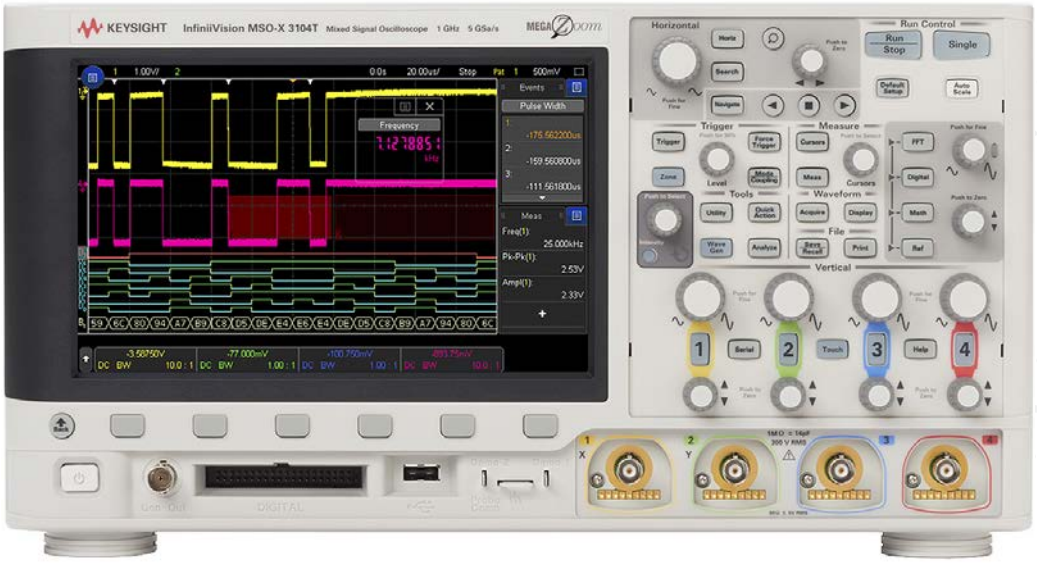
DATA SHEET

InfiniiVision 3000T X-Series Oscilloscopes



KEYSIGHT TECHNOLOGIES

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Touch, Discover, Solve

The InfiniiVision 3000A X-Series redefined oscilloscopes. It saw the most signal detail, provided more functionality than any other oscilloscope, and gave you maximum investment protection. It was also the most successful oscilloscope in Hewlett Packard, Agilent and Keysight Technologies, Inc.'s history. The 3000T X-Series continues that legacy.

The 3000T X-Series takes everything that was revolutionary about the A model and adds a capacitive touch screen, a user interface designed for **touch**, and the exclusive zone touch trigger, all combined with an industry-leading uncompromised update rate of 1 million wfm/s to give you the confidence that you're seeing all of your signal detail, and the ability to **discover** any issues. And the addition of new analysis capabilities help you **solve** your hardest problems quickly.

The 3000T X-Series once again redefines what you can expect in a general purpose oscilloscope by providing all of the performance and capability you need to get to measurement insights faster:

Touch:
- 8.5-inch capacitive touch screen
- Designed for touch interface

Discover:
- Industry's fastest uncompromised waveform update rate
- Exclusive zone touch trigger

Solve:
- Wide range of serial decodes
- 7-in-1 instrument integration
- Time/frequency domain correlation

Figure 1. InfiniiVision 3000 X-Series with MegaZoom IV smart memory technology.

Touch: Designed-For-Touch Interface and Capacitive Touch Screen Simplify Use

From the start of product development, we designed every aspect of this oscilloscope to be seamlessly driven by a touch interface. Large, easy-to-touch targets, a graphical user interface that adapts to show you more and be easier to touch, and a large, sensitive, capacitive touch screen all combine to make operation quick and natural, just like your favorite tablet devices.

Figure 2. The industry's first 8.5" capacitive touch display with large, touchable targets.

Capacitive touch screen technology enables productivity

The user interface allows you to use the alphanumeric pad for quick annotation, place waveforms or cursors in exact positions and drag docking panels across the screen to see more measurement information.

The 3000T X-Series offers three ways to access key menus and features: touch GUI for those that prefer tablet or smart phone touch interfaces, front panel buttons and knobs for the traditional oscilloscope users, and Keysight Insight pull down menu for users who prefer Windows-like operations. The 3000T X-Series also offers a "touch off" button as well as USB mouse and keyboard support.

Figure 3. Side bar with movable docks allows information to be placed on the screen precisely where you want it for documentation.

Touch interface simplifies documentation

The availability of up to 10 annotations on screen makes it easy to highlight key items on screen shots. Streamline documentation with the ability to input information via a pop-up soft keyboard on the touch screen or a USB keyboard. A sidebar displays additional information without covering the waveform graticule, and allows you to dock and scroll through multiple measurement values. Touch gestures (like flicking) make navigating lists or moving between segment waveforms easy.

In addition to the benefits of touch, built-in USB host and USB device ports make PC connectivity easy. The BV0004B oscilloscope control and automation application within BenchVue lets you control and visualize the 3000T X-Series and multiple measurements simultaneously. It lets you build automated test sequences just as easily as you can with the front panel. Save time with the ability to export measurement data to Excel, Word and MATLAB in three clicks. Monitor and control your 3000T X-Series with a mobile device from anywhere. Simplify your testing with BenchVue software. Learn more at **www.keysight.com/find/BenchVue**.

Figure 4. Use BenchVue for remotely logging and plotting measurement data.

Touch: Designed-For-Touch Interface and Capacitive Touch Screen Simplify Use (Continued)

Figure 5. See up to ten annotations on screen at once for documentation. The standard touch screen makes inputting notes simple.

Figure 6. With the optional LAN/VGA module you can email yourself setups, data and screenshots.

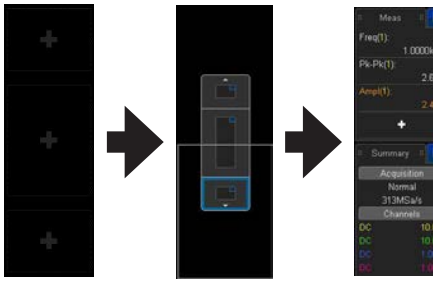


Figure 7. A dock-able sidebar allows you to customize how you view your measurements.

Redefine your remote Web control oscilloscope experience

The 3000T X-Series offers traditional control via a PC Web browser, but also supports remote control through popular tablet devices when using the optional LAN/VGA interface.

Figure 8. Remotely control the 3000T X-Series via tablet device.

Discover: The Industry's Fastest Uncompromised Update Rate Increases the Chance of Finding Anomalies

Industry-leading uncompromised update rate

If you can't see the problem, you can't fix the problem. With an industry-leading update rate of over one million waveforms per second, the InfiniiVision 3000T X-Series gives you the highest probability of capturing random and infrequent events that you would miss on an oscilloscope with a lower waveform update rate.

Powered by MegaZoom IV smart memory technology, the InfiniiVision 3000T X-Series not only lets you see more waveforms, but it has the uncompromised ability to find the most difficult problems in your design under any conditions. Unlike other oscilloscopes, uncompromised ability means:

- Always-fast, responsive operation
- No slowdown with logic channels on
- No slowdown with protocol decoding on
- No slowdown with math functions on
- No slowdown with measurements on
- No slowdown with vectors on
- No slowdown with sinx/x interpolation on

What is waveform update rate?

As oscilloscopes acquire data, process it, and plot it to the screen, there is inevitable "dead time," or the time oscilloscopes miss signals completely. In general, the faster the waveform update rate, the shorter the dead time. The shorter the dead time, the more likely an oscilloscope is to capture anomalies and infrequent events. This is why it is important to select an oscilloscope with a fast waveform update rate. Figures 7 and 8 demonstrate the difference between a slower update rate and a faster update rate.

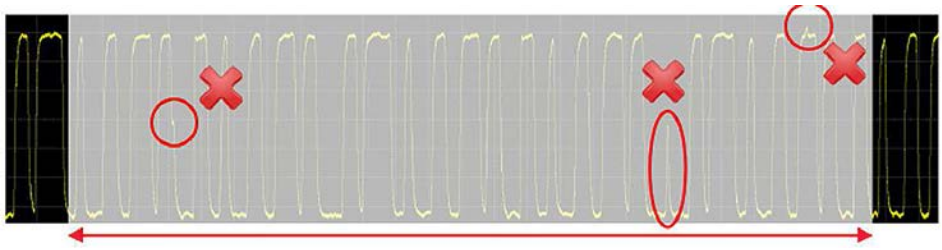


Figure 9. Other vendor's oscilloscope with 50,000 waveforms/second. A long dead time decreases your chances of capturing infrequent events.

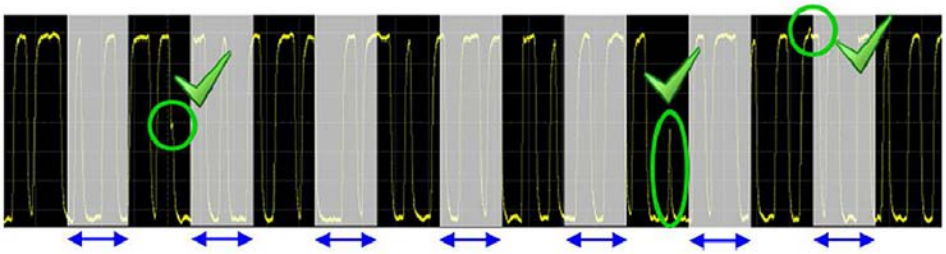


Figure 10. InfiniiVision 30000T X-Series with 1,000,000 waveforms/second. A short dead time increases your chancs of capturing infrequent events.

Discover: The Industry's Fastest Uncompromised Update Rate Increases the Chance of Finding Anomalies (Continued)

But all specs aren't equal.

Many vendors claim an update rate specification, but that is only in a special mode, or without any features turned on. Table 1 shows the 3000T X-Series' update rate versus a competing oscilloscope.

While all scopes update rate will vary to some degree by the timebase setting, it is critical that the update rate remain constant regardless of the functionality you are using within the oscilloscope.

Table 1. Measured update rate between the 3000T X-Series and the Danaher Tektronix MDO3000. Note how the update rate fluctuates wildly on the MDO3000 based on different settings/features.

	10 ns/div			
	Keysight 3000T X-Series		**Tektronix MDO3000 Series**	
	Update rate	Probability	Update rate	Probability
Max with no features on	1,114,000	94%	281,000	50%
Max with digital ch on	1,101,000	94%	132	0.03%
Max with measurements on	1,114,000	94%	2,200	0.55%
Max with FFT on	1,114,000	94%	2,200	0.55%
Max with serial on	1,100,000	94%	1,800	0.45%
Max with search on	1,113,000	94%	2,200	0.55%
Max with ref wfms on	1,113,000	94%	2,200	0.55%

Why is an uncompromised update rate important?

When debugging or troubleshooting a project, it is important that you see as much signal detail as possible. A fast update rate is just part of the overall equation to determine the likelihood of seeing an anomaly. The frequency of the anomaly, the timebase setting of the oscilloscope and the amount of time you allow the oscilloscope to see the anomaly all come in to play:

$$P_t = 100 \times (1-[1-RW]^{(U \times t)})$$

where

P_t = Probability of capturing anomaly in "t" seconds
t = Observation time
U = Scope's measured waveform update rate
R = Anomalous event occurance rate
W = Display acquisition window = Timebase setting x 10

Therefore, it is important to select an oscilloscope with the fastest uncompromised update rate to allow enough time to increase your chances of seeing the glitch. In Table 1, in addition to the measured update rate, we show the probability of seeing a glitch that happens 5 times a second while allowing the oscilloscope to acquire for 5 seconds. With the 3000T X-Series you maximize your chances of seeing the infrequent glitch. With the competing scope, if you are using any of the other features like measurements, or search or digital channels, the update rate slows considerably. The only option you have in this case is to allow the oscilloscope to run longer. For example, if you are using digital channels you'll have to let the scope run over 8,000 times longer to get a similar probability to the uncompromised update rate of the 3000T X-Series. That's almost 12 hours of time versus 5 seconds!

Discover: The Industry's Fastest Uncompromised Update Rate Increases the Chance of Finding Anomalies (Continued)

MegaZoom IV smart memory technology enables uncompromised update rate

Traditionally, CPU processing was the major bottleneck for oscilloscope waveform update rate and responsiveness. Typically, the CPU handles interpolations, logic channel plotting, serial bus decoding, measurements and more, and the waveform update rate drops dramatically as these features are turned on.

The InfiniiVision 3000T X-Series requires minimum support from a CPU, as most core operations are handled by Keysight proprietary technology, the MegaZoom IV smart memory ASIC. MegaZoom includes hardware serial decoders and hardware mask/limit testing capability, plots analog and digital data directly to the display, supports GUI operation, and integrates additional instruments like the WaveGen function/arbitrary waveform generator.

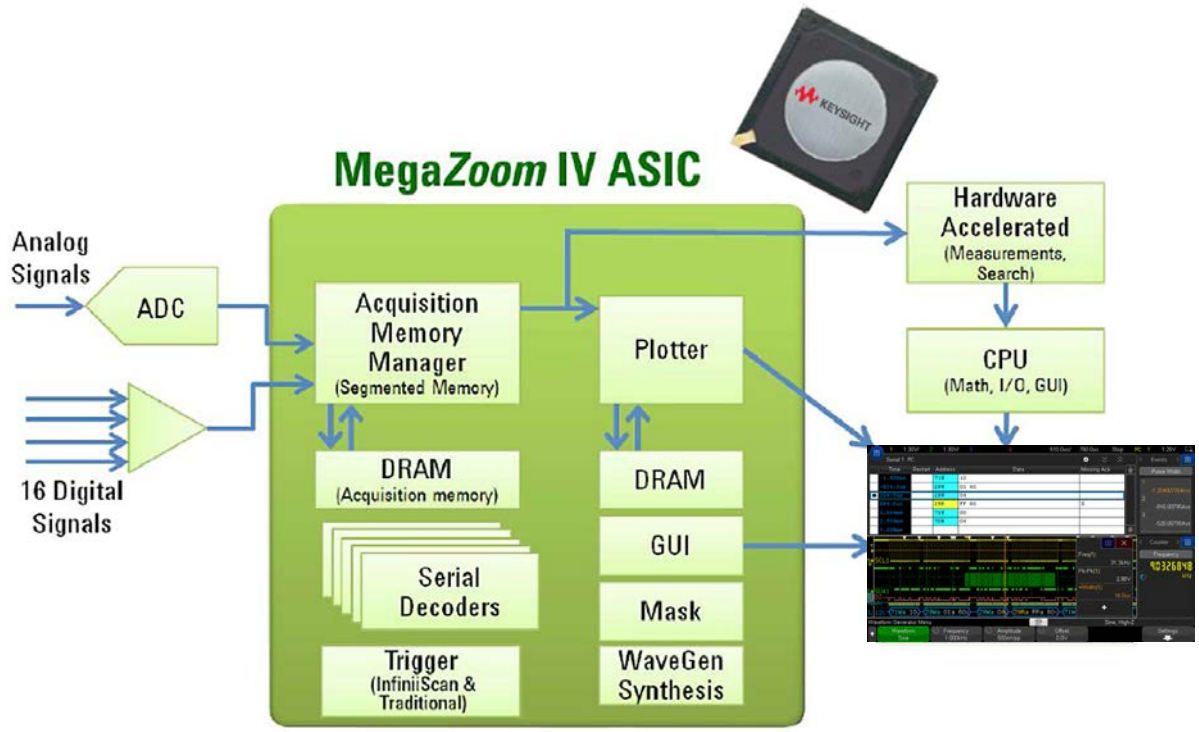


Figure 11. The 3000T X-Series oscilloscopes' uncompromised responsiveness, speed and waveform update rate are enabled by the MegaZoom IV, smart memory ASIC. The CPU is not used for core waveform operations.

Discover: Excellent Signal Integrity Allows you to See More Signal Detail

The 3000T X-Series has excellent signal integrity, including full bandwidth to 1 mV/div and the ability to get up to 12-bits of resolution using the high resolution acquisition mode.

Some oscilloscopes in this class limit their bandwidth at smaller volt-per-division settings without on-display user notifications. This is likely to keep the noise acceptable at lower volt-per-division settings.

Table 2 shows a comparison of the typical noise floor at 20 µ/div between the normal and high resolution mode. You will notice that the noise floor performance improves as much as five times.

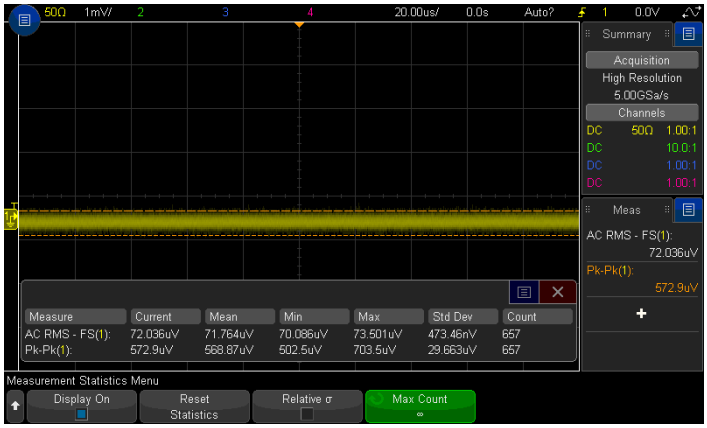


Figure 12. High resolution mode allows you to lower your noise and increase your resolution up to 12-bits.

Table 2. Noise comparison between the normal and high-resolution mode at 20 µ/div.

	50 Ω 1 GHz bandwidth Vrms measurement (units = mV)		
Vertical setting	**Normal mode**	**High resolution mode**	**Notes**
1 mV	0.277	0.072	Some other manufacturers will limit their bandwidth significantly at these vertical settings, but the Keysight 3000T X-Series provides full bandwidth at all settings.
2 mV	0.277	0.072	
5 mV	0.297	0.081	
10 mV	0.352	0.081	
20 mV	0.597	0.102	
50 mV	1.500	0.340	
100 mV	2.560	0.480	
200 mV	5.500	1.050	
500 mV	15.200	3.630	
1 V	26.000	4.830	

Discover: Industry Exclusive Zone Touch Trigger Makes Triggering Simple

An uncompromised update rate allows you to see an anomaly, but to continue the debug process you have to isolate it. Setting up a trigger has been a challenge since oscilloscopes introduced a triggered waveform. While oscilloscopes have added more and more triggering capability over the years, setting up triggers has remained complex at best and impossible at worst.

