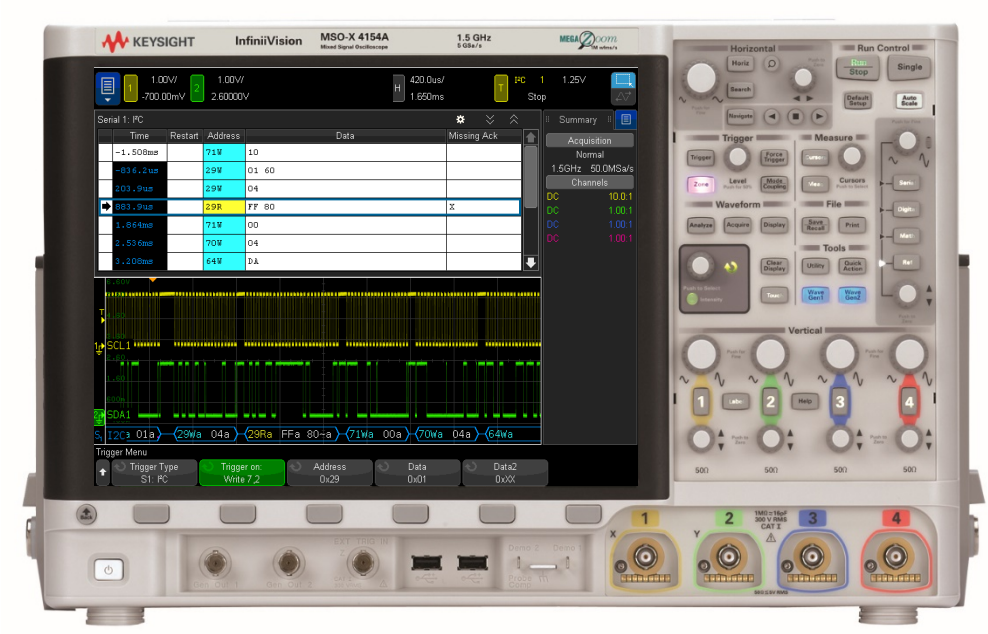
DATA SHEET

Embedded Software Package

for InfiniiVision X-Series Oscilloscopes

The Embedded Software Package for Keysight's InfiniiVision oscilloscopes enables protocol triggering and decode for a broad range of the most common serial buses used today for embedded and mixed-signal designs. This package also enables other advanced analysis capabilities including mask testing and frequency response analysis to help test today's electronic designs.



KEYSIGHT TECHNOLOGIES

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Introduction

The primary reason engineers use oscilloscopes to debug and characterize embedded serial buses, such as I²C, SPI, and UART (RS-232 or RS-485), is because of an oscilloscope's inherent ability to characterize the analog quality of these signals and to also time-correlate serial activity with other analog and digital I/O signals in their designs.

Many of the most popular embedded protocol decode and triggering capabilities and advanced analysis features such as mask testing and frequency response analysis (Bode plots) are enabled on InfiniiVision X-Series oscilloscope if licensed with the Embedded Software Package. Table 1 lists the specific measurement capabilities that are enabled on each series with the Embedded Package.

Table 1. Embedded Software Packages for InfiniiVision Oscilloscopes

InfiniiVision X-Series		2000A	3000A	3000T	4000A	6000A	P9240	M9240
Embedded Software Package Model Number		D2000GENB	D3000GENB	D3000GENB	D4000GENB	D6000GENB	P9240GENC	M9240GENB
Serial Trigger & Decode	I²C	✓	✓	✓	✓	✓	✓	✓
	SPI	✓	✓	✓	✓	✓		
	UART (RS-232/485)	✓	✓	✓	✓	✓	✓	✓
	I²S (Audio)		✓	✓	✓	✓		
	USB-PD			✓	✓	✓	✓	✓
Advanced Analysis	Mask Limit Test	✓	✓	✓	✓	✓	✓	✓
	Measurement Limit Test			✓	✓	✓	✓	✓
	Frequency Response Analysis (Bode Plots)			✓	✓	✓	✓	✓
	Enhanced HDTV Video Test		✓	✓	✓	✓	✓	✓
	Advanced Math	Std	✓	Std	Std	Std	Std	Std

Today's embedded designs based on microcontrollers (MCUs) and digital signal processors (DSPs) often include a combination of real-world analog signals, digital I/O buses, and serial buses. Although microcontrollers and DSPs are often thought of as simply digital control and processing devices, most MCUs and DSPs today are mixed-signal devices. Signals that need to be monitored and verified in systems such as these using an oscilloscope include analog I/O, digital I/O ports, and serial communication buses. I²C, SPI, and UART/RS-232 are often used for chip-to-chip communication between MCUs and memory chips, as well as other peripherals. Keysight's InfiniiVision X-Series oscilloscopes have some unique advantages over other oscilloscope when it comes to triggering on and decoding serial buses including the following.

