Appendix B: Specification

This subsection begins with a general description of the traits of the TDS 400 Digitizing Oscilloscopes. Three subsections follow, one for each of three classes of traits: *nominal traits, warranted characteristics,* and *typical characteristics*.

General

Tektronix TDS 400 Digitizing Oscilloscopes are portable instruments suitable for use in a variety of test and measurement applications and systems. Key features include:

- Four input channels on the TDS 420 and TDS 460 (two input channels on the TDS 410), each with a record length of 500 to 15,000 points and 8-bit vertical resolution. (Option 1M extends the maximum record length to 60,000 points.)
- Video triggering capabilities (with Option 5, Video Trigger).
- Full programmability and printer/plotter output.
- Advanced functions, such as continuously updated measurements.
- Specialized display modes, such as infinite and variable persistence.
- A unique graphical user interface (GUI), an on-board help mode, and a logical front-panel layout which combine to deliver a new standard in usability.
- Advanced waveform math (with Option 2F, Advanced DSP Math). Compute and display the integral of a waveform, the differential of a waveform, and the FFT (Fast Fourier Transform) of a waveform.

Nominal Traits

This subsection contains a collection of tables that list the various *nominal traits* that describe the TDS 400 Digitizing Oscilloscopes. Included are electrical and mechanical traits.

Nominal traits are described using simple statements of fact such as "Four, all identical" for the trait "Input Channels, Number of," rather than in terms of limits that are performance requirements.

Table A-7: Nominal Traits — Signal Acquisition System

Name	Description	
Bandwidth Selections	20 MHz, 100 MHz, and FULL (TDS 410 and TDS 420: 150 MHz, TDS 460: 350 MHz)	
Digitizers, Number of	TDS 410: Two, both identical TDS 420 and TDS 460: Four, all identical	
Digitized Bits, Number of	8 bits[1]	
Input Channels, Number of	TDS 410: Two, both identical, called CH 1 and CH 2 TDS 420 and TDS 460: Four, all identical, called CH 1 through CH 4	
Input Coupling	DC, AC, or GND	
Input Resistance Selections	1 MΩ or 50Ω	
Ranges, Offset, All Channels	**Volts/Div Setting**	**Offset Range**
	1 mV/div to 99.5 mV/div	±1 V
	100 mV/div to 995 mV/div	±10 V
	1 V/div to 10 V/div	±100 V
Range, Position	±5 divisions	
Range, Sensitivity[2]	1 mV/div to 10 V/div	

[1]Displayed vertically with 25 digitization levels (DLs) per division and 10.24 divisions dynamic range with zoom off. A DL is the smallest voltage level change resolved by the 8-bit A-D Converter, with the input scaled to the volts/division setting of the channel used. Expressed as a voltage, a DL is equal to 1/25 of a division times the volts/division setting.

[2]The sensitivity ranges from 1 mV/div to 10 V/div in a 1–2–5 sequence of coarse settings. Between consecutive coarse settings, the sensitivity can be finely adjusted with a resolution of 1% of the more sensitive setting. For example, between 50 mV/div and 100 mV/div, the volts/division can be set with 0.5 mV resolution.

Table A-7: Nominal Traits — Signal Acquisition System (Cont.)

Name	Description	
Rise Time[3] (TDS 410 and TDS 420)	**Volts/Div Setting**	**Rise Time**
	5 mV/div–10 V/div	2.3 ns
	2 mV/div–4.98 mV/div	3.2 ns
	1 mV/div–1.99 mV/div	3.9 ns
Rise Time[3] (TDS 460)	**Volts/Div Setting**	**Rise Time**
	5 mV/div–10 V/div	1.0 ns
	2 mV/div–4.98 mV/div	1.4 ns
	1 mV/div–1.99 mV/div	3.5 ns

[3]Rise time is defined by the following formula:

$$Rise\ \ Time\ \ (ns) = \frac{350}{BW\ \ (MHz)}$$

Table A-8: Nominal Traits — Time Base System

Name	Description
Range, Sample-Rate[1,3]	2.5 Samples/s to 100 MSamples/s
Range, Equivalent Time or Interpolated Waveform Rate[2,3]	200 MSamples/s to 50 GSamples/s
Range, Seconds/Division	1 ns/div to 20 s/div
Range, Time Base Delay Time	0 to 20 seconds (settings of 20 µs and slower are displayed in roll mode)
Reference Frequency, Time Base	100 MHz
Record Length Selection	500 points, 1,000 points, 2,500 points, 5,000, and 15,000 points. Record lengths of 30,000 and 60,000 points are available with Option 1M.[4]

[1]The range of real-time rates, expressed in samples/second, at which a digitizer samples signals at its inputs and stores the samples in memory to produce a record of time-sequential samples

[2]The range of waveform rates for equivalent time or interpolated waveform records.

