High Resolution Oscilloscope Guide 2024

12-bit

Every Bench. Every Engineer. Every Day.

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Key Specifications

When comparing oscilloscopes or determining their value in a given application, there are a few top-level specifications that usually come up:

- **Sampling Rate**
- **Resolution**
- **Memory**
- **Bandwidth/filtering**

These 4 specifications actually work together in a number of ways that create tradeoffs and capability for a number of applications. Let's look at what they each mean and how they interact in common use cases.

Sampling Rate

Sampling rate and sampling precision affect analysis and measurements of time and frequency. We measure this in GSa/sec. This is especially true for frequency measurements made by FFT.

One downside is that higher frequency sampling will capture and display higher bandwidth noise. This is also true of higher actual bandwidth.

What sampling do we typically see in High-Resolution scopes? There are a wide range of 10 and 12 bit oscilloscopes available on the market. Start by selecting an oscilloscope with at least **2.5 times the frequency** you want to measure or analyze. Many oscilloscopes' sampling can change with the number of active channels.

As we will see, having extra oversampling capability can be very important to signal analysis because it allows the engineer flexibility in bandwidth and filtering to optimize their signal fidelity.

Series	Max Sampling	Max 4 channel Sampling
SDS800X HD	2 GSamples/sec	500 MSamples/sec
SDS1000X HD	2 GSamples/sec	500 MSamples/sec
SDS2000X HD	2 GSamples/sec	1 GSamples/sec
SDS3000X HD	4 GSamples/sec	2 GSamples/sec
SDS7000A H12	20 GSamples/sec	10 GSamples/sec

Resolution

True Resolution is equivalent to the number of bits captured by the ADC for each sample. Additional bits of resolution are often discussed as a result of filtering or averaging. But we need to start with true resolution.

Quantization error is the voltage difference between consecutive values on the A2D itself. Each additional bit drops the quantization error in half. Everything else being equal, a 12-bit ADC has a quantization error of 1/16th of an 8 bit ADC. As we will see though, if you design an oscilloscope for signal fidelity everything else isn't equal.

Full Scale	Smallest Voltage Step	
	8-bit	12-bit
80 V	312.5 mV	19.5 mV
40 V	156.2 mV	9.76 mV
20 V	78.1 mV	4.88 mV
8 V	31.3 mV	1.95 mV
4 V	15.6 mV	976 µV

From a specification perspective, the quantization is typically rolled into the offset error for a given scope range.

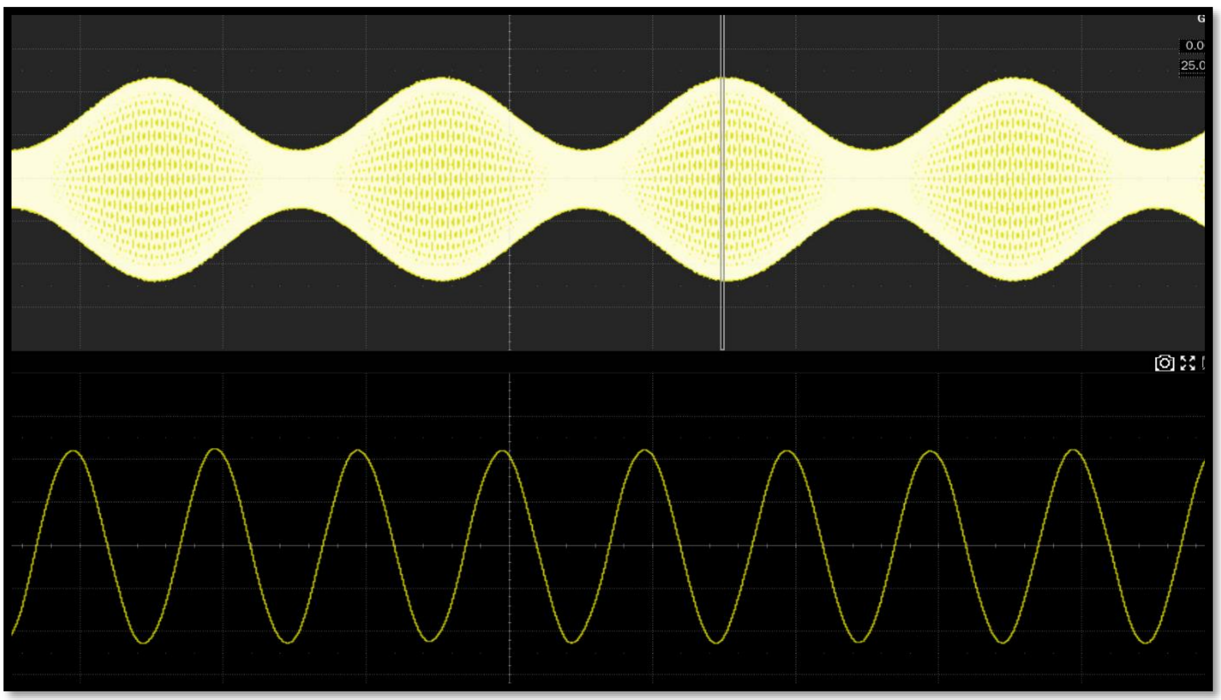
Memory Depth

Memory, Bandwidth, and filtering are specifications that work with sample rate and resolution to create opportunities and tradeoffs.

First, memory and sampling work together to bound the longest time that can be captured with maximum sampling and bandwidth.

For instance, an oscilloscope like the SDS7000A with up to 1 billion points of memory can capture a channel at 20 GSa/sec for 50 ms total.

This means you can set the horizontal to 5 ms/div and still fully capture the 4 GHz signal. This is useful for slow developing signals or rare signal artifacts. The SDS7000A can then zoom in millions of times to view fast signal artifacts in context.



Bandwidth/filtering

Most applications, even for performance scopes, don't require max bandwidth for most measurements. This is where the memory can be used flexibly and purposed specifically to the application.

This is effectively a type of boxcar filtering where combining consecutive samples in groups allows us to further reduce the quantization error by estimating voltage levels between actual bits. This ability to optimize is dramatically reduced if the scope starts out short on memory or sample rate.

These tradeoffs create opportunities to improve and optimize noise and ultimately signal fidelity within a smaller bandwidth. Using this method, effectively reduces the bandwidth along with the sampling reduction.

Here is an example of the filtering options available on the SDS7404A. Exceptionally deep memory means that even when consuming a number of samples to generate a single filtered data point, the instrument can still capture long enough events for debug and analysis.

Model	Full BW (GHz)	Channels in use	Actual Sampling (GSa/s)	ERES Mode (bits)	Effective Nyquist Bandwidth (MHz)(typ)	Total Bit Resolution	Noise (uVrms AC) 50 Ohm load
SDS7404A	4	1 or 2	20	0	4000	12	220
				0.5	4000	12.5	201
				1	2300	13	148
				1.5	1100	13.5	94
				2	560	14	69
				2.5	280	14.5	52
				3	140	15	42
				3.5	70	15.5	35
				4	34	16	28

Make sure to understand the tradeoffs and requirements for memory, sampling, and bandwidth in the application.

