Keysight Technologies
Serial Bus Options for InfiniiVision X-Series Oscilloscopes

Data Sheet

KEYSIGHT TECHNOLOGIES

Introduction

Serial buses are pervasive in today's digital designs and are used for a variety of purposes including on-board chip-to-chip communication, CPU to peripheral control, as well as for remote sensor data transfer and control.

Without intelligent oscilloscope serial bus triggering and protocol decode, it can be difficult to debug these buses and correlate data transfers with other mixed signal interactions in your system. Keysight Technologies, Inc. InfiniiVision X-Series oscilloscopes (DSOs) and mixed-signal oscilloscopes (MSOs) offer optional integrated serial bus triggering and hardware-based protocol decoding solutions that give you the tools you need to accelerate debug of your designs that include serial bus communication.

Supported Protocols and Features

- I^2C
- SPI
- RS232/UART
- CAN
- CAN FD (4000 X-Series only)
- CAN-dbc symbolic decode and trigger (4000 and 6000 X-Series only)
- LIN
- SENT (4000 X-Series only)
- USB 2.0 low- and full-speed (4000 and 6000 X-Series only)
- USB 2.0 hi-speed (4000 and 6000 X-Series only)
- USB 2.0 signal quality (4000 and 6000 X-Series only)
- I^2S (3000, 4000 and 6000 X-Series only)
- FlexRay (3000, 4000 and 6000 X-Series only)
- MIL-STD 1553 (3000, 4000 and 6000 X-Series only)
- ARINC 429 (3000, 4000 and 6000 X-Series only)
- Hardware-based decoding
- Multi-bus analysis (3000, 4000 and 6000 X-Series only
- Automatic search and navigation
- Compatibility with segmented memory acquisition
- Eye-diagram mask files available for CAN, FlexRay, MIL-STD 1553, and ARINC 429 (requires DSOX2MASK/DSOX3MASK/DSOX4MASK/DSOX6MASK mask test option)
- FlexRay physical layer conformance test software (3000, 4000 and 6000 X-Series only)

Hardware-Based Decoding

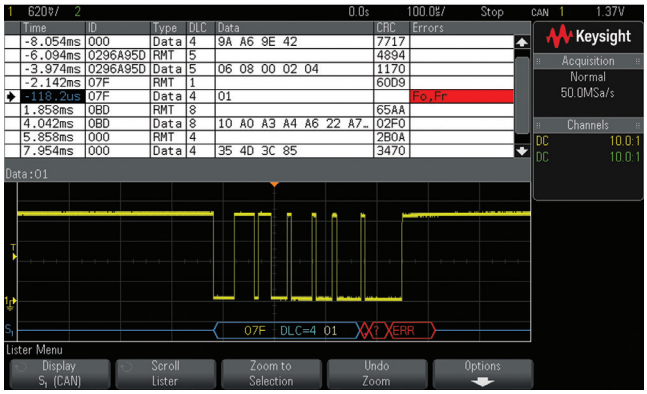


Figure 1: Hardware-based decoding quickly reveals serial communication errors.

Keysight's InfiniiVision Series oscilloscopes are the industry's only scopes to use hardware-based decoding. Most other vendor's scopes with serial bus triggering and protocol decode, use software post-processing techniques to decode serial packets/frames. With these software techniques, waveform- and decode-update rates tend to be slow (sometimes seconds per update.) That's especially true when using deep memory, which is often required to capture multiple packetized serial bus signals. And when analyzing multiple serial buses simultaneously, software techniques can make decode update rates even slower.

Faster decoding with hardware-based technology enhances scope usability, and more importantly, the probability of capturing infrequent serial communication errors. Figure 1 shows an example of a Keysight InfiniiVision X-Series scope capturing a random and infrequent CAN error frame. The upper half of the scope's display shows the decoded data in a "Lister" format, along with a time-correlated decode trace shown below the waveform.

Symbolic Trigger and Decode

With the DSOX4AUTO or DSOX6AUTO option licensed on a 4000 X-Series oscilloscope, you can import a .dbc file that defines your multi-node CAN network. The oscilloscope can then trigger on and decode the CAN bus symbolically as shown in Figure 2.

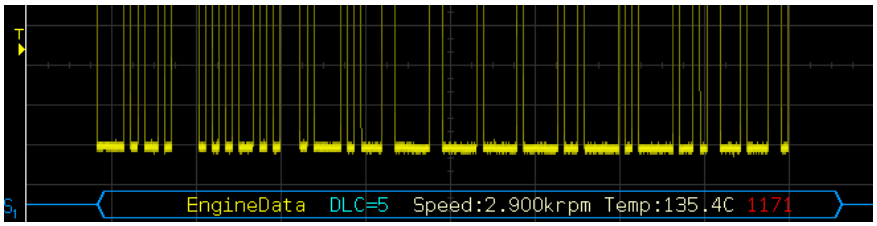


Figure 2: Symbolically decoding the CAN bus.

Automatic Search and Navigation

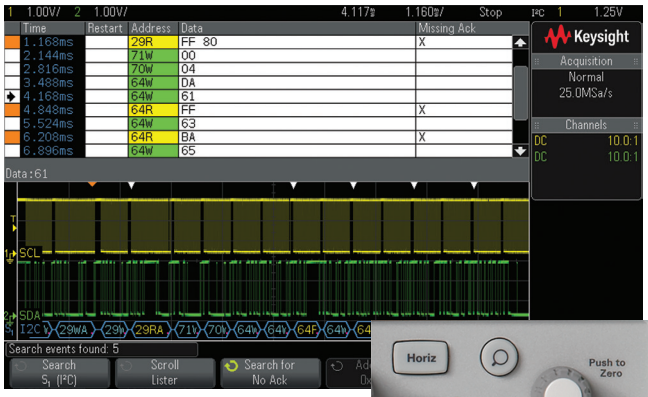


Figure 3: Automatic "Search & Navigation" quickly finds user-specified serial bus frames/bytes of interest.

After capturing a long record of serial bus communication using the InfiniiVision scope's MegaZoom deep memory, you can easily perform a search operation based on specific criteria that you enter. Then, you can quickly navigate to bytes/frames of serial data that satisfy the entered search criteria. Figure 3 shows an example of searching on captured I^2C data to find all occurrences of Read or Write operations with "No Ack." In this case, the scope found five occurrences of data transfers with "No Ack," and marked each occurrence with a white triangle to show where in time they happened relative to the captured waveform. Navigating and zooming-in on each marked byte/frame is quick and easy using the scope's front panel navigation keys.

Multi-bus Analysis

Figure 4: An interleaved "Lister" makes it easier to time-correlate activity between two decoded serial buses.

Many of today's designs include multiple serial buses. Sometimes it may be necessary to correlate data from one serial bus to another. Keysight's InfiniiVision 3000, 4000 and 6000 X-Series oscilloscopes can decode two serial buses simultaneously using hardware-based decoding. Plus they are the only scopes on the market that can also display the captured data in a time-interleaved "Lister" display, as shown in Figure 4. In this particular example, the scope has simultaneously decoded and interleaved a CAN and LIN bus in an automotive system.

Using Segmented Memory to Capture Multiple Serial Bus Packets

Figure 5: Segmented memory acquisition selectively captures more packets/bytes of serial bus activity.

The segmented memory option for Keysight's InfiniiVision X-Series oscilloscopes (standard in 4000 and 6000 X-Series) can optimize your scope's memory, letting you capture more packets/frames of serial bus activity. Segmented memory acquisition optimizes the number of packetized serial communication frames that can be captured consecutively. Segmented memory does this by capturing just the selective frames/bytes of interest while ignoring (not digitizing) idle time and other unimportant frames/bytes. Figure 5 shows an example of the oscilloscope capturing 500 consecutive hi-speed USB split packets for a total acquisition time of approximately 200 ms. Capturing this much data using conventional oscilloscope acquisition memory would require 1G bytes of memory.

Keysight's InfiniiVision X-Series oscilloscopes are the only scopes on the market today that can acquire segments on up to four analog channels of acquisition, and time-correlated segments on digital channels (using an MSO model), along with automatic hardware-based serial bus decoding for each segment. In addition, you can use the scope's Search & Navigation capability after a segmented memory acquisition has been performed.

Serial Bus Eye-diagram and Pulse Mask Testing

With the addition of the DSOX2MASK, DSOX3MASK, DSOX4MASK or DSOX6MASK mask test option, which can perform over 200,000 pass/fail tests (50,000 on 2000 X-Series) per second, you can perform eye-diagram and pulse mask testing on CAN signals on all InfiniiVision X-Series oscilloscopes. Eye-diagram mask testing on FlexRay, MIL-STD 1553, and ARINC 429 signals can be performed using an InfiniiVision 3000, 4000 or 6000 X-Series oscilloscope. Eye-diagram measurements provide a comprehensive signal quality test of the integrity of your transmitted and received signals. Keysight provides various mask files that you can download at no charge. The mask files are based on published industry mask standards and/or derived from physical layer/electrical specifications.

