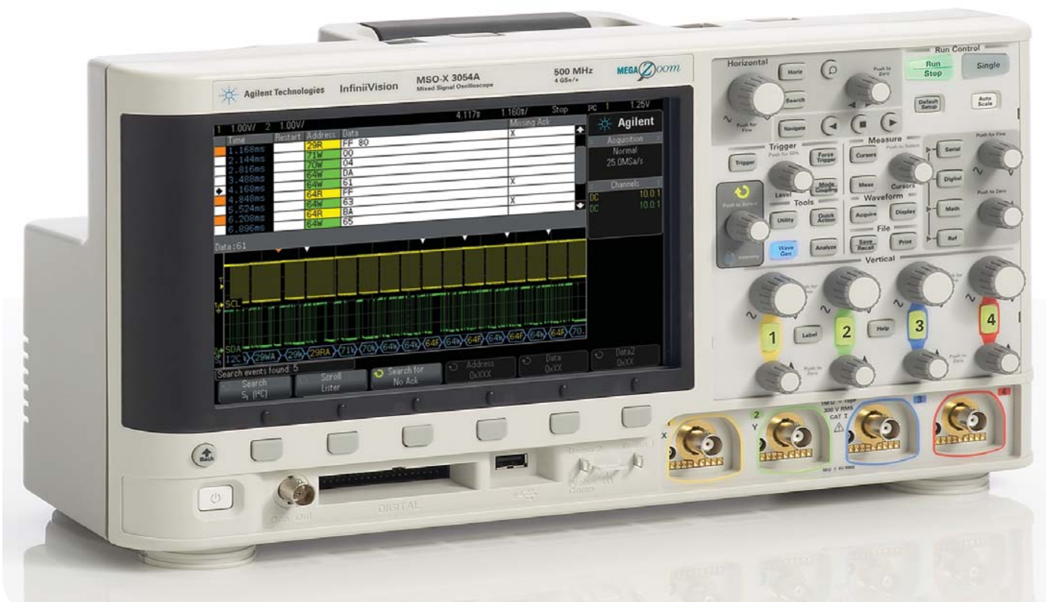
Serial Bus Applications for InfiniiVision 3000 X-Series Oscilloscopes

Data Sheet



Supported protocols and features

- I^2C
- SPI
- RS232/UART
- I^2S
- CAN
- LIN
- FlexRay
- MIL-STD 1553
- ARINC 429
- Hardware-based decoding
- Multi-bus analysis
- Automatic search and navigation
- Compatibility with segmented memory acquisition
- Eye-diagram mask files available for FlexRay, MIL-STD 1553, and ARINC 429 (requires DSOX3MASK mask test option)

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. Agilent's InfiniiVision 3000 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 efficiently and effectively debug your designs that include serial bus communication.

Agilent Technologies

Hardware-Based Decoding

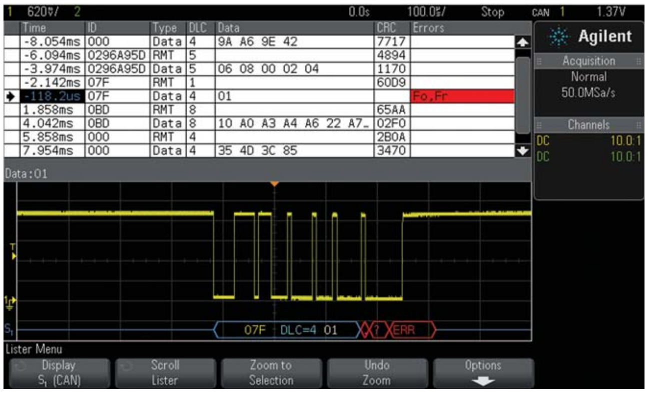


Figure 1: Hardware-based decoding quickly reveals serial communication errors.

Agilent's InfiniiVision Series oscilloscopes are the industry's only scopes to use hardware-based decoding. 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 an Agilent 3000 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.