[3]The Waveform Rate (WR) is the equivalent sample rate of a waveform record. For a waveform record acquired by real-time sampling of a single acquisition, the waveform rate is the same as the real-time sample rate; for a waveform created by interpolation of real-time samples from a single acquisition or by equivalent-time sampling of multiple acquisitions, the waveform rate is faster than the real time sample rate. For all three cases, the waveform rate is 1/(Waveform Interval) for the waveform record, where the waveform interval (WI) is the time between the samples in the waveform record.

[4]The maximum record length of 60,000 points available with Option 1M is selectable with all acquisition modes except Hi Res and Average. In Hi Res and Average, the maximum record length is 15,000 points.

Table A-9: Nominal Traits — Triggering System

Name	Description	
Range, Events Delay	1 to 9,999,999	
Ranges, Trigger Level or Threshold	**Source**	**Range**
	Any Channel	±12 divisions from center of screen
	Line	±400 Volts

Table A-10: Nominal Traits — Display System

Name	Description
Video Display Resolution	640 pixels horizontally by 480 pixels vertically in a display area of 5.04 inches horizontally by 3.78 inches vertically
Waveform Display Graticule	A single graticule 401 × 501 pixels (8 × 10 divisions, with divisions that are 1 cm by 1 cm)
Waveform Display Grey Scale	16 levels in infinite-persistence and variable-persistence display styles

Table A-11: Nominal Traits — Data Storage

Name	Description
Capacity, Nonvolatile Waveform Memory	Standard Instrument: Total capacity is 60,000 points. Option 1M Equipped Instrument: Total capacity is 60,000 points (one to four waveforms acquired with any combination of record lengths that add up to 60,000 points). For available record lengths, see "Record Length Selection" on page A-11 of this section.
Capacity, Nonvolatile Setup Memory	Ten setups.
Batteries[1] Required	Two lithium poly-carbon monofluoride. Both are type BR2/3A, UL listed. Both are rated at 3.0 volt, 1.2 amp-hour.

[1]Batteries are not accessible from the outside of the instrument; therefore, they can only be replaced by a service technician.

Table A-12: Nominal Traits — GPIB Interface, Video Output, and Power Fuse

Name	Description
Interface, GPIB	GPIB interface complies with IEEE Std 488.1-1987 and IEEE Std 488.2-1987.
Output, Video	Provides a video signal, non-interlaced, with levels that comply with ANSI RS343A. For oscilloscopes SN B030099 and below, output is through a rear-panel DB9 connector. For oscilloscopes SN B030100 and above, output is through a rear-panel DB-15 connector.
Fuse Rating	Either of two fuses[1] may be used: a .25″ × 1.25″ (UL 198.6, 3AG): 5 A FAST, 250 V, or a 5 mm × 20 mm, (IEC 127): 4 A (T), 250 V.

[1]Each fuse type requires its own fuse cap.

Table A-13: Nominal Traits — Mechanical

Name	Description
Cooling Method	Forced-air circulation with no air filter.
Construction Material	Chassis parts constructed of aluminum alloy; front panel constructed of plastic laminate; circuit boards constructed of glass-laminate. Plastic parts are polycarbonate.
Finish Type	Tektronix Blue textured finish on aluminum cabinet.
Weight	Standard digitizing oscilloscope 8.6 kg (19.0 lbs), oscilloscope only. 10.2 kg (22.5 lbs), with front cover, accessories, and accessories pouch installed. 14.5 kg (32.0 lbs), when packaged for domestic shipment. Rackmount digitizing oscilloscope 8.2 kg (18.0 lbs) plus the weight of rackmount parts, for the rackmounted digitizing oscilloscope (Option 1R). 16.3 kg (36.0 lbs), when the rackmounted digitizing oscilloscope is packaged for domestic shipment. Rackmount conversion kit 4.5 kg (10.0 lbs), parts only; 7.9 kg (17.5 lbs), parts plus package for domestic shipping.