The following CAN mask files are available:

- 125 kbps – 400 meters
- 250 kbps – 200 meters
- 500 kbps – 10 meters
- 500 kbps – 80 meters
- 800 kbps – 40 meters
- 1000 kbps – 25 meters

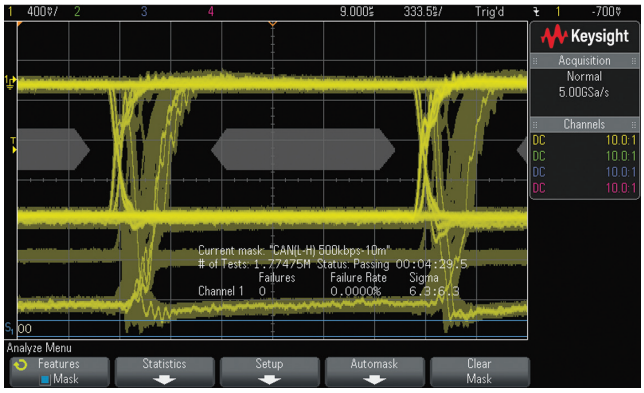


Figure 6: CAN 500 kbps mask test on 10 meter system.

The following FlexRay mask test files are available:

- TP1 standard voltage (10 Mbps only)
- TP1 increased voltage (10 Mbps only)
- TP11 standard voltage (10 Mbps only)
- TP11 increased voltage (10 Mbps only)
- TP4 10 Mbps
- TP4 5 Mbps
- TP4 2.5 Mbps

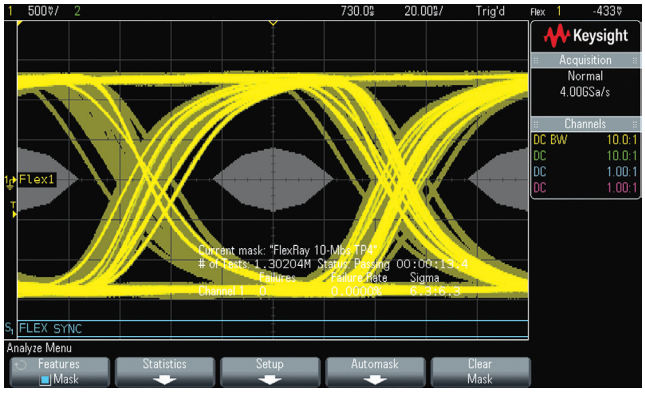


Figure 7: FlexRay TP4 eye-diagram mask test.

The following MIL-STD 1553 mask test files are available:

- System xfmr-coupled Input
- System direct-coupled Input
- BC xfmr-coupled Input
- BC direct-coupled Input
- RT xfmr-coupled Input
- RT direct-coupled Input

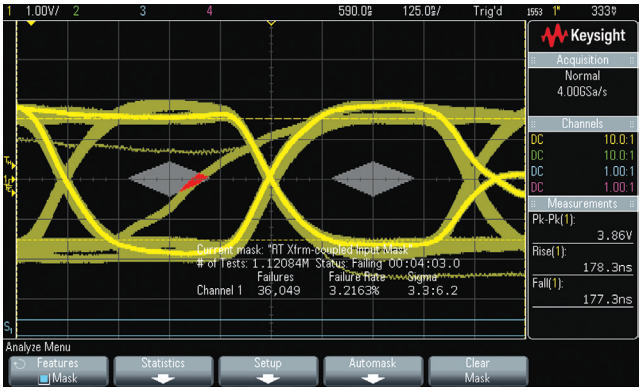


Figure 8: MIL-STD 1553 BC to RT xfrm-coupled input mask test reveals a shifted bit that violates the pass/fail mask.

Serial Bus Eye-diagram and Pulse Mask Testing

The following ARINC 429 mask/pulse test files are available:

- 100 kbps Eye Test
- 100 kbps 1's Pulse Test
- 100 kbps 0's Pulse Test
- 100 kbps Null Level Test
- 12.5 kbps Eye Test
- 12.5 kbps 1's Pulse Test
- 12.5 kbps 0's Pulse Test
- 12.5 kbps Null Level Test

For additional information about eye-diagram mask testing on CAN, FlexRay, MIL-STD 1553, and ARINC 429 signals, refer to the application notes listed at the end of this document.

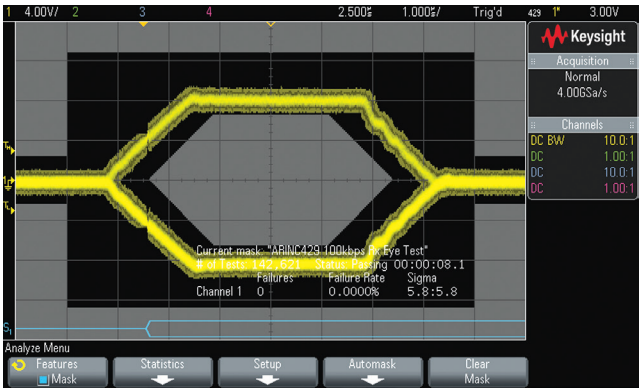


Figure 9: ARINC 429 100 kbps eye-diagram mask test.

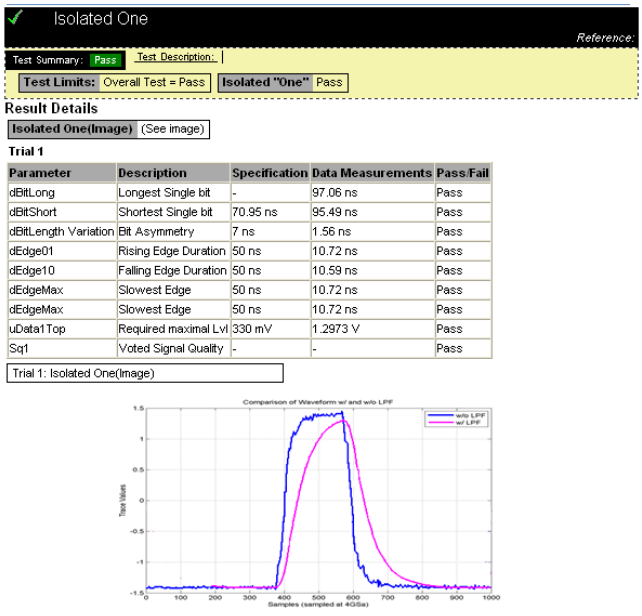
Automated Physical Layer Conformance Testing

To perform USB 2.0 signal quality testing based on USB-IF compliance standards, Keysight offers the DSOX4USBSQ or DSOX6USBSQ options on InfiniiVision 4000 or 6000 X-Series oscilloscopes. Figure 10 shows an example of the USB 2.0 real-time eye test. Also included with this option is complete signal quality test report generation in HTML format. To see the complete list of supported tests, refer to the DSOX4USBSQ/DSOX6USBSQ signal quality test option data sheet listed at the ended of this document.

Figure 10: USB 2.0 signal quality eye test based on USB-IF physical layer compliance standards.

To perform physical layer conformance testing on the differential FlexRay bus, Keysight provides a PC-based software package that you can download from Keysight's website at no additional charge. If the InfiniiVision X-Series scope is licensed with the FlexRay, mask test, and segmented memory, you can perform automated physical layer tests at either receiver input or transmitter output test points. Figure 10 shows an example of the generated report from a signal integrity voting test on a 10-Mbs isolated "1" pulse. The test report includes comprehensive pass/fail and margin analysis based on published specifications.

Refer to the tables in the Specifications/Characteristics section of this document on page 17 to see the entire list of 33 available FlexRay tests that can be selected and performed using the FlexRay physical layer conformance test software package.


Isolated One

Reference:

Test Summary: Pass Test Description:

Test Limits: Overall Test = Pass Isolated "One" Pass

Result Details

Isolated One(Image) (See image)

Trial 1

Parameter	Description	Specification	Data Measurements	Pass/Fail
dBitLong	Longest Single bit	-	97.06 ns	Pass
dBitShort	Shortest Single bit	70.95 ns	95.49 ns	Pass
dBitLength Variation	Bit Asymmetry	7 ns	1.56 ns	Pass
dEdge01	Rising Edge Duration	50 ns	10.72 ns	Pass
dEdge10	Falling Edge Duration	50 ns	10.59 ns	Pass
dEdgeMax	Slowest Edge	50 ns	10.72 ns	Pass
dEdgeMax	Slowest Edge	50 ns	10.72 ns	Pass
uData1Top	Required maximal Lvl	330 mV	1.2973 V	Pass
Sq1	Voted Signal Quality	-	-	Pass

Trial 1: Isolated One(Image)

Figure 11: FlexRay signal integrity voting test performed on an isolated "1" bit.