Automatic Search and Navigation

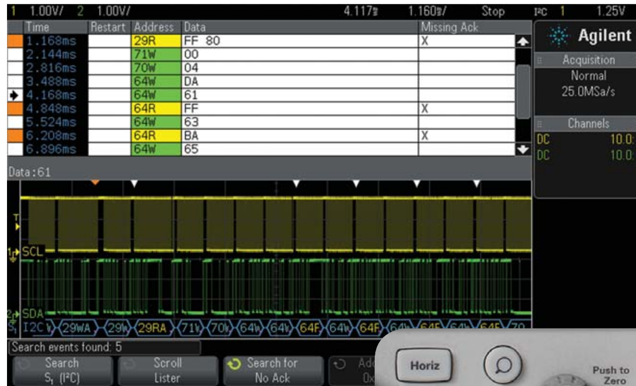


Figure 2: Automatic "Search & Navigation" quickly finds user-specified serial bus frames/bytes of interest.

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 2 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

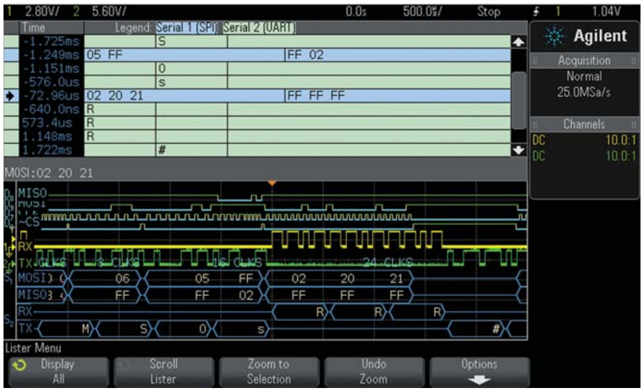


Figure 3: An interleaved "Lister" makes it easier to time-correlate activity between two decoded serial buses.

Many of today's designs include multiple serial buses. Sometimes it may be necessary to correlate data from one serial bus to another. Agilent's InfiniiVision 3000 X-Series oscilloscope can decode two serial buses simultaneously using hardware-based decoding. Plus it is the only scope on the market that can also display the captured data in a time-interleaved "Lister" display, as shown in Figure 3. In this particular example, the scope has decoded a 4-wire SPI bus in a HEX format, along with transmit and receive RS232/UART signals in an ASCII-decoded format.

Using Segmented Memory to Capture Multiple Serial Bus Packets

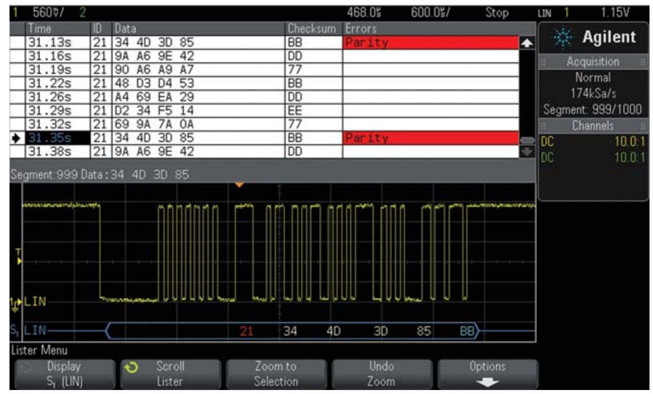


Figure 4: Segmented memory acquisition selectively captures more packets/bytes of serial bus activity.

The segmented memory option for Agilent's InfiniiVision 3000 X-Series oscilloscope 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 4 shows an example of the 3000 X-Series oscilloscope capturing 1,000 consecutive LIN serial bus frames qualified with a 21_{HEX} frame ID for a total acquisition time of over 30 seconds. Capturing this much data using conventional oscilloscope acquisition memory would be impossible.

Agilent's InfiniiVision 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 DSOX3MASK mask test option, witch can perform over 200,000 pass/fail tests per second, you can perform eye-diagram and pulse mask testing on FlexRay, MIL-STD 1553, and ARINC 429 signals. Eye-diagram measurements provide a comprehensive signal quality test of the integrity of your transmitted and received signals. Agilent 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 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

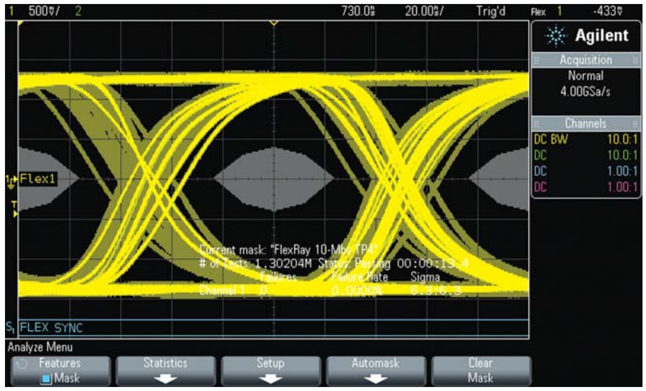


Figure 5: FlexRay TP4 eye-diagram mask test.

