User Manual

Tektronix

SD-24
TDR/Sampling Head

070–7052–02

Instrument Serial Numbers

Each instrument manufactured by Tektronix has a serial number on a panel insert or tag, or stamped on the chassis. The first letter in the serial number designates the country of manufacture. The last five digits of the serial number are assigned sequentially and are unique to each instrument. Those manufactured in the United States have six unique digits. The country of manufacture is identified as follows:

B010000	Tektronix, Inc., Beaverton, Oregon, USA
E200000	Tektronix United Kingdom, Ltd., London
J300000	Sony/Tektronix, Japan
H700000	Tektronix Holland, NV, Heerenveen, The Netherlands

Instruments manufactured for Tektronix by external vendors outside the United States are assigned a two digit alpha code to identify the country of manufacture (e.g., JP for Japan, HK for Hong Kong, IL for Israel, etc.).

Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077

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In order to obtain service under this warranty, Customer must notify Tektronix of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. Customer shall be responsible for packaging and shipping the defective product to the service center designated by Tektronix, with shipping charges prepaid. Tektronix shall pay for the return of the product to Customer if the shipment is to a location within the country in which the Tektronix service center is located. Customer shall be responsible for paying all shipping charges, duties, taxes, and any other charges for products returned to any other locations.

This warranty shall not apply to any defect, failure or damage caused by improper use or improper or inadequate maintenance and care. Tektronix shall not be obligated to furnish service under this warranty a) to repair damage resulting from attempts by personnel other than Tektronix representatives to install, repair or service the product; b) to repair damage resulting from improper use or connection to incompatible equipment; or c) to service a product that has been modified or integrated with other products when the effect of such modification or integration increases the time or difficulty of servicing the product.

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Introduction

The SD-24 TDR/Sampling Head is a high-performance sampling head that can be installed in the 11800 Series Digital Sampling Oscilloscopes, the SM-11 Multi-Channel Unit, and the CSA 803 Series Communications Signal Analyzers.

The SD-24 TDR/Sampling Head provides the following features:

- Two independent channels with signal acquisition and step generator capabilities. In addition to signal sampling, the two channels let you perform differential and common mode TDR and TDT measurements.
- Both step generators have switchable polarity, with 250 mV amplitude.
- A 28 ps typical displayed TDR incident rise time and a 17.5 ps or less acquisition risetime. The reflected rise time is 35 ps or less.
- A 20 GHz typical bandwidth provides high-speed signal capture.
- Displayed noise is 750 μV_{RMS} typical without smoothing and 350 µV typical with smoothing on. Older sampling heads have a different noise specification; see Specifications on page 33.
- Precision 3.5 mm connectors
- A Channel Select button for quick trace acquisition and selection from the sampling head front panel.

As shown in Figure 1, the SD-24 has two independent channels; each has its own acquisition and step generation circuitry. The strobe drive signal from the mainframe controls the timing of the strobe assertion to each acquisition system. The strobe generator in the sampling head is common to both channels, guaranteeing sampling coincidence between the two channels.

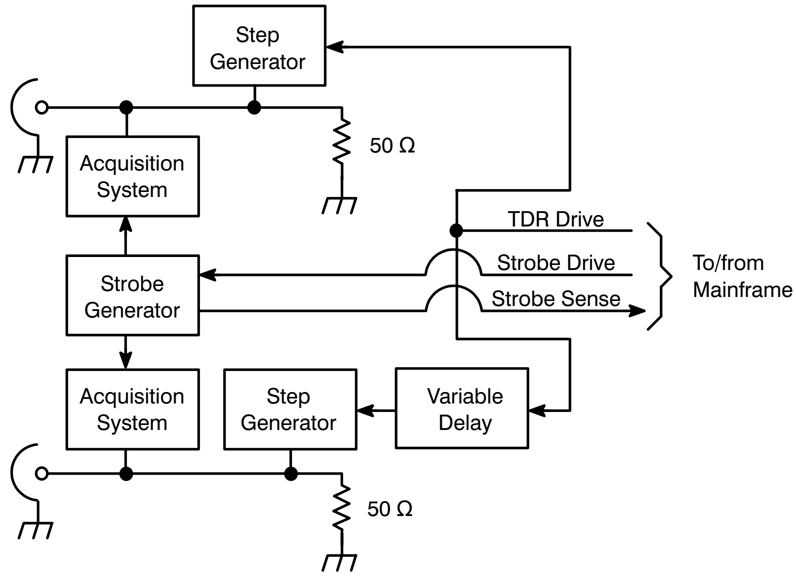

Figure 1: SD-24 Sampling Head Block Diagram

The strobe sense signal is a part of the strobe signal returned to the mainframe. The mainframe monitors the time duration of the strobe drive/strobe sense loop and adjusts a delay (inside the mainframe) to maintain correct strobe timing.

Both channels have a step generator. The step generators can independently assert a negative-going or positive-going step. Using both channels, you can perform differential and common mode Time Domain Reflectometry (TDR) and two-port, time-domain network analysis.

The acquisition risetime is 17.5 ps or less. The displayed TDR reflected risetime is 35 ps or less. To ensure proper timing between the two step outputs, the second channel is equipped with a variable delay.

Safety

Terms in Manuals

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

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

Terms on Equipment

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

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols in Manuals

Static Sensitive Devices

Symbols on Equipment

DANGER
High Voltage

Protective
ground (earth)
terminal

ATTENTION
Refer to
manual

Grounding the Instrument

The sampling head is grounded through the instrument. To avoid electric shock, make sure that the instrument is plugged into a properly wired receptacle where earth ground has been verified by a qualified service person. Without the protective ground, all parts of the instrument and the sampling head are shock hazards. This includes knobs and controls that may appear to be insulators.

Do Not Operate in Explosive Atmospheres

The sampling head provides no explosion protection from static discharges or arcing components. Do not operate the instrument in an atmosphere of explosive gases.

Electrostatic Discharge

To prevent electrostatic damage to the instrument and sampling heads, follow the precautions described in this manual and other manuals accompanying your sampling head and instrument.

Acquisition circuitry in the sampling heads is very susceptible to damage from electrostatic discharge and from overdrive signals and DC voltages. Be sure to operate the mainframe instrument only in a static-controlled environment. Be sure to discharge to ground any electrostatic charge that may be present on cables before attaching the cable to the sampling head.

CAUTION

To prevent damage from electrostatic discharge, install short-circuit terminations on the sampling head connectors before removing from an instrument or storing a sampling head. Be sure to store the head in a static-free container such as the shipping container. Whenever you move the sampling head from one instrument to another, use a static-free container to carry the sampling head.