- Hardware-based decoding for responsiveness
- Dual-bus time-interleaved protocol lister display
- Decoding of all frames captured using segmented memory
- Real-time frame/error counter for some protocols

Figure 1 shows an example of a Keysight InfiniiVision X-Series oscilloscope decoding and triggering on an I²C EEPROM data read operation, while also capturing time-correlated analog and digital waveforms.

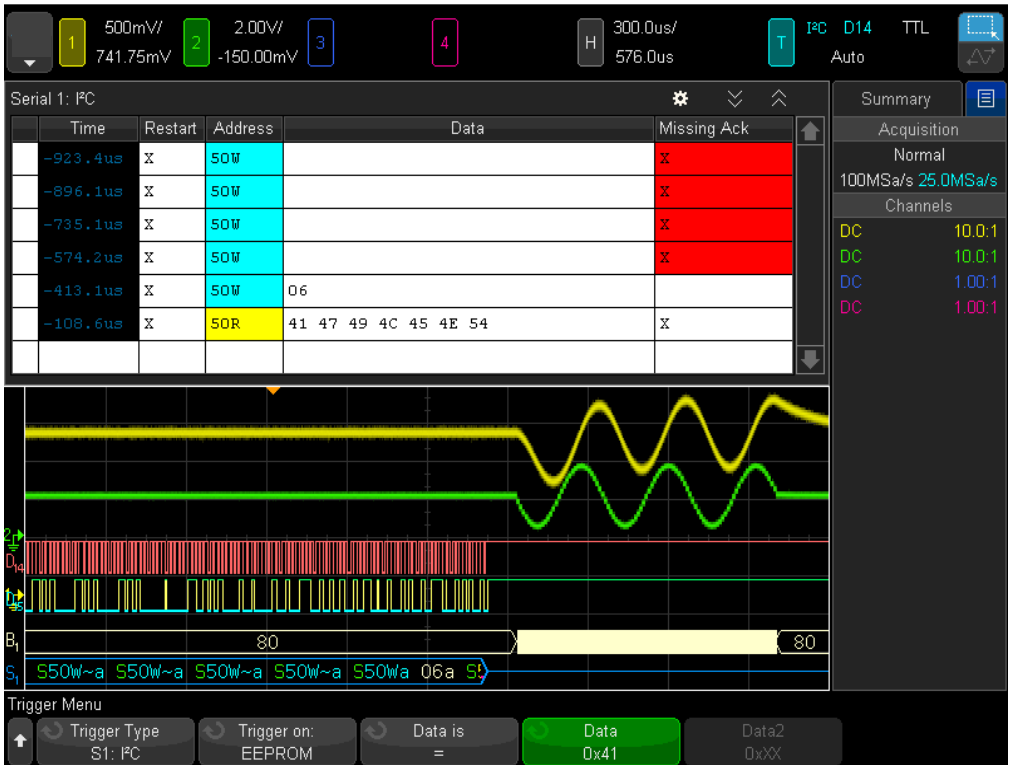

Figure 1. Decoding and triggering on an I²C bus using a Keysight mixed signal oscilloscope (MSO) licensed with the Embedded Software Package.

Serial Trigger and Decode

I²C

Table 2. I²C Performance Characteristics

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)

