HP 54503A Digitizing Oscilloscope

Front-Panel Operation

HEWLETT PACKARD

Publication 54503-90901

Printed in the U.S.A. July 1989

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Safety This product has been designed and tested according to International Safety Requirements. To ensure safe operation and to keep the product safe, the information, cautions, and warnings in this manual must be heeded.

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Appendix B:

Specifications and Characteristics

Introducing the HP 54503A 1

Introduction

The HP 54503A Digitizing Oscilloscope is a general purpose, 500 MHz bandwidth oscilloscope. The HP 54503A has four channels with full sensitivity. Full HP-IB programmability has been incorporated into the HP 54503A for use in a broad range of HP-IB applications, from high-speed ATE to device characterization in research and developement applications.

The HP 54503A features an easy-to-use human interface, yet has many sophisticated capabilities and multiple triggering functions. Waveforms are easily strored for future reference, waveform measurements are automatic, and instant hardcopy can be made when the HP 54503A is teamed with an HP-IB compatible printer or HP-GL plotter.

Some of the key features of the HP 54503A 500 MHz Digitizing Oscilloscope are listed below. A complete list of specifications and operating characteristics are listed in appendix B of this manual.

- Repetitive bandwidth - dc to 500 MHz
- Single shot bandwidth - 2 MHz (2 channels, simultaneous)
- Sample rate - 20 Megasamples/second
- Four channel input and display
- Maximum vertical sensitivity - 1 mV/division
- Minimum vertical sensitivity - 5 V/division
- Vertical resolution (A/D) - 8 bits
- Autoscale for automatic setup
- Automatic measurements, with user definition and statistics
- Hardcopy output
- Measurement limit test
- Waveform math (+ , -, x, vs, invert, only)
- Waveform Record Length - 1024 points (HP-IB) 501 points (display)
- Four nonvolatile set-up memories

- Four nonvolatile waveform memories
- Two volatile pixel memories
- Dual timebase windowing
- Advanced logic triggering (including 1.5 ns glitch trigger)
- TV triggering
- Pre- and post-trigger viewing capability
- ECL/TTL presets

Instrument Setup 2

Introduction

This chapter contains information for unpacking, applying power, and connecting optional accessories to the HP 54503A. Inspection, power requirements, and instruction for running the HP 54503A selftest for performance verification are also included in this chapter.

Initial Inspection

Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, keep it until the contents of the shipment have been checked. Check the shipment for completeness and the instrument electrically and mechanically.

If the contents are incomplete, there is mechanical damage or defect, or if the instrument does not pass the selftest performance verification, notify the nearest Hewlett-Packard Office. Keep the shipping materials for carrier's inspection. The Hewlett-Packard Office will arrange for repair or replacement at HP option without waiting for claim settlement.

Contents of Shipment

The following items are shipped with the HP 54503A Digitizing Oscilloscope:

- Two HP 10430A Probes
- Probe to BNC Adapter, 1250-1454
- One Power Cord
- *HP 54503A Getting Started Guide*
- *HP 54503A Front-Panel Reference*
- *HP 54503A Programming Reference*
- *HP 54503A Service Manual*
- *Feeling Comfortable with Digitizing Oscilloscopes (A Guide to Technology)*

Available Accessories

The following optional accesories are available for use with the HP 54503A:

- Carrying Case, HP Part Number 1540-1066
- Rack Mount Kit, HP Part Number 5061-6175
- HP 10100C 50 Ω Feedthrough Terminator
- HP 1133A TV/Video Sync Pod
- HP 10024A Integrated Circuit 16-pin Test Clip
- HP 10211A Integrated Circuit 24-pin Test Clip
- PC Board Horizontal Mini Probe Socket, HP Part Number 1250-1737
- PC Board Vertical Mini Probe Socket, HP Part Number 1250-1918
- HP 10437A 1:1 Probe
- HP 10438A 1:1 Probe (1 meter)
- HP 10439A 1:1 Probe (2 meter)
- HP 10002A 50:1 1 MΩ (1000V peak) Probe
- HP 1137A High Voltage 1000:1 Divider Probe
- HP 10200A Resistive Divider Probe Kit
- BNC to Miniature Probe Adapter, HP Part Number 1250-1454
- HP 10240B BNC Blocking Capacitor
- HP 11094B 75Ω Feedthrough Termination
- HP 5061-6183 Front Panel Cover

Operating Environment

The HP 54503A oscilloscope is operated in a normal lab or bench environment without any additional considerations. Note the non-condensing humidity limitation in the list of characteristics supplied in this manual. Condensation in the instrument cabinet can cause poor operation or malfunction. Protection should be provided against temperature extremes which cause condensation.

Storage and Shipping

The HP 54503A may be stored or shipped in environments with the following limitations:

- Temperature: -40° C to +75° C
- Humidity: Up to 90% at 65° C
- Altitude: Up to 15,300 meters (50,000 feet)

If the HP 54503A is to be shipped to a Hewlett-Packard Service Center for service or repair, attach a tag to the instrument identifying owner, address of owner, complete instrument model number and serial number and a description of required service.

If the original packaging material is no longer available, identical packing material is available through local Hewlett-Packard offices. Mark the container FRAGILE to ensure careful handling. In any correspondence, refer to the instrument by the model and serial number.

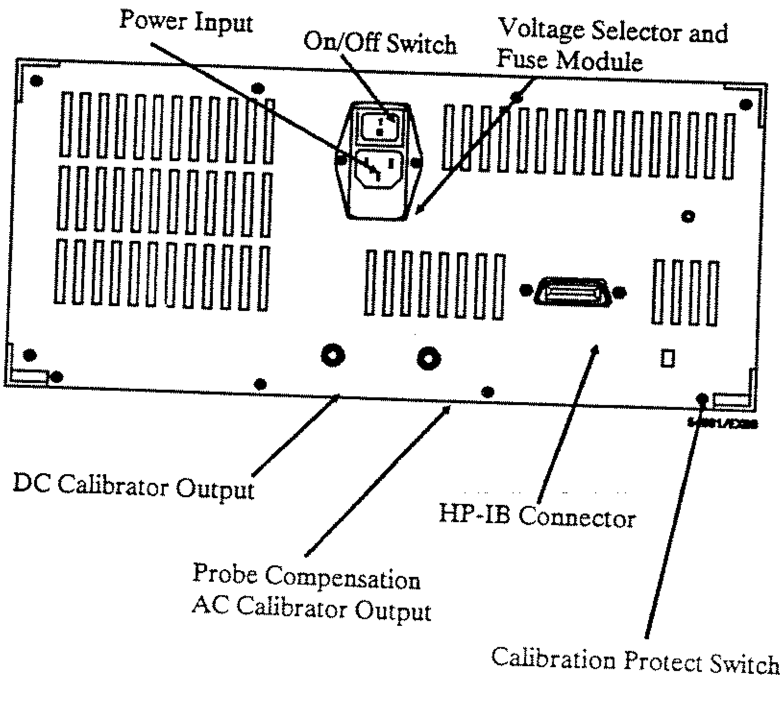


Figure 2-1. HP 54503A Rear Panel

Rear Panel

The rear panel of the HP 54503A contains the power input, voltage selector module, power switch, external connectors, and calibrator protection switches as shown in figure 2-1.

Power Requirements

The HP 54503A requires a power source of either 115 or 230 Vac, -22% to +10%; single phase, 48 to 66 Hz; 200 Watts maximum power.

Selecting Line Voltage

The fuse module has been set at the factory to the line voltage used in the country of destination. Check the setting of the fuse module to verify it is in the correct position for the voltage to be used. If the setting needs to be changed, use the following procedure.

CAUTION

BEFORE APPLYING POWER TO THE INSTRUMENT,BE SURE THE FUSE MODULE IS SET TO THE CORRECT LINE VOLTAGE POSITION. Severe damage will occur if the line voltage is not properly set.

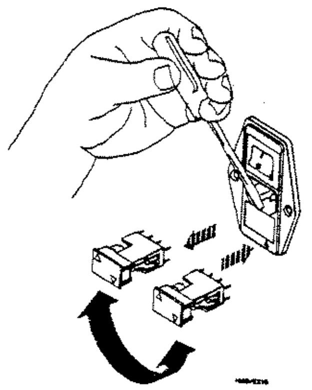


Figure 2-2. Selecting Line Voltage

Change the fuse module position by pulling the fuse module out and reinserting it with the appropriate arrows aligned.

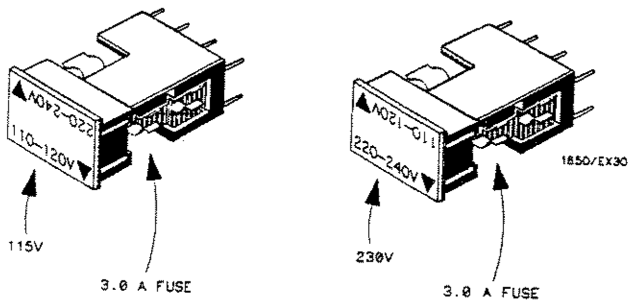


Figure 2-3. Checking for the Correct Fuse

- Carefully pry at the top center of the module as shown, until it can be grasped and pulled out.

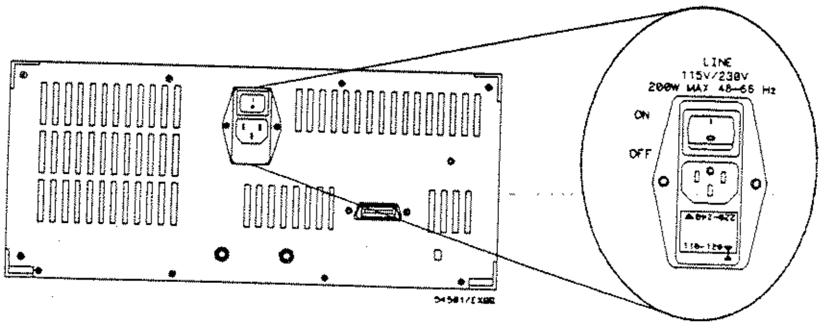
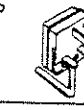
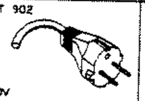
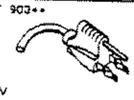
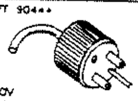
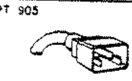
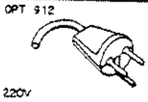
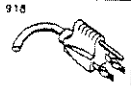


Figure 2-4. Line Switch

PLUG TYPE	CABLE PART NO.	PLUG DESCRIPTION	LENGTH IN/CM	COLOR	COUNTRY
OPT 900  250V	8120-1351 8120-1703	Straight *BS1363A 90°	90/228 90/228	Gray Mint Gray	United Kingdom, Cyprus, Nigeria, Zimbabwe, Singapore
OPT 901  250V	8120-1369 8120-0696	Straight *NZSS198/ASC 90°	79/200 87/221	Gray Mint Gray	Australia New Zealand
OPT 902  250V	8120-1689 8120-1692 8120-2857	Straight *CEE7-Y11 90° Straight (Shielded)	79/200 79/200 79/200	Mint Gray Mint Gray Coco Brown	East and West Europe, Saudi Arabia, So. Africa, India (Unpolarized in many nations)
OPT 903**  125V	8120-1378 8120-1521 8120-1992	Straight *NEMA5-15P 90° Straight (Medical) UL544	90/228 90/228 96/244	Jade Gray Jade Gray Black	United States, Canada, Mexico, Phillipines, Taiwan
OPT 904**  250V	8120-0698	Straight *NEMA6-15P	90/228	Black	United States, Canada
OPT 905  250V	8120-1396 8120-1625	CEE22-V1 (System Cabinet Use) 250V	30/76 96/244	Jade Gray	For interconnecting system components and peripherals. United States and Canada only
OPT 906  250V	8120-2104 8120-2296	Straight *SEV1011 1959-24507 Type 12 90°	79/200 79/200	Mint Gray Mint Gray	Switzerland
OPT 912  220V	8120-2956 8120-2957	Straight *DHCK107 90°	79/200 79/200	Mint Gray Mint Gray	Denmark
OPT 917  250V	8120-4211 8120-4600	Straight SABS164 90°	79/200 79/200	Jade Gray	Republic of South Africa India
OPT 918  100V	8120-4753 8120-4754	Straight Miti 90°	90/230 90/230	Dark Gray	Japan

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*Part number shown for plug is industry identifier for plug only. Number shown for cable is HP part number for complete cable including plug.
**These cords are included in the CSA certification approval of the equipment.
E=Earth Ground
L=Line
N=Neutral

Figure 2-5. Available Power Cords

Verifying the Fuse If it is necessary to check or change fuses, remove the fuse module and look at each fuse for its amperage and voltage ratings.

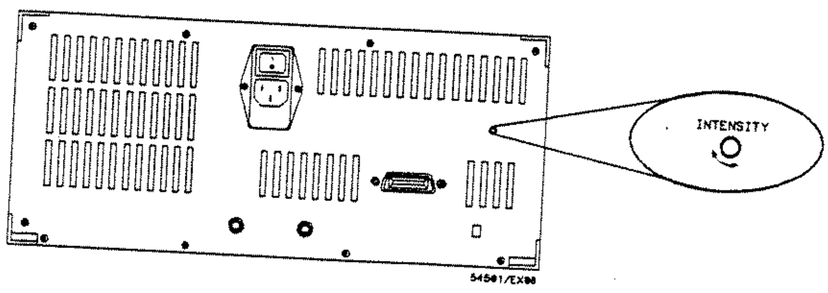


Figure 2-6. Intensity Control

Power Cord The HP 54503A is a Safety Class 1 instrument with an exposed chassis that is directly connected to earth via the power supply cord to meet IEC Standard 348. This instrument is provided with a three-wire power cable. When connected to an appropriate AC power outlet, this cable grounds the instrument cabinet. The type of power cable plug shipped depends on the country of destination. See figure 2-5 for available power cords.

Line Switch The line switch is located on the rear panel. Turn on the oscilloscope by pressing 1 on the rocker switch. The rocker switch is labelled 1 and 0, corresponding to on and off.

Intensity Control Once the oscilloscope has been turned on, the display intensity can be adjusted, if necessary. The intensity is adjusted with the Display Intensity control on the rear panel.

Air Flow Requirements The HP 54503A must have an unrestricted airflow for the fan and ventilation openings in the rear panel. The HP 54503A may be stacked under, over, or between other instruments provided the the other instruments are adequately cooled.

Connecting External Equipment

The HP 54503A is equipped with an HP-IB connector on the rear panel. This is a direct connection to an HP-IB compatible printer, plotter, or external controller.

Connect an HP-IB cable to the oscilloscope and any HP-IB compatible device. Tighten the HP-IB cable with the captive screws of the cable to eliminate the potential of an inadvertant disconnection.

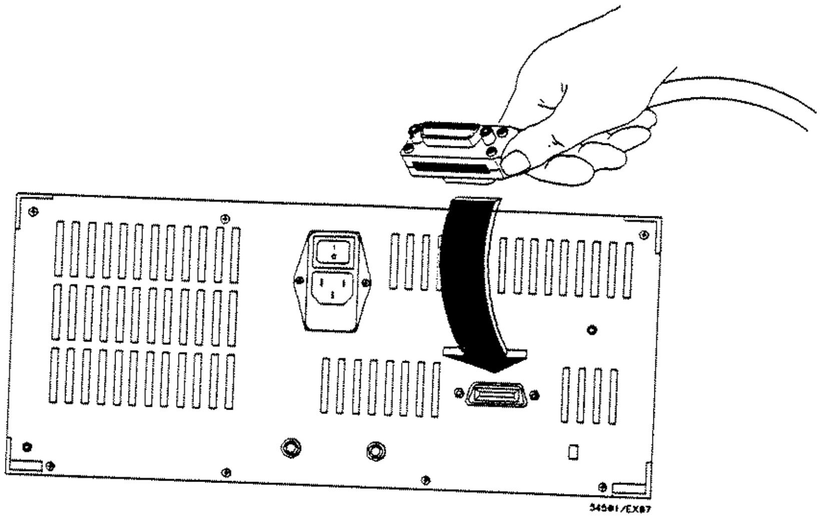


Figure 2-7. Connecting External Equipment

The HP 54503A must be properly addressed to communicate with the connected device. The HP 54503A HP-IB address is set in the HP-IB submenu. See Chapter 12 for detailed information about the HP-IB submenu.

Front Panel Overview 3

Introduction to the Front Panel

This chapter describes the functional sections of the HP 54503A front panel. The explanation of each area also contains their interaction with each other and provide a basis for applications and usages.

The HP 54503A front panel is separated into six functional areas.

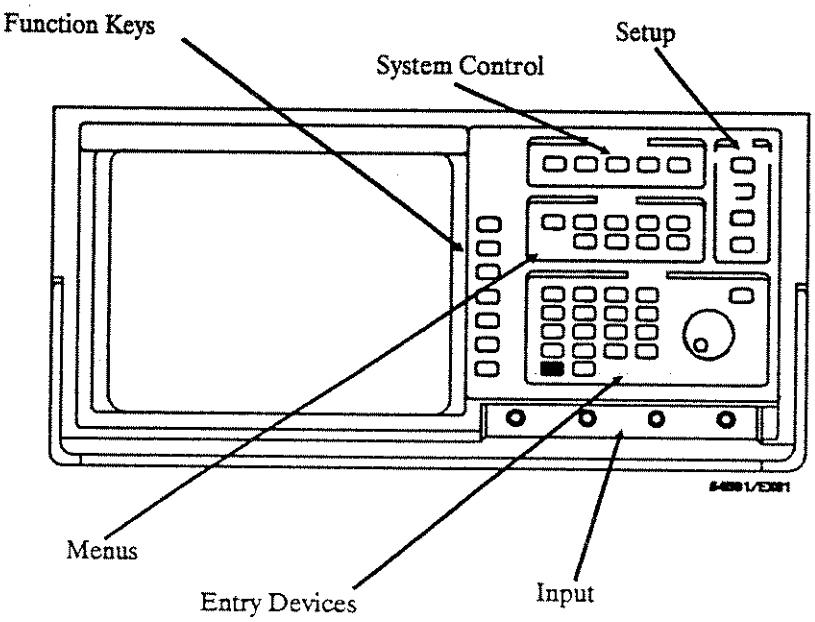


Figure 3-1. HP 54503A Front Panel

System Control

The SYSTEM CONTROL keys are located along the top of the oscilloscope to the right of the CRT. This section controls the following functions:

- Dynamic display features
- Selecting local control
- Activating hardcopy

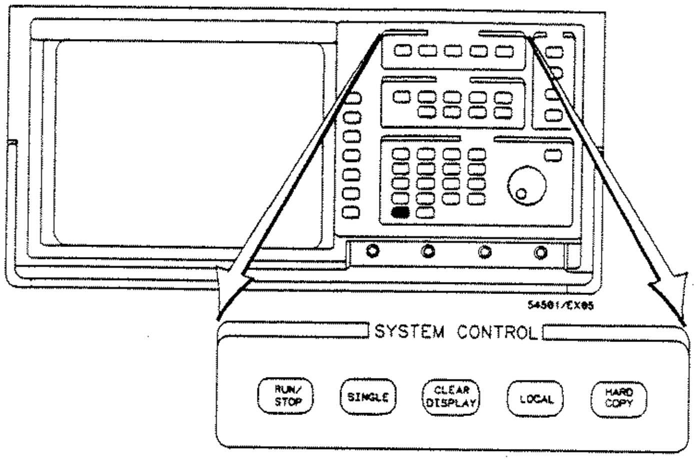


Figure 3-2. System Control Section

Selection of any key in the SYSTEM CONTROL section causes the oscilloscope to execute that command immediately.

RUN/STOP Key

The RUN/STOP key toggles the acquisition status of the HP 54503A. If the oscilloscope is currently running (current status is displayed in the top left corner of the CRT in the message field) the instrument is placed in the **stopped** mode. In this mode, normal acquisition is stopped and the last acquired data is displayed. If the oscilloscope is stopped, it is immediately changed to another mode (**running**, **awaiting trigger**, **auto-trigger**, etc).

SINGLE Key The SINGLE key activates the acquistion system for one trigger event. One acquisiton is made, displayed and then the data acquisition and display cycle is stopped. This single acquistion is superimposed on the current displayed data. If the display has been cleared before the SINGLE key is pressed, only one acquisition is displayed.

CLEAR DISPLAY Key The CLEAR DISPLAY key clears the display and resets all associated measurements. If the oscilloscope is in the stopped mode, all data that is currently displayed is be erased. If the oscilloscope is **running**, all data is erased, however, new data is displayed on the next acquisition. The RUN/STOP and SINGLE keys are not affected.

The RUN/STOP, SINGLE, and CLEAR DISPLAY keys have a relationship that make it possible to manipulate data acquisitions and view one, two, or several acquisitions. It is possible to stop acquiring, clear the display and capture one acquisition for evaluation. The display can be cleared while acquiring to capture new data. When acquisitions are manipulated with these three keys other keys and settings are not affected.

LOCAL Key The LOCAL key sends a return to local control message to the HP-IB interface and returns control to the front panel. This key can be locked out if a local lockout command is executed over the HP-IB.

This is the only active front panel key while the oscilloscope is in remote operation, if it has not been locked out.

HARDCOPY Key The HARDCOPY key executes an immediate hardcopy of the currently displayed data on a compatible graphics printer or plotter and stops all other oscilloscope functions while the hardcopy is in progress.

The oscilloscope must be in talk only, and the printer must be in listen always. Setup of the hardcopy options are accessed in the HP-IB submenu (see Chapter 12, "Utility Menu.").

Selection of any key will abort the hardcopy action.

Setup

The SETUP section of the front panel controls subsystems for proper display of input data. This section controls display information:

- AUTOSCALE for automatic scaling of the waveform display area
- SAVE and RECALL setups
- Quick access to channel, function, and trigger information on the SHOW screen.

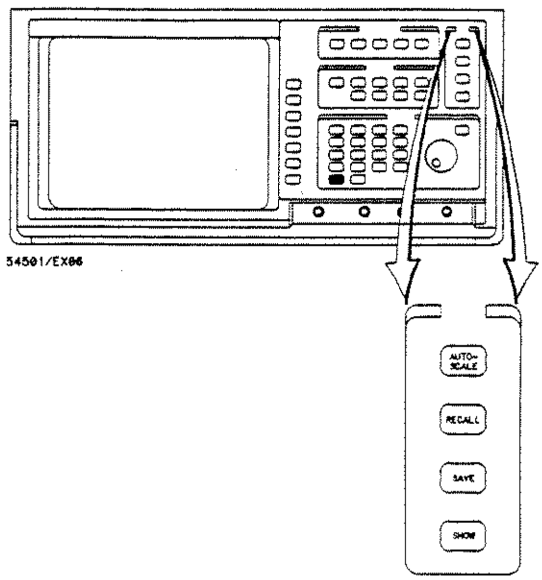


Figure 3-3. Setup Section

AUTOSCALE Key This key causes the oscilloscope to evaluate all input signals and set the correct conditions to display the signals. When AUTOSCALE is pressed the following conditions are set:

- Vertical sensitivity on all channels
- Vertical offset on all channels
- Sets trigger to edge mode with minimum persistence, holdoff, positive slope, and proper trigger level for the trigger source
- Sets time base for approximately 1 full period of the input signal

In addition, AUTOSCALE includes a soft reset:

- Sets oscilloscope to auto trigger mode of acquisition
- Displays the correct number of screens
- Turns Δt/ΔV markers off
- Turns all measurements off
- Turns measurement limit test off
- Turns waveform math functions off
- Turns timebase window off
- Turns waveform/pixel memory display off
- Turns measurement limit test off
- Turns connect-the-dots off
- Displays SHOW menu

The previous oscilloscope settings are stored in volatile memory RECALL 0. To recall settings, press RECALL 0.

RECALL Key The RECALL key has three primary functions:

- By pressing the RECALL key and then selecting 1, 2, 3, or 4, the HP 54503A executes a recall of a previously saved setup configuration.

- The oscilloscope automatically saves the current configuration before executing an autoscale, recall, or setting up ECL/TTL presets. RECALL 0 is an undo of these actions. You cannot save to RECALL 0.

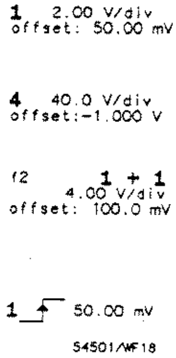
- RECALL CLEAR executes an instrument reset and returns the HP 54503A to default/power-up settings. The oscilloscope does not perform power-up self-tests (see Instrument Reset, in this chapter).

SAVE Key

The SAVE key immediately stores the oscilloscope setup configuration in volatile memory. Press SAVE, and then select a save register: 1, 2, 3, or 4. An advisory is displayed above the waveform display area indicating the setup configuration has been saved.

SHOW Key

The SHOW key displays the following information:



- Channel scaling
- Channel offset
- Channel coupling
- Probe attenuation
- Math function operation
- Math function scaling
- Math function offset
- Memories
- Trigger source
- Trigger level

The SHOW key toggles between the currently selected menu and the SHOW screen (as illustrated).

This screen presents the most complete and detailed instrument setup information. Select this screen before making a hardcopy and all SHOW screen information is included on the hardcopy.

Menus

The MENUS section consists of nine keys:

- TIMEBASE
- CHANNEL
- TRIG
- DISPLAY
- Δt/ΔV
- WFORM MATH
- WFORM SAVE
- DEFINE MEAS
- UTIL

Each of these menus is discussed in the following chapters.

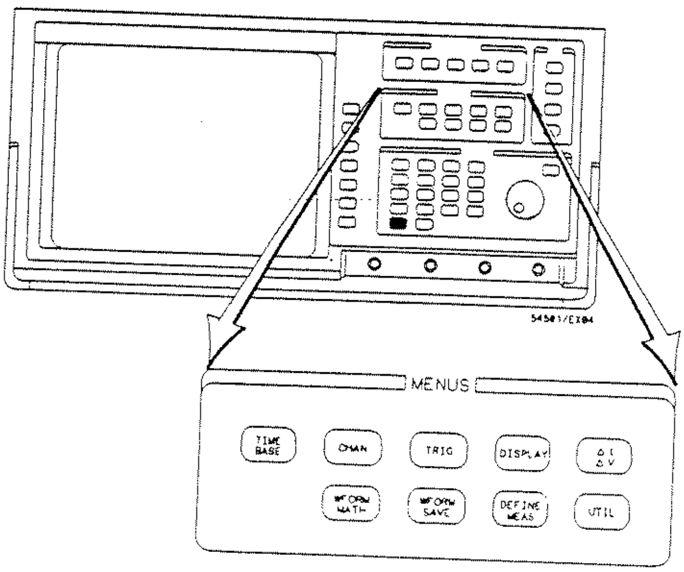


Figure 3-4. MENUS Section

Entry

The ENTRY devices are a multi-function numeric keypad, a selection knob, and a FINE key.

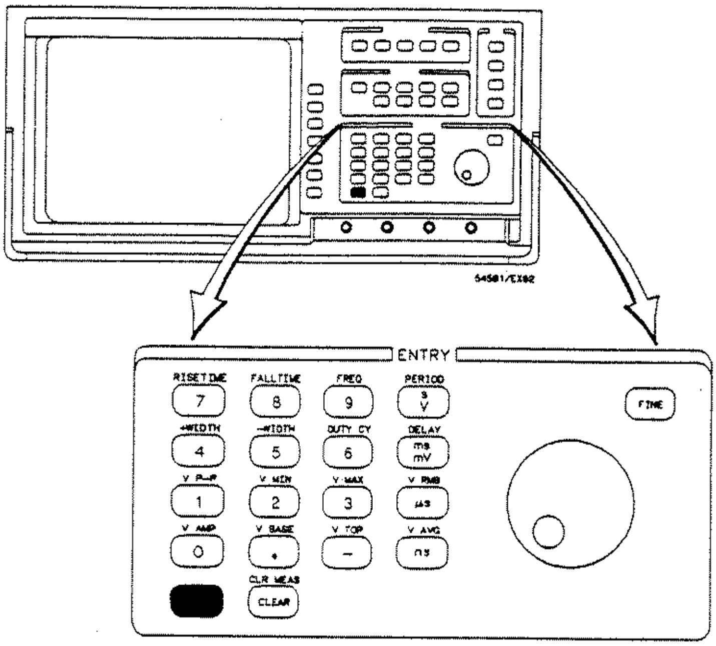


Figure 3-5. ENTRY Section

Numeric Keypad

The keys on the numeric keypad are for direct numeric input. To input known values directly, press the associated softkey to activate the desired field on screen, and then select the units with the numeric keys. For example, to set the vertical sensitivity to 500 mV:

- Ensure V/div in the Channel menu is the active field (displayed in fullbright)
- Press **5**, **0**, **0**, **mv** on the numeric keypad.

The blue key on the numeric keypad selects the alternate function when pressed before the key. The CLEAR key clears any selections made for the active field.

Knob The knob changes values within each function. It increments, decrements, or toggles the selection in the active field or function. The current selection displayed in full-bright in the displayed menu area can be changed with the knob.

FINE Key The FINE key changes the increment and decrement sequence. Instead of sequencing in the normal sequence, the values increment/decrement in more precise values. Use this feature when the normal sequence is too coarse for precision measurements or settings.

When the HP 54503A is operating in the fine mode, the word **fine** is displayed in the lower right corner of the CRT.

Input

The input section consists of connectors for signal input. All inputs have a nominal 1 MΩ input impedance shunted by approximately 7 pF at the input BNC and a maximum tolerance of 250 V.

Channels 1 through 4 are full-range channels. Use channels 1 and 2 or 3 and 4 if continuous dual channel acquisition.

Display

The display section contains the screen and menu softkeys.

The vertical column on the right side of the screen is the function display. The functions that are displayed at any one time correspond to a key in the function key column. These keys select any function or field that is displayed in half-bright.

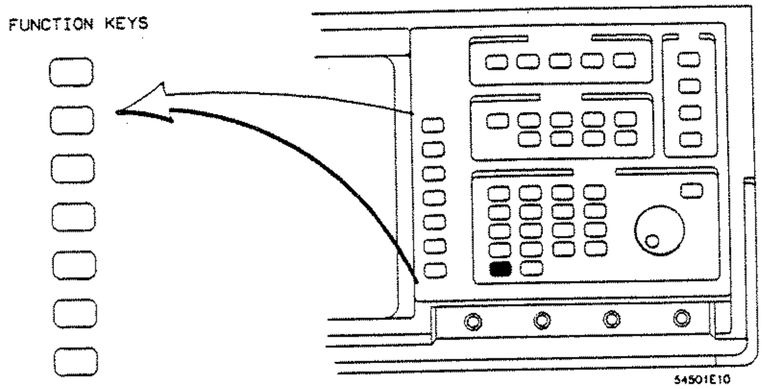


Figure 3-6. Function Keys

- Numeric key fields displayed in full-bright are changed by either numeric keys on the keypad or the knob. When these functions are not active, they are displayed in half-bright; when displayed in full-bright they are active.

- Non-numeric fields displayed in half-bright toggle with the corresponding function key. These fields are displayed in half-bright, but are active for the function keys.

Instrument Reset

The HP 54503A has two methods of instrument reset.

- Key-down power up is a hard reset of the oscilloscope. It is done by pressing and holding any front panel key while cycling power. If input signals are not present, the oscilloscope will power-up displaying a baseline in the SHOW screen and set to all default settings (see Table 3-1).

- RECALL CLEAR performs a soft reset of the oscilloscope. All default conditions are set (see Table 3-1). RECALL CLEAR is the same as a key-down power-up except that the the previous menu selections are retained.

Table 3-1. Reset Default Conditions

Timebase Menu	
reference	cntr
Time/Div	100 µs
delay	0.00 s
timebase window	off
Channel Menu	
Channel 1	on
Channel 2-4	off
Volts/Div	500 mV
offset	0.00
coupling	dc
probe attenuation	1.000:1

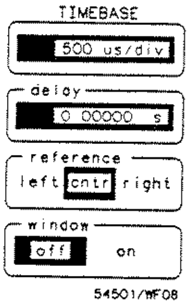
Table 3-1. Reset Default Conditions (continued)

Trigger Menu	
Mode	edge
source	Channel 1
level	0.0 V
slope	positive
holdoff	40 ns
Display Menu	
Mode	norm
persistence	minimum
# of screens	1
off/frame/axes/grid	axes
connect dots	off
Δt/ΔV Menu	
Δt markers	off
ΔV markers	off
Waveform Math Menu	
f1	off
f2	off
chan/mem	chan 1
operator	+
chan/mem	chan 1
function sensitivity	1.00 V/div
function offset	0.0 V
Waveform Save Menu	
waveform/pixel	waveform
nonvolatile	m1
display	off
source	chan 1
Define Meas Menu	
meas/def/limit	meas
continuous	on

Timebase Menu 4

Introduction to the Timebase

This chapter contains a description of the TIMEBASE menu and how the entire horizontal display and parameters are controlled with this menu.



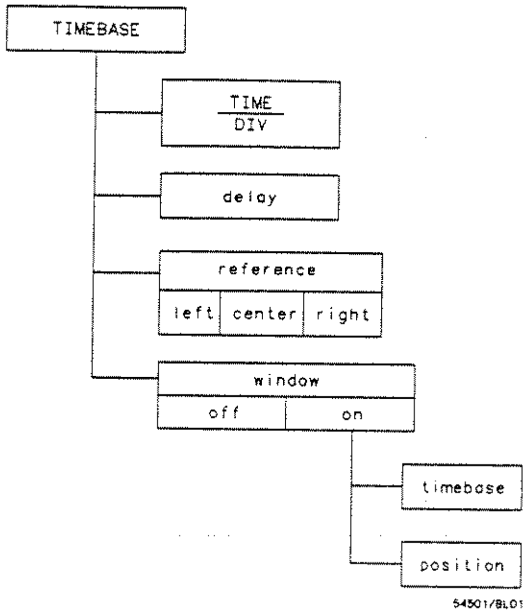


Figure 4-1. Timebase Menu

Time/Div Key

The time/division function controls the sweep speed on the horizontal axis from 200 ps/div to 5 sec/div. The main timebase is incremented and decremented in a 1-2-5 sequence. The FINE key does not affect the timebase settings.

During slow sweep speeds (200 ms/div to 5 sec/div) the acquisition and write cycle changes. At these sweep speeds the oscilloscope needs up to 2.5 seconds to generate a trigger and acquisition, therefore, the displayed data is updated for each data sample. The HP 54503A must accommodate two trigger conditions for acquisition and display:

- *auto triggered scroll* is used in **auto** trigger. The oscilloscope acquires and displays data in the auto triggered scroll mode and displays each data sample as it is acquired. As it samples and displays, a message is displayed at the top left corner of the CRT indicating this acquisition mode. A dot moves across the top of the screen at the point of the waveform where data is being acquired.

- *triggered scroll* is used in the **trig'd** mode, requiring scrolled acquisition. Triggered scroll acquisitions are not displayed until all data is available (similar to normal acquisitons) to display. As data is being sampled the advisory **n s to initialize** is displayed while pre-trigger data is collected and **n s to complete** is displayed while post-trigger data is collected. This message indicates the time needed to complete acquisition where **n** is the remaining time (in seconds, **s**) and countdown continues until the time has elapsed. The advisory **running** is displayed as the write cycle to the screen is executed and displayed data is updated.

If the reference point is set to **left**, the only advisory displayed is **n s to complete** because all data is post-trigger. When right reference is set, all data is pre-trigger and the advisory is **n s to initialize**.