Always use a wrist strap (provided with your instrument) when handling your sampling head or making connections.

Connector Care

The front of the sampling head has two precision 3.5 mm connectors, one for each channel. They are for attaching the signal cable or the device under test. These are high-precision connectors with a closer mechanical tolerance than standard SMA cables. Never attach a cable to a sampling head connector if the cable has a worn or damaged connector because the sampling head connector may be damaged.

Use extra care when attaching or removing a cable from the connectors. Turn only the nut, not the cable. When attaching a cable to a sampling head connector, align the connectors carefully before turning the nut. Use light finger pressure to make this initial connection. Then tighten the nut lightly with a wrench.

For best repeatability and to prolong the life of both connectors, use a torque wrench and tighten the connection to the range of 7–10 lb-in (79–112 N-cm).

If the sampling head connectors will receive heavy use, such as in a production environment, you should install adapters (for example, connector savers) on the sampling head to make connections to the device under test.

Installing the Sampling Head

The SD-24 TDR/Sampling Head fits into the front panel of a compatible instrument, such as the 11801 Series Digital Sampling Oscilloscopes or CSA 803 Series Communications Signal Analyzers. Figure 2 shows the front panel of an 11801B Digital Sampling Oscilloscope and a CSA 803A Communications Signal Analyzer and the locations of the sampling head compartments. Note that on the CSA 803 Series, only two compartments provide signal acquisition capability. The other two compartments only provide power, for example to power an optical-to-electrical converter.

At least one sampling head must be installed in an 11800 Series or a CSA 803 Series instrument to sample signals.

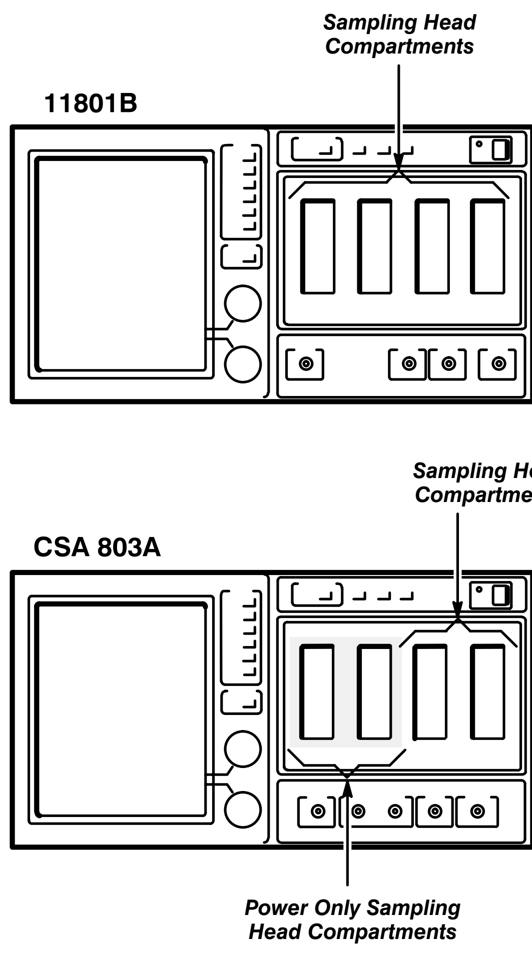

Figure 2: Sampling Head Compartments in an 11801B and a CSA 803A

With the ON/STANDBY switch set to STANDBY, place the sampling head in a compartment and slowly push it in with firm pressure. Once the sampling head is seated, turn the lock-down screw to tighten the sampling head into place.

CAUTION

To prevent damage to the sampling head or instrument, never install or remove a sampling head when the instrument's PRINCIPAL POWER SWITCH is ON (powered-on).

To install a sampling head, first power-off the instrument. Then place the sampling head in a compartment and slowly push it in with firm pressure. Once the head is seated, turn the lock-down screw on the sampling head to tighten the head into place. See Figure 3.

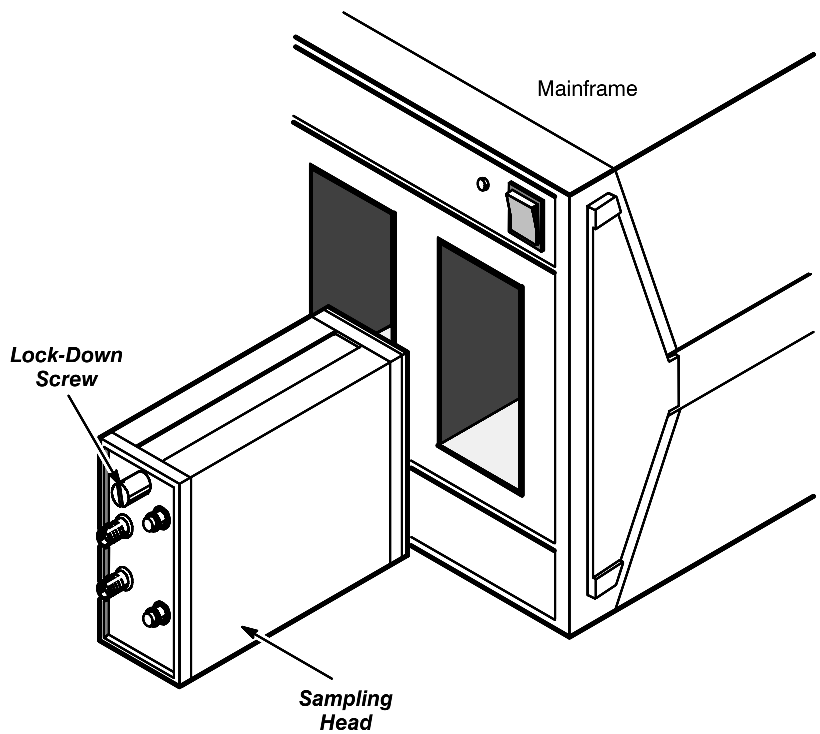

Figure 3: Installing a Sampling Head in an Instrument

Using the Sampling Head

Front Panel

Figure 4 shows the front panel of the SD-24 TDR/Sampling Head and identifies the buttons, lights, and connectors.