Key Design Features

Overall design quality is more important to the actual signal fidelity than just the number of bits on the analog to digital converter. There are 3 key facets of design for signal fidelity where SIGLENT's high resolution oscilloscopes excel:

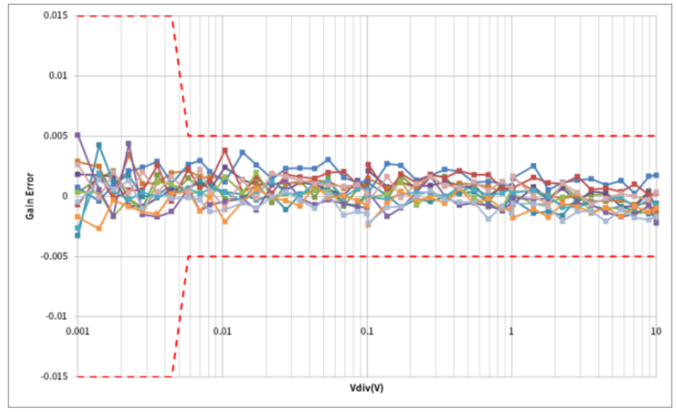
- **Noise**
- **Gain Accuracy**
- **Isolation**

Noise

Low noise design starts with component selection, EMI, and power cleanliness in the front end. Noise increases with bandwidth and sampling rate. An oscilloscope's noise can be characterized by range, bandwidth, and configuration. It's important to start with good performance at full bandwidth and sampling, but then as we saw in the SDS7000A table above, the noise can be optimized by trading off bandwidth and sampling via filtering. SIGLENT oscilloscopes have an additional channel independent hardware bandwidth limit filter that can further address noise. In some tests, these limits are more effective than filtering. In this excerpt from the SDS7000A table with an additional line, we see that the BW limit eliminates more noise than the step beyond it in filtering:

Setup	Bandwidth (MHz)	µVrms Noise
ERES 2.5 bits	280	52
2.5 ERES bits + BW Limit 200 MHz	200	38
ERES 3 bits	140	42

Gain Accuracy



0.5% DC gain accuracy

Measurement precision requires careful design and innovation throughout the instrument. DC Gain Accuracy is an important component of precision that defines the error in a measurement as the signal moves further away from ground. SIGLENT's HD Oscilloscopes improve upon gain accuracy beyond competitive oscilloscopes. This makes it possible to accurately visualize signals even as they ride on top of other signals or voltage levels. This is critical to expanded scale offsets which is an important visualization tool.

Compare SIGLENT Oscilloscopes to the specifications for competitive midrange and performance oscilloscopes:

Brand	Series	Range	DC Gain Accuracy
SIGLENT	**All X HD Scopes**	**≥5mV/div**	**0.5%**
R & S	RTB2000	>5mV/div	1.5%
Keysight	MSOX2000A	≥10mV/div	3%
Tektronix	MSO 2 Series	all	3%
SIGLENT	**SDS7000A**	**≥5mV/div**	**0.5%**
Tek	MSO64B	≥2mV/div	1%
Keysight	EXR	all	1%
R & S	RTO2000	≥5mV/div	1.5%

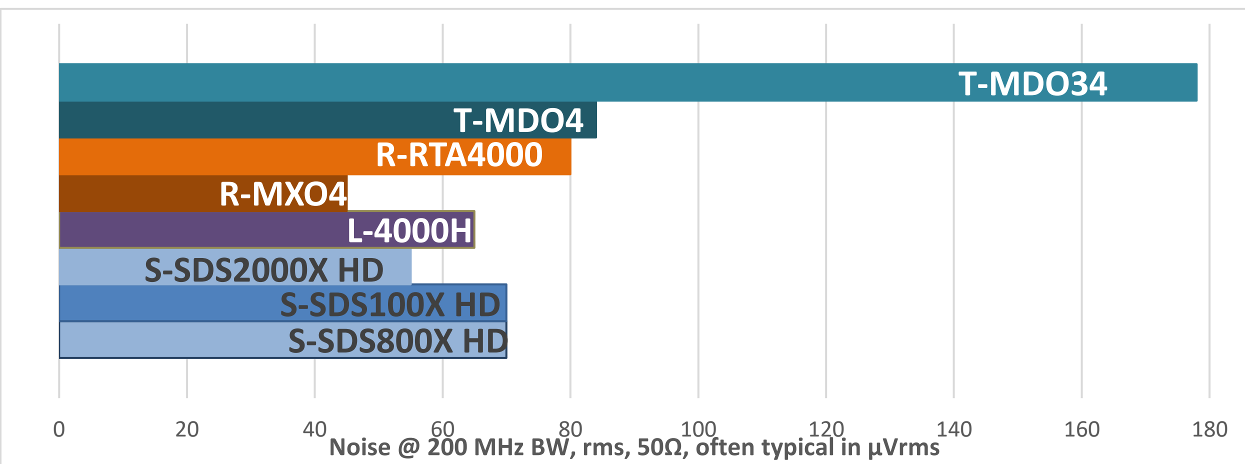
Isolation

Isolation - often expressed as a ratio. This is the error injected to our signal from another channel's signal path. This is largely related to layout, part quality, and EMI design considerations. It can be important to look out for oscilloscopes with surprisingly low isolation as this may also leave them susceptible to other coupling or noise sources.

	High-Res Competitor	SDS2000X HD
Channel isolation	>100:1,< 500 MHz	>1000:1, < 500 MHz > 3000:1, < 350 MHz

Improved isolation, gain accuracy, and noise performance work together to provide a high signal fidelity platform for measurements and analysis of signals.

Design for Signal Quality



SIGLENT's design for signal quality means we have some of the most accurate high-resolution scopes on the market. When compared to brand label high resolution scopes (per their datasheets above), our overall accuracy is very competitive. When compared to 8 bit oscilloscopes or value high resolution models, SIGLENT demonstrates exceptional accuracy and signal fidelity.

Visualization Tools

Many oscilloscope applications focus on signal visualization for verification. The tools and capabilities provided to improve the visual experience of an oscilloscope are some of the most important for engineers. Three key visualization tools that are improved by SIGLENT's high resolution design are:

- **Vertical Zoom**
- **Scale Offset**
- **FFT**

Vertical Zoom

While all modern scopes have zoom capability, not all have a powerful vertical zoom. With high resolution and a good design, signal artifacts can be discovered in less than 0.1% of the capturing range. The zoom window (bottom half) shows a 20X zoom on the vertical scale for a small section of the time base.

