Training Guide

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For Safety Information, Warranties, and Regulatory information, see the pages behind the Index.

Agilent 54654A Self-Paced Training Kit for Agilent 54600B/01B/02B/03B, 54610B, 54615B/16B/16C, 54620A/20C, and 54645A/45D

Agilent 54600-Series Instruments – a self-paced training guide

This booklet and its accompanying signal board will acquaint you quickly with the features and operation of the 54600-Series of basic oscilloscopes, the 54645A oscilloscope with Agilent MegaZoom technology, the 54620A/C logic analyzer, and the 54645D mixed signal oscilloscope. After you have completed the exercises, you will have used most of the major features of these instruments. You will see how similar the digital oscilloscope is to analog oscilloscopes that you have used in the past, and you will experience many of the advantages that digitizing architectures bring to today's oscilloscopes. Using the logic analyzer, you will see how similar it is to the oscilloscope you're familiar with, and how much more power it has for troubleshooting and debugging digital circuits. Using the mixed signal oscilloscope you will be able to make measurements on both analog and digital parts of your circuit using one instrument.

Agilent 54600-Series Basic Oscilloscopes

The 54600-Series basic oscilloscopes are simple, easy-to use oscilloscopes that are the solution of choice for troubleshooting devices that contain a mixture of analog and digital technology.

The 54600-Series oscilloscopes feature highly interactive displays, which mean that signal changes are instantaneously displayed in real time. This rapid display update speed simplifies adjustments by eliminating the lag time between making changes and observing the results. Also, rapidly changing signals, like amplitude modulation are displayed as expected.

Direct, responsive controls let you access and manipulate the powerful features with a minimum of menu layers. The intuitive interface insures a short learning curve, allowing you to be up and running quickly, whether you are a brand-new oscilloscope user, or an experienced user switching from an analog oscilloscope.

Powerful digital features such as negative time, storage, measurement automation, hard copy, and computer control solve your most difficult test problems. Agilent's advanced integrated circuit technology puts analog look and feel together with digital power in a small-size, lightweight package, ideal for your troubleshooting needs.

Unique three-processor architecture in these oscilloscopes produces bright, crisp, high-fidelity displays of the most demanding signals all sweep speeds and delayed sweep magnifications. Storage for glitch and transient analysis, is as simple as pressing a button. Negative time lets you view events that would be missed by analog oscilloscopes.

The 54645A version is also enhanced with Agilent MegaZoom technology. This technology, based on multiple processor architecture, gives the 54645A version oscilloscope the ability to capture long records and still remain highly responsive to control inputs and have exceptionally high speed display response. The Agilent MegaZoom technology guarantees that waveform acquisition, storage and display tasks are performed by processors that are optimized for their work.

Materials needed for basic oscilloscope exercises

- One Agilent 54600-series oscilloscope.
- Two Agilent 10071 10:1 probes, or equivalent (supplied with the instrument)
- One Agilent 54654-66502 training board and 9-volt battery (both are provided in the Agilent 54654A Training Kit).
- This Training Guide.

The 54645D Mixed Signal Oscilloscope

The 54645D Mixed Signal Oscilloscope (MSO) is the all-in-one answer for mixed signal testing. Combining powerful digital oscilloscope features with equally powerful logic analyzer features provides a seamlessly integrated solution that guarantees quick troubleshooting and debugging.

On one highly interactive display, you can see both the analog circuit operation displayed on the 100 MHz oscilloscope channels and the logic timing displayed on up to 16 logic channels. These two views of the circuit's operation are aligned in time so that events viewed in one can be related to the other. The MSO also has a control panel that is direct and easy to use. Simple scope-like knobs control both the scope and logic channels. This intuitive interface guarantees access to powerful features with a minimum of menu layers.

As with all Agielnt 54600 instruments, the MSO setup is simplified with the powerful Autoscale operation. Autoscale turns on and displays all channels that have activity. The time base is set to show an optimally-scaled display of the analog channels and the digital timing.

Agilent MegaZoom technology, based on multiple processor architecture, gives the 54645D the ability to capture long records and still remain highly responsive to control inputs and have exceptionally high speed display response. The technology guarantees that waveform acquisition, storage and display tasks are performed by processors that are optimized for their work. This eliminates the long waits commonly associated with troubleshooting a mixed signal system.

Powerful triggering capabilities let you solve a wide range of triggering problems. Simple oscilloscope-like edge triggering is useful for most everyday uses. Pattern triggering allows you to set a pattern of high, low, and don't care levels across 18 channels. Advanced trigger modes give you the choice of glitch, TV and advanced pattern triggering. In advanced pattern trigger mode, you can search for a combination of two trigger pattern terms, which can then be combined in one of several Boolean relations.

Materials needed for the Agilent 54645D mixed signal oscilloscope exercises

- One 54645D mixed signal oscilloscope.
- Two 10074 10:1 probes (or equivalent)
- One 54654-66502 training board and 9-volt battery (both are provided in the 54654A Training Kit).
- This Training Guide.

Agilent 54600-Series Logic Analyzers

If you are an oscilloscope user, you already know how to operate these logic analyzers. The 54620A/C 16-channel, 500-MSa/s logic analyzer is designed to be used with your oscilloscope to quickly troubleshoot and debug your mixed-signal and digital circuits.

This logic analyzer has a control panel that is very much like that of your oscilloscope. You can simply turn a knob to change the time per division, reposition a channel in the display, or enter a duration value.

The logic analyzer setup is simplified with the powerful Autoscale operation. Autoscale turns on and displays all channels that have activity. The time base is set to show an optimally-scaled display of all of the active signals. The undo Autoscale option in the save/recall setup returns the logic analyzer to the setup used before the last Autoscale.

Oscilloscope-like triggering is provided in the edge triggering mode. Pattern mode extends triggering capability to be a pattern of high, low, and don't care levels across all of the 16 input channels, as well as the external trigger input port; you can qualify this pattern with an edge. Advanced trigger mode is useful in applications where you need more triggering power to isolate the event of interest.

The 54620A/C logic analyzer uses an advanced four-processor architecture. This provides a powerful instrument that can display changing waveforms in your system that would be missed by more traditional analyzers. Another benefit of the high-speed display system is that the 54620 responds instantly to your control inputs entered on the front panel.

Materials needed for the logic analyzer exercises

- One 54620 logic analyzer and probes.
- One BNC cable, approximately 1 meter long (Agilent 10503A or equivalent).
- One 54654-66502 training board and 9-volt battery (both are provided in the 54654A Training Kit).
- This Training Guide.

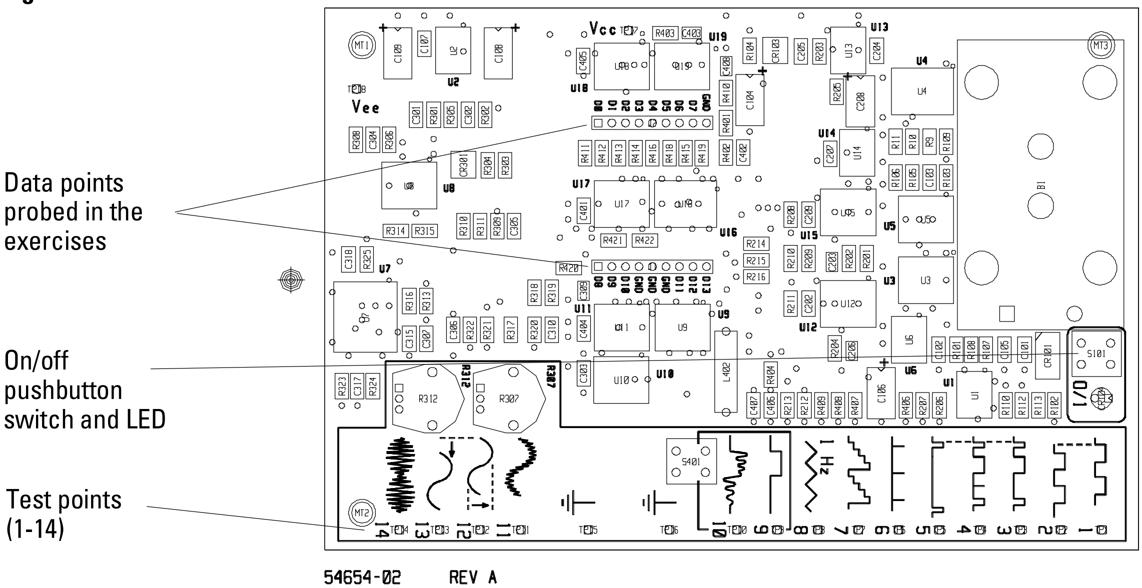
The Training Signal Board

The training signal board has a battery, data probing points, an on/off switch, potentiometers, and scope and analyzer test points.

CAUTION

The training signal board has components that can be damaged by electrostatic discharge. Before you touch the board, touch the battery holder first. Also, when you pick up the board, it is safest to grasp it by the battery and holder. When you connect oscilloscope probes to the board, connect the probe ground lead to the board's ground test point first. This way, any charge on the probe is safely grounded so that it cannot damage delicate components when you connect to a signal test point.

Figure 1



Training Board component locator

The battery

A standard 9-V alkaline battery is used to power the training signal board. The battery is shipped disconnected from the board, because even with the power turned off, there is a current drain of about 80 µA. Normally, with the battery installed, it will have a shelf life of at least eight months. When the board is turned on, the battery drain is about 5 mA, which provides over 100 hours of operation. The red LED begins flashing when there are about 10 hours of operation remaining. The signal board has a “battery saver” feature that automatically turns the power off after two hours of use. If the power turns off during use, simply press the on/off pushbutton to restore operation.

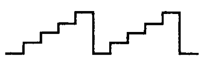
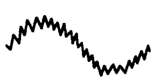
Signal outputs and controls

On the edge of the training signal board there are fourteen test points and two grounds. Next to each of the test points is a graphical representation of the signal that is available at that test point.

Near the center of the board are the logic analyzer test points on two 0.1" center-post connectors. These test points are labeled D0 through D13, and include multiple grounds (GND).

Output impedance for digital waveforms is 316 Ω; output impedance for analog waveforms are as high as 50 kΩ. It is important that you use high impedance 10:1 probes, not 1:1 probes, to connect to the board. The 1:1 probes have high-input shunt capacitance which overloads the outputs, causing distortion.

Waveforms available from this board are typical of those encountered in both real-life digital and analog circuits. Exact waveforms will vary slightly from board to board.

Test Point	Waveform	Description
1		Square wave, 500 kHz, 3.7 Vp-p.
2		Square wave, same as test point 1, but delayed in time by a partial period.
3		Complex pulse train with pulses of various widths and variable time spacing; pulse train repeats every 28.6 µs, 3.7 Vp-p.
4		Same as test point 3, but with an additional narrow glitch pulse occurring at a lower repetition rate.
5		Pulse with period of 28.2 µs, 3.7 Vp-p, and duty cycle of 6.6%.
6		Narrow pulse with low duty cycle, period 6.4 ms, width 325 ns.
7		Noisy stair step with glitches; height of each step is about 65 mV, period 7.5 µs.
8		Slow saw tooth waveform, period 1.6 s, 1.2 Vp-p.
9		Single-shot pulse activated by a momentary-contact pushbutton near the test point; width 90 µs, 3.6 Vp-p.
10		Single-shot pulse, similar to that on test point 9 but with ringing on the pulse top; ringing frequency about 190 kHz.
11		Noisy sine wave; frequency 1.1 kHz, 1.4 Vp-p.
12		Variable amplitude sine wave; frequency 1.1 kHz; amplitude is varied by turning a potentiometer near the test point.
13		Sine wave is similar to that available on test point 12, but with variable phase shift referenced to the test point 12 waveform. Phase shift is varied by turning a potentiometer near the test point.
14		Modulated carrier waveform; carrier frequency about 260 kHz, modulating frequency about 1.1 kHz.

Concepts and features

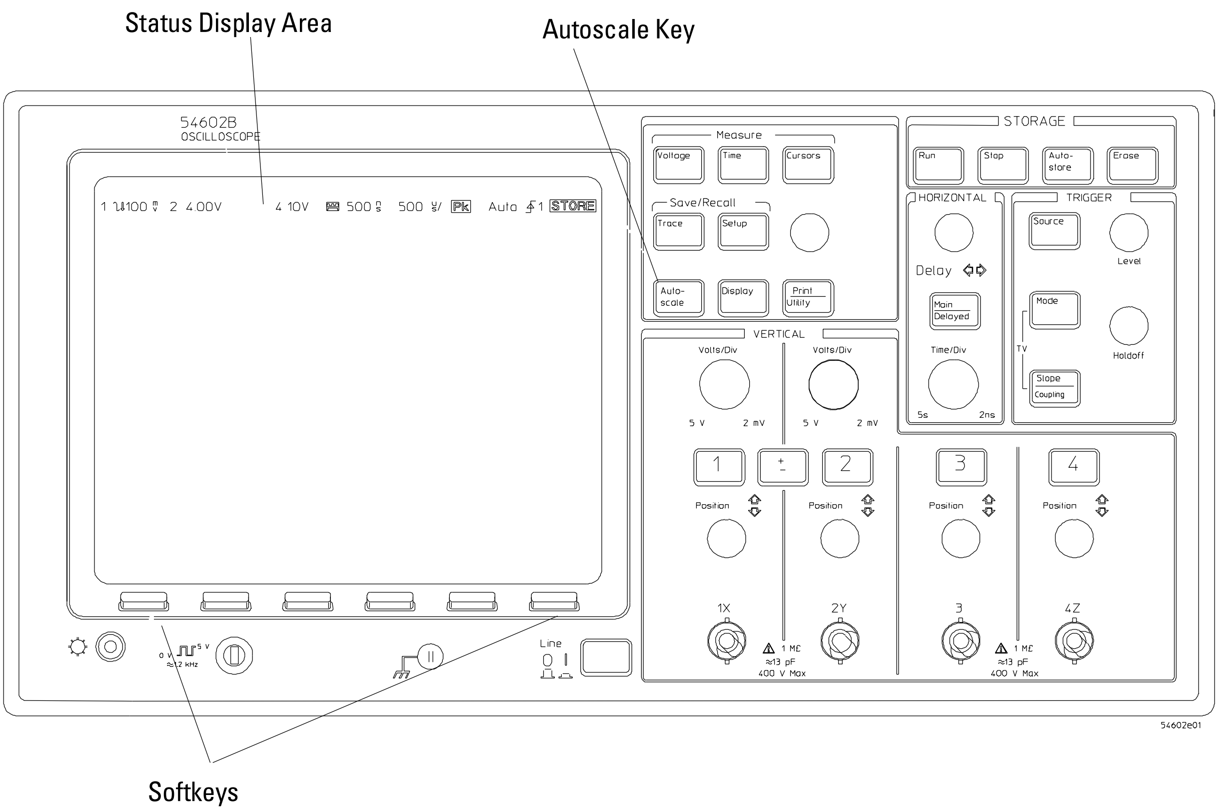
We have carefully designed the Agielnt 54600-oscilloscopes and logic analyzers to make them look and feel like the instruments that most oscilloscope users already know how to use.

The front panels have knobs, grey keys, and white keys. The knobs are used most often and are similar to knobs on oscilloscopes. To reduce the number of pushbuttons, grey keys on the front panel bring up softkey menus at the bottom of the display. Each of the softkeys just below the display corresponds to a menu item just above on the display. The white keys are instant action keys which do not have associated menus.

Throughout this book, front-panel keys are denoted by a box around the name of the key, and softkeys are denoted by a change in the text type. For example, `Pattern` is a grey key in the trigger portion of the front panel, and **Source** is a softkey. The word "**Source**" is at the bottom of the display directly above a softkey. The function of the softkeys change as you press other front-panel keys.

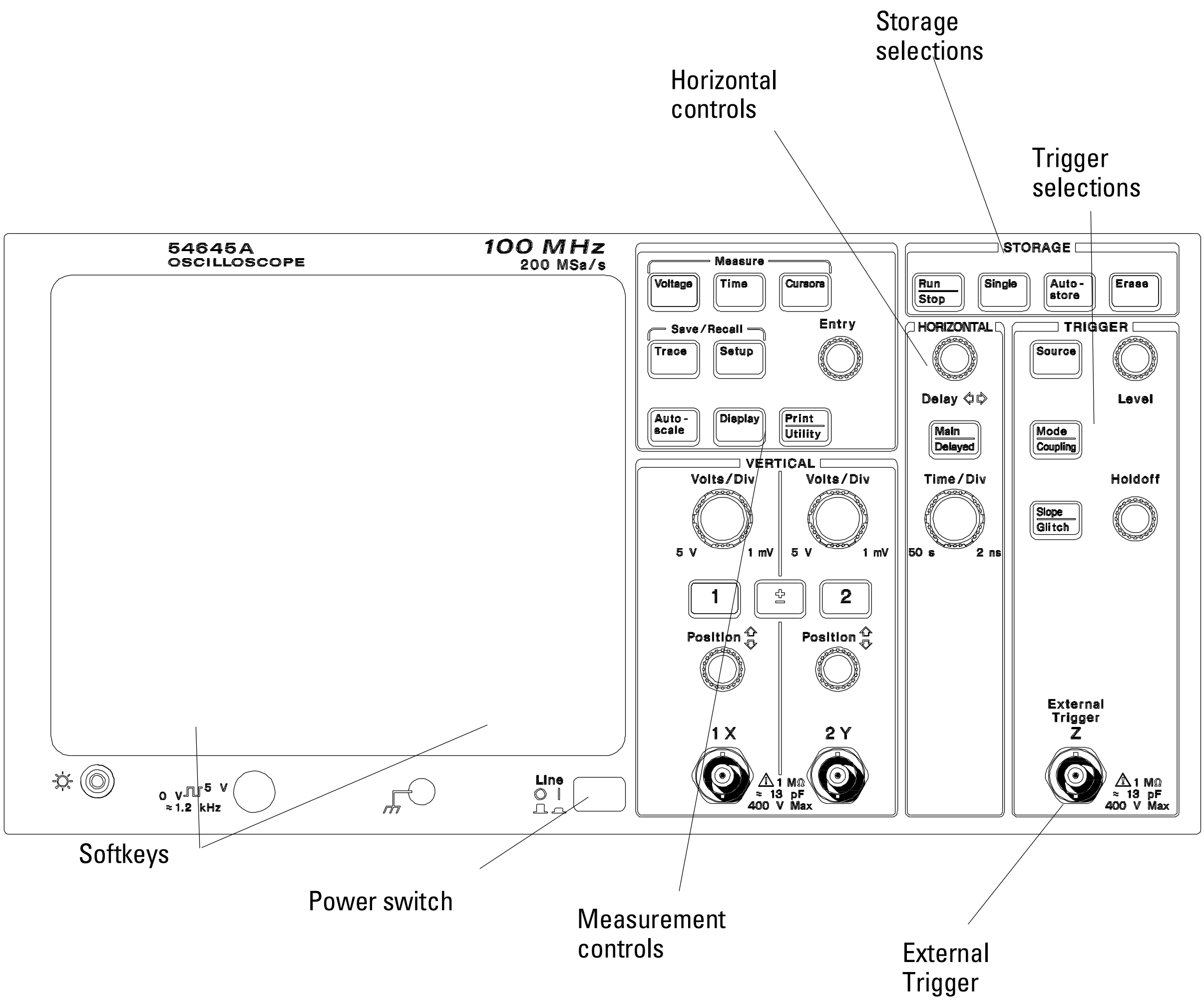
The status line, located at the top of the display, lets you quickly determine the setup of the instrument, including the sampling rate, whether the instrument is in glitch mode, the time/division setting, the trigger mode, Autostore status, and whether the measurement is running or stopped.

