Keysight Technologies

Optical Signal Measurements Using A Real-Time Oscilloscope

Application Note

KEYSIGHT TECHNOLOGIES

Table of Contents

Digital oscilloscopes fall into two groups – real-time and sampling oscilloscope (also known as equivalent-time sampling oscilloscope). When it came to optical signal measurement with an oscilloscope, a sampling oscilloscope has almost always been used for most optical waveform analysis because of its ability to perform reference receiver testing and its bandwidth performances keeping up with the fast fiber optics and measurements optimized for optical analysis.

However, as bandwidths of the oscilloscopes continue to increase, sampling oscilloscopes and real-time oscilloscopes have begun to overlap in many application spaces, including that of optical signal analysis.

Real-Time vs Sampling Oscilloscope

The first thing you may notice when looking at the bandwidth and sample rate characteristics of two different types of oscilloscopes is that a real-time oscilloscope samples at a rate faster than the signal being observed, according to the Nyquist theory saying that the sampling rate should be, at least, twice the highest analog frequency component of input signal to avoid undesirable measurements in the form of aliasing or distortion.

Sampling rate > 2*fmax of signal where fmax is the highest analog frequency component. However, in the sampling oscilloscope, the actual sample rate is much slower than the signal being observed.

The real-time oscilloscope captures the entire waveform in one acquisition cycle and an interpolation technique such as sine x/x is used to fill in the points in between actual sampled points. Therefore, the real-time oscilloscope is excellent for capturing transient, non-repetitive single shot events as well as repetitive signals.

On the other hand, a sampling oscilloscope captures only one sample at each trigger. The next sample is taken at a slight time delay compared to the previous sample, and it goes on and on. Through multiple passes of the signal trigger and sample captures, the waveform can be precisely reconstructed. Because only one sample is taken at each trigger, the A /D process can have a very high resolution with very low noise and jitter.

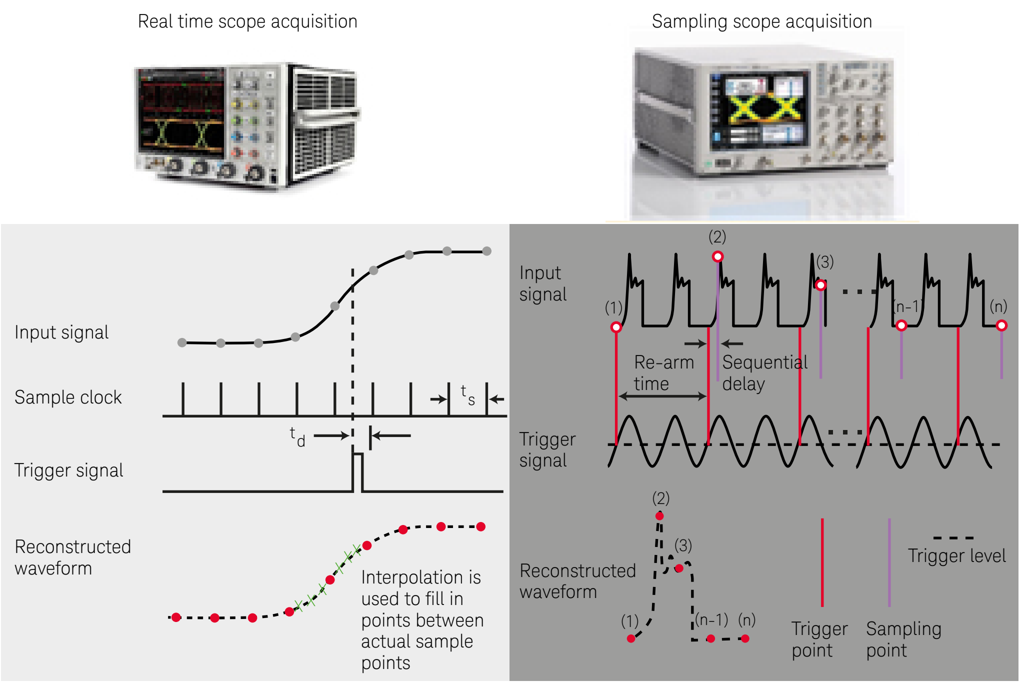


Figure 1. Real time scope vs sample scope acquisition.

Triggering

When it comes to a difference in triggering, a real-time oscilloscope has a built-in trigger source, and no explicit trigger is needed to capture a waveform.