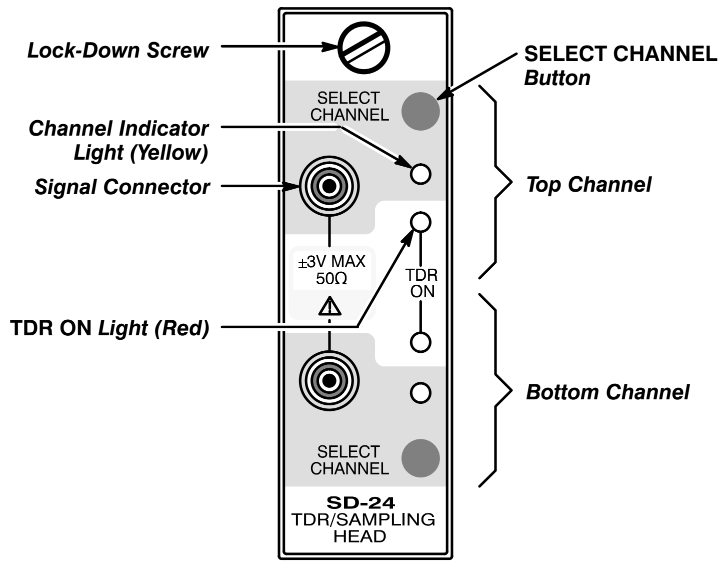

Figure 4: Sampling Head Front Panel

Each channel has a 3.5 mm connector for signal input/step output, a SELECT CHANNEL button, and a yellow channel indicator light.

CAUTION

Applying a voltage outside the range ±3 V can result in damage to the sampling head or instrument. Use a wrist strap to prevent electrostatic damage to the sampling head or instrument.

The input diodes used in the sampling heads are very susceptible to damage from overdrive signal or DC voltages and from electrostatic discharge. Never apply a voltage outside the range of ±3 V. Operate the instrument only in a static-controlled environment.

Always use a wrist strap when handling sampling heads or making connections.

Connecting Signals

The signal connector for each channel is used to connect signals for sampling and to output TDR steps. These are precision 3.5 mm connectors, which are mechanically compatible with the SMA standard. Input impedance is 50 Ω.

Use extra care with the sampling head connectors. See the Connector Care section.

Buttons and Lights

Each channel has a SELECT CHANNEL button, a yellow channel light, and a red TDR ON light.

The yellow channel light can have three states: off, on steady, or blinking. The operation of the channel button depends on the state of the light:

- If the yellow light is off, then the channel is not acquiring trace data, and no trace is displayed from that channel. When the light is off, pressing the SELECT CHANNEL button causes the channel to acquire trace data and display a trace of that channel. Input from that channel becomes the selected trace, so the yellow light blinks.
- If the yellow light is on steady, the channel is acquiring trace data. The trace data is displayed as a single trace and/or may be part of another displayed trace. However, the trace is not the selected trace. When the light is on steady, pressing the SELECT CHANNEL button selects that trace, causing the light to blink.
- If the yellow light is blinking, the channel is part or all of the selected trace. When the light is blinking, pressing the button removes *all* traces displaying that channel. The channel stops acquisitions and the yellow light turns off.

The red TDR ON light indicates whether or not the SD-24 is sending out a step from the step generator through the signal connector.

You cannot control the TDR function from the SD-24 front panel; the mainframe instrument turns this feature on or off.

Instrument/Sampling Head Interaction

The SD-24 TDR/Sampling Head is a part of a larger instrument system. Most of the SD-24 functions are controlled automatically by the mainframe instrument. These include such things as vertical scaling and horizontal sampling rate. You do not directly control these parameters; they are controlled for you as you perform tasks on the mainframe. The parameters that you can control from the SD-24 front panel are covered in the Buttons and Lights section.

There are additional SD-24 functions that you control directly, but from the mainframe instrument. These functions are:

- Smoothing — when enabled, reduces noise in the signal before it is digitized.

NOTE

Turning smoothing on or off on one channel affects both SD-24 channels.

- TDR/TDT — when enabled, turns on the step generator and sends a step out the signal connector. This step is synchronized with the internal clock of the mainframe.
- TDR Polarity — determines whether the TDR step is negative-going or positive-going.
- TDR Head Δ Delay — adjusts the time delay of the channel 2 TDR step (lower channel) with respect to the channel 1 TDR step (upper channel).
- External Channel Attenuation — enables you to enter a number representing any external attenuation you have added to a channel.

Commands From the Mainframe Front Panel

The Waveform major menu lets you access the **Sampling Head Fnc's** pop-up menu. Both of these are shown in Figure 5.

You first select the channel you want to set in the **Selected Channel** section of the pop-up menu. Touch the **Smoothing**, **TDR/TDT**, or **TDR Polarity** selectors to change those settings. Touch the **TDR Head Δ Delay** selector to assign the knobs to that parameter.

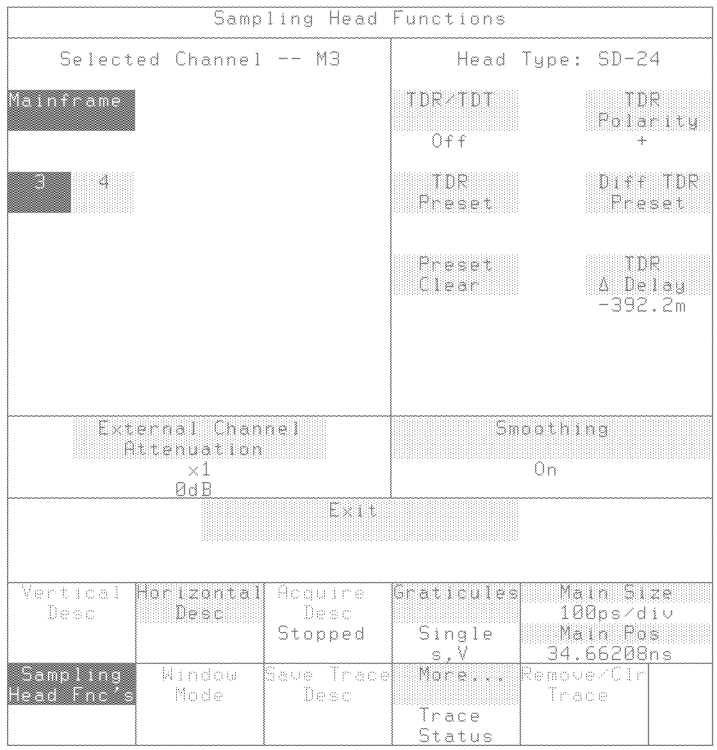

Figure 5: The Sampling Head Fnc's Pop-Up Menu

Programmer Interface Commands

Commands from a remote computer to the 11800 Series or CSA 803 Series instrument (via an IEEE−488 or RS-232-C interface) can control the sampling head functions. These commands are described below.

For these commands, *<alpha>* indicates the unit letter (M for mainframe or A, B, C, or D for an SM-11 Multi-Channel unit; for the CSA 803 Series *<alpha>* is always M) and *<ui>* indicates the channel number for the channel you want to affect.

- `CH<alpha><ui> SMOOTHING: ON | OFF`

  This command turns smoothing on or off.