Figure 2



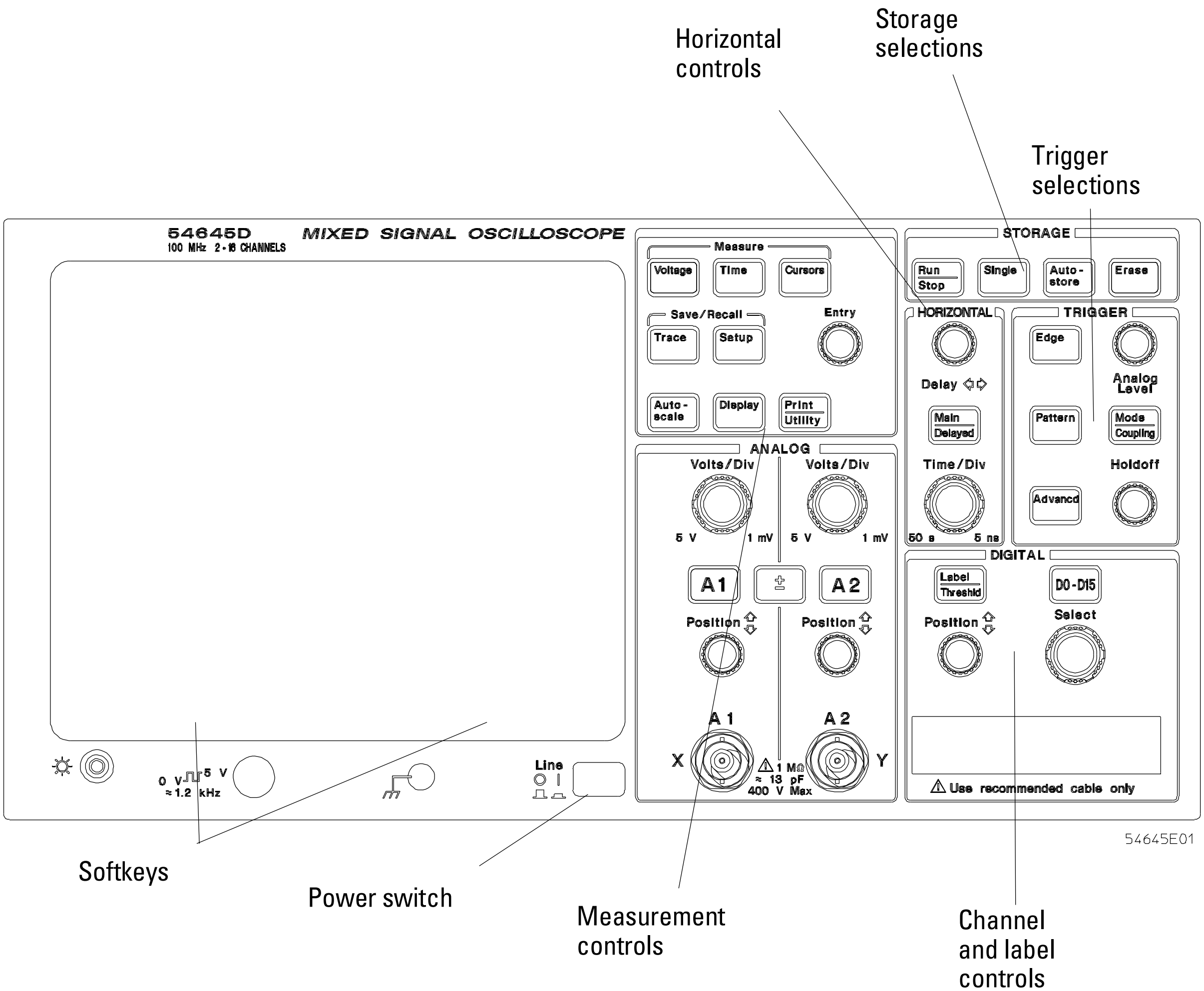
The Agilent 54602B front panel

Figure 3



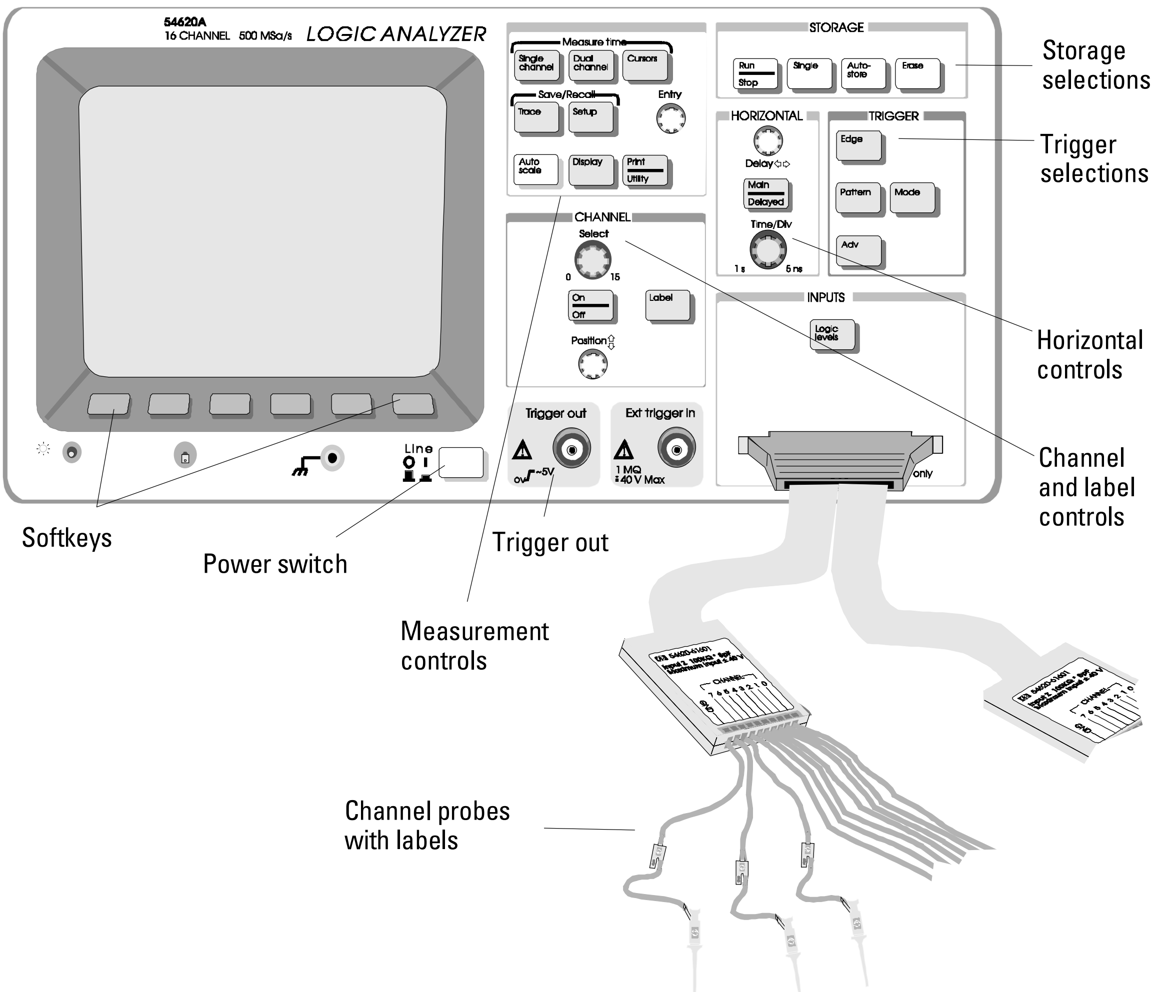
The Agilent 54645A front panel

Figure 4



The Agilent 54645D front panel

Figure 5



The Agilent 54620A front panel

In This Book

This book is a self-paced training guide to quickly acquaint you with Agilent 54600-Series Oscilloscopes, the 54645D mixed signal oscilloscope, and the 54620A/C logic analyzers. You will learn how to set up these instruments and begin making measurements right away.

Getting Started

Chapter 1 shows you how to get started with your particular instrument, including how to:

- Install the battery.
- Turn on the training board
- Turn on the oscilloscope or logic analyzer.

Basic Oscilloscope Operations

Chapter 2 shows you how to:

- Use basic oscilloscope operations.
- Make measurements.
- Use the trigger holdoff.
- Use storage operations.
- Use advanced oscilloscope operations.

Using MegaZoom Technology

Chapter 3 shows you how to make the most of the Agilent MegaZoom technology if you are using the 54645A oscilloscope or the 54645D mixed signal oscilloscope.

Mixed Signal Oscilloscope Exercises

Chapter 4 shows you how to make the most of the combined oscilloscope features and the logic analysis features in the 54645D mixed signal oscilloscope. This chapter shows you how to:

- Use basic logic analysis features of the mixed signal oscilloscope.
- Make measurements.
- Capture and measure a glitch.
- Use the logic analysis and oscilloscope features together.

Digital Circuitry Measurement Exercises

Chapter 5 shows you how to:

- Use basic logic analyzer operations.
- Use the logic analyzer to make measurements in four exercises.
- Connect the logic analyzer probes to the training board.
- Display, reorder, and label channels.
- Use cursors and the measurement capability.
- Use the Autostore feature.
- Capture and measure the width of a glitch.
- Connect to and trigger the oscilloscope.

If you need more details on operation, refer to the User and Service Guide supplied with your oscilloscope or logic analyzer.

Which exercises are for you

		54600-Series* Basic Oscilloscope	**54645A with Agilent MegaZoom Technology**	**54620A/C Logic Analyzer**	**54645D Mixed Signal Oscilloscope**
Chapter 1 Getting Started with...	...the 54600 series* Basic Oscilloscope	√	√		
	...the 54645D Mixed Signal Oscilloscope				√
	...the 54620A/C Logic Analyzer			√	
Chapter 2 Basic Oscilloscope Operations	Entire chapter	√	√		√
Chapter 3 Agilent MegaZoom Technology	Entire chapter		√		√
Chapter 4 Mixed Signal Oscilloscope Exercises	Entire chapter				√
Chapter 5 Digital Circuitry Measurement Exercises	Entire chapter			√	

*Note: In this table, Agilent 54600-Series Basic Oscilloscopes are the following: 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, and 54616B/C.

Contents

4 Mixed Signal Oscilloscope Exercises

5 Digital Circuitry Measurement Exercises

1

Getting Started

Getting Started

These exercises are designed to get you started with your oscilloscope or logic analyzer.

The self-contained sections describe getting started with the following instruments, respectively:

- 54600, 54601B, 54602B, 54603B, 54610B, 54615B, 54616B/C basic oscilloscopes
- 54645A oscilloscope with Agilent MegaZoom technology
- 54645D mixed signal oscilloscope
- 54620A/C logic analyzer

Turn to the section in this chapter that describes your instrument. At the end of the appropriate section you will be directed to the next set of exercises that apply to your oscilloscope or logic analyzer.

Getting started with the 54600 Basic Oscilloscopes or the 54645A Oscilloscope

In this section you will learn how to turn on both the training board and the oscilloscope. You will also learn how to set the oscilloscope for proper probe attenuation factor and how to compensate the probes.

This section applies to the following oscilloscopes: the 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, 54616B/C basic oscilloscopes, and the 54645A oscilloscope with Agilent MegaZoom technology.

Install the battery

1 Remove the insulating material from the battery holder.

This material is used to separate the terminals on the battery from those on the battery holder.

2 To prevent unnecessary strain on the board, place two fingers on the battery-holder terminals. Then, push on the bottom of the battery with your thumb to snap the battery into its sockets.

Take care to install the battery with correct polarity. Board circuits are protected from accidental exposure to reverse polarity through the use of a shunting diode. Momentary contact with reverse polarity will not damage the circuits.

> It is not always necessary to turn off power to the training board before making or changing measurements in the exercises that follow, unless you are instructed to do so.

Turn on the board

- Press the pushbutton near the battery holder next to the red LED. Push once to turn on. Push again to turn off.

  When power is applied, the LED is lit.

Turn on the oscilloscope

1 Plug the power cord into the socket on the rear panel.

WARNING Only use power sources with an approved three-contact outlet. Sockets with polarized two-conductor plugs will not ground the chassis, and they are a shock hazard.

2 Plug the other end of the cord into a line outlet, 100 V ac to 240 V ac, 48 Hz to 445 Hz. (The line voltage selection is automatic.)

3 Push in the line switch button (below the lower-right side of the display).

Set up the oscilloscope in a default state

1 Press the grey `Setup` .

2 Press the **Default Setup** softkey at the lower right side of the display.

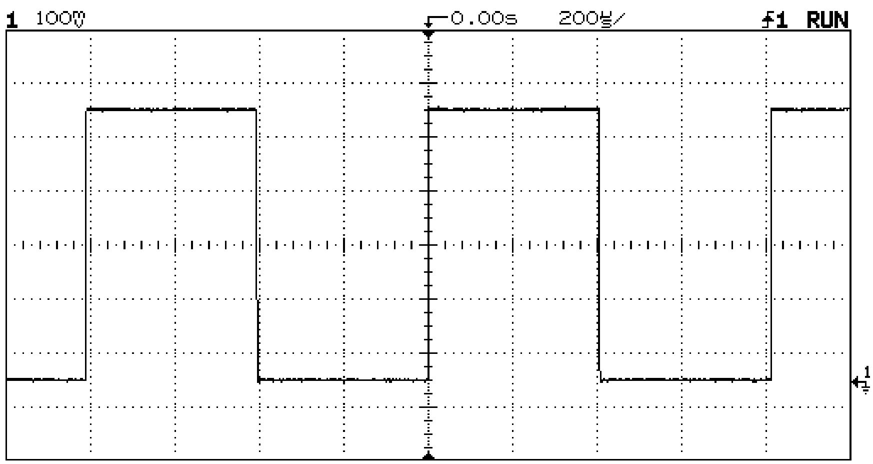
By doing this, your oscilloscope displays will resemble the screens shown in this section.

Display a waveform

1 Connect one of the probes supplied with the instrument to the channel 1 BNC connector at the bottom of the front panel.
2 Connect the probe to the oscilloscope probe compensation test point on the lower-left side of the front panel.
3 Press the `Autoscale` key located just to the right of the display.

You should now see a stable calibrator waveform. The Autoscale feature automatically sets the vertical, time base, and trigger for a stable display of most signals with a frequency greater than 50 Hz and a duty cycle greater than 1%. This key eliminates the tedious setup of several controls that is necessary on most analog oscilloscopes.

Figure 1–1



Autoscaled waveform

About Probes:
The 54600B, 54601B, 54602B, and 54603B oscilloscopes are supplied with Agilent 10071 10:1 probes. The 54610B, 54615B, and 54616B/C oscilloscopes are supplied with Agilent 10073 10:1 probes.
The 54645A oscilloscope with Agilent MegaZoom technology and the 54645D mixed signal oscilloscope are supplied with Agilent 10074 10:1 probes.

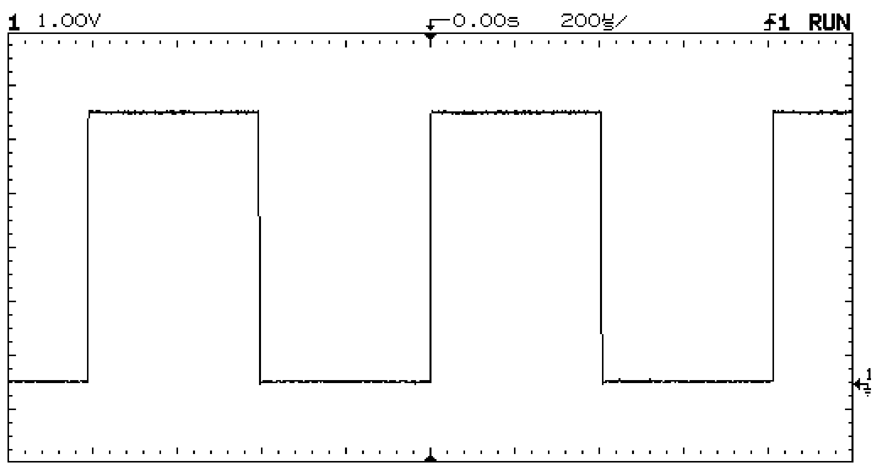
Set the probe attenuation factor

1 Press the grey [1] key.

2 Toggle the **Probe** softkey, at the lower-right side of the display, to 10. (Note that the 54610B, 54615B, 54616B/C, and the 54645A oscilloscopes have automatic probe attenuation factor selection).

Important operating hint!
You must set the probe attenuation factor correctly or measurement voltage data will be wrong. Notice that toggling the probe attenuation factor does not change the waveform display. It does change the scale factor for channel 1. The status line shows V/div based on the attenuation factor that you have selected.

Figure 1–2



Autoscaled waveform

On the body of the probe there is an orange button. When you press this button, the input signal is momentarily interrupted and the probe is connected to ground. This makes it easy to identify the channel to which the probe is connected.

Compensate your probes

1 Insert the nonmetallic screwdriver (provided with the probe) into the adjustment hole on the BNC end of the probe. Then, adjust the compensation for the flattest waveform possible on the display.

2 Remove the first probe from the oscilloscope, then adjust a second 10:1 probe as in step one.

Compensating the probe for the flattest pulse response ensures a distortion-free display of test waveforms. Compensation adjusts the frequency response of the probe so that distortion, as a function of frequency or rise time, does not occur.

Figure 1–3

Overcompensation causes pulse peaking.

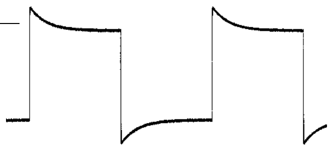


Figure 1–4

Correct compensation with a flat pulse top.

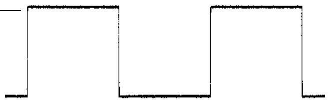
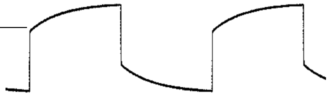


Figure 1–5

Undercompensation causes pulse rolloff.

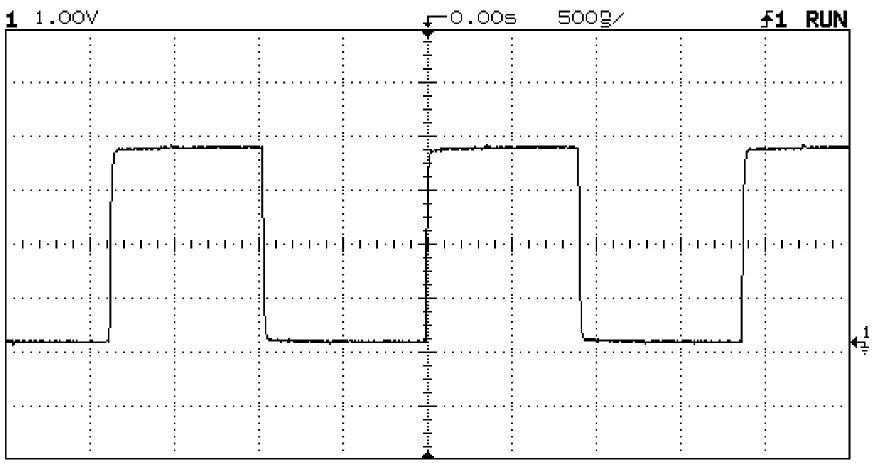


View a signal on the training signal board

1 Remove the probe from the calibrator test point on the oscilloscope.
2 Connect the probe ground to a ground test point on the training signal board, then connect the probe to the number 1 test point.
3 Turn on the board by pressing the pushbutton near the battery.
4 Press `Autoscale` .

You now have a display of the test point 1 waveform.

Figure 1–6



Test point 1 waveform displayed

The Next Step: Selecting exercises for 54600 Basic Oscilloscopes or the 54645A Oscilloscopes

If you are using the 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, 54616B/C oscilloscopes, proceed to the basic oscilloscope exercises in Chapter 2. After completing the exercises in Chapter 2, your training will be complete.

If you are using the 54645A oscilloscope with Agilent MegaZoom technology, proceed first to the basic oscilloscope exercises in Chapter 2. After completing the exercises in Chapter 2, you will be directed to further exercises for your instrument which use the MegaZoom technology.

Getting Started with the 54645D Mixed Signal Oscilloscope

In this section you will learn how to turn on both the training board and the oscilloscope and set it up in its default state.

Install the battery

1 **Remove the insulating material from the battery holder.**

This material is used to separate the terminals on the battery from those on the battery holder.

2 **To prevent unnecessary strain on the board, place two fingers on the battery-holder terminals. Then, push on the bottom of the battery with your thumb to snap the battery into its sockets.**

Take care to install the battery with correct polarity. Board circuits are protected from accidental exposure to reverse polarity through the use of a shunting diode. Momentary contact with reverse polarity will not damage the circuits.

> It is not always necessary to turn off power to the training board before making or changing measurements in the exercises that follow, unless you are instructed to do so.

Turn on the board

- Press the pushbutton near the battery holder next to the red LED. Push once to turn on. Push again to turn off.

  When power is applied, the LED is lit.

Turn on the oscilloscope

1 Plug the power cord into the socket on the rear panel.

WARNING

Only use power sources with an approved three-contact outlet. Sockets with polarized two-conductor plugs will not ground the chassis, and they are a shock hazard.

2 Plug the other end of the cord into a line outlet, 100 V ac to 240 V ac, 48 Hz to 445 Hz. (The line voltage selection is automatic.)

3 Push in the line switch button (below the lower-right side of the display).

Set up the oscilloscope in a default state

1 Press the grey `Setup` .

2 Press the **Default Setup** softkey at the lower right side of the display.

By doing this, your oscilloscope displays will resemble the screens shown in this section.

View a signal on the training signal board

1 Connect the probe ground to a ground test point on the training signal board, then connect the probe to the number 1 test point.
2 Turn on the board by pressing the pushbutton near the battery.
3 Press `Autoscale` .

You now have a display of the test point 1 waveform.

The Next Step: Selecting exercises for the 54645D Mixed Signal Oscilloscope

All of the exercises in Chapters 2, 3, and 4 apply to the Mixed Signal Oscilloscope. If you are a new digital oscilloscope user, we recommend that you begin with Chapter 2 and work through the other chapters in order.

Getting Started with the 54620A/C Logic Analyzer

In this section you will learn how to turn on both the training board and the logic analyzer. Following the exercises, you will be directed to the next section of exercises.

The 54620C logic analyzer has a color display. Please refer to the *User and Service Guide* supplied with the product for operation of the color display.

Install the battery

1 **Remove the insulating material separating the terminals on the battery from those on the battery holder.**

2 **To prevent unnecessary strain on the training board, place two fingers on the batter-holder terminals. Then, push on the bottom of the battery with your thumb to snap the battery into its sockets.**

Take care to install the battery with correct polarity. Board circuits are protected from accidental exposure to reverse polarity through the use of a shunting diode. Momentary contact with reverse polarity will not damage the circuits.

> It is not always necessary to turn off power to the training board before making or changing measurements in the exercises that follow, unless you are instructed to do so.

Turn on the training board

1 Locate the on/off pushbutton near the battery holder next to the red LED.
2 Push once to turn on. Push again to turn off.

> To conserve the battery life, the training board will turn itself off after a period of no activity. If this happens, just press the pushbutton near the battery holder to turn the board on again.

Turn on the Logic Analyzer

1 Verify the power cord is plugged into the socket in the rear panel.

WARNING Only use power sources with an approved three-contact outlet, 100 V ac to 240 V ac, 40 Hz to 445 Hz. The line voltage is automatic.

2 Locate the pushbutton power switch on the front panel.
3 Push the power switch once to turn on.

Probe the signals and apply power

1 Connect the black analyzer probe lead to GND on the training board.
2 Connect the channel 0 probe to D0.
3 Connect the channel 1 probe to D1.
4 Connect the channel 2 probe to D2.
5 Press the pushbutton on the training board near the battery to apply power.
The red LED on the training board will be lit.

View the status line and corresponding controls

1 Press `Setup` . Then press the Default Setup softkey

2 **Take hold of the HORIZONTAL Time/Div knob. Turn it to the right several inches. Then turn it to the left. Observe the status line at the top of the screen.**

In the status line at the top of the screen, notice that the time per division indicator changes as you turn the knob. Notice also that the sample rate changes as the seconds per division change.

"GL" indicates that glitch detection is turned on. Glitch detection turns on automatically when the analyzer is acquiring data at sample rates slower than 4 ns.

3 **Take hold of the HORIZONTAL Delay knob. Turn it to the right and observe the delay number at the top of the screen.**

In the status line at the top of the screen, observe the delay-from-trigger number. Notice also how the waveform move right and left on the screen as you turn the knob.

A solid bar at the bottom of the screen also moves when you turn the knob. This is the memory bar, which is discussed in the User's Guide.

