

Service Manual

TDS1000B and TDS2000B Series Digital Storage Oscilloscopes

077-0356-00



077035600

Service Manual



TDS1000B and TDS2000B Series Digital Storage Oscilloscopes

077-0356-00

This document applies to firmware version 1.00 and above.

Warning

The servicing instructions are for use by qualified personnel only. To avoid personal injury, do not perform any servicing unless you are qualified to do so. Refer to all safety summaries prior to performing service.

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General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it.

To avoid potential hazards, use this product only as specified.

Only qualified personnel should perform service procedures.

To Avoid Fire or Personal Injury

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

Connect and Disconnect Properly. Connect the probe output to the measurement instrument before connecting the probe to the circuit under test. Connect the probe reference lead to the circuit under test before connecting the probe input. Disconnect the probe input and the probe reference lead from the circuit under test before disconnecting the probe from the measurement instrument.

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

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

Connect the probe reference lead to earth ground only.

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

Power Disconnect. The power switch disconnects the product from the power source. See instructions for the location. Do not block the power switch; it must remain accessible to the user at all times.

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

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

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

Do Not Operate in Wet/Damp Conditions.

Do Not Operate in an Explosive Atmosphere.

Keep Product Surfaces Clean and Dry.

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

Terms in this Manual

These terms may appear in this manual:



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



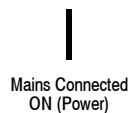
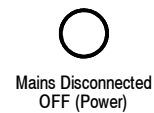
CAUTION. Caution statements identify conditions or practices that could result in damage to this product or other property.

Symbols and Terms on the Product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking.
- WARNING indicates an injury hazard not immediately accessible as you read the marking.
- CAUTION indicates a hazard to property including the product.

The following symbols may appear on the product:



Service Safety Summary

Only qualified personnel should perform service procedures. Read this *Service Safety Summary* and the *General Safety Summary* before performing any service procedures.

Do Not Service Alone. Do not perform internal service or adjustments of this product unless another person capable of rendering first aid and resuscitation is present.

Disconnect Power. To avoid electric shock, switch off the instrument power, then disconnect the power cord from the mains power.

Use Care When Servicing With Power On. Dangerous voltages or currents may exist in this product. Disconnect power, remove battery (if applicable), and disconnect test leads before removing protective panels, soldering, or replacing components.

To avoid electric shock, do not touch exposed connections.

Preface

This service manual provides information to verify performance of, calibrate, troubleshoot, disassemble, and replace parts on the TDS1000B and TDS2000B Series Digital Storage Oscilloscopes.

Unless noted otherwise, the term “oscilloscope” refers to all models in the TDS1000B and TDS2000B series.

Manual Conventions

This manual uses certain conventions that you should become familiar with before attempting service.

Modules Throughout this manual, any replaceable component, assembly, or part is referred to by the term *module*. A module is composed of electrical and mechanical assemblies, circuit cards, interconnecting cables, and user-accessible controls.

Replaceable Parts This manual refers to any field-replaceable assembly or mechanical part specifically by its name or generically as a replaceable part. In general, a replaceable part is any circuit board or assembly, such as the hard disk drive, or a mechanical part, such as the I/O port connectors, that is listed in the replaceable parts list.

Safety Symbols and terms related to safety appear in the *Service Safety Summary* found at the beginning of this manual.

Related Documentation

To read about	Use these documents
Installation and Operation	<i>TDS1000B and TDS2000B Series Digital Storage Oscilloscopes User Manual</i> (available in 11 languages)
Programmer Commands	<i>TDS200, TDS1000/2000, TDS1000B/2000B, and TPS2000 Series Digital Oscilloscopes Programmer Manual</i>
Analysis and Connectivity Tools	<i>Getting Started with OpenChoice™ Solutions Manual</i>



Specifications

Specifications

These specifications apply to all TDS1000B and TDS2000B series oscilloscopes. To verify that an oscilloscope meets specifications, it must first meet the following conditions:

- The oscilloscope must have been operating continuously for twenty minutes within the specified operating temperature.
- You must perform the Do Self Cal operation, accessible through the Utility menu, if the operating temperature has changed by more than 5 °C (9 °F) since the last time the Do Self Cal operation was performed.
- The oscilloscope must be within the factory calibration interval of one year.

Specifications begin in Table 1-1. All specifications are guaranteed unless noted “typical.” Specifications that are marked with the ✓ symbol are checked in the chapter *Performance Verification*.

Table 1- 1: Oscilloscope specifications

Acquisition		
Acquisition Modes	Sample, Peak Detect, and Average	
Acquisition Rate, typical	Up to 180 waveforms per second, per channel (Sample acquisition mode, no measurements)	
Single Sequence	<i>Acquisition Mode</i>	<i>Acquisition Stops After</i>
	Sample, Peak Detect	Single acquisition, all channels simultaneously
	Average	N acquisitions, all channels simultaneously. N is selectable from 4, 16, 64, and 128

Table 1-1: Oscilloscope specifications (Cont.)

Inputs				
Input Coupling	DC, AC, or GND			
Input Impedance, DC Coupled	1 M Ω \pm 2% in parallel with 20 pF \pm 3 pF			
P2220 Probe Attenuation	1X, 10X			
Supported Probe Attenuation Factors	1X, 10X, 20X, 50X, 100X, 500X, 1000X			
Supported Current Probe Scales	5 V/A, 1 V/A, 500 mV/A, 200 mV/A, 100 mV/A, 20 mV/A, 10 mV/A, 1 mV/A			
Maximum Voltage Between Signal and Reference at input BNC	<i>Overvoltage Category*</i>		<i>Maximum Voltage</i>	
	CAT I and CAT II		300 V _{RMS}	
	Derate at 20 dB/decade above 100 kHz to 13 V peak AC at 3 MHz [†] and above.			
	For non-sinusoidal waveforms, peak value must be less than 450 V. Excursion above 300 V should be less than 100 ms duration and the duty factor is limited to \leq 44%.			
	RMS signal level including any DC component removed through AC coupling must be limited to 300 V.			
If these values are exceeded, damage to the oscilloscope may result.				
Channel-to-Channel Common Mode Rejection, typical	<i>TDS1001B</i>	<i>TDS1002B, TDS2002B, TDS2004B</i>	<i>TDS1012B, TDS2012B, TDS2014B, TDS2022B, TDS2024B</i>	
	100:1 at 60 Hz 20:1 at 20 MHz [†]	100:1 at 60 Hz 20:1 at 30 MHz [†]	100:1 at 60 Hz 10:1 at 50 MHz [†]	
	Measured on MATH Ch1 - Ch2 waveform, with test signal applied between signal and common of both channels, and with the same VOLTS/DIV and coupling settings on each channel			
Measured on MATH Ch3 - Ch4 waveform for 4-channel models				
Channel-to-Channel Crosstalk	<i>TDS1001B</i>	<i>TDS1002B, TDS2002B, TDS2004B</i>	<i>TDS1012B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	\geq 100:1 at 20 MHz [†]	\geq 100:1 at 30 MHz [†]	\geq 100:1 at 50 MHz [†]	\geq 100:1 at 100 MHz [†]
	Measured on one channel, with test signal applied between signal and common of the other channel, and with the same VOLTS/DIV and coupling settings on each channel			

* Refer to the **Overvoltage Category** description in the *TDS1000B and TDS2000b User manual*, available on the Tektronix Web site at www.tektronix.com/manuals.

† Bandwidth reduced to 6 MHz with a 1X probe.

Table 1- 1: Oscilloscope specifications (Cont.)

Vertical§				
Digitizers	8-bit resolution (except when set to 2 mV/div), each channel sampled simultaneously			
VOLTS/DIV Range	2 mV/div to 5 V/div at input BNC			
Position Range, typical	2 mV/div to 200 mV/div, ± 2 V > 200 mV/div to 5 V/div, ± 50 V			
✓ Vertical Position Accuracy	<i>Measurement Type</i>		<i>Volts/Div Setting Position Accuracy</i>	
	Accuracy of the nominal voltage level represented by the code at the center of the dynamic range of the A/D converter		2 mV/div to 200 mV/div $\pm(1\% \text{ X selected value} + 0.1 \text{ div} + 5 \text{ mV})$ within the range $\pm 1.8 \text{ V}$ ¶ > 200 mV/div to 5 V/div $\pm(1\% \text{ X selected value} + 0.1 \text{ div} + 125 \text{ mV})$ within the range $\pm 45 \text{ V}$ ¶	
✓ Analog Bandwidth in Sample and Average modes at BNC or with P2220 probe set to 10X, DC Coupled	<i>TDS1001B</i>	<i>TDS1002B, TDS2002B, TDS2004B</i>	<i>TDS1012B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	40 MHz*†	60 MHz*†	100 MHz*†	200 MHz*† 0 °C to +35 °C (32 °F to 95 °F) 160 MHz*† 0 °C to +50 °C (32 °F to 122 °F)
	20 MHz* (when vertical scale is set to < 5 mV)			
Analog Bandwidth in Peak Detect mode (50 s/div to 5 $\mu\text{s}/\text{div}$ ‡), typical	<i>TDS1001B</i>	<i>TDS1002B, TDS2002B, TDS2004B</i>	<i>TDS1012B, TDS2012B, TDS2014B, TDS2022B, TDS2024B</i>	
	30 MHz*†	50 MHz*†	75 MHz*†	
	20 MHz* (when vertical scale is set to < 5 mV)			
Selectable Analog Bandwidth Limit, typical	20 MHz*			
Lower Frequency Limit, AC Coupled	≤ 10 Hz at BNC ≤ 1 Hz when using a 10X passive probe			
Rise Time at BNC, typical	<i>TDS1001B</i>	<i>TDS1002B, TDS2002B, TDS2004B</i>	<i>TDS1012B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	< 8.4ns	< 5.8 ns	< 3.5 ns	< 2.1 ns
Peak Detect Response‡	Captures 50% or greater amplitude of pulses ≥ 12 ns wide typical (50 s/div to 5 $\mu\text{s}/\text{div}$) in the center 8 vertical divisions For TDS1001B, the pulse must be at least 13 ns wide			

§ Specifications are with the Probe ► Voltage ► Attenuation option set to 1X.

¶ The “selected value” is the offset value indicated by the oscilloscope in the hint line (not the measurement).

* Bandwidth reduced to 6 MHz with a 1X probe and the Bandwidth Limit is turned off.

† When vertical scale is set to ≥ 5 mV.

‡ The oscilloscope reverts to Sample mode when the SEC/DIV (horizontal scale) is set from 2.5 $\mu\text{s}/\text{div}$ to 5 ns/div on 1 GS/s models, or from 2.5 $\mu\text{s}/\text{div}$ to 2.5 ns/div on 2 GS/s models. The Sample mode can still capture 10 ns glitches.

Table 1-1: Oscilloscope specifications (Cont.)

Vertical§		
✓ DC Gain Accuracy	±3% for Sample or Average acquisition mode, 5 V/div to 10 mV/div	
	±4% for Sample or Average acquisition mode, 5 mV/div and 2 mV/div	
Volts Measurement Repeatability, Average Acquisition Mode	Delta volts between any two averages of ≥ 16 waveforms acquired under same setup and ambient conditions	±(3% × reading + 0.05 div)
DC Measurement Accuracy, Average Acquisition Mode	<i>Measurement Type</i>	<i>Accuracy</i>
	Average of ≥ 16 waveforms with vertical position at zero	±(3% × reading + 0.1 div + 1 mV) when 10 mV/div or greater is selected
	Average of ≥ 16 waveforms with vertical scale with Vertical Scale 2 mV/div to 200 mV/div and -1.8 V < Vertical Position < 1.8V	±[3% × (reading + vertical position) + 1% of vertical position + 0.2 div + 7 mV]
	Average of ≥ 16 waveforms with vertical position with Vertical Scale > 200 mV/div and -45 V < Vertical Position < 45 V	±[3% × (reading + vertical position) + 1% of vertical position + 0.2 div + 175 mV]
Horizontal		
Sample Rate Range	<i>TDS1001B, TDS1002B, TDS2004B, TDS1012B, TDS2002B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	5 S/s to 1 GS/s	5 S/s to 2 GS/s
Waveform Interpolation	(sin x)/x	
Record Length	2500 samples for each channel	
SEC/DIV Range	<i>TDS1001B, TDS1002B, TDS2004B, TDS1012B, TDS2002B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	5 ns/div to 50 s/div, in a 1, 2.5, 5 sequence	2.5 ns/div to 50 s/div, in a 1, 2.5, 5 sequence
✓ Sample Rate and Delay Time Accuracy	±50 parts per million (ppm) over any ≥1 ms time interval	
Delta Time Measurement Accuracy (Full Bandwidth)	<i>Conditions</i>	<i>Accuracy</i>
	Single-shot, Sample mode	±(1 sample interval + 100 ppm × reading + 0.6 ns)
	> 16 averages	±(1 sample interval + 100 ppm × reading + 0.4 ns)
	Sample interval = s/div ÷ 250	
Position Range	<i>TDS1001B, TDS1002B, TDS2004B, TDS1012B, TDS2002B, TDS2012B, TDS2014, TDS2022B, TDS2024B</i>	
	5 ns/div to 10 ns/div	(-4 div × s/div) to 20 ms
	25 ns/div to 100 μs/div	(-4 div × s/div) to 50 ms
	250 μs/div to 10 s/div	(-4 div × s/div) to 50 s
	25 s/div to 50 s/div	(-4 div × s/div) to 250 s
	<i>TDS2022B, TDS2024B</i>	
	2.5 ns/div	(-4 div × s/div) to 20 ms

§ Specifications are with the Probe ► Voltage ► Attenuation option set to 1X.

Table 1-1: Oscilloscope specifications

Trigger				
✓ Trigger Sensitivity, Edge Trigger Type, DC coupling, with a stable display of a trigger event	<i>Coupling</i>	<i>Sensitivity</i>	<i>TDS1001B, TDS1002B, TDS1012B, TDS2002B, TDS2004B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	DC	EXT	200 mV from DC to 100 MHz*	200 mV from DC to 100 MHz* 350 mV from 100 MHz to 200 MHz*
		EXT/5	1 V from DC to 100 MHz*	1 V from DC to 100 MHz* 1.75 V from 100 MHz to 200 MHz*
		CH1, CH2, CH3, CH4 ≥5 mV/div	1 div from DC to 10 MHz* 1.5 div from 10 MHz to Full	1 div from DC to 10 MHz* 1.5 div from 10 MHz to 100 MHz 2 div from 100 MHz to Full
		CH1, CH2, CH3, CH4 2 mV/div	2.5 div from DC to 10 MHz* 4 div from 10 MHz to 20 MHz	
Trigger Sensitivity, Edge Trigger Type, DC Coupling, Frequency Counter, typical	<i>Coupling</i>	<i>Sensitivity</i>	<i>TDS1001B, TDS1002B, TDS1012B, TDS2002B, TDS2004B, TDS2012B, TDS2014B</i>	<i>TDS2022B, TDS2024B</i>
	DC	EXT	300 mV from DC to 100 MHz*	300 mV from DC to 100 MHz* 500 mV from 100 MHz to 200 MHz*
		EXT/5	1.5 V from DC to 100 MHz*	1.5 V from DC to 100 MHz* 3 V from 100 MHz to 200 MHz*
		CH1, CH2, CH3, CH4 ≥5 mV/div	1.5 div from DC to 10 MHz* 3 div from 10 MHz to Full	
		CH1, CH2, CH3, CH4 2 mV/div	4 div from DC to 10 MHz* 7.5 div from 10 MHz to 20 MHz	
Trigger Sensitivity, Edge Trigger Type, not DC Coupling, typical	<i>Coupling</i>	<i>Sensitivity</i>		
	AC	Same as DC at 50 Hz and above		
	NOISE REJ	Reduces the DC-coupled trigger sensitivity by 2 times for > 10 mV/div to 5 V/div		
	HF REJ	Same as the DC-coupled limit from DC to 7 kHz, attenuates signals above 80 kHz		
	LF REJ	Same as the DC-coupled limits for frequencies above 300 kHz, attenuates signals below 300 kHz		

* Bandwidth reduced to 6 MHz with a 1X probe.

Table 1-1: Oscilloscope specifications (Cont.)

Trigger		
Trigger Level Range, typical	<i>Source</i>	<i>Range</i>
	CH1, CH2, CH3, CH4	±8 divisions from center of screen
	EXT	±1.6 V
	EXT/5	±8 V
	AC Line	Can not be set
Trigger Level Accuracy, typical	Accuracies are for signals having rise and fall times ≥ 20 ns	
	<i>Source</i>	<i>Accuracy</i>
	Internal	±0.2 div × volts/div within ±4 divisions from center screen
	EXT	±(6% of setting + 40 mV) for signals within ±800 mV
	EXT/5	±(6% of setting + 200 mV) for signals within ±4 V
SET LEVEL TO 50%, typical	Operates with input signals ≥ 50 Hz	
Default Settings, Video Trigger	Coupling is AC and Auto mode except for a single sequence acquisition	
Sensitivity, Video Trigger Type, typical	Composite video signal	
	<i>Source</i>	<i>Range</i>
	Internal	Peak-to-peak amplitude of 2 divisions
	EXT	400 mV
	EXT/5	2 V
Signal Formats and Field Rates, Video Trigger Type	Supports NTSC, PAL, and SECAM broadcast systems for any field or any line	
Holdoff Range	500 ns to 10 s	
Pulse Width trigger		
Pulse Width Trigger modes	Trigger when < (Less than), > (Greater than), = (Equal), or ≠ (Not Equal); Positive pulse or Negative pulse	
Pulse Width Trigger Point	<p>Equal: The oscilloscope triggers when the trailing edge of the pulse crosses the trigger level.</p> <p>Not Equal: If the pulse is narrower than the specified width, the trigger point is the trailing edge. Otherwise, the oscilloscope triggers when a pulse continues longer than the time specified as the Pulse Width.</p> <p>Less than: The trigger point is the trailing edge.</p> <p>Greater than (also called time-out trigger): The oscilloscope triggers when a pulse continues longer than the time specified as the Pulse Width.</p>	

Table 1- 1: Oscilloscope specifications (Cont.)

Pulse Width trigger	
Pulse Width Range	Selectable from 33 ns to 10 s
Pulse Width Resolution	16.5 ns or 1 part per thousand, whichever is larger
Equal Guardband	$t > 330 \text{ ns}$: $\pm 5\% \leq \text{guardband} < \pm(5.1\% + 16.5 \text{ ns})$ $t \leq 330 \text{ ns}$: guardband = $\pm 16.5 \text{ ns}$
Not Equal Guardband	$t > 330 \text{ ns}$: $\pm 5\% \leq \text{guardband} < \pm(5.1\% + 16.5 \text{ ns})$ $165 \text{ ns} < t \leq 330 \text{ ns}$: guardband = $-16.5 \text{ ns}/+33 \text{ ns}$ $t \leq 165 \text{ ns}$: guardband = $\pm 16.5 \text{ ns}$
Trigger frequency counter	
Readout Resolution	6 digits
Accuracy (typical)	± 51 parts per million including all frequency reference errors and ± 1 count errors
Frequency Range	AC coupled, 10 Hz minimum to rated bandwidth
Signal Source	Pulse Width or Edge Trigger modes: all available trigger sources The Frequency Counter measures trigger source at all times in Pulse Width or Edge modes, including when the oscilloscope acquisition is halted due to changes in the run status, or acquisition of a single shot event has completed. Pulse Width Trigger mode: The oscilloscope counts pulses of significant magnitude inside the 250 ms measurement window that qualify as triggerable events, such as narrow pulses in a PWM pulse train if set to < mode and the width is set to a relatively small time. Edge Trigger mode: The oscilloscope counts all edges of sufficient magnitude and correct polarity. Video Trigger mode: The Frequency Counter does not operate.
Measurements	
Cursors	Amplitude difference between cursors (ΔV , ΔA , ΔVA) Time difference between cursors (Δt) Reciprocal of Δt in Hertz ($1/\Delta t$)
Automatic Measurements	Frequency, Period, Mean, Pk-Pk, Cycle RMS, Min, Max, Rise Time, Fall Time, Pos Width, Neg Width

Table 1-2: Oscilloscope general specifications

Display		
Display Type	145 mm (5.7 in) diagonal liquid crystal	
Display Resolution	320 horizontal by 240 vertical pixels	
Display Contrast*	Adjustable, temperature compensated	
Backlight Intensity, typical	Monochrome display	Color display
	75 cd/m ²	65 cd/m ²
Probe compensator output		
Output Voltage, typical	5 V into $\geq 1 \text{ M}\Omega$ load	
Frequency, typical	1 kHz	
Power Source		
Source Voltage	100 - 240 V _{ACRMS} ($\pm 10\%$) 50/60 Hz ($\pm 10\%$)	
	115 V _{ACRMS} ($\pm 10\%$) 400 Hz ($\pm 10\%$)	
Power Consumption	Less than 30 W	
Fuse	1 A, T rating, 250 V	
Environmental		
Pollution Degree	Pollution degree 2†, for indoor use only. Do not operate in an environment where conductive pollutants may be present.	
Temperature	Operating	0 °C to +50 °C (32 °F to 122 °F)
	Non-Operating	-40 °C to +71 °C (-40 °F to 159.8 °F)
Cooling Method	Convection	
Humidity	+40 °C or below (+104 °F or below)	5% to 85% relative humidity
	+41 °C to +50 °C (106 °F to 122 °F)	5% to 45% relative humidity
	>+50 °C to +71 °C (>122 °F to 160 °F)	Wet bulb temperature of < 37 °C, which is 12% at +71 °C
Altitude	3,000 m (approximately 10,000 ft.)	
Random Vibration	Operating	0.31 g _{RMS} from 5 Hz to 500 Hz, 10 minutes on each axis
	Non-Operating	2.46 g _{RMS} from 5 Hz to 500 Hz, 10 minutes on each axis
Mechanical Shock	Operating	50 g, 11 ms, half sine

Table 1-2: Oscilloscope general specifications (Cont.)

Mechanical		
Size	Height	158 mm (6.220 in)
	Width	326.3 mm (12.845 in)
	Depth	124.1 mm (4.885 in)
Weight (approximate)	Instrument only	2.0 kg (4.375 lbs)

* Adjustable through the Display menu.

† As defined in IEC 61010-1:2001.



Operating Information

Operating Information

For information on installing and operating your TDS1000B and TDS2000B Series Digital Storage Oscilloscope, refer to the *TDS1000B and TDS2000B Series Digital Storage Oscilloscope User Manual*. The user manuals are available in eleven languages and are on the Web at www.tektronix.com.



Theory of Operation

Theory of Operation

This chapter describes the electrical operation of the TDS1000B and TDS2000B series oscilloscopes to the module level. It describes the basic operation of each functional circuit block shown in Figures 3-1 and 3-2. Of necessity, the descriptions for the two and four channel units, and the color and monochrome units, are slightly different.

