy disk.

Besides being able to save several complete setups, the digitizing 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 state of the digitizing oscilloscope.

Saving a Setup

First, you need to create an instrument setup you want to save. The next several steps establish a two-waveform display with a measurement on one waveform. The setup created 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 1-7 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 SETUP → Save Current Setup (main) to display the Setup main menu (see Figure 1-20).

Note that the setup locations shown in the side menu are labeled either user or factory. If you save your current setup in a location labeled user, you will overwrite the user setup previously stored there. If you work in a laboratory environment where several people share the digitizing oscilloscope, check with the other users before you overwrite their setup. 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.
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. Press **MEASURE → Positive Width** (side) to add that measurement to the display.

---

**Recalling a Setup**

To recall the setup, Press **SETUP → Recall Saved Setup** (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.

This completes the tutorial. You can restore the default settings by pressing **SETUP → Recall Factory Setup** (main) → **OK Confirm Factory Init** (side).
Example 4: Saving Setups
Overview

This section describes the basic concepts of operating the digitizing oscilloscope. Understanding the basic concepts of your digitizing oscilloscope will help you use it much more effectively.

The first part, *At a Glance*, quickly shows you how the oscilloscope is organized and gives some very general operating instructions. It also contains an overview of all the main menus. This part includes:

- Front Panel Map
- Rear Panel Map
- Display Map
- Basic Menu Operation
- Menu Map

The second part explains the following concepts:

- The *triggering* system, which establishes conditions for acquiring signals. Properly set, triggers can convert displays from unstable jumbles or blank screens into meaningful waveforms. See *Triggering* on page 2-13.

- The *acquisition* system, which converts analog data into digital form. See *Acquisition* on page 2-19.

- The *waveform scaling and positioning* system, which changes the dimensions of the waveform display. Scaling waveforms involves increasing or decreasing their displayed size. Positioning means moving them up, down, right, or left on the display. See *Scaling and Positioning Waveforms* on page 2-22.

- The *measurement* system, which provides numeric information on the displayed waveforms. You can use graticule, cursor, and automated measurements. See *Measurements* on page 2-26.

At the end of each topic, *For More Information* will point you to sources where more information can be found.

To explore these topics in more depth and to read about topics not covered in this section, see *Reference*. Page 3-1 lists the topics covered.
Overview
The At a Glance section contains illustrations of the display, the front and rear panels, and the menu system. These will help you understand and operate the digitizing oscilloscope. This section also contains a visual guide to using the menu system.

Front Panel Map — Left Side

File System, page 3-53 (Optional on TDS 620A & TDS 640A)

ON/STBY Switch, page 1-3

Main Menu Buttons, page 2-7

CLEAR MENU Removes Menus from the Display

Side Menu Buttons, page 2-7
Front Panel Map —
Right Side
Rear Panel Map

Principal Power Switch, page 1-3
Centronics Connector (Optional on TDS 620A & TDS 640A)
RS-232 Connector (Optional on TDS 620A & TDS 640A)
GPIB Connector, page 3-116

Fuse, page 1-3
Serial Number
Power Connector, page 1-3
VGA Output (Color with TDS 644A, Monochrome with TDS 620A & TDS 640A)

Rear Panel Connectors
Security Bracket

SIGNAL OUTPUT – (Provides analog signal output)
AUX TRIGGER INPUT – (Provides auxiliary trigger signal input)
MAIN TRIGGER OUTPUT – (Provides main trigger (TTL) output)
DELAYED TRIGGER OUTPUT – (Provides delayed trigger (TTL) output)
Display Map

- The acquisition status, page 3-3
- Trigger position (T), page 3-132
- The value entered with the general purpose knob
- When present, the general purpose knob makes coarse adjustments; when absent, fine adjustments

- Indicates position of vertical bar cursors in the waveform record, page 3-136
- Shows what part of the waveform record is displayed, page 3-66

- 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 3-136

- The main menu with choices of major actions
- Cursor measurements, page 3-15
- The side menu with choices of specific actions
- Trigger parameters, page 3-134
- Horizontal scale and time base type, page 3-66

Run: 5.00G/s ET Sample
Trigger Level: 252mV
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.
At a Glance

To Operate a Pop-Up Menu

Press to display pop-ups.

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.
Menu Map

Press these buttons:  To bring up these menus:

**Acquire Menu**
(see page 3-3)

**Application Menu**
(see the Programmer manual for more details)

**Cursor Menu**
(see page 3-15)

**Delayed Trigger Menu**
(see page 3-20)

**Display Menu – Color**
(TDS 644A) (see page 3-10)

**Display Menu – Display**
(TDS 644A) (see page 3-26)

**Display Menu – Display**
(TDS 620A & TDS 640A)
(see page 3-26)

**Horizontal Menu**
(see page 3-66)
At a Glance

Press these buttons:                To bring up these menus:

**Hardcopy Menu**  
(TDS 620A & TDS 640A)  
(see page 3-57)

![SHIFT][MENU][HARDCOPY]

<table>
<thead>
<tr>
<th>Format</th>
<th>Interface</th>
<th>Layout</th>
<th>Portrait</th>
<th>Port</th>
<th>GPIB</th>
<th>Clear</th>
<th>Spool</th>
<th>File Utilities</th>
</tr>
</thead>
</table>

**Hardcopy Menu**  
(TDS 644A)  
(see page 3-57)

![SHIFT][MENU][HARDCOPY]

<table>
<thead>
<tr>
<th>Format</th>
<th>Interface</th>
<th>Layout</th>
<th>Portrait</th>
<th>Palette</th>
<th>Harcopy</th>
<th>Port</th>
<th>GPIB</th>
<th>Clear</th>
<th>Spool</th>
<th>File Utilities</th>
</tr>
</thead>
</table>

**Main Trigger Menu – Edge**  
(see page 3-32)

![DELAYED TRIG][TRIGGER MENU]

<table>
<thead>
<tr>
<th>Type</th>
<th>Source Ch</th>
<th>Coupling</th>
<th>Slope</th>
<th>Mode &amp; Holdoff</th>
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<tbody>
<tr>
<td>&lt;Edge&gt;</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Main Trigger Menu – Logic**  
(see page 3-75)

![DELAYED TRIG][TRIGGER MENU]

<table>
<thead>
<tr>
<th>Type</th>
<th>Class</th>
<th>Define Inputs</th>
<th>Define Logic AND</th>
<th>Trigger When Goes TRUE</th>
<th>Set Thresholds</th>
<th>Mode &amp; Holdoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Logic&gt;</td>
<td>&lt;Pattern&gt;</td>
<td></td>
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<td></td>
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</table>

**Main Trigger Menu – Pulse**  
(see page 3-109)

![DELAYED TRIG][TRIGGER MENU]

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<thead>
<tr>
<th>Type</th>
<th>Class</th>
<th>Source Ch</th>
<th>Polarity &amp; width</th>
<th>Glitch Accept</th>
<th>Level 240.0 mV</th>
<th>Mode &amp; Holdoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Pulse&gt;</td>
<td>&lt;Glitch&gt;</td>
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</tr>
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</table>

**Measure Menu**  
(see page 3-83)

![APPLICATION][MEASURE]

<table>
<thead>
<tr>
<th>Select Measurement for Ch</th>
<th>Remove Measurement</th>
<th>Gating Off</th>
<th>High-Low Setup</th>
<th>Histogram</th>
<th>Reference Levels</th>
<th>Snapshot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1-Ch2, Ch1-Ch2, Inv(Ch1)</td>
<td>Ref1</td>
<td>Ref2</td>
<td>Ref3</td>
<td>Ref4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**More Menu**  
(see page 3-148)

![MORE]

<table>
<thead>
<tr>
<th>Math1</th>
<th>Math2</th>
<th>Math3</th>
<th>Inv(Ch1)</th>
<th>Ref1</th>
<th>Ref2</th>
<th>Ref3</th>
<th>Ref4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1-Ch2</td>
<td>Ch1-Ch2</td>
<td>Ch1-Ch2</td>
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</table>

**Save/Recall Setup Menu**  
(see page 3-120)

![SETUP]

<table>
<thead>
<tr>
<th>Recall Setup</th>
<th>Save Current Setup</th>
<th>Recall Factory Setup</th>
<th>File Utilities</th>
</tr>
</thead>
</table>

**Save/Recall Waveform Menu**  
(see page 3-123)

![SAVE/RECALL][WAVEFORM]

<table>
<thead>
<tr>
<th>Recall Wfm To Ref</th>
<th>Save Wfm Ch</th>
<th>Delete Ref</th>
<th>File Utilities</th>
</tr>
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</table>

**Status Menu**  
(see page 3-130)

![SHIFT][STATUS][HELP]

<table>
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<tr>
<th>Status</th>
<th>Banner</th>
<th></th>
</tr>
</thead>
</table>

---

2-10 Operating Basics
Press these buttons:  

**Utility Menu – Calibration**  
(see page )

**Utility Menu – Config**  
(see pages )

**Utility Menu – Diagnostics**  
(see the Service manual)

**Utility Menu – I/O – GPIB**  
(see page 3-116)

**Utility Menu – I/O – RS232**  
(optional on TDS 620A & TDS 640A) (see page 3-116)

**Vertical Channel Menu**  
(see page 3-136)

**Zoom Menu**  
(see page 3-151)

---

To bring up these menus:

---
At a Glance
This section describes the edge trigger of the main trigger system and explores, in a general sense, the topic of triggering. This oscilloscope also has logic and pulse triggers in the main trigger system and a delayed trigger system. They are described in Section 3.

Triggers determine when the digitizing oscilloscope starts acquiring and displaying a waveform. They help create meaningful waveforms from unstable jumbles or blank screens (see Figure 2-1).

![Triggered Waveform](image1)

![Untriggered Waveforms](image2)

**Figure 2-1: Triggered Versus Untriggered Displays**

The trigger event establishes the time-zero point in the waveform record, and all points in the record are located in time with respect to that point. The digitizing 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 digitizing 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.

The basic trigger is the edge trigger. An edge trigger event occurs when the trigger source (the signal that the trigger circuit monitors) passes through a specified voltage level in a specified direction (the trigger slope).

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**Trigger Sources**

You can derive your trigger from various sources.

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

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

- **Auxiliary Trigger** — this trigger source is useful in 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.

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**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 in individual articles found in the *Reference* section. A brief definition of each type follows:

- **Edge** — 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** — special trigger primarily used on digital circuits. Three classes of pulse triggers are *width*, *runt*, and *glitch*. Pulse triggering is available on the main trigger only.

- **Logic** — special trigger primarily used on digital logic circuits. You select Boolean operators for the trigger sources. Triggering occurs when the Boolean conditions are satisfied. There are two kinds of logic triggers, *state* and *pattern*. (Logic triggers are available on the main trigger system only.)

- **Video** — (with option 05) 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.

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**Trigger Modes**

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

- **Normal** — this trigger mode lets the oscilloscope 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.)
Triggering

- **Automatic** — this trigger mode (auto mode) lets the oscilloscope 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.

---

**Holdoff**

When a trigger event is recognized, the oscilloscope 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.

  Digital pulse trains are good examples (see Figure 2-2). 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 digitizing oscilloscope to trigger on the correct edge, resulting in a stable display.
Figure 2-2: Trigger Holdoff Time Ensures Valid Triggering

Holdoff is settable from 0% (minimum holdoff available) to 100% (maximum available). To see how to set holdoff, see Mode & Holdoff on page 3-35. The minimum and maximum holdoff varies with the horizontal scale. See Holdoff, Variable, Main Trigger in the TDS 620A, 640A, & 644A Performance Verification Manual, Section 2 on Specification, Typical Characteristics for typical minimum and maximum values.

Coupling

Trigger coupling determines what part of the signal is passed to the trigger circuit. Available coupling types include AC, DC, Low Frequency Rejection, High Frequency Rejection, and Noise Rejection:

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

- **AC**
  - AC coupling passes only the alternating components of an input signal. (AC components above 10 Hz are passed if the source channel is in 1 MΩ coupling; above 200 kHz are passed in 50 Ω coupling.) It removes the DC components from the trigger signal.

- **High frequency rejection** 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.

- **Low frequency rejection** does the opposite of high frequency rejection. Low frequency rejection attenuates signals below 80 kHz.

- **Noise Rejection** lowers trigger sensitivity. It requires additional signal amplitude for stable triggering, reducing the chance of falsely triggering on noise.
Trigger Position

The adjustable 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.

Many users find displaying pretrigger information a valuable troubleshooting technique. For example, if you are trying to find the cause of an unwanted glitch in your test circuit, it may prove valuable to 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 the source of the glitch.

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 2-3).

You set trigger slope by selecting Slope in the Main Trigger menu and then selecting from 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 2-3).

Figure 2-3: Slope and Level Controls Help Define the Trigger

The digitizing oscilloscope lets you set the main trigger level with the trigger MAIN LEVEL knob.
Delayed Trigger

As mentioned earlier in this section there is also 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.

For More Information

See Delayed Triggering, on page 3-20.
See Edge Triggering, on page 3-32.
See Horizontal Controls, on page 3-66.
See Logic Triggering, on page 3-75.
See Pulse Triggering, on page 3-109.
See Triggering, on page 3-132.
Acquisition

Acquisition is the process of sampling the analog input signal, converting it into digital data, and assembling it into a waveform record. The oscilloscope creates a digital representation of the input signal by sampling the voltage level of the signal at regular time intervals (Figure 2-4).

![Figure 2-4: Acquisition: Input Analog Signal, Sample, and Digitize](image)

The sampled 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.

You specify how the digitizing oscilloscope acquires data points and assembles them into the waveform record.

---

**Sampling and Digitizing**

The trigger point marks time zero in a waveform record. All record points before the trigger event make up the pretrigger portion of the waveform record. Every record point after the trigger event is part of the posttrigger portion. All timing measurements in the waveform record are made relative to the trigger event.

Each time it takes a sample, the oscilloscope digitizer produces a numeric representation of the signal.

The digitizer can use the extra samples to perform additional processing, such as averaging or looking for minimum and maximum values.

The digitizing oscilloscope creates a waveform record containing a user-specified number of data points. Each record point represents a certain voltage level that occurs a determined amount of time from the trigger event.

**Record Length**

The number of points that make up the waveform record is defined by the record length. You can set the record length in the Horizontal menu. The digitizing oscilloscope provides record lengths of 500, 1000, and 2000 points.
Sampling

Sampling is the process of converting the analog input signal to digital for display and processing (see Figure 2-5).

![Record Points](image)

**Figure 2-5: Real-Time Sampling**

Interpolation

Turning the horizontal **SCALE** knob clockwise causes the scope to assign shorter time periods to the waveform record. The smaller the time period gets, the faster the oscilloscope needs to acquire record points to fill up the record.

If you turn the horizontal **SCALE** knob to a point that the time base is faster than 25 ns, the digitizing oscilloscope will not acquire enough samples for a complete waveform record. When that happens, the digitizing oscilloscope uses a process called interpolation to create the intervening points in the waveform record. There are two options for interpolation: linear or \sin(x)/x.

*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 wish to set the display style so that the real samples are displayed intensified relative to the interpolated samples. The instructions under Display Style on page 3-26 explain how to turn on intensified samples.*
Acquisition Modes

The digitizing oscilloscope supports three acquisition modes:

- **Sample**
- **Envelope**
- **Average**

Bandwidth

*Bandwidth* refers to the range of frequencies that an oscilloscope can acquire and display accurately (that is, with less than 3 dB attenuation).

You can set different bandwidths with the digitizing oscilloscope. Lower bandwidth settings let you eliminate the higher frequency components of a signal. The TDS 600A series offers **Full** (500 MHz), **100 MHz**, and **20 MHz** bandwidth settings.

Coupling

You can couple your input signal to the digitizing oscilloscope three ways. You can choose between AC, DC, or Ground (GND). You can also set the input impedance.

- **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 MΩ 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, the optional P6205 probe automatically switches the input coupling to 50 Ω. This setting is appropriate for active probes like the P6205. If changing to a passive probe, or using any input signal that is not from a 50 Ω system, be sure to switch the channel input coupling to 1 MΩ.*

For More Information

See *Scaling and Positioning Waveforms*, on page 2-22.

See *Acquisition Modes*, on page 3-3.
Scaling and Positioning Waveforms

Scaling and positioning waveforms means increasing or decreasing their displayed size and moving them up, down, right, and left on the display.

Two display icons, the channel reference indicator and the record view, help you quickly see the position of the waveform in the display (see Figure 2-6). The channel reference icon points to the ground of the waveform record when offset is set to 0 V. This is the point about which the waveform contracts or expands when the vertical scale is changed. The record view, at the top of the display, indicates where the trigger occurs and what part of the waveform record is displayed.

![Figure 2-6: Scaling and Positioning](image-url)
Vertical System

You can adjust the vertical position of the selected waveform by moving it up or down on the display. For example, when trying to compare multiple waveforms, you can put one above another and compare them, or you can overlay the two waveforms on top of each other. To move the selected waveform turn the vertical POSITION knob.

You can also alter the vertical scale. The digitizing oscilloscope shows the scale (in volts per division) for each active channel toward the bottom left of the display. 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 counter-clockwise the scale increases allowing you to see more of the waveform but with lower resolution.

Besides using the position and scale knobs, you can set the vertical scale and position with exact numbers. You do that with the Vertical menu Fine Scale and Position selections and the general purpose knob and/or the keypad.

Offset

Vertical offset changes where the channel reference indicator is shown with respect to the graticule. Offset adds a voltage to the reference indicator without changing the scale. That feature allows you to move the waveform up and down over a large area without decreasing the resolution.

Offset is useful in cases where a waveform has a DC bias. One example is looking at a small ripple on a power supply output. You may be trying to look at a 100 mV ripple on top of a 15 V supply. The range available with offset can prove valuable as you try to move and scale the ripple to meet your needs.

Horizontal System

Adjusting the horizontal position of waveforms moves them right or left on the display. That is useful when the record length of the waveform is so large (greater than 500 points) that the digitizing oscilloscope cannot display the entire waveform record at one time. You can also adjust the scale of the waveform. For example, you might want to see just one cycle of a waveform to measure the overshoot on its rising edge.

You adjust the horizontal scale of the displayed waveform records using the horizontal SCALE knob and the horizontal position using the horizontal POSITION knob.

The digitizing oscilloscope shows the actual scale in the bottom right of the display. The scale readout shows the time per division used. Since all live waveforms use the same time base, the digitizing oscilloscope only displays one value for all the active channels.
Aliasing

When aliasing happens, you see a waveform with a frequency lower than the actual waveform being input or a waveform is not stable even though the light next to TRIG'D is lit. Aliasing occurs because the oscilloscope cannot sample the signal fast enough to construct an accurate waveform record (Figure 2-7).

![Aliasing Diagram](image)

One simple way to check for aliasing is to slowly change the horizontal scale (time per division setting). If the shape of the displayed waveform changes drastically, you may have aliasing.

In order to represent a signal accurately and avoid aliasing, you must sample the signal 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.

There are various ways to prevent aliasing. Try adjusting the horizontal scale, or simply press the AUTOSET button. You can also counteract some aliasing by changing the acquisition mode in the Acquisition menu. For example, if you are using the sample mode and suspect aliasing, you may want to change to the envelope mode. Since the envelope mode searches for multiple acquisitions with the highest and lowest values, it can detect faster signal components over time.

Delayed Time Base

You can set a main time base and a delayed time base. Each time base has its own trigger. There are two types of delayed time base acquisitions. Each type is based on its triggering relationship to the main time base. These are delayed runs after main and delay triggerable (after time, events, or both) acquisitions.

The delayed time base is useful in displaying events that follow other events. See Triggering on page 2-13 for more information on the delayed trigger.
Scaling and Positioning Waveforms

Zoom
You can use zoom to see more detail without changing the acquired signal. When you press the ZOOM button, a portion of the waveform record can be expanded or compressed on the display, but the record points stay the same.

Zoom is very useful when you wish to temporarily expand a waveform to inspect small feature(s) on that waveform. For example, you might use zoom 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. (The zoom feature is also handy if you have acquired a waveform while using the fastest time per division and want to further expand the waveform horizontally.)

Autoset
Autoset lets you quickly obtain a stable waveform display. It automatically adjusts a wide variety of settings including vertical and horizontal scaling. Other settings affected include trigger coupling, type, position, slope, and mode and display intensities. Autoset on page 3-8 describes in detail what autoset does.

For More Information
See Autoset, on page 3-8.
See Delayed Triggering, on page 3-20.
See Horizontal Control, on page 3-66.
See Vertical Control, on page 3-136.
See Zoom, on page 3-151.
Measurements

The digitizing oscilloscope not only displays graphs of voltage versus time, it also can help you measure the displayed information (see Figure 2-8).

![Diagram](https://via.placeholder.com/150)

**Figure 2-8: Graticule, Cursor and Automated Measurements**

**Measurement Sources**

The oscilloscope provides three measurement classes. They are: automated, cursors, and graticule measurements.

**Automated Measurements**

You make automated measurements merely by pressing a few buttons. The digitizing oscilloscope does all the calculating for you. Because these measurements use the waveform record points, automated measurements are more accurate than cursor or graticule measurements.

Press the **MEASURE** button for the automated measurement menus. These menus let you make **amplitude** (typically in volts; sometimes in %), **time** (typically in seconds or hertz), and **area** (in volt-seconds) measurements. You can select and display up to four measurements at a time. (See Table 3-4 on page 3-83 for a list of all the automatic measurements and their definitions.)

You can make automated measurements on the entire waveform record or just on a specific part. The gating selection in the Measurement menu lets you use the vertical cursors to limit the measurement to a section of the waveform record.
The snapshot selection in the Measurement menu lets you display almost all of the measurements at once. You can read about snapshot under *Snapshot of Measurements*, on page 3-92.

Automated measurements use readouts to show measurement status. These readouts are updated as the oscilloscope acquires new data or if you change settings.

**Cursor Measurements**

 Cursors are fast and easy-to-understand measurements. You take measurements by moving the cursors and reading their numeric values from the on-screen readouts, which update as you adjust the position of the cursors.

 Cursors appear in pairs. One cursor is active and the other inactive. You move the active cursor (the solid line) using the general purpose knob. The **SELECT** button lets you select (toggle) which cursor bar is active or inactive. The inactive cursor is a dashed line on the display.

 To get the cursor menu, press the **CURSOR** button. There are three kinds of cursors available in that menu:

- **Horizontal bar cursors** measure vertical parameters (typically volts).
- **Vertical bar cursors** measure horizontal parameters (typically time or frequency).
- **Paired cursors** measure both vertical parameters (typically volts) and horizontal parameters (typically time or frequency).

 There are also two modes for cursor operation available in the cursor menu — independent and tracking (See Figure 2-9).

![Figure 2-9: Cursor Modes](image)

- **Independent mode** cursors operate as was earlier described; that is, you move one cursor at a time (the active cursor) using the general purpose knob, and you use the **SELECT** button to toggle which cursor is active.
- *Tracking mode* cursors operate in tandem: you move both cursors at the same time using the general purpose knob. To adjust the solid cursor relative to the dashed cursor, you push the **SELECT** button to suspend cursor tracking and use the general purpose knob to make the adjustment. A second push toggles the cursors back to tracking.

You can read more detailed information about how to use cursors in *Cursor Measurements*, beginning on page 3-15.

**Graticule Measurements**

Graticule measurements provide you with quick, visual estimates. For example, you might look at a waveform amplitude and say “it is a little more than 100 mV.”

You can perform simple measurements by counting the number of major and minor graticule divisions involved and multiplying by the scale factor.

For example, if you counted five major vertical graticule divisions between the minimum and maximum values of a waveform and knew you had a scale factor of 100 mV/division, then you could easily calculate your peak-to-peak voltage:

\[
5 \text{ divisions} \times 100 \text{ mV/division} = 500 \text{ mV.}
\]

**NOTE**

*AUX 1 and AUX 2 (TDS 620A) can not be set to the volts per division needed to match video graticules.*

When you select the NTSC graticule, the volts per division of all selected channels is set to 143 mV/div (152 mV/div for PAL) where the divisions are those of the conventional graticule, not the divisions of the video graticules. For NTSC, the actual grid lines represent 10 IRE, and for PAL the lines are 100 mV apart.

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**For More Information**

See *Appendix B: Algorithms*, on page A-7, for details on how the digitizing oscilloscope calculates each automatic measurement.

See *Cursor Measurements*, on page 3-15, for more information on cursor measurements.

See *Measurement System*, on page 3-83, for more information on automatic measurements.

See *Tutorial Example 3: Automated Measurements*, on page 1-18, for more information on automatic measurements.

See *Waveform Math*, on page 3-148, for using cursors to measure math waveforms.
Overview

This section describes the details of operating the digitizing oscilloscope. It contains an alphabetical list of tasks you can perform with the digitizing oscilloscope. Use this section to answer specific questions about instrument operation. These tasks include:

- Acquisition Modes
- Autoset
- Color
- Cursor Measurements
- Delayed Triggering
- Display Modes
- Edge Triggering
- Fast Fourier Transforms
- File System
- Hardcopy
- Help
- Horizontal Control
- Limit Testing
- Logic Triggering
- Measurement System
- Probe Cal
- Probe Compensation
- Probe Selection
- Pulse Triggering
- Remote Communication
- Saving and Recalling Setups
- Saving and Recalling Waveforms
- Selecting Channels
- Signal Path Compensation
- Status
- Triggering
- Vertical Control
- Waveform Differentiation
- Waveform Integration
- Waveform Math
- Zoom

Many of these tasks list steps you perform to accomplish the task. You should read Conventions on page ii of Welcome before reading about these tasks.
Overview
Acquisition Modes

The acquisition system has several options for converting analog data into digital form. The Acquisition menu lets you determine the acquisition mode and how to start and stop acquisitions.

Description of Modes

The digitizing oscilloscope supports three acquisition modes.

- Sample
- Envelope
- Average

Sample mode operates in real-time on a single trigger event, provided the digitizing oscilloscope can acquire enough samples for each trigger event. Envelope and average modes operate on multiple acquisitions. The digitizing oscilloscope averages or envelopes several waveforms on a point-by-point basis.

Figure 3-1 illustrates the different modes and lists the benefits of each. It will help you select the appropriate mode for your application.

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.) This is the default mode.
### Acquisition Modes

<table>
<thead>
<tr>
<th>Takes One Acquisition per Trigger</th>
<th>Acquisition Mode</th>
<th>Waveform Drawn on CRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://example.com/sample.png" alt="Sample" /></td>
<td>Uses first sample in each interval over single acquisition</td>
<td><img src="https://example.com/waveform.png" alt="Waveform" /></td>
</tr>
<tr>
<td>This is the default mode.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Takes a User-Specified Number of Acquisitions per Trigger</th>
<th>Acquisition Mode</th>
<th>Waveform Drawn on CRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://example.com/envelope.png" alt="Envelope" /></td>
<td>Finds highest and lowest record points over many acquisitions</td>
<td><img src="https://example.com/waveform.png" alt="Waveform" /></td>
</tr>
<tr>
<td>Use to reveal variations in the signal across time.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiple Waveform Acquisitions</th>
<th>Uses Sample Mode for Each Acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://example.com/average.png" alt="Average" /></td>
<td>Calculates average value for each record point over many acquisitions</td>
</tr>
<tr>
<td>Use to reduce apparent noise in a repetitive signal.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3-1: How the Acquisition Modes Work**

**Envelope Mode**

Envelope mode lets you acquire and display a waveform record that shows the extremes in variation over several acquisitions. You specify the number of acquisitions over which to accumulate the data. The oscilloscope saves the highest and lowest values in two adjacent intervals. Envelope mode 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.

Acquisition Readout

The acquisition readout at the top of the display (Figure 3-2) shows the state of the acquisition system (running or stopped). The “running” state shows the sample rate and acquisition mode. The “stopped” state shows the number of acquisitions acquired since the last stop or major change.

Operation

To bring up the acquisition menu (Figure 3-2) press SHIFT ACQUIRE MENU.

Acquisition Mode

To choose how the digitizing oscilloscope will create points in the waveform record:

Press SHIFT ACQUIRE MENU → Mode (main) → Sample, Envelope, or Average (side).
Acquisition Modes

When you select **Envelope** or **Average**, you can enter the number of waveform records to be enveloped or averaged using the keypad or the general purpose knob.

**NOTE**

*The digitizing oscilloscope interpolates between samples at horizontal scale settings faster than 25 ns/div. See Sampling and Digitizing on page 2-19 for a discussion of interpolation.*

**Stop After**

You can choose to acquire exactly one waveform sequence or to acquire waveforms continuously under manual control.

Press **SHIFT ACQUIRE MENU → Stop After** (main) → **RUN/STOP button only**, **Single Acquisition Sequence**, or **Limit Test Condition Met** (side) (see Figure 3-3).

![Figure 3-3: Acquire Menu — Stop After](image)

- **RUN/STOP button only** (side) lets you start or stop acquisitions by toggling the **RUN/STOP** button. Pressing the **RUN/STOP** button once will stop the acquisitions. The upper left hand corner in the display will say **Stopped** and show the number of acquisitions. If you press the button again, the digitizing oscilloscope will resume taking acquisitions.
Press **Single Acquistion Sequence** (side). That selection lets you run a single sequence of acquisitions by pressing the **RUN/STOP** button. In Sample mode, the digitizing oscilloscope will acquire a waveform record with the first valid trigger event and stop.

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

Hint: 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.)

- **Limit Test Condition Met** (side) lets you 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**

*In order for the digitizing 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. You can create the template waveform against which to compare incoming waveforms, using the **Create Limit Test Template** main menu item. You can then specify that the comparison is to be made, and the channel to compare against the template, using the **Limit Test Sources** main menu item.

**For More Information**

See **Acquisition**, on page 2-19.

See **Limit Testing**, on page 3-70.
Autoset

The autoset function lets you quickly obtain and display a stable waveform of usable size. 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 makes adjustments in these areas:

- Acquisition
- Display
- Horizontal
- Trigger
- Vertical

**NOTE**

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

---

**Operation**

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 digitizing 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 digitizing oscilloscope will turn on channel one (CH 1) and scale it.

---

**Autoset Defaults**

Table 3-1 on the following page lists the autoset defaults.
Table 3-1: Autoset Defaults

<table>
<thead>
<tr>
<th>Control</th>
<th>Changed by Autoset to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected channel</td>
<td>Numerically lowest of the displayed channels</td>
</tr>
<tr>
<td>Acquire Mode</td>
<td>Sample</td>
</tr>
<tr>
<td>Acquire Stop After</td>
<td>RUN/STOP button only</td>
</tr>
<tr>
<td>Display Style</td>
<td>Vectors</td>
</tr>
<tr>
<td>Display Intensity — Overall (TDS 640A &amp; TDS 620A)</td>
<td>If less than 50%, set to 75%</td>
</tr>
<tr>
<td>Display Format</td>
<td>YT</td>
</tr>
<tr>
<td>Horizontal Position</td>
<td>Centered within the graticule window</td>
</tr>
<tr>
<td>Horizontal Scale</td>
<td>As determined by the signal frequency</td>
</tr>
<tr>
<td>Horizontal Time Base</td>
<td>Main Only</td>
</tr>
<tr>
<td>Horizontal Record Length</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Limit Test</td>
<td>Off</td>
</tr>
<tr>
<td>Trigger Position</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Trigger Type</td>
<td>Edge</td>
</tr>
<tr>
<td>Trigger Source</td>
<td>Numerically lowest of the displayed channels (the selected channel)</td>
</tr>
<tr>
<td>Trigger Level</td>
<td>Midpoint of data for the trigger source</td>
</tr>
<tr>
<td>Trigger Slope</td>
<td>Positive</td>
</tr>
<tr>
<td>Trigger Coupling</td>
<td>DC</td>
</tr>
<tr>
<td>Trigger Holdoff</td>
<td>0</td>
</tr>
<tr>
<td>Vertical Scale</td>
<td>As determined by the signal level</td>
</tr>
<tr>
<td>Vertical Coupling</td>
<td>DC unless AC was previously set. AC remains unchanged.</td>
</tr>
<tr>
<td>Vertical Bandwidth</td>
<td>Full</td>
</tr>
<tr>
<td>Vertical Offset</td>
<td>0 volts</td>
</tr>
<tr>
<td>Zoom</td>
<td>Off</td>
</tr>
</tbody>
</table>
Color (TDS 644A)

The TDS 644A can display information in different colors. The Color menu lets you choose palettes of colors and decide what colors to assign to what pieces of information.

Operation

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 3-4).

Figure 3-4: Display Menu — Setting

Color lets you alter color settings for various display components such as waveforms and text. Display lets you adjust the style, intensity level, graticule, and format features. For more information on display, see Display on page 3-26.
Choose Palette

You can choose a palette of 13 colors from a menu of pre-set 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 wish 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 hardcopy preview palette comprise a white background and fully saturated primary colors which generally produce the best result.*

Change Palette Colors

You can change the current palette colors. You do this by selecting a color and varying its hue, lightness, and saturation. Hue is the wavelength of light reflected from the surface. It varies continuously along the color spectrum as produced by a rainbow. Lightness refers to the amount of light reflected from the surface. It varies from black, to the nominal color, to white. Saturation is the intensity of color. Completely desaturated color is gray. Completely saturated color of any hue is that color at its most intense level.

1. Select the main menu **Change Colors** item (see Figure 3-5).
2. Select one of the 13 colors by pressing (repeatedly) **Color** in the side menu.

3. If you want to use the factory default for this color, 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 360 = 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.

**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 3-6).

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 3-6: Display Menu — Map Reference Colors](image-url)
Select Options

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

1. Press the **Options** main menu item.
2. Select that you wish to use a special color to mark collision zones by toggling **Collision Contrast** in the side menu to **ON**.

Restore Colors

To restore colors to their factory default settings:

1. Press the main menu **Restore Colors** item (see Figure 3-7).
2. Select what you wish to restore by pressing **Reset Current Palette To Factory**, **Reset All Palettes To Factory** or **Reset All Mappings To Factory** in the side menu.

![Figure 3-7: Display Menu — Restore Colors](image)

For More Information

See *Display Modes*, on page 3-26.
Cursor Measurements

Use the cursors to measure the difference (either in time or voltage) between two locations in a waveform record.

**Description**

Cursors are made up of two markers that you position with the general purpose knob. You move one cursor independently or both cursors in tandem, depending on the cursor mode. As you position the cursors, readouts on the display report measurement information.

There are three cursor types: **horizontal bar**, **vertical bar**, and **paired** (Figure 3-8).

*Horizontal bar cursors* measure vertical parameters (typically volts).

*Vertical bar cursors* measure horizontal parameters (typically time or frequency).

*Paired cursors* measure both vertical parameters (typically volts) and horizontal parameters (typically time) simultaneously.

Look at Figure 3-8. Note that each of the two paired cursors has a long vertical bar paired with an X. The Xs measures vertical parameters (typically volts); the long vertical bars measure horizontal parameters (typically time or frequency). (See *Cursor Readouts* on page 3-16 for more information.)

![Cursor Types](image-url)
Cursor Measurements

NOTE

When cursors measure certain math waveforms, the measurement may not be of time, frequency, or voltage. Cursor measurement of those math waveforms that are not of time, frequency, or voltage is described in Waveform Math, which begins on page 3-148.

There are two cursor modes: independent and tracking (see Figure 3-9).

![Cursor Modes Diagram]

**Figure 3-9: Cursor Modes**

In independent mode you move only one cursor at a time using the general purpose knob. The active, or selected, cursor is a solid line. Press SELECT to change which cursor is selected.

In tracking mode you normally move both cursors in tandem using the general purpose knob. The two cursors remain a fixed distance (time or voltage) from each other. Press SELECT to temporarily suspend cursor tracking. You can then use the general purpose knob to adjust the distance of the solid cursor relative to the dashed cursor. A second push toggles the cursors back to tracking.

---

**Cursor Readouts**

The cursor readout shows the absolute location of the selected cursor and the difference between the selected and non-selected cursor. The readouts differ depending on whether you are using H Bars or V Bars.