4 **Observe the trigger mode and status indicator in the status line, next to the RUN indicator.**

This indicates that the current trigger selected is a rising edge on channel zero. The trigger appears as a small solid triangle in the top waveform in the center of the screen. If the trigger is not located in the center of the screen, turn the Delay knob until the delay-from-trigger number is 0.

5 **Press the pushbutton on the training board to turn off power.**

In the status line at the top of the screen, note that the trigger mode and status indicator is flashing. This indicates the absence of the trigger.

6 **Turn on the training board**

The RUN indicator in the status line indicates the current status.

7 Press `Run/Stop` .

The status is now stopped and the last acquisition of data remains on screen.

8 Press `Single` several times.

Notice how a new trace of data is captured each time you press this key.

9 Press `Run/Stop` again to start the acquisition

The Next Step: Selecting exercises for the 54620A/C Logic Analyzer

Proceed directly to Chapter 5 for digital circuitry measurement exercises using the 54620 logic analyzer. After completing the exercises in Chapter 5, your training will be complete.

2

Basic Oscilloscope Operations

Basic Oscilloscope Operations

These exercises are designed for use with the 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, 54616B/C basic oscilloscopes, the 54645A oscilloscope with Agilent MegaZoom technology, or the 54645D Mixed Signal Oscilloscope.

The exercises are listed in the same order as the test points on the training signal board. They are designed for you to do in a particular order, because later exercises depend on knowledge gained from previous ones. Front-panel setups also depend upon previous exercises. If you try an exercise out of sequence, refer to previous exercises that contain setup steps required for your chosen exercise. For convenience, names of these exercises (if they are required) are listed just before the first step in each exercise.

Who should do these exercises?

You should do these exercises if you are using one of following instruments:

- 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, or 54616B/C basic oscilloscope
- 54645A oscilloscope with Agilent MegaZoom technology
- 54645D mixed signal oscilloscope

Be sure that you have worked through the appropriate "Getting Started With..." exercises in Chapter 1 that apply to your instrument before doing the exercises in this chapter.

If you are doing these exercises using the 54645D mixed signal oscilloscope, your display will look slightly different than those illustrated in this chapter because, though they will be turned off, your display also reflects the logic analyzer channels.

At the end of this chapter you will be directed to the next step in your training.

Which Chapter 2 exercises are for you

	54600-Series* Basic Oscilloscope	**54645A Basic Oscilloscope with MegaZoom technology**	**54620A/C Logic Analyzer**	**54645D Mixed Signal Oscilloscope**
Entire chapter	√	√		√

*Note: In this table, 54600-Series Basic Oscilloscopes are the following: 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, and 54616B/C.

Using Oscilloscope Operations

In this section you will learn how to set up the vertical, time base, and trigger controls on the oscilloscope.

Set up the vertical

Before doing this exercise, make sure you have performed the steps in "View a signal on the training signal board" in Chapter 1.

1 Turn the channel 1 Volts/Div knob and notice changes in the waveform and status line at the top of the display.

2 Press [1]. Leave channel 1 on.

A softkey menu appears on the display. Pushing this button turns channel 1 off and on.

3 Turn on the Vernier softkey (at the bottom of the display) and notice its effect as you vary the Volts/Div knob. Also, notice the changes to the status line.

The vernier mode is calibrated (unlike with analog oscilloscopes).

4 Turn off the Vernier softkey.

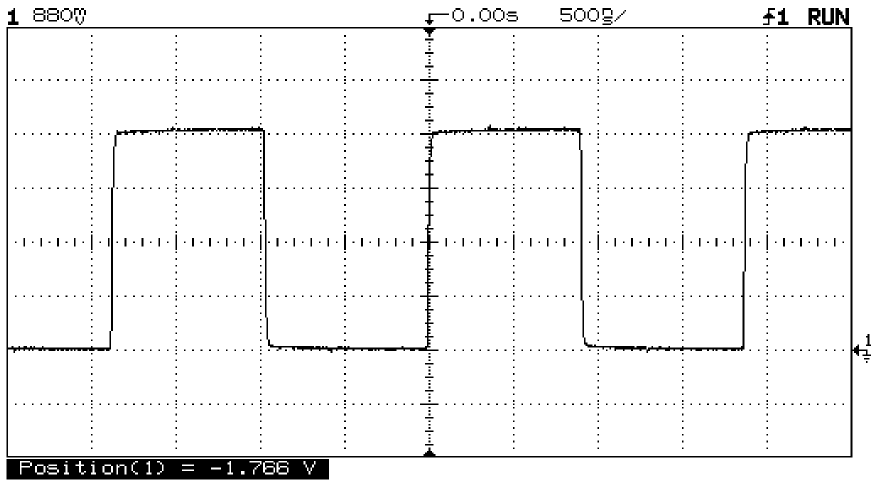
5 Rotate the channel 1 Position knob and notice changes to the display.

As you change vertical sensitivity with the Volts/Div knob, the left side of the status line shows the V/div setting. Selecting vernier allows a more precise setting of vertical sensitivity. The ground location for channel 1 is shown at the right side of the display.

Rotating the Position knob activates an inverse video field at the bottom left of the display that shows the position of the ground point with respect to the center of the display. You can verify this by moving the bottom of the waveform to center screen with the Position knob. Ground is at 0 volts.

You can turn a channel on or off by pressing the appropriate channel key or the On/Off softkey.

Figure 2–1



Positioning a waveform vertically on the display

Set up the main time base

Before doing this exercise, make sure you have performed the steps in "View a signal on the training signal board" in Chapter 1.

1 **Turn the Time/Div knob and notice its effect on the waveform and status line.**

2 **Turn the Delay knob and notice its effect on the waveform and status line.**

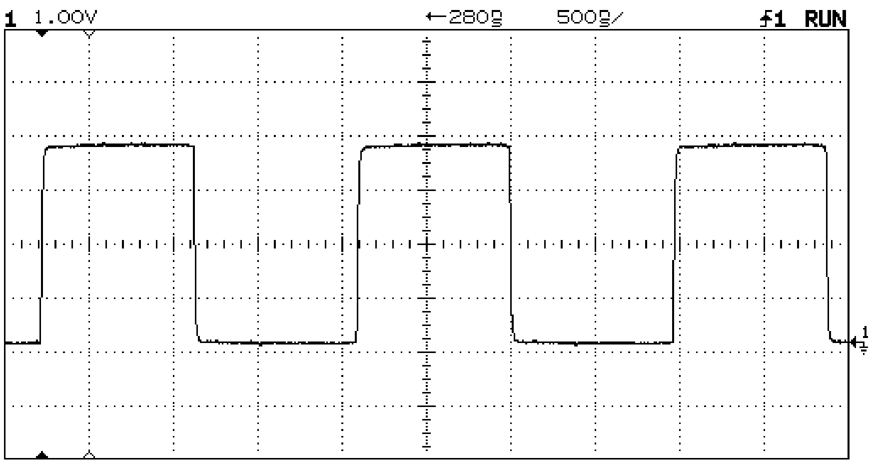
3 **Press `Main/Delayed` and notice that a softkey menu appears at the bottom of the display.**

The Main/Delayed key brings up a menu that allows you to choose between the horizontal modes of operation: main, delayed, or XY. Notice it also allows you to select a finer vernier operation. The far right softkey places the time reference of the oscilloscope at either one division from the left or at the center of the display. The time reference point is the trigger point when zero delay is selected.

As the Delay knob is rotated, you will notice a small pointer triangle (∇) that moves at the top of the display. The solid triangle (▼) indicates where the trigger point is; the hollow triangle shows where your selected time reference is.

Notice the small inverse video box in the status line that lights up when you rotate the Delay knob. The numbers inside this box show you the position of the time reference with respect to the trigger point—how much delay, either positive (after the trigger) or negative (before the trigger) that you have selected. Only digitizing architectures allow you to select negative delay to see events before the trigger. This feature is valuable in troubleshooting faults when you must determine what conditions led to a trigger event.

Figure 2–2



Positioning the waveform horizontally on the display

Use the delayed time base

Before doing this exercise, make sure you have performed the steps in "View a signal on the training signal board" in Chapter 1.

1 Press `Main/Delayed` .

2 Press the **Delayed** softkey.

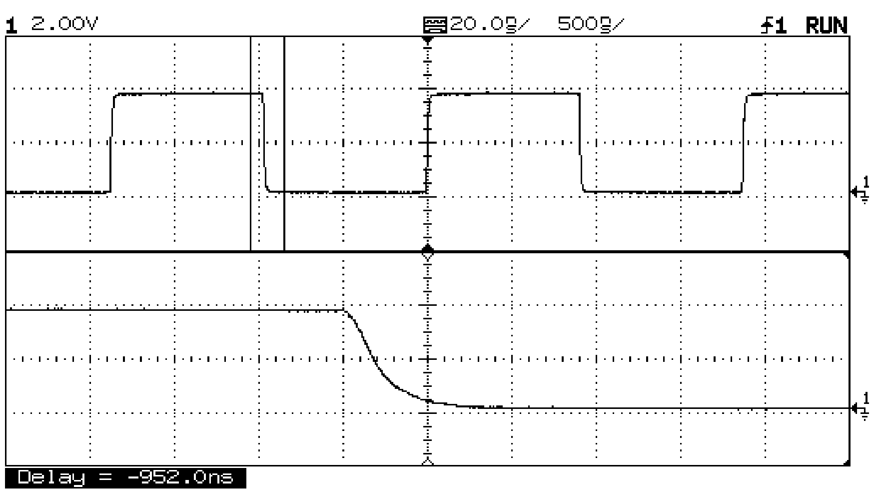
3 Turn the Time/Div knob and notice the changes to the upper and lower display.

4 Turn the Delay knob and notice the changes to the upper and lower display.

The upper half of the display shows the main time base waveform. The two vertical lines in this upper main sweep display define the portion of the main sweep that is acquired at a faster sweep speed and displayed in the lower, delayed-sweep half of the display.

This area of the main sweep that is magnified is usually indicated with a change in intensity in an analog oscilloscope. Notice that both time base s/div settings are displayed in the status line at the top of the display. The ability to exactly frame a desired portion of a waveform is valuable when making automatic measurements.

Figure 2–3



Using the delayed time base

Set up normal trigger

Before doing this exercise, make sure you have performed the steps in “Use the delayed time base” in the last module.

1 Press the `Mode` key (the `Mode/Coupling` key on the 54645A or 54645D).

2 Press the **Normal** softkey.

3 Rotate the level knob and notice its effect on the waveform and that the trigger level voltage appears at bottom of the display in inverse video. Set the level at the middle of the upper waveform.

4 Press the `Slope/Coupling` key (the `Slope/Glitch` on the 54645A) and notice the softkey choices.

The Mode key on the 54600 series basic oscilloscopes activates a softkey menu that allows selection of several different trigger modes. You will use some of these other modes later.

The Mode/Coupling key on the 54645A/D activates a softkey menu that allows selection of trigger modes as well as functions that select the trigger to be ac or dc coupled, filtered with high frequency, low frequency or noise rejection filters.

The Slope/Coupling key on the 54600 series basic oscilloscopes activates softkeys that have functions that select the trigger to be: on the rising or falling edge of the waveform, ac or dc coupled, filtered with high frequency or low frequency filters. Notice the symbols at the far left in this menu that indicate positive or negative trigger slope. These same symbols appear at the right side of the status line at the top of the display. The trigger source is displayed next to this symbol. Channel numbers are shown in bold numerals, and External (54600B, 54603B only) or Line trigger is indicated with an “E” or “L”, respectively. If the display is not triggered, the symbols flash in inverse video.

The Slope/Glitch key on the 54645A activates softkeys that have functions that select the trigger to be on the rising or falling edge of the waveform, and allows you to set glitch or TV triggers.

Making Measurements

In this section you will learn how to make both automatic and manual measurements of time and voltage.

Use time cursors

Before doing this exercise, make sure you have performed the steps in “View a signal on the training signal board” in Chapter 1.

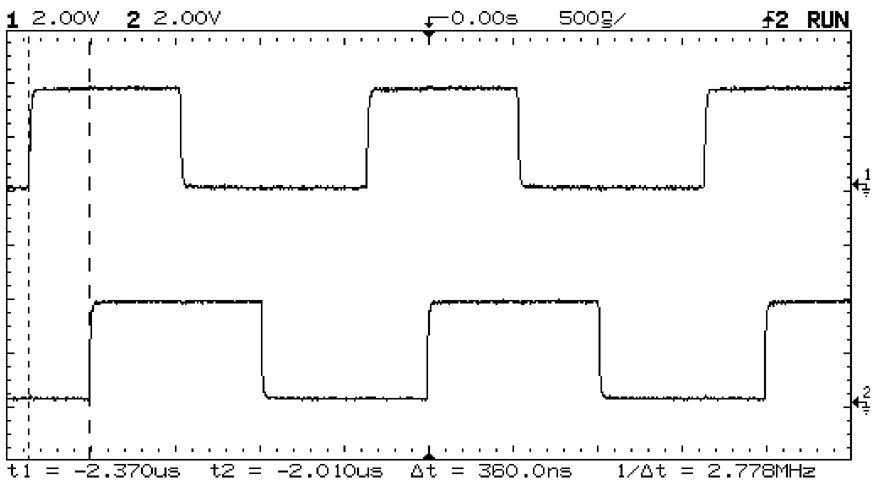
1 Connect a second compensated probe between channel 2 on the oscilloscope and test point 2 on the training signal board. Be sure to connect the probe ground to one of the ground test points on the signal board.
2 Press `Autoscale` .
3 Press `Cursors` at the top of the front panel in the Measure section, then press the **t1** softkey.
4 Notice that **t1** is active as denoted by its inverse video display in the softkey area at the bottom of the display.
5 Turn the knob just below and to the right of the Cursors key, and notice the movement of the cursor. Set **t1** to the left-most positive pulse edge on channel 1.
6 Press the **t2** softkey. Using the same knob as in step 5, set **t2** to the left-most positive pulse edge on channel 2.

7 **Notice the delta t (Δt) reading just below the graticule at the bottom of the display.**

The time location of each time cursor with respect to the time reference (the solid triangle at the top of the display) is shown below the graticule. Delta t is the difference of those two numbers; in this case, it is the amount of delay between the pulse on channel 1 and the pulse on channel 2.

When using time cursors, set the time base speed to the fastest speed possible that allows you to view both points in the waveform that you are measuring. You can also use delay to move the waveform so that both cursors are on the display at the faster sweep speed. This allows better resolution when setting the cursors. Notice that you can use time cursors to measure between points on one waveform or between points on multiple waveforms because all signals have the same s/div and time reference.

Figure 2–4



Setting cursors to make a measurement

Use voltage cursors

Before doing this exercise, make sure you have performed the steps in “View a signal on the training signal board” in Chapter 1, and “Use time cursors” in the previous module. Note that the voltage cursors do not apply to the 54645D mixed signal oscilloscope.

1 Press `Cursors` . (If you just did the previous time cursor exercise, the Cursors key is already active.)

2 Press the **V1** softkey, and notice that just to the left of the **V1** softkey is a softkey labeled **Source**.

3 Toggle the **Source** softkey to 1.

4 Using the knob just below and to the right of the Cursors key, move the **V1** cursor to the top of the pulse on channel 1.

5 Select **V2**. Using the same knob as in step 4, move the **V2** cursor to the bottom of the pulse on channel 1.

6 Read the delta V (ΔV) value just below the bottom of the graticule.

The voltage with respect to ground is listed for both cursors just below the bottom of the graticule. Delta V is the difference of these two numbers; in this case, it is the peak-to-peak voltage of the pulse.

Helpful hint!
Be sure that you select the correct source for the cursors. Because the V/div setting can be different for different channels, you must select the source so that the cursors are calibrated to the channel that you wish to measure. Also, make sure that you selected the correct probe attenuation factor. See “To set the probe attenuation factor.”

Make automatic voltage measurements

Automatic measurements are a great time saver. Before doing this exercise, make sure you have performed the steps in "View a signal on the training signal board"in Chapter 1, and "Use time cursors" in a previous module in this chapter.

1 Press `Autoscale` . (You are doing this to make sure that you are starting out with the correct initial conditions.)

2 Press `Voltage` .

3 Toggle the **Source** softkey to select Channel 1. Then press the **Vp-p** softkey and notice that the V p-p reading slides across the display.

4 Press each of the Voltage Measurements softkeys to see what they do.

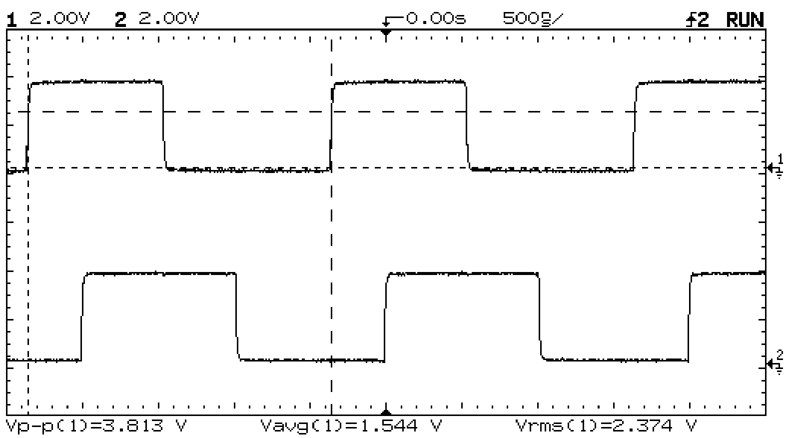
5 Press the **Next Menu** softkey, then try each of the other Voltage Measurements that are available.

6 Toggle the **Show Meas** softkey and notice that the cursors appear and disappear on the display.

The show measure softkey allows you to see where on the waveform the automatic measurement was made. Notice that the measurements are continuous.

When the delayed time base is on, automatic measurements are made on the delayed time base waveform (whenever that is possible). This way, you can frame exactly the portion of a waveform that you wish to measure.

Figure 2–5



Making automatic voltage measurements

Make automatic time measurements

Before doing this exercise, make sure you have performed the steps in "View a signal on the training signal board" in Chapter 1, and "Use time cursors" in a previous module in this chapter.

1 Press `Autoscale` , then press `Time` .

2 Toggle the **Source** softkey to select channel 2.

3 Press the three measurement softkeys available in the Time Measurements softkey area and notice the displayed results.

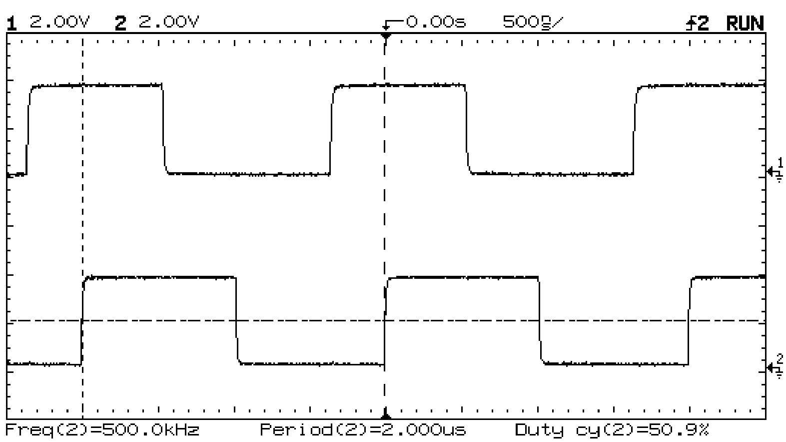
4 Press the **Next Menu** softkey, then try the other time measurements that are available.

5 Press the **Previous Menu** softkey, then press the **Clear Meas** softkey.

For measurements of frequency, period, and duty cycle, at least one complete period of the signal must be displayed. A "not found" prompt will appear when insufficient information is displayed to perform an automatic measurement. Similarly, for width measurements, a complete pulse with both rising and falling edges must be displayed to make the measurement.

For rise time and fall time measurements, accuracy is increased by increasing the sweep speed so that the edge you are measuring is stretched out to provide greater resolution. You must keep all of the edge, plus a section of the top and bottom of the pulse, on the display.

Figure 2–6



Making automatic timing measurements

Using Trigger Holdoff

In this section you will learn how to obtain stable, triggered displays of complex waveforms using the trigger holdoff feature.

Trigger on a repeating serial pattern

1 Disconnect the channel 2 probe from the training signal board and from the channel 2 BNC connector.

2 Connect the channel 1 probe to test point 3 on the training signal board. (Connect the probe ground lead also.)

3 Press `Autoscale` . Notice that a stable waveform appears, but that it is multivalued, indicating that a repeating serial pattern may be present.

4 Rotate the Time/Div knob counterclockwise to 10 µs/div.

5 Rotate the Holdoff knob clockwise until you have adjusted the holdoff to about 18 µs. Then, slowly rotate the knob until you get a stable single-valued waveform.

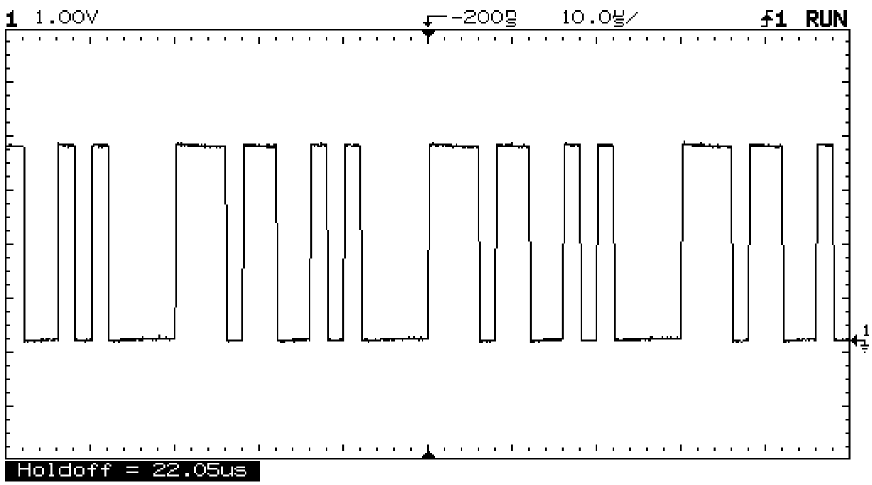
6 Notice that the signal consists of a repeating pattern of four positive pulses.