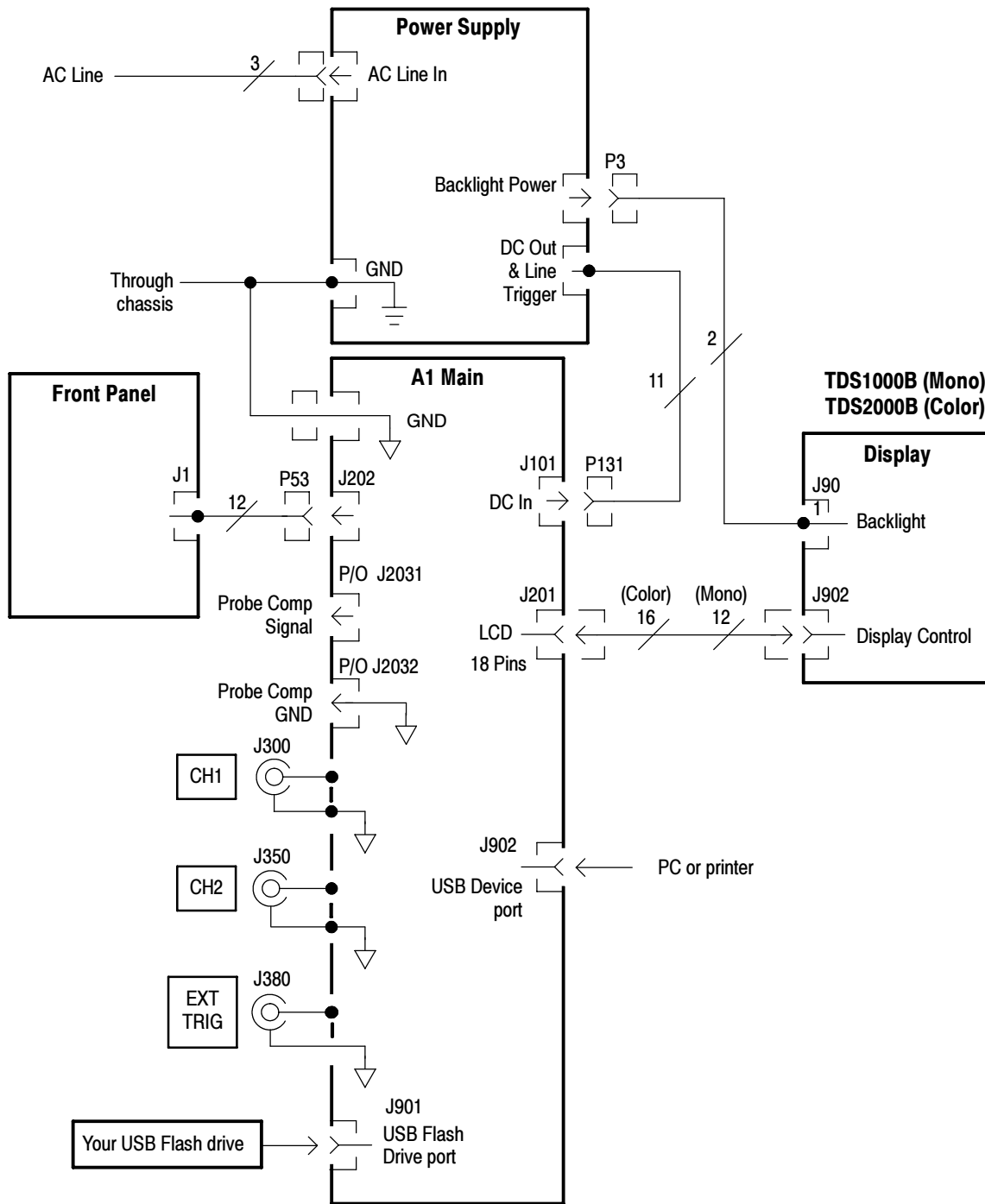


Figure 3-1: Module-level block diagram (two channel)

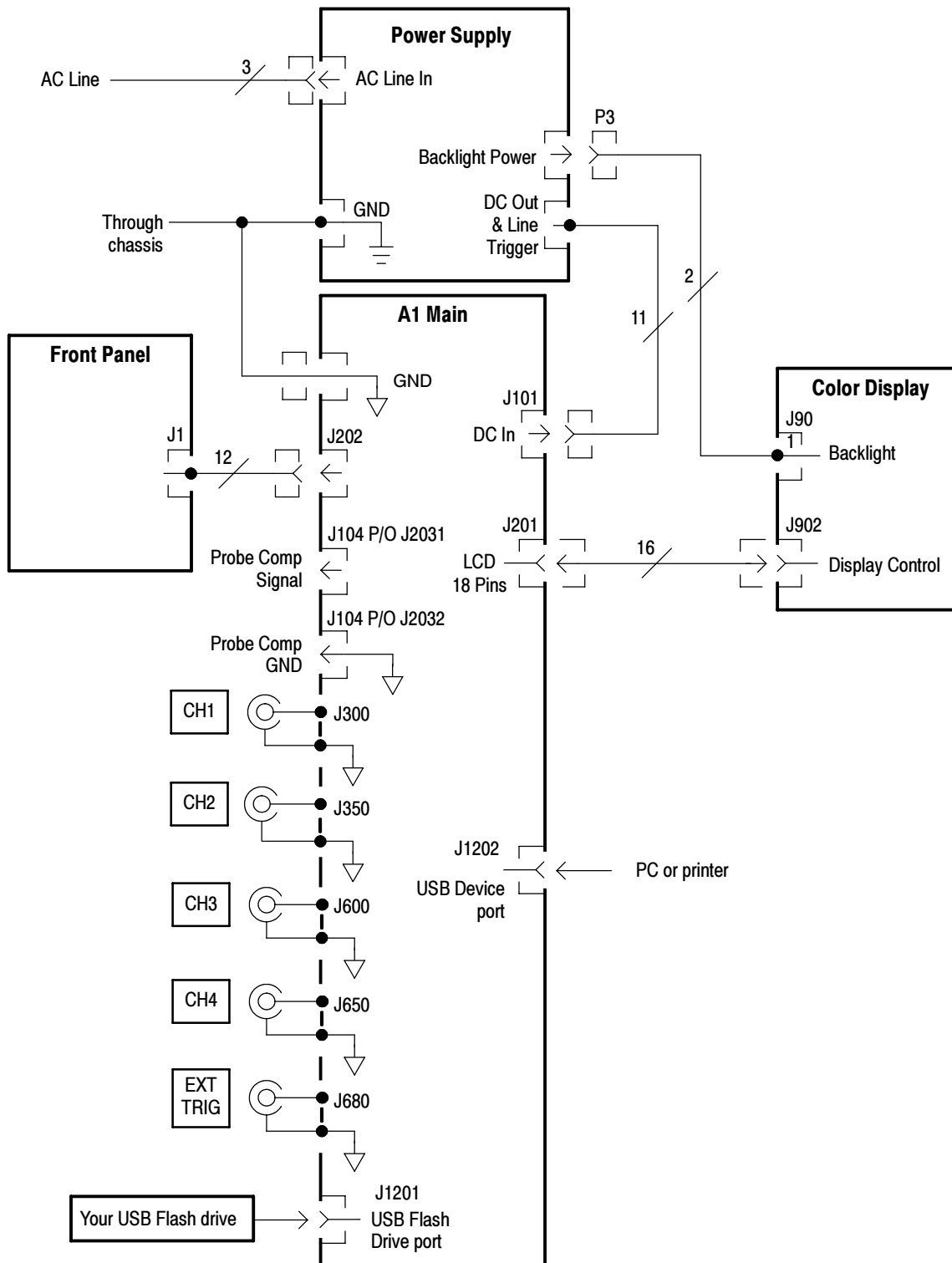


Figure 3-2: Module-level block diagram (four channel)

Main Board

The Main board is also called the acquisition board. The Main board of the four-channel oscilloscopes is essentially 2, two-channel oscilloscopes tied together through a common microprocessor, and some special interconnects to support combining the display and trigger systems. For this reason, the focus of the main board discussion will be the two-channel system, with differences noted as necessary.

At a minimum, the main board contains attenuators, an amplifier ASIC, a digitizer/trigger system ASIC, a signal processing/display/system services ASIC, RAM, flash PROM, a system microprocessor, USB controller, USB RAM, system communication RAM, and special power supplies. For a four-channel oscilloscope, the attenuators and ASICs are duplicated. Most of the other aspects of the circuitry remain unchanged.

Acquisition System

Signals from the CH 1, CH 2 and other input connectors pass through attenuators and an AC-coupling switch to the amplifier ASIC. The EXT TRIG input has an abbreviated version of this path, lacking some of the attenuator settings and the AC coupling switch.

The amplifier ASIC contains buffers and variable gain amplifiers, as well as filters that provide 20 MHz bandwidth limiting. The task of the amplifier ASIC is to convert from a 1 M Ω single-ended environment in the front end to a much lower impedance differential (and thus less noise-sensitive) environment for the acquisition process. The amplifier ASIC assures that the input signal is amplified to approximately the correct level to allow the fullest possible use of the digitizer.

The acquisition ASIC contains samplers and peak detectors for each input channel, a common amplifier, an A/D converter, and the trigger logic. The digitized waveform samples are transferred to the processing and display ASIC. In four-channel systems, the two acquisition ASICs are interconnected so that a trigger on one ASIC can cause a trigger on the other.

The processor system adds the microprocessor and flash PROM to the processing and display system. The processor system interprets the front-panel control changes detected by the display ASIC, provides control parameters based upon user setting requests, computes waveform measurements, and manages the USB interfaces via the dedicated USB controller. Saved setups, waveforms, and calibration constants are stored in nonvolatile memory sections within the flash PROM. The processor system shares DRAM with the display system.

Processing and Display System	<p>The processing and display system consists of the display ASIC, DRAM, and system oscillator. Digitized acquisition samples are received by the display ASIC and stored in DRAM. Once data are received by the display ASIC, various corrections are applied, display rasterization is performed, and the waveform is placed into a display buffer. At the same time, the waveform is being read from the display buffers and written to the LCD. Additional circuitry in the display ASIC supports scanning the front panel, handling DRAM refresh, providing the processor clock, and performing various memory mapping tasks required by all elementary microprocessor based systems. In a four-channel system, the two display ASICs are interconnected so that one ASIC may provide display information for the second.</p> <p>The processing and display system handles some of the computational tasks. Other tasks are performed by the processor system. Since all array processing is performed in the processing and display system, no computations can be performed that involve data from two different channel sets. Thus, subtracting channel 3 data from channel 2 is prohibited. Channel 1 and Channel 2 data may be combined in all of the supported ways.</p>
Input Signal Interface	<p>BNC connectors are mounted on the main board for all signal inputs. The signal inputs are compatible with the supplied P2220 probes.</p>
Probe Compensation	<p>The PROBE COMP and ground terminals are provided for probe adjustment.</p>
External Trigger	<p>The EXT TRIG channel is processed on the chain containing the highest numbered normal input channel.</p>
Main Board Power	<p>To support various functions on the main board, a number of secondary power supplies are generated. For the amplifier and acquisition ASICs, the main board creates a +2.5 V and -2.5 V supply. The +2.5 V supply is derived from the +3.3 V logic supply. The -2.5 V supply is derived from the -4 V supply. One three terminal regulator provides +5 V for internal uses. A second three terminal regulator provides USB power to preclude USB faults from seriously disrupting operation of the oscilloscope.</p> <p>An additional power supply provides the LCD bias voltage which ranges from +19 V to +28 V, depending on contrast setting and display type. This +28 V supply has a temperature sensor on the front-panel board that varies the output voltage of the supply to maintain contrast over a wide temperature range.</p>

Power Supply

The main power supply module for the TDS1000B and TDS2000B series oscilloscopes is a wide input range universal supply. It is capable of providing about 25 W of power for the oscilloscope while allowing the input to run from about 90 V to 264 V. Input frequency ranges from 47 Hz to 440 Hz, which allows operation in virtually all countries in the world and in a number of off-grid environments, such as power on military aircraft.

The secondary supplies from the power supply and the approximate current draws are listed in the table on page 6-25 with the associated connector pins on J101.

For information on voltages used in the oscilloscope, refer to the *Troubleshooting* section of this manual.

Display Module

The display module is a standard passive liquid crystal display (LCD). The monochrome unit is patterned with 320 columns by 240 rows, and has the associated drivers and backlight. The color unit is patterned with 320 columns x 3 sub-columns by 240 rows and has the associated drivers and backlight. In both displays, the backlight tube is in a 5mA top lamp configuration.

Front Panel

Two-Channel Oscilloscopes

You can manipulate all of the switches, and position encoders on the front-panel board of two-channel oscilloscopes. Several LEDs are used to indicate when the Multipurpose knob is active, when Autorange is active, and when a Save action is in progress. For more information on the LEDs, refer to the User Manual for your oscilloscope.

Additionally, an IC on the front-panel board provides buffering and multiplexing of switch signals to the main board. Two signals and a sense line are provided by the main board to support the front panel. One of these lines resets the scan; a second clocks the scan to the next position; and the sense line receives the current state of the selected switch or encoder position.

For the encoders, some amount of debouncing occurs inside the front-panel IC. All key debouncing is handled in the display ASIC on the main board.

The LEDs are controlled by latching the value of the Channel 1-2 front panel scan counter when the appropriate scan value is set.

**Four-Channel
Oscilloscopes**

The front-panel board of the four channel units is effectively two panels in parallel. The left side of the board is largely handled by the display ASIC for channels 1 and 2. The right side of the board is handled by the channel 3 and 4 ASIC. Separate front-panel ICs support these data paths.



Performance Verification

Performance Verification

This chapter contains performance verification procedures for the specifications marked with the ✓ symbol. The following equipment, or a suitable equivalent, is required to complete these procedures.

Required Equipment

Description	Minimum requirements	Examples
DC Voltage Source	17.5 mV to 7 V, $\pm 0.5\%$ accuracy	Wavetek 9100 Universal Calibration System with Oscilloscope Calibration Module (Option 250)
Leveled Sine Wave Generator	50 kHz and 200 MHz, $\pm 3\%$ amplitude accuracy	Fluke 5500A Multi-product Calibrator with Oscilloscope Calibration Option (Option 5500A-SC)
Time Mark Generator	10 ms period, ± 10 ppm accuracy	
50 Ω BNC Cable	BNC male to BNC male, ≈ 1 m (36 in) long	Tektronix part number 012-0482-XX
50 Ω BNC Cable	BNC male to BNC male, ≈ 25 cm (10 in) long	Tektronix part number 012-0208-XX
50 Ω Feedthrough Termination	BNC male and female connectors	Tektronix part number 011-0049-XX
Dual Banana to BNC Adapter	Banana plugs to BNC female	Tektronix part number 103-0090-XX
BNC T Adapter	BNC male to dual BNC female connectors	Tektronix part number 103-0030-XX
Splitter, Power	Frequency range: DC to 4 GHz. Tracking: $>2.0\%$	Tektronix part number 015-0565-XX
Adapter (four required)	Male N-to-female BNC	Tektronix part number 103-045-XX
Adapter	Female N-to-male BNC	Tektronix part number 103-0058-XX
Leads, 3 Black	Stacking Banana Plug Patch Cord, ≈ 45 cm (18 in) long	Pomona #B-18-0
Leads, 2 Red	Stacking Banana Plug Patch Cord, ≈ 45 cm (18 in) long	Pomona #B-18-2

Test Record

Model number	Serial number	Procedure performed by	Date

Test	Passed	Failed
1. Self Test		
2. Self Calibration		
3. Oscilloscope tests		

Oscilloscope tests		Low limit	Test result	High limit
Channel 1 DC Gain Accuracy	5 mV/div	33.6 mV		36.4 mV
	200 mV/div	1.358 V		1.442 V
	2 V/div	13.58 V		14.42 V
Channel 2 DC Gain Accuracy	5 mV/div	33.6 mV		36.4 mV
	200 mV/div	1.358 V		1.442 V
	2 V/div	13.58 V		14.42 V
Channel 3 DC Gain Accuracy ¹	5 mV/div	33.6 mV		36.4 mV
	200 mV/div	1.358 V		1.442 V
	2 V/div	13.58 V		14.42 V
Channel 4 DC Gain Accuracy ¹	5 mV/div	33.6 mV		36.4 mV
	200 mV/div	1.358 V		1.442 V
	2 V/div	13.58 V		14.42 V
Channel 1 Bandwidth		2.12 V		— ₂
Channel 2 Bandwidth		2.12 V		— ₂
Channel 3 Bandwidth ¹		2.12 V		— ₂
Channel 4 Bandwidth ¹		2.12 V		— ₂
Sample Rate and Delay Time Accuracy		-2 divs		+2 divs
Channel 1 Edge Trigger Sensitivity		Stable trigger		— ₃
Channel 2 Edge Trigger Sensitivity		Stable trigger		— ₃
Channel 3 Edge Trigger Sensitivity ¹		Stable trigger		— ₃
Channel 4 Edge Trigger Sensitivity ¹		Stable trigger		— ₃
External Edge Trigger Sensitivity		Stable trigger		— ₃

Oscilloscope tests	Low limit	Test result	High limit
Channel 1 Vertical Position Accuracy, Minimum margin	0		—
Channel 2 Vertical Position Accuracy, Minimum margin	0		—
Channel 3 Vertical Position Accuracy ¹ , Minimum margin	0		—
Channel 4 Vertical Position Accuracy ¹ , Minimum margin	0		—

¹ Channels 3 and 4 are only available on four channel oscilloscopes.

² The bandwidth test does not have a high limit.

³ The limits vary by model. Check the procedure for the correct limits.

Performance Verification Procedures

Before beginning these procedures, two conditions must first be met:

- The oscilloscope must have been operating continuously for twenty minutes within the operating temperature range specified.
- You must perform the Self Calibration operation described below. If the ambient temperature changes by more than 5 °C, you must perform the Self Calibration operation again.

The time required to complete the entire procedure is approximately one hour.



WARNING. Some procedures use hazardous voltages. To prevent electrical shock, always set voltage source outputs to 0 V before making or changing any interconnections.

Self Test

This internal procedure is automatically performed every time the oscilloscope is powered on. No test equipment or hookups are required. Verify that no error messages are displayed before continuing with this procedure.

Self Calibration

The self calibration routine lets you quickly optimize the oscilloscope signal path for maximum measurement accuracy. You can run the routine at any time, but you should always run the routine if the ambient temperature changes by 5 °C or more.

1. Disconnect any probes or cables from the channel input connectors (CH 1, CH 2, CH 3, CH 4).
2. Push the UTILITY button and select the Do Self Cal option to start the routine. The routine takes approximately one minute to complete.

3. Verify that self calibration passed.

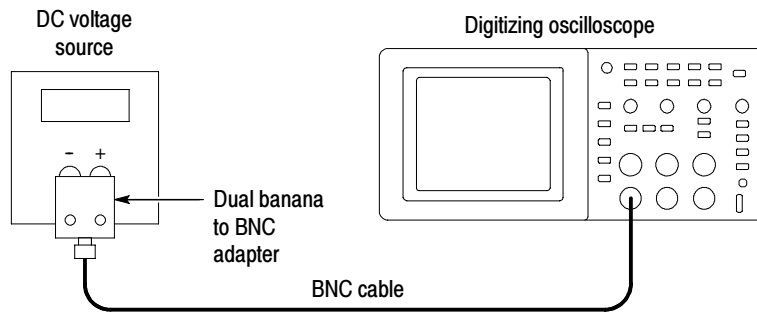
Check DC Gain Accuracy

This test checks the DC gain accuracy of all input channels.

1. Set the DC voltage source output level to **0 V**.
2. Set up the oscilloscope using the following steps:

Push menu button	Select menu option	Select setting
1. DEFAULT SETUP	—	—
2. CH 1	Probe	1X
3. ACQUIRE	Average	16
4. MEASURE	Source	Channel under test
	Type	Mean

3. As shown below, connect the oscilloscope channel selected in the table to the DC voltage source.



4. For each VOLTS/DIV setting listed below, perform the following steps:
 - a. Set the DC voltage source output level to the positive voltage listed and then record the mean measurement as V_{pos} .
 - b. Reverse the polarity of the DC voltage source and then record the mean measurement as V_{neg} .
 - c. Calculate $V_{diff} = V_{pos} - V_{neg}$ and then compare V_{diff} to the accuracy limits in the table.

VOLTS/DIV setting	DC voltage source output levels	Accuracy limits for V_{diff}
5 mV/div	+17.5 mV, -17.5 mV	33.6 mV to 36.4 mV
200 mV/div	+700 mV, -700 mV	1.358 V to 1.442 V
2 V/div	+7.00 V, -7.00 V	13.58 V to 14.42 V

- Set DC voltage source output level to **0 V**.
- Disconnect the test setup.
- Repeat steps 1 through 6 until all input channels have been checked.

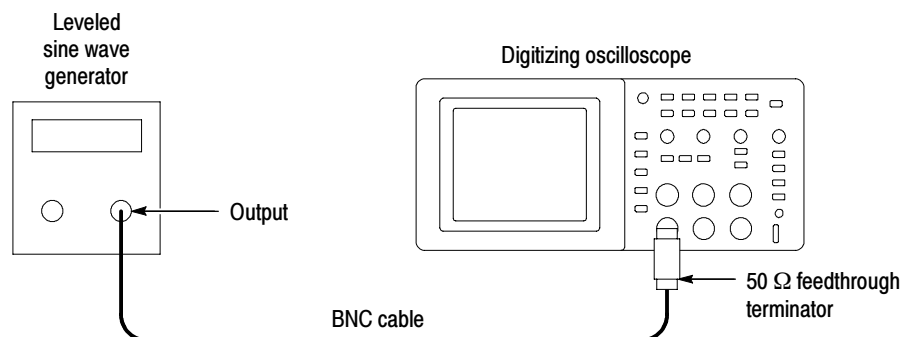
Check Bandwidth

This test checks the bandwidth of all input channels.

- Set up the oscilloscope using the following steps:

Push menu button	Select menu option	Select setting
DEFAULT SETUP	—	—
CH 1	Probe	1X
ACQUIRE	Average	16
TRIGGER	Coupling	Noise Reject
MEASURE	Source	Channel under test
	Type	Pk-Pk

- As shown below, connect the oscilloscope channel selected in the table to the leveled sine wave generator.



- Set the oscilloscope VOLTS/DIV to **500 mV/div**.
- Set the oscilloscope SEC/DIV to **10 μs/div**.

5. Set the leveled sine wave generator frequency to **50 kHz**.
6. Set the leveled sine wave generator output level so the peak-to-peak measurement is between **2.98 V** and **3.02 V**.
7. Set the leveled sine wave generator frequency to:
 - **40 MHz** if you are checking a TDS1001B
 - **60 MHz** if you are checking a TDS1002B, TDS2002B, or TDS2004B
 - **100 MHz** if you are checking a TDS1012B, TDS2012B, or TDS2014B
 - **200 MHz** if you are checking a TDS2022B, or TDS2024B
8. Set the oscilloscope SEC/DIV to **10 ns/div**.
9. Check that the peak-to-peak measurement is ≥ 2.12 V.
10. Disconnect the test setup.
11. Repeat steps 1 through 10 until all input channels have been checked.

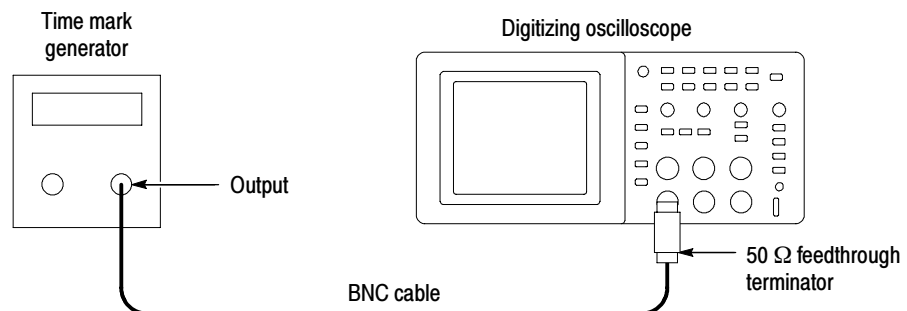
Check Sample Rate Accuracy and Delay Time Accuracy

This test checks the time base accuracy.