Both entry devices change the time/division sweep speed.

delay Key

Selection of the **delay** function assigns delay as the active function. When delay is set to 0 the trigger event occurs at the delay reference point. Positive delay indicates time after trigger and negative delay indicates time before trigger. Therefore, a delay setting of -50 ns indicates the trigger event occurs 50 ns after the delay reference point.

reference = trigger event + delay

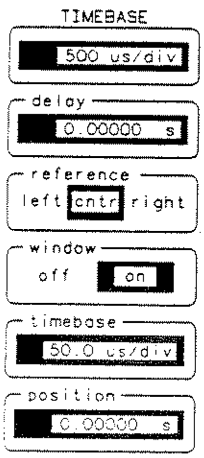
reference Key

The reference key changes the delay reference point to one of three reference points:

- left
- cntr (center)
- right

If delay is set to 0, the reference point consists of pre-trigger data to the left and post-trigger data to the right.

window Key



54501/WF09

The window function turns on an expanded timebase and the oscilloscope is placed in a multiple screen mode. The normal waveform, in the original timebase setting, is displayed in the top screen with markers, vertical dotted lines, that enclose a portion of the displayed waveform. Only the enclosed portion, between the markers, is displayed in the bottom screen.

Note

The displayed timebase information under the waveform display area is windowed timebase information. When the window is on all measurement results and information are windowed information.

Note

The time base window feature of the HP 54503A is fully operational when acquisitions are running. Once the STOP or SINGLE key is pressed, the latest window display is maintained. The window cannot be changed until the RUN key is pressed again. Waveforms stored in the WAVEFORM SAVE MENU cannot be expanded into the window and all screen information and measurement results are based on the main time base.

The window feature is much the same as the delayed sweep on an analog oscilloscope, however with the dual screen, the windowed portion of the wavveform can be viewed simultaneously.

The timebase of the windowed waveform can be varied from equal to the normal timebase to 1/20 of the normal timebase. This equates to 1/2 of a major division.

When the reference position is set to left, only the right window marker moves when the window timebase is changed. When reference is set to right, only the left marker moves, and when center is selected, both markers move. This maintains a specified time reference without changing any timebase settings and the ability to move the reference points for better viewing.

When the window function is enabled, two selections are available for placing and sizing the window:

- Window timebase
- Window position

timebase Key This key is activated only when the window function is turned on and sets the timebase in the window.

As the window timebase is increased the time in the window displayed in the bottom screen is increased. The markers in the top screen move farther apart. When the window reaches full screen the main timebase and the window timebase become equal. As the window timebase is decreased the markers move closer together.

position Key This key is activated only when the window function is turned on.

The window can be placed anywhere on the normal waveform. By adjusting the window position you can see any part of the waveform.

Note

When window timebase = time/division, there is only one possible setting for window position. Turning the knob will have no effect.

Window Exercise

For demonstration on how the window is useful in making measurements and viewing the windowed waveform, perform the following exercise.

Setting the Input Signal

For this exercise use a simulated ECL input signal, a 1 volt, 2 kHz squarewave with adequate offset to display the signal at midscreen.

Set up an HP 8116A Pulse/Function Generator or another signal generator capable of the same signal.

- Mode = NORM
- Set AMP = 1.00 V
- Set FRQ = 2 kHz
- Set DTY = 50%
- Set OFS = -1.20 V
- Set signal to squarewave

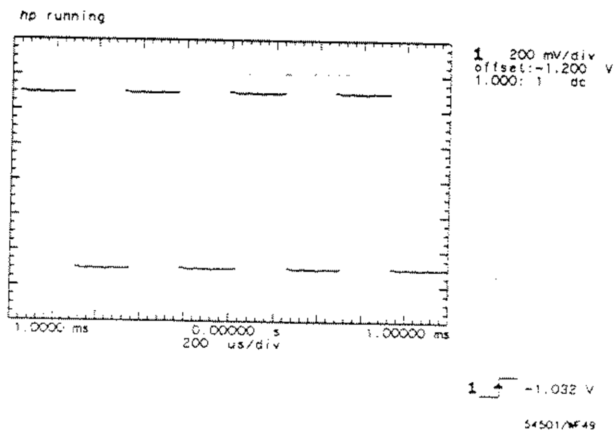


Figure 4-2. Input Signal for Window Viewing

Setting the Oscilloscope

Input this signal to channel 1 on the HP 54503A and disconnect any inputs to any other channel.

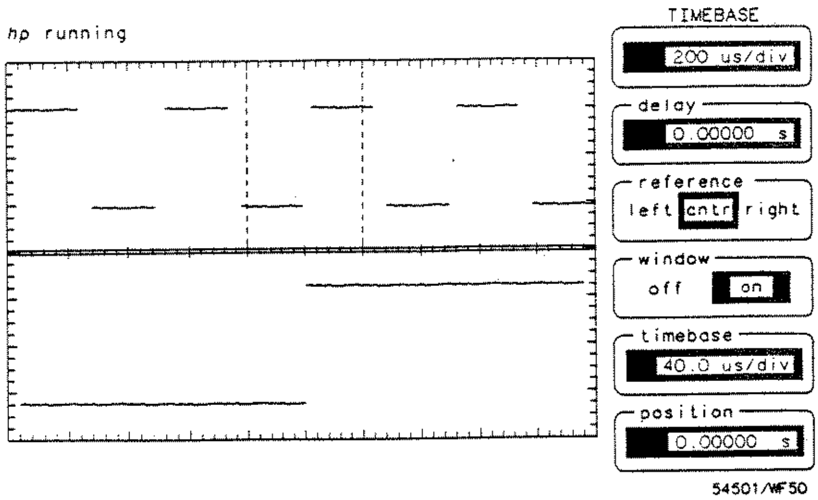


Figure 4-3. Input Signal with Window Turned On

- Press AUTOSCALE (see Figure 4-2).
- Press the TIMEBASE menu key.
- Press the function key to turn on the **window**.
- Set the **window timebase** to 40 **µs/div** (see Figure 4-3).

Note

The timebase factors under the waveform display area have changed to reflect the window.

Viewing the Window

The timebase width in the window is 40 µs (1/20 of 1 ms) with the trigger point at center reference and 0 time delay. The knob has the following actions when these fields are active:

- **time/division field (top)** - the knob changes both timebases and displayed waveforms will change until window timebase equals the normal timebase.

- **delay** - the knob moves the window and waveform sideways while maintaining the same size. This allows viewing of the same section of the waveform at a different point in time. The two timebases will not change.

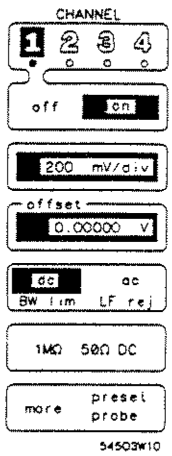
- window **timebase** - the knob changes only the window timebase. The range is from 1/20 of the normal timebase to equal the normal timebase.

- window **position**, as the knob is turned, the window changes position on the normal waveform for viewing different sections of the waveform.

Channel Menu 5

Introduction to Channels

The channel menu controls the vertical operation of the HP 54503A. This chapter describes the use of the four channels, including vertical sensitivity, offset, coupling, attenuation and preset levels.



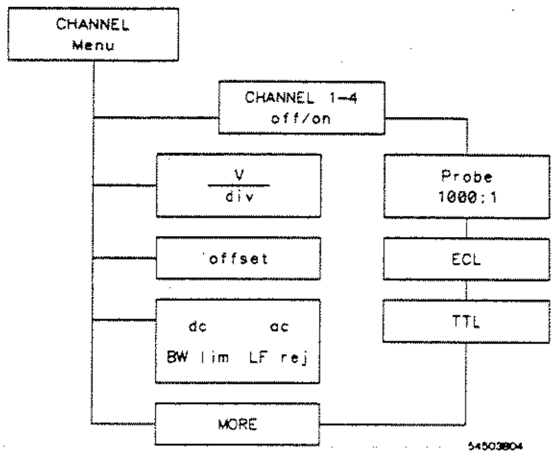


Figure 5-1. HP 54503A Channel Menu

CHANNEL Key

The channel menu is a two level menu. The top key in the channel menu is channel selection. The key toggles channels one through four. When a channel is selected (highlighted in inverse video) it can then be turned on. When a channel is turned on the small circle immediately below the channel number is highlighted.

Note

It is possible to have a channel turned on and view it while being in the vertical control menu of another channel. When making changes, ensure the proper channel and function are selected and the intended channels is being changed.

Vertical Sensitivity Key

The vertical sensitivity key is the third key from the top in the channel menu. The field itself is not labeled, however, the current volts/division is displayed with the units of the current selection. When this function is selected, either of the entry devices can be used for data entry.

The range of the vertical sensitivity for the HP 54503A is from 1 mV/division to 5 V/division. Vertical sensitivity changes in a 1-2-5 sequence in the normal mode or can be changed in the fine mode.

offset Key

When offset is selected, 0 volts is on the vertical midpoint of the display. Offset is the voltage level from mid-screen.

Offset moves the displayed signal up or down, similar to the vertical position adjustment on an analog oscilloscope. However, offset on the HP 54503A has a range of ± 16 divisions from center screen and is calibrated.

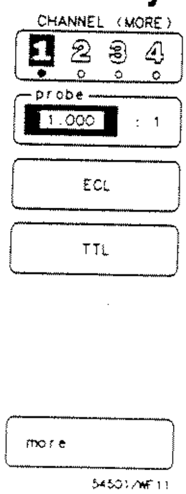
coupling Key

The coupling key has several selection variables:

- ac
- ac bandwidth limit
- dc
- dc bandwidth limit
- LF reject

Bandwidth limit reduces the effective bandwidth to ≈ 30 MHz. It reduces the noise in the display path as well as the trigger path.

more Key



The **more** key toggles the two levels of the channel menu.

probe Key

The probe key selects probe attenuation with a range of 0.9000:1 to 1000:1. Attenuation is adjusted by either knob or entry keypad. When the knob is in coarse mode, adjustments are incremented or decremented in the familiar 1-2-5 sequence. When in fine mode adjustments are in 0.1. increments

Probe attenuation affects scaling factors for the display, not sensitivity at the input.

Attenuation factors are saved with the front panel setup.

ECL Key

The ECL key sets the oscilloscope to levels optimized for ECL circuits:

- V/Div: 200 mV/div
- offset: -1.3 V
- coupling: dc
- Trigger level: -1.3 V
- Trigger slope: no change

RECALL 0 returns the menu to the previous settings.

TTL Key

The TTL key sets the oscillosocpe to levels are optimized for TTL circuits:

- V/Div: 1 V/div
- offset: 2.5 V
- coupling: dc
- Trigger level: 1.4 V
- Trigger slope: no change

To return to the previous settings press RECALL 0.

Trigger Menu 6

Introduction to the Triggers

The trigger modes of the HP 54503A provide many distinctive techniques to trigger and capture data. The triggering capabilities range from simple edge triggering to logic triggering on multiple signals.

This chapter contains descriptions of the triggering modes, explanations on how to use them, and exercises detailing some real life applications. The HP 54503A has five triggering modes:

- edge
- pattern
- state
- delay
- tv

Trigger Mode Interaction

The trigger level (threshold) for each channel is set in the edge trigger mode and is independent for each channel. It is carried over to all other modes, except the tv trigger mode. These levels are important settings because the high and low levels in the pattern, state, and delay modes are greater than or less than the trigger level.

The tv trigger level is a special case and is set in the tv trigger menu.

Edge Trigger Mode

The edge trigger mode has the following selections:

- trig'd/auto
- trigger source
- trigger level
- slope
- holdoff

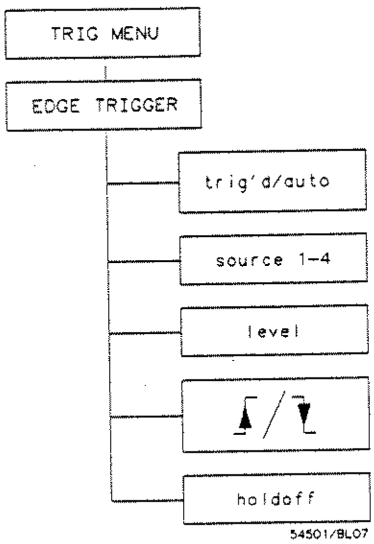
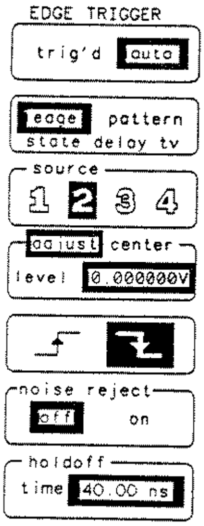


Figure 6-1. Edge Trigger Menu

trig'd/auto Key The trig'd/auto selection toggles between the two trigger modes. The current selection is displayed in inverse video. This field is available in all trigger menus.



54503w11

In the triggered mode, the oscilloscope does not acquire data until all of the trigger requirements are satisfied. In the auto mode the oscilloscope generates a trigger if one is not present. If a trigger is not found, a trigger is generated and acquired data is displayed. A status message is displayed in the upper left corner of the screen.

If the oscilloscope is auto-triggered and the sweep speed is 200 ms/div, 500 ms/div, 1 s/div, 2 s/div, or 5 s/div, it operates in the triggered scroll mode and displays data points as they are acquired (see Chapter 4, "Timebase Menu").

source Key This key selects the trigger source. The options are channels 1-4. The current selection is highlighted in inverse video.

adjust/center Key This key sets the trigger level. The range on this function is ±6 divisions from center. It provides flexibility for setting exact triggering points and specifies levels used in the more sophisticated triggering modes.

slope Key This field is not labeled, however, the available selections are graphic representations of the rising edge and falling edge The current selection is highlighted in inverse video.

noise reject Key Turn the noise reject on for triggering on noisy signals to avoid the problem of false triggering.

holdoff Key Pressing the holdoff key assigns the entry devices to control holdoff. Holdoff disables the trigger circuit for a selectable time period or number of events after the trigger event. Holdoff is selected in time units, from 40 ns to 320 ms, or in number of edges, 2 to 16000000.

Holdoff Exercise

This exercise sets up the oscilloscope and a signal generator to view some of the features of the edge trigger. Holdoff is used to gain a stable trigger. This technique is not necessary for most applications and waveforms, however, for many non-recurring and irregular waveforms it is useful.

Instrument Setup

Follow the instructions for setting up the signal generator. The signal for this exercise is a burst pattern with two positive cycles that repeats every 5 μs. Use an HP 8116A Pulse/Function Generator with the burst option or a signal generator capable of the same signal.

Make the following settings:

- MODE: I.BUR
- RPT: 5.00 μs
- BUR: 2
- FRQ: 1 MHz
- DTY: 50%
- AMP: 1 V
- OFS: -200 mV
- Set the signal for a square wave.

Oscilloscope Setup

Connect the the signal generator to the channel 1 input and disconnect all other inputs.

- Press AUTOSCALE (see Figure 6-2).

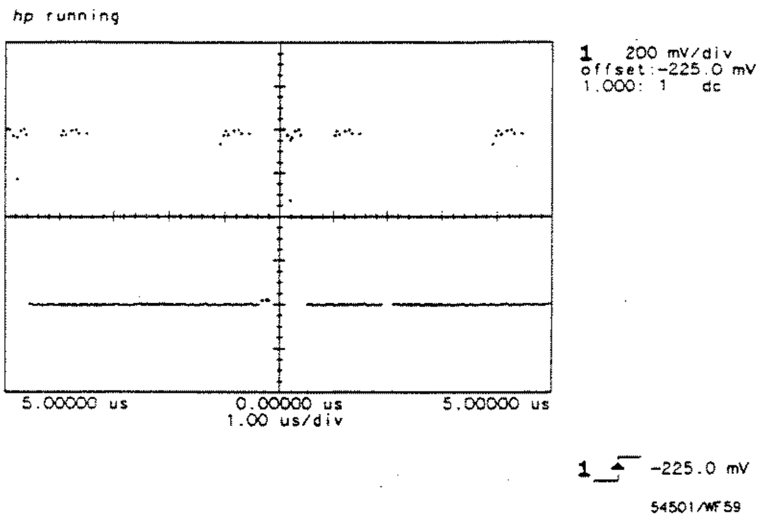


Figure 6-2. Two-Burst Waveform after Autoscale

- Select the **TIMEBASE menu.**
- Set the sweep speed to **500 ns/div.**

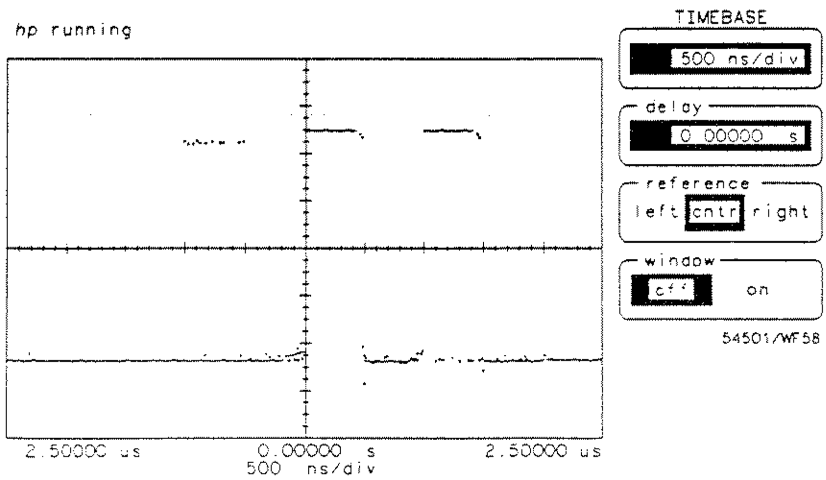


Figure 6-3. Two-Burst Pulse

The HP 54503A sets up the display parameters. It is now attempting to trigger on the first rising edge of the two cycle burst.

- Enter **TRIGGER MENU** and press the **slope** key.

The oscilloscope is now triggering on the first falling edge of the two cycle burst. Press the **slope** key again to trigger on the positive edge.

Note

The signal generator is set for two 500 ns pulses. The display on the oscilloscope appears to have three pulses. This is an unstable trigger condition The following steps explain this condition and how to overcome it.

- Press the **holdoff** key.

- Set **holdoff** to **1.02000** µs, using either of the entry devices.

Holdoff on the HP 54503A has a minimum time setting of 40 ns. The input signal to the oscilloscope has two 500 ns pulses. On the first rising edge a trigger occurs and activates the 40 ns holdoff. When the holdoff time has elapsed the oscilloscope triggers on the next rising edge. The oscilloscope times a 40 ns holdoff and looks for another trigger. The oscilloscope triggers on the first rising edge of the second burst. Each trigger event occurs on a different pulse, and consequently the trigger condition is unstable.

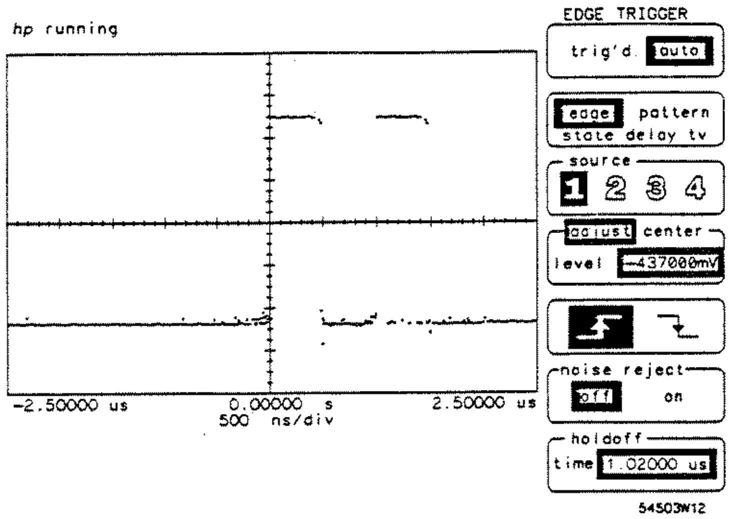
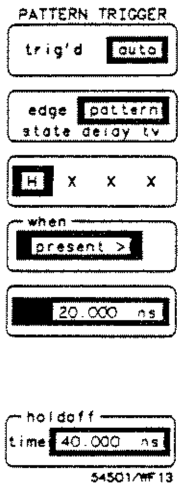


Figure 6-4. Two-Burst Pulse w/Stable Trigger

By adjusting the holdoff to wait until the rising edge of the second pulse passes, the oscilloscope triggers only on the first rising edge and the signal is stable. In this case the trigger becomes stable with approximately 1.02 μs holdoff.

Pattern Trigger Mode



The pattern mode defines a four-bit pattern for the oscilloscope to recognize and then generate a trigger event. When the inputs satisfy the trigger pattern and conditions, the HP 54503A triggers and displays the desired portion of the waveform. The logic highs (H) and lows (L) use the threshold set in the edge trigger as the reference level.

The pattern mode is very useful for glitch detection because the HP 54503A can trigger on a glitch as narrow as 1.5 ns.

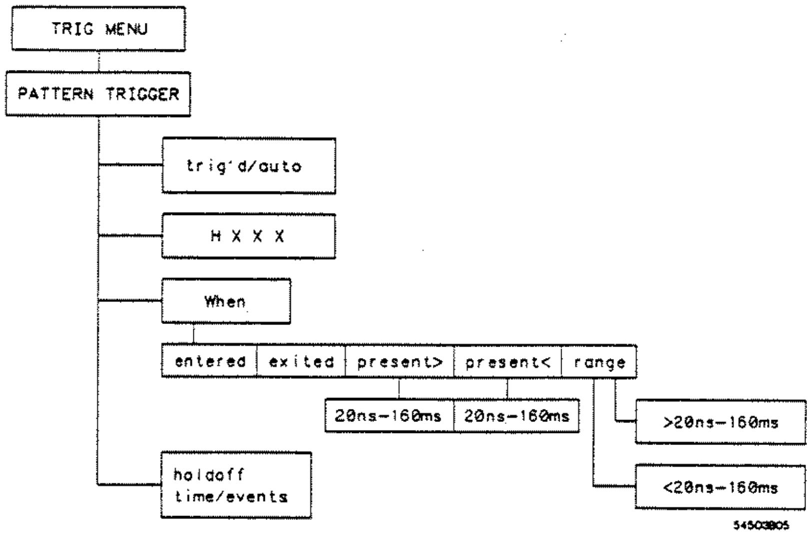


Figure 6-5. Pattern Trigger Menu

The top two function keys remain the same as the Edge Trigger mode.

pattern Key This is an unlabelled field. The display depicts the 4-bit pattern. The active field is displayed in fullbright and can be changed with the knob. The function key changes the bit selection of three levels:

- **H** - high
- **L** - low
- **X** - don't care

The criteria for high is higher than the current trigger level, and low is lower than the current trigger level set in the edge trigger menu.

The 4-bit pattern is representative of the four-channel input.

For example, if the pattern is LXXH, the voltage on channel 1 must be lower than the trigger level set for channel 1, channels 2 and 3 are don't cares so the input levels are disregarded, and the channel 4 input must be higher than the trigger level set for channel four. If these conditions are satisfied by the inputs, then the oscilloscope generates a trigger event.

Note

When any channel is not being used in the qualifier pattern, it should be set as don't care. The trigger level is still compared to the no input channel and a high or low is determined. The only true don't care is X.

If the pattern XXXX is selected, a trigger event does not occur because a trigger event is not defined.

when Key This key controls five sets of conditions that must be satisfied to generate a trigger event. These conditions are as follows:

- **when entered:** a trigger is generated on the first transition that makes a pattern true. The pattern must be false and go true to generate the trigger.

- **when exited:** a trigger is generated on the first transition that makes the pattern false. The pattern must be true and go false to generate a trigger.

- **when present >** : a trigger is generated when a trigger pattern is true longer than a specified minimum time period. This time period is specified in the next selection key that is activated when present > is selected. The present > time ranges from 20 ns to 160 ms.

- **when present <** : a trigger is generated when a trigger pattern is true less than a specified maximum time period. This time period is specified in the next selection key that is activated when **present <** is selected. The **present <** time ranges from 20 ns to 160 ms and pulses as narrow as 1.5 ns generate a stable trigger.

- **range:** this trigger condition is a combination of **present <** and **present >**. A trigger is generated when a trigger pattern is true for longer than a specified minimum and shorter than a specified maximum time period. These time periods are specified in the next two selection keys that are activated when **range** is selected. The first range time setting must be less than the second range time setting.

holdoff Key The **holdoff** key assigns the entry devices to control holdoff. Holdoff disables the trigger circuit for a selectable time period or number of events after the trigger event. Holdoff is selected in time units, from 40 ns to 320 ms and incremented in 20 ns intervals, or in number of patterns from 2 to 16000000.

Pattern Trigger Exercise

This exercise demonstrates how to define the 4-bit pattern and how it affects the trigger and the resulting display.

Note

Set the trigger level for each trigger source while in the edge mode. These trigger levels must be set before going into the pattern mode, or proper triggering may not occur.

Instrument Setup To perform the following exercise use the HP 8116A Pulse/Function Generator, or another function generator capable of producing the same 1 MHz, 1 volt, squarewave signal.

Set up the HP 8116A Pulse/Function Generator:

- Mode = NORM
- FRQ = 1.00 MHz
- DTY = 50%
- AMP = 1.00 V
- OFS = -2.00 V
- Pulse = squarewave

Connect the signal to a BNC tee on channel 1 using a 1-meter coaxial cable. Connect another 1-meter cable from the other side of the BNC tee to channel 4.

Oscilloscope Setup

The extra cable length between channels 1 and 4 provides a time delay between the signals displayed on the oscilloscope. The propagation of a 1-metre coaxial cable is approximately 6 to 7 ns. This time delay is used to demonstrate the HP 54503A triggering capability.

- Press AUTOSCALE.

Set up the HP 54503A as follows:

- Timebase = 10.00 ns/div
  delay = 0.00 s
  reference = cntr
  window = off
- Channel 1
  Vertical sensitivity = 500 mV/div
  offset = -200.00 mV
  dc coupling
- Channel 4
  Vertical sensitivity = 500 mV/div
  offset = -200.00 mV
  dc coupling

- Display
  - zero persistence
  - 2 screens
  - axes
- Trigger
  - Channel 1 level = -200 mV
  - Channel 4 level = -200 mV
  - Set the trigger mode to pattern.

Set the pattern to HXXL as follows:

- Press the function key until the first character is highlighted.
- Turn the knob until the highlighted area is H.
- Select the next character in the pattern and repeat the procedure.
- Continue until all characters are selected in the HXXL pattern.
- Press the **when** key until **entered** is selected.

The display should be similar to the following figure.

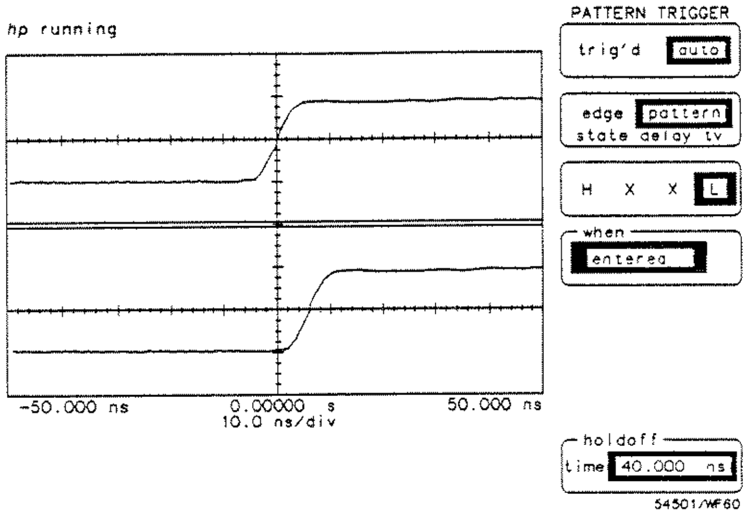


Figure 6-6. HXXL when entered Pattern

Channel 1 is displayed in the top screen. To satisfy the conditions of the bit pattern, channel 1 must be high (higher than the channel 1 trigger level or greater than -200 mV). When the signal on channel 1 goes higher than -200 mV and channel 4 is still low (less than -200 mV) the pattern conditions have been satisfied as the signal is entering the trigger conditions and the HP 54503A triggers.

- Press the **when** key and change the condition to when exited.

The oscilloscope triggers on the first transition that makes the bit pattern false, in this case when channel 4 goes high.

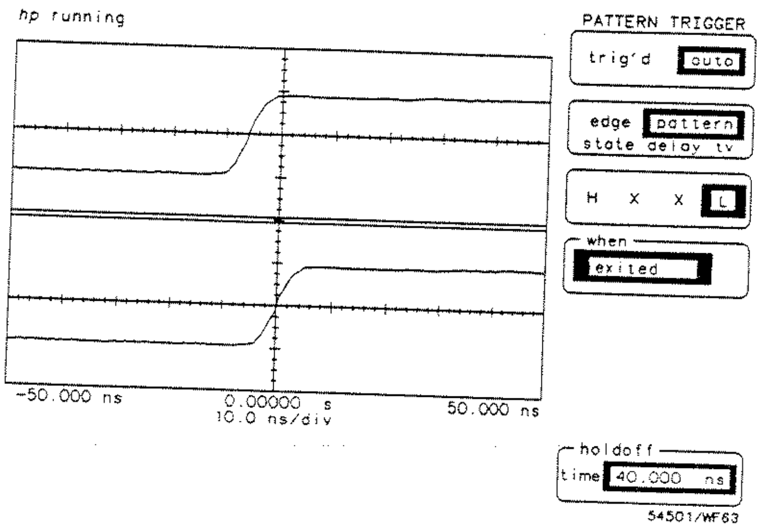


Figure 6-7. HXXL when exited Pattern

- Change the bit pattern to HXXH and select the **entered** condition.

To satisfy this bit condition both channels must be high. The oscilloscope does not trigger until channel 4 goes high while channel 1 is high.

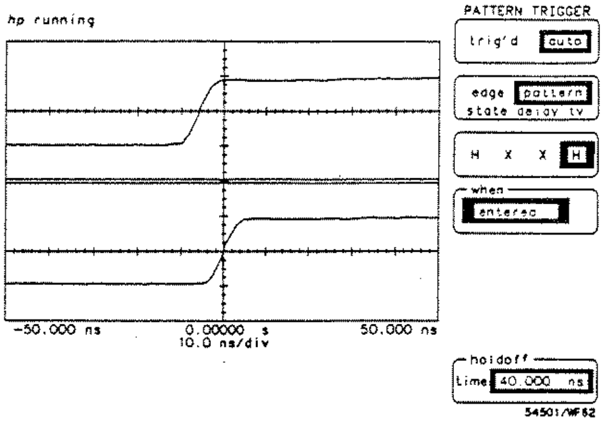


Figure 6-9. HXXH when entered Pattern

- Change the trigger condition to **when exited.**

While channel 4 is still high, when channel 1 goes low the bit pattern is no longer true and the HP 54503A triggers.

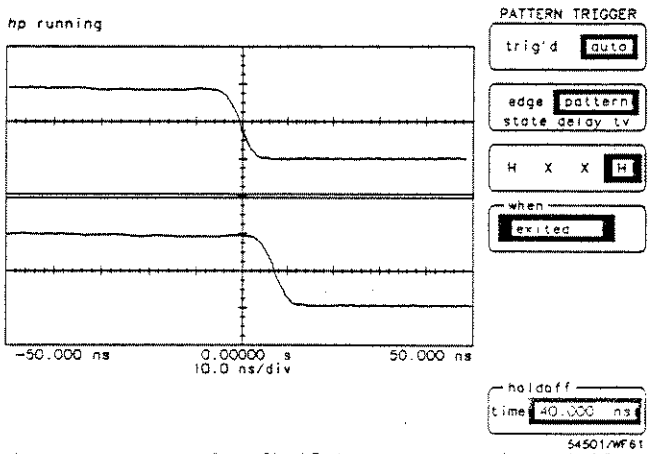
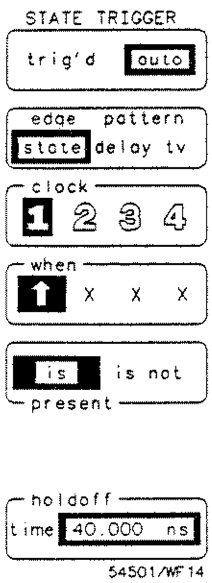


Figure 6-8. HXXH when exited Pattern

State Trigger Mode



The state trigger mode is similar to the pattern trigger mode except that one channel is selected as a clock edge and the other three channels define a pattern. When the pattern becomes true the HP 54503A triggers on the next clock edge if the pattern meets setup and hold criteria.

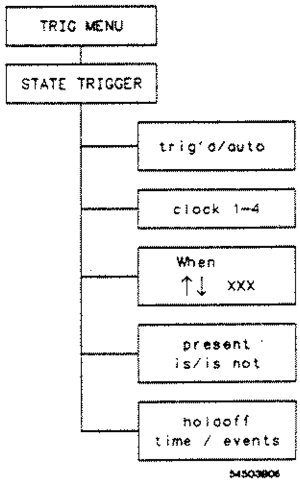


Figure 6-10. State Trigger Menu

The **trig'd/auto** and trigger mode function keys remain displayed in all trigger modes.

clock Key Select any channel to be used as the state clock. Select the channel by pressing the function key until the desired channel is highlighted. The clock selection is reflected in the next field with an arrow, pointing either up for a positive slope or down for a negative slope.

when Key The **when** key depicts the desired pattern. The displayed pattern shows the arrow at the selected clock channel. The other three channels define the logic pattern that must be satisfied to generate a trigger event using the H, L, X convention described in the pattern trigger mode.

To change the pattern:

- Press the function key until the bit to be changed is highlighted.
- Rotate the knob until the desired setting is highlighted.
- Select the arrow to change the trigger slope, if necessary, and turn the knob until the desired settings appear.

present Key A trigger event is generated on the selected edge when the pattern is true and **is present** is selected, or a trigger occurs when the pattern is false and **not present** is selected.

holdoff Key The **holdoff** key assigns the entry devices to control holdoff. Holdoff disables the trigger circuit for a selectable time period or number of events after the trigger event. Holdoff is selected in time units, from 40 ns to 320 ms, or number of patterns, 2 to 16000000.

State Trigger Exercise

This exercise demonstrates how an input pattern is used to qualify a clock edge as a trigger.

State triggering extends the logic triggering capability of the HP 54503A by selecting one of the inputs as a clock and using the other inputs as qualifiers.

This is useful when it is necessary to synchronize the display with a system clock to detect a system state. For example, consider a synchronous memory bus. The state trigger mode enables only those events that occur when reading from a block of memory to be captured and displayed.

Instrument Setup To perform the following exercise use an HP 8116A Pulse/Signal generator or another signal generator capable of the same 1 MHz, 1 volt squarewave.

Set up the HP 8116A as follows:

- Mode = NORM
- FRQ = 1.00 MHz
- DTY = 50%
- AMP = 1.00 V
- OFS = -200 mV

Connect the signal to a BNC tee on channel 1 using a 1-meter coaxial cable. Connect another 1-meter cable from the other side of the BNC tee to channel 4.

Oscilloscope Setup

The extra cable length between channels 1 and 4 provides a time delay between the signals displayed on the oscilloscope. The propagation of a 1-meter coaxial cable is approximately 6 to 7 ns. This time delay demonstrates the HP 54503A triggering capability.

- Press AUTOSCALE.

Set up the HP 54503A as follows:

- Timebase = 10.00 ns/div
  delay = 0.00 s
  reference = cntr
  window = off
- Channel 1 turned on
  Vertical sensitivity = 400 mV/div
  offset = 1.25 V
  dc coupling
- Channel 4 turned on
  Vertical sensitivity = 400 mV/div
  offset = -75 mV
  dc coupling
- Display
  zero persistence
  2 screens

- Trigger
  Channel 1 level = 125 mV
  Channel 4 level = -100 mV
  Set the trigger mode to state

- Set the pattern to ↑XXL as follows:

  1. Press the function key until the first bit is highlighted.
  2. Turn the knob until the highlighted area is ↑.
  3. Select the next bit in the pattern and select H
  4. Continue until all bits are selected in the ↑XXL pattern

- Press the **when** key until **is present** is selected (see Figure 6-11).