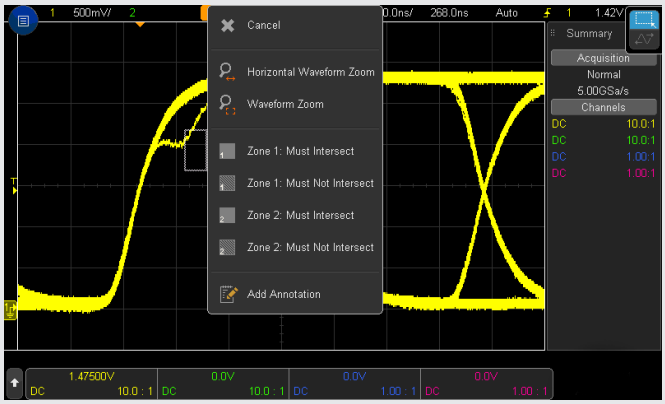
Zone touch trigger eliminates the complexity of setting up advanced triggers. Now, if you can see the event on the display of the oscilloscope, you can trigger on it just by drawing a box on the signal you want to isolate.

See how easy Zone touch triggering can be with these examples.

Steps to isolate a non-monotonic edge: 3000T X-Series:

- Draw box on non-monotonic edge
- Select “must intersect”

In some cases you may have to select the appropriate source if it wasn’t already selected.



Traditional Scopes with Advanced Triggers (assuming the update rate is fast enough to see what you want to trigger on):

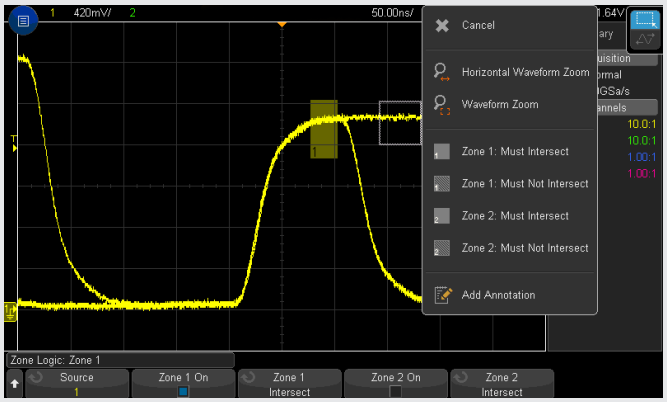
1. Determine what trigger makes the most sense for the signal you are trying to isolate. In this case, we’ll try a rise-time trigger first.
2. Select cursors
3. Move cursor a to 10% level
4. Move cursor b to 90% level on the non-monotonic edge
5. Obtain the delta time (rise time) between the cursors
6. Select trigger menu
7. Press trigger type
8. Select Rise/Fall time Trigger
9. Select your source
10. Select your slope
11. Select when you want it to trigger – is it less than, greater than, equal to, not equal to. We’ll select greater than.
12. Dial in the “greater than” setting to the measured rise time
13. Adjust your low threshold to the 10% level
14. Adjust your high threshold to the 90% level

Discover: Industry Exclusive Zone Touch Trigger Makes Triggering Simple (Continued)

Steps to trigger on a runt signal: 3000T X-Series:

1. Draw box on the runt
2. Select “must intersect”
3. Draw a second box if needed to further isolate the runt from other runts
4. Select “must intersect” or “must not intersect”

In some cases you may have to select the appropriate source if it wasn’t already selected.



Traditional Scopes with Advanced Triggers (assuming the update rate is fast enough to see what you want to trigger on):

1. Determine what trigger makes the most sense for the signal you are trying to isolate. In this case, we’ll use a runt trigger first.
2. Select trigger menu
3. Press trigger type
4. Select runt Trigger
5. Select your source
6. Select the runt’s polarity
7. Adjust your low threshold to below the runt
8. Adjust your high threshold to above the runt
9. Select when you’ll trigger – in this case, we want to trigger on the exact pulse width of the runt
10. Select cursors
11. Move cursor a to the rising edge of the pulse at the 50% mark
12. Move cursor b to the falling edge of the pulse at the 50% mark
13. Obtain the delta time (pulse width) between the cursors
14. Adjust the runt width to be equal to the pulse width that was measured

Discover: Standard Segmented Smart Memory Allows you to Capture Longer Periods of Time at High Sample Rates

Acquisition memory size is an essential oscilloscope specification because it determines sustainable sample rate and the amount of time you can capture in a single acquisition. In general, longer memory is better. However, no memory will always be long enough to capture all the signals you need, especially when capturing infrequent anomalies, data bursts, or multiple serial bus packets. Segmented memory acquisition lets you selectively capture and store important signal activity without capturing unimportant signal idle time. In addition, it provides a time stamp of each segment relative to the first trigger event to enable analysis of the frequency of the event. Segmented memory comes standard on the 3000T X-Series.

Figure 13 shows segmented memory successfully capturing 100 small and large glitch events at 5 GSa/s in 47 seconds. Traditional memory architecture would require almost 203 Gpts of memory to accomplish the same result! This memory is not available on any scope in the market.

Furthermore, segmented memory discovered that the worst offender glitch happened 40 seconds from the first trigger event, or at the 95th glitch. It also found out a unique glitch took place 13 seconds after the first glitch. As shown in figure 13a, you can overlay all segments to have a comprehensive view as well.

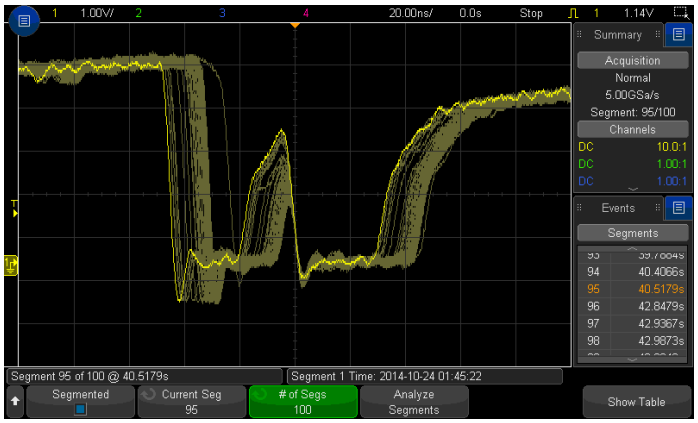


Figure 13a. Screen showing an overlay of all 100 segments for worst case waveform analysis.

Figure 13. Segmented memory reveals different types of glitches are taking place.

Discover: Dedicated Search and Navigation Helps you Navigate Deep Memory

Parametric and serial bus search and navigation comes standard on the 3000T X-Series oscilloscopes. When you are capturing long, complex waveforms using an oscilloscope's acquisition memory, manually scrolling through stored waveform data to find specific events of interest can be slow and cumbersome. With automatic search and navigation capability, you can easily set up specific search criteria and then quickly navigate to "found and marked" events. Available search criteria include edges, pulse width (time-qualified), rise/fall times (time-qualified), runt pulses (time-and level-qualified), frequency peaks (FFT function, threshold and excursion qualified), and serial bus frames, packets, and errors.

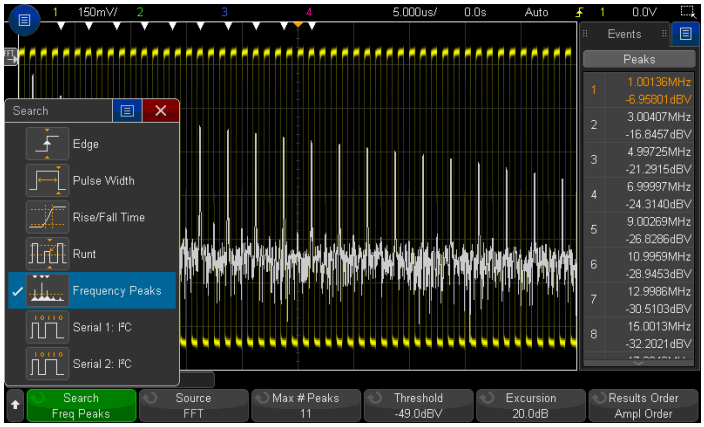


Figure 14. The 3000T X-Series was set up to capture clock signals for FFT analysis. Using the search and navigation capability, the scope was able to find, mark (white triangles) and quickly navigate to the first 11 frequency peaks occurrences. You can sort it in the order of frequency or amplitude.

Close-up on buttons on the front panel of the scope. Alternatively, you also can use the touch navigation control.

Solve: Integrated Hardware-Based Serial Decoding and Triggering (Option) Makes Easy Work of Low Speed Serial Buses

Keysight InfiniiVision oscilloscopes, including the new 3000T X-Series, use hardware-based serial protocol decoding. Some other vendors use software post-processing techniques to decode serial packets/frames, and therefore have slow waveform and decode capture rates and could miss critical events and errors due to a long dead-time. Faster decoding with hardware-based technology enhances the probability of capturing infrequent serial communication errors.

After capturing serial bus communication, you can easily perform a search operation based on specific criteria and then quickly navigate to bytes/frames of serial data that satisfy that search criteria. The 3000T X-Series can decode two serial buses simultaneously using hardware based decoding, and display the captured data in a time interleaved "lister" display.

Serial protocol decoding can be used simultaneously with segmented memory and Zone touch triggering. The 3000T X-Series has the most decode/trigger options in this class of instrument including: I^2C, SPI, RS232/422/485/UART, CAN, CAN-FD (CAN-FD ISO), CAN-dbc, LIN, LIN symbolic, SENT, CXPI, FlexRay, MIL-STD 1553, ARINC 429, and I^2S.

SERIAL DECODE AND TRIGGER OPTIONS

The 3000T X-Series supports a range of different serial decode and trigger options including:

- I^2C
- SPI (2/3/4 wire)
- RS232/422/485/UART
- CAN
- CAN-dbc
- CAN-FD (CAN-FD ISO)
- LIN
- LIN symbolic
- SENT
- CXPI
- FlexRay
- MIL-STD 1553
- ARINC 429
- USB PD
- I^2S
- User-definable Manchester
- User-definable NRZ

Figure 15. I^2C decode and trigger.

Figure 16. RS232 decode and trigger.

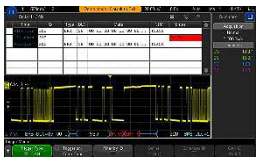


Figure 17. CAN-FD decode and trigger.

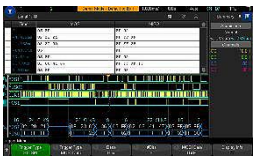


Figure 18. SPI 4wire decode and trigger.

Figure 19. Multi-bus time aligned decode.

Solve: Segmented Smart Memory Combined With Protocol Analysis Enables Insights Over Long Periods Of Time

Segmented memory works in conjunction with any of the optional serial protocol decodes. For example, by setting the trigger condition to “SENT serial bus error,” segmented memory captures and stores only SENT pulse period error packets and stitches together each segment for easy viewing of the decoded data in the lister. You can quickly compare time tags to discover time intervals between errors.

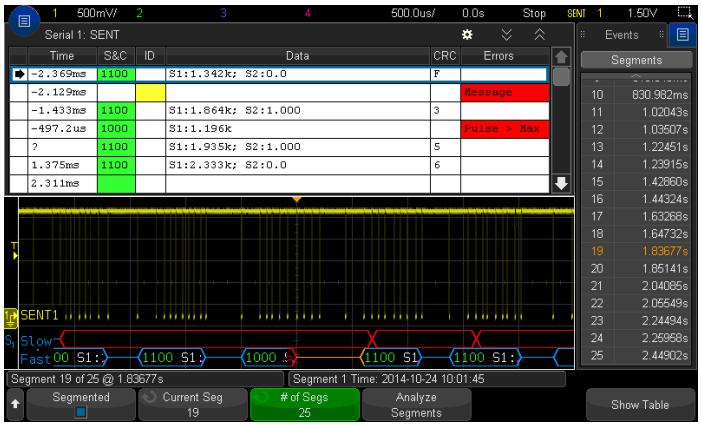


Figure 20. Segmented memory being used in conjunction with SENT bus serial decode resulting in maximum insight to the serial bus.

Solve: Dedicated Frequency/Spectrum Analysis Allows you to Time-Correlate Analog, Digital, and frequency Domain Signals in a Single Instrument

Viewing the frequency content of waveforms is greatly simplified by a dedicated FFT button and level adjustment knobs. Pop up keypads make inputting start, stop, span and center frequency easy. And the new problem solving feature called “gated FFT”, unique in this class of instrument, lets you time correlate the analog, digital, and frequency domain to aid in analysis and debug. In addition, there are new capabilities for peak searching, max and min hold and averaging of FFTs to increase dynamic range.

When gated FFT is on, the oscilloscope goes into zoom mode. The FFT analysis shown in the zoomed (bottom) window is taken from the period of time indicated by the zoom box in the main (top) window. In the gated FFT mode, touch and flick the zoom box through the acquisition to investigate how the FFT analysis changes over time, correlating the RF phenomenon with the analog and digital phenomenon.

Figure 21a through 21d show a simple gated FFT example observing a RF signal frequency transition from 400 MHz to 200 MHz, time correlated to both the SPI controlling signal (digital) and a VCO enable signal (analog). Note, you can also visualize the RF signal itself in the time domain to gain additional insight such as a gap in the RF time domain waveform.

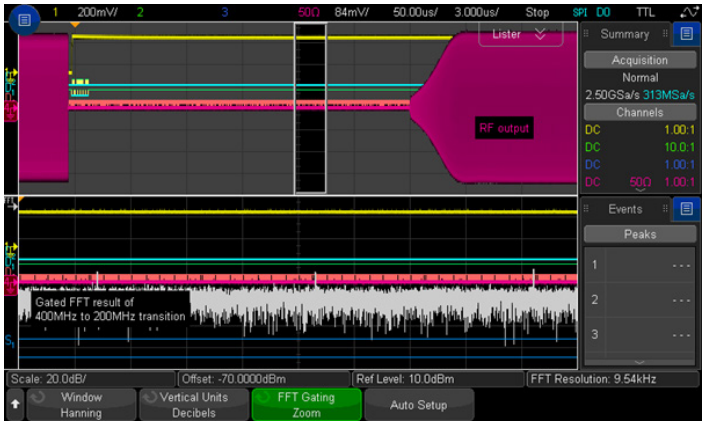


Figure 21b. No RF activities in this zoomed time.

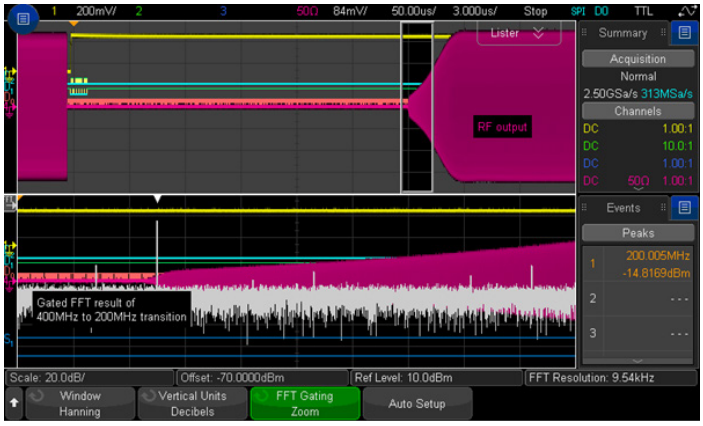


Figure 21c. Start observing the RF signal at 200 MHz. You can validate this from the RF analog waveform as well.

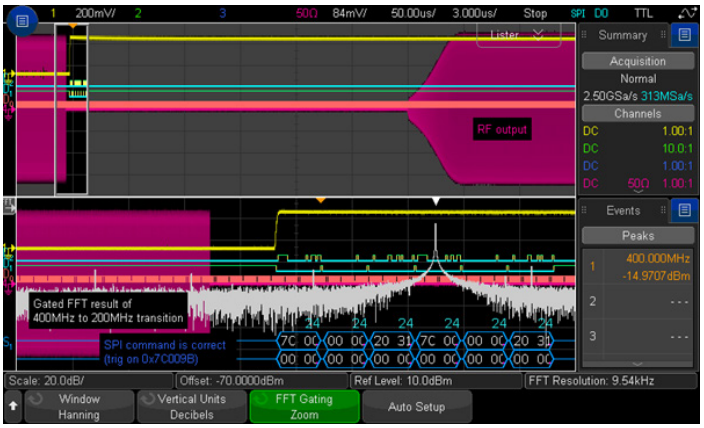


Figure 21a. Triggered on a SPI command, the RF signal is still at 400 MHz as indicated in the frequency peak search result lister.

Figure 21d. RF signal settled down at 200 MH as indicated in the search lister.

Solve: Standard Advanced Math Capabilities Allow New Views of Signals

Advanced math analysis provides a variety of additional math functions and comes standard on the 3000T X-Series. Additionally, math functions can be nested to provide additional insight into your designs. You can create up to two math functions, with one math function and FFT displayed at a time.

ADVANCED MATH

The 3000T X-Series supports up to two math functions with an assortment of operators, transforms, filters and visualizations:

Operators
- Add, subtract, multiply, divide

Transforms
- Differentiate, integrate
- FFT (magnitude and phase)
- Ax + B
- Squared, square root
- Absolute value
- Common logarithm, natural logarithm
- Exponential, base 10 exponential

Filters
- Low-pass filter, high-pass filter
- Averaged value
- Smoothing
- Envelope

Visualizations
- Magnify
- Max and min hold
- Measurement trend
- Chart logic bus timing, chart logic bus state
- Maximum and minimum
- Peak-Peak

Solve: Class Leading Measurements Provide Quick Answers

Automatic measurements are the essential tool of an oscilloscope. In order to make quick and efficient measurements, the 3000T X-Series provides 37 powerful automatic measurements and can display up to 8 at a time. Measurements can be gated by auto select, main window, zoom window, or cursors and include full statistics.

MEASUREMENTS

The 3000T X-Series supports 38 automated measurements:

Voltage
- Peak-to-peak, maximum, minimum, amplitude, top, base, overshoot, pre-shoot, average- N cycles, average- full screen, DC RMS- N cycles, DC RMS- full screen, AC RMS- N cycles, AC RMS- full screen (standard deviation), ratio- N cycles, ratio- full screen

Time
- Period, frequency, counter, + width, - width, burst width, duty cycle, bit rate, rise time, fall time, delay, phase, X at min Y, X at max Y

Count
- Positive pulse count, negative pulse count, rising edge count, falling edge count

Mixed
- Area- N cycles, area- full screen

Counter
- Built-in frequency counter

Solve: 7-in-1 Integration Allows New Measurement Possibilities

In addition to the class leading oscilloscope and powerful serial protocol analysis capabilities, the 3000T X-Series offers five additional integrated instrument capabilities not always found in this class of oscilloscope.