1. Set up the oscilloscope using the following steps:

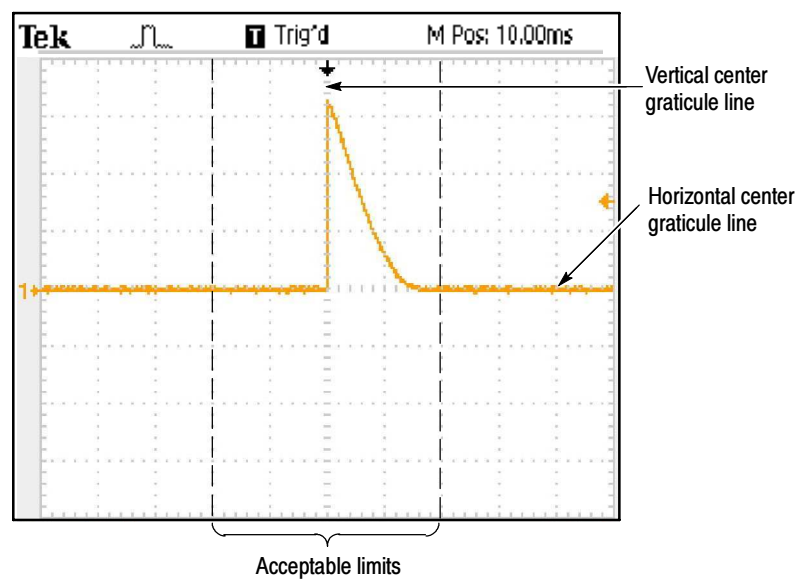
Push menu button	Select menu option	Select setting
DEFAULT SETUP	—	—
CH 1	Probe	1X

2. Connect the oscilloscope to the time mark generator as shown below.



3. Set the time mark generator period to **10 ms**.
4. Set the oscilloscope VOLTS/DIV to **500 mV/div**.

5. Set the oscilloscope Main SEC/DIV to **1 ms/div**.
6. Push **SET TO 50%**.
7. Use the vertical POSITION control to center the test signal on screen.
8. Use the horizontal POSITION control to set the position to **10.00 ms**.
9. Set the oscilloscope SEC/DIV to **250 ns/div**.
10. Check that the rising edge of the marker crosses the center horizontal graticule line within ± 2 divisions of the vertical center graticule line.



NOTE. One division of displacement from graticule center corresponds to a 25 ppm time base error.

11. Disconnect the test setup.

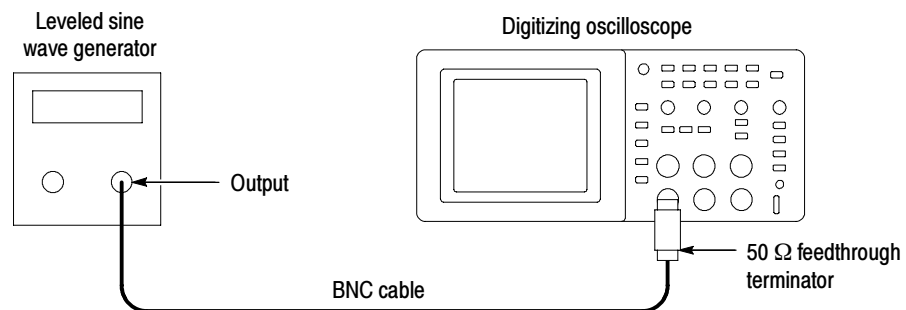
Check Edge Trigger Sensitivity

This test checks the edge trigger sensitivity for all input channels.

1. Set up the oscilloscope using the following steps:

Push menu button	Select menu option	Select setting
DEFAULT SETUP	—	—
CH 1	Probe	1X
TRIGGER	Mode	Normal
ACQUIRE	Sample	—
MEASURE	Source	Channel under test
	Type	Pk-Pk

2. As shown below, connect the oscilloscope channel selected in the table to the leveled sine wave generator.



3. Set the oscilloscope VOLTS/DIV to **500 mV/div**.
4. Set the oscilloscope SEC/DIV to **25 ns/div**.
5. Set the leveled sine wave generator frequency to **10 MHz**.
6. Set the leveled sine wave generator output level to approximately **500 mV_{p-p}** so that the measured amplitude is approximately **500 mV**. (The measured amplitude can fluctuate around 500 mV.)
7. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
8. Set the leveled sine wave generator frequency to:
 - **40 MHz** if you are checking a TDS1001B
 - **60 MHz** if you are checking a TDS1002B, TDS2002B, or TDS2004B

- **100 MHz** if you are checking a TDS1012B, TDS2012B, TDS2014B, TDS2022B, or TDS2024B
9. Set the oscilloscope SEC/DIV to **5 ns/div**.
 10. Set the leveled sine wave generator output level to approximately **750 mV_{p-p}** so that the measured amplitude is approximately **750 mV**. (The measured amplitude can fluctuate around 750 mV.)
 11. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
 12. For the TDS2022B and TDS2024B models, set the frequency to 200 MHz, and increase the amplitude to 1 V_{p-p}. Verify stable triggering.
 13. Set the oscilloscope SEC/DIV to **2.5 ns/div**.
 14. Change the oscilloscope setup using the following step:

Push menu button	Select menu option	Select setting
TRIGGER	Slope	Falling

15. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
16. Disconnect the test setup.
17. Repeat steps 1 through 16 until all input channels have been checked.

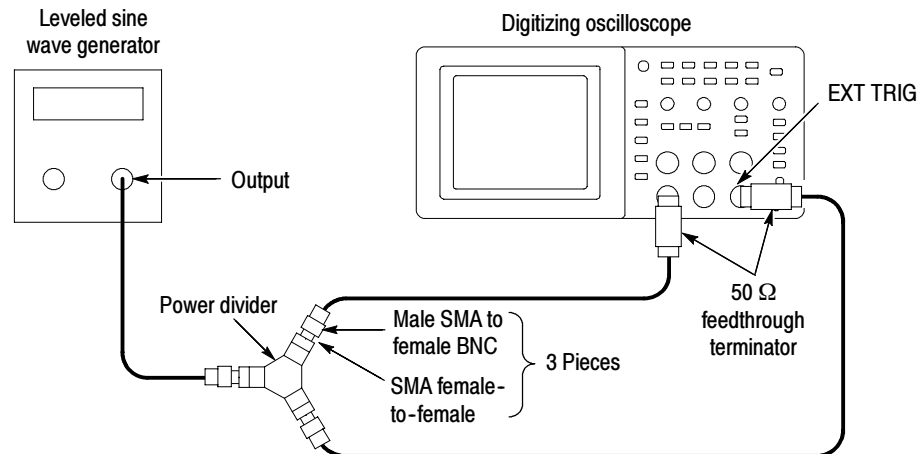
Check External Edge Trigger Sensitivity

This test checks the edge trigger sensitivity for the external trigger.

1. Set up the oscilloscope using the following steps:

Push menu button	Select menu option	Select setting
DEFAULT SETUP	—	—
CH 1	Probe	1X
TRIGGER	Source	Ext
	Mode	Normal
ACQUIRE	Sample	—
MEASURE	Source	CH1
	Type	Pk-Pk

2. Connect the oscilloscope to the leveled sine wave generator as shown below using CH 1 and EXT TRIG.



3. Set the oscilloscope VOLTS/DIV to **100 mV/div**.
4. Set the oscilloscope SEC/DIV to **25 ns/div**.
5. Set the leveled sine wave generator frequency to **10 MHz**.
6. Set the sine wave generator output level to approximately **300 mV_{p-p}** into the power splitter. This will be about **200 mV_{p-p}** on CH1 of the oscilloscope.
The EXT TRIG input will also be receiving approximately 200 mV_{p-p}. Small deviations from the nominal 200 mV_{p-p} oscilloscope display are acceptable.
7. Set the leveled sine wave generator frequency to:
 - **40 MHz** if you are checking a TDS1001B
 - **60 MHz** if you are checking a TDS1002B, TDS2002B, or TDS2004B
 - **100 MHz** if you are checking a TDS1012B, TDS2012B, TDS2014B, TDS2022B, or TDS2024B
8. Set the oscilloscope SEC/DIV to **5 ns/div**.
9. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
10. For TDS2022B and TDS2024B models, set the sine wave generator output level for a CH 1 display to approximately **350 mV_{p-p}**.
11. For TDS2022B and TDS2024B models, set the sine wave generator frequency to **200 MHz**.

12. Set the oscilloscope SEC/DIV to **2.5 ns/div**.
13. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
14. Change the oscilloscope setup using the following step:

Push menu button	Select menu option	Select setting
TRIGGER	Slope	Falling

15. Push **SET TO 50%**. Adjust **TRIGGER LEVEL** as necessary and then check that triggering is stable.
16. Disconnect the test setup.

Check Vertical Position Accuracy

The results of this test and the DC Gain Accuracy test together define the DC Measurement Accuracy of the oscilloscope. The DC Measurement Accuracy specification encompasses two different ranges of operation over two different attenuator settings:

- DC Gain Accuracy: Identifies errors, mostly from the A/D converter, when the vertical position (known as offset in these oscilloscopes) is set to 0 divisions (or a grounded input will show screen center)
- Vertical Position Accuracy: Identifies errors, mostly from the position control, made when the vertical position is set to a non-zero value

The two attenuator settings operate identically, so verification of the attenuation range from -1.8 V to 1.8 V also verifies the attenuation range of -45 V to 45 V.

To set up the test, follow these steps:

1. Set up the oscilloscope as shown in the next table.

Push menu button	Select menu option	Select setting
DEFAULT SETUP	—	—
CH 1, CH 2, CH 3, CH 4	Probe	1X
CH 1, CH 2, CH 3, CH 4	Volts/Div	50 mV/div
TRIGGER	Source	Ext*
	Mode	Auto
ACQUIRE	Sample	—

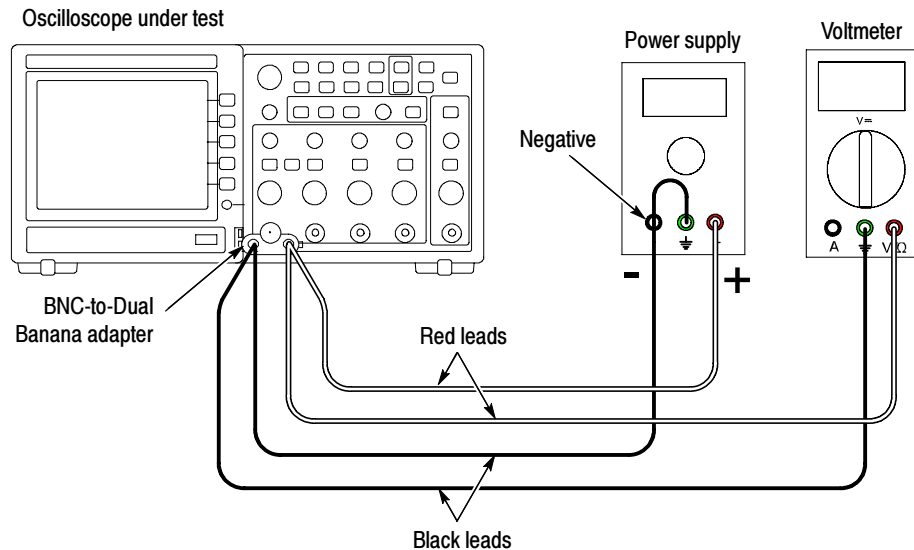
Push menu button	Select menu option	Select setting
MEASURE	Source	Channel under test
	Type	Mean

* The test operates without a trigger. To maintain uniformity and to avoid false triggering on noise, the Ext trigger is the recommended source.

- Make a spreadsheet approximately as shown in the example in Appendix A. You only need to enter the values for column A and the equations. The values in columns B, C, D, E, F, and G are examples of the measured or calculated values.

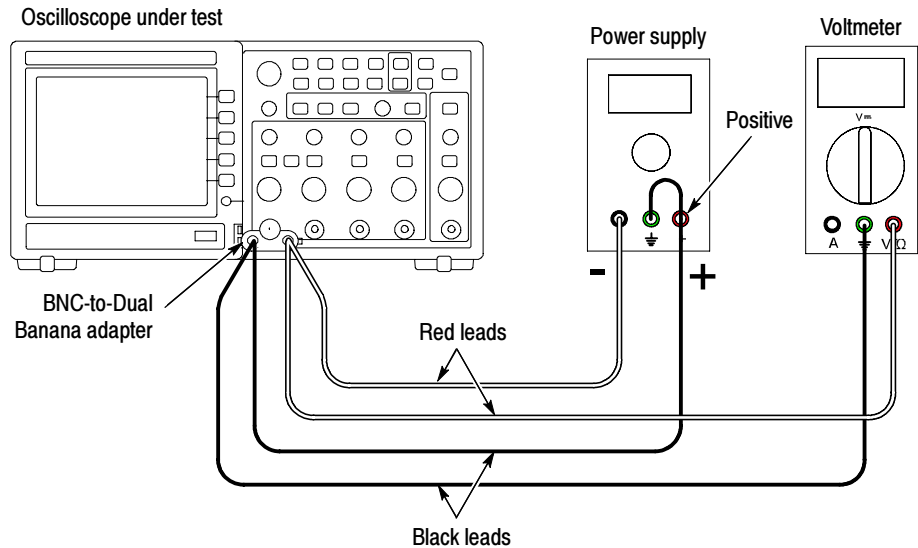
The PDF version of the TDS1000B and TDS2000B service manual (which you can download from the www.tektronix.com Web site), includes an empty spreadsheet for your convenience. To access and save the test spreadsheet, see the instructions in *Appendix A: Example of a Vertical Position Accuracy Test Spreadsheet* on page A-1.

- Connect the oscilloscope, power supply and voltmeter as shown next.



- Set the power supply to the 1.8 V value shown in column A, the Approximate Test Voltage.
- Adjust the vertical position knob for the DC line to position the line in the center of the screen.
- Enter the voltage on the voltmeter and on the oscilloscope into the spreadsheet in the appropriate columns, B and C.
- Repeat steps 4 through 6 for the values of 1.76 V through 0 V.

8. Swap the connections to the positive terminal of the power supply with those at the negative terminal as shown next.



9. Repeat steps 4 through 6 for the values of -0.04 V through -1.8 V.
10. Enter the Minimum Margin number (cell I16) for the channel tested in the test record.
11. Repeat steps 1 through 10 until all input channels have been checked.

Data Verification. To verify data, set the spreadsheet to present a line graph of columns D, E, and F. Verify that no error values (the blue line in the center) go above the yellow line (upper line), or below the purple line (lower line). For calculations involved in this example, refer to the data in the previous table.

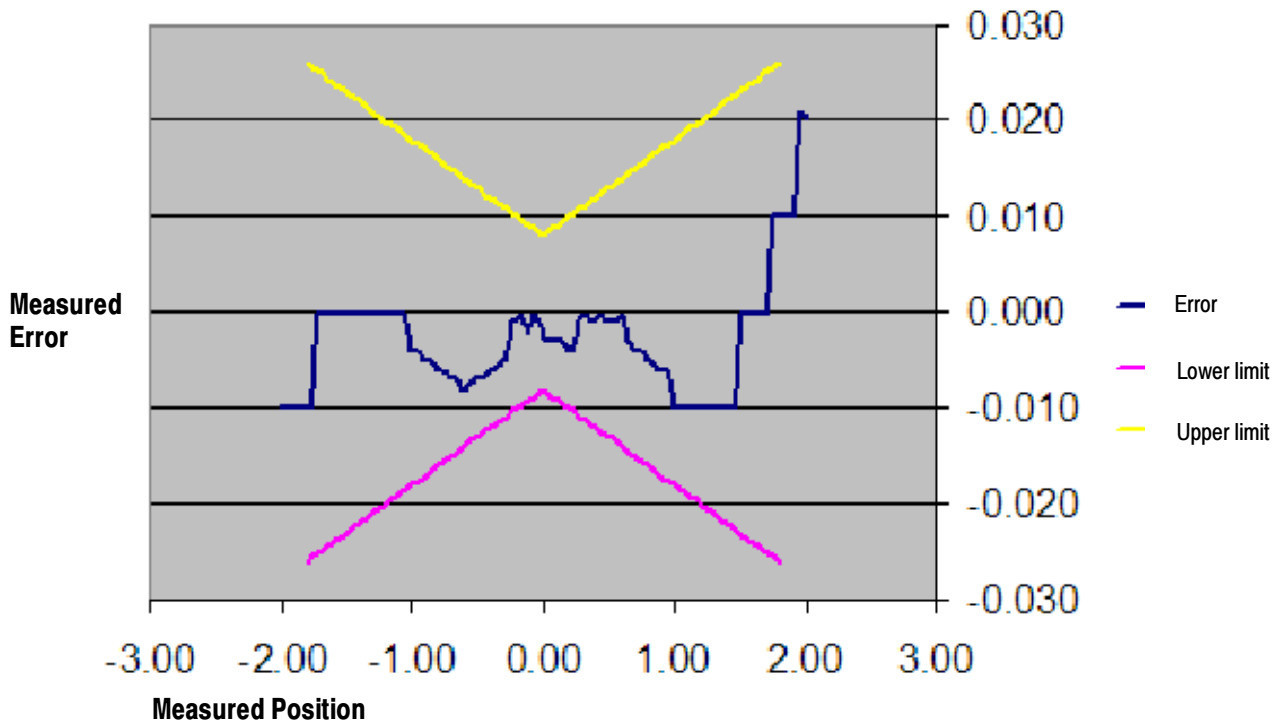


Figure 4- 1: Example of a line graph for the Vertical Position Accuracy test



Adjustment Procedures

Adjustment Procedures

This chapter contains adjustment procedures for the TDS1000B and TDS2000B series oscilloscopes.

Only qualified personnel should perform service procedures. Read the *Service Safety Summary* and the *General Safety Summary* at the beginning of this manual before performing any service procedures. Also refer to the user manual for information about using the TDS1000B and TDS2000B oscilloscopes.

NOTE. *The voltage references inside the TDS1000B and TDS2000B oscilloscopes are very stable over time and should not require routine updates. Before performing any procedure in this chapter, first verify that the oscilloscope does not meet specifications. Refer to the chapter Performance Verification to verify the specifications.*

Required Equipment

The equipment described in Table 5-1, or a suitable equivalent, is required to complete these procedures.

Table 5-1: Required equipment

Description	Minimum requirements	Examples
DC Voltage Source	-20 V to 20 V, $\pm 0.1\%$ accuracy	Wavetek 9100 Universal Calibration System with Oscilloscope Calibration Module (Option 250)
Leveled Sinewave Generator	5 kHz and 200 MHz, $\pm 0.6\%$ amplitude accuracy	Fluke 5500A Multi-product Calibrator with Oscilloscope Calibration Option (Option 5500A-SC)
50 Ω BNC Cable	BNC male to BNC male, ≈ 1 m (36 in) long	Tektronix part number 012-0482-XX
50 Ω BNC Cable (seven)	BNC male to BNC male, ≈ 25 cm (10 in) long	Tektronix part number 012-0208-XX
50 Ω Feedthrough Termination	BNC male and female connectors	Tektronix part number 011-0049-XX

Table 5-1: Required equipment (Cont.)

Description	Minimum requirements	Examples
Dual Banana to BNC Adapter	Banana plugs to BNC female	Tektronix part number 103-0090-XX
BNC T (three)	One male and two female BNC connectors	Tektronix part number 103-0030-XX

Adjustment Procedure

The adjustment procedure consists of 70 steps for the two-channel oscilloscope, and 106 steps for the four-channel model. Each step requires an external voltage source for new calibration constants.

Before performing the adjustment procedure, warm up the oscilloscope for at least ten minutes in an ambient temperature between 20 °C and 30 °C. Adjustments performed prior to warm-up or outside this temperature range may result in poor performance.

If all steps in the procedure are completed successfully, a “Pass” message is displayed and the new calibration constants take affect. If any step fails, the procedure is aborted and the current calibration is not affected. You can choose to abort the procedure at any step, without affecting the current calibration, by selecting FCAL ABORT.

NOTE. While performing the adjustment procedure, keep in mind that some of the steps take a significant amount of time (up to 5 minutes) to complete.

The equipment setups, shown in Figure 5-1, are required to complete the adjustment procedure. Table 5-2 on page 5-6 lists the steps in the procedure and the signal requirement for each step.

Enable the Service Menu

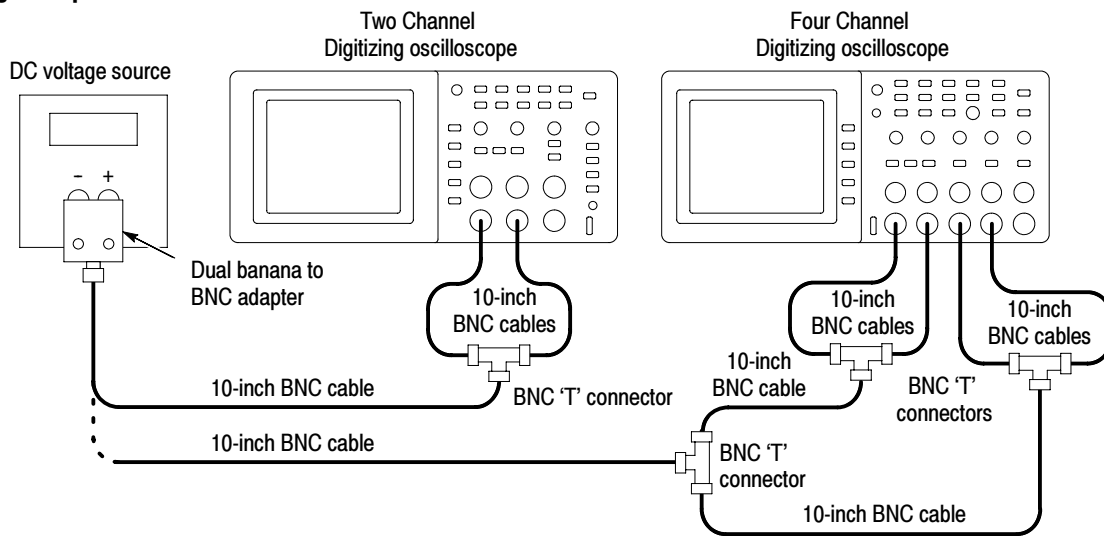
You must enable the Service menu to perform the adjustment procedure. To do this:

1. Power on the oscilloscope.
2. Push the front-panel **MEASURE** button to access the MEASURE menu.
3. Push the top option button to access the Measure 1 menu.
4. Push and hold the front-panel **SINGLE SEQ** button.
5. Push and hold the front-panel **AUTOSET** button.
6. Wait at least two seconds.

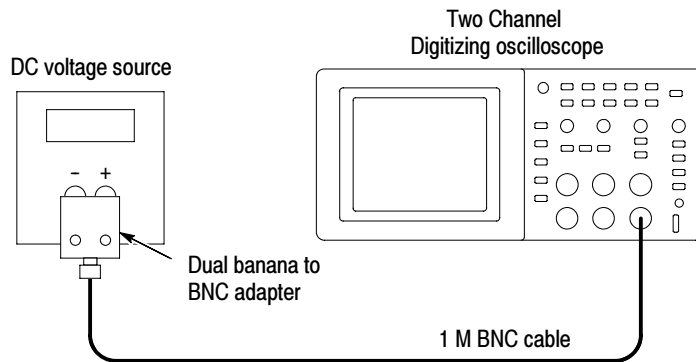
7. Release the **SINGLE SEQ** button.
8. Release the **AUTOSET** button. A message appears in the lower left corner of the screen stating “Service mode ON.”
9. Push the front-panel **UTILITY** button. The last item in the Utility menu is now “Service.”

At completion of the Adjust procedure disable the “Service” menu through the **UTILITY** front panel button, the “Service” option button, and the “Service” Mode Off” option button.