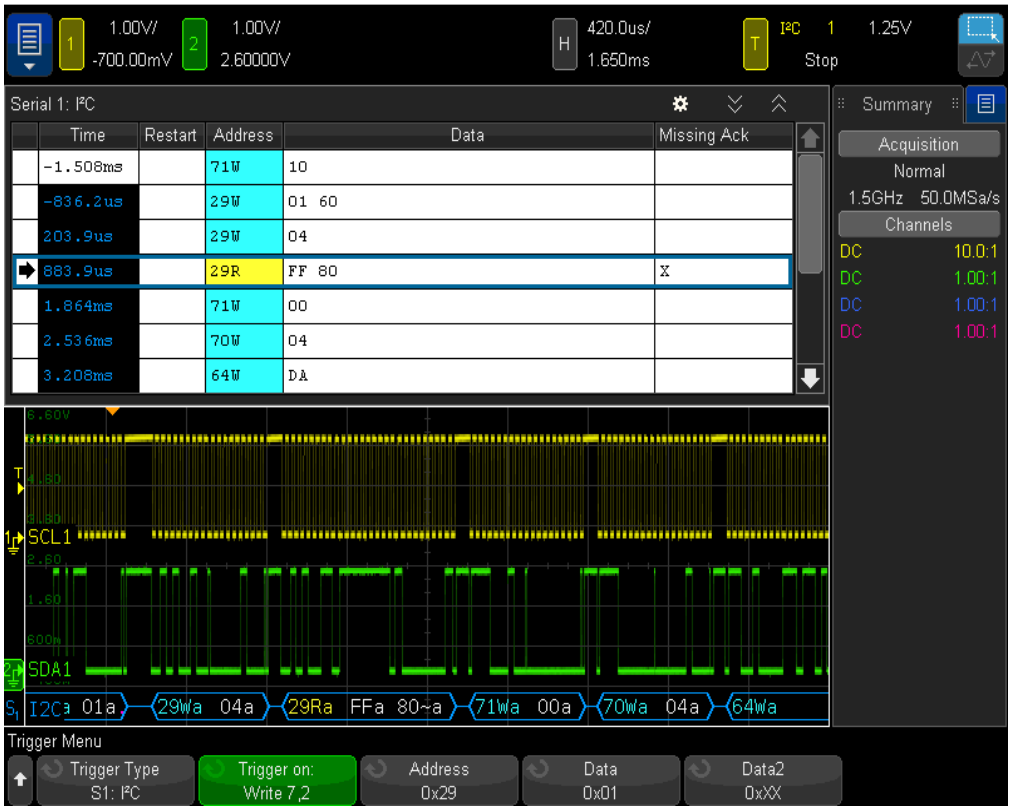

Figure 2. I²C decode on an InfiniiVision X-Series oscilloscope.

SPI

Table 3. SPI Performance Characteristics

MOSI, MISO, Clock and CS input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 (excluding 2000 X-Series)
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. (excluding 2000 X-Series)

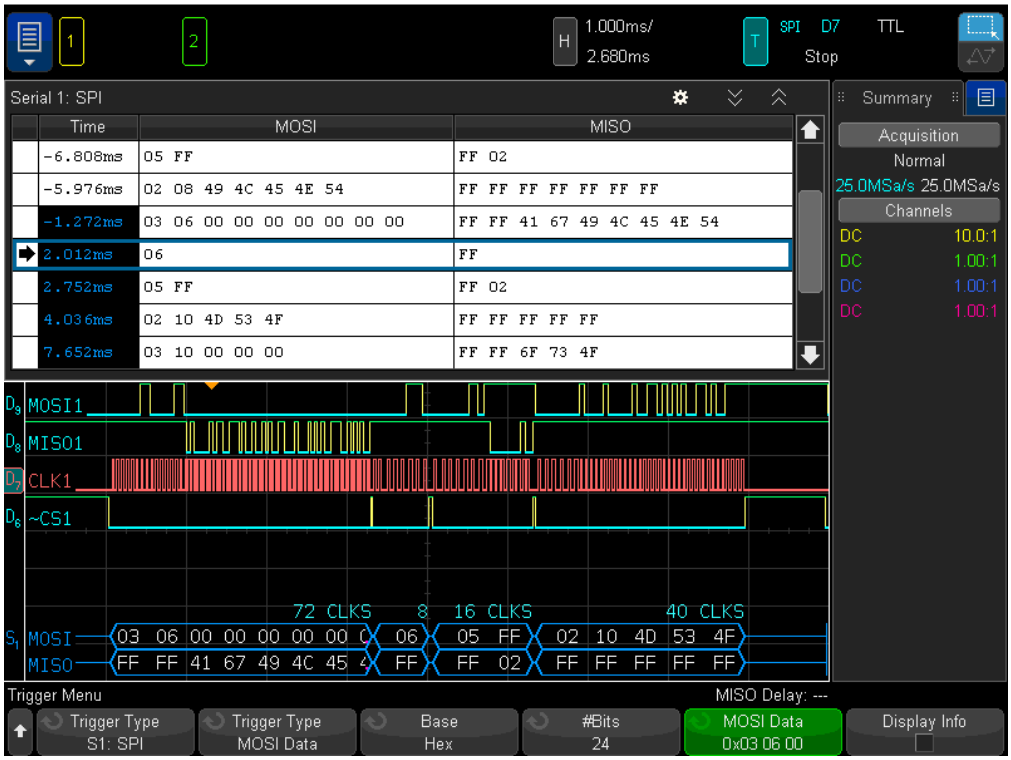

Figure 3. SPI decode on an InfiniiVision X-Series oscilloscope.