Integrated mixed signal oscilloscope (MSO - optional)

The 3000T X-Series offers 16 optional, integrated and upgradable digital channels. Digital content is everywhere in today's designs and traditional 2 and 4 channel oscilloscopes do not always provide enough channels for the job at hand.

With an additional 16 integrated digital channels, you now have up to 20 channels of time-correlated acquisition and viewing on the same instrument. In addition to offering powerful triggering across the analog and digital channels, this also gives you additional channels to use for serial decode and triggering. And if you buy a 2 or 4 channel DSO, you can upgrade it at any time to an MSO with a software license.

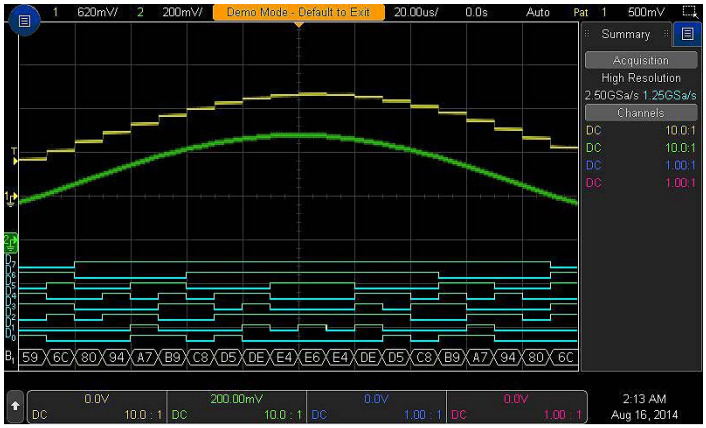


Figure 24. Optional digital channels allow a timing view of up to 16 channels. Tightly integrated, they work with the analog triggers and serial triggers/decoding.

Frequency Response Analysis (FRA) Option

Frequency Response Analysis (FRA) is an often-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). InfiniiVision 3000T X-Series oscilloscopes licensed with the DSOXT3FRA option use the oscilloscope's built-in waveform generator (WaveGen) to stimulate the circuit under test at various frequency settings and capture the input and output signals using two oscilloscope channels. At each test frequency, the oscilloscope measures, computes, and plots gain (20LogVout/Vin) and phase logarithmically.

Integrated WaveGen: Built-in 20 MHz function/ arbitrary waveform generator (optional)

The 3000T X-Series offers an integrated 20 MHz function/ arbitrary waveform generator, available with modulation support (DSOX3WAVEGEN). The function generator provides stimulus output of sine, square, ramp, pulse, DC, Sinc (x), exponential rise/fall, cardiac, Gaussian Pulse and noise waveforms to your device under test. The modulation feature supports AM, FM, and FSK modulations with modulation shapes of sine, square, and ramp. The generator can output a continuous or a single-shot waveform. With AWG functionality, you can store waveforms from analog channels or reference memory to the arbitrary memory and output from WaveGen. Then easily create or edit the waveform using the built-in editor via touch and the large screen or by using Keysight's Benchlink Waveform Builder software: **www.keysight.com/find/33503**.

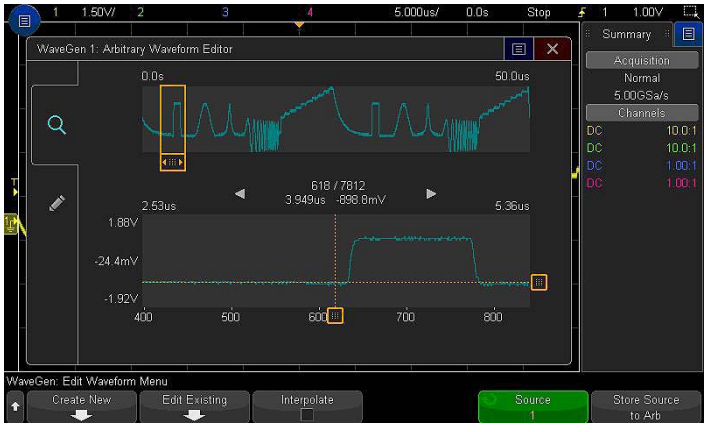


Figure 25. Optional arbitrary waveform generator provides easy access to stimulus. The integrated arbitrary waveform generator makes capturing, modifying and replaying signals simple.

Solve: 7-in-1 Integration Allows New Measurement Possibilities (Continued)

Integrated DVM: Standard 3-digit digital voltmeter

An integrated 3-digit voltmeter is included standard on your 3000T X-Series oscilloscope. The voltmeter operates through the same probes as the oscilloscope channels. However, the DVM measurements are made independently from the oscilloscope acquisition and triggering system so you can make both the DVM and triggered oscilloscope waveform captures with the same connection. The voltmeter results are always displayed, keeping these quick characterization measurements at your fingertips.

Figure 26. DVM and counter takes advantage of separate signal paths to provide measurements without a trigger, while still using the scope probes.

Integrated frequency measurements: Standard 8-digit counter and totalizer

Traditional oscilloscope counter measurements offer only five or six digits of resolution, which may not be enough for the most critical frequency measurements are being made.

With the 3000T X-Series' standard 8-digit counter, you can see your measurements with the precision you would normally expect only from a standalone counter. Because the integrated counter measures frequencies up to a wide bandwidth of 1.0 GHz, you can use it for many high-frequency applications as well.

The counter's totalizer feature adds another valuable capability to the oscilloscope. It can count the number of events (totalize), and it also can monitor the number of trigger-condition-qualified events. The trigger-qualified events totalizer does not require an actual trigger to occur. It only requires a trigger-satisfying event to take place. In other words, the totalizer can monitor events faster than the trigger rate of a scope, as fast as 25 million events per second (a function of the oscilloscope's holdoff time, which has the minimum of 40 ns). Figures 27 shows example of a totalizer counting the number of CAN-FD CRC delimiter bit error packets that took place in a design.

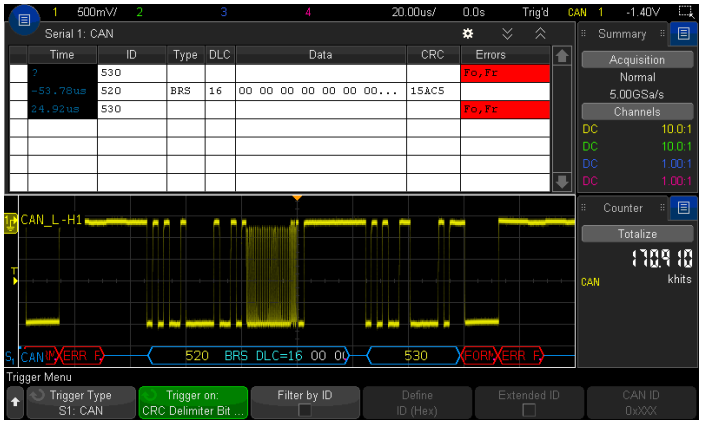


Figure 27. Totalizer counts the number of events. In addition, it can count the number of trigger-condition-qualified events as fast as 25 million events a second.

Solve: Hardware Accelerated Mask/Limit Testing (Option) Makes It Easy to See the Performance of your Device

Whether you are performing pass/fail tests to specified standards in manufacturing or testing for infrequent signal anomalies, mask/limit testing can be a valuable productivity tool (DSOX3MASK). The 3000T X-Series features powerful hardware-based mask testing that can perform up to 270,000 tests per second. You can select multiple test criteria, including the ability to run tests for a specific number of acquisitions, a specified time, or until detection of a failure.

See **www.keysight.com/find/DSOX3MASK** for more information.

Figure 28. Hardware accelerated mask testing allows testing against a golden waveform or user created mask to find violations. In this example we captured over 5M tests in only 30 seconds.

Solve: Integrated Power Measurements and Analysis (Option) Make Short Work of Power Measurements

When you are working with switching power supplies and power devices, the power measurements application (DSOX3PWR) provides a full suite of power measurements and analysis in the oscilloscope.

Included with the DSOX3PWR is a license for the U1881A PC-based power analysis software package, which provides additional offline measurements and report generation.

See **www.keysight.com/find/DSOX3PWR** for more information.

In addition there are several power specific probes that make analysis of your power supplies (e.g. switch mode power supplies) and power consuming devices (e.g. batteries) easy.

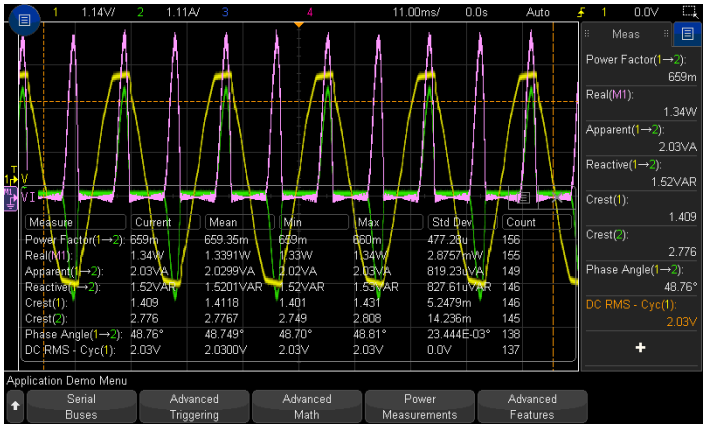


Figure 29a. Integrated power measurements make quick work of analyzing power producing and power consuming devices.

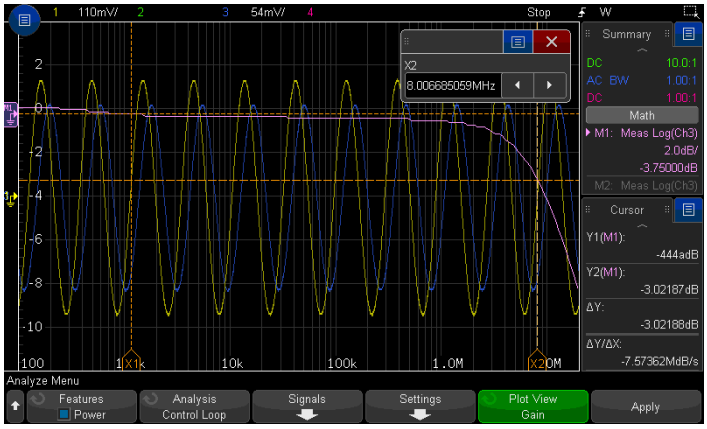


Figure 29b. New control loop response analysis (bode plot) shows the gain/phase plot over frequency sweep.

Solve: Innovative Power Rail Probe (Option) Allows Enhanced Views

The power rail noise, ripple, and transients measurements can be challenging due to required offset range and mV sensitivity. With its ± 24 V offset range, ultra-low noise 1:1 attenuation ratio, and 2-GHz bandwidth, the N7020A power rail probe is for users making critical power integrity measurements that need mV sensitivity on their DC power rails.

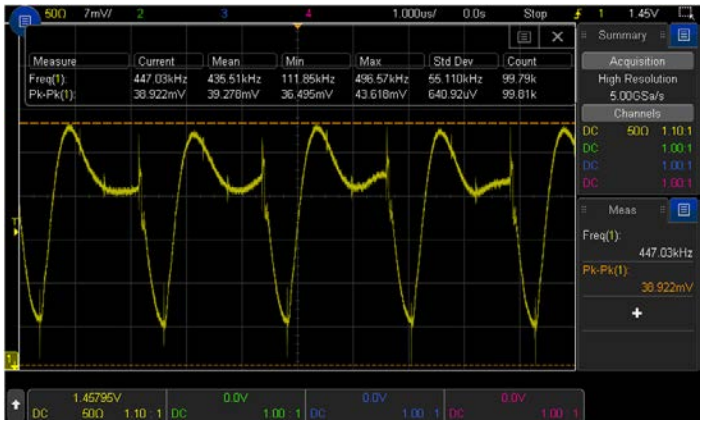


Figure 30a. 3000T X-Series and N7020A acquire not only the power rail ripples but the high frequency transients as well.

Figure 30b. N7020A Power Rail Probe.

Solve: Video Analysis (Option)

Whether you are debugging consumer electronics with HDTV or characterizing a design, the HDTV measurement application (DSOX3VID) provides support for a variety of HDTV standards for triggering and analysis.

See **www.keysight.com/find/DSOX3VID** for more information.

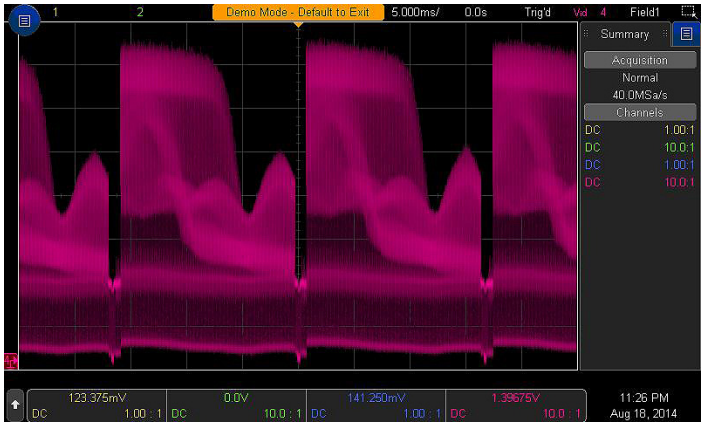


Figure 31.

While the “Touch, Discover, Solve” elements of the scope highlight the key features that will make it easy to debug and troubleshoot your device, there are other features that you may also want to consider when choosing your next oscilloscope.

Total cost of ownership

The 3000T X-Series offers an extremely low cost of ownership. Between an industry leading mean time between failure (MTBF) of over 250,000 hours and a market-leading calibration period of 3 years, you can rest assured that your investment in a 3000T X-Series will be protected for years to come. In addition, because needs change over time, you can purchase just what you need today and then upgrade the scope’s bandwidth or measurement application easily over time as your projects evolve.

Educator and training kit

Have new hires that need to quickly become familiar with the scope? Or are you a professor that wants to teach your students what an oscilloscope is and how to perform basic measurements? The Educator’s Oscilloscope Training Kit makes that easy. It includes training tools created specifically for electrical engineering and physics undergraduate students and professors. It contains an array of built-in training signals, a comprehensive oscilloscope lab guide and tutorial written specifically for the undergraduate student and an oscilloscope fundamentals PowerPoint slide set for professors and lab assistants. The built-in training signals are included standard on the oscilloscope, while the lab guide and slide set are available to download at **www.keysight.com/find/dsoxedk**.

Built-in features to help the infrequent user

In addition to the educator’s training kit, the oscilloscope includes a localized front panel and GUI available in 15 languages, along with an integrated (and localized) help system. Just hold any hard key or soft panel button and a brief overview will appear that explains how to use that feature.

30-day trial license

The 3000T X-Series comes with a one-time 30-day, all optional-features trial license. You can choose to start the 30-day trial at any time. In addition you can redeem individual optional feature 30-day trial licenses at any time by visiting **www.keysight.com/find/30daytrial**. This enables you to receive in effect 60 days of trial license of each optional feature.

Next generation probing

All 3000T X-Series come standard with a newly designed, very robust 500 MHz 10:1 passive probe per channel. In addition, MSOs include a newly designed cable with a flexible cable management system that makes probing with the 16-digital channels easy.

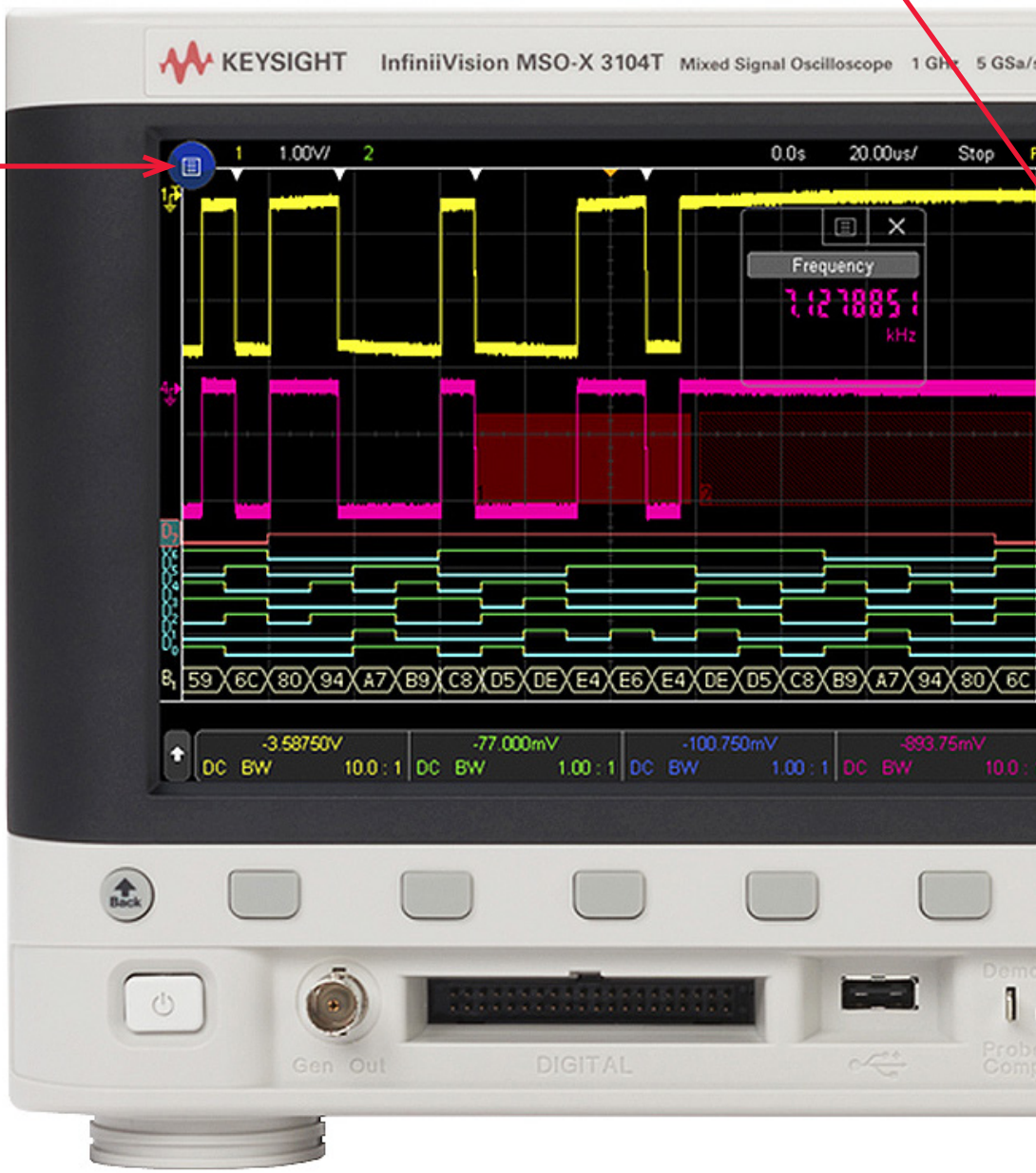
LOCALIZED GUI AND FRONT PANEL OPTIONS

The 3000T X-Series supports 15 different languages:

- English
- Japanese
- Simplified Chinese
- Traditional Chinese
- Thai
- Korean
- German
- French
- Spanish
- Russian
- Portuguese
- Italian
- Polish
- Czech
- Turkish

7-in-1 instruments helps you solve your problems: oscilloscope channels digital channels, frequency response analysis, serial protocol analysis, WaveGen, DVM, and 8-digit counter-totalizer. ***Fully upgradeable*** including bandwidth.