Table A-13: Nominal Traits — Mechanical (Cont.)

Name	Description	
Overall Dimensions	Standard digitizing oscilloscope	
	Height	191 mm (7.5 in), when feet and accessories pouch are installed. 165 mm (6.5 in), without the accessories pouch installed.
	Width	362 mm (14.25 in), with handle.
	Depth	471 mm (18.55 in), oscilloscope only; 490 mm (19.28 in), with optional front cover installed; 564 mm (22.2 in), with handle fully extended.
	Rackmount digitizing oscilloscope	
	Height	178 mm (7.0 in).
	Width	483 mm (19.0 in).
	Depth	472 mm (18.6 in), without front-panel handles; 517 mm (20.35 in), with front-panel handles installed.

Warranted Characteristics

This subsection lists the various *warranted characteristics* that describe the TDS 400 Digitizing Oscilloscopes. Included are electrical and environmental characteristics.

Warranted characteristics are described in terms of quantifiable performance limits which are warranted. This subsection lists only warranted characteristics. A list of *typical characteristics* starts on page A-21.

Performance Conditions

The electrical characteristics found in these tables of warranted characteristics apply when the oscilloscope is adjusted at an ambient temperature between +20° C and +30° C, has had a warm-up period of at least 20 minutes, and is operating at an ambient temperature between 0° C and +50° C (unless otherwise noted).

Table A-14: Warranted Characteristics — Signal Acquisition System

Name	Description	
Accuracy, DC Voltage Measurement, Averaged	**Measurement Type**	**DC Accuracy**
	Average of ≥16 waveforms	±(1.5% × |(reading − Net Offset[1])| + Offset Accuracy + 0.06 div)
	Delta volts between any two averages of ≥16 waveforms[2]	±(1.5% × |reading| + 0.1 div + 0.3 mV)
Accuracy, DC Gain [3]	±1.5%	

[1]Net Offset = Offset − (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter dynamic range. Offset Accuracy is the accuracy of this voltage level.

[2]The samples must be acquired under the same setup and ambient conditions.

[3]DC Gain Accuracy is confirmed in the Performance Verification Procedure by passing the checks for Offset Accuracy and DC Voltage Measurement Accuracy (Averaged).

Table A-14: Warranted Characteristics — Signal Acquisition System (Cont.)

Name	Description	
Accuracy, Offset	**Volts/Div Setting**	**Offset Accuracy**
	1 mV/div–9.95 mV/div	±(0.4% × |Net Offset[1]| + 0.9 mV + 0.1 div)
	10 mV/div–99.5 mV/div	±(0.4% × |Net Offset[1]| +1.5 mV + 0.1 div)
	100 mV/div–995 mV/div	±(0.4% × |Net Offset[1]| + 15 mV + 0.1 div)
	1 V/div–10 V/div	±(0.4% × |Net Offset[1]| + 150 mV + 0.1 div)
Accuracy, Position[4]	±(1.5% × (Position × Volts/div) + Offset Accuracy + 0.04 div)	
Analog Bandwidth, DC-50 Ω Coupled and DC-1 MΩ with Standard-accessory Probe Attached (TDS 410 and TDS 420)	**Volts/Div**	**Bandwidth[5]**
	5 mV/div–10 V/div	DC–150 MHz
	2 mV/div–4.98 mV/div	DC–110 MHz
	1 mV/div–1.99 mV/div	DC–90 MHz
Analog Bandwidth, DC-50 Ω Coupled and DC-1 MΩ with Standard-accessory Probe Attached (TDS 460)	**Volts/Div**	**Bandwidth[5]**
	5 mV/div–10 V/div	DC–350 MHz
	2 mV/div–4.98 mV/div	DC–250 MHz
	1 mV/div–1.99 mV/div	DC–100 MHz
Cross Talk (Channel Isolation)	**Volts/Div**	**Isolation**
	>500 mV/div	≥40:1 at 50 MHz for any two channels having equal volts/division settings
	≤9.95 mV/div	≥40:1 at 50 MHz for any two channels having equal volts/division settings
	10 mV/div–500 mV/div	≥80:1 at 100 MHz and ≥30:1 at full bandwidth for any two channels having equal volts/division settings
Delay Between Channels, Full Bandwidth, Equivalent Time	≤200 ps between CH 1 and CH 2 (all models) and between CH 3 and CH 4 (TDS 420 and TDS 460) when both channels have equal volts/division and coupling settings	
	≤450 ps for any other combination of two channels with equal volts/division and coupling settings (TDS 420 and TDS 460).	