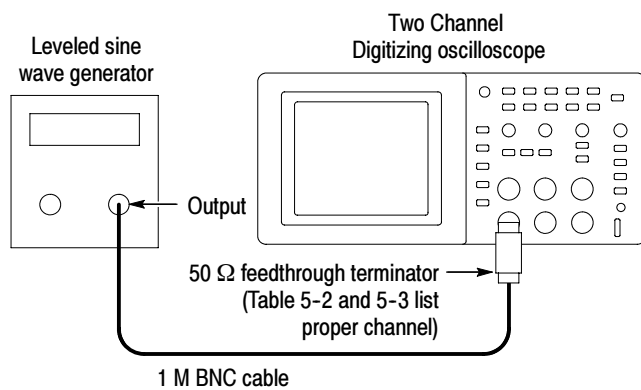
DC voltage setup 1



DC voltage setup 2



Sinewave generator setup



Edge setup

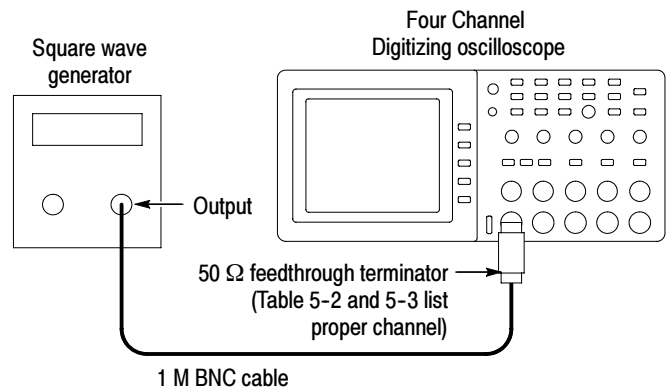


Figure 5-1: Adjustment setups

Adjustment Procedure

Use this procedure to load new calibration constants.

1. Enable the Service menu as described on page 5-2.
2. Push the **Service** option button.
3. Push the **Factory Cal** option button.
4. Push the **Warmup Timer** option button.
5. Push the **Start Timer** option button to ensure a 10-minute warm up. After 10 minutes pass, the oscilloscope displays a large black or green cross.
6. Press the front-panel **UTILITY** button and push the **Service** option button.
7. Push the **Factory Cal** option button.
8. Push the **FCAL INIT** option button to initiate the factory calibration routine. You are now in step 1 of the procedure.
9. As indicated by Step 1 in Table 5-2, connect a 0.0 V_{DC} source to the channel inputs.
10. Press **FCAL STEP** to load the calibration constant for step 1.
11. Follow the screen prompts along with Table 5-2 for the remainder of the routine, applying the proper signal for each step.

NOTE. *During some steps, the oscilloscope may appear to be idle for several minutes while it is processing information internally. You must wait for the screen prompt to continue.*

If any step in the procedure fails, the procedure terminates. Failure will result if an incorrect signal source is connected. If this happens, you must start the procedure over from the beginning.

If the procedure completes successfully, a “Pass” message is displayed and the new adjustment takes effect.

12. Compensate the signal path by performing the self-calibration routine. Disconnect any probes or cables from the channel input connectors. Then, press the **UTILITY** button and select **Do Self Cal** to confirm that you are ready to proceed.
13. Disable the Service menu option by pushing the **UTILITY** front-panel button, and the **Service** and **Service Mode Off** option buttons.

Table 5-2: Adjustment steps

Step number (Two-channel models)	Step number (Four-channel models)	Signal	Signal source setting	Input
Refer to the DC voltage setup 1 diagram				
1	1	DC Voltage 1	0.0 V	CH1 through CHx
2	2	DC Voltage 1	-20.0 V	
3	3	DC Voltage 1	-2.0 V	
4	4	DC Voltage 1	-1.6 V	
5	5	DC Voltage 1	-1.2 V	
6	6	DC Voltage 1	-0.8 V	
7	7	DC Voltage 1	-0.4 V	
8	8	DC Voltage 1	-0.32 V	
9	9	DC Voltage 1	-0.2 V	
10	10	DC Voltage 1	-0.16 V	
11	11	DC Voltage 1	-0.08 V	
12	12	DC Voltage 1	-0.04 V	
13	13	DC Voltage 1	-0.03 V	
14	14	DC Voltage 1	-0.02 V	
15	15	DC Voltage 1	-0.015 V	
16	16	DC Voltage 1	0.015 V	
17	17	DC Voltage 1	0.02 V	
18	18	DC Voltage 1	0.03 V	
19	19	DC Voltage 1	0.04 V	
20	20	DC Voltage 1	0.08 V	
21	21	DC Voltage 1	0.16 V	
22	22	DC Voltage 1	0.2 V	
23	23	DC Voltage 1	0.32 V	
24	24	DC Voltage 1	0.4 V	
25	25	DC Voltage 1	0.8 V	
26	26	DC Voltage 1	1.2 V	
27	27	DC Voltage 1	1.6 V	
28	28	DC Voltage 1	2.0 V	
29	29	DC Voltage 1	20.0 V	
30	30	DC Voltage 1	0.0 V	

Table 5-2: Adjustment steps (Cont.)

Step number (Two-channel models)	Step number (Four-channel models)	Signal	Signal source setting	Input
Refer to the DC voltage setup 2 diagram				
31	31	DC Voltage 2	-5.0 V	EXT TRIG
32	32	DC Voltage 2	-1.0 V	
33	33	DC Voltage 2	1.0 V	
34	34	DC Voltage 2	5.0 V	
Refer to the Sinewave generator setup diagram. BWL refers to the maximum bandwidth of the oscilloscope.				
35	35	Sinewave Generator, 50 Ohm	5 kHz, 1 V _{p-p}	CH1
36	36	Sinewave Generator, 50 Ohm	1 MHz, 100 mV _{p-p}	
37	37	Sinewave Generator, 50 Ohm	1 MHz, 1 V _{p-p}	
38	38	Sinewave Generator, 50 Ohm	50 kHz, 1 V _{p-p}	
39	39	Sinewave Generator, 50 Ohm	20 MHz, 1 V _{p-p}	
40	40	Sinewave Generator, 50 Ohm	BWL, 25 mV _{p-p}	
41	41	Sinewave Generator, 50 Ohm	BWL, 50 mV _{p-p}	
42	42	Sinewave Generator, 50 Ohm	BWL, 100 mV _{p-p}	
43	43	Sinewave Generator, 50 Ohm	BWL, 250 mV _{p-p}	
44	44	Sinewave Generator, 50 Ohm	BWL, 500 mV _{p-p}	
45	40	Sinewave Generator, 50 Ohm	BWL, 1 V _{p-p}	
46	46	Sinewave Generator, 50 Ohm	5 kHz, 2.5 V _{p-p}	
47	47	Sinewave Generator, 50 Ohm	1 MHz, 2.5 V _{p-p}	
48	48	Sinewave Generator, 50 Ohm	50 kHz, 2.5 V _{p-p}	
49	49	Sinewave Generator, 50 Ohm	20 MHz, 2.5 V _{p-p}	
50	50	Sinewave Generator, 50 Ohm	BWL, 2.5 V _{p-p}	
51	51	Sinewave Generator, 50 Ohm	BWL, 5 V _{p-p}	
52	52	Sinewave Generator, 50 Ohm	BWL, 1.6 V _{p-p}	
53	53	Edge, 50 Ohm. Refer to Edge setup diagram.	1 kHz, 0 to -800 mV	

Table 5-2: Adjustment steps (Cont.)

Step number (Two-channel models)	Step number (Four-channel models)	Signal	Signal source setting	Input
54	54	Sinewave Generator, 50 Ohm	5 kHz, 1 V _{p-p}	CH2
55	55	Sinewave Generator, 50 Ohm	1 MHz, 100 mV _{p-p}	
56	56	Sinewave Generator, 50 Ohm	1 MHz, 1 V _{p-p}	
57	57	Sinewave Generator, 50 Ohm	50 kHz, 1 V _{p-p}	
58	58	Sinewave Generator, 50 Ohm	20 MHz, 1 V _{p-p}	
59	59	Sinewave Generator, 50 Ohm	BWL, 25 mV _{p-p}	
60	60	Sinewave Generator, 50 Ohm	BWL, 50 mV _{p-p}	
61	61	Sinewave Generator, 50 Ohm	BWL, 100 mV _{p-p}	
62	62	Sinewave Generator, 50 Ohm	BWL, 250 mV _{p-p}	
63	63	Sinewave Generator, 50 Ohm	BWL, 500 mV _{p-p}	
64	64	Sinewave Generator, 50 Ohm	BWL, 1 V _{p-p}	
65	65	Sinewave Generator, 50 Ohm	5 kHz, 2.5 V _{p-p}	
66	66	Sinewave Generator, 50 Ohm	1 MHz, 2.5 V _{p-p}	
67	67	Sinewave Generator, 50 Ohm	50 kHz, 2.5 V _{p-p}	
68	68	Sinewave Generator, 50 Ohm	20 MHz, 2.5 V _{p-p}	
69	69	Sinewave Generator, 50 Ohm	BWL, 2.5 V _{p-p}	
70	70	Sinewave Generator, 50 Ohm	BWL, 5 V _{p-p}	

Table 5-2: Adjustment steps (Cont.)

Step number (Two-channel models)	Step number (Four-channel models)	Signal	Signal source setting	Input
NA	71	Sinewave Generator, 50 Ohm	5 kHz, 1 V _{p-p}	CH3
	72	Sinewave Generator, 50 Ohm	1 MHz, 100 mV _{p-p}	
	73	Sinewave Generator, 50 Ohm	1 MHz, 1 V _{p-p}	
	74	Sinewave Generator, 50 Ohm	50 kHz, 1 V _{p-p}	
	75	Sinewave Generator, 50 Ohm	20 MHz, 1 V _{p-p}	
	76	Sinewave Generator, 50 Ohm	BWL, 25 mV _{p-p}	
	77	Sinewave Generator, 50 Ohm	BWL, 50 mV _{p-p}	
	78	Sinewave Generator, 50 Ohm	BWL, 100 mV _{p-p}	
	79	Sinewave Generator, 50 Ohm	BWL, 250 mV _{p-p}	
	80	Sinewave Generator, 50 Ohm	BWL, 500 mV _{p-p}	
	81	Sinewave Generator, 50 Ohm	BWL, 1 V _{p-p}	
	82	Sinewave Generator, 50 Ohm	5 kHz, 2.5 V _{p-p}	
	83	Sinewave Generator, 50 Ohm	1 MHz, 2.5 V _{p-p}	
	84	Sinewave Generator, 50 Ohm	50 kHz, 2.5 V _{p-p}	
	85	Sinewave Generator, 50 Ohm	20 MHz, 2.5 V _{p-p}	
	86	Sinewave Generator, 50 Ohm	BWL, 2.5 V _{p-p}	
	87	Sinewave Generator, 50 Ohm	BWL, 5 V _{p-p}	
	88	Sinewave Generator, 50 Ohm	BWL, 1.6 V _{p-p}	
	89	Edge, 50 Ohm. Refer to the Edge setup diagram.	1 kHz, 0 to -800 mV	

Table 5-2: Adjustment steps (Cont.)

Step number (Two-channel models)	Step number (Four-channel models)	Signal	Signal source setting	Input
NA	90	Sinewave Generator, 50 Ohm	5 kHz, 1 V _{p-p}	CH4
	91	Sinewave Generator, 50 Ohm	1 MHz, 100 mV _{p-p}	
	92	Sinewave Generator, 50 Ohm	1 MHz, 1 V _{p-p}	
	93	Sinewave Generator, 50 Ohm	50 kHz, 1 V _{p-p}	
	94	Sinewave Generator, 50 Ohm	20 MHz, 1 V _{p-p}	
	95	Sinewave Generator, 50 Ohm	BWL, 25 mV _{p-p}	
	96	Sinewave Generator, 50 Ohm	BWL, 50 mV _{p-p}	
	97	Sinewave Generator, 50 Ohm	BWL, 100 mV _{p-p}	
	98	Sinewave Generator, 50 Ohm	BWL, 250 mV _{p-p}	
	99	Sinewave Generator, 50 Ohm	BWL, 500 mV _{p-p}	
	100	Sinewave Generator, 50 Ohm	BWL, 1 V _{p-p}	
	101	Sinewave Generator, 50 Ohm	5 kHz, 2.5 V _{p-p}	
	102	Sinewave Generator, 50 Ohm	1 MHz, 2.5 V _{p-p}	
	103	Sinewave Generator, 50 Ohm	50 kHz, 2.5 V _{p-p}	
	104	Sinewave Generator, 50 Ohm	20 MHz, 2.5 V _{p-p}	
	105	Sinewave Generator, 50 Ohm	BWL, 2.5 V _{p-p}	
106	Sinewave Generator, 50 Ohm	BWL, 5 V _{p-p}		



Maintenance

Maintenance

This chapter contains the information needed to do periodic and corrective maintenance on the oscilloscope, as well as repackaging instructions if you need to return the oscilloscope to Tektronix for service.

Preventing ESD

Before servicing this product, read the *Safety Summary* and *Introduction* at the front of the manual and the electrostatic discharge (ESD) information below.



CAUTION. *Static discharge can damage any semiconductor component in this oscilloscope.*

When performing any service which requires internal access to the oscilloscope, adhere to the following precautions. These precautions help you avoid damaging internal modules and their components due to electrostatic discharge (ESD).

- Minimize handling of static-sensitive modules.
- Transport and store static-sensitive modules in their static protected containers or on a metal rail. Label any package that contains static-sensitive modules.
- Discharge the static voltage from your body by wearing a grounded antistatic wrist strap while handling these modules.
- Service static-sensitive modules only at static-free workstations. Do not allow anything capable of generating or holding a static charge on the workstation surface.
- Handle circuit boards by the edges when possible.
- Do not slide the modules over any surface.
- Avoid handling modules in areas that have a floor or work-surface covering capable of generating a static charge.

Inspection and Cleaning

Inspection and cleaning are done as preventive maintenance. Preventive maintenance, when done regularly, may prevent oscilloscope malfunction and enhance its reliability.

Preventive maintenance consists of visually inspecting and cleaning the oscilloscope, and using general care when operating it. How often you do maintenance depends on the severity of the environment in which you use the oscilloscope. A good time to perform preventive maintenance is just before adjustment of the oscilloscope.

General Care

For optimum performance, follow these recommendations:

- Protect the oscilloscope from adverse weather conditions. The oscilloscope is not waterproof.
- Do not store or leave the oscilloscope where the liquid crystal display (LCD) will be exposed to direct sunlight or high humidity for long periods of time.
- The front and rear cases help keep dust out of the oscilloscope and must be in place during normal operation.
- To avoid damage to the oscilloscope or probes, do not expose them to any sprays, liquids, or solvents.

Interior Cleaning

Use a dry, low-velocity stream of air to clean the interior of the chassis. Use a soft-bristle, non-static-producing brush for cleaning around components. If you must use a liquid for minor interior cleaning, use a 75% isopropyl alcohol solution and rinse with deionized water.



WARNING. *To avoid injury, power down the instrument and disconnect it from line voltage before performing any procedure that follows.*

Exterior Cleaning

Clean the exterior surfaces of the chassis with a dry lint-free cloth or a soft-bristle brush. If any dirt remains, use a cloth or swab dipped in a 75% isopropyl alcohol solution. Use a swab to clean narrow spaces around controls and connectors. Do not use abrasive compounds on any part of the chassis that may damage the chassis.

Clean the On/Standby switch using a dampened cleaning towel. Do not spray or wet the switch directly.



CAUTION. Avoid the use of chemical cleaning agents, which might damage the plastics used in this oscilloscope. Use only deionized water when cleaning the menu buttons or front-panel buttons. Use a 75% isopropyl alcohol solution as a cleaner and rinse with deionized water. Before using any other type of cleaner, consult your Tektronix Service Center or representative.

Exterior Inspection

Inspect the outside of the oscilloscope for damage, wear, and missing parts, using Table 6-1 as a guide. Immediately repair defects that could cause personal injury or lead to further damage to the oscilloscope.

Table 6-1: External inspection check list

Item	Inspect for	Repair action
Front and rear case	Cracks, scratches, deformations, damaged hardware	Repair or replace defective module
Front-panel knobs	Missing, damaged, or loose knobs	Repair or replace missing or defective knobs
Connectors	Broken shells, cracked insulation, and deformed contacts. Dirt in connectors	Repair or replace defective modules. Clear or wash out dirt.
Carrying handle, and cabinet feet	Correct operation	Repair or replace defective module
Accessories	Missing items or parts of items, bent pins, broken or frayed cables, and damaged connectors	Repair or replace damaged or missing items, frayed cables, and defective modules

If the display is very dirty, moisten the wipe with distilled water or a 75% isopropyl alcohol solution and gently rub the display surface. Avoid using excess force or you may damage the plastic display surface.



CAUTION. To prevent getting moisture inside the oscilloscope during external cleaning, use only enough liquid to dampen the cloth or applicator.

Interior Inspection

To access the inside of the oscilloscope for inspection and cleaning, refer to the *Removal Procedures* in this section.

Use Table 6-2 as a guide to inspect the internal portions of the oscilloscope for damage and wear. Repair any defects immediately.

If any circuit board is repaired or replaced, check Table 6-2 to see if it is necessary to adjust the oscilloscope.



CAUTION. To prevent damage from electrical arcing, ensure that circuit boards and components are dry before applying power to the oscilloscope.

Table 6-2: Internal inspection check list

Item	Inspect for	Repair action
Circuit boards	Loose, broken, or corroded solder connections. Burned circuit boards. Burned, broken, or cracked circuit-run plating.	Remove and replace damaged circuit board.
Resistors	Burned, cracked, broken, blistered condition.	Remove and replace damaged circuit board.
Solder connections	Cold solder or rosin joints.	Resolder joint and clean with isopropyl alcohol.
Capacitors	Damaged or leaking cases. Corroded solder on leads or terminals.	Remove and replace damaged circuit board.
Wiring and cables	Loose plugs or connectors. Burned, broken, or frayed wiring.	Firmly seat connectors. Repair or replace modules with defective wires or cables.
Chassis	Dents, deformations, and damaged hardware.	Straighten, repair, or replace defective hardware.

Cleaning Procedure, Interior. To clean the oscilloscope interior, perform the following steps:

1. Blow off dust with dry, low-pressure, deionized air (approximately 9 psi).
2. Remove any remaining dust with a lint-free cloth dampened in isopropyl alcohol (75% solution) and then wipe with a lint-free cloth dampened with warm deionized water. A cotton-tipped applicator is useful for cleaning in narrow spaces and on circuit boards.

STOP. If, after performing steps 1 and 2, a module is clean upon inspection, skip steps 3, 4, and 5. Proceed with step 6.

3. If steps 1 and 2 do not remove all the dust or dirt, all modules in the oscilloscope except the Display Module and Front Panel Module may be spray washed using a solution of 75% isopropyl alcohol.
 - During cleaning of the Acquisition board (main board), use care to assure that no residue is left in the attenuators. Debris or residue can cause a number of problems with signal fidelity that cannot be corrected by calibration. When handling the board, avoid handling the attenuators since skin oils may cause problems.
 - Extensive cleaning of the Display Module is difficult because water must not be trapped between the display shield and the display. The polarizers integrated into the display degrade with long-term exposure to water. The display shield and display must be replaced as an assembly if significant moisture or debris become trapped inside. Cotton tipped applicators and lint-free rags moistened in isopropyl alcohol and/or deionized water offer the best cleaning with the least opportunity for damage to the assembly.
 - The Front Panel module can be damaged by deposition of film or debris inside the knob encoders. To avoid this, care must be taken to not drip liquid or blow debris into the encoders.
4. Spray wash dirty parts with the 75% isopropyl alcohol solution and wait 60 seconds for the majority of the alcohol to evaporate.
5. Use hot (49 °C to 60 °C / 120 °F to 140 °F) deionized water to thoroughly rinse the parts.
6. Dry all parts with low-pressure, deionized air.
7. Dry all components and assemblies in an oven or drying compartment using low-temperature (52 °C to 66 °C / 125 °F to 150 °F) circulating air.

Lubrication. Periodic lubrication is not required for the oscilloscope.

Removal and Installation Procedures

Refer to Figures 6-1 and 6-2 for the location of modules that you are removing or installing. If you are disassembling the instrument for cleaning, refer to the *Inspection and Cleaning* procedure on page 6-2 for instructions.

List of Modules

The *Replaceable Parts List* provides a list of all replaceable modules. Any replaceable component, assembly, or part is referred to by the term module.



WARNING. Only qualified personnel should perform service procedures. Before doing this or any other procedure in this manual, read the General Safety Summary and Service Safety Summary found at the beginning of this manual. To prevent damage to electrical components, read Preventing ESD on page 6-1.

Always disconnect the power cord before disassembling any portion of the oscilloscope.

Summary of Procedures

Complete disassembly is best achieved by following the procedures in the order given in Table 6-3.

Table 6-3: List of procedures

Procedure	Begins on page
Rear Feet	6-8
Flip Feet	6-8
Front-Panel Knobs and Power Button	6-9
Rear Case	6-9
Front Feet	6-10
Power Supply Module	6-11
Internal Assembly	6-12
Display Cable	6-12
Front-Panel Cable	6-14
Main Board Module	6-15
Color Display Module	6-16
Monochrome Display Module	6-16
Front-Panel Module	6-18
Keypad	6-18
Front Case	6-19

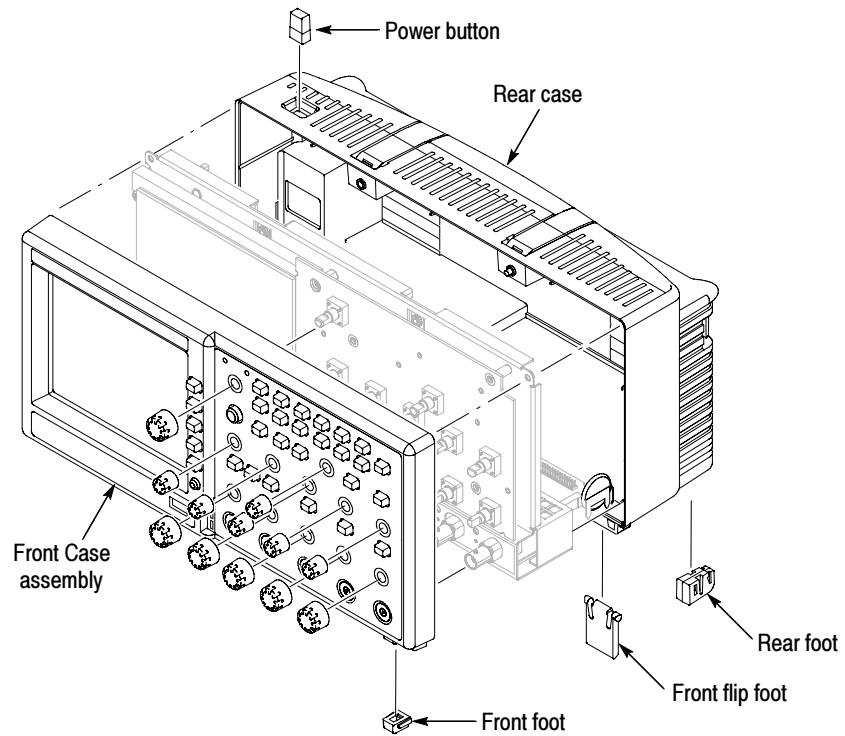


Figure 6-1: Locator for trim and cabinet removal

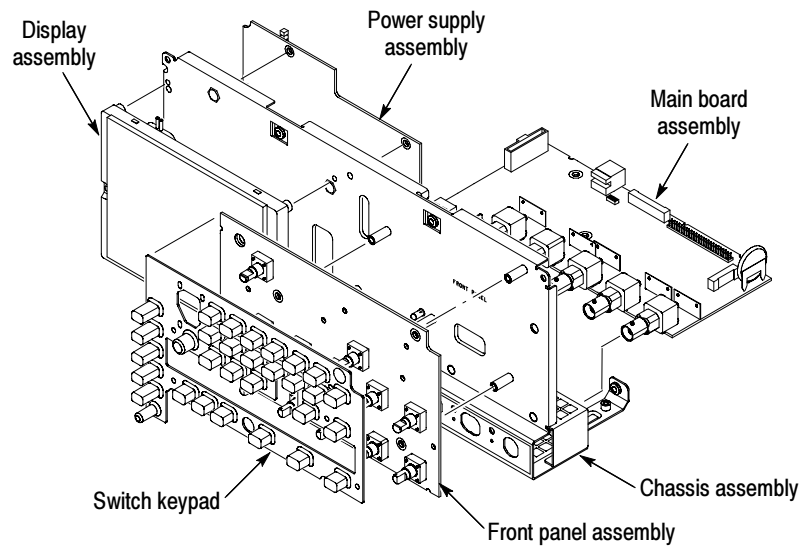


Figure 6-2: Locator for internal modules

Required Tools

Use the following tools to remove and replace all modules in the oscilloscope:

- Torque-limiting screwdriver, long shank, 12 in-lb (1.3 N·m) range with Torx® T-15 tip; if you use a magnetic screwdriver with interchangeable bits, the T-15 bit must be a long bit, at least 5 cm (2 in) overall length
- Torque-limiting screwdriver with Torx T-8 bit
- 5/8 inch deep socket with wide center hole (S·K Hand Tool Corp., S-K #40820, or equivalent)
- Torque wrench to 40 in-lb (4.5 N·m)
- Screwdriver with 1/4 inch flat blade
- Pliers (all-purpose and needle-nose)
- Sharp knife (X-ACTO® knife or equivalent)
- 3M Electrical Tape 92 with 1-mil polyimide Kapton backing, temperature rated 180 °C, UL510 Flame Retarded

Rear Feet

You will need a flat-blade screwdriver to remove the rear feet.