"Designed for Touch". ***8.5 inch capacitive touch screen with gesture support.***



Uncompromised 1,000,000 waveform per second update rate minimize the dead-time for maximum probability of capturing infrequent events and anomalies.

Built-in features to help the infrequent user - ***GUI available in 15 languages.***

Display up to ***8 measurements*** simultaneously, without compromising other key info. 38 automatic measurements. ***Gated by cursors*** supported.

Integrated DVM and ***8-digit counter with totalizer.*** Wide coverage of application and serial protocol solutions including ***CAN-FD and SENT trigger and decode.***

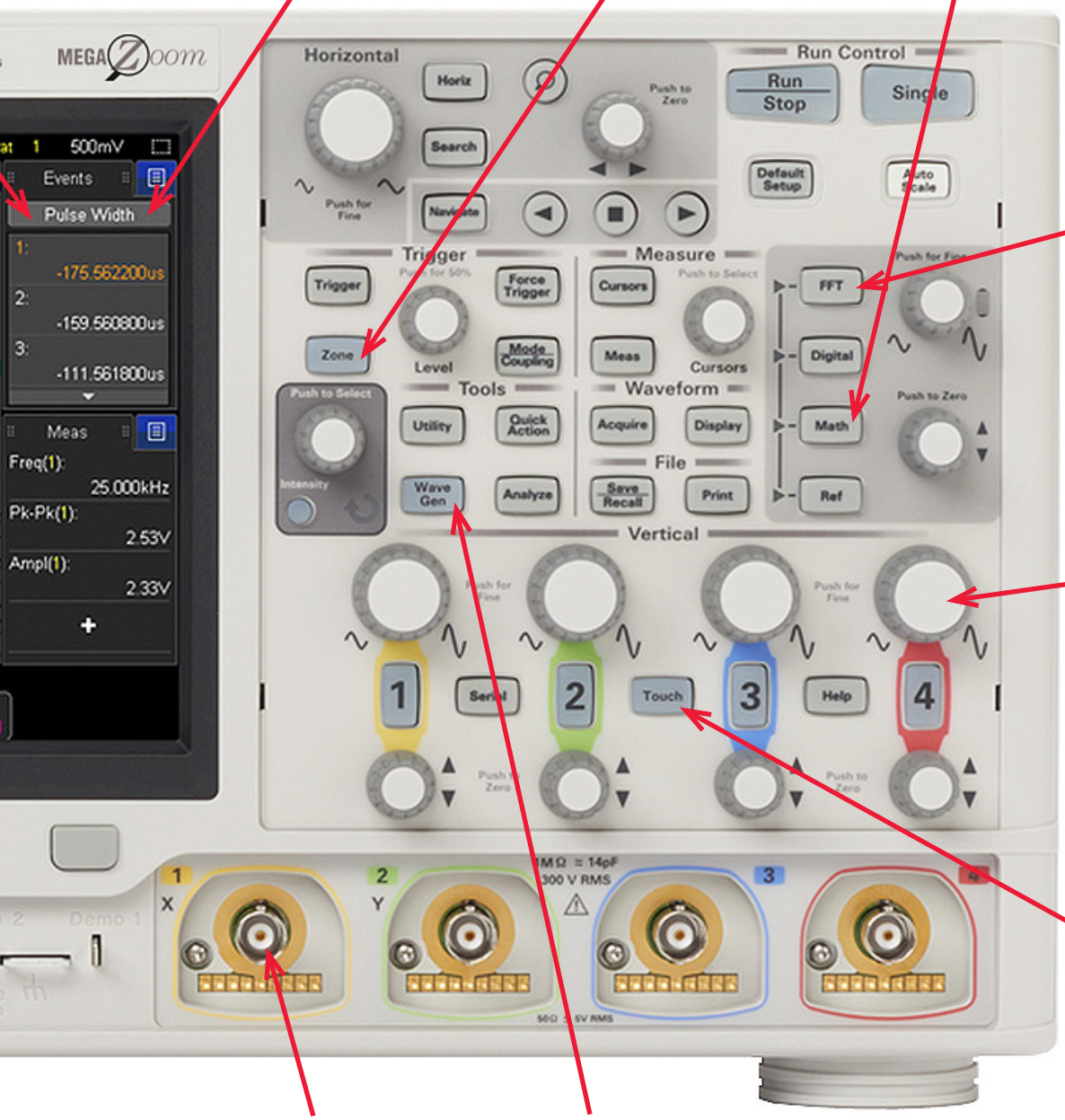
Both ***USB keyboard and mouse*** are supported in 3000T X-Series for additional ease of use.

Standard segment memory with event lister powered by ***MegaZoom IV*** smart memory technology intelligent capture of just the signals of interest.

Reconfigurable Docking panels with the capacitive touch screen adds a new dimension to the usability.

Zone touch trigger, if you can see it, you can trigger on it by drawing a box.

Standard advanced math displays ***FFT and one math functions*** for your deep analysis.



Standard ***Gated FFT*** for your time correlated analog, digital, and frequency domain signal analysis.

Independent knobs per channel for fast operation. All front panel knobs are ***push-able*** for access to common controls.

Not a touch screen fan? ***Turn off the touch screen*** from a front panel button.

AutoProbe interface supports various active, differential, and current probes.

Build in WaveGen function/arbitrary generator allows you to capture and regenerate the signals immediately.

Configuration

Step 1.

Choose your bandwidth and number of channels.

3000 X-Series specification overview											
		3012T	3014T	3022T	3024T	3032T	3034T	3052T	3054T	3102T	3104T
Bandwidth (–3 dB)		100 MHz		200 MHz		350 MHz		500 MHz		1 GHz	
Calculated rise time (10 to 90%)		≤ 3.5 ns		≤ 1.75 ns		≤ 1 ns		≤ 700 ps		≤ 450 ps	
Input channels	DSOX	2	4	2	4	2	4	2	4	2	4
	MSOX	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16

For example, if you chose 1 GHz, 4+16 channels, the model number will be MSOX3104T.

Step 2.

Tailor your oscilloscope with integrated capabilities and measurement applications to save time and money. After purchase upgrade model numbers are listed below (values in parentheses are factory-installed option numbers).

Description	Model number
Oscilloscope features	
MSO upgrade	DSOXT3MSO [1]
Serial protocols	
Embedded serial triggering and analysis (I²C, SPI)	DSOX3EMBD
Computer serial triggering and analysis (RS232/UART)	DSOX3COMP
Sensor triggering and analysis (SENT)	DSOXT3SENSOR [1]
Automotive serial triggering and analysis (CAN/CAN-FD (CAN-FD ISO)/CAN-dbc/LIN/LIN symbolic)	DSOXT3AUTO [1]
CXPI serial triggering and analysis	DSOXT3CXPI
FlexRay serial triggering and analysis	DSOX3FLEX
Audio serial triggering and analysis (I²S)	DSOX3AUDIO
MIL-STD 1553 and ARINC 429 serial triggering and analysis	DSOX3AERO
USB-PD serial triggering and analysis	DSOXT3UPD
User-definable Manchester/NRZ	DSOXT3NRZ
Measurement applications	
WaveGen 20 MHz arbitary/function generator	DSOX3WAVEGEN
Power analysis application	DSOX3PWR
Frequency Response Analysis (FRA)	DSOXT3FRA
Near field communication testing	DSOXT3NFC
Mask limit testing	DSOX3MASK
Enhanced video/TV application package	DSOX3VID
Productivity tools	
Infiniium Offline oscilloscope analysis software	N8900A
User-defined Application (UDA) software	N5467B/C
BenchVue oscilloscope application	BV0004B
Vector signal analyzer software	89601B (version 20.20 and higher)
Benchlink waveform builder pro and basic	33503A
Application bundle	
	DSOXT3APPBNDL [1] (include DSOX3AERO, DSOX3AUDIO, DSOXT3AUTO, DSOX3COMP, DSOX3EMBD, DSOX3FLEX, DSOX3MASK, DSOX3PWR, DSOXT3SENSOR, DSOX3VID, DSOX3WAVEGEN, DSOXT3NFC, DSOXT3CXPI, DSOXT3NRZ, DSOXT3FRA)

1. These options are compatible with the 3000T X-Series, but are not compatible with the 3000A X-Series.

Configuration (Continued)

Step 3.

Choose your probes.

For a complete list of compatible probes, visit **www.keysight.com/find/scope_probes**. In general, the 3000T X-Series supports up to two active probes simultaneously with some exceptions. Contact Keysight for more detail.

Probes		
N2843A	Passive probe 500 MHz, 10:1, 1 MΩ, 11 pF	Standard (1 per channel)
N2756A	16 digital channel MSO cable	Standard on MSOX models & DSOXT3MSO
N2870A	Passive probe 35 MHz, 1:1, 1 MΩ	Optional
10076C	Passive probe 500 MHz 100:1 attenuation (4 kV)	Optional
N2804A	300 MHz 100:1 differential probe, 4 MΩ, 4 pF, ± 300 V DC+peak AC	Optional
N2805A	200 MHz 100:1 differential probe, 4 MΩ, 4 pF, ± 100 V, 5 m cable	Optional
N2790A	100 MHz 50:1/500:1 high voltage differential probe, 8 MΩ, 3.5 pF, ± 1,400 V	Optional
N2795A	Active single-ended probe 1 GHz 1 pF 1 MΩ with AutoProbe	Optional
N2797A	Active single-ended probe 1.5 GHz extreme temperature	Optional
N2750A	InfiniiMode differential probe 1.5 GHz 700 fF 200 kΩ with AutoProbe	Optional
N2790A	Differential active probe 100 MHz, ± 1.4 kV with auto probe	Optional
N2791A	Differential active probe 25 MHz, ± 700 V	Optional
N2818A	200 MHz 10:1 differential probe with AutoProbe	Optional
N2819A	800 MHz 10:1 differential probe with AutoProbe	Optional
1147B	AC/DC current probe 50 MHz 15 A with auto probe	Optional
N2893A	AC/DC current probe 100 MHz 15 A with auto probe	Optional
N2820A	2-channel high-sensitivity current probe 50 µA to 5 A	Optional
N2821A	1-channel high-sensitivity current probe 50 µA to 5 A	Optional
N7020A	Power rail probe 2 GHz, 1:1, ± 24 V offset range at 50 Ω	Optional
N7040A	23 MHz, 3 kA, AC current probe	Optional
N7041A	30 MHz, 600 A, AC current probe	Optional
N7042A	30 MHz, 300 A, AC current probe	Optional
N7026A	AC/DC high-sensitivity current probe 150 MHz, 40 Apk with AutoProbe interface	Optional

Step 4.

Choose your accessories.

Recommended accessories		
DSOXLAN	LAN/VGA connection module	Optional
DSOXGPIB	GPIB connection module	Optional
N2747A	Front panel cover	Optional
N6456A	Rack mount kit	Optional
N6457A	Soft carrying case with front panel cover	Optional
Hard transit case	CaseCruzer 3F1112-1510J (available from **http://www.casecruzer.com/**)	Optional

Step 5.

Calibration plans.

Calibration and warranties		
D/MSOX3000T-A6J	ANSI Z540-1-1994 calibration	Optional
D/MSOX3000T-AMG	ISO17025 compliant calibration with accreditation	Optional

Performance Characteristics

DSO and MSO 3000 X-Series oscilloscopes

3000T X-Series specification overview											
		3012T	**3014T**	**3022T**	**3024T**	**3032T**	**3034T**	**3052T**	**3054T**	**3102T**	**3104T**
Bandwidth [1] (–3 dB)		100 MHz		200 MHz		350 MHz		500 MHz		1 GHz	
Calculated rise time (10 to 90%)		≤ 3.5 ns		≤ 1.75 ns		≤ 1 ns		≤ 700 ps		≤ 450 ps	
Input channels	DSOX	2	4	2	4	2	4	2	4	2	4
	MSOX	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16	2 + 16	4 + 16
Maximum sample rate		5 GSa/s half channels, 2.5 GSa/s all channels									
Maximum memory depth		Standard 4 Mpts, Standard segmented memory									
Display size and type		8.5-inch capacitive touch gesture-enabled display									
Waveform update rate		> 1,000,000 waveforms per second									
Vertical system analog channels											
Hardware bandwidth limits		Approximately 20 MHz (selectable)									
Input coupling		AC, DC									
Input impedance		Selectable: 1 MΩ ± 1% (14 pF), 50 Ω ± 1.5%									
Input sensitivity range		100 MHz ~ 500 MHz models: 1 mV/div to 5 V/div [2] (1 MΩ and 50 Ω)									
		1 GHz models: 1 mV/div to 5 V/div [2] (1 MΩ), 1 mV/div to 1 V/div (50 Ω)									
Vertical resolution		8 bits (measurement resolution is 12 bits with averaging)									
Maximum input voltage		135 Vrms; 190 Vpk									
		Probing technology allows testing of higher voltages. For example, the included N2843A 10:1 probe supports testing up to 300Vrms									
		Use this instrument only for measurements within its specified measurement category (not rated for CAT II, III, IV). No transient overvoltage allowed									
DC vertical accuracy		± [DC vertical gain accuracy + DC vertical offset accuracy + 0.25% full scale] [2]									
DC vertical gain accuracy [1]		± 2.0% full scale [2]									
DC vertical offset accuracy		± 0.1 div ± 2 mV ± 1% of offset setting									
Channel-to-channel isolation		> 100:1 from DC to maximum specified bandwidth of each model (measured with same V/div and coupling on channels)									
Offset range		± 2 V (1 mV/div to 200 mV/div)									
		± 50 V (> 200 mV/div to 5 V/div)									
Vertical system digital channels											
Digital input channels		16 digital (D0 to D15. pod 1: D7 ~ D0, Pod 2: D15 ~ D8)									
Thresholds		Threshold per pod									
Threshold selections		TTL (+1.4 V), 5 V CMOS (+2.5 V), ECL (–1.3 V), user-defined (selectable by pod)									
User-defined threshold range		± 8.0 V in 10 mV steps									
Maximum input voltage		± 40 V peak CAT I									
Threshold accuracy [1]		± (100 mV + 3% of threshold setting)									
Maximum input dynamic range		± 10 V about threshold									
Minimum voltage swing		500 mVpp									
Input impedance		100 kΩ ± 2% at probe tip									
Input capacitance		~8 pF									
Vertical resolution		1 bit									

1. Denotes warranted specifications, all others are typical.
2. Specifications are valid after a 30-minute warm-up period and ± 10 °C from firmware calibration temperature. 1 mV/div and 2 mV/div are a magnification of 4 mV/div setting. For vertical accuracy calculations, use full scale of 32 mV for 1 mV div and 2 mV/div sensitivity setting.

Performance Characteristics (Continued)

Horizontal system analog channels											
		3012T	**3014T**	**3022T**	**3024T**	**3032T**	**3034T**	**3052T**	**3054T**	**3102T**	**3104A**
Time base range		5 ns/div to 50 s/div		2 ns/div to 50 s/div				1 ns/div to 50 s/div		500 ps/div to 50 s/div	
Time base accuracy [1]		± 1.6 ppm + aging factor (1st year: ± 0.5 ppm, 2nd year: ± 0.7 ppm, 5 years: ± 1.5 ppm, 10 years: ± 2.0 ppm)									
Time base delay time range	Pre-trigger	Greater of 1 screen width or 250 µs									
	Post-trigger	1 s to 500 s									
Channel-to-channel deskew range		± 100 ns									
Δ Time accuracy (using cursors)		± (time base acc. x reading) ± (0.0016 x screen width) ± 100 ps									
Modes		Main, zoom, roll, XY									
XY		On channels 1 and 2 only. Z Blanking on Ext Trigger Input, 1.4 V threshold									
		Bandwidth: Maximum bandwidth. Phase error at 1 MHz: < 0.5 degree									
Horizontal system digital channels											
Minimum detectable pulse width		5 ns									
Channel-to-channel skew		2 ns (typical); 3 ns (maximum)									
Acquisition system											
Maximum analog channels sample rate		5 GSa/s half channel interleaved, 2.5 GSa/s all channel									
Maximum analog channels record length		4 Mpts half channel interleaved, 2 Mpts all channel									
Maximum digital channels sample rate		1.25 GSa/s all pods									
Maximum digital channels record length		2 Mpts (with digital channels only)									
Acquisition mode	Normal	Default mode									
	Peak detect	Capture glitches as narrow as 250 ps at all time base settings									
	Averaging	Selectable from 2, 4, 8, 16, 64, ... to 65,536									
	High resolution	Real time boxcar averaging reduces random noise and effectively increases vertical resolution 12 bits of resolution when ≥ 10 µs/div at 5 GSa/s or ≥ 20-µs/div at 2.5 GSa/s									
	Segmented	Segmented memory optimizes available memory for data streams that have long dead times between activity. Maximum segments = 1000. Re-arm time = 1 µs (minimum time between trigger events)									
Time mode	Normal	Default mode									
	Roll	Displays the waveform moving across the screen from right to left. Available at the time base 50 ms/div or slower									
	XY	Displays the volts-versus-volts display. Time base can be set from 200 ns/div to 50 ms/div									

1. Denotes warranted specifications, all others are typical. Specifications are valid after a 30-minute warm-up period and ± 10 °C from firmware calibration temperature.