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

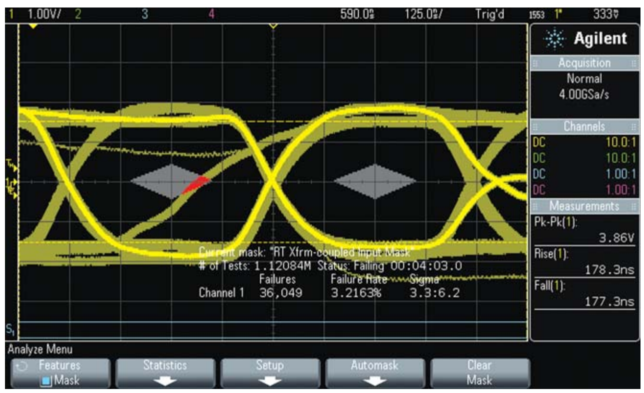


Figure 6: MIL-STD 1553 BC to RT xfrm-coupled input mask test reveals a shifted bit that violates the pass/fail mask.

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

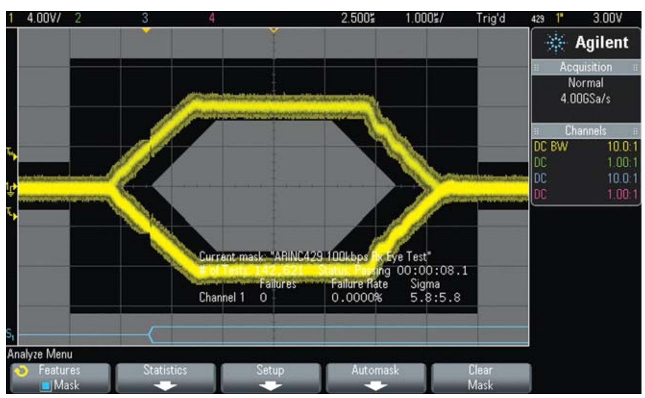


Figure 7: ARINC 429 100 kbps eye-diagram mask test.

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

Probing Differential Serial Buses

Some of today's serial buses are based on differential signaling, such as CAN, FlexRay, MIL-STD 1553, and ARINC 429. Probing differential serial buses such as these requires that you use a differential active probe. Agilent offers a range of differential active probes compatible with the InfiniiVision 3000 X-Series oscilloscopes for various bandwidth and dynamic range applications.

For CAN, MIL-STD 1553, and ARINC 429 differential bus applications, Agilent recommends the 25-MHz bandwidth N2791A differential active probe shown in Figure 8.

For FlexRay applications, Agilent recommends the 200-MHz bandwidth N2792A differential active probe shown in Figure 9. Also available for FlexRay applications is the 800-MHz bandwidth N2793A differential active probe.

If you need to connect to DB9-SubD connectors on your differential CAN and/or FlexRay bus, Agilent also offers the CAN/FlexRay DB9 probe head (Part number 0960-2926). This differential probe head, which is shown in the insert of Figure 8, is compatible with both the N2791A and N2792A differential active probes and allows you to connect easily to your CAN and/or FlexRay differential bus.