- `CH<alpha><ui> TDRSTATE: ON | OFF`

  This command turns the TDR step generator on or off.

- `CH<alpha><ui> TDRPOLARITY: PLUS | MINUS`

  This command selects a negative-going or positive-going TDR step.

- `CH<alpha><ui> TDRDELAY: <NRx>`

  This command specifies the delay *<NRx>* of the channel 2 step generator step (lower channel) relative to channel 1 (upper channel).

- `CH<alpha><ui> EXTAttenuation: <NRx>`

  This command specifies the External Channel Attenuation of the specified channel, where *<NRx>* is a floating point attenuation factor.

For complete information about how to use the SD-24 to display traces, see the appropriate mainframe user reference manual.

Adjusting Parameters

To get the best performance from your SD-24 TDR/Sampling Head, you may need to adjust sampling head parameters. These parameters affect how the sampling head acquires signals and affect the accuracy of the resulting trace.

Typically, you may want to adjust sampling head parameters whenever you have moved the sampling head to another slot or if the ambient temperature has changed more than $\pm 5°$ C since the parameters were last adjusted. At the factory, the parameters are set in an environment with an ambient temperature of 25° C.

NOTE

You should adjust sampling head parameters after a 20 minute warm up.

You can adjust sampling head parameters at any time. However, during instrument warm-up, the values may change as the temperature varies. You should adjust the sampling head parameters after the instrument has been on for at least 20 minutes.

There are three different parameters that you can adjust on each channel of your sampling head.

- Loop gain
- Offset null
- TDR step amplitude

The actual procedure for performing the adjustment is dependent on the mainframe instrument. For the 11800 Series and the CSA 803 Series, you can use the Enhanced Accuracy feature to adjust sampling head parameters. It is a quick and simple process. See the *User Manual* for your instrument for instructions to perform these adjustments.

Stored Parameters

The SD-24 contains nonvolatile memory that stores two values, the *factory default value* and the *user constant,* for each of the above parameters. These values are *always* remembered in the sampling head, even if you remove the sampling head from the instrument.

The factory default values for the sampling head parameters are set at the factory. These default values are appropriate for many conditions.

If you decide to adjust a sampling head parameter, the parameter is immediately applied to the head, but is lost when you power-off the instrument. However, you can store the new parameter value as the user constant. The user constants are stored in an EEPROM in the sampling head, so that they are not lost at power-off and are restored at power-on.

If you initialize the mainframe instrument, the last-used values are applied to the sampling head.

If you are not sure of the current user value for a sampling head parameter, you can assign the user parameter value to equal the factory default value. The factory default value offers a reasonable parameter value for many conditions. See the Enhanced Accuracy section in your instrument's *User Manual* for more information.

Loop Gain

Loop gain determines the sampling head's ability to accurately follow an input voltage change that occurs between two adjacent samples. How accurately the sampling head output follows the input signal is termed the dot transient response.

When loop gain is unity (1), the value of the first sample acquired after an input voltage change accurately reflects the voltage change, indicating a good dot transient response. Figure 6 shows this condition.

If loop gain is adjusted too low, then the value of the first sample acquired after an input voltage change will lie somewhere between the value of the last sample and the new voltage.

If loop gain is adjusted too high, the value of the first sample acquired after the input voltage change will be greater than the new voltage level.

Figure 6 shows displayed trace results for the three loop gain conditions.

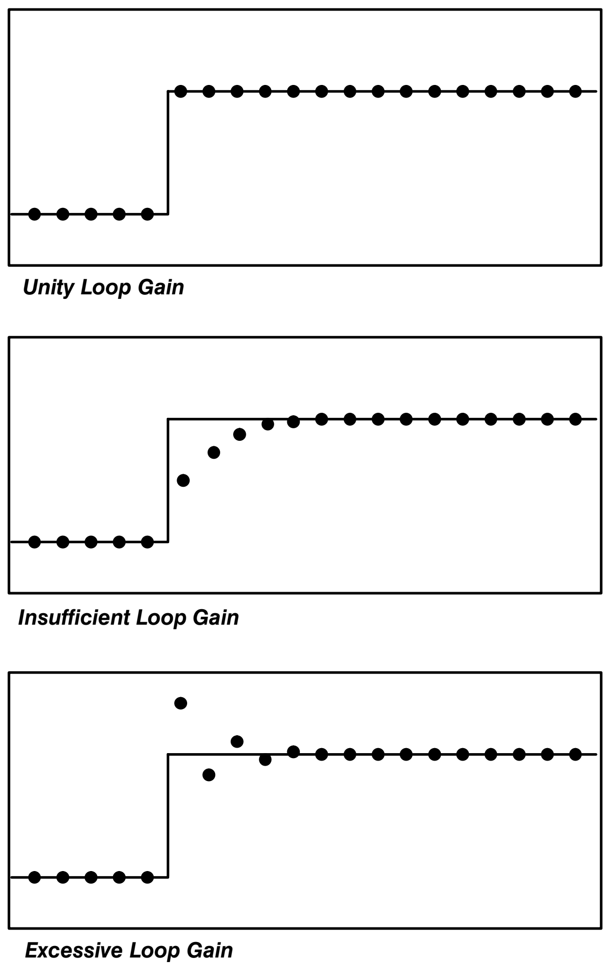

Figure 6: Displayed Trace with Three Loop Gain Settings

Adjusting Loop Gain

For the 11800 Series and CSA 803 Series, you can adjust loop gain automatically or manually from the Enhanced Accuracy menu. If you prefer to adjust loop gain manually, the 11800 Series and CSA 803 Series also provide a divide-by-two feature. This feature is helpful if you are using the Calibrator signal or TDR signal generator output to adjust loop gain. You can also use the divide-by-two feature if you are using the trigger output of the instrument to trigger an external generator.

You might consider adjusting the loop gain whenever you are sampling a trace that has peak-to-peak voltages and transition-speed characteristics that are substantially different from the previous trace. In this case, you can use the actual signal that you want to measure, and turn off vectoring so that you can see each sample individually.

For instructions to adjust the loop gain, see the Enhanced Accuracy section in your instrument's *User Manual*.

The SD-24 contains nonvolatile memory that stores two values for the loop gain adjustment, the factory default value and the user value. These were discussed at the beginning of this section.

Offset Null

The offset null adjustment removes unwanted DC offset that may be present in the sampling head. This adjustment effectively “zeroes” the sampling head so that a 0 V amplitude input signal delivers a 0 V output.

If offset null is not adjusted correctly, measurements taken at the mainframe will be incorrect. The absolute voltage values for any cursors displayed on the trace will also be incorrect.

