

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.

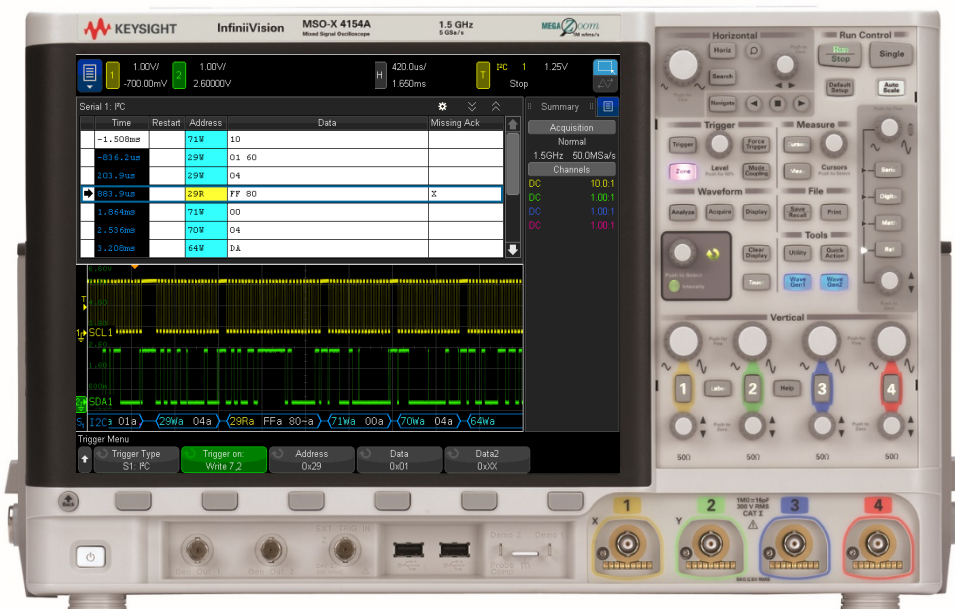


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Introduction

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 | I ² C | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | SPI | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| | UART (RS-232/485) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | I ² S (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.

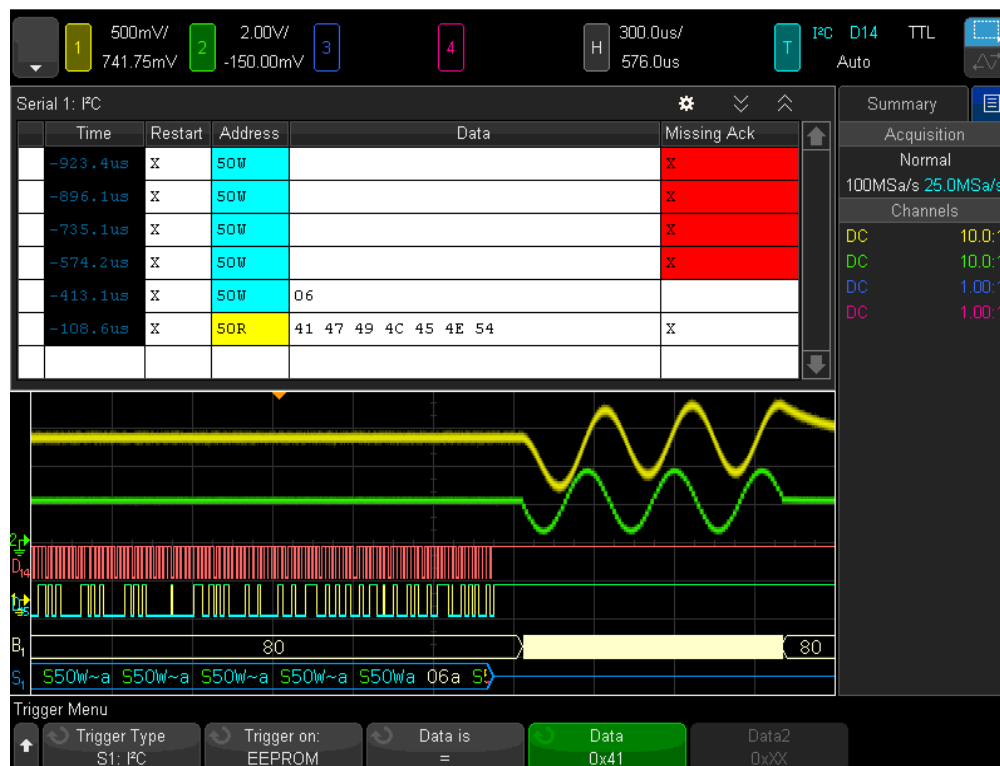


Figure 1. Decoding and triggering on an I²C bus using a Keysight mixed signal oscilloscope (MSO) licensed with the Embedded Software Package.