When you suspect repeating complex waveforms and the period of the signal is unknown, slowly add holdoff until a true stable, single-valued waveform is displayed.

Trigger Holdoff on 54600-series oscilloscopes is adjustable from 200 ns to about 13 seconds. The function of holdoff is to delay the arming of a new trigger for a selected period of time immediately after completing a signal acquisition (similar to a sweep in an analog oscilloscope). Using this feature, it is possible to get a stable waveform on signals that have a repeating serial pattern.

With the 54600-series digitizing architecture, holdoff is independent of s/div settings. This feature allows you to adjust the sweep speed without having to reset holdoff. This is not possible with analog oscilloscopes.

Figure 2–7



Adjusting the holdoff

Trigger in the presence of repeating glitches

Before doing this exercise, make sure you have performed the steps in "Trigger on a repeating serial pattern" in the previous module.

1 Connect a second probe between channel 2 and test point 4 on the training signal board. (Connect the probe ground leads also.)

2 Press `Autoscale` .

3 Turn the Holdoff knob clockwise until the holdoff is 18 µs, and notice that the trigger is unstable. Continue to increase holdoff by slowly turning the Holdoff knob clockwise until you obtain a stable single-valued waveform. Notice that the required amount of holdoff differs from the previous exercise.

4 Set the Time/Div to 10 µs/div.

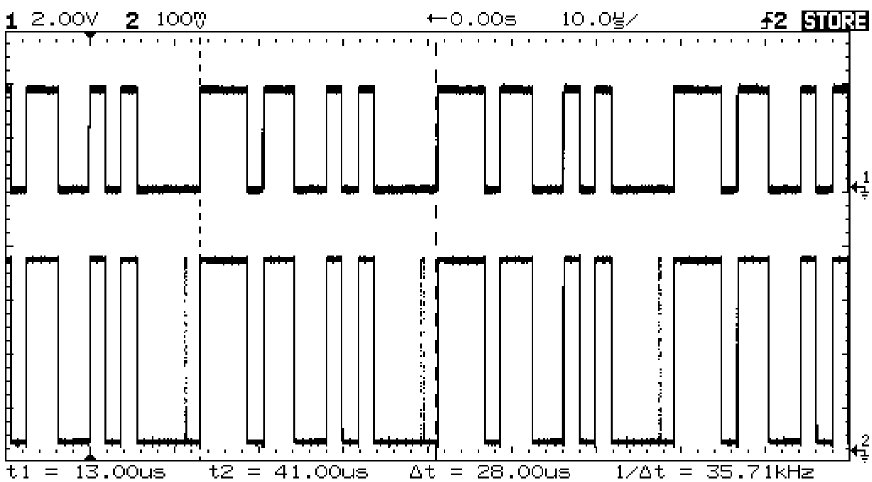
5 Press `Autostore` and watch the channel 2 waveform build up; it has a glitch that is not on channel 1.

The signal at test point 4 is the same as that on test point 3, except that an infrequent glitch is added that repeats occasionally at the same place in the complex waveform.

When more than one channel is in use, Autoscale selects the highest numbered channel as the trigger source, in this case, channel 2. The channel 2 signal, with its occasional repeating glitch, caused the display to sporadically trigger until holdoff was adjusted. The new holdoff resulted in a value where the trigger was held off until after the glitch so that it did not affect the stability of the waveform display.

Helpful hint!
To determine the amount of holdoff needed to trigger on a complex waveform, reduce the time base speed on the multivalued, incorrectly-triggered display until a repeating pattern is observed. Then, use the time cursors to determine the period of the multivalued pattern. This amount of holdoff will give you a starting point around which to adjust holdoff while searching for the single-valued, correctly triggered display.

Figure 2–8



Trigger in the presence of repeating glitches

Using Storage Operations

In this section you will learn how to store waveforms and front-panel setups.

Store a trace

Before doing this exercise, make sure you have performed the steps in "Trigger on a repeating serial pattern," and "Trigger in the presence of repeating glitches" in the two previous modules.

1. Press `Trace` .
2. Toggle the **Trace** softkey to select **Mem 1**. Then, press the **Clear Mem 1** softkey.
3. Press the **Save to Mem 1** softkey.
4. Press `Stop` .
5. Press `Erase` .

6 Press the **Trace Mem 1** softkey to turn memory 1 on. (This allows you to view the stored waveform.)

7 Turn the **Trace Mem 1** softkey off.

You can make measurements on the stored waveform with the voltage and time cursors. To make these measurements, you must make sure that the time base and vertical setups are the same as when the waveform was stored.

- To recall the time base and vertical setups for the stored trace, press the **Recall Setup** softkey.

There are two volatile trace memories in 54600-series oscilloscopes.
If an optional module is installed on the rear of the oscilloscope, the trace memories become nonvolatile. Trace memories are convenient for comparing a test waveform to a standard waveform.

If an optional measurement storage module is installed on the rear of the oscilloscope, the trace memories become nonvolatile, and storage for up to 100 traces is added.

Store a trace using a measurement storage module

1 Press `Trace` .

2 Press the **Clear Trace1** softkey.

3 Press the **Save to Trace1** softkey.

4 Press `Stop` .

5 Press `Erase` .

Store a front-panel setup

Before doing this exercise, make sure you have performed the steps in "Trigger on a repeating serial pattern," and "Trigger in the presence of repeating glitches" in the previous two modules.

1 Press `Setup`.

2 Select **Memory 2** by either toggling through the 16 setup memories with the **Setup Memory** softkey or by turning the Cursors knob.

3 Press the **Save** softkey.

4 Press `Autoscale` to change the setup.

5 Press the **Recall** softkey; your saved setup is activated.

There are 16 nonvolatile setup memories in 54600-series oscilloscopes, and 10 nonvolatile setup memories on the 54645A/D oscilloscopes. Setup memories are convenient for production line test situations where several front-panel setups are repeated many times.

Notice the **undo Autoscale** softkey in this menu. This key returns the oscilloscope to its setup just prior to pressing the Autoscale key. This can reduce frustration if you accidentally press Autoscale causing you to lose a setup that you wanted to keep.

Using Advanced Oscilloscope Operations

In this section you will learn about more advanced 54600-series oscilloscope features.

- You will use peak detect to view narrow pulses at low sweep speeds.
- You will see how an HF-reject trigger filter can stabilize the display of waveforms that are full of noise and glitches.
- You will view both very low-frequency and single-shot waveforms, and you will use averaging to clean up the display of noisy signals.
- Finally, you will learn how to use X-Y mode to compare the relative phase of two signals, and you will see how 54600-series oscilloscope technology handles the task of displaying an RF envelope.

See narrow pulses at low sweep speeds

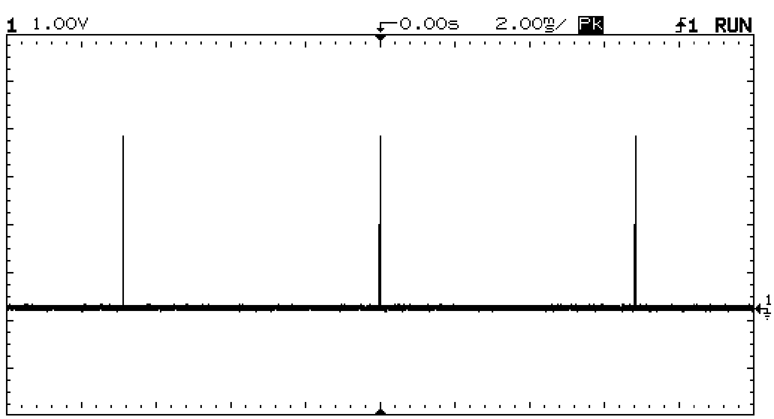
1 Disconnect the channel 2 probe from the training signal board and from the channel 2 BNC connector.
2 Connect the channel 1 probe to test point 6 on the signal board. (Connect the ground.)
3 Press `Autoscale` .
4 Press `Display` .
5 Press the **Peak Det** softkey.
6 Press the **Grid** softkey to view the signal more clearly.

Peak detect lets you know if narrow pulses or glitches are present when you are operating the oscilloscope at low sweep speeds. Without peak detect, you might miss them in the normal mode. Peak detect is operable at sweep speeds of 50 µs/div and slower (500 µs/div for the 54615B and 54616BC; 5 µs/div for the 54645A/D). The status line indicates that peak detect is active by displaying the initials **Pk** in inverse video.

You can use Peak Detect to display narrow, low-duty-cycle glitches or pulses, 50 ns wide (1 ns for 54615B and 54616BC; 5 ns for 54645A/D) for single channel and 100 ns wide for 2 channels, at low sweep speeds.

At fast sweep speeds, 54600-series oscilloscopes give you bright displays even with low-duty-cycle signals like this one.

Figure 2–9



Viewing narrow pulses at low sweep speeds

Use HF reject to trigger on signals with narrow glitches

1 Connect the probe on channel 1 to test point 7 on the training signal board. (Connect the probe ground lead.)
2 Press `Autoscale` .
3 Press `Slope/Coupling` (press `Mode/Coupling` on the 54645A/D).
4 Press the **HF Reject** softkey and notice how the display stabilizes.
5 Press `Autostore` , then wait a few seconds to see the infrequent glitches in the signal at test point 7.
6 Press `Autoscale` again and notice that the status line changes from STORE to RUN. Keep the oscilloscope in the RUN mode.

HF reject is useful for triggering on signals that have high-frequency noise in them. For example, this includes narrow glitches that cause intermittent triggering. Changing the trigger level or selecting noise reject can also be useful for clearing up marginal triggers on difficult signals like this one.

Autostore is very useful for detecting and displaying infrequent glitches as seen with this signal. Without it, some of the glitches are not even visible. The brighter portion of the image in Autostore operation is the latest signal acquisition (similar to the current sweep displayed on an analog oscilloscope). The half bright portion of the waveform is a record of prior acquisitions.

View a low-frequency waveform

1 Connect the channel 1 probe to test point 8. (Connect the probe ground lead.)

2 Press `Run`, then press `Erase`.

3 Set channel 1 to 500 mV/div using the Volts/Div knob.

4 Press `Mode`, then press the **Auto** softkey.

5 Press `Main/Delayed`, then toggle the **Time Reference** softkey to **Left**.

6 Rotate the Time/Div knob counterclockwise to 1 s/div.

Digital storage makes viewing low-frequency waveforms much easier than with analog oscilloscopes that display only a moving dot. The waveform that you see is auto triggered.

You can make either automatic or cursor measurements on low-frequency waveforms.

- To make cursor measurements on very low frequency waveforms, simply wait until the oscilloscope displays a full screen of sweep, then press the **Stop** key at top of the front panel. Now you can use the cursors on the stopped waveform.

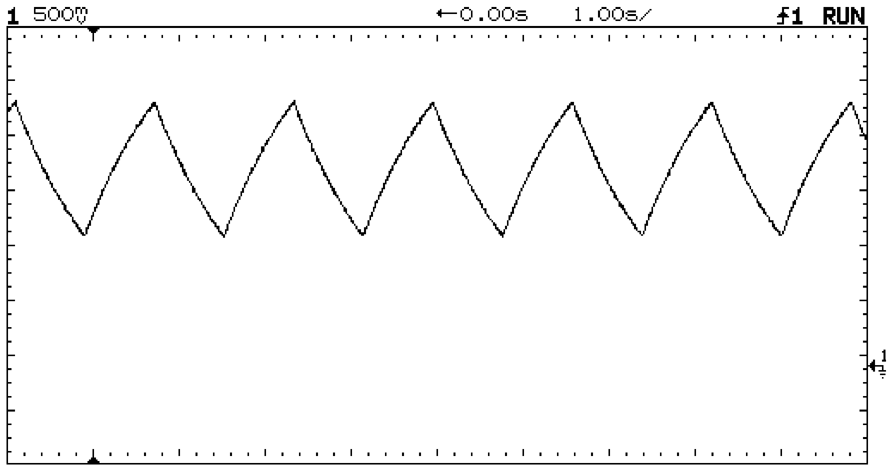
  If you have forgotten how to use the cursors, see "To use time cursors" or "To use voltage cursors."

  You can also use the normal trigger mode. See "To setup normal trigger." Do not use Autoscale for this purpose because the frequency of this signal is too low.

7 Press `Main/Delayed`. Then, press the **Roll** softkey.

Roll mode gives a display much like a strip chart recorder. It allows the waveform to roll across the screen.

Figure 2–10



Viewing a low-frequency waveform

Single-shot events

Single-shot events are waveforms that occur only once, or once in a great while, and never exactly repeat themselves. An example is a switch closure, a power supply turn on, the impact of an object on the floor. All of these things, and a huge variety of other signals, do not repeat, and you must catch them in their entirety the first time (the only time).

The waveforms on test points 9 and 10 are simulations of single-shot waveforms. To catch single-shot events, one must already have some knowledge of the waveform. You must know the approximate amplitude, duration, and dc offset (or vertical position). With this information, you can set the trigger level, volts/division, position, and time/division controls so that the single-shot event is displayed correctly when it occurs.

Set up the oscilloscope for single-shot events

1. Connect the probe on channel 1 to test point 9. (Connect the ground, and make sure that the probe attenuation factor is set to 10:1.)
2. Connect a second probe between channel 2 and test point 10. (Connect the ground, and make sure that the probe attenuation factor is set to 10:1.)
3. Turn on channel 2 and set Volts/Div for both channel 1 and channel 2 to 2 V/div.
4. Set Time/Div to 20 µs/div.
5. Press `Source` (press `Edge` on the 54645D) , then press the **2** softkey (A2 on the 54645A/D) to select channel 2 as the trigger source.
6. Press `Mode` (press `Mode/Coupling` on the 54645D) , then press the **Single** softkey (the `Single` white key on the 54645A/D) to set the trigger mode to single. Make sure that the trigger mode is set to Normal.
7. Set the position control for channel 1 to the third major division from the top of the display (2.0 V). Set the position control for channel 2 to the second major division from the bottom of the display (–4 V).

   Position is displayed by the ground symbols at the right side of the display.
8. Set the trigger level to one division above the channel 2 ground position on the display (2.0 V).
9. Set the Time reference to left. (Press `Main/Delayed` , then toggle the **Time Ref** softkey to **left**).

   As you can see, preparing to capture single-shot events includes several steps. With most repetitive signals the Autoscale key does all of this for you. To capture a single shot, the key is having the oscilloscope set to trigger on the desired event, and having the time base and vertical scaled so that the waveforms are displayed correctly. This is why it is important to know something about the signal in advance.

View single-shot signals

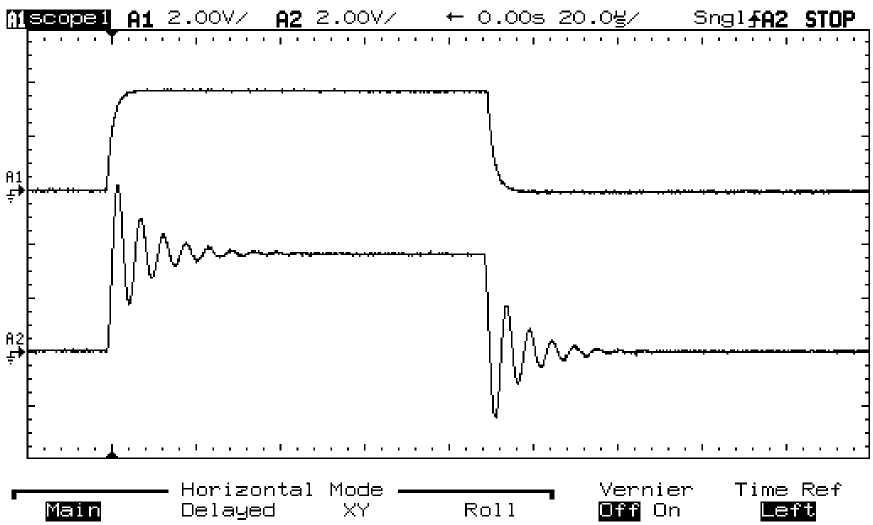
1 Press [Erase] .

2 Press [Run] (the [Single] white key on the 54645A/D)

3 Press the pushbutton near test points 9 and 10 on the training signal board.

Notice that there are two single-shot waveforms on the display.

Figure 2– 11



Displaying the single-shot waveforms on TP9 and TP10

4 Turn channel 1 off.

5 Press [Run] (the [Single] white key on the 54645A/D) to rearm the trigger.

6 Press the single-shot button on the signal board again.

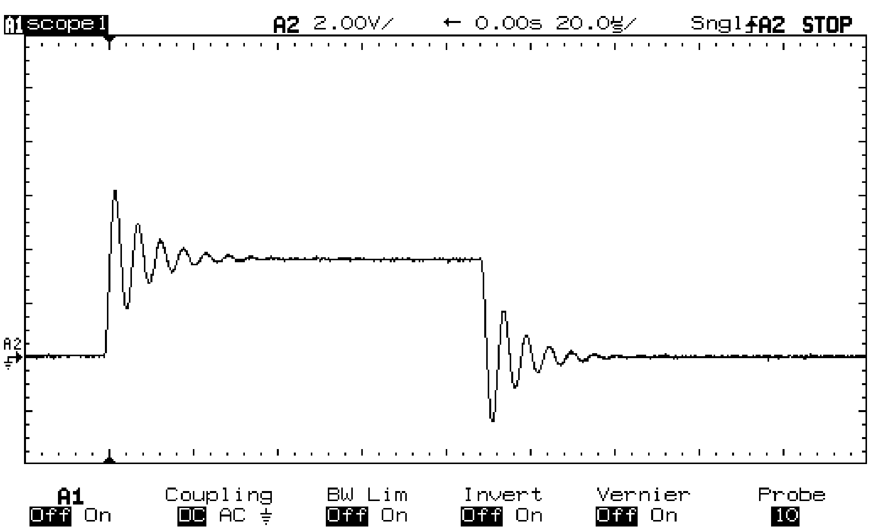
The 54600-series of scopes offers a wide range of single-shot capabilities as summarized in the following table.

Single-shot bandwidth capabilities

Model	Description	Max. single-shot bandwith
5460x, 54610	20MSa, 3-processor technology	2 MHz single channel, 1 MHz dual channel
54615B	1GSa	250 MHz single or dual channel
54616B/C	2GSa	500 MHz single or dual channel
5464x	200 MSa MegaZoom technology	25MHz single or double channel

Helpful hint!
If you did not get a waveform display when you tried step 3, check the probe attenuation factor. See "To set the probe attenuation factor." If the probe attenuation factor is not set at 10:1, the trigger level and vertical scaling will not be correct.

Figure 2–12



Displaying one of the single-shot waveforms

The actual sample rate of an oscilloscope is related to the maximum sample rate, sweep speed, and the memory depth.

samples / second = memory depth / time swept across screen

This example shows:

2000 pts (one channel on) / 200 µs (10 x 20 µs/div) = 10 MS/s

Sampling speed is displayed on the status line of the 54615B or the 54616B/C oscilloscope.

Sampling speed is displayed when the Main/Delayed button is pressed on the 54645A/D instruments.

Use averaging to clean up the display of noisy signals

1 Disconnect the channel 2 probe from the training signal board and from the oscilloscope.
2 Connect the channel 1 probe to test point 11. (Connect the ground.)
3 Press `Autoscale` .
4 Press `Slope/coupling` , then press the **HF Rej** softkey to turn on the 50-kHz, high-frequency reject filter in the trigger circuit.
5 Adjust the Time/Div knob so that 2 periods of the waveform are displayed.
6 Press `Display` .
7 Press the **Average** softkey, then toggle the **# Average** softkey and notice how it affects the waveform.

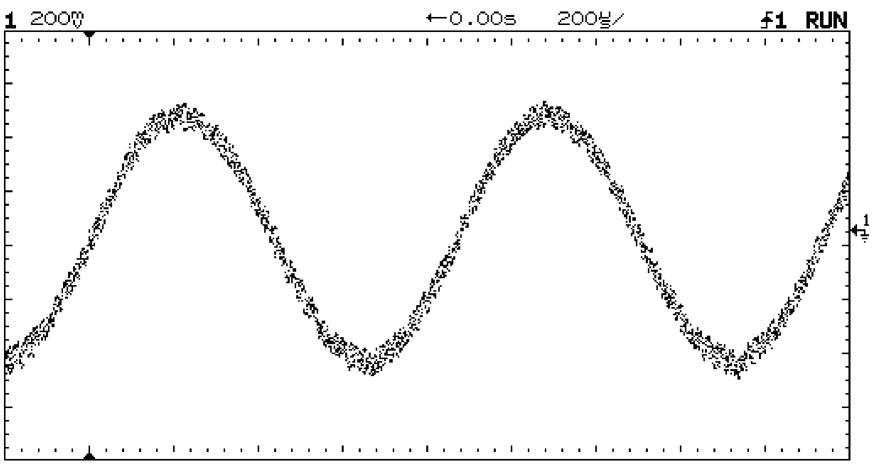
   You can set averaging for 8, 64, or 256 averages through multiple presses of the **# Average** softkey. Averaging removes noncoherent noise from the signal.

For viewing the waveform, averaging is often preferable to using a high-frequency, bandwidth-limit filter because averaging does not affect the bandwidth of the viewed channel. However, using a high-frequency filter in the trigger circuit is effective because removal of high-frequency noise increases trigger stability. We are not concerned that the trigger bandwidth is less, only that it provides a stable trigger point for the viewed waveform.

When making measurements, it is often helpful to use averaging because the repeatability of automatic measurements is much greater with the noise level reduced. Averaging does slow down update rate.

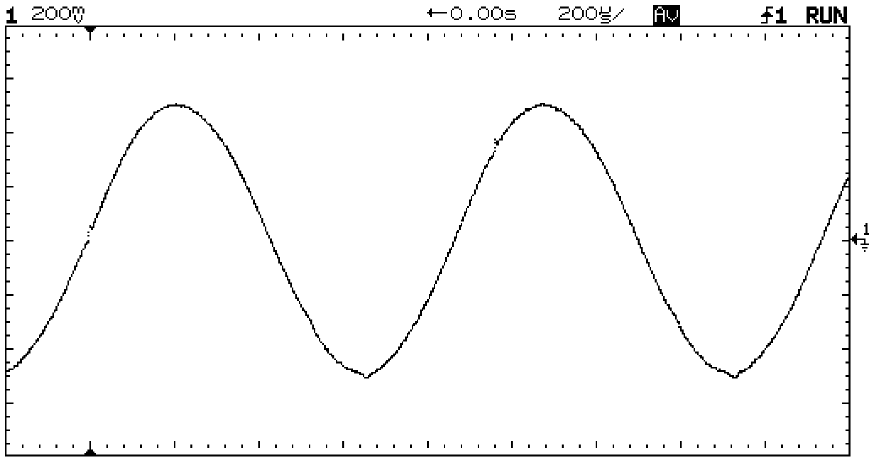
54600-series oscilloscopes have bandwidth-limit filters in channels 1 and 2. Use these filters when display update speed is more important than bandwidth.