- **H Bars**: the value after Δ shows the voltage difference between the cursors. The value after @ shows the voltage of the selected cursor relative to ground (see Figure 3-10). With the video trigger option, you can also display the voltage in IRE units.

- **V Bars**: the value after Δ shows the time (or frequency) difference between the cursors. The value after @ shows the time (frequency) of the selected cursor relative to the trigger point. With the video trigger option, you can also display the line number.
In FastFrame mode, the @ shows the time position of the selected cursor relative to the trigger point of the frame that the selected cursor is in. The Δ shows the time difference between the two cursors only if both cursors are in the same frame.

- **Paired**: the value after one Δ shows the voltage difference between the two Xs; the other Δ shows the time (or frequency) difference between the two long vertical bars. The value after @ shows the voltage at the X of the selected cursor relative to ground (see Figure 3-11).

In FastFrame mode, the Δ shows the time difference between the two cursors only if both cursors are in the same frame.

![Cursor Measurements](image)

**Figure 3-10: H Bars Cursor Menu and Readouts**

Paired cursors can only show voltage differences when they remain on screen. If the paired cursors are moved off screen horizontally, **Edge** will replace the voltage values in the cursor readout.

---

**Operation**

To take cursor measurements, press **CURSOR** to display the Cursor menu (Figure 3-10).

**Function**

Select the type of cursors you want using the **Function** menu item:

Press **CURSOR → Function (main) → H Bars, V Bars, Paired**, or **Off** (side).
Mode

Select the cursor mode you want using the Mode menu item.

1. Press CURSOR → Mode (main) → Independent or Tracking (side):
   - Independent makes each cursor positionable without regard to the position of the other cursor.
   - Tracking makes both cursors positionable in tandem; that is, both cursors move in unison and maintain a fixed horizontal or vertical distance between each other.

2. Use the general purpose knob to move the selected (active) cursor if Independent was selected in step 1. Press SELECT to change which cursor is active and moves. A solid line indicates the active cursor, and a dashed line the inactive cursor.

   or

   Use the general purpose knob to move both cursors in tandem if Tracking was selected in step 1. Press SELECT to temporarily suspend cursor tracking; then use the general purpose knob to adjust the distance of the solid cursor relative to the dashed cursor. Press SELECT again to resume tracking. A solid line indicates the adjustable cursor and a dashed line the fixed cursor.
Time Units

You can choose to display vertical bar cursor results in units of time or frequency. If you have Option 5 Video, you can also display the results in terms of video line number.

Press CURSOR → Time Units (main) → seconds or 1/seconds (Hz) or, with Option 5, video line number (side).

Amplitude Units

If you are measuring NTSC signals, you can choose to display vertical readings in IRE units. If you are trying to do this, you should have option 05 Video Trigger installed as it would be difficult to trigger on composite video waveforms without option 05.

Press CURSOR → Amplitude Units (main) → IRE (NTSC)

To return to normal:

Press CURSOR → Amplitude Units (main) → Base

Cursor Speed

You can change the cursors speed by pressing SHIFT before turning the general purpose knob. The cursor moves faster when the SHIFT button is lighted and the display reads Coarse Knobs in the upper right corner.

For More Information

See Measurements, on page 2-26.

See Waveform Math, on page 3-148, for information on cursor units with multiplied waveforms.

See Fast Fourier Transforms on page 3-36, Waveform Differentiation on page 3-139, and Waveform Integration on page 3-143, if your oscilloscope is equipped with Option 2F Advanced DSP Math (standard on the TDS 644A), for information on cursor units with integrated, differentiated, and FFT waveforms.

See the TDS Family Option 05 Video Trigger Interface, if your oscilloscope is equipped with the video trigger option, for information on cursor units with video waveforms.
Delayed Triggering

The TDS 600A Series oscilloscopes provide a main time base and a delayed time base. The delayed time base, like the main time base, requires a trigger signal and an input source dedicated to that signal. You can only use delay with respect to the main edge trigger and certain classes of main pulse triggers.

There are two different ways to delay the acquisition of waveforms: *delayed runs after main* and *delayed triggerable*. Only delayed triggerable uses the delayed trigger system.

*Delayed runs after main* looks for a main trigger, then waits a user-defined time, and then starts acquiring (see Figure 3-12).

![Figure 3-12: Delayed Runs After Main](image)

*Delayed triggerable* looks for a main trigger and then, depending on the type of delayed trigger selected, makes one of the three types of delayed triggerable mode acquisitions listed below (see Figure 3-13).

![Figure 3-13: Delayed Triggerable](image)
Delayed Triggering

- **After Time** waits the user-specified time, then waits for the next delayed trigger event, and then acquires.
- **After Events** waits for the specified number of delayed trigger events and then acquires.
- **After Events/Time** waits for the specified number of delayed trigger events, then waits the user-specified time, and then acquires.

The digitizing oscilloscope is always acquiring samples to fill the pretrigger part of the waveform record. When and if delay criteria are met, it takes enough posttrigger samples to complete the delayed waveform record and then displays it. Refer to Figure 3-14 for a more detailed look at how delayed records are placed in time relative to the main trigger.

**NOTE**

When using the delayed triggerable mode, the digitizing oscilloscope provides a conventional edge trigger for the delayed time base. The delayed time base will not trigger if the main trigger type (as defined in the Main Trigger menu) is logic, if the main trigger type is edge with its source set to auxiliary, or if the main trigger type is pulse with the runt trigger class selected.

---

**Operation**

You use the Horizontal menu to select and define either delayed runs after main or delayed triggerable. Delayed triggerable, however, requires further selections in the Delayed Trigger menu.

**Delayed Runs After Main**

1. Press **HORIZONTAL MENU → Time Base** (main) → **Delayed Only (side)** → **Delayed Runs After Main** (side). Use the general purpose knob or the keypad to set the delay time.

   If you press **Intensified** (side), you display an intensified zone on the main timebase record that shows where the delayed timebase record occurs relative to the main trigger. For Delayed Runs After Main mode, the start of the intensified zone corresponds to the start of the delayed timebase record. The end of the zone corresponds to the end of the delayed record.
Delayed Triggering

Delayed Runs After Main

Delayed Triggerable By Events

Delayed Triggerable By Time

Delayed Triggerable By Events/Time

Figure 3-14: How the Delayed Triggers Work
Delayed Triggerable

You must make sure that the Main Trigger menu settings are compatible with Delayed Triggerable.

1. Press TRIGGER MENU.

2. If Type is set to Logic, press Type (main) to change it to either Edge or Pulse as fits your application. Logic type is incompatible with Delayed Triggerable.

3. If Source is set to Auxiliary, press Source (main). Select any source other than Auxiliary from the side menu according to your application.


**NOTE**

*The Delayed Triggerable menu item is not selectable unless incompatible Main Trigger menu settings are eliminated. (See the steps at the beginning of this procedure.) If such is the case, the Delayed Triggerable menu item is dimmer than other items in the menu.*

By pressing Intensified (side), you can display an intensified zone that shows where the delayed timebase record may occur (a valid delay trigger event must be received) relative to the main trigger on the main time base. For Delayed Triggerable After mode, the start of the intensified zone corresponds to the possible start point of the delayed time base record. The end of the zone continues to the end of main time base, since a delayed time base record may be triggered at any point after the delay time elapses.

To learn how to define the intensity level of the normal and intensified waveform, see Display Modes on page 3-26.

Now you need to bring up the Delayed Trigger menu so you can define the delayed trigger event.

5. Press SHIFT DELAYED TRIG → Delay by (main) → Triggerable After Time, Events, or Events/Time (side) (Figure 3-15).

6. Enter the delay time or events using the general purpose knob or the keypad. If you selected Events/Time, use Time (side) and Events (side) to switch between setting the time and the number of events.

Hint: You can go directly to the Delayed Trigger menu (see step 5). By selecting one of Triggerable After Time, Events, or Events/Time, the oscilloscope automatically switches to Delayed Triggerable in the Horizontal menu. You will still need to display the Horizontal menu if you wish to leave Delayed Triggerable.

The Source menu lets you select which input will be the delayed trigger source.
7. Press **Source** (main) → **Ch1, Ch2, Ch3 (Ax1 on the TDS 620A), Ch4 (Ax2 on the TDS 620A), or Auxiliary** (side).

![Delayed Triggering Menu](image)

**Figure 3-15: Delayed Trigger Menu**

8. Press **Coupling** (main) → **DC, AC, HF Rej, LF Rej**, or **Noise Rej** (side) to define how the input signal will be coupled to the delayed trigger. For descriptions of these coupling types, see *Triggering* on page 2-13.

9. Press **Slope** (main) to select the slope that the delayed trigger will occur on. Choose between the rising edge and falling edge slopes.

When using Delayed Triggerable mode to acquire waveforms, two trigger bars are displayed. One trigger bar indicates the level set by the main trigger system; the other indicates the level set by the delayed trigger system.

10. Press **Level** (main) → **Level, Set to TTL, Set to ECL, or Set to 50%** (side).
    - **Level** lets you enter the delayed 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 Vertical SCALE smaller than 200 mV, the oscilloscope reduces the Set to TTL or Set to ECL trigger levels below standard TTL and ECL levels. That happens 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 delayed trigger level to 50% of the peak-to-peak value of the delayed trigger source signal.

---

For More Information

For more information, see Triggering, on page 2-13.

For more information, see Triggering, on page 3-132.
Display Modes

The digitizing oscilloscope can display waveform records in different ways. The Display menu lets you adjust the oscilloscope display style, intensity level, graticule, and format.

**Operation**

To bring up the Display menu:

1. Press **DISPLAY** to show the Display menu.

2. On the TDS 644A, press **Setting** in the main menu until you select **Display** from the pop-up menu.

**Display** lets you adjust the style, intensity level, graticule, and format features described below. **Color** (TDS 644A) lets you alter color settings for various display components such as waveforms and text. For more information on color, see **Color** on page 3-10.

**Display Style**

Press **DISPLAY → Style** (main) → **Vectors, Intensified Samples, Dots, Infinite Persistence**, or **Variable Persistence** (side) (Figure 3-16).

![Figure 3-16: Display Menu — Style](image-url)
- **Vectors** has the display draw vectors (lines) between the record points.
- **Dots** display waveform record points as dots.
- **Intensified Samples** also displays waveform record points as dots. However, the points actually sampled are displayed in the Zone color (TDS 644A) or intensified relative to the interpolated points.

In addition to choosing Intensified Samples in the side menu, the oscilloscope must be interpolating or Zoom must be on with its horizontal expansion greater than 1X. See interpolation on page 2-20; see Zoom beginning on page 3-151.

- **Variable Persistence** lets the record points accumulate on screen over many acquisitions and remain displayed 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. On color instruments, record points are also displayed with colors that vary depending on the points persistence. See Choose Palette on page 3-11.

- **Infinite Persistence** lets the record points accumulate until you change some control (such as scale factor) causing the display to be erased.

**Intensity**

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

Press **DISPLAY → Intensity** (main) → **Overall** (TDS 640A & TDS 620A), **Text/Grat, Waveform**, or **Contrast** (TDS 640A & TDS 620A) (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).

Contrast (TDS 640A & TDS 620A) operates over a range from 100% (no contrast) to 250% (intensified portion at full brightness).

**NOTE**

*The Intensified setting for Timebase in the horizontal menu causes a zone on the waveform to be displayed in the Zone color (TDS 644A) or intensified relative to the rest of the waveform. If the contrast is set to 100%, you won’t be able to distinguish the intensified portion from the rest of the waveform because both are the same brightness.*
Display Readout

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. Press **DISPLAY → Readout** (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 3-17. 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 timebase. The trigger bar is a visual indicator of the trigger level.

   Sometimes, especially when using the hardcopy feature, you may wish to display the current date and time on screen. For more information about displaying and setting date and time, see **Date/Time Stamping Your Hardcopy** on page 3-60.

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

![Figure 3-17: Trigger Point and Level Indicators](image)
Filter Type
The display filter types are sin(x)/x interpolation and linear interpolation. For more information see the Concepts section, page 2-20.

Press DISPLAY → Filter (main) → Sin(x)/x Interpolation or Linear Interpolation (side).

NOTE

When the horizontal scale is set to rates faster than 25 ns/div, 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 needed. See Sampling and Digitizing on page 2-19 for a discussion of sampling including interpolation.

Graticule Type
To change the graticule:

Press DISPLAY → 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 wish to recall the factory setup or other stored setup after selecting a different graticule.

Format
There are two kinds of format: YT and XY.

**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 digitizing 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.

To set the display axis format:

Press `DISPLAY → Format` (main) → *XY* or *YT* (side).

When you choose the XY mode, the input you have selected is assigned to the X-axis, and the digitizing oscilloscope automatically chooses the Y-axis input (see Table 3-2).

**Table 3-2: XY Format Pairs**

<table>
<thead>
<tr>
<th>X-Axis Channel (User Selectable)</th>
<th>Y-Axis Channel (Fixed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 1</td>
<td>Ch 2</td>
</tr>
<tr>
<td>Ch 3 (TDS 644A &amp; TDS 640A) (Aux 1 on the TDS 620A)</td>
<td>Ch 4 (TDS 644A &amp; TDS 640A) (Aux 2 on the TDS 620A)</td>
</tr>
<tr>
<td>Ref 1</td>
<td>Ref 2</td>
</tr>
<tr>
<td>Ref 3</td>
<td>Ref 4</td>
</tr>
</tbody>
</table>

For example, if you press the **CH 1** button, the digitizing oscilloscope will display a graph of the channel 1 voltage levels on the X-axis against the channel 2 voltage levels on the Y-axis. That will occur whether or not you are displaying the channel 2 waveform in YT format. If you later press the **WAVEFORM OFF** button for either channel 1 or 2, the digitizing oscilloscope will delete the XY graph of channel 1 versus channel 2.

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

See Acquisition, on page 2-19.

See Color, on page 3-10.

See Measurements, on page 2-26.
Edge Triggering

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.

You can select the edge source, coupling, slope, level, and mode (auto or normal).

---

**Edge Trigger Readouts**

The Trigger readout shows some key trigger parameters (Figure 3-18).

---

**Operation**

The Edge Trigger menu lets you select the source, coupling, slope, trigger level, mode, and holdoff.

To bring up the Edge Trigger menu:

Press **TRIGGER MENU → Type** (main) → **Edge** (pop-up) (see Figure 3-19).

---

**Source**

To select which source you want for the trigger:

Press **TRIGGER MENU → Type** (main) → **Edge** (pop-up) → **Source** (main) → Ch1, Ch2, Ch3 (Ax1 on the TDS 620A), Ch4 (Ax2 on the TDS 620A), **AC Line**, or **Auxiliary** (side).
**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 (above 10 Hz). 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** does the opposite of high frequency rejection. 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.
Edge Triggering

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. Alternatives for slope are the rising and falling edges.

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. That happens 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.
Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu item. See Triggering on page 2-13 for more details.

1. Press the TRIGGER MENU → Mode & Holdoff (main) → Auto or Normal (side).
   - 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 % 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 0% (minimum holdoff available) to 100% (maximum available). See Holdoff, Variable, Main Trigger in the TDS 620A, 640A, & 644A Performance Verification Manual, Section 2 on Specifications, Typical Characteristics for typical minimum and maximum values.

Holdoff is automatically reset to 0% when you change the main time base time/division setting. However, it is not reset if you change the delayed time base time/division (that is, when the time base setting in the Horizontal menu is Intensified or Delayed Only).

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For More Information

See Triggering, on page 2-13.

See Triggering, on page 3-132.
Fast Fourier Transforms

Advanced DSP Math (optional on TDS 620A & TDS 640A), provides the Fast Fourier Transform (FFT). The FFT allows you to transform a waveform from a display of its amplitude against time to one that plots the amplitudes of the various discrete frequencies the waveform contains. Further, you can also display the phase shifts of those frequencies. Use FFT math waveforms in the following applications:

- Testing impulse response of filters and systems
- Measuring harmonic content and distortion in systems
- Characterizing the frequency content of DC power supplies
- Analyzing vibration
- Analyzing harmonics in 50 and 60 cycle lines
- Identifying noise sources in digital logic circuits

Description

The FFT computes and displays the frequency content of a waveform you acquire as an FFT math waveform. This frequency domain waveform is based on the following equation:

\[
X(k) = \frac{1}{N} \sum_{n=-\frac{N}{2}}^{\frac{N}{2}-1} x(n)e^{-j\frac{2\pi nk}{N}} \quad \text{for} \quad k = 0 \text{ to } N - 1
\]

Where:
- \(x(n)\) is a point in the time domain record data array
- \(X(k)\) is a point in the frequency domain record data array
- \(n\) is the index to the time domain data array
- \(k\) is the index to the frequency domain data array
- \(N\) is the FFT length
- \(j\) is the square root of \(-1\)

The resulting waveform is a display of the magnitude or phase angle of the various frequencies the waveform contains with respect to those frequencies. For example, Figure 3-20 shows the non-transformed impulse response of a system in channel 2 at the top of the screen. The FFT-transformed magnitude and phase appear in the two math waveforms below the
impulse. The horizontal scale for FFT math waveforms is always expressed in frequency per division with the beginning (left-most point) of the waveform representing zero frequency (DC).

The FFT waveform is based on digital signal processing (DSP) of data, which allows more versatility in measuring the frequency content of waveforms. For example, DSP allows the oscilloscope to compute FFTs of source waveforms that must be acquired based on a single trigger, making it useful for measuring the frequency content of single events.

Figure 3-20: System Response to an Impulse

**Operation**

To obtain an FFT of your waveform:

1. Connect the waveform to the desired channel input and select that channel.

2. Adjust the vertical and horizontal scales and trigger the display (or press AUTOSET).

   The topic *Offset, Position, and Scale*, on page 3-44, provides in depth information about optimizing your setup for FFT displays.

3. Press MORE to access the menu for turning on math waveforms.

4. Select a math waveform. Your choices are Math1, Math2, and Math3 (main).
5. If the selected math waveform is not FFT, press **Change Math Definition** (side) → **FFT** (main). See Figure 3-21.

6. Press **Set FFT Source to** (side) repeatedly until the channel source selected in step 1 appears in the menu label.

7. Press **Set FFT Vert Scale to** (side) repeatedly to choose from the following vertical scale types:
   - **dBV RMS** — Magnitude is displayed using log scale, expressed in dB relative to 1 V_{RMS} where 0 dB = 1 V_{RMS}.
   - **Linear RMS** — Magnitude is displayed using voltage as the scale.
   - **Phase (deg)** — Phase is displayed using degrees as the scale, where degrees wrap from −180° to +180°.
   - **Phase (rad)** — Phase is displayed using radians as the scale, where radians wrap from −π to +π.

   The topic *Considerations for Phase Displays*, on page 3-47, provides in depth information on setup for phase displays.

8. Press **Set FFT Window to** (side) repeatedly to choose from the following window types:
   - **Rectangular** — Best type for resolving frequencies that are very close to the same value but worst for accurately measuring the amplitude of those frequencies. Best type for measuring the frequency spectrum of non-repetitive signals and measuring frequency components near DC.
- **Hamming** — Very good window for resolving frequencies that are very close to the same value with somewhat improved amplitude accuracy over the rectangular window.

- **Hanning** — Very good window for measuring amplitude accuracy but degraded for resolving frequencies.

- **Blackman-Harris** — Best window for measuring the amplitude of frequencies but worst at resolving frequencies.

The topic *Selecting the Window*, on page 3-49, provides in depth information on choosing the right window for your application.

9. If you did not select **Phase (deg)** or **Phase (rad)** in step 7, skip to step 12. Phase suppression is only used to reduce noise in phase FFTs.

10. If you need to reduce the effect of noise in your phase FFT, press **Suppress phase at amplitudes <** (side).

11. Use the general purpose knob (or the keypad if your oscilloscope is so equipped) to adjust the phase suppression level. FFT magnitudes below this level will have their phase set to zero.

The topic *Adjust Phase Suppression*, on page 3-48, provides additional information on phase suppression.

12. Press **OK Create Math Wfm** (side) to display the FFT of the waveform you input in step 1 (see Figure 3-22).

![Figure 3-22: FFT Math Waveform in Math1](image-url)
Cursor Measurements of an FFT

Once you have displayed an FFT math waveform, use cursors to measure its frequency amplitude or phase angle.

1. Be sure **MORE** is selected in the channel selection buttons and that the FFT math waveform is selected in the **More** main menu.

2. Press **CURSOR → Mode** (main) → **Independent** (side) → **Function** (main) → **H Bars** (side).

3. Use the general purpose knob to align the selected cursor (solid line) to the top (or to any amplitude on the waveform you choose).

4. Press **SELECT** to select the other cursor. Use the general purpose knob to align the selected cursor to the bottom (or to any amplitude on the waveform you choose).

5. Read the amplitude between the two cursors from the **Δ**: readout. Read the amplitude of the selected cursor relative to either 1 \( V_{\text{RMS}} \) (0 dB), ground (0 volts), or the zero phase level (0 degrees or 0 radians) from the **@**: readout. (The waveform reference indicator at the left side of the graticule indicates the level where phase is zero for phase FFTs.)

   Figure 3-23 shows the cursor measurement of a frequency magnitude on an FFT. The **@**: readout reads 0 dB because it is aligned with the 1 \( V_{\text{RMS}} \) level. The **Δ**: readout reads 24.4 dB indicating the magnitude of the frequency it is measuring is \(-24.4 \text{ dB}\) relative to 1 \( V_{\text{RMS}} \). The source waveform is turned off in the display.

   The cursor units will be in dB or volts for FFTs measuring magnitude and in degrees or radians for those FFTs measuring phase. The cursor unit depends on the selection made for **Set FFT Vert Scale to** (side). See step 7 on page 3-38 for more information.

6. Press **V Bars** (side). Use the general purpose knob to align one of the two vertical cursors to a point of interest along the horizontal axis of the waveform.

7. Press **SELECT** to select the alternate cursor.

8. Align the selected cursor to another point of interest on the math waveform.

9. Read the frequency difference between the cursors from the **Δ**: readout. Read the frequency of the selected cursor relative to the zero frequency point from the **@**: readout.

   The cursor units will always be in Hz, regardless of the setting in the **Time Units** side menu. The first point of the FFT record is the zero frequency point for the **@**: readout.
Figure 3-23: Cursor Measurement of an FFT Waveform

10. Press **Function** (main) → **Paired** (side).

11. Use the technique just outlined to place the vertical bar of each paired cursor to the points along the horizontal axis you are interested in.

12. Read the amplitude between the X of the two paired cursors from the top-most $\Delta$: readout. Read the amplitude of the short horizontal bar of the selected (solid) cursor relative to either $V_{\text{RMS}}$ (0 dB), ground (0 volts), or zero phase level (0 degrees or 0 radians) from the @: readout. Read the frequency between the long horizontal bars of both paired cursors from the bottom $\Delta$: readout.

**Automated Measurements of an FFT**

You can also use automated measurements to measure FFT math waveforms. Use the same procedure as is found under *Waveform Differentiation* on page 3-140.

---

**Considerations for Using FFTs**

There are several characteristics of FFTs that affect how they are displayed and should be interpreted. Read the following topics to learn how to optimize the oscilloscope setup for good display of your FFT waveforms.
The FFT Frequency Domain Record

The following topics discuss the relation of the source waveform to the record length, frequency resolution, and frequency range of the FFT frequency domain record. (The FFT frequency domain waveform is the FFT math waveform that you display.)

FFTs May Not Use All of the Waveform Record — The FFT math waveform is a display of the magnitude or phase data from the FFT frequency domain record. This frequency domain record is derived from the FFT time domain record, which is derived from the waveform record. All three records are described below.

Waveform Record — the complete waveform record acquired from an input channel and displayed from the same channel or a reference memory. The length of this time domain record is user-specified from the Horizontal menu. The waveform record is not a DSP Math waveform.

FFT Time Domain Record — that part of the waveform record that is input to the FFT. This time domain record waveform becomes the FFT math waveform after it is transformed. Its record length depends on the length of the waveform record defined above.

FFT Frequency Domain Record — the FFT math waveform after digital signal processing converts data from the FFT time domain record into a frequency domain record.

Figure 3-24 compares the waveform record to the FFT time domain record. Note the following relationships:

- For waveform records ≤10 K points in length, the FFT uses all of the waveform record as input.
- For waveform records >10 K points, the first 10 K points of the waveform record becomes the FFT time domain record.
- Each FFT time domain record starts at the beginning of the acquired waveform record.
- The zero phase reference point for a phase FFT math waveform is in the middle of the FFT time domain record regardless of the waveform record length.
**FFT Time Domain Record = Waveform Record**

Waveform Record ≤ 10 K

Zero Phase Reference

**FFT Time Domain Record = 10k**

Waveform Record > 10 K

Zero Phase Reference

**Figure 3-24: Waveform Record vs. FFT Time Domain Record**

**FFTs Transform Time Records to Frequency Records** — The FFT time domain record just described is input for the FFT. Figure 3-25 shows the transformation of that time domain data record into an FFT frequency domain record. The resulting frequency domain record is one half the length of the FFT input because the FFT computes both positive and negative frequencies. Since the negative values mirror the positive values, only the positive values are displayed.

**Figure 3-25: FFT Time Domain Record vs. FFT Frequency Domain Record**

**FFT Frequency Range and Resolution** — When you turn on an FFT waveform, the oscilloscope displays either the magnitude or phase angle of the FFT frequency domain record. The resolution between the discrete frequencies displayed in this waveform is determined by the following equation:
Fast Fourier Transforms

\[ \Delta F = \frac{\text{Sample Rate}}{\text{FFT Length}} \]

Where: \( \Delta F \) is the frequency resolution.

*Sample Rate* is the sample rate of the source waveform.

*FFT Length* is the length of the FFT Time Domain waveform record.

The sample rate also determines the range these frequencies span; they span from 0 to \( \frac{1}{2} \) the sample rate of the waveform record. (The value of \( \frac{1}{2} \) the sample rate is often referred to as the Nyquist frequency or point.) For example, a sample rate of 20 Megasamples per second would yield an FFT with a range of 0 to 10 MHz. The sample rates available for acquiring data records vary over a range the limits of which depend on your oscilloscope model. TDS oscilloscopes display the sample rate in the acquisition readout at the top of the oscilloscope screen.

**Offset, Position, and Scale**

The following topics contain information to help you display your FFT properly.

**Adjust for a Non-Clipped Display** — To properly display your FFT waveform, scale the source waveform so it is not clipped.

- You should scale and position the source waveform so it is contained on screen. (Off screen waveforms may be clipped, resulting in errors in the FFT waveform).

  Alternately, to get maximum vertical resolution, you can display source waveforms with amplitudes up to two divisions greater than that of the screen. If you do, turn on **Pp-Pp** in the measurement menu and monitor the source waveform for clipping.

- Use vertical position and vertical offset to position your source waveform. As long as the source waveform is not clipped, its vertical position and vertical offset will not affect your FFT waveform except at DC. (DC correction is discussed below.)

**Adjust Offset and Position to Zero for DC Correction** — Normally, the output of a standard FFT computation yields a DC value that is twice as large as it should be with respect to the other frequencies. Also, the selection of window type introduces errors in the DC value of an FFT.

The displayed output of the FFT on TDS oscilloscopes is corrected for these errors to show the true value for the DC component of the input signal. The **Position** and **Offset** must be set to zero for the source waveform in the Vertical menu. When measuring the amplitude at DC, remember that 1 VDC equals 1 Vrms and the display is in dB.
Record Length

Most often, you will want to use a short record length because more of the FFT waveform can be seen on screen and long record lengths can slow oscilloscope response. However, long record lengths lower the noise relative to the signal and increase the frequency resolution for the FFT. More important, they might be needed to capture the waveform feature you want to include in the FFT.

To speed up oscilloscope response when using long record lengths, you can save your source waveform in a reference memory and perform an FFT on the saved waveform. That way the DSP will compute the FFT based on saved, static data and will only update if you save a new waveform.

Acquisition Mode

Selecting the right acquisition mode can produce less noisy FFTs.

Set up in Sample or Normal Mode — Use sample mode until you have set up and turned on your FFT. Sample mode can acquire repetitive and nonrepetitive waveforms and does not affect the frequency response of the source waveform.

Hi Res and Average Reduce Noise — After the FFT is set up and displayed, it might be useful to turn on Hi Res mode, on TDS models so equipped, to reduce the effect of noise in the signal. Hi Res operates on both repetitive and nonrepetitive waveforms; however, it does affect the frequency response of the source waveform.

If the pulse is repetitive, Average mode may be used to reduce noise in the signal at a cost of slower display response. Average operates on repetitive waveforms only, and averaging does affect the frequency response of the source waveform.

Peak Detect (on TDS models so equipped) and Envelope mode can add significant distortion to the FFT results and are not recommended for use with FFTs.

Zoom and Interpolation

Once you have your waveform displayed optimally, you may magnify (or reduce) it vertically and horizontally to inspect any feature you desire. Just be sure the FFT waveform is the selected waveform. (Press MORE, then select the FFT waveform in the More main menu. Then use the Vertical and Horizontal SCALE knobs to adjust the math waveform size.)

If you wish to see the zoom factor (2X, 5X, etc.) you need to turn Zoom on: press ZOOM → On (side). The vertical and horizontal zoom factors appear on screen.

Whether Zoom is on or off, you can press Reset Zoom Factors (side) to return the zoomed FFT waveform to no magnification.
Fast Fourier Transforms

Zoom always uses either sin(x)/x or linear interpolation when expanding displayed waveforms. To select the interpolation method: press DISPLAY → Setting (main) → Display (pop-up) → Filter (main) → Sin(x)/x or Linear (side), or if your oscilloscope does not have color, press DISPLAY → Filter (main) → Sin(x)/x or Linear (side).

If the source waveform record length is 500 points, the FFT will use 2X Zoom to increase the 250 point FFT frequency domain record to 500 points. Therefore, FFT math waveforms of 500 point waveforms are always zoomed 2X or more with interpolation. Waveforms with other record lengths can be zoomed or not and can have minimum Zooms of 1X or less.

Sin(x)/x interpolation may distort the magnitude and phase displays of the FFT depending on which window was used. You can easily check the effects of the interpolation by switching between sin(x)/x and linear interpolation and observing the difference in measurement results on the display. If significant differences occur, use linear interpolation.

Undersampling (Aliasing)

Aliasing occurs when the oscilloscope acquires a source waveform with frequency components outside of the frequency range for the current sample rate. In the FFT waveform, the actual higher frequency components are undersampled, and therefore, they appear as lower frequency aliases that “fold back” around the Nyquist point (see Figure 3-26).

The greatest frequency that can be input into any sampler without aliasing is ½ the sample frequency. Since source waveforms often have a fundamental frequency that does not alias but have harmonic frequencies that do, you should have methods for recognizing and dealing with aliases:

- Be aware that a source waveform with fast edge transition times creates many high frequency harmonics. These harmonics typically decrease in amplitude as their frequency increases.
- Sample the source signal at rates that are at least 2X that of the highest frequency component having significant amplitude.
- Filter the input to bandwidth limit it to frequencies below that of the Nyquist frequency.
- Recognize and ignore the aliased frequencies.

If you think you have aliased frequencies in your FFT, select the source channel and adjust the horizontal scale to increase the sample rate. Since you increase the Nyquist frequency as you increase the sample rate, the alias signals should appear at their proper frequency.
Considerations for Phase Displays

When you set up an FFT math waveform to display the phase angle of the frequencies contained in a waveform, you should take into account the reference point the phase is measured against. You may also need to use phase suppression to reduce noise in your FFTs.

Establish a Zero Phase Reference Point — The phase of each frequency is measured with respect to the zero phase reference point. The zero reference point is the point at the center of the FFT math waveform but corresponds to various points on the source (time domain) record. (See Figure 3-24 on page 3-43.)

To measure the phase relative to most source waveforms, you need only to center the positive peak around the zero phase point. (For instance, center the positive half cycle for a sine or square wave around the zero phase point.) Use the following method:

- First be sure the FFT math waveform is selected in the More menu, then set horizontal position to 50% in the Horizontal menu. This positions the zero phase reference point to the horizontal center of the screen.
- In the Horizontal menu, vary the trigger position to center the positive peak of the source waveform at the horizontal center of screen. Alternately, you can adjust the trigger level (knob) to bring the positive peak to center screen if the phase reference waveform has slow enough edges.

When impulse testing and measuring phase, align the impulse input into the system to the zero reference point of the FFT time domain waveform:

- Set the trigger position to 50% and horizontal position to 50% for all record lengths less than 15 K. (Your model oscilloscope may not have record lengths of 15 K or longer — consult your User manual.)
Fast Fourier Transforms

- For records with a 15 K length, set the trigger position to 33%. Use the horizontal position knob to move the trigger T on screen to the center horizontal graticule line.

- For records with 30 K, 50 K, or 60 K lengths (not all lengths are available for all TDS models — consult your User manual), set the trigger position to 16.6%, 10%, or 8.3%, respectively. Use the horizontal position knob to move the trigger T on screen and to the center horizontal graticule line.

- Trigger on the input impulse.

Adjust Phase Suppression — Your source waveform record may have a noise component with phase angles that randomly vary from –pi to pi. This noise could make the phase display unusable. In such a case, use phase suppression to control the noise.

You specify the phase suppression level in dB with respect to 1 \( V_{RMS} \). If the magnitude of the frequency is greater than this threshold, then its phase angle will be displayed. However, if it is less than this threshold, then the phase angle will be set to zero and be displayed as zero degrees or radians. (The waveform reference indicator at the left side of the graticule indicates the level where phase is zero for phase FFTs.)

It is easier to determine the level of phase suppression you need if you first create a frequency FFT math waveform of the source and then create a phase FFT waveform of the same source. Do the following steps to use a cursor measurement to determine the suppression level:

1. Do steps 1 through 7 of Operation that begins on page 3-37. Select dBV RMS (side) for the Set FFT Vert Scale to (side).

2. Press CURSOR \( \rightarrow \) Mode (main) \( \rightarrow \) Independent (side) \( \rightarrow \) Function (main) \( \rightarrow \) H Bars (side). Use the general purpose knob to align the selected cursor to a level that places the tops of the magnitudes of frequencies of interest above the cursor but places other magnitudes completely below the cursor.

3. Read the level in dB from the @: readout. Note the level for use in step 5.

4. Press MORE (main) \( \rightarrow \) Change Waveform Definition menu (side). Press Set FFT Vert Scale to (side) repeatedly to choose either Phase (rad) or Phase (deg).

5. Press Suppress Phase at Amplitudes (side). Use the general purpose knob (or keypad if your oscilloscope is so equipped) to set phase suppression to the value obtained using the H Bar cursor. Do not change the window selection or you will invalidate the results obtained using the cursor.
FFT Windows

To learn how to optimize your display of FFT data, read about how the FFT windows data before computing the FFT math waveform. Understanding FFT windowing can help you get more useful displays.

Windowing Process — The oscilloscope multiplies the FFT time domain record by one of four FFT windows before it inputs the record to the FFT function. Figure 3-27 shows how the time domain record is processed.

The FFT windowing acts like a bandpass filter between the FFT time domain record and the FFT frequency domain record. The shape of the window controls the ability of the FFT to resolve (separate) the frequencies and to accurately measure the amplitude of those frequencies.

Selecting a Window — You can select your window to provide better frequency resolution at the expense of better amplitude measurement accuracy in your FFT, better amplitude accuracy over frequency resolution, or to provide a compromise between both. You can choose from these four windows: Rectangular, Hamming, Hanning, and Blackman-Harris.

In step 8 (page 3-38) in Displaying an FFT, the four windows are listed in order according to their ability to resolve frequencies versus their ability to accurately measure the amplitude of those frequencies. The list indicates that the ability of a given window to resolve a frequency is inversely proportional to its ability to accurately measure the amplitude of that frequency. In general, then, choose a window that can just resolve between the frequencies you want to measure. That way, you will have the best amplitude accuracy and leakage elimination while still separating the frequencies.
Fast Fourier Transforms

**Figure 3-27: Windowing the FFT Time Domain Record**

You can often determine the best window empirically by first using the window with the most frequency resolution (rectangular), then proceeding toward that window with the least (Blackman-Harris) until the frequencies merge. Use the window just before the window that lets the frequencies merge for best compromise between resolution and amplitude accuracy.