Performance Characteristics (Continued)

Trigger system	
Trigger sources	Analog channel (1 ~ 4), digital channel (D0 ~ D15), line, external, WaveGen (1 or mod) (FM/FSK)
Trigger modes	Normal (triggered): Requires trigger event for scope to trigger
	Auto: Triggers automatically in absence of trigger event
	Single: Triggers only once on a trigger event, press **[Single]** again for scope to find another trigger event, or press **[Run]** to trigger continuously in either Auto or Normal mode
	Force: front panel button that forces a trigger
Trigger coupling	DC: DC coupled trigger
	AC: AC coupled trigger, cutoff frequency: < 10 Hz (internal); <50 Hz (external)
	HF reject: High frequency reject, cutoff frequency ~ 50 kHz
	LF reject: Low frequency reject, cutoff frequency ~ 50 kHz
	Noise reject: Selectable OFF or ON, decreases sensitivity 2x
Trigger holdoff range	40 ns to 10.00 s
Trigger sensitivity	
Internal [1]	< 10 mV/div: Greater of 1 div or 5 mV; ≥ 10 mV/div: 0.6 div
External [1]	200 mVpp from DC to 100 MHz
	350 mVpp 100 MHz to 200 MHz
Trigger level range	
Any channel	± 6 div from center screen
External	± 8 V
Trigger type selections	
Zone (HW zone qualifier)	Trigger on user-defined zones drawn on the display. Applies to one analog channel at a time. Specify zones as either “must intersect” or “must not intersect.” Up to two zones. > 200,000 scans/sec update rate
	Supported modes: normal, peak detect, high resolution
	Also works simultaneously with the serial trigger and mask/limit test
Edge	Trigger on a rising, falling, alternating or either edge of any source
Edge then edge (B trigger)	Arm on a selected edge, wait a specified time, then trigger on a specified count of another selected edge
Pulse width	Trigger on a pulse on a selected channel, whose time duration is less than a value, greater than a value, or inside a time range
	Minimum duration setting: 2 ns (500 MHz, 1 GHz), 4 ns (350 MHz), 6 ns (200 MHz), 10 ns (100 MHz)
	Maximum duration setting: 10 s
	Range minimum: 10 ns
Runt	Trigger on a position runt pulse that fails to exceed a high level threshold. Trigger on a negative runt pulse that fails to exceed a low level threshold. Trigger on either polarity runt pulse based on two threshold settings. Runt triggering can also be time-qualified (< or >) with a minimum time setting of 2 ~ 10 ns and maximum timesetting of 10 s
	Minimum time setting: 2 ns (500 MHz, 1 GHz), 4 ns (350 MHz), 6 ns (200 MHz)
	10 ns (100 MHz)
Setup and hold	Trigger and clock/data setup and/or hold time violation. Setup time can be set from –7 to 10 s. Hold time can be set from 0 s to 10 ns
Rise/fall time	Trigger on rise-time or fall-time edge speed violations (< or >) based on user-selectable threshold
	Select from (< or >) and time settings range between
	Minimum: 1 ns (500 MHz, 1 GHz), 2 ns (350 MHz), 3 ns (200 MHz), 5 ns (100 MHz)
	Maximum: 10 s

1. Denotes warranted specifications, all others are typical. Specifications are valid after a 30-minute warm-up period and ±10 °C from firmware calibration temperature.

Performance Characteristics (Continued)

Trigger type selections	
N^{th} edge burst	Trigger on the Nth (1 to 65535) edge of a pulse burst. Specify idle time (10 ns to 10 s) for framing
Pattern	Trigger when a specified pattern of high, low, and don't care levels on any combination of analog, digital, or trigger channels is [entered | exited]. Pattern must have stabilized for a minimum of 2 ns to qualify as a valid trigger condition
	Minimum duration setting: 2 ns (500 MHz, 1 GHz), 4 ns (350 MHz), 6 ns (200 MHz), 10 ns (100 MHz)
	Maximum duration setting: 10 s
	Range minimum: 10 ns
Or	Trigger on any selected edge across multiple analog or digital channels
Video	Trigger on all lines or individual lines, odd/even or all fields from composite video, or broadcast standards (NTSC, PAL, SECAM, PAM-M)
Enhanced Video (optional)	Trigger on lines and fields of enhanced and HDTV standards (480p/60, 567p/50, 720p/50, 720p/60, 1080p/24, 1080p/25, 1080p/30, 1080p/50, 1080p/60, 1080i/50, 1080i/60)
USB	Trigger on start of packet, end of packet, reset complete, enter suspend, or exit suspend. Support USB low-speed and full-speed
I^2C (optional)	Trigger at a start/stop condition or user defined frame with address and/or data values. Also trigger on missing acknowledge, address with no accq, restart, EEPROM read, and 10-bit write
SPI (optional)	Trigger on SPI (Serial Peripherial Interface) data pattern during a specific framing period. Supports positive and negative Chip Select framing as well as clock Idle framing and user-specified number of bits per frame. Supports MOSI and MISO data
RS-232/422/485/UART (optional)	Trigger on Rx or Tx start bit, stop bit or data content or parity error
I^2S (optional)	Trigger on 2's complement data of audio left channel or right channel (=, ≠, <, >, > <, < >, increasing value, or decreasing value)
CAN (optional)	Trigger on CAN (controller area network) version 2.0A,2.0B, and CAN-FD (Flexible Data-rate) signals. Trigger on the start of frame (SOF), the end of frame (EOF), data frame ID, data frame ID and data (non-FD), data frame ID and data (FD), remote frame ID, remote or data frame ID, error frame, acknowledge error, from error, stuff error, CRC error, spec error (ack or form or stuff or CRC), all errors, BRS Bit (FD), CRC delimiter bit (FD), ESI bit active (FD), ESI bit passive (FD), overload frame., message, message and signal (non-FD), message and signal (FD, first 8 bytes only)
LIN (optional)	Trigger on LIN (Local Interconnect Network) sync break, sync frame ID, or frame ID and data, parity error, checksum error, frame (symbolic), frame and signal (symbolic)
CXPI (optional)	Trigger on the start of frame (SOF), the end of frame (EOF), PTYPE, frame ID, data and info frame ID, data and info frame ID (long frame), CRC field error, parity error, inter-byte space error, inter-frame space error, framing error, data length error, sample error, all errors, sleep frame, wakeup pulse
FlexRay (optional)	Trigger on frame ID, frame type (sync, start-up, null, normal), cycle-repetitive, cycle-base, and errors.
MIL-STD 1553 (optional)	Trigger on MIL-STD 1553 signals based on word type (Data or Command/Status), Remote Terminal Address, data, and errors (parity, sync, Manchester encoding)
ARINC 429 (optional)	Trigger on ARINC429 data. Trigger on word start/stop, label, label + bits, label range, error conditions (parity, word, gap, word or gap, all), all bits (eye), all 0 bits, all 1 bits
SENT (optional)	Trigger on SENT bus. start of fast channel message, start of slow channel message, fast channel SC and data, slow channel message ID, slow channel message ID and data, tolerance violation, fast channel CRC error, slow channel CRC error, all CRC errors, pulse period error, successive sync pulses error (1/64)
User-definable Manchester/NRZ (optional)	Trigger on start-of-frame (SOF), bus value, and Manchester errors
USB PD (optional)	Trigger on preamble, EDP, ordered sets, preamble errors, CRC errors, header content (control messages, data messages, extended messages and value in HEX)

Performance Characteristics (Continued)

Waveform measurements		
Cursors [2]		Single cursor accuracy: ± [DC vertical gain accuracy + DC vertical offset accuracy + 0.25% full scale]
		Dual cursor accuracy: ± [DC vertical gain accuracy + 0.5% full scale] [1]
		Units: Seconds(s), Hz (1/s), phase (degrees), ratio (%)
Automatic measurements		Measurements continuously updated with statistics. Cursors track last selected measurement. Select up to eight measurements from the list below: Snapshot All: Measure all single waveform measurements (31) Voltage: Peak-to-peak, maximum, minimum, amplitude, top, base, overshoot, pre-shoot, average- N cycles, average- full screen, DC RMS- N cycles, DC RMS- full screen, AC RMS- N cycles, AC RMS- full screen (std deviation), ratio- N cycle, ratio- full screen Time: Period, frequency, counter, + width, - width, burst width, +duty cycle, -duty cycle, bit rate, rise time, fall time, delay, phase, X at min Y, X at max Y Count: Positive pulse count, negative pulse count, rising edge count, falling edge count Mixed: Area- N cycles, area- full screen
Automatic measurement logging		Available via BenchVue
Counter		Built-in frequency counter
		Source: On any analog or digital channel
		Resolution: 5 digits
		Maximum frequency: Bandwidth of scope
Waveform math		
Number of math functions		Two, displays FFT and one math simultaneously. Can be cascaded
Arithmetic		Add, subtract, multiply, divide, differentiate, integrate, FFT, Ax + B, squared, square root, absolute value, common logarithm, natural logarithm, exponential, base 10 exponential, low pass filter, high pass filter, averaged value, smoothing, envelope, magnify, max hold, min hold, measurement trend, chart logic bus (Timing or State)
Enhanced FFT	Record size	Up to 64 kpts resolution
	Window types	Hanning, Flat Top, Rectangular, Blackman-Harris, Bartlett
	Time gated FFT	Gate the time range of data for FFT analysis in the zoom view. For time and frequency domain correlated analysis.
	Waveforms	FFT, max hold, min hold, average
	Peak search	Max 11 peaks, threshold and excursion control
Search, navigate, and lister		
Type		Edge, pulse width, rise/fall, runt, frequency peak, serial bus 1, serial bus 2
Copy		Copy to trigger, copy from trigger
Frequency peak	Source	Math functions
	Max # of peaks	11
	Control	Results order in frequency or amplitude
Result display		Event lister or navigation. Manual or auto scroll via navigation or touch event lister entry to jump to a specific event
Display characteristics		
Display		8.5-inch capacitive touch/gesture enabled TFT LCD
Resolution		800 (H) x 480 (V) pixel format (screen area)
Graticules		8 vertical divisions by 10 horizontal divisions with intensity controls
Format		YT, XY, and Roll
Maximum waveform update rate		> 1,000,000 wfms/s
Persistence		Off, infinite, variable persistence (100 ms to 60 s)
Intensity gradation		64 intensity levels

1. Denotes warranted specifications, all others are typical.
   Specifications are valid after a 30-minute warm-up period and ± 10 °C from firmware calibration temperature.
2. 1 mV/div and 2 mV/div is a magnification of 4 mV/div setting. For vertical accuracy calculations, use full scale of 32 mV for 1 mV/div and 2 mV/div sensitivity setting.

Performance Characteristics (Continued)

WaveGen – Built-in function/arbitrary waveform generator (specifications are typical)	
WaveGen out	Front-panel BNC connector
Waveforms	Sine, Square, Ramp, Pulse, DC, Noise, Sine Cardinal (Sinc), Exponential Rise, Exponential Fall, Cardiac, Gaussian Pulse, and Arbitrary
Modulation	Modulation types: AM, FM, FSK Carrier waveforms: sine, ramp, sine cardinal, exponential rise, exponential fall, and cardiac Modulation source: internal (no external modulation capability) AM: Modulation: sine, square, ramp Modulation frequency: 1 Hz to 20 kHz Depth: 0% to 100% FM: Modulation: sine, square, ramp Modulation frequency: 1 Hz to 20 kHz Minimum carrier frequency: 10 Hz Deviation: 1 Hz to carrier frequency or (2e12 / carrier frequency), whichever is smaller FSK: Modulation: 50% duty cycle square wave FSK rate: 1 Hz to 20 kHz Hop frequency: 2 x FSK rate to 10 MHz
Sine	Frequency range: 0.1 Hz to 20 MHz
	Amplitude flatness: ± 0.5 dB (relative to 1 kHz)
	Harmonic distortion: –40 dBc
	Spurious (non harmonics): –40 dBc
	Total harmonic distortion: 1%
	SNR (50 Ω load, 500 MHz BW): 40 dB (Vpp > = 0.1 V); 30 dB (Vpp < 0.1V)
Square wave /pulse	Frequency range: 0.1 Hz to 10 MHz
	Duty cycle: 20 to 80%
	Duty cycle resolution: Larger of 1% or 10 ns
	Pulse width: 20 ns minimum
	Rise/fall time: 18 ns (10 to 90%)
	Pulse width resolution: 10 ns or 5 digits, whichever is larger
	Overshoot: < 2%
	Asymmetry (at 50% DC): ± 1% ± 5 ns
	Jitter (TIE RMS): 500 ps
Ramp/triangle wave	Frequency range: 0.1 Hz to 200 kHz
	Linearity: 1%
	Variable symmetry: 0 to 100%
	Symmetry resolution: 1%
Noise	Bandwidth: 20 MHz typical
Sine Cardinal (Sinc)	Frequency range: 0.1 Hz to 1.0 MHz
Exponential Rise/Fall	Frequency range: 0.1 Hz to 5.0 MHz
Cardiac	Frequency range: 0.1 Hz to 200.0 kHz
Gaussian Pulse	Frequency range: 0.1 Hz to 5.0 MHz
Arbitrary	Waveform length: 1 to 8k points
	Amplitude resolution: 10 bits (including sign bit) [1]
	Repetition rate: 0.1 Hz to 12 MHz
	Sample rate: 100 MSa/s
	Filter bandwidth: 20 MHz

1. Full resolution is not available at output due to internal attenuator stepping.

Performance Characteristics (Continued)

WaveGen – Built-in function/arbitrary waveform generator (specifications are typical) (Continued)		
Frequency		Sine wave and ramp accuracy: 130 ppm (frequency < 10 kHz) 50 ppm (frequency > 10 kHz)
		Square wave and pulse accuracy: [50+frequency/200] ppm (frequency < 25 kHz) 50 ppm (frequency ≥ 25 kHz)
		Resolution: 0.1 Hz or 4 digits, whichever is larger
Amplitude		Range: 20 mVpp to 5 Vpp into Hi-Z [1] 10 mVpp to 2.5 Vpp into 50 Ω [1]
		Resolution: 100 µV or 3 digits, whichever is higher
		Accuracy: 2% (frequency = 1 kHz)
DC offset		Range: ± 2.5 V into Hi-Z [1] ± 1.25 V into 50 Ω [1]
		Resolution: 100 µV or 3 digits, whichever is higher
		Accuracy (waveform modes): ± 1.5% of offset setting ± 1% of amplitude ± 1 mV
		Accuracy (DC mode): ± 1.5% of offset setting ± 3 mV
Trigger output		Trigger output available on Trig out BNC
Main output		Impedance: 50 Ω typical
		Isolation: Not available, main output BNC is grounded
		Protection: Overload automatically disables output
Output mode		Normal
		Single-shot (arbitrary, sine, ramp, sine cardinal, exp rise/fall, cardiac, Gaussian pulse)
Digital voltmeter (Specifications are typical)		
Functions		ACrms, DC, DCrms
Resolution		ACV/DCV: 3 digits
Measuring rate		100 times/second
Autoranging		Automatic adjustment of vertical amplification to maximize the dynamic range of measurements
Range meter		Graphical display of most recent measurement, plus extrema over the previous 3 seconds
Precision counter/totalizer (Specification are typical)		
Counter	Source	Any analog channel or trigger qualified event
	Resolution	8 digits (8 digits for trigger qualified event)
	Max frequency	1 GHz
	Trig qual events	1/(trigger hold off time) for trigger qualified events (max 25 MHz, minimum dead time of 40 ns)
Measurement		Frequency, period, totalize
Totalizer	Counter size	64 bit totalizing counter
	Edge	Rise or fall
	Gating	Positive or negative level. Select from analog channels except the source

1. Gaussian Pulse: 4 Vpp maximum into Hi-Z; 2 Vpp maximum into 50 Ω.

Performance Characteristics (Continued)

Connectivity	
Standard ports	One USB 2.0 hi-speed device port on rear panel. Supports USBTMC protocol
	Two USB 2.0 hi-speed host ports, front and rear panel
	Supports memory devices, printers and keyboards
Optional ports	GPIB, LAN (10/100Base-T), WVGA video out
Trigger out	BNC connector on the rear panel. Supported modes: triggers, mask, and waveform generator sync pulse
General and environmental characteristics	
Power line consumption	Max 100 W
Power voltage range	100 to 120 V, 50/60/400 Hz; 100 to 240 V, 50/60 Hz
Environmental rating	5 to 55°C, 4000 m max Maximum Relative Humidity (non-condensing): 95%RH up to 40°C, decreases linearly to 45%RH at 55°C From 40°C to 55°C, the maximum % Relative Humidity follows the line of constant dew point
Electromagnetic compatibility	Meets EMC directive (2004/108/EC), meets or exceeds IEC 61326-1:2005/EN 61326-1:2006 Group 1 Class A requirement CISPR 11/EN 55011 IEC 61000-4-2/EN 61000-4-2 IEC 61000-4-3/EN 61000-4-3 IEC 61000-4-4/EN 61000-4-4 IEC 61000-4-5/EN 61000-4-5 IEC 61000-4-6/EN 61000-4-6 IEC 61000-4-11/EN 61000-4-11 Canada: ICES-001:2004 Australia/New Zealand: AS/NZS
Safety	ANSI/UL Std. No. 61010-1:2012; CAN/CSA-C22.2 No. 61010-1-12
	ANSI/UL Std. No. 61010-2-030:2012; CAN/CSA-C22.2 No. 61010-2-030-12
Vibration	Meets IEC60068-2-6 and MIL-PRF-28800; class 3 random
Shock	Meets IEC 60068-2-27 and MIL-PRF-28800; class 3 random; (Operating 30 g, ½ sine. 11 ms duration, 3 shocks/axis along major axis, total of 18 shocks
Dimensions (W x H x D)	381 mm (15 in) x 204 mm (8 in) x 142 mm (5.6 in)
Weight	Net: 4.0 kg (9.0 lbs), shipping: 4.2 kg (9.2 lbs)

Performance Characteristics (Continued)

Nonvolatile storage		
Reference waveform display		Two internal waveforms or USB thumb drive. Displays 1 reference waveform at a time
Data/file save	Setup/image	Setup (*.scp), 8 or 24-bit Bitmap image (*.bmp), PNG 24-bit image (*.png)
	Waveform data	CSV data (*.csv), ASCII XY data (*.csv), Binary data (*.bin), Lister data (*.csv), Reference waveform data (*.h5), multi-channel waveform data (*.h5), Arbitrary Waveform data (*.csv)
	Application data	Mask (*.msk), Power harmonics data (*.csv), USB signal quality (*.html & *.bmp)
	Analysis results (*.csv)	Cursor data, measurement results, mask test statistics, search, segmented timestamps
Max USB flash drive size		Supports industry standard flash drives
Set ups without USB flash drive		10 internal setups
Set ups with USB flash drive		Limited by size of USB drive
Included standard with oscilloscope		
Calibration		Certificate of calibration, 3-year calibration interval
Mean time before failure (MTBF)		> 250,000 hours
Standard secure erase		
Probes		
N2843A Passive probe 500 MHz 10:1 attenuation		1 per channel
N2756A 16 digital channel MSO cable		1 per scope included on all MSO models and DSOXT3MSO
Interface and built-in help language support		English, Chinese (simplified), Chinese (traditional), Czech, French, German, Italian, Japanese, Korean, Portuguese, Russian, Spanish, Polish, Thai, Turkish
Documentation		CD containing localized user's guide, service guide, and programmer's manual
Localized power cord and overlay		

For MET/CAL procedures, click on the Cal Labs solutions link **http://www.callabsolutions.com/products/Keysight/**. These procedures are FREE to customers.