Scale Offset

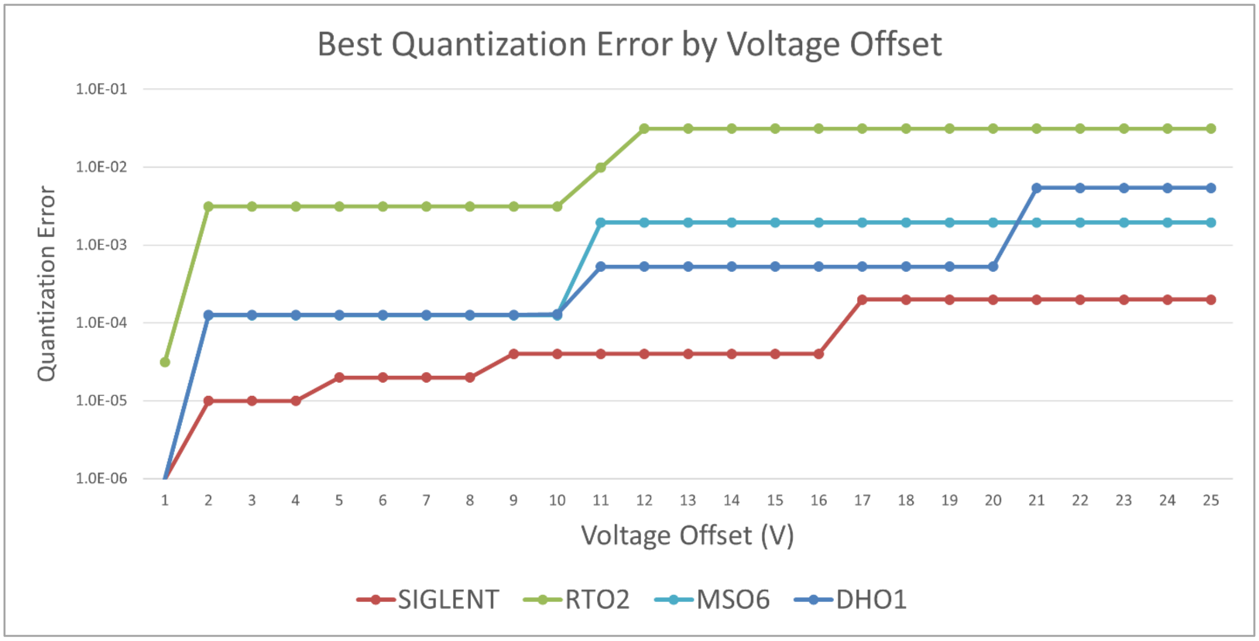
Wider offset capabilities are important as they allow engineers to get more out of the high resolution by using a smaller range to visualize a signal away from ground. This reduces quantization noise, improving zoom function.

Remember 8 to 12 bits is a 16X decrease in quantization error. In many cases, SIGLENT's wider range allows for 8X the offset meaning that when testing applications like evaluating a small signal riding on a larger signal, scale offset can be as valuable as 3 extra bits of resolution.

SIGLENT High-Res Scopes ≤ 1 GHz		RIGOL DS70000	
1 MΩ:	0.5 mV/div ~ 5 mV/div: ±1.6 V; 5.1 mV/div ~ 10 mV/div: ±4 V; 10.2 mV/div ~ 20 mV/div: ±8 V; 20.5 mV/div ~ 100 mV/div: ±16 V; 102 mV/div ~ 200 mV/div: ±80 V; 205 mV/div ~ 1 V/div: ±160 V; 1.02 V/div ~ 10 V/div: ±400 V	1 MΩ:	1 mV/div ~ 50 mV/div: ±1 V; 51 mV/div ~ 260 mV/div: ±30 V; 265 mV/div ~ 10 V/div: ±100 V;
50 Ω:	0.5 mV/div ~ 5 mV/div: ±1.6V; 5.1 mV/div ~ 10 mV/div: ±4 V; 10.2 mV/div ~ 20 mV/div: ±8 V; 20.5 mV/div ~ 1 V/div: ±10 V	50 Ω:	1 mV/div ~ 100 mV/div: ±1 V; 102 mV/div ~ 1 V/div: ±4 V;

R&S RTO2000		Tek MSO6	
1 MΩ:	1 mV/div ~ 31.6 mV/div : ±1 V; 31.6 mV/div ~ 100 mV/div: ±1.15 V; 100 mV/div ~ 316 mV/div: ±10 V; 316 mV/div ~ 1 V/div: ±11.5 V; 1 V/div ~ 3.16 V/div: ±100 V; 3.16 V/div ~ 10 V/div: ±115 V	1 MΩ:	0.5 mV/div ~63 mV/div: ±1 V; 64 mV/div ~ 999 mV/div: ±10 V; 1 V/div ~ 10 V/div: ±100 V;
50 Ω:	1 mV/div ~ 100 mV/div: ±1 V; 100 mV/div ~ 316 mV/div: ±3 V; 316 mV/div ~ 1 V/div: ±10 V;	50 Ω:	1 mV/div ~ 99 mV/div: ±1 V; 100 mV/div ~ 1 V/div: ±10 V;

With more ranges and more range offset capability, SIGLENT scopes can utilize lower ranges for more signals, further improving usability of the noise and resolution. See how the SIGLENT lowers quantization error when measuring signals offset nd:



At many offset voltages, SIGLENT's range is 10x better for small signal capture than competitive oscilloscopes.