Probing Differential Serial Buses

Many of today's serial buses are based on differential signaling including USB, CAN, CAN FD, FlexRay, MIL-STD 1553, and ARINC 429. In addition, serial buses based on the RS232/UART protocol are often differential if implemented with RS422 or RS485 output drivers/transceivers. Keysight offers a wide range of differential active probes compatible with the InfiniiVision X-Series oscilloscopes for various bandwidth and dynamic range applications. Table 1 shows the differential probes that Keysight recommends for each of the listed differential serial buses.

Table 1: Recommended Probes for Differential Buses

Differential bus (max bit rate)	N2791A (25-MHz bandwidth)	N2818A[1] (200-MHz bandwidth)	N2750A (1.5-GHz bandwidth)
CAN (1 Mbps)	X	X	
CAN FD (10 Mbps data phase)		X	
FlexRay (10 Mbps)		X	
MIL-STD 1553 (1 Mbps)	X	X	
ARINC 429 (100 kbps)	X	X	
RS422/RS485 (10 Mbps)	X	X	
Hi-speed USB (480 Mbps)			X

Note 1: The N2818A differential probe is not compatible with Keysight's InfiniiVision 2000 X-Series oscilloscopes.

If you need to connect to DB9-SubD connectors on your differential CAN, CAN FD and/or FlexRay bus, Keysight also offers the CAN/FlexRay DB9 probe head (part number 0960-2926). This differential probe head, which is shown in the inset picture of Figure 12, is compatible with both the N2791A and N2818A differential active probes and allows you to easily connect to your CAN, CAN FD and/or FlexRay differential bus.

The N2750A differential active probe shown in Figure 13, which is recommended for hi-speed USB 2.0 measurement applications, is based on Keysight's InfiniiMode technology. With the press of a button, you can quickly toggle between viewing the differential signal, high-side signal, low-side signal, or the common mode signal on the USB 2.0 hi-speed bus without moving probe connections. Note that this probe also comes with a built-in headlight.

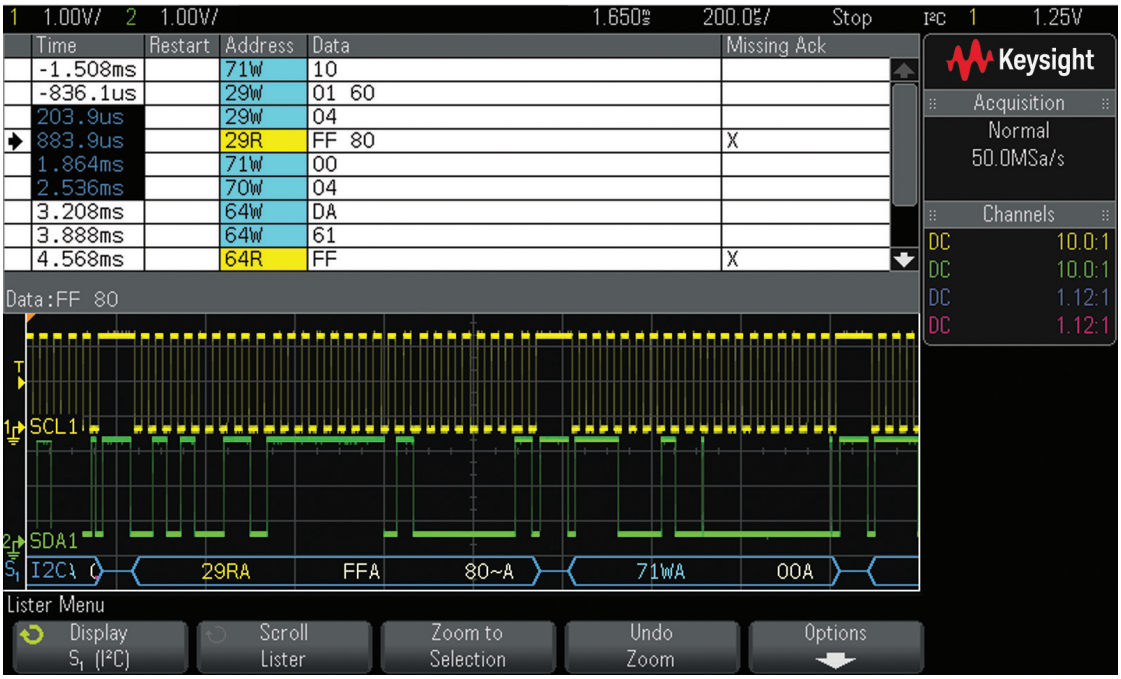
For more information about Keysight's probing solutions, refer to the InfiniiVision Series Oscilloscope Probes & Accessories data sheet (publication number 5968-8153EN) listed at the end of this document.

Figure 12: Keysight's N2818A 200-MHz differential active probe.

Figure 13: Keysight's N2750A 1.5-GHz InfiniiMode differential active probe.

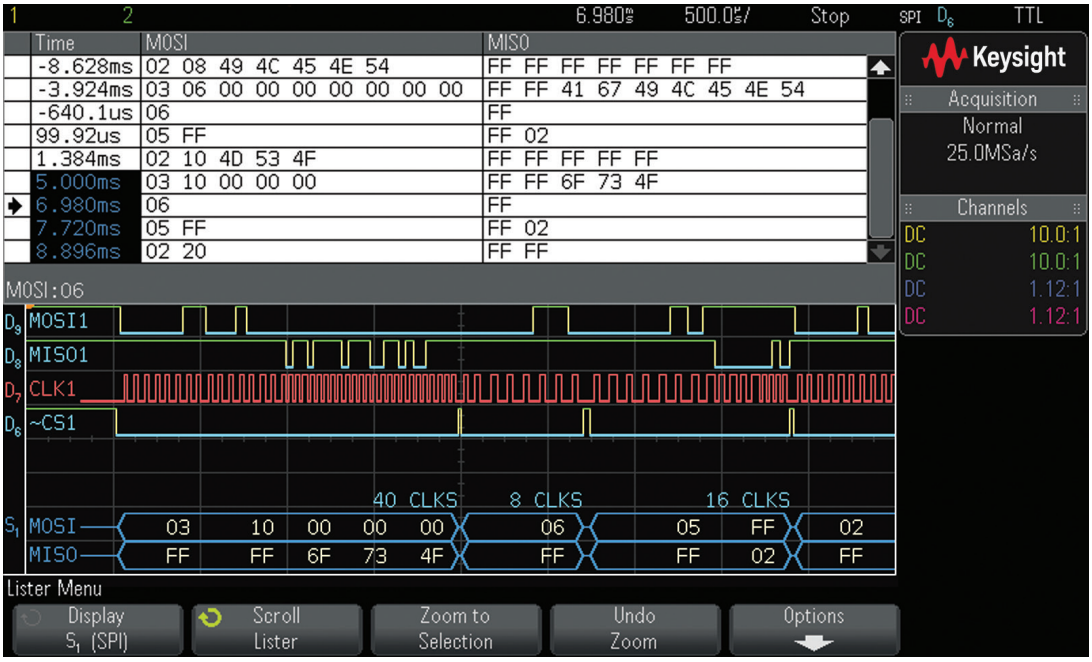
Specifications/Characteristics

I²C specifications/characteristics (DSOX2EMBD, DSOX3EMBD, DSOX4EMBD and DSOX6EMBD)	
Clock and data input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 (3000, 4000 AND 6000 X-Series only)
Max clock/data rate	Up to 3.4 Mbps
Triggering	Start condition Stop condition Missing acknowledge Address with no acknowledge Restart EEPROM data read Frame (Start:Addr7:Read:Ack:Data) Frame (Start:Addr7:Write:Ack:Data) Frame (Start:Addr7:Read:Ack:Data:Ack:Data2) Frame (Start:Addr7:Write:Ack:Data:Ack:Data2) 10-bit write
Hardware-based decode	Data (HEX digits in white) Address decode size: 7 bits (excludes R/W bit) or 8 bits (includes R/W bit) Read address (HEX digits followed by “R” in yellow) Write address (HEX digits followed by “W” in light-blue) Restart addresses (“S” in green, followed by HEX digits, followed by “R” or “W”) Acknowledges (suffixes “A” or “~A” in the same color as the data or address preceding it) Idle bus (mid-level bus trace in dark blue) Active bus (bi-level bus trace in dark blue) Unknown/error bus (bi-level bus trace in red)
Multi-bus analysis	I²C plus one other serial bus, including another I²C bus. (3000, 4000 AND 6000 X-Series only)