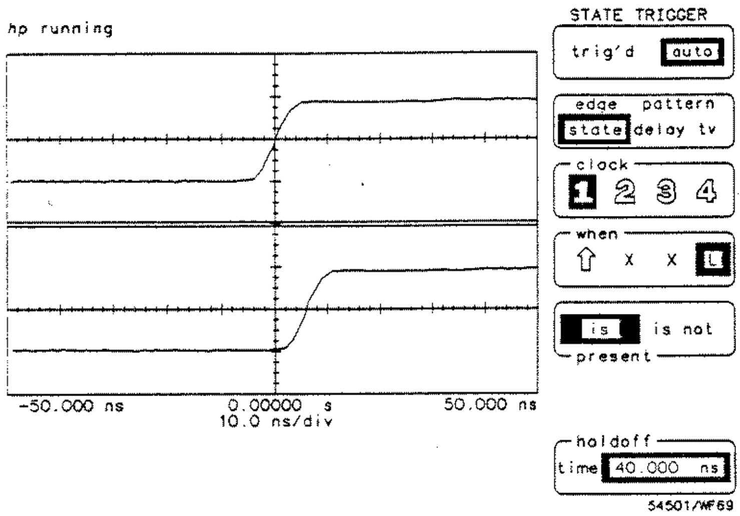


Figure 6-11. Channel 1 Clock XXL State

Channel 1 is displayed in the top screen. To satisfy the conditions of the bit pattern, channel 4 must be high (higher than the channel 4 trigger level or greater than 125 mV). When the signal on channel 1 goes higher than 125 mV and channel 4 is still low (less than -100 mV) the pattern conditions have been satisfied, the HP 54503A triggers on the next positive pulse on channel 1.

- Press the **is/is not present** key and change the condition to **not present.**

The pattern becomes false when channel 4 turns high.

- Change the bit pattern to ↑XXH and select the **is not present** condition.

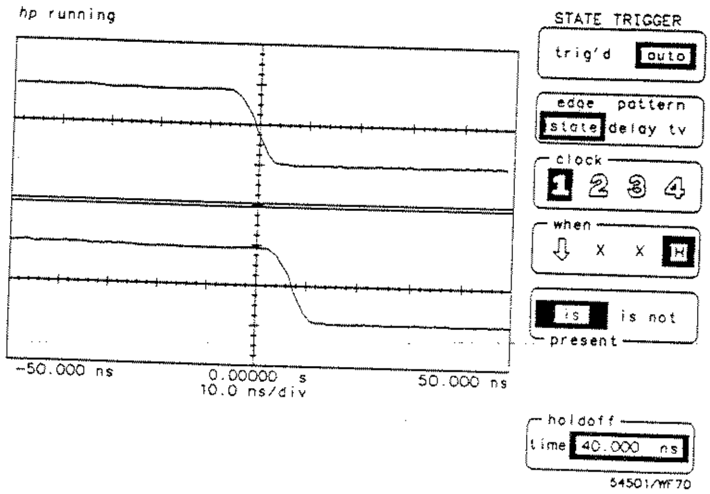
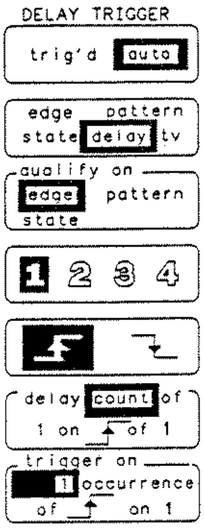


Figure 6-12. Channel 1 Clock XXH State

To satisfy this bit condition the clock channel must go low while channel 4 is high. The oscilloscope does not trigger until channel 1 goes low while channel 4 is high.

Delay Trigger Mode

The delay trigger mode qualifies on a signal edge, pattern, or state, delay for a period of time (or occurrence of edges), and then triggers on a selected edge from any source.



54501/WF 15

This trigger mode is versatile and accommodates most complex triggering situations. It has the flexibility to select different trigger sources, delay times, delay counts and then display various points of the waveform. A trigger holdoff of 40 ns occurs after the delayed trigger happens.

qualify on Key

The **qualify on** key selects which mode to qualify the trigger before a delay is defined.

The options are:

- edge
- pattern
- state

qualify on edge

Select the edge qualifier and the next two function keys define the parameters. The first key following the qualify on edge key is an unlabelled field that selects the channel to be the source. The second key below the edge selection is the slope selection.

qualify on pattern When the pattern trigger option is selected, the next function key defines the qualifier pattern. Defining a pattern is the same as in the pattern trigger mode.

- Highlight the bit to be changed by pressing the function key.
- Change the bit by rotating the knob.

After selecting through all four bits, the active field is changed to the condition field. This field to sets conditions as in the pattern trigger mode:

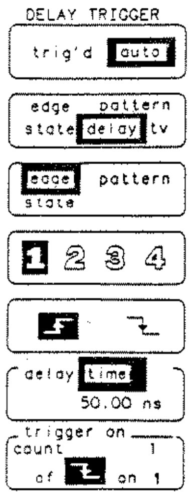
- **when entered**
- **when exited**
- **when present >**
- **when present <**
- **range**

These settings activate the next field, as appropriate, so the specific time parameters can be set.

qualify on state If the state trigger option is selected the next two function keys define the state conditions.

As in the state trigger mode, select the channel to define the state clock. This selection is reflected in the pattern with an arrow and the slope is depicted with the arrowhead pointing up or down. Use the function key to move the highlighted bit to change the pattern. When the pattern is set, the **is/not present** setting can be changed by moving the highlight to the **is/not present** field label and pressing the function key again. When the label is highlighted, toggle the setting between **is/not present** with the knob.

delay Key This field selects between two delay options. To change between the **time** and **count** options rotate the knob until the desired option is displayed in the inverse video field.



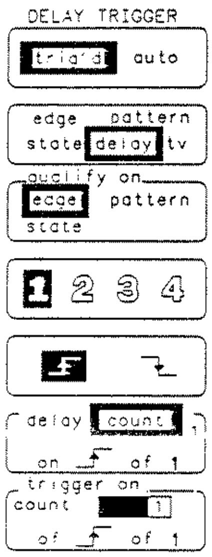
54501/WF16

delay time disables the trigger circuit for a selected period of time, from 30 ns to 160 ms after the trigger has been qualified

Note

Time delay is not available in the time qualified pattern settings of when present >, when present <, or range

- Press the function key until the highlight is on the first numeric field. This field selects the amount of delay after qualification, ranging from 30 ns to 160 ms.



54501/WF84

delay count (delay by edges) disables the trigger circuit for a selected count from 1 to 16,000,000 or a dely by events (**time**), after the trigger has been qualified. After the selected count has been attained the HP 54503A will look for the user specified trigger edge.

- Press the function key until the highlight is on the first numeric field. This field to selects the number of edges to delay after the trigger has been qualified (from 1 to 16,000,000).
- Press the funtion key once more to activate the **rising edge/falling** edge option and select the desired edge using the knob.
- Press the function key once more to highlight the third option field and select the channel to delay on.
- Press the function key a fourth time to return to the first numeric field.

trigger on Key This key selects a specific edge to trigger on after the qualification and delay conditions have been satisfied. All other keys in this menu have dealt with defining qualifying conditions, however, this field sets the trigger point. This is another three position option switch.

- Press the function key to highlight the numeric field and select which occurence to trigger, using the knob to set the number (1 to 16,000,000).
- Press the function key again and move the highlighted field to select the slope. The knob toggles the selection between rising and falling edge.
- Press the function key again and highlight the channel selection. The knob is used to change the channel selection.

Delay Trigger Exercise

This exercise demonstrates how to use the delay trigger and trigger on the exact point of a waveform. The exercis leads through setting up a complex signal, setting up the HP 54503A, and changing settings and counts for viewing various points on the waveform.

Instrument Setup Set up an HP 8116A (or comparable signal/generator) for a burst pulse with ten bursts that repeats every 50 μseconds.

Set up the HP 8116A Pulse/Function Generator:

- Mode = I.BUR
- RPT = 50 μs
- BUR = 10
- FRQ = 5.0 MHz
- DTY = 50%
- AMP = 1.00 V
- OFS = -200 mV

Connect the signal to channel 1 of the HP 54503A.

Oscilloscope Setup

The HP 54503A autoscales and displays this signal, however, for this example make the listed triggering changes after autoscaling.

- Press AUTOSCALE.

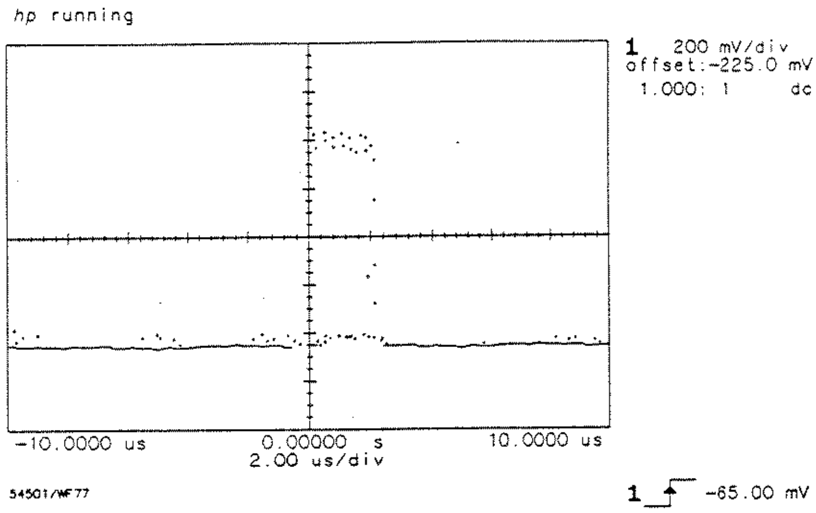


Figure 6-13. Ten Burst Pulse after AUTOSCALE

Set up the HP 54503A as follows:

- Press TRIG and select **trig'd** display.
- Select **delay** trigger mode.
- **Qualify on edge** and the rising edge of channel 1 as the source.
- Select a delay time of **2.5** µs to gain a stable trigger.
- Set **trigger on** to trigger on rising edge 1 of channel 1.

This trigger setup qualifiess on the first rising edge of the burst, delays through the remaining portion of the burst, then triggesr on the specified edge of the next burst.

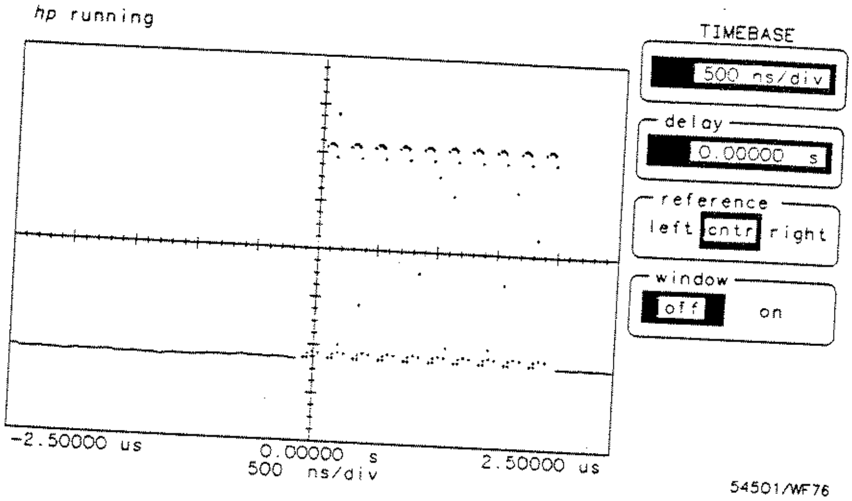


Figure 6-14. Ten Burst Pulse w/Stable Trigger

- Press TIMEBASE and set time/division to **500 ns.**
- Return to the trigger menu and set **trigger on count** to **5.** This tells the oscilloscope to trigger on the 5th rising edge of the burst (see Figure 6-15).

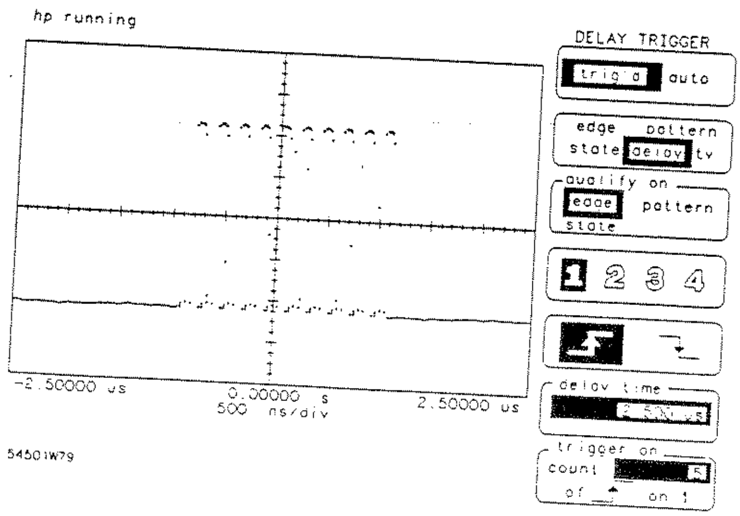


Figure 6-15. Ten Burst Pulse Triggered on Pulse 5

- Change the **trigger on count** key to 9 (see Figure 6-16).

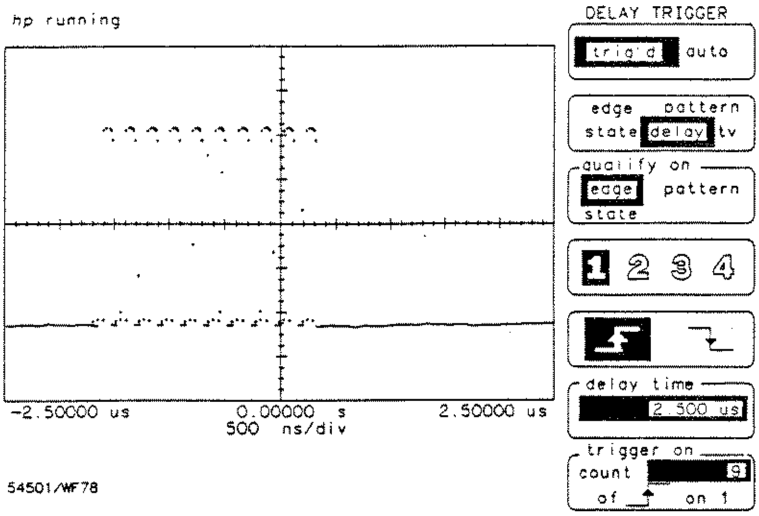
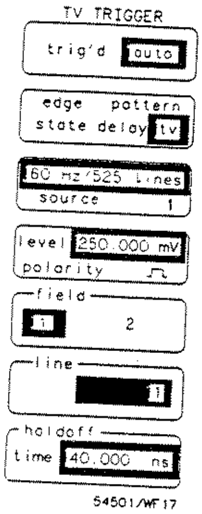


Figure 6-16. Ten Burst Pulse Triggered on Pulse 9

By setting the oscilloscope to the delay trigger mode, a specific time or count to delay between qualification and trigger can be added.

In this exercise, the trigger was delayed to get a stable display. When the time delay had elapsed the HP 54503A began counting rising edges until it found the edge set.

TV Trigger Mode



The **TV TRIGGER** menu enables the HP 54503A to trigger on clamped tv signals. The two most common tv standards; 60 Hz/525 lines or NTSC is the standard used in the United States, 50 Hz/625 lines is the standard used in most European countries. This trigger menu also allows for user defined tv signals that may be used in other parts of the world.

To move the highlighted inverse video window within a field you must press the selection key and to change the value displayed in the window you must rotate the knob.

Note

Pay close attention to the movement of the highlighted window; it moves to various options within the field.

Standard Select Key

The source key chooses between the NTSC standard tv signal used in the United States with a 60 Hz and 525 lines per frame, the standard of 50 Hz and 625 lines per frame used in most countries in Europe. The third option is for user defined ranges of the tv signal.

To make the desired selection:

- Press the selection key and select the standard by rotating the knob. The active field is highlighted in inverse video.

Source Select Key

To select the trigger channel to be used as a source,

- Press the function key and move the highlighted field, rotate the knob until the desired channel is displayed.

level/polarity Key The level option sets the trigger level that is applicable only to the tv trigger source.

- Press the function key again and the highlighted window moves to the polarity option and selects the rising edge or falling sync pulses to trigger on.

field Key The field key selects field, 1 or 2.

line Key The line key selects which line the trigger will be generated on. This selection is dependent upon which field has been selected previously.

If the previous selection is the 60 Hz, 525 lines standard, the options available depend upon which field, 1 or 2 is selected:

- If field 1 is selected, select from line 1 to 263 in field 1.
- If field 2 is selected, choose from line 1 to 262 in field 2.

This tv trigger mode is compatible with broadcast standard M.

If the 50 Hz, 625 lines standard is selected, the options are also dependent upon field settings:

- If field 1 is selected the range of lines is from 1 to 313,
- If field 2 is selected the range of lines is from 314 to 625.

This tv trigger mode is compatible with broadcast standards: B, C, D, G, H, I, K, K1, L, and N.

holdoff Key The holdoff key enables the oscilloscope to hold off the trigger event from 40 ns to 320 ms and is incremented in 20 ns time frames.

TV Trigger Exercise

Video signals are unique, and as such have unique requirements for proper triggering. This exercise demonstrates how to display and work with video signals on the HP 54503A.

Instrument Setup

Use a standard NTSC signal generator with clamped video output for this exercise. Turn color bars on.

Oscilloscope Setup

Connect the NTSC video signal to channel 1 of the HP 54503A.

- Press AUTOSCALE.
- Select the **tv** trigger mode.
- Set **60 Hz/525 lines** and **channel 1** as the **source.**

Determine the polarity of the sync pulse.

- Select the trigger level and rotate the knob until a stable display is attained. When a sync pulseis visible, determine the polarity, select **polarity** (press the function key) and set the sync pulse in accordance with the actual pulse.

- Set the trigger **level** at approximately the midpoint of the sync pulse.

This sets the trigger level just below the middle of the sync pulse and tells the oscilloscope to trigger on the leading edge.

- Set **trig'd/auto** to **trig'd.**

This eliminates the possibility of a premature trigger event occurring.

- Select **field 1** and **line 1.**
- Press TIMEBASE and set time/division to 100 µs/div.

- Press DISPLAY and set persistence to ≈ 600.0 ms to accommodate video signals.

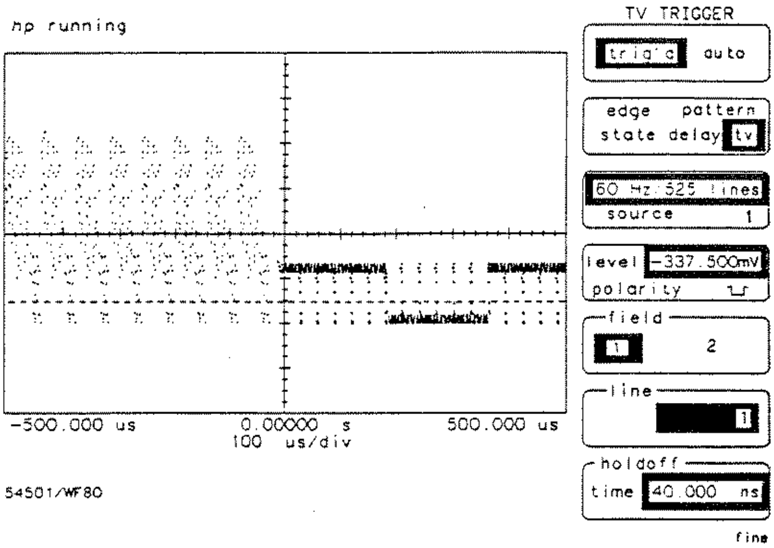


Figure 6-17. Trigger at Field 1, Line 1

The HP 54503A is triggering on the first equalizing pulse of field 1, the first pulse in the vertical interval. The pretrigger data that is being viewed (left half of the screen) is field 2, lines 256-262.

- Set time/division to 10 μs/div and set the trigger to **field 1, line 10.**

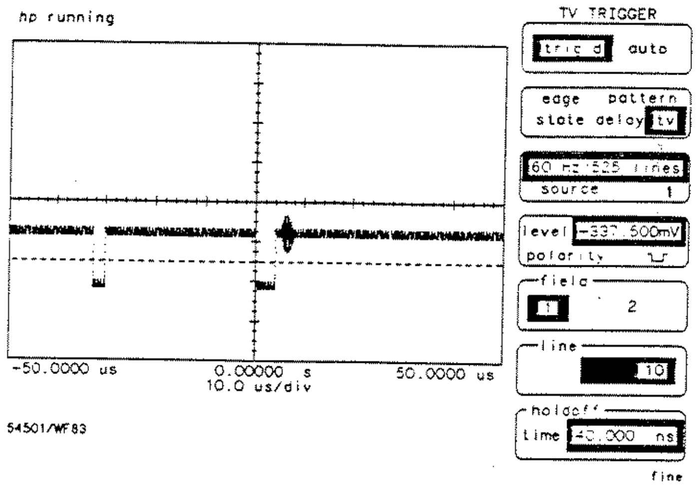


Figure 6-18. Trigger on Field 1, Line 10

The trigger is now on the first horizontal sync pulse in the vertical interval with color burst information.

- Change the trigger point to **field 1, line 21.**

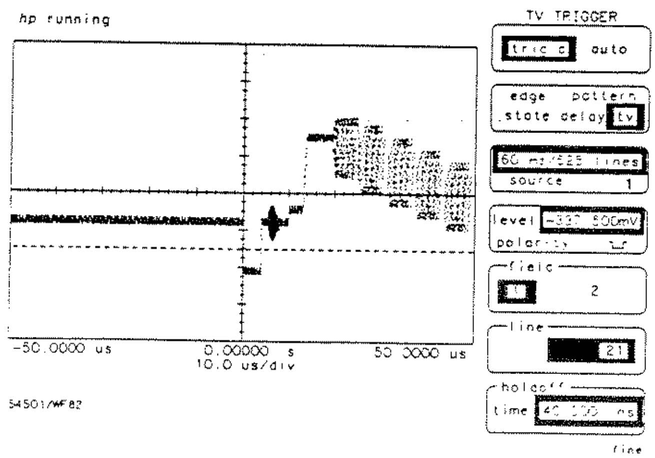


Figure 6-19. Trigger on Field 1, Line 21

The trigger point is now on the last sync pulse of the vertical interval. The next line contains color information, in this case color bars are present.

- Change the trigger to **field 2, line 1.**

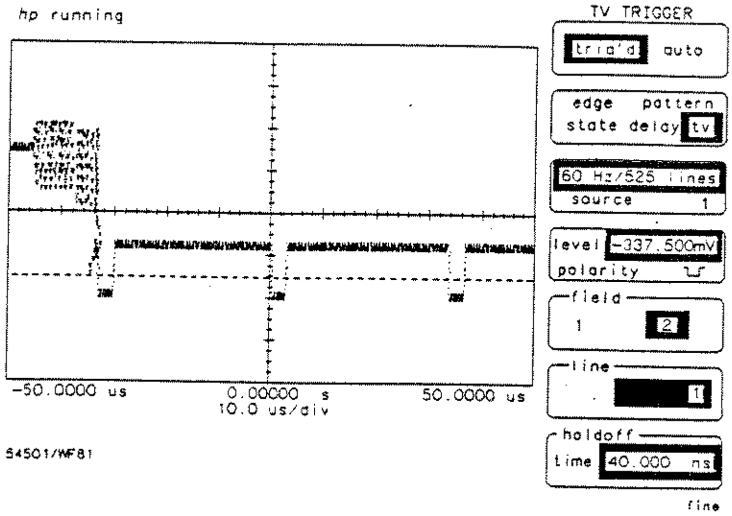


Figure 6-20. Trigger on Field 2, Line 1

The trigger point is on the second sync pulse of the vertical interval. This is the correct trigger point because fields 1 and 2 are interlaced.

Display Menu 7

Introduction to the Display

The **DISPLAY** menu controls most of the features that dictate how the acquired data is displayed. These features include ways to manipulate data for clarity, to eliminate noise, viewing best case/worst case situations, or the displayed background.

This chapter describes the **DISPLAY** menu, three submenus, how to control all the features, and how to display the most meaningful waveform for measurements.

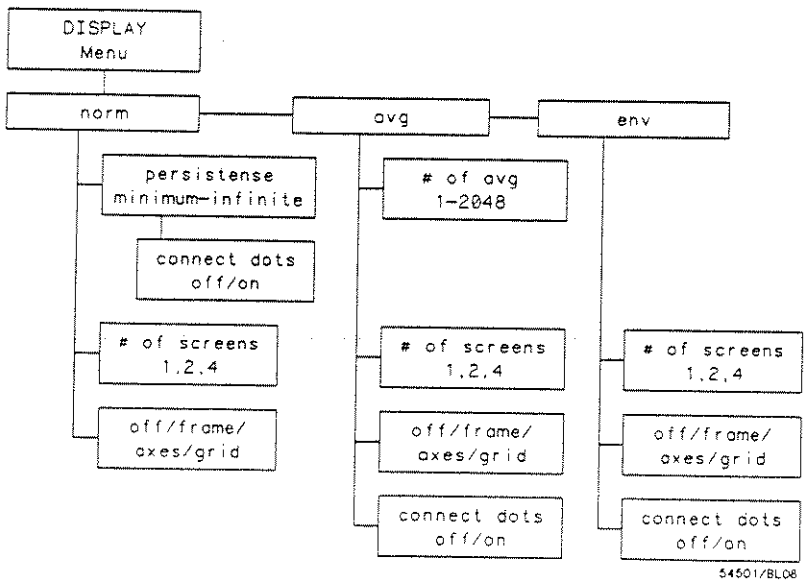
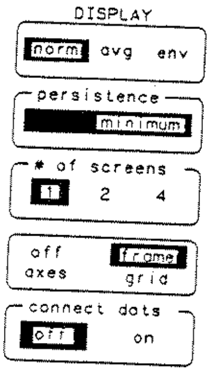


Figure 7-1. Display Menu

Display Mode Key

The display mode key selects one of the three display modes:

- normal
- averaged
- envelope



54501/WF71

norm The **norm** mode sets the time parameters for displaying data, or persistence. The range in the variable persistence mode is from minimum, which rewrites the waveform on each acquisition, to infinite which maintains acquired waveforms on the screen indefinitely. Settings in-between, from 200 ms to 10 seconds are also selectable. This means data display records can be preset to any of the persistence settings.

- Minimum persistence rewrites each waveform on the display as it is acquired. The current display is always the most recent acquisition.

- Variable persistence settings are useful when the input signal is changing and immediate feedback is needed.

- Longer persistence is useful when observing long-term changes in the signal or low signal repetition rates.

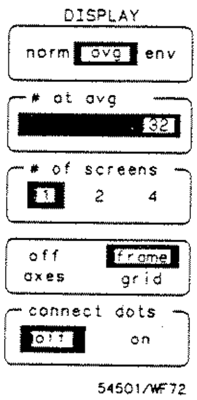
- Infinite persistence can be used for worst-case characterizations of signal noise, jitter, drift, etc. In this mode the HP 54503A is used as a storage oscilloscope and is without the fade or bloom of an analog oscilloscope.

When the keypad is used to change persistence settings, any entry longer than 10 seconds displays the message **value out of range, set to limit** and **persistence** is set to **infinite**. Any entry less than 200 ms displays the same message and **persistence** is set to **minimum**.

Connect-the-dots is available only when in **norm** mode and **minimum** peristence.

either of the entry devices. Connect the dots is only available when in norm mode and minimum persistence.

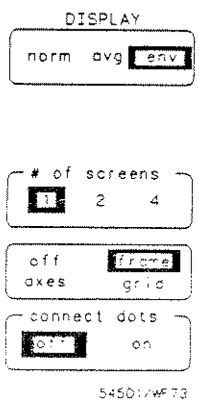
avg The averaged mode selects the number of waveform acquistions that are averaged to generate the displayed waveform. The range for the averaging function is 1-2048 in powers of 2.



When averaged mode is selected the next function key is activated and the number of averages is set with either entry device.

Displayed signal noise is significantly reduced using the averaging mode. As the number of averages is increased from 1 to 2048, the display becomes less responsive to changes to the input signal(s), however, using more averages reduces the effects of displayed signal noise and improves resolution.

env The envelope mode needs no other parameters set. The display reflects the minimum and maximum voltages in each horizontal position. This is useful in viewing voltage or time jitter.



of screens Key

The next function key chooses the number of screens to view:

- **1:** the entire display area is one screen and any displayed waveforms are superimposed on top of each other.
- **2:** the display area is divided into two screens. Channels 1 and 2 will be displayed in the top screen and channels 3 and 4 will be displayed in the bottom screen (See Figure 7-2).
- **4:** the display is divided into four equal screens with one waveform displayed in each screen (See Figure 7-3).

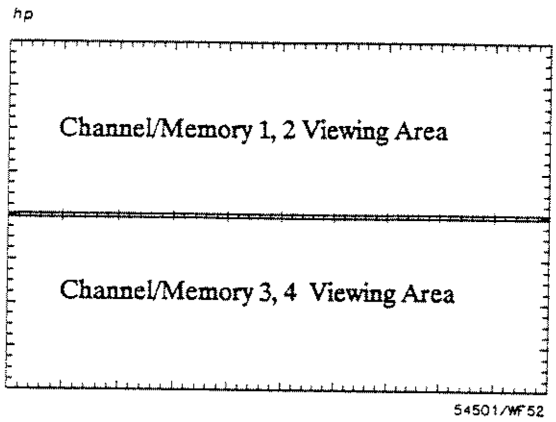


Figure 7-2. Dual Screen Display

When waveform math functions or the dual timebase window are turned on they are displayed in the lower half of the screen and the channels are displayed in the top half.

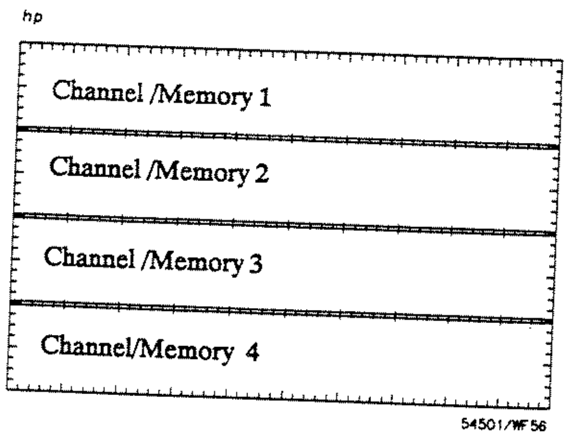


Figure 7-3. Quad Screen Display

off/frame/ axes/grid Key

This unlabelled field selects one of four display backgrounds:

- **off:** The off option turns the background graticule off. The displayed waveform and waveform information is not turned off.
- **frame:** The frame option displays the outside border with a measurement scale. The measurement scale is incremented/decremented with major divisions and minor divisions based on the vertical and horizontal measurement settings.
- **axes:** The axes setting displays a background with the measurement scale crossing at mid-screen.
- **grid:** The grid background is a complete graticule with ten horizontal major divisions and eight vertical major divisions. Only the axis portion of the graticule has a minor division scale.

connect dots Key

Connect-the-dots is a technique used to display waveform with all data points connected. This makes viewing the waveforms easier because the signal is complete and has no breaks.

Note

Connect-the-dots does not interpolate data and generate data points. The HP 54503A connects data points linearly.

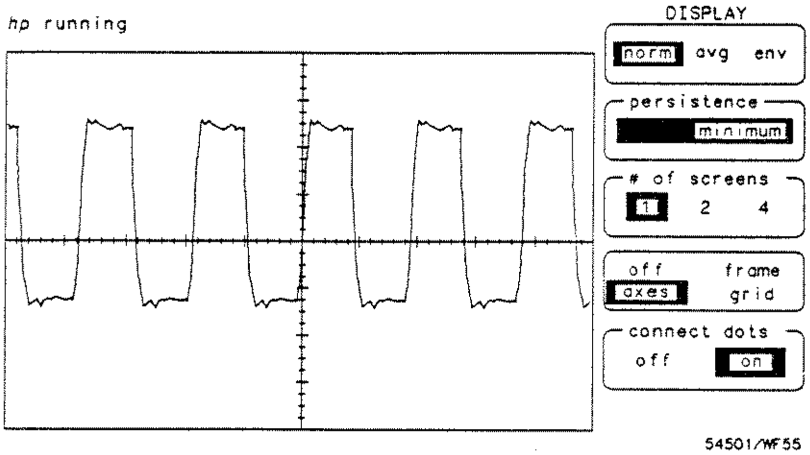


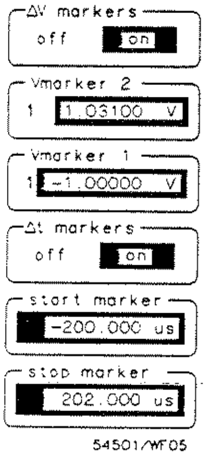
Figure 7-4. Connect-the-Dots

Delta t/Delta V Menu 8

Introduction to the Markers

This chapter describes how to use the markers and make manual measurements on displayed waveforms.

In this menu, two sets of markers are controlled. These markers are the **ΔV markers** (horizontal voltage markers) and the **Δt markers** (vertical time markers). When the desired set of markers have been turned on and the two marker fields are turned on. The markers are controlled individually.



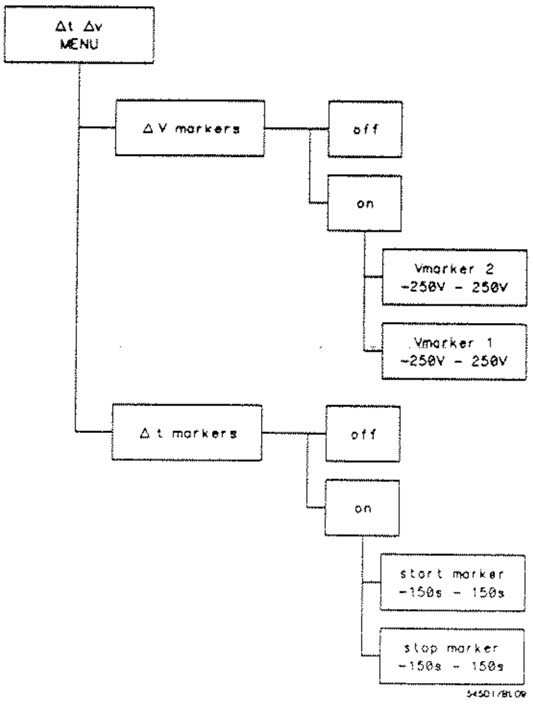
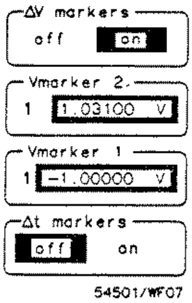


Figure 8-1. Delta t/Delta V Menu

ΔV markers



This function key toggles the markers on and off. With the ΔV function turned on the next two fields are activated and the two markers are controlled individually.

When the ΔV markers are turned on, *Vmarker2, Vmarker1*, and *delta V* appears in the factors display area. The delta V entry is calculated as the following:

Vmarker 2 - Vmarker 1 = delta V

If delta V is negative, Vmarker 1 is located at a more positive voltage level than Vmarker 2.

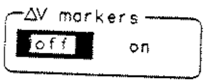
Vmarker 2 This function key is a two function control field. The first function selects the desired channel, memory, or function to place Vmarker 2 for measurement. By pressing the function key again, the highlighted field moves to the numeric display to select the voltage level. Typically, place Vmarker 2 at the desired level on the waveform display and read the level, both in the highlighted field, and in the factors area of the waveform display.

Vmarker 2 is the voltage marker with shorter dashes.