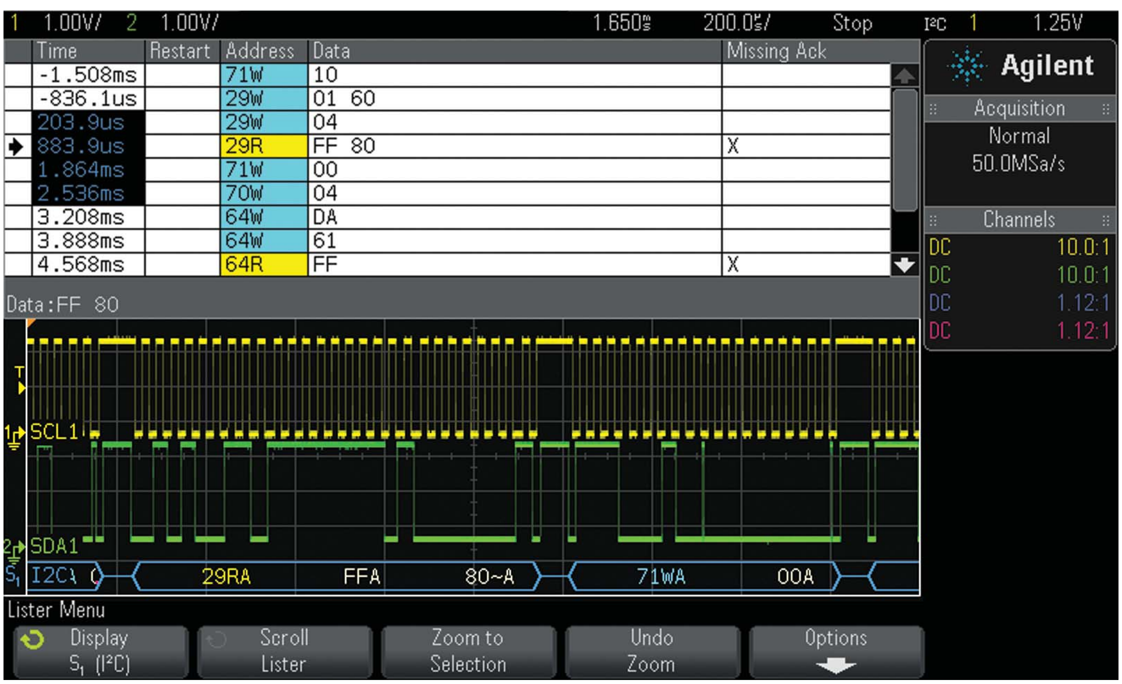
If you already own a significant installed-base of Tektronix active probes, Agilent offers a Tek-to-Agilent probe adapter (N2744A). Agilent also offers a variety of higher bandwidth differential and single-ended active probes not shown here.

Figure 8: Agilent N2791A 25-MHz differential active probe.

Figure 9: Agilent N2792A 200-MHz differential active probe.

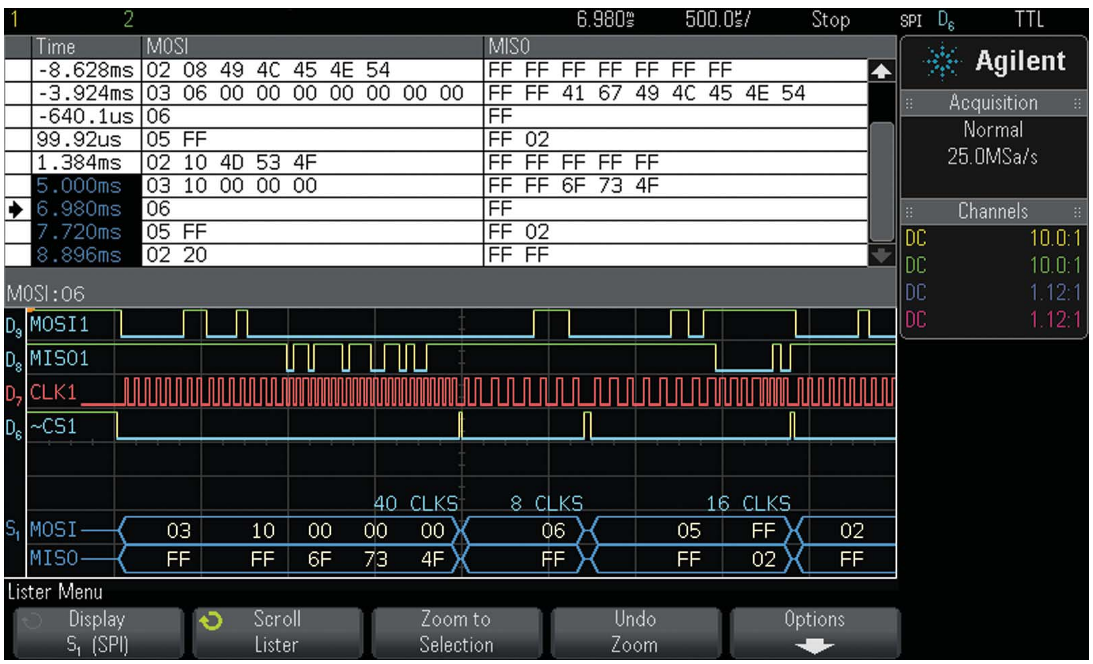
Specifications/Characteristics

I²C specifications/characteristics (DSOX3EMBD)	
Clock and data input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15
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)



