Keysight Technologies
Evaluating Oscilloscope Signal Integrity

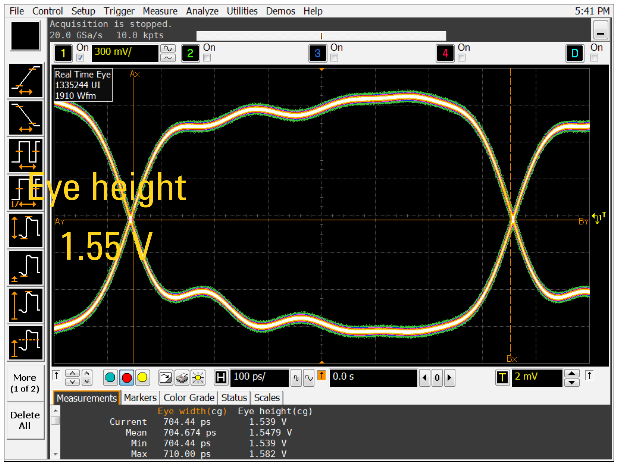
Application Note

KEYSIGHT TECHNOLOGIES

Introduction

The term “signal integrity” surfaces regularly in electronic test. Signal integrity is the primary measure of signal quality, and signal integrity importance increases with bandwidth, the need to view small signals, or the need to see small changes on larger signals. Why does oscilloscope signal integrity matter? Signal integrity impacts all scope measurements. The amount of impact signal integrity can make on signal shape and measurement values might surprise you. Oscilloscopes themselves are subject to the signal integrity challenges of distortion, noise, and loss. Scopes with superior signal integrity attributes provide a better representation of signals under test, while scopes with poor signal integrity attributes show a poorer representation of signals under test. This difference impacts engineers’ ability to gain insight, understand, debug, and characterize designs. Results from oscilloscopes with poor signal integrity can increase risk in development cycles times, production quality, and components chosen. To minimize this risk, it is a good idea to evaluate and choose an oscilloscope that has high signal integrity attributes.

Infiniium DSO9404A (4 GHz)



Infiniium DSOS404A (4 GHz)

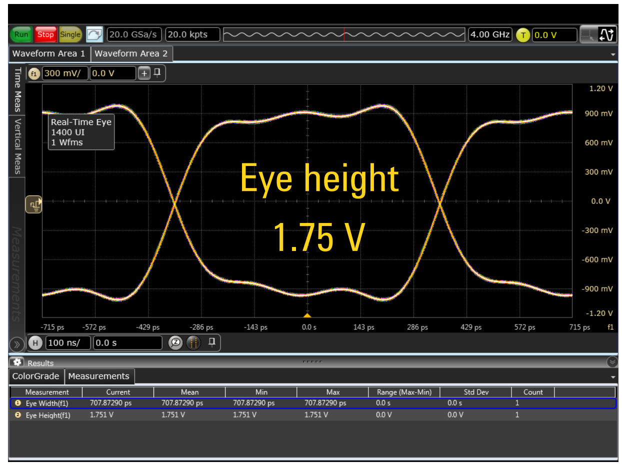
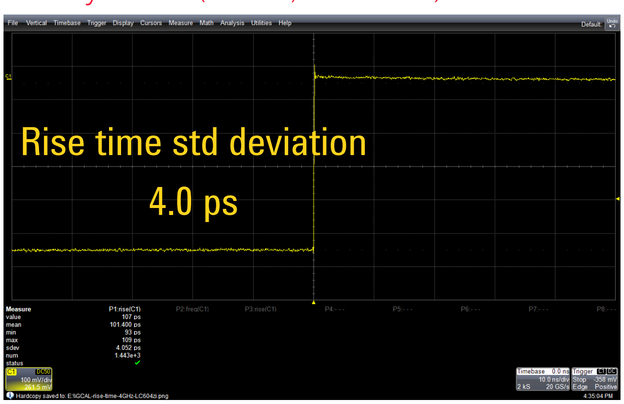


Figure 1(a). Even scopes from the same vendor rated at equal bandwidths can have varying signal integrity qualities. Here we show an eye diagram from the same source on two scopes each rated at 4 GHz. The scopes have identical bandwidth, vertical, and horizontal settings. The Infiniium S-Series show a more representative eye shape and has an eye height measurement 200 mV higher than what the DSO9404A shows. The lower value and more representative shape is a result of superior signal integrity.

Signal integrity is made of many attributes and this application note walks through each of them in detail. The principles here can be applied to scopes in all bandwidth ranges. This application note articulates key signal integrity attributes and uses Keysight Technologies, Inc. Infiniium S-Series oscilloscopes for examples in the 500 MHz to 8 GHz bandwidth ranges.

There are multiple scope attributes that work in conjunction with each other and hence the topic must be considered holistically. There are many banner specifications that are said to give you the 'best'; resolution, noise floor, jitter, etc. But you need to be mindful that one good specification will not ensure the best representation of the signal. Only considering multiple attributes together will solidify what oscilloscope to choose. Looking at only a single signal integrity attribute in the absence of others; can lead a user to false conclusions.

LeCroy 604Zi (4 GHz, 20 GSa/s)



Infiniium DSOS404A (4 GHz, 20 GSa/s)

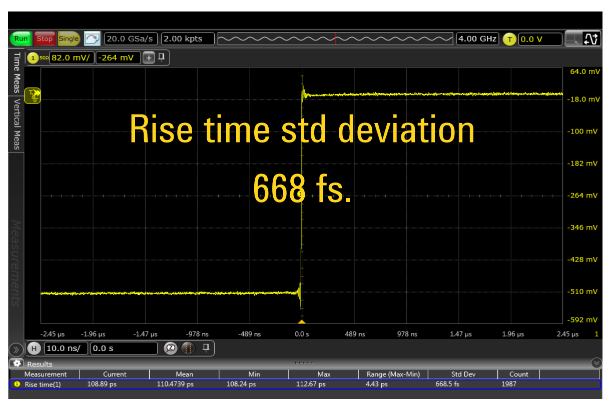


Figure 1(b). Note the difference in the standard deviation of rise time measurements. Both scopes are rated at 4 GHz bandwidth, are sampling at 20 GSa/s and set to the same settings. When measuring a fast rise time, the Infiniium S-Series reports a rise time value with standard deviation of 668 fs while the LeCroy scope reports a standard deviation of 4 ps, six times larger than the standard deviation measured by the Infiniium S-Series. Small standard deviations when measuring rise time on the same signal indicate superior signal integrity and a better horizontal system.

ADC Bits and Minimum Resolution

A key technology block for vertical signal integrity is the analog-to-digital converter (ADC). The higher the number of ADC bits, the more resolution the scopes has. A 10-bit ADC ideally provides 4 times the resolution as a scope with an 8 bit ADC. Similarly, a 12-bit ADC provides 4 more times the resolution that a 10-bit ADC. In the case of the Infiniium S-Series there is a 10-bit ADC (shown in Figure 2) that enables more resolution than a scope with only an 8-bit.