Vmarker 1 Vmarker 1 operation is identical to Vmarker 2, except it is represented by longer dashes.

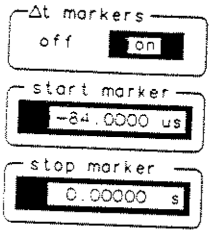
Δt markers

This function key toggles the time markers on and off. With the Δt function turned on the next two fields are activated and the two markers are controlled individually



The markers are placed on the display respective of the trigger point. Positive time values are to the right of the trigger point and negative time values are to the left. Delta t values are determined by the following:

stop marker - start marker = delta t



54501/WF64

There is no such thing as negative delta t, this only means that the start marker is placed later in time than the stop marker.

1/delta t is the inverse of delta t. Since the inverse of time is frequency, this ratio produces an answer in frequency, however, be alerted that if the markers are placed across parts of a waveform of differing time frames the answer may not be valid. This feature is useful when looking for the frequency in a burst that is different from the rest of the waveform. Place the time markers across the burst (at similar points on the waveform) and determine the frequency of the burst.

start marker To set the start marker press the function function key to highlight the field. This makes the start marker field active. Set the marker using the knob.

The start marker is represented with long dashes.

stop marker The stop marker is identical to the start marker, except that it is represented by short dashes.

Waveform Math Menu 9

Introduction to the Functions

The **WAVEFORM MATH** menu defines one and/or two functions. The functions are used on data that is displayed on screen from any of the four channels or from any of the four waveform memories.

A function is generated by mathematically manipulating one or two operands with known operations. The HP 54503A uses these mathematical operations:

- plus (+)
- minus (-)
- times (x)
- versus (vs)
- **only**
- **invert**

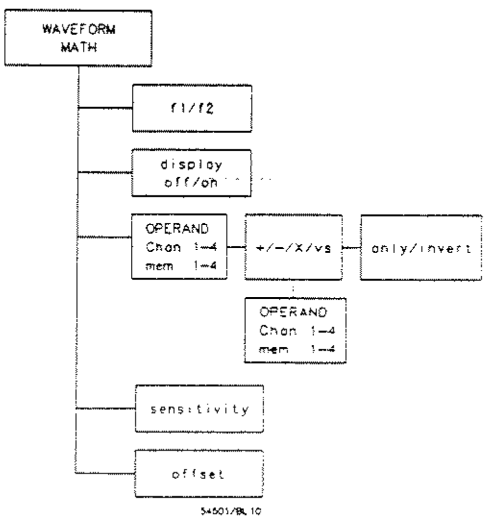


Figure 9-1. Waveform Math Menu

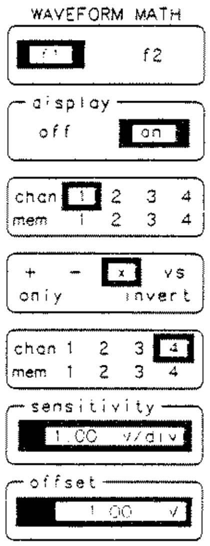
The vertical display and offset can be adjusted to place the function for best viewing.

When the function is calculated, it can be used in the following manner:

- displayed
- evaluated with the measurement features
- stored in memory
- output over the HP-IB

Defining a Function

The **WAVEFORM MATH** menu selects and presets any of various operations, sources, and displayed results.



54501/WF65

Function Key This key selects either function 1 or function 2.

display Key The display key turns the selected function on or off. The vertical sensitivity and offset are displayed in the function menu fields.

If the function display is turned on the screen will split with the original waveforms displayed in the top half screen while the functions are displayed in the bottom half screen. Both functions can be on at the same time and are displayed superimposed or in two screens in the bottom half of the CRT if multiple screens have been selected.

The timebase window is automatically turned off when a function is turned on.

chan/mem Key Press this key to select the first operand of the mathematical operation, or the waveform to be manipulated. The choice can be any displayed channel or any waveform memory that has a waveform stored. Ensure that the source is turned on.

If the operator is only or invert, it is the only operand that can be selected.

Operator Key This key selects any of the six functions. Continue pressing the function key until the operation desired is highlighted:

- **plus (+)**: The two selected operands are added together in this function. Addition is calculated on a point-by-point basis.
- **minus (-)**: The minus operation subtracst the second operand from the first.
- **times (x)**:The times operation multiplies the value of the first operand with the value of the second operand. Each data point is multiplied with a corresponding data point and the product is placed on the function display. The displayed waveform will usually be scaled to correspond to a different sized waveform.
- **vs (versus)**: The versus function draws a volts versus volts display of the two selected operands. Versus cannot be stored in a waveform memory because measurements cannot be made on the resultant waveform, however, it can be stored in pixel memory.

- **only:** The only function displays the first operand and scales it.
- **invert:** The invert function inverts the data of the first operand.

chan/mem Key This key selects the second operand, or the waveform that is manipulated against the first operand. The source choices are any of the displayed channels or any of the memories.

This key is not available if the operator is **only** or **invert**.

sensitivity Key The vertical sensitivity of the function is set with this key. This setting is for ease of viewing and making measurements with the newly developed waveform.

offset Key The offset of the function is set with this key.

Vertical Scaling Units

The fundamental measuring units of an oscilloscope are volts/division in the vertical axis and time/division on the horizontal axis. This philosophy is used regardless of the mathematical function chosen. No provisions have been made to manage units for all combinations of operands and operations.

For example, apply a +2V signal to channel 1 and a -3V signal to channel 2. The HP 54503A displays the product as -6V, when in reality it is $-6V^2$.

Displaying Functions

The HP 54503A has several screen variations available to accommodate a 4 channel display, as well as two functions.

In the single screen mode with a function on, the mathematical results are displayed in the bottom half of the screen while the operands are superimposed in the top half of the screen.

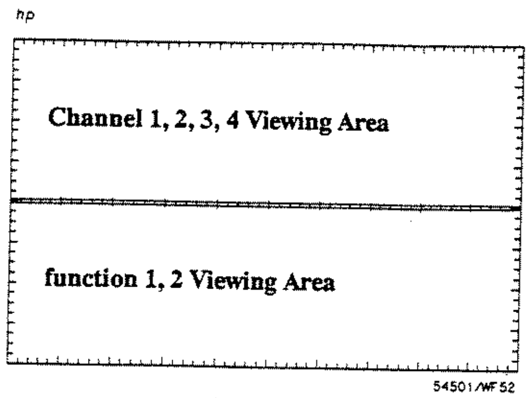


Figure 9-2. Single Screen w/Function On

- In the dual screen mode the functions are again displayed in the bottom half of the screen, however, the dual screens are displayed in the top half.

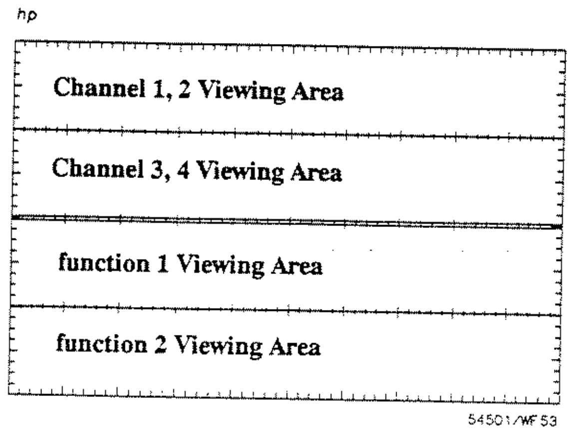


Figure 9-3. Dual Screen w/Function On

- In the quad screen mode, all four screens are displayed in the top half of the display while the functions are displayed in the bottom half.

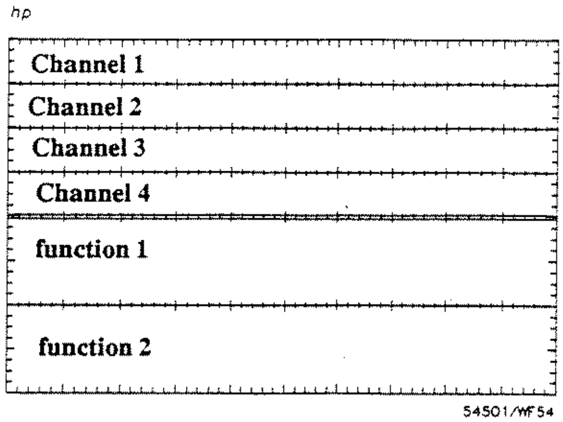


Figure 9-4. Quad Screen w/Function On

Waveform Math Exercise

In this exercise you will use the Waveform Math menu to subtract one waveform from another.

Instrument Setup

Set up an HP 8116A, or a signal generator capable of a 1 MHz, 1 volt squarewave, as follows:

- MODE = NORM
- FRQ = 1 MHz
- DTY = 50%
- AMP = 1.00 V
- OFS = 0.00 V
- Pulse = squarewave

Connect the signal to a BNC tee on channel 1 using a 1 meter coaxial cable. Connect another 1 meter cable from the other side of the BNC tee and terminate in 50 Ω to channel 4.

Oscilloscope Setup

The extra cable length between channels 1 and 4 provides a time delay between the signals on the oscilloscope. The propagation of a 1 meter coaxial cable is approximately 6 to 7 ns. This delay is used to demonstrate the math function.

The following procedure will assist you in setting up the HP 54503A for optimal viewing.

- Press AUTOSCALE.
- Press DISPLAY to set the best viewing conditions. Set display mode to *avg*, *# of avg* to 8, *# of screens* to 2.
- Press WFORM MATH to define the function. Select **f1** and turn the display on. Select **chan 1**, **-** (minus), **chan 4** and set the function sensitivity to 2.00 V/div.

Now you can see the function of subtracting channel 4 from channel 1. The propagation between channels has allowed a 6 to 7 ns spike. To better view the results:

- Press TIMEBASE and set the horizontal display to 50.0 ns/div (see Figure 9-5).

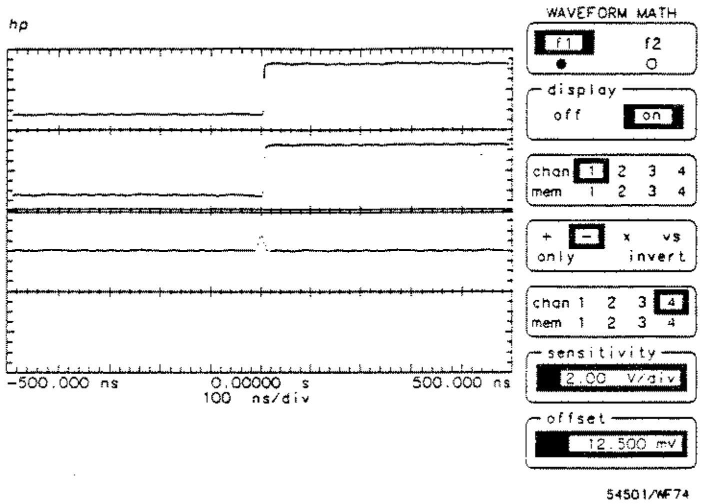


Figure 9-5. Channel 1 minus Channel 4

Waveform Save Menu — 10

Introduction to the Memories

This chapter describes how to select the waveform and pixel memories on the HP 54503A. The menu consists of two submenus:

- waveform memories m1 - m4 are non-volitile memories used to store one waveform at a time.
- pixel memories p1 and p2 are volitile memories used for screen store. In this manner the memories are used as a storage oscilloscope.

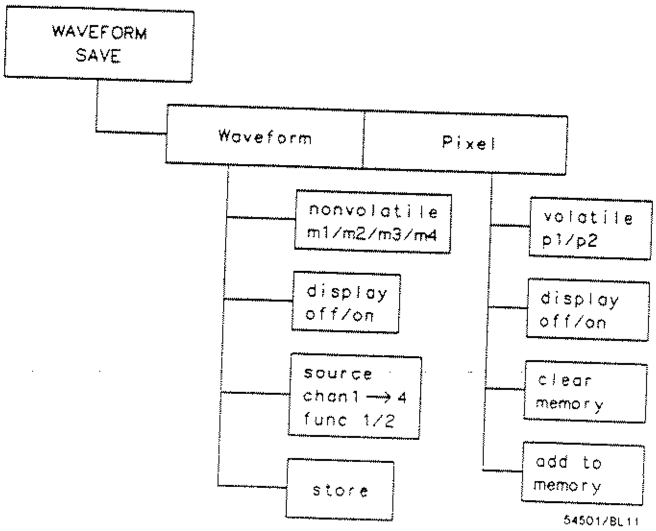
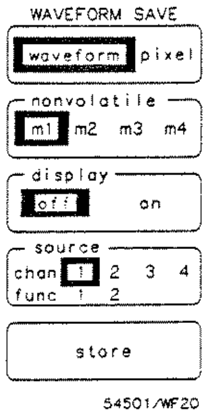


Figure 10-1. Waveform Save Menu

waveform/pixel Key

This is the selection key used to chose the desired type of memory. The active menu is highlighted. Each memory type, waveform or pixel, has a separate menu. When this key is pressed, the rest of the menu changes.

waveform Menu



The waveform menu has four available memories, m1, m2, m3, and m4. These memories are nonvolatile and are not cleared during AUTOSCALE, RECALL CLEAR, or recycling power. This permits disconnection of power and transportion of the oscilloscope without losing the contents of waveform memories.

A waveform memory consists of a single waveform record, including the horizontal and vertical scaling parameters. This allows measurements on stored waveform and function data. Voltage and time markers can be set on waveforms when they are displayed.

When the HP 54503A is in the envelope display mode and a waveform store is executed, the min value and max value are stored separately. The min value will be stored in m1 if m1 or m3 are the selected store locations, or m2 if m2 or m4 are the storage locations. The max values are stored in m3 or m4 respectively. A store message is displayed above the waveform display area informing you of the storage locations of both values.

nonvolatile Key This key selects which memory to use. The selections are nonvolatile memories m1, m2, m3 and m4. When a memory is turned on the small circle below the label is highlighted.

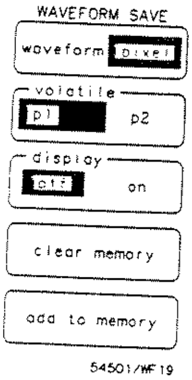
The waveform memories are record memories that store 2001 points of waveform information in each memory.

display Key This key toggles the selected memory display on or off.

source Key The source key selects the source waveform to be stored. The source alternatives are any channel or either function.

store Key This is the active key in the menu. This key stores the specified waveform in the specified memory. When the key is pressed, an immediate erase of the selected memory and a write to the memory is executed.

pixel Menu



The pixel submenu selects the pixel memories. These memories are very useful when additive memory capabilities are needed. Waveforms can be stored and added to indefinitely.

volatile Key This is the memory select key. The alternatives are pixel memory 1 or 2. The pixel memories are complete pixel saves of the waveform area (excluding the graticule and markers) in volatile memory. The waveform display area is 256 X 451 pixels.

In pixel memory the entire screen is saved, therefore, data is mapped directly onto the display and displayed in halfbright. There are no measurement capabilities on pixel memories.

Pixel memories are additive. When all pixels are full, add to memory will merely overwrite existing data.

display Key This key toggles the selected pixel memories on or off.

clear memory Key This key purges all data from the selected pixel memory.

add to memory Key By pressing this key, the currently displayed waveforms are added to the specified pixel memory.

Waveform Save Exercise

This exercise demonstrates how to store a waveform, changes the offset setting, and recalls the stored waveform to be compared with the current display.

Instrument Setup

Set up an HP 8116A or a signal generator capable of a 6 kHz, 1 volt squarewave:

- Mode = NORM
- FRQ = 6.00 kHz
- DTY = 50%
- AMP = 1.00 V
- OFS = 0.00 V
- Pulse = squarewave

Oscilloscope Setup

This procedure assists in setting up the HP 54503A for optimal viewing.

- Connect this signal to the Channel 1 input.
- Press AUTOSCALE.
- Press WFORM SAVE and select the **waveform** submenu.
- Press the **nonvolatile** key until **m3** is selected.
- Press the **source** key until **chan 1** is selected.

- Press the **store** key.

The currently displayed waveform is in nonvolatile memory m3. The remainder of this exercise demonstrates how to recall the stored waveform.

- Press the **display** key to turn on the **m3** display.

- Press the CHAN menu key, change the **offset** of channel 1.

This moves the current display so the stored waveform can be viewed. The display should look like the following figure.

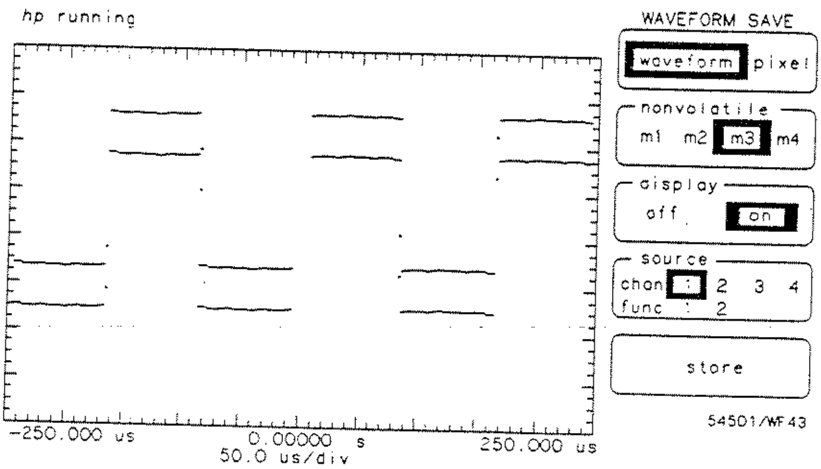


Figure 10-2. Displayed Memory

Define Measure Menu 11

Introduction to Measurements

This chapter contains a description of how to use the measurement menu. This is a very powerful and encompassing feature. Press the front panel key DEFINE MEAS to access the entire measurement function.

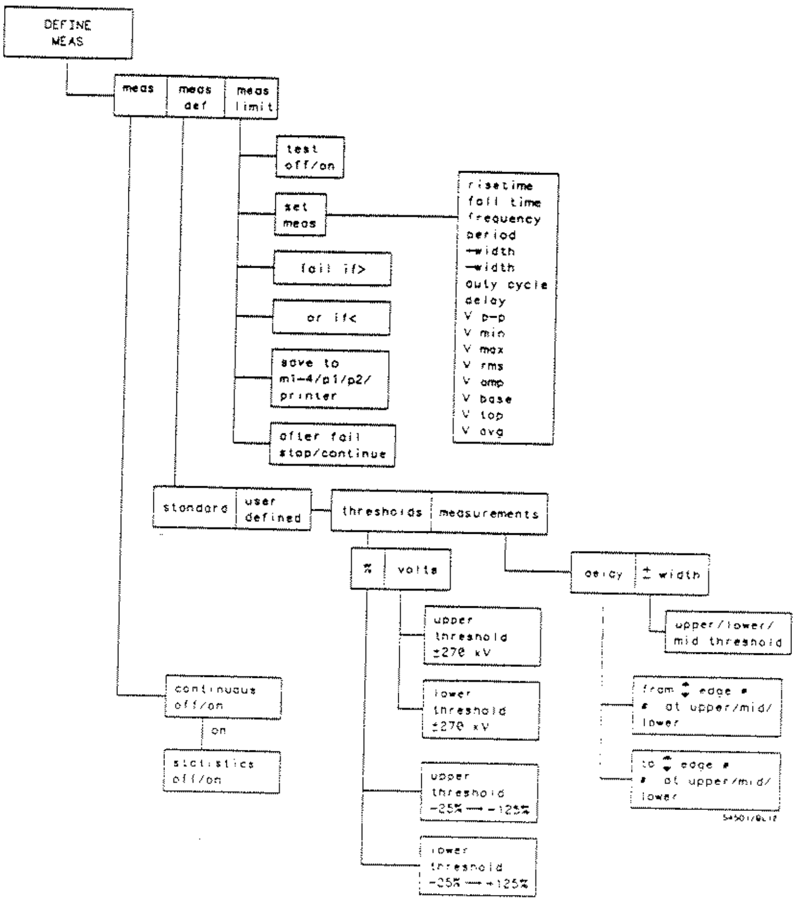


Figure 11-1. Define Measure Menu

The first menu sets the dynamic controls for the measurement. The second sets user-defined parameters for the measurements. And the third sets up the measurement comparison test.

Measurement Selection

Each key in the numeric keypad section has a secondary function. Above each key is a measurement selection printed in blue. To make an immediate measurement of the displayed waveform perform the following keystrokes:

- Press the blue (Shift) key on the numeric keypad to access the secondary keys.
- Press the key that corresponds to the measurement.
- Rotate the knob to select the measurement source (channel number, c#; memory number, m#; or function number, f#). The choice is displayed below the waveform display area.
- Press the appropriate number to select the source, channels 1-4, memories 1-4, or functions 1-2.

To make a selected measurement on a waveform source, it must be turned on. Upon selection of the measurement the time and voltage markers are placed on the waveform to show where the measurement was made if continuous measurements are off.

To clear measurements, press Shift and then CLR MEAS.

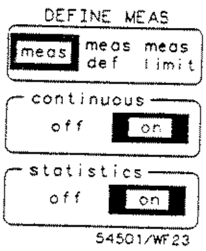
For complete details of the measurement definitions and algorithms, see Appendix A, "Algorithms."

meas/meas def/meas limit Key

This key is the primary sub-menu function key. Press to select one of the available sub-menus. This field is always the top selection so other submenus can be selected at any time.

meas Submenu

The measure submenu is the default condition. The continuous and statistics options can also be accessed.



continuous Key

If this option is turned on when a measurement selection is made, the displayed measurement is updated periodically. All subsequent measurements are continuously updated as they are selected.

When **continuous** is off, the measurement is made once and the Δt/ΔV markers are placed on that measurement showing where the measurement was made.

statistics Key

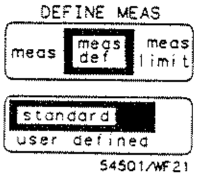
The continuous function must be on before the statistics key is available. When **continuous** is on, statistics display the **min value**, **max value**, average value, and **current value** of up to three measurements.

Measure Define Submenu

The measure define submenu selects measurement standards assigned by the user. This gives the option of making measurements based on signal width or delay settings or threshold parameters.

standard/user defined Key

If **standard** is selected, no other choices are available and the HP 54503A will make measurements based on the IEEE standards for the particular measurement.

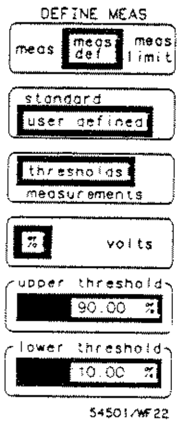


If, however, **user defined** is selected, two sets of test conditions are available to define the measurements.

thresholds/ measurements Key

This key sets the vertical test conditions, voltage or percentage ratios, independent of the horizontal test conditions, edge, slope, and count. Both sets of test conditions must be set to define the measurement.

The **thresholds** submenu sets the vertical test conditions at:



- percentage ratio from -25% to 125%
- voltage levels from -250 kV to +250 kV

Note

The upper and lower thresholds must be set to levels that will fall on the displayed waveform. If either threshold is not on the waveform the measurement results will be the message 'not found.'

Threshold settings apply to all user defined front panel measurements.

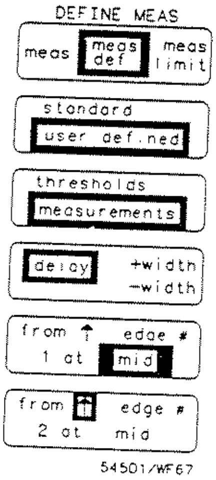
This feature is useful when measuring for excessive overshoot or ringing. By defining the measurements, testing for specific pass/fail criteria from the front panel, or set the HP 54503A in the limit test and allow the oscilloscope to report without supervision.

Note

If the user defined upper and lower thresholds are placed too close together it is possible the HP 54503A will not be able to determine the mid-point. The message 'not found' will be displayed in the measurement factors area.

Measurements defines more parameters, the horizontal test conditions, for three specific front panel keypad measurements:

- delay
- + width
- - width



When any of the three measurements are selected the measurement is made on the selected edge count, slope, and transition point. The HP 54503A starts counting edges from the left edge of the screen, not at the reference point. The selected edge must be displayed. If the edge is not displayed, the message not found is displayed in the measurement results area below the screen.

Measurement delay, not to be confused with timebase delay (see Chapter 4, 'Timebase Menu') is useful when measuring source-to-source delays or measuring time separation on the same source or a different source. The front panel delay measurement can be redefined by edge slope, edge count (from 1 to 100), and what part of the transition edge (upper, lower, mid) is used as a reference point.

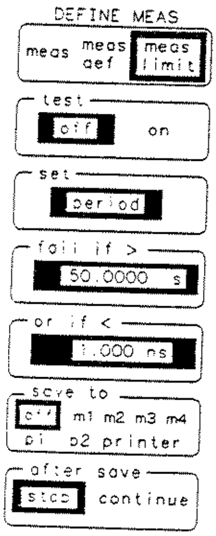
- When setting edge count fields, it is handy to press the fine key. In the course mode the HP 54503A increments/decrements by tens (1, 11, 21,...100). In the fine mode the increment/decrement sequence is in 1's.

When the delay measurement is selected from the front panel, the sources (**c#**, **f#**, **m#**) and the source number must be selected next.

+ width chooses only the point on the waveform transition (upper, lower, mid) to measure when making the positive width of a displayed waveform.

- width chooses only the point on the waveform transition (upper, lower, mid) to measure when making the negative width of a displayed waveform.

Measure Limit Sub-menu



54501/WF24

The HP 54503A can run limit tests on up to three measurements. The menu presets certain conditions and stores any failure data for evaluation at a later time. Set the limit test while in this menu and select the measurement from the front panel.

When a test is running, statistical data is displayed describing the test:

- current measurement
- minimum value
- maximum value
- average value

Failure data, as well as information regarding memory and save data is displayed.

Note

At least one measurement and up to three measurements must be selected from the keypad. The limit test will be run on front panel measurements.

test Key This switch toggles the test routine on and off. When the test is turned on the oscilloscope runs in the test mode on the most current measurements that are selected.

set Key This key selects the measurement. There are sixteen measurements available; the same ones as are available on the numeric keypad.

- Press the function key to highlight the field and rotate the knob to select the desired measurement.

fail if > Key This field sets the upper failure threshold. The range on this field is dependent upon the units of the desired measurement.

or if < Key This key sets the lower threshold of the failure parameters.

save to Key The data associated with the failure can be saved to memories or to a hardcopy device. The channel that is saved is selected in the WAVEFORM SAVE menu.

- In the case of saving to nonvolatile memory, one memory may be selected. If multiple failures occur, only the last failure data will be saved because the most current data will overwrite the memory contents.

- If the data is saved to pixel memory, an accumulated save occurs. No measurements may be made on the pixel data.

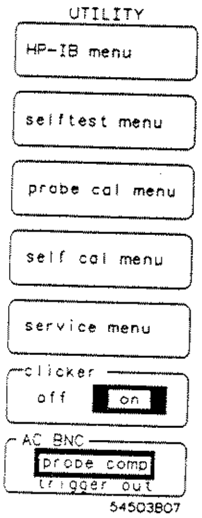
- A save to a printer immediately sends the data to the peripheral device.

- The **save to** key can be turned off and no save will be effected.

after fail Key The test can be stopped after a failure occurs, or continue the test.

Utility Menu 12

Introduction to the Utilities



The **UTILITY** menu accesses the calibration and service functions, as well as sets up the HP-IB interface. The submenus include self-test, calibration, service and a listing for the current firmware revision date.

This menu controls all of the service functions that maintain the reliable performance of the oscilloscope:

- HP-IB menu
- Selftest menu
- Probe cal menu
- Self cal menu
- Service menu
- Clicker control
- AC BNC

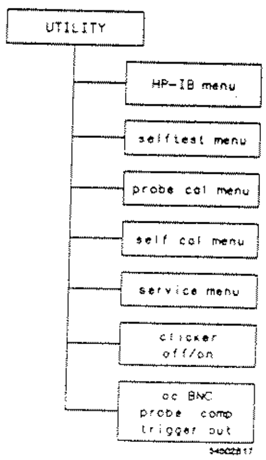
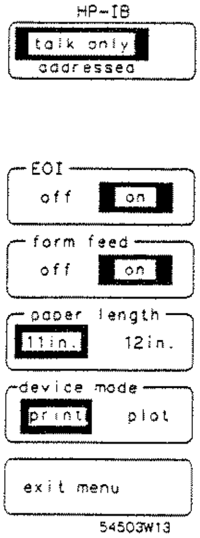


Figure 12-1. Utility Menu

HP-IB menu



The HP-IB submenu makes settings so the HP 54503A can talk to peripheral devices. This interface includes two primary settings:

- talk only mode
- addressed mode

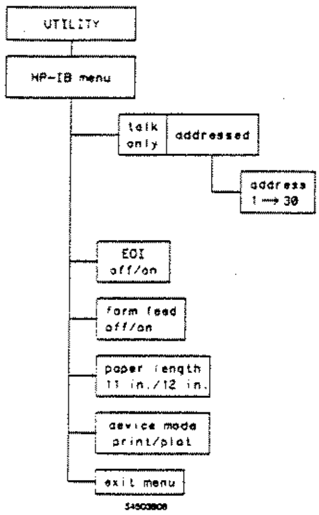


Figure 12-2. HP-IB Menu

talk only mode

Set the oscilloscope to **talk only** to perform a hardcopy without intervention from an external controller. The attached printer must be set in the **listen only** or **listen always** mode.

addressed mode

This mode allows a controlling device to selectively address the HP 54503A for talking or listening. The address of the HP 54503A can be selected while the instrument is in the addressed mode.

The range of available addresses is 0-30

EOI Key The EOI (End or Identify) key toggles this function on or off. EOI is a line on the HP-IB asserted with the last data byte of a message. If this function is on, EOI is asserted by the HP 54503A on the last byte of each message sent. If it is off, EOI is not asserted.

This function only affects messages sent from the HP 54503A. The HP-IB accepts any of the legal IEEE 488.2 message terminators regardless of the setting of this function.

Note

IEEE 488.2 requires that EOI is asserted. Therefore, with EOI off, the HP 54503A will send messages that do not follow IEEE 488.2 rules concerning EOI. EOI should only be turned off if the controller does not deal with EOI appropriately.

form feed Key If the form feed option is on, the printer performs a form feed at the end of the hardcopy. If form feed is off, the page is scrolled up four lines when the hardcopy is complete.

paper length Key Select between 11-inch or 12-inch pagelengths for auto form feed. This is used to set the 11-inch page, the U.S. standard, or the 12-inch page, U.K. and European standard.

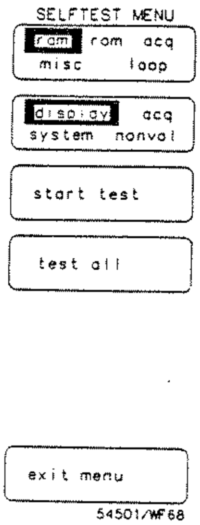
device mode Key This key selects whether the hardcopy goes to a printer or plotter. The HP 5503A has been designed to send hardcopoy to HP printers and plotters with HP-IB options.

The following printers have been successfully tested with the HP 54503A: HP 2225A HP-IB ThinkJet, HP 2227B QuietJet, and HP 3630A Option 002 PaintJet.

The following plotters have been successfully tested with the HP 54503A: HP 7440A Color Pro, HP 7470A Option 002, HP 7475A Option 002, HP 7550A and HP 9872C.

exit menu Key Pressing this key returns the UTILITY menu to the screen..

SELFTEST MENU



The HP 54503A is designed to perform internal diagnostics. This selftest submenu tests the oscilloscope to give a high confidence level of instrument functionality. Before starting any self-test, always perform a key-down power-up (RECALL CLEAR). This resets critical parameters to known values to assure erroneous test failures do not occur.

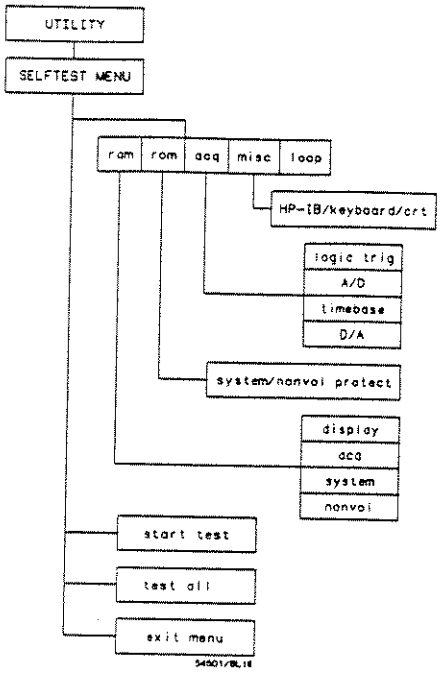


Figure 12-3. Self-Test Menu

If the HP 54503A fails any selftest perform the following:

- Recalibrate the oscilloscope.
- If that does not fix the problem, refer to the *HP 54502 Service* manual.

The HP 54503A self-diagnostics and self-tests are designed to run operational tests on the following:

- RAM
- ROM
- Acquisition
- Miscellaneous

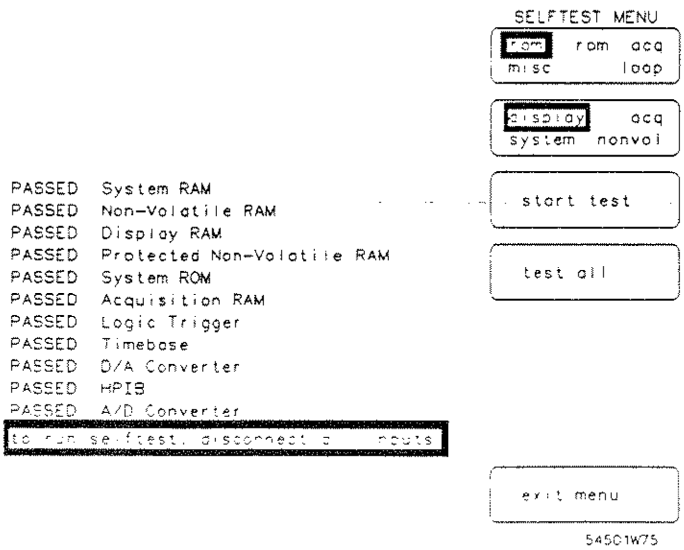


Figure 12-4. Results of Selftest

ram Test The RAM test is a multiple selection field with the following options:

- display
- acquisition
- system
- unprotected nonvolatile memory

rom Test Two ROM tests are available:

- system
- protected nonvolatile memory

acquisition Test Four acquisiton tests are available:

- logic trigger
- A/D
- timebase
- D/A

Miscellaneous Test Three miscellaneous tests are available:

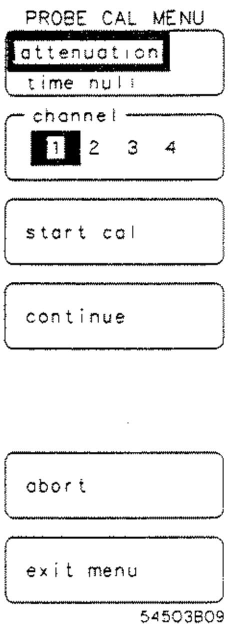
- HP-IB
- keyboard
- CRT

loop Test The loop test is a function designed for use by qualified service personnel. It is unnecessary to use this function for normal oscilloscope operation. When a self-test loop has been initiated it runs until stopped by pressing and holding any key.

start test Key Pressing this key begins the selected test.

exit menu Key Pressing this key returns the Utility menu to the screen.

probe cal menu



Two probe calibration procedures are available in the **PROBE CAL MENU:**

- Attenuation
- Time null

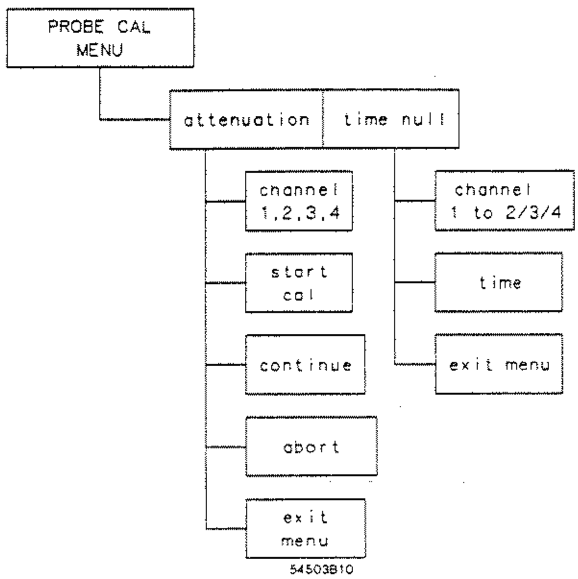


Figure 12-5. Probe Cal Menu

attenuation submenu The attenuation submenu calibrates channel gain at the probe tip. Channel gain can be corrected through probe attenuation down to 0.9 attenuation.