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 | I ² C plus one other serial bus, including another I ² C bus. (3000, 4000 and 6000 X-Series only) |

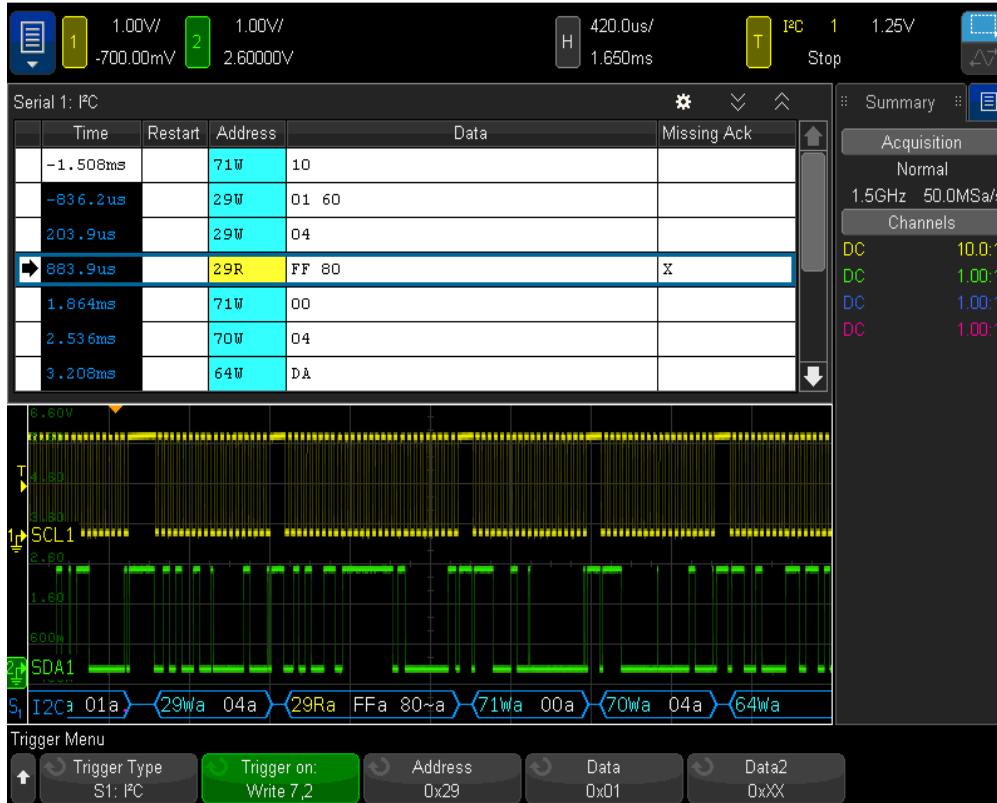


Figure 2. I²C decode on an InfiniiVision X-Series oscilloscope.

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) |
| Multi-bus analysis | 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) |