**NOTE**

If the Hanning window merges the frequencies, try the Hamming window before settling on the rectangular window. Depending on the distance of the frequencies you are trying to measure from the fundamental, the Hamming window sometimes resolves frequencies better than the Hanning.
**Window Characteristics** — When evaluating a window for use, you may want to examine how it modifies the FFT time domain data. Figure 3-28 shows each window, its bandpass characteristic, bandwidth, and highest side lobe. Consider the following characteristics:

- The narrower the central lobe for a given window, the better it can resolve a frequency.

- The lower the lobes on the side of each central lobe are, the better the amplitude accuracy of the frequency measured in the FFT using that window.

- Narrow lobes increase frequency resolution because they are more selective. Lower side lobe amplitudes increases accuracy because they reduce leakage.

  Leakage results when the FFT time domain waveform delivered to the FFT function contains a non-integer number of waveform cycles. Since there are fractions of cycles in such records, there are discontinuities at the ends of the record. These discontinuities cause energy from each discrete frequency to “leak” over on to adjacent frequencies. The result is amplitude error when measuring those frequencies.

  The rectangular window does not modify the waveform record points; it generally gives the best frequency resolution because it results in the most narrow lobe width in the FFT output record. If the time domain records you measured always had an integer number of cycles, you would only need this window.

  Hamming, Hanning, and Blackman-Harris are all somewhat bell-shaped widows that taper the waveform record at the record ends. The Hanning and Blackman/Harris windows taper the data at the end of the record to zero; therefore, they are generally better choices to eliminate leakage.
### Fast Fourier Transforms

<table>
<thead>
<tr>
<th>FFT Window Type</th>
<th>Bandpass Filter</th>
<th>-3 dB Bandwidth</th>
<th>Highest Side Lobe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Window</td>
<td></td>
<td>0.89</td>
<td>-13 dB</td>
</tr>
<tr>
<td>Hamming Window</td>
<td></td>
<td>1.28</td>
<td>-43 dB</td>
</tr>
<tr>
<td>Hanning Window</td>
<td></td>
<td>1.28</td>
<td>-32 dB</td>
</tr>
<tr>
<td>Blackman-Harris Window</td>
<td></td>
<td>1.28</td>
<td>-94 dB</td>
</tr>
</tbody>
</table>

**Figure 3-28: FFT Windows and Bandpass Characteristics**

Care should be taken when using bell shaped widows to be sure that the most interesting parts of the signal in the time domain record are positioned in the center region of the window so that the tapering does not cause severe errors.

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**For More Information**

See [Waveform Differentiation](#), on page 3-139.

See [Waveform Integration](#), on page 3-143.

See [Waveform Math](#), on page 3-148.
File System (Optional on TDS 620A & TDS 640A)

The File Utilities menu, which comes with the Hardcopy, Save Setup, and Save Waveforms menus, gives you a variety of features for managing the floppy disk.

Operation

The File Utilities menu lets you delete, rename, copy, print files, create a new directory, operate the confirm delete and overwrite lock, and format disks.

To bring up the File Utilities menu:

1. Press the SETUP button to bring up the Save/Recall Setup menu, or press the WAVEFORM button to bring up the Save/Recall Waveform menu, or press the Shift HARDCOPY button to bring up the Hardcopy menu.

2. Press File Utilities in the main menu to bring up the File Utilities side menu. (see Figure 3-29).

Figure 3-29: File Utilities
NOTE

The amount of free space on the disk is shown in the upper right corner of the display. The digitizing oscilloscope shows the amount in K bytes. To convert the amount to bytes, you simply multiply the K bytes amount times 1024. Thus, the 711 kB shown in Figure 3-29 = 711 Kbytes * 1024 bytes/K = 728,064 bytes.

Delete

To delete a file or directory, turn the general purpose knob until it scrolls the cursor over the name of the file or directory to delete. Then, press the side menu Delete button.

To delete all files in the file list, set the cursor to the *.* selection.

The digitizing oscilloscope deletes directories recursively. That means it deletes both the directories and all their contents.

Rename

To rename a file or directory, turn the general purpose knob until it scrolls the cursor over the name of the file or directory to delete. For example, to rename the target file whose default name is TEK????? set the cursor over its name. Then, press the side menu Rename button.

The labelling menu should appear. Turn the general purpose knob or use the main-menu arrow keys to select each letter. Press Enter Char from the main menu to enter each letter. When you have entered the name, press the side menu OK Accept item (See Figure 3-30).
Copy

To copy a file or directory, turn the general purpose knob until it scrolls the cursor over the name of the file to copy. Then, press the side menu Copy button. The file menu will reappear with the names of directories to copy to. Select a directory and press the side-menu button labelled Copy <name> to Selected Directory.

To copy all files, select the *.* entry.

The digitizing oscilloscope copies all directories recursively. That means it copies both the directories and all their contents.

Print

To print a file, turn the general purpose knob until it scrolls the cursor over the name of the file to print. Then, press the side-menu Print button.

The Print-To side menu should appear. Select the port to print to from GPIB, RS-232, or Centronics. (See Figure 3-30) Then the digitizing oscilloscope will send the file in its raw form out the port. The device (printer) receiving the file must be capable of printing the particular file format.

Create Directory

To create a new directory, press the side menu Create Directory button.
The labelling menu should appear. Turn the general purpose knob or use the main-menu arrow keys to select each letter. Press **Enter Char** from the main menu to enter each letter. When you have entered the name, press the side menu **OK Accept** item. (See Figure 3-30)

**Confirm Delete**

To turn on or off the confirm delete message, toggle the side menu **Confirm Delete** button.

When the confirm delete option is OFF, the digitizing oscilloscope can immediately delete files or directories. When the confirm option is ON, the digitizing oscilloscope warns you before it deletes files and gives you a chance to reconsider.

**Overwrite Lock**

To turn on or off the file overwrite lock, toggle the side menu **Overwrite Lock** button.

When overwrite lock is on, the digitizing oscilloscope will not permit you to write over an existing file of the same name. An important reason to allow overwriting is to let you write files using a target file name that contains wild card characters (“?”). This means the digitizing oscilloscope creates sequential files whose names are similar except for the sequential numbers that go in the real name in the place of the question marks.

**Format**

To format a 720 Kbyte or 1.44 Mbyte disk, turn the general purpose knob until it scrolls the cursor over the name of the drive to format in. (fd0:) Then, press the side menu **Format** button.
Hardcopy

You can get a copy of the digitizing oscilloscope display by using the hardcopy feature. Depending on the output format you select, you create either an image or a plot. Images are direct bit map representations of the digitizing oscilloscope display. Plots are vector (plotted) representations of the display.

**Hardcopy Formats**

Different hardcopy devices use different formats. The digitizing oscilloscope supports the following formats:

- HP Thinkjet inkjet printer
- HP Deskjet inkjet printer
- HP Laserjet laser printer
- Epson
- DPU-411/II portable thermal printer
- DPU-412 portable thermal printer
- PCX (PC Paintbrush)
- PCX Color (PC Paintbrush) (TDS 644A)
- TIFF (Tag Image File Format)
- BMP Mono (Microsoft Windows file format)
- BMP Color (Microsoft Windows file format) (TDS 644A)
- RLE Color (Microsoft Windows color image file format — compressed) (TDS 644A)
- EPS Mono Image (Encapsulated Postscript, mono-image)
- EPS Color Image (Encapsulated Postscript, color-image) (TDS 644A)
- EPS Mono Plot (Encapsulated Postscript, mono-plot)
- EPS Color Plot (Encapsulated Postscript, color-plot)
- Interleaf
- HPGL Color Plot

Some formats, particularly Interleaf, EPS, TIFF, PCX, BMP, and HPGL, are compatible with various desktop publishing packages. That means you can paste files created from the oscilloscope directly into a document on any of those desktop publishing systems.

EPS Mono and Color formats are compatible with Tektronix Phaser Color Printers, HPGL is compatible with the Tektronix HC100 Plotter, and Epson is compatible with the Tektronix HC220 Printer.
Operation

Before you make a hardcopy, you need to set up communications and hardcopy parameters. This discussion assumes that the hardcopy device is already connected to the GPIB port on the rear panel. If that is not the case see Connection Strategies on page 3-61.

Setting Communication Parameters

To set up the communication parameters to talk to a printer attached directly to the oscilloscope GPIB port:

Press SHIFT UTILITY → System (main) → I/O (pop-up) → Port → GPIB (pop-up) → Configure (main) → Hardcopy (Talk Only) (side).

To set up the communication parameters to talk to a printer attached directly to the oscilloscope RS-232 port:

Press SHIFT UTILITY → System (main) → I/O (pop-up) → Port → RS232 (pop-up) → Hardware Setup (main).

Press the side-menu Baud Rate, Stop Bits, Parity and Hard Flagging items and enter data as desired to match the hardcopy device (see Figure 3-31).

Press Software Setup (main) and toggle the side-menu Soft Flagging item to turn software flagging on or off as desired.

![Figure 3-31: Utility Menu — System I/O](image-url)
Setting Hardcopy Parameters

To specify the hardcopy format, layout, and type of port using the hardcopy menu:

1. Press **SHIFT HARDCOPY MENU** to bring up the Hardcopy menu.

2. Press **Format** (main) → Thinkjet, Deskjet, Laserjet, Epson, DPU-411, DPU-412, PCX, PCX Color (TDS 644A), TIFF, BMP Mono, BMP Color (TDS 644A), RLE Color (TDS 644A), EPS Mono Img, EPS Color Image (TDS 644A), EPS Mono Plt, EPS Color Plt, Interleaf, or HPGL (side). (Press **more** (side) to see all of these format choices.)

3. Press **SHIFT HARDCOPY MENU** → **Layout** (main) → **Landscape** or **Portrait** (side) (see Figure 3-32).

![Landscape Format](image1.png) ![Portrait Format](image2.png)

*Figure 3-32: Hardcopy Formats*

4. Press **SHIFT HARDCOPY MENU** → **Port** (main) to specify the output channel to send your hardcopy through. The choices are GPIB, RS-232, Centronics, and File (RS-232, Centronics, and File are optional on the TDS 620A & TDS 640A).

   If you choose File, the file-list scrollbar will appear. Turn the general purpose knob to select the desired file.

5. For hardcopy formats that support palettes, press **SHIFT HARDCOPY MENU** → **Palette** (main) → **Hardcopy** or **Current** (side). Choose Hardcopy to have the hardcopy created using the Hardcopy Preview palette in the Color Palette menu. The default settings for this palette provide a white background. Choose Current to have the hardcopy created in colors that closely match the current display.

Printing the Hardcopy

You can print a single hardcopy or send additional hardcopies to the spool (queue) while waiting for earlier hardcopies to finish printing. To print your hardcopy(ies):

Press **HARDCOPY** to print your hardcopy.

While the hardcopy is being sent to the printer, the oscilloscope will display the message “Hardcopy in process — Press HARDCOPY to abort.”
To stop and discard the hardcopy being sent, press **HARDCOPY** again while the hardcopy in process message is still on screen.

To add additional hardcopies to the printer spool, press **HARDCOPY** again after the hardcopy in process message is removed from the screen.

You can add hardcopies to the spool until it is full. When the spool is filled by adding a hardcopy, the message “Hardcopy in Process — Press HARDCOPY to abort” remains displayed. You can abort the last hardcopy sent by pressing the button while the message is still displayed. When the printer empties enough of the spool to finish adding the last hardcopy it does so and then removes the message.

To remove all hardcopies from the spool:

Press **SHIFT HARDCOPY MENU → Clear Spool** (main) → **OK Confirm Clear Spool** (side).

This oscilloscope takes advantage of any unused RAM when spooling hardcopies to printers. The size of the spool is, therefore, variable. The number of hardcopies that can be spooled depends on three variables:

- the amount of unused RAM
- the hardcopy format chosen
- the complexity of the display

Although not guaranteed, usually about 2.5 hardcopies can be spooled before the oscilloscope must wait to send the rest of the third copy.

**Date/Time Stamping Your Hardcopy**

You can display the current date and time on screen so that they appear on the hardcopies you print. To date and time stamp your hardcopy:

1. Press **DISPLAY → Readout Options** (main) → **Display Date and Time** (side) to toggle the setting to **On**.

2. Press **Clear Menu** to remove the menu from the display so the date and time can be displayed (see Figure 3-33). (The date and time are removed from the display when menus are displayed.)

3. Press **HARDCOPY** to print your date/time stamped hardcopy.

   If you need to set the date and time of the oscilloscope:

4. Press **SHIFT UTILITY → Config** (pop-up) → **Set Date & Time** (main) → **Year, Day Month, Hour, or Minute**.
Figure 3-33: Date and Time Display

5. Use the general purpose knob or the keypad to set the parameter you have chosen to the value desired. (The format when using the keypad is day.month. For example, use 23.6 for the 23rd of June.)

6. Repeat steps 4 and 5 to set other parameters as desired.

7. Press OK Enter Date/Time (side) to put the new settings into effect. This sets the seconds to zero.

**NOTE**

*When setting the clock, you can set to a time slightly later than the current time and wait for it to catch up. When current time catches up to the time you have set, pressing Ok Enter Date/Time (side) synchronizes the set time to the current time.*

8. Press CLEAR MENU to see the date/time displayed with the new settings.

9. Press HARDCOPY to print your date/time stamped hardcopy.

---

**Connection Strategies**

The ability of the digitizing oscilloscope to print a copy of its display in many formats (see page 3-57) gives you flexibility in choosing a hardcopy device. It also makes it easier for you to place oscilloscope screen copies into a desktop publishing system.
Strategies for actually printing a copy include:

- Send output straight to a printer/plotter.
- Send the data to a computer to print from there and/or to import into your favorite desktop publishing or other application package.
- Send your data to a floppy disk file (optional on the TDS 620A & TDS 640A) for later printing from a computer capable of reading the MS-DOS compatible floppy disk.

**Printing Directly to a Hardcopy Device**

You can connect the digitizing oscilloscope directly to a hardcopy device (see Figure 3-34). An example of a GPIB hardcopy device is the Tektronix HC100 Plotter. Many printers, such as the Tektronix HC220, use Centronics interfaces. Many hardcopy devices, including the HC100 with option 03, provide RS-232 support.

![Diagram of Digitizing Oscilloscope and Hardcopy Device](image)

**Figure 3-34: Connecting the Digitizing Oscilloscope Directly to the Hardcopy Device**

**Using a Controller**

You can put a controller with two ports between the digitizing oscilloscope and the hardcopy device (see Figure 3-35). Use a GPIB port to remotely request and receive a hardcopy from the digitizing oscilloscope. Use an RS-232 or a Centronics port on the controller to print output.
Figure 3-35: Connecting the Digitizing Oscilloscope and Hardcopy Device Via a PC

If your controller is PC-compatible and it uses the Tektronix GURU or S3FG210 (National Instruments GPIB-PCII/IIA) GPIB package, you can operate this setup as follows:

1. Use the MS-DOS `cd` command to move to the directory that holds the software that came with your GPIB board. For example, if you installed the software in the GPIB-PC directory, type: `cd GPIB-PC`

2. Run the IBIC program that came with your GPIB board. Type: `IBIC`

3. Type: `IBFIND DEV1` where “DEV1” is the name for the digitizing oscilloscope you defined using the IBCONF.EXE program that came with the GPIB board.

**NOTE**

If you defined another name then, of course, use it instead of “DEV1”. Also, remember that the device address of the digitizing oscilloscope as set with the IBCONF.EXE program should match the address set in the digitizing oscilloscope Utility menu (typically, use “1”).

4. Type: `IBWRT “HARDCOPY START”` Be sure the digitizing oscilloscope Utility menu is set to **Talk/Listen** and not **Hardcopy (Talk Only)** or you will get an error message at this step. Setting the digitizing oscilloscope Utility menu was described in the start of this Hardcopy section under the heading **Setting Communication Parameters**. Be sure to set the controller time-out longer than the time required to transfer the hardcopy.
5. Type: **IBRDF <Filename>** where <Filename> is a valid DOS file name you want to call your hardcopy information. It should be \( \leq 8 \) characters long with up to a 3 character extension. For example, you could type “ibrdf screen1”.

6. Exit the IBIC program by typing: **EXIT**

7. Type: **COPY <Filename> <Output port> />** where <Filename> is the name you defined in step 5 and <Output port> is the PC output port your hardcopy device is connected to (such as LPT1 or LPT2). Copy the data from your file to your hardcopy device. First, ensure your printer or plotter is properly attached to your PC. Then copy the file. For example, if your file is called *screen1* and your printer is attached to the *lpt1* parallel port, type “copy screen1 lpt1: />”.

**NOTE**

*If you transmit hardcopy files across a computer network, use a binary (8-bit) data path.*

Your hardcopy device should now print a picture of the digitizing oscilloscope screen.

---

**For More Information**

Help

The on-line help system provides brief information about each of the digitizing oscilloscope controls.

Operation

To use the on-line help system:

Press **HELP** to provide on-screen information on any front panel button, knob or menu item (see Figure 3-36).

When you press that button, the instrument changes mode to support on-line help. Press **HELP** again to return to regular operating mode. Whenever the oscilloscope is in help mode, pressing any button (except **HELP** or **SHIFT**), turning any knob, or pressing any menu item displays help text on the screen that discusses that control.

The menu selections that were displayed when **HELP** was first pressed remain on the screen. On-line help is available for each menu selection displayed at the time the **HELP** button was first pressed. If you are in help mode and want to see help on selections from non-displayed menus, you first exit help mode, display the menu you want information on, and press **HELP** again to re-enter help mode.

![Figure 3-36: Initial Help Screen](image-url)
Horizontal Control

You can control the horizontal part of the display (the time base) using the horizontal menu and knobs.

Horizontal Knobs

By changing the horizontal scale, you can focus on a particular portion of a waveform. By adjusting 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, use the horizontal POSITION and horizontal SCALE knobs (see Figure 3-37). These knobs manage the time base and horizontal waveform positioning on the screen. When you use either the horizontal SCALE or POSITION knobs, you affect all the waveform records displayed.

When you use either the horizontal SCALE or POSITION knobs, you affect all displayed waveform records. 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 speeds up significantly.

Figure 3-37: Horizontal Controls
**Horizontal Readouts**

At the top of the display, the Record View shows the size and location of the waveform record and the location of the trigger relative to the display (see Figure 3-38). The Time Base readout at the lower right of the display shows the time/division settings and the time base (main or delayed) being referred to (see Figure 3-38).

![Record View and Time Base Readouts](image)

**Figure 3-38: Record View and Time Base Readouts**

**Horizontal Menu**

The Horizontal menu lets you select either a main or delayed view of the time base for acquisitions. It also lets you set the record length, set the trigger position, and change the position or scale.

**Main and Delayed Time Base**

To select between the Main and Delayed views of the time base:

Press **HORIZONTAL MENU → Time Base (main) → Main Only, Intensified, or Delayed Only (side).**

By pressing **Intensified**, you display a colored or intensified zone that shows where the delayed trigger record length could occur relative to the main trigger. The start of the zone corresponds to the possible start point of the delayed trigger. The end of the zone corresponds to the end of the delayed view of the time base.
You also can select Delayed Runs After Main or Delayed Triggerable. For more information on how to use these two menu items, see Delayed Triggering on page 3-20.

**Trigger Position**

To define how much of the record will be pretrigger and how much posttrigger information using the Trigger Position menu item:

Press HORIZONTAL MENU → Trigger Position (main) → Set to 20%, Set to 50%, or Set to 80% (side), or use the general purpose knob or the keypad to change the value.

**Record Length and Fit To Screen**

To set the waveform record length, press HORIZONTAL MENU → Record Length (main). The side menu lists various discrete record length choices.

To fit an acquired waveform 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 provides similar functionality to being in zoom mode 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**

You can 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. The Horizontal Lock setting in the Zoom menu determines which waveforms the horizontal position knob adjusts whether zoom is on or not. Specifically, it acts as follows:

- **None** — only the waveform currently selected can be zoomed and positioned horizontally
- **Live** — all channels (including AUX channels for the TDS 620A) can be zoomed and positioned horizontally at the same time
**Horizontal Control**

- **All** — all waveforms displayed (channels, math, and/or reference) can be zoomed and positioned horizontally at the same time

See *Zoom*, on page 3-151 for the steps to set the horizontal lock feature.

---

**For More Information**

See *Scaling and Positioning Waveforms*, on page 2-22.

See *Delayed Triggering*, on page 3-20.

See *Zoom*, on page 3-151.

See *Display Modes*, on page 3-26.
Limit Testing

Limit testing provides a way to automatically compare each incoming or math waveform against a template waveform. You set an envelope of limits around a waveform and let the digitizing oscilloscope find waveforms that fall outside those limits (see Figure 3-39). When it finds such a waveform, the digitizing oscilloscope can generate a hardcopy, ring a bell, stop and wait for your input, or any combination of these actions.

![Figure 3-39: Comparing a Waveform to a Limit Template](image)

When you use the limit testing feature, the first task is to create the limit test template from a waveform. Next, specify the channel to compare to the template. Then you specify the action to take if incoming waveform data exceeds the set limits. Finally, turn limit testing on so that the parameters you have specified will take effect.

---

**Operation**

To access limit testing:

Press **SHIFT ACQUIRE MENU** to bring up the Acquire menu.

**Create Limit Test Template**

To use an incoming or stored waveform to create the limit test template, first select a source.

1. Press **Create Limit Test Template** (main) → **Template Source** (side) → **Ch1, Ch2, Math1, Math2, Math3, Ref1, Ref2, Ref3, or Ref4** (side). (See Figure 3-40).
NOTE

The template will be smoother if you acquire the template waveform using Average acquisition mode. If you are unsure how to do this, see Acquisition Modes on page 3-5.

Once you have selected a source, select a destination for the template.

2. Press Template Destination (side) → Ref1, Ref2, Ref3, or Ref4.

![Image of the Acquire Menu — Create Limit Test Template]

Figure 3-40: Acquire Menu — Create Limit Test Template

Now create the envelope by specifying the amount of variation from the template that you will tolerate. Tolerance values are expressed in fractions of a major division. They represent the amount by which incoming waveform data can deviate without having exceeded the limits set in the limit test. The range is from 0 (the incoming waveform must be exactly like the template source) to 5 major divisions of tolerance.

3. Press ±V Limit (side). Enter the vertical (voltage) tolerance value using the general purpose knob or keypad.

4. Press ±H Limit (side). Enter the horizontal (time) tolerance value using the general purpose knob or keypad.

5. When you have specified the limit test template as you wish, press OK Store Template (side). This action stores the specified waveform in the specified destination, using the specified tolerances. Until you have done so, the template waveform has been defined but not created.
Limit Testing

If you wish to create another limit test template, store it in another destination to avoid overwriting the template you have just created.

If you wish to view the template you have created, press the MORE button. Then press the button corresponding to the destination reference memory you have used. The waveform appears on the display.

**NOTE**

To view the waveform data as well as the template envelope, it might be useful to select the Dots display style (see Display Modes on page 3-26).

**Limit Test Sources**

Now specify the channel that will acquire the waveforms to be compared against the template you have created.

1. Press **SHIFT ACQUIRE MENU → Limit Test Sources** (main) → Compare Ch1 to, Compare Ch2 to, Compare Ch3 to, Compare Ch4 to, Compare Math1 to, Compare Math2 to or Compare Math3 to (side).

2. Once you have selected one of the four channels or a math waveform as a waveform source from the side menu, press the same side menu button to select one of the reference memories in which you have stored a template.

Valid selections are any of the four reference waveforms **Ref1** through **Ref4** or **None**. Choosing **None** turns limit testing off for the specified channel.

**NOTE**

Specify the same reference memory you chose as the template destination if you wish to use the template you just created.

If you have created more than one template, you can compare one channel to one template and the other channel to another template.

**Limit Test Setup**

Now specify the action to take if waveform data exceeds the limits set by the limit test template.

1. Press **SHIFT ACQUIRE MENU → Limit Test Setup** (main) to bring up a side menu of possible actions.

2. Ensure that the side button corresponding to the desired action reads **ON**.
If you want to send a hardcopy command when waveform data exceeds the limits set, toggle **Hardcopy if Condition Met** (side) to **ON**. You can set the hardcopy system to send the hardcopy to the file system (optional on the TDS 620A & TDS 640A). (Do not forget to set up the hardcopy system. See **Hardcopy** on page 3-57 for details.)

If you want the bell to ring when waveform data exceeds the limits set, toggle **Ring Bell if Condition Met** (side) to **ON**.

If you want the digitizing oscilloscope to stop when waveform data exceeds the limits set, toggle **Stop After Limit Test Condition Met** (side) to **ON**.

**NOTE**

*The button labeled Stop After Limit Test Condition Met corresponds to the Limit Test Condition Met menu item in the Stop After main menu. You can turn this button on in the Limit Test Setup menu, but you cannot turn it off. In order to turn it off, press Stop After and specify one of the other choices in the Stop After side menu.*

Now that you have set up the instrument for limit testing, you must turn limit testing on in order for any of these actions to take effect.

3. Ensure that **Limit Test** (side) reads **ON**. If it reads **OFF**, press **Limit Test** (side) once to toggle it to **ON**.

When you set **Limit Test** to **ON**, the digitizing oscilloscope compares incoming waveforms against the waveform template stored in reference memory according to the settings in the **Limit Test Sources** side menu.

---

**Single and Multiple Waveforms**

You can compare a single waveform against a single template, more than one waveform against a single template, or more than one waveform with each one compared against its own template. How Limit Test operates depends on which type of these comparisons you choose.

**Single Waveform Comparisons**

When making a single waveform versus a single template comparison, consider the following operating characteristics:

- The waveform will be repositioned horizontally to move the first sample in the waveform record that is outside of template limits to center screen.

- The position of the waveform template will track that of the waveform.
Multiple Waveform Comparisons

When comparing one or more waveforms, each against a common template or against its own template, consider the following operating characteristics:

- You should set **Horizontal Lock** to **None** in the Zoom side menu (push ZOOM and press (repeatedly) **Horizontal Lock to None**).

- With horizontal lock set as just described, the oscilloscope will reposition each waveform horizontally to move the first sample in the waveform record that is outside of template limits to center screen.

- If you are comparing each waveform to its own template, the position of each waveform template will track that of its waveform.

- If you are comparing two or more waveforms to a common template, that template will track the position of the failed waveform. If more than one waveform fails *during the same acquisition*, the template will track the position of the waveform in the highest numbered channel. For example, CH 2 is higher than CH 1.

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**For More Information**

See *Acquisition*, on page 2-19.

See *Acquisition Modes*, on page 3-3.

See *Display Modes*, on page 3-26.

See *Zoom*, on page 3-151.
Logic Triggering

There are two classes of logic triggering: pattern and state.

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 for the TDS 640A & TDS 644A and 1, 2, Aux 1, and Aux 2 for the TDS 620A)
- 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 (see page 3-80).

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 for the TDS 640A & TDS 644A (1, 2, and Ax1 on the TDS 620A)
- The direction of the state change for the clock input, channel 4 (Aux 2 for the TDS 620A)
- 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)

Table 3-3 on page 3-77 lists the preconditions required for each logic function to issue a pattern or state logic trigger.
Logic Trigger Readouts

At the bottom of the display, the Trigger readout shows some of the key parameters of the logic trigger (see Figure 3-41).

**Figure 3-41: Logic Trigger Readouts**

**NOTE**

*When Logic is the selected trigger type, the threshold levels that help determine triggering are set for each channel individually in the Set Thresholds menu. Therefore, the Trigger Level readout will disappear on the display and the Trigger Level knob can be used to set the threshold level while the Main Trigger menu is set to Logic.*

**Definitions**

Table 3-3 lists the definitions for the four types of logic functions available. Keep in mind the following operating modes for the two classes, pattern and state, of logic triggers as you apply the definitions.

**Pattern** — At the end of trigger holdoff, the oscilloscope samples the inputs from all the channels. The oscilloscope then triggers if the conditions defined in Table 3-3 are met. *(Goes TRUE or Goes FALSE must be set in the Trigger When menu.)* The other settings in that menu are described in Define a Time Qualified Pattern Trigger on page 3-80.

**State** — At the end of trigger holdoff, the oscilloscope waits until the edge of channel 4 (Aux 2 on the TDS 620A) 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 3-3 are met.
Table 3-3: Logic Triggers

<table>
<thead>
<tr>
<th>Pattern</th>
<th>State</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="AND" /></td>
<td>Clocked AND</td>
<td>If all the preconditions selected for the logic inputs are true, then the oscilloscope triggers.</td>
</tr>
<tr>
<td><img src="image" alt="NAND" /></td>
<td>Clocked NAND</td>
<td>If not all of the preconditions selected for the logic inputs are true, then the oscilloscope triggers.</td>
</tr>
<tr>
<td><img src="image" alt="OR" /></td>
<td>Clocked OR</td>
<td>If any of the preconditions selected for the logic inputs are true, then the oscilloscope triggers.</td>
</tr>
<tr>
<td><img src="image" alt="NOR" /></td>
<td>Clocked NOR</td>
<td>If none of the preconditions selected for the logic inputs are true, then the oscilloscope triggers.</td>
</tr>
</tbody>
</table>

1Note that for State class triggers, the definition must be met at the time the clock input changes state. See the descriptions for Pattern and State in this section.

2The 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.

3The logic inputs are channels 1, 2, 3, and 4 for the TDS 640A & TDS 644A and 1, 2, Aux 1 and Aux 2 for the TDS 620A when using Pattern Logic Triggers. For State Logic Triggers, channel 4 (Aux 2 for the TDS 620A) becomes the clock input, leaving the remaining channels as logic inputs.

---

Operations Common to Pattern and State

The Logic Trigger menu (Figure 3-42) lets you select when to trigger (true or false), set the thresholds for each channel, select the mode (auto or normal), and adjust the holdoff.

Press TRIGGER MENU → Type (main) → Logic (pop-up) → Class (main) → Pattern or State (pop-up).
Logic Triggering

**Figure 3-42: Logic Trigger Menu**

**Trigger When**

This menu item lets you determine if the oscilloscope will trigger when the logic condition is met (**Goes TRUE**) or when the logic condition is not met (**Goes FALSE**). (The **True when less than** and **True when greater than** menu items are only used for pattern logic triggering and are covered on page 3-80.)

Press **TRIGGER MENU → Type** (main) → **Logic** (pop-up) → **Class** (main) → **Pattern** or **State** (pop-up) → **Trigger When** (main) → **Goes TRUE** or **Goes FALSE** (side).

**Set Thresholds**

To set the logic threshold for each channel:

1. Press **TRIGGER MENU → Type** (main) → **Logic** (pop-up) → **Class** (main) → **Pattern** or **State** (pop-up) → **Set Thresholds** (main) → **Ch1, Ch2, Ch3** (Ax1 on the TDS 620A), or **Ch4** (Ax2 on the TDS 620A) (side).
2. Use the **MAIN TRIGGER LEVEL** knob, the general purpose knob, or the keypad to set each threshold.
Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu item.

1. Press TRIGGER MENU → Type (main) → Logic (pop-up) →
   Class (main) → Pattern or State (pop-up) → Mode & Holdoff (main) →
   Auto or Normal (side).
   - 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. Press Holdoff (side). Enter the value in percent using the general pur-
pose knob or the keypad.

Depending on whether you chose the class Pattern or State, there are
different menus for defining the channel inputs and the combinational logic.

Pattern Operations

When you select Pattern, the oscilloscope will trigger on a specified logic
combination of the four input channels. See page 3-77 for details on opera-
tions common to both pattern and state triggers.

Define Inputs

To set the logic state for each of the input channels (Ch1, Ch2, ...):

1. Press TRIGGER MENU → Type (main) → Logic (pop-up) →
   Class (main) → Pattern (pop-up) → Define Inputs (main) → Ch1, Ch2,
   Ch3, or Ch4 (side). (On the TDS 620A, Ch3 and Ch4 are replaced by
   Ax1 and Ax2.)

2. Repeatedly press each input selected in step 1 to choose either High
   (H), Low (L), or Don’t Care (X) for each channel.

Define Logic

To choose the logic function you want applied to the input channels (see
page 3-76 for definitions of the logic functions for both pattern and state
triggers):

Press TRIGGER MENU → Type (main) → Logic (pop-up) →
Class (main) → Pattern (pop-up) → Define Logic (main) → AND, OR,
NAND, or NOR (side).
Logic Triggering

**Define a Time Qualified Pattern Trigger**

You can also time qualify a pattern logic trigger. That is, you specify a time that the boolean logic function (AND, NAND, OR, or NOR) must be TRUE (logic high). You also choose the type of time qualification (greater or less than the time limit specified) as well as the time limit using the Trigger When menu selection.

1. Press TRIGGER MENU → Type (main) → Logic (pop-up) → Class (main) → Pattern (pop-up) → Trigger When (main) → True for less than or True for more than (side).

2. Use the knob and keypad to set the time in the side menu.

When you select **True for less than** and specify a time using the general purpose knob, the input conditions you specify must drive the logic function high (TRUE) for less than the time you specify. Conversely, **True for more than** requires the boolean function to be TRUE for longer than the time you specify.

Note the position of the trigger indicator in Figure 3-43. Triggering occurs at the point the logic function you specify is determined to be true within the time you specify. The digitizing oscilloscope determines the trigger point in the following manner:

- It waits for the logic condition to become true
- It starts timing and waits for the logic function to become false
- It compares the times and, if the time TRUE is longer (for **True for more than** or shorter (for **True for less than**), then it triggers a waveform display at the point the logic condition became false. This time can be, and usually is, different from the time set for **True for more than** or **True for less than**.

In Figure 3-43, the delay between the vertical bar cursors is the time the logic function is TRUE. Since this time is more (216 µs) than that set in the **True for more than** menu item (150 µs), the oscilloscope issues the trigger at that point, not at the point at which it has been true for 216 µs.
State Operations

When you select State logic triggering, the oscilloscope uses channel 4 (Aux 2 on the TDS 620A) as a clock for a logic circuit made from the rest of the channels. See page 3-77 for details on operations common to both pattern and state triggers.

The state trigger logic works as follows: the oscilloscope waits until the fourth channel meets the selected slope and voltage threshold. It then checks the logic function applied to the first three channels, and if the function condition is as specified in the Trigger When menu (Goes TRUE or Goes FALSE) a trigger occurs.

Define Inputs

To set the logic state for each of the input channels (Ch1, Ch2, ...):

1. Press TRIGGER MENU → Type (main) → Logic (pop-up) → Class (main) → State (pop-up) → Define Inputs (main).

2. Choose either High (H), Low (L), or Don’t Care (X) (side) for the first three channels. The choices for Ch4 (Aux 2 on the TDS 620A) are rising edge and falling edge.
Logic Triggering

Define Logic
To choose the type of logic function you want applied to the input channels:

Press TRIGGER MENU → Type (main) → Logic (pop-up) →
Class (main) → State (pop-up) → Define Logic (main) → AND, OR,
NAND, or NOR (side).

For More Information
See Triggering, on page 2-13.
See Triggering, on page 3-132.
Measurement System

There are various ways to measure properties of waveforms. You can use graticule, cursor, or automatic measurements. This section describes automatic measurements; cursors and graticules are described elsewhere. (See Cursor Measurements on page 3-15 and Measurements on page 2-26.)

Automatic measurements are generally more accurate and quicker than, for example, manually counting graticule divisions. The oscilloscope will continuously update and display these measurements. (There is also a way to display all the measurements at once — see Snapshot of Measurements on page 3-92.)

Automatic measurements calculate waveform parameters from acquired data. Measurements are performed over the entire waveform record or the region specified by the vertical cursors, if gated measurements have been requested. (See page 3-88 for a discussion of gated measurements.) They are not performed just on the displayed portions of waveforms.