Related literature

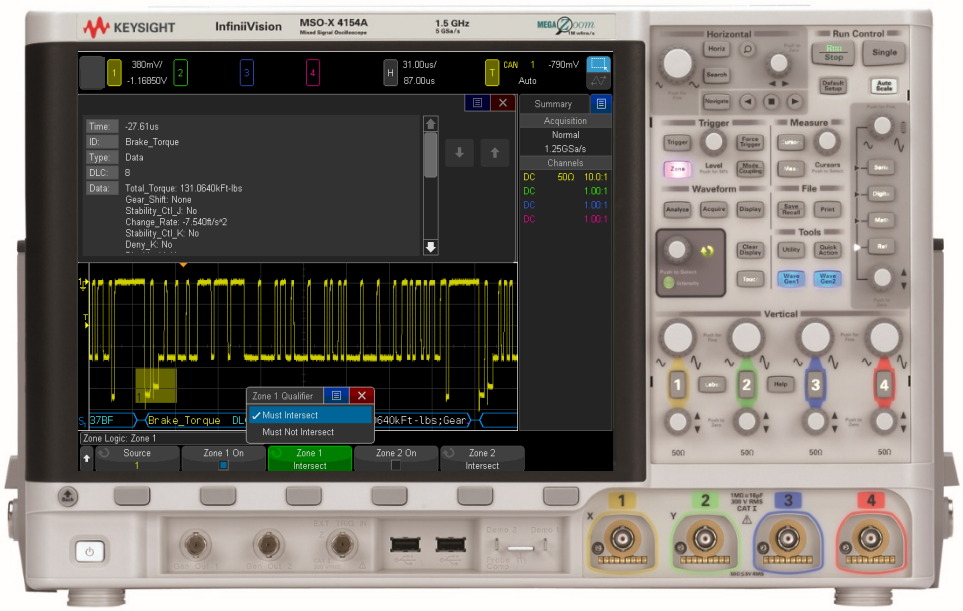
Publication title	Publication number
Mask/Waveform Limit Testing For InfiniiVision Series Oscilloscopes - Data Sheet	5990-3269EN
Serial Bus Options for InfiniiVision X-Series Oscilloscopes - Data Sheet	5990-6677EN
DSOX3PWR/DSOX4PWR/DSOX6PWR Power Measurement Options - Data Sheet	5990-8869EN
Triggering on Infrequent Anomalies and Complex Signals using Zone Trigger - Application Note	5991-1107EN
InfiniiVision 3000T X-Series versus Danaher-Tektronix MDO3000 Series Oscilloscopes - Competitive Comparison	5992-0116EN
InfiniiVision 3000T X-Series Oscilloscopes - Product Fact Sheet	5992-0150EN
Using an Oscilloscope Time Gated Fast Fourier Transforms for Time Correlated Mixed Domain Analysis - Application Note	5992-0244EN
DSOXT3NFC/DSOX4NFC Automated NFC Test Software, N2116A/N2134A/N2135A Programmable NFC 3-in-1 Antenna - Data Sheet	5992-1593EN
DSOXT3FRA/DSOX4FRA/DSOX6FRA Frequency Response Analyzer (FRA) Option - Data Sheet	5992-2209EN

DATA SHEET

Automotive Software Package

for InfiniiVision X-Series oscilloscopes

The Automotive Software Package for Keysight's InfiniiVision oscilloscopes enables protocol triggering and decode for a broad range of the most common automotive serial buses used today for power train and body control and monitoring. This package also enables other advanced analysis capabilities including eye-diagram mask testing and frequency response analysis to help test and debug automotive electronic systems.



KEYSIGHT TECHNOLOGIES

Table of Contents

Introduction

The primary reason engineers use oscilloscopes to debug and characterize automotive serial buses, such as CAN, CAN FD, LIN, SENT, PSI5, CXPI and FlexRay, is because of an oscilloscope's inherent ability to characterize the analog quality of these signals. Performing analog characterization using an oscilloscope is often referred to as "physical layer" measurements.

Many of the most popular automotive serial bus protocol decode & triggering capabilities and advanced analysis features are enabled on InfiniiVision X-Series oscilloscope if licensed with the Automotive Software Package. Table 1 lists the specific measurement capabilities that are enabled on each series with the Automotive Package.

Table 1. Automotive Software Packages InfiniiVision Oscilloscopes

InfiniiVision Series:		2000A	3000A	3000T	4000A	6000A	P9240	M9240
Automotive Package Model Number:		D2000AUTA	D3000AUTA	D3000AUTA	D4000AUTA	D6000AUTA	P9240AUTB	M9240AUTB
Serial Trigger & Decode	CAN[1]	✓	✓	✓	✓	✓	✓	✓
	CAN FD[1]			✓	✓	✓	✓	✓
	LIN[2]	✓	✓	✓	✓	✓	✓	✓
	FlexRay		✓	✓	✓	✓		
	SENT			✓	✓	✓	✓	✓
	PSI5 (User-definable Manchester)			✓	✓	✓	✓	✓
	User-definable NRZ			✓	✓	✓	✓	✓
	CXPI			✓	✓	✓	✓	✓
Advanced Analysis	Mask Test[3]	✓	✓	✓	✓	✓	✓	✓
	Frequency Response Analysis			✓	✓	✓	✓	✓
	Advanced Math	Std	✓	Std	Std	Std	Std	Std

Notes:

1. Symbolic decoding supported by importing a .dbc file, except on the 2000A and 3000A Series.
2. Symbolic decoding supported by importing a .ldf file, except on the 2000A and 3000A Series.
3. CAN, CAN FD, FlexRay, and SENT mask files available for download at no additional charge.

Although there are many oscilloscopes on the market today from multiple vendors that offer automotive-focused options, Keysight's InfiniiVision Series oscilloscopes offer some unique measurement capabilities for debugging and characterizing the physical layer of automotive serial buses including:

- CAN and CAN FD symbolic trigger and decode (based on .dbc file import)
- LIN symbolic trigger and decode (based on .ldf file import)
- CAN eye-diagram mask testing
- CAN FD eye-diagram mask testing
- FlexRay eye-diagram mask testing
- SENT mask pulse-shape physical layer testing
- Dual-bus time-interleaved protocol lister display
- Hardware-based decoding for responsiveness
- Decoding of all frames captured using segmented memory
- Real-time frame/error counter with bus load measurement
- Zone trigger to isolate occurrences of CAN bus arbitration

To learn more about these advanced measurement capabilities, refer to the extensive list of Keysight automotive-focused application notes listed at the end of this document.

Figure 1 shows an example of symbolically decoding the CAN bus with a .dbc file while triggering on occurrences of arbitration with an InfiniiVision oscilloscope's unique zone trigger capability.

Figure 1. Capturing CAN bus arbitration while decoding CAN messages symbolically.

Serial Trigger and Decode

CAN (2000A and 3000A X-Series models)

Table 2: CAN Performance Characteristics (2000A and 3000A X-Series only)

CAN input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 non-differential. (except 2000 X-Series)
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 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)
Multi-bus analysis	CAN plus one other serial bus, including another CAN bus. (except 2000 X-Series)
Totalize function	Total frames, total overload frames, total error frames, bus utilization (bus load)
Eye-diagram mask testing	Various downloadable mask files available based on differential probing polarity, baud rate and network length

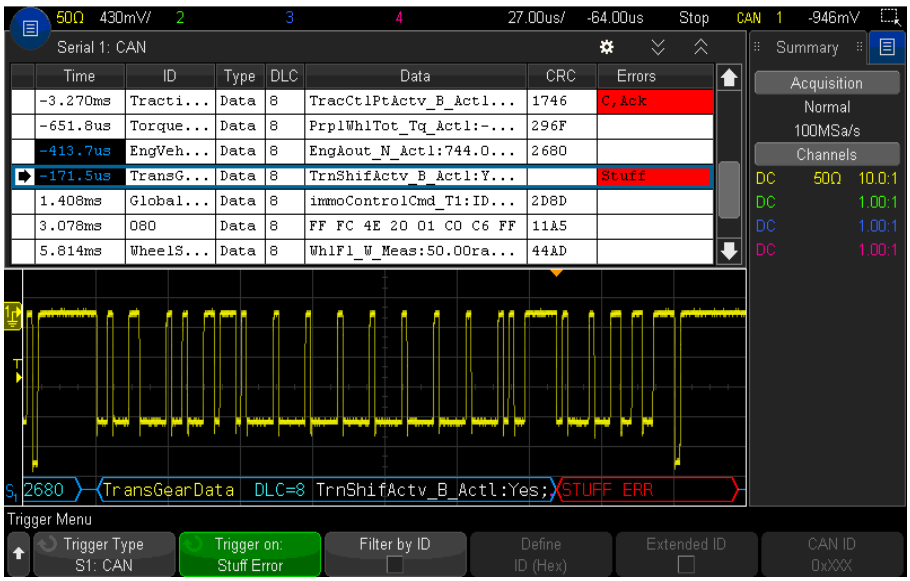


Figure 2. CAN decode on an InfiniiVision X-Series oscilloscope.

CAN/CAN FD (3000T, 4000A, 6000A, P9240, and M9240 X-Series models)

Table 3: CAN/CAN FD Performance Characteristics

Note: "Classic" CAN 2.0 specifications are a subset of the combined CAN/CAN FD ISO specifications. CAN FD trigger and decode supports ISO and non-ISO CAN FD specifications.	
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 (based on .dbc file)	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 (based on .dbc file)	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 %
CAN/CAN FD Eye-diagram mask testing	Various downloadable mask files available based on differential probing polarity, baud rate and network length

Table 4: LIN Performance Characteristics

LIN input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 (except 2000A X-Series)
LIN standards	LIN 1.3 or LIN 2.X
Baud rates	2400 b/s to 625 kb/s
Triggering	Sync break
	Frame ID (0X00HEX to 0X3FHEX)
	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)
Symbolic triggering based on -ldf file (except 2000A and 3000A X-Series)	Message names
	Message and signal values/encoded states
Multi-bus analysis	LIN plus one other serial bus, including another LIN bus. (except 2000A X-Series)

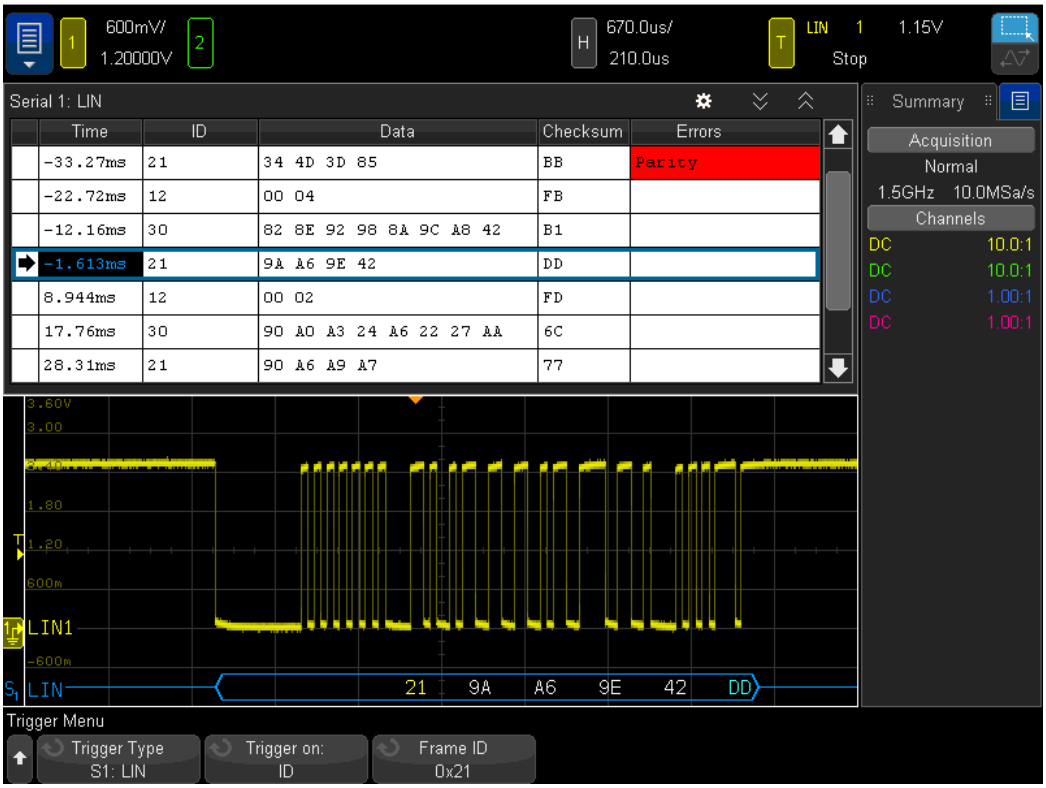


Figure 3. LIN decode on an InfiniiVision X-Series oscilloscope.

Table 5: FlexRay Performance Characteristics

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 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 5 Mbps and TP4 2.5 Mbps
Multi-bus analysis	FlexRay plus one other serial bus (including another FlexRay bus)

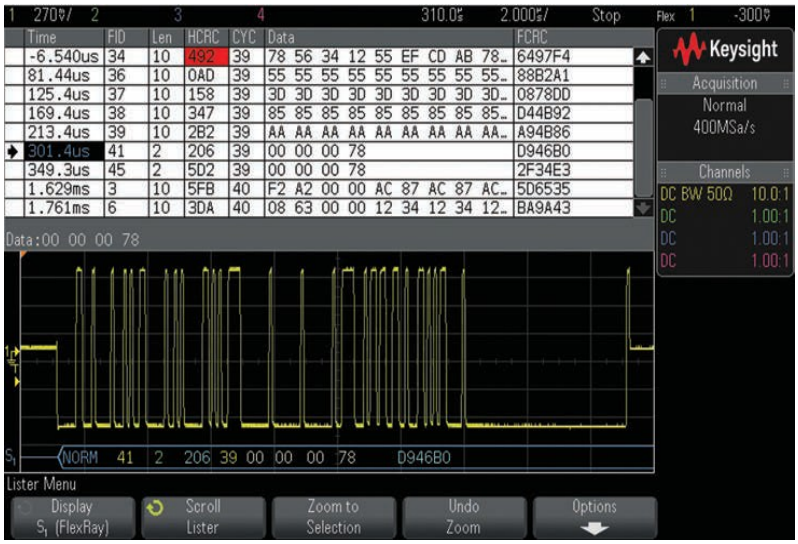


Figure 4. FlexRay decode on an InfiniiVision X-Series oscilloscope

SENT (Single Edge Nibble Transmission)

Table 6: SENT Performance Characteristics

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/SPC mode	Pause On, Pause Off, or SPC Mode
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 and 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

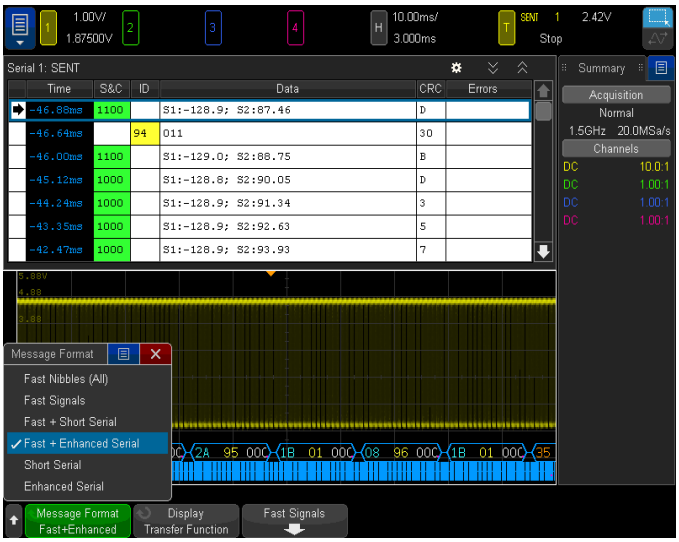


Figure 5. SENT decode on an InfiniiVision X-Series oscilloscope.