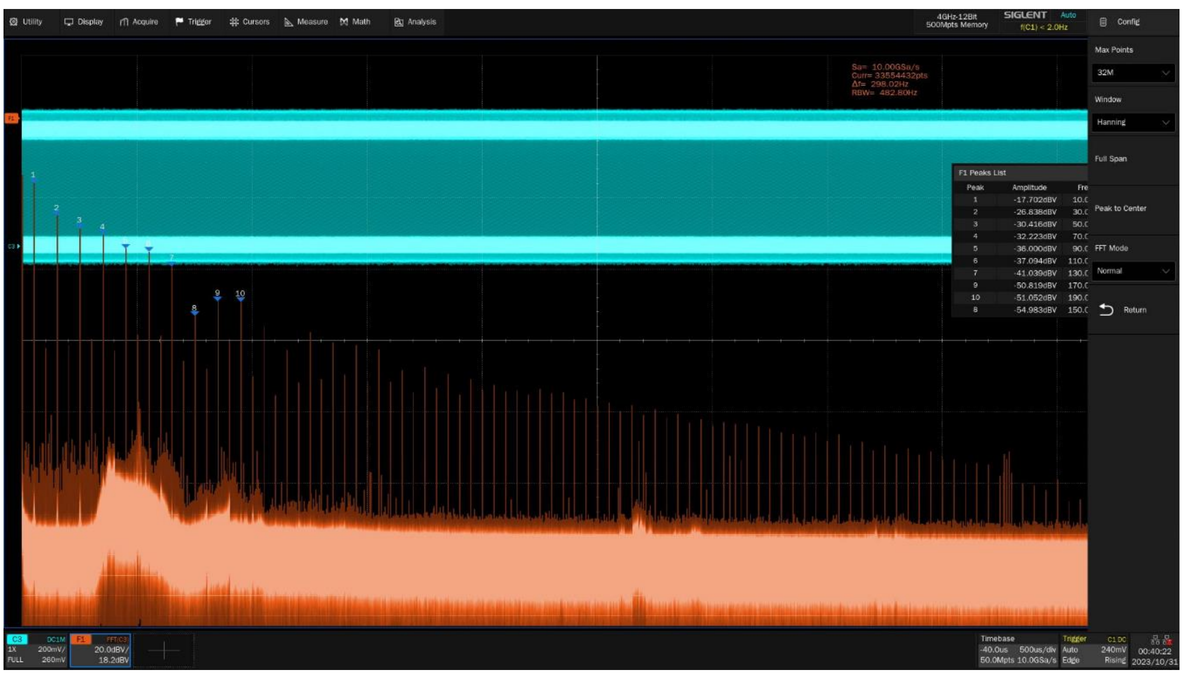
The combination of vertical zoom and robust scaling on the front end provides excellent flexibility in usability and visualization for a wide range of signals.

FFT Quality

The combination of high resolution and excellent design quality has a large impact on RF measurements as well. Visualizing signals using the FFT is improved by these factors and is important in many mixed domain, EMI, and analysis applications.

SIGLENT high-resoultion oscilloscopes offer up to 32 Mpts of 12 bit data in the FFT.

For instance, you can set up a 100 MHz span with 4 MPt that has a 386 Hz RBW. With the full 32 MPts you can produce a 1 GHz span with 482 Hz RBW and a sample rate of 10 GSa/sec. This creates frequency points less than 300 Hz apart across that span:



Combine this with markers, peak readings, and scaling tools to capture signals equivalent to a wideband Real-Time Spectrum Analyzer that you can correlate with your other time domain signals.

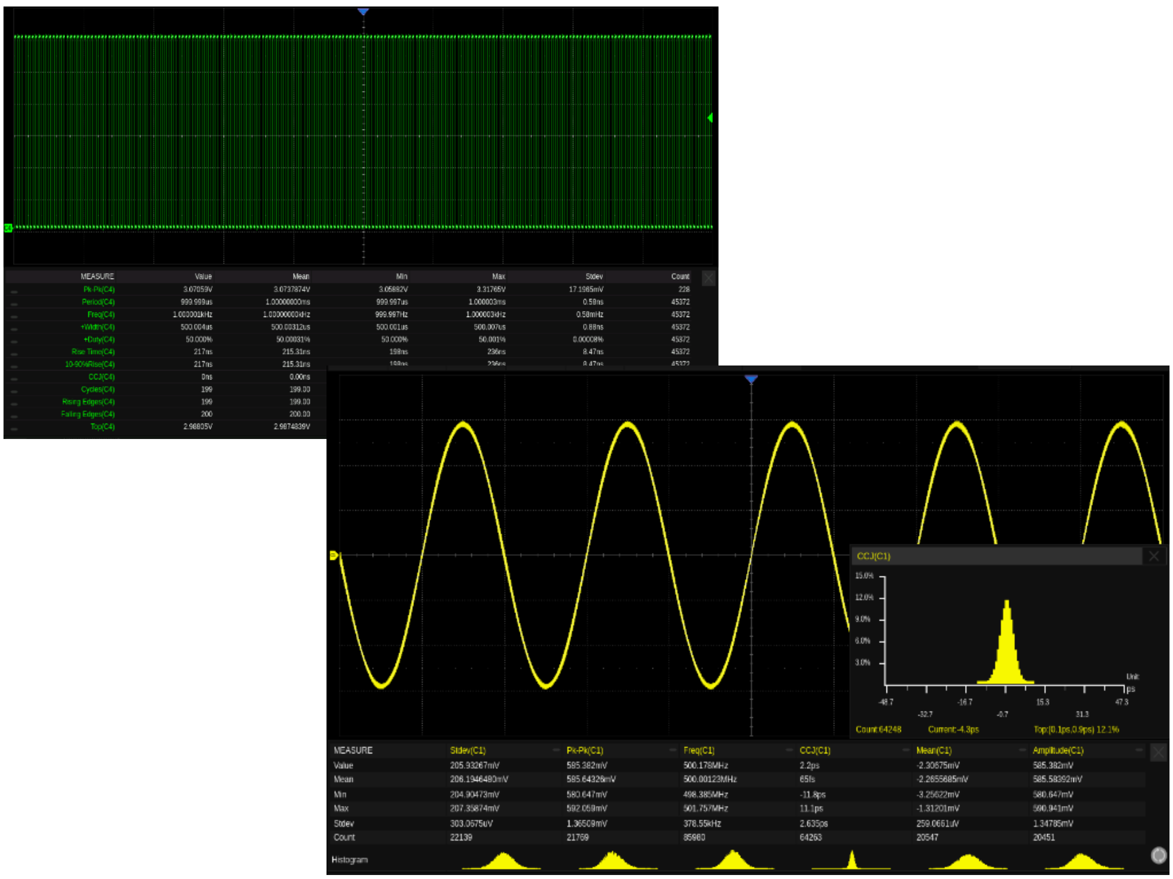
Isolation is critical in these applications as well since RF signals are especially good at creating crosstalk on adjacent channels.

Analysis Tools

Many oscilloscope applications require advanced statistical analysis. Increased resolution and a design for signal quality make these tools even more productive.