Resolution is the smallest quantization level determined by the analog-to-digital converter (ADC) in the oscilloscope. A scope's ADC with a resolution of 8 bits can encode an analog input to one in 256 different levels, since $2^8 = 256$. We'll refer to these as quantization or Q levels. The ADC operates on the scope's full scale vertical value. For both current and voltage measurements, the Q-level steps are associated with the full-scale vertical scope setting. If the user adjusts the vertical setting to 100 mV per division, full screen equals 800 mV (8 divisions * 100 mV/div) and Q-level resolution is equal to 800 mV divided by 256 levels, or 3.125 mV.

Let's look at a specific example as shown in Figure 3. Two scopes are both scaled to 800 mV full screen. A scope with an 8-bit ADC has resolution of 800 mV/(2^8 = 256 Q levels), or 3.125 mV. A scope with a 10-bit ADC has resolution of 800 mV/(2^{10} = 1024 quantization levels), or 0.781 mV. In normal mode, each scope can only resolve signals down to the smallest Q level.

When excess sample rate is available coupled with an analog front end to prevent aliasing, scopes typically offer another mode called high-res mode. Oversampling techniques combined with DSP filters can increase vertical resolution. Vendors often refer to this increase in terms of "bits of resolution." In the case of Infiniium S-Series, high-res increases bits of resolution from 10-bits (native ADC resolution), to 12-bits of resolution. This technique requires an ADC that has been architected with excess sample rate relative to the hardware band-width needed for a particular measurement.

Increased ADC bits and a wider range vertical sensitivity increases resolution.

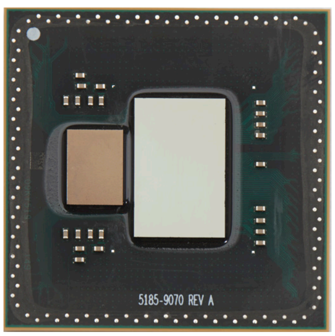


Figure 2. While most oscilloscopes incorporate an 8-bit ADC, S-Series oscilloscopes include a 40 GSa/s, 10-bit ADC. This results in four times the resolution versus 8-bit oscilloscopes.

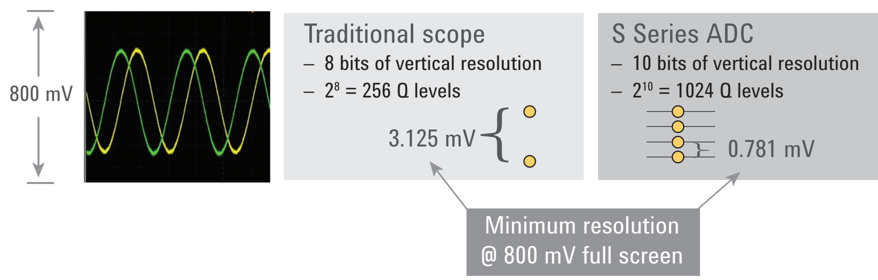


Figure 3. Resolution is an important signal integrity attribute. Having a scope with more ADC bits, and proper vertical scaling are two ways to increase resolution.

Scaling Impact on Resolution

Scaling has a huge impact on getting the most resolution from your oscilloscope. Scaling the waveform to take the whole display of the scope enables the scope's analog-to-digital (ADC) converter. If a signal is scaled to take up only ½ of the vertical display, you've just decreased the number of ADC bits being used from 8 to 7. Scale the waveform to ¼ of the vertical display and you've reduced the number of ADC bits used from 8 to 6. Scale the waveform to take close to consuming full vertical display and now you are using all 8 bits of the oscilloscope's ADC. To get the best resolution, use the most sensitive vertical scaling setting while keeping the waveform on the display.

The combination of the ADC, the scope's front-end architecture, and the probe used determine how low the oscilloscope hardware supports vertical scaling can go. At a certain point, each family of scopes cannot go to a lower vertical scale internal to the scope—even though the knobs of the scope allow the user to dial a smaller setting. Vendors will often refer to this as the point where the scope moves into software magnification. Turning the scope's vertical scale to a smaller number simply magnifies the displayed signal and doesn't result in any additional resolution as the user would naturally expect. Most traditional scopes employ software magnification below 10 mV/div. Additionally, some scope vendors bandwidth limit at small vertical settings (below 10 mV/div). This is because their scopes have significant front-end noise that would make it near impossible to see small signals at full bandwidth.

Let's compare two scopes as an example.
A small signal has magnitude such that a vertical scaling of 16 mV full screen allows the signal to consume almost all of the vertical display height.

- A traditional scope such as the Keysight Infiniium 9000 scopes has an 8-bit ADC and goes into SW magnification at 7 mV div. Minimal full screen resolution equals 56 mV (7 mV/div * 8 div)/256 Q levels. This results in minimum resolution of 218 uV.

- An Infiniium S-Series oscilloscope has a 10-bit ADC and stays in hardware all the way down to 2 mV/div with no required bandwidth reduction. Minimal full screen resolution equals 16 mV (2 mV/div * 8 div)/1024 Q levels. This results in minimum resolution of 16.6 uV—13 times the resolution as the traditional 8-bit scope as shown in as shown in Figure 4.

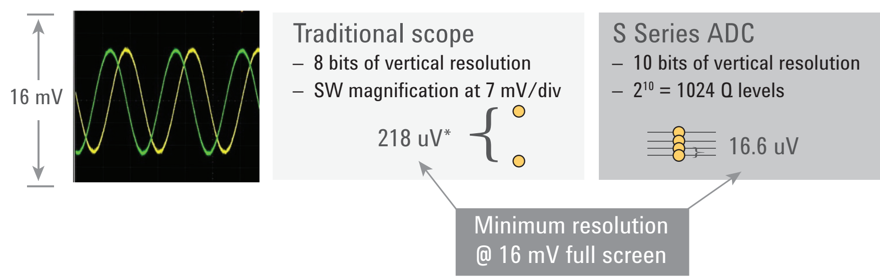


Figure 4. If you need to look at small signal detail, knowing the minimal vertical setting a scope supports in hardware will be important in order to see small detail.

Noise

Having a scope with low noise (high dynamic range) is critical if you really want visibility to small currents and voltages, or to see small changes on larger signals.

> Note: You won't be able to see signal detail smaller than the noise level of the scope.

If noise levels are higher than ADC quantization levels, users won't be able to take advantage of the additional ADC bits.

Noise can come from a variety of sources, including the front end of the scope, the ADC in the scope and the probe or cable used connected to the device. The ADC itself has quantization error. For oscilloscopes quantization noise typically plays a lesser role in contribution of overall noise and the front end of the oscilloscope plays a more significant role.