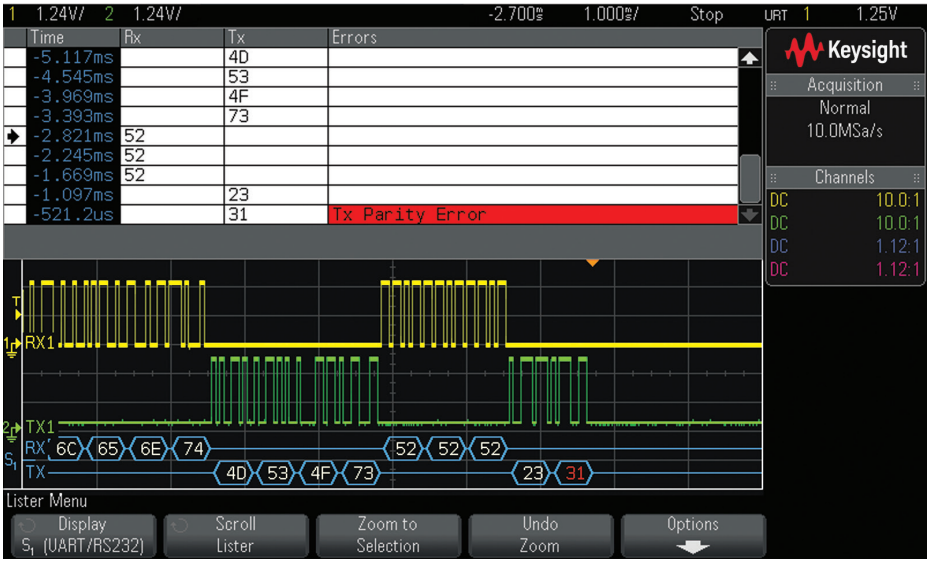
Specifications/Characteristics (continued)

SPI specifications/characteristics (DSOX2EMBD, DSOX3EMBD, DSOX4EMBD and DSOX6EMBD)	
MOSI, MISO, Clock, and CS input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 (3000, 4000 and 6000 X-Series only)
Max clock/data rate	Up to 25 Mb/s
Triggering	4- to 64-bit data pattern during a user-specified framing period Framing period can be a positive or negative chip select (CS or ~CS) or clock idle time (timeout)
Hardware-based decode	Number of decode traces: 2 independent traces (MISO and MOSI) Data (hex digits in white) Unknown/error bus (bi-level bus trace in red) Number of clocks/packet ("XX CLKS" in light-blue above data packet) Idle bus (mid-level bus trace in dark blue) Active bus (bi-level bus trace in dark blue)
Multi-bus analysis	SPI plus one other serial bus, excluding another SPI bus. (3000, 4000 and 6000 X-Series only)



Specifications/Characteristics (continued)

RS232/UART specifications/characteristics (DSOX2COMP, DSOX3COMP, DSOX4COMP and DSOX6COMP)	
Tx and Rx input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 (3000, 4000 and 6000 X-Series only)
Bus configuration	
Baud rates	100 b/s up to 8 Mb/s
Number of bits	5 to 9
Parity	None, odd, or even
Polarity	Idle low or idle high
Bit order	LSB out first or MSB out first
Triggering	Rx start bit Rx stop bit Rx data Rx 1:data (9-bit format) Rx 0:data (9-bit format) Rx X:data (9-bit format) Rx or Tx parity error Tx start bit Tx stop bit Tx data Tx 1:data (9-bit format) Tx 0:data (9-bit format) Tx X:data (9-bit format) Burst (nth frame within burst defined by timeout)
Hardware-based decode	
Number of decode traces	2 independent traces (Tx and Rx)
Data format	Binary, hex, or ASCII-code characters
Data byte display	White characters if no parity error, red characters if parity or bus error
Idle bus trace	Mid-level bus trace in blue
Active bus trace	Bi-level trace in blue
Multi-bus analysis	RS232/UART plus one other serial bus, including another RS232/UART bus. (3000, 4000 and 6000 X-Series only)
Totalize/counter function	Total received frames Total transmitted frames Total parity error frames (with percentage)

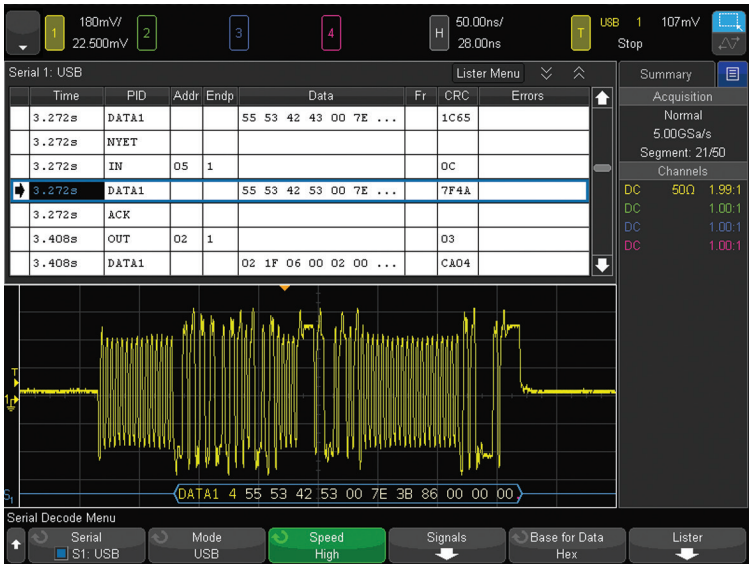


Specifications/Characteristics (continued)

USB 2.0 low- and full-speed specifications/characteristics (DSOX4USBFL and DSOX6USBFL)	
USB input source (D+ & D-)	Analog channels 1, 2, 3, 4 Digital channels D0-D15
Speed	Low (1.5 Mb/s) and Full (12 Mb/s)
Triggering	Start of packet (SOP) End of packet (EOP) Suspend – when bus is idle for > 3 ms Resume – when exiting an idle state > 10 ms Reset – when SE0 is > 10 ms Token packet with specified content Data packet with specified content Handshake packet with specified content Special packet with specified content All errors – any of the below error conditions PID error – if packet type field does not match check field CRC5 error – if 5 bit CRC error is detected CRC16 error – if 16 bit CRC error is detected Glitch error – if two transitions occur in half a bit time Bit stuff error – if >6 consecutive "ones" are detected SE1 error – if SE1 > 1 bit time
Hardware-based decode	
Base format	Hex, Binary, ASCII, or Decimal data decode
Token packets (excluding SOF, 3 bytes)	PID (yellow, "OUT", "IN", "SETUP", "PING") PID Check (yellow when valid, red when error detected) – numeric value Address (blue, 7 bits) Endpoint (green, 4 bits) CRC (blue when valid, red when error detected, 5 bits)
Token packets (SOF, 3 bytes)	PID (yellow, "SOF") PID Check (yellow when valid, red when error detected, 5 bits) Frame (green, 11-bits) – the frame number CRC (blue when valid, red when error detected, 5 bits)
Data packets (3 to 1027 bytes)	PID (yellow, "DATA0", "DATA1", DATA2", "MDATA") PID Check (yellow when valid, red when error detected, 16 bits)
Handshake packets (1 byte)	PID (yellow, "ACK", "NAK", "STALL", "NYET", "PRE", "ERR") PID Check (yellow when valid, read when error detected) – numeric value Hub Addr (green, 7 bits) SC (blue, 1 bit) Port (green, 7 bits) S & E|U (blue, 2 bits) ET (green, 2 bits) CRC (blue when valid, red when error detected, 5 bits
Multi-bus analysis	USB low-full-speed plus one other serial bus (including another USB bus)