The TDS 600A Digitizing Oscilloscope provides you with 25 automatic measurements (see Table 3-4).

---

Definitions

The following are brief definitions of the automated measurements in the digitizing oscilloscope (for more details see Appendix C: Algorithms, page A-7).

**Table 3-4: Measurement Definitions**

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
</table>
| 🐝 ⬤ Amplitude | Voltage measurement. The high value less the low value measured over the entire waveform or gated region.  
  \[
  \text{Amplitude} = \text{High} - \text{Low}
  \]  |
| 🐝 ⬤ Area   | Voltage over time measurement. The area over the entire waveform or gated region in volt-seconds. Area measured above ground is positive; area below ground is negative.  |
| 🐝 ⬤ Cycle Area | Voltage over time measurement. The area over the first cycle in the waveform, or the first cycle in the gated region, in volt-seconds. Area measured above ground is positive; area below ground is negative.  |
| 🐝 ⬤ Burst Width | Timing measurement. The duration of a burst. Measured over the entire waveform or gated region.  |
| 🐝 ⬤ Cycle Mean | Voltage measurement. The arithmetic mean over the first cycle in the waveform or the first cycle in the gated region.  |
| 🐝 ⬤ Cycle RMS  | Voltage measurement. The true Root Mean Square voltage over the first cycle in the waveform or the first cycle in the gated region.  |
Table 3-4: Measurement Definitions (Cont.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>Timing measurement. The time between the MidRef crossings of two different traces or the gated region of the traces.</td>
</tr>
<tr>
<td>Fall Time</td>
<td>Timing measurement. Time taken for the falling edge of the first pulse in the waveform or gated region to fall from a High Ref value (default = 90%) to a Low Ref value (default = 10%) of its final value.</td>
</tr>
<tr>
<td>Frequency</td>
<td>Timing measurement for the first cycle in the waveform or gated region. The reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.</td>
</tr>
<tr>
<td>High</td>
<td>The value used as 100% whenever High Ref, Mid Ref, and Low Ref values are needed (as in fall time and rise time measurements). Calculated using either the min/max or the histogram method. The min/max method uses the maximum value found. The histogram method uses the most common value found above the mid point. Measured over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Low</td>
<td>The value used as 0% whenever High Ref, Mid Ref, and Low Ref values are needed (as in fall time and rise time measurements). May be calculated using either the min/max or the histogram method. With the min/max method it is the minimum value found. With the histogram method, it refers to the most common value found below the mid point. Measured over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Maximum</td>
<td>Voltage measurement. The maximum amplitude. Typically the most positive peak voltage. Measured over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Mean</td>
<td>Voltage measurement. The arithmetic mean over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Minimum</td>
<td>Voltage measurement. The minimum amplitude. Typically the most negative peak voltage. Measured over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Negative Duty Cycle</td>
<td>Timing measurement of the first cycle in the waveform or gated region. The ratio of the negative pulse width to the signal period expressed as a percentage.</td>
</tr>
<tr>
<td></td>
<td>$\text{Negative Duty Cycle} = \frac{\text{Negative Width}}{\text{Period}} \times 100%$</td>
</tr>
<tr>
<td>Negative Overshoot</td>
<td>Voltage measurement. Measured over the entire waveform or gated region.</td>
</tr>
<tr>
<td></td>
<td>$\text{Negative Overshoot} = \frac{\text{Low} - \text{Min}}{\text{Amplitude}} \times 100%$</td>
</tr>
<tr>
<td>Negative Width</td>
<td>Timing measurement of the first pulse in the waveform or gated region. The distance (time) between MidRef (default 50%) amplitude points of a negative pulse.</td>
</tr>
<tr>
<td>Peak to Peak</td>
<td>Voltage measurement. The absolute difference between the maximum and minimum amplitude in the entire waveform or gated region.</td>
</tr>
<tr>
<td>Phase</td>
<td>Timing measurement. The amount one waveform leads or lags another in time. Expressed in degrees, where 360° comprise one waveform cycle.</td>
</tr>
</tbody>
</table>
Table 3-4: Measurement Definitions (Cont.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>Timing measurement. Time it takes for the first complete signal cycle to happen in the waveform or gated region. The reciprocal of frequency. Measured in seconds.</td>
</tr>
<tr>
<td>Positive Duty Cycle</td>
<td>Timing measurement of the first cycle in the waveform or gated region. The ratio of the positive pulse width to the signal period expressed as a percentage.</td>
</tr>
<tr>
<td>PositiveOvershoot</td>
<td>Voltage measurement over the entire waveform or gated region.</td>
</tr>
<tr>
<td>Positive Width</td>
<td>Timing measurement of the first pulse in the waveform or gated region. The distance (time) between MidRef (default 50%) amplitude points of a positive pulse.</td>
</tr>
<tr>
<td>Rise time</td>
<td>Timing measurement. Time taken for the leading edge of the first pulse in the waveform or gated region to rise from a Low Ref value (default = 10%) to a High Ref value (default = 90%) of its final value.</td>
</tr>
<tr>
<td>RMS</td>
<td>Voltage measurement. The true Root Mean Square voltage over the entire waveform or gated region.</td>
</tr>
</tbody>
</table>
**Measurement System**

**Measurement Display**
The readout area for measurements is on the right side of the waveform window. You can display and continuously update as many as four measurements at any one time. When menus are displayed, the readouts appear in the graticule area. If the menu area is empty, then the readouts are displayed to the far right (see Figure 3-44).

![Measurement Readout Area](image)

**Figure 3-44: Measurement Readouts**

**Operation**
To use the automatic measurements you first need to obtain a stable display of the waveform to be measured. Pressing **AUTOSET** may help. Once you have a stable display, press **MEASURE** to bring up the Measure menu (see Figure 3-45).

**Selecting a Measurement**
Measurements are made on the selected waveform. The measurement display tells you the channel the measurement is being made on.

1. Press **MEASURE → Select Measmt** (main).
2. Select a measurement from the side menu.

   The following are hints on making automatic measurements:
   - You can only take a maximum of four measurements at a time. To add a fifth, you must remove one or more of the existing measurements.
To vary the source for measurements, simply select the other channel and then choose the measurements you want.

Be careful when taking automatic measurements on noisy signals. You might measure the frequency of the noise and not the desired waveform.

Your digitizing oscilloscope helps identify such situations by displaying a low signal amplitude or low resolution warning message.

Figure 3-45: Measure Menu

Removing Measurements

The **Remove Measrmnt** selection provides explicit choices for removing measurements from the display according to their readout position.

Measurement 1 is the top readout. Measurement 2 is below it, and so forth. Once a measurement readout is displayed in the screen area, it stays in its position even when you remove any measurement readouts above it. To remove measurements:

1. Press **MEASURE → Remove Measrmnt** (main).

2. Select the measurement to remove from the side menu. If you want to remove all the measurements at one time, press **All Measurements** (side).
**Gated Measurements**

The gating feature lets you limit measurements to a specified portion of the waveform. When gating is Off, the oscilloscope makes measurements over the entire waveform record.

When gating is activated, vertical cursors are displayed. Use these cursors to define the section of the waveform you want the oscilloscope to measure. This is called the *gated region*.

1. Press **MEASURE** → **Gating** (main) → **Gate with V Bar Cursors** (side) (see Figure 3-46).

![Figure 3-46: Measure Menu — Gating](image)

2. Using the general purpose knob, move the selected (the active) cursor. Press **SELECT** to change which cursor is active.

Displaying the cursor menu and turning V Bar cursors off will *not* turn gating off. (Gating arrows remain on screen to indicate the area over which the measurement is gated.) You must turn gating off in the Gating side menu.
NOTE

Cursor are displayed relative to the selected waveform. If you are making a measurement using two waveforms, this can be a source of confusion. If you turn off horizontal locking and adjust the horizontal position of one waveform independent of the other, the cursors appear at the requested position with respect to the selected waveform. Gated measurements remain accurate, but the displayed positions of the cursors change when you change the selected waveform.

High-Low Setup

The High-Low Setup item provides two choices for how the oscilloscope determines the High and Low levels of waveforms. These are histogram and min-max.

- Histogram sets the values statistically. It selects the most common value either above or below the mid point (depending on whether it is defining the high or low reference level). Since this statistical approach ignores short term aberrations (overshoot, ringing, etc.), histogram is the best setting for examining pulses.

- Min-max uses the highest and lowest values of the waveform record. This setting is best for examining waveforms that have no large, flat portions at a common value, such as sine waves and triangle waves — almost any waveform except for pulses.

To use the high-low setup:

Press MEASURE → High-Low Setup (main) → Histogram or Min-Max (side). If you select Min-Max, you may also want to check and/or revise values using the Reference Levels main menu.

Reference Levels

Once you define the reference levels, the digitizing oscilloscope will use them for all measurements requiring those levels. To set the reference levels:

1. Press MEASURE → Reference Levels (main) → Set Levels (side) to choose whether the References are set in % relative to High (100%) and Low (0%) or set explicitly in the units of the selected waveform (typically volts). See Figure 3-47. Use the general purpose knob or keypad to enter the values.

- % is the default selection. It is useful for general purpose applications.

- Units is helpful for setting precise values. For example, if you are trying to measure specifications on an RS-232-C circuit, you can set the levels precisely to RS-232-C specification voltage values by defining the high and low references in units.
2. Press **High Ref, Mid Ref, Low Ref, or Mid2 Ref** (side).

- **High Ref** — Sets the high reference level. The default is 90%.
- **Mid Ref** — Sets the middle reference level. The default is 50%.
- **Low Ref** — Sets the low reference level. The default is 10%.
- **Mid2 Ref** — Sets the middle reference level used on the second waveform specified in the Delay or Phase Measurements. The default is 50%.

![Figure 3-47: Measure Menu — Reference Levels](image)

**Delay Measurement**

The delay measurement lets you measure from an edge on the selected waveform to an edge on another waveform. You access the Delay Measurement menu through the Measure main menu:

Press **MEASURE → Select Measrmnt** (main) → **Delay** (side). This brings up the Measure Delay main menu (see Figure 3-48).

**Delay to** — To select the waveform you want to measure to, use the main menu item **Delay to**. The waveform you are measuring from is the selected waveform.

1. Press **MEASURE → Select Measrmnt** (main) → **Delay** (side) → **Delay To** (main) → **Measure Delay to**.
2. Press **Measure Delay to** (side) repeatedly to choose the delay to waveform. The choices are Ch1, Ch2, Ch3, Ch4 (on the TDS 644A & TDS 640A); Ch1, Ch2, Ax1, Ax2 (on the TDS 620A); and Math1, Math2, Math3, Ref1, Ref2, Ref3, and Ref4.

**Figure 3-48: Measure Delay Menu — Delay To**

**Delay Edges** — The main menu item **Edges** lets you specify which edges you want the delayed measurement to be made between.

Press **MEASURE** → Select Measmnt (main) → **Delay** (side) → **Edges** (main). A side menu of delay edges and directions will appear. Choose from one of the combinations displayed on the side menu.

The upper waveform on each icon represents the *from* waveform and the lower one represents the *to* waveform.

The direction arrows on the choices let you specify a forward search on both waveforms or a forward search on the *from* waveform and a backwards search on the *to* waveform. The latter choice is useful for isolating a specific pair of edges out of a stream.
Creating the Delay Measurement — Once you have specified the waveforms you are measuring between and which edges to use, you need to notify the digitizing oscilloscope to proceed with the measurement.

Press **Delay To (main)** → **OK Create Measurement** (side).

To exit the Measure Delay menu without creating a delay measurement, press **CLEAR MENU**, which returns you to the Measure menu.

**Snapshot of Measurements**

Sometimes you may want to see all of the automated measurements on screen at the same time. To do so, use Snapshot. Snapshot executes all of the single waveform measurements available on the selected waveform once and displays the results. (The measurements are not continuously updated.) All of the measurements listed in Table 3-4 on page 3-83 except for Delay and Phase are displayed. (Delay and Phase are dual waveform measurements and are not available with Snapshot.)

The readout area for a snapshot of measurements is a pop up display that covers about 80% of the graticule area when displayed (see Figure 3-49). You can display a snapshot on any channel or ref memory, but only one snapshot can be displayed at a time.

![Figure 3-49: Snapshot Menu and Readout](image-url)
To use snapshot, obtain a stable display of the waveform to be measured. Pressing **AUTOSET** may help.

1. Press **MEASURE → SNAPSHOT** (main).

2. Press either **SNAPSHOT** (main) or **AGAIN** (side) to take another snapshot.

**NOTE**

*The snapshot display tells you the channel that the snapshot is being made on.*

3. Push **Remove Measrmnt**.

**Considerations When Taking Snapshots**

Be aware of the following items when using snapshot:

- Be sure to display the waveform properly before taking a snapshot. Snapshot does not warn you if a waveform is improperly scaled (clipped, low signal amplitude, low resolution, etc.).
- To vary the source for taking a snapshot, simply select another channel, math, or ref memory waveform and then execute snapshot again.
- A snapshot is taken on a single waveform acquisition (or acquisition sequence). The measurements in the snapshot display are not continuously updated.
- Be careful when taking automatic measurements on noisy signals. You might measure the frequency of the noise and not the desired waveform.
- Note that pushing any button in the main menu (except for Snapshot) or any front panel button that displays a new menu removes the snapshot from display.
- Use High-Low Setup (page 3-89), Reference Levels (page 3-89), and Gated Measurements (page 3-88) with snapshot exactly as you would when you display individual measurements from the **Select Measrmnt** menu.

---

**For More Information**


See *Measurements*, on page 2-26.

Probe Cal

This oscilloscope lets you compensate the entire signal path, from probe tip to digitized signal, to improve the gain and offset accuracy of the probe. By executing Probe Cal on a channel with its probe installed, you can optimize the oscilloscope capability to make accurate measurements using that channel and probe.

Run a Probe Cal anytime you wish to ensure that the measurements you make are made with the most accuracy possible. You should also run a Probe Cal if you have changed to a different probe since the last Probe Cal was performed.

Probe Cal vs. Probe Type

Some types of probes can be gain compensated, some can be offset compensated, and some can be compensated for both. Some probes cannot be compensated.

If your probe has an attenuation factor of greater than 20X, it cannot be compensated. If you attempt to compensate such a probe you will get an error message.

The digitizing oscilloscope cannot compensate probes whose gain and/or offset errors are too great (>2% gain and/or >50 mV offset). If these errors are within specified limits for your probe, you may wish to use another probe. If they are not within specification, have your probe checked by service personnel.

Operation

If you are installing an active probe, such as the P6205, there are no prerequisites to performing this procedure. Start at step 1.

If you are compensating for a passive probe with this procedure you must first compensate the low frequency response of the probe. First, do steps 1 and 2 below, and then perform the instructions found under Probe Compensation on page 3-100. Then continue with step 3 of this procedure.

1. Install the probe on the input channel on which it is to be used.

2. Power on the digitizing oscilloscope and allow a 20 minute warm-up before doing this procedure.


4. Look at the status label under Signal Path in the main menu. If the status does not read Pass, perform a signal path compensation (Signal Path Compensation, page 3-128), and then continue with this procedure.

5. Press the front-panel button corresponding to the input channel on which you installed the probe.
6. Press **VERTICAL MENU → Cal Probe** (main).

   Your oscilloscope will detect the type of probe you have installed and display screen messages and menu choices for compensation of probe gain, offset, or both (see Figure 3-50). The following steps will have you run probe gain, offset, or both depending on the probe the oscilloscope detects.

7. If the message on screen is *Probe Offset Compensation* rather than *Probe Gain Compensation*, skip to step 15.

8. Connect the probe tip to **PROBE COMPENSATION SIGNAL**; connect the probe ground lead to **PROBE COMPENSATION GND**.


10. Wait for gain compensation to complete (one to three minutes).

    When gain compensation completes, the following actions occur:

    - The clock icon will disappear.

    - If offset compensation is required for the probe installed, the Probe **Offset Compensation** message will replace the Probe **Gain Compensation** message.

    - If gain compensation did not complete successfully, you may get a “Probe is not connected” message (examine the probe connections to the digitizing oscilloscope, be sure the probe tip is properly installed in its retractor, etc., and repeat step 9).

    - If gain compensation did not complete successfully, you may get the message “Compensation Error.” This error implies that the probe gain (2% error) and/or offset (50 mV) is too great to be compensated. You can substitute another probe and continue. Have your probe checked by service personnel.
11. If the Probe Offset Compensation message is displayed, continue with step 15; otherwise, continue with step 12.

12. If the Compensation Error message is displayed, continue with step 13; otherwise continue with step 18.

13. Press **SHIFT UTILITY → System** (main) → **Diag/Err** (pop-up) → **Error Log** (main). If there are too many error messages to be seen on screen, rotate the general purpose knob clockwise to scroll to the last message.

14. Note the compensation error amount. Skip to step 19.

15. Disconnect the probe from any signal you may have connected it to. Leave the probe installed on its channel.


17. Wait for offset compensation to complete (one to three minutes).

   When offset compensation completes, the following occurs:

   - The clock icon will disappear.
   - If offset compensation did not complete successfully, you may get the message "Compensation Error." This error implies that the probe offset scale (10% error) and/or offset (50 mV) is too great to be compensated. You can substitute another probe and continue. Have your probe checked by service personnel. You can also check the error log by doing steps 13 through 14.

18. After the clock icon is removed, verify the word **Initialized** changed to **Pass** under **Cal Probe** in the main menu. (See Figure 3-50.)
19. If desired, repeat this procedure beginning at step 1 to compensate for other probe/channel combinations. But before you do so, be sure you take note of the following requirements:

- Remember to first low frequency compensate any passive probe you connect (see Prerequisites at the beginning of this procedure).
- Remember to connect all but simple passive probes to the oscilloscope for a twenty minute warm up before running Probe Cal.

Usage

The following topic contains information you should consider when using input channels that have stored a Probe Cal.

Changing Probes After a Probe Cal

If a Probe Cal has never been performed on an input channel or if its stored Probe Cal data is erased using the Re-use Probe Calibration Data menu (discussed later), the oscilloscope displays Initialized status in its vertical menu. It also displays initialized whenever you remove a probe from an input.

If you execute a successful Probe Cal on an input channel, the oscilloscope stores the compensation data it derived in non-volatile memory. Therefore, this data is available when you turn the oscilloscope off and back on, when you change probes, etc.

When you install a probe or power on the oscilloscope with probes installed, the oscilloscope tests the probe at each input. Depending on the probe it finds on each input, it takes one of the following actions:

- If the probe has a complex oscilloscope interface (it can convey additional information, such as a unique identification number), the oscilloscope determines whether it is the same probe for which data was stored. If it is, the oscilloscope sets status to pass; if not, it sets the status to Initialized.
- If a probe has a simple oscilloscope interface, the oscilloscope can usually determine if it has a different probe attenuation factor than that stored for the last Probe Cal. It can also determine if the last Probe Cal was for a probe with a complex interface. If either is the case, the probe installed is different from that stored for the last Probe Cal. Therefore, the oscilloscope sets the status to Initialized.
- If a probe has a simple oscilloscope interface and the probe attenuation factor is the same as was stored at the last Probe Cal, the oscilloscope cannot determine whether it is the same probe. Therefore, it displays the Re-use Probe Calibration data? menu (see Figure 3-51).
Probe Cal

Figure 3-51: Re-use Probe Calibration Data Menu

If the Re-use Probe Calibration data? menu is displayed, you can choose one of the following options:

- Press OK Use Existing Data (side) to use the Probe Cal data last stored to compensate the probe.
- Press OK Erase Probe Cal Data (side) to erase the Probe Cal data last stored and use the probe uncompensated.
- Press CLEAR MENU on the front panel to retain the Probe Cal data last stored and use the probe uncompensated.

Table 3-5 shows the action the oscilloscope takes based on the probe connected and user operation performed.

Table 3-5: Probe Cal Status

<table>
<thead>
<tr>
<th>Cal'd?</th>
<th>User</th>
<th>Simple Interface</th>
<th>Complex Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Doesn’t Matter</td>
<td><em>Initialized</em></td>
<td><em>Initialized</em></td>
</tr>
<tr>
<td>Yes</td>
<td>Power off (probe data is retained)</td>
<td><em>Initialized</em> (probe data is retained)</td>
<td><em>Initialized</em> (probe data is retained)</td>
</tr>
<tr>
<td>Yes</td>
<td>Power on</td>
<td>Can not detect different probe: Display Re-use Probe Calibration Data menu</td>
<td>Cal’d Probe: <em>Pass</em></td>
</tr>
</tbody>
</table>

Different probe: *Initialized* Different probe: *Initialized*
Table 3-5: Probe Cal Status (Cont.)

<table>
<thead>
<tr>
<th>Probe Cal'd?</th>
<th>User Action</th>
<th>Simple Interface</th>
<th>Complex Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Disconnect Probe</td>
<td><em>Initialized</em></td>
<td><em>Initialized</em></td>
</tr>
<tr>
<td>Yes</td>
<td>Connect Probe</td>
<td>Can not detect different probe: <em>Display Re-use Probe Calibration Data menu</em></td>
<td>Cal’d Probe: <em>Pass</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Different probe: <em>Initialized</em></td>
<td>Different probe: <em>Initialized</em></td>
</tr>
</tbody>
</table>

1Refer to a channel input that was successfully compensated at the time Probe Cal was last executed for the input channel.

2If no probe is connected, the probe status in the vertical main menu is always *initialized*.

3A probe with a simple interface is a probe that can convey very limited information to the oscilloscope. Most passive probes (such as the standard accessory P6139A) have simple interfaces.

4A probe with a complex interface is a probe that can convey additional information. For instance, it might automatically set the oscilloscope input channel impedance to match the probe, send the oscilloscope a unique probe identification number, etc. Some optical probes and most active probes (including the optional P6205) have complex interfaces.
Probe Compensation

Passive probes require compensation to ensure maximum distortion-free input to the digitizing oscilloscope and to avoid high frequency amplitude errors (see Figure 3-52).

![Probe Compensated Correctly](image)

![Probe Overcompensated](image)

![Probe Undercompensated](image)

Figure 3-52: How Probe Compensation Affects Signals

Operation

To compensate your probe:

1. Connect the probe to the probe compensation signal on the front panel.
2. Press AUTOSET.

**NOTE**

When you connect an active probe to the oscilloscope (such as the P6205), the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a high resistance passive probe (like the P6139A) you need to set the input impedance back to 1 MΩ. Step 4 explains how to change the input impedance.

You now need to limit the bandwidth and change the acquisition mode.

3. Press VERTICAL MENU → Bandwidth (main) → 20 MHz (side).
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. Adjust the probe until you see a perfectly flat top square wave on the display. Figure 3-53 shows where the adjustment is located.

![Figure 3-53: P6139A Probe Adjustment](image)

---

**For More Information**

See *Probe Selection*, on page 3-102.
Probe Selection

The probes included with your digitizing oscilloscope are useful for a wide variety of tasks. However, for special measurement situations you sometimes need different probes. This section helps you select the right probe for the job.

Once you have decided the type of probe you need, use Table 3-6 (page 3-107) to determine the specific probe compatible with your TDS 600A Digitizing Oscilloscope. Or use Table 3-7 (page 3-108) if you want to select the probe by application.

There are five major types of probes: passive, active, current, optical, and time-to-voltage probes. Most of these types are discussed here; see your Tektronix Products Catalog for more information.

---

**Passive Voltage Probes**

Passive voltage probes measure voltage. They employ passive circuit components such as resistors, capacitors, and inductors. There are three common classes of passive voltage probes:

- General purpose (high input resistance)
- Low impedance ($Z_0$)
- High voltage

**General Purpose (High Input Resistance) Probes**

High input resistance probes are considered “typical” oscilloscope probes. The high input resistance of passive probes (typically 10 MΩ) provides negligible DC loading and makes them a good choice for accurate DC amplitude measurements.

However, their 8 pF to 12 pF (over 60 pF for 1X) capacitive loading can distort timing and phase measurements. Use high input resistance passive probes for measurements involving:

- Device characterization (above 15 V, thermal drift applications)
- Maximum amplitude sensitivity using 1X high impedance
- Large voltage range (between 15 and 500 V)
- Qualitative or go/no-go measurements

**Low Impedance ($Z_0$) Probes**

Low impedance probes measure frequency more accurately than general purpose probes, but they make less accurate amplitude measurements. They offer a higher bandwidth to cost ratio.
These probes must be terminated in a 50 Ω scope input. Input capacitance is much lower than high Z passive probes, typically 1 pF, but input resistance is also lower (500 to 5000 Ω typically). Although that DC loading degrades amplitude accuracy, the lower input capacitance reduces high frequency loading to the circuit under test. That makes $Z_0$ probes ideal for timing and phase measurements when amplitude accuracy is not a major concern.

$Z_0$ probes are useful for measurements up to 40 V.

**High Voltage Probes**

High voltage probes have attenuation factors in the 100X to 1000X range. The considerations that apply to other passive probes apply to high voltage probes with a few exceptions. Since the voltage range on high voltage probes varies from 1 kV to 20 kV (DC + peak AC), the probe head design is mechanically much larger than for a passive probe. High voltage probes have the added advantage of lower input capacitance (typically 2-3 pF).

![Figure 3-54: The P6009 and P6015A High Voltage Probes](image)
Active Voltage Probes

Active voltage probes, sometimes called “FET” probes, use active circuit elements such as transistors. There are three classes of active probes:

- **High speed active**
- **Differential active**
- **Fixtureed active**

Active voltage measuring probes use active circuit elements in the probe design to process signals from the circuit under test. All active probes require a source of power for their operation. Power is obtained either from an external power supply or from the oscilloscope itself. (Your digitizing oscilloscope powers the optional accessory P6205 probes.)

**NOTE**

*When you connect an active probe to the oscilloscope (such as the P6205), 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. Vertical Control on page 3-136 explains how to change the input impedance.*

**High Speed Active Probes**

Active probes offer low input capacitance (1 to 2 pF typical) while maintaining the higher input resistance of passive probes (10 kΩ to 10 MΩ). Like $Z_O$ probes, active probes are useful for making accurate timing and phase measurements. However, they do not degrade the amplitude accuracy. Active probes typically have a dynamic range of ±10 to ±15 V.

**Differential Probes**

Differential probes determine the voltage drop between two points in a circuit under test. Differential probes let you simultaneously measure two points and to display the difference between the two voltages.

Active differential probes are stand-alone products designed to be used with 50 Ω inputs. The same characteristics that apply to active probes apply to active differential probes.

**Fixtureed Active Probes**

In some small-geometry or dense circuitry applications, such as surface mounted devices (SMD), a hand-held probe is too big to be practical. You can instead use fixtured (or probe card mounted) active probes (or buffered...
amplifiers) to precisely connect your instrument to your device-under-test. These probes have the same electrical characteristics as high speed, active probes but use a smaller mechanical design.

**Current Probes**

Current probes enable you to directly observe and measure current waveforms, which can be very different from voltage signals. Tektronix current probes are unique in that they can measure from DC to 1 GHz.

Two types of current probes are available: one that measures AC current only and AC/DC probes that utilize the Hall effect to accurately measure the AC and DC components of a signal. AC-only current probes use a transformer to convert AC current flux into a voltage signal to the oscilloscope and have a frequency response from a few hundred Hertz up to 1 GHz. AC/DC current probes include Hall effect semiconductor devices and provide frequency response from DC to 50 MHz.

Use a current probe by clipping its jaws around the wire carrying the current that you want to measure. (Unlike an ammeter which you must connect in series with the circuit.) Because current probes are non-invasive, with loading typically in the milliohm to low Ω range, they are especially useful where low loading of the circuit is important. Current probes can also make differential measurements by measuring the results of two opposing currents in two conductors in the jaws of the probe.

![Figure 3-55: A6303 Current Probe Used in the AM 503S Opt. 03](image-url)
Optical Probes

Optical probes let you blend the functions of an optical power meter with the high-speed analog waveform analysis capability of an oscilloscope. You have the capability of acquiring, displaying, and analyzing optical and electrical signals simultaneously.

Applications include measuring the transient optical properties of lasers, LEDs, electro-optic modulators, and flashlamps. You can also use these probes in the development, manufacturing, and maintenance of fiber optic control networks, local area networks (LANs), fiber-based systems based on the FDDI and SONET standard, optical disk devices, and high-speed fiber optic communications systems.

**NOTE**

*When you connect any level 2 probe to the oscilloscope, the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a high input impedance passive probe you need to set the input impedance back to 1 MΩ. Vertical Control, on page 3-136, explains how to change the input impedance.*

Time-to-Voltage Converter

The instantaneous time-interval to voltage converter (TVC) continuously converts consecutive timing measurements to a time-interval versus time waveform.

Timing variations typically appear as left-to-right motion, or jitter, on an oscilloscope. Time base or trigger holdoff adjustments may improve display stability, but they do not show timing dynamics. The TVC untangles the often confusing waveforms and delivers a coherent real-time view.

The TVC adds three measurement functions to the voltage versus time capability of your oscilloscope: time delay versus time, pulse-width versus time, and period versus time.
### Probes by Type

Table 3-6 lists TDS 600A compatible probes classified by type.

<table>
<thead>
<tr>
<th>Probe Type</th>
<th>Tektronix Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive, high impedance</td>
<td>P6139A (std.)</td>
<td>10X, 500 MHz</td>
</tr>
<tr>
<td>voltage</td>
<td>P6101A</td>
<td>1X, 15 MHz</td>
</tr>
<tr>
<td>Passive, SMD</td>
<td>P6563AS</td>
<td>20X, 500 MHz</td>
</tr>
<tr>
<td>Passive, low impedance Z₀</td>
<td>P6156</td>
<td>10X, 3.5 GHz, for 50 Ω inputs (1X, 20X, 100X optional)</td>
</tr>
<tr>
<td>Passive, high voltage</td>
<td>P6009</td>
<td>100X, 1.5 kV, DC + peak AC</td>
</tr>
<tr>
<td></td>
<td>P6015A</td>
<td>1000X, 20 kV, DC + peak AC</td>
</tr>
<tr>
<td>Active, high speed voltage</td>
<td>P6204</td>
<td>DC to 1 GHz FET. DC Offset capability (requires Tektronix 1103 TekProbe Power Supply for offset capability)</td>
</tr>
<tr>
<td>Active, high speed voltage</td>
<td>P6205</td>
<td>DC to 750 MHz FET</td>
</tr>
<tr>
<td>Active, differential voltage</td>
<td>P6046</td>
<td>1X/10X, DC to 100 MHz</td>
</tr>
<tr>
<td>Active, fixtured voltage</td>
<td>A6501</td>
<td>Buffer Amplifier, 1 GHz, 1 MΩ, 10X</td>
</tr>
<tr>
<td></td>
<td>P6501</td>
<td>Microprobe with TekProbe Power Cable, 750 MHz, 1 MΩ, 10X</td>
</tr>
<tr>
<td>Current</td>
<td>AM 503S</td>
<td>AC/DC. Uses A6302 Current Probe.</td>
</tr>
<tr>
<td></td>
<td>P6021</td>
<td>AC. 120 Hz to 60 MHz.</td>
</tr>
<tr>
<td></td>
<td>P6022</td>
<td>AC. 935 kHz to 120 MHz.</td>
</tr>
<tr>
<td></td>
<td>CT-1/CT-2</td>
<td>Designed for permanent or semi-permanent in-circuit installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT-1: 25 kHz to 1 GHz, 50 Ω input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT-2: 1.2 kHz to 200 MHz, 50 Ω input</td>
</tr>
<tr>
<td></td>
<td>CT-4</td>
<td>Current Transformer for use with AM 503S and P6021. Peak pulse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 kA, 0.5 Hz to 20 MHz with AM 503S</td>
</tr>
<tr>
<td>Logic Word Trigger</td>
<td>P6408</td>
<td>16 channel, one qualifier channel, TTL compatible, +5 V power supply required</td>
</tr>
<tr>
<td>Optical</td>
<td>P6701A</td>
<td>500 to 950 nm, DC to 850 MHz, 1 V/mW</td>
</tr>
<tr>
<td>(Opto-Electronic Converters)</td>
<td>P6703A</td>
<td>1100 to 1700 nm, DC to 1 GHz, 1 V/mW</td>
</tr>
<tr>
<td></td>
<td>P6711</td>
<td>500 to 950 nm, DC to 250 MHz, 5 V/mW</td>
</tr>
<tr>
<td></td>
<td>P6713</td>
<td>1100 to 1700 nm, DC to 300 MHz, 5 V/mW</td>
</tr>
<tr>
<td>Time-to-Voltage Converter</td>
<td>TVC 501</td>
<td>Time delay, pulse width and period measurements</td>
</tr>
</tbody>
</table>
Probes by Application

Another way to classify probes is by application. Different applications demand different probes. Use Table 3-7 to select a probe for your application.

Table 3-7: Probes by Application

<table>
<thead>
<tr>
<th>Probe Type</th>
<th>Telecommunications &amp; High-Speed Logic</th>
<th>Industrial Electronics</th>
<th>Consumer/Computer Electronics</th>
<th>High Energy Pulsed Power</th>
<th>Certification, Regulatory, &amp; Compliance Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive, high-impedance voltage</td>
<td>P6139A(^1), P6101A(^1), P6563AS(^1)</td>
<td>P6139A(^1,2), P6101A(^1,2), P6563AS(^1)</td>
<td>P6139A(^1,2,3), P6101A(^1), P6563AS(^1)</td>
<td>P6139A(^1,2,3), P6101A(^1), P6563AS(^1)</td>
<td>P6139A(^1,2,3), P6101A(^1,2)</td>
</tr>
<tr>
<td>Active, high-speed digital voltage</td>
<td>P6205(^2,3), P6204(^2,3)</td>
<td>P6205(^2,3)</td>
<td>P6205(^2,3)</td>
<td>P6204 w/1103 power supply(^2,3)</td>
<td>P6205(^2,3)</td>
</tr>
<tr>
<td>Low impedance (Z_0) (low capacitance)</td>
<td>P6156(^1,2,3)</td>
<td></td>
<td>P6156(^1,2,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive, high voltage</td>
<td>P6009(^1,2)</td>
<td>P6009(^1,2,3), P6015A(^1,2,3)</td>
<td>P6009(^1,2)</td>
<td>P6009(^1,2,3), P6015A(^1,2,3)</td>
<td>P6009(^1,2,3), P6015A(^1,2,3)</td>
</tr>
<tr>
<td>Active, differential voltage</td>
<td>P6046(^2,3)</td>
<td>P6046(^2,3)</td>
<td>P6046(^2,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>AM 503S(^2,3), P6021(^1,2)</td>
<td>AM 503S(^2,3), P6021(^1,2)</td>
<td>AM 503S(^2,3), P6021(^1,2)</td>
<td>AM 503S(^2,3), P6021(^1,2)</td>
<td>AM 503S(^2,3), P6021(^1,2), CT(^1,2), CT(^1,2)</td>
</tr>
<tr>
<td>Fixtured</td>
<td>A6501(^2,3), P6501(^2,3)</td>
<td></td>
<td>A6501(^2,3), P6501(^2,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logic Word Trigger</td>
<td>P6408(^2,3)</td>
<td></td>
<td>P6408</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical</td>
<td>P6701A(^2,3), P6703A(^2,3), P671(^2,3), P6713(^2,3)</td>
<td>P6701A(^2,3), P6703A(^2,3), P671(^2,3), P6713(^2,3)</td>
<td>P6701A(^2,3), P6703A(^2,3), P671(^2,3), P6713(^2,3)</td>
<td></td>
<td>P6701A(^2,3), P6703A(^2,3), P671(^2,3), P6713(^2,3)</td>
</tr>
<tr>
<td>Time-to-voltage converter</td>
<td>TVC 501(^2,3)</td>
<td>TVC 501(^2,3)</td>
<td>TVC 501(^2,3)</td>
<td>TVC 501(^2,3)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Qualitative signal evaluation — use when a great deal of accuracy is not required, such as when making go/no go measurements.  
\(^2\)Functional testing — use when the device under test is being compared to some standard. 
\(^3\)Quantitative Signal Evaluation — use when detailed evaluation is needed.
Pulse Triggering

Pulse triggering can be very useful. For example, you might be testing a product with a glitch in the power supply. The glitch appears once a day. So instead of sitting by and waiting for it to appear, you can use pulse triggering to automatically capture your data.