UART (RS-232/485)

Table 4. UART Performance Characteristics

Tx and Rx input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 (except 2000 X-Series)
Bus configuration	
• Baud rates	100 b/s up to 12 Mb/s (maximum 10 Mb/s on 2000X)
• 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	UART plus one other serial bus, including another UART bus. (except 2000 6000 X-Series)
Totalize/counter function	Total received frames
	Total transmitted frames
	Total parity error frames (with percentage)

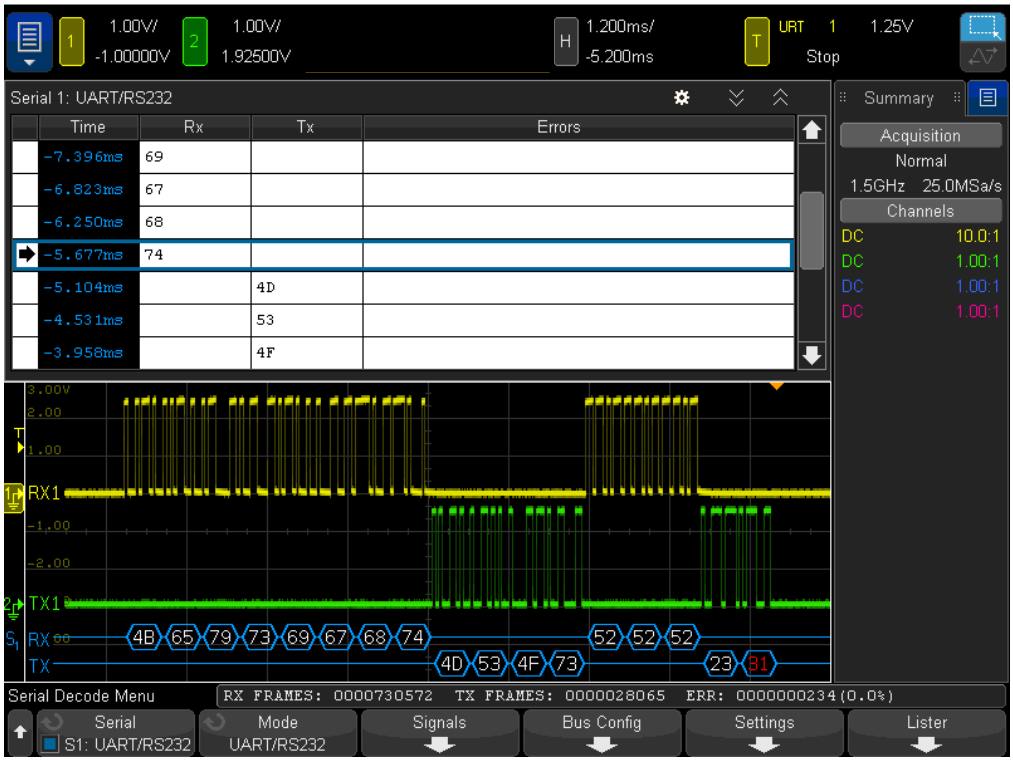

Figure 4. UART decode on an InfiniiVision X-Series oscilloscope.

I²S (Audio)

Table 5. I²S Performance Characteristics

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)

Figure 5. I²S decode on an InfiniiVision X-Series oscilloscope.

USB PD (Power Delivery)

Table 6. USB PD Performance Characteristics

USB Type-C CC wire input source	Analog channels 1, 2, 3, or 4
Baud rate	300 kbps ± 10%
Triggering	Preamble start
	EOP
	Ordered sets:
	• SOP, SOP', SOP", SOP' debug, SOP" debug, hard reset, cable reset
	Errors:
	• CRC error, Preamble error
	Header content (qualified on SOP, SOP', SOP", or none):
	• Control message (GoodCRC, Accept, Reject, Get_Source_Cap, etc. 1)
	• Data message (Source_Cap, Request, BIST, etc. 1)
	• Extended message (Source_Cap_Extended, Status, Battery_Cap, etc. 1)
	• Value (Hex – 4 nibbles)
Hardware-based decode (Time-correlated decode trace below waveform and protocol lister table above waveform)	Preamble (PRE in blue)
	Ordered set (symbolic name in blue)
	Header (Hex digits in yellow)
	Data (32-bit Hex objects in white)
	CRC (Hex in green)
	End of packet (EOP in blue)
	Symbolic:
	• Control messages
	• Data messages
	• Extended messages
	• Source capabilities (in Volts/Amps)
	• Sink capabilities (in Volts/Amps)
	• Structured vendor defined message commands
Multi-bus analysis	USB PD plus one other serial bus