Adjusting Offset Null

You can adjust offset null automatically or manually from the Enhanced Accuracy menu. If you prefer to adjust offset null manually, be sure to adjust the loop gain first.

You can adjust offset null by terminating the channel input connector with a 50 Ω terminator and adjusting the offset null (with the knob) so that the displayed “trace” is set to the 0 V position on the screen.

If you adjust offset null manually, the offset null setting is valid only for the current setting of the smoothing parameter (on or off).

For example, if smoothing is set to off and you adjust offset null manually, and you then turn smoothing on, the offset null value may not be valid. However, the SD-24 remembers the offset null values for when smoothing is on and off, so if you change the smoothing setting, the correct offset null value is applied.

Note that the SD-24 stores four offset null values: the two factory default values for when smoothing is on and smoothing is off and the two user constants for when smoothing is on and smoothing is off.

If you adjust offset null automatically, using the Enhanced Accuracy menu, the 11800 Series and CSA 803 Series instruments adjust both offset null values (smoothing on and smoothing off).

TDR Amplitude

The SD-24 has an internal step generator that is used with the acquisition channel to let you perform TDR measurements. You can adjust the amplitude of the TDR step.

The TDR step amplitude setting is highly stable and insensitive to temperature variations. You should not need to adjust this parameter very often.

You can adjust the TDR amplitude automatically or manually using the Enhanced Accuracy menu.

You can adjust the TDR step for a negative or positive polarity. With the channel output terminated by a 50 Ω load, the TDR amplitude is adjustable from 0 V to 250 mV, positive or negative. The repetition rate of the TDR step is set by the mainframe.

If you adjust the TDR step automatically using the Enhanced Accuracy menu, the instrument adjusts the amplitude for both the positive- and negative-going steps.

The SD-24 contains nonvolatile memory that stores two values, the factory default value and the user value, for the TDR amplitude adjustment. See Stored Parameters, earlier in this section, for more information.

Taking TDR Measurements

This section describes how to use the SD-24 to perform time domain reflectometry (TDR) measurements.

TDR Step Generation

Both channels in the SD-24 TDR/Sampling Head have a step generator which gives both channels TDR measurement capabilities. You can use the outputs of both generators to perform differential and common mode TDR measurements.

The step generator circuitry consists, fundamentally, of an adjustable current source and a diode switch. Initially, before the step, the diode switch is biased to conduct current to the output. When the diode switch opens, the step occurs. Figure 7, a simplified diagram, shows the switch and the current source.

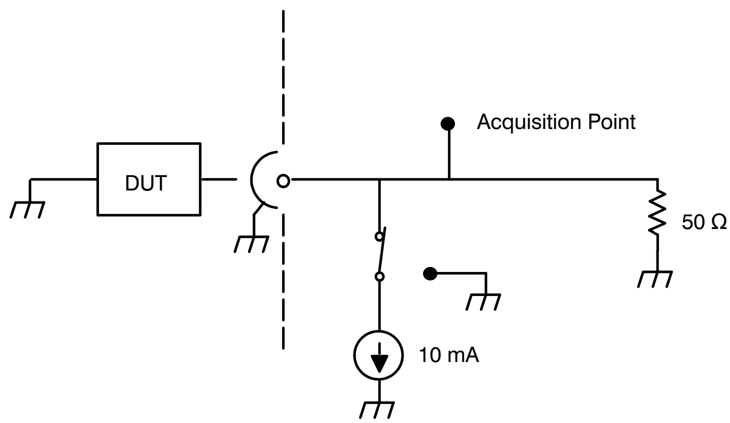

Figure 7: Step Generator Simplified Schematic Diagram

Because of the architecture of the step generator, the output voltage of the step depends on the DC resistance to ground of the device under test. The following sections describe the operation with a short circuit, an open circuit, and a 50 Ω load.

Operation Into a Short Circuit

Initially, the diode switch is conducting −10 mA. Since the step generator output is initially shorted, the resistance to ground is 0 Ω and the output voltage is 0 V.

When the diode switch opens (reverse-biased), apparent resistance to ground at the acquisition point (and at the channel connector) is 25 Ω because the internal termination resistance is 50 Ω and the connector impedance is 50 Ω. The voltage at the acquisition point rises to +250 mV.

The transition propagates to the short in the device under test and is negatively reflected back to the acquisition point, cancelling the transition. The time displayed from the first transition to the second transition is the propagation time from the acquisition point to the short in the device under test and back. See Figure 8.

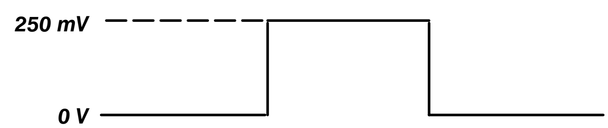

Figure 8: Step Generator with a Shorted Output

Operation Into a 50 Ω Load

Initially, the diode switch is conducting. Since the step generator output is connected to a 50 Ω load, the resistance to ground at the acquisition point is 25 Ω (because of the internal 50 Ω impedance). The 10 mA current source places −250 mV at the acquisition point.

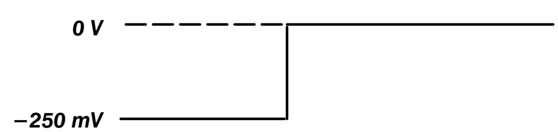

Figure 9: Step Generation with a 50 Ω Load

When the diode switch opens (reverse-biased), the return path to ground is broken and the acquisition point rises to 0 V. The matched impedance allows the acquisition point to remain at 0 V. See Figure 9.

Operation Into an Open Circuit

Initially, the diode switch is conducting. Since the step generator output is open, the resistance to ground at the acquisition point is 50 Ω (because of the internal 50 Ω impedance). The −10 mA current source places −500 mV at the acquisition point as a starting condition.

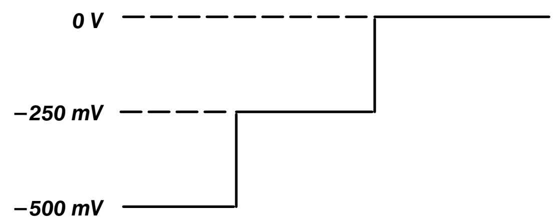

Figure 10: Step Generation with an Open Circuit

When the diode switch opens (reverse-biased), apparent resistance to ground at the acquisition point (and at the channel connector) is 25 Ω, because the internal circuit impedance is 50 Ω and the connector impedance is 50 Ω. This causes the acquisition point to rise to −250 mV.

The transition propagates to the open in the device under test and is reflected back to the acquisition point, causing the voltage at the acquisition point to rise to 0 V. At the acquisition point, the time displayed from the first step to the second step is the propagation time from the acquisition point to the open in the device under test and back. See Figure 10.