There are three classes of pulse triggering: glitch, runt, and width.

- A **glitch** trigger occurs when the trigger source detects a pulse narrower (or wider) in width than some specified time. It can trigger on glitches of either polarity. Or you can set the glitch trigger to reject glitches of either polarity.

- A **runt** trigger occurs when the trigger source detects a short pulse that crosses one threshold but fails to cross a second threshold before recrossing the first. You can set the oscilloscope to detect positive or negative runt pulses.

- A **width** trigger occurs when the trigger source detects a pulse that is inside or, optionally, outside some specified time range (defined by the upper limit and lower limit). The oscilloscope can trigger on positive or negative width pulses.

Figure 3-56 shows the pulse trigger readouts. Table 3-8, on page 3-110, describes the choices for pulse triggers.

![Figure 3-56: Pulse Trigger Readouts](image-url)
### Table 3-8: Pulse Trigger Definitions

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Glitch positive]</td>
<td>Triggering occurs if the oscilloscope detects positive spike widths less than the specified glitch time.</td>
</tr>
<tr>
<td>![Glitch negative]</td>
<td>Triggering occurs if the oscilloscope detects negative spike widths less than the specified glitch time.</td>
</tr>
<tr>
<td>![Glitch either]</td>
<td>Triggering occurs if the oscilloscope detects positive or negative widths less than the specified glitch time.</td>
</tr>
<tr>
<td>![Runt positive]</td>
<td>Triggering occurs if the oscilloscope detects a positive pulse that crosses one threshold going positive but fails to cross a second threshold before recrossing the first going negative.</td>
</tr>
<tr>
<td>![Runt negative]</td>
<td>Triggering occurs if the oscilloscope detects a negative going pulse that crosses one threshold going negative but fails to cross a second threshold before recrossing the first going positive.</td>
</tr>
<tr>
<td>![Runt either]</td>
<td>Triggering occurs if the oscilloscope detects a positive or negative going pulse that crosses one threshold but fails to cross a second threshold before recrossing the first.</td>
</tr>
<tr>
<td>![Width positive]</td>
<td>Triggering occurs if the oscilloscope finds a positive pulse with a width between, or optionally outside, the user-specified lower and upper time limits.</td>
</tr>
<tr>
<td>![Width negative]</td>
<td>Triggering occurs if the oscilloscope finds a negative pulse with a width between, or optionally outside, the user-specified lower and upper time limits.</td>
</tr>
</tbody>
</table>
Operations Common to Glitch, Runt, and Width

The pulse trigger menus let you define the pulse source, select the mode (auto or normal), and adjust the holdoff. To bring up the Pulse Trigger menu:

Press TRIGGER MENU → Type (main) → Pulse (pop-up) → Class (main) → Glitch, Runt, or Width (pop-up) (see Figure 3-57).

Figure 3-57: Main Trigger Menu — Glitch Class

Source

Use this main menu item to specify which channel becomes the pulse trigger source.

Press TRIGGER MENU → Type (main) → Pulse (pop-up) → Source (main) → Ch1, Ch2, Ch3 (Ax1 on the TDS 620A), or Ch4 (Ax2 on the TDS 620A) (side).

Mode & Holdoff

To change the holdoff time and select the trigger mode:

1. Press TRIGGER MENU → Type (main) → Pulse (pop-up) → Mode and Holdoff (main) → Auto or Normal (side).
   - 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.
Pulse Triggering

- In **Normal** mode the oscilloscope acquires a waveform only if there is a valid trigger. (You can force a single acquisition by pressing **FORCE TRIGGER**.)

2. To change the holdoff time, press **Holdoff** (side). Use the general purpose knob or the keypad to enter the value in percent.

Glitch Operations

When you select the pulse class **Glitch**, the oscilloscope will trigger on a pulse narrower (or wider) in width than some specified time.

### Polarity & Width

This menu item lets you define the glitch in terms of polarity (positive, negative, or either) and width.

1. Press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Polarity and Width** (main) → **Positive, Negative, or Either** (side).

- **Glitch Positive** looks at positive-going pulses.
- **Glitch Negative** looks at negative-going pulses.
- **Glitch Either** looks at both positive and negative pulses.

2. Press **Width** (side), and set the glitch width using the general purpose knob or keypad.

### Glitch (Accept or Reject)

To specify whether to trigger on glitches or filter out glitches using the **Glitch** main menu item, press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Class** (main) → **Glitch** (pop-up) → **Glitch** (main) → **Accept Glitch** or **Reject Glitch** (side).

If you choose **Accept Glitch**, the oscilloscope will trigger only on pulses narrower than the width you specified. If you select **Reject Glitch**, it will trigger only on pulses wider than the specified width.

### Level

To set the trigger level with the **Level** main menu item (or the front panel trigger **LEVEL** knob), press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Level** (main) → **Level, Set to TTL, Set to ECL, or Set to 50%** (side).

- If you select **Level**, enter a value with the general purpose knob or the keypad.
- If you select **Set to TTL**, the trigger level is set to the TTL switching threshold.
- If you select **Set to ECL**, the trigger level is set to the ECL switching threshold.
Pulse Triggering

- If you select **Set to 50%**, you cause the digitizing oscilloscope to search for the point halfway between the peaks of the trigger source signal and set the trigger level to that point.

## Runt Operation

When you select the pulse class **Runt**, the oscilloscope will trigger on a short pulse that crosses one threshold but fails to cross a second threshold before recrossing the first. To set up runt triggering:

1. Press **TRIGGER MENU → Type (main) → Pulse (pop-up) → Class (main) → Runt (pop-up) → Source (main) → Ch1, Ch2, Ch3 (Ax1 on the TDS 620A), or Ch4 (Ax2 on the TDS 620A) (side).** (See Figure 3-58.)
2. Press **Polarity (main) → Positive, Negative, or Either (side).**
3. Press **Thresholds (main), and set the upper and lower thresholds for runt detection with the side menu selections and the keypad or the general purpose knob.**

### Polarity

Use this menu item to specify the direction of the runt pulse.

Press **TRIGGER MENU → Type (main) → Pulse (pop-up) → Class (main) → Runt (pop-up) → Polarity (main) → Positive, Negative, or Either (side).**

- **Positive** looks for positive-going runt pulses.
- **Negative** looks for negative-going runt pulses.
- **Either** looks for both positive and negative runt pulses.
Pulse Triggering

**Figure 3-58: Main Trigger Menu—Runt Class**

**Thresholds**

To set the two threshold levels used in detecting a runt pulse:

1. Press **TRIGGER MENU → Type (main) → Pulse (pop-up) → Class (main) → Runt (pop-up) → Thresholds (main).**

2. Use the general purpose knob or keypad to set the values for the high and low thresholds.

Hint: To use the Trigger Bar feature to set the threshold levels on the pulse train, press **DISPLAY → Readout Options (main) → Trigger Bar Style (side) until Long appears in that menu item.**

Note the position of the trigger indicator in Figure 3-58. Triggering occurs at the point the pulse returns over the first (lower) threshold going negative without crossing the second threshold level (upper). Be aware of the following considerations when using Runt triggering:

- **When Positive** is set in the **Polarity** side menu, the **lower** threshold must be first crossed going **positive**, then recrossed going **negative** without crossing the **upper** threshold at all.

- **When Negative** is set in the **Polarity** side menu, the **upper** threshold must be first crossed going **negative**, then recrossed going **positive** without crossing the **lower** threshold at all.

- **When Either** is set in the **Polarity** side menu, **one** threshold must be first crossed going in **either** direction, then recrossed going in the **opposite** direction without crossing the **other** threshold at all.
- Regardless of the polarity setting, triggering occurs at the point the runt pulse recrosses its first threshold.

### Width Operation

When you select the pulse class **Width**, the oscilloscope will trigger on a pulse narrower (or wider) than some specified range of time (defined by the upper limit and lower limit).

### Polarity

To define whether the pulses are positive or negative:

Press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Class** (main) → **Width** (pop-up) → **Polarity** (main) → **Positive** or **Negative** (side).

### Trig When

This menu item lets you establish the range of widths (in units of time) the trigger source will search for and whether to trigger on pulses that are outside this range or ones that fall within the range.

1. Press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Class** (main) → **Width** (pop-up) → **Trig When** (main).

2. Press **Within Limits** (side) if you want the oscilloscope to trigger on pulses that fall within the specified range. If you want it to trigger on pulses that are outside the range, then press **Out of Limits** (side).

3. To set the range of pulse widths in units of time, press **Upper Limit** (side) and **Lower Limit** (side). Enter the values with the general purpose knob or keypad. The **Upper Limit** is the maximum valid pulse width the trigger source will look for. The **Lower Limit** is the minimum valid pulse width. The oscilloscope will always force the **Lower Limit** to be less than or equal to the **Upper Limit**.

### Level

To set the trigger level with the **Level** main menu:

Press **TRIGGER MENU → Type** (main) → **Pulse** (pop-up) → **Class** (main) → **Width** (pop-up) → **Level** (main) → **Level, Set to TTL, Set to ECL**, or **Set to 50%** (side).

### For More Information


See **Triggering**, on page 3-132.
Remote Communication

You may want to integrate your oscilloscope into a system environment and remotely control your oscilloscope or exchange measurement or waveform data with a computer. You can control your oscilloscope remotely via the IEEE Std 488.2–1987 (GPIB) interface.

GPIB Protocol

GPIB enables data transfers between instruments that support the GPIB protocols. It provides:

- Remote instrument control
- Bidirectional data transfer
- Device compatibility
- Status and event reporting

Besides the base protocols, Tektronix has defined codes and formats for messages to travel over the GPIB. Each device that follows these codes and formats, such as the TDS 620A, TDS 640A, & TDS 644A, supports standard commands. Use of instruments that support these commands can greatly simplify development of GPIB systems.

GPIB Interface Requirements

You can connect GPIB networks in many configurations if you follow these rules:

- No more than 15 devices, including the controller, can be on a single bus.
- Connect one device load every two meters (about six feet) of cable length to maintain bus electrical characteristics. (Generally, each instrument represents one device load on the bus.)
- The total cumulative cable length must not exceed 20 meters (about 65 feet).
- At least two-thirds of the device loads must be turned on when you use your network.
- There must be only one cable path from each device to each other device on your network (see Figure 3-59), and you must not create loop configurations.
Figure 3-59: Typical GPIB Network Configuration

Cables — An IEEE Std 488.1–1987 GPIB cable (available from Tektronix, part number 012–0991–00) is required to connect two GPIB devices.

Connector — A 24-pin GPIB connector is located on the oscilloscope rear panel. The connector has a D-type shell and conforms to IEEE Std 488.1–1987. You can stack GPIB connectors on top of each other (see Figure 3-60).

Figure 3-60: Stacking GPIB Connectors

GPIB Parameters

In the Utility menu you need to define two important GPIB parameters: *mode* and *address*. You need to set the mode to talker/listener, talk only, or off the bus. You also need to specify the primary communication address.
Operation

To set up remote communications, ensure that your oscilloscope is physically cabled to the controller and that the oscilloscope parameters are correctly set. Plug an IEEE Std 488.2–1987 GPIB cable into the GPIB connector on the oscilloscope rear panel and into the GPIB port on your controller (see Figure 3-61).

![Diagram](image)

**Figure 3-61: Connecting the Digitizing Oscilloscope to a Controller**

To set remote communications parameters:

Press **SHIFT UTILITY → System** (main) → **I/O** (pop-up).

**Port Selection**

Now you need to configure the port to match the controller (see Figure 3-62).

Press **SHIFT UTILITY → System** (main) → **I/O** (pop-up) → **Port** (main) → **GPIB** (pop-up) → **Configure** (main) → **Talk/Listen Address**, **Hardcopy (Talk Only)**, or **Off Bus** (side)

- Choose **Talk/Listen Address** for normal, controller-based system operation. Use the general purpose knob or the keypad to define the address.

- Use **Hardcopy (Talk Only)** to use the hardcopy port of your digitizing oscilloscope. Once the port is configured this way, the oscilloscope will send the hardcopy data to any listeners on the bus when the **HARDCOPY** button is pressed.

  If the port is configured any other way and the **HARDCOPY** button is pressed, an error will occur and the digitizing oscilloscope will display a message saying the selected hardcopy port is currently unavailable.

- Use **Off Bus** to disconnect the digitizing oscilloscope from the bus.
For More Information

See *Hardcopy*, on page 3-57.

See the *TDS Family Digitizing Oscilloscopes Programmer Manual.*
Saving and Recalling Setups

You may want to save and reuse setups for many reasons. For example, after changing the setting during the course of an experiment, you may want to quickly return to your original setup. You can save and recall up to ten instrument setups from internal oscilloscope memory. The information is retained even when you turn the oscilloscope off or unplug it.

Operation

To save the current setup of the digitizing oscilloscope:

1. Press SETUP → Save Current Setup (main).

   **STOP**

   Before doing step 2 that follows, note that if you choose a setup location labeled user, you will overwrite the user setup previously stored there. You can store setups in setup locations labeled factory without disturbing previously stored setups.

2. To store to a setup internally, choose one of the ten internal storage locations from the side menu To Setup 1, To Setup 2, ... (see Figure 3-63). Now the current setup is stored in that location.

![Figure 3-63: Save/Recall Setup Menu](image)

---

Reference
To store a setup to disk (optional on the TDS 620A & TDS 640A), press **File**. Then use the general purpose knob to select the exact file from the resulting scrollbar list. Finally, press the side-menu **Save To Selected File** to complete the operation.

**Recalling a Setup**

To recall a setup stored internally, press **SETUP → Recall Saved Setup** (main) → (Recall Setup 1, Recall Setup 2 ... (side).

To recall a setup stored on disk (optional on the TDS 620A & TDS 640A), press **From File**. Then use the general purpose knob to select the exact file from the resulting scrollbar list. Only files with .set extensions will be displayed. Finally, press the side-menu **Recall From Selected File** to complete the operation.

Recalling a setup will not change the menu that is currently displayed. If you recall a setup that is labeled **factory** in the side menu, you will recall the factory setup. (The conventional method for recalling the factory setup is described below.)

**Recalling the Factory Setup**

To reset your oscilloscope to the factory defaults:

Press **SETUP → Recall Factory Setup** (main) → **OK Confirm Factory Init** (side).

See **Factory Initialization Settings**, on page A-23, for a list of the factory defaults.

**Deleting All Setups and Waveforms—Tek Secure®**

Sometimes you might use the digitizing oscilloscope to acquire waveforms that are confidential. Furthermore, before returning the oscilloscope to general usage, you might want to remove all such waveforms and any setups used to acquire them. (Be sure you want to remove all waveforms and setups, because once they are removed, you cannot retrieve them.) To use Tek Secure to remove all reference setups and waveforms (does not affect mass storage disk):

Press **SHIFT UTILITY → System** (main) → **Config** (pop-up) → **Tek Secure Erase Memory** (main) → **OK Erase Ref & Panel Memory** (side).

Executing Tek Secure accomplishes the following tasks:

- Replaces all waveforms in reference memories with zero sample values.
- Replaces the current front panel setup and all setups stored in setup memory with the factory setup.
- Calculates the checksums of all waveform memory and setup memory locations to verify successful completion of setup and waveform erasure.
If the checksum calculation is unsuccessful, displays a warning message; if the checksum calculation is successful, displays a confirmation message.

**Running File Utilities**

To run file utilities (optional on the TDS 620A & TDS 640A), see the *File System* article on page 3-53.

---

**For More Information**

See *Tutorial Example 4: Saving Setups*, on page 1-24.

See *Appendix D, Factory Initialization Settings*, on page A-23.
Saving and Recalling Waveforms

You can store a waveform in any of the four internal reference memories of the digitizing oscilloscope. That information is retained even when you turn the oscilloscope off or unplug it. You can save any combination of different size waveform records.

The digitizing oscilloscope can display up to 11 waveforms at one time. That includes waveforms from the four input channels, four reference waveforms, and three math waveforms.

You will find saving waveforms useful when working with many waveforms and channels. If you have more waveforms than you can display, you can save one of the waveforms and then stop acquiring it. That lets you display another waveform without forcing you to lose the first one.

Operation

To save a waveform, do the following steps:

1. Select the channel that has the waveform you want to save.

Before doing step 2 that follows, note that if you choose a reference memory location labeled active (see Figure 3-64), you will overwrite the waveform that was previously stored there. You can store waveforms in reference locations labeled empty without disturbing previously stored waveforms.

2. To store a waveform internally, press save/recall WAVEFORM → Save Waveform (main) → Ref1, Ref2, Ref3, Ref4, or File (side).

To store a waveform to disk (optional on the TDS 620A & TDS 640A), press To File. Then use the general purpose knob to select the exact file from the resulting scrollbar list. Finally, press the side-menu Save To Selected File to complete the operation.
Deleting Waveforms

You can choose the Delete Refs main menu item and then select the references you no longer need from the side menu (Delete Ref1, Delete Ref2, Delete Ref3, Delete Ref4, or Delete All Refs).

Deleting All Waveforms and Setups

You can remove all stored reference waveforms and setups using the feature called Tek Secure. It is described under Saving and Recalling Setups. See “Deleting All Setups and Waveforms” on page 3-121.

Displaying a Saved Waveform

To display a waveform in internal reference memory:

Press MORE → Ref1, Ref2, Ref3, or Ref4 (main).

Note that in Figure 3-65, the main menu items Ref2, Ref3, and Ref4 appear shaded while Ref1 does not. References that are empty appear shaded in the More main menu.

Recalling a Waveform From Disk

To recall a waveform from disk (optional on the TDS 620A & TDS 640A) to an internal reference memory, press save/recall WAVEFORM → Recall Wfm To Ref. Then use the general purpose knob to select the exact file from the
resulting scrollbar list. Only files with .WFM extensions are displayed. Finally, press from the side-menu To Ref1, To Ref2, To Ref3, or To Ref4 choices to complete the operation.

![Image of a waveform display](image)

**Figure 3-65: More Menu**

**Autosave (TDS 640A and 644A only)**

To use autosave, press **Autosave (main) → Autosave Single Seq ON (side).**

Also turn on **Single Acquisition Sequence** in the Acquire menu (see page 3-6).

To disable this feature, simply press **Autosave (main) → Autosave Single Seq OFF (side).**

If you enable both autosave and single sequence, the TDS will save all live channels to reference waveforms at the completion of each single sequence event. All previous reference waveform data will be erased.

**Running File Utilities**

To run file utilities (optional on the TDS 620A & TDS 640A), see the *File System* article on page 3-53.

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**For More Information**

See *Selecting Channels*, on page 3-126.
Selecting Channels

The selected channel is the channel that the digitizing oscilloscope applies all waveform-specific activities to (such as measurements or vertical scale and position).

Channel Readout and Reference Indicator

The channel readout shows the selected channel in inverse video in the lower left corner of the display. The channel reference indicator for the selected channel appears along the left side of the display. See Figure 3-66.

Channel Selection Buttons

Selecting channels on the TDS 600A series oscilloscopes is straightforward and easy.

The channel selection buttons are on the right of the display and are labeled CH 1, CH 2, CH 3 (AUX 1 on the TDS 620A), CH 4 (AUX 2 on the TDS 620A), and MORE. They determine which channel is selected. The MORE button allows you to select internally stored Math and Ref waveforms for display and manipulation.

The selected channel is indicated by the lighted LED above each button.
To selecting a channel:

Pressing CH 1, CH 2, CH 3 (AUX 1 on the TDS 620A), or CH 4 (AUX 2 on the TDS 620A) turns the channel on if it is not already on.

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

Removing Waveforms From the Display

The WAVEFORM OFF button turns OFF the display of the selected channel waveform. It will also remove from the display any automated measurements being made on that waveform.

When you turn off a waveform, the digitizing oscilloscope automatically selects the next highest priority waveform. Figure 3-67 shows how the oscilloscope prioritizes waveforms.

1. CH1
2. CH2
3. CH3 (AUX 1 on the TDS 620A)
4. CH4 (AUX 2 on the TDS 620A)
5. MATH1
6. MATH2
7. MATH3
8. REF1
9. REF2
10. REF3
11. REF4

Figure 3-67: Waveform Selection Priority

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.

For More Information

See Saving and Recalling Waveforms, on page 3-123.

See Waveform Math, on page 3-148.
Signal Path Compensation

This oscilloscope lets you compensate the internal signal path used to acquire the waveforms you acquire and measure. By executing the signal path compensation feature (SPC), you can optimize the oscilloscope capability to make accurate measurements based on the ambient temperature.

Run an SPC anytime you wish to ensure that the measurements you make are made with the most accuracy possible. You should also run an SPC if the temperature has changed more than 5° C since the last SPC was performed.

**NOTE**

_When making measurements at volts/division settings less than or equal to 5 mV, you should run SPC at least once per week. Failure to do so may result in the oscilloscope not meeting warranted performance levels at those volts/div settings. (Warranted characteristics are listed in the Performance Verification manual.)_

---

**Operation**

1. Power on the digitizing oscilloscope and allow a 20 minute warm-up before doing this procedure.

2. Disconnect any input signals you may have connected from all four input channels.

   ![Stop Icon]

   When doing steps 3 and 4, do not turn off the oscilloscope until signal-path compensation completes. If you interrupt (or lose) power to the instrument while signal-path compensation is running, a message is logged in the oscilloscope error log. If such a case occurs, rerun signal-path compensation.

3. Press **SHIFT UTILITY → System** (main) → **Cal** (pop-up) → **Signal Path** (main) → **OK Compensate Signal Paths** (side).

4. Wait for signal path compensation to complete (one to three minutes). While it progresses, a “clock” icon (shown at left) is displayed on-screen. When compensation completes, the status message will be updated to **Pass** or **Fail** in the main menu.

5. Verify the word **Pass** appears under **Signal Path** in the main menu. (See Figure 3-68.)
Signal Path Compensation

Signal Path Compensation (SPC) corrects for DC inaccuracies caused by ambient temperature variations and/or long-term drift. SPC can be run at any time after the oscilloscope is **POWERED ON**, and should be run whenever the oscilloscope's ambient temperature has changed by more than 5°C.

SPC will be adversely affected by input signals with AC components. Disconnect or shunts these signals prior to running SPC.

Figure 3-68: Performing a Signal Path Compensation
Status

The Status menu lets you see information about the oscilloscope state.

Operation

To operate the Status menu:

Press **SHIFT STATUS → Status** (main) → **System, Display, Trigger, Waveforms**, or **I/O** (side). Note: some oscilloscopes do not have a main Status menu. On these instruments, press **SHIFT STATUS → System, Display, Trigger, Waveforms**, or **I/O** (side).

- **System** displays information about the Horizontal, Zoom, Acquisition, Measure, and Hardcopy systems (Figure 3-69). This display also tells you the firmware version.
- **Display** provides parameter information about the display and color systems.
- **Trigger** displays parameter information about the triggers.
- **Waveforms** displays information about the various waveforms, including live, math, and reference.
- **I/O** displays information about the I/O port(s).

![Figure 3-69: Status Menu — System](image)
Banner

To display the banner (firmware version, options, copyright, and patents):

**NOTE**

Some TDS 644A oscilloscopes do not have a Status main menu with a banner. However, all instruments display the banner briefly at power-on.

Press **SHIFT STATUS → Banner** (main) (see Figure 3-70).

![Banner Display](image)

**Figure 3-70: Banner Display**
Triggering

Triggers determine when the digitizing oscilloscope starts acquiring and displaying a waveform. The TDS 600A has four types of trigger: edge, logic, pulse, and, with option 5, video.

Although these triggers are unique, they have some common characteristics that can be defined and modified using the Trigger menu, buttons, and knob. This article discusses these common characteristics.

To learn about the general concept of triggering, see Triggering in the Operating Basics section. To learn more about using specific triggers and using the delayed trigger system, see For More Information on page 3-135.

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**Trigger Button and Knobs**

The trigger buttons and knob let you quickly adjust the trigger level or force a trigger (see Figure 3-71).

![Trigger Status Lights](image)

**Figure 3-71: TRIGGER Controls and Status Lights**

**MAIN LEVEL Knob**

The MAIN LEVEL knob lets you manually change the trigger level when triggering in Edge mode or certain threshold levels when triggering in Logic or Pulse modes. It adjusts the trigger level (or threshold level) instantaneously no matter what menu, if any, is displayed.
To Set to 50%

You can quickly obtain an edge or pulse trigger (except for the Runt class) by pressing SET LEVEL TO 50%. The oscilloscope sets the trigger level to the halfway point between the peaks of the trigger signal.

You can also set the level to 50% in the Trigger menu under the main menu item Level if Edge or Pulse (except for Runt class) 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.

Force Trigger

By pressing the FORCE TRIG front panel button, you can force the oscilloscope to immediately start acquiring a waveform record even without a trigger event. 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, etc.).

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.

Single Trigger

If your goal is to act on the next valid trigger event and then stop, press SHIFT FORCE TRIG. Now you can initiate the single sequence of acquisitions by pressing the RUN/STOP button.

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 3-6 for further discussion of single sequence acquisitions.

Readouts

The digitizing oscilloscope has display readouts and status lights dedicated to monitoring the trigger circuitry.

Trigger Status Lights

There are three status lights in the Trigger control area (Figure 3-71) indicating the state of the trigger circuitry. The lights are labeled TRIG'D, READY, and ARM.

- When TRIG'D is lighted, it means the digitizing oscilloscope has recognized a valid trigger and is filling the posttrigger portion of the waveform.
Triggering

- When READY is lighted, it means the digitizing oscilloscope can accept a valid trigger event, and the digitizing 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 digitizing oscilloscope has recognized a valid main trigger and is waiting for a delayed trigger. When the digitizing 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.

Trigger Display Readout

At the bottom of the display, the Trigger readout shows some of the key trigger parameters (Figure 3-72). The readouts are different for edge, logic and pulse triggers.

![Main Time Base Time/Div](image)

**Main Time Base Time/Div**

**Main Time Base**

**Main Trigger Source = Ch 1**

**Main Trigger Slope = Rising Edge**

**Main Trigger Level**

**Figure 3-72: Example Trigger Readouts**

The record view at the top of the display shows the location of the trigger signal in the waveform record and with respect to the display (see Figure 3-73).

**Trigger Position and Level Indicators**

In addition to the numerical readouts of trigger level, there are also graphic indicators of trigger position and level which you can optionally display. These indicators are the trigger point indicator, the long trigger level bar, and the short trigger level bar. Figure 3-73 shows the trigger point indicator and short-style trigger level bar.

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.
Figure 3-73: Record View, Trigger Position, and Trigger Level Bar Readouts

Both the trigger point indicator and level bar are displayed from the Display menu. See Display Readout on page 3-28 for more information.

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Trigger Menu

Each trigger type (edge, logic, and pulse) has its own main trigger menu, which is described in a separate part of this section (see For More Information).

To select the trigger type, press TRIGGER MENU → Type (main) → Edge, Logic, or Pulse (pop-up).

---

For More Information

See Delay Triggering, on page 3-20.

See Edge Triggering, on page 3-32.

See Logic Triggering, on page 3-75.

See Pulse Triggering, on page 3-109.

See Triggering, on page 2-13.

See the Option 05 Video Trigger Interface Instruction Manual, Tektronix part number 070-8748-XX.
Vertical Control

You can control the vertical position and scale of the selected waveform using the vertical menu and knobs.

--

**Vertical Knobs**

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. That is particularly useful when you are comparing two or more waveforms.

To change the vertical scale and position, use the vertical **POSITION** and vertical **SCALE** knobs. The vertical controls only affect the selected waveform.

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 article).

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 speeds up significantly.

--

**Vertical Readouts**

The Vertical readout at the lower part of the display shows each displayed channel (the selected channel is in inverse video), and its volts/division setting (see Figure 3-74).

--

**Vertical Menu**

The Vertical menu (Figure 3-74) lets you select the coupling, bandwidth, and offset for the selected waveform. It also lets you numerically change the position or scale instead of using the vertical knobs.
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 MΩ 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 P6205), 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.
Vertical Control

Bandwidth

To eliminate the higher frequency components, change the bandwidth of the selected channel:

Press VERTICAL MENU → Bandwidth (main) → Full, 100 MHz, or 20 MHz (side).

Fine Scale

Press VERTICAL MENU → Fine Scale (main) to make fine adjustments to the vertical scale using the general purpose knob or the keypad.

Position

Press VERTICAL MENU → Position (main) to let the general purpose knob control the vertical position. 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

Offset lets you subtract DC bias from the waveform, so the oscilloscope can acquire the exact part of the waveform you are interested in.

Offset is useful when you want to examine a waveform with a DC bias. For example, you might be trying to look at a small ripple on a power supply output. It may be a 100 mV ripple on top of a 15 V supply. Using offset, you can display the ripple and scale it to meet your needs.

To use offset, press VERTICAL MENU → Offset (main). Use the general purpose knob to control the vertical offset. Press Set to 0 V (side) if you want to reset the offset to zero.

For More Information

See Acquisition, on page 2-19.

See Scaling and Positioning Waveforms, on page 2-22.
Waveform Differentiation

Advanced DSP Math (optional on TDS 620A & TDS 640A), provides waveform differentiation that allows you to display a derivative math waveform that indicates the instantaneous rate of change of the waveform acquired. Such waveforms are used in the measurement of slew rate of amplifiers and in educational applications. You can store and display a derivative math waveform in a reference memory, then use it as a source for another derivative waveform. The result is the second derivative of the waveform that was first differentiated.

Description

The math waveform, derived from the sampled waveform, is computed based on the following equation:

\[ Y_n = \frac{(X_{(n+1)}) - X_n)}{T} \]

Where:
- \(X\) is the source waveform
- \(Y\) is the derivative math waveform
- \(T\) is the time between samples

Since the resultant math waveform is a derivative waveform, its vertical scale is in volts/second (its horizontal scale is in seconds). The source signal is differentiated over its entire record length; therefore, the math waveform record length equals that of the source waveform.

Operation

To obtain a derivative math waveform:

1. Connect the waveform to the desired channel input and select that channel.
2. Adjust the vertical and horizontal scales and trigger the display (or press AUTOSET).
3. Press MORE \(\rightarrow\) Math1, Math2, or Math3 (main) \(\rightarrow\) Change Math Definition (side) \(\rightarrow\) Single Wfm Math (main). See Figure 3-21.
4. Press Set Single Source to (side). Repeatedly press the same button (or use the general purpose knob) until the channel source selected in step 1 appears in the menu label.
5. Press Set Function to (side). Repeatedly press the same button (or use the general purpose knob) until diff appears in the menu label.

6. Press OK Create Math Wfm (side) to display the derivative of the waveform you input in step 1.

You should now have your derivative math waveform on screen. Use the Vertical SCALE and POSITION knobs to size and position your waveform as you require.

Automated Measurements of a Derivative Waveform

Once you have displayed your derivative math waveform, you can use automated measurements to make various parameter measurements. Do the following steps to display automated measurements of the waveform:

1. Be sure MORE is selected in the channel selection buttons and that the differentiated math waveform is selected in the More main menu.

2. Press MEASURE → Select Measrmnt (main).

3. Select up to four measurements in the side menu (see Figure 3-76).
Figure 3-76: Peak-Peak Amplitude Measurement of a Derivative Waveform

Cursor Measurement of a Derivative Waveform

You can also use cursors to measure derivative waveforms. Use the same procedure as is found under Waveform Integration on page 3-144. When using that procedure, note that the amplitude measurements on a derivative waveform will be in volts per second rather than in volt-seconds as is indicated for the integral waveform measured in the procedure.

Usage Considerations

When creating differentiated math waveforms from live channel waveforms, consider the following topics.

Offset, Position, and Scale

Note the following tips for obtaining a good display:

- You should scale and position the source waveform so it is contained on screen. (Off screen waveforms may be clipped, resulting in errors in the derivative waveform).

- You can use vertical position and vertical offset to position your source waveform. The vertical position and vertical offset will not affect your derivative waveform unless you position the source waveform off screen so it is clipped.
Waveform Differentiation

- When using the vertical scale knob to scale the source waveform, note that it also scales your derivative waveform.

Because of the method the oscilloscope uses to scale the source waveform before differentiating that waveform, the derivative math waveform may be too large vertically to fit on screen — even if the source waveform is only a few divisions on screen. You can use Zoom to reduce the size of the waveform on screen (see Zoom that follows), but if your waveform is clipped before zooming, it will still be clipped after it is zoomed.

If your math waveform is a narrow differentiated pulse, it may not appear to be clipped when viewed on screen. You can detect if your derivative math waveform is clipped by expanding it horizontally using Zoom so you can see the clipped portion. Also, the automated measurement **Pk-Pk** will display a clipping error message if turned on (see Automated Measurements of a Derivative Waveform on page 3-140).

If your derivative waveform is clipped, try either of the following methods to eliminate clipping:

- Reduce the size of the source waveform on screen. (Select the source channel and use the vertical **SCALE** knob.)

- Expand the waveform horizontally on screen. (Select the source channel and increase the horizontal scale using the horizontal **SCALE** knob.) For instance, if you display the source waveform illustrated in Figure 3-75 on page 3-140 so its rising and falling edges are displayed over more horizontal divisions, the amplitude of the corresponding derivative pulse will decrease.

Whichever method you use, be sure Zoom is off and the zoom factors are reset (see Zoom below).

**Zoom**

Once you have your waveform optimally displayed, you can also magnify (or contract) it vertically and horizontally to inspect any feature. Just be sure the differentiated waveform is the selected waveform. (Press MORE, then select the differentiated waveform in the More main menu. Then use the Vertical and Horizontal **SCALE** knob to adjust the math waveform size.)

If you wish to see the zoom factor (2X, 5X, etc.), you need to turn zoom on: press **ZOOM → ON** (side). The vertical and horizontal zoom factors appear on screen.

Whether zoom is on or off, you can press **Reset Zoom Factors** (side) to return the zoomed derivative waveform to no magnification.

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**For More Information**

See **Waveform Integration**, on page 3-143.

See **Fast Fourier Transforms**, on page 3-36.

Waveform Integration

Advanced DSP Math (optional on TDS 620A & TDS 640A), provides waveform integration that allows you to display an integral math waveform that is an integrated version of the acquired waveform. Such waveforms find use in the following applications:

- Measuring of power and energy, such as in switching power supplies
- Characterizing mechanical transducers, as when integrating the output of an accelerometer to obtain velocity

**Description**

The integral math waveform, derived from the sampled waveform, is computed based on the following equation:

\[
y(n) = \text{scale} \sum_{i=1}^{n} \frac{x(i) + x(i-1)}{2} T
\]

*Where:*
- \(x(i)\) is the source waveform
- \(y(n)\) is a point in the integral math waveform
- \(\text{scale}\) is the output scale factor
- \(T\) is the time between samples

Since the resultant math waveform is an integral waveform, its vertical scale is in volt-seconds (its horizontal scale is in seconds). The source signal is integrated over its entire record length; therefore, the math waveform record length equals that of the source waveform.

**Operation**

To obtain an integral math waveform:

1. Connect the waveform to the desired channel input and select that channel.
2. Adjust the vertical and horizontal scales and trigger the display (or press AUTOSET).
4. Press Set Single Source to (side). Repeatedly press the same button until the channel source selected in step 1 appears in the menu label.
5. Press **Set Function** to (side). Repeatedly press the same button until **intg** appears in the menu label.

6. Press **OK Create Math Waveform** (side) to turn on the integral math waveform.

You should now have your integral math waveform on screen. See Figure 3-77. Use the Vertical **SCALE** and **POSITION** knobs to size and position your waveform as you require.

![Integral Math Waveform](image)

**Figure 3-77: Integral Math Waveform**

**Cursor Measurements of an Integral Waveform**

Once you have displayed your integrated math waveform, use cursors to measure its voltage over time.

1. Be sure **MORE** is selected (illuminated) in the channel selection buttons and that the integrated math waveform is selected in the **More** main menu.