Most oscilloscope vendors will characterize noise for a specific model numbers and include these values on the product datasheet. If not, you can ask for the information, or find out yourself. It's easy to measure in a few minutes. Disconnect all inputs from the front of the scope and set the scope to 50 Ω input path. You can also run the test for the 1 MΩ path. Turn on a decent amount of acquisition memory such as 1 Mpt, with sample rate fixed at high sample rate to ensure you are getting the full scope bandwidth. Run the scope with infinite persistence and see how thick the resulting waveform is. The thicker the waveform, the more noise the scope is producing internally.

Each scope channel will have unique noise qualities at each vertical setting. You can view the noise visually just by looking at wave shape thickness, or you can be more analytical and take a V_{rms} AC measurement to quantify. Create a chart like the one shown in Figure 7. These measurements will enable you to know how much noise each scope channel has at various vertical settings to measure signals that are less than the noise of the scope. All acquired vertical values are subject to deviation up to the noise value of the scope. Noise impacts both horizontal as well as vertical measurements.

The lower your oscilloscope's noise, the better the measurement results will be.

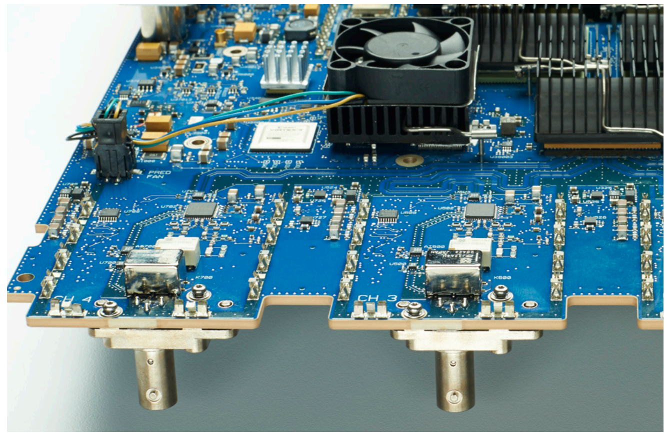


Figure 5. Infiniium S-Series oscilloscopes include a new low-noise front end designed as a companion to the 10-bit ADC, that reduces noise by 2x.

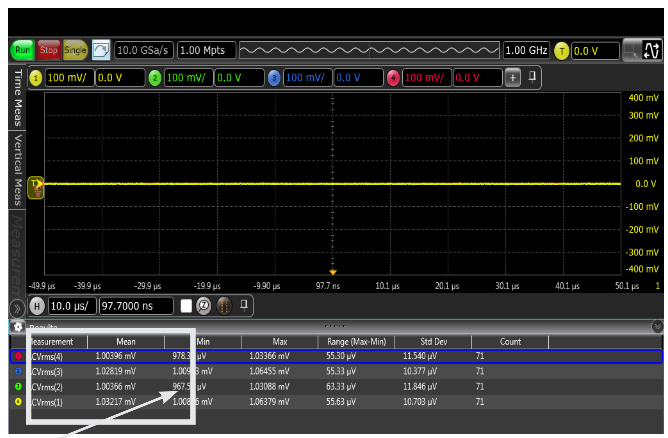


Figure 6. See how much noise your scope has. Disconnect inputs from the scope and measure noise (Volts RMS) at each vertical setting. In this example, each channel shows equal noise of just 1 mVrms.

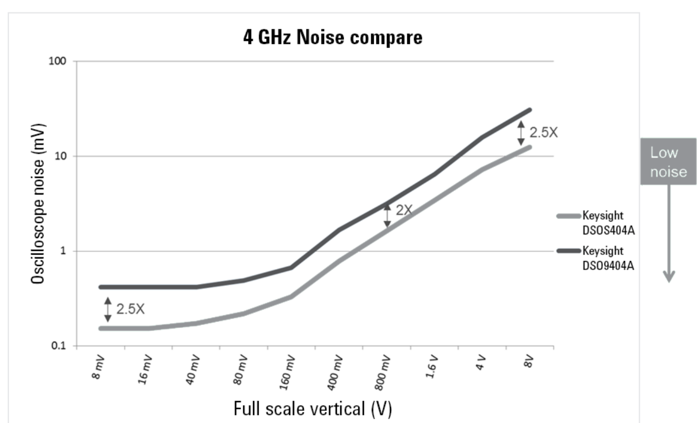


Figure 7. Scope noise plots allow users to quickly compare models across different vendors. This example shows two different 4 GHz Infiniium models at 4 GHz bandwidth. The lower the noise, the better signal integrity you can expect.

Frequency Responses

Each oscilloscope model will have unique frequency response that is a quantitative measure of the scope's ability to accurately acquire signals up to the rated bandwidth. Three requirements must be kept in order for oscilloscopes to accurately acquire waveforms.

1. The oscilloscope must have a flat frequency response.
2. The oscilloscope must have a flat phase response.
3. Captured signals must be in the bandwidth of the oscilloscope.

Deviation from one or more of these requirements will cause an oscilloscope to inaccurately acquire and draw a waveform. The more variance from these requirements, the greater the error in acquiring and drawing the waveform.

Fast edges contain multiple harmonics, and scope users expect the oscilloscope to accurately measure each harmonic component using the correct magnitude. Ideally oscilloscopes would have a uniform flat magnitude response up to the bandwidth of the scope, with the signal delayed by precisely the same amount of time at all frequencies (phase). Flat frequency responses, indicate that the oscilloscope is treating all frequencies equally, and without a flat phase response, the scope will show distorted waveforms.

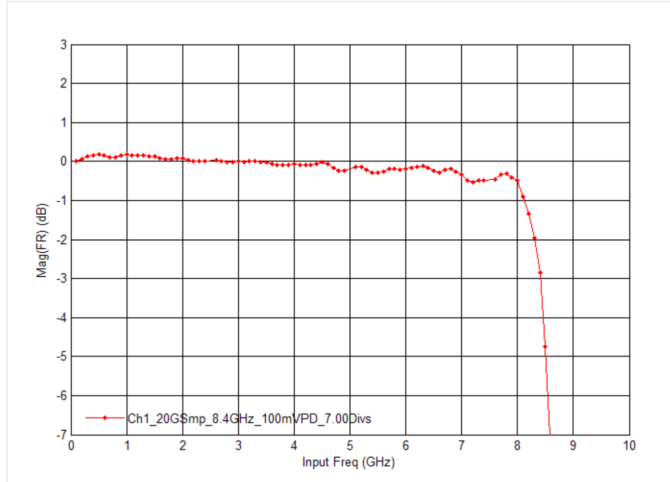


Figure 8. Each model will have a unique frequency response. Uniform flatness is highly desired for signal integrity. Brick wall roll-off minimizes out-of-band noise, while Gaussian roll-off minimizes edge ringing. Shown is an example magnitude response for Infiniium DSOS804A up to full bandwidth in excess of 8 GHz. The vertical scaling is zoomed in to 1 db/div and magnitude varies slightly before roll off.