Figure 2–13



Noisy signal displayed without using averaging

Figure 2–14



Noisy signal displayed with averaging turned on

Observe the phase differences between signals

1 Connect the channel 1 probe to test point 12. (Connect the probe ground lead.)

2 Connect a second probe between channel 2 and test point 13. (Connect the probe ground lead.)

3 Press `Autoscale` .

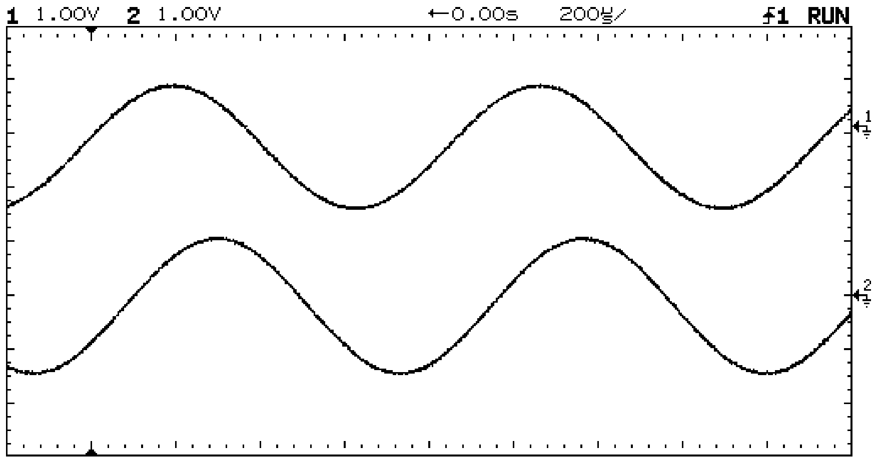
4 Rotate the two potentiometers near test points 12 and 13. Notice that one controls amplitude, and the other changes the phase delay between waveforms. Also notice the fast screen update rate. Changes are displayed real time.

5 Notice that the trigger source is channel 2. (This information is in the status line.)

6 Change the trigger source to channel 1, then rotate the phase control potentiometer on the training signal board.

When two signals change in phase with each other, the signal that is the trigger source stands still on the display, and its trigger point is the reference. The other signal is then shifted in time based on the amount of phase difference between the signals. You can observe the phase difference by comparing the two waveforms.

Figure 2–15



Observing phase difference

Use X versus Y mode to display phase differences

Before doing this exercise, make sure you have performed the steps in "Observe the phase difference between signals.” in the previous module.

1 Adjust the signal board amplitude potentiometer for maximum output. If necessary, press `Autoscale` to get both waveforms entirely on the display.

2 Press `Main/Delayed`, then press the **XY** softkey.

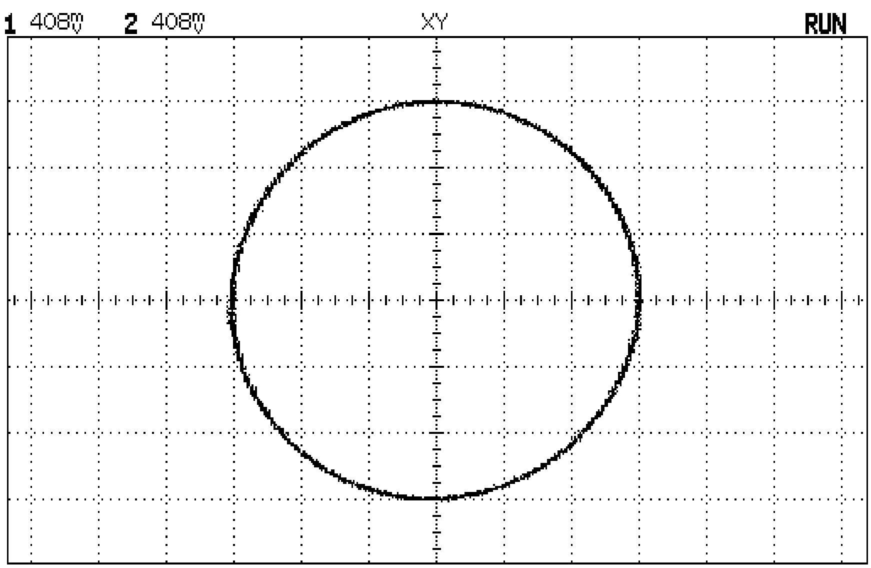
3 Rotate the phase control potentiometer on the signal board and observe the results.

4 Change the Vertical Position knobs for both channels and notice how they affect the display.

5 Change the Volts/Div knobs for both channels and notice how they affect the display.

54600-series oscilloscopes have full screen X versus Y capability. You can use this feature to display phase relationships between two signals.

Figure 2–16



Using X and Y mode to display phase differences

A straight line slanted to the right indicates that the sine waves are in phase with each other. A circle indicates that the sine waves are 90 degrees out of phase (both channel amplitudes must be the same or an ellipse will result). A straight line leaning to the left indicates that the sine waves are 180 degrees out of phase.

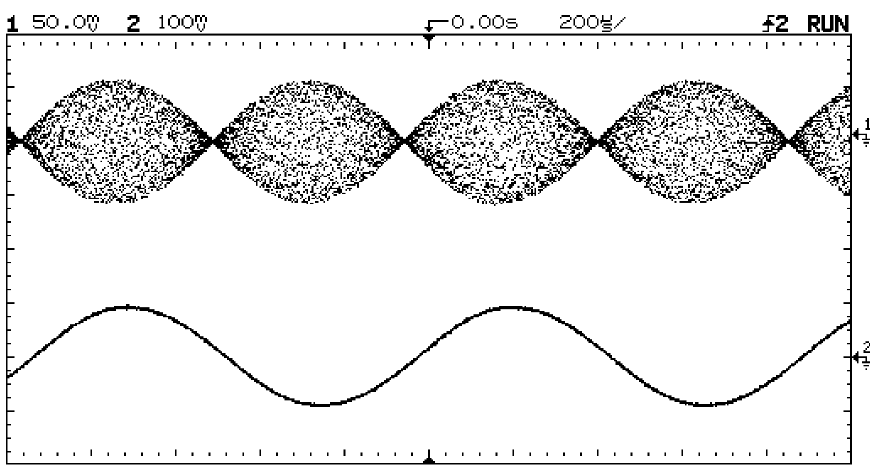
View a modulated RF envelope

1 Connect the channel 2 probe to test point 13. (Connect the ground.)
2 Connect the channel 1 probe to test point 14. (Connect the ground.)
3 Press `Autoscale` .

54600-series display technology gives a familiar view of this type of waveform. The waveform displayed on channel 1 has balanced amplitude modulation. The waveform displayed on channel 2 is the modulating signal.

Helpful hint!
For optimal viewing of modulated signals, turn vectors off.

Figure 2–17



Viewing a modulated RF envelope

Conclusion

This ends the series of basic oscilloscope exercises. There are lots of imaginative combinations available from the signal board if you wish to continue. By now, you should have a very good idea of how 54600-series oscilloscopes operate.

If you are using the 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, or the 54616B/C oscilloscope, you have completed the training exercises, and we hope that you have found the training experience with this kit both enjoyable and helpful

If you are using the 54645A oscilloscope with Agilent MegaZoom technology, proceed to the exercises in Chapter 3 to explore the technology.

If you are using the 54645D Mixed Signal Oscilloscope, proceed first to the exercises in Chapter 3 to explore the MegaZoom technology, then to Chapter 4 to explore the logic analysis features of the instrument.

3

Using Agilent MegaZoom Technology

Using Agilent MegaZoom Technology

These exercises are designed to give you practice in using the Agilent MegaZoom technology that is featured in the 54645A Oscilloscope and the 54645D Mixed Signal Oscilloscope. These exercises are supplemental to those in Chapters 2 and 4. They are not in any particular order, and you may do any or all of them. If you are new to the Agilent family of oscilloscopes, we recommend working through the exercises in Chapters 2 for an overview of basics before exploring the Agilent MegaZoom technology using these exercises.

Who should do these exercises?

You should do these exercises if you are using the 54645A oscilloscope or the 54645D Mixed Signal Oscilloscope. The exercises demonstrate the Agilent MegaZoom technology that is featured in those two instruments.

If you are using the 56400B, 54601B, 54602B, 54603B, 54610B, 54615B or 54616B/C oscilloscope, or the 54620A/C logic analyzer, your instrument is not equipped with the Agilent MegaZoom technology and you cannot use these instruments to do these exercises.

Be sure that you have worked through the appropriate "Getting Started with..." exercises in Chapter 1 that apply to your instrument.

At the end of this chapter you will be directed to the next step in your training.

Which Chapter 3 exercises are for you

	54600-Series* Basic Oscilloscope	**54645A Basic Oscilloscope with MegaZoom technology**	**54620A/C Logic Analyzer**	**54645D Mixed Signal Oscilloscope**
Entire chapter		√		√

*Note: In this table, Agilent 54600-Series Basic Oscilloscopes are the following: 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, and 54616B/C

Probing a signal and adjusting the time base (sweep speed)

In this section, you will probe a signal on the training board, then adjust the time base (sweep speed) and view the waveform.

Probe the signal and autoscale

1 **Turn the training board off and disconnect the existing probes from the training board.**

2 **Connect the probe ground to a ground test point on the training board, then connect the probe to the number 14 test point.**

3 **Turn on the board by pressing the pushbutton near the battery.**

4 **Press `Autoscale` .**

5 **Press `Run/Stop` .**

You now have a display of the test point 14 waveform.

View the waveform

1 **Turn the Time/Div knob clockwise (to the right) and note the change in the waveform.**

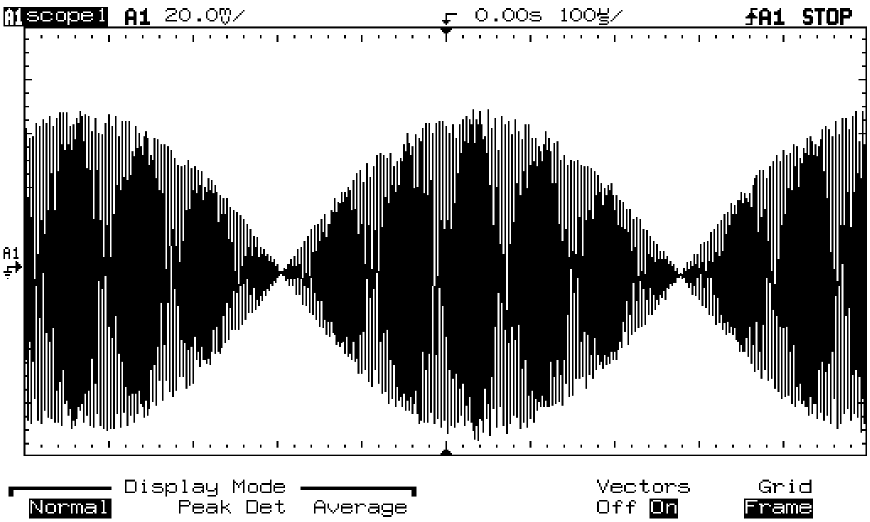
Turning the Time/Div knob clockwise increases the sweep speed and decreases the amount of time per division on the display.

2 **Turn the Time/Div knob (counterclockwise) to the left and note the change in the waveform.**

Turning the Time/Div knob counterclockwise decreases the sweep speed and increases the amount of time per division on the display. Note the display of the modulation envelope.

3 Press `Display` , then turn the vectors on and off to view the difference in the display. Switch between Normal and Peak Detect modes and view the difference in the display.

Figure 3–1



Waveform with altered time base

Setting a glitch trigger mode and panning and zooming the display

In this section you will learn how to set the glitch trigger mode for capture and pan and zoom the resulting display.

Probe the test point and autoscale

1 Turn the training board off and disconnect the existing probes from the training board.
2 Connect the probe ground to a ground test point on the training board, then connect the probe to the number 4 test point.
3 Turn on the board by pressing the pushbutton near the battery.
4 Press `Autoscale` .
5 Press `Run/Stop` .
6 Press `Mode/Coupling` , then set the trigger level to Normal.

You now have a display of the test point 4 waveform.

Set the glitch trigger

1 Press the `Advanced` key, (the `Slope/Glitch` key on the 54645A) then press the Glitch softkey to set the trigger mode to Glitch
2 Using the Glitch triggering menu, set the polarity to negative and the qualifier to < 400ns.

Pan and zoom the display

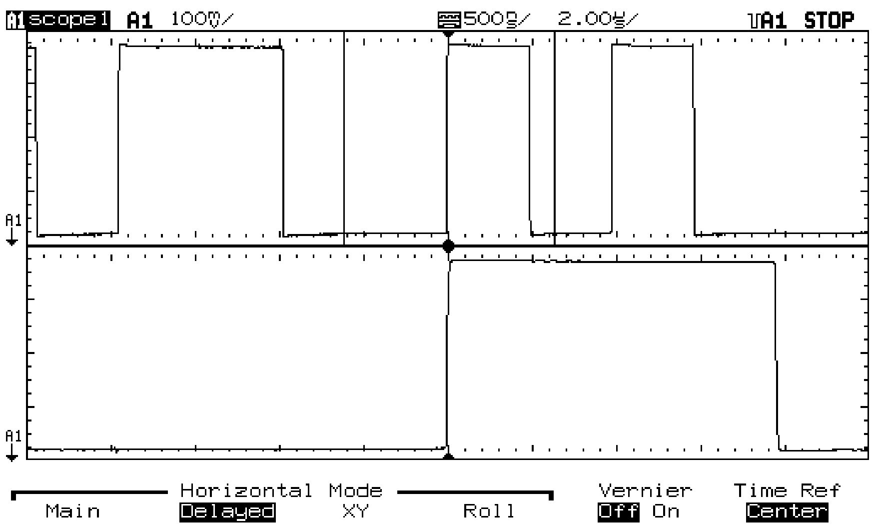
1 Press the `Main/Delayed` button, then select the Delayed softkey to zoom on a portion of the waveform.

The display is divided into a main and delayed sweep. The delayed sweep is shown in the bottom half and represents the portion of the waveform indicated by the vertical lines outlining a window in the upper half.

2 Turn the Delay knob to pan the display.

The Delay knob adjusts the amount of time between the trigger event and the time reference point on the display.

Figure 3–2



Panned and zoomed waveform

Capturing a single shot glitch and panning and zooming the display

In this section you will capture a single shot glitch and pan and zoom through the display.

Before performing this exercise, be sure the probe is set to test point 4 as described in the previous exercise.

Capture the single shot glitch

1. **Turn the training board off.**
2. **Press the `Single` Key.**
3. **Turn the signal board on.**

   Observe that the scope triggered on the single shot.

Pan and zoom the display

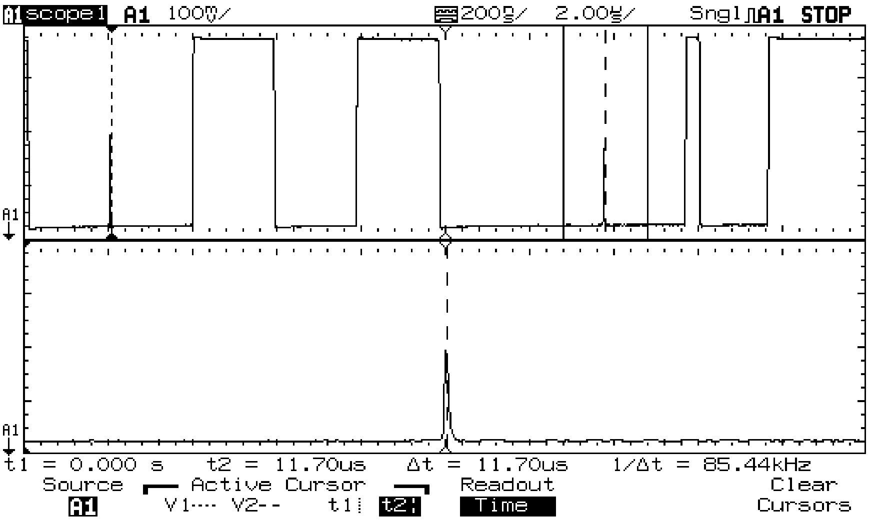
1. **Press the `Main/Delayed` button, then select the Delayed softkey to zoom on a portion of the waveform.**

   The display is divided into a main and delayed sweep. The delayed sweep is shown in the bottom half and represents the portion of the waveform indicated by the vertical lines outlining a window in the upper half.
2. **Turn the Delay knob to pan the display until you reach the first glitch.**

   The Delay knob adjusts the amount of time between the trigger even and the time reference point on the display.
3. Press the `Cursors` **button, then place the t1 cursor on the first glitch.**
4. **Turn the Delay knob to pan the display until you reach the next glitch. Place the t2 cursor on that glitch.**

   Note that the glitch frequency is near 85 kHz.

Figure 3–3



Viewing the single-shot glitch

Hint:
Turning the vectors on makes the glitch easier to view.

Conclusion

This ends the series of exercises focusing on the Agilent MegaZoom technology. By now you should have a good idea of how the technology operates in the 54645A oscilloscope or the 54645D mixed signal oscilloscope.

If you are using the 54645A oscilloscope, you have completed the training, and we hope you have found using this training kit both enjoyable and helpful.

If you are using the 54645D mixed signal oscilloscope, proceed to Chapter 4 for information that is specific to using that instrument.

Mixed Signal Oscilloscope Exercises

Mixed Signal Oscilloscope Exercises

These exercises are designed for use with the 54645D Mixed Signal Oscilloscope.

The exercises are designed to give you practice in taking full advantage of the combined oscilloscope and logic analysis functions in the 54645D. They should be done in the order they are listed because later exercises depend on knowledge gained from previous ones. If you try an exercise out of sequence, refer to previous exercises that contain setup steps required for your chosen exercise. For convenience, names of those exercises (if they are required) are listed just before the first step of each exercise.

If you are new to the Agilent family of oscilloscopes, we recommend working through the exercises in Chapters 2 and 3 for an overview of basics before doing these exercises.

Who should do these exercises?

You should do these exercises if you are using the 54645D Mixed Signal Oscilloscope

Be sure that you have worked through the appropriate "Getting Started With.." exercises in Chapter 1 that apply to your instrument before doing the exercises in this chapter.

At the end of this chapter you will be directed to the next step in your training.

Which Chapter 4 exercises are for you

	54600-Series* Basic Oscilloscope	**54645A Oscilloscope with MegaZoom technology**	**54620A/C Logic Analyzer**	**54645D Mixed Signal Oscilloscope**
Entire chapter				√

*Note: In this table, 54600-Series Basic Oscilloscopes are the following: 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, and 54616B/C

Using Basic Logic Analysis Features of the Mixed Signal Oscilloscope

This section shows you how to select and position a waveform, to turn channels off and on, and to label channels.

Probe the signals and apply power

1 Disconnect any probes from the training signal board
2 Connect the black Mixed Signal Oscilloscope probe lead to GND on the training board.
3 Connect the channel 0 probe to D0.
4 Connect the channel 1 probe to D1.
5 Connect the channel 2 probe to D2.
6 Press the pushbutton on the training board near the battery to apply power.
   The red LED on the training board will be lit.
7 Turn on the instrument
8 Press [D0-D15]. From the softkey menu, turn channels D0-D7 on, and channels D8-D15 on.

Select and position a waveform

1 Take hold of the Select knob. Turn it back and forth and notice how the highlighting moves among the channels.
   The highlighted channel designates the active channel which will be affected by the actions you take.
2 Turn the Select knob to select channel 0.
3 Take hold of the Position knob. Turn it back and forth and notice how channel 0 is repositioned on the display.
4 Position channel 0 at the top of the display.

Turn channels off and on

1 Press `D0-D15` . Then press the **D8 - D15 Off** softkey.

Note how channels 8 through 15 are turned off, and the remaining channels are resized to fit the display.

2 Turn the Select knob until channel 3 is highlighted. Press the leftmost softkey **CH03 Off On** softkey.

Note how the channel is turned off, and that the highlight for channel 3 is moved to the upper left corner of the display.

3 Turn the Select knob to the left several notches.

Note how the channels that are turned off are shown highlighted in the upper left corner of the display. These channels are displayed this way so that you can select and turn them on individually.

4 Press `Autoscale` .

Note how the channels with activity are turned on, and a seconds/division setting is chosen so that several cycles are displayed on screen. All inactive channels are turned off.

The Mixed Signal Oscilloscope also automatically sets up the proper threshold voltage for the signals found. For the training board, these levels are TTL. To set other values you would press the Label/Threshold key, then press the **Threshold** softkey and use the options that are displayed.