Histogram & Statistical Measurements

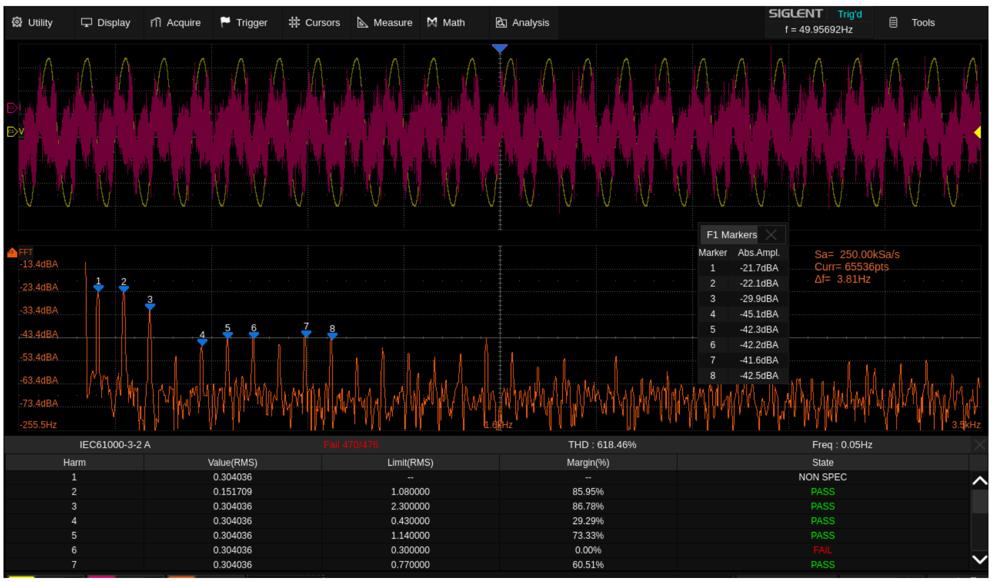
View more than 50 measurements of channel data or view multiple histograms for additional debugging and analysis:



Power Analysis

Power Analysis is used to verify and debug power supply designs. Using a combination of FFTs and arithmetic functions on current and voltage readings, important aspects of a power design can be analyzed including safe operating area, harmonics, ripple, inrush current, and more.

Low noise, isolation, filtering, and FFT quality all have an important impact on these measurements.



Use the **DF2001A** deskew fixture to simplify setup.

All SIGLENT high resolution oscilloscopes can conduct power analysis, but select for advanced ERES filtering capabilities and automatic probe interfaces on the SDS3000X HD or SDS7000A series.

Serial Decode

Serial bus decoding is important for design and debug of many electronics including IoT systems. Analyzing RF and analog signals together is the best way to determine root cause and improve firmware or hardware operation. This type of mixed domain analysis is an important application for high resolution oscilloscopes.

All SIGLENT high resolution oscilloscopes offer:

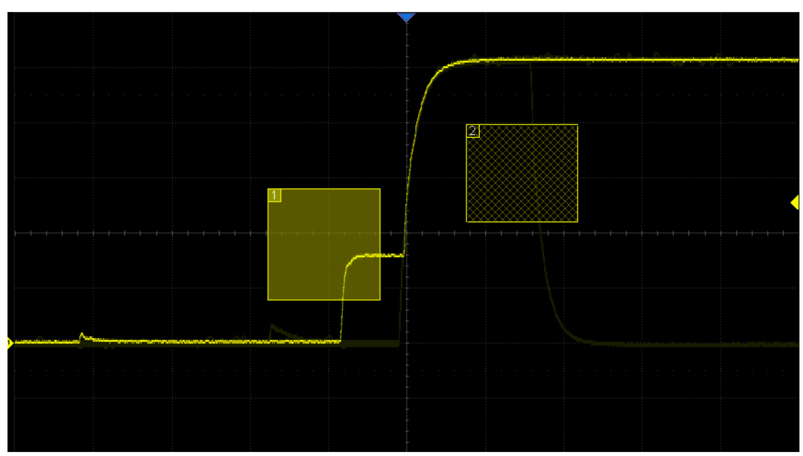
I2C, SPI, UART, CAN, LIN

Advanced models also offer:

CAN FD, FlexRay, I2S, MIL-STD-1553B, SENT, Manchester, ARINC429, and USB2.0

Zone Trigger

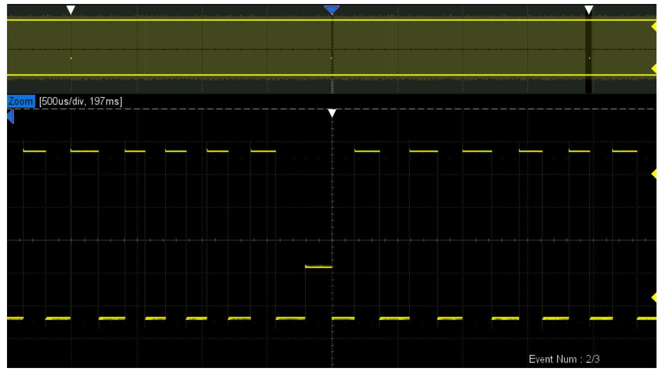
On the SDS2000X HD, SDS3000X HD and SDS7000X HD add visual zone triggering to traditional triggering options. Utilize zone triggering to identify infrequent or unusual events or combinations of events for complex debugging challenges.

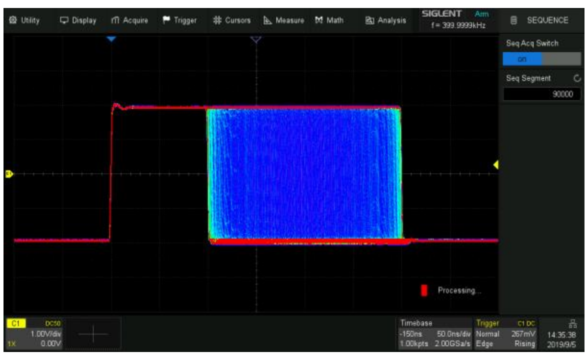


Additional debugging capabilities include methods to search through captured signals for anomalies and ultimately find root cause.

Search & Navigate

Search and mark events, then navigate by time or frames to review on screen.





Split the memory into segments and review these sequences of trigger events using **Sequence mode** and combine this with temperature display mode, zone trigger, and persistence views.

Or use the **history mode** to automatically capture and allow playback of waveforms to locate signals of interest over time.

Search Analysis Capabilities for SIGLENT High Resolution Oscilloscopes:

Series	History or sequence frames	Sequence minimum interval
SDS800X HD	80,000	2 µsec
SDS1000X HD	80,000	2 µsec
SDS2000X HD	80,000	2 µsec
SDS3000X HD	80,000	1.2 µsec
SDS7000A H12	124,000	0.9 µsec

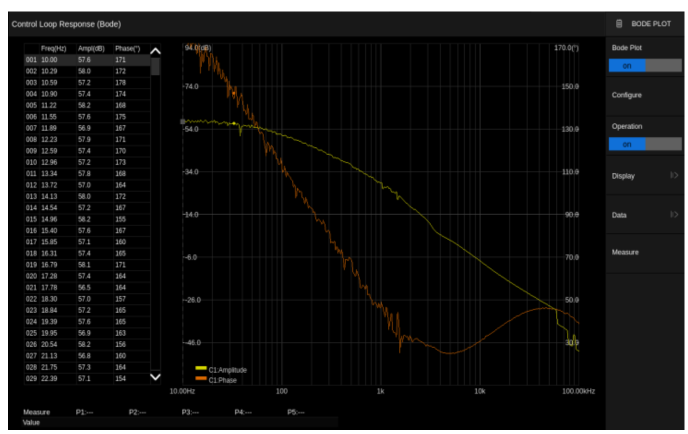
Bode Plot Analysis

Frequency Analysis is a specialized application for devices like amplifiers, filters, and attenuators that graphs gain and phase relationship changes over frequency on a bode plot. This is an example of RF or high-speed device testing that is an important capability for high resolution oscilloscopes.