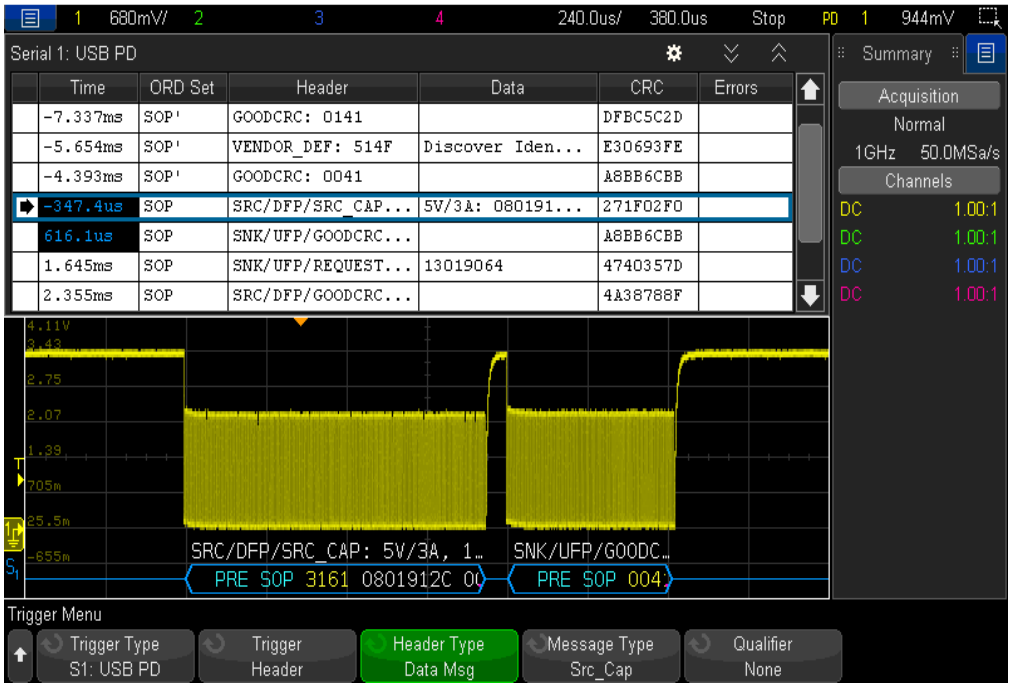

Figure 6. USB PD decode on an InfiniiVision X-Series oscilloscope.

Advanced Analysis

Mask Test

If you need to validate the quality and stability of your electronic components and systems, the InfiniiVision oscilloscope's mask/waveform limit testing capability, which is enabled with the Embedded Software Package, can save you time and provide pass/fail statistics almost instantly. Mask testing offers a fast and easy way to test your signals to specified standards, as well as the ability to uncover unexpected signal anomalies, such as glitches. Mask testing on other oscilloscopes is usually based on software-intensive processing technology, which tends to be slow.

The InfiniiVision scope's mask testing is based on hardware technology, meaning that they can perform up to 270,000 real-time waveform pass/fail tests per second. This makes your testing throughput orders of magnitude faster than you can achieve on other oscilloscope mask test solutions.

Features

- Test up to 270,000 waveforms per second with the industry's fastest hardware-accelerated mask testing technology
- Automatic mask creation using input standard
- Easily download multi-region masks and setups based on industry standards
- Detailed pass/fail statistics
- Test to high-quality standards based on sigma
- Multiple user-selectable test criteria