Label the channels

1 Press `Label/Threshold` .

2 Press the **Labels Off On** softkey.

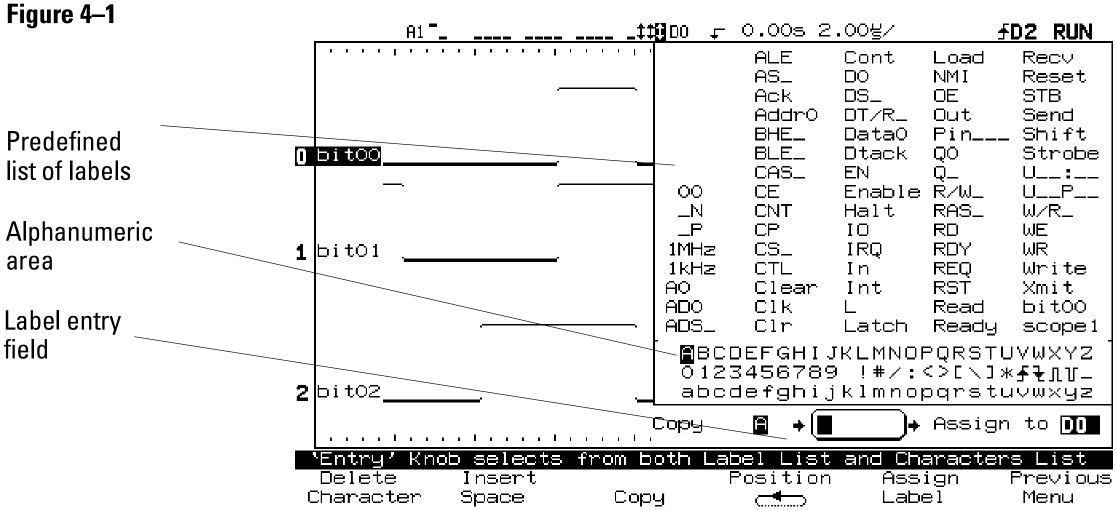
Note how the labels on the left side of the waveforms are removed to show more waveform area. The channel numbers remain on screen.

3 Press the **Labels Off On** softkey again to turn on the labels.

4 Press the **Define Labels** softkey.

A new window, which allows you to define labels, is displayed. The upper portion of the window shows the predefined list of labels. Below this list is the alphanumeric area, from which you can select individual letters, numbers, and characters to define labels. Below the window is the entry area, which allows you to enter a predefined label or define a label with letters and characters.

Figure 4–1



Defining a label

5 Turn the Select knob until channel 0 is highlighted.

6 Turn the Entry knob until the letter "O" is highlighted in the alphanumeric area. Then, press the **Copy** softkey.

The O is copied into the label window.

7 Do step 6 for the letters "u" and "t".

8 Press the **Assign Label** softkey.

Note how the label "Out" has been assigned to channel 0.

9 Turn the Select knob until channel 1 is highlighted.

10 Turn the Entry knob until the word "In" is highlighted in the list of predefined labels. Press the **Copy** softkey.

If "In" is not present in the list, press **Previous Menu**, **Initialize Label List**, **Yes**, **Yes**, and then **Define Labels** to reset the list to the factory set of labels.

11 Turn the Entry knob until the number "1" is highlighted in the row of numbers and special characters. Press the **Copy** softkey.

12 Press **Assign Label** and note how channel 1 has been relabeled "In1".

Note how channel 2 is now selected. Note also that the entry field below the alphanumeric area has been changed to "In2".

13 Press **Assign Label** to relabel channel 2.

14 Press the **Previous Menu** softkey to return to the normal waveform display.

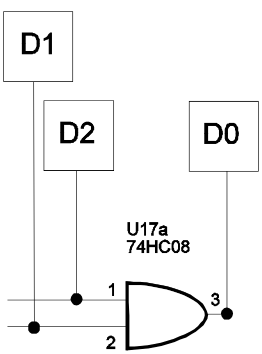
Using Simple Triggering Techniques

In this section you will verify the operation of the AND gate shown below. You will learn about the fundamental triggering capabilities of the logic analyzer feature of the Mixed Signal Oscilloscope. You will use the measurement capability to measure the propagation delay of the AND gate.

This section shows you how to:

- Probe the signals and apply power.
- Define an edge trigger.
- Define a pattern trigger.
- Set up a measurement.
- Make a measurement using cursors.

Figure 4–2



And Gate U17a

Probe the signals and apply power

1 **Make sure the same probe connection setup is used as described in the previous section.**

2 **Turn on the training board if it is not already on.**

The red LED on the training board will be lit.

3 **Turn on the Mixed Signal Oscilloscope if it is not already on.**

4 **Press `Autoscale` .**

Define an edge trigger

1 **Press `Edge` .**

2 **Press the Source channel softkey to select channel 0.**

Or, you could turn the Select knob until channel 0 (labeled CH00 or Out) is shown on the softkey.

3 **Press the rising edge softkey.**

Observe that the rising edge on channel 0 appears at the center of the screen.

Note the operation of the AND gate. The output goes high when both of the inputs go high.

4 **Press `Single` several times.**

Observe the various times the AND gate produces a “1” on the output.

Define a pattern trigger

1 Press `Pattern` .

2 Press `Run/Stop` if the status is not currently running ("RUN").

Observe the random triggering of the waveforms. This is occurring because the pattern is currently set to "don't care" ("X") on all channels.

3 Turn the Select knob until channel 0 is selected

4 Press the rising edge softkey.

5 Turn the Select knob until channel 1 is selected.

6 Press the **High** softkey.

Observe that the rising edge of channel 1 is now at the center of the screen.

7 Turn the Select knob until channel 2 is selected.

8 Press the **High** softkey.

Observe that both channel 1 and channel 2 are always at a logic "1" at the center of the display.

9 Press `Single` several times and observe the function of the AND gate.

The Mixed Signal Oscilloscope is triggering when both of the inputs to the AND gate are high. The low-to-high transition of either of the input signals that went high is the point where the pattern is "entered."

When the two inputs are both high, the output transitions to a logic "1". Occasionally, both of the inputs switch nearly at the same time, and a logic level "1" is not produced on the output because of the gate response time. At the time per division value set by Autoscale, these delays cannot be discerned.

10 Turn the Time/Div knob clockwise until the "Time/Div at limit" message is displayed.

11 Press `Run/Stop` or `Single` and observe the gate delay.

Set up a measurement

1 Press `Edge`.

2 Turn the Select knob until channel 0 is selected.

3 Press the rising edge softkey.

4 Press `Run/Stop` if the Mixed Signal Oscilloscope is not currently running.

5 Adjust the Time/Div knob fully clockwise.

6 Press `Main/Delayed` to confirm that the sampling speed is 200MSa

The setting should be 5.00 ns/.

7 Observe the delay from channel 1 (In1) to channel 0 (Out).

This is the propagation delay of the AND gate.

Make a measurement using cursors

Now you are ready to measure the propagation delay of the AND gate. Propagation delay is the time it takes for the output of a gate to change states after the input changes, and is dominantly caused by switching time.

1 Press `Cursors`.

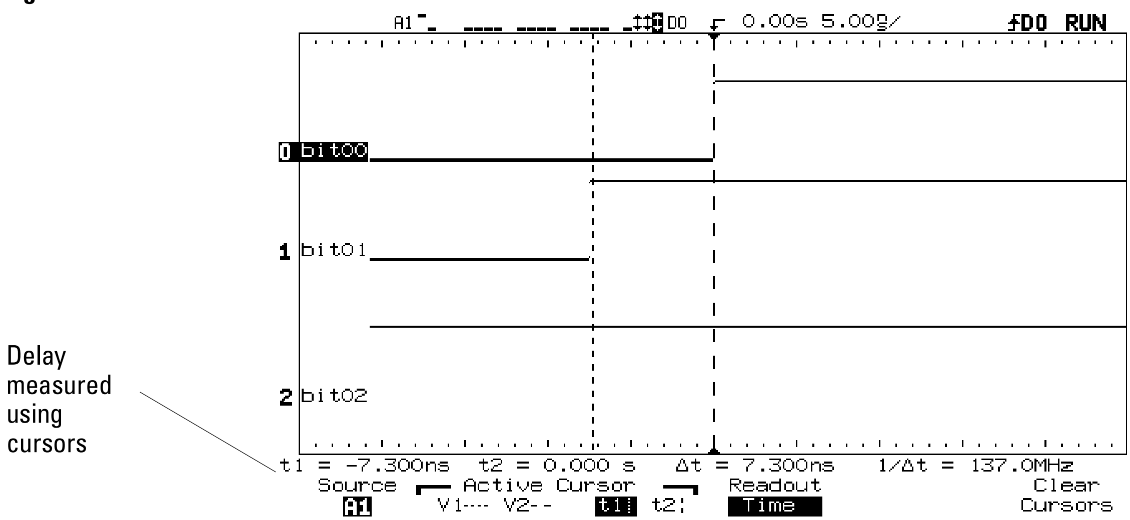
The softkey menu across the bottom of the display shows active cursors t1 and t2. The t1 cursor may be highlighted, and its vertical dotted bar appears on screen.

2 Make sure the **t1** (leftmost) softkey is highlighted.

3 Turn the Entry knob counter-clockwise until the vertical line (the t1 cursor) moves to the position of one of the rising edges on channel 1.

The two edges reflect the sampling uncertainty of 2.5 ns. The delta t (Δ t) readout on the line just below the screen (the “Measurement Line”) gives the propagation delay of the gate, which is approximately 7 ns. The jitter you observe is the sampling speed. This will be 5 ns if both pods are active.

Figure 4–3



Using cursors to measuring the propagation delay of the AND gate

Using Advanced Triggering Techniques

A common problem in digital circuits is finding glitches and very narrow pulses. After finding signals of these types, you can usually find the cause.

The training board includes a pulse train that is made up of a series of high and low values, producing the sequence 000011101100101. In addition, a narrow pulse occasionally appears somewhere in this sequence. The advanced trigger capability will allow you to detect the narrow pulse in this pulse train.

In this exercise you will:

- Probe the signals.
- Examine the pulse train.
- Define an advanced trigger.
- Observe the narrow pulse.
- Trigger on the narrow pulse.
- View the advanced triggering overview menu.

Probe the signals

1 Make sure the black probe ground lead is attached to a GND connector on the training board.

2 Attach the channel 3 Mixed Signal Oscilloscope probe to connector D3.

3 Attach the channel 6 Mixed Signal Oscilloscope probe to connector D6.

4 You may disconnect Mixed Signal Oscilloscope probes 0, 1, and 2 from the training board.

   Doing this will provide a simpler display when viewing the channel activity.

5 Press `Setup` . Then press the **Default Setup** softkey.

6 Press `Autoscale` .

7 You may label the channels "Clk" for channel 3 and "Data" for channel 6 by using `Label` and the **Define Labels** softkey as shown in the previous section.

   Defining these labels will cause your Mixed Signal Oscilloscope display to resemble the screens shown in this section.

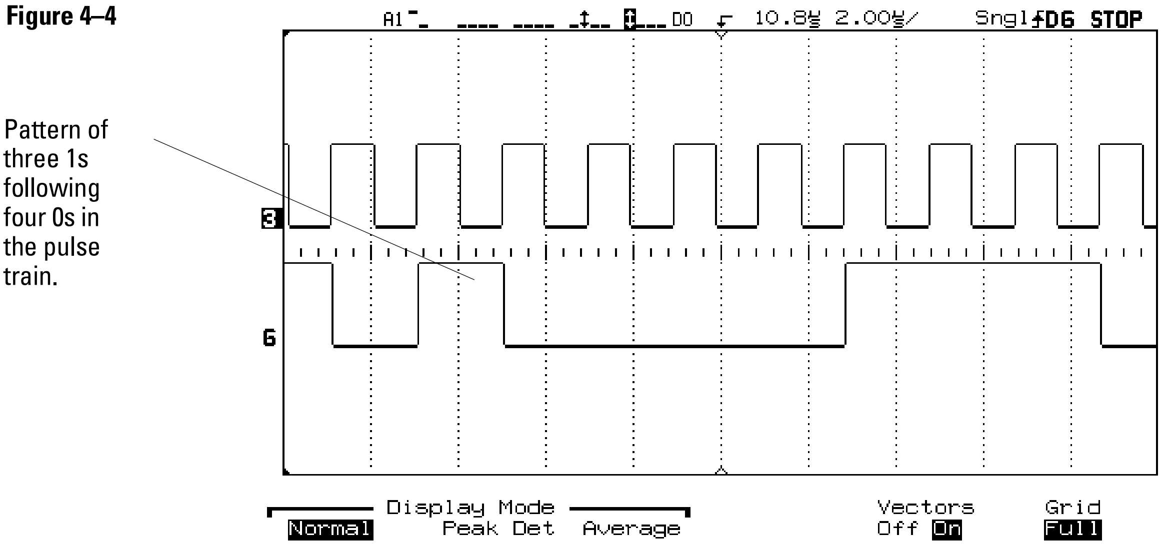
Examine the pulse train

The pulse train is a PRBS which is clocked by the rising edge of the signal on channel 3. The length of the four zeros in the pulse train on channel 6 equal four periods of the clock on channel 3, and the three ones that follow exist for three periods of the clock.

1 Stop the acquisition if it is running.

2 Look at the pulse train on channel 6. Verify that the pulse train is correct by observing a pattern of four zeros (logic lows) followed by three ones (logic highs).

Figure 4–4



Examining the pulse train

Define an advanced trigger

1. Press `Adv` .

   The menu at the bottom of the screen shows the trigger pattern and duration, and lets you define the source of the trigger and the duration.

2. Press the **Pattern** softkey until **Pat 1** appears.
3. Press the **Define** softkey.
4. Turn the Select knob or press the leftmost softkey until channel 6 (**Data**) is selected.
5. Press the **Level High** softkey.
6. Press the **Previous Menu** softkey.
7. Press the **Operator** softkey until **Duration >** appears.
8. Press `Run/Stop` to start the acquisition.
9. Turn the Entry knob clockwise while observing the duration value above the fourth softkey from the left.

   When the duration value exceeds approximately 4 µs, as shown in the next diagram, the display will stabilize. This is because all pulses less than 4 µs (two clock periods) have been excluded, and only the pulse of interest remains.

Observe the narrow pulse

Occasionally a narrow pulse appears to the left of the pulse that equals the three logical ones.

1 Press `Autostore` .

Note the STORE status indicator in the top right corner of the display. All data acquisitions are now "held" on screen.

2 Let the Mixed Signal Oscilloscope run for a while until the narrow pulse appears and is stored on the screen in half bright.

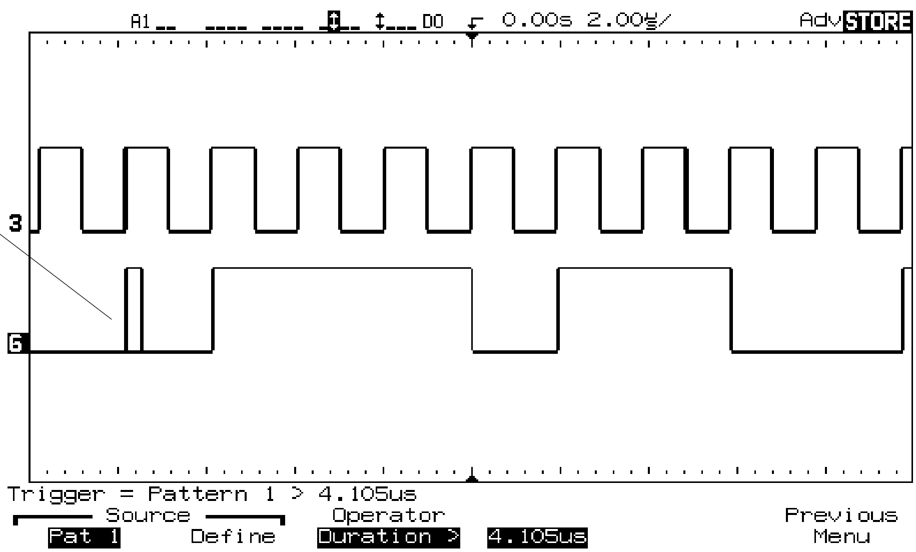
The STORE mode causes the waveform and narrow pulse to be stored on the display until you erase it.

3 Press `Erase` **to clear the stored waveforms.**

Note how the narrow pulse appears again after a while, which demonstrates its infrequent nature. The 54645D can trigger on this narrow pulse.

Figure 4–5

Narrow pulse displayed with Autostore turned on



Narrow pulse in the pulse train

Trigger on the narrow pulse

1 Press `Autostore` to turn off the Autostore feature.

2 Press `Erase` to clear the stored waveforms.

3 Press the **Operator** softkey until **Duration <** appears.

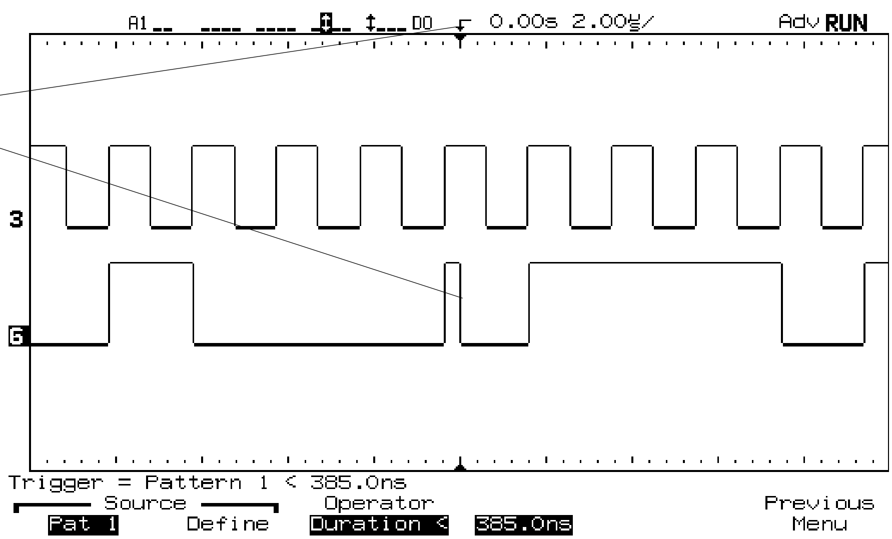
4 Gradually turn the Entry knob counterclockwise until the screen displays stable waveforms.

The waveforms should stabilize at a duration reading of approximately 350 ns. However, the actual reading depends on your particular training board.

The Mixed Signal Oscilloscope is now triggering on the infrequent narrow pulse, and is excluding all of the normal, single-clock period pulses.

Figure 4–6

Analyzer triggering on the narrow pulse



Mixed signal oscilloscope triggering on the narrow pulse

View the advanced triggering overview menu

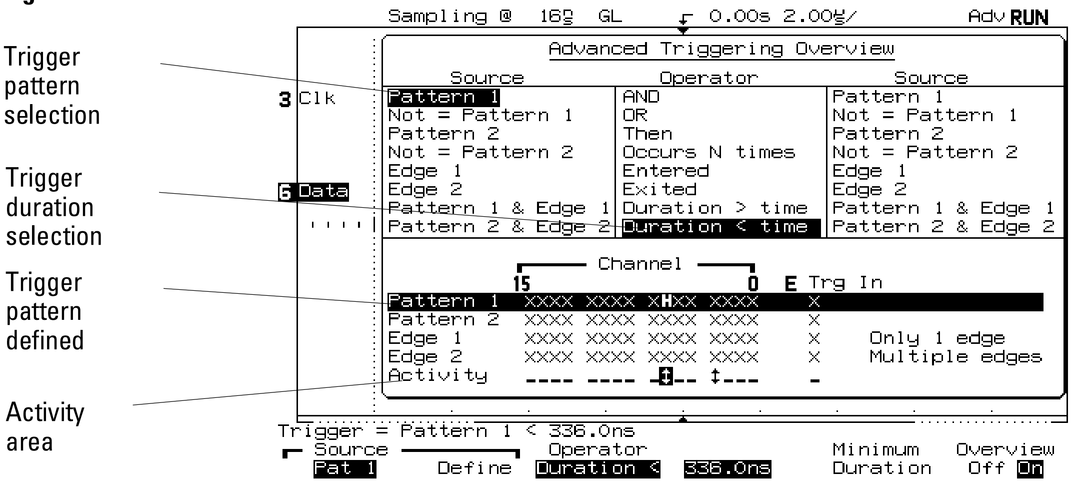
1 Press the `Advanced` button.

2 Press the **HelpOn** softkey.

The following triggering menu is displayed, showing the currently selected pattern and operator, and that channel 6 is set high in the trigger pattern. This menu gives you an overall detailed look at various ways in which you can define advanced triggers. Notice how the channel activity area on screen reflects changes in the clock and data channels.

3 Press the **HelpOff** softkey to return to the waveform display.

Figure 4–7



Viewing the advanced triggering overview menu

Using Oscilloscope Features and the Logic Analysis Features Together

In this exercise you will use the logic analysis functions of the Mixed Signal Oscilloscope to trigger and view an eight-step staircase waveform on the oscilloscope portion of the display.

In this exercise you will:

- Probe the signals.
- Define the logic analyzer trigger.
- Trigger the oscilloscope and view the waveform.
- Change the trigger and view the new waveform.

Probe the signals

1. Disconnect any probes from the training signal board
2. Make sure the digital cable black ground probe lead is connected to GND on the training board.
3. Connect channel 11 to D11 .
4. Connect channel 12 to D12 .
5. Connect channel 13 to D13
6. Connect the analog probe ground lead to a ground point on the training board. Then, connect the channel 1 probe to test point 7 on the training board.
7. Press `Autoscale` .

Define the logic analyzer trigger

When defining a trigger to the oscilloscope portion, you can use the edge, pattern, or advanced trigger capability of the Mixed Signal Oscilloscope portion. In this exercise you will use a pattern trigger.

1. Press `Setup` . Then, press the **Default Setup** softkey.
2. If the grid and vectors are not on, press `Display` . Then use the softkeys to turn the vectors on and the grid to full.
3. Press `Autoscale` .
4. Press `Pattern` and note the trigger pattern at the bottom of the screen.
5. Press the leftmost softkey, or use the Select or Entry knobs, to select channel 11.
6. Press the **Low** softkey.
7. Set the channel 12 and 13 trigger bits to “low” in the same manner.

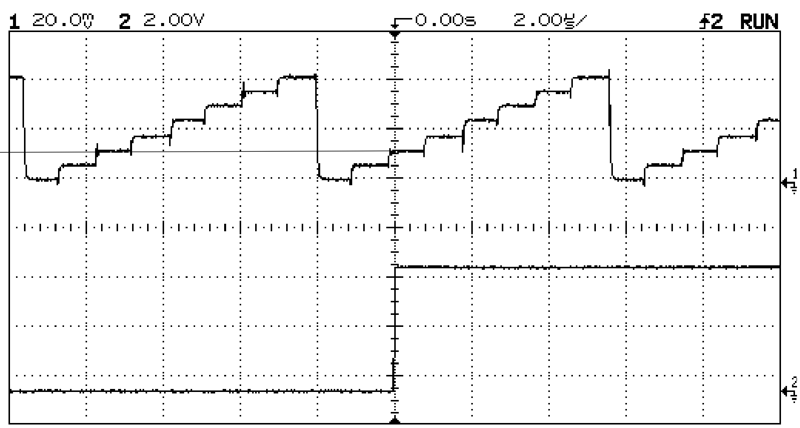
Change the trigger and view the new waveform

1 Select channel 12. Then, press the **High** softkey.
2 Press `Run/Stop` to cause it to start using this pattern as the trigger.
3 Press `Run/Stop` again to increase the frequency of the trigger output signal.