Baseline Correction

Baseline correction is a feature of the11800 Series and CSA 803 Series. This feature holds the displayed baseline of a trace in one location despite variations of the offset in the sampling head. These offset variations are caused by changes in impedance at the device under test.

Baseline correction is especially useful with TDR/TDT measurements. Without baseline correction, changes in the DC resistance to ground for the cable or device under test would cause the entire step to move vertically on the display.

Baseline correction keeps the baseline in one location vertically. For the 11800 Series and CSA 803 Series, you can enable baseline correction from the Graticules pop-up menu. For more information on baseline correction, see the *User Manual* for your instrument.

Example: Taking TDR Measurements

This example demonstrates the TDR feature of the SD-24 sampling heads. TDR is a method of examining and measuring a network or transmission line by sending a step into the network and monitoring the reflections.

For this example you will need a instrument mainframe with at least one SD-24 installed. Also, you will need one SMA cable, preferably of 5 ns length.

☐ **Step 1:** Initialize the instrument (press UTILITY and touch **Initialize**).

☐ **Step 2:** Connect your wrist strap to the antistatic connector on the front of your instrument.

☐ **Step 3:** Attach one end of the cable to any SD-24 sampling head input. Leave the other end unattached. See Figure 11.

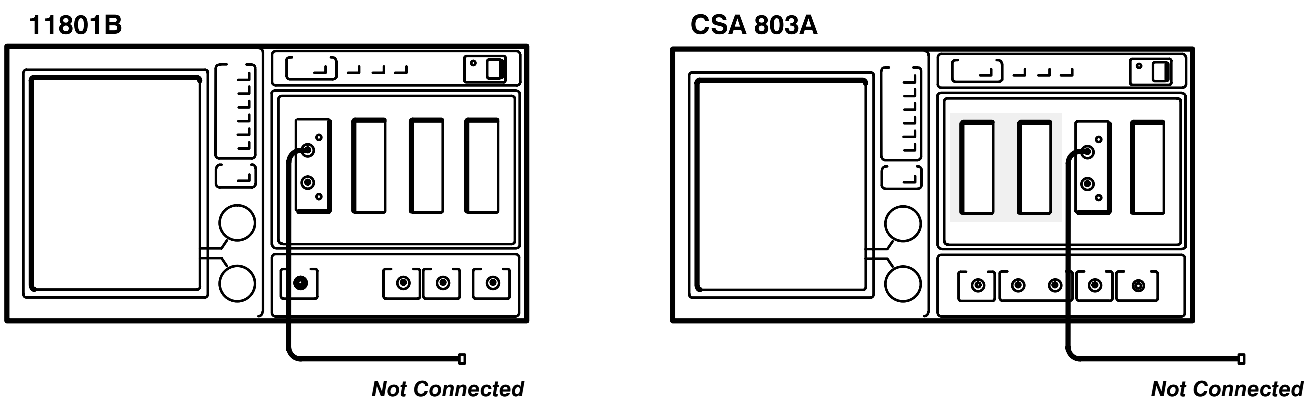

Figure 11: Connections for Example

☐ **Step 4:** Press the SELECT CHANNEL button on the sampling head input channel to which you have connected the cable.

☐ **Step 5:** Press the WAVEFORM button and touch the **Sampling Head Fnc's** selector.

☐ **Step 6:** Touch **TDR Preset** to turn it on, set **Trigger** to **Internal Clock**, and autoset the trace. Touch **Exit** to remove the pop-up menu.

The sampling head will turn on a red light next to the channel input connector, indicating that TDR is activated for that channel. TDR can be used on each channel independently.

☐ **Step 7:** Adjust the display sizes and positions to show a trace similar to that shown in Figure 12. The vertical (↕) and horizontal (↔) icons will let you make fine adjustments.

NOTE

Leave at least one division of baseline trace to the left of the first rise.

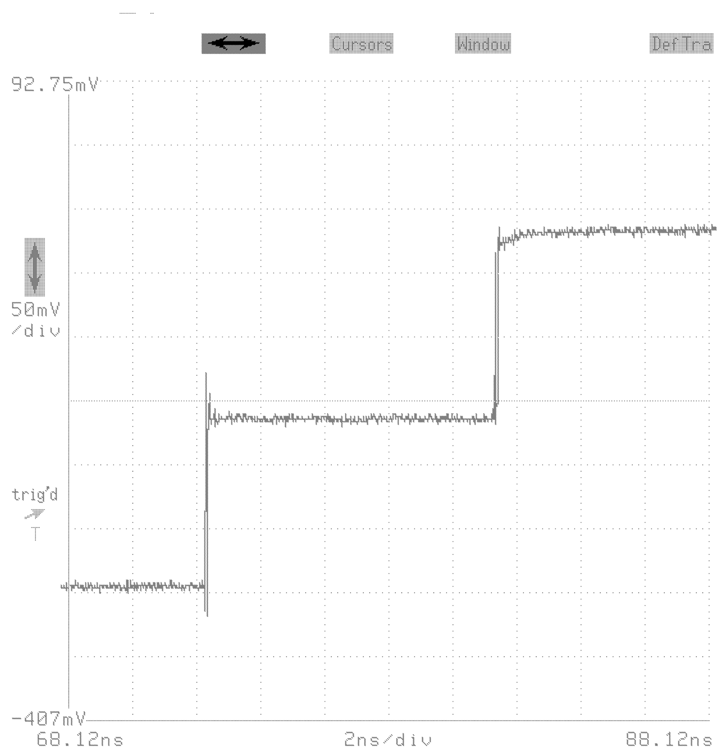

Figure 12: TDR Step and Reflection

The first rise of this trace is the incident TDR step leaving the sampling head; the second rise is the reflection of the step returning from the end of the cable.

Changing Graticule Units for TDR

The units of measure commonly used in TDR are units of rho (ρ), measured on the vertical axis, and time, measured on the horizontal axis. You can change the measurements by using the **Graticules** selector on the Waveform major menu.