Removal. To remove the rear feet, refer to Figure 8-4 and follow these steps:

1. Place the oscilloscope face down on a soft surface such as an anti-static mat.
2. Use a flat-blade screwdriver to pry out the foot, or twist the foot as you are removing it so that it disengages from the guides. Use care not to mar the surface of the rear case.

Installation. To install the rear feet, refer to Figure 8-4 and follow these steps:

1. Place the oscilloscope face down on a soft surface such as an anti-static mat.
2. Align the slots of the rear foot with the guides in the rear case and press the foot in.

Flip Feet

You will need a pair of needle-nose pliers to remove the flip feet.

Removal. To remove the flip feet, refer to Figure 8-4 and follow these steps:

1. Place the oscilloscope face down on a soft surface such as an anti-static mat.
2. Grip the flip foot with the pliers as close to the notches as possible and squeeze gently on the foot.
3. Twist slightly to swing one hinge free of the slot.

Installation. To install the flip feet, refer to Figure 8-4, and follow these steps:

1. Place the oscilloscope face down on a soft surface such as an anti-static mat.
2. Hold the flip foot with the smooth side facing down.
3. Gently squeeze the foot so that the hinge on one side fits into the slot, and twist slightly to snap into the slot on the other side.

Front-Panel Knobs

Remove each front-panel knob by firmly grasping the knob (with pliers if necessary) and pulling it away from the front panel.

NOTE. *Wrap the plier jaws with tape (such as electrical) to avoid marring the knob surface.*

Install front-panel knobs by aligning the keyed knob with the shaft and pressing the knob onto the shaft.

Power Button

Remove the power button by firmly grasping the button with pliers, and pull it straight out of the cabinet.

NOTE. *Wrap the plier jaws with tape (such as electrical) to avoid marring the button surface.*

Install the button by pressing it onto the power button shaft until it snaps into place.

Rear Case

You will need a torque-limiting Torx T-15 screwdriver and pliers for this procedure.

Removal. To remove the rear case, refer to Figure 8-4, and follow these steps:

1. Remove the power button using the procedure on page 6-9.
2. Place the oscilloscope face down on a soft surface such as an anti-static mat.
3. Remove the five screws located on the rear case. Tilt the handle to gain better access to the top two screws.
4. Lift the rear case off of the oscilloscope.

Installation. Use this procedure to install the rear case.

1. Place the oscilloscope face down on a soft surface (such as an anti-static mat).
2. Place the rear case onto the assembled oscilloscope and ensure that:
 - All of the edges align with the front case.
 - The Li-ION battery is vertical in the battery location.
 - The slots align near the USB connector and near the battery.



CAUTION. *Be careful not to pinch any wires or other parts between the front and rear cases.*

3. Install the five screws in the rear case. Tilt the handle to better access the top two holes.



CAUTION. *Avoid cross threading the screws that secure the rear case to the front case. An easy way to avoid this is to slip the screw into the hole and, using slight pressure, slowly rotate the screw counterclockwise until you feel the screw slip into the screw threads. Then tighten the screw clockwise. A properly started screw will have very little resistance going in.*

4. Install the power button as described on page 6-9.

Front Feet

You will need a torque-limiting Torx T-15 screwdriver and pliers for this procedure.

Removal. First, remove the power button and rear case using the procedures on page 6-9. Then, slide the front feet out of the front case as shown in Figure 8-1 for 2-channel models, or Figure 8-2 for 4-channel models.

Installation. Slide the feet into the slots provided in the front case as shown in Figure 8-1 for 2-channel models, or Figure 8-2 for 4-channel models. Use the installation procedures for each module removed to reassemble the oscilloscope.

NOTE. *If the front feet are not installed, but are available, they can be inserted by carefully pinching them and pushing them into their slots. For example, you may need to do this if the rear case has been removed, and a foot has been rubbed off and unnoticed until the case is being reassembled.*

Power Supply Module

Use a torque-limiting Torx T-15 screwdriver and pliers for this procedure.

Removal. To remove the module, refer to Figure 8-3 and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Disconnect the following wires:
 - The ground wire on the power supply module from the chassis ground lug.
 - The two-conductor backlight cable on the power supply module.
 - The power supply cable on the main board at J101. Press down on the latch while pulling up on the cable.
3. Remove the five screws connecting the power supply module to the chassis and lift the module from the internal assembly.

Installation. To install the power supply module, refer to Figure 8-3 and follow these steps:

1. Align and place the power supply module into the internal assembly.
2. Install the two longer screws with thread lock into the IEC connector mounting holes.
3. Install the three shorter screws through the power supply and into the chassis.
4. Reconnect the following wire and cables:
 - The ground wire on the power supply module to the chassis ground lug. You may need to use pliers to secure the wire in place.
 - The two-conductor backlight cable to the power supply module.
 - The power supply cable to the main board at J101. Twist the cable to keep it from contact with the boards and chassis.

NOTE. *Wind up the power supply cable until it is tight; loops are okay. This keeps the cable bundle together.*

5. Use the installation procedure for each module removed to reassemble the oscilloscope.

Internal Assembly

You will need a torque-limiting Torx T-15 screwdriver and a pair of pliers for this procedure.

Removal. To remove the internal assembly, refer to Figure 8-4 and follow these steps:

1. Remove the front-panel knobs, power button, and rear case using the procedures on page 6-9.
2. Remove the five screws attaching the internal assembly to the front case.
3. Lift the entire internal assembly (consisting of the chassis, all of the boards, and the display screen) out of the front case.

NOTE. *The switch keypad will most likely remain inside the front case. It does not need to be removed with the internal assembly.*

Installation. To install the internal assembly, refer to Figure 8-4 and follow these steps:

1. Use the installation procedure for each module removed to reassemble the oscilloscope.
2. Install the switch mat in the front case.
3. Place the internal assembly into the front case.
4. Install the five screws to attach the internal assembly to the front case.

Display Cable

You will need a torque-limiting Torx T-15 screwdriver and pliers for this procedure.

Removal. To remove the display cable, refer to Figure 8-3 and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Remove the power supply using the procedure on page 6-11.
3. Disconnect the display cable at J201 on the main board by pulling straight up from the connector.
4. Remove the cable tie, and remove the tape to release the display cable.

5. Remove the display.
6. Disconnect the display cable on the display module.
7. Thread the cable out of the chassis.

Installation. To install the display cable, refer to Figure 8-3 and follow these steps:

1. Remove the display module using the procedure on page 6-16.
2. Attach the display cable to the appropriate connector on the display module at the location shown in Figure 8-3: 12-pin for the monochrome display, and 15-pin for the color display.
3. With the display module in place but not connected, thread the display cable through the appropriate slot on the chassis.
4. Twist the cable to keep it from contact with the boards and chassis.

NOTE. *Wind up the display cable until it is tight; loops are okay. This keeps the cable bundle together.*

5. Connect the display cable at J201 on the main board by pushing the cable straight down into the connector.
6. Secure the display cable to the chassis with the cable tie.
7. Apply 3 strips of 3M Electrical Tape 92 to secure the cable to the chassis. Figure 6-3 shows where to apply the tape for good results.

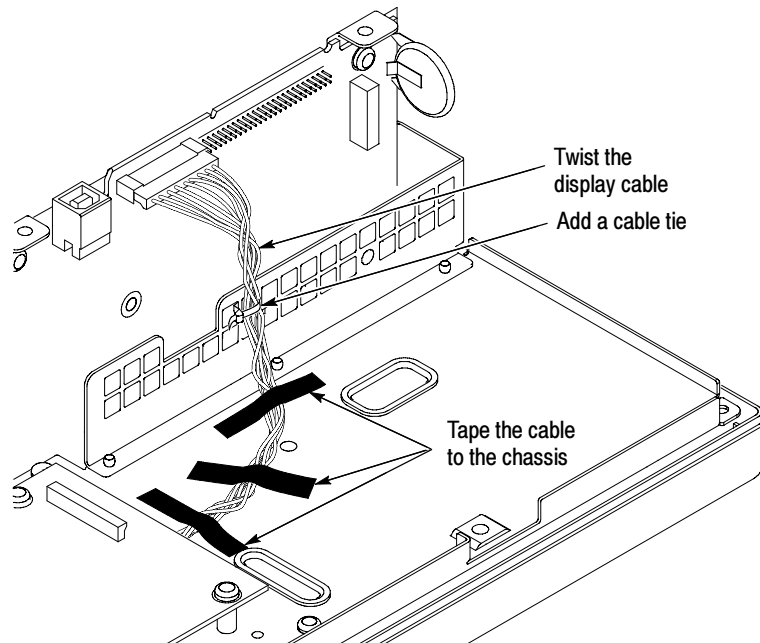


Figure 6-3: Securing the display cable to the chassis

8. Install the four screws to attach the display module to the internal assembly.

Front-Panel Cable

You will need a torque-limiting Torx T-15 screwdriver and pliers for this procedure.

Removal. To remove the front-panel cable, refer to Figure 8-3 and follow these steps:

1. Remove the front-panel knobs, power button, and rear case using the procedures on page 6-9.
2. Remove the internal assembly using the procedure on page 6-12.
3. Remove the five screws attaching the front panel board to the chassis.
4. Untwist the cable tie to release the front-panel cable.
5. Disconnect the front-panel cable at J202 on the main board by pulling straight up from the connector.
6. Disconnect the front-panel cable at J1 on the front-panel module.

Installation. To install the front-panel cable, refer to Figure 8-3 and follow these steps:

1. Connect the front-panel cable to the front-panel module at J1 through the appropriate slot on the chassis.
2. Twist the cable to keep it from contact with the boards and chassis, and secure using the right cable tie.

NOTE. Wind up the front-panel cable until it is tight; loops are okay. This keeps the cable bundle together.

3. Connect the front-panel cable at J202 on the main board by pushing the cable straight down into the connector.
4. Install the five screws to attach the front panel module to the chassis.

Main Board Module

You will need a torque-limiting Torx T-15 long shank screwdriver, a torque wrench, and a 5/8 inch deep socket for this procedure.



CAUTION. The main board module is particularly sensitive to ESD. Read the Preventing ESD section on page 6-1 before removing or installing the main board.

Removal. To remove the main board module, refer to Figure 8-3 and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Remove the internal assembly from the front case using the procedure on page 6-12.
3. Disconnect the following wires from the main board by pulling straight up from the connector:
 - The power supply cable at J101. Press down on the latch while pulling up on the cable.
 - The display cable at J201.
 - The front-panel cable at J202.
4. Use the screwdriver to remove the three screws attaching the main board module to the internal assembly.
5. Use the socket to remove the nuts and washers from the BNC connectors.

6. Pull the board out from the front slots of the internal assembly.

Installation. To install the main board module, refer to Figure 8-3 and follow these steps:

1. Work from the bottom of the internal assembly, and place the front of the main board module into the slots on the internal assembly near the the BNC connectors.
2. Use the deep socket to attach the washers and nuts to each BNC connector so that the main board is securely attached to the chassis.

Support the BNC to prevent it from twisting the main board, and torque the nuts to 40 in-lbs (4.5 N·m) using the torque wrench.

3. Install the three screws attaching the main board module to the internal assembly.
4. Reconnect the following wires on the main board:
 - The power supply cable at J101.
 - The display cable at J201.
 - The front-panel cable at J202.
5. Use the installation procedure for each module removed to reassemble the oscilloscope.

Display Module

You will need a torque-limiting Torx T-15 screwdriver, a torque-limiting Torx T-8 screwdriver, and pliers for this procedure.

Removal. To remove the display module, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Remove the internal assembly from the front case using the procedure on page 6-12.
3. Disconnect the backlight cable from the power supply module.
4. For color displays, follow these steps:
 - a. Remove the power supply module using the procedure on page 6-11.
 - b. Remove the four screws attaching the display module to the chassis. The screws were exposed when the power supply module was removed.

5. For monochrome displays, remove the four screws attaching the display module to the internal assembly.
6. Disconnect the display cable using the procedure on page 6-12.

NOTE. *Be careful that you do not loosen the mounting posts from the chassis. If the mounting posts should become loosened, it will be necessary to remove the power supply module to access the screws at the other end of the post.*



CAUTION. *The display shield is attached to the display module. Removing the shield will destroy the attaching gasket.*

Installation. To install the display module, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Reconnect the display cable at J201 on the main board by pushing the cable straight down into the connector.
2. Route the display cable through the opening in the chassis. For more information, see the display cable procedure on page 6-12.
3. For color displays, use the Torx T-8 screwdriver and install the four screws to attach the display module to the chassis. Torque the nuts to 3 in-lbs (0.33 N·m) using the torque wrench (2.864 +/- .26 in-lbs).

For 2-channel models, the location and type of screws shown in Figure 8-1 will vary between the color and monochrome displays.

4. For monochrome displays, install the four screws to attach the display module to the internal assembly.
5. Install the power supply module using the procedure on page 6-11.
6. Route the backlight cable through the opening in the internal assembly.
7. Reconnect the backlight cable to the power supply module.

Connect to the black socket for a monochrome display, and to the white socket for a color display.

8. Reconnect the display cable using the installation procedure on page 6-13.
9. Use the installation procedure for each module removed to reassemble the oscilloscope.

Front-Panel Module

You will need a torque-limiting Torx T-15 screwdriver and a flat-blade screwdriver for this procedure.

Removal. To remove the front-panel module, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Remove the power button and rear case using the procedures on pages 6-9.
2. Remove the entire internal assembly from the front case using the procedure on page 6-12.
3. Disconnect the front-panel cable at J202 on the main board by pulling straight up from the connector.
4. Remove the five screws attaching the front-panel module to the internal assembly.
5. Pull the module away from the internal assembly.

Installation. To install the front-panel module, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Reconnect the front-panel cable at J202 on the main board by pushing the cable straight down into the connector.
2. Route the front-panel cable through the opening in the internal assembly. For more information, see the procedure on page 6-14.
3. Install the five screws to attach the front-panel module to the internal assembly.
4. Use the installation procedure for each module removed to reassemble the oscilloscope.

Keypad

You will need a torque-limiting Torx T-15 screwdriver for this procedure.

Removal. To remove the switch keypad, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Remove the entire internal assembly from the front case using the procedure on page 6-12.
3. Lift the keypad out of the front case.



CAUTION. *Keep the electrical contacts on the back of the keypad clean. Skin oils and dust will inhibit good electrical contact.*

Installation. To install the switch keypad, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Place the front case face down on a soft surface.
2. Align the switch keypad into the front case using the guide posts and the holes in the keypad.



CAUTION. *Keep the electrical contacts on the back of the switch pad clean. Skin oils and dust will inhibit good electrical contact.*

3. Check that all buttons are properly seated into place before proceeding.
4. Place the entire internal assembly into the front case.
5. Use the installation procedure for each module removed to reassemble the oscilloscope.

Front Case

You will need a torque-limiting Torx T-15 screwdriver for this procedure.

Removal. To remove the front case, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Remove the power button and rear case using the procedures on page 6-9.
2. Remove the entire internal assembly from the front case using the procedure on page 6-12.
3. Remove the switch keypad using the procedure on page 6-18.

Installation. To install the front case, refer to Figure 8-1 for 2-channel models or Figure 8-2 for 4-channel models, and follow these steps:

1. Place the switch keypad into the front case.
2. Place the entire internal assembly into the front case.
3. Use the installation procedure for each module removed to reassemble the oscilloscope.

Troubleshooting

This section contains information and procedures to help you isolate a defective module in the oscilloscope.



WARNING. Before doing this or any other procedure in this manual, read the General Safety Summary and Service Safety Summary found at the beginning of this manual. Also, to prevent possible injury or damage to electrical components, read Preventing ESD on page 6-1.

Adjustment After Repair

If you replace the main board or power supply, you must adjust the oscilloscope after repair. Refer to the chapter *Adjustment Procedures*.

Required Tools and Equipment

You may need the the following tools and equipment to troubleshoot the oscilloscope:

Tools and equipment	Example
Oscilloscope with 1X/10X and 100X probes	Tektronix TDS1000B or TDS2000B series oscilloscope with standard accessory 1X/10X probe (P2220) and optional 100X probe (P5100 or P5200)
DMM	3.5 or greater digit DMM
USB flash drive	Tektronix part number 119-7276-00, 128 MB
USB type A to type B cable	Tektronix part numbers: 174-4401-00, .91 meters (3 feet) 174-5194-00, 1.83 meters (6 feet)
PC with USB host port and with TekVISA (OpenChoice PC Communications) installed	PC with USB communication port

Troubleshooting Tree

To isolate a problem to a specific troubleshooting procedure, use the troubleshooting tree in Figures 6-4, 6-5, 6-6 and 6-7. Detailed procedures follow the tree.

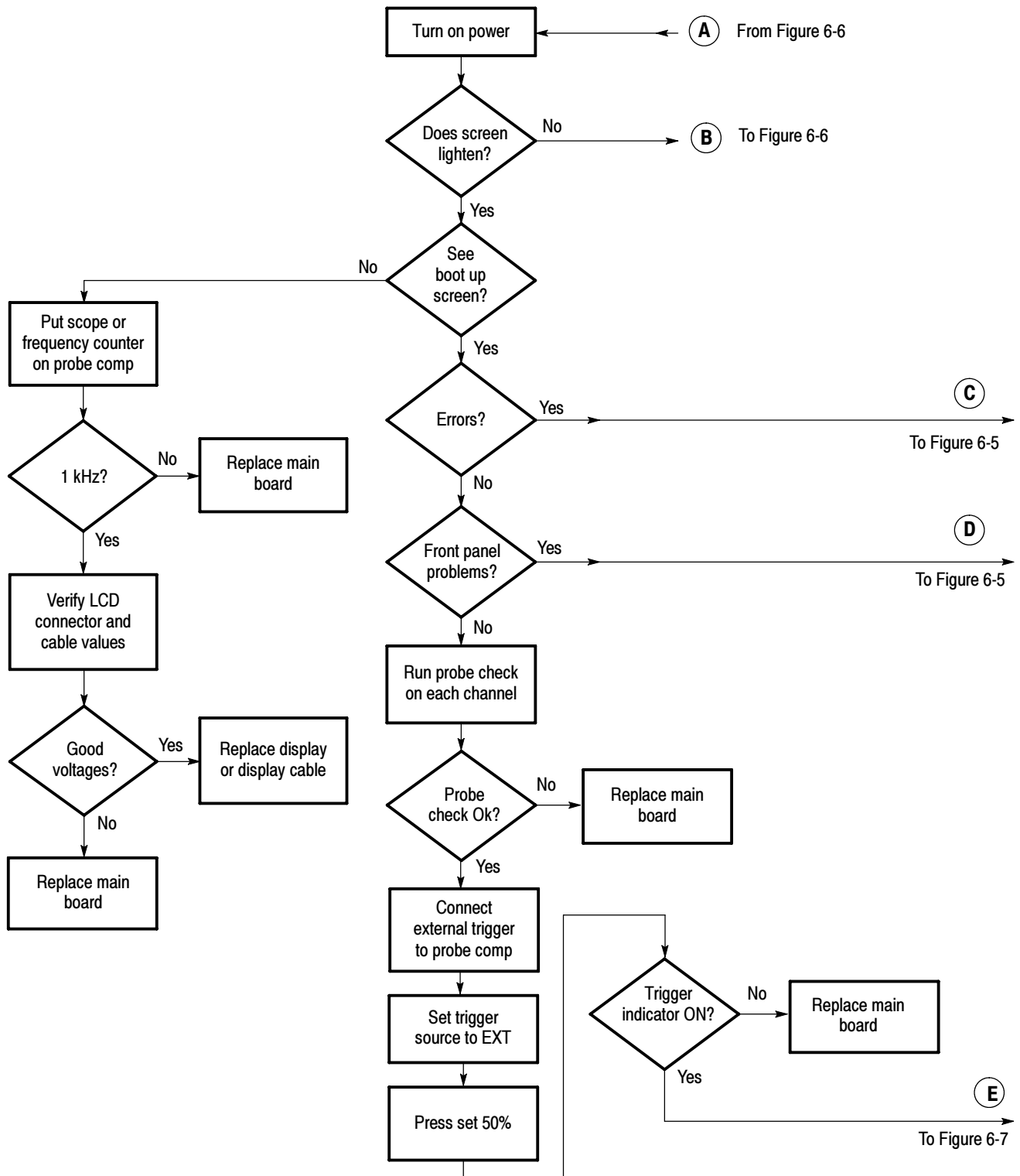


Figure 6-4: Oscilloscope troubleshooting tree (1 of 4)