- Below 0.9 the error message **Attenuation less than 1, see manual for action** is displayed. The corrective action is to recalibrate the HP54503A.

If the probe is not connected to the DC CALIBRATOR OUTPUT on the rear panel or the probe attenuation exceeds approximately 250, the error message **Attenuation too high or bad connection** is displayed. The corrective action is to check the connections and recalibrate. If recalibration is unsuccessful, refer to the *HP 54503A Service* manual.

- If the probe attenuation calibration is successful the displayed message is **Probe Attenuation = n.nnnnn This value has been entered into your channel probe setting.**

channel Key Pressing this key selects a channel to calibrate. By continually pressing the key, the fields are incremented by channel.

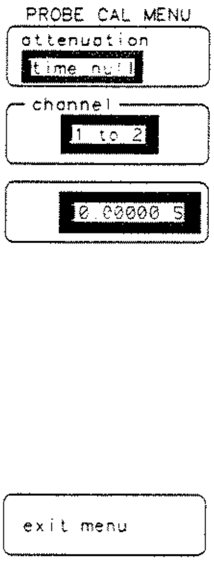
start cal Key When the channel to be calibrated has been selected, press **start cal.** The advisory appears at the bottom of the waveform display area **Connect the DC Cal rear panel bnc to the probe of channel n, then press continue.** Pressing this key prompts for setup requirements.

continue Key Press this key when all setup requirements have been satisfied. The actual calibration process begins.

abort Key This is the only active front panel key during the calibration process. If you press this key, the calibration process is terminated with the previous calibration factors intact.

exit menu Key Pressing this key returns the UTILITY menu to the screen.

time null submenu



54503B11

Time null sets the timing of all channels to correspond to each other. This eliminates any time discrepancies between channels and guarantees that channel to channel skew variations are non-existent. This is useful to manually adjust any differences in cable length.

time Key This is an unlabelled field. The time null between the two channels can be set using either of the entry devices. The range is ± 70 ns.

exit menu Key Pressing this key returns the UTILITY menu to the screen.

Self Cal menu

The self cal menu calibrates two internal functions:

- vertical cal
- delay cal

cal select Key This field selects which of the calibration processes to perform. Press the cal select key and the highlighted window increments through 0-1 and the active field in the display changes to correspond with the selection.

channel Key The channel key selects the channel to calibrate.

start cal Key When the channel to calibrate is selected, and the specific cal routine is selected, press the **start cal** key and follow the instructions displayed.

continue Key When all of the setup requirements are satisfied, press the **continue** key and the actual calibration process begins.

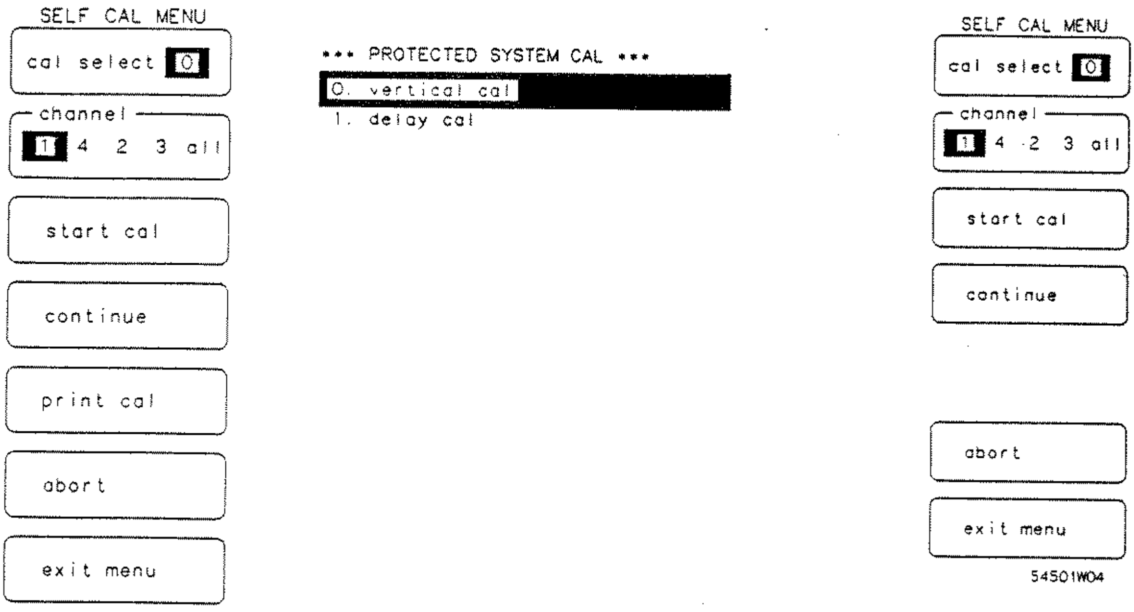


Figure 12-6. Self Cal Options

abort Key This is the only active front panel key during the calibration process. Pressing this key terminates the calibration process leaving the previous calibration factors intact.

exit menu Key This key returns to the UTILITY menu.

Note

Cal 0 must pass before Cal 1 can be performed successfully.

service menu

The service menu is used for firmware calibrations, hardware adjustments and calibrations that need not be performed often. These are explained in the service manual and are to be used only by qualified service personnel.

Note

When certain calibrations have been performed, other calibrations must be continued. Only qualified service personnel, with access to the service manual, are to perform calibrations in the service manual.

See the *HP 54503A Service Manual* for complete information on the service menu and calibration cycles.

clicker Key

The clicker key turns on the clicker function. When the clicker is turned on, an audible click is heard each time a key is pressed. The selections are either on or off.

Calibration Procedure

There are two levels of calibration for the HP 54503A. The first level is in the self cal menu and suggested by HP to be performed under the following conditions:

- at six month intervals or every 1000 hours of use,
- if the ambient temperature changes more than 10 ° C from the temperature at full calibration,
- or, the user would like to optimize measurement accuracy.

Self cals do not require equipment other than cables. It is necessary to UNPROTECT the calibration. Follow the Self Cal Menu calibration procedures to perform this first level of self cal.

The second level of self calibrations are to be performed only by qualified service personnel with access to the service manual.

Note

Before the HP 54503A can be calibrated the CALIBRATION toggle switch on the rear panel must be set to UNPROTECTED.

The procedure for calibration is:

- Set the rear panel CALIBRATION switch to UNPROTECTED.

- Enter the self cal menu.

- Select 0 in the **cal select** field and calibrate the vertical factors. This routine calibrates the A/D, vertical gain, offset, and trigger with the rear panel calibrator signal..

- Select 1 in the cal select field and calibrate the delay.

When the software calibrations are complete reset the CALIBRATION switch on the rear panel to PROTECTED.

Algorithms A

One of the primary features of the HP 54503A is the ability to make automatic measurements on displayed waveforms. This chapter provides details on how automatic measurements are calculated and some tips on how to improve results.

Measurement Setup

Measurements typically should be made at the fastest possible sweep speed for the most accurate measurement results. The entire portion of the waveform that is to be measured must be displayed on the oscilloscope. That is:

- at least one complete cycle must be displayed for period or frequency measurements
- the entire pulse must be displayed for width measurements
- the leading edge of the waveform must be displayed for risetime measurements
- the trailing edge of the waveform must be displayed for falltime measurements

Making Measurements

If more than one waveform, edge, or pulse is displayed, the measurements are made on the first (leftmost) portion of the displayed waveform that can be used. If there are not enough data points the oscilloscope will display ≤ with the measurement results. This is to remind you that the results may not be as accurate as possible. It is recommended that you re-scale the displayed waveform and make your measurement again.

Standard Measurements

When any of the standard measurements are requested, the HP 54503A first determines the top-base voltage levels at 100%-0%. From this information, it can determine thresholds (10%, 90%, and 50%) needed to make the measurements. The 10% and 90% thresholds are used in the risetime and falltime measurements. The 50% mid-point is used for measuring frequency, period, pulse width, and duty cycle.

The voltage thresholds are precise settings and sets specific locations on the waveform. If the thresholds are not placed on the waveform (above or below) the HP 54503A cannot make a measurement.

User defined Measurements

When any of the user defined measurements are requested, the HP 54503A still must determine the top-base voltage thresholds. From this information it can determine user defined upper and lower thresholds. The mid-point is then determined to be the 50% point between the upper and lower threshold.

Automatic Top-Base

Top-Base is the heart of most automatic measurements. It is used to determine V_{top} and V_{base}, the 0% and 100% voltage levels at the top and the bottom of the waveform. From this information the oscilloscope can determine the 10%, 50%, and 90% points, which are also used in most measurements. The top or base of the waveform is not necessarily the maximum or minimum voltage present on the waveform. Consider a pulse that has slight overshoot. It would be wrong to select the highest point of the waveform as the top since the waveform normally rests below the perturbation.

Top-Base performs a histogram on the waveform and finds the most prevalent point above and below the waveform midpoint. The most prevalent point is one that represents greater than approximately 5% of the total display points (501) and is considered to be either the top or base. If no point accounts for more than 5% of the total, then the top is chosen as the absolute maximum and the base is chosen as the absolute minimum.

Edge Definition

Both rising and falling edges are defined as transitional edges that must cross three thresholds.

A rising edge must cross the lower threshold in a positive direction (defining it as a rising edge), cross the mid threshold (any number of crossings, both positive and negative are permissible) and then cross the upper threshold without any crossing of the lower threshold.

A falling edge must cross the upper threshold in a negative direction, cross the mid threshold (any number of times), and then cross the lower threshold without crossing the upper threshold.

Note

Most time measurements are made based on the position of the first crossing of the middle threshold.

Algorithm Definitions

Following are the definitions that all measurements are based on:

delay There are three types of delay measurement:

- jitter
- standard
- user-defined

Jitter occurs only under the following circumstances:

- standard/user-defined key is set to standard
- two delay parameters are the same
- display mode is envelope

if

first edge on minimum waveform is rising

then
delay = mid-threshold of first rising edge of max waveform minus mid-threshold of first rising edge on min waveform

else
delay = mid-threshold of first falling edge on min waveform minus mid-threshold of first falling edge on max waveform

The standard delay measurement occurs when in the standard mode (not user-defined) and is not a jitter measurement.

standard delay = mid-threshold of the first edge of second parameter minus mid-threshold of the first edge of the first parameter

Note

Negative delay is possible

User defined delay = second channel edge minus first channel edge

+ width The + width algorithm has standard and user-defined considerations.

if
first edge is rising

then
+ width = mid-threshold crossing of first falling edge - mid-threshold crossing of first rising edge

else
+ width = mid-threshold crossing of second falling edge - mid-threshold crossing of first rising edge

User-defined is the same as Standard definition except user-defined threshold.

- width The - width algorithm has standard and user-defined considerations:

if
first edge is rising

then
- width = second rising edge - first falling edge

else
- width = first rising edge - first falling edge

Period	**if** first edge is rising **then** period = second rising edge - first rising edge
Frequency	frequency = 1/period
Duty Cycle	duty cycle = (+ width/period) * 100

Note

+ width is always calculated using mid-threshold.

Risetime	risetime = time at upper threshold - time at lower threshold
Falltime	falltime = time at lower threshold - time at upper threshold
V_{max}	V_{max} = voltage of the maximum point on screen
V_{min}	V_{min} = voltage of the minimum point on screen
V_{p-p}	$V_{p-p} = V_{max} - V_{min}$
V_{top}	V_{top} = most prevalent point above waveform midpoint
V_{base}	V_{base} = most prevalent point below waveform midpoint
V_{amp}	$V_{amp} = V_{top} - V_{base}$

V_{avg} Average voltage of the first cycle of the displayed signal is measured. If a complete cycle is not present the oscilloscope will average all data points.

V_{rms} The rms voltage of the first cycle of the displayed signal is measured. If a complete cycle is not present, the measurement will compute rms on all data points.

$$\text{Vrms (ac)} = \{ 1/n \ \Sigma^{n}{}_{j=1} Vj^{2} - 1/n \ \Sigma^{n}{}_{j=1} Vj \}^{1/2}$$

Specifications and Characteristics

B

Specifications

The following are performance specifications for the HP 54503A Digitizing Oscilloscope.

Vertical

Bandwidth(-3dB, dc coupled)
Repetitive:[1] dc to 500 MHz
Single-shot: dc to 2 MHz (based on 10 points per period of input signal)

Risetime:[2] 700 ps

Input R (selectable): 1 MΩ ±1% or 50 Ω ±1%

Maximum Input Voltage[3]
1 MΩ: ±250 V [dc + peak ac(< 10 kHz)]
50Ω: 5 V_{rms}

Offset Accuracy:[4] ±(0.5% of ch. offset + 2% of full scale)

Voltage Measurement Accuracy (dc)[4,5]
Dual Cursor: ±(1.25% of full scale + 0.032 × V/div)
Single Cursor: ±(1.25% of full scale + offset accuracy + 0.016 × V/div)

Horizontal

Time Base Reference Accuracy: 0.005%

Delta-t Accuracy
Real-time: ±(2% × s/div + 0.005% × delta-t + 100 ps)

Trigger

Trigger Sensitivity

≥5 mV/div
dc to 100 MHz: 0.063 × full scale
100 MHz to 500 MHz: 0.156 × full scale

< 5mV/div
dc to 100 MHz: 2.5 mV
100 MHz to 500 MHz: 6 mV

NOTES: Specifications valid for temperature range ±10°C from software calibration temperature with eitht or more averages selected.

1. Upper bandwidth reduces by 2.5 MHz for each °C above 35°C.
2. Rise time figure is calculated from: tr = 0.35/Bandwidth.
3. On ranges ≤50 mV/div the maximum overdrive of the input must not exceed 1000 times the V/div setting.
4. Expansion is used below 7 mV/div range so vertical resolution and accuracies are correspondingly reduced.
5. Accuracy decreases 0.08% per °C from software calibration temperature.

Characteristics

The following are performance characteristics of the HP 54503A Digitizing Oscilloscope.

Vertical

Switchable Bandwidth Limits
ac-coupled (lower -3 dB frequency): 90 Hz
LF reject (lower -3 dB frequency): 450 Hz
bandwidth limit (upper -3dB frequency): dc to 30 MHz

Number of channels:[1] 4

Vertical Sensitivity Range (all channels): 1 mV/div to 5 V/div

Vertical Gain Accuracy (dc):[2,3] ±1.25%

Vertical Resolution:[3] ±0.4% (8-bit A/D)
±0.1% (10 bits via HP-IB with averaging)

Maximum Sample Rate: 20 MSa/s

Waveform Record Length[4]
501 points (display)
1024 points (via HP-IB)

Input C: 7 pF nominal

Input coupling: ac, dc

Offset Range:

Vertical Sensitivity	Available Offset
1 mV - 50 mV/div	±2 V
>50 mV - 250 mV/div	±10 V
>250 mV - 1.25 V/div	±50 V
>1.25 V - 5 V/div	±250 V

Dynamic range (dc + peak ac): ±1.5 × full scale from center of screen

Channel-to-channel Isolation

(with channels at equal sensitivity)	**40 dB:** dc to 100 MHz **30 dB:** 100 to 500 MHz

NOTES: Specifications valid for temperature range ±10°C from software calibration temperature with eight or more averages selected and channel(s) in sensitivity range 1, 2, or 5.

1. Simultaneous acquisition on two channels. channels 1 and 4 are acquired simultaneously. If four channels are used, data is acquired alternately by channels 1 and 4, then 2 and 3.

2. Accuracy decreases 0.08% per °C from software calibration temperature.

3. Expansion is used below 7 mV/div range so vertical resolution and accuracies are correspondingly reduced.

4. For single-shot via HP-IB, waveform record length is 500 points. In repetitive mode:
   200 ps/div time base range, waveform record length is 100 points
   500 ps/div time base range, waveform record length is 250 points
   1 ns/div time base range, waveform record length is 500 points
   ≥ 2 ns/div time base range, waveform record length is 1000 points

Horizontal

Timebase Range: 200 ps/div to 5 s/div

Timebase Resolution: 20 ps

	Time/div Setting	Available Delay
Delay Range (post-trigger)	50 ms - 5 s	40 × (s/div)
	100 µs - 20 ms	1 s
	200 ps - 50 µs	10,000 × (s/div)
Delay Range (pretrigger)	5 µs - 5 s	−39.96 × (s/div)
	10 ns - 2 µs	−99.9 µs
	200 ps - 5 ns	−10,000 × (s/div)

Trigger

Trigger Pulse Width (minimum): 1.5 ns

Trigger Level Range: ±1.5 × full scale from center of screen

Operating Characteristics

Vertical

Deflection Factors: All channels: With single screen selected, attenuation factors are adjustable from 1 mV/div to 5 V/div in a 1-2-5 sequence with the knob. Finer adjustments can be made using direct keypad entry or the knob with the fine key selected.

Probe Attenuation Factors: Values from 0.9 to 1000 may be entered to scale the oscilloscope for external probes or attenuators attached to the channel inputs. When probe tip calibration is done, this value is calculated automatically.

Input Impedance: 1 MΩ or 50 Ω selectable for each input.

Bandwidth limit (HF Reject): Can be selected for each input individually. Provides low pass filter with a −3 dB point at approximately 30 MHz for both triggering and signal display.

LF Reject: Can be selected for each input individually. Provides high pass filter with a −3 dB point at approximately 450 Hz for both triggering and signal display.

AC Coupling: Can be selected for each input individually. Provides high pass filter with a −3 dB point at approximately 90 Hz and a two-pole rolloff for both triggering and signal display.

ECL/TTL Presets: Vertical deflection factor, offset, and trigger level can be preset independently on each channel for ECL and TTL levels.

Horizontal

Dual Timebase Windowing: Allows user to zoom in on portions of the waveform using cursors that are displayed on the top half of the screen. An expanded timebase is displayed on the lower half of the screen. The window timebase can be set to provide as much as a 20:1 expansion ratio.Waveform measurements are performed on the the dual timebase window information when windowing is turned on.

Delay Between Channels: Difference in delay between channels can be nulled out to compensate for differences in input cables or probe length. Use the "time null cal" found in the Utility menu.

Reference Location: The reference point can be located at the left edge, center, or right edge of the display. The reference point is equal to trigger point plus the delay time.

Trigger Modes

Edge Trigger: Positive or negative edge can be selected for trigger on any of the four channel inputs.

Pattern Trigger: A pattern can be specified using all four of the inputs. Each of the inputs can be specified as a *high, low,* or *don't care* with respect to the level setting in the edge trigger menu. Trigger can be selected to occur on the last edge to enter the specified pattern or the first edge to exit the specified pattern.

Time Qualified Pattern Trigger: A trigger will occur on the first edge to exit a pattern only if it meets the specified time criteria. The available time qualified modes are:

- pattern present < [time]
- pattern present > [time]
- range − pattern present > [time1] and < [time2]

The time settings are adjustable from 20 ns to 160 ms (±3% ±2 ns). The time filter recovery time is ≤12 ns. In the "pattern present < [time]" mode, the pattern must be present > 1.5 ns for the trigger to respond.

Glitch Trigger: Use "pattern present < [time]" with [time] selected such that it is just less than the pulse width of the signal you are analyzing. The minimum glitch width is 1.5 ns.

State Trigger: A pattern is specified on any three of the four inputs, with the fourth input used as a clock. A trigger will occur on the rising or falling edge of the input specfied as the clock when the pattern is present or not present. Setup time for the pattern with respect to the clock is less than or equal to 10 ns; hold time is zero.

Delayed Trigger

Event-delayed Mode: The trigger can be qualified by an edge, pattern, time qualified pattern or state. The delay can be specified as a number of occurrences of a rising or falling edge on any one of the four inputs. After the delay, an occurrence of a rising or falling edge on any one of the four inputs will generate the trigger. The occurrence value of the edge to trigger on is selectable from 1 to 16,000,000. The maximum edge counting rate is 70 MHz.

Time-delayed Mode: The trigger can be qualified by an edge, pattern or state. The delay is selectable from 30 ns to 160 ms. After the delay, an occurrence of a rising or falling edge on any one of the four inputs will generate the trigger. The occurrence value of the edge to trigger on is selectable from 1 to 16,000,000. The maximum edge counting edge is 70 MHz.

TV Trigger

60 Hz / 525 Lines: Source is selected to be any one of the four inputs. Trigger level is adjustable for the selected source. Polarity is selected for positive or negative synchronizing pulses. A trigger occurs on the selected line and field of a 2/1 interlaced composite video signal. Line numbering is 1 to 263 for field 1 and 1 to 262 for field 2. This TV trigger mode is compatible with broadcast standard M.

50 Hz / 625 Lines: Source is selected to be any one of the four inputs. Trigger level is adjustable for the selected source. Polarity is selected for positive or negative synchronizing pulses. A trigger occurs on the selected line and field of a 2/1 interlaced composite video signal. Line numbering is 1 to 313 for field 1 and 314 to 625 for field 2. This TV trigger mode is compatible with broadcast standards B,C,D,G,H,I,K,K1,L and N.

User-defined Mode: Source is selected to be any one of the four inputs. Trigger level is adjustable for the selected source. The trigger is qualified with a high or low pulse that meets a selectable time range. The trigger is an occurrence of a rising or falling edge of the source after the qualifying pulse. The time settings for the qualifier are selectable from 20 ns to 160 ms (±3% ±2 ns). The trigger occurrence value is selectable from 1 to 16,000,000.

NOTE: *All TV trigger modes require a clamped video signal for stable triggering. Use the HP 1133A TV pod to provide clamped video output that can be used in conjunction with the HP 54503A's TV triggering capabilities.*

Trigger Holdoff: Trigger can be held off by either time or events over the ranges:

- Time: 40 ns - 320 ms
- Events: 2 - 16,000,000

An Event is defined as the specified trigger condition. A separate holdoff setting (time or events) is available for each trigger mode except delayed trigger, which is set to 40 ns.

Noise Reject Trigger: Improves triggering on noisy signals by increasing hysteresis.

Display

Data Display Resolution: 451 points horizontally by 256 points vertically.

Number of Screens: 1, 2 or 4 screens can be selected. This enables overlapping channels or memories for comparison, or displaying them in up to 4 data display areas.

Display Modes

Minimum Persistence: One waveform data value is displayed in each horizontal position of the display. The waveform is updated as new data is acquired for a particular horizontal position.

Variable Persistence: The time that each data point is retained on the display can be varied from 200 ms to 10 seconds, or it can be displayed infinitely long.

Averaging: The number of averages (n) can be specified in powers of 2, up to 2048. On each acquisition, 1/n times the new data is added to (n −1)/n of the previous value at each time coordinate. Averaging operates continuously, except for the HP-IB digitize command, for which averaging terminates at the specified number of averages.

Envelope: Provides a display of the running maximum and minimum voltage levels at each horizontal position for a repetitive waveform.

Graticules: The user may choose full grid, axes, frame, or no graticule.

Connect-the-dots: Provides a continuous display, connecting the sample points with straight lines. Connect-the dots is operative for modes in which a single valued waveform can be connected, including average, envelope and minimum persistence modes.

Scroll Mode: In the Auto Mode at settings from 200 ms/div to 5 s/div the 54503A automatically selects the scroll mode display. It will also select scroll display in the triggered mode with delay reference (= left and delay ≥0). Scroll mode updates each data point on the displayed waveform as the data is acquired.

Delta t /Delta V

Markers: Dual voltage markers and dual time markers are available. Voltage markers can be independently assigned to channels, memories, or functions.

Waveform Math

Two independent functions are provided for waveform math. The operators are +, −, ×, vs, invert, and only. The vertical channels and the waveform memories can be used as operands for the waveform math. Sensitivity and offset for these functions can be adjusted independently.

Waveform Save

Four non-volatile waveform memories and two volatile pixel memories are provided. Waveform memories store single-valued waveforms, such as an averaged waveform. If an envelope waveform is stored to a waveform memory, it will automatically be stored with the upper waveform in one waveform memory and the lower waveform in another. Pixel memories store an entire screen of waveform data. They are very useful for storing multiple overlapping waveforms and infinite persistence waveforms.

Automatic Pulse Parameter Measurements

The 54503A offers 16 automatic pulse parameter measurements from the front panel (shown below) and additional measurements via HP-IB including All, Overshoot and Preshoot. The standard measurements are performed with 10%, 50% and 90% voltage thresholds, as defined by IEEE standard 194-1977, "IEEE Standard Pulse Terms and Definitions."

Automatic measurements available on the HP 54503A.

Risetime	Pulse Width +	Volts amp	Volts avg	Preshoot (HP-IB only)
Falltime	Pulse width −	Volts base	Volts max	Overshoot (HP-IB only)
Frequency	Duty Cycle	Volts top	Volts min	
Period	Delay	Volts p-p	Volts RMS	

User-Definable Measurement Thresholds

The HP 54503A allows you to set your own thresholds for automatic measurements. Both the upper and lower thresholds can be set, either in % or Volts, as long as the upper threshold value is always ≥ the lower threshold. The mid threshold is always equal to the mid-value between the upper and lower threshold.

Continuous Measurements: Allows automatic measurements to be continuously updated, and most recent measurement results displayed. With continuous measurements off, the voltage and time markers are placed on the waveform to indicate the last measurement is taken.

Measurement Statistics: The maximum, minimum and average of continuously updated measurements are calculated and displayed. Any three measurements can be selected for simultaneous display.

Measurement Limit Test: Maximum and minimum limits can be set for three of the automatic measurements. These continuously updated measurements are compared to the maximum and minimum limits. If the measurements are found to be outside the defined limits, the acquisition is stopped and the waveform can be stored to a memory or the screen can be sent to a printer. In addition, the HP-IB Service Request line can be set, to flag the controller.Measurement limit test can be set to stop after test limits have exceeded, or to continue testing.

Setup Aids

Auto-Scale: Pressing the Auto-Scale button automatically adjusts the vertical and horizontal deflection factors and the trigger level for a display appropriate to the signals applied to the inputs. The Auto-Scale feature requires a signal with a duty cycle greater than

0.5% and a frequency greater than 50 Hz. Auto-Scale is operative only for relatively stable input signals.

Save/Recall: Four front panel setups (1-4) may be saved in non-volatile memory.

Recall Clear: Resets the HP 54503A to its factory default settings.

Recall 0: If Auto-Scale, ECL or TTL preset, or recall setup are inadvertently selected, recall 0 restores the instrument to its last state prior to selection.

Show

Displays instrument status, including volts/div, offset, and trigger condition.

Hardcopy

The CRT display contents, including menus and measurement answers, can be transferred directly to an HP-IB raster graphics printer, including the HP 2225A Thinkjet.

Full HP-IB Programmability

Instrument settings and operating modes, including automatic measurements, may be remotely programmed via HP-IB (IEEE-488). HP-IB programming complies with IEEE 488.2-1988 "Standard Codes, Formats, Protocols, and Common Commands."

Data Acquisition and Waveform Transfer Rate: A 500 point waveform data record can be acquired and transferred to a computer at a rate of approximately 10 times per second, as tested with an HP 9000, Series 200 Controller. The acquired data was type normal, completion criteria 100%, with the oscilloscope at a time/division setting of 5 μsec/div.

Data Transfer Rates: Approx. 120 kbytes/sec.

Probe Compensation, AC Calibrator Output: An approximately 1.5 kHz signal is provided for probe compensation. A probe-to-BNC adapter is used to connect the probe to the rear panel Probe Compensation BNC output. During calibration, this output is used to provide other calibration signals, as described in the Service Manual. This same BNC connector is used for trigger output. The utility menu allows the user to switch the BNC from probe compensation and calibration signals to a trigger output pulse. The leading (rising) edge, with amplitude from approximately −400 mV to 0V (when a terminted in 50 Ω), is synchronous with system trigger. The trailing (falling) edge of this pulse occurs approximately at the end of holdoff. The leading (rising) edge should be used as the edge synchronous with trigger.

DC Calibrator Output: this output is used for vertical calibration of the 54503A, as described in the Service Manual.

Product Support

Built-in Self Test and Calibration Routines: Internal self-test capabilities provide a 90% confidence that the instrument is operating properly. External test procedures in the service manual provide 100% confidence. Self-calibration routines, also selected through the front panel "utility" menu, ensure that the instrument is operating with its greatest accuracy and requires no external test equipment.

Low Cost of Ownership: The HP 54503A carries a three-year warranty. HP's board exchange program assures economical and timely repair of units, reducing cost-of-ownership.

Solutions: HP's System Engineering Organization can help you configure an HP-IB system and provide software support for your application.Contact your Hewlett-Packard sales and service office for more information.

General Characteristics

Environmental Conditions

Temperature
Operating: 0°C to + 55°C
Non-operating: − 40°C to + 70°C

Humidity
Operating: up to 95% relative humidity (non-condensing) at + 40°C
Non-operating: up to 90% relative humidity at + 65°C.

Altitude
Operating: up to 4 600 meters (15 000 ft)
Non-operating: up to 15 300 meters (50 000 ft).

Vibration
Operating: Random vibration 5-500 Hz, 10 minutes per axis, 0.3 G_{rms}
Non-operating: Random vibration 5-500 Hz, 10 minute per axis, 2.41

G_{rms}; Resonant search 5 to 500 Hz swept sine, 1 Octave/minute sweep rate, (0.75G), 5 minute resonant dwell @ 4 resonances per axis.

Power Requirements

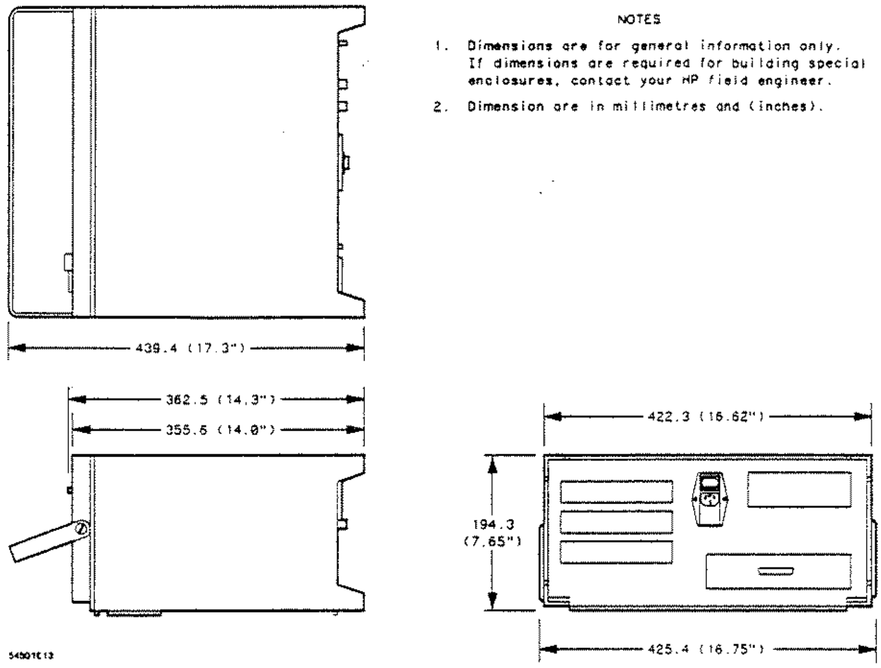
Voltage: 115/230 V ac, – 25% to + 15%, 48-66 Hz.
Power: 350 VA maximum.

Weight

Net: approximately 10 kg (22 lb).
Shipping: approximately 20 kg (44 lb).

Dimensions

Refer to outline drawings below.



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Getting Started Guide

HP 54501A, HP 54502A and HP 54503A

Digitizing Oscilloscopes

HEWLETT PACKARD

Publication 5958-0351

Printed in the U.S.A. April 1989

About this book ...

This getting started guide is an hands-on introduction to the HP 54501A, HP 54502A and HP 54503A Digitizing Oscilloscopes.

Whether a novice oscilloscope user or just new to this particular model, this book gives a working knowledge of the operation of these oscilloscopes. The items covered are:

- front-panel layout,
- applying power to the instrument,
- setting up the oscilloscope,
- making some measurements,
- using and interpreting the display, and
- using some other basic features.

The names of keys (**AUTOSCALE, TIME/DIV**) are in bold type. The actions (rotate the knob, press the **AUTOSCALE** key) are set off by bullets. The text indented under the bullets explain the action.

The HP 54501A was used for most of the examples and figures in this guide. Although all three oscilloscopes operate very similarly, there are some differences in the features of each. The HP 54501A and HP 54503A have ac calibrator signal of approximately 1.5 kHz and the HP 54502A calibrator signal is approximately 500 Hz. Therefore, some of the values on the display and in the menus of the figures may be different than those displayed on the HP 54502A.

Every feature and function of the oscilloscopes is not covered in this guide. All menus and functions are described in the *Front-Panel Reference* for each oscilloscope.

For an understanding of digitizing oscilloscopes ... or a refresher, *Feeling Comfortable with Digitizing Oscilloscopes*, HP Part Number 9320-5776, is supplied with each oscilloscope.

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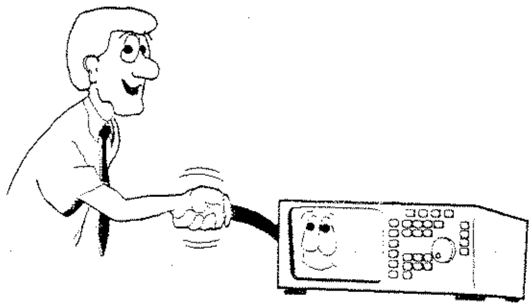
Introduction 1

The HP 54501A, HP 54502A, and HP 54503A are affordable general purpose digitizing oscilloscopes. These oscilloscopes are portable and completely HP-IB programmable.

All three digitizing oscilloscopes have the following features:

- Ability to view signal events prior to trigger
- Instant Hardcopy Output
- Autoscale for Automatic Setup
- Full HP-IB Programmability
- Automatic Measurements with User Defined and Statistics
- Measurement Limit Test
- Waveform Math (+, -, X, vs, invert, only)
- 4 Nonvolitile Set-up Memories
- 4 Nonvolatile Waveform Memories
- 2 Volatile Pixel Memories
- Dual Timebase Windowing
- Advance Logic Triggering
- TV Triggering



Each model has separate features that make it different from the other two models.