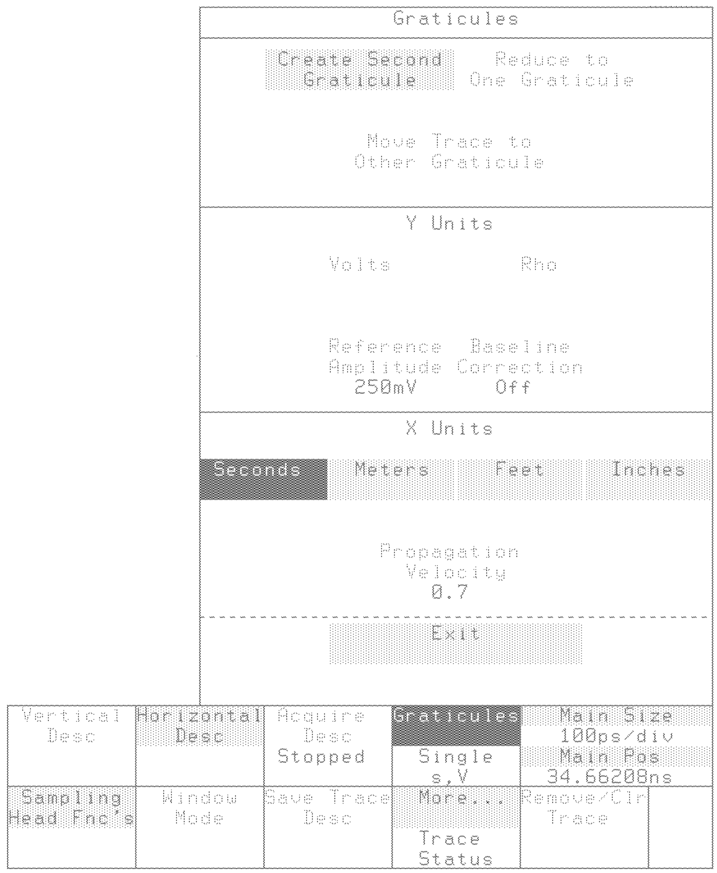

Figure 13: The Graticules Pop-Up Menu

☐ **Step 8:** Touch **Graticules** in the Waveform major menu and **Feet** or **Meters** in the pop-up menu. If you know that the propagation velocity of your cable differs from the default, touch the **Propagation Velocity** selector and adjust this parameter. If you don't know the velocity or are using Tektronix SMA cables, accept the 0.7 default. This unitless number represents the fraction of the speed of light at which signals pass through your network or transmission line.

Example: Differential and Common Mode TDR

The SD-24 TDR/Sampling Head is able to perform differential and common mode TDR measurements. As described earlier, the sampling head has two sampling input channels and two independent step generators.

The step generator output for each channel is selectable for positive or negative polarity and amplitude. This example will show you how to use the two channels and step generators of the SD-24 to perform differential and common mode TDR measurements.

For this example you need an instrument with at least one SD-24 installed in the left-most slot. You also need two SMA cables, preferably of 5 ns length.

- ☐ **Step 1:** Initialize the instrument (press UTILITY and touch **Initialize**).
- ☐ **Step 2:** Connect your wrist strap to the antistatic connector on the front of your instrument.
- ☐ **Step 3:** Attach one end of each cable to the upper and lower channel connectors on the same sampling head.
- ☐ **Step 4:** Press the SELECT CHANNEL button for the upper channel on the sampling head.
- ☐ **Step 5:** Press the WAVEFORM button and touch the **Sampling Head Fnc's** selector.
- ☐ **Step 6:** Touch **Diff TDR Preset** to turn both TDRs on, set **Trigger** to **Internal Clock**, and autoset the upper channel. The display should be similar to Figure 14.
- ☐ **Step 7:** Touch the **Sampling Head Fnc's** selector again. The lower channel on each sampling head has an internal delay adjustment. This lets you set the time at which the step generator for the lower channel asserts the TDR step. Touch the **TDR Head** △ **Delay** selector. Then touch **Exit** to remove the pop-up menu.
- ☐ **Step 8:** Turn either knob on the mainframe to adjust the delay for channel 2. This varies the time when channel 2 asserts the TDR step.

Notice that the second edge moves horizontally, relative to the first edge.

- ☐ **Step 9:** Press the WAVEFORM button. On the display, touch **Sampling Head Fnc's**. Touch **2** and the **TDR Polarity** selector. This causes channel 2 to assert a positive TDR step. Touch **Exit**.

Notice that the upper channel is asserting a positive TDR step. This is common mode TDR.

When the TDR steps on the two channels are the same polarity (both positive or negative), you can define a trace that represents the true common mode signal by touching the **DefTra** icon and touching **Mainframe** *(11801 Series only)*, **1**, **+**, **Mainframe** *(11800 Series only)*, **2**, **Enter**.

When the TDR steps on the two channels are opposite (one positive and one negative), you can now define a trace that represents the true differential signal by touching the **DefTra** icon and touching **Mainframe** *(11801 Series only)*, **1**, **–**, **Mainframe** *(11801 Series only)*, **2**, **Enter**.

TDT Measurements

You can make forward and reverse Time Domain Transmission (TDT) measurements using the SD-24. To perform a TDT measurement, connect one sampling head channel to the input of the device under test and the other sampling head channel to the output of the device under test. You can then alternately enable the step generators on both channels and sample the transmitted signal on the other channel to perform forward and reverse TDT measurements.

More About TDR Measurements

When making differential or common mode TDR measurements, it is important that the two steps arrive at the same time at the reference plane (usually the connection point to the device under test). To check and adjust this condition, disconnect the transmission cables from the device under test *at the point where the cables connect to the device*. Then adjust the TDR step delay for the second channel so that the propagation delay between the incident edges is equal to the propagation delay between the reflected edges, as shown in Figure 14.

For some measurements and comparisons, you may want to visually line up the leading edges of both TDR steps, even though you have delayed the step assertion time for one channel. To do this, create a window of each trace and place each window trace in the lower graticule. Then select one of the window traces and, using the vertical (↕) icon and the lower knob, position the leading edge of the trace. This does not affect the arrival of the TDR steps at the reference plane.

See the *User Manual* for your instrument for more information about windows.