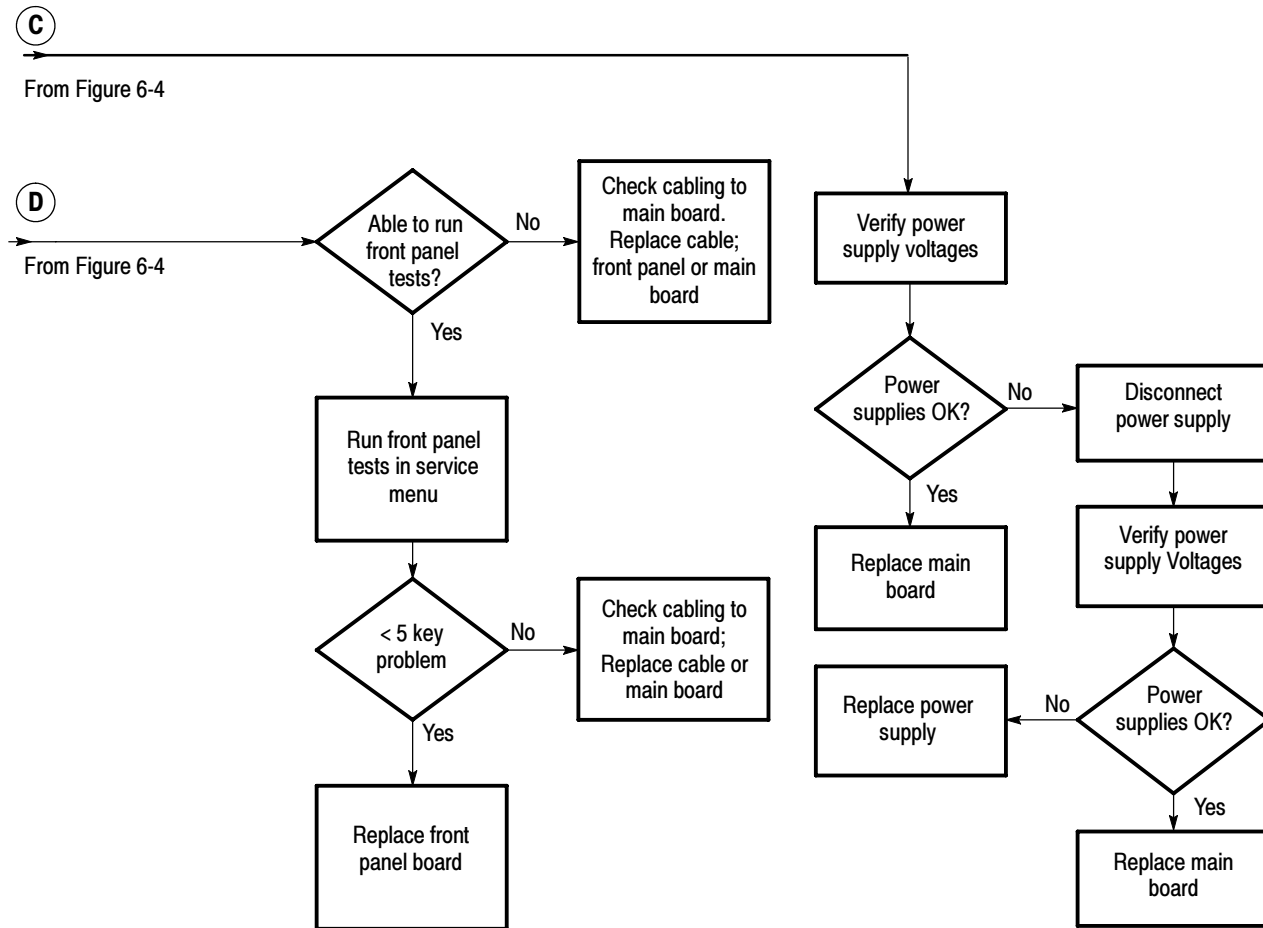


Figure 6-5: Oscilloscope troubleshooting tree (2 of 4)

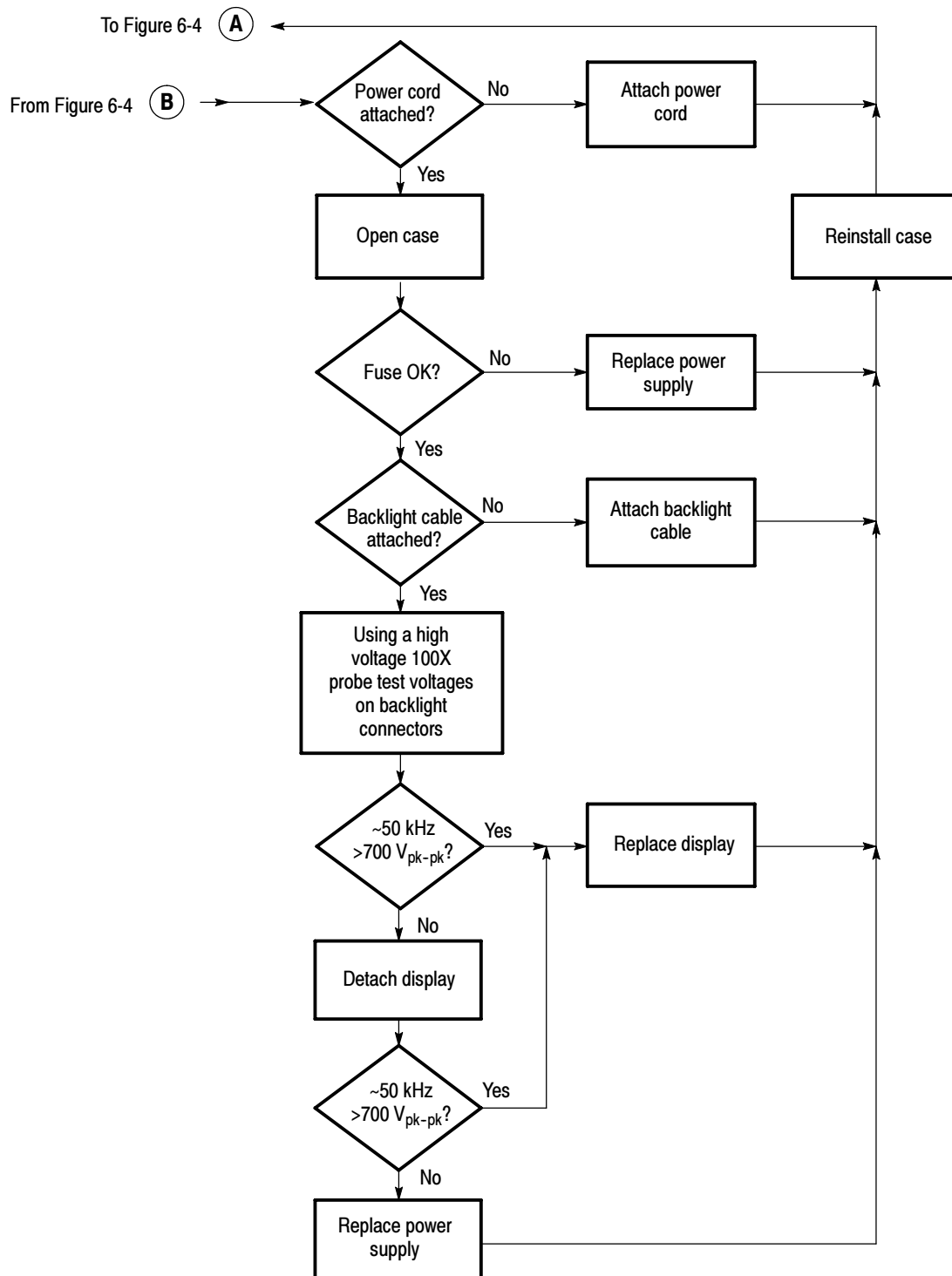
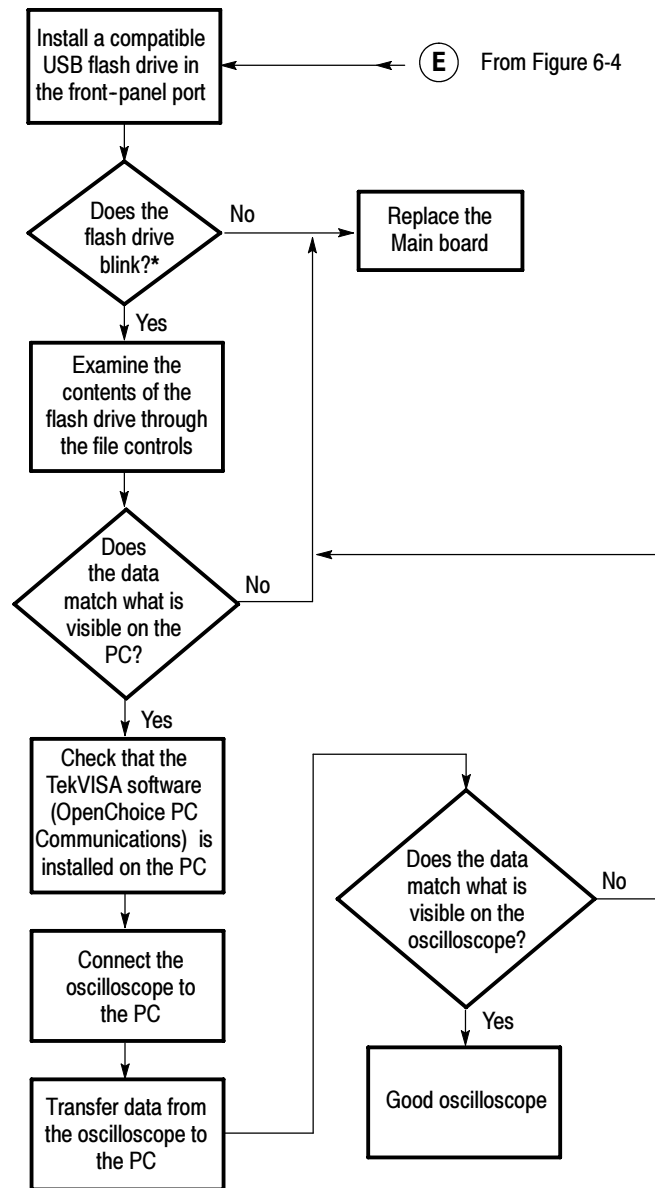


Figure 6-6: Oscilloscope troubleshooting tree (3 of 4)



* The oscilloscope displays a clock symbol when the flash drive is active, and a hint line when a save or recall operation is complete.

Figure 6-7: Oscilloscope troubleshooting tree (4 of 4)

PROBE COMP Output

When the oscilloscope is on and operating properly, the PROBE COMP output should generate a square wave, approximately 5 V in amplitude, at a 1 kHz frequency. Use the oscilloscope and set the Attenuation switch to 10X on the P2220 probe to probe this output.

As shown in the table below, there are two cases of defects. Either the 1 kHz signal is on and the power supply and main board are both active and functionally capable of doing acquisition, or one of those two modules is not performing correctly. While a large number of different possible frequencies exist, all involve detected failures on the main board due to main board failure or power supply failure.

Signal at PROBE COMP	Possible problem
1 kHz signal, no display	Refer to <i>Troubleshooting the Display</i> (page 6-26)
Non-1 kHz signal	Refer to <i>Troubleshooting the Main Board</i> (page 6-32)
No signal	Refer to <i>Troubleshooting the Power Supply</i> (page 6-25)

Troubleshooting the Power Supply

To troubleshoot the power supply, follow these steps:

1. Remove the rear case using the procedure *Rear Case* on page 6-9.
2. Use the test oscilloscope to measure the voltages from the power supply module at J101 on the main board module. The table below lists the voltages you should expect to see.

Supply	Voltage range*	Maximum current draw	J101 power pins	J101 return pins	Derived supplies
35 V	30 V _{DC} to 40 V _{DC} floating. Pin 2 connected to +3.3 V on the main board.	15 mA	1	2	+28 V LCD
+6 V	5.5 V to 6.5 V	0.7 A	4	3, 5, 8, 10	+5 V
+3.3 V	3.0 V to 3.6 V. Requires minimum load to maintain regulation.	1.5 A	6, 7	3, 5, 8, 10	3.3 V, +2.5 V
-4 V	-5.0 V to -3.5 V	0.8 A	9	3, 5, 8, 10	-2.5 V
Line trigger	-2 V to 6 V open circuit. ±1 diode drop when attached to the main board.	1 mA	11	3, 5, 8, 10	Line trigger

Supply	Voltage range*	Maximum current draw	J101 power pins	J101 return pins	Derived supplies
Backlight (mono-chrome or color)	>500 V _{pk-pk} , ~50 kHz		NA	NA	NA

* With 3 W minimum load; still functions with no load.

3. If all of the voltages are present, the main board is probably defective. Replace it.
4. If all or some of the voltages are missing, turn off the oscilloscope and disconnect the cable at connector J101 on the main board module.
5. Turn on the oscilloscope and check the voltages at the loose end of the cable disconnected from J101, checking for the same voltages as in step 2.
6. If all of the voltages are missing, check the line fuse on the power supply module. If the fuse is defective, replace the power supply module.
7. If the fuse is okay, and all or some of the voltages are missing, the power supply module is probably defective. Replace it.

Troubleshooting the Display

To troubleshoot a nonfunctional display, follow these steps:

1. Remove the rear case using the procedure *Rear Case* on page 6-9.
2. Turn on the oscilloscope and ensure that the display lights up. If it does not, either the display or power supply is defective. If this procedure is not conclusive, continue with *Troubleshooting the Power Supply* on page 6-25.

NOTE. Without a functional display module, the simplest way to verify that the oscilloscope is on and functioning is to check for a signal at the PROBE COMP output. The PROBE COMP output generates approximately a 5 V, 1 kHz square wave.

3. Use the test oscilloscope and set the Attenuation switch to 10X on the P2200 probe to probe the display cable connector at J201 on the main board. The following table describes the signals you should expect to see.

See the exploded diagrams in *Replaceable Parts* for the location and orientation of the connector on the main board.

Signal at J201	Description, Monochrome	Description, Color
Pin 1 (marked with ◀)	No fixed pattern. Depends upon display data.	No fixed pattern. Depends upon display data.
Pin 2	No fixed pattern. Depends upon display data.	No fixed pattern. Depends upon display data.
Pin 3	No fixed pattern. Depends upon display data.	No fixed pattern. Depends upon display data.
Pin 4	No fixed pattern. Depends upon display data.	No fixed pattern. Depends upon display data.
Pin 5	Not connected	No fixed pattern. Depends upon display data.
Pin 6	Not connected	No fixed pattern. Depends upon display data.
Pin 7	Not connected	No fixed pattern. Depends upon display data.
Pin 8	Not connected	No fixed pattern. Depends upon display data.
Pin 9	24 V _{DC} ¹	26.5 V _{DC} ¹
Pin 10	Ground	Ground
Pin 11	+5 V _{DC}	+5 V _{DC}
Pin 12	HI when display active	HI when display active
Pin 13	Data rate clock. 1.36 MHz Square wave ²	Data rate clock. 1.36 MHz Square wave
Pin 14	Line rate clock 17 kHz, 500 ns high pulse from low baseline ²	Line rate clock 11.4 kHz, 500 ns high pulse from low baseline
Pin 15	Frame rate clock 70 Hz, 750 ns high pulse from low baseline ²	Frame rate clock 43 Hz, 350 ns high pulse from low baseline
Pin 16	Low ³	High (> 2.4 V)
Pin 17	Ground	Ground
Pin 18	Ground	Ground

¹ Value varies with temperature, contrast setting, and display type.

² Frequency may vary slightly with software version.

³ With monochrome display cable attached. If no cable is attached, default condition is High (color).

4. If all the signals are present, the display module is probably defective. Replace it.
5. If all or some of the signals are missing, turn off the oscilloscope and disconnect the display cable at J201 on the main board. Carefully pull the cable straight up from the connector to avoid damage.
6. Turn on the oscilloscope.
7. Probe the pins of J201, checking for the same signals as in step 3.
8. If any of the signals are missing, the main board module is probably defective. Replace it.

Troubleshooting the Backlight

To troubleshoot a nonfunctional backlight, follow these steps:

1. Remove the rear case using the procedure *Rear Case* on page 6-9.
2. Turn on the oscilloscope.



WARNING. *To avoid electrical shock, do not touch the backlight connectors on the power supply module. See Figure 6-8 for the location of the connectors. Typically, the monochrome connector is black and the color connector is white.*

3. Set the test oscilloscope (with a 100X probe) to measure a $1270 V_{pk-pk}$ ($450 V_{RMS}$) signal at approximately 50 kHz.
4. Attach the probe ground lead to the ground lug on the AC line connector and the probe tip to one of the leads on the backlight connector as shown in Figure 6-8. Record the voltage of the signal.
5. Attach the probe tip to the other lead on the backlight connector as shown in Figure 6-8. Record the voltage of the signal.

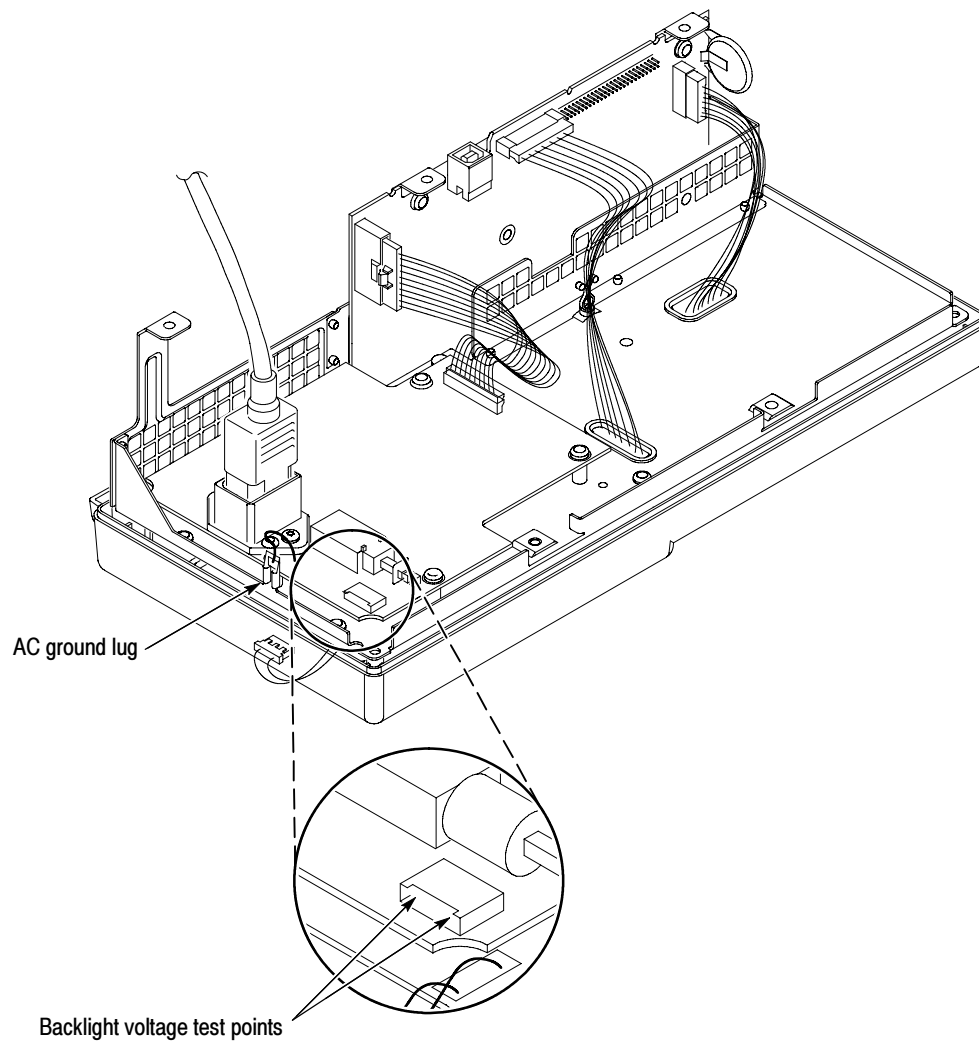


Figure 6-8: Measuring the backlight voltage

6. Add the results of both readings. If a signal greater than $1400 V_{pk-pk}$ is present, the backlight is probably defective. Replace the display.

If the signal is not present, proceed with step 7.

7. If the signal is missing, detach the display using the procedure on page 6-16 and probe the backlight connector leads again.
8. Add the results of both readings. If a signal greater than $1400 V_{pk-pk}$ is present, the display is probably defective. Replace it.

If the signal is not present, the power supply module is probably defective. Replace it.

Troubleshooting the Front Panel

To troubleshoot an improperly functioning front panel, follow these steps:

1. To execute the internal diagnostic tests, remove all input signals from the oscilloscope and enable the Service menu as described on page 5-2.
2. Push the **UTILITY** button and push the **Service** option button. The following options appear:

Menu	Comments
Factory Cal	Steps through the calibration routine steps.
Total Init	Writes factory default settings to all saved setups, writes factory default data to all reference waveforms, turns off Service Mode, and performs the same actions as the front-panel DEFAULT SETUP button.
Service Diag.	Displays the service diagnostics menus.
Service Mode Off	Disables the Service menu.

3. Select **Service Diag.** The following options appear:

Menu	Comments
Mfg. Tests	Displays a front-panel simulation used to check that all front panel controls are operational.
Loop Diag.	Opens a menu that enables you to re-run a subset of the power-on self tests.
Peek/Poke	For engineering use only
Clear Error Log	Removes all Error Log entries from memory and sets the power cycle count to zero.

4. Select **Mfg. Tests** to start the front-panel controls test. The following options appear:

Menu	Comments
Test FP	Displays a front-panel simulation used to check the operation of all front panel controls. All buttons must be pushed and all knobs must be turned in both directions before you can exit this test.
Test Screen	Checks the display screen pixels with different patterns from each push of the button.
Contrast	Allows you to check the display contrast operation across 100% of the hardware range.

Menu	Comments
Warmup Timer	Ensures a ten-minute warm-up time for the oscilloscope before executing the calibration procedure.
Stop Test	Exits the front-panel test (Test FP) and the screen test (Test Screen).

5. Select **Test FP** to start the front-panel controls test.
6. Push each button and rotate each knob to verify the operation of all controls. If all buttons and knobs have passed the test, pushing the lower menu button (EXIT) exits the test.
7. If any button fails to operate, inspect and/or clean the switch keypad and the front panel board contacts. If cleaning does not solve the problem, the switch keypad, front panel board, or main board may be defective. Follow the remaining steps in this procedure below to isolate the problem.
8. Replace the switch keypad and then retest the buttons. If the problem persists, proceed to step 9.
9. Use the test oscilloscope and set the Attenuation switch to 10X on the P2200 probe to probe the front-panel cable connector at J202 on the main board (two-channel models) or J1 (four-channel models). The table below describes the signals you should expect to see.

Signal at J202 (2-channel models) or J1 (4-channel models)	Description
1 FPLED_P	LED latch line 6.44kHz. High with 120 ns low pulses. Location of pulse relative to FPCLR_12_P determines which lights are lit.
2 FPCLR_12_P	Clear Front Panel Scan line A 6.44kHz. Low pulsing high with 50ns pulses. Determines beginning of a scan sequence for first half of front panel.
3 FPCLK_12_P	Front Panel Clock line A 405 kHz. High with 50 ns pulses going low. Each clock after FPCLR_12_P increments the scan location by one.
4 FPDATA_12_P	Front Panel Scan Data line A No fixed pattern. Stable when triggered from FPCLR_12_P. Pattern depends upon rotation of knobs being scanned.
5 GND	0 V (ground)
6 FP THERMSTR_P	Front Panel Temp Sense About 2 V _{DC} depending upon temperature, contrast setting, and display type.
7 FP_PWR 3.3V	3.3 V _{DC}

Signal at J202 (2-channel models) or J1 (4-channel models)	Description
8 FP THERMGND_P	Temp Sense Return Ground.
9 GND	0 V (ground)
10 FPDATA_34_P ¹	Front Panel Scan Data line B No fixed pattern. Stable when triggered from FPCLR_34_P. Pattern depends upon rotation of knobs being scanned.
11 FPCLR_34_P ²	Front Panel Clock line B 405 kHz. High with 50 ns pulses going low. Each clock after FPCLR_34_P increments the scan location by one.
12 FPCLK_34_P ²	Clear Front Panel Scan line B 6.44 kHz. Low pulsing high with 50 ns pulses. Determines beginning of a scan sequence for second half of front panel.

¹ **Unused and open on two-channel models.**

² **Unused and tied low on two-channel models.**

10. If all of the signals are present, the front-panel board is probably defective. Replace it.

11. If some or all of the signals are missing, continue with step 12.

12. Turn off the oscilloscope and disconnect the front-panel cable from the main board at connector J202 (two-channel models) or J1 (four-channel models).

13. Turn on the oscilloscope and check connector J202 (two-channel models) or J1 (four-channel models) for the same signals as in step 9.

14. If some or all of the signals are missing, the main board is probably defective. Replace it.

Troubleshooting the Main Board

To troubleshoot the main board (acquisition module), follow these steps:

1. Remove the rear case using the procedure *Rear Case* on page 6-9.

- Use the test oscilloscope to measure the voltages from the power supply module at J101 on the main board module. The table below lists the voltages you should expect to see.