The oscilloscope portion should now be triggering on the level of the stairstep which represents the value of 2 into the D-to-A converter.

The Mixed Signal Oscilloscope is now triggering when the counter that drives the D-to-A converter enters the zero state. The display should look like the following.

Figure 4–8



Oscilloscope triggering on level 2 in the stairstep

Note how the oscilloscope is triggering on the level zero step in the stairstep waveform.

Conclusion

This ends the series of exercises focusing on the combined oscilloscope and logic analyzer features of the 54645D Mixed Signal Oscilloscope. By now you should have a good idea of how the 54645D Mixed Signal Oscilloscope operates.

You have completed the training, and we hope that you have found the training experience with this kit both enjoyable and helpful.

5

Digital Circuitry Measurement Exercises

Digital Circuitry Measurement Exercises

These exercises are designed for use with the 54620A/C logic analyzer.

The exercises in this chapter work together in a practical way to show you how you can use the 54620 logic analyzer to perform real-life application measurements.

Who should do these exercises?

You should do these exercises if you are using the 54620A/C logic analyzer

For digital circuitry measurement practice in using the logic analysis functions of the 54645D mixed signal oscilloscope, please turn to Chapter 5.

Be sure that you have worked through the appropriate "Getting Started With.." exercises in Chapter 1 that apply to your instrument before doing the exercises in this chapter.

At the end of this chapter you will be directed to the next step in your training.

Which Chapter 5 exercises are for you

	54600-Series* Basic Oscilloscope	**54645A Oscilloscope with MegaZoom technology**	**54620A/C Logic Analyzer**	**54645D Mixed Signal Oscilloscope**
Entire chapter			√	

*Note: In this table, 54600-Series Basic Oscilloscopes are the following: 54600B, 54601B, 54602B, 54603B, 54610B, 54615B, and 54616B/C

Using Basic Logic Analyzer Controls

This section shows you how to select and position a waveform, to turn channels off and on, and to label channels.

Select and position a waveform

1 **Take hold of the Select knob. Turn it back and forth and notice how the highlighting moves among the channels.**

The highlighted channel designates the active channel which will be affected by the actions you take.

2 **Turn the Select knob to select channel 0.**

3 **Take hold of the Position knob. Turn it back and forth and notice how channel 0 is repositioned on the display.**

4 **Position channel 0 at the top of the display.**

Turn channels off and on

1 **Press `On/Off`. Then press the Chan 8 - 15 Off softkey.**

Note how channels 8 through 15 are turned off, and the remaining channels are resized to fit the display.

2 **Turn the Select knob until channel 3 is highlighted. Press the leftmost softkey CH03 Off On softkey.**

Note how the channel is turned off, and that the highlight for channel 3 is moved to the upper left corner of the display.

3 **Turn the Select knob to the left several notches.**

Note how the channels that are turned off are shown highlighted in the upper left corner of the display. These channels are displayed this way so that you can select and turn them on individually.

4 Press `Autoscale` .

Note how the channels with activity are turned on, and a seconds/division setting is chosen so that several cycles are displayed on screen. All inactive channels are turned off.

The logic analyzer also automatically sets up the proper threshold voltage for the signals found. For the training board, these levels are TTL. To set other values you would press the `Logic Levels` key and use the options that are displayed.

Label the channels

1 Press `Label` .

2 Press the **Labels Off On** softkey.

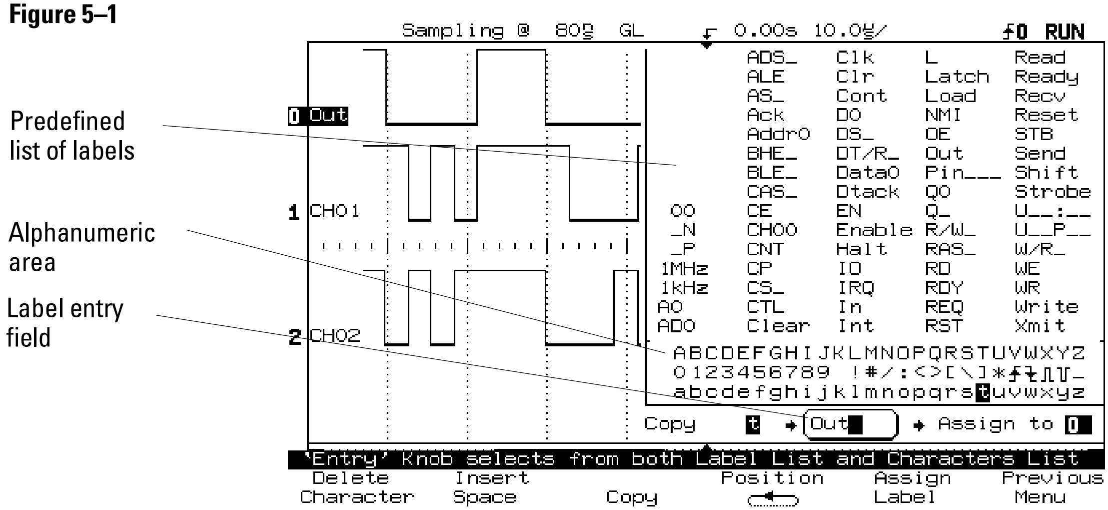
Note how the labels on the left side of the waveforms are removed to show more waveform area. The channel numbers remain on screen.

3 Press the **Labels Off On** softkey again to turn on the labels.

4 Press the **Define Labels** softkey.

A new window, which allows you to define labels, is displayed. The upper portion of the window shows the predefined list of labels. Below this list is the alphanumeric area, from which you can select individual letters, numbers, and characters to define labels. Below the window is the entry area, which allows you to enter a predefined label or define a label with letters and characters.

Figure 5–1



Defining a label

5 Turn the Select knob until channel 0 is highlighted.

6 Turn the Entry knob until the letter “O” is highlighted in the alphanumeric area. Then, press the **Copy** softkey.

The O is copied into the label window.

7 Do step 6 for the letters “u” and “t”.

8 Press the **Assign Label** softkey.

Note how the label “Out” has been assigned to channel 0.

9 Turn the Select knob until channel 1 is highlighted.

10 Turn the Entry knob until the word “In” is highlighted in the list of predefined labels. Press the **Copy** softkey.

If “In” is not present in the list, press **Previous Menu**, **Initialize Label List**, **Yes**, **Yes**, and then **Define Labels** to reset the list to the factory set of labels.

11 Turn the Entry knob until the number “1” is highlighted in the row of numbers and special characters. Press the **Copy** softkey.

12 Press **Assign Label** and note how channel 1 has been relabeled “In1”.

Note how channel 2 is now selected. Note also that the entry field below the alphanumeric area has been changed to “In2”.

13 Press **Assign Label** to relabel channel 2.

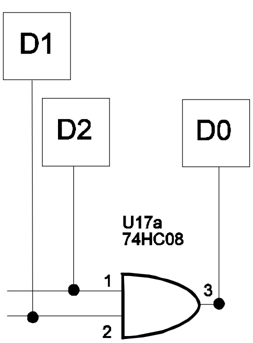
14 Press the **Previous Menu** softkey to return to the normal waveform display.

In this section you will verify the operation of the AND gate shown below. You will learn about the fundamental triggering capabilities of the logic analyzer. You will use the measurement capability of the logic analyzer to measure the propagation delay of the AND gate.

This section shows you how to:

- Probe the signals and apply power.
- Define an edge trigger.
- Define a pattern trigger.
- Set up a measurement.
- Make a measurement using cursors.
- Make an automated measurement.

Figure 5–2



And Gate U17a

Probe the signals and apply power

1 **Make sure the same probe connection setup is used as described in the previous section.**

2 **Turn on the training board if it is not already on.**

The red LED on the training board will be lit.

3 **Turn on the logic analyzer if it is not already on.**

4 **Press `Autoscale` .**

Define an edge trigger

1 **Press `Edge` .**

2 **Press the Source channel softkey to select channel 0.**

Or, you could turn the Select knob until channel 0 (labeled CH00 or Out) is shown on the softkey.

3 **Press the rising edge softkey.**

Observe that the rising edge on channel 0 appears at the center of the screen.

Note the operation of the AND gate. The output goes high when both of the inputs go high.

4 **Press `Single` several times.**

Observe the various times the AND gate produces a "1" on the output.

Define a pattern trigger

1 Press `Pattern`.

2 Press `Run/Stop` if the status is not currently running ("RUN").

Observe the random triggering of the waveforms. This is occurring because the pattern is currently set to "don't care" ("X") on all channels.

3 Turn the Select knob until channel 1 is selected.

4 Press the **High** softkey.

Observe that the rising edge of channel 1 is now at the center of the screen.

5 Turn the Select knob until channel 2 is selected.

6 Press the **High** softkey.

Observe that both channel 1 and channel 2 are always at a logic "1" at the center of the display.

7 Press `Single` several times and observe the function of the AND gate.

The logic analyzer is triggering when both of the inputs to the AND gate are high. The low-to-high transition of either of the input signals that went high is the point where the pattern is "entered."

When the two inputs are both high, the output transitions to a logic "1". Occasionally, both of the inputs switch nearly at the same time, and a logic level "1" is not produced on the output because of the gate response time. At the time per division value set by Autoscale, these delays cannot be discerned.

8 Turn the Time/Div knob clockwise until the "Time/Div at limit" message is displayed.

9 Press `Run/Stop` or `Single` and observe the gate delay.

Set up a measurement

1 Press `Edge` .

2 Turn the Select knob until channel 0 is selected.

3 Press the rising edge softkey.

4 Press `Run/Stop` if the analyzer is not currently running.

5 Adjust the Time/Div knob fully clockwise.

The setting should be 5.00 ns/ and the sampling period should be 2 ns.

6 Observe the delay from channel 1 (In1) to channel 0 (Out).

This is the propagation delay of the AND gate.

Make a measurement using cursors

Now you are ready to measure the propagation delay of the AND gate. Propagation delay is the time it takes for the output of a gate to change states after the input changes, and is dominantly caused by switching time.

There are at least two ways to measure the propagation delay—using the cursors and using the dual-channel automatic measurement. Both can be just as accurate. You will measure the delay using both methods.

1 Press `Cursors` .

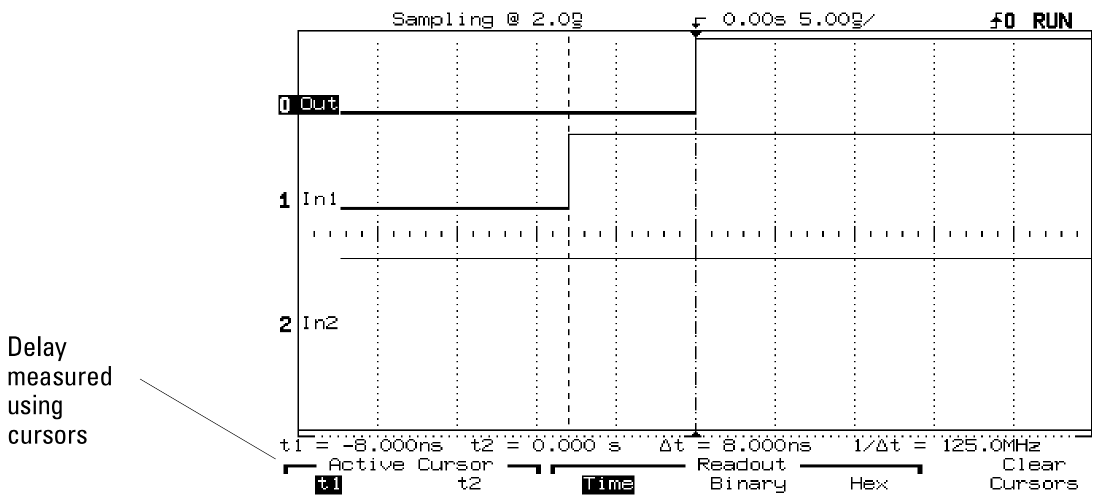
The softkey menu across the bottom of the display shows active cursors t1 and t2. The t1 cursor may be highlighted, and its vertical dotted bar appears on screen.

2 Make sure the **t1** (leftmost) softkey is highlighted.

3 Turn the Entry knob counter-clockwise until the vertical line (the t1 cursor) moves to the position of one of the rising edges on channel 1.

The two edges reflect the sampling uncertainty of 2 ns. The delta t (Δ t) readout on the line just below the screen (the "Measurement Line") gives the propagation delay of the gate, which is approximately 7 ns.

Figure 5–3



Using cursors to measuring the propagation delay of the AND gate

Make an automated measurement

1 Press `Dual channel` .

2 Press the **Ch Delay** softkey.

This displays a set of softkeys you will use to set up the measurement.

3 Press the second softkey from the left (labeled **Channel**) until it indicates channel 1 (In1).

Once the channel softkey has been highlighted, you can use the Entry knob to select a channel.

4 Press the leftmost **Edge** softkey (third key from the left) until the rising edge is selected.

5 Press the right **Channel** softkey (fourth from the left) and select channel 0 (Out).

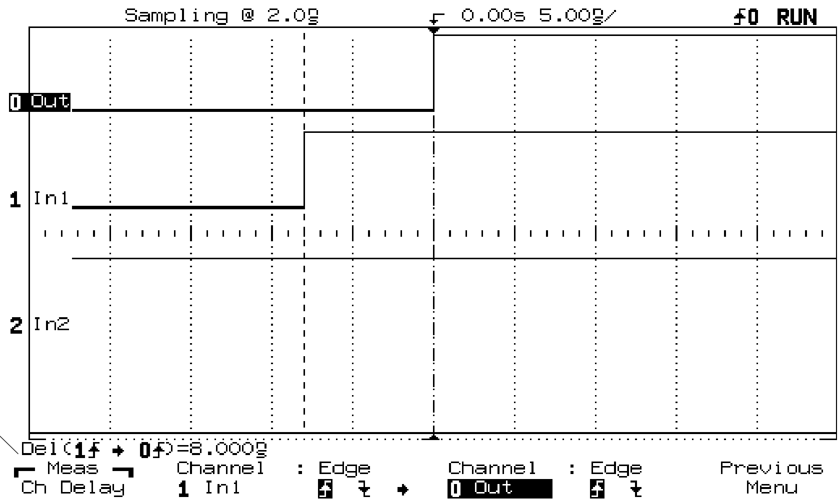
6 Press the rightmost **Edge** softkey (fifth from the left) until rising is selected.

7 Press the **Meas Chan Delay** softkey (the leftmost key).

Observe the delay measurement readout on the Measurement Line of the display. The propagation delay is measured in the range of 4-8 ns.

With each new acquisition, the measurement is retaken and the result is displayed.

Figure 5–4



Automatic delay measurement

Using dual-channel capability to automatically measure the delay

8 Press `Previous Menu` .

Note the **Show Meas** softkey is turned on.

9 Turn the **Show Meas** (show measurements) softkey off.

The cursors used to show the delay measurement are turned off.

10 Turn the **Show Meas** softkey on.

Note that as the cursor moves with the rising edge of the channel 1 (In1) signal the delay value in the Measurement Line changes to reflect the value measured.

Using Advanced Triggering Techniques

A common problem in digital circuits is finding glitches and very narrow pulses. After finding signals of these types, you can usually find the cause.

The training board includes a pulse train that is made up of a series of high and low values, producing the sequence 000011101100101. In addition, a narrow pulse occasionally appears somewhere in this sequence. The advanced trigger capability will allow you to detect the narrow pulse in this pulse train.

In this exercise you will:

- Probe the signals.
- Examine the pulse train.
- Measure the clock period.
- Define an advanced trigger.
- Observe the narrow pulse.
- Trigger on the narrow pulse.
- View the advanced triggering overview menu.

Probe the signals

1 Make sure the black probe ground lead is attached to a GND connector on the training board.

2 Attach the channel 3 analyzer probe to connector D3.

3 Attach the channel 6 analyzer probe to connector D6.

4 You may disconnect analyzer probes 0, 1, and 2 from the training board.

Doing this will provide a simpler display when viewing the channel activity.

5 Press `Setup`. Then press the **Default Setup** softkey.

6 Press `Autoscale`.

7 You may label the channels “Clk” for channel 3 and “Data” for channel 6 by using `Label` and the **Define Labels** softkey as shown in the previous section.

Defining these labels will cause your analyzer display to resemble the screens shown in this section.

Examine the pulse train

The pulse train is a PRBS which is clocked by the rising edge of the signal on channel 3. The length of the four zeros in the pulse train on channel 6 equal four periods of the clock on channel 3, and the three ones that follow exist for three periods of the clock.

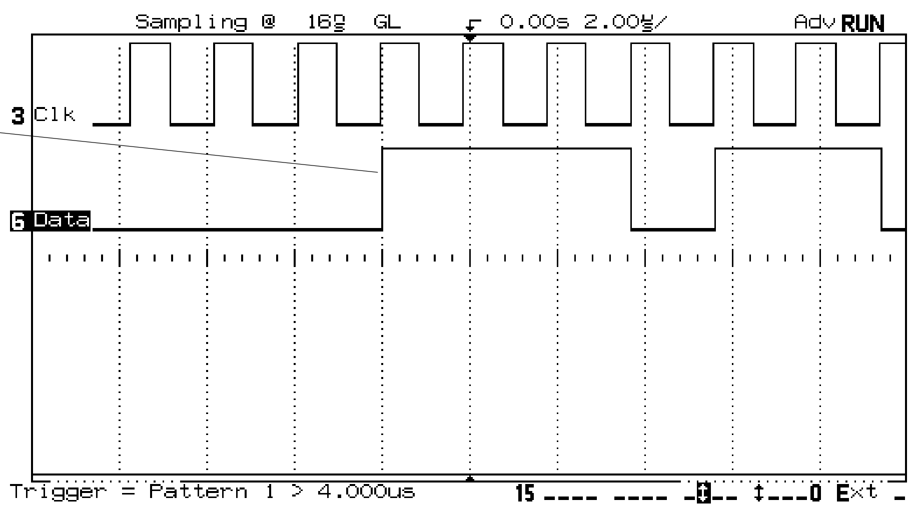
1 Stop the acquisition if it is running.

2 Look at the pulse train on channel 6. Verify that the pulse train is correct by observing a pattern of four zeros (logic lows) followed by three ones (logic highs).

3 Start the acquisition.

Figure 5–5

Pattern of three 1s following four 0s in the pulse train.



Examining the pulse train

Measure the clock period

1 Press `Single channel` .

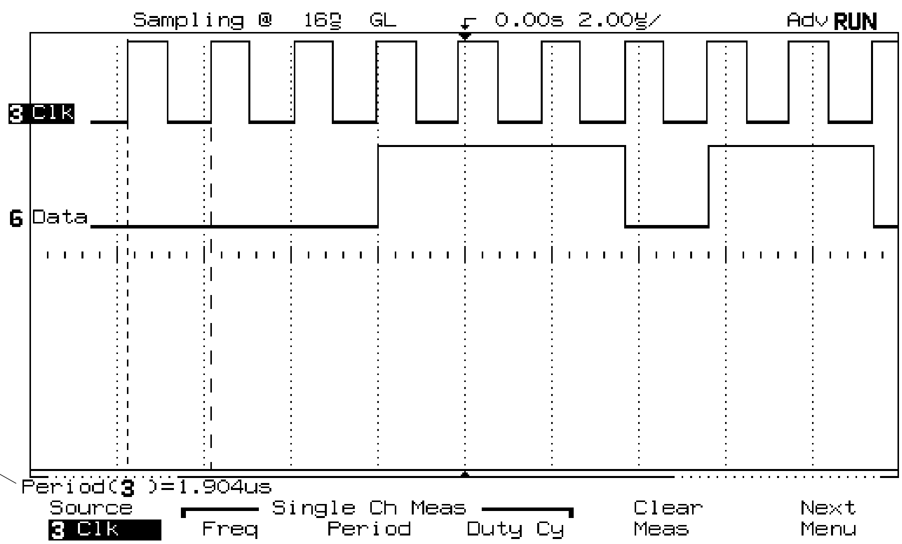
2 Turn the Select knob or press the leftmost softkey (labeled **Source**) until channel 3 (**Clk**) is selected.

3 Press the **Period** softkey. Observe that the clock period is approximately 2 µs.

Because the clock period is approximately 2 µs, the three logic ones in the Data signal will be high for approximately 6 µs.

Figure 5–6

Automated measurement of clock period



Measuring the clock period

Define an advanced trigger

1 Press [Adv] .

The menu at the bottom of the screen shows the trigger pattern and duration, and lets you define the source of the trigger and the duration.

2 Press the leftmost softkey until **Pat 1** appears.

3 Press the **Define** softkey.

4 Turn the Select knob or press the leftmost softkey until channel 6 (**Data**) is selected.

5 Press the **Level High** softkey.

6 Press the **Previous Menu** softkey.

7 Press the **Operator** softkey until **Duration >** appears. Then, press the **Minimum Duration** softkey.

8 Press [Run/Stop] to start the acquisition.

9 Turn the Entry knob clockwise while observing the duration value above the fourth softkey from the left.

When the duration value exceeds approximately 4 µs, as shown in the next diagram, the display will stabilize. This is because all pulses less than 4 µs (two clock periods) have been excluded, and only the pulse of interest remains.

Observe the narrow pulse

Occasionally a narrow pulse appears to the left of the pulse that equals the three logical ones.

1 Press `Autostore`.

Note the STORE status indicator in the top right corner of the display. All data acquisitions are now "held" on screen.