PSI5 (based on User-definable Manchester)

Table 7: User-definable Manchester Performance Characteristics

Input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 non-differential
Baud rate	500 bps to 5 Mbps
	Automatic RF demodulation at 212 kbps and 424 kbps (NFC-F)
Baud rate tolerance	5 to 30%
Display format	Word or bits
Polarity	Rising edge = 1 or falling edge = 1
Bit order	MSB or LSB (MSB only in binary display format)
Idle	1.5 to 32 bits
Sync size	0 to 255 bits
Header size (word format only)	0 to 32 bits
Number of words (word format only)	1 to 255 or auto
Data word size (word format only)	2 to 32 bits
Trailer size (word format only)	0 to 32 bits (0 if using "Auto" number of words)
Triggering	SOF (Start-of-frame)
	Value (first 4 to 128 bits entered in binary format)
	Manchester error
Decoding (word format)	Decode base (HEX, ASCII or unsigned decimal)
	Header field (all digits in yellow)
	Data field (all digits in white)
	Trailer (all digits in blue)
Decoding (bit format)	All binary digits in white
Multi-bus analysis	User-definable Manchester plus one other serial bus

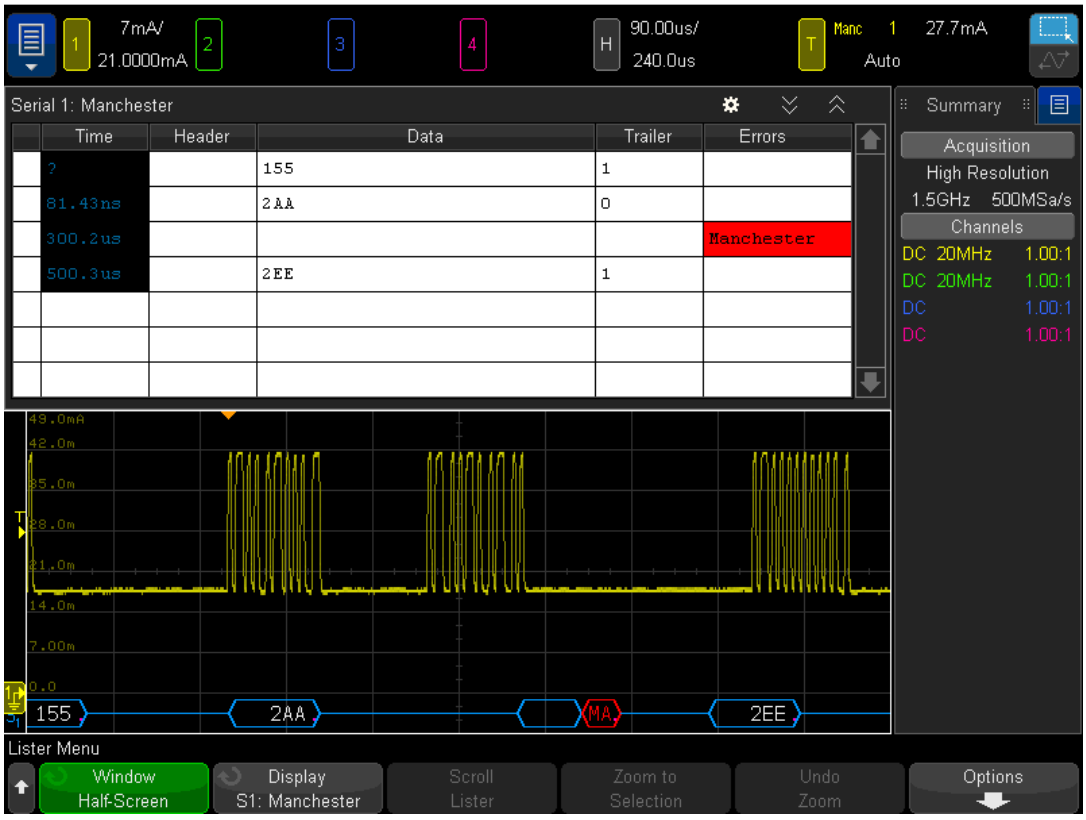


Figure 6. PSI5 decode on an InfiniiVision X-Series oscilloscope.

User-definable NRZ (non-return to zero)

Table 8: User-definable NRZ Performance Characteristics

Input source	Analog channels 1, 2, 3 or 4
	Digital channels D0 to D15 non-differential
Baud rate	5 kbps to 5 Mbps
Display format	Word or bits
Polarity	High = 1 or low = 1
Bit order	MSB or LSB (MSB only in binary display format)
Idle	1.5 to 32 bits
Idle state	High or low
Number of start bits	0 to 255 bits
Header size (word format only)	0 to 32 bits
Number of words (word format only)	1 to 255
Data word size (word format only)	2 to 32 bits
Trailer size (word format only)	0 to 32 bits
Triggering	SOF (Start-of-frame)
	Value (first 4 to 128 bits entered in binary format)
Decoding (word format)	Decode base (HEX, ASCII or unsigned decimal)
	Header field (all digits in yellow)
	Data field (all digits in white)
	Trailer (all digits in blue)
Decoding (bit format)	All binary digits in white
Multi-bus analysis	User-definable NRZ plus one other serial bus

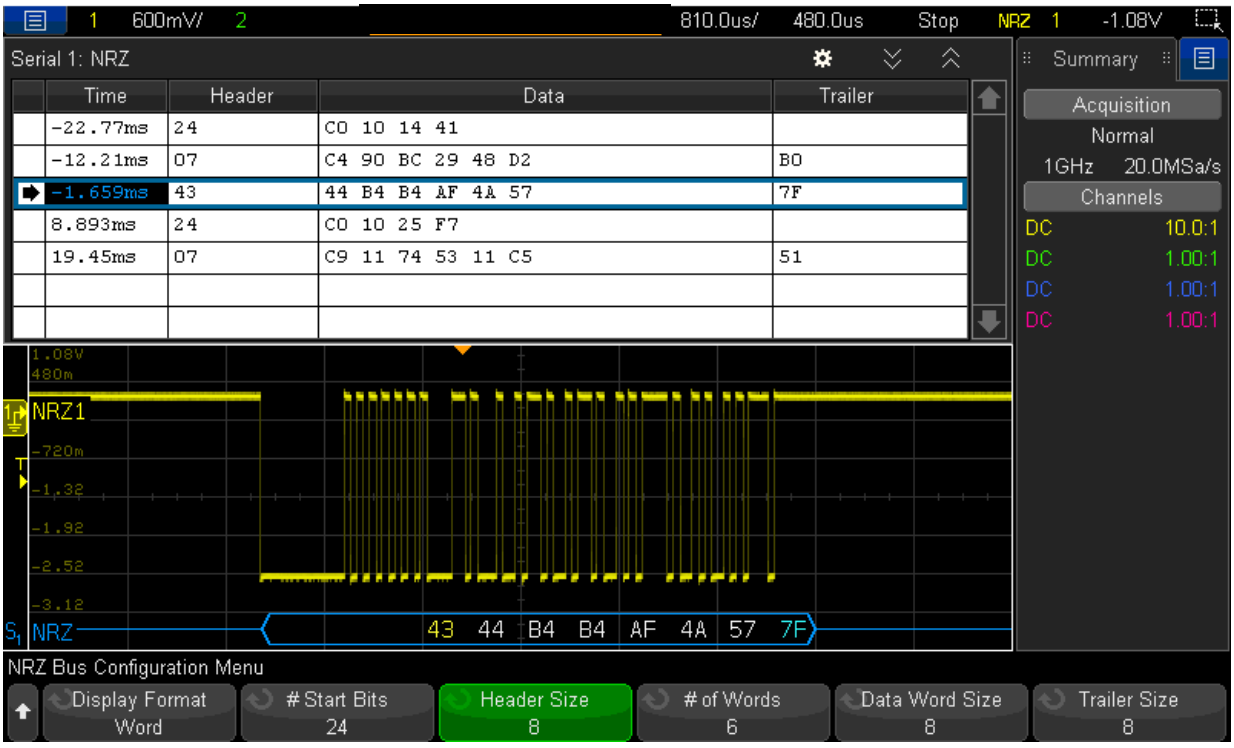


Figure 7. User-definable NRZ decode on an InfiniiVision X-Series oscilloscope.

Table 9: CXPI Performance Characteristics

CXPI input source	Analog channels 1, 2, 3 or 4
Baud rates	9.6 kb/s to 40 kb/s (20 kb/s typical) with tolerance setting
Triggering	SOF (Start-of-frame)
	EOF (End-of-frame)
	PTYPE
	Frame ID (PTPYE present or not present)
	Frame ID + info + data
	Frame ID + info + data (long frame)
	CRC field error (filtered by ID)
	Parity error
	Inter-byte space error (filtered by ID)
	Inter-frame space error (filtered by ID)
	Framing error (filtered by ID)
	Data length error (filtered by ID)
	Sample error
	All errors
	Sleep frame
	Wakeup pulse
Hardware-based decode	Frame ID (hex digits in yellow if valid or red if parity error)
	Data length code (DLC = with decimal digits in blue)
	Network management (NM) bits (binary digits in green)
	Counter (CT) bits (binary digits in yellow)
	Data (hex digits in white)
	CRC (hex digits in blue = valid, hex digits in red = error)
	Idle bus (mid-level dark blue bus trace)
	Active bus (bi-level dark blue bus trace with embedded decode within)
	Inter-byte space error (IBS ERR in red)
	Data length error (LEN ERR in red)
	Sleep mode (SLEEP MODE in orange within bi-level orange bus trace)
	Wakeup pulse (WAKEUP PULSE in blue with bi-level blue bus trace)
Multi-bus analysis	CXPI plus one other serial bus

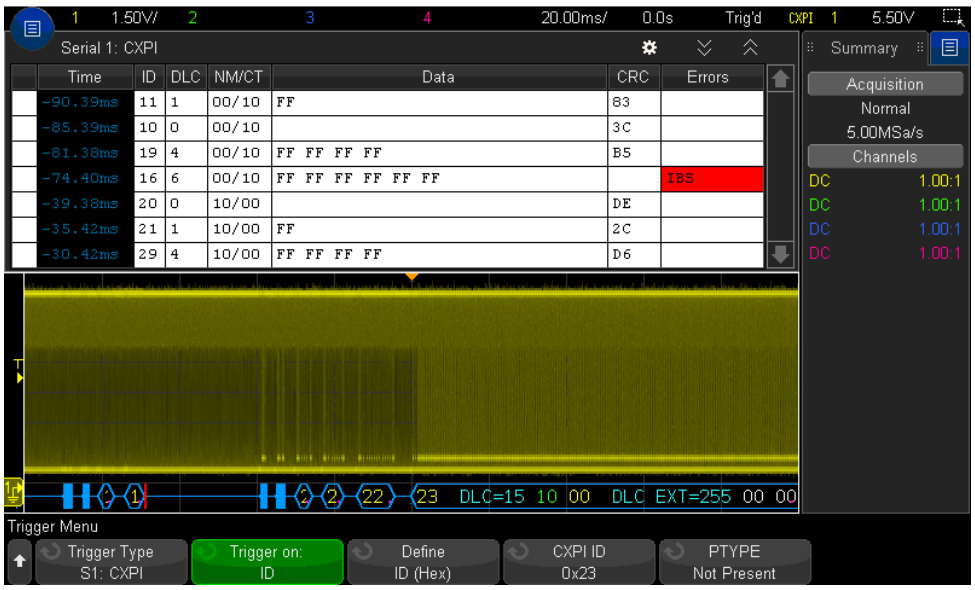


Figure 8. CXPI decode on an InfiniiVision X-Series oscilloscope.

Advanced Analysis

Mask Test (pass/fail waveform limit testing)

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 Automotive 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.

Figure 9. CAN FD eye-diagram mask testing.

The InfiniiVision scope's mask testing is based on hardware-based 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.

- 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 (CAN, CAN FD, and SENT eye-diagram and pulse-shape mask files available for download at no charge)
- Detailed pass/fail statistics
- Test to high-quality standards based on sigma
- Multiple user-selectable test criteria

Table 10. 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 Automotive 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.

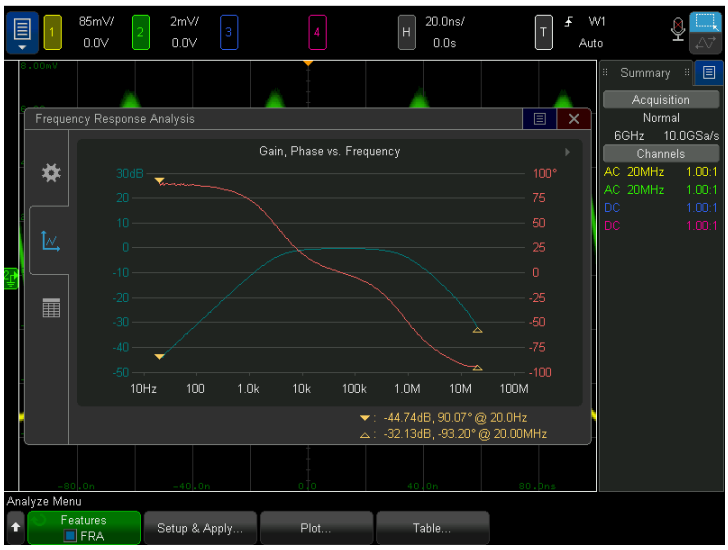


Figure 10. Frequency response analysis (gain & phase) on a bandpass filter.

- 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

Table 11. 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 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	

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 Automotive 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 Automotive Software Package 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

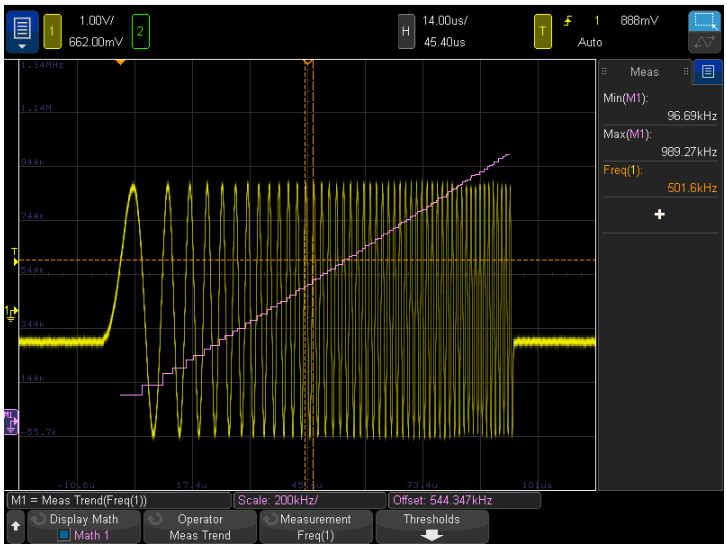


Figure 10. Measurement trend math function used to plot frequency versus time of a FM burst.

Probing Differential Serial Buses

Many of today's serial buses are based on differential signaling including CAN, CAN FD, and FlexRay. Keysight offers a wide range of differential active probes compatible with the InfiniiVision X-Series oscilloscopes for various bandwidth and dynamic range applications. Table 12 shows the differential probes that Keysight recommends for each of the listed automotive differential serial buses.

Figure 11. Keysight's N2818A 200-MHz differential active probe.

Table 12. Recommended probes for automotive differential buses

Differential bus (max bit rate)	N2791A (25-MHz bandwidth)	N2818A [1] (200-MHz bandwidth)
CAN (1 Mbps)	X	X
CAN FD (10 Mbps data phase)		X
FlexRay (10 Mbps)		X

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) shown in Figure 12. This probe head makes it quick and easy to connect to your serial buses during the prototype phase of development and is compatible with Keysight's various differential probing solutions.

Figure 12. DB9-SubD probe head adapter.

Extreme Temperature Probing

When probing differential signals inside environmental chambers at extreme temperatures, Keysight offers the N7013A extreme temperature extension kit shown in Figure 12. The N7013A is compatible with the N2791A and N2818A differential probes and can operate in temperatures ranging from –40 to +85 °C. To learn more about Keysight's extreme temperature probing solutions for automotive applications, refer to the Extreme Temperature Probing Solutions selection guide (publication number 5991-3504EN) listed at the end of this document.

Figure 13. Extreme temperature probing kit.

Related Literature

Table 13. Related literature

Publication title	Publication number
Debug Automotive Serial Buses Faster – Application Note	5991-0512EN
CAN-dbc Symbolic Trigger and Decode - Application Note	5991-2847EN
CAN Eye-Diagram Mask Testing - Application Note	5991-0484EN
CAN FD Eye-Diagram Mask Testing - Application Note	5992-0437EN
Characterizing CAN Bus Arbitration - Application Note	5991-4166EN
FlexRay Physical Layer Eye-diagram Mask Testing - Application Note	5990-4923EN
SENT Automotive Sensor Physical Layer Testing – Application Note	5992-3167EN
PSI5 Sensor Serial Bus Testing - Application Note	5992-2269EN
Decoding Automotive Key Fob Communication based on Manchester-encoded ASK Modulation - Application Note	5992-2260EN
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 - Selection Guide	5968-8153EN
Extreme Temperature Probing Solutions - Data Sheet	5990-3504EN
N2792A/N2818A 200 MHz and N2793A/N2819A 800 MHz Differential Probes - Data Sheet	5990-4753EN

Ordering Information

Table 14. Automotive Software Package model numbers

InfiniiVision Series	Automotive Software Package
2000 X-Series	D2000AUTA
3000 X-Series	D3000AUTA
4000 X-Series	D4000AUTA
6000 X-Series	D6000AUTA
P9240 Series	P9240AUTB
M9240 Series	M9240AUTB

Table 15. Recommended probing solutions

Recommended probes & accessories	Model number
25 MHz differential active probe	N2791A
200 MHz differential active probe (recommended for differential CAN, CAN FD, and FlexRay buses)	N2818A
400 MHz extreme temperature 10:1 passive probe	N7007A
Extreme temperature probing kit for differential probes	N7013A
DB9 probe head adapter (for CAN, CAN FD and FlexRay buses)	0960-2926
150 MHz, 1 mA/div high-sensitivity current probe (for PSI5 measurements)	N7026A

DATA SHEET

Aero Software Package

For InfiniiVision X-Series Oscilloscopes

The Aero Software Package for Keysight's InfiniiVision oscilloscopes enables protocol triggering and decode for the MIL-STD 1553 and ARINC 429 serial buses. This package also enables other advanced analysis capabilities including eye-diagram mask testing and frequency response analysis (FRA) to help test and debug electronic systems found in the aerospace & defense industries.

KEYSIGHT TECHNOLOGIES

Table of Contents

Introduction

The primary reason engineers use oscilloscopes to debug and characterize serial buses, such as MIL-STD 1553 and ARINC 429 is because of an oscilloscope's inherent ability to characterize the analog quality of these signals. Performing analog characterization using an oscilloscope is often referred to as "physical layer" measurements. Table 1 lists the specific measurement capabilities that are enabled on each series with the Aero Software Package for Keysight Technologies InfiniiVision X-Series oscilloscopes.

Table 1. Aero Software Packages for InfiniiVision Oscilloscopes

InfiniiVision X-Series:		3000A	3000T	4000A	6000A	P9240	M9240
Aero Package Model Number:		D3000AERA	D3000AERA	D4000AERA	D6000AERA	P9240AERB	M9240AERB
Serial Trigger & Decode	MIL-STD 1553	✓	✓	✓	✓	✓	✓
	ARINC 429	✓	✓	✓	✓	✓	✓
Advanced Analysis	Mask Test	✓	✓	✓	✓	✓	✓
	Frequency Response Analysis (Bode plots)		✓	✓	✓	✓	✓
	Enhanced HDTV Video Triggering & Analysis	✓	✓	✓	✓	✓	✓
	Advanced Math	✓	Std	Std	Std	Std	Std

Although there are many oscilloscopes on the market today from multiple vendors that offer aero-focused options, Keysight's InfiniiVision X-Series oscilloscopes offer some unique measurement capabilities for debugging and characterizing the physical layer of aerospace/defense serial buses including:

- MIL-STD 1553 trigger and decode
- MIL-STD 1553 eye-diagram mask testing
- ARINC 429 trigger and decode
- ARINC 429 eye-diagram mask testing
- Dual-bus time-interleaved protocol lister display
- Hardware-based decoding for responsiveness
- Decoding of all frames captured using segmented memory

To learn more about these advanced measurement capabilities, refer to the list of Keysight aero-focused application notes listed at the end of this document.