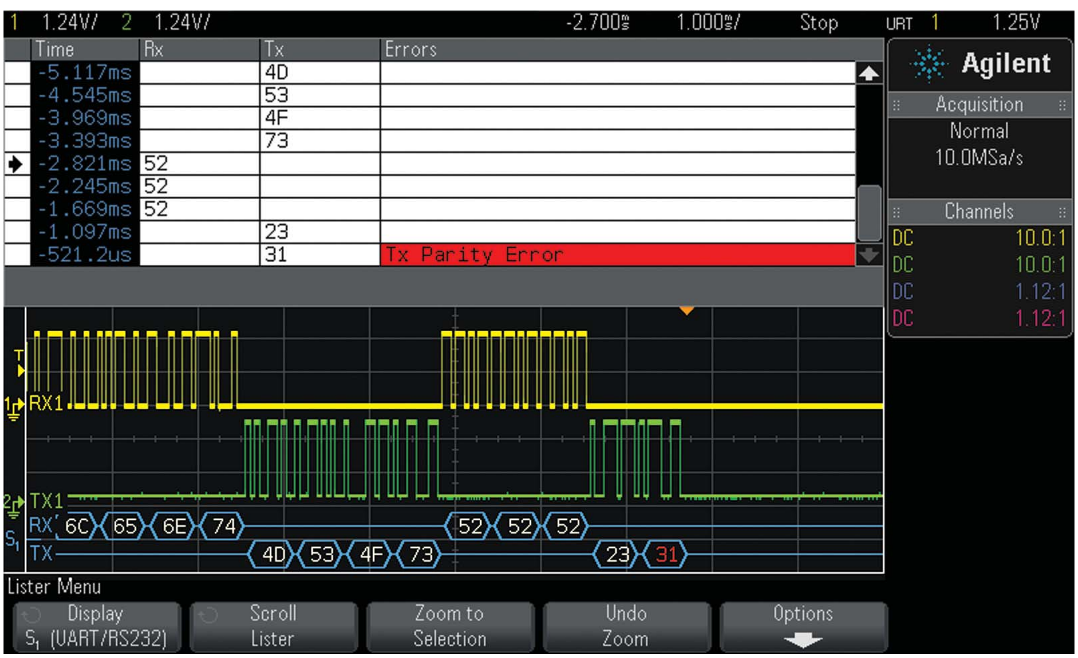
Specifications/Characteristics

SPI specifications/characteristics (DSOX3EMBD)	
MOSI, MISO, Clock, and CS input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15
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)