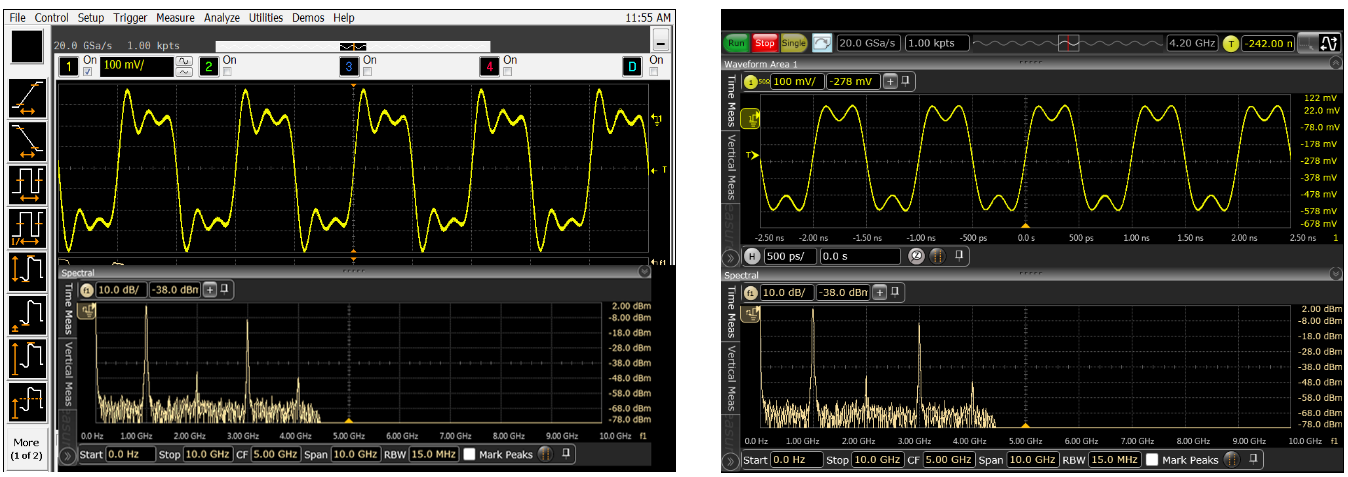


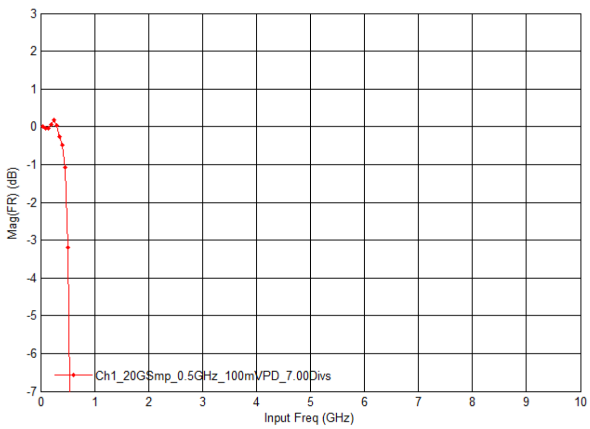
Figure 9. Two oscilloscopes were connected to the identical signal. Both have identical bandwidth rating, sample rate and other settings. On the right shows a waveform that accurately matches the spectral content of the signal. Why the difference? The one on the right uses correction filters to produce a flat magnitude and phase response, while the one on the left doesn't incorporate correction filters in the product.

Frequency Responses (continued)

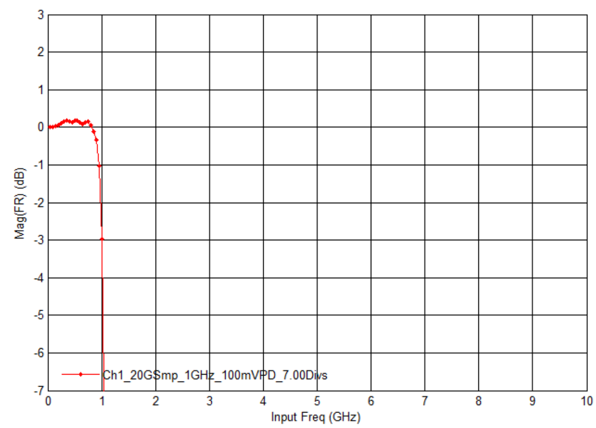
A frequency response that is not flat will cause distortions in the displayed signal. You can ask your oscilloscope vendor to provide a frequency response for an oscilloscope you are considering. These plots are typically not in data sheets, but can be made available. For convenience sake, shown are frequency responses for each model bandwidth of Infiniium S-Series oscilloscopes. The plots were made at maximum sample rate of 20 GSa/s, vertical scaling of 100 mV/div with signal scaling of 7.2 divisions.

Your scope's overall frequency response will be a combination of the oscilloscopes frequency response combined with the frequency response of any probes or cables connected between the device under test and the instrument. If you put a BNC cable that has bandwidth of 1.5 GHz on the front of a 4 GHz scope, the overall bandwidth of the system is limited by the BNC cable and not the oscilloscope. The same principle applies for both probes, and accessories that attach to the probes. Probes and cables also have their own frequency response. If you need to make a precision measurement, make sure your probes, accessories, and cables aren't the limiting factor.

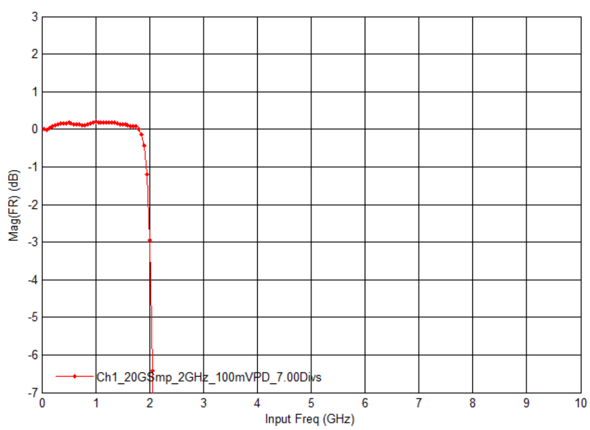
Magnitude response for 500 MHz DSOS054A oscilloscope



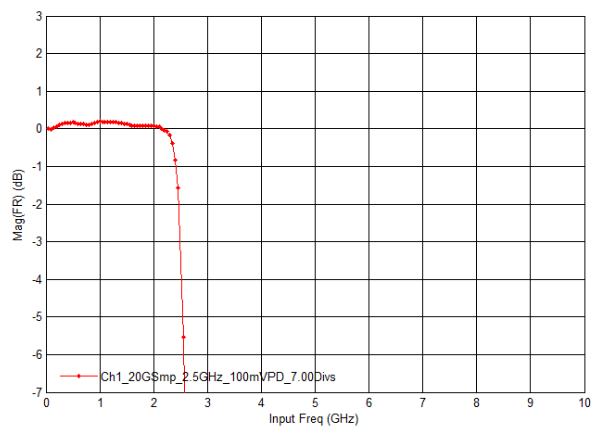
Frequency response for 1 GHz DSOS104A oscilloscope