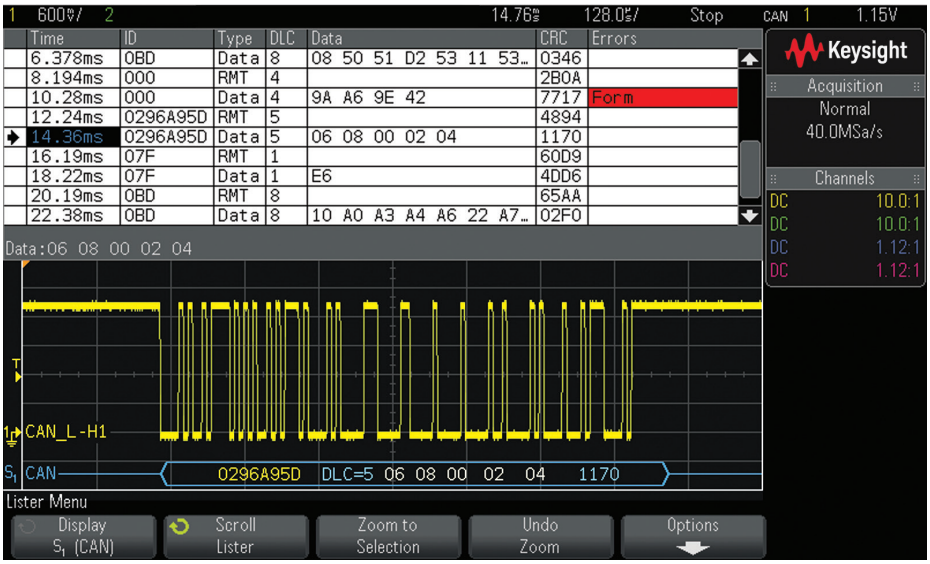
Specifications/Characteristics (continued)

USB 2.0 high-speed specifications/characteristics (DSOX4USBH and DSOX6USBH)	
USB differential input source	Analog channels 1, 2, 3, 4 (using a differential active probe)
Speed	High (480 Mb/s)
Triggering	Token packet with specified content Data packet with specified content Handshake packet with specified content Special packet with specified content All errors – any of the below error conditions PID error – if packet type field does not match check field CRC5 error – if 5 bit CRC error is detected CRC16 error – if 16 bit CRC error is detected Glitch error – if two transitions occur in half a bit time
Hardware-based decode	
Base format	Hex, Binary, ASCII, or Decimal data decode
Token packets (excluding SOF, 3 bytes)	PID (yellow, “OUT”, “IN”, “SETUP”, “PING”) PID check (yellow when valid, red when error detected) – numeric value Address (blue, 7 bits) Endpoint (green, 4 bits) CRC (blue when valid, red when error detected, 5 bits)
Token packets (SOF, 3 bytes)	PID (yellow, “SOF”) PID check (yellow when valid, red when error detected, 5 bits) Frame (green, 11-bits) – the frame number CRC (blue when valid, red when error detected, 5 bits)
Data packets (3 to 1027 bytes)	PID (yellow, “DATA0”, “DATA1”, DATA2”, “MDATA”) PID check (yellow when valid, red when error detected, 16 bits)
Handshake packets (1 byte)	PID (yellow, “ACK”, “NAK”, “STALL”, “NYET”, “PRE”, “ERR”) PID check (yellow when valid, read when error detected) – numeric value Hub Addr (green, 7 bits) SC (blue, 1 bit) Port (green, 7 bits) S & E|U (blue, 2 bits) ET (green, 2 bits) CRC (blue when valid, red when error detected, 5 bits
Multi-bus analysis	N/A



Specifications/Characteristics (continued)

CAN specifications/characteristics (DSOX2AUTO, DSOX3AUTO, and DSOX6AUTO)	
CAN input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 non-differential. (3000 and 6000 X-Series only)
Signal types	Rx, Tx, CAN_L, CAN_H, Diff (L-H), Diff (H-L)
Baud rates	10 kb/s up to 5 Mb/s
Triggering	Start-of-frame (SOF) Remote frame ID (RMT) Data frame ID (~RMT) Remote or data frame ID Data frame ID and data Error frame All errors (includes protocol “form” errors that may not generate flagged error frames) Acknowledge errors Overload frames ID length: 11 bits or 29 bits (extended)
Symbolic triggering (DSOX4AUTO only)	Message names Message and signal values/encoded states
Hardware-based decode	Frame ID (hex digits in yellow) Remote frame (RMT in green) Data length code (DLC in blue) Data bytes (hex digits in white) CRC (hex digits in blue = valid, hex digits in red = error) Error frame (bi-level bus trace and ERR message in red) Form error (bi-level bus trace and “?” in red) Overload frame (“OVRLD” in blue) Idle bus (mid-level bus trace in dark blue) Active bus (bi-level bus trace in dark blue)
Symbolic decode (DSOX4AUTO only)	Message names (alpha-numeric characters in yellow) Signal names, value/encoded state, and units (alpha-numeric characters in white)
Multi-bus analysis	CAN plus one other serial bus, including another CAN bus. (3000 and 6000 X-Series only)
Totalize function	Total frames, total overload frames, total error frames, bus utilization (bus load)
Eye-diagram mask testing (requires DSOX3MASK /DSOX6MASK)	Various downloadable mask files available based on differential probing polarity, baud rate, and network length

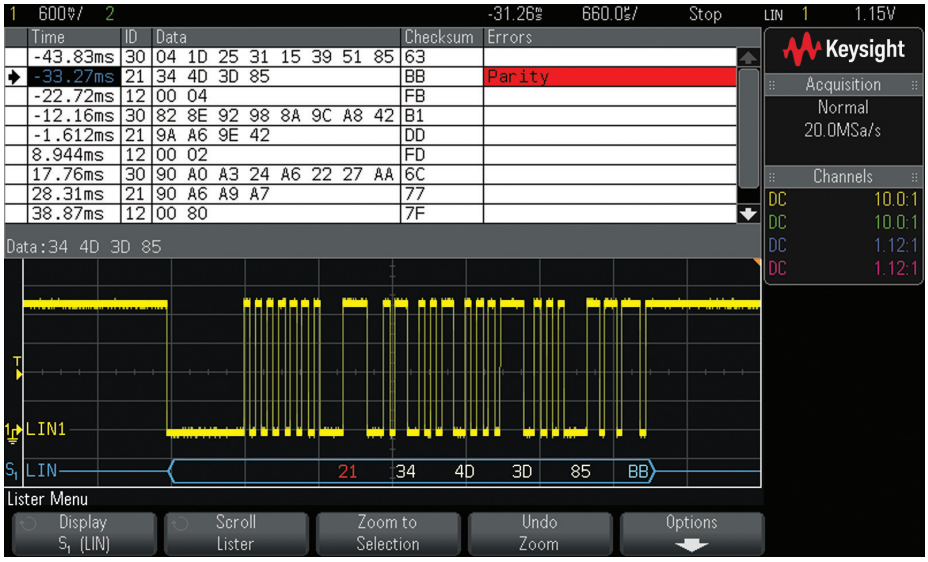


Specifications/Characteristics (continued)

CAN/CAN FD specifications/characteristics (DSOX4AUTO Only)	
Note: “Classic” CAN 2.0 is a subset of the CAN FD specification. Both of these protocol standards are supported with the DSOX4AUTO option in an InfiniiVision 4000 X-Series oscilloscope.	
CAN input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 non-differential.
Signal types	Rx, Tx, CAN_L, CAN_H, Diff (L-H), Diff (H-L)
Standard baud rates	10 kb/s up to 5 Mb/s
FD baud rates	10 kb/s up to 10 Mb/s
Triggering	SOF (Start-of-frame) EOF (End-of-frame, filtered by ID) Data frame ID (11 bits or 29 bits: Extended) Data frame ID and data – non FD Data frame ID and data - FD Remote frame ID (RTR) Remote or data frame ID Error frame (filtered by ID) Acknowledge error (filtered by ID) Form error (filtered by ID) Stuff error (filtered by ID) CRC error (filtered by ID) Spec error (includes Ack, Form, Stuff, or CRC error; filter by ID) All errors (includes any Spec error or Error frame; filtered by ID) BRS bit (filtered by ID of FD frames only) CRC delimiter bit (filtered by ID of FD frames only) ESI bit active (filtered by ID of FD frames only) ESI bit passive (filtered by ID of FD frame only) Overload frames
Symbolic triggering	Message names Message and signal values/encoded states (first 8 bytes)
Hardware-based decode	Frame ID (hex digits in yellow) Remote frame (RMT in green) Data length code (DLC = with decimal digits in blue) Data bytes (hex digits in white) ESI bit passive (frame type column in lister shaded yellow; FD frames only) Error frame (bi-level red bus trace with ERR FRAME in red) Stuff bit error (bi-level red bus trace with STUFF ERR in red) Form error (bi-level red bus trace with FORM ERR in red) Acknowledge error (bi-level red bus trace with ACK ERR in red) CRC (hex digits in blue = valid, hex digits in red = error) Overload frame (“OVRLD” in blue) Idle bus (mid-level dark blue bus trace) Active bus (bi-level dark blue bus trace with embedded decode within)
Symbolic decode (DSOX4AUTO only)	Message names (alpha-numeric characters in yellow) Signal names, value/encoded state (first 8 bytes), and units (alpha-numeric characters in white)
Multi-bus analysis	CAN/CAN FD plus one other serial bus, including another CAN/CAN FD bus.
Totalize function (real time)	Total frames, total error frames with %, total spec errors, bus load in %
Eye-diagram mask testing	Various downloadable mask files available based on differential probing polarity, baud rate, and network length. Eye-diagram mask testing supports “classic” CAN 2.0 protocol only.