The HP 54501A features:

- Repetitive Bandwidth - dc to 100 MHz
- Single Shot Bandwidth - dc to 1 MHz
- Maximum Vertical Sensitivity - 5 mV/div
- Sample Rate - 10 MSa/s
- Number of Channels - 2 + 2
- Memory Depth - 1K/channel

The HP 54502A features:

- Repetitive Bandwidth - dc to 400 MHz
- Single Shot (Realtime) Bandwidth - dc to 100 MHz
- Maximum Vertical Sensitivity - 2mV/div
- Maximum Sample Rate - 400 MSa/s
- Number of Channels - 2
- Memory Depth - 2K/channel
- External Trigger - 1 channel

The HP 54503A features:

- Repetitive Bandwidth - 500 MHz
- Single Shot Bandwidth - dc to 2 MHz
- Maximum Vertical Sensitivity 1 mV/div
- Maximum Sample Rate - 20 MSa/s
- Number of Channels - 4
- Memory Depth 1K/channel

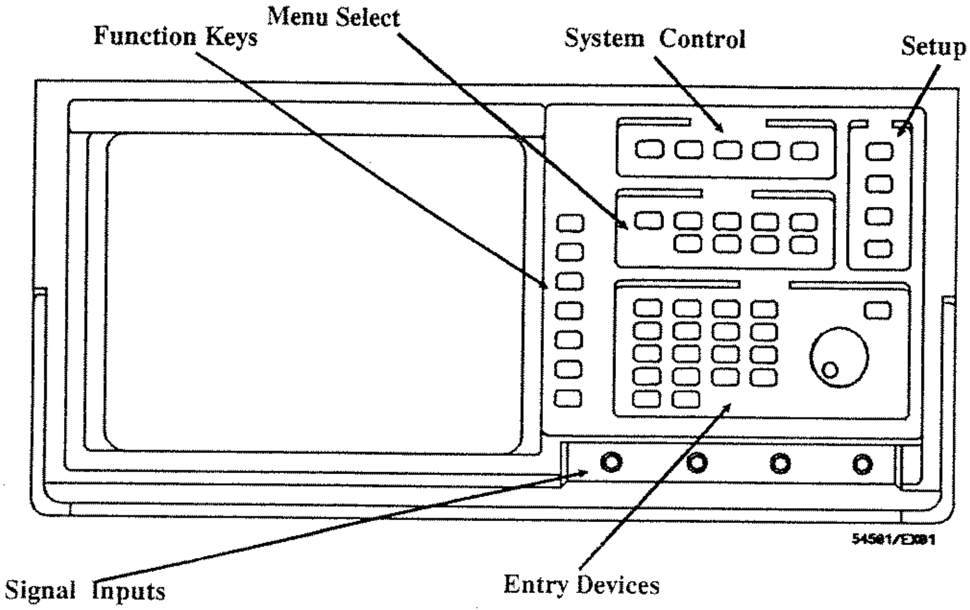
Complete specfications and characteristics are listed in appendix A of the *Front-Panel Reference* for each oscilloscope model.

Layout and Setup 2

Front Panel Layout

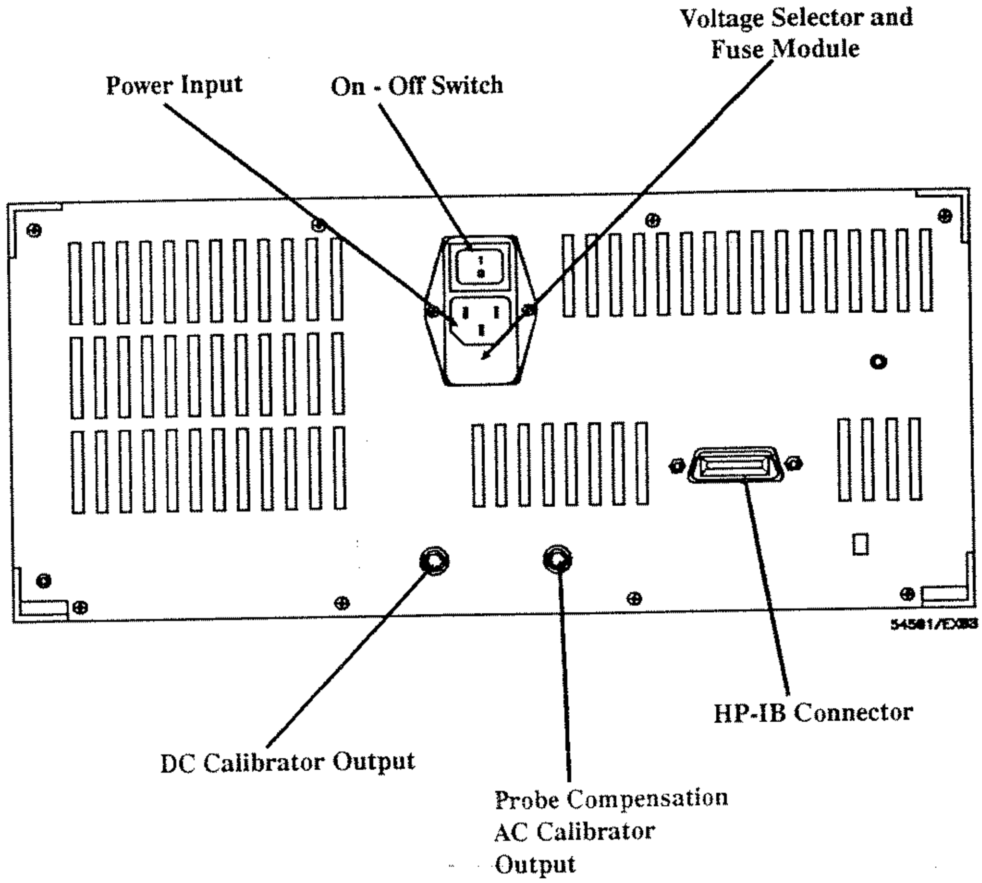
The oscilloscope front panel is organized into six functional areas. Typical front panel operation consists of these three main steps.

- select a menu (MENU Select),
- select a function (Function keys),
- enter numeric value (Entry Devices).



Rear Panel Layout

The rear panel of the instrument contains the power input, voltage selector module, and power switch.



Start Up

Refer to the *Front-Panel Reference* for complete installation instructions.

Connecting Power

To ensure safe operation, the following items should be checked before power is applied to the instrument:

- Before connecting the instrument to an ac power source, ensure that the line voltage selector module is installed for the correct voltage. On the voltage selector module, the correct voltage selection must be at the bottom.

- Make sure that the correct power cord is supplied with the oscilloscope to provide chassis ground for the instrument when it is plugged into the power receptacle.

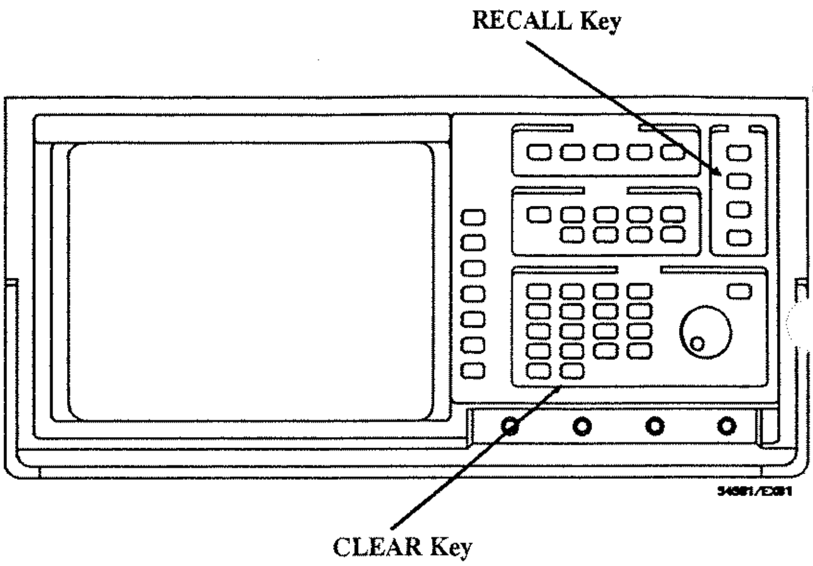
Applying Power

After the power cord has been connected to the instrument and appropriate power source, set the rear-panel power switch ON to start instrument operation (0 indicates OFF and 1 indicates ON).

Resetting the Instrument

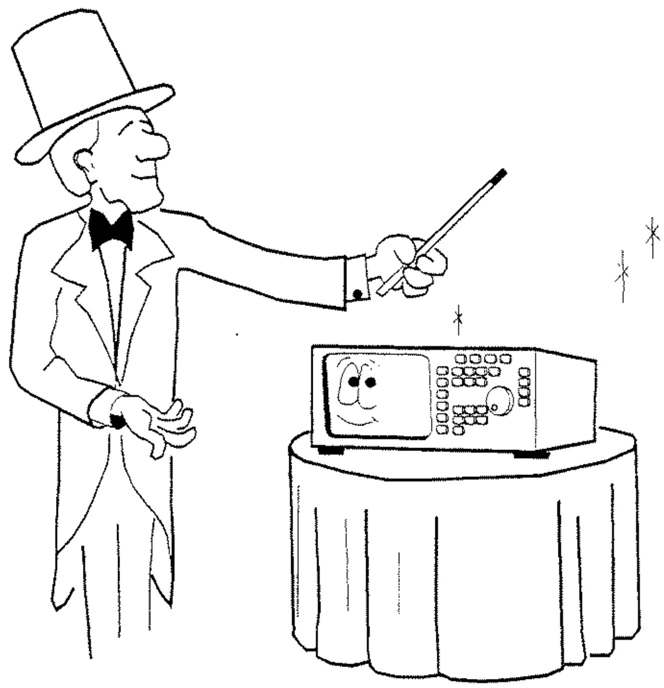
This instrument stores all settings in nonvolitile memory when power is removed or turned off. These settings are remembered on power-up. In order to get all settings and keys to a known starting position, for the following procedures, reset the instrument.

- Press the front panel **RECALL** key and then the **CLEAR** key.



Instant Setup 3

In this chapter a basic oscilloscope setup is performed. The oscilloscope is set up automatically and manually. Generally, the automatic setup is used on an unknown signal or signals, then adjusted (fine tuned) manually.

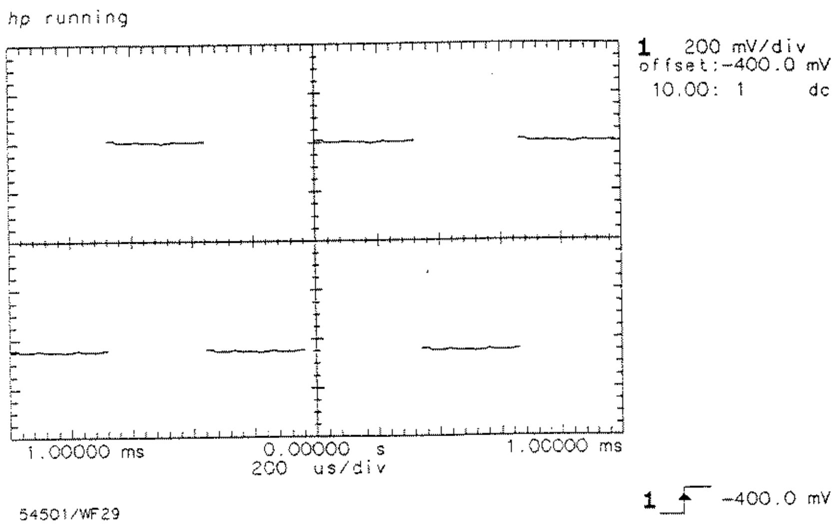


Autoscale

Autoscale automatically finds, scales, and displays the input waveform.

- Connect the ac calibrator output, on the rear panel of the oscilloscope to channel 1 input with the supplied probe and probe-to-BNC adapter.

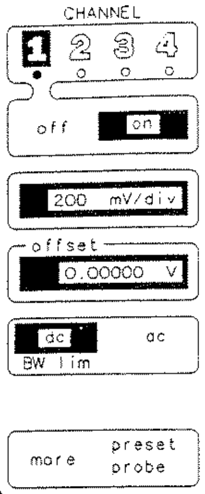
- Press **AUTOSCALE** key.



The channel settings and trigger information are displayed along the right edge of the display.

Vertical Setup

The vertical setup displays the signal at most amplitude levels.



54501W10

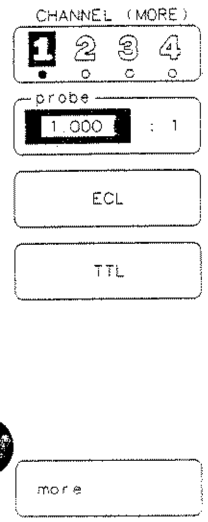
- Press **CHAN** Menu key.

  Channel menu is displayed along the right edge of the display and volts/divison is active function (displayed in full-bright inverse video.)

- Press **more** key.

- Change probe attenuation to 10:1 (attenuation of probe supplied with oscilloscope) with keypad or knob.

  Notice the voltage information changes but the displayed waveform does not.



54501W11

- Press **more** key again to return to the first channel menu and rotate the knob slowly.

  The volts/division changes and the waveform amplitude on the display changes.

  Notice the volts/division changes in much smaller increments because of the change in probe attenuation.

- Enter 250 mvolts.

  Press **2**, **5**, **0**, **mV** keys in order. The unit key completes the entry.

- Press **channel ON/OFF** function key.

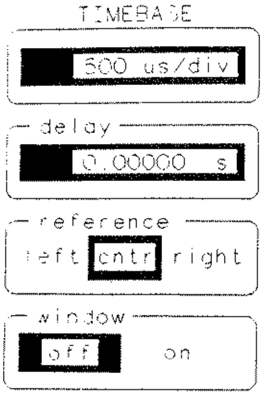
Turn channel 1 display off.

The dot below the channel selection changes from inverse video to an outlined dot. This indicates that the channel is turned off.

- Press **channel On/Off** function key again.

Turn the channel 1 display back on and the dot becomes an inverse video diplay.

Timebase Setup



54501W08

Setting the timebase displays the signal at different time/division settings (Remember the frequency of the HP 54502A is different than the HP 54501A and HP 54503A and will have different values displayed.)

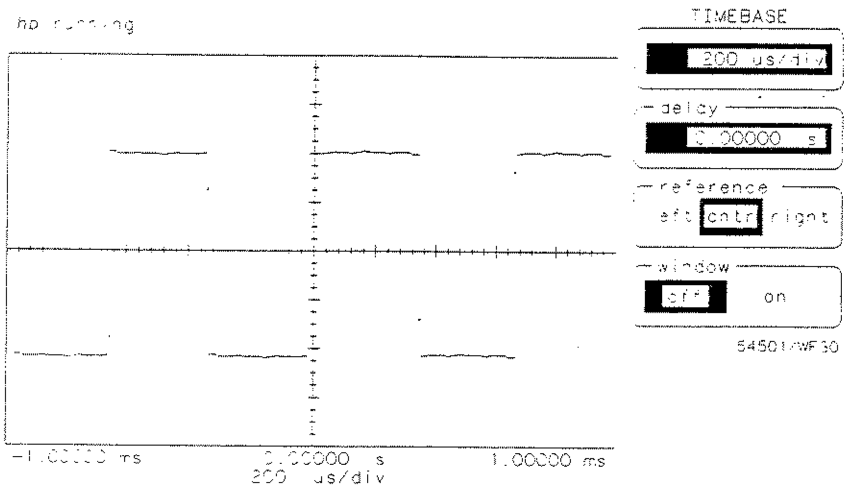
- Press **TIMEBASE** menu key.

The displayed menu changes to the timebase menu.

The selected function is time/division (top key in menu, displayed in full bright).

- Rotate the knob.

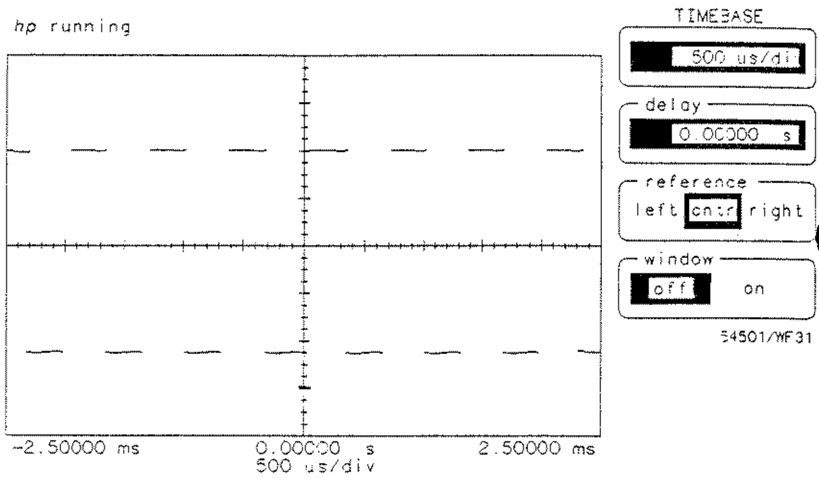
The time/division changes in a 1, 2, 5 sequence as the knob is rotated.



- Enter 500 μseconds.

Press **5, 0, 0, μs** keys in order.

When using the keypad, press a units key (s, ms, μs, or ns) to complete the entry.



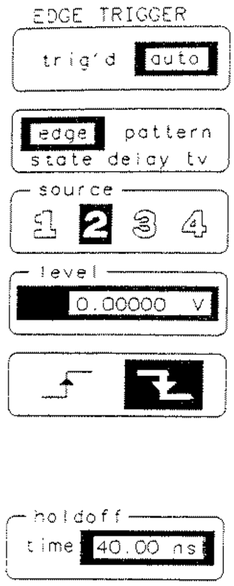
Trigger Setup

The oscilloscope can be set to trigger at any threshold level with the trigger level function.

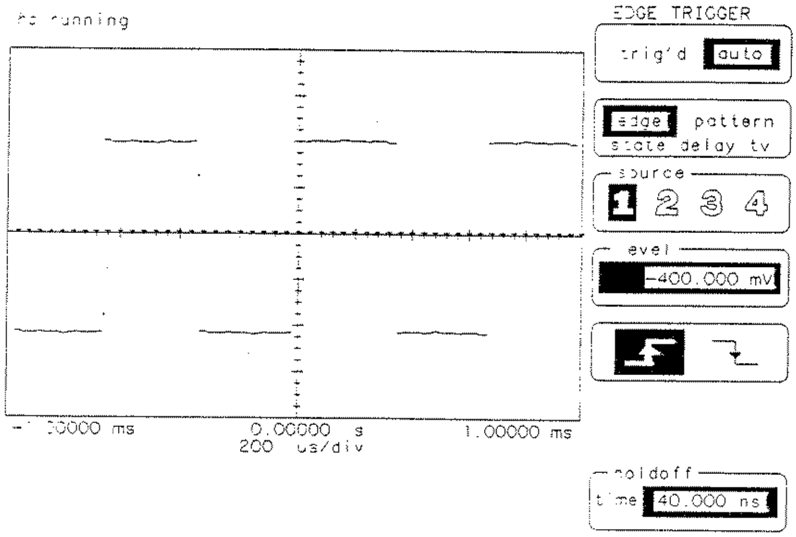
- Press **TRIG** menu entry key.

The trigger menu is displayed on the right edge of the display.

The level function is selected (full-bright).



54501W12



54501/WF32

- Rotate the knob.

As the knob is turned the trigger level value is changed.

The trigger level is a horizontal dotted line that moves up and down as the knob is turned.

- Set trigger level to -650 mvolts.

Enter this value with the keypad.

- Press SHOW key.

Key is located at the right of the oscilloscope in the SETUP section.

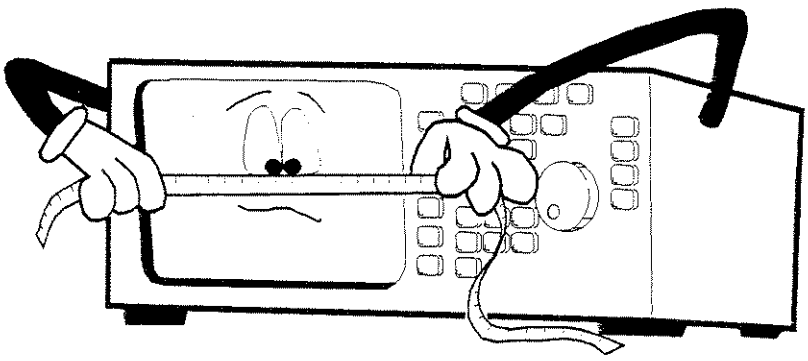
Channel and trigger setup information is displayed.

- Press SHOW key.

Return to trigger menu.

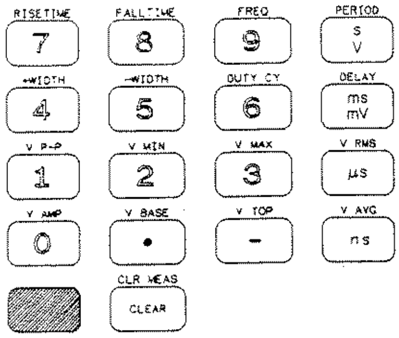
Making Automatic Measurements 4

There are 16 parametric measurements these oscilloscopes can make automatically. These measurements are made with preset (standard) measurement definitions or by user defined measurement thresholds. This chapter performs measurements using the standard measurement definitions. For more information on user defined measurements, refer to the Define Measure Menu chapter of the *Front-Panel Reference*.



Making the Measurements

This exercise measures frequency and peak-to-peak voltage of the displayed waveform.



- Connect the ac calibrator signal from the rear panel to channel 1.
- Press **AUTOSCALE**.

Display and trigger the signal from channel 1.

- Press **SHIFT** (blue) entry key.

Select the alternate (blue letter) functions of the keypad.

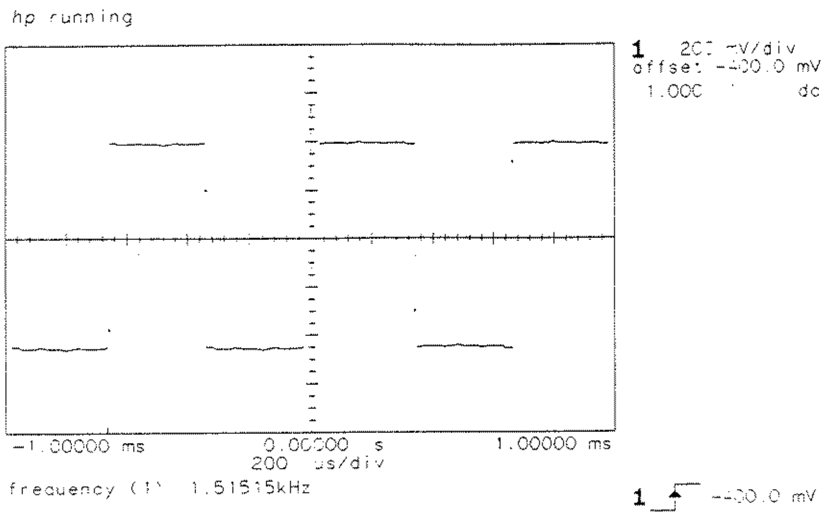
- Press **FREQ [9]** entry key.

Select frequency as the measurement to be made.

At least one complete cycle of the signal must be displayed.

- Press the 1 entry key to select channel 1 as measurement source.

- The result of the frequency measurement is displayed as in figure below. (Frequency of HP 54502A rear panel calibrator signal is approximately 500 Hz rather than the approximate 1.515 kHz of HP 54501A and HP 54503A.)



54501W34

- Press **SHIFT** key.

Select the measurement functions.

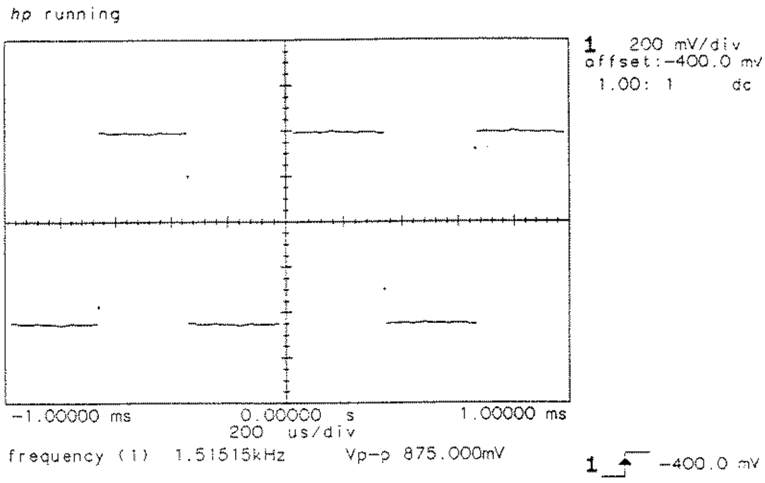
- Press **Vp-p [1]** entry key.

Select peak-to-peak voltage as the measurement.

- Press the **1** entry key.

To select channel 1 as the measurement source.

Time and voltage markers would be displayed showing where the measurement was made if continuous measurements were turned off.



54501W35

- Read the measurement results.

Measurement results are displayed below the waveforms. Up to eight measurements can be displayed at a time.

If another measurement is made, after the screen is full, it is placed on the bottom display line and the top set of measurements are erased from the display.

Clearing the Measurements

This portion of the exercise shows how to eliminate the measurements from the display.

- Press **SHIFT** entry key then the **CLEAR** entry key.

All measurement results are erased from the display.

Measuring Other Sources

Measurements can also be made on a waveform that is stored in a Waveform Memory or on the results of a mathematical calculation, a Waveform Function.

- Press **SHIFT** entry key then the **V P-P [1]** entry key.

  At this time the measurement source prompt is **c#** (for channel number).

- Rotate the knob slowly.

  The measurement source prompt cycles through **m#**, **f#**, and **c#**.

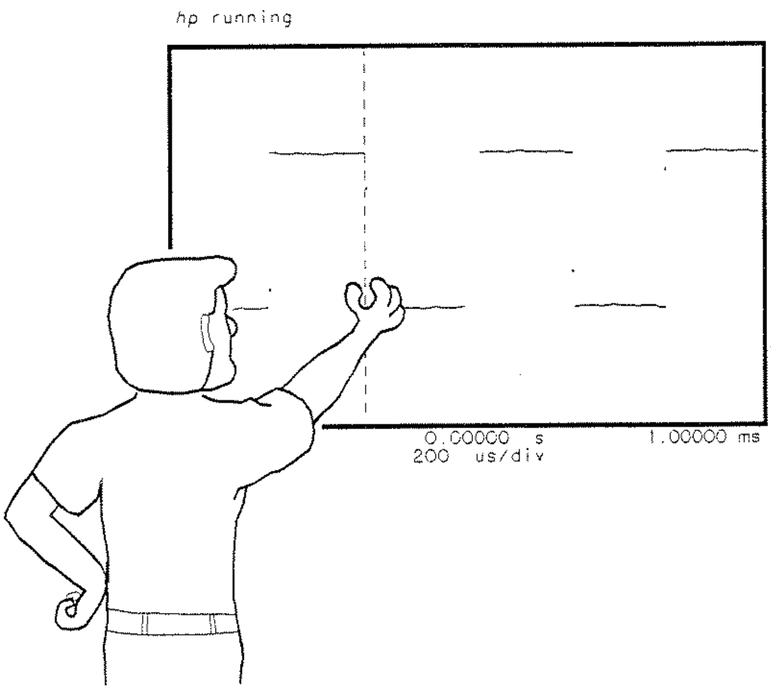
  When **m#** is selected a waveform memory number can be selected as the measurement source, and when **f#** is selected a waveform function number can be selected as the measurement source.

- Press **SHIFT** entry key.

  The measurement is cancelled.

Making Manual Measurements 5

Two sets of markers (cursors) are available on the oscilloscopes to make manual time and voltage measurements. These procedures make voltage and time measurements with the voltage markers and time markers.



Making Voltage Measurements

Voltage measurements are made with a pair of voltage markers to determine 1 or 2 specific voltage points on a waveform.

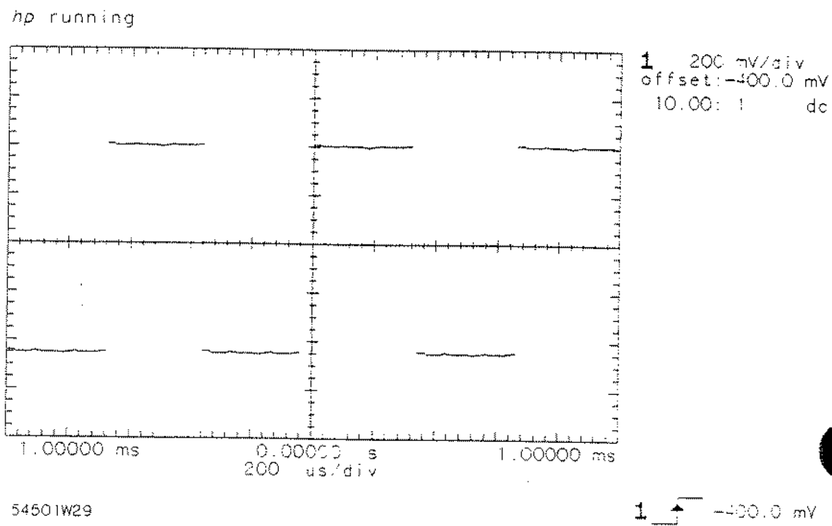
The oscilloscope automatically calculates the voltage difference between the two markers and displays that difference as the delta voltage value.

The following procedure makes a peak-to-peak voltage measurement, then a positive peak measurement with the voltage markers.

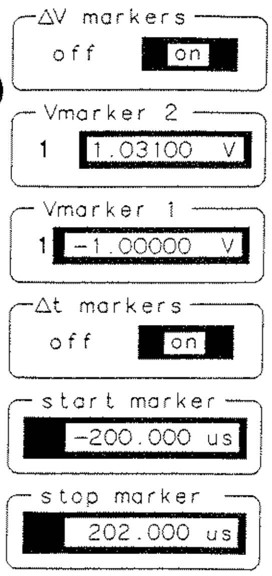
- Connect the ac calibrator output to the channel 1 input.
- Press the **AUTOSCALE** key (or set up the channel display manually).

Display and trigger the waveform.

- Press Δt/ΔV menu key.



54501W29



54501W05

Selects the Δt and ΔV function.

The Δt/ΔV markers are off by default. Turn the Δt markers off if they are on.

- Press ΔV markers function key to select **on** to enable the two markers.
- Press **Vmarker 2** function key several times.

The selected function (intensified display) toggles between the Vmarker 2 source and the Vmarker 2 voltage.

- Select the source function for control and slowly rotate the knob clockwise.

The selected source changes.

As the knob is rotated all sources are displayed one at a time (channels, waveform memories, and waveform functions).

- Set the source selection to **1** (channel 1) using the knob.
- Press the **Vmarker 2** function key to select the Vmarker 2 voltage function.
- Rotate the knob.

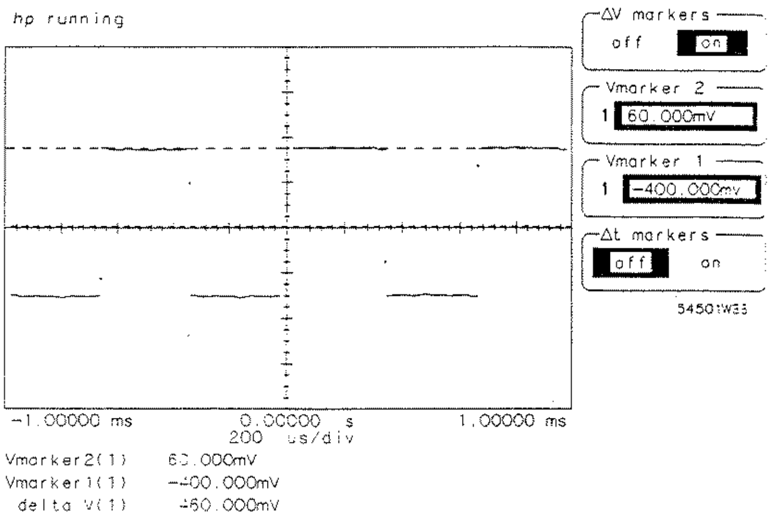
Vmarker 2 is at the top of the waveform.

- Read the voltage at Vmarker 2.

The actual voltage at Vmarker 2 with respect to the voltage reference is displayed as "Vmarker2(**1**) XXXX V."

The number in parentheses is the source for the measurement.

- Ensure the Vmarker 1 source is set to **1** (channel 1).

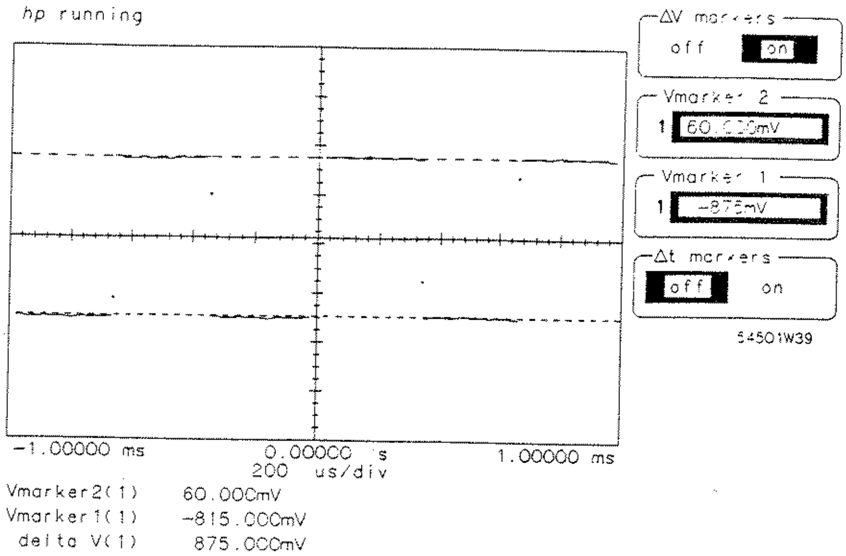


This key also toggles between a measurement source and a voltage level.

- Press the **Vmarker 1** function key to select the Vmarker 1 voltage.
- Rotate the knob until Vmarker is at bottom of waveform.
- Read the voltage at Vmarker 1.

Vmarker1 (1) XXXX V.

- Read the peak-to-peak voltage.



The peak-to-peak value is the *delta V* reading at the bottom of the display.

For more information about setting and using voltage markers, refer to the Δt/ΔV MENU section in the *Front-Panel Reference* of the oscilloscope.

What are Time Interval Measurements?

Time interval measurements are made with one or both of the time markers to determine the relationship of a specific point on a waveform to the trigger point. The oscilloscope automatically calculates the time difference between the two markers. The "delta t" calculation is always made by subtracting the time at the "start marker" from the time at the "stop marker." Therefore it is possible to obtain negative time readings on "delta t" if the "stop marker" is placed on the display before the "start marker."

After an Autoscale, the trigger point is displayed at the center of the display. When a time marker is placed on the left half of the display the time for that marker is negative, indicating it is before the trigger. Any marker to the right of the trigger point is after the trigger and its time reading is positive. The reference for the display (trigger point) can be changed to left, cntr (center), or right of the display in the TIMEBASE menu.

Measuring a Waveform Period

The following procedure measures the period of a complete cycle of the calibrator signal.

- Connect the ac calibrator output to the channel 1 input.
- Press **AUTOSCALE** (or set up the oscilloscope display manually).
- Press Δt/ΔV menu key.
- Press **Δt markers** function key to turn on the markers.

- Press **start marker** function key.

The **start marker** is now controlled by the ENTRY devices. Full-bright inverse video indicates a function is selected.

- Rotate the knob.