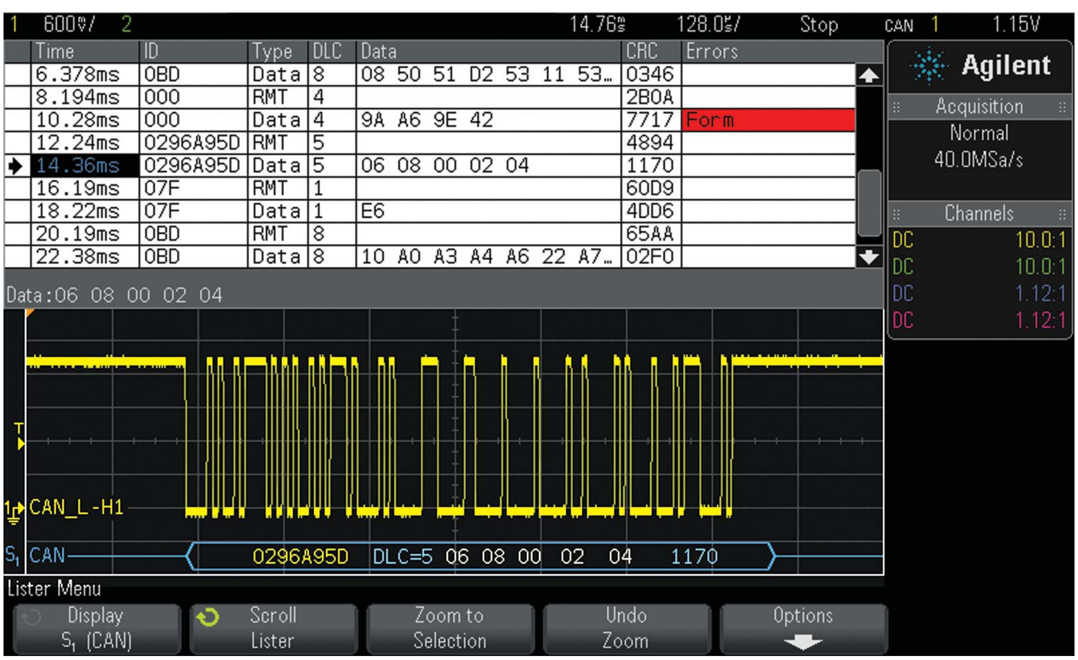
Specifications/Characteristics

RS232/UART specifications/characteristics (DSOX3COMP)	
Tx and Rx input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15
Bus configuration Baud rates Number of bits Parity Polarity Bit order	 100 b/s up to 8 Mb/s 5 to 9 None, odd, or even Idle low or idle high 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 Data format Data byte display Idle bus trace Active bus trace	 2 independent traces (Tx and Rx) Binary, hex, or ASCII-code characters White characters if no parity error, red characters if parity or bus error Mid-level bus trace in blue Bi-level trace in blue
Multi-bus analysis	RS232/UART plus one other serial bus (including another RS232/UART bus)
Totalize/counter function	Total received frames Total transmitted frames Total parity error frames (with percentage)



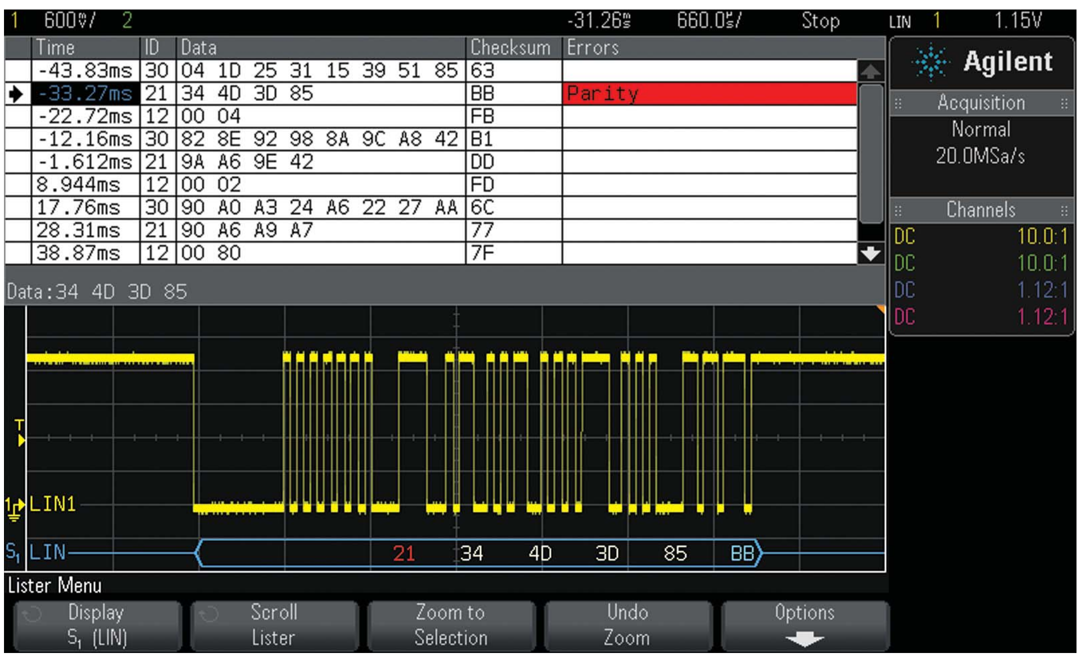
Specifications/Characteristics

CAN specifications/characteristics (DSOX3AUTO)	
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)
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)
Hardware-based secode	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)
Multi-bus analysis	CAN plus one other serial bus (including another CAN bus)
Totalize function	Total frames Total overload frames Total error frames Bus utilization (bus load)