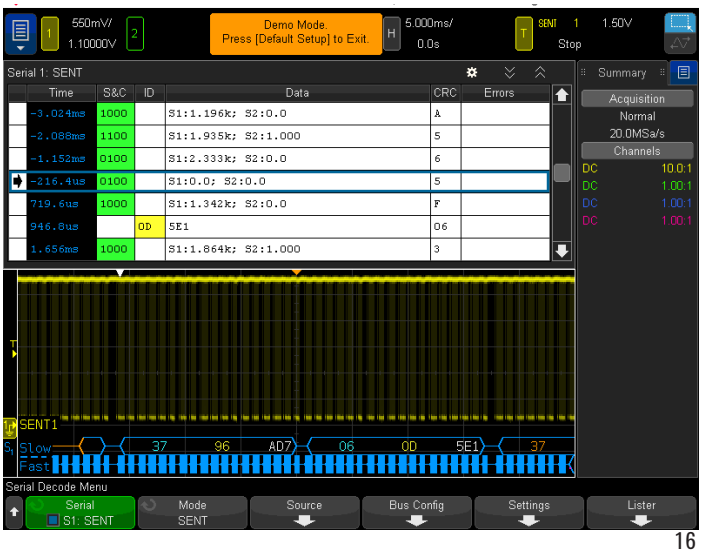
Specifications/Characteristics (continued)

LIN specifications/characteristics (DSOX2AUTO, DSOX3AUTO, DSOX4AUTO and DSOX6AUTO)	
LIN input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 (3000, 4000 and 6000 X-Series only)
LIN standards	LIN 1.3 or LIN 2.X
Baud rates	2400 b/s to 625 kb/s
Triggering	Sync break Frame ID ($0X00_{HEX}$ to $0X3F_{HEX}$) Frame ID and data Parity error Checksum error
Hardware-based decode	Frame ID (6-bit hex digits in yellow) Frame ID and optional parity bits (8-bit hex digits in yellow if valid, red if parity bit error) Data bytes (hex digits in white) Check sum (hex digits in blue = valid, hex digits in red = error) Sync error (“SYNC” in red) THeader-max (“THM” in red) TFrame-max (“TFM” in red) Parity error (“PAR” in red) LIN 1.3 wake-up error (“WUP” in red) Idle bus (mid-level bus trace in dark blue) Active bus (bi-level bus trace in dark blue)
Multi-bus analysis	LIN plus one other serial bus, including another LIN bus. (3000, 4000 and 6000 X-Series only)



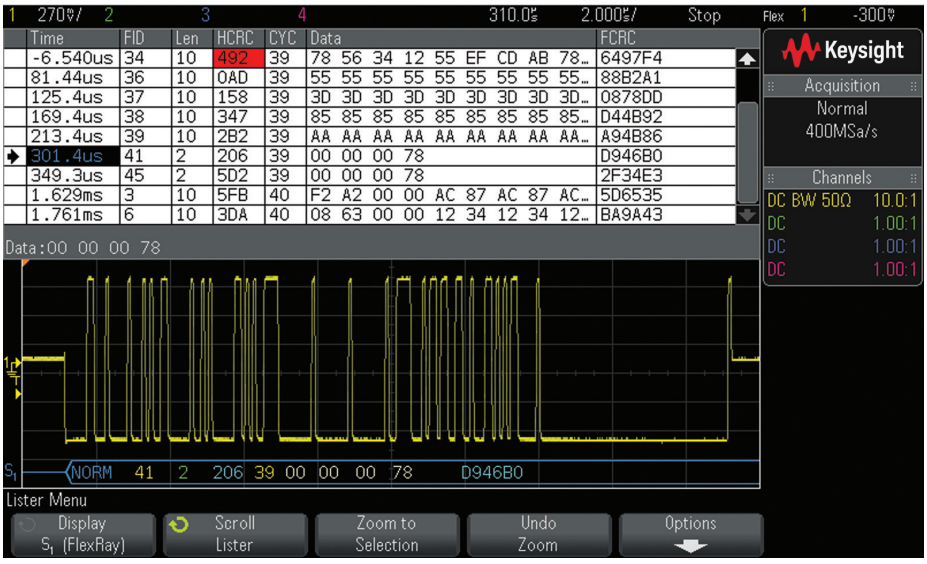
Specifications/Characteristics (continued)

SENT specifications/characteristics (DSOX4SENSOR Only)	
CAN input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15 non-differential.
Clock period	1 µs to 300 µs with user-defined tolerance setting from 3% to 30%
Number of nibbles	1 to 6
Idle state	High or low
CRC format	2008 or 2010 standards
Pause pulse	On/Off
Message format	Fast Nibbles (All) Fast Signals (only) Fast + Short Serial Fast + Enhanced Serial (automatically detects bit format: 12-bit data/8-bit ID or 16-bit data/4-bit ID) Short Serial (only) Enhanced Serial (only)
Number of defined signals	1 to 6 (each specified by start bit #, number of bits, and nibble order)
Numerical format of signals	Hexadecimal, unsigned decimal, or transfer function with user-defined multiplier and offset for each defined signal
Triggering	Start of fast channel message Start of slow channel message Fast channel status & communication nibble + data Slow channel message ID Slow channel message ID + data Tolerance violation (sync pulse width exceeds user-specified tolerance) Fast channel CRC error Slow channel CRC error All CRC errors Pulse period error (if nibbles are < 12 or > 27 ticks wide) Successive sync pulses error (if consecutive sync pulse widths are greater than 1/64 difference)
Fast channel decode	Status & communication nibble (binary digits in green) Data (hex, unsigned decimal, or transfer function digits in white based on user-defined signal format) CRC error (hex digit in blue = valid, hex digit in red = error) Pulse period error (< or > in red)
Slow channel decode	Message ID (hex digits in yellow) Data (hex digits in white) CRC (hex digits in blue = valid, hex digits in red = error)
Multi-bus analysis	SENT plus one other serial bus, including another SENT bus.



Specifications/Characteristics (continued)

FlexRay specifications/characteristics (DSOX3FLEX, DSOX4FLEX and DSOX6FLEX)	
FlexRay input source	Channel 1, 2, 3, or 4 (using differential probe)
FlexRay channels	A or B
Baud rates	2.5 Mbps, 5.0 Mbps, and 10 Mbps
Frame triggering	– Frame type: startup (SUP), not startup (~SUP), sync (SYNC), not sync (~SYNC), null (NULL), not null (~NULL), normal (NORM), and All – Frame ID: 1 to 2047 (decimal format), and All – Cycle - – Base: 0 to 63 (decimal format), and All – Repetition: 1, 2, 4, 8, 16, 32, 64 (decimal format), and All
Error triggering	– All errors – Header CRC error – Frame CRC error
Event triggering	– Wake-up – TSS (transmission start sequence) – BSS (byte start sequence) – FES/DTS (frame end or dynamic trailing sequence)
Frame decoding	– Frame type (NORM, SYNC, SUP, NULL in blue) – Frame ID (decimal digits in yellow) – Payload-length (decimal number of words in green) – Header CRC (hex digits in blue if valid, or red digits if invalid) – Cycle number (decimal digits in yellow) – Data bytes (HEX digits in white) – Frame CRC (hex digits in blue if valid, or red digits
Totalize function	– Total frames – Total synchronization frames – Total null frames
Eye-diagram mask testing (requires DSOX3MASK mask test option plus down-loadable mask files)	TP1 standard voltage (10 Mbps only) TP1 increased voltage (10 Mbps only) TP11 standard voltage (10 Mbps only) TP11 increased voltage (10 Mbps only) TP4 10 Mbps, TP4 5 Mbps and TP4 2.5 Mbps
Multi-bus analysis	FlexRay plus one other serial bus (including another FlexRay bus)



FlexRay Physical Layer Conformance Test software

Requires FlexRay option (DSOX3FLEX/DSOX4FLEX/DSOX6FLEX)
Mask test option (DSOX3MASK/DSOX4MASK/DSOX6MASK)
Segmented memory option (DSOX3SGM or standard on 4000 and 6000 X-Series)