Figure 1 shows an example of triggering on and decoding two lanes of Manchester-encoded MIL-STD 1553 bus traffic consisting of command words from the bus controller and status and data word responses from remote terminals.

Figure 1. Capturing CAN bus arbitration while decoding CAN messages symbolically.

MIL-STD 1553 Trigger and Decode

Table 2. MIL-STD 1553 Performance Characteristics

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 (downloadable mask files available at no charge)	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)

Figure 2. MIL-STD 1553 decode on an InfiniiVision X-Series oscilloscope.

ARINC 429 Trigger and Decode

Table 3. ARINC 429 Performance Characteristics

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 errors
	Total words
	100 kbps eye test
Eye-diagram and pulse mask testing (requires DSOX3MASK plus downloadable mask files)	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)

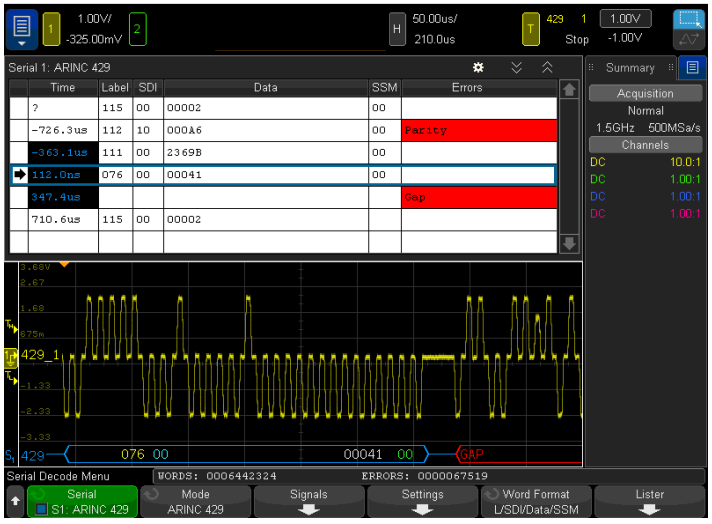


Figure 2. ARINC 429 decode on an InfiniiVision X-Series oscilloscope.

Mask Testing (pass/fail waveform limits)

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 Aero 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.

Figure 4. MIL-STD 1553 eye-diagram mask test.

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 (MIL-STD 1553 and ARINC eye-diagram and pulse-shape mask files available for download at no charge)
- Detailed pass/fail statistics
- Test to high-quality standards based on sigma
- Multiple user-selectable test criteria

Table 4. 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 Aero 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.

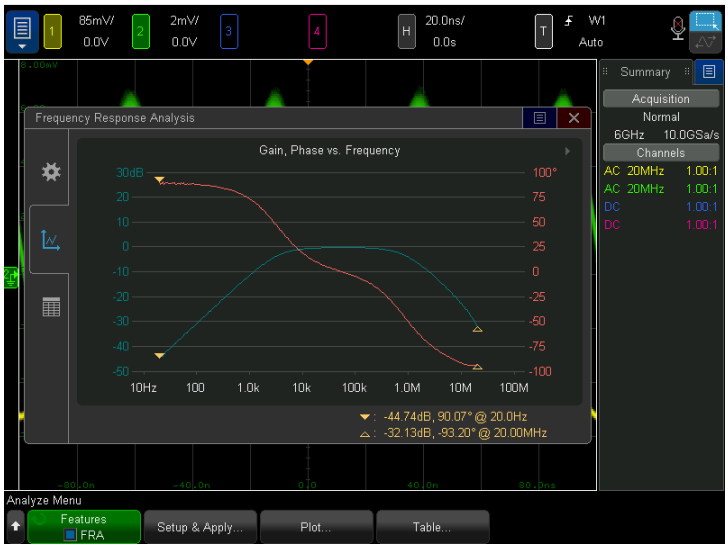


Figure 5. Frequency response analysis (gain & phase) on a bandpass filter.

- 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

Table 5. 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

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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 6. 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 Aero 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 Aero Software Package 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

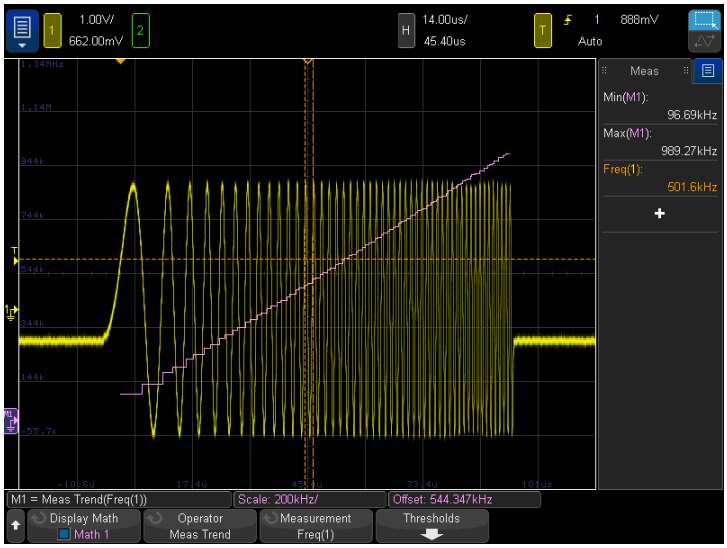

Figure 10. Measurement trend math function used to plot frequency versus time of a FM burst.

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

Table of Contents

Introduction

The primary reason engineers use oscilloscopes to debug and characterize embedded serial buses, such as I^2C, 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 & 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 Series:	**2000A**	**3000A**	**3000T**	**4000A**	**6000A**	**P9240**	**M9240**
	Embedded Software Package Model Number:	D2000GENA	D3000GENA	D3000GENA	D4000GENA	D6000GENA	P9240GENB	M9240GENB
Serial Trigger & Decode	I^2C	✓	✓	✓	✓	✓	✓	✓
	SPI	✓	✓	✓	✓	✓		
	UART (RS-232/485)	✓	✓	✓	✓	✓	✓	✓
	I^2S (Audio)		✓	✓	✓	✓		
	USB-PD			✓	✓	✓	✓	✓
Advanced Analysis	Mask 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.

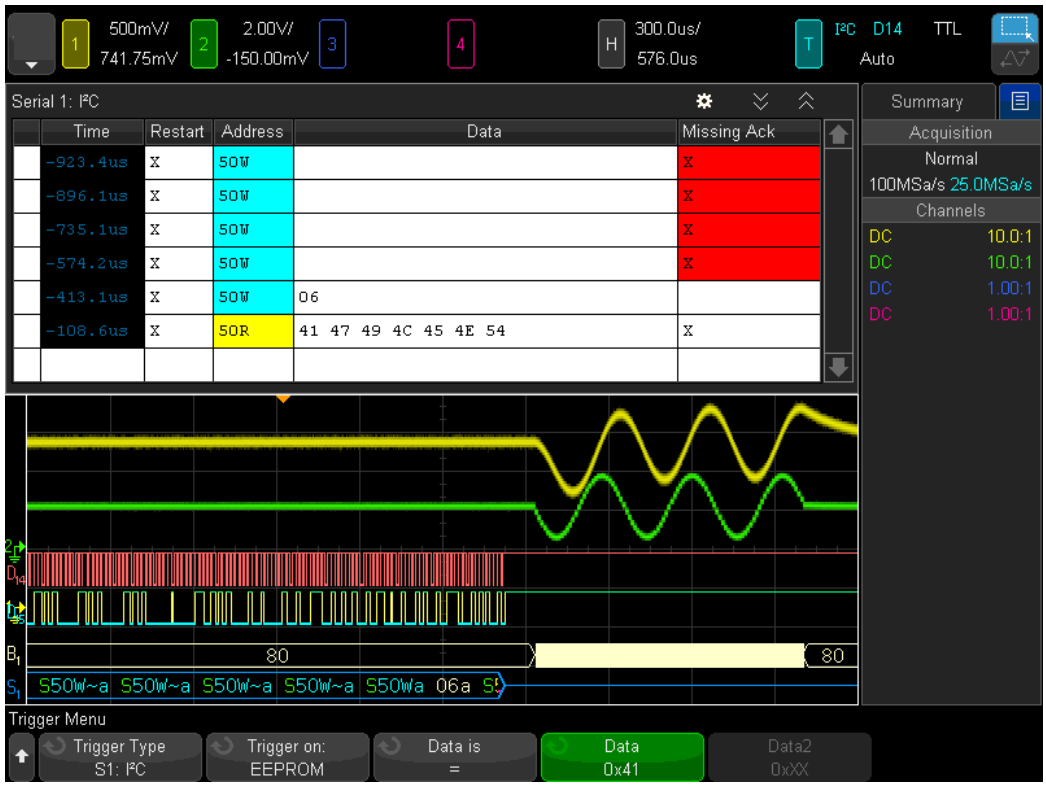

Figure 1. Decoding and triggering on an I²C bus using a Keysight mixed signal oscilloscope (MSO) licensed with the Embedded Software Package.

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)

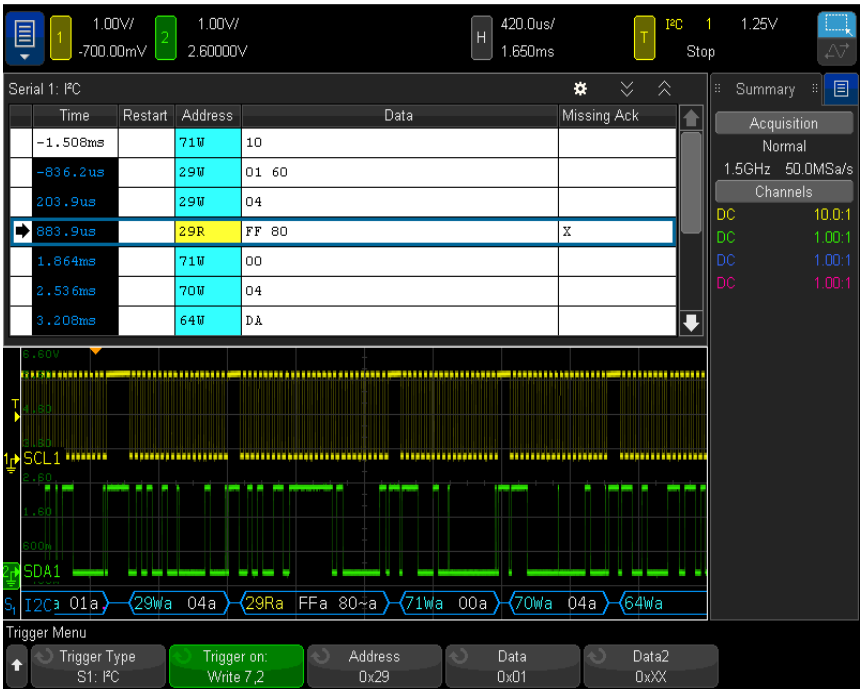

Figure 2. I²C decode on an InfiniiVision X-Series oscilloscope.

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)

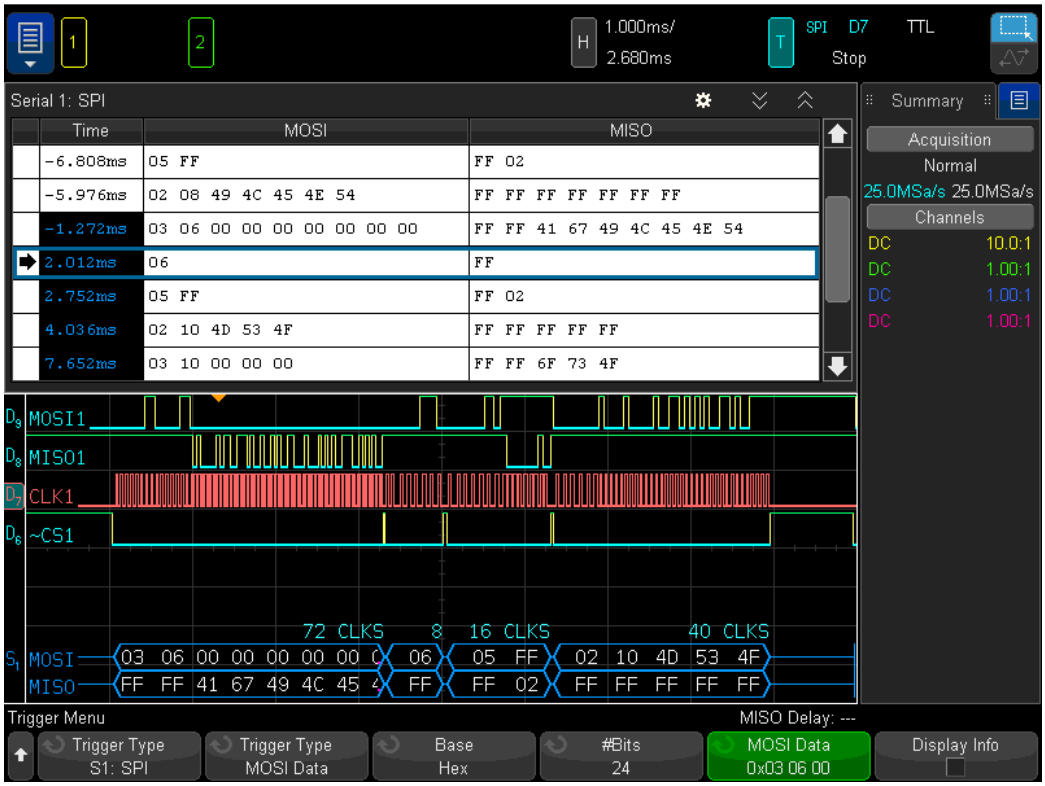

Figure 3. SPI decode on an InfiniiVision X-Series oscilloscope.

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

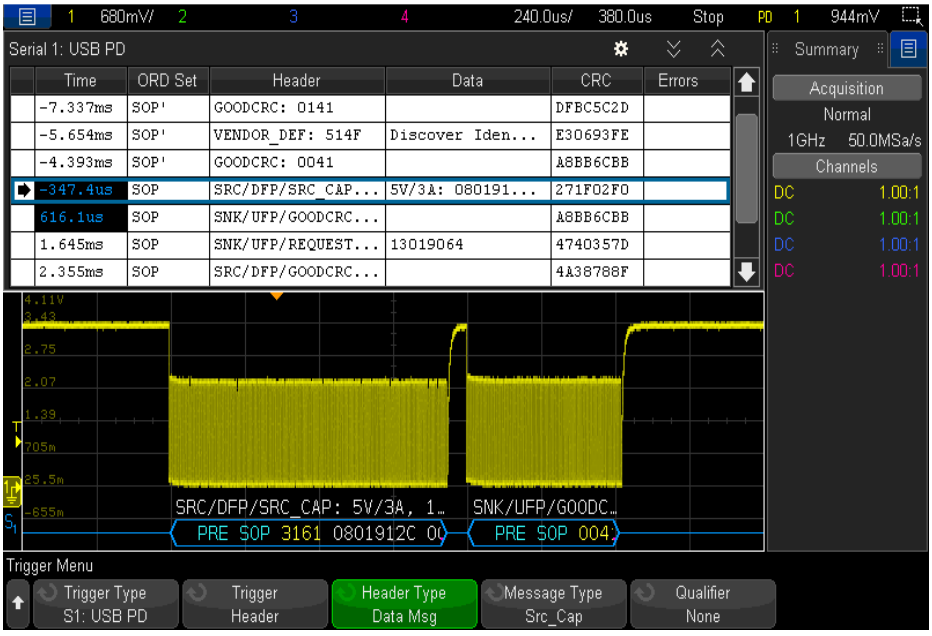

Figure 6. USB PD decode on an InfiniiVision X-Series

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.

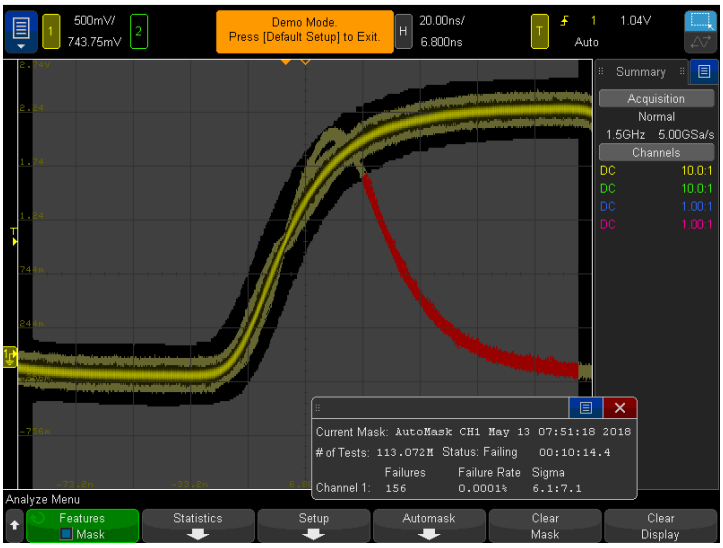

Figure 7. Frequency response of a bandpass filter.

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

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.

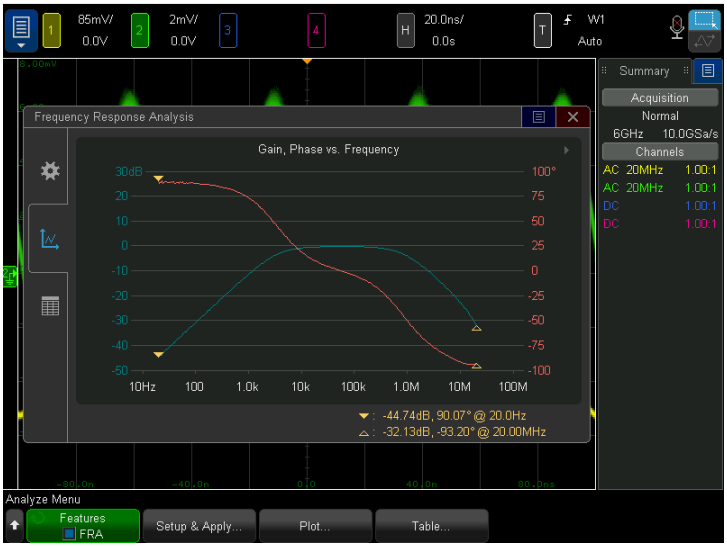

Figure 8. Frequency response analysis (gain & phase) on a bandpass filter.

- 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

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	

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Figure 9. Triggering on 1080p HDTV.

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- 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.