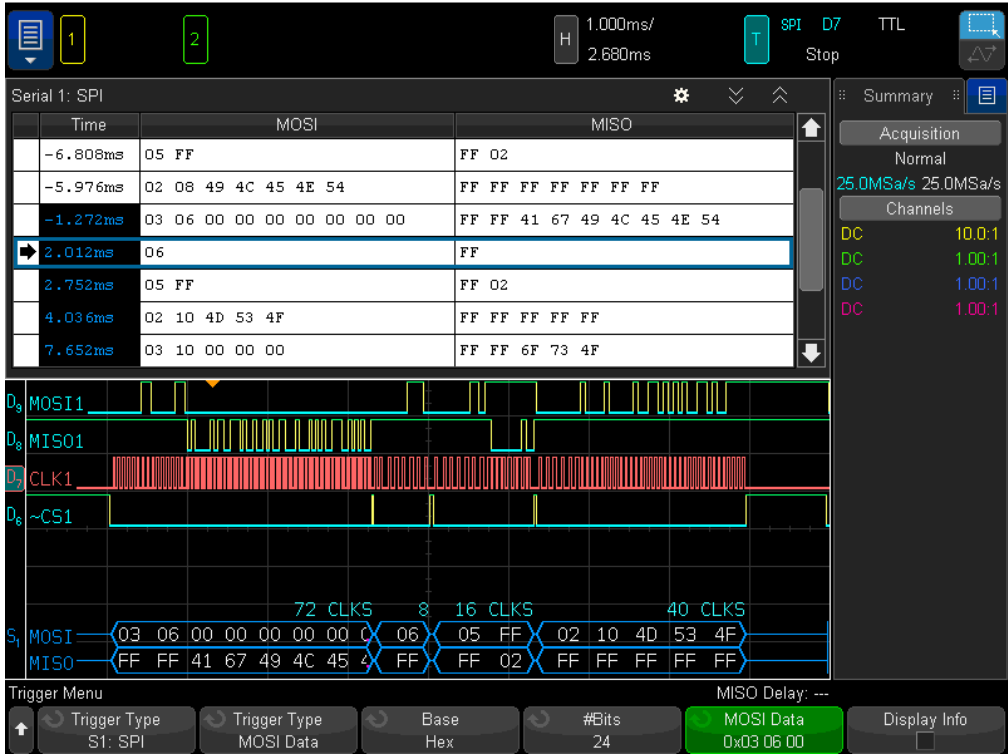


Figure 3. SPI decode on an InfiniiVision X-Series oscilloscope.

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) |

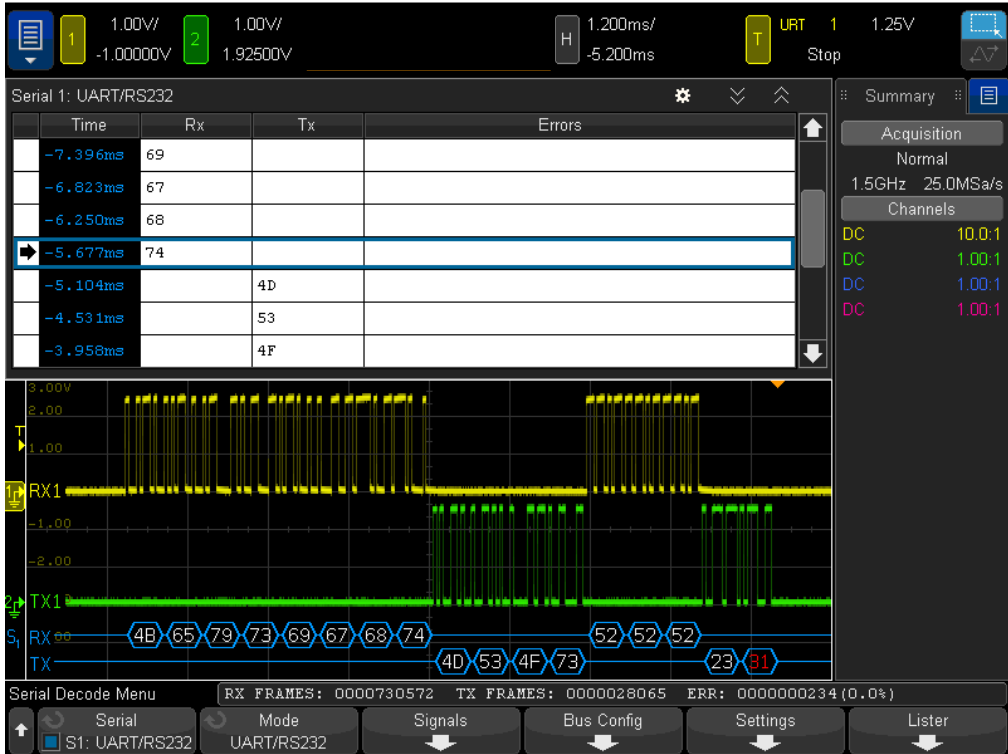


Figure 4. UART decode on an InfiniiVision X-Series oscilloscope.

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 | I ² S plus one other serial bus (excluding another I ² S bus) |