Table 1: Receiver input tests

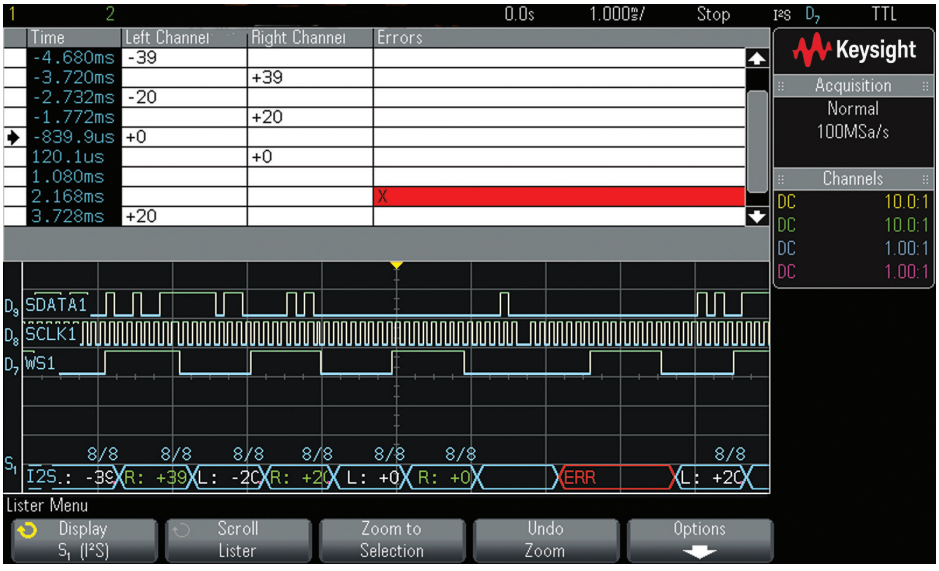
Parameter tested	Test description
Eye-diagram mask tests:	
TP4 – All	Receiver mask test on all frames
TP4 – ID	Receiver mask test on specified frame
Signal integrity voting tests on 13 MHz low-pass filtered Isolated “1”:	
uData1Top	Required maximal level
dBitShort	Shortest single bit
dBitLengthVariation	Bit asymmetry
dEdge01	Rising edge duration (-300 mV to +300 mV)
dEdge10	Falling edge duration (+300 mV to -300 mV)
dEdgeMax	Slowest edge
Sq1	Isolated “1” voted signal quality
Signal integrity voting tests on 13 MHz low-pass filtered Isolated “0”:	
uData0Top	Required minimal level
dBitShort	Shortest single bit
dBitLengthVariation	Bit asymmetry
dEdge01	Rising edge duration (-300 mV to +300 mV)
dEdge10	Falling edge duration (+300 mV to -300 mV)
dEdgeMax	Slowest edge
Sq0	Isolated “0” voted signal quality
Advanced diagnostic tests:	
gdTSSTransmitter	Transmitted TSS width @ receiver
MCT	Mean corrected cycle time
uBusRx-Data	Data 1 amplitude
-uBusRx-Data	Data 0 amplitude
uRx-Idle	Mean idle level
dBusRx01	Rise time Data0 to Data1 (–300 mV to +300 mV)
dBusRx10	Fall time Data1 to Data0 (+300 mV to -300 mV)

Table 2: Transmitter output tests

Parameter tested	Test description
Eye-diagram mask tests (10 Mbs only):	
TP1 – Std V	Mask test on standard voltage bus driver output
TP1 – Incr V	Mask test on increased voltage bus driver output
TP11 – Std V	Mask test on standard voltage active star output
P11 – Incr V	Mask test on increased voltage active star output
Advanced diagnostic tests:	
gdTSSTransmitter	Transmitted TSS width
uBusTx-Data	Data 1 amplitude
-uBusTx-Data	Data 0 amplitude
uRx-Idle	Mean idle level
dBusTx01	Rise time Data0 to Data1 (20% to 80%)
dBusTx10	Fall time Data1 to Data0 (80% to 20%)

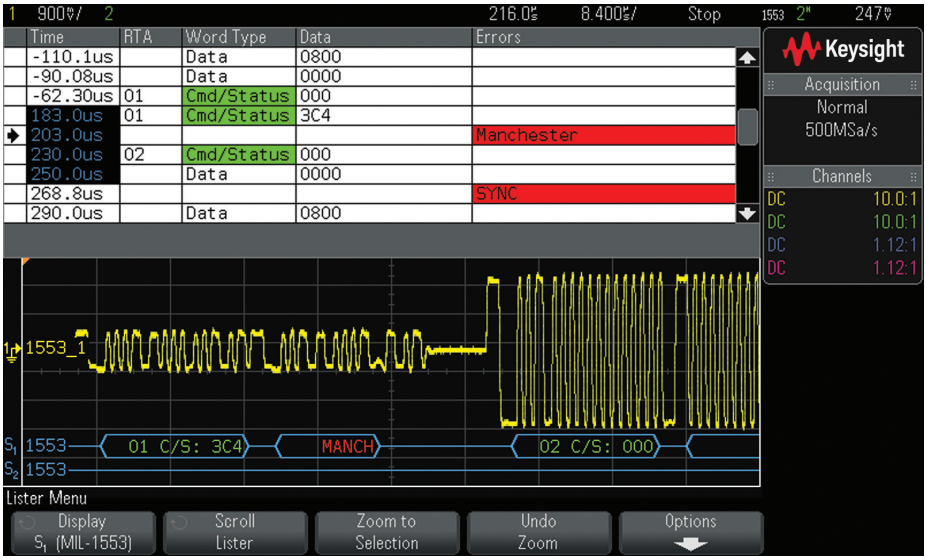
Specifications/Characteristics (continued)

I²S specifications/characteristics (DSOX3AUDIO, DSOX4AUDIO, and DSOX6AUDIO)	
SCLK, WS, and SDATA input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15
Bus configuration:	
Transmitted word size	4 to 32 bits (user selectable)
Decoded/receiver word size	4 to 32 bits (user selectable)
Alignment	Standard, left-justified, or right-justified
Word select - low	Left-channel or right-channel
SCLK slope	Rising edge or falling edge
Decoded base	Hex (2's complement) or signed decimal
Baud rates	2400 b/s to 625 kb/s
Triggering:	
Audio channel	Audio left, audio right, or either
Trigger modes	= (Equal to entered data value) ≠ (Not equal to entered data value) < (Less than entered data value) > (Greater than entered data value) >< (Within range of entered data values) <> (Out of range of entered data values) Increasing value that crosses armed (<=) and trigger (>=) entered data values Decreasing value that crosses armed (>=) and trigger (<=) entered data values
Hardware-based decode:	
Left channel	L: "decoded value" in white
Right channel	R: "decoded value" in green
Error	ERR in red (mismatch between transmitted and received word size, or invalid input signaling)
Word size indicator	"# of TX / # of RX" CLKS in blue displayed above each decoded work
Multi-bus analysis	I²S plus one other serial bus (excluding another I²S bus)



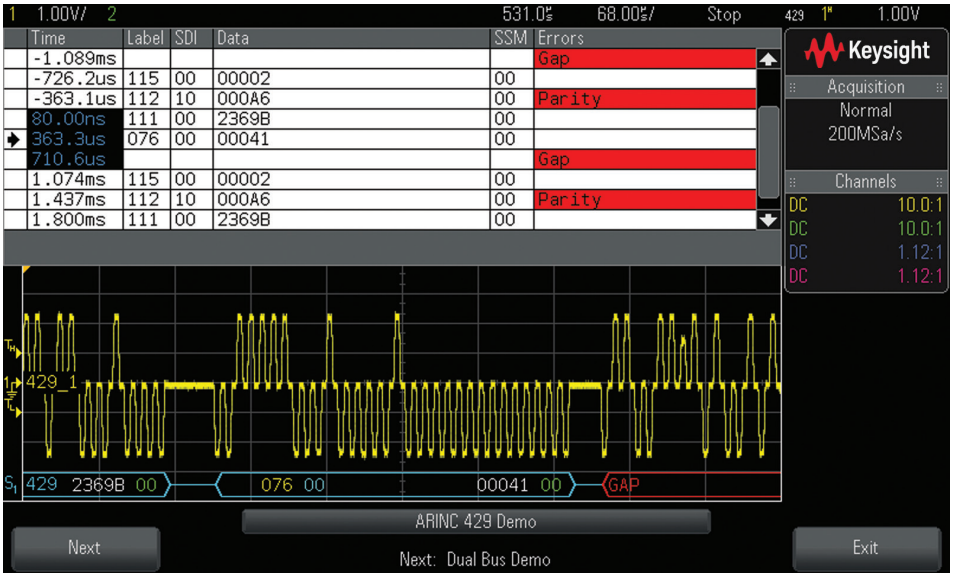
Specifications/Characteristics (continued)