2. Press **CURSOR → Mode** (main) → **Independent** (side) → **Function** (main) → **H Bars** (side).

3. Use the general purpose knob to align the selected cursor (solid) to the top (or to any amplitude level you choose).

4. Press **SELECT** to select the other cursor.

5. Use the general purpose knob to align the selected cursor (to the bottom (or to any amplitude level you choose).
6. Read the integrated voltage over time between the cursors in volt-seconds from the $\Delta$: readout. Read the integrated voltage over time between the selected cursor and the reference indicator of the math waveform from the $@$: readout. See Figure 3-78.

![Diagram](image-url)

**Figure 3-78: H Bars Cursors Measure an Integral Math Waveform**

7. Press **Function** (main) $\rightarrow$ **V Bars** (side). Use the general purpose knob to align one of the two vertical cursors to a point of interest along the horizontal axis of the waveform.

8. Press **SELECT** to select the alternate cursor.

9. Align the alternate cursor to another point of interest on the math waveform.

10. Read the time difference between the cursors from the $\Delta$: readout. Read the time difference between the selected cursor and the trigger point for the source waveform from the $@$: readout.

11. Press **Function** (main) $\rightarrow$ **Paired** (side).

12. Use the technique just outlined to place the long vertical bar of each paired cursor to the points along the horizontal axis you are interested in.

13. Read the following values from the cursor readouts:
   - Read the integrated voltage over time between the Xs of both paired cursors in volt-seconds from the $\Delta$: readout.
Waveform Integration

- Read the integrated voltage over time between the X of the selected cursor and the reference indicator of the math waveform from the @: readout.
- Read the time difference between the long vertical bars of the paired cursors from the Δ: readout.

**Automated Measurements of a Integral Waveform**

You can also use automated measurements to measure integral math waveforms. Use the same procedure as is found under *Waveform Differentiation* on page 3-140. When using that procedure, note that your measurements on an integral waveform will be in volt-seconds rather than in volts per second as is indicated for the differential waveform measured in the procedure.

**Usage Considerations**

When creating integrated math waveforms from live channel waveforms, consider the following topics.

**Offset, Position, and Scale**

Note the following requirements for obtaining a good display:

- You should scale and position the source waveform so it is contained on screen. (Off screen waveforms may be clipped, which will result in errors in the integral waveform).
- You can use vertical position and vertical offset to position your source waveform. The vertical position and vertical offset will not affect your integral waveform unless you position the source waveform off screen so it is clipped.
- When using the vertical scale knob to scale the source waveform, note that it also scales your integral waveform.

**DC Offset**

The source waveforms that you connect to the oscilloscope often have a DC offset component. The oscilloscope integrates this offset along with the time varying portions of your waveform. Even a few divisions of offset in the source waveform may be enough to ensure that the integral waveform saturates (clips), especially with long record lengths.

You may be able to avoid saturating your integral waveform if you choose a shorter record length. (Press HORIZONTAL MENU → Record Length (main).) Reducing the sample rate (use the HORIZONTAL SCALE knob) with the source channel selected might also prevent clipping. You can also select AC coupling (on TDS models so equipped) in the vertical menu of the source waveform or otherwise DC filter it before applying it to the oscilloscope input.
Zoom

Once you have your waveform optimally displayed, you may magnify (or reduce) it vertically and horizontally to inspect any feature you desire. Just be sure the integrated waveform is the selected waveform. (Press MORE, then select the integrated waveform in the More main menu. Then use the Vertical and Horizontal SCALE knobs to adjust the math waveform size.)

If you wish to see the zoom factor (2X, 5X, etc.) you need to turn Zoom on: press ZOOM → On (side). The vertical and horizontal zoom factors appear on screen.

Whether Zoom is on or off, you can press Reset Zoom Factors (side) to return the zoomed integral waveform to no magnification.

For More Information

See Waveform Differentiation, on page 3-139.
See Fast Fourier Transforms, on page 3-36.
See Waveform Math, on page 3-148.
Waveform Math

You can mathematically manipulate your waveforms. For example, you might have a waveform clouded by background noise. You can obtain a cleaner waveform by subtracting the background noise from your original waveform.

This section describes the invert, add, subtract, divide, and multiply waveform math features. If your oscilloscope is equipped with Advanced DSP Math (optional on TDS 620A & TDS 640A), see Fast Fourier Transforms on page 3-36, Waveform Differentiation on page 3-139, and Waveform Integration on page 3-143.

Operation

To perform waveform math, press the MORE button to bring up the More menu (Figure 3-79). The More menu allows you to display, define, and manipulate three math functions.

![Figure 3-79: More Menu]

Math1, Math2, and Math3

1. Press MORE → Math1, Math2, or Math3 (main) to select the waveform that you want to display or change.
NOTE

If your digitizing oscilloscope is equipped with Advanced DSP Math (optional on TDS 620A & TDS 640A), the menu item FFT will be at the same brightness as the menu items Single Wfm Math and Dual Wfm Math; otherwise, FFT will be dimmed. See pages 3-36, 3-139, and 3-143 for information on FFTs and other advanced math waveforms.

2. Press Average (side) and enter a value with the general purpose knob or the keypad to take an average of multiple acquisitions. Press No Extended Processing (side) to perform math operations only on one acquisition.

3. If desired, turn on or turn off math averaging. To turn on math averaging, press Average (side) and turn the general purpose knob (or use the keypad) to enter the number of times to successively average the math waveform before completing an acquisition. Press No Extended Processing (side) to turn off math averaging.

4. Press Change Math waveform definition (side) → FFT (if your oscilloscope contains Advanced DSP Math), Single Wfm Math, or Dual Wfm Math (main) to alter the present math waveform definition (see Figure 3-80).

The single and dual waveform operations are described separately in the following topics. For descriptions of Advanced DSP Math, see Fast Fourier Transforms on page 3-36, Waveform Differentiation on page 3-139, and Waveform Integration on 3-143.

Single Wfm Math

1. Press MORE → Math1, Math2, or Math3 (main) → Change Math waveform definition (side) → Single Wfm Math (main). Press Set Function to (side) to select inv (invert), intg (if your oscilloscope contains Advanced DSP Math), or diff (if your oscilloscope contains Advanced DSP Math). Waveform integration (intg) is described on page 3-143, and waveform differentiation (diff) is described on page 3-139.

2. To define the source waveform, press Set Single Source to (side).

3. When you are ready to perform the function, press OK Create Math Wfm (side).
Waveform Math

Figure 3-80: Dual Waveform Math Main and Side Menus

Dual Wfm Math

1. Select the sources with MORE → Math1, Math2, or Math3 (main) → Change Math waveform definition (side) → Dual Wfm Math (main) → Set 1st Source to and Set 2nd Source to (side). Enter the sources by repeatedly pressing the appropriate channel selection button.

2. To enter the math operator, press Set operator to (side) to cycle through the choices. Supported operators are +, −, * and /.

3. Press OK Create Math Wfm (side) to perform the function.

NOTE

If you select *, for multiply, in step 2, the cursor feature will measure amplitude in the units volts squared VV rather than in volts V.

For More Information

If your oscilloscope is equipped with Advanced DSP Math, you can also create integrated, differentiated, and Fast Fourier Transform waveforms. See Fast Fourier Transforms on page 3-36, Waveform Integration on page 3-139, and Waveform Differentiation on page 3-143.
At times, you may want to expand or compress a waveform on the display without changing the acquisition parameters. You can do that with the zoom feature.

**Zoom and Interpolation**

When you zoom in on a waveform on the display, you expand a portion of the waveform. The digitizing oscilloscope may need to show more points for that portion than it has acquired. If it needs to do this, it interpolates. The instrument can interpolate in either of two ways: linear or sin(x)/x. (The interpolation methods are described on page 2-20.)

When you zoom, the display redraws the waveforms using the interpolation method you selected in the Display menu (linear interpolation or sin(x)/x). If you selected sin(x)/x (the default), it may introduce some overshoot or undershoot to the waveform edges. If that happens, change the interpolation method to linear, following the instructions on page 3-152.

To differentiate between the real and interpolated samples, set the display style to **Intensified Samples**.

**Operation**

When you turn on the zoom feature, the vertical and horizontal scale and vertical position knobs now control the displayed size and position of waveforms, allowing them to be expanded and repositioned on screen. They cease to affect waveform acquisition, but you can alter acquisition by using the corresponding menu items. Zoom mode does not change the way horizontal position operates.

To use zoom, do the following steps:

1. Press **ZOOM → ON** (side). The **ZOOM** front-panel button should light up.

2. Choose which waveforms to zoom by repeatedly pressing **Horizontal Lock** (side).

   - **None** — only the waveform currently selected can be magnified and positioned horizontally (Figure 3-81).

   - **Live** — all channels (including AUX channels for the TDS 620A) can be magnified and positioned horizontally at the same time. (Waveforms displayed from an input channel are live; math and reference waveforms are not live.)

   - **All** — all waveforms displayed (channels, math, and/or reference) can be magnified and positioned horizontally at the same time.
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 2.

![Zoom Mode with Horizontal Lock Set to None](image)

**Figure 3-81: Zoom Mode with Horizontal Lock Set to None**

**Setting Interpolation**

To change the interpolation method used:

Press **DISPLAY → Filter (main) → Sin(x)/x Interpolation** or **Linear Interpolation** (side).
Reset Zoom

To reset all zoom factors to their defaults (see Table 3-9), press ZOOM → Reset Zoom Factors (side).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoom Vertical Position</td>
<td>0</td>
</tr>
<tr>
<td>Zoom Vertical Gain</td>
<td>1X</td>
</tr>
<tr>
<td>Zoom Horizontal Position</td>
<td>Tracking Horizontal Position</td>
</tr>
<tr>
<td>Zoom Horizontal Gain</td>
<td>1X</td>
</tr>
</tbody>
</table>

Press ZOOM → Off (side) to return to normal oscilloscope (non-zoom) operation.

For Further Information

See Acquisition, on page 2-19.

See Display Modes, on page 3-26.
Appendix A: Options and Accessories

This section describes the options, the standard accessories, and the optional accessories that are available for the TDS 600A Digitizing Oscilloscopes.

Options

The following options are available:

Options A1–A5: International Power Cords

Besides the standard North American, 110 V, 60 Hz power cord, Tektronix ships any of five alternate power cord configurations with the oscilloscope when ordered by the customer.

<table>
<thead>
<tr>
<th>Option</th>
<th>Power Cord</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Universal European — 220 V, 50 Hz</td>
</tr>
<tr>
<td>A2</td>
<td>UK — 240 V, 50 Hz</td>
</tr>
<tr>
<td>A3</td>
<td>Australian — 240 V, 50 Hz</td>
</tr>
<tr>
<td>A4</td>
<td>North American — 240 V, 60 Hz</td>
</tr>
<tr>
<td>A5</td>
<td>Switzerland — 220 V, 50 Hz</td>
</tr>
</tbody>
</table>

Option 1K: K420 Scope Cart

With this option, Tektronix ships the K420 Scope Cart. The cart can help you transport the oscilloscope around many lab environments.

Service Assurance Options

The standard warranty appears following the title page in this manual. The following options add to the services available with the standard warranty:

- **Option R2**: When Option R2 is ordered, Tektronix provides two years of post-warranty repair protection.
- **Option C5**: When Option C5 is ordered, Tektronix provides five years of calibration services.
- **Option M2**: When Option M2 is ordered, Tektronix provides five years of warranty/remedial service.
Option 1F: File System (Standard on TDS 644A)

With this option, Tektronix ships the digitizing oscilloscope with a floppy disk drive and a variety of features for managing the floppy disk. With the file system you can save and recall setups, waveforms, and hardcopies on a floppy disk.

Option 1R: Rackmounted Digitizing Oscilloscope

Tektronix ships the digitizing oscilloscope, when ordered with Option 1R, configured for installation in a 19 inch wide instrument rack. Customers with instruments not configured for rackmounting can order a rackmount kit (016-1136-00 for field conversions).

Instructions for rackmounting the digitizing oscilloscope are shipped with the Option 1R.

Option 13: RS-232/Centronics Hardcopy Interface (Standard on TDS 644A)

With this option, Tektronix ships the oscilloscope equipped with a RS-232 and a Centronics interface that can be used to obtain hardcopies of the oscilloscope screen.

Option 2D: Delete Two Probes (TDS 620A only)

With this option, Tektronix ships the instrument without the two probes normally included as standard accessories.

Option 4D: Delete Four Probes (TDS 640A & 644A only)

With this option, Tektronix ships the instrument without the four probes normally included as standard accessories.

Option 05: Video Trigger

With this option, Tektronix ships the instrument with tools for investigating events that occur when a video signal generates a horizontal or vertical sync pulse. It allows you to investigate a range of NTSC, PAL, SECAM, and high-definition TV signals.

Option 2F: Advanced DSP Math (Standard on TDS 644A)

With this option, the oscilloscope can compute and display three advanced math waveforms: integral of a waveform, differential of a waveform, and an FFT (Fast Fourier Transform) of a waveform.
Option 23: Additional Probes — (TDS 620A only)

With this option, Tektronix ships two additional probes identical to the two standard-accessory P6205 probes normally shipped with the instrument. This provides one probe for each front-panel input.

Option 24: Add Four Passive Probes

With this option, Tektronix ships four passive 10X P6139A probes.

Option 95: Calibration Data Report

With this option, Tektronix ships a calibration data report with the instrument.

Option 96: Calibration Certificate

With this option, Tektronix ships a Certificate of Calibration. This certificate states the instrument meets or exceeds all warranted specifications and has been calibrated using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology, an accepted value of a natural physical constant, or a ratio-calibration technique. The calibration is in compliance with US MIL-STD-45662A. This option includes a test data report for the oscilloscope.

Standard Accessories

The following standard accessories are included with the digitizing oscilloscope:

<table>
<thead>
<tr>
<th>Accessory</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Manual</td>
<td>070-8715-XX</td>
</tr>
<tr>
<td>Programmer Manual</td>
<td>070-8709-XX</td>
</tr>
<tr>
<td>Reference</td>
<td>070-8711-XX</td>
</tr>
<tr>
<td>Performance Verification</td>
<td>070-8717-XX</td>
</tr>
<tr>
<td>Front Cover</td>
<td>200-3696-00</td>
</tr>
<tr>
<td>U.S. Power Cord</td>
<td>161-0230-01</td>
</tr>
<tr>
<td>Probes, TDS 640A, TDS 644A (quantity four),</td>
<td>P6139A</td>
</tr>
<tr>
<td>10X Passive; 500 MHz</td>
<td></td>
</tr>
<tr>
<td>TDS 620A (quantity two), 10X Active;</td>
<td>P6205 (single unit)</td>
</tr>
<tr>
<td>750 MHz</td>
<td></td>
</tr>
</tbody>
</table>
Optional Accessories

You can also order the following optional accessories:

<table>
<thead>
<tr>
<th>Accessory</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Manual</td>
<td>070-8718-XX</td>
</tr>
<tr>
<td>Plotter (GPIB and Centronics Standard)</td>
<td>HC100</td>
</tr>
<tr>
<td>Oscilloscope Cart</td>
<td>K218</td>
</tr>
<tr>
<td>Rack Mount Kit (for field conversion)</td>
<td>016-1136-00</td>
</tr>
<tr>
<td>Oscilloscope Camera</td>
<td>C9</td>
</tr>
<tr>
<td>Oscilloscope Camera Adapter</td>
<td>016-1154-00</td>
</tr>
<tr>
<td>Soft-Sided Carrying Case</td>
<td>016-0909-01</td>
</tr>
<tr>
<td>Transit Case</td>
<td>016-1135-00</td>
</tr>
<tr>
<td>GPIB Cable (1 meter)</td>
<td>012-0991-01</td>
</tr>
<tr>
<td>GPIB Cable (2 meter)</td>
<td>012-0991-00</td>
</tr>
</tbody>
</table>

Accessory Probes

The following optional accessory probes are recommended for use with your digitizing oscilloscope:

- P6101A 1X, 15 MHz, Passive probe.
- P6156 10X, 3.5 GHz, Passive, low capacitance, (low impedance $Z_0$) probe.
- P6205 10X, 750 MHz, Active probe
- P6009 Passive, high voltage probe, 100X, 1500 VDC + Peak AC.
- P6015A Passive high voltage probe, 1000X, 20 kVDC + Peak AC (40 kV peak for less than 100 ms).
- P6204 Active, high speed digital voltage probe. FET. DC to 1 GHz. DC offset. 50 Ω input. Use with 1103 TekProbe Power Supply for offset control.
- P6563AS Passive, SMD probe, 20X, 500 MHz
- P6046 Active, differential probe, 1X/10X, DC to 100 MHz, 50 Ω input.
- A6501 Buffer Amplifier (active fixtured), 1 GHz, 1 MΩ, 10X.
- P6501 Option 02: Microprobe with TekProbe power cable (active fixtured), 750 MHz, 1 MΩ, 10X.
- AM 503S — DC/AC Current probe system, AC/DC. Uses A6302 Current Probe.
Appendix A: Options and Accessories

- AM 503S Option 03: DC/AC Current probe system, AC/DC. Uses A6303 Current Probe.
- P6021 AC Current probe. 120 Hz to 60 MHz.
- P6022 AC Current probe. 935 kHz to 120 MHz.
- CT-1 Current probe — designed for permanent or semi permanent in-circuit installation. 25 kHz to 1 GHz, 50 Ω input.
- CT-2 Current probe — designed for permanent or semi permanent in-circuit installation. 1.2 kHz to 200 MHz, 50 Ω input.
- CT-4 Current Transformer — for use with the AM 503S (A6302) and P6021. Peak pulse 1 kA. 0.5 Hz to 20 MHz with AM 503S (A6302).
- P6701A Opto-Electronic Converter, 500 to 950 nm, DC to 850 MHz, 1 V/mW.
- P6703A Opto-Electronic Converter, 1100 to 1700 nm, DC to 1 GHz, 1 V/mW.
- P6711 Opto-Electronic Converter, 500 to 950 nm, DC to 250 MHz, 5 V/mW.
- P6713 Opto-Electronic Converter, 1100 to 1700 nm, DC to 300 MHz, 5 V/mW.
- TVC 501 Time-to-voltage converter. Time delay, pulse width and period measurements.

Accessory Software

The following optional accessories are Tektronix software products recommended for use with your digitizing oscilloscope:

<table>
<thead>
<tr>
<th>Software</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>EZ-Test Program Generator</td>
<td>S45F030</td>
</tr>
<tr>
<td>Wavewriter: AWG and waveform creation</td>
<td>S3FT400</td>
</tr>
<tr>
<td>TekTMS: Test management system</td>
<td>S3FT001</td>
</tr>
<tr>
<td>LabWindows</td>
<td>S3FG910</td>
</tr>
</tbody>
</table>

Warranty Information

Check for the full warranty statements for this product, the probes, and the products listed above on the first page after the title page of each product manual.
Appendix B: Algorithms

TDS 600A Digitizing Oscilloscopes can take 25 automatic measurements. By knowing how they make these calculations, you may better understand how to use your TDS 600A and how to interpret your results.

Measurement Variables

TDS 600A Digitizing Oscilloscopes use a variety of variables in their calculations. These include:

**High, Low**

*High* is the value used as the 100% level in measurements such as fall time and rise time. For example, if you request the 10% to 90% rise time, then the oscilloscope will calculate 10% and 90% as percentages with *High* representing 100%.

*Low* is the value used as the 0% level in measurements such as fall time and rise time.

The exact meaning of *High* and *Low* depends on which of two calculation methods you choose from the **High-Low Setup** item of the Measure menu. These are **Min-max** and **Histogram**.

**Min-Max Method** — defines the 0% and the 100% waveform levels as the lowest amplitude (most negative) and the highest amplitude (most positive) samples. The min-max method is useful for measuring frequency, width, and period for many types of signals. Min-max is sensitive to waveform ringing and spikes, however, and does not always measure accurately rise time, fall time, overshoot, and undershoot.

The min-max method calculates the High and Low values as follows:

\[
High = Max
\]

and

\[
Low = Min
\]

**Histogram Method** — attempts to find the highest density of points above and below the waveform midpoint. It attempts to ignore ringing and spikes when determining the 0% and 100% levels. This method works well when measuring square waves and pulse waveforms.

The oscilloscope calculates the histogram-based *High* and *Low* values as follows:

1. It makes a histogram of the record with one bin for each digitizing level (256 total).
2. It splits the histogram into two sections at the halfway point between \( \text{Min} \) and \( \text{Max} \) (also called \( \text{Mid} \)).

3. The level with the most points in the upper histogram is the \( \text{High} \) value, and the level with the most points in the lower histogram is the \( \text{Low} \) value. (Choose the levels where the histograms peak for \( \text{High} \) and \( \text{Low} \).)

   If \( \text{Mid} \) gives the largest peak value within the upper or lower histogram, then return the \( \text{Mid} \) value for both \( \text{High} \) and \( \text{Low} \) (this is probably a very low amplitude waveform).

   If more than one histogram level (bin) has the maximum value, choose the bin farthest from \( \text{Mid} \).

This algorithm does not work well for two-level waveforms with greater than about 100% overshoot.

**HighRef, MidRef, LowRef, Mid2Ref**

The user sets the various reference levels, through the Reference Level selection of the Measure menu. They include:

- **HighRef** — the waveform high reference level. Used in fall time and rise time calculations. Typically set to 90%. You can set it from 0% to 100% or to a voltage level.

- **MidRef** — the waveform middle reference level. Typically set to 50%. You can set it from 0% to 100% or to a voltage level.

- **LowRef** — the waveform low reference level. Used in fall and rise time calculations. Typically set to 10%. You can set it from 0% to 100% or to a voltage level.

- **Mid2Ref** — the middle reference level for a second waveform (or the second middle reference of the same waveform). Used in delay time calculations. Typically set to 50%. You can set it from 0% to 100% or to a voltage level.

**Other Variables**

The oscilloscope also measures several values itself that it uses to help calculate measurements.

- **RecordLength** — is the number of data points in the time base. You set it with the Horizontal menu **Record Length** item.

- **Start** — is the location of the start of the measurement zone (X-value). It is 0.0 samples unless you are making a gated measurement. When you use gated measurements, it is the location of the left vertical cursor.
End — is the location of the end of the measurement zone (X-value). It is 
(RecordLength − 1.0) samples unless you are making a gated measurement.
When you use gated measurements, it is the location of the right vertical cursor.

Hysteresis — The hysteresis band is 10% of the waveform amplitude. It is used in MCross1, MCross2, and MCross3 calculations.

For example, once a crossing has been measured in a negative direction, the waveform data must fall below 10% of the amplitude from the MidRef point before the measurement system is armed and ready for a positive crossing. Similarly, after a positive MidRef crossing, waveform data must go above 10% of the amplitude before a negative crossing can be measured. Hysteresis is useful when you are measuring noisy signals, because it allows the digitizing oscilloscope to ignore minor fluctuations in the signal.

**MCross Calculations**

**MCross1, MCross2, and MCross3** — refer to the first, second, and third MidRef cross times, respectively. See Figure A-1.

The polarity of the crossings does not matter for these variables, but the crossings alternate in polarity; that is, MCross1 could be a positive or negative crossing, but if MCross1 is a positive crossing, MCross2 will be a negative crossing.

The oscilloscope calculates these values as follows:

1. Find the first MidRefCrossing in the waveform record or the gated region. This is MCross1.
2. Continuing from MCross1, find the next MidRefCrossing in the waveform record (or the gated region) of the opposite polarity of MCross1. This is MCross2.
3. Continuing from MCross2, find the next MidRefCrossing in the waveform record (or the gated region) of the same polarity as MCross1. This is MCross3.

**MCross1Polarity** — is the polarity of first crossing (no default). It can be rising or falling.

**StartCycle** — is the starting time for cycle measurements. It is a floating-point number with values between 0.0 and (RecordLength − 1.0), inclusive.

\[ StartCycle = MCross1 \]

**EndCycle** — is the ending time for cycle measurements. It is a floating-point number with values between 0.0 and (RecordLength − 1.0), inclusive.

\[ EndCycle = MCross3 \]
Waveform[<0.0 ... RecordLength–1.0>] — holds the acquired data.

TPOS — is the location of the sample just before the trigger point (the time reference zero sample). In other terms, it contains the domain reference location. This location is where time = 0.

TSOFF — is the offset between TPOS and the actual trigger point. In other words, it is the trigger sample offset. Values range between 0.0 and 1.0 samples. This value is determined by the instrument when it receives a trigger. The actual zero reference (trigger) location in the measurement record is at (TPOS + TSOFF).

Measurement Algorithms

The automated measurements are defined and calculated as follows.

Amplitude

\[
\text{Amplitude} = \text{High} - \text{Low}
\]

Area

The arithmetic area for one waveform. Remember that one waveform is not necessarily equal to one cycle. For cyclical data you may prefer to use the cycle area rather than the arithmetic area.

If Start = End then return the (interpolated) value at Start.

Otherwise,

\[
\text{Area} = \int_{\text{Start}}^{\text{End}} \text{Waveform}(t) dt
\]
For details of the integration algorithm, see page A-17.

**Cycle Area**

Amplitude (voltage) measurement. The area over one waveform cycle. For non-cyclical data, you might prefer to use the Area measurement.

If StartCycle = EndCycle then return the (interpolated) value at StartCycle.

$$\text{CycleMean} = \int_{\text{StartCycle}}^{\text{EndCycle}} \text{Waveform}(t) dt$$

For details of the integration algorithm, see page A-17.

**Burst Width**

Timing measurement. The duration of a burst.

1. Find MCross1 on the waveform. This is MCrossStart.

2. Find the last MCross (begin the search at EndCycle and search toward StartCycle). This is MCrossStop. This could be a different value from MCross1.

3. Compute BurstWidth = MCrossStop - MCrossStart

**Cycle Mean**

Amplitude (voltage) measurement. The mean over one waveform cycle. For non-cyclical data, you might prefer to use the Mean measurement.

If StartCycle = EndCycle then return the (interpolated) value at StartCycle.

$$\text{CycleMean} = \frac{\int_{\text{StartCycle}}^{\text{EndCycle}} \text{Waveform}(t) dt}{(\text{EndCycle} - \text{StartCycle}) \times \text{SampleInterval}}$$

For details of the integration algorithm, see page A-17.

**Cycle RMS**

The true Root Mean Square voltage over one cycle.

If StartCycle = EndCycle then CycleRMS = Waveform[Start].

Otherwise,

$$\text{CycleRMS} = \sqrt{\frac{\int_{\text{StartCycle}}^{\text{EndCycle}} (\text{Waveform}(t))^2 dt}{(\text{EndCycle} - \text{StartCycle}) \times \text{SampleInterval}}}$$
For details of the integration algorithm, see page A-17.

Delay

Timing measurement. The amount of time between the MidRef and Mid2Ref crossings of two different traces, or two different places on the same trace.

Delay measurements are actually a group of measurements. To get a specific delay measurement, you must specify the target and reference crossing polarities and the reference search direction.

\[ \text{Delay} = \text{the time from one MidRef crossing on the source waveform to the Mid2Ref crossing on the second waveform.} \]

Delay is not available in the Snapshot display.

Fall Time

Timing measurement. The time taken for the falling edge of a pulse to drop from a HighRef value (default = 90%) to a LowRef value (default = 10%).

Figure A-2 shows a falling edge with the two crossings necessary to calculate a Fall measurement.

1. Searching from Start to End, find the first sample in the measurement zone greater than HighRef.

2. From this sample, continue the search to find the first (negative) crossing of HighRef. The time of this crossing is THF. (Use linear interpolation if necessary.)

3. From THF, continue the search, looking for a crossing of LowRef. Update THF if subsequent HighRef crossings are found. When a LowRef crossing is found, it becomes TLF. (Use linear interpolation if necessary.)

4. FallTime = TLF – THF
**Appendix B: Algorithms**

**Figure A-2: Fall Time**

**Frequency**

Timing measurement. The reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.

If Period = 0 or is otherwise bad, return an error.

\[
Frequency = \frac{1}{Period}
\]

**High**

100% (highest) voltage reference value. (See “High, Low” earlier in this section)

Using the min-max measurement technique:

\[
High = Max
\]

**Low**

0% (lowest) voltage reference value calculated. (See “High, Low” earlier in this section)

Using the min-max measurement technique:

\[
Low = Min
\]
Appendix B: Algorithms

**Maximum**

Amplitude (voltage) measurement. The maximum voltage. Typically the most positive peak voltage.

Examine all $Waveform[j]$ samples from Start to End inclusive, and set $Max$ equal to the greatest magnitude $Waveform[j]$ value found.

**Mean**

The arithmetic mean for one waveform. Remember that one waveform is not necessarily equal to one cycle. For cyclical data you may prefer to use the cycle mean rather than the arithmetic mean.

If $Start = End$ then return the (interpolated) value at $Start$.

Otherwise,

$$Mean = \frac{\int_{Start}^{End} Waveform(t)dt}{(End - Start) \times SampleInterval}$$

For details of the integration algorithm, see page A-17.

**Minimum**

Amplitude (voltage) measurement. The minimum amplitude. Typically the most negative peak voltage.

Examine all $Waveform[j]$ samples from Start to End inclusive, and set $Min$ equal to the smallest magnitude $Waveform[j]$ value found.

**Negative Duty Cycle**

Timing measurement. The ratio of the negative pulse width to the signal period expressed as a percentage.

$NegativeWidth$ is defined in **Negative Width**, below.

If $Period = 0$ or undefined then return an error.

$$NegativeDutyCycle = \frac{NegativeWidth}{Period} \times 100\%$$

**Negative Overshoot**

Amplitude (voltage) measurement.

$$NegativeOvershoot = \frac{Low - Min}{Amplitude} \times 100\%$$

Note that this value should never be negative (unless High or Low are set out-of-range).
Negative Width

Timing measurement. The distance (time) between *MidRef* (default = 50%) amplitude points of a negative pulse.

\[ \text{if } \text{MCross1Polarity} = '-' \]
then
\[ \text{NegativeWidth} = (\text{MCross2 - MCross1}) \]
else
\[ \text{NegativeWidth} = (\text{MCross3 - MCross2}) \]

Peak to Peak

Amplitude measurement. The absolute difference between the maximum and minimum amplitude.

\[ \text{PeaktoPeak} = \text{Max} - \text{Min} \]

Period

Timing measurement. Time taken for one complete signal cycle. The reciprocal of frequency. Measured in seconds.

\[ \text{Period} = \text{MCross3} - \text{MCross1} \]

Phase

Timing measurement. The amount of phase shift, expressed in degrees of the target waveform cycle, between the *MidRef* crossings of two different waveforms. Waveforms measured should be of the same frequency or one waveform should be a harmonic of the other.

Phase is a dual waveform measurement; that is, it is measured from a target waveform to a reference waveform. To get a specific phase measurement, you must specify the target and reference sources.

Phase is determined in the following manner:

1. The first *MidRef Crossing (MCross1Target)* and third (*MCross3*) in the source (target) waveform are found.
2. The period of the target waveform is calculated (see “Period” above).
3. The first *MidRef Crossing (MCross1Ref)* in the reference waveform crossing in the same direction (polarity) as that found *MCross1Target* for the target waveform is found.
4. The phase is determined by the following:

\[ \text{Phase} = \frac{\text{MCross1Ref} - \text{MCross1Target}}{\text{Period}} \times 360 \]
If the target waveform leads the reference waveform, phase is positive; if it lags, negative.

Phase is not available in the Snapshot display.

**Positive Duty Cycle**

Timing measurement. The ratio of the positive pulse width to the signal period, expressed as a percentage.

\[ \text{PositiveDutyCycle} = \frac{\text{PositiveWidth}}{\text{Period}} \times 100\% \]

**Positive Overshoot**

Amplitude (voltage) measurement.

\[ \text{PositiveOvershoot} = \frac{\text{Max} - \text{High}}{\text{Amplitude}} \times 100\% \]

Note that this value should never be negative.

**Positive Width**

Timing measurement. The distance (time) between MidRef (default = 50%) amplitude points of a positive pulse.

If \( \text{MCross1Polarity} \) = ‘+’,

then

\[ \text{PositiveWidth} = (\text{MCross2} - \text{MCross1}) \]

else

\[ \text{PositiveWidth} = (\text{MCross3} - \text{MCross2}) \]

**Rise Time**

Timing measurement. Time taken for the leading edge of a pulse to rise from a LowRef value (default = 10%) to a HighRef value (default = 90%).

Figure A-3 shows a rising edge with the two crossings necessary to calculate a Rise Time measurement.

1. Searching from \( \text{Start to End} \), find the first sample in the measurement zone less than LowRef.

2. From this sample, continue the search to find the first (positive) crossing of LowRef. The time of this crossing is the low rise time or TLR. (Use linear interpolation if necessary.)
3. From TLR, continue the search, looking for a crossing of HighRef. Update TLR if subsequent LowRef crossings are found. If a HighRef crossing is found, it becomes the high rise time or THR. (Use linear interpolation if necessary.)

4. RiseTime = THR − TLR

![Figure A-3: Rise Time](image)

**RMS:**

Amplitude (voltage) measurement. The true Root Mean Square voltage.

If Start = End then RMS = the (interpolated) value at Waveform[Start].

Otherwise,

\[
RMS = \sqrt{\frac{\int_{Start}^{End} (Waveform(t))^2 dt}{(End - Start) \times SampleInterval}}
\]

For details of the integration algorithm, see below.

**Integration Algorithm**

The integration algorithm used by the digitizing oscilloscope is as follows:

\[
\int_{A}^{B} W(t)dt \text{ is approximated by } \int_{A}^{B} \hat{W}(t)dt \text{ where:}
\]
Appendix B: Algorithms

\[ W(t) \] is the sampled waveform
\[ \hat{W}(t) \] is the continuous function obtained by linear interpolation of \( W(t) \)

\( A \) and \( B \) are numbers between 0.0 and \( \text{RecordLength} - 1.0 \)

If \( A \) and \( B \) are integers, then:

\[
\int_{A}^{B} \hat{W}(t) dt = s \times \sum_{j=A}^{B} \frac{W(j) + W(j + 1)}{2}
\]

where \( s \) is the sample interval.

Similarly,

\[
\int_{A}^{B} (W(t))^2 dt \text{ is approximated by } \int_{A}^{B} \left( \hat{W}(t) \right)^2 dt \text{ where:}
\]

\( W(t) \) is the sampled waveform
\( \hat{W}(t) \) is the continuous function obtained by linear interpolation of \( W(t) \)

\( A \) and \( B \) are numbers between 0.0 and \( \text{RecordLength} - 1.0 \)

If \( A \) and \( B \) are integers, then:

\[
\int_{A}^{B} \left( \hat{W}(t) \right)^2 dt = s \times \sum_{j=A}^{B} \frac{(W(j))^2 + W(j) \times W(j + 1) + (W(j + 1))^2}{3}
\]

where \( s \) is the sample interval.

---

**Measurements on Envelope Waveforms**

Time measurements on envelope waveforms must be treated differently from time measurements on other waveforms, because envelope waveforms contain so many apparent crossings. Unless otherwise noted, envelope waveforms use either the minima or the maxima (but not both), determined in the following manner:

1. Step through the waveform from Start to End until the sample min and max pair DO NOT straddle MidRef.
2. If the pair > MidRef, use the minima, else use maxima.

   If all pairs straddle MidRef, use maxima. See Figure A-4.

The Burst Width measurement always uses both maxima and minima to determine crossings.
Missing or Out-of-Range Samples

If some samples in the waveform are missing or off-scale, the measurements will linearly interpolate between known samples to make an “appropriate” guess as to the sample value. Missing samples at the ends of the measurement record will be assumed to have the value of the nearest known sample.

When samples are out of range, the measurement will give a warning to that effect (for example, “CLIPPING”) if the measurement could change by extending the measurement range slightly. The algorithms assume the samples recover from an overdrive condition instantaneously.

![Diagram of waveform with annotations for choosing minima or maxima to use for envelope measurements.]