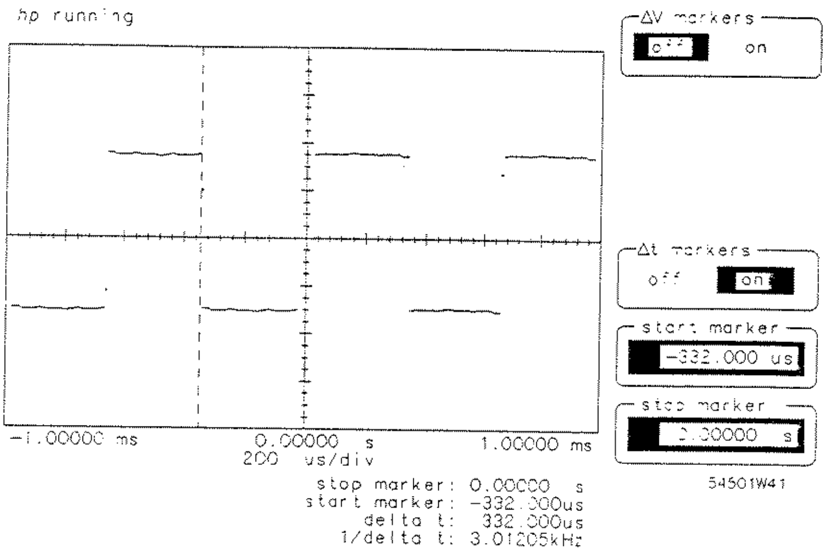
Set the start marker on the first displayed negative-going waveform edge.

- Press **stop marker** key.

Select the stop marker as the active function.

- Rotate the knob.

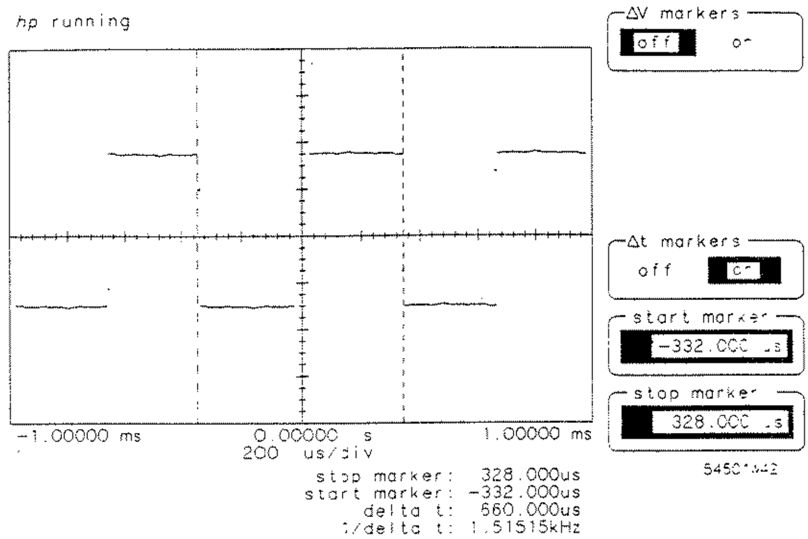
Place the stop marker on the second displayed negative-going waveform edge.



- Read the start marker time, stop marker time, and delta t time.

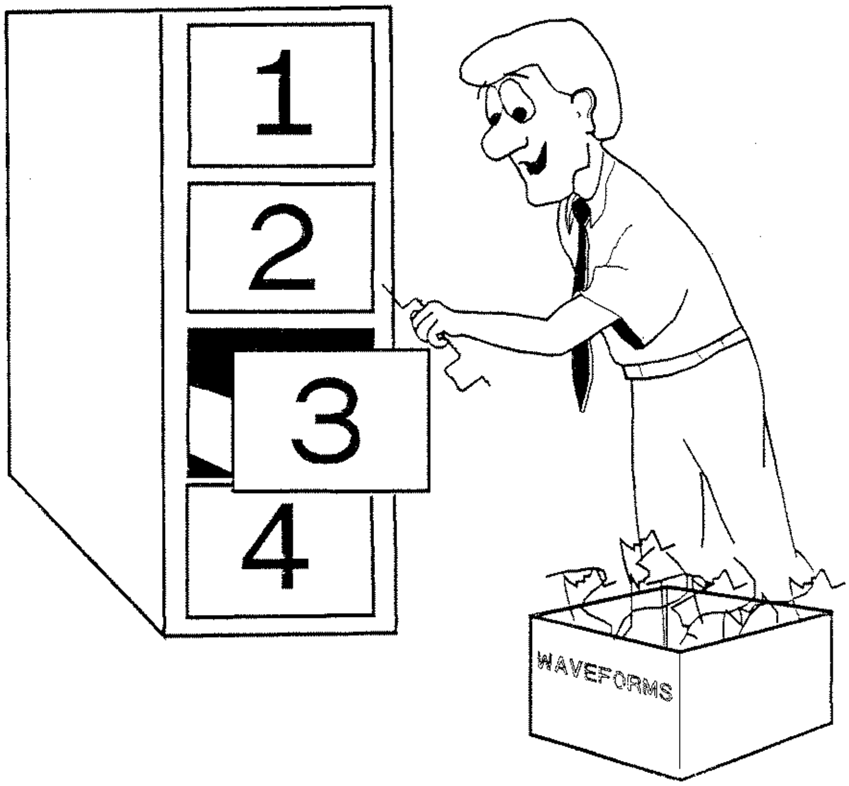
The delta t value is the time at the stop marker minus the time at the start marker. At this time the delta t value is the period of the waveform.

The 1/delta t reading displays the frequency of the selected period.



Storing Setups and Waveforms 6

The oscilloscope stores and recalls up to four front-panel setups and four waveforms in nonvolatile memories. These procedures save and recall front-panel setups and waveforms.



Storing Front-Panel Set Ups

Connect a signal to the channel 1 input.

Use the ac calibrator or any other handy signal.

- Set the oscilloscope to display the waveform.

Use **AUTOSCALE** for ease.

- Press **SAVE** key then the **4** key.

This saves the current front-panel setup in SAVE/RECALL register number 4. There are four SAVE/RECALL memories numbered 1 through 4. Any one can be selected.

- Change some front-panel settings.

For example, change the time/division in the TIMEBASE menu and the volts/division in the CHAN menu.

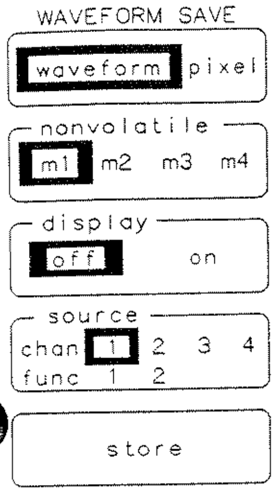
- Press the **RECALL** key, then the **4** key.

The instrument returns to the set up that was saved.

The SAVE/RECALL registers save all front-panel selections and settings. It will not cause any actions to take place, for example when a front-panel setting is recalled, it cannot initiate a measurement.

Storing a Waveform

This procedure stores a waveform, changes the offset setting, then recalls the stored waveform and compares it to the currently displayed waveform.



54501W20

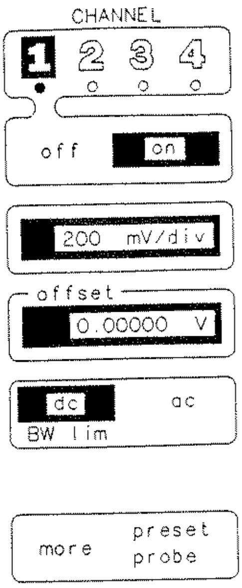
- Connect a signal to the channel 1 input.
- Set the oscilloscope to display a waveform.

  Use **AUTOSCALE**.

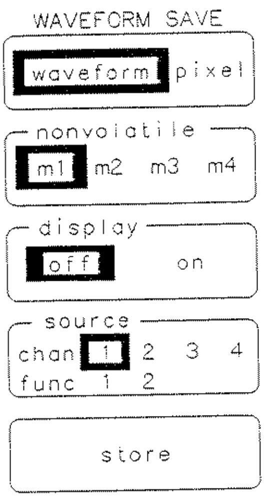
- Press **WFORM SAVE** menu key.

  Select the waveform save menu.

- Select **waveform** with **waveform/pixel** function key.
- Press **nonvolatile** function key and select memory 3 (**m3**).



54501W10



54501W20

- Press **source** of store function key.

  Select 1 (channel 1).

  This selects channel 1 waveform to be stored. If waveform is displayed on channel 2, 3, or 4, select that source at this point.

- Press **store** function key.

  The channel 1 (or selected) waveform is now stored in nonvolatile memory.

- Press **CHAN** menu key.
- Press **offset** function key.
- Rotate knob to move the displayed waveform up or down.

  This step changes the currently displayed waveform to make it easier to tell the difference.

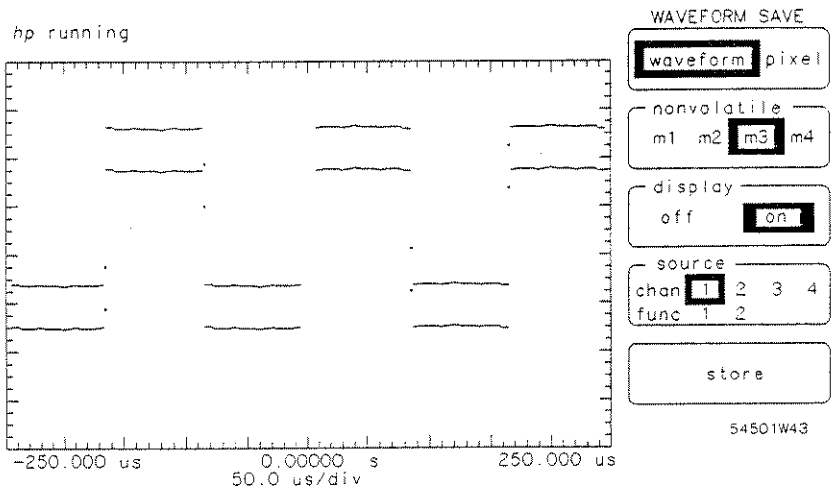
- Reselect **WFORM SAVE** menu.
- If **nonvolatile m3** is not selected, select it at this time.

- Press **display** function key in the waveform save menu.

Display the memory 3 (**m3**) waveform.

At this time two waveforms are displayed, the one that has the offset changed is the current waveform (displayed in fullbright) and the other the stored waveform (displayed in halfbright).

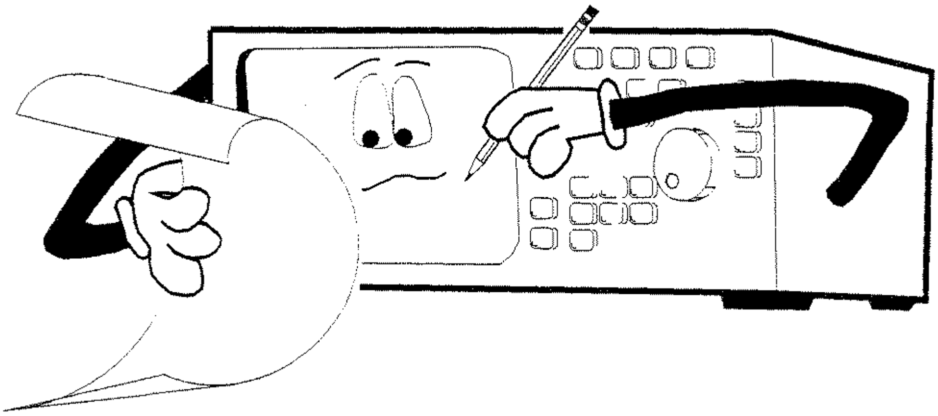
To see the stored waveform better, select the **CHAN** menu and turn the active display **off**.



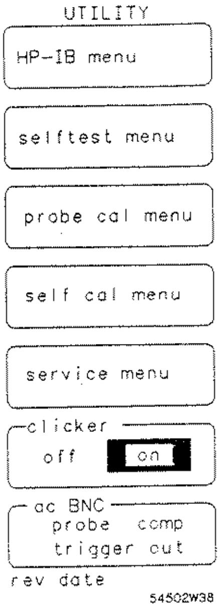
Making a Hardcopy Output 7

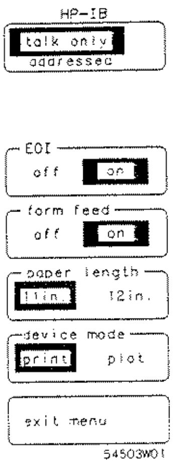
The procedures in this chapter demonstrate how to get a hardcopy output of the oscilloscope display. An HP-IB compatible printer or plotter can be used with the HP 54502A and HP 54503A. This procedure uses an ®HP THINKJET printer as the output device. The first portion of the procedure sets up the HP-IB interface for proper operation between the printer and oscilloscope.

If the oscilloscope and plotter or printer are already operating together, skip to the second portion of this procedure.



Setting Up the HP-IB





Connect the printer to the oscilloscope with a standard HP-IB cable. The menus in this procedure are from the HP 54502A. Plotter compatablity is not available with HP 54501A.

- Set the printer to LISTEN ALWAYS.

  Switch 2 on the printer must be set to the up position.

- Apply power to the printer.

  If any printer switches have been changed, the printer power must be cycled so the new settings are read.

- Press **UTIL** key on the oscilloscope.

  Selects the Utility menu functions.

- Press the top function key to select the HP-IB functions.

  Shows a second level function to set the **talk only/addressed** mode.

- If **talk only** is not selected, press the **talk only/addressed** key.

  This sets the oscilloscope to the **talk only** mode. In this mode, the oscilloscope becomes an HP-IB talker.

- If **print** is not selected in HP 54502A and HP 54503A device mode function, select it now.

  The oscilloscope and printer are now set to operate together.

Hardcopy Output

Connect a signal to the oscilloscope input.

- Use AUTOSCALE or set up the oscilloscope to display the input signal manually.
- Make some automatic measurements.

This is only to demonstrate the output.

- Press **SHOW** key.

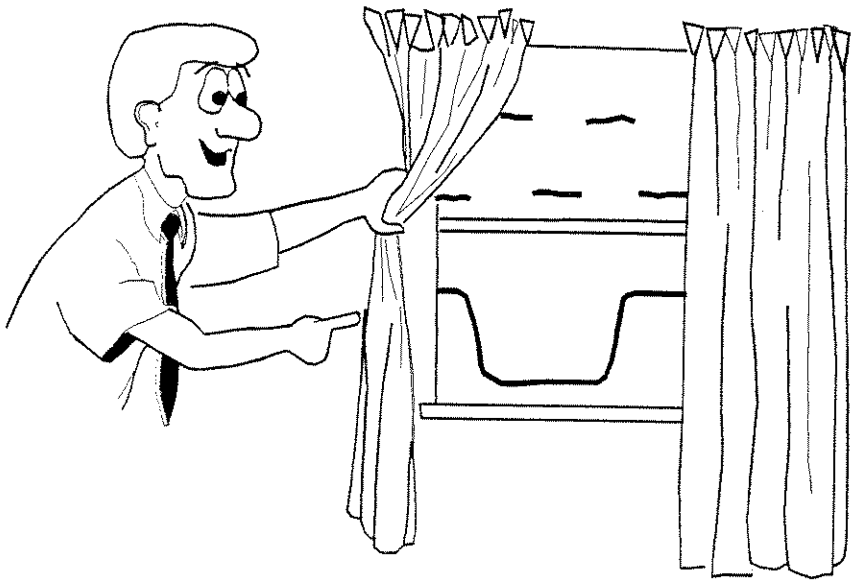
Displays the setup information. Again this is not required to make the hardcopy.

- Press **HARDCOPY** key (front panel SYSTEM CONTROL section).

The printer receives a copy of the oscilloscope display, including the measurements and setup information.

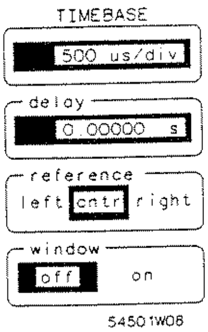
Dual Timebase Windowing 8

This chapter uses the TIMEBASE WINDOW function to make waveform parametric measurements. Also, a risetime measurement is made with the oscilloscope.



Using the Window

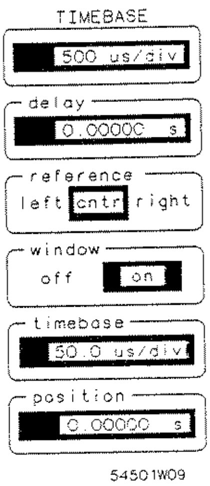
This procedure uses the TIMEBASE WINDOW function to measure the risetime of the signal generator output.



The Timebase window function is similar to dual timebase in analog oscilloscopes. This function picks a portion of the main sweep and display it below the main sweep waveform. The display can contain up to four main sweep waveforms and four timebase window waveforms, using two sweep speeds.

- Connect the input signal to channel 1 input.
- Press AUTOSCALE (or set up the oscilloscope display manually).
- Select **TIMEBASE** menu.
- Press **window** function key.

  Until **on** is selected.



- Press window **timebase** function key.

  Assigns ENTRY devices to control the width of the window.

- Rotate knob to display an entire positive pulse.
- Press window **position** key.

  Assigns ENTRY devices to control the window position.

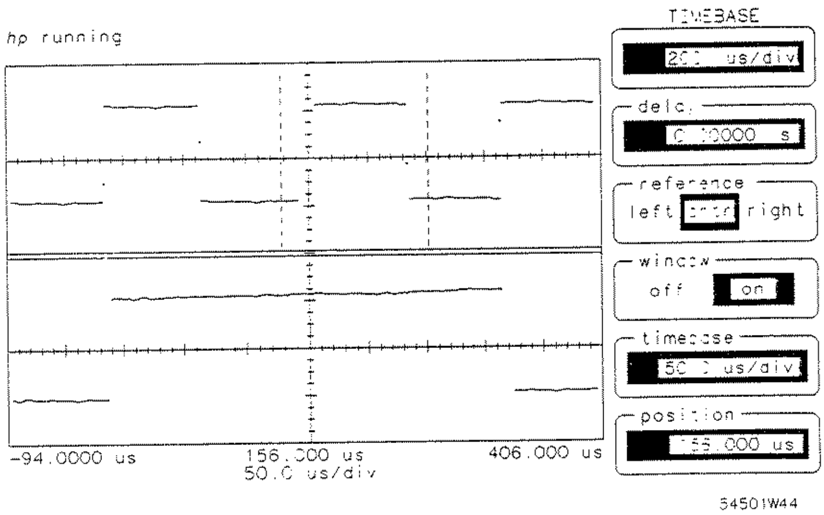
- Rotate knob.

Position the window markers around the positive-going waveform edge of the main sweep.

While window position value changes, the expanded positive-going waveform edge moves horizontally on the lower (windowed) display.

The window position and window timebase functions should be positioned to display the entire positive pulse.

All waveform information dislayed is based on the windowed waveform.



Making Measurements in the Window

- Press **SHIFT** (blue) entry key.

Selects the measurement functions.

- Press the **+WIDTH** [4] entry key.

Tells the instrument which measurement to make.

- Press the **1** entry key.

Selects the measurement source.

If delta t and delta v markers are still on from the previous example in this guide, then they will appear in the window display. The measurement is made on the windowed waveform any time the window function is turned on.

Feeling Comfortable With Digitizing Oscilloscopes

HEWLETT PACKARD

Manual Part Number 9320-5776

Printed in U.S.A. March 1987

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1

Digitizing or Analog?

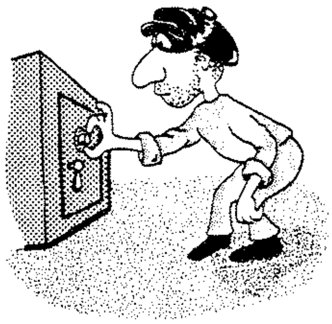
You've finally captured an intermittent glitch on your analog storage scope and you're trying to get a picture of it with your scope camera. Unfortunately, before you can get a good picture, the trace fades away. Or, you're trying to determine the rise time of an edge with your scope, so you expand the trace to five vertical divisions, center the trace with the vertical position control, adjust the vertical expansion, readjust the position, and then count divisions. Unfortunately, the edge doesn't have enough horizontal expansion and only covers two time divisions, so you change the time/division knob and reposition the waveform.

While the analog scope has been a mainstay in the electronics industry, it has some shortcomings that we have all accepted because there wasn't anything better. Until recently, that is. The analog scope is being challenged by one of its offspring, the digitizing scope. Because of its newness and different means of displaying and capturing data, there is often some confusion about how digitizing scopes work and what they are good for. Learning about a new type of scope also involves a time investment, which may not be easy to justify without a view of the advantages.

The goal of this book is to point out and put into perspective the advantages of digitizing storage scopes. We're not going to tell you that a digitizing scope is better for every application; both analog and digitizing scopes have their shortcomings. We would, however, like to help sort out some of the misconceptions and confusion about where digitizing and analog scopes fit, while giving some basic information about how each works. We will also discuss some digitizing scope specifications to look for, as well as what they mean. All in all we hope this will help you to see that the advantages of digitizing scopes make the transition from analog well worthwhile.

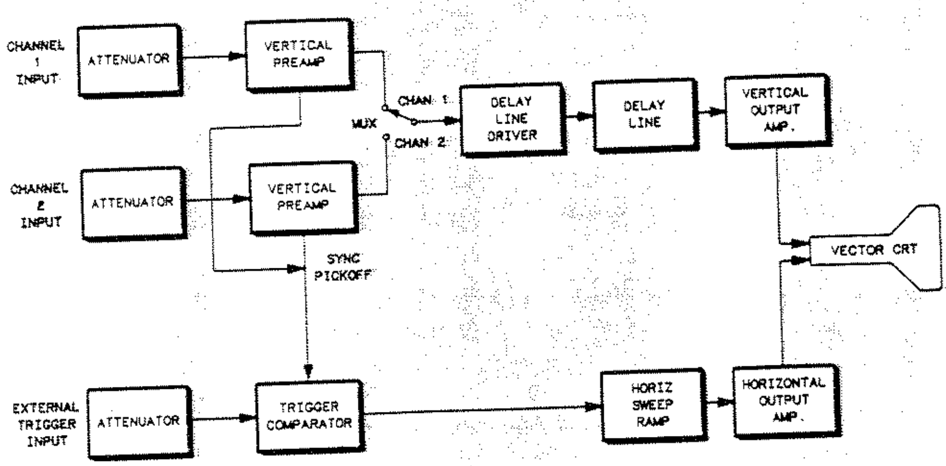
2 Analog Scopes: How Do They Work?

What's Inside?



Before we talk about the advantages of analog scopes, let's review how they work for a few moments.

As you can see in the diagram below, an analog scope has two major signal paths. The first is the vertical signal path, which ultimately is responsible for deflecting the CRT beam vertically in response to the input signal. The second path is the horizontal. It triggers the scope and moves the beam from left to right across the screen. In a typical display, time is represented horizontally and voltage is represented by the vertical axis.

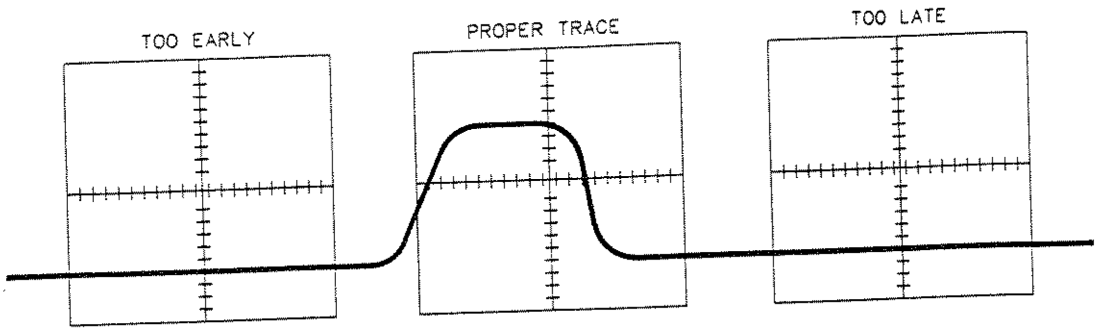


The Vertical Channels

When a signal comes into an analog scope, the first thing it sees are the attenuators. Attenuators match the high impedance of the scope probes (typically 1 MΩ or 10 MΩ) to the low impedance of the vertical preamplifiers. The attenuators also scale the input signals to a level the vertical preamps can handle. The amount of attenuation and preamp gain is set by the front panel vertical sensitivity knob.

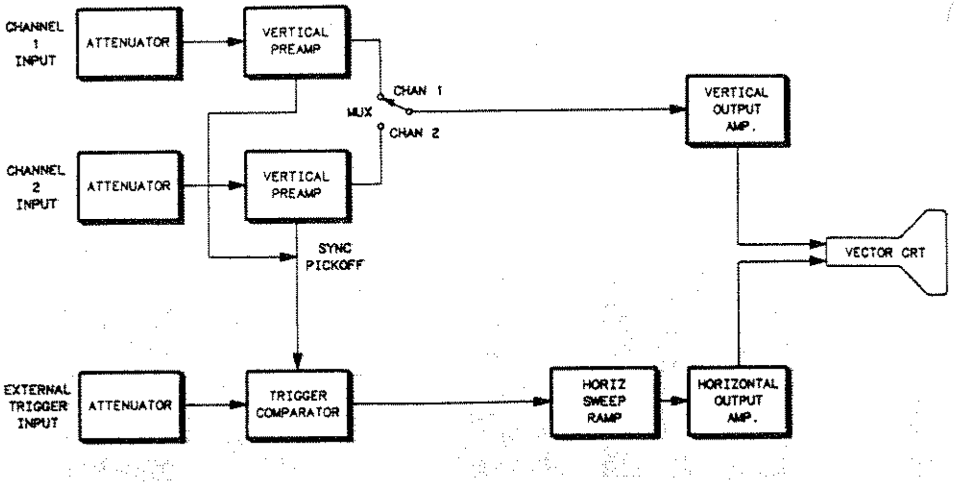
Triggering

The triggering portion plays a very important part in the operation of a scope--it determines where (in time) the trace starts. In essence, the triggering circuits tell the horizontal section when to start moving the beam from the left side of the CRT to the right. If the trace starts too early, the part of interest on the signal won't be seen. The same is true if it starts too late. The figure below gives you an idea of what happens.



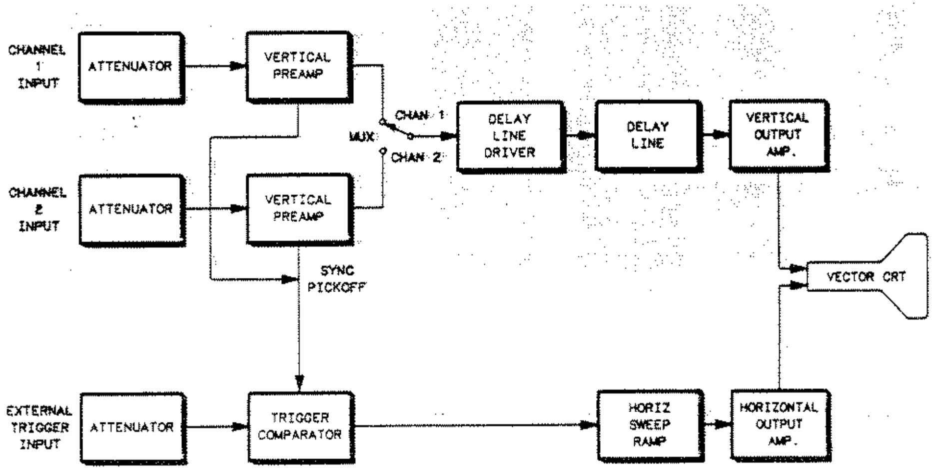
How does the trigger circuit know when to trigger? It gets a replica of the signal, called the sync pickoff, from the selected trigger source. This sync pickoff is compared to a pre-set trigger voltage that is set with the front panel trigger level knob. Most analog scopes let you specify a slope as well as a trigger voltage. This allows you to trigger at a specific point on a rising or falling transition.

When the trigger circuit finds a voltage and transition from the source that matches those set with the trigger controls, it tells the horizontal sweep circuits to start moving the beam from left to right. The speed of the beam is determined by the seconds/division knob on the front panel. As the beam is moved horizontally across the screen, the vertical amplifiers move the beam up and down, relative to the input voltage.



Both the horizontal sweep and vertical deflection information have to arrive at the CRT at the same time. If they don't, the scope won't be able to display the voltage information properly.

Look at the block diagram at the top of the page. Since the delays in the horizontal path are longer, vertical information will reach the CRT before the horizontal information. The solution to the problem is to put a calibrated delay into the vertical path so both horizontal and vertical signals will get to the CRT at the same time.

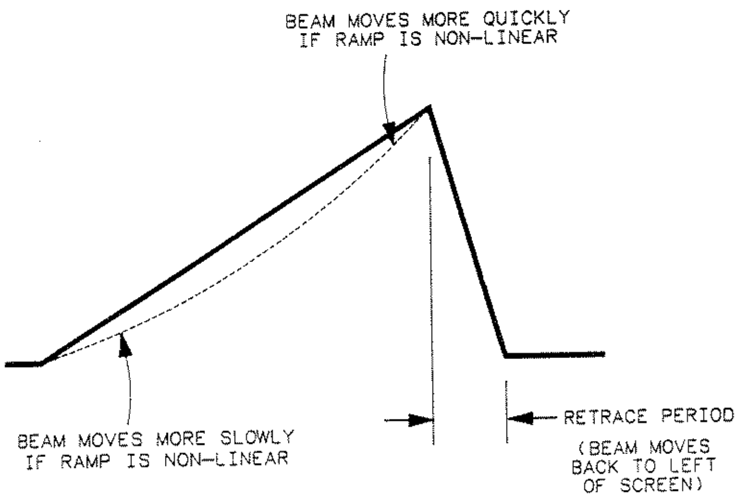


The Horizontal Section

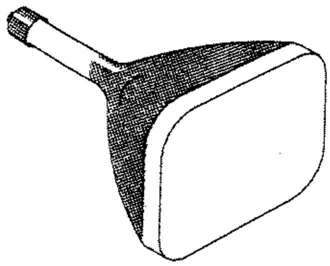
For external triggering, the horizontal path of an analog scope has an attenuator like the vertical channels. This attenuator serves the same purpose as those in the vertical channels, i.e., impedance matching and scaling the external trigger signal. However, the horizontal attenuator is followed by trigger comparison circuits, instead of a preamp, as in the vertical channels.

The horizontal portion of the scope, which is responsible for moving the trace along the time or horizontal axis, directly affects the time accuracy of an analog scope. The horizontal beam movement is controlled by a voltage ramp (called the sweep ramp); the time interval accuracy of the scope depends heavily on this ramp.

Once the trigger comparator has found a valid trigger, it tells the horizontal sweep ramp generator to start. As the ramp rises, it causes the beam to move from left to right across the CRT. Since the left to right movement represents time on the CRT, the ramp must be very linear. If the ramp has nonlinearities, the beam moves at different rates across the screen. Typically, ramp linearity controls time interval accuracy of an analog scope within ±3%.



The CRT



The last major portion of an analog scope is the display or CRT. Analog CRTs are vector displays that can move the beam to any point directly. A signal from the vertical amplifier moves the beam in the vertical direction. This may seem obvious, but it brings up a very important point. The CRT and its drivers must be able to deflect the beam vertically as fast as the signal rises. What this means is that the CRT bandwidth must be the same as the input bandwidth of the scope! High bandwidth CRTs pose several problems. As CRT bandwidth goes up, the following happens:

Cost of the CRT goes up;

Accuracy of the CRT goes down;

Reliability of the CRT goes down.

To keep the cost of the CRT down while keeping the accuracy and reliability up, the scope must use as low a bandwidth CRT as possible. However, since the CRT must have the same bandwidth as the scope, high bandwidth analog scopes demand high bandwidth CRTs. The only real solution is to move to a new architecture.

Summary

In this first section we have talked about how an analog scope works. We also pointed out some of the shortcomings of current analog scope architecture. Here are some of the key points to remember about analog scopes:

- There are two major signal paths--horizontal and vertical;
- Everything (including the CRT) must work at the same speed as the input signal;
- All input channels are usually multiplexed through a single vertical path to the CRT;
- The horizontal path is responsible for triggering;
- The scope triggers on a voltage level and rising or falling slope;
- As input bandwidth goes up, cost of the CRT also goes up, while reliablility and accuracy of the CRT go down.

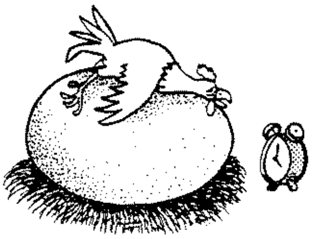
In the next section we will look at digital architectures that eliminate the need for all parts of the scope to work at the same speed as the input signal. These digital architectures give some measurement capabilities not available with analog scopes.

3 Why a Digitizing Scope?

The digitizing storage oscilloscope is a natural evolution of the analog storage scope. Advances in technology have allowed analog scopes to offer some impressive features over the years. However, because of the analog scope's architecture, it will be difficult or impossible to implement many new features that users have asked for. One such feature is the ability to capture data and send it to a computer in an automated test system. Another is the capability to store a captured waveform on screen indefinitely.

On the other hand, these features are easily implemented on a digitizing scope. In the next two sections we'll investigate how a digitizing scope works. We'll also see how this differs from analog scopes. As we talk about these subjects, we'll see how a digitizing architecture allows a whole new set of additional measurements that previously were either time-consuming or simply couldn't be done.

4 Digitizing Scopes: How Do They Work?

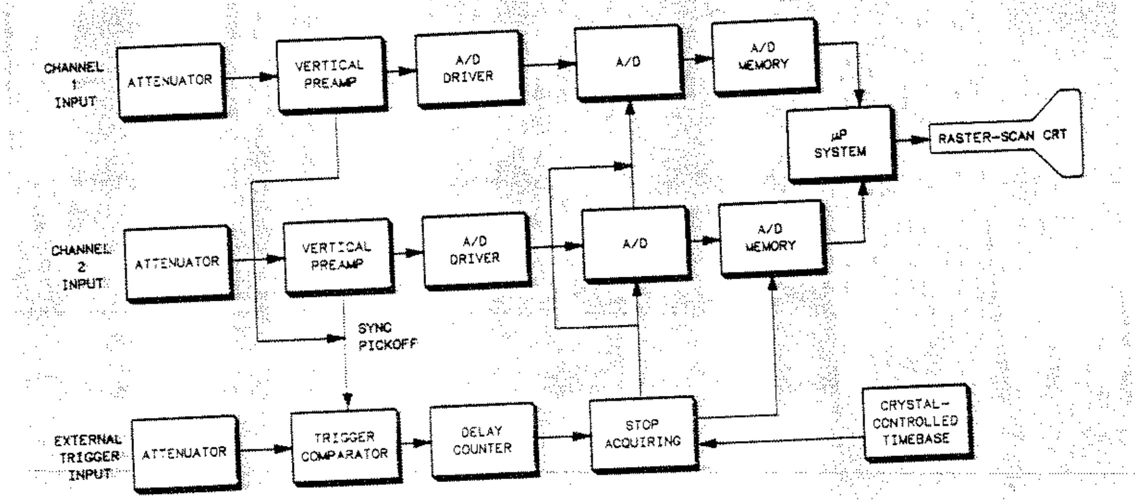


In the first section of this book we talked about analog scopes. A key principle is that everything in the scope must operate at the same speed as the signal you're capturing. On the other hand, digitizing scopes have some parts that resemble analog scope parts, but they work on a completely different principle.

Notice the digitizing scope block diagram below. Rather than amplify the input signal and use it to drive the CRT, a digitizing scope takes discrete samples of the signal, then reconstructs it on screen. This isn't a new concept in scopes—very high frequency digitizers and sampling scopes have used the concept for years. However, these were special usage instruments with analog deflection circuits and CRTs.

Why the Long Wait?

Why has it taken so long for digitizing scopes to become widely available? Until recently the technology didn't exist to build hybrid A/D convertors that were fast enough and accurate enough to make digitizing scopes practical as general purpose instruments. Also, digitizing scopes must have memories that can store input data as fast as it is sampled. Again, such memories have not been available until recently.