Supply	Voltage range*	Maximum current draw	J101 power pins	J101 return pins	Derived supplies
35 V	30 V _{DC} to 40 V _{DC} floating. Pin 2 connected to +3.3 V on the main board.	15 mA	1	2	+28 V LCD
+6 V	5.5 V to 6.5 V	0.7 A	4	3, 5, 8, 10	+5 V
+3.3 V	3.0 V to 3.6 V. Requires minimum load to maintain regulation.	1.5 A	6, 7	3, 5, 8, 10	3.3 V, +2.5 V
-4 V	-5.0 V to -3.5 V	0.8 A	9	3, 5, 8, 10	-2.5 V
Line trigger	-2 V to 6 V open circuit. ±1 diode drop when attached to the main board.	1 mA	11	3, 5, 8, 10	Line trigger

*With 3 W minimum load; still functions with no load.

- If all of the voltages are present, the main board is probably defective. Replace it.

Running Diagnostics

The oscilloscope runs an extensive self-diagnostic routine at every power-on. Running the diagnostics from the Service menu will provide no additional information and therefore is not needed. The menu selections are only used during manufacturing of the oscilloscope.

Troubleshooting Input Connections

Follow these steps to troubleshoot the input connections only if the oscilloscope appears to function normally in every way. However, you have determined that an input signal is not getting into the oscilloscope as expected.

- Remove the rear case using the procedure *Rear Case* on page 6-9.
- Check that the coaxial connections to the back side of the BNC connectors are intact. Use the DMM to measure continuity from the front side of the BNC connector to the point where it attaches to the Main board.

NOTE. The ground side of the BNC has three connections (two mounting lugs and one signal wire) while the center connection has one. Incomplete or poor connection of the ground side may cause AC signal quality problems without affecting DC measurement capability.

3. If no problem is found and the trouble persists, the main board is probably defective in some way that the internal diagnostics cannot detect. Replace it.

Troubleshooting the USB Interface

To troubleshoot the USB interface, if the acquisition is working, and the USB is not, replace the main board.

Using the Error Log

Failures that occur during the power-up diagnostics or normal oscilloscope operation place an entry in the error log.

Accessing the error log. The error log list can be accessed anytime by pushing the UTILITY button and selecting Error Log. Table 6-4 lists the error codes and probable causes.

Table 6-4: List of error codes

Error code	Description	Probable cause
0 DI	Diagnostics internal error	Contact Tektronix
1 DI	ADG522 diagnostics failed	Main board or power supply failure
2 DI	PROM diagnostics failed	Main board or power supply failure
3 DI	MEMORY diagnostics failed	Main board or power supply failure
4 DI	CH1 diagnostics failed	Main board or power supply failure
5 DI	CH2 diagnostics failed	Main board or power supply failure
6 DI	Line trigger diagnostics failed	Main board or power supply failure
7 DI	ADG421 diagnostics failed	Main board or power supply failure
12 DI	CH3 diagnostics failed	Main board or power supply failure
13 DI	CH4 diagnostics failed	Main board or power supply failure
14 DI	ADG421 #2 diagnostics failed	Main board or power supply failure
15 DI	ADG522 #2 diagnostics failed	Main board or power supply failure
16 DI	DRAM2 diagnostics failed	Main board or power supply failure
17 DI	USB diagnostics failed	Main board or power supply failure
255	Software	Contact Tektronix

Clearing the Error Log. To clear the error log after fixing a problem, follow these steps:

1. Enable the Service menus as described on page 5-2.
2. Push the **UTILITY** button and push the **Service** option button to display the Service menu.
3. Push the **Service Diag.** option button to display the Diagnostics menu.
4. Push the **Clear Error Log** option button to clear the error log of past failures. This also sets the Power Cycle count to zero.

Repackaging Instructions

Use these procedures to repack the oscilloscope for shipment or storage.

Packaging

Use a corrugated cardboard shipping carton having a test strength of at least 125 kg (275 pounds), and with an inside dimension at least 15.25 cm (six inches) greater than the oscilloscope dimensions. Make sure that the oscilloscope is adequately padded with a cushioning material like foam, paper, or bubble wrap. The oscilloscope should not move around inside of the carton when sealed.

If the oscilloscope is being shipped to a Tektronix Service Center, enclose the following information:

- The owner address
- Name and phone number of a contact person
- Type and serial number of the oscilloscope
- Reason for returning
- A complete description of the service required

Seal the shipping carton with an industrial stapler or strapping tape.

Mark the address of the Tektronix Service Center and also your own return address on the shipping carton in two prominent locations.

Storage

The oscilloscope should be stored in a clean, dry environment. The following environmental characteristics apply for both shipping and storage (oscilloscope not operating):

- Temperature range: -40 °C to +71 °C (-40 °F to 159.8 °F)
- Altitude: To 3,000 m (approximately 10,000 ft)

See the chapter *Specifications* for a complete listing of the environmental characteristics.



Diagrams

Diagrams

This section describes the electrical operation of the TDS1000B and TDS2000B series oscilloscopes using the major circuit blocks or modules. Figure 7-1 shows the oscilloscope module interconnections.

The shaded area in Figure 7-1 represents modules and circuits used only in four-channel oscilloscopes.

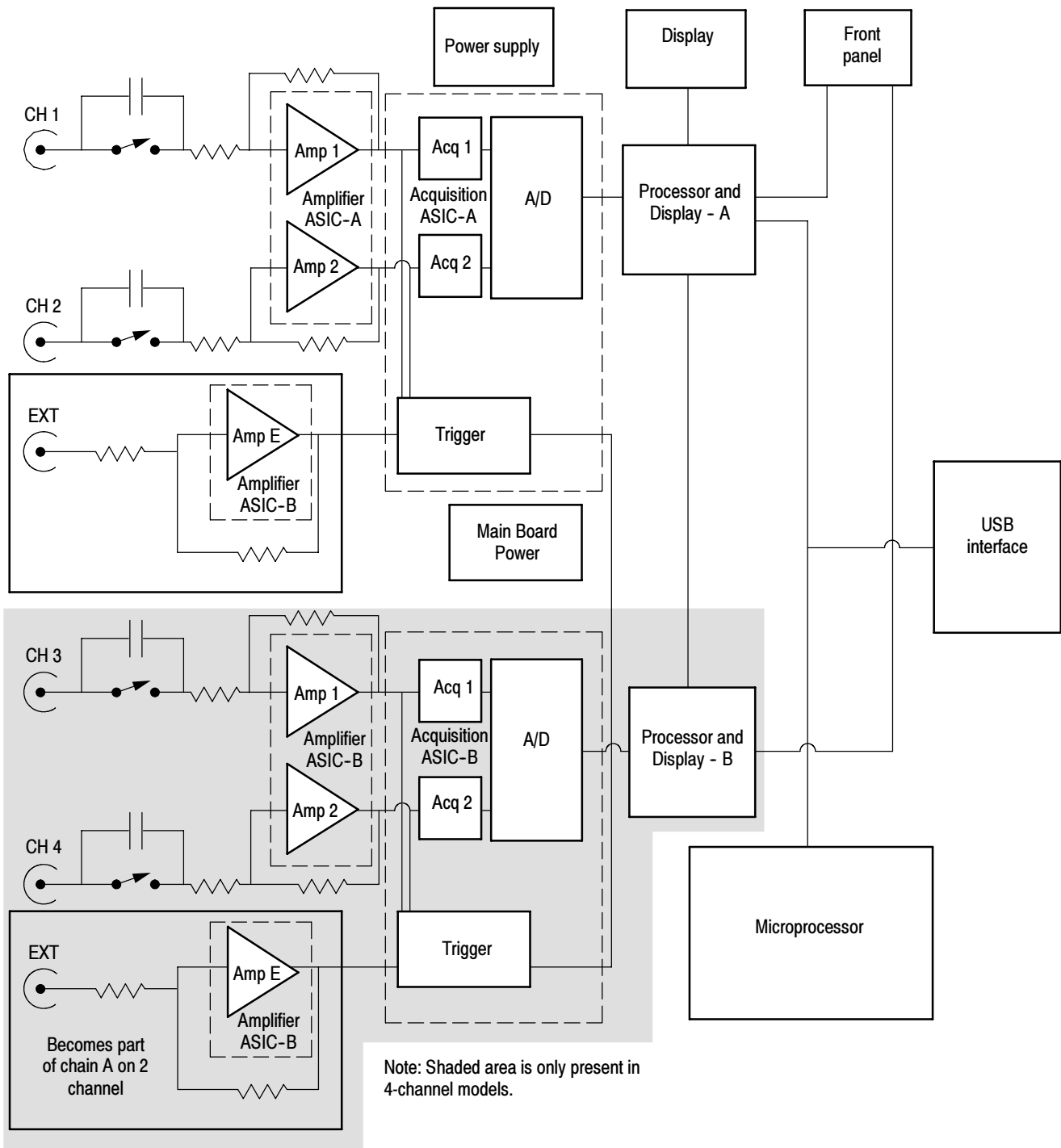


Figure 7-1: TDS1000B and TDS2000B series block diagram



Replaceable Parts

Replaceable Parts

This chapter contains a list of the replaceable modules for the TDS1000B and TDS2000B oscilloscopes. Use this list to identify and order replacement parts.

Parts Ordering Information

Replacement parts are available through your local Tektronix field office or representative.

Changes to Tektronix products are sometimes made to accommodate improved components as they become available and to give you the benefit of the latest improvements. Therefore, when ordering parts, it is important to include the following information in your order.

- Part number
- Instrument type or model number
- Instrument serial number
- Instrument modification number, if applicable

If you order a part that has been replaced with a different or improved part, your local Tektronix field office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

Part Number Revision Level

Tektronix part numbers contain two digits that show the revision level of the part. For some parts in this manual, you will find the letters XX in place of the revision level number.



When you order parts, Tektronix will provide you with the most current part for your product type, serial number, and modification (if applicable). At the time of your order, Tektronix will determine the part number revision level needed for your product, based on the information you provide.

Module Servicing

Modules can be serviced by selecting one of the following two options. Contact your local Tektronix service center or representative for repair assistance.

Module Exchange. In some cases you may exchange your module for a remanufactured module. These modules cost significantly less than new modules and meet the same factory specifications. For more information about the module exchange program, call 1-800-833-9200 and select option 2.

New Modules. You may purchase replacement modules in the same way as other replacement parts.

Using the Replaceable Parts List

This section contains a list of the mechanical and/or electrical components that are replaceable for the oscilloscope. Use this list to identify and order replacement parts. The table below describes each column in the parts list.

Column	Column name	Description
1	Figure & Index Number	Items in this section are referenced by figure and index numbers to the exploded view illustrations that follow.
2	Tektronix Part Number	Use this part number when ordering replacement parts from Tektronix.
3 and 4	Serial Number	Column three indicates the serial number at which the part was first effective. Column four indicates the serial number at which the part was discontinued. No entries indicates the part is good for all serial numbers.
5	Qty	This indicates the quantity of parts used.
6	Name & Description	An item name is separated from the description by a colon (:). Because of space limitations, an item name may sometimes appear as incomplete. Use the U.S. Federal Catalog handbook H6-1 for further item name identification.

Abbreviations Abbreviations conform to American National Standard ANSI Y1.1-1972.

Exploded Views Figures 8-1 through 8-4 show the module-level exploded views of the TDS1000B and TDS2000B oscilloscopes. On the adjacent page is the list of components for that exploded view, indexed by the numbers in the figure.

Table 8-1: Replaceable parts list, 2-channel models

Fig. & index number	Tektronix part number	Serial no. effective	Serial no. discont'd	Qty	Name & description
8-1					2-CHANNEL MODELS
-1	650-4974-00			1	FRONT CASE ASSY; COVER,W/FEET;TDS1001B,TDS1002B,TDS1012B;MONO
	650-4975-00			1	FRONT CASE ASSY; COVER,W/FEET;TDS2002B,TDS2012B,TDS2022B;COLOR
-2	366-0863-00			1	ASSEMBLY, KNOB; .685 DIAMETER
-3	366-0862-00			1	ASSEMBLY, KNOB; .470 DIAMETER
-4	335-1480-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, FRENCH
	335-1481-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, ITALIAN
	335-1482-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, GERMAN
	335-1483-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, SPANISH
	335-1484-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, JAPANESE
	335-1485-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, PORTUGUESE
	335-1486-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, SIMPLIFIED CHINESE
	335-1487-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, TRADITIONAL CHINESE
	335-1488-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, KOREAN
	335-1489-00			1	MARKER, IDENTIFICATION 2CH LANGUAGE, RUSSIAN
-5	260-2820-00			1	SWITCH,KEYPAD; ELASTOMERIC,FRONT PANEL,2CH MONO
	260-2821-00			1	SWITCH,KEYPAD; ELASTOMERIC,FRONT PANEL,2CH COLOR
-6	211-1198-00			5	SCREW,MACHINE; 6-32 X 0.250,PNH,STL,ZNPL,T-15 TORX DR
-7	870-0188-01			1	CIRCUIT BD ASSY; FRONT PANEL BOARD 2CH,389-3835-00 WIRED
-8	441-2454-00			1	CHASSIS ASSEMBLY; 2 CHANNEL
-9	870-0008-00			1	CIRCUIT BD ASSY; MAIN,2 CH,40MHZ,TESTED & CONFIGURED,MONO,389-3843-00 WIRED;TDS1001B
	870-0009-00			1	CIRCUIT BD ASSY; MAIN,2 CH,60MHZ,TESTED & CONFIGURED,MONO,389-3843-00 WIRED;TDS1002B
	870-0010-00			1	CIRCUIT BD ASSY; MAIN,2 CH,60MHZ,TESTED & CONFIGURED,COLOR,389-3843-00 WIRED;TDS2002B
	870-0012-00			1	CIRCUIT BD ASSY; MAIN,2 CH,100MHZ,TESTED & CONFIGURED,MONO,389-3843-00 WIRED;TDS1012B
	870-0013-00			1	CIRCUIT BD ASSY; MAIN,2 CH,100MHZ,TESTED & CONFIGURED,COLOR,389-3843-00 WIRED;TDS2012B
	870-6178-01			1	CIRCUIT BD ASSY; MAIN,2 CH,200MHZ,TESTED & CONFIGURED,COLOR,389-3843-00 WIRED;TDS2022B
-10	210-1544-00			1	WASHER, SPRING; 0.610 OD X 0.490 ID X 0.007 THK, WAVE SHAPE, STAINLESS STEEL
-11	220-0265-00			1	NUT,PLAIN,HEX; 0.5-28 X 0.625 HEX,BRS CD PL
-12	385-0079-00			4	SPACER,POST; 0.375 L W/6-32 THD THRU,AL 0.25 HEX, MONO
-13	211-0747-00			8	SCREW,MACHINE; 6-32 X 0.188,PNH,STL,CDPL,T-15 TORX DR, MONO
-14	650-4605-70			1	FRAME ASSEMBLY; DISPLAY,MONO (NANYA); EXPORT
-15	211-1216-00			4	SCREW, PT; K-30, 3MM, PAN HEAD, T-8, COLOR
-16	650-4889-70			1	FINAL ASSEMBLY;DISPLAY COLOR
-17	348-1525-00			1	FOOT; FRONT,SANTOPRENE,BLACK,64 DEROMETER,TEXTURED

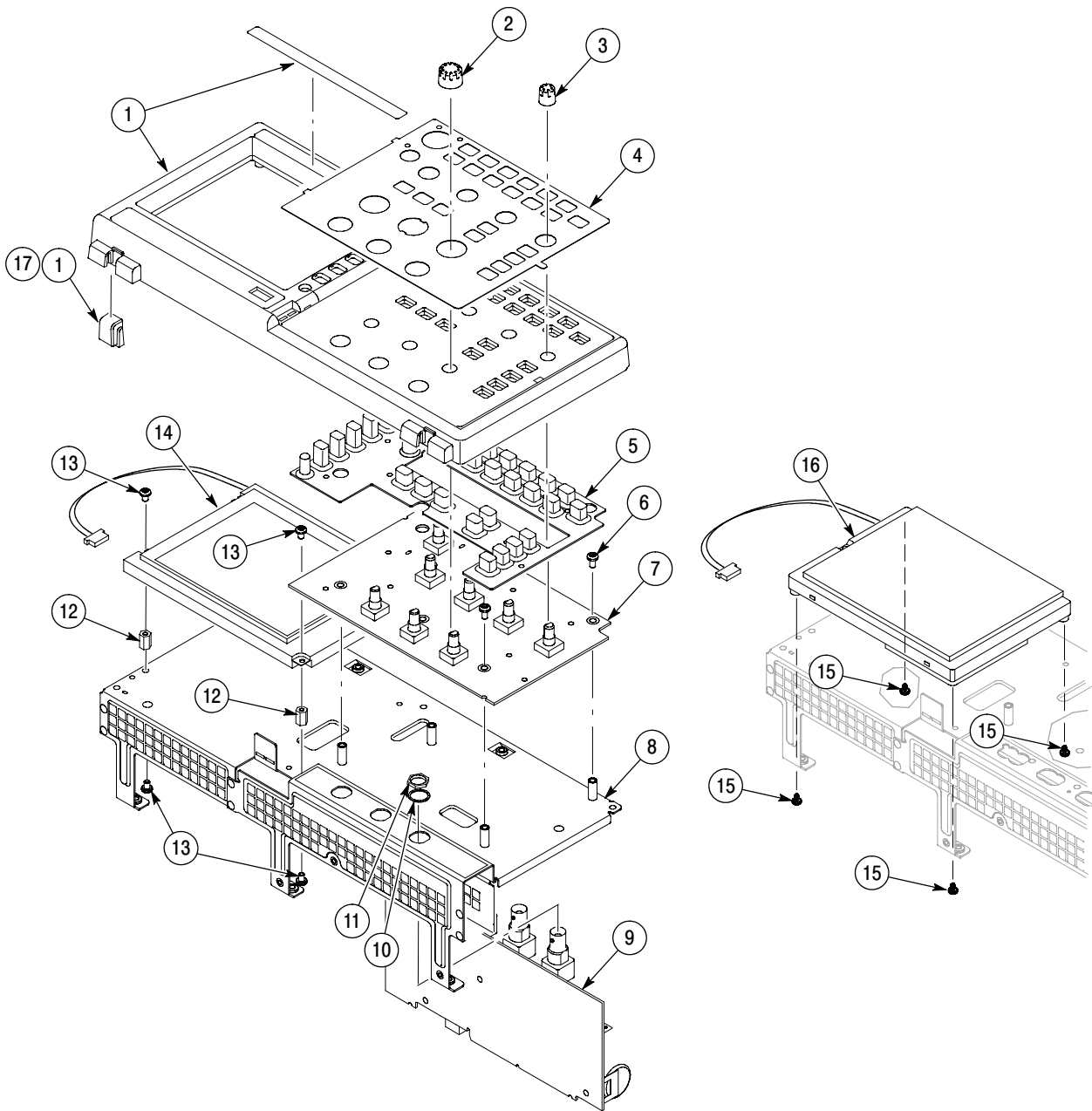


Figure 8-1: Exploded diagram, 2-channel models

Table 8-2: Replaceable parts list, 4-channel models

Fig. & index number	Tektronix part number	Serial no. effective	Serial no. discont'd	Qty	Name & description
8-2					4-CHANNEL MODELS
-1	650-4976-00			1	FRONT CASE ASSY; COVER,W/FEET;TDS2004B,TDS2014B,TDS2024B;COLOR
-2	366-0863-00			1	ASSEMBLY, KNOB; .685 DIAMETER
-3	366-0862-00			1	ASSEMBLY, KNOB; .470 DIAMETER
-4	335-1490-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, FRENCH
	335-1491-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, ITALIAN
	335-1492-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, GERMAN
	335-1493-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, SPANISH
	335-1494-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, JAPANESE
	335-1495-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, PORTUGUESE
	335-1496-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, SIMPLIFIED CHINESE
	335-1497-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, TRADITIONAL CHINESE
	335-1498-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, KOREAN
	335-1499-00			1	MARKER, IDENTIFICATION 4CH LANGUAGE, RUSSIAN
-5	260-2822-00			1	SWITCH,KEYPAD; ELASTOMERIC,FRONT PANEL,4CH COLOR
-6	211-1198-00			5	SCREW,MACHINE; 6-32 X 0.250,PNH,STL,ZNPL,T-15 TORX DR
-7	870-0190-01			1	CIRCUIT BD ASSY; FRONT PANEL BOARD 4CH,389-3836-00 WIRED
-8	441-2455-00			1	CHASSIS ASSEMBLY; 4 CHANNEL
-9	870-0011-00			1	CIRCUIT BD ASSY; MAIN,4 CH,60MHZ,TESTED & CONFIGURED,COLOR,389-3844-00 WIRED;TDS2004B
	870-0014-00			1	CIRCUIT BD ASSY; MAIN,4 CH,100MHZ,TESTED & CONFIGURED,COLOR,389-3844-00 WIRED;TDS2014B
	870-6179-01			1	CIRCUIT BD ASSY; MAIN,4 CH,200MHZ,TESTED & CONFIGURED,COLOR,389-3844-00 WIRED;TDS2024B
-10	210-1544-00			1	WASHER, SPRING; 0.610 OD X 0.490 ID X 0.007 THK, WAVE SHAPE, STAINLESS STEEL
-11	220-0265-00			1	NUT,PLAIN,HEX; 0.5-28 X 0.625 HEX,BRS CD PL
-12	211-1216-00			4	SCREW, PT; K-30, 3MM, PAN HEAD, T-8
-13	650-4889-70			1	FINAL ASSEMBLY;DISPLAY COLOR
-14	348-1525-00			1	FOOT; FRONT,SANTOPRENE,BLACK,64 DEROMETER,TEXTURED