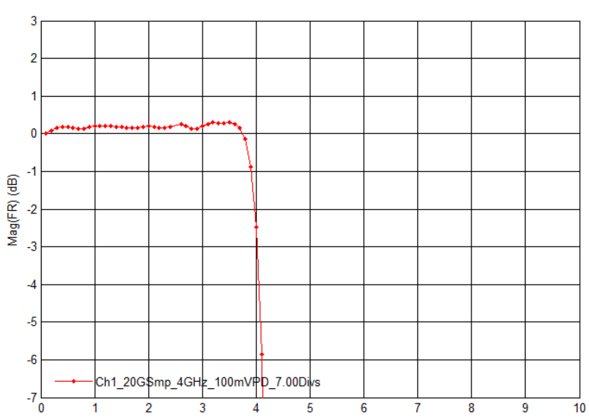
Magnitude response of 2 GHz DSOS204A



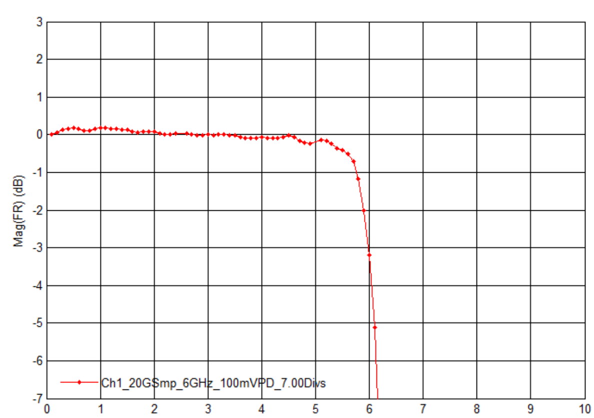
Magnitude response for 2.5 GHz DSOS254A oscilloscope



Magnitude response for 4 GHz DSOS404A oscilloscope



Magnitude response for 6 GHz DSOS604A oscilloscope



Correction Filters

Some oscilloscopes have strictly analog front-end filters that determine frequency response, while others apply correction filters in real time. Correction filters are typically implemented in hardware DSP blocks and are tuned for a particular family of oscilloscopes to create a flat magnitude and phase response. Combining correction filters with front-end analog filters creates flatter magnitude and phase responses verses raw analog filters alone. Oscilloscopes of superior quality include both analog as well as correction filters to create a uniform and flat frequency response.

Frequency response shapes generally are named by their roll-off characteristics. Responses that have brick-wall filters are desired as they produce less noise by more quickly attenuating out-of-band noise. For fast edges, out-of-band higher harmonics are quickly attenuated resulting in slight under- and over-shoot. Responses that have a Gaussian roll-off don't show as much ringing, but with the trade-off is additional noise.

Software Filters

In addition to correction filters, oscilloscopes can employ filters in software. Software bandwidth filters typically require the scope to operate at maximum sample rate to prevent aliasing, run slower, and generally don't have the signal integrity characteristics of equivalent hardware or analog filters. However, these filters can be quite flexible.

One example of a software filter is the Infiniium PrecisionProbe application. The application is aimed at increasing signal integrity by de-embedding the effects of channels, probes, or cables on the measurement. The application allows for a quick 2-minute characterization of a probe or cable's S21 parameter using the oscilloscope's internal calibration signal that has a very fast edge. Using this information, the application creates a filter inversely proportional to the cable's filter up to the roll off point, allowing the measurement to be show with the effects of the BNC cable extracted.

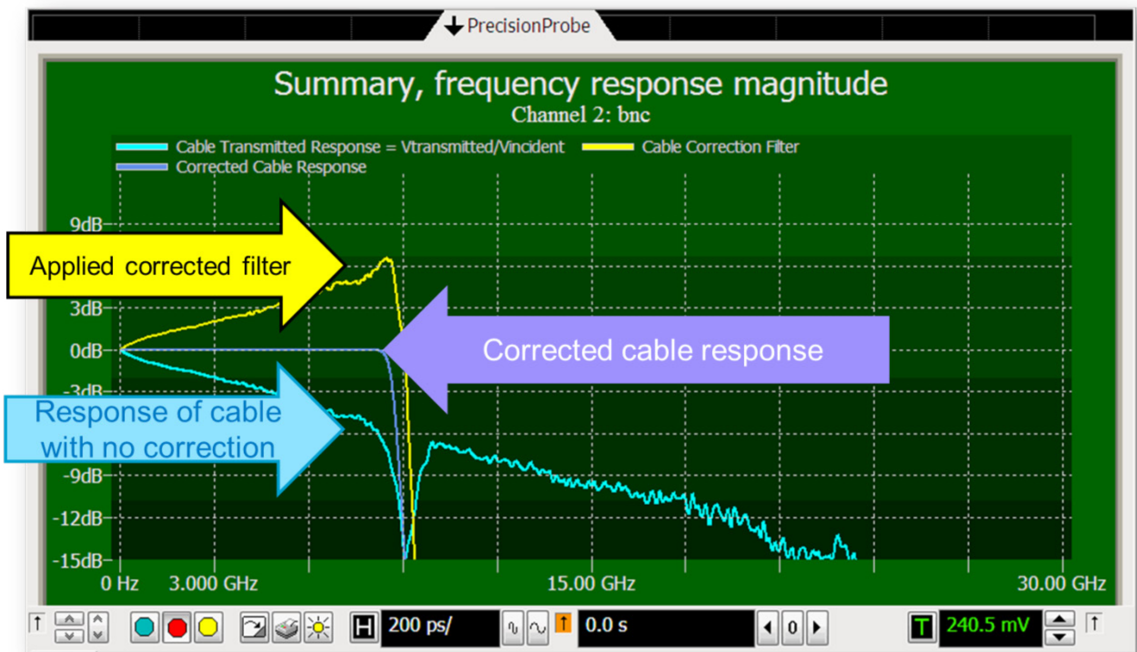


Figure 10. Infiniium PrecisionProbe is an example of an application that utilizes the flexibility of software-based bandwidth filters. This application can help engineers quickly determine the frequency response of cables or probes, then applies a correction filter.

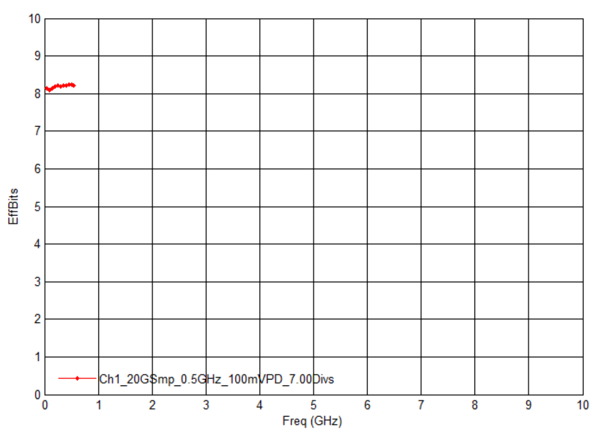
ENOB (Effective Number of Bits)

Effective number of bits (ENOB) is a measure of the dynamic performance. While some oscilloscope vendors may give the ENOB value of the oscilloscope's ADC by itself, this figure has no value. ENOB of the entire system is what is important. While the ADC could have a great ENOB, poor oscilloscope front-end noise would dramatically lower the ENOB of the entire measurement system. While oscilloscope vendors generally don't publish overall ENOB values, vendors typically do characterize and will provide these values when requested for a specific model number.