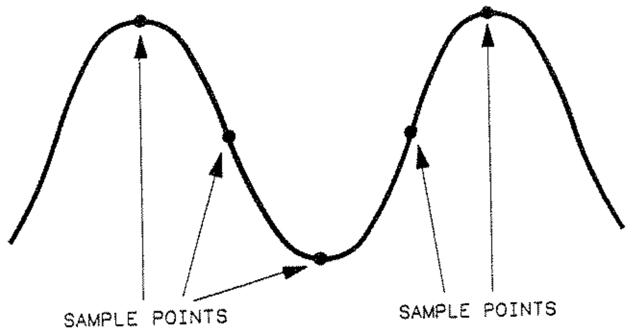


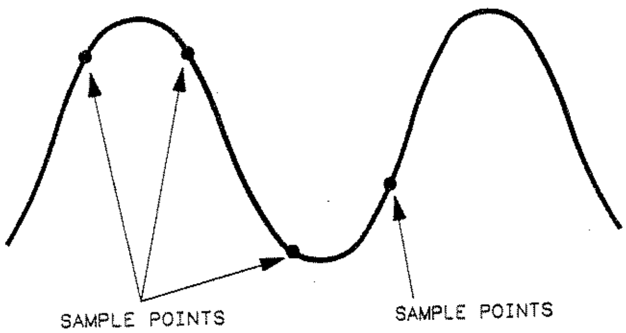
Some Digitizing Concepts

Before we talk about exactly how a digitizing scope works, let's look at some of the concepts behind one. There are three issues at hand when capturing an unknown signal: frequency, phase, and fidelity (for our purposes, fidelity includes shape and amplitude of the signal). In the realm of frequency we get some help from Nyquist. In his original article dated 1924, Nyquist formulated a theorem that says if we sample a signal at a rate of 2F, the best information we can get is of frequency F. Said another way, in order to discern a frequency F from a signal, we must sample at a rate of at least 2F.

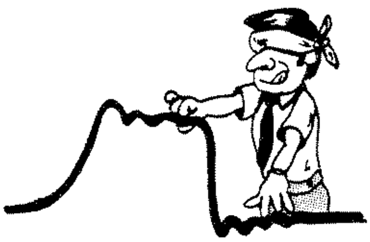
Does this mean that a digitizing scope must sample at twice the bandwidth frequency? Well, no. That's really a misinterpretation of Nyquist's Theorem. One of the boundaries of Nyquist's Theorem assumes that you sample a signal infinitely in both directions if you are to completely reconstruct that signal from two points per period (with single shot sampling). Since digitizing scopes can't take an infinite number of samples in a single shot system and still display the waveform, manufacturers must limit the size of the sample window to something more reasonable. However, this also limits the accuracy of the reconstruction. The other alternative is to sample more than two times per period.

Since technology limits how fast we can sample, to get more samples per period we must lower the bandwidth limit. In other words, if we sample only twice per period for a limited amount of time, we limit the accuracy of the reconstructed signal. By sampling at a higher rate per period, we can make a more accurate reconstruction. Hewlett-Packard bandwidth limits their single-shot digitizing scopes so there are four points per period at the bandwidth.





What Shape Is It?



Suppose you have a 100 MHz analog scope and you put a 100 MHz square wave into it. What would you expect to see on screen? Well, unless your scope is broken you'd see a distorted 100 MHz sine wave! Why? Because a 100 MHz square wave is made up of a 100 MHz sine wave and an ideally infinite number of odd harmonics. At 100 MHz, the input signal is attenuated to −3dB and the higher the frequency, the greater the attenuation. At 100 MHz the scope has bandwidth limited most of the higher harmonics. What you have left are the fundamental and lower harmonics.

With many points per period, it is easy to reconstruct an input waveform from the digitized points. Such is the case at frequencies well below the bandwidth of the scope. As the bandwidth of the scope is approached, however, the number of points available for reconstruction drops (as we mentioned earlier, HP single-shot digitizing scopes have four points per period at bandwidth). Four points per period is adequate to characterize a sine wave. But what if the input signal is a square wave? Can a digitizing scope adequately reconstruct a square wave from four points?

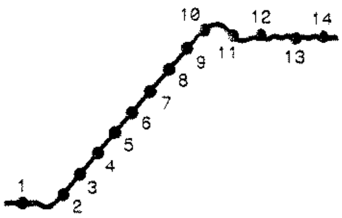
To explain the point, let's use the previous example of a 100 MHz square wave. If we put a 100 MHz square wave into a 100 MHz digitizing scope, the scope will pass the square wave through a 100 MHz bandwidth limit filter. The output of this filter, which is a slightly distorted 100 MHz sine wave, will then go the the A/D. That means that the A/D is not digitizing a square wave but a sine wave with some small amount of harmonic information (the same information that the 100 MHz analog scope displays on the CRT). Since we can reconstruct a sine wave well from four points, this isn't too much of a problem. In other words, at or near the bandwidth frequency, the A/D will be digitizing sine waves (or nearly so) and reconstructing them as such. That doesn't mean that a digitizing scope sees everything as a sine wave. At frequencies less than the bandwidth we will have more sample points per period and can make a better determination of the actual shape—just as the analog oscilloscope will display a proper waveshape if the input frequency is considerably less than the specified −3dB bandwidth.

How Do We Sample?

There are two basic methods we can use to acquire these points on a waveform. We can capture them as they occur in real time by sampling at a very high rate, or by making several passes on the waveform and getting some points on each pass. We call the first method real time or single-shot sampling, as illustrated below.

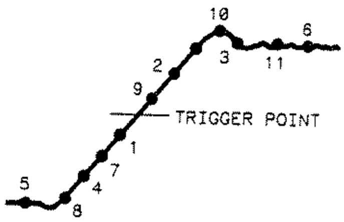
Real-Time Sampling

In this case, we sequentially sample the waveform on its first occurrence. The higher the sample rate in comparison to the frequency of the signal, the better our signal picture. Sometimes, additional points are interpolated mathematically between the actual data points. Real-time sampling allows you to capture and display events that occurred before the trigger (what we call negative time viewing).



Repetitive Sampling

The second method, called repetitive sampling, captures data on the waveform by acquiring points on more than one occurrence of the signal. This, of course, requires that the waveform itself is repetitive and not a single-shot event. On each occurrence of the trigger event a few more points are acquired until these points are put together into a very accurate composite reconstruction. Since the data is not all captured in real time on one pass, Nyquist criteria does not apply to repetitive sampling. As such, there is not necessarily any relationship between sample rate in a repetitive sampling scope and the bandwidth. As a matter of fact, the sample rate will usually be lower than the bandwidth. And, since many points are acquired on the waveform, simply connecting the data points with lines provides a very good picture of the waveform.



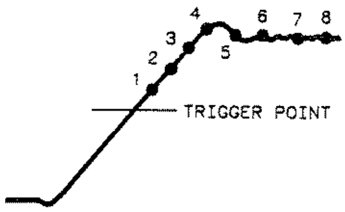
Random Repetitive Sampling

One type of repetitive sampling is random repetitive. The sampling is done constantly, not waiting for a trigger event. On each occurrence of the signal, more points are acquired. Then, all the sampled points are put together into one composite picture of the waveform. Each point is put into its proper place by measuring the amount of time that elapsed between it and the trigger point. Since all points are acquired asynchronous to the trigger point, the sampling is random in relation to the trigger point.

Because the sampled data is captured before and after the trigger point, we can actually see what happened before the trigger. We call this capability "negative time."

Sequential Sampling

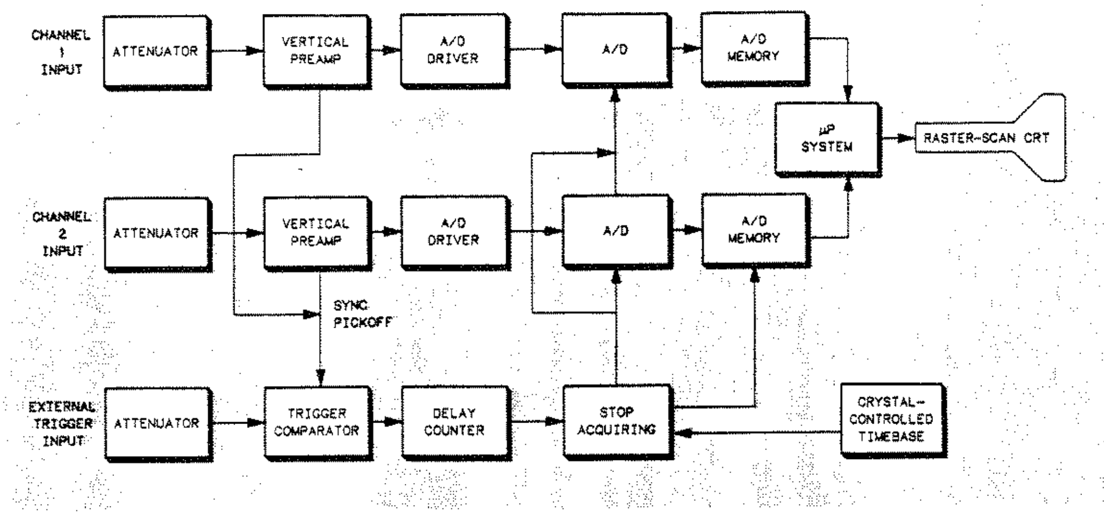
A second method of repetitive sampling looks for the trigger point on each pass, waits a predetermined amount of time, then takes a sample. On the next pass, the predetermined time interval is incremented and a new sample is taken. After a number of passes, the waveform is reconstructed just as in the random repetitive method. However, there is one major difference—with sequential sampling all the samples are taken after the trigger. This means that you can't have negative time



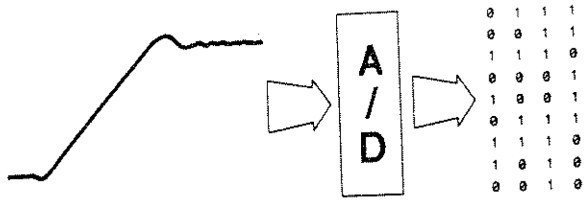
(i.e., data before the trigger) viewing. Sequential sampling does provide very accurate waveform reconstruction since it can use a slower, higher resolution A/D.

The Vertical Channels

If you look at the figure below, you'll notice that this block diagram of a digitizing scope has separate paths for each input channel. This is in contrast to most analog scopes that have only one vertical path to the CRT. By having separate paths for each channel, a digitizing scope can capture data on all channels simultaneously.



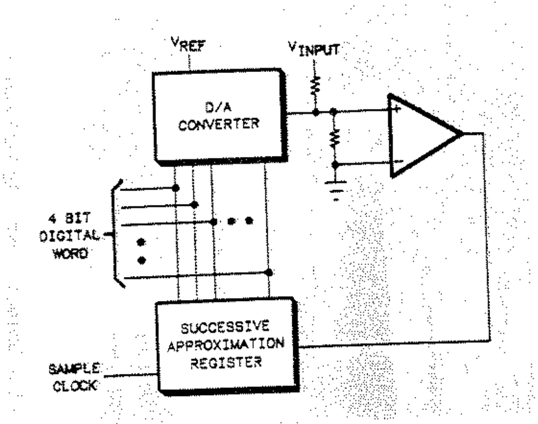
Like an analog scope, a digitizing scope has attenuators to scale and match impedances to the preamp. They also have vertical preamps to amplify the input signals to the A/Ds. The part of the block diagram following the vertical preamp is where a digitizing scope takes on a different look than its analog predecessor. Instead of amplifying the input signal and using it to drive the vertical deflection plates of the CRT, a digitizing scope changes the input signal into a digital word through the A/D convertor.



Converting to Digital

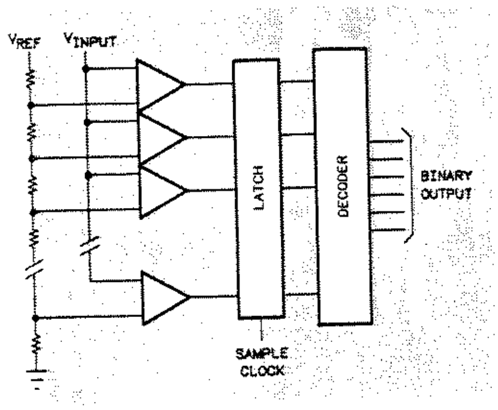
There are several ways to convert an analog input to a digital word in a scope. Digitizing scopes typically use either successive approximation convertors or flash A/D convertors.

Successive approximation convertors are relatively simple from a hardware standpoint, since they require only one voltage comparator, as you can see below. This is essentially a serial step-by-step process.



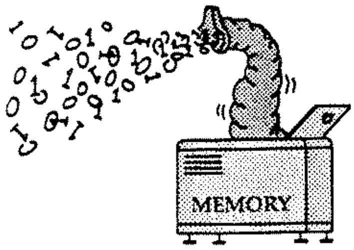
It takes N passes (where N is the number of bits of resolution) and N clocks for a successive approximation convertor to convert an analog voltage to a digital output. While this scheme provides high resolution, it is not fast enough for use in a single-shot digitizing scope. Since a repetitive digitizing scope doesn't have to sample as quickly as a single-shot one, the successive approximation A/D may be used in repetitive architectures.

Single-shot digitizing scopes need a fast conversion A/D, since they digitize input voltages "on-the-fly." In such cases the flash A/D convertor, similar to the one shown below, is used. A flash A/D convertor is essentially a parallel process. Although fast, flash A/D convertors are more complex hardware-wise. Its architecture requires 2^N-1 voltage convertors, again where N is the number of bits of resolution. To put that in perspective, a 6-bit flash A/D requires 63 convertors, a 10-bit needs 1023, while a 12-bit has to have 4095 convertors!



Memory

Once the data has been put in digital form, it is stored in memory. The memory must be able to store at the same rate as the A/D samples for most digital architectures. That means that if the sample rate is 200 MHz, the memory must have a write cycle time of 5 ns. Most digitizing scopes use special FISO (Fast In, Slow Out) memories for storage.

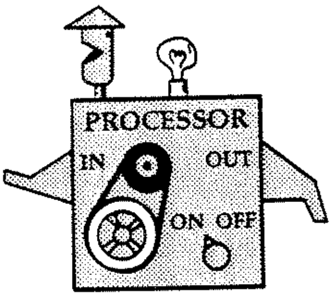


To allow the use of slower digitizers and storage memories, some manufacturers store the incoming waveform in CCDs (Charge Coupled Devices). Since the waveform can be read out of the CCD to the A/D at a slower rate, slow, high resolution A/Ds can be used. Shortcomings of this technique include noise, cell size and cell leakage, which limit horizontal and vertical resolution.

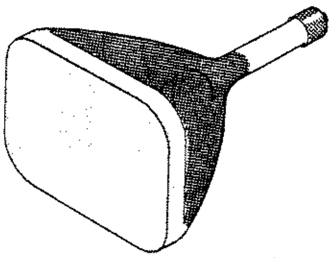
Once the digitized waveform is stored in semiconductor memory, the image can be held indefinitely without deteriorating.

The Processor

All digitizing scopes incorporate a microprocessor of some sort. The power of a processor in a digitizing scope profoundly affects its capabilities. Because the data is in digital form, it's easy to have the processor perform some specific tasks on the data. For instance, we can automatically measure such parameters as time intervals, rise and fall times, frequency and more. The processor can also allow such functions as waveform math. And surely not least of all, it's a simple matter to format it for output to a printer or plotter. This eliminates the need for scope cameras.



The CRT



The last fundamental difference between digitizing and analog scopes is the CRT. In Section 1 we talked about CRTs in analog scopes needing to be as fast as the input bandwidth. A digitizing scope, however, divorces the CRT from the input bandwidth by storing everything in memory. Data is stored in memory at the same rate it is digitized, but is taken out at a slower rate and displayed. This means that the CRT needn't run any faster than the processor can write data to it. Since the data is not written at the same speed as the input signal, a slower, less expensive raster CRT can be used. This brings some additional benefits besides cost savings, like higher reliability, lower cost, and longer life than high frequency analog CRTs. Other capabilities, like color, can be more easily implemented than is possible with high-speed analog CRTs.

Summary

In this section we talked about the concepts behind digitizing scopes while exploring how they work. We saw how digitizing scopes capture data by sampling it, storing it in memory, and then reconstructing it on screen. The major conceptual difference between this scheme and the way analog scopes work is that everything past the A/D convertor doesn't need to work as fast as the signal. In a digitizing scope everything following the memory works at the same speed as the microprocessor, instead of having to work at the same rate as the incoming signal. This makes it possible for the scope to process the waveform data and automatically measure parameters such as rise time, frequency, time intervals, and the like.

- There are two basic types of digitizing scopes-real time and repetitive. Real time digitizing scopes capture a waveform on a single pass, while repetitive digitizing scopes take a number of passes.

- Repetitive scopes can be further categorized into sequential and random repetitive. Sequential digitizing does not provide negative time viewing.

- Sample rate and bandwidth are related only in real time digitizing scopes.

In the next section we will look at how analog and digitizing scopes differ when being used to make the same measurements.

5 Specifications and Measurements

Instrument specifications have meaning only when they help you solve a problem. We will talk about some important specs here; more importantly, we'll show you how these specs relate to actual measurements. We'll also contrast how analog and digitizing scopes attack common measurement problems.

Vertical Resolution

The number of bits in the A/D of a digitizing scope helps set the vertical resolution. For example, a one-bit digitizer can measure two levels of a signal—one and zero, or high and low. A two-bit digitizer can discern four levels, a three bit gives eight levels, and so on. In general, a digitizer can discern 2^n discrete levels of an input signal. If you divide the input signal by the number of discrete levels of the A/D, you'll get an idea of what bits of resolution means in terms of voltage. For example, given a 1 V P-P input displayed full screen, a six-bit digitizing scope can measure voltage increments of

$$\frac{1\text{ V (input V)}}{2^6-1} = 15.9\text{ mV.}$$

This 15.9 mV is the resolution of the least significant bit (LSB) of the digitizing scope's A/D. In more general form we can say:

$$\frac{\text{Input Voltage}}{2^{(\text{Number of A/D Ranges})}-1} = \text{1 LSB or Minimum Discernable Level}$$

Manufacturers may even specify the resolution in terms of the LSB.

What does vertical resolution mean in terms of measurements? The issue that really concerns most users is what may be happening between those digitized levels. The maximum ideal error is ±1/2 LSB. To use the example on the previous page, if there is noise on the signal that's less than 15 mV, the digitizing scope may not display it. The only way to overcome this problem in a digitizing scope is to have more vertical resolution. However, having more bits in the A/D doesn't necessarily mean more vertical resolution. There are factors other than the number of A/D bits that affect the effective vertical resolution of a digitizing scope.

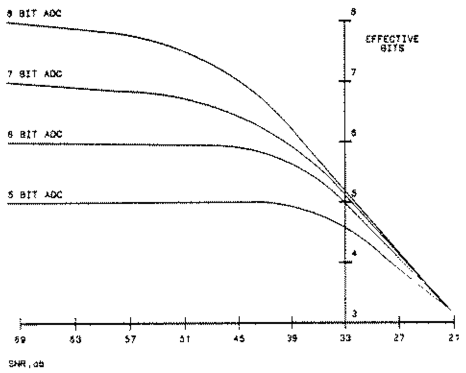
In Section 4, while talking about how to sample (page 4-11), we mentioned that some digitizing scopes use CCDs (Charge Coupled Devices) to capture the input waveform before it is digitized. This way a slower, higher resolution A/D may be used. While this allows more bits in the A/D, it also introduces more noise into the system before the waveform is digitized. So, while a higher resolution A/D can be used, there is more uncertainty given to the A/D in the form of noise. If you think of noise as high frequency components that are above the input bandwidth, you'll begin to understand why such noise is particularly undesirable. The input signal is bandwidth limited because the scope can't deal with frequencies higher than the bandwidth. However, CCDs add high frequency components (noise) that are not attenuated by the input filters because they are introduced from within the scope. Consequently, some of the additional resolution is negated by the effects of the internally generated noise. So, to get higher vertical resolution you must not only increase the number of bits in the A/D, you must also keep the internal system noise to a minimum.

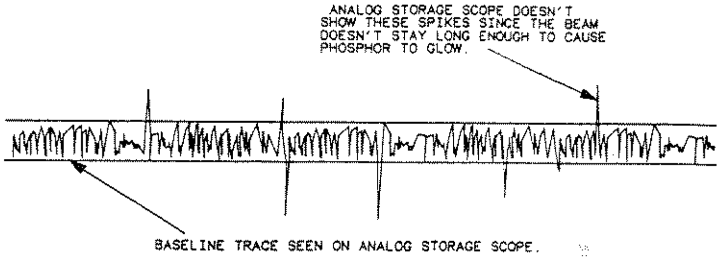
Effective Bits of Resolution

How do you measure the vertical resolution of a digitizing scope if it involves more that just the number of bits in the A/D? We believe the best specification is one called "effective bits" of resolution. Effective bits is the resolution the user will see on the screen of the scope. To say it another way, effective bits of resolution quantizes internal system noise and its effect on the vertical resolution of a scope. An easy way to define effective bits is to think of it as an expression of a signal to noise ratio. In the last paragraph we talked about noise and how it lowers the effectiveness of the A/D. This lowered effectiveness is expressed by the quantity of effective bits. Effective bits takes a less than ideal A/D convertor system and expresses it in terms of an ideal A/D convertor system, i.e., one without noise and distortion. Effective bits will always be lower than the number of A/D bits and generally decreases as frequency goes up. How much lower depends on noise sources and nonlinearities within the scope (amplifiers, CCDs, etc.). The diagram below gives an idea of how noise can affect the A/D. Notice that as noise in the scope goes up, the effectiveness of the A/D goes down quite rapidly. So, when looking at digitizing scope specs, you need to know more than just the number of bits in the A/D.

How does a manufacturer measure effective bits of resolution? One of the more common methods is called the "sine curve fit." With this method, a very stable sine wave of known frequency and amplitude is put into the scope. The digitized points are then read out to a computer. The computer calculates where the points should be for a sine function and then compares the digitized scope points to them. The difference between the calculated points and actual digitized points are used to calculate the number of effective bits.

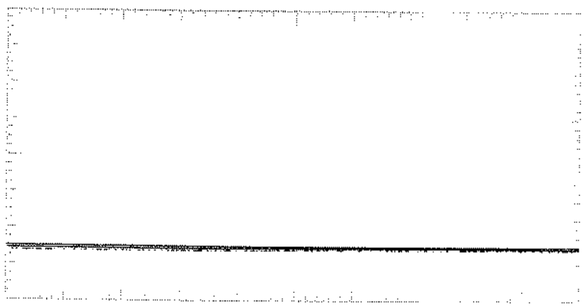
Effective Bits vs Input Noise for Ideal A to D Converters





Trace Noise

Because of the limited number of levels in the A/D of a digitizing scope, analog scopes are generally better than digitizing scopes for seeing some low levels of noise on a signal. However, digitizing scopes are often quieter internally than analog storage scopes. If you look at a baseline trace on an analog scope line, like the one above, it looks narrower than that of a digitizing scope. The digitizing scope trace, shown below, would seem to be much noisier. However, if you could turn up the intensity to maximum on an analog scope, without



it blooming, you'd notice that the trace is much fatter. Even that, however, doesn't give an accurate appraisal of how noisy the scope is internally. The beam of the scope is actually being deflected to higher levels, but since the beam doesn't stay at those levels for very long the phosphor doesn't receive enough energy to phosphoresce. Consequently, the trace looks much narrower than it actually is, indicating a lower level of noise.

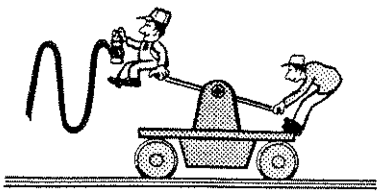
What this all means is that an analog scope may display a much lower noise level than is actually there. In addition, you have very little idea how much is scope noise and how much is signal noise. The governing principle is

$$\text{Noise}_{\text{Displayed}} = \text{Noise}_{\text{System}} + \text{Noise}_{\text{Measuring Instrument.}}$$

On the other hand, if you leave a digitizing scope in storage mode with no input, it will display every level it sees. In the picture below, a digitizing scope left for some time reaches a steady state of three digitized levels (zero, one level above zero, and one level below zero). You have a way of quantifying the system noise in a digitizing scope that you don't have with an analog scope.

If you don't know how much noise the measuring instrument (scope) is adding, you can't accurately determine how much of the displayed noise is from your system. With a digitizing scope you have a method of quantifying how much noise the instrument is adding to the measurement.

Time Interval Measurements

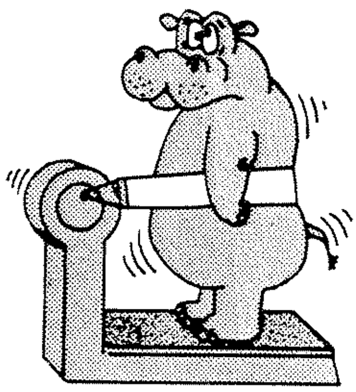


Some of the most common scope measurements are those involving a time interval. These measurements include finding a rise or fall time, determining a time interval, or measuring the frequency of a waveform. Traditionally, making such measurements with an analog scope meant displaying a part of the waveform and counting time divisions on the scope screen. Although these were time consuming measurements, there wasn't an easier way to make them with a scope. That is, until the digitizing scope.

For example, a rise or fall time measurement on an analog scope involves displaying an edge, expanding it to five vertical divisions, moving the edge up or down on screen, then counting the time divisions between the 10% and 90% lines.

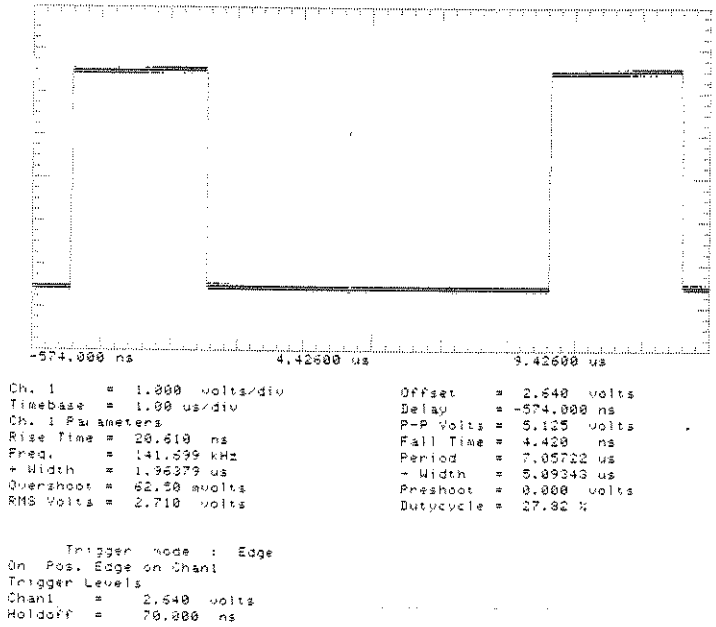
There is an easier way to make such measurements with a digitizing scope. For instance, in order to measure the rise time of an input waveform on an HP 54110D digitizing scope, you press the RISE TIME key. The scope displays the rise time at the bottom of the screen. As a matter of fact, any waveform parameter is just as easy to measure. If you want all of the parameters, you press the ALL key, and the scope measures the parameters shown at the bottom of the screen illustrated below.

Jitter

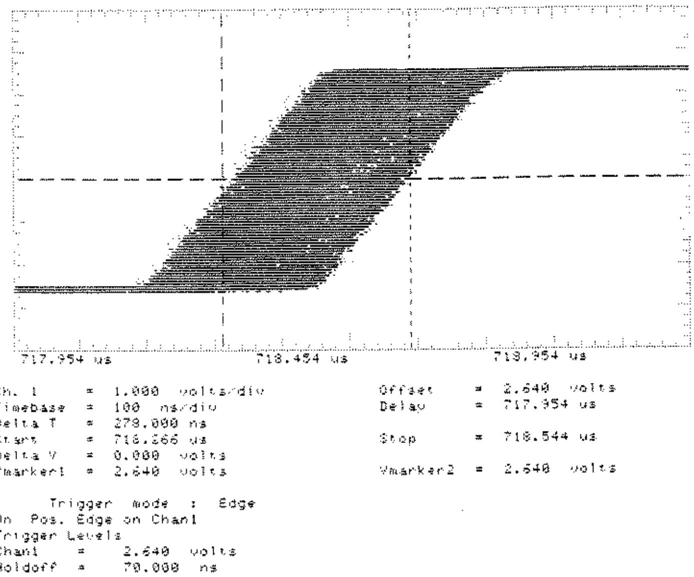


Another important time interval measurement is jitter. With an analog scope you display an edge, and then try to determine where the greatest excursions occur on screen before they fade. A common practice is to mark those excursions on the face of the CRT with a grease pencil.

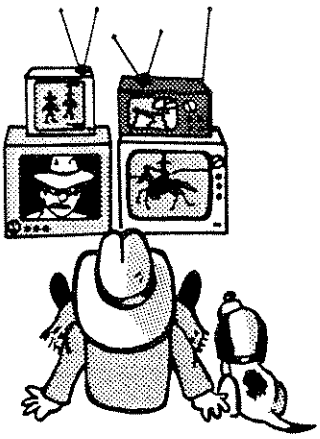
The same measurement can be made more easily with a digitizing scope. You can put the scope in INFINITE PERSISTENCE mode, which lets all the data accumulate indefinitely. As you can see in the picture on the next page, every movement of the edge is accumulated on screen, making



it very easy to determine the total amount of jitter. Some digitizing scopes provide an ENVELOPE mode, which shows only the minimum and maximum excursions, making it even easier to measure the total amount of edge movement.



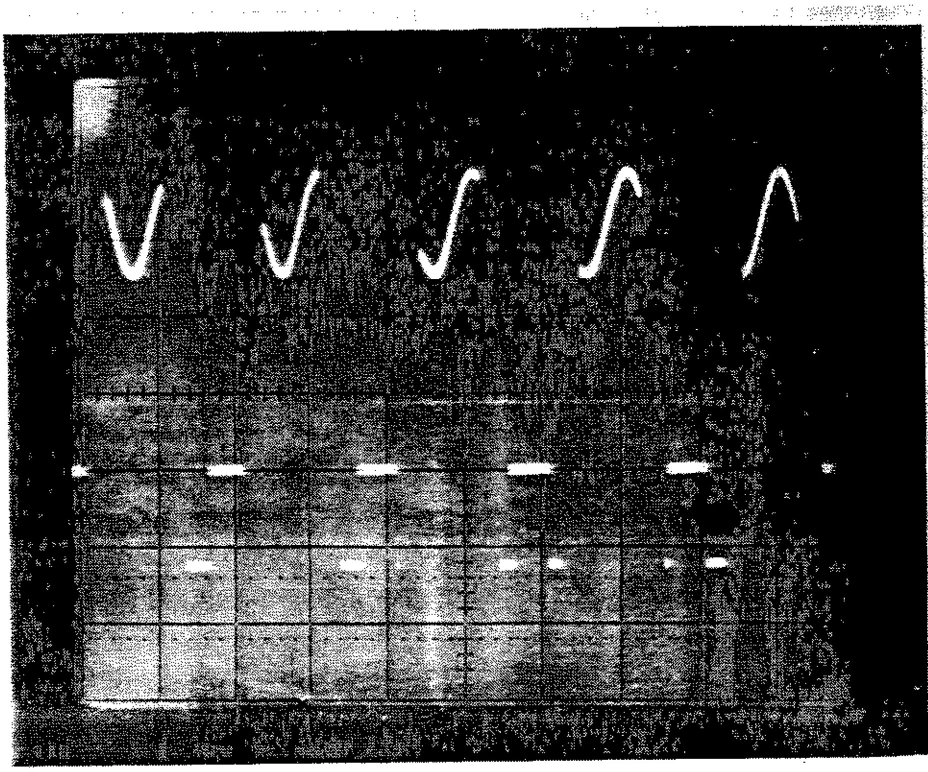
Multi-Channel Display



Many applications require a scope to display more than one channel. Most of us take that for granted. But let's look at some differences in bandwidth and display capability between analog and digitizing scopes when it comes to multi-channel displays.

An analog scope has several methods of displaying multiple channels. The best is a dual-beam CRT. A dual beam scope, as the name implies, has two electron beams. Since the CRT has two electron beams, one can be dedicated to each channel. However, their expense keeps many users from buying dual beam scopes for general purpose use.

The second method is called CHOP mode. CHOP mode uses a single CRT beam to draw both channels on a single sweep. The beam switches between channels at a rate between 100 kHz and 1 MHz. CHOP is used when you are trying to capture two asynchronous events and preserve their time relationship to one another. However, there is one drawback to CHOP that we can illustrate with an example. Suppose we have two 2 MHz signals we want to display. If we have the scope sweep speed set to 1 μs/div and the CHOP switching rate is 1 MHz, the beam spends 1 μs on one channel before switching to the other. That means the display shows one division of one channel and then spends the next time division (1 μs) on the other trace. When it switches back to the first trace, there is a 1 μs "hole" left in the trace. This continues throughout the trace on both channels as you can see below.



The truth is that in CHOP mode these "holes" are always there, but at slower sweep speeds, they are less noticeable and may even seem to disappear if the switching rate is fast in comparison to the sweep speed. At higher sweep speeds you may be missing critical information that occurs during the holes.

The third method of displaying multiple channels on an analog scope is ALTERNATE mode. In ALTERNATE the scope draws one complete trace and then draws the other. This method eliminates the "holes" in the traces produced by CHOP mode, but it introduces another problem. Since the scope triggers, draws one trace, then triggers again to draw the second trace, both triggers are shown at the left of the screen. How much time actually occurred between the triggers? We really have no idea—the time correlation between channels has not been preserved.

How does a digitizing scope overcome these multi-channel display problems? By having separate A/Ds. Information is captured and digitized simultaneously. By capturing data on all channels simultaneously, the time relationship among them is preserved. Secondly, since both channels are captured in their entirety, there are none of the holes associated with an analog scope's CHOP mode.

Storing Images On Screen

A major frustration with analog storage scopes is the limited amount of time images can be kept on screen. Within a few seconds the stored image fades positive (blooms), which means that the trace gets cloudy until it is just a bright cloud on the CRT. This is particularly true with single-shot events. This tendency to fade positive is related to the fact that the trace is stored electrically on a mesh inside the CRT (called the storage mesh). Because of a number of interactions within the CRT, the trace stored on the mesh tends to "spread" or become less distinct electrically, causing the bright cloud on screen. The end result is that the trace is obscured.

A digitizing scope stores traces in RAM rather than on an electrically-charged mesh. Once stored, the image can't change. Consequently, the trace can be kept on screen for an infinite amount of time without change.

Hardcopy Output

While developing a lab notebook or test procedure, it is desirable to have a picture of what we see on the screen of an oscilloscope. One frustration when keeping such records is using a scope camera. Anyone who has used a scope camera can probably remember taking several pictures before getting the proper exposure.

Again, because of their processor-based architecture, digitizing scopes simplify the task greatly. With scopes like the HP 54100 and HP 54200 series, you can use printers and/or plotters for hardcopy output. Once you have what you want on screen, you can transfer the waveforms along with setup and measurement information to the printer or plotter with the push of one button.

Summary

While adding a whole new set of measurement capability not possible with analog scopes, digitizing scopes have simplified most of the classic scope measurements. Because of their microprocessor-based architecture, digitizing scopes can easily interface with desktop and minicomputers in automated test environments. Here are some of the key points to remember about digitizing scopes.

- More A/D bits doesn't necessarily mean more resolution.
- Sample rate and bandwidth are not always related.
- Data is captured on all channels simultaneously, eliminating the need for CHOP and ALTERNATE modes found on analog scopes.
- The image can be kept on screen indefinitely without degradation.
- Because of their microprocessor architecture, automatic measurement of parameters like frequency, rise time, period, etc., is possible.
- You can easily copy what's on screen to a printer or plotter without having to use a scope camera.
- Connection to a desktop computer or minicomputer is easy for use in computer automated test systems.
- Waveforms can be stored in internal memory or on mass storage for future use and comparison.