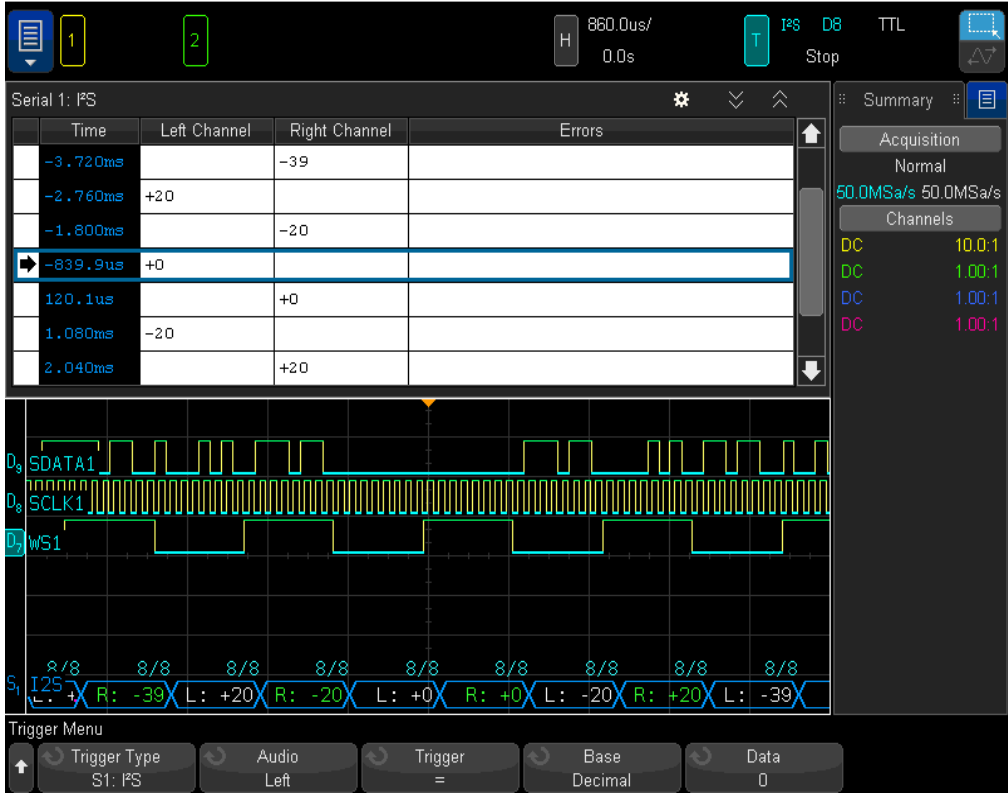


Figure 5. I2S decode on an InfiniiVision X-Series oscilloscope.

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: |
| | <ul style="list-style-type: none"> SOP, SOP', SOP'', SOP' debug, SOP'' debug, hard reset, cable reset |
| | Errors: |
| | <ul style="list-style-type: none"> CRC error, Preamble error |
| | Header content (qualified on SOP, SOP', SOP'', or none): |
| | <ul style="list-style-type: none"> Control message (GoodCRC, Accept, Reject, Get_Source_Cap, etc. 1) |
| | <ul style="list-style-type: none"> Data message (Source_Cap, Request, BIST, etc. 1) |
| | <ul style="list-style-type: none"> Extended message (Source_Cap_Extended, Status, Battery_Cap, etc. 1) |
| Hardware-based decode (Time-correlated decode trace below waveform and protocol lister table above waveform) | Value (Hex – 4 nibbles) |
| | 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: |
| | <ul style="list-style-type: none"> Control messages Data messages Extended messages Source capabilities (in Volts/Amps) Sink capabilities (in Volts/Amps) Structured vendor defined message commands |
| | Multi-bus analysis |