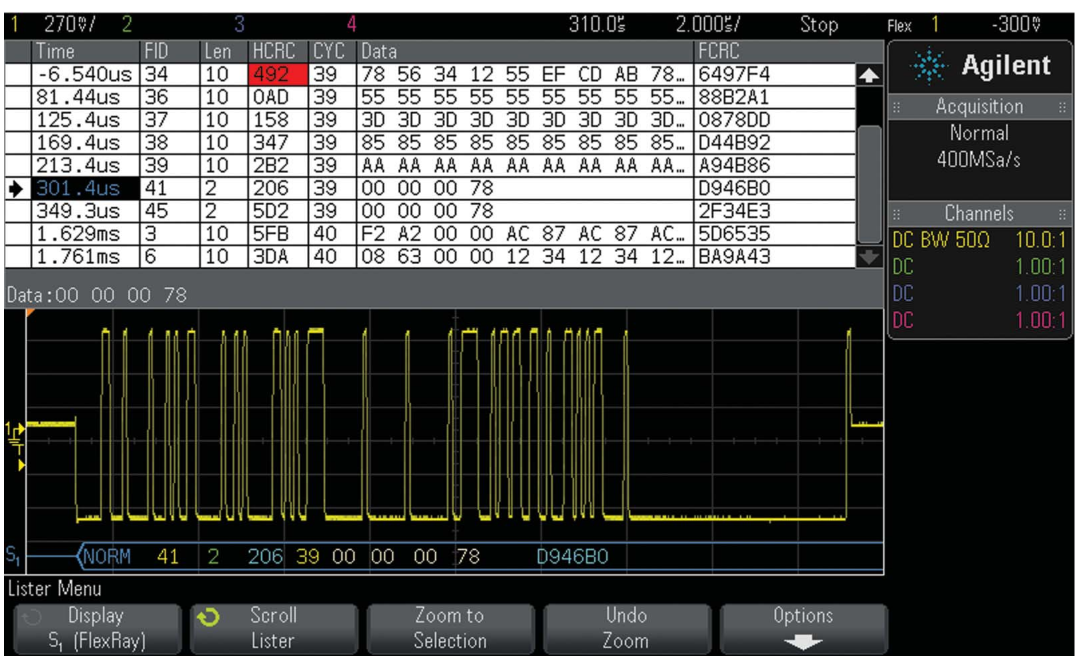
Specifications/Characteristics

LIN specifications/characteristics (DSOX3AUTO)	
LIN input source	Analog channels 1, 2, 3, or 4 Digital channels D0 to D15
LIN standards	LIN 1.3 or LIN 2.0
Baud rates	2400 b/s to 625 kb/s
Triggering	Sync break Frame ID (0X00$_{HEX}$ to 0X3F$_{HEX}$) Frame ID and data
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) Lin 2.0 check sum (hex digits in white) Lin 1.3 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) LIN 1.3 idle bus (mid-level bus trace in dark blue) LIN 2.0 idle bus (bi-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)