Frequency analysis benefits from improved signal quality for accuracy in gain measurements as well as sampling and resolution to monitor phase changes. With multiple channels and an automated test sequence, isolation and range optimization are also important.

Power supply loop response is a popular test using this configuration.

All SIGLENT high resolution oscilloscopes can conduct bode plot analysis, but select for 50 Ohm capabilities, embedded or separate generators, and display size.



Advanced Communication Analysis with the SDS7000A Series

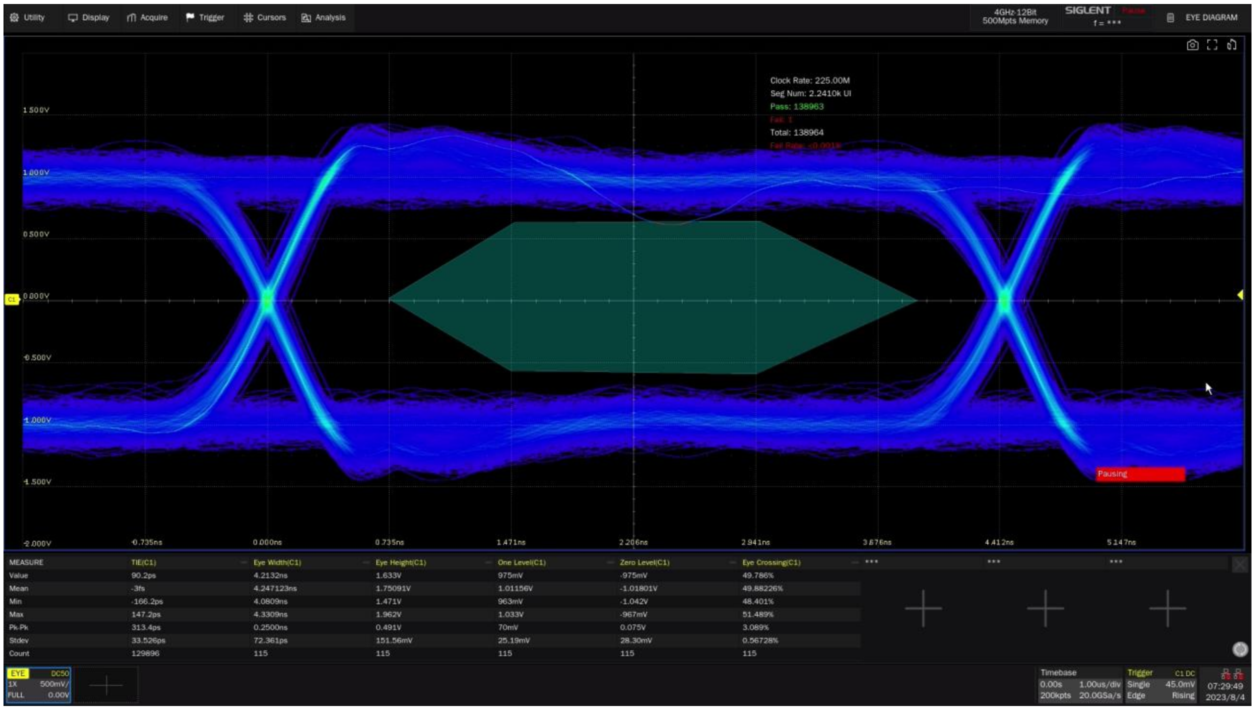
Jitter Analysis & Real Time Eye Diagrams

Take analysis even further with applications packages that utilize the histogram and deep memory capabilities of the **SDS7000A series** including Jitter and Real Time Eye:

The Jitter toolkit includes multiple views for analyzing random, deterministic, period jitter, and more. Combine histograms, trends, and spectrum views for signals of interest. The bathtub display is an important view for jitter decomposition.

High sample rate and deep memory enable accurate characterization of frequency changes within the clock signal with enough signal fidelity to debug and analyze the underlying statistics.

![SIGLENT®]



Real Time Eye visualizes communication signals with bandwidth, noise, and jitter. It includes eye measurements as well as custom mask settings. Deep memory is folded over into frames within the eye diagram to generate statistical data for these communication signals.

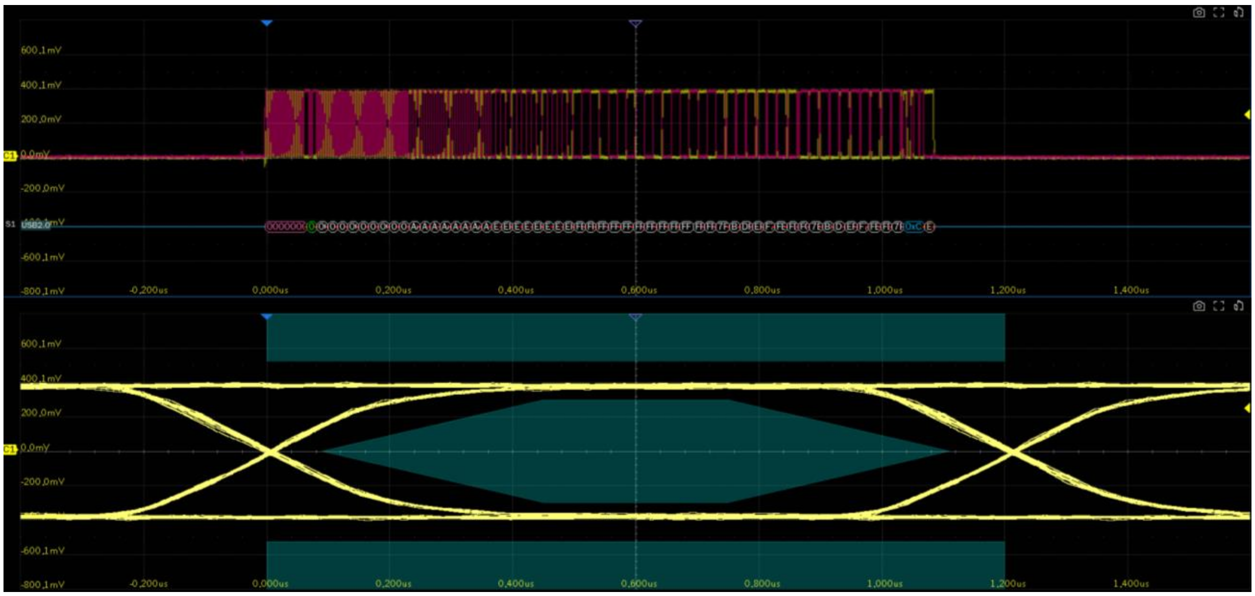
Jitter and Real-Time Eye are available in the **SDS7000A-EJ** option.