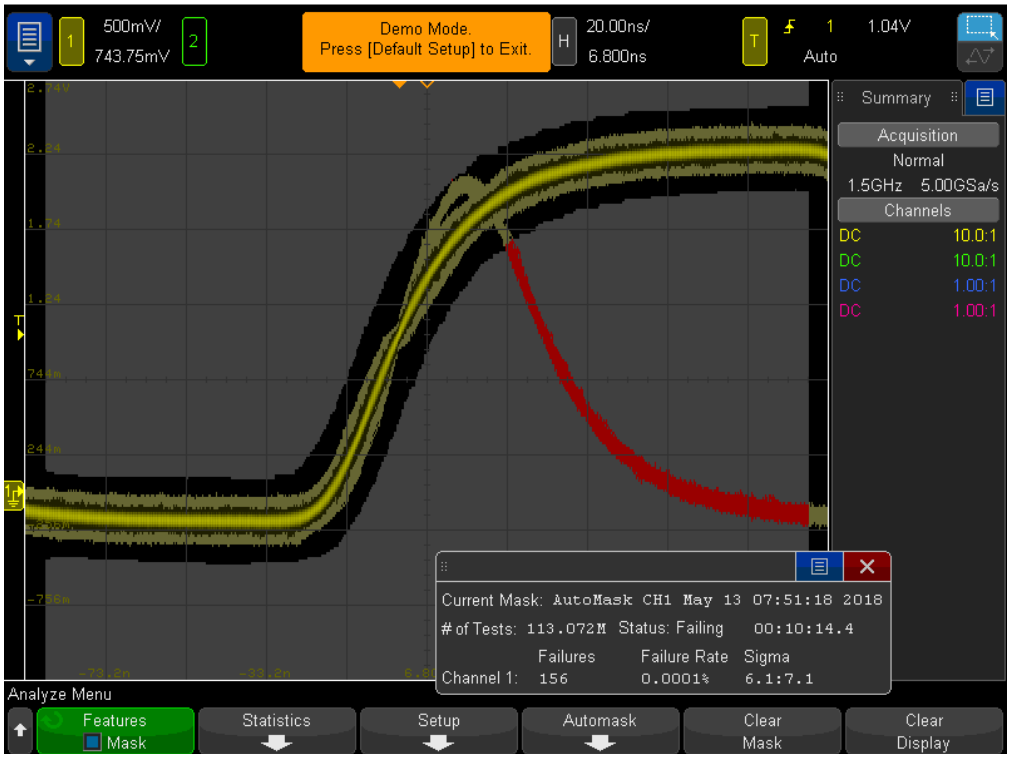

Figure 7. Frequency response of a bandpass filter.

Table 7. Mask Test Performance Characteristics

Mask test source	Analog channels 1, 2, 3, or 4
Maximum test rate	2000 X-Series: Up to 50,000 waveforms tested per second
	3000 and 4000 X-Series: Up to 270,000 waveforms tested per second
	6000 X-Series: Up to 130,000 waveforms tested per second
Acquisition modes	Real-time sampling–non-averaged, Real-time sampling–averaged
Mask creation	
• Automask-divisions	± X divisions, ± Y divisions
• Automask-absolute	± X seconds, ± Y volts
• Mask file import	Up to 8 failure regions (created in text editor)
Mask scaling	Source lock on (mask automatically re-scales with scope settings)
	Source lock off (mask scaling fixed relative to display when loaded or created)
Test criteria	Run until forever, Minimum number of tests, Minimum time, Minimum sigma
Action on error	Stop acquisitions, save image, print, perform measurements
Trigger output	On failure
Statistics display	Number of tests, Number of failures (for each channel tested), Failure rate (for each channel tested), Test time (hours – minutes – seconds), Sigma (actual versus maximum without failures)
Display formats	Mask – translucent gray, Failing waveform segments – red, Passing waveform segments – channel color
Save/recall	4 non-volatile internal registers (.msk format), USB memory stick (.msk format)

Frequency Response Analysis (Bode gain & phase plots)

Frequency Response Analysis (FRA) is often a critical measurement used to characterize the frequency response (gain and phase versus frequency) of a variety of today's electronic designs, including passive filters, amplifier circuits, and negative feedback networks of switch mode power supplies (loop response). FRA capability is included in the Embedded Software Package. This frequency-domain measurement capability is achieved with a swept gain and phase measurement versus frequency (Bode plot). The InfiniiVision oscilloscope uses the scope's built-in waveform generator (WaveGen) to stimulate the circuit under test at various frequency settings and then captures the input and output signals using two channels of the oscilloscope. At each test frequency, the scope measures, computes, plots gain ($20\text{Log}V_{OUT}/V_{IN}$) logarithmically and phase linearly.

- Dynamic range: > 80 dB (typical)
- Frequency range: 10 Hz to 20 MHz
- Sweep or single frequency test modes
- Fixed test amplitude or custom Amplitude Profile
- 60 to 1000 points across Start/Stop sweep range
- Two pair of tracking gain and phase markers
- Plots gain and phase and tabular view of test results
- Easily export and/or save measurement results in .csv format for offline analysis