[1]Net Offset = Offset – (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter's dynamic range. Offset Accuracy is the accuracy of this voltage level.

[4]Position Accuracy is confirmed in the Performance Verification Procedure (Section 4) by passing the checks for Offset Accuracy and DC Voltage Measurement Accuracy (Averaged).

[5]The limits given are for the ambient temperature range of 0°C to +30°C. Reduce the upper bandwidth frequencies by 2.5 MHz for each °C above +30°C.

Table A-14: Warranted Characteristics — Signal Acquisition System (Cont.)

Name	Description	
Input Impedance, DC-1 MΩ Coupled	1 MΩ ±0.5% in parallel with 15 pF ±2.0 pF. Matched between channels to within ±1% for resistance and ±1.0 pF for capacitance	
Input Impedance, DC-50 Ω Coupled (TDS 410 and TDS 420)	50 Ω ±1% with VSWR ≤1.2:1 from DC–150 MHz	
Input Impedance, DC-50 Ω Coupled (TDS 460)	50 Ω ±1% with VSWR ≤1.6:1 from DC–350 MHz	
Input Voltage, Maximum, DC-1 MΩ, AC-1 MΩ, or GND Coupled	**Volt/Div**	**Rating**
	0.1 V/div–10 V/div	±400 V (DC + peak AC); derate at 20 dB/decade above 10 MHz until the minimum rating of ±5 V (DC + peak AC) is reached
	1 mV/div–9.99 mV/div	±400 V (DC + peak AC); derate at 20 dB/decade above 10 kHz until the minimum rating of ±5 V (DC + peak AC) is reached
Input Voltage, Maximum, DC-50 Ω or AC-50 Ω Coupled	5 V rms, with peaks less than or equal to ±30 V	
Lower Frequency Limit, AC Coupled	≤10 Hz when AC–1 MΩ coupled; ≤200 kHz when AC-50 Ω coupled[6]	

[6]The AC Coupled Lower Frequency Limits are reduced by a factor of 10 when 10X, passive probes are used.

Table A-15: Warranted Characteristics — Time Base System

Name	Description
Accuracy, Long Term Sample Rate and Delay Time	±150 ppm over any ≥1 ms interval
Accuracy, Absolute Time and Delay Time Measurements[1, 2]	For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 100 MHz: ±(1 WI + 150 ppm of |Reading| + 450 ps) For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 20 MHz: ±(1 WI + 150 ppm of |Reading| + 1.3 ns) For repetitive acquisitions using average acquisition mode with ≥8 averages and a bandwidth limit setting of FULL: ±(1 WI + 150 ppm of |Reading| + 200 ps)

[1]For input signals ≥ 5 divisions in amplitude and a slew rate of ≥ 2.0 divisions/ns at the delta time measurement points. Signal must have been acquired at a volts/division setting ≥ 5 mV/division and not in Events mode.
[2]The WI (waveform interval) is the time between the samples in the waveform record. Also, see the footnotes for *Sample Rate Range* and *Equivalent Time or Interpolated Waveform Rates* in Table A-8 on page A-11.

Table A-15: Warranted Characteristics — Time Base System (Cont.)

Name	Description
Accuracy, Delta Time Measurement[1, 2]	For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 100 MHz: ±(1 WI + 150 ppm of |Reading| + 650 ps) For repetitive acquisitions using average acquisition mode with ≥8 averages and a bandwidth limit setting of FULL: ±(1 WI + 150 ppm of |Reading| + 300 ps)

[1]For input signals ≥ 5 divisions in amplitude and a slew rate of ≥ 2.0 divisions/ns at the delta time measurement points. Signal must have been acquired at a volts/division setting ≥ 5 mV/division and not in Events mode.
[2]The WI (waveform interval) is the time between the samples in the waveform record. Also, see the footnotes for *Sample Rate Range* and *Equivalent Time or Interpolated Waveform Rates* in Table A-8 on page A-11.