MIL-STD 1553 specifications/characteristics (DSOX3AERO, DSOX4AERO, and DSOX6AERO)	
MIL-Std 1553 Input Source	Analog channels 1, 2, 3, or 4 (using a differential active probe)
Triggering	– Data word start – Data word stop – Command/status word start – Command/status word stop – Remote terminal address (hex) – Remote terminal address (hex) + 11 bits (binary) – Parity error – Sync error – Manchester error
Color-coded, hardware-accelerated decode	– Base: HEX or binary – Command or status word (“C/S” in green) – Remote terminal address (hex or binary digits in green) – 11 Bits following RTA (hex or binary digits in green) – Data word (“D” in white) – Data word bits (hex or binary digits in white) – Parity error (all decoded text in red) – Synchronization error (“Sync” in red) – Manchester error (“Manch“ in red)
Eye-diagram mask testing (requires DSOX3MASK mask test option plus downloadable mask files)	– System xfmr-coupled Input – System direct-coupled Input – BC xfmr-coupled Input – BC direct-coupled Input – RT xfmr-coupled Input – RT xfmr-coupled Input
Multi-bus analysis	MIL-STD 1553 plus one other serial bus, (including another MIL-STD 1553 bus)



Specifications/Characteristics (continued)

ARINC 429 specifications/characteristics (DSOX3AERO, DSOX4AERO and DSOX6AERO)	
ARINC 429 input source	Analog channels 1, 2, 3, or 4 (using a differential active probe)
Baud rates	High (100 kbps) Low (12.5 kbps)
Triggering	Word start Word stop Label (octal) Label (octal) + bits (binary) Label range (octal) Parity error Word error Gap error Word or gap error All errors All bits (useful for eye-diagram testing)) All 0 bits All 1 bits
Color-coded, hardware-accelerated decode	Word format: label/SDI/data/SSM or label/data/SSM or label/data Label (octal digits in yellow) SDI (binary digits in blue) Data (hex or binary digits in white) SSM (binary digits in green) Errors (text in red)
Totalize function	Total words Total errors
Eye-diagram and pulse mask testing (requires DSOX3MASK plus downloadable mask files)	100 kbps eye test 100 kbps 1's test 100 kbps 0's test 100 kbps null test 12.5 kbps eye test 12.5 kbps 1's test 12.5 kbps 0's test 12.5 kbps null test
Multi-bus analysis	ARINC 429 plus one other bus (including another ARINC 429 bus)



Ordering Information

The various serial bus options are compatible on most models of the Keysight InfiniiVision 3000, 4000 and 6000 X-Series oscilloscopes. The entry-level 2000 X-Series oscilloscopes support only the I^2C/SPI, RS232/UART, and CAN/LIN options. Existing InfiniiVision X-Series oscilloscopes can also be upgraded with these options.

For most model numbers, the number after DSOX tells you to which series of oscilloscope it applies. For example, DSOX2EMBD applies to the 2000 X-Series and DSOX3EMBD applies to the 3000 X-Series.

Model number	Description
DSOX2EMBD, DSOX3EMBD, DSOX4EMBD or DSOX6EMBD	I^2C and SPI trigger and decode
DSOX2COMP, DSOX3COMP, DSOX4COMP or DSOX6COMP	RS232/UART trigger and decode
DSOX2AUTO, DSOX3AUTO or DSOX6AUTO	CAN and LIN trigger and decode (CANdbc Symbolic on 6000 X-Series models)
DSOX4AUTO	CAN, CAN FD, and LIN trigger and decode, including CAN-dbc symbolic decoding (4000 X-Series only)
DSOX4SENSOR	Single Edge Nibble Transmission (SENT) trigger and decode (4000 X-Series only)
DSOX3FLEX, DSOX4FLEX or DSOX6FLEX	FlexRay trigger and decode
DSOX3AERO, DSOX4AERO or DSOX6AERO	MIL-STD 1553 and ARINC 429 trigger and decode
DSOX3AUDIO, DSOX4AUDIO or DSOX6AUDIO	I^2S trigger and decode
DSOX4USBFL or DSOX6USBFL	USB 2.0 low- and full-speed trigger and decode
DSOX4USBH or DSOX6USBH	USB 2.0 hi-speed trigger and decode (1 GHz and 1.5 GHz bandwidth models of 4000 X-Series only)
DSOX4USBSQ or DSOX6USBSQ	USB 2.0 signal quality test (hi-speed tests require 1.5 GHz bandwidth models)
DSOX2SGM and DSOX3SGM	Segmented memory (standard on 4000 and 6000 X-Series models)
DSOX2MASK, DSOX3MASK, DSOX4MASK or DSOX6MASK	Mask test option
N2791A	25-MHz differential active probe
N2818A	200-MHz differential active probe
N2750A	1.5 GHz differential active probe (recommended for USB 2.0 hi-speed applications)
0960-2926	DB9 probe head adapter for N2791A and N2818A

Additional options and accessories are available for Keysight's InfiniiVision oscilloscopes. Refer to the first four documents in the list below for ordering information about these additional options and accessories.

Related Keysight literature

Publication Title	Publication Type	Publication Number
InfiniiVision 2000 X-Series Oscilloscope	Data sheet	5990-6618EN
InfiniiVision 3000 X-Series Oscilloscope	Data sheet	5990-6619EN
InfiniiVision 4000 X-Series Oscilloscope	Data sheet	5991-1103EN
InfiniiVision 6000 X-Series Oscilloscope	Data sheet	5991-4087EN
InfiniiVision Series Oscilloscope Probes and Accessories	Selection guide	5968-8153EN
N2818A/N2819A 200/400 MHz Differential Active Probes	Data sheet	5990-4753EN
N2750A/51A/52A InfiniiMode Differential Active Probes	Data sheet	5991-0560EN
DSOX4USBSQ USB 2.0 Signal Quality Test Option	Data sheet	5991-1762EN
Using Oscilloscope Segmented Memory for Serial Bus Applications	Application note	5990-5817EN
Characterizing Hi-speed USB 2.0 Serial Buses in Embedded Designs	Application note	5991-1148EN
Debug Automotive Designs Faster with CAN-dbc Symbolic Trigger and Decode	Application note	5991-2847EN
CAN Eye-diagram Mask Testing	Application note	5991-0484EN
FlexRay Eye-diagram Mask Testing	Application note	5990-4923EN
MIL-STD 1553 Eye-diagram Mask Testing	Application note	5990-9324EN
ARINC 429 Eye-diagram Mask Testing	Application Note	5990-9325EN

To download these documents, insert the publication number in the URL:
http://cp.literature.keysight.com/litweb/pdf/xxxx-xxxxEN.pdf

Product Web site

For the most up-to-date and complete application and product information, please visit our product Web sites at:
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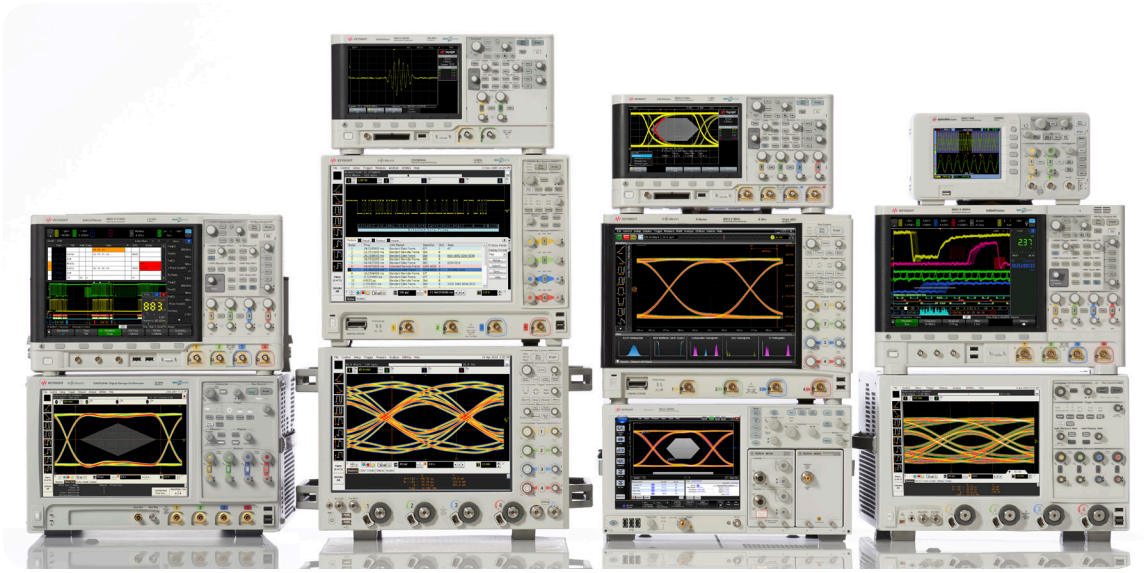

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