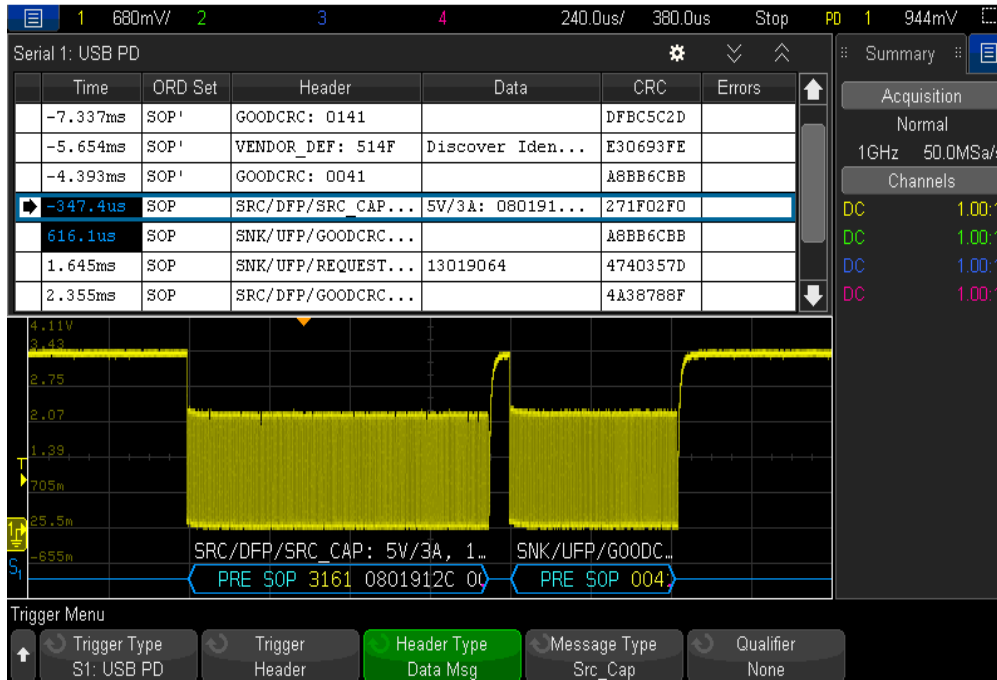


Figure 6. USB PD decode on an InfiniiVision X-Series oscilloscope.

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

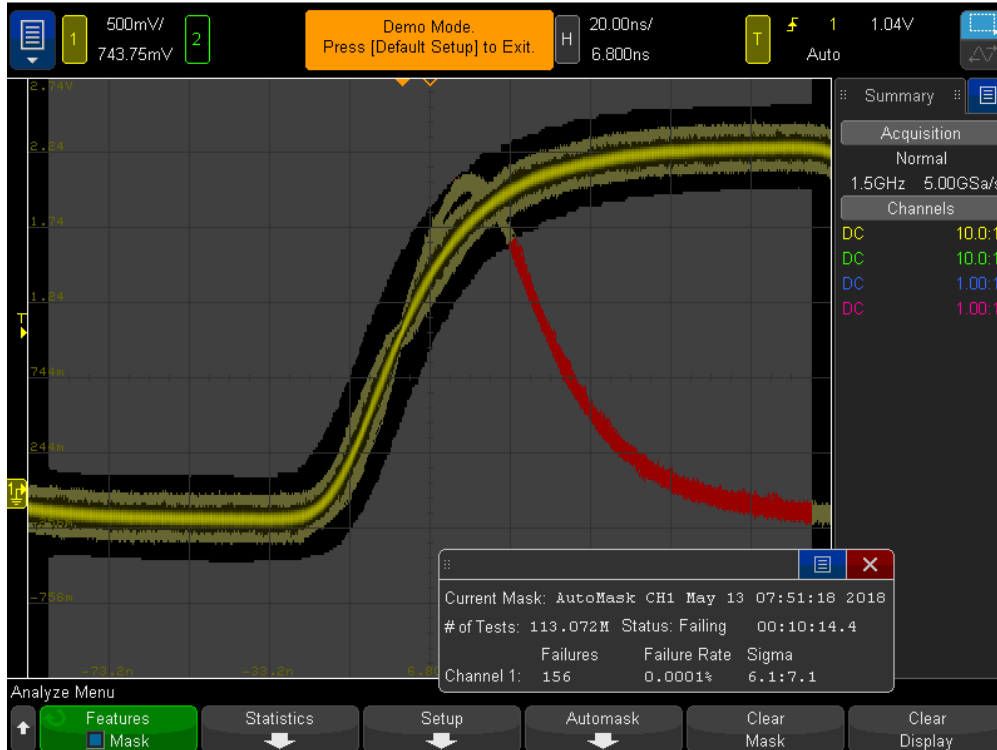


Figure 7. Frequency response of a bandpass filter.

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 | $\pm X$ divisions, $\pm Y$ divisions |
| • Automask-absolute | $\pm X$ seconds, $\pm Y$ 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 ($20\text{Log}V_{\text{OUT}}/V_{\text{IN}}$) 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