Custom mask testing is a hardware function available on all SIGLENT high resolution oscilloscopes, but is especially useful in eye diagram testing on the SDS7000A.

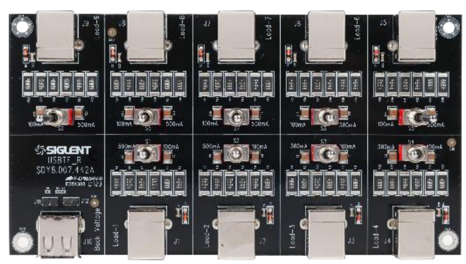
Compliance Packages

Also available on the SDS7000A series are compliance packages for USB 2.0, 100Base-TX, 1000Base-T, 100Base-T1, and 1000Base-T1.

These are automated test that work with an accessory fixture to complete the test and generate a report that can be viewed or archived.



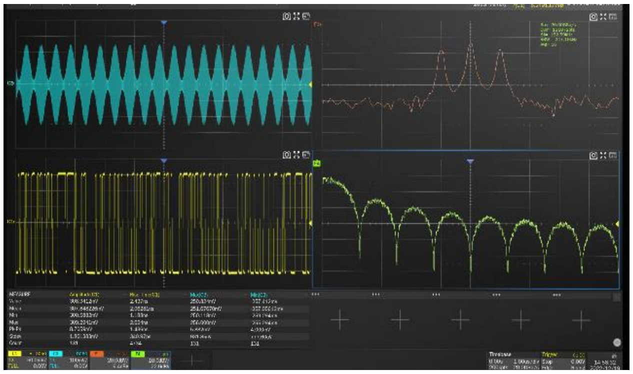
Fixtures:



Model	Description
FX-USB2	USB 2.0 test fixture
FX-ETH	100Base-TX & 1000Base-T compliance test fixture
FX-AMETH	100Base-T1 & 1000Base-T1 compliance test fixture

High Resolution Key Applications

Mixed Domain Debugging

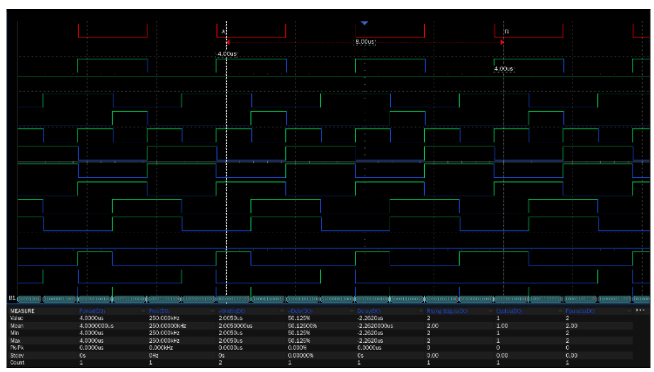


Compare digital, analog, and RF signals to find the root cause of an issue on the first try.

Utilize decoding, FFT quality, window views, and SIGLENT design for signal quality to quickly debug complex IoT devices and systems.

Logic Analysis

Add *Logic Analysis* to any SIGLENT high resolution oscilloscope to analyze 16 channels of digital signals alongside the analog channels by adding one of the logic probes and the 16LA option license:



Series	Logic Probe	Max Memory	Max Sampling
SDS800X HD	SLA1016	10 MPts/ch	1 GSa/sec
SDS1000X HD	SLA1016	10 MPts/ch	1 GSa/sec
SDS2000X HD	SPL2016	50 MPts/ch	500 MSa/sec
SDS3000X HD	SPL2016	100 MPts/ch	1 GSa/sec
SDS7000A H12	SPL2016	100 MPts/ch	1 GSa/sec

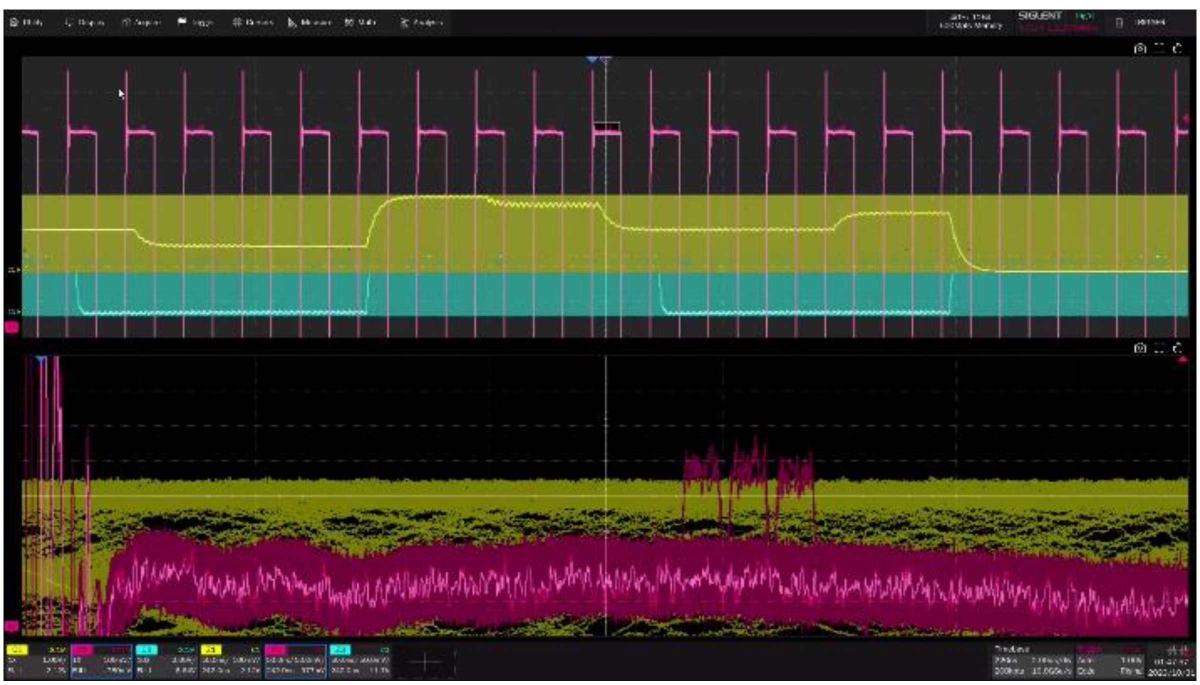
Signal on Signal Analysis

Capture and analyze small signals with precision and accuracy even in the presence of larger signals or offsets.

EMI, isolation, and other signal fidelity challenges can cause design and reliability problems.