Table A-16: Warranted Characteristics — Triggering System

Name	Description
Accuracy, Trigger Level or Threshold, DC Coupled	±(2% of |Setting − Net Offset[1]| + 0.2 div × volts/div setting + Offset Accuracy) for any channel as trigger source and for signals having rise and fall times ≥ 20 ns.
Sensitivity, Edge-Type Trigger, DC Coupled[2]	0.35 division from DC to 50 MHz, increasing to 1 division at 350 MHz (TDS 410 and TDS 420) or 500 MHz (TDS 460) for any channel as trigger source
Sensitivity, Video-Type, TV Field and TV Line[2]	0.6 division of video sync signal
Pulse Width, minimum, Events-Delay	5 ns
Auxiliary Trigger Input	Connector: BNC at rear panel Input Load: equivalent to three TTL gate loads Input Voltage (maximum): −5 VDC to +10 VDC
Auxiliary Trigger, Maximum Input Frequency	10 MHz Duty Cycle High and low levels must be stable for ≥ 50 ns

[1]Net Offset = Offset − (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter dynamic range. Offset Accuracy is the accuracy of this voltage level.

[2]The minimum sensitivity for obtaining a stable trigger. A stable trigger results in a uniform, regular display triggered on the selected slope. The trigger point must not switch between opposite slopes on the waveform, and the display must not "roll" across the screen on successive acquisitions. The TRIG'D LED stays constantly lighted when the SEC/DIV setting is 2 ms or faster but may flash when the SEC/DIV setting is 10 ms or slower.

Table A-17: Warranted Characteristics — Probe Compensator Output

Name	Description	
Output Voltage and Frequency, Probe Compensator	**Characteristic**	**Limits**
	Voltage	0.5 V (base-top) ±5% into a 1 MΩ load
	Frequency	1 kHz ±5%

Table A-18: Warranted Characteristics — Power Requirements

Name	Description
Source Voltage and Frequency	90 to 132 VAC rms, continuous range, for 48 Hz through 62 Hz 100 to 132 VAC rms, continuous range, for 48 Hz through 440 Hz 180 to 250 VAC rms, continuous range, for 48 Hz through 440 Hz
Power Consumption	≤240 Watts (370 VA)

Table A-19: Warranted Characteristics — Environmental, Safety, and Reliability

Name	Description
Atmospherics	Temperature: 0° C to +50° C, operating; −40° C to +75° C, non-operating Relative humidity: 0 to 95%, at or below +30° C; 0 to 75%, +31° C to +50° C Altitude: To 15,000 ft. (4570 m), operating; to 40,000 ft. (12190 m), non-operating
Emissions[1,2]	Meets or exceeds the requirements of the following standards: Vfg. 243/1991 Amended per Vfg 46/1992 FCC 47 CFR, Part 15, Subpart B, Class A EN50081-1 European Community Requirements EN55022 Radiated Emissions Class B EN55022 Conducted Emissions Class B
Susceptibility	Meets or exceeds the requirements of the following standards: EN50082-1 European Community Requirements IEC 801-3 Radiated Susceptibility 3 V/meter from 27 MHz to 500 MHz unmodulated. Performance Criteria: < + 0.2 division waveform displacement, or < 0.2 division increase in p-p noise when the oscilloscope is subjected to the EMI specified in the standard. IEC 801-2 Electrostatic Discharge, Performance Criteria B
Dynamics	Random vibration[3]: 0.31 g rms, from 5 to 500 Hz, 10 minutes each axis, operating; 2.46 g rms, from 5 to 500 Hz, 10 minutes each axis, non-operating

[1]To maintain emission requirements when connecting to the IEEE 488 GPIB interface of this oscilloscope, use only a high-quality, double-shielded (braid and foil) GPIB cable. The cable shield must have low impedance connections to both connector housings. Acceptable cables are Tektronix part numbers 012-0991-00, -01, -02, and -03.

[2]To maintain emission requirements when connecting to the VGA-compatible video output of this oscilloscope, use only a high-quality double-shielded (braid and foil) video cable with ferrite cores at either end. The cable shield must have low impedance connections to both connector housings. An acceptable cable is NEC® part number 73893013. (Use an appropriate adapter when other than a 9-pin monitor connection is needed.)

[3]Does not apply to rackmounted instrument