Figure A-4: Choosing Minima or Maxima to Use for Envelope Measurements
Appendix B: Algorithms

For example, if \textit{MidRef} is set directly, then \textit{MidRef} would not change even if samples were out of range. However, if \textit{MidRef} was chosen using the \% choice from the \textbf{Set Levels in \% Units} selection of the Measure menu, then \textit{MidRef} could give a "CLIPPING" warning.

\textbf{NOTE}

\textit{When measurements are displayed using Snapshot, out of range warnings are NOT available. However, if you question the validity of any measurement in the snapshot display, you can select and display the measurement individually and then check for a warning message.}
Appendix C: Packaging for Shipment

If you ship the digitizing oscilloscope, pack it in the original shipping carton and packing material. If the original packing material is not available, package the instrument as follows:

1. Obtain a corrugated cardboard shipping carton with inside dimensions at least 15 cm (6 in) taller, wider, and deeper than the digitizing oscilloscope. The shipping carton must be constructed of cardboard with 170 kg (375 pound) test strength.

2. If you are shipping the digitizing oscilloscope to a Tektronix field office for repair, attach a tag to the digitizing oscilloscope showing the instrument owner and address, the name of the person to contact about the instrument, the instrument type, and the serial number.

3. Wrap the digitizing oscilloscope with polyethylene sheeting or equivalent material to protect the finish.

4. Cushion the digitizing oscilloscope in the shipping carton by tightly packing dunnage or urethane foam on all sides between the carton and the digitizing oscilloscope. Allow 7.5 cm (3 in) on all sides, top, and bottom.

5. Seal the shipping carton with shipping tape or an industrial stapler.

NOTE

Do not ship the digitizing oscilloscope with a disk inside the disk drive (optional on TDS 620A & TDS 640A). When the disk is inside the drive, the disk release button sticks out. This makes the button more prone to damage than otherwise.
Appendix C: Packaging for Shipment
Appendix D: Factory Initialization Settings

The factory initialization settings provide you a known state for the digitizing oscilloscope.

---

**Settings**

Factory initialization sets values as shown in Table A-5.

**Table A-5: Factory Initialization Defaults**

<table>
<thead>
<tr>
<th>Control</th>
<th>Changed by Factory Init to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquire mode</td>
<td>Sample</td>
</tr>
<tr>
<td>Acquire stop after</td>
<td>RUN/STOP button only</td>
</tr>
<tr>
<td>Acquire # of averages</td>
<td>16</td>
</tr>
<tr>
<td>Acquire # of envelopes</td>
<td>10</td>
</tr>
<tr>
<td>Channel selection</td>
<td>Channel 1 on, all others off</td>
</tr>
<tr>
<td>Cursor H Bar 1 position</td>
<td>10% of graticule height (~3.2 divs from the center)</td>
</tr>
<tr>
<td>Cursor H Bar 2 position</td>
<td>90% of the graticule height (+3.2 divs from the center)</td>
</tr>
<tr>
<td>Cursor V Bar 1 position</td>
<td>10% of the record length</td>
</tr>
<tr>
<td>Cursor V Bar 2 position</td>
<td>90% of the record length</td>
</tr>
<tr>
<td>Cursor amplitude units</td>
<td>Base</td>
</tr>
<tr>
<td>Cursor mode</td>
<td>Independent</td>
</tr>
<tr>
<td>Cursor function</td>
<td>Off</td>
</tr>
<tr>
<td>Cursor time units</td>
<td>Seconds</td>
</tr>
<tr>
<td>Date and time</td>
<td>No change</td>
</tr>
<tr>
<td>Delayed edge trigger coupling</td>
<td>DC</td>
</tr>
<tr>
<td>Delayed edge trigger level</td>
<td>0 V</td>
</tr>
<tr>
<td>Delayed edge trigger slope</td>
<td>Rising</td>
</tr>
<tr>
<td>Delayed edge trigger source</td>
<td>Channel 1</td>
</tr>
<tr>
<td>Delay trigger average #</td>
<td>16</td>
</tr>
<tr>
<td>Control</td>
<td>Changed by Factory Init to</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>Delay trigger envelope #</td>
<td>10</td>
</tr>
<tr>
<td>Delay time</td>
<td>16 ns</td>
</tr>
<tr>
<td>Delay events, triggerable after main</td>
<td>2</td>
</tr>
<tr>
<td>Delayed, delay by ...</td>
<td>Delay by Time</td>
</tr>
<tr>
<td>Delayed, time base mode</td>
<td>Delayed Runs After Main</td>
</tr>
<tr>
<td>Display clock</td>
<td>No Change</td>
</tr>
<tr>
<td>Display color – collision contrast (TDS 644A)</td>
<td>Off</td>
</tr>
<tr>
<td>Display color – map math colors (TDS 644A)</td>
<td>Color ‘Math’</td>
</tr>
<tr>
<td>Display color – map reference colors (TDS 644A)</td>
<td>Color ‘Ref’</td>
</tr>
<tr>
<td>Display color – palette (TDS 644A)</td>
<td>Normal</td>
</tr>
<tr>
<td>Display color – palette colors (TDS 644A)</td>
<td>The colors of each palette are re-set to factory hue, saturation, and lightness (HLS) values</td>
</tr>
<tr>
<td>Display color – persistence palette (TDS 644A)</td>
<td>Temperature</td>
</tr>
<tr>
<td>Display format</td>
<td>YT</td>
</tr>
<tr>
<td>Display graticule type</td>
<td>Full</td>
</tr>
<tr>
<td>Display intensity – contrast (TDS 620A &amp; TDS 640A)</td>
<td>175%</td>
</tr>
<tr>
<td>Display intensity – text</td>
<td>TDS 620A &amp; TDS 640A: 60%</td>
</tr>
<tr>
<td></td>
<td>TDS 644A: 100%</td>
</tr>
<tr>
<td>Display intensity – waveform</td>
<td>TDS 620A &amp; TDS 640A: 80%</td>
</tr>
<tr>
<td></td>
<td>TDS 644A: 100%</td>
</tr>
<tr>
<td>Display intensity – overall (TDS 620A &amp; TDS 640A)</td>
<td>85%</td>
</tr>
<tr>
<td>Display interpolation filter</td>
<td>Sin(x)/x</td>
</tr>
<tr>
<td>Display style</td>
<td>Vectors</td>
</tr>
<tr>
<td>Display trigger bar style</td>
<td>Short</td>
</tr>
<tr>
<td>Display trigger “T”</td>
<td>On</td>
</tr>
<tr>
<td>Display variable persistence</td>
<td>500 ms</td>
</tr>
</tbody>
</table>
### Table A-5: Factory Initialization Defaults (Cont.)

<table>
<thead>
<tr>
<th>Control</th>
<th>Changed by Factory Init to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge trigger coupling</td>
<td>DC</td>
</tr>
<tr>
<td>Edge trigger level</td>
<td>0.0 V</td>
</tr>
<tr>
<td>Edge trigger slope</td>
<td>Rising</td>
</tr>
<tr>
<td>Edge trigger source</td>
<td>Channel 1</td>
</tr>
<tr>
<td>GPIB parameters</td>
<td>No change</td>
</tr>
<tr>
<td>Hardcopy</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Layout</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Palette</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Port</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Horizontal – delay trigger position</td>
<td>50%</td>
</tr>
<tr>
<td>Horizontal – delay time/division</td>
<td>50 µs</td>
</tr>
<tr>
<td>Horizontal – fit to screen</td>
<td>Off</td>
</tr>
<tr>
<td>Horizontal – main trigger position</td>
<td>50%</td>
</tr>
<tr>
<td>Horizontal – position</td>
<td>50%</td>
</tr>
<tr>
<td>Horizontal – record length</td>
<td>500 points (10 divs)</td>
</tr>
<tr>
<td>Horizontal – main time/division</td>
<td>500 µs</td>
</tr>
<tr>
<td>Horizontal – time base</td>
<td>Main only</td>
</tr>
<tr>
<td>Limit template ±V Limit</td>
<td>40 mdiv</td>
</tr>
<tr>
<td>Limit template ±H Limit</td>
<td>40 mdiv</td>
</tr>
<tr>
<td>Limit template destination</td>
<td>Ref1</td>
</tr>
<tr>
<td>Limit template source</td>
<td>Ch1</td>
</tr>
<tr>
<td>Limit test sources</td>
<td>Ch1 compared to Ref1; all others compared to none.</td>
</tr>
<tr>
<td>Limit Testing</td>
<td>Off</td>
</tr>
<tr>
<td>Limit Testing – hardcopy if condition met</td>
<td>Off</td>
</tr>
<tr>
<td>Limit Testing – ring bell if condition met</td>
<td>Off</td>
</tr>
<tr>
<td>Logic pattern trigger Ch4 (Ax2) input</td>
<td>X (don’t care)</td>
</tr>
<tr>
<td>Logic state trigger Ch4 (Ax2) input</td>
<td>Rising edge</td>
</tr>
<tr>
<td>Logic trigger input (pattern and state)</td>
<td>Channel 1 = H (high), Channels 2 &amp; 3 (Ax1) = X (don’t care)</td>
</tr>
</tbody>
</table>
### Table A-5: Factory Initialization Defaults (Cont.)

<table>
<thead>
<tr>
<th>Control</th>
<th>Changed by Factory Init to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic trigger pattern time qualification</td>
<td></td>
</tr>
<tr>
<td>Lower limit</td>
<td>5 ns</td>
</tr>
<tr>
<td>Upper limit</td>
<td>5 ns</td>
</tr>
<tr>
<td>Logic trigger threshold (all channels)</td>
<td>1.2 V</td>
</tr>
<tr>
<td>(pattern and state)</td>
<td></td>
</tr>
<tr>
<td>Logic trigger class</td>
<td>Pattern</td>
</tr>
<tr>
<td>Logic trigger logic (pattern and state)</td>
<td>AND</td>
</tr>
<tr>
<td>Logic trigger triggers when ... (pattern and state)</td>
<td>Goes TRUE</td>
</tr>
<tr>
<td>Main trigger holdoff</td>
<td>0%</td>
</tr>
<tr>
<td>Main trigger mode</td>
<td>Auto</td>
</tr>
<tr>
<td>Main trigger type</td>
<td>Edge</td>
</tr>
<tr>
<td>Math1 definition</td>
<td>Ch 1 + Ch 2</td>
</tr>
<tr>
<td>Math1 extended processing</td>
<td>No extended processing</td>
</tr>
<tr>
<td>Math2 definition</td>
<td>Ch 1 – Ch 2 (FFT of Ch 1 on instruments with Option 2F Advanced DSP Math)</td>
</tr>
<tr>
<td>Math2 extended processing</td>
<td>No extended processing</td>
</tr>
<tr>
<td>Math3 definition</td>
<td>Inv of Ch 1</td>
</tr>
<tr>
<td>Math3 extended processing</td>
<td>No extended processing</td>
</tr>
<tr>
<td>Measure Delay to</td>
<td>Channel 1 (Ch1)</td>
</tr>
<tr>
<td>Measure Delay edges</td>
<td>Both rising and forward searching</td>
</tr>
<tr>
<td>Measure High-Low Setup</td>
<td>Histogram</td>
</tr>
<tr>
<td>Measure High Ref</td>
<td>90% and 0 V (units)</td>
</tr>
<tr>
<td>Measure Low Ref</td>
<td>10% and 0 V (units)</td>
</tr>
<tr>
<td>Measure Mid Ref</td>
<td>50% and 0 V (units)</td>
</tr>
<tr>
<td>Measure Mid2 Ref</td>
<td>50% and 0 V (units)</td>
</tr>
<tr>
<td>Pulse glitch trigger polarity</td>
<td>Positive</td>
</tr>
<tr>
<td>Pulse runt high threshold</td>
<td>1.2 V</td>
</tr>
<tr>
<td>Pulse runt low threshold</td>
<td>0.8 V</td>
</tr>
<tr>
<td>Pulse runt trigger polarity</td>
<td>Positive</td>
</tr>
</tbody>
</table>
### Table A-5: Factory Initialization Defaults (Cont.)

<table>
<thead>
<tr>
<th>Control</th>
<th>Changed by Factory Init to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse trigger class</td>
<td>Glitch</td>
</tr>
<tr>
<td>Pulse glitch filter state</td>
<td>On (Accept glitch)</td>
</tr>
<tr>
<td>Pulse glitch width</td>
<td>2.0 ns</td>
</tr>
<tr>
<td>Pulse trigger level</td>
<td>0.0 V</td>
</tr>
<tr>
<td>Pulse trigger source (Glitch, runt, and width)</td>
<td>Channel 1 (Ch1)</td>
</tr>
<tr>
<td>Pulse width trigger when ...</td>
<td>Within limits</td>
</tr>
<tr>
<td>Pulse width upper limit</td>
<td>2.0 ns</td>
</tr>
<tr>
<td>Pulse width lower limit</td>
<td>2.0 ns</td>
</tr>
<tr>
<td>Pulse width trigger polarity</td>
<td>Positive</td>
</tr>
<tr>
<td>Repetitive signal</td>
<td>On</td>
</tr>
<tr>
<td>RS-232 parameters</td>
<td>No change</td>
</tr>
<tr>
<td>Saved setups</td>
<td>No change</td>
</tr>
<tr>
<td>Saved waveforms</td>
<td>No change</td>
</tr>
<tr>
<td>Stop after</td>
<td>R/S button</td>
</tr>
<tr>
<td>Vertical bandwidth (all channels)</td>
<td>Full</td>
</tr>
<tr>
<td>Vertical coupling (all channels)</td>
<td>DC</td>
</tr>
<tr>
<td>Vertical impedance (termination) (all channels)</td>
<td>1 $\text{M} \Omega$</td>
</tr>
<tr>
<td>Vertical offset (all channels)</td>
<td>0 V</td>
</tr>
<tr>
<td>Vertical position (all channels)</td>
<td>0 divs.</td>
</tr>
<tr>
<td>Vertical volts/division (all channels)</td>
<td>100 mV/division</td>
</tr>
<tr>
<td>Zoom horizontal (all channels)</td>
<td>1.0X</td>
</tr>
<tr>
<td>Zoom horizontal lock</td>
<td>All</td>
</tr>
<tr>
<td>Zoom horizontal position (all channels)</td>
<td>50% = 0.5 (the middle of the display)</td>
</tr>
<tr>
<td>Zoom state</td>
<td>Off</td>
</tr>
<tr>
<td>Zoom vertical (all channels)</td>
<td>1.0X</td>
</tr>
<tr>
<td>Zoom vertical position (all channels)</td>
<td>0 divisions</td>
</tr>
</tbody>
</table>
Appendix D: Factory Initialization Settings
AC coupling
A type of signal transmission that blocks the DC component of a signal but uses the dynamic (AC) component. Useful for observing an AC signal that is normally riding on a DC signal.

Accuracy
The closeness of the indicated value to the true value.

Acquisition
The process of sampling signals from input channels, digitizing the samples into data points, and assembling the data points into a waveform record. The waveform record is stored in memory. The trigger marks time zero in that process.

Acquisition interval
The time duration of the waveform record divided by the record length. The digitizing oscilloscope displays one data point for every acquisition interval.

Active cursor
The cursor that moves when you turn the general purpose knob. It is represented in the display by a solid line. The @ readout on the display shows the absolute value of the active cursor.

Aliasing
A false representation of a signal due to insufficient sampling of high frequencies or fast transitions. A condition that occurs when a digitizing oscilloscope digitizes at an effective sampling rate that is too slow to reproduce the input signal. The waveform displayed on the oscilloscope may have a lower frequency than the actual input signal.

Amplitude
The High waveform value less the Low waveform value.

AND
A logic (Boolean) function in which the output is true when and only when all the inputs are true. On the digitizing oscilloscope, that is a trigger logic pattern and state function.

Area
Measurement of the waveform area taken over the entire waveform or the gated region. Expressed in volt-seconds. Area above ground is positive; area below ground is negative.
Attenuation
The degree the amplitude of a signal is reduced when it passes through an attenuating device such as a probe or attenuator. That is, the ratio of the input measure to the output measure. For example, a 10X probe will attenuate, or reduce, the input voltage of a signal by a factor of 10.

Automatic trigger mode
A trigger mode that causes the oscilloscope to automatically acquire if triggerable events are not detected within a specified time period.

Autoset
A function of the oscilloscope that automatically produces a stable waveform of usable size. Autoset sets up front-panel controls based on the characteristics of the active waveform. A successful autoset will set the volts/div, time/div, and trigger level to produce a coherent and stable waveform display.

Average acquisition mode
In this mode the oscilloscope acquires and displays a waveform that is the averaged result of several acquisitions. Averaging reduces the apparent noise. The oscilloscope acquires data as in the sample mode and then averages it according to a specified number of averages.

Bandwidth
The highest frequency signal the oscilloscope can acquire with no more than 3 dB (× .707) attenuation of the original (reference) signal.

Burst width
A timing measurement of the duration of a burst.

Channel
One type of input used for signal acquisition. The TDS 644A & TDS 640A have four channels; the TDS 620A has two.

Channel Reference Indicator
The indicator on the left side of the display that points to the position around which the waveform contracts or expands when vertical scale is changed. This position is ground when offset is set to 0 V; otherwise, it is ground plus offset.

Coupling
The association of two or more circuits or systems in such a way that power or information can be transferred from one to the other. You can couple the input signal to the trigger and vertical systems several different ways.

 Cursors
Paired markers that you can use to make measurements between two waveform locations. The oscilloscope displays the values (expressed in volts or time) of the position of the active cursor and the distance between the two cursors.
**Cycle area**
A measurement of waveform area taken over one cycle. Expressed in volt-seconds. Area above ground is positive; area below ground is negative.

**Cycle mean**
An amplitude (voltage) measurement of the arithmetic mean over one cycle.

**Cycle RMS**
The true Root Mean Square voltage over one cycle.

**DC coupling**
A mode that passes both AC and DC signal components to the circuit. Available for both the trigger system and the vertical system.

**Delay measurement**
A measurement of the time between the middle reference crossings of two different waveforms.

**Delay time**
The time between the trigger event and the acquisition of data.

**Digitizing**
The process of converting a continuous analog signal such as a waveform to a set of discrete numbers representing the amplitude of the signal at specific points in time. Digitizing is composed of two steps: sampling and quantizing.

**Display system**
The part of the oscilloscope that shows waveforms, measurements, menu items, status, and other parameters.

**Edge Trigger**
Triggering occurs when the oscilloscope detects the source passing through a specified voltage level in a specified direction (the trigger slope).

**Envelope acquisition mode**
A mode in which the oscilloscope acquires and displays a waveform that shows the variation extremes of several acquisitions.

**Fall time**
A measurement of the time it takes for trailing edge of a pulse to fall from a HighRef value (typically 90%) to a LowRef value (typically 10%) of its amplitude.

**Frequency**
A timing measurement that is the reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.

**Gated Measurements**
A feature that lets you limit automated measurements to a specified portion of the waveform. You define the area of interest using the vertical cursors.
General purpose knob
The large front-panel knob with an indentation. You can use it to change the value of the assigned parameter.

Glitch positive trigger
Triggering occurs if the oscilloscope detects positive spike widths less than the specified glitch time.

Glitch negative trigger
Triggering occurs if the oscilloscope detects negative spike widths less than the specified glitch time.

Glitch either trigger
Triggering occurs if the oscilloscope detects either positive or negative spike widths less than the specified glitch time.

GPIB (General Purpose Interface Bus)
An interconnection bus and protocol that allows you to connect multiple instruments in a network under the control of a controller. Also known as IEEE 488 bus. It transfers data with eight parallel data lines, five control lines, and three handshake lines.

Graticule
A grid on the display screen that creates the horizontal and vertical axes. You can use it to visually measure waveform parameters.

Ground (GND) coupling
Coupling option that disconnects the input signal from the vertical system.

Hardcopy
An electronic copy of the display in a format useable by a printer or plotter.

High
The value used as 100% in automated measurements (whenever high ref, mid ref, and low ref values are needed as in fall time and rise time measurements). May be calculated using either the min/max or the histogram method. With the min/max method (most useful for general waveforms), it is the maximum value found. With the histogram method (most useful for pulses), it refers to the most common value found above the mid point. See Appendix B: Algorithms for details.

Holdoff, trigger
A specified amount of time after a trigger signal that elapses before the trigger circuit will accept another trigger signal. Trigger holdoff helps ensure a stable display.

Horizontal bar cursors
The two horizontal bars that you position to measure the voltage parameters of a waveform. The oscilloscope displays the value of the active (moveable) cursor with respect to ground and the voltage value between the bars.
Interpolation
The way the digitizing oscilloscope calculates values for record points when the oscilloscope cannot acquire all the points for a complete record with a single trigger event. That condition occurs when the oscilloscope is limited to real time sampling and the time base is set to a value that exceeds the effective sample rate of the oscilloscope. The digitizing oscilloscope has two interpolation options: linear or \( \sin(x)/x \) interpolation.

Linear interpolation calculates record points in a straight-line fit between the actual values acquired. \( \sin(x)/x \) computes record points in a curve fit between the actual values acquired. It assumes all the interpolated points fall in their appropriate point in time on that curve.

Intensity
Display brightness.

Knob
A rotary control.

Logic state trigger
The oscilloscope checks for defined combinatorial logic conditions on channels 1, 2, and 3 on a transition of channel 4 that meets the set slope and threshold conditions. If the conditions of channels 1, 2, and 3 are met then the oscilloscope triggers.

Logic pattern trigger
The oscilloscope triggers depending on the combinatorial logic condition of channels 1, 2, 3, and 4. Allowable conditions are AND, OR, NAND, and NOR.

Low
The value used as 0% in automated measurements (whenever high ref, mid ref, and low ref values are needed as in fall time and rise time measurements). May be calculated using either the min/max or the histogram method. With the min/max method (most useful for general waveforms), it is the minimum value found. With the histogram method (most useful for pulses), it refers to the most common value found below the mid point. See Appendix B: Algorithms for details.

Main menu
A group of related controls for a major oscilloscope function that the oscilloscope displays across the bottom of the screen.

Main menu buttons
Bezel buttons under the main menu display. They allow you to select items in the main menu.

Maximum
Amplitude (voltage) measurement of the maximum amplitude. Typically the most positive peak voltage.
Glossary

**Mean**
Amplitude (voltage) measurement of the arithmetic mean over the entire waveform.

**Minimum**
Amplitude (voltage) measurement of the minimum amplitude. Typically the most negative peak voltage.

**NAND**
A logic (Boolean) function in which the output of the AND function is complemented (true becomes false, and false becomes true). On the digitizing oscilloscope, that is a trigger logic pattern and state function.

**Negative duty cycle**
A timing measurement representing the ratio of the negative pulse width to the signal period, expressed as a percentage.

**Negative overshoot measurement**
Amplitude (voltage) measurement.

\[
\text{Negative Overshoot} = \frac{\text{Low} - \text{Min}}{\text{Amplitude}} \times 100\%
\]

**Negative width**
A timing measurement of the distance (time) between two amplitude points — falling-edge *MidRef* (default 50%) and rising-edge *MidRef* (default 50%) — on a negative pulse.

**Normal trigger mode**
A mode on which the oscilloscope does not acquire a waveform record unless a valid trigger event occurs. It waits for a valid trigger event before acquiring waveform data.

**NOR**
A logic (Boolean) function in which the output of the OR function is complemented (true becomes false, and false becomes true). On the digitizing oscilloscope, that is a trigger logic pattern and state function.

**OR**
A logic (Boolean) function in which the output is true if any of the inputs are true. Otherwise the output is false. On the digitizing oscilloscope, that is a trigger logic pattern and state function.

**Oscilloscope**
An instrument for making a graph of two factors. These are typically voltage versus time.

**Peak-to-Peak**
Amplitude (voltage) measurement of the absolute difference between the maximum and minimum amplitude.

**Period**
A timing measurement of the time covered by one complete signal cycle. It is the reciprocal of frequency and is measured in seconds.
Phase
A timing measurement between two waveforms of the amount one leads or lags the other in time. Phase is expressed in degrees, where 360° comprise one complete cycle of one of the waveforms. Waveforms measured should be of the same frequency or one waveform should be a harmonic of the other.

Pixel
A visible point on the display. The oscilloscope display is 640 pixels wide by 480 pixels high.

Pop-up Menu
A sub-menu of a main menu. Pop-up menus temporarily occupy part of the waveform display area and are used to present additional choices associated with the main menu selection. You can cycle through the options in a pop-up menu by repeatedly pressing the main menu button underneath the pop-up.

Positive duty cycle
A timing measurement of the ratio of the positive pulse width to the signal period, expressed as a percentage.

Positive overshoot
Amplitude (voltage) measurement.

\[
PositiveOvershoot = \frac{Max - High}{Amplitude} \times 100\%
\]

Positive width
A timing measurement of the distance (time) between two amplitude points — rising-edge MidRef (default 50%) and falling-edge MidRef (default 50%) — on a positive pulse.

Posttrigger
The specified portion of the waveform record that contains data acquired after the trigger event.

Pretrigger
The specified portion of the waveform record that contains data acquired before the trigger event.

Probe
An oscilloscope input device.

Quantizing
The process of converting an analog input that has been sampled, such as a voltage, to a digital value.

Probe compensation
Adjustment that improves low-frequency response of a probe.

Pulse trigger
A trigger mode in which triggering occurs if the oscilloscope finds a pulse, of the specified polarity, with a width between, or optionally outside, the user-specified lower and upper time limits.
Real-time sampling
A sampling mode where the digitizing oscilloscope samples fast enough to completely fill a waveform record from a single trigger event. Use real-time sampling to capture single-shot or transient events. (All TDS 600A series oscilloscopes use real time sampling at all acquisition rates.)

Record length
The specified number of samples in a waveform.

Reference memory
Memory in a oscilloscope used to store waveforms or settings. You can use that waveform data later for processing. The digitizing oscilloscope saves the data even when the oscilloscope is turned off or unplugged.

Rise time
The time it takes for a leading edge of a pulse to rise from a LowRef value (typically 10%) to a HighRef value (typically 90%) of its amplitude.

RMS
Amplitude (voltage) measurement of the true Root Mean Square voltage.

Runt trigger
A mode in which the oscilloscope triggers on a runt. A runt is a pulse that crosses one threshold but fails to cross a second threshold before recrossing the first. The crossings detected can be positive, negative, or either.

Sample acquisition mode
The oscilloscope creates a record point by saving the first sample during each acquisition interval. That is the default mode of the acquisition.

Sample interval
The time interval between successive samples in a time base. For real-time digitizers, the sample interval is the reciprocal of the sample rate. For equivalent-time digitizers, the time interval between successive samples represents equivalent time, not real time.

Sampling
The process of capturing an analog input, such as a voltage, at a discrete point in time and holding it constant so that it can be quantized. Two general methods of sampling are: real-time sampling and equivalent-time sampling.

Select button
A button that changes which of the two cursors is active.

Selected waveform
The waveform on which all measurements are performed, and which is affected by vertical position and scale adjustments. The light over one of the channel selector buttons indicates the current selected waveform.
Side menu
Menu that appears to the right of the display. These selections expand on main menu selections.

Side menu buttons
Bezel buttons to the right of the side menu display. They allow you to select items in the side menu.

Slope
The direction at a point on a waveform. You can calculate the direction by computing the sign of the ratio of change in the vertical quantity (Y) to the change in the horizontal quantity. The two values are rising and falling.

Tek Secure
This feature erases all waveform and setup memory locations (setup memories are replaced with the factory setup). Then it checks each location to verify erasure. This feature finds use where this digitizing oscilloscope is used to gather security sensitive data, such as is done for research or development projects.

Time base
The set of parameters that let you define the time and horizontal axis attributes of a waveform record. The time base determines when and how long to acquire record points.

Trigger
An event that marks time zero in the waveform record. It results in acquisition and display of the waveform.

Trigger level
The vertical level the trigger signal must cross to generate a trigger (on edge trigger mode).

Vertical bar cursors
The two vertical bars you position to measure the time parameter of a waveform record. The oscilloscope displays the value of the active (moveable) cursor with respect to the trigger and the time value between the bars.

Waveform
The shape or form (visible representation) of a signal.

Waveform interval
The time interval between record points as displayed.

XY format
A display format that compares the voltage level of two waveform records point by point. It is useful for studying phase relationships between two waveforms.

YT format
The conventional oscilloscope display format. It shows the voltage of a waveform record (on the vertical axis) as it varies over time (on the horizontal axis).
**Index**

**Numbers**

1/seconds (Hz), Cursor menu, 3-19
100 MHz, Vertical menu, 3-138
20 MHz, Vertical menu, 3-138

**A**

AC coupling, 2-16–2-17, Glossary-1
AC line voltage, trigger input, 2-14
AC, Main Trigger menu, 3-33
Accept Glitch, Main Trigger menu, 3-112
Accessories, A-1–A-6
  Optional, A-4
Probes, A-4–A-6
Software, A-5–A-6
Accuracy, Glossary-1
Acquire menu, 3-5, 3-70
  Average, 3-5
  Average mode, 3-71
  Compare Ch1 to, 3-72
  Compare Ch2 to, 3-72
  Compare Ch3 to, 3-72
  Compare Ch4 to, 3-72
  Compare Math1 to, 3-72
  Compare Math2 to, 3-72
  Compare Math3 to, 3-72
  Create Limit Test Template, 3-70
  Envelope, 3-5
  H Limit, 3-71
  Hardcopy if Condition Met, 3-73
  Limit Test, 3-73
  Limit Test Condition Met, 3-73
  Limit Test Setup, 3-72, 3-73
  Limit Test Sources, 3-72
  Mode, 3-5
  OK Store Template, 3-71
  Ring Bell if Condition Met, 3-73
  RUN/STOP, 3-6
  Sample, 3-5
  Single Acquisition Sequence, 3-7
  Stop After, 3-6, 3-73

Stop After Limit Test Condition
Met, 3-73
Template Source, 3-70
V Limit, 3-71
ACQUIRE MENU button, 3-5, 3-70
Acquisition, 2-19–2-21, 3-8, Glossary-1
  Interval, Glossary-1
  Modes
    Average, 3-5
    Sample, 3-3
  Readout, 3-5
Active cursor, Glossary-1
Active voltage probes, 3-104–3-105
active, Saved waveform status, 3-123
Algorithms, A-7–A-20
Aliasing, 2-24, 3-46, Glossary-1
Amplitude, 3-83, Glossary-1
Amplitude Units, Cursor menu, 3-19
  AND, Glossary-1
  AND, Main Trigger menu, 3-79, 3-82
Applications
derivative math waveforms, 3-139
  FFT math waveforms, 3-36
  integral math waveforms, 3-143
Area, 3-83, Glossary-1
Attenuation, Glossary-2
Auto, Main Trigger menu, 3-35, 3-79, 3-111
Automated Measurements, Snapshot
  of, 1-22
Automated measurements, 1-18, 2-26,
  3-83
  of derivative math waveforms,
  3-140
  (procedure), 3-140
  of FFT math waveforms, 3-41
  of integral math waveforms, 3-146
Automatic trigger mode, 2-15, Glossary-2
Autosave, Save/Recall Waveform
  menu, 3-125
Auto, 1-11, 2-25, 3-8–3-9, Glossary-2
AUTOSET button, 1-12, 3-8, 3-128
AUX TRIGGER INPUT, BNC, 2-5
Auxiliary trigger, 2-14
Average acquisition mode, 3-5, Glossary-2
Average mode, Acquire menu, 3-71
Average, Acquire menu, 3-5
Average, More menu, 3-149

**B**

Bandwidth, 1-1, 2-21, Glossary-2
Bandwidth, Vertical menu, 3-138
Base, Cursor menu, 3-19
Baud Rate, Utility menu, 3-58
Blackman-Harris window, 3-39
BMP, 3-57
BMP Color, Hardcopy menu, 3-59
BMP Mono, Hardcopy menu, 3-59
BNC
  AUX TRIGGER INPUT, 2-5
  DELAYED TRIGGER OUTPUT, 2-5
  MAIN TRIGGER OUTPUT, 2-5
  SIGNAL OUTPUT, 2-5
Bold, Color menu, 3-11
Burst width, 3-83

Button
  ACQUIRE MENU, 3-5, 3-70
  AUTOSET, 1-12, 2-24, 3-8, 3-128
  CLEAR MENU, 1-10, 1-19, 1-20,
    2-3, 2-8, 3-92
  CURSOR, 2-27, 3-17
  DELAYED TRIG, 2-18, 3-23
  DISPLAY, 3-10, 3-26
  FORCE TRIG, 3-133
  HARDCOPY, 3-53, 3-59, 3-118
  HELP, 3-65
  HORIZONTAL MENU, 2-18, 3-21
  MEASURE, 3-86
  MORE, 3-124, 3-126, 3-148
  ON/STBY, 1-5, 2-3
Cables, 3-117, 3-118
Cal Probe, Vertical menu, 3-94
Calibration Certificate, A-3
Calibration Data Report, A-3
Cart, Oscilloscope, A-1
CAUTION
statement in manuals, xi
statement on equipment, xi
Centronics, 2-5
Port, 3-59
CH1, CH2 ... buttons, 3-126
Ch1, Ch2 ..., Delayed Trigger menu, 3-24
Ch1, Ch2 ..., Main Trigger menu, 3-32, 3-78, 3-79, 3-81, 3-111, 3-113
Change Colors, Color menu, 3-11
Change Math waveform definition, More menu, 3-149
Channel, 3-126-3-127, Glossary-2
Readout, 2-6, 3-126
Reference Indicator, 2-6
Selection buttons, 1-14, 3-126
Trigger input, 2-13-2-18
Channel readout, 2-6
Channel reference indicator, Glossary-2
Circuit loading, Glossary-2
Class, Main Trigger menu, 3-77, 3-111, 3-113
CLEAR MENU button, 1-10, 1-19, 1-20, 2-3, 2-8, 3-92
Clear Spool, Hardcopy menu, 3-60
Clipping
derivative math waveforms, 3-141
FFT math waveforms, 3-44
how to avoid, 3-44, 3-141, 3-146
integral math waveforms, 3-146
Collision Contrast, Color menu, 3-14
Color, 3-10-3-14
Color Matches Contents, Color menu, 3-13
Color menu, 3-10
Bold, 3-11
Change Colors, 3-11
Collision Contrast, 3-14
Color, 3-12, 3-13
Color Matches Contents, 3-13
Hardcopy, 3-11
Hue, 3-12
Lightness, 3-12
Map Math, 3-12
Map Reference, 3-13
Math, 3-12
Monochrome, 3-11
Normal, 3-11
Options, 3-14
Palette, 3-11
Persistence Palette, 3-11
Ref, 3-13
Reset All Mappings To Factory, 3-14
Reset All Palettes To Factory, 3-14
Reset Current Palette To Factory, 3-14
Reset to Factory Color, 3-12
Restore Colors, 3-14
Saturation, 3-12
Spectral, 3-11
Temperature, 3-11
View Palette, 3-11
Color, Color menu, 3-12, 3-13
Color, Display menu, 3-10
Compare Ch1 to, Acquire menu, 3-72
Compare Ch2 to, Acquire menu, 3-72
Compare Ch3 to, Acquire menu, 3-72
Compare Ch4 to, Acquire menu, 3-72
Compare Math1 to, Acquire menu, 3-72
Compare Math2 to, Acquire menu, 3-72
Compare Math3 to, Acquire menu, 3-72
Compensation, 3-100
Configure, Utility menu, 3-58, 3-118
Confirm Delete, File Utilities menu, 3-56
Connector
AUX TRIGGER INPUT, 2-5
Centronics, 2-5
DELAYED TRIGGER OUTPUT, 2-5
GPIOB, 2-5, 3-117
MAIN TRIGGER OUTPUT, 2-5
Power, 2-5
RS-232, 2-5
SIGNAL OUTPUT, 2-5
VGA, 2-5
Contrast, Display menu, 3-27
Conventions, ii
Copy, File Utilities menu, 3-55
Coupling, 1-15
AC, 2-16
DC, 2-16
Ground, Glossary-4
Input Signal, 2-21
Trigger, 2-16
Coupling, Delayed Trigger menu, 3-24
Coupling, Main Trigger menu, 3-33
Coupling, Vertical menu, 3-137
Create Directory, File Utilities menu, 3-55
Create Limit Test Template, Acquire menu, 3-70
Create Measrmt, Measure Delay menu, 3-92
Cross Hair, Display menu, 3-29
Current probes, 3-105
Cursor
Horizontal bar, 2-27, 3-15
Measurements, 2-27
Mode, 2-27-2-28
Independent, 2-27-2-28
Tracking, 2-28
Paired, 2-27, 3-15
Vertical bar, 2-27, 3-15