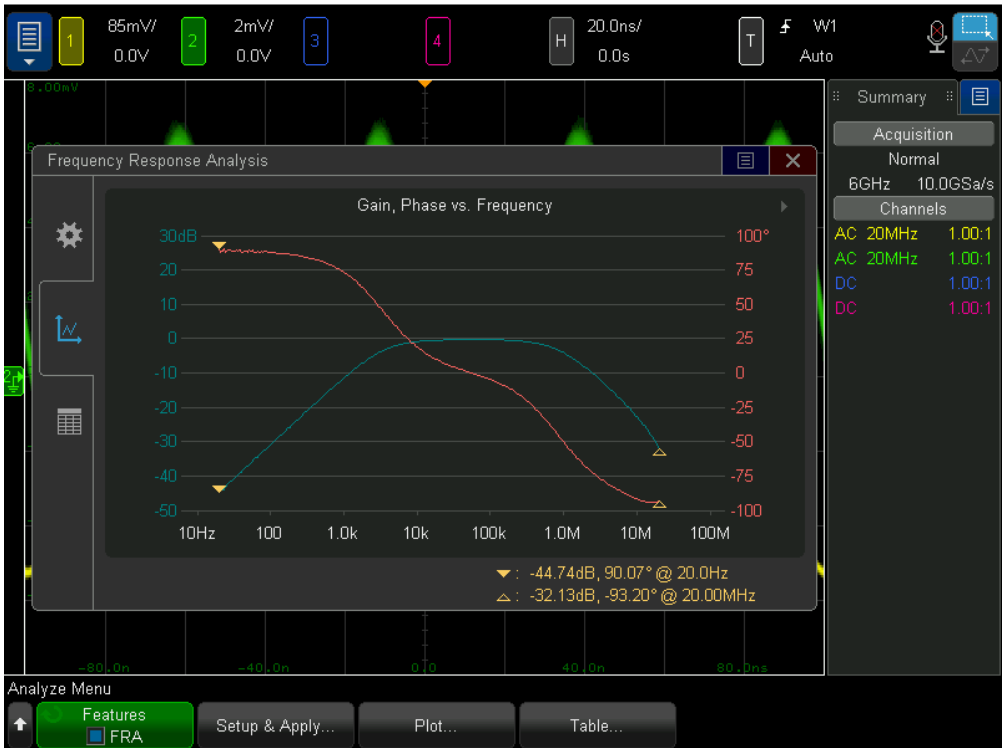

Figure 8. Frequency response analysis (gain & phase) on a bandpass filter.

Table 8. Frequency Response Analysis Performance Characteristics

	Frequency Response Analysis	
Frequency mode	Sweep or single	
Frequency range	10 Hz to 20 MHz	
Test amplitude modes	Fixed or amplitude profile	
Test amplitude range	3000T	10 mVpp to 2.5 Vpp into 50-Ω load
		20 mVpp to 5.0 Vpp into high impedance load
	4000A/6000A	10 mVpp to 5.0 Vpp in 50-Ω load
		20 mVpp to 10.0 Vpp into high impedance load
Input and output sources	Channel 1, 2, 3, and 4	
Number of test points	60 to 1000 points across Start/Stop sweep range	
Test results	Overlaid gain and phase plot and tabular view	
Dynamic range	> 80 dB (typical) based on 0 dBm (630 mVpp) input into 50-Ω load	
Measurements	Dual pair of tracking gain and phase markers	
Plot scaling	Auto-scaled during test and manual setting after test	

Enhanced HDTV Video Triggering and Analysis

Whether you are debugging consumer electronics with HDTV or characterizing a design, the enhanced HDTV video triggering and analysis capabilities that's included in the Aero Package provides support for a variety of HDTV standards for triggering and analysis. This enhanced video measurement capability supports a video IRE display grid with cursor measurements performed in video IRE units for NTSC and PAL standards. In addition, enhanced video analysis provides an array of additional HDTV triggering standards that will help speed debug and characterization for engineers working on HDTV video applications.

Enhanced video analysis provides triggering on an array of HDTV standards, including:

- 480p/60, 567p/50, 720p/50, 720p/60
- 1080i/50, 1080i/60
- 1080p/24, 1080p/25, 1080p/30, 1080p/50, 1080p/60
- Generic (custom bi-level and tri-level sync video standards)

Note that InfiniiVision X-Series oscilloscopes already come standard with NTSC, PAL, PAL-M, and SECAM support.

Figure 9. Triggering on 1080p HDTV.

Advanced Waveform Math (3000A X-Series only)

Advanced waveform math functions come standard on all models of the InfiniiVision X-Series oscilloscopes except for the 3000A Series. Refer to the appropriate InfiniiVision X-Series oscilloscope data sheet to see a complete list of standard waveform math functions on each model. When licensed with Embedded Software Package, advanced waveform math functions are also enabled on the InfiniiVision 3000A Series oscilloscope.