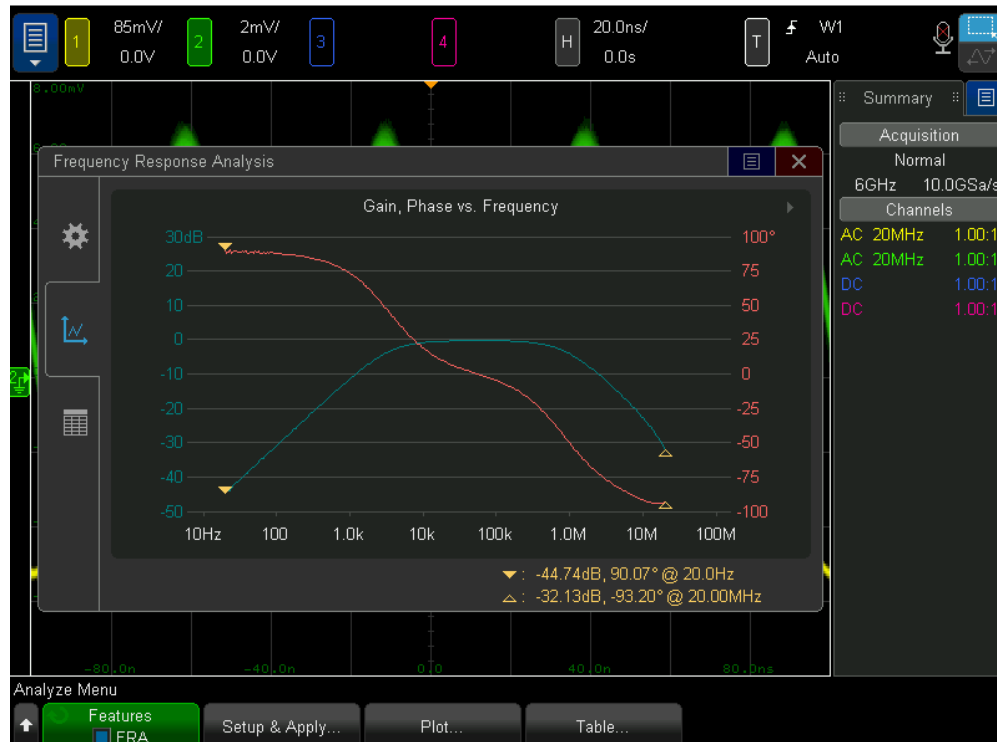


Figure 8. Frequency response analysis (gain & phase) on a bandpass filter.

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

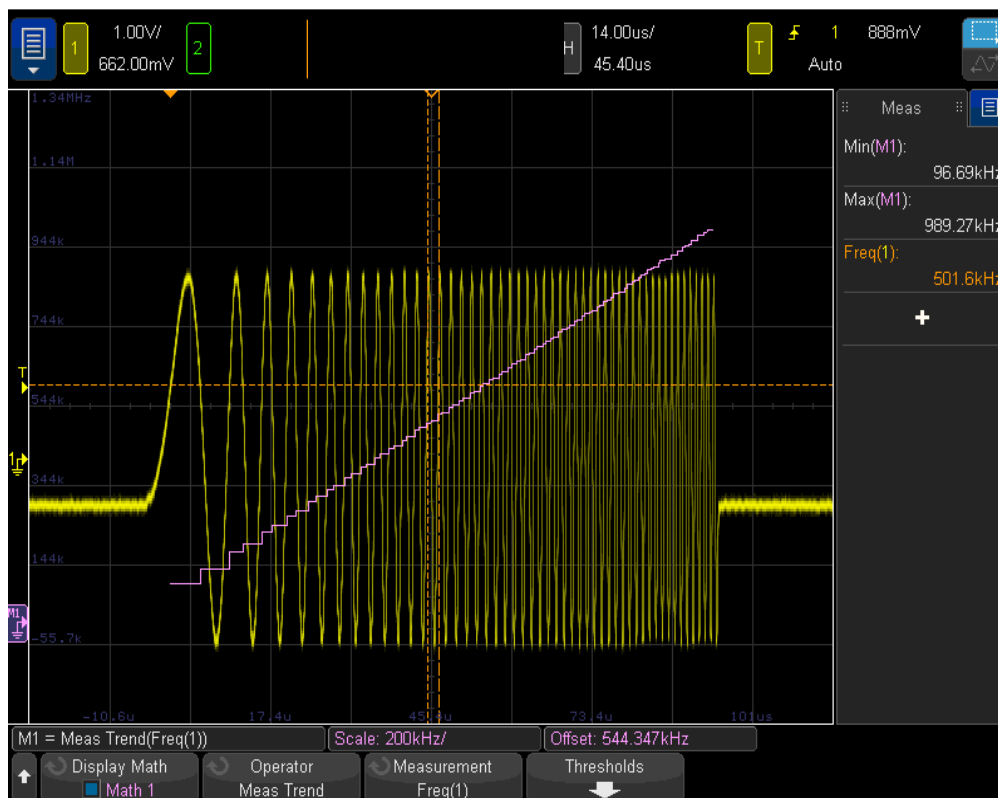


Figure 10. Measurement trend math function used to plot frequency versus time of a FM burst.

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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