CURSOR button, 3-17

CURSOR menu, 3-17, 3-40, 3-144
1/seconds (Hz), 3-19
Amplitude Units, 3-19
Base, 3-19
Function, 3-17, 3-18
H Bars, 3-17, 3-18
Independent, 3-18
IRE (NTSC), 3-19
seconds, 3-19
Time Units, 3-19
Tracking, 3-18
Video Line Number, 3-19

Cursor readout
H-Bars, 3-40, 3-141, 3-145
Paired, 3-141
Paired cursors, 3-41, 3-145
V-Bars, 3-40, 3-141, 3-145

Cursor Readouts, 3-16

Cursor Speed, 3-19

Cursors, 2-27, 3-15-3-19, Glossary-2
with derivative waveforms, 3-141
with FFT waveforms, 3-40
with integral waveforms, 3-144
Cycle area, 3-83, Glossary-3
Cycle mean, 3-83, Glossary-3
Cycle RMS, 3-83, Glossary-3

Delay by Events, Delayed Trigger menu, 3-23
Delay by Time, Delayed Trigger menu, 3-23

Delay by, Delayed Trigger menu, 3-23
Delay measurement, 3-90, Glossary-3
Delay time, Glossary-3

Delay To, Measure Delay menu, 3-90

Delayed Only, Horizontal menu, 3-21
Delayed Runs After Main, 2-18

Delayed Runs After Main, Horizontal menu, 3-21, 3-68

Delayed Scale, Horizontal menu, 3-68

DELAYED TRIG button, 2-18, 3-23

Delayed trigger, 2-18, 3-20-3-25

Delayed Trigger menu, 2-23-3-25

Ch1, Ch2 ..., 3-24
Coupling, 3-24
Delay by, 3-23
Delay by Events, 3-23
Delay by Time, 3-23

Falling edge, 3-24

Level, 3-24
Rising edge, 3-24

Set to 50%, 3-25
Set to ECL, 3-24

Set to TTL, 3-24
Slope, 3-24
Source, 3-24

DELAYED TRIGGER OUTPUT, BNC, 2-5

Delayed Triggerable, 2-18

Delayed Triggerable, Horizontal menu, 3-23, 3-68

Delete Refs, Save/Recall Waveform menu, 3-124

Delete, File Utilities menu, 3-54

Delete, Main Trigger menu, 3-79, 3-81

Define Inputs, Main Trigger menu, 3-79, 3-82

Define Logic, Main Trigger menu, 3-79, 3-82

D

DANGER, statement on equipment, xi
Date/Time
On hardcopies, 3-60
To set, 3-60

DC coupling, 2-16, Glossary-3

DC offset, 3-44
for DC correction of FFTs, 3-44
with math waveforms, 3-44, 3-146

DC, Main Trigger menu, 3-33

Define Inputs, Main Trigger menu, 3-79, 3-81

Define Logic, Main Trigger menu, 3-79, 3-82

Differentiation
of a derivative, 3-139
waveform, 3-139

Digitizing, Glossary-3

Digitizing rate, 1-1

Disk drive, 3-53-3-56

Display, 2-6, 3-8
Options, 3-26-3-31
Record View, 3-134
System, Glossary-3

Display ’T’ @ Trigger Point, Display menu, 3-28

DISPLAY button, 3-10, 3-10, 3-26

Display menu, 3-10, 3-26
Color, 3-10
Contrast, 3-27
Cross Hair, 3-29
Display, 3-26

Display ’T’ @ Trigger Point, 3-28
Dots, 3-27

Dots style, 3-72
Filter, 3-29
Format, 3-30
Frame, 3-29
Full, 3-29

Gnatcliffe, 3-29
Grid, 3-29

Infinite Persistence, 3-27
Intensified Samples, 3-27

Intensity, 3-27
Linear interpolation, 3-29
NTSC, 3-29

Overall, 3-27
PAL, 3-29

Readout, 3-28

Settings, 3-10, 3-26

Sin(x)/x interpolation, 3-29
Style, 3-26

Text/Grat, 3-27

Trigger Bar, 3-28

Variable Persistence, 3-27

Vectors, 3-27

Waveform, 3-27

XY, 3-30
Y, 3-30

Display, Display menu, 3-26

Display, Status menu, 3-130

Dots, 3-27

Dots style, Display menu, 3-72
Index

Dots, Display menu, 3-27
DPU411 – II, Hardcopy menu, 3-59
DPU412, Hardcopy menu, 3-59
Dual Wfm Math, More menu, 3-149
Duty cycle, 1-19, Glossary-6, Glossary-7

Fast Fourier Transforms (FFTs), applications, 3-36
FastFrame interactions, 3-17
FFT frequency domain record, 3-42 defined, 3-42-3-52
length of, 3-43
FFT math waveform, 3-36 acquisition mode, 3-45
aliasing, 3-46 automated measurements of, 3-41
DC correction, 3-44
derivation of, 3-36 displaying phase, 3-38
frequency range, 3-43
frequency resolution, 3-43
interpolation mode, 3-45, 3-46
magnifying, 3-45
phase display, setup considerations, 3-47-3-52
phase suppression, 3-39, 3-48
procedure for displaying, 3-37
procedure for measuring, 3-40
record length, 3-43
reducing noise, 3-45
undersampling, 3-46
zero phase reference, 3-47
FFT time domain record, defined, 3-42
File System, 3-53-3-56
Optional File System, A-2
File Utilities menu, 3-53
Confirm Delete, 3-56
Copy, 3-55
Create Directory, 3-55
Delete, 3-54
File Utilities, 3-53
Format, 3-56
Overwrite Lock, 3-56
Print, 3-55
Rename, 3-54

File Utilities, File Utilities menu, 3-53
File Utilities, Save/Recall Setup menu, 3-122
File Utilities, Save/Recall Waveform menu, 3-125
Filter, Display menu, 3-29
Fine Scale, Vertical menu, 3-138
Firmware version, 3-130
Fit to screen, Horizontal menu, 3-68
Fixed active probes, 3-104
FORCE TRIG button, 3-133

Format, Display menu, 3-30
Format, File Utilities menu, 3-56
Format, Hardcopy menu, 3-59
Frame, Display menu, 3-29
Frequency, 1-19, 3-84, Glossary-3
Front Cover removal, 1-5
Front panel, 2-4
Full, Display menu, 3-29
Full, Vertical menu, 3-138
Function, Cursor menu, 3-17, 3-18
Fuse, 1-4, 2-5

G

Gated Measurements, 3-88, Glossary-3
Gating, Measure menu, 3-88
General purpose (high input resistance) probes, 3-102
General purpose knob, 1-20, 2-7, Glossary-4
Glitch trigger, 3-109, 3-110, Glossary-4
Glitch, Main Trigger menu, 3-111, 3-112
Goes FALSE, Main Trigger menu, 3-78
Goes TRUE, Main Trigger menu, 3-78
GPIB, 2-5, 3-118-3-119, Glossary-4
GPIB, Hardcopy menu, 3-59
GPIB, Utility menu, 3-58, 3-118
Graticule, 3-29, Glossary-4
Measurements, 2-28
Graticule, Display menu, 3-29
Grid, Display menu, 3-29
Ground coupling, Glossary-4

H

H Bars, Cursor menu, 3-17, 3-18
H Limit, Acquire menu, 3-71

Index-4
Hamming window, 3-39
Hanning window, 3-39
**Hard Flagging**, Utility menu, 3-58
Hardcopy, 3-57–3-64, Glossary-4
**Hardcopy (Talk Only)**, Utility menu, 3-58
**HARDCOPY** button, 3-53, 3-59, 3-118
**Hardcopy if Condition Met**, Acquire menu, 3-73
Hardcopy Interface, Optional RS-232/Centronic, A-2

Hardcopy menu
- **BMP Color**, 3-59
- **BMP Mono**, 3-59
- **Clear Spool**, 3-59, 3-60
- **Deskjet**, 3-59
- **DPU411 ~ II**, 3-59
- **DPU412**, 3-59
- **EPS Color Img**, 3-59
- **EPS Color Plt**, 3-59
- **EPS Mono Img**, 3-59
- **EPS Mono Plt**, 3-59
- **Epson**, 3-59
- **Format**, 3-59
- **GPIB**, 3-59
- **HPGL**, 3-59
- **Interleaf**, 3-59
- **Landscape**, 3-59
- **Laserjet**, 3-59
- **Layout**, 3-59
- **OK Confirm Clear Spool**, 3-60
- **PCX**, 3-59
- **PCX Color**, 3-59
- **Port**, 3-59
- **Portrait**, 3-59
- **RLE Color**, 3-59
- **Thinkjet**, 3-59
- **TIFF**, 3-59

**Hardcopy, Color menu**, 3-11
**Hardcopy, Utility menu**, 3-118
**Hardware Setup**, Utility menu, 3-58
- **HC100 Plotter**, 3-57
- **HC220 Printer**, 3-57
- **HELP** button, 3-65
Help system, 3-65
**HF Rej**, Main Trigger menu, 3-33
- **High**, 3-84, Glossary-4
- **High frequency rejection**, 2-16
**High Ref**, Measure menu, 3-90

**High speed active probes**, 3-104
**High voltage probes**, 3-103–3-104
**High-Low Setup**, Measure menu, 3-89
**Histogram**, Measure menu, 3-89
**Holdoff**, Main Trigger menu, 3-79, 3-111
Holdoff, trigger, 2-15, Glossary-4
**Horiz Pos**, Horizontal menu, 3-68
**Horiz Scale**, Horizontal menu, 3-68

**Horizontal**, 3-8
- **Bar cursors**, 2-27, 3-15, Glossary-4
- **Control**, 3-66–3-69
- **Menu**, 2-18
- **Position**, 3-66
- **POSITION** knob, 2-23
- **Readouts**, 3-67
- **Scale**, 3-66
- **SCALE** knob, 1-11, 2-23
System, 1-11, 2-23

**Horizontal menu**, 3-21
- **Delayed Only**, 3-21
- **Delayed Runs After Main**, 3-21, 3-68
- **Delayed Scale**, 3-68
- **Delayed Triggerable**, 3-23, 3-68
- **Fit to screen**, 3-68
- **Horiz Pos**, 3-68
- **Horiz Scale**, 3-68
- **Intensified**, 3-21, 3-23
- **Main Scale**, 3-68
- **Record Length**, 3-68
- **Set to 10%**, 3-68
- **Set to 50%**, 3-68
- **Set to 90%**, 3-68
- **Time Base**, 3-21, 3-67
- **Trigger Position**, 3-68

**HORIZONTAL MENU** button, 2-18, 3-21

**Horizontal POSITION** knob, 3-66
**Horizontal Readouts**, 3-67
**Horizontal SCALE** knob, 3-66
**HPGL**, 3-57
**HPGL**, Hardcopy menu, 3-59
**Hue**, Color menu, 3-12

**I/O**, Status menu, 3-130
**I/O**, Utility menu, 3-58, 3-118
**Icons**, 1-1
**Independent Mode**, Cursor, 2-27–2-28
**Independent**, Cursor menu, 3-18
**Infinite Persistence**, Display menu, 3-27
**Installation**, 1-3–1-4
**Integral math waveform**, 3-143
  **applications**, 3-143
  **automated measurements of**, 3-146
  **derivation of**, 3-143
  **magnifying**, 3-142, 3-147
  **procedure for displaying**, 3-143
  **procedure for measuring**, 3-144
  **record length of**, 3-143
**Integration**, Waveform, 3-143

**Intensified Samples**, Display menu, 3-27

**Intensified**, Horizontal menu, 3-21, 3-23
**Intensity**, 3-27, Glossary-5

**Intensity**, Display menu, 3-27
**Interleaf**, 3-57

**Interleaf**, Hardcopy menu, 3-59
**Interpolation**, 2-20, 3-6, 3-29, Glossary-5
  **FFT distortion**, 3-46
  **linear versus sin(x)/x**, 3-46

**IRE (NTSC)**, Cursor menu, 3-19

**K**

**Keypad**, 1-21
**Knob**, Glossary-5
  **General purpose**, 1-20, 2-7, Glossary-4
  **Horizontal POSITION**, 1-11, 2-23, 3-66
Horizontal SCALE, 1-11, 2-23, 3-66
MEASURE, 2-26
Trigger MAIN LEVEL, 1-12, 2-17
Vertical POSITION, 1-11, 2-23, 3-136
Vertical SCALE, 1-11, 2-23, 3-136

L

Labelling menu, Enter Char, 3-54, 3-55
Landscape, Hardcopy menu, 3-59
Laserjet, 3-57
Laserjet, Hardcopy menu, 3-59
Layout, Hardcopy menu, 3-59
Level, Delayed Trigger menu, 3-24
Level, Main Trigger menu, 3-34, 3-112, 3-115
Level, Trigger, 2-17
LF Rej, Main Trigger menu, 3-33
Lightness, Color menu, 3-12
Limit Test Condition Met, Acquire menu, 3-73
Limit Test Setup, Acquire menu, 3-72, 3-73
Limit Test Sources, Acquire menu, 3-72
Limit Test, Acquire menu, 3-73
Limit testing, 3-70-3-74
Linear interpolation, 2-20, 3-29, Glossary-5
Linear interpolation, Display menu, 3-29
Logic trigger, 2-14, 3-77
Definitions, 3-77
Pattern, 3-76, Glossary-5
State, 3-76, Glossary-5
Logic triggering, 3-75-3-82
Logic, Main Trigger menu, 3-135
Low, 3-84, Glossary-5
Low frequency rejection, 2-16
Low impedance Zo probes, 3-102
Low Ref, Measure menu, 3-90

M

Main menu, Glossary-5
Main menu buttons, 2-3, Glossary-5
Main Scale, Horizontal menu, 3-68
Main Trigger Menu
Falling edge, 3-34
Rising edge, 3-34
Main Trigger menu, 2-10, 3-32, 3-77, 3-111, 3-113, 3-135
AC, 3-33
Accept Glitch, 3-112
AND, 3-79, 3-82
Auto, 3-35, 3-79, 3-111
Ch1, Ch2 ..., 3-32, 3-78, 3-79, 3-81, 3-111, 3-113
Class, 3-77, 3-111, 3-113
Coupling, 3-33
DC, 3-33
Define Inputs, 3-79, 3-81
Define Logic, 3-79, 3-82
Edge, 3-32, 3-135
Either, 3-112, 3-113
Falling edge, 3-81
Glitch, 3-111, 3-112
Goes FALSE, 3-78
Goes TRUE, 3-78
HF Rej, 3-33
Holdoff, 3-79, 3-111
Level, 3-34, 3-112, 3-115
LF Rej, 3-33
Mode & Holdoff, 3-35, 3-79, 3-111
NAND, 3-79, 3-82
Negative, 3-112, 3-113
Noise Rej, 3-33
NOR, 3-79, 3-82
Normal, 3-35, 3-79, 3-111
OR, 3-79, 3-82
Pattern, 3-77
Polarity, 3-113
Polarity and Width, 3-112
Positive, 3-112, 3-113
Pulse, 3-111, 3-113, 3-135
Reject Glitch, 3-112
Rising edge, 3-81
Runt, 3-113
Set Thresholds, 3-78
Set to 50%, 3-34, 3-113, 3-133
Set to ECL, 3-34, 3-112
Set to TTL, 3-34, 3-112
Slope, 3-34

Source, 3-32, 3-111, 3-113
State, 3-77, 3-81
Thresholds, 3-113
Trigger When, 3-78, 3-80
True for less than, 3-80
True for more than, 3-80
Type, 3-32, 3-111, 3-113, 3-135
Width, 3-112

MAIN TRIGGER OUTPUT, BNC, 2-5
Map Math, Color menu, 3-12
Map Reference, Color menu, 3-13
Math Waveform
Differential, A-2
FFT, A-2
Integral, A-2
Optional Advanced, A-2
Math waveform
derivative. See Derivative math waveform
FFT. See FFT math waveform
integral. See Integral math waveform
Math waveforms, 3-148
Math, Color menu, 3-12
Math1/2/3, More menu, 3-148
Maximum, 3-84, Glossary-5
Mean, 3-84, Glossary-6
MEASURE button, 3-86
Measure Delay menu
Create Measrmnt, 3-92
Delay To, 3-90
Edges, 3-91
Measure Delay To, 3-90
OK Create Measurement, 3-92
Measure Delay To, Measure Delay menu, 3-90
Measure menu, 2-10, 3-86, 3-93
Gating, 3-88
High Ref, 3-90
High-Low Setup, 3-89
Histogram, 3-89
Low Ref, 3-90
Mid Ref, 3-90
Mid2 Ref, 3-90
Min-Max, 3-89
Reference Levels, 3-89
Remove Measrmnt, 3-87, 3-93
Select Measrmnt, 3-86, 3-90
Set Levels in % units, 3-89
Snapshot, 3-93
Measurement
Amplitude, 3-83, Glossary-1
Area, 3-83, Glossary-1
Burst width, 3-83, Glossary-2
Cycle area, 3-83, Glossary-3
Cycle mean, 3-83, Glossary-3
Cycle RMS, 3-83, Glossary-3
Delay, 3-90, Glossary-3
Duty cycle, 1-19, Glossary-6, Glossary-7
Fall time, 3-84
Frequency, 1-19, 3-84, Glossary-3
Gated, Glossary-3
High, 3-84, Glossary-4
Low, 3-84, Glossary-5
Maximum, 3-84, Glossary-5
Mean, 3-84, Glossary-6
Minimum, 3-84, Glossary-6
Negative duty cycle, 3-84
Negative overshoot, 3-84
Negative width, 3-84
Overshoot, Glossary-7
Peak to peak, 3-84, Glossary-6
Period, 3-85, Glossary-6
Phase, 3-84, Glossary-7
Positive duty cycle, 3-85
Positive overshoot, 3-85
Positive width, 3-85
Propagation delay, 3-84
Readout, 3-86
Reference levels, 1-20
Rise time, 1-19, 3-85, Glossary-8
RMS, 3-85, Glossary-8
Undershoot, Glossary-6
Width, 1-19, Glossary-6, Glossary-7
Measurement Accuracy, Ensuring maximum, 3-94–3-99, 3-128–3-129
Measurements, 2-26–2-28, 3-83–3-93
Algorithms, A-7–A-20
Automated, 1-18, 2-26
Cursor, 2-27, 3-15
Gated, 3-88
Graticule, 2-28
Snapshot of, 3-92
Memory, Waveform, 3-124
Menu
Acquire, 3-5, 3-70
Color, 3-10
Cursor, 3-17
Delayed Trigger, 3-23–3-25
Display, 3-10, 3-26
File Utilities, 3-53
Horizontal, 2-18, 3-21
Main, 2-6
Main Trigger, 2-10, 3-32, 3-77, 3-111, 3-113, 3-135
Measure, 2-10, 3-86, 3-93
More, 2-10, 3-37, 3-124, 3-139, 3-148
See also More menu
Operation, 2-7
Pop-up, 2-8, Glossary-7
Pulse trigger, 2-10
Save/Recall, 3-120
Save/Recall Setup, 2-10
Save/Recall Waveform, 2-10, 3-123
Setup, 1-8
Status, 2-10, 3-130–3-131
Utility, 2-11, 3-58, 3-118
Mid Ref, Measure menu, 3-90
Mid2 Ref, Measure menu, 3-90
Min-Max, Measure menu, 3-89
Minimum, 3-84, Glossary-6
Mode, Cursor, 2-27–2-28
Mode & Holdoff, Main Trigger menu, 3-35, 3-79, 3-111
Mode, Acquire menu, 3-5
Model number location, 2-3
Monochrome, Color menu, 3-11
MORE button, 3-72, 3-124, 3-126, 3-148
More menu, 2-10, 3-124, 3-139, 3-148
Average, 3-149
Blackman-Harris, 3-39
Change Math waveform definition, 3-38, 3-139, 3-143, 3-149
dBV RMS, 3-38
diff, 3-140
Dual Wfm Math, 3-149
FFT, 3-38
Hamming, 3-39
Hanning, 3-39
Intg, 3-144
Linear RMS, 3-38
Math1, Math2, Math3, 3-37, 3-139, 3-143
Math1/2/3, 3-148
No Process, 3-149
OK Create Math Waveform, 3-144, 3-149
Phase (deg), 3-38
Phase (rad), 3-38
Rectangular, 3-38
Reference waveform status, 3-124
Set 1st Source to, 3-150
Set 2nd Source to, 3-150
Set FFT Source to, 3-38
Set FFT Vert Scale to, 3-38
Set FFT Window to, 3-38
Set Function to, 3-149
Set Function to, 3-140, 3-144
Set operator to, 3-150
Set Single Source to, 3-149
Set Single Source to, 3-139, 3-143
Single Wfm Math, 3-139, 3-143, 3-149

N
NAND, Glossary-6
NAND, Main Trigger menu, 3-79, 3-82
Negative duty cycle, 3-84
Negative overshoot, 3-84
Negative width, 3-84
Negative, Main Trigger menu, 3-112, 3-113
No Process, More menu, 3-149
Noise
reducing in FFTs, 3-45
reducing in phase FFTs, 3-39, 3-48
Noise Rej, Main Trigger menu, 3-33
NOR, Glossary-6
NOR, Main Trigger menu, 3-79, 3-82
Normal trigger mode, 2-14, Glossary-6
Normal, Color menu, 3-11
Normal, Main Trigger menu, 3-35, 3-79, 3-111
NTSC, Display menu, 3-29
Nyquist frequency, 3-46

O
Off Bus, Utility menu, 3-118
Offset
DC, See DC Offset
Vertical, 2-23, 3-138
vertical, 3-44, 3-141, 3-146
Offset, Vertical menu, 3-138
OK Confirm Clear Spool, Hardcopy menu, 3-60
Index

OK Create Math Wfm, More menu, 3-149
OK Create Measurement, Measure Delay menu, 3-92
OK Erase Ref & Panel Memory, Utility menu, 3-121
OK Store Template, Acquire menu, 3-71
ON/STBY button, 1-5, 2-3
Optical probes, 3-106
Options, A-1–A-6
OR, Glossary-6
OR, Main Trigger menu, 3-79, 3-82
Oscilloscope, Glossary-6
Overall, Display menu, 3-27
Overshoot, Glossary-7
Overwrite Lock, File Utilities menu, 3-56

Plotter, HC100, 3-57
Polarity and Width, Main Trigger menu, 3-112
Polarity, Main Trigger menu, 3-113
Pop-up menu, 2-8, Glossary-7
Port, Hardcopy menu, 3-59
Port, Utility menu, 3-58, 3-118
Portrait, Hardcopy menu, 3-59
Position
Vertical, 2-23, 3-136
vertical, 3-44, 3-141, 3-146
Position, Vertical menu, 3-138
Positive duty cycle, 3-85
Positive overshoot, 3-85
Positive width, 3-85
Positive, Main Trigger menu, 3-112, 3-113
Postscript, 3-57
Posttrigger, Glossary-7
Power connector, 1-4, 2-5
Power cords, A-1
Power off, 1-6
Power on, 1-5
Pretrigger, Glossary-7
Principal power switch, 1-5, 2-5
Print, File Utilities menu, 3-55
Printer
HC220, 3-57
Phaser, 3-57
Probe Cal, 3-94–3-99
Probes
Accessories, A-4–A-6
Active voltage, 3-104–3-105
Additional, A-3
By applications, 3-107, 3-108
Compensation, 1-11, 3-100, Glossary-7
Connection, 1-7
Current, 3-105
Definition, Glossary-7
Delete Four Option, A-2
Delete Two Option, A-2
differential active, 3-104
Fixed active, 3-104
General purpose (high input resistance), 3-102
High speed, 3-104
High voltage, 3-103–3-104
Low impedance Zo, 3-102
Optical, 3-106
Passive, 3-100
Passive voltage, 3-102–3-103
Selection, 3-102–3-108
Time-to-voltage converter, 3-106
Propagation delay, 3-84
Pulse trigger, 2-14, 3-109
Pulse Trigger menu, 2-10
Pulse, Main Trigger menu, 3-111, 3-113, 3-135

Q
Quantizing, Glossary-7

R
Rack mounting, A-2
Readout
Acquisition, 3-5
Channel, 2-6, 3-126
Cursor, 2-6
Edge trigger, 3-32, 3-76
General purpose knob, 2-6
Measurement, 2-27, 3-86
Record view, 2-6
Snapshot, 3-92
Time base, 2-6
Trigger, 2-6, 3-134
Trigger Level Bar, 3-28
Trigger Point, 3-28
Readout, Cursor, Paired, 3-141
Readout, cursor
H-Bars, 3-40, 3-141, 3-145
Paired cursors, 3-41, 3-145
V-Bars, 3-40, 3-141, 3-145
Readout, Display menu, 3-28
Real-time sampling, Glossary-8
Rear panel, 2-5, 3-118
Recall, Setups, 3-120–3-122
Recall Factory Setup, Save/Recall Setup menu, 3-121
Recall Saved Setup, Save/Recall Setup menu, 3-121

P6205 Active Probe, 1-3
Packaging, A-21
Paired cursor, 2-27, 3-15
PAL, Display menu, 3-29
Palette, Color menu, 3-11
Parity, Utility menu, 3-58
Passive voltage probes, 3-102–3-103
Pattern trigger, 3-75, 3-79
Pattern, Main Trigger menu, 3-77
PCX, 3-57
PCX Color, Hardcopy menu, 3-59
PCX, Hardcopy menu, 3-59
Peak to peak, 3-84, Glossary-6
Period, 3-85, Glossary-6
Persistence, 3-27
Persistence Palette, Color menu, 3-11
Phase, 3-84, Glossary-7
Phase suppression, 3-48
Phaser Color Printer, 3-57
Pixel, Glossary-7

Index-8
Recalling, Waveforms, 3-123
Record length, 1-1, 2-19, 3-68, Glossary-8
derivative math waveforms, 3-139
integral math waveforms, 3-143
Record Length, Horizontal menu, 3-68
Record View, 2-6, 2-22, 3-67, 3-134
Rectangular window, 3-38
Ref, Color menu, 3-13
Ref1, Ref2, Ref3, Ref4, File, Save/Recall Waveform menu, 3-124
Ref1, Ref2, Ref3, Ref4, Reference waveform status, 3-124
Reference levels, 1-20, 3-89
Reference Levels, Measure menu, 3-89
Reference memory, Glossary-8
Reject Glitch, Main Trigger menu, 3-112
Remote communication, 3-116-3-119
Remove Measmnt, Measure menu, 3-87, 3-93
Rename, File Utilities menu, 3-54
Reset All Mappings To Factory, Color menu, 3-14
Reset All Palettes To Factory, Color menu, 3-14
Reset Current Palette To Factory, Color menu, 3-14
Reset to Factory Color, Color menu, 3-12
Reset Zoom Factors, Zoom menu, 3-153
Restore Colors, Color menu, 3-14
Ring Bell if Condition Met, Acquire menu, 3-73
Rise time, 1-19, 3-85, Glossary-8
Rising edge, Delayed Trigger menu, 3-24
Rising edge, Main Trigger menu, 3-34, 3-81
RLE Color, Hardcopy menu, 3-59
RMS, 3-85, Glossary-8
RS-232, 2-5
RS-232, Port, 3-59
RS232, Utility menu, 3-58
RUN/STOP, Acquire menu, 3-6
Runt trigger, 3-109, 3-110, 3-113, Glossary-8
Runt, Main Trigger menu, 3-113
Select Measmnt, Measure menu, 3-86, 3-90
Selected waveform, Glossary-8
Select Function to, More menu, 3-150
Select 2nd Source to, More menu, 3-150
Set Function to, More menu, 3-149
SET LEVEL TO 50% button, 3-133
Set Levels in % units, Measure menu, 3-89
Set operator to, More menu, 3-150
Set Single Source to, More menu, 3-149
Set Thresholds, Main Trigger menu, 3-78
Set to 10%, Horizontal menu, 3-68
Set to 50%, Delayed Trigger menu, 3-25
Set to 50%, Horizontal menu, 3-68
Set to 50%, Main Trigger menu, 3-34, 3-113, 3-133
Set to 90%, Horizontal menu, 3-68
Set to ECL, Delayed Trigger menu, 3-24
Set to ECL, Main Trigger menu, 3-34, 3-112
Set to TTL, Delayed Trigger menu, 3-24
Set to TTL, Main Trigger menu, 3-34, 3-112
Set to Zero, Vertical menu, 3-138
Setting Up for the Examples, 1-7
Settings, Display menu, 3-10, 3-26
Setup menu, 1-8
Setups, Save and recall, 3-120-3-122
Shipping, A-21
Side menu, Glossary-9
Side menu buttons, 2-3, Glossary-9
SIGNAL OUTPUT, BNC, 2-5
Signal Path Compensation, 1-3, 3-128-3-129
Sin(x)/x interpolation, 2-20, 3-29, Glossary-5


Index-9
Sin(x)/x interpolation, Display menu, 3-29

Single Acquisition Sequence, Acquire menu, 3-7

SINGLE TRIG button, 3-7, 3-133

Single Wfm Math, More menu, 3-149

Slope, Glossary-9

Slope, Delayed Trigger menu, 3-24

Slope, Main Trigger menu, 3-34

Slope, Trigger, 2-17

Snapshot, Readout, 3-92

Snapshot of Measurements, 1-22, 3-92

Snapshot, Measure menu, 3-93

Soft Flagging, Utility menu, 3-58

Software, 1-1

Software Setup, Utility menu, 3-58

Software version, 3-130

Source, Delayed Trigger menu, 3-24

Source, Main Trigger menu, 3-32, 3-111, 3-113

Spectral, Color menu, 3-11

Spooler, Hardcopy, 3-60

Start up, 1-3

State trigger, 3-81

State, Main Trigger menu, 3-77, 3-81

STATUS button, 3-130

Status menu, 2-10, 3-130–3-131

Display, 3-130

Firmware version, 3-130

I/O, 3-130

System, 3-130

Trigger, 3-130

Waveforms, 3-130

Stop After Limit Test Condition Met, Acquire menu, 3-73

Stop After, Acquire menu, 3-6, 3-73

Stop Bits, Utility menu, 3-58

Style, Display menu, 3-26

Switch, principal power, 1-5, 2-5

System, Status menu, 3-130

System, Utility menu, 3-58, 3-118

Talk/Listen Address, Utility menu, 3-118

Tek Secure, 3-121, Glossary-9

Tek Secure Erase Memory, Utility menu, 3-121

Temperature compensation, 3-128–3-129

Temperature, Color menu, 3-11

Template Source, Acquire menu, 3-70

Text/Grat, Display menu, 3-27

Thinkjet, 3-57

Thinkjet, Hardcopy menu, 3-59

Thresholds, Main Trigger menu, 3-113

TIFF, 3-57

TIFF, Hardcopy menu, 3-59

Time base, Glossary-9

Time Base, Horizontal menu, 3-21, 3-67

Time Units, Cursor menu, 3-19

Time-to-voltage converter, 3-106

TOGGLE button, 3-18

Tracking Mode, Cursor, 2-28

Tracking, Cursor menu, 3-18

Trigger, 2-13–2-18, 3-8, Glossary-9

AC Line Voltage, 2-14

Auxiliary, 2-14

Coupling, 2-16

Delay, 2-18

Delayed, 3-20–3-25

Edge, 2-14, 3-32, Glossary-3

Glitch, 3-109, 3-110, Glossary-4

Holdoff, 2-15

Level, 2-17, Glossary-9

Logic, 2-14, 3-75–3-82

Mode, 2-14

Pattern, 3-75, 3-79

Position, 2-17, 3-68

Pulse, 2-14, 3-109

Readout, 3-134

Runt, 3-109, 3-110, 3-113, Glossary-8

Slope, 2-13, 2-17

Source, 2-17

State, 3-81

Status Lights, 3-133

Types, 3-135

Video, 2-14

Width, 3-109, 3-115

Trigger Bar, 2-6

Trigger Bar Style, Display menu, 3-28

Trigger Level Bar, Readout, 3-28

Trigger MAIN LEVEL knob, 1-12, 2-17, 3-132

TRIGGER MENU button, 3-32, 3-77, 3-111, 3-113, 3-135

Trigger Point, Readout, 3-28

Trigger Position, Horizontal menu, 3-68

Trigger Status Lights, 3-133

Trigger When, Main Trigger menu, 3-78, 3-80

Trigger, Status menu, 3-130

True for less than, Main Trigger menu, 3-80

True for more than, Main Trigger menu, 3-80

Type, Main Trigger menu, 3-32, 3-111, 3-113, 3-135

Undershoot, Glossary-6

user, Saved setup status, 3-120

UTILITY button, 3-58, 3-118

Utility Menu

OK Erase Ref & Panel Memory, Glossary-9

Tek Secure Erase Memory, 3-121

Utility menu, 2-11, 3-58, 3-118

Baud Rate, 3-58

Configure, 3-58, 3-118

GPIB, 3-58, 3-118

Hard Flagging, 3-58

Hardcopy, 3-118
Hardcopy (Talk Only), 3-58
Hardware Setup, 3-58
I/O, 3-58, 3-118
Off Bus, 3-118
Parity, 3-58
Port, 3-58, 3-118
RS232, 3-58
Soft Flagging, 3-58
Software Setup, 3-58
Stop Bits, 3-58
System, 3-58, 3-118
Talk/Listen Address, 3-118

Vertical Readout, 3-136
Vertical SCALE knob, 3-136
VGA Output, 2-5
Video Line Number, Cursor menu, 3-19
Video Trigger, Option 5, 4-2
Video trigger, 2-14
View Palette, Color menu, 3-11

WARNING, statement in manual, xi
Waveform, Glossary-9
Interval, Glossary-9
Math, 3-148–3-150
Off priority, 3-127
Waveform clipping. See Clipping
Waveform differentiation, 3-139
Waveform FFTs, 3-36
Waveform integration, 3-143
Waveform memory, 3-124
WAVEFORM OFF button, 1-17, 3-30, 3-127
Waveform record
FFT, 3-42
FFT frequency domain, 3-42
length of, 3-42
FFT source, 3-42
acquisition mode, 3-45
defined, 3-42
long versus short, 3-45
FFT time domain, 3-42–3-52
Waveform, Display menu, 3-27
Waveforms, Math, 3-148
Waveforms, Status menu, 3-130
Width, 1-19, Glossary-6, Glossary-7
Width trigger, 3-109, 3-115
Width, Main Trigger menu, 3-112
Window, 3-49
Blackman-Harris, 3-39, 3-49, 3-52
characteristics of, 3-51
Hamming, 3-39, 3-49, 3-52
Hanning, 3-39, 3-49, 3-52
rectangular, 3-38, 3-49, 3-52
rectangular vs. bell-shaped, 3-51
selecting, 3-49
Windowing, process, 3-49
Windows, descriptions of, 3-38–3-39

X

XY, Format, 3-29–3-31
XY format, Glossary-9
XY, Display menu, 3-30

Y

YT, Format, 3-29–3-31
YT format, Glossary-9
YT, Display menu, 3-30

Z

Zero phase reference point, 3-42, 3-47
establishing for impulse testing, 3-47–3-52
Zoom, 3-151–3-154
derivative math waveforms, 3-142
on FFT math waveforms, 3-45
on integral math waveforms, 3-147
ZOOM button, 3-151
Zoom feature, 2-25
Zoom menu
Reset Zoom Factors, 3-153
Zoom Off, 3-153
Zoom Off, Zoom menu, 3-153