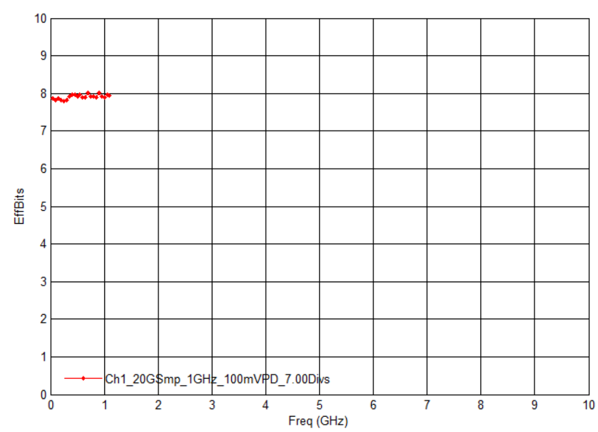
Oscilloscope ENOB isn't a specific number, but rather a series of curves. ENOB is measured as a fixed amplitude sine wave is swept in frequency. Each curve is created at a specific vertical setting while frequency is varied. The resulting voltage measurements are captured and evaluated. Using time-domain methods, ENOB is calculated by subtracting the theoretical best fit sine wave from what was measured. The error between these curves can come from the front-end of the oscilloscope from attributes such as phase non-linarites and amplitude variations over frequency sweeps. Error can also come from interleaving distortion from ADCs. Evaluating the same signal in the frequency domain, ENOB is calculated by subtracting the power associated with the primary tone from the entire broadband power. Both techniques provide the same result.

ENOB values will be lower than the oscilloscope's ADC bits. For example, at 1 GHz bandwidth, the 8-bit Infiniium 9000 has a system ENOB of about 6.5. A 1 GHz DSOS104A with a 10-bit ADC and extremely low-noise front end has a system ENOB of about 8. The following ENOB plots for Infiniiuum S-Series oscilloscopes were taken using signal scaling of 7.2 divisions, and with maximum sample rate of 20 GSa/s.

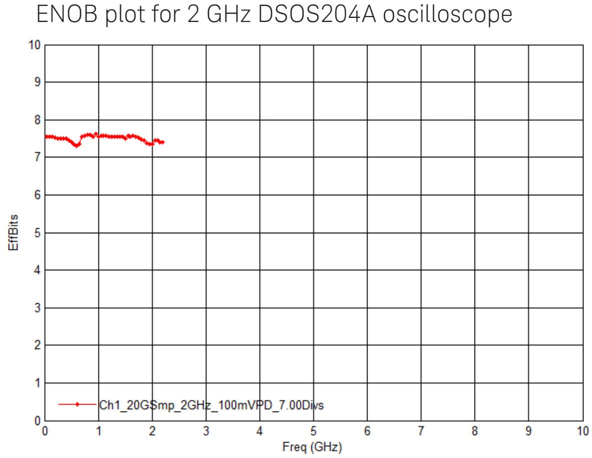
ENOB plot for 500 MHz DSOS054A oscilloscope



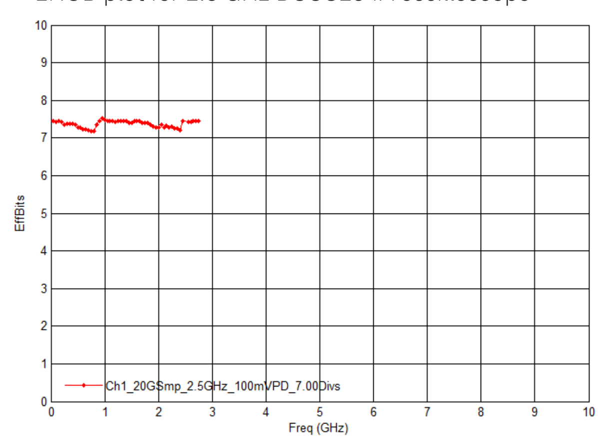
ENOB plot for 1 GHz DSOS104A oscilloscope



ENOB plot for 2 GHz DSOS204A oscilloscope



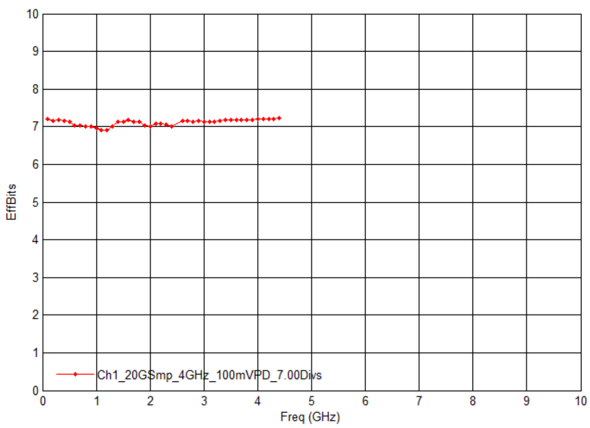
ENOB plot for 2.5 GHz DSOS254A oscilloscope



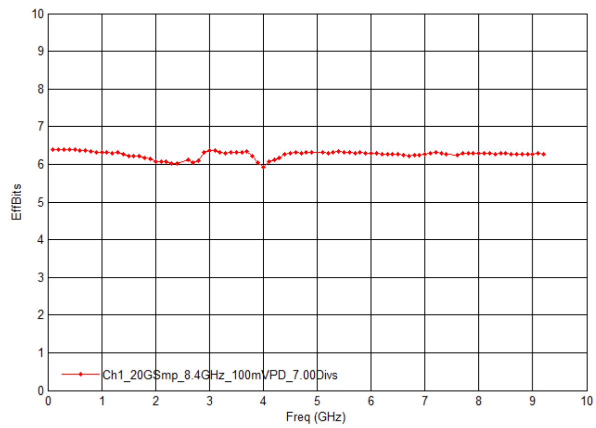
ENOB (Effective Number of Bits)
(continued)

In general, a higher ENOB is better. However, a couple cautions need to accompany engineers who look exclusively at ENOB to gauge signal integrity goodness. ENOB doesn't take into account offset errors or phase distortion that the scope may inject.