2 Let the analyzer run for a while until the narrow pulse appears and is stored on the screen in half bright.

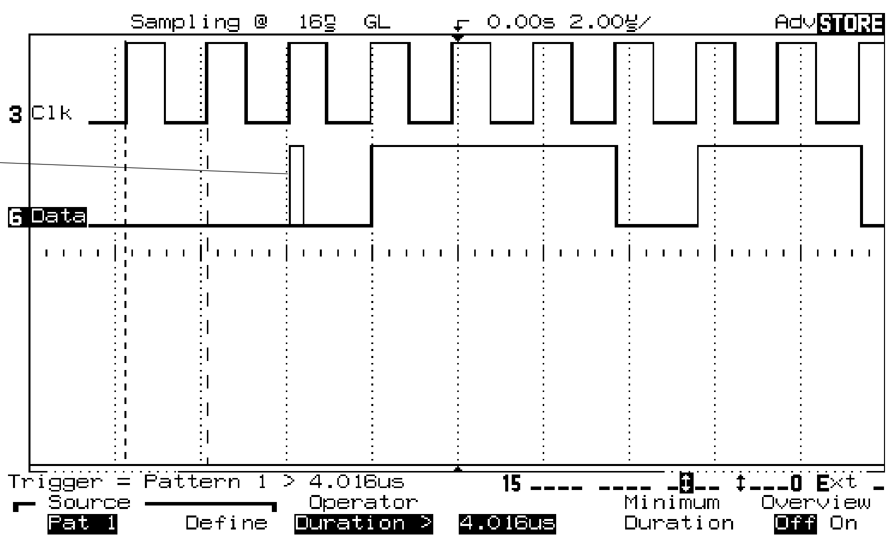
The STORE mode causes the waveform and narrow pulse to be stored on the display until you erase it.

3 Press `Erase` to clear the stored waveforms.

Note how the narrow pulse appears again after a while, which demonstrates its infrequent nature. The 54620A can trigger on this narrow pulse.

Figure 5–7

Narrow pulse displayed with Autostore turned on



Narrow pulse in the pulse train

Trigger on the narrow pulse

1 Press `Autostore` to turn off the Autostore feature.

2 Press `Erase` to clear the stored waveforms.

3 Press the **Operator** softkey until **Duration <** appears. Then, press the **Minimum Duration** softkey.

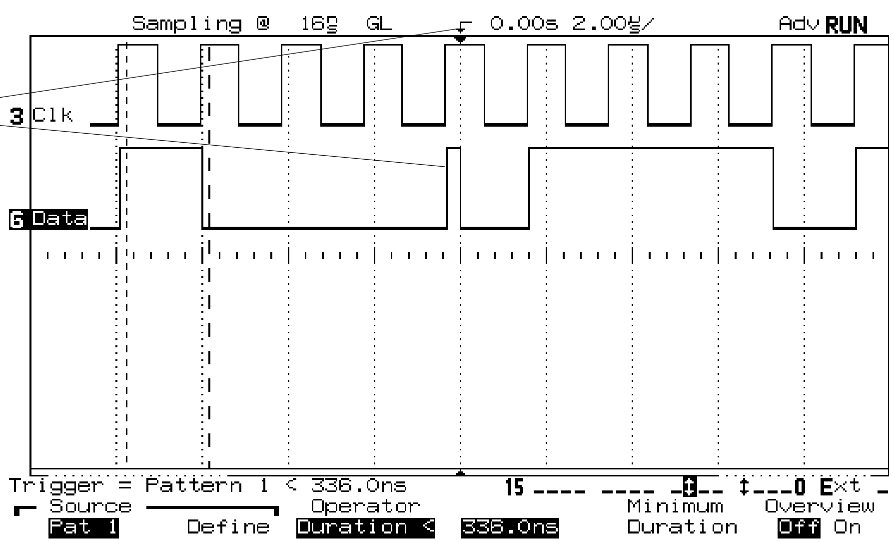
4 Gradually turn the Entry knob clockwise until the screen displays stable waveforms.

The waveforms should stabilize at a duration reading of approximately 300 ns. However, the actual reading depends on your particular training board.

The analyzer is now triggering on the infrequent narrow pulse, and is excluding all of the normal, single-clock period pulses.

Figure 5–8

Analyzer triggering on the narrow pulse



Analyzer triggering on the narrow pulse

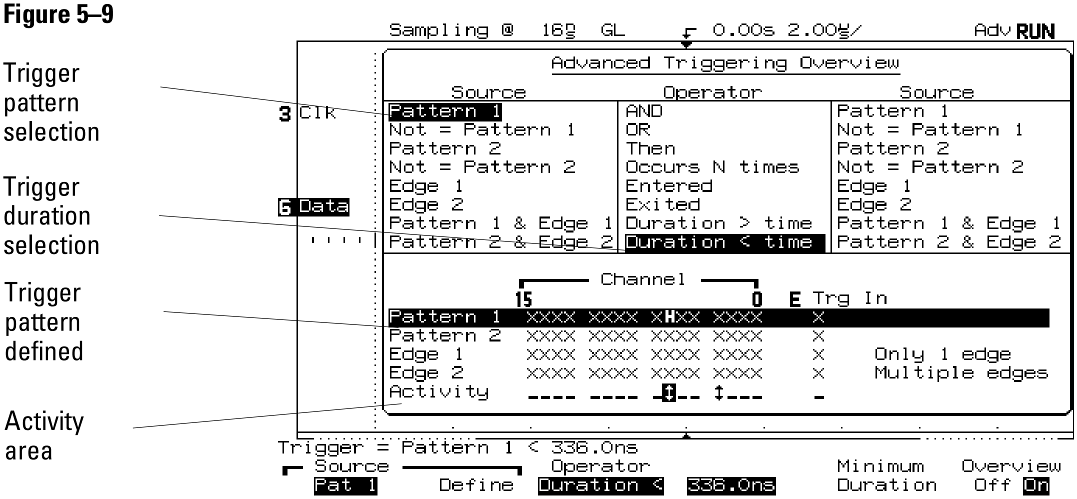
View the advanced triggering overview menu

1 Press the **Overview On** softkey.

The following triggering menu is displayed, showing the currently selected pattern and operator, and that channel 6 is set high in the trigger pattern. This menu gives you an overall detailed look at various ways in which you can define advanced triggers. Notice how the channel activity area on screen reflects changes in the clock and data channels.

2 Press the **Overview Off** softkey to return to the waveform display.

Figure 5–9



Viewing the advanced triggering overview menu

Using an External Oscilloscope and the Logic Analyzer Together

Using only an oscilloscope to view a noisy signal can be very difficult. However, the 54620A/C logic analyzer lets you easily trigger the oscilloscope on a noisy waveform.

In this exercise you will use the logic analyzer to trigger the oscilloscope and view an eight-step staircase waveform on the oscilloscope. This stairstep signal is generated by the three-bit counter and the digital-to-analog converter. To make this measurement, you need a cable which includes BNC connectors on both ends, and an oscilloscope probe.

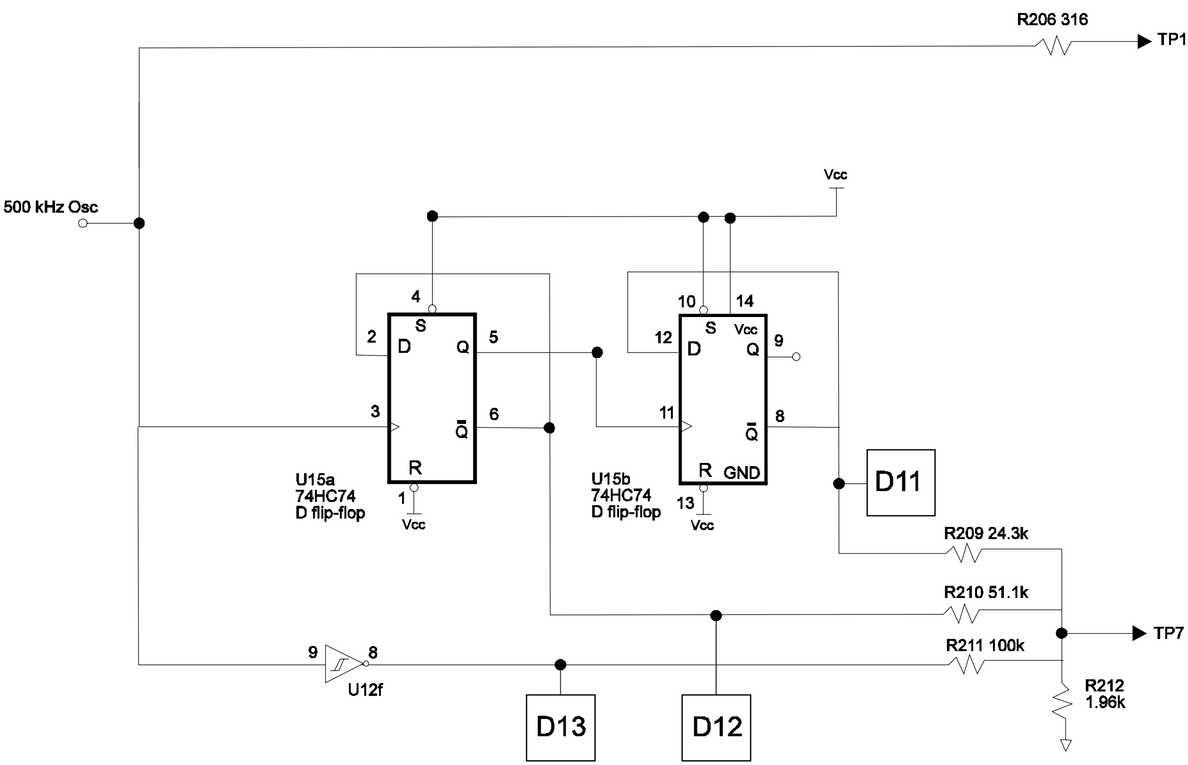
In this exercise you will:

- Examine the schematic.
- Probe the signals.
- Connect the instruments and apply power.
- Define the logic analyzer trigger.
- Trigger the oscilloscope and view the waveform.
- Change the trigger and view the new waveform.
- Configure an oscilloscope manually to receive a trigger.

Examine the schematic

1 Examine the D flip-flops labeled U15a and U15b on the following partial schematic of the training board.
2 Examine the data points labeled D11, D12 and D13.
3 Examine the outputs labeled TP1 and TP7. These are test points. Refer to the "Introduction" to this book to view these test point waveforms and their descriptions.

Figure 5–10



Flip-flops used to generate the stairstep waveform

Probe the signals

1. Make sure the analyzer black ground probe lead is connected to GND on the training board.
2. Connect channel 11 to D11 (this is U15b pins 8 and 12).
3. Connect channel 12 to D12 (this is U15a pins 2 and 6).
4. Connect channel 13 to D13 (this is U12f pin 8).
5. You may disconnect analyzer probes 3 and 6 from the training board.

   Doing this will provide a simpler display when viewing the channel activity, and will cause your screens to resemble the ones shown in this section.
6. Connect an oscilloscope probe to channel 1 on the oscilloscope.
7. Connect the oscilloscope probe ground lead to a ground point on the training board. Then, connect the channel 1 probe to test point 7 on the training board.

   The signal on test point 7 is the output of a D-to-A converter. This output is driven by a three-bit counter which is being probed by the logic analyzer.

Connect the instruments and apply power

1. Attach a BNC cable from the Trigger out connector on the front of the logic analyzer to the channel 2 input on the front of the oscilloscope.

   If you are using an oscilloscope that does not have an external trigger, use channel 2 to receive the trigger output signal from the logic analyzer, and refer to the instructions at the end of this chapter titled “Configure an oscilloscope manually to receive a trigger.”
2. Turn on the logic analyzer.
3. Turn on the oscilloscope.
4. Turn on the training board if it is not already on.

Define the logic analyzer trigger

When defining a trigger to an external instrument, you can use the edge, pattern, or advanced trigger capability of the logic analyzer. In this exercise you will use a pattern trigger.

1 Press `Setup` on the logic analyzer. Then, press the **Default Setup** softkey.

2 Press `Autoscale` on the logic analyzer.

3 Press `Label` . Then press the **Labels** softkey to turn labels off.

4 Press `Pattern` and note the trigger pattern at the bottom of the screen.

5 Press the leftmost softkey, or use the Select or Entry knobs, to select channel 11.

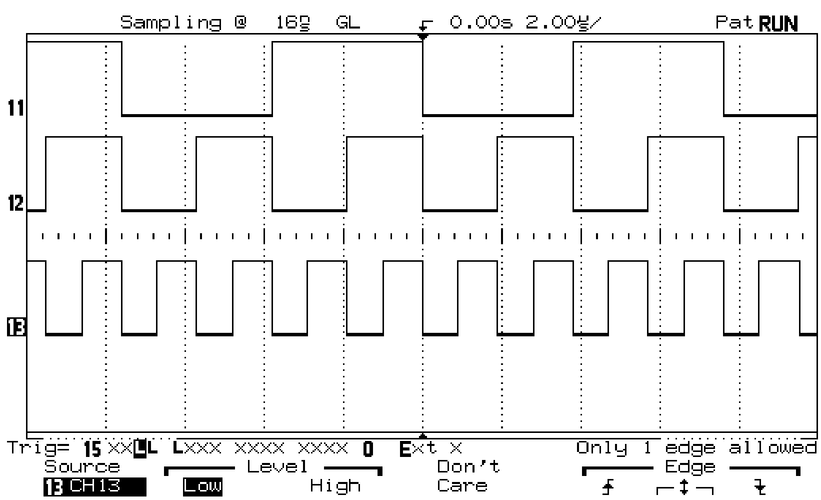
   The channel 11 bit is highlighted in the trigger pattern.

6 Press the **Low** softkey.

7 Set the channel 12 and 13 trigger bits to “low” in the same manner.

   The logic analyzer is now triggering when the counter that drives the D-to-A converter enters the zero state. The display should look like the following.

Figure 5–11



Waveforms displayed on channels 11, 12, and 13

Trigger the oscilloscope and view the waveform

1 Press `Run/Stop` on the logic analyzer.

This will cause the logic analyzer to stop drawing waveforms, and will enable it to send trigger signals through the Trigger out port to the oscilloscope at a faster rate. Doing this enables the oscilloscope to more easily autoscale on the trigger signal. If you are using an analog oscilloscope, doing this will produce more visible waveforms.

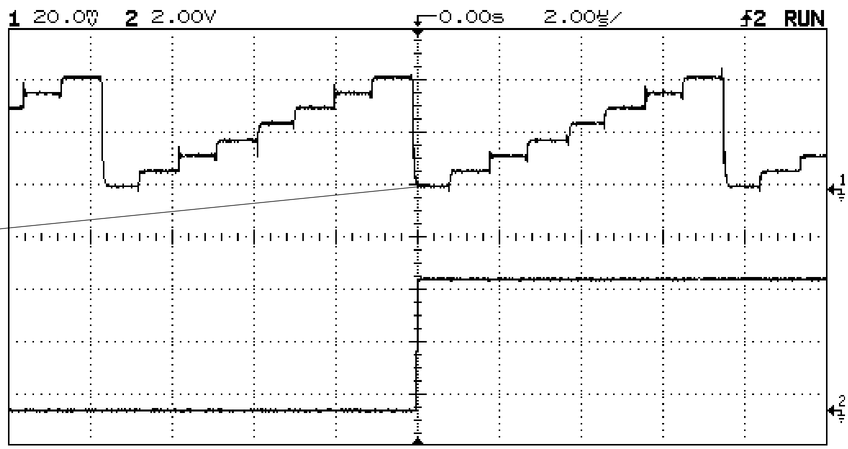
2 Press `Setup` on the oscilloscope. Then press the **Default Setup** softkey.

3 Press `Autoscale` on the oscilloscope.

4 Change the timebase to 2.00 µs/div.

The oscilloscope display should look like the following. Note how the oscilloscope is triggering on the level zero step in the stairstep waveform.

Figure 5–12



Oscilloscope triggering on level 0 in the stairstep

Oscilloscope triggering on the level 0 step in the waveform

In this display vectors are turned on. With newer oscilloscope models, vectors are turned on automatically. However, with older models, turning vectors on requires that the acquisition be stopped. Depending on the oscilloscope model you are using, your display may differ from this one slightly.

Change the trigger and view the new waveform

1 On the logic analyzer, select channel 12. Then, press the **High** softkey.

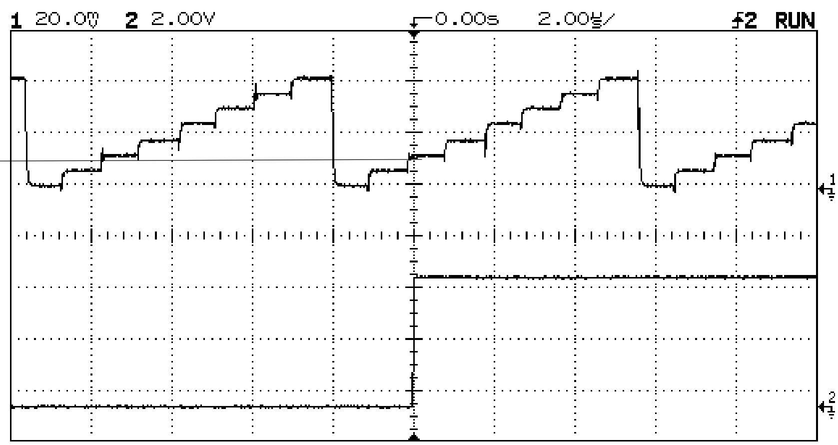
2 Press `Run/Stop` to on the analyzer to cause it to start using this pattern as the trigger.

3 Press `Run/Stop` again on the logic analyzer to increase the frequency of the trigger output signal.

The oscilloscope should now be triggering on the level of the stairstep which represents the value of 2 into the D-to-A converter.

Figure 5–13

Oscilloscope triggering on level 2 in the stairstep



Oscilloscope triggering on the level 2 step in the waveform

This shows how the logic analyzer triggering capability can be used to pinpoint analog events that may be impossible to trigger on, or that would produce an unstable trigger if you were using only an oscilloscope.

Configure an oscilloscope manually to receive a trigger

The following steps show how most other oscilloscopes should be configured to receive the triggers shown in the previous two sections, and display the stairstep waveforms.

1 To trigger on the signal from the logic analyzer Trigger out port, set the signal slope to rising.

2 Set the trigger level to 2.5 volts.

3 Set the coupling to DC.

4 Display test point 7 at 200 millivolts/division, with the coupling set to DC.

5 Set the timebase to 2 µs/division.

6 Turn autotrigger off.

Stop the acquisition to increase trigger output rate
When the 54620A/C is running, it can only generate trigger outputs as fast as it can acquire data and update the waveform display. This is normally fast enough to trigger digital oscilloscopes. However, it is not fast enough to ensure a viewable display for analog oscilloscopes. To obtain a stable trigger for analog scopes, stop the acquisition on the logic analyzer. The logic analyzer will continue to recognize its trigger condition and will drive the trigger output, but does not have the overhead of display updates. Thus, the trigger output is generated at a much higher rate. Changes to the logic analyzer trigger are not reflected in the trigger out signal until Run/Stop or Single is pressed.

Conclusion

This ends the series of digital circuitry measurement exercises. There are lots of imaginative combinations available from the signal board if you wish to continue. By now, you should have a very good idea of how the 54620A/C logic analyzer.

You have completed the training exercises, and we hope that you have found the training experience with this kit both enjoyable and helpful.

Index

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Safety

This apparatus has been designed and tested in accordance with IEC Publication 348, Safety Requirements for Measuring Apparatus, and has been supplied in a safe condition. This is a Safety Class I instrument (provided with terminal for protective earthing). Before applying power, verify that the correct safety precautions are taken (see the following warnings). In addition, note the external markings on the instrument that are described under "Safety Symbols."

Warning

- Before turning on the instrument, you must connect the protective earth terminal of the instrument to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. You must not negate the protective action by using an extension cord (power cable) without a protective conductor (grounding). Grounding one conductor of a two-conductor outlet is not sufficient protection.
- Only fuses with the required rated current, voltage, and specified type (normal blow, time delay, etc.) should be used. Do not use repaired fuses or short-circuited fuseholders. To do so could cause a shock of fire hazard.
- Service instructions are for trained service personnel. To avoid dangerous electric shock, do not perform any service unless qualified to do so. Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.
- If you energize this instrument by an auto transformer (for voltage reduction), make sure the common terminal is connected to the earth terminal of the power source.
- Whenever it is likely that the ground protection is impaired, you must make the instrument inoperative and secure it against any unintended operation.
- Do not operate the instrument in the presence of flammable gasses or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.
- Do not install substitute parts or perform any unauthorized modification to the instrument.
- Capacitors inside the instrument may retain a charge even if the instrument is disconnected from its source of supply.
- Use caution when exposing or handling the CRT. Handling or replacing the CRT shall be done only by qualified maintenance personnel.

Safety Symbols

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Instruction manual symbol: the product is marked with this symbol when it is necessary for you to refer to the instruction manual in order to protect against damage to the product.

Hazardous voltage symbol.

Earth terminal symbol: Used to indicate a circuit common connected to grounded chassis.

WARNING

The Warning sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a Warning sign until the indicated conditions are fully understood and met.

CAUTION

The Caution sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a Caution symbol until the indicated conditions are fully understood or met.

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Product Warranty

This Agilent Technologies product has a warranty against defects in material and workmanship for a period of three years from date of shipment. During the warranty period, Agilent Technologies will, at its option, either repair or replace products that prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by Agilent Technologies.

For products returned to Agilent Technologies for warranty service, the Buyer shall prepay shipping charges to Agilent Technologies and Agilent Technologies shall pay shipping charges to return the product to the Buyer. However, the Buyer shall pay all shipping charges, duties, and taxes for products returned to Agilent Technologies from another country.

Agilent Technologies warrants that its software and firmware designated by Agilent Technologies for use with an instrument will execute its programming instructions when properly installed on that instrument. Agilent Technologies does not warrant that the operation of the instrument software, or firmware will be uninterrupted or error free.

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Assistance

Product maintenance agreements and other customer assistance agreements are available for Agilent Technologies products.

For any assistance, contact your nearest Agilent Technologies Sales Office.

Certification

Agilent Technologies certifies that this product met its published specifications at the time of shipment from the factory. Agilent Technologies further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology, to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

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New editions are complete revisions of the manual. Many product updates do not require manual changes; and, conversely, manual corrections may be done without accompanying product changes. Therefore, do not expect a one-to-one correspondence between product updates and manual updates.