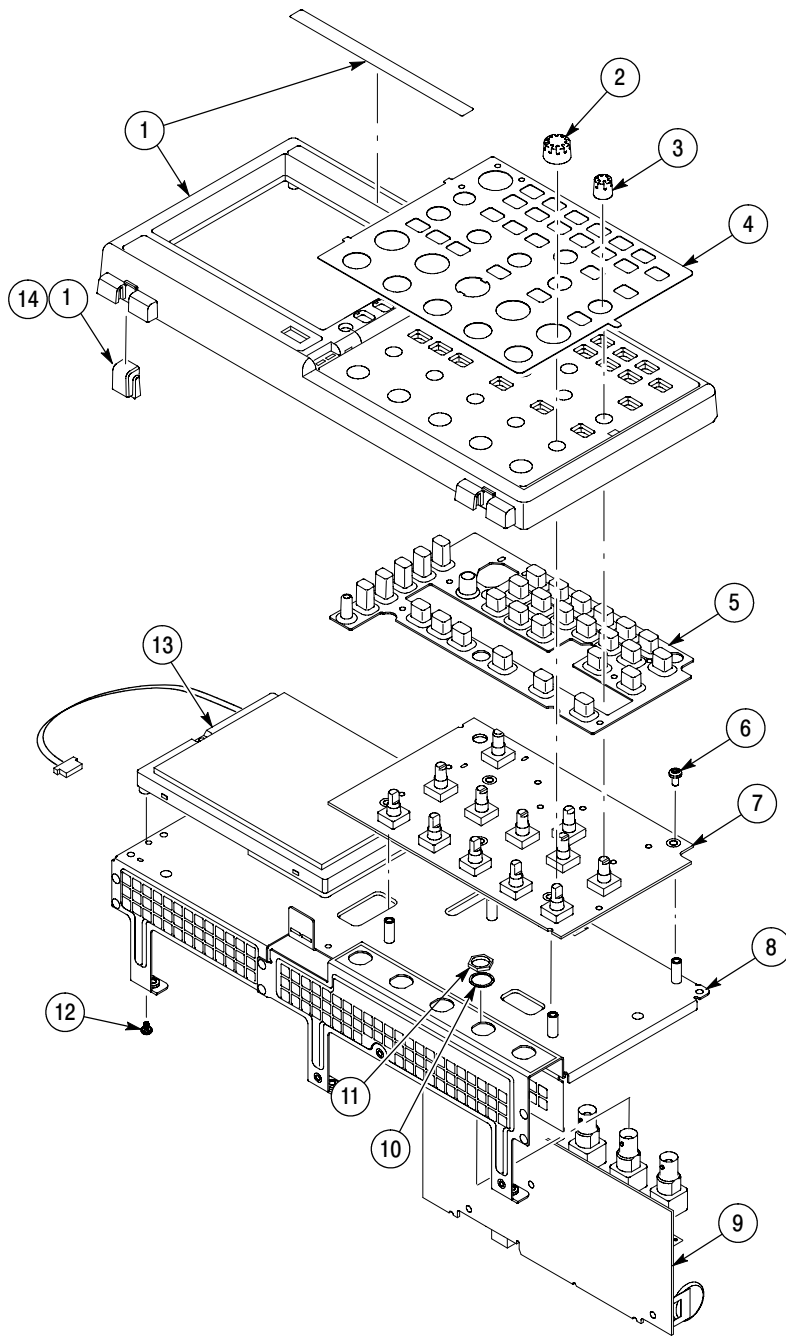


Figure 8-2: Exploded diagram, 4-channel models

Table 8-3: Replaceable parts list, power supply module, cables, and wires

Fig. & index number	Tektronix part number	Serial no. effective	Serial no. discont'd	Qty	Name & description
8-3					POWER SUPPLY, CABLES, WIRES
-1	119-7228-00			1	POWER SUPPLY; CUSTOM,TDS2000B SERIES,AC-DC;85-275 VAC 45-440HZ IN;+6VDC 0.7A,+3.3VDC 1.5A,-4VDC 0.8A,35V 0.015A OUT;PLUS CCFL BACKLIGHT INVERTER & LINE TRIGGER OUTPUT;SAFETY CONTROLLED
-2	174-4673-00			1	CA ASSY,SP; DATA,COLOR,7.0 L
	174-5150-00			1	CA ASSY, SP; DATA, MONO LCD TO CPU BD, 7.0 INCH L, MOLEX 51021-1200 TO AMP 1-353908-8
-3	174-4658-00			1	CA ASSY,SP; DISCRETE,26 AWG,5.5 L,FEMALE,1 X 12,0.059 (1.5 MM) CTR,DUAL ENDED,FRONT PANEL
-4	211-1198-00			6	SCREW,MACHINE; 6-32 X 0.250,PNH,STL,ZNPL,T-15 TORX DR
-5	211-1174-00			4	SCREW,MACHINE; W/HEAVY PATCH THREADLOCKING MATERIAL; 6-32 X 0.312 L,PNH,STL CAD PLT,T15
-6	342-1673-00			1	CLAMP,CABLE; CABLE TIE,NYLON 6/6, COLOR NATURAL
-7	346-0299-00			1	BAND; BAND, PA

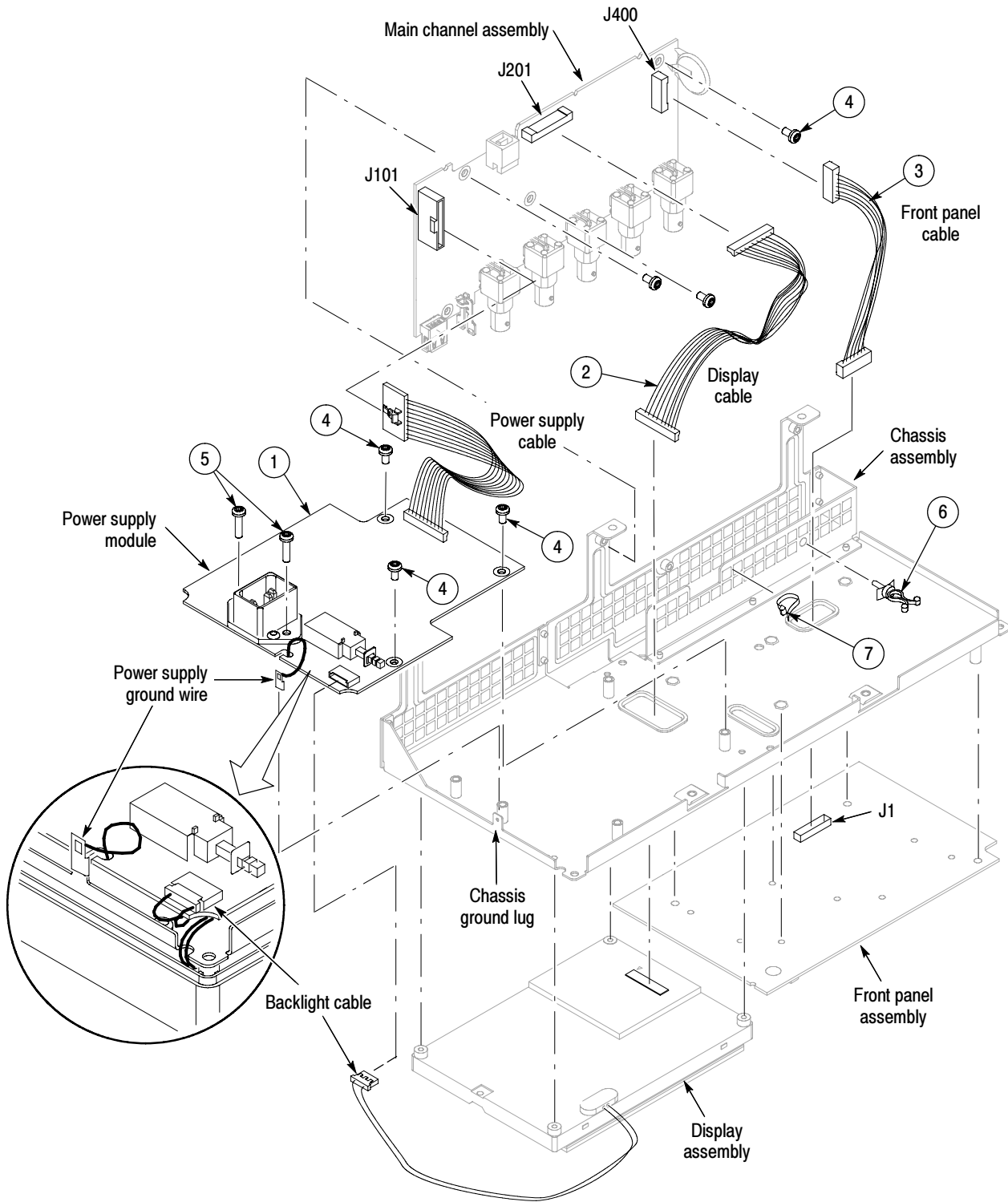


Figure 8-3: Exploded diagram, power supply module, cables and wires

Table 8-4: Replaceable parts list, back case and trim

Fig. & index number	Tektronix part number	Serial no. effective	Serial no. discont'd	Qty	Name & description
8-4					BACK CASE, TRIM
-1	650-4973-00			1	REAR CASE ASSY; COVER,W/FEET & HANDLE;TDS1000B,TDS2000B SERIES
-2	348-1703-00			1	FOOT; FRONT,FLIPMPC/ABS,SILVER GRAY
-3	348-1704-00			1	FOOT; REAR,SANTOPRENE,BLACK
-4	211-1198-00			5	SCREW,MACHINE; 6-32 X 0.250,PNH,STL,ZNPL,T-15 TORX DR
-5	366-0856-00			1	PUSH BUTTON; POWER
-6	211-1143-00			5	SCREW,PT; K35-1.57,PAN HEAD,T-15

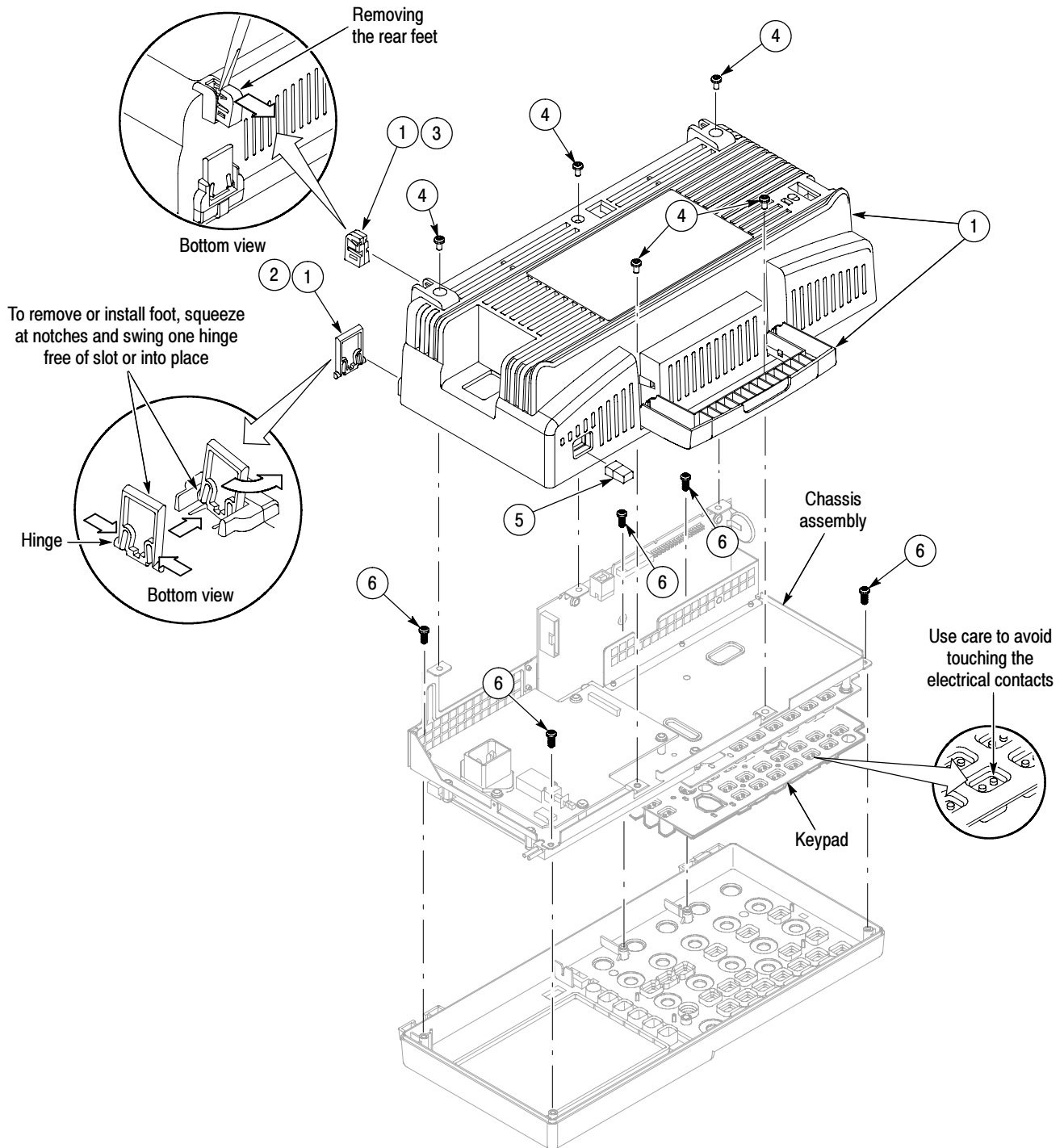


Figure 8-4: Exploded diagram, back case and trim

Table 8-5 lists the replaceable standard accessories for the oscilloscope and the instrument options that included them in the original shipment. These accessories are not shown in Figure 8-1.

Table 8-5: Standard accessories

Description of accessory	Tektronix part number or nomenclature
Passive 1X/10X probes	P2220
Replacement user manual	
English	071-1817-XX
French	071-1818-XX
Italian	071-1819-XX
German	071-1820-XX
Spanish	071-1821-XX
Japanese	071-1822-XX
Portuguese	071-1823-XX
Simplified Chinese	071-1824-XX
Traditional Chinese	071-1825-XX
Korean	071-1826-XX
Russian	071-1827-XX
Replacement power cords	
Option A0, Std North American 120 V, 60 Hz	161-0066-00
Option A1, European 230 V, 50 Hz	161-0066-09
Option A2, United Kingdom 230 V, 50 Hz	161-0066-10
Option A3, Australian 240 V, 50 Hz	161-0066-11
Option A5, Switzerland 230 V, 50 Hz	161-0154-00
Option A6, Japan 100 V, 60 Hz	161-0298-00
Option A10, China 220 V, 50/60 Hz	161-0304-00
Option A11, India 230 V, 50 Hz	161-0400-00
Option A99 No power cord	

The PC Communications software that was on the CD that came with your oscilloscope is downloadable from the Web site at www.tektronix.com.

Table 8-6: Optional accessories

Description of accessory	Tektronix part number or nomenclature
Replacement programmer manual	071-1075-XX
Soft case	AC2100
Transit case*	HCTEK4321
Rackmount Kit	RM2000B

* Requires the soft case which fits inside.



Appendix

Appendix A: Example of a Vertical Position Accuracy Test Spreadsheet

This appendix contains a filled-in example of the vertical position accuracy (VPA) test spreadsheet that is used on page 4-11.

The PDF version of the TDS1000B and TDS2000B service manual (Tektronix part number 077-0356-00, this manual) includes an empty VPA test spreadsheet for your convenience. To access and save the test spreadsheet:

1. Go to the Tektronix Web site (www.tektronix.com) and click on the **Manuals** link (in the left column on the screen).
2. Enter **077035600** in the **Search By Keyword** field and then click **Go**.
3. Click the **TDS1000B and TDS2000B Series Service Manual** link.
4. Click the **Download File** button and follow on-screen instructions to save the PDF file to your PC.
5. Open the PDF file in Adobe Reader (version 7 or later).
6. Click the **paper clip** icon (lower left of the screen) to display the Attachments panel. If the paper clip icon is not shown, click **View > Navigation Panels > Attachments**.
7. Double-click on the **VPA Test Table.xls** file.
8. Click **OK** in the **Launch Attachment** dialog box. The test spreadsheet opens in your spreadsheet application and shows the **Blank Test Record** spreadsheet tab.
9. Click **File > Save As** to save the file to a name and location that you enter. You can now use the spreadsheet to enter values for the vertical position accuracy test.

Example Filled-in Vertical Position Accuracy Test Spreadsheet

	A	B	C	D	E	F	G	H	I
1	Approximate Test Voltage	DVM Measured Voltage	Oscilloscope Measured Voltage	Error	Lower Limit	Upper Limit	Margin		
2	2.00			0.000	*	*	*	Volts/div	0.05
3	1.96			0.000	*	*	*		
4	1.92			0.000	*	*	*	Offset as a fractional division	0.1
5	1.88			0.000	*	*	*	Offset in volts	0.005
6	1.84			0.000	*	*	*	Total voltage offset	0.01=I2*I4+I5
7	1.80	1.80	1.79	0.010	-0.028	0.028	0.018		
8	1.76	1.76	1.75	0.010	-0.0276	0.0276	0.018	Gain error	1%
9	1.72	1.72	1.72	0.000	-0.0272	0.0272	0.027		
10	1.68	1.68	1.68	0.000	-0.0268	0.0268	0.027	Equation for cell D7	=B7-C7
11	1.64	1.64	1.64	0.000	-0.0264	0.0264	0.026	Equation for cell E7	=-F7
12	1.60	1.6	1.6	0.000	-0.026	0.026	0.026	Equation for cell F7	=(ABS(B7)*\$I\$8+ \$I\$6)
13	1.56	1.56	1.56	0.000	-0.0256	0.0256	0.026		
14	1.52	1.52	1.52	0.000	-0.0252	0.0252	0.025	Equation for cell G7	=MIN(D7-E7,F7-D7)
15	1.48	1.48	1.49	-0.010	-0.0248	0.0248	0.015		
16	1.44	1.44	1.45	-0.010	-0.0244	0.0244	0.014	Minimum margin	0.007=MIN(G7:G97)
17	1.40	1.4	1.41	-0.010	-0.024	0.024	0.014		
18	1.36	1.36	1.37	-0.010	-0.0236	0.0236	0.014		
19	1.32	1.32	1.33	-0.010	-0.0232	0.0232	0.013		
20	1.28	1.28	1.29	-0.010	-0.0228	0.0228	0.013		
21	1.24	1.24	1.25	-0.010	-0.0224	0.0224	0.012		
22	1.20	1.2	1.21	-0.010	-0.022	0.022	0.012		
23	1.16	1.16	1.17	-0.010	-0.0216	0.0216	0.012		
24	1.12	1.12	1.13	-0.010	-0.0212	0.0212	0.011		
25	1.08	1.08	1.09	-0.010	-0.0208	0.0208	0.011		
26	1.04	1.04	1.05	-0.010	-0.0204	0.0204	0.010		
27	1.00	1	1.01	-0.010	-0.02	0.02	0.010		
28	0.96	0.96	0.966	-0.006	-0.0196	0.0196	0.014		
29	0.92	0.92	0.926	-0.006	-0.0192	0.0192	0.013		
30	0.88	0.88	0.886	-0.006	-0.0188	0.0188	0.013		
31	0.84	0.84	0.845	-0.005	-0.0184	0.0184	0.013		

Appendix A: Example of a Vertical Position Accuracy Test Spreadsheet

	A	B	C	D	E	F	G	H	I
32	0.80	0.8	0.805	-0.005	-0.018	0.018	0.013		
33	0.76	0.76	0.764	-0.004	-0.0176	0.0176	0.014		
34	0.72	0.72	0.724	-0.004	-0.0172	0.0172	0.013		
35	0.68	0.68	0.683	-0.003	-0.0168	0.0168	0.014		
36	0.64	0.64	0.643	-0.003	-0.0164	0.0164	0.013		
37	0.60	0.6	0.6	0.000	-0.016	0.016	0.016		
38	0.56	0.56	0.561	-0.001	-0.0156	0.0156	0.015		
39	0.52	0.52	0.521	-0.001	-0.0152	0.0152	0.014		
40	0.48	0.48	0.481	-0.001	-0.0148	0.0148	0.014		
41	0.44	0.44	0.44	0.000	-0.0144	0.0144	0.014		
42	0.40	0.4	0.401	-0.001	-0.014	0.014	0.013		
43	0.36	0.36	0.361	-0.001	-0.0136	0.0136	0.013		
44	0.32	0.32	0.32	0.000	-0.0132	0.0132	0.013		
45	0.28	0.28	0.281	-0.001	-0.0128	0.0128	0.012		
46	0.24	0.24	0.244	-0.004	-0.0124	0.0124	0.008		
47	0.20	0.2	0.204	-0.004	-0.012	0.012	0.008		
48	0.16	0.16	0.163	-0.003	-0.0116	0.0116	0.009		
49	0.12	0.12	0.123	-0.003	-0.0112	0.0112	0.008		
50	0.08	0.08	0.083	-0.003	-0.0108	0.0108	0.008		
51	0.04	0.04	0.043	-0.003	-0.0104	0.0104	0.007		
52	0.00	0	0.002	-0.002	-0.01	0.01	0.008		
53	-0.04	-0.04	-0.039	-0.001	-0.0104	0.0104	0.009		
54	-0.08	-0.079	-0.079	0.000	-0.01079	0.01079	0.011		
55	-0.12	-0.12	-0.118	-0.002	-0.0112	0.0112	0.009		
56	-0.16	-0.159	-0.159	0.000	-0.01159	0.01159	0.012		
57	-0.20	-0.199	-0.198	-0.001	-0.01199	0.01199	0.011		
58	-0.24	-0.239	-0.238	-0.001	-0.01239	0.01239	0.011		
59	-0.28	-0.279	-0.274	-0.005	-0.01279	0.01279	0.008		
60	-0.32	-0.319	-0.314	-0.005	-0.01319	0.01319	0.008		
61	-0.36	-0.359	-0.353	-0.006	-0.01359	0.01359	0.008		
62	-0.40	-0.399	-0.393	-0.006	-0.01399	0.01399	0.008		
63	-0.44	-0.439	-0.432	-0.007	-0.01439	0.01439	0.007		
64	-0.48	-0.48	-0.473	-0.007	-0.0148	0.0148	0.008		
65	-0.52	-0.52	-0.513	-0.007	-0.0152	0.0152	0.008		

Appendix A: Example of a Vertical Position Accuracy Test Spreadsheet

	A	B	C	D	E	F	G	H	I
66	-0.56	-0.56	-0.552	-0.008	-0.0156	0.0156	0.008		
67	-0.6	-0.6	-0.592	-0.008	-0.016	0.016	0.008		
68	-0.64	-0.64	-0.633	-0.007	-0.0164	0.0164	0.009		
69	-0.68	-0.68	-0.673	-0.007	-0.0168	0.0168	0.010		
70	-0.72	-0.72	-0.713	-0.007	-0.0172	0.0172	0.010		
71	-0.76	-0.76	-0.754	-0.006	-0.0176	0.0176	0.012		
72	-0.80	-0.8	-0.794	-0.006	-0.018	0.018	0.012		
73	-0.84	-0.84	-0.835	-0.005	-0.0184	0.0184	0.013		
74	-0.88	-0.88	-0.875	-0.005	-0.0188	0.0188	0.014		
75	-0.92	-0.92	-0.915	-0.005	-0.0192	0.0192	0.014		
76	-0.96	-0.96	-0.956	-0.004	-0.0196	0.0196	0.016		
77	-1.00	-1	-0.996	-0.004	-0.02	0.02	0.016		
78	-1.04	-1.04	-1.04	0.000	-0.0204	0.0204	0.020		
79	-1.08	-1.08	-1.08	0.000	-0.0208	0.0208	0.021		
80	-1.12	-1.12	-1.12	0.000	-0.0212	0.0212	0.021		
81	-1.16	-1.16	-1.16	0.000	-0.0216	0.0216	0.022		
82	-1.20	-1.2	-1.2	0.000	-0.022	0.022	0.022		
83	-1.24	-1.24	-1.24	0.000	-0.0224	0.0224	0.022		
84	-1.28	-1.28	-1.28	0.000	-0.0228	0.0228	0.023		
85	-1.32	-1.32	-1.32	0.000	-0.0232	0.0232	0.023		
86	-1.36	-1.36	-1.36	0.000	-0.0236	0.0236	0.024		
87	-1.40	-1.4	-1.4	0.000	-0.024	0.024	0.024		
88	-1.44	-1.44	-1.44	0.000	-0.0244	0.0244	0.024		
89	-1.48	-1.48	-1.48	0.000	-0.0248	0.0248	0.025		
90	-1.52	-1.52	-1.52	0.000	-0.0252	0.0252	0.025		
91	-1.56	-1.56	-1.56	0.000	-0.0256	0.0256	0.026		
92	-1.60	-1.6	-1.6	0.000	-0.026	0.026	0.026		
93	-1.64	-1.64	-1.64	0.000	-0.0264	0.0264	0.026		
94	-1.68	-1.68	-1.68	0.000	-0.0268	0.0268	0.027		
95	-1.72	-1.72	-1.72	0.000	-0.0272	0.0272	0.027		
96	-1.76	-1.76	-1.75	-0.010	-0.0276	0.0276	0.018		
97	-1.80	-1.8	-1.79	-0.010	-0.028	0.028	0.018		
98	-1.84				*	*	*		
99	-1.88				*	*	*		

	A	B	C	D	E	F	G	H	I
100	-1.92				*	*	*		
101	-1.96				*	*	*		
102	-2.00				*	*	*		

* These test values are outside of the range in the specification.



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