ENOB plot for 4 GHz DSOS404A oscilloscope



ENOB plot for 8 GHz DSOS804A oscilloscope



Intrinsic Jitter

Jitter describes deviation from ideal horizontal position and is measured in ps rms or ps pp. A number of jitter contributors naturally occur in high-speed digital systems. Jitter sources include thermal and random mechanical noise from crystal vibration. Additionally, traces, cables, and connectors can further add jitter to a system through intersymbol interference. Excessive jitter is bad. Jitter can cause timing violations that result in incorrect system behavior. Too much jitter in communication systems will cause unacceptable bit error rates (BER) resulting in incorrect transmissions. Measurement of jitter is necessary for ensuring high-speed system reliability.

If you need to make jitter measurements, understanding how well your oscilloscope will make those measurements is critical to interpreting your jitter measurement results. Oscilloscopes sample and store digitized waveforms. Each waveform is constructed of a collection of sample points. A perfect oscilloscope would acquire a waveform with all sample points equally spaced in time. However, in the real world, imperfections in the internal scope circuitry horizontally displace the ADC sample points from their ideal locations and this value is represented in the jitter measurements that the oscilloscope makes. Oscilloscopes themselves have jitter and when they make a jitter measurement, they can't determine which portion of the jitter measurement result came from the device under test versus the scope itself.

A perfect oscilloscope would report zero jitter if it took a jitter measurement on a perfect jitter free signal. However, scopes are not free from jitter themselves. Oscilloscope jitter can come from interleaving errors, the jitter of the ADCs sample clock input signal, and other internal sources. This collection of horizontal error sources produce a total time error called the equivalent sample clock jitter, or simply sample clock jitter. This is also called the intrinsic source jitter clock (SJC). Oscilloscope vendors shorten the term to "intrinsic jitter" and use this term to mean the minimum intrinsic jitter value over short time record.

Jitter measurement floor = function (noise, signal slew rate, intrinsic jitter)

An oscilloscope will report a non-zero jitter measurement, even if it was measuring a perfect jitter free signal. The term "jitter measurement floor" refers to the jitter value that the oscilloscope reports when it measures a perfect jitter free signal. The jitter measurement floor value is comprised not only of the sample clock jitter described above, but also of vertical error sources, such as vertical noise and aliased signal harmonics. These vertical error sources also affect horizontal time measurements because they change the signal of threshold crossings.

The scope's circuitry that is associated with horizontal accuracy is known as the time base. The time base is responsible for time scale accuracy as well as the horizontal component of jitter. Oscilloscopes with well-designed time bases contribute less to horizontal jitter component of jitter and hence will report a lower value.

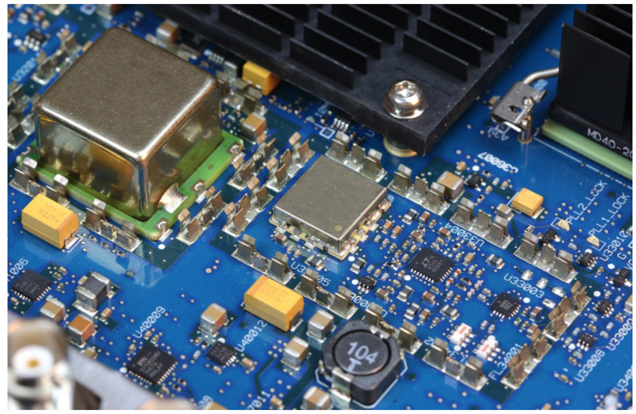
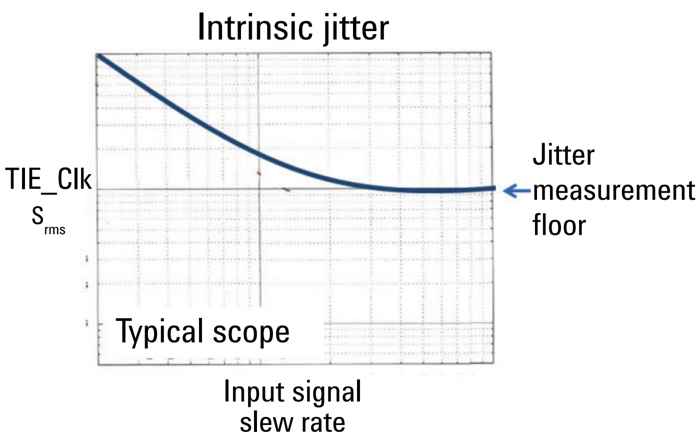


Figure 11. Infiniium S-Series oscilloscopes include a new time base technology block. It's clock accuracy is an impressive 75 parts per billion. Intrinsic jitter for short record lengths is less than 130 fs.

Figure 12. Real-world jitter measurements using Infiniium S-Series oscilloscopes. All models in the family utilize the same time base technology block and a low horizontal component of jitter measuring less than 130 fs over short record lengths.

Intrinsic Jitter (continued)

Infiniium DSO9404A



Infiniium DSOS404A

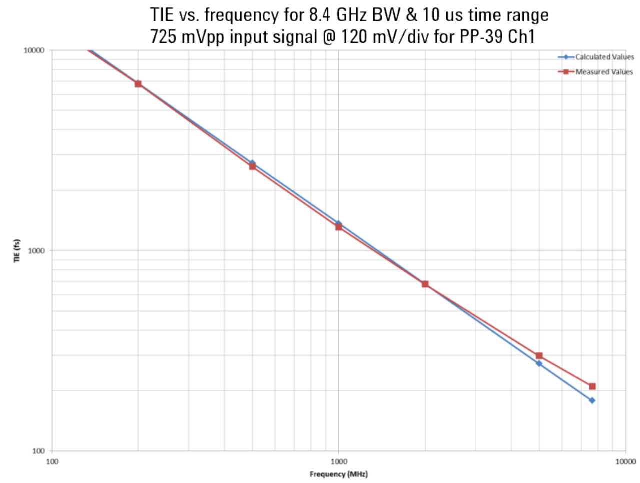


Figure 13. Oscilloscope vendors characterize jitter measurement floor of an oscilloscope by plotting TIE measurements vs input signal slew rate (can also use frequency if sine waves are used). All oscilloscopes in the world except the Infiniium S-Series have an intrinsic jitter plot that resembles the one on the left. The plot shows that intrinsic jitter values are dominated by slew rate and vertical noise until the horizontal system becomes the biggest contributor. This is known as the jitter measurement floor. The impressive S-Series jitter curve is a function of vertical noise and slew rate--meaning that the oscilloscope's horizontal system is a non-contributor to overall intrinsic jitter. Infiniium S-Series has in-band intrinsic jitter of under 120 fs for input sine waves of 8 GHz (max BW).

Summary

Evaluating a new oscilloscope and want to make sure it provides the best view of signals under test over a wide frequency range? If so, make sure you choose an oscilloscope that has characteristics across all attributes of signal integrity: high resolution, low intrinsic noise, flat frequency response, and ENOB. Infiniium S-Series oscilloscopes include new time base, front-end, and ADC technology blocks for superior measurements, including the best jitter measurement floor in class, and best vertical signal attributes. S-Series oscilloscopes range from 500 MHz to 8 GHz and are part of the Infiniium oscilloscope lineup that goes up to 63 GHz bandwidth.