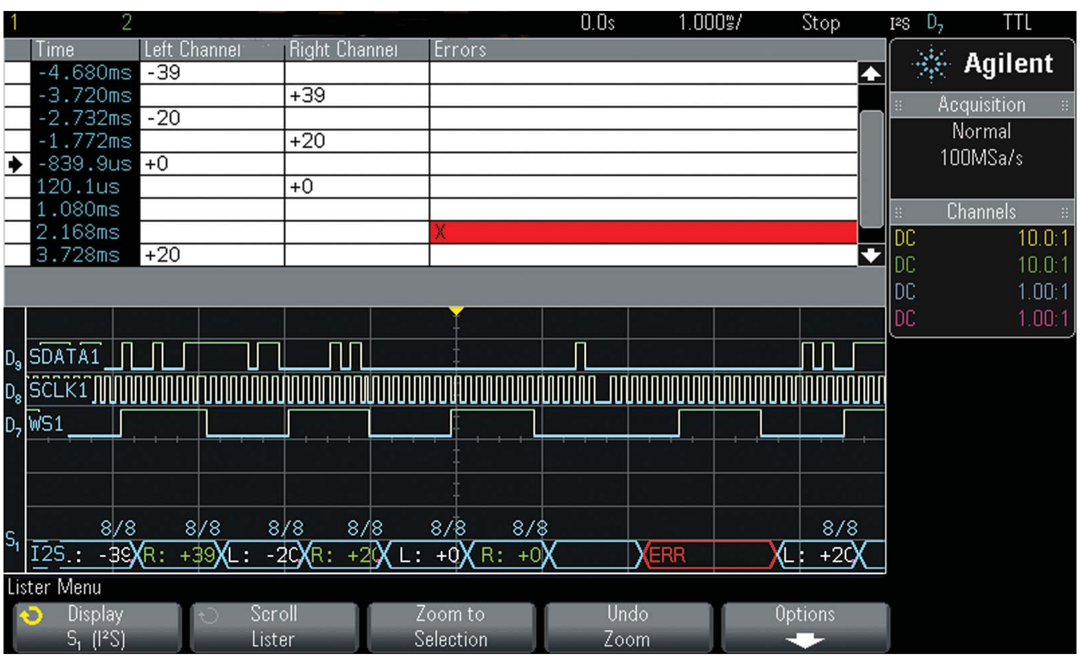
Specifications/Characteristics

FlexRay specifications/characteristics (DSOX3FLEX)	
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 downloadable 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 2.5 Mbps and TP4 10 Mbps
Multi-bus Analysis	FlexRay plus one other serial bus (including another FlexRay bus)



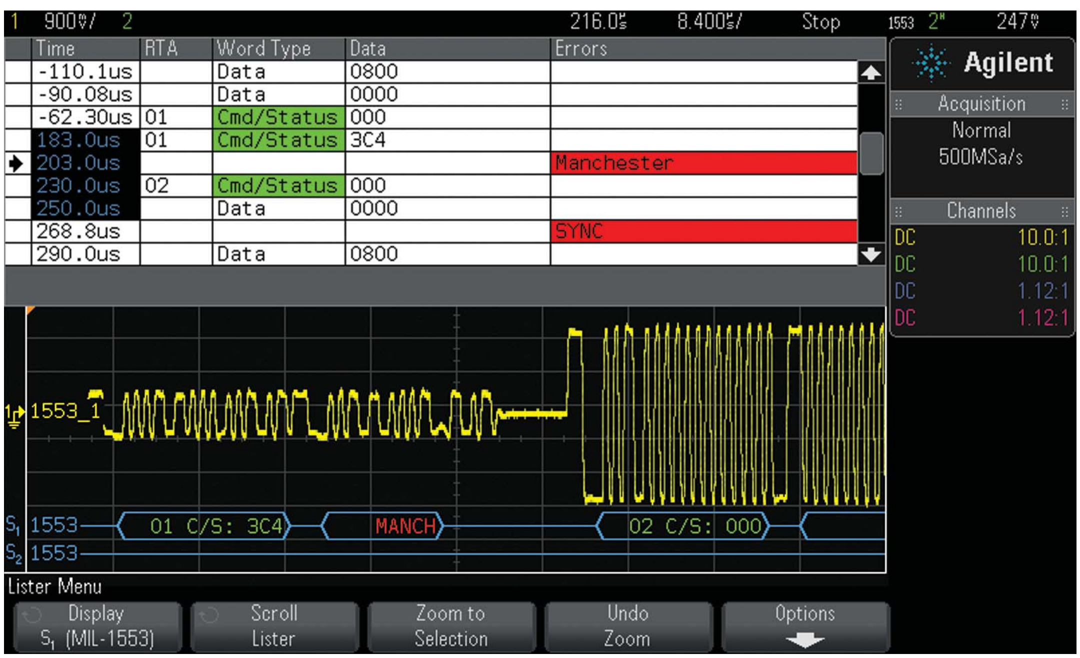
Specifications/Characteristics

I^{2}S specifications/characteristics (DSOX3AUDIO)	
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	I^{2}S plus one other serial bus (excluding another I^{2}S bus)



Specifications/Characteristics

MIL-STD 1553 specifications/characteristics (DSOX3AERO)	
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

ARINC 429 specifications/characteristics (DSOX3AERO)	
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)