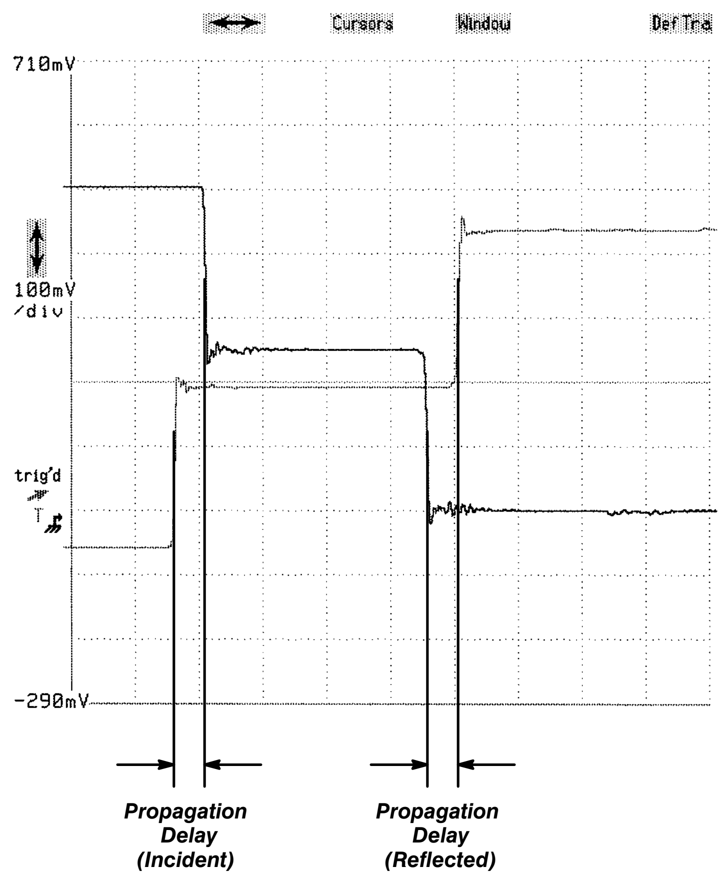

Figure 14: TDR Propagation Delay

Specifications

Table 1: Acquisition Electrical Specifications

Characteristics	Specifications
Bandwidth	20 GHz typical
Sampling Repetition Rate	
Maximum	200 kHz
Minimum	100 Hz
Rise Time	17.5 ps or less, 10% to 90%
Aberrations	
10 ns to 20 ps before step	±3% or less, typical
<300 ps after step	+10%, −5% or less, typical
300 ps to 5 ns after step	+3% or less, typical
5 ns to 100 ns	±1% or less, typical
elsewhere	±0.5% or less, typical
Maximum Safe Input Signal Voltage	±3 V
Maximum Signal Voltage	1.0 V_{p-p}
Dot Transient Response	
Accuracy after calibration at operating temperature	±5% for signals up to 0.5 V_{p-p}
Adjustment Range	Adjustable to unity for signals up to 1.0 V_{p-p}
Displayed Noise	
Unity Dot Response	(SN B020652 and above) 1.2 mV_{RMS} max, 750 μV_{RMS} typical (SN B010651 and below) 1.3 mV_{RMS} typical
With Smoothing	(SN B020652 and above) 550 μV_{RMS} max, 350 μV_{RMS} typical (SN B010651 and below) 600 μV_{RMS} typical
Input Termination Impedance	50 ±0.5 Ω

Table 1: Acquisition Electrical Specifications (Cont.)

Characteristics	Specifications
Isolation Between Channels	≤1% p-p voltage transmission from channel driven with 067–1338–00 to quiescent channel
Time Coincidence Between Channels	
Accuracy	10 ps
Stability	<0.2 ps/° C

Table 2: Step Generator Electrical Specifications

Characteristics	Specifications
Maximum Repetition Rate	100 kHz
Output Amplitude	±250 mV
Channel 2 Delay Adjustment	±50 ps typical relative to channel 1
Insertion Delay Stability	
One Channel	±1 ps/° C
Between Channels	±0.2 ps/° C

Table 3: TDR Electrical Specifications

Characteristics	Specifications
Displayed Rise Time	
Incident	28 ps typical, 10% to 90%, at +250 mV or –250 mV output
Reflected	35 ps or less, 10% to 90%, at +250 mV or –250 mV output
Maximum Repetition Rate	100 kHz
Incident Aberrations at +250 mV or	–250 mV
10 ns to 20 ps before step	±3% or less
<300 ps after step	+10%, –5% or less, typical
300 ps to 5 ns after step	±3% or less
5 ns to 100 ns	±1% or less
elsewhere	±0.5% or less

Table 4: Environmental and Mechanical Specifications

Characteristics	Specifications
Weight	314 grams (11 oz)
Height	71.05 mm (2.9 in)
Width	23.28 mm (0.95 in)
Depth	91.39 mm (3.8 in)
Ambient Temperature	
Operating	0° C to 50° C (32° F to 122° F)
Non operating	−40° C to 75° C (−40° F to 167° F)
Altitude	
Operating	to 4.5 km (15,000 feet)
Non operating	to 15 km (50,000 feet)
Humidity	to 95% relative humidity at up to 50° C (122° F)
MilSpec	Meets MIL−T−28800E, Type III, Class 5
Electromagnetic Compatibility	
United States	MIL−STD−461B: CE−03 Pt 4 Curve 1, CS−01 Pt 7, CS−02 Pt 4, CS−06 Pt 5, RE−02 Pt 7, RS−01 Pt 4, RS−02, Pt 5, RS−03 Pt 7 (limited to 1 GHz)

Glossary

Autoset
A means of letting the instrument mainframe set itself to provide a stable and meaningful display of a given trace.

Baseline Correction
The process of maintaining the displayed vertical placement of a trace, correcting for changes in the signal levels that would ordinarily move the trace up or down.

Channel
A place to connect a signal or attach a network or transmission line to sampling heads. Also, the smallest component of a trace expression.

Channel Number
The number assigned to a specific signal input connector. The top channel of the left-most sampling head compartment of the instrument mainframe is always mainframe channel 1, regardless of any repositioning or omission of sampling heads.

Common Mode
A circumstance where a signal is induced in phase on both sides of a differential network.

Default Measurement Parameter
A value from the default set of measurement parameters. The operator can change the default values. Whenever a trace is created, the measurement parameters are copied from the default set.

Differential Mode
A method of signal transmission where the true signal and its logical compliment are transmitted over a pair of conductors.

Incident Step
When making TDR measurements, the initial transmitted step on a single conductor.

Initialize
Setting the instrument mainframe to a completely known, default condition.

Internal Clock
A trigger source that is synchronized with the Calibrator signal.

Reflected Step
When making TDR measurements, the step returned due to the reflection of the incident step, due to a mismatch in impedance.

Rho (ρ)
When making TDR measurements, the ratio of the incident step to the reflected step. A value of one (1) indicates complete reflection.

Setting
The state of the front panel and system at a given time.

Smoothing
Processing applied by the sampling head prior to the digitization of a trace, to reduce apparent noise. With smoothing, the sampling head samples the signal eight times instead of once, and the average of the samples is then used by hardware measurements and the digitizing circuitry.

Time Domain Reflectometry (TDR)
A method of characterizing a transmission line or network by transmitting a signal from one end and monitoring the electrical reflections.

Time Domain Transmission (TDT)
A method of characterizing a transmission line or network by transmitting a signal through the network and monitoring the output.

Trigger
An electrical event that initiates acquisition of a trace as specified by the time base.

Waveform
The visible representation of an input signal or combination of signals. Identical to trace.

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