Signal integrity metric	Scope technology block	Where can you find the answer?
Resolution	ADC bits	Product datasheet
Noise	Front-end	Most vendors include in product datasheet.
Vertical scaling supported in HW	ADC/front-end	Datasheets don't always specify when SW magnification starts. Some vendors BW limit at small sensitivities.
Frequency response flatness	Analog filters and correction filters	Not typically included in product datasheets. You will need to ask the vendor to see a magnitude and phase response for the model you are evaluating.
Time scale accuracy	Time base	Product datasheet
Amount of intrinsic jitter	Time base	Some vendors include, others don't. If not in the datasheet, ask the vendor.
ENOB (Effective Number of Bits)	Combination of both vertical and horizontal scope system	Some vendors include, others don't. If not in the datasheet, ask the vendor.

Keep in mind while each attribute is important the most overall accuracy will be seen in the oscilloscope that has a better overall composite of these 7 attributes.

Glossary

ADC (analog to digital converter): Device in oscilloscope that converts voltage to a digital amplitude value. Total quantization or output levels of the ADC will equal 2n where n equals the number of ADC bits.

Bits of resolution: Bits of resolution defines total potential output levels the oscilloscope can create using ADC bits, high-resolution mode, and/or averaging.

ENOB (Effective number of bits): The dynamic range of an ADC or oscilloscope is often summarized in terms of its effective number of bits (ENOB). ENOB accounts for noise and a number of other sources of vertical distortion. The ENOB of the scope's ADC will be greater than the scope's overall ENOB.

Filter: A filter is a circuit or algorithm with specific frequency response characteristics. Filters can be implemented from discrete analog circuits, done in hardware where they are referred to as DSP hardware filter, or can be performed more slowly but with greater flexibility in software.

Frequency response: The frequency response describes the magnitude or phase characteristics of an oscilloscope over a specific bandwidth range. Ideal frequency response plots are flat with a brick-wall roll-off.

Front end: Front end describes the oscilloscope circuitry between the BNC input on the oscilloscope and the scope's ADC. The front-end includes analog filters, switching between 1 MΩ and 50 Ω paths, and attenuation required to scale the signal properly for the ADC.

Jitter: Jitter describes deviation from ideal horizontal position. Oscilloscopes are great tools for measuring jitter of target systems. Scopes also inherently include jitter sources internal to the scope that contribute to jitter measurements.

Intrinsic jitter: Intrinsic jitter associated with a scope includes the jitter measurement internal to the scope. This is also called the intrinsic source jitter clock (SJC). Scope vendors often use intrinsic jitter to mean the minimum intrinsic jitter value over short time record.

Jitter measurement floor: Jitter measurement floor is the error added to the jitter measurement signal by the scope. Another description is the jitter value that the oscilloscope reports when it measures a perfect jitter free signal. The value is comprised not only of the sample clock jitter described above, but also of vertical error sources, such as vertical noise and aliased signal harmonics

Noise: Noise is vertical deviation from a true signal value. You won't be able to see signal detail smaller than the noise level of the scope. If noise levels are higher than ADC quantization levels, users won't be able to take advantage of the additional ADC bits. The front end tend to be the most significant contribution of oscilloscope noise.

Resolution: Resolution for a scope ADC is the smallest quantization level determined by the analog-to-digital (A/D) converter in the oscilloscope. Oscilloscopes can achieve smaller resolution through averaging where points in time across multiple acquisitions are averaged, or high-res mode where oversampling combined with a DSP filter enables more resolution.

Sample clock jitter (SCJ): Sample clock jitter is the horizontal component of jitter.

Time base: The time base is the circuitry in the oscilloscope responsible for horizontal accuracy and keeping sample clock jitter low.

Related Literature

Publication title	Publication type	Publication number
Keysight Infiniium S-Series Oscilloscopes (500 MHz to 8 GHz)	Data sheet	5991-3904EN
Keysight Infiniium 90000A Series Oscilloscopes (2.5 to 13 GHz)	Data sheet	5989-7819EN
Keysight Infiniium 90000 X-Series Oscilloscopes (13 to 33 GHz)	Data sheet	5990-5271EN
Keysight Infiniium 90000 Q-Series Oscilloscopes (20 to 63 GHz)	Data sheet	5990-5299EN
Keysight EZJIT and EZJIT Plus Jitter Analysis for Infiniium Oscilloscopes	Data sheet	5989-0109EN
Finding Sources of Jitter with Real-time Jitter Analysis	Application note	5988-9740EN
Analyzing Jitter using Keysight EZJIT Plus Software	Application note	5989-3776EN
Choosing the ISI Filter Size for EZJIT Plus Arbitrary Data Jitter Analysis	Application note	5989-4974EN
Selecting RJ Bandwidth in EZJIT Plus Software	Application note	5989-5056EN

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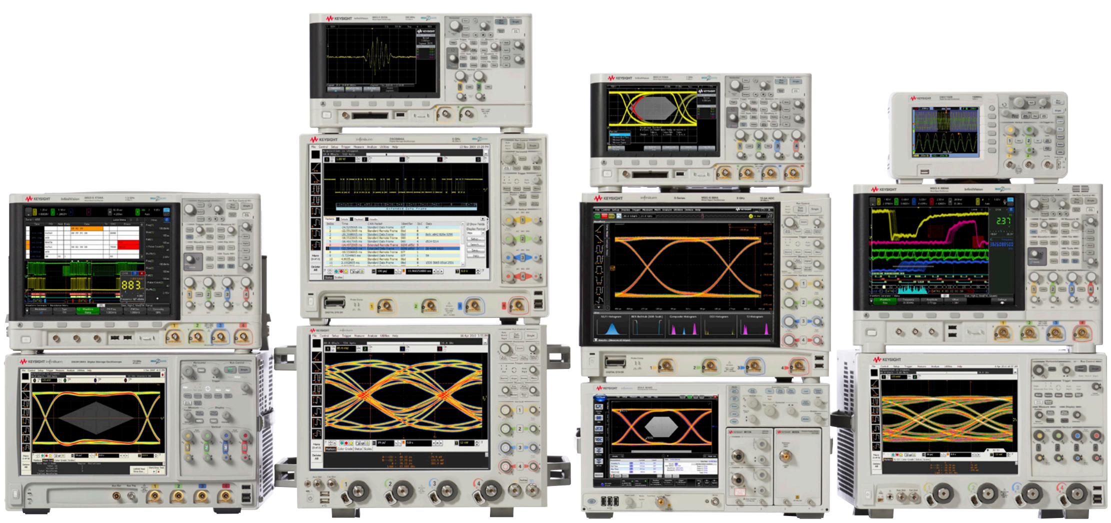

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