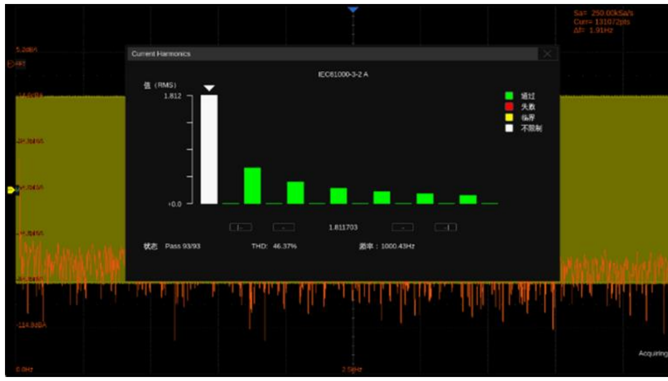
Quickly identify and resolve issues with SIGLENT's design for quality that provides a low noise environment with visualization tools to debug on the fly.

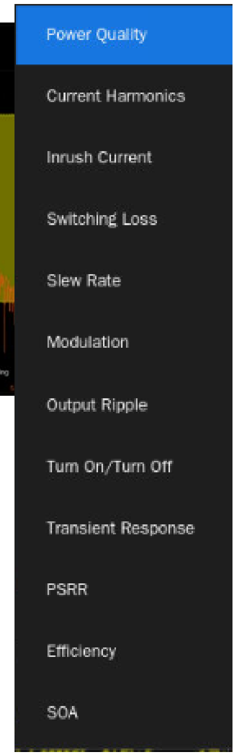
This image shows a small aberrant pulse train on top of large square wave with overshoot making it difficult to trigger on. Dynamic ranges and vertical zoom work together with persistence modes to make this signal easy to capture.



Power Supply Design Testing

Power supply design challenges require complex and accurate signal analysis.



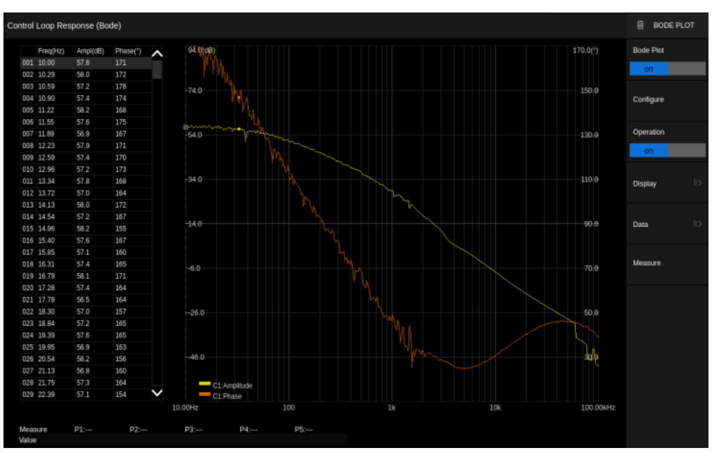


Utilize the visualization tools, probe options, and power analysis toolkit to characterize the complete power system with high resolution and improved signal fidelity.

New SCP5000 series current probes are powered directly from the probe interface on the SDS3000X HD or SDS7000A oscilloscopes.

Frequency Analysis

Bode plot analysis characterizes how devices operate across frequency. Enable this advanced function by adding an external waveform



generator or enabling a built-in generator along with the FG option license depending on the oscilloscope model. Accurate measurements across frequency extends the value of a bench top oscilloscope with added automation and capabilities.

SIGLENT High Resolution Comparison Chart

Specifications	 SDS800X HD	 SDS1000X HD	 SDS3000X HD	 SDS7000A
Bandwidth	70-100 MHz	100-200 MHz	350 MHz – 1 GHz	3-4 GHz
Vertical resolution	12 bits			
ERES bits			+4 bits	+4 bits
Analog channels	2-4	2-4	4	4
Max sample rate	2 GSa/sec	2 GSa/sec	4 GSa/sec	20 GSa/sec
All channels max sample rate	500 MSa/sec	500 MSa/sec	2 GSa/sec	10 GSa/sec
Max Memory depth	50 Mpts	100 Mpts	400 Mpts	500 Mpts (1Gpts opt)
Normal Waveform capture rate	80,000	120,000	200,000	1,000,000
Impedance	1 MΩ	1 MΩ and 50 Ω	1 MΩ and 50 Ω	1 MΩ and 50 Ω
Noise Floor (uVrms) (typ)	70 uVrms @ 200 MHz	70 uVrms @ 200 MHz	125 uVrms @ 1 GHz	220 uVrms @ 4 GHz
ENOB (typ)	8.4	8.4	8.2	7.3
Touchscreen size	7”	10.1”	10.1”	15.6”
Isolation	>40dB	>40dB	50 dB up to 500 MHz	60 dB up to 500 MHz
Zone Trigger			Supported	Supported
Serial Decode	I2C, SPI, UART, CAN, LIN	I2C, SPI, UART, CAN, LIN	I2C, SPI, UART, CAN, LIN options: CAN FD, FlexRay, I2S, MIL-STD-1553B, SENT, Manchester, ARINC429	I2C, SPI, UART, CAN, LIN options: CAN FD, FlexRay, I2S, MIL-STD-1553B, SENT, Manchester, ARINC429, USB 2.0
Sequence segments	80,000 with 2 us dead time	80,000 with 2 us dead time	80,000 with 1.2 us dead time	124,000 with 0.9 us dead time
History Frames	80,000	80,000	80,000	124,000
Max FFT Depth	2 Mpts	2 Mpts	4 Mpts	32 Mpts
Video Output				HDMI, DisplayPort
Probe Support	passive	auto recognize passive	All	All

Resource & Document Links

Scope Family Documents

SDS800X HD Series Web Page

SDS800X HD Series Manuals

SDS1000X HD Series Web Page

SDS1000X HD Series Manuals

SDS3000X HD Series Web Page

SDS3000X HD Series Manuals

Additional Documents

Probe Datasheet

Signal Fidelity Webinar Video

Webinar video focused on the SDS7000A Series

Oscilloscope Usage Tips

Configuring Network Drives

Connecting to Wireless Networks

SIGLENT®

About SIGLENT

SIGLENT is an international high-tech company, concentrating on R&D, sales, production and services of electronic test & measurement instruments.

SIGLENT first began developing digital oscilloscopes independently in 2002. After more than a decade of continuous development, SIGLENT has extended its product line to include digital oscilloscopes, isolated handheld oscilloscopes, function/arbitrary waveform generators, RF/MW signal generators, spectrum analyzers, vector network analyzers, digital multimeters, DC power supplies, electronic loads and other general purpose test instrumentation. Since its first oscilloscope was launched in 2005, SIGLENT has become the fastest growing manufacturer of digital oscilloscopes. We firmly believe that today SIGLENT is the best value in electronic test & measurement.

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