The Keysight 3000A X-Series oscilloscopes come standard with the following waveform math functions:

- Add
- Subtract
- Multiply
- Divide
- Integrate
- Differentiate
- Square Root
- FFT

The Embedded SoftwarePackage adds the following waveform math functions on the Keysight 3000A X-Series:

- Ax + B
- Square
- Absolute
- Common Logarithm
- Natural Logarithm
- Exponential
- Base 10 Exponential
- Low-pass Filter
- High-pass Filter
- Measurement Trend
- Magnify
- Chart Logic Bus Timing
- Chart Logic Bus State

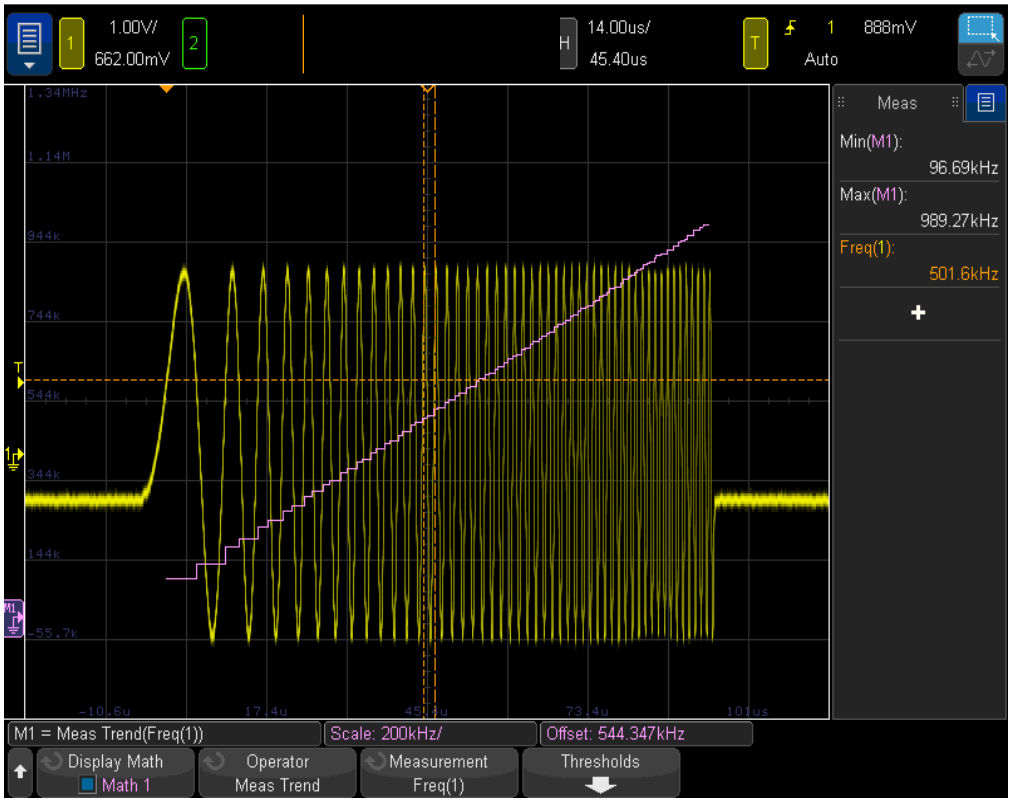

Figure 10. Measurement trend math function used to plot frequency versus time of a FM burst.

Related Literature

Table 9. Related literature

Publication title	Publication number
Segmented Memory for Serial Bus Applications - Application Note	5990-5817EN
InfiniiVision 2000 X-Series Oscilloscopes - Data Sheet	5990-6618EN
InfiniiVision 3000T X-Series Oscilloscopes - Data Sheet	5992-0140EN
InfiniiVision 4000 X-Series Oscilloscopes - Data Sheet	5991-1103EN
InfiniiVision 6000 X-Series Oscilloscopes - Data Sheet	5991-4087EN
M924XA InfiniiVision PXIe Modular Oscilloscopes - Data Sheet	5992-2003EN
P924XA InfiniiVision USB Oscilloscopes - Data Sheet	5992-2897EN
InfiniiVision Oscilloscope Probes and Accessories – Technical Overview	5968-8153EN

Ordering Information

Table 10. Embedded Software Package model numbers

InfiniiVision Series	Embedded Software Package
2000 X-Series	D2000GENB
3000 X-Series	D3000GENB
4000 X-Series	D4000GENB
6000 X-Series	D6000GENB
P9240 Series	P9240GENC
M9240 Series	M9240GENB

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