However, a sampling oscilloscope requires a clock, typically from a pattern generator, to trigger the oscilloscope and provide a synchronized pattern to the DUT. It can be somewhat troublesome at the system level testing, where no clock is available on the system.

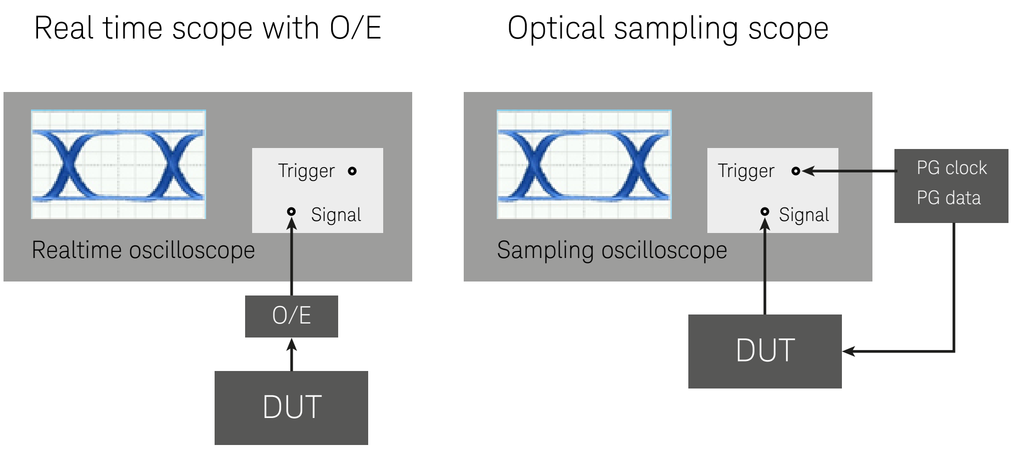


Figure 2. Triggering dif ference between real time scope and sampling scope.

What happens if you don't have a clock to drive the oscilloscope? For a real-time oscilloscope, because the trigger is built-in, testing at the system level without a clock is just easy.

However, with a sampling oscilloscope, a clock recovery accessory is required to pick off some signal and extract a clock. Due to this clock extraction process, you lose some signal amplitude, and what's left for the oscilloscope input may not be enough for good measurements.

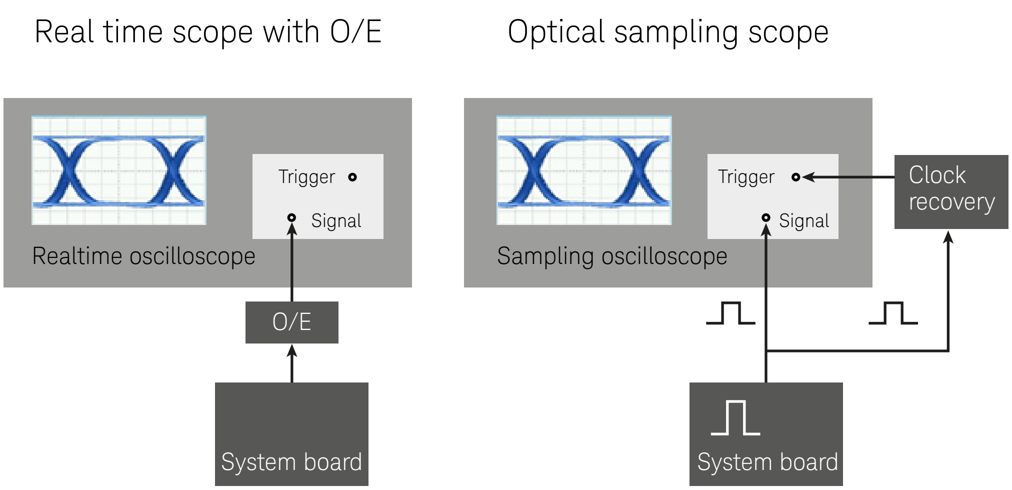


Figure 3. What happens if you don't have a clock to drive the oscilloscope?

Triggering (Continued)

Therefore, the real-time oscilloscope is better suited for system level testing, where there are mixed electrical and embedded optical signals on the board with no clock patterns to drive the trigger. It would be ideal for debugging or troubleshooting the system board where you want to look at the correlation between the electrical signal measured with a probe and the optical signal taken with an O/E converter.

However, a sampling oscilloscope is optimized for testing an optical component or transceiver, in which a typical test configuration involves the DUT component and signal source for generating the signal impairments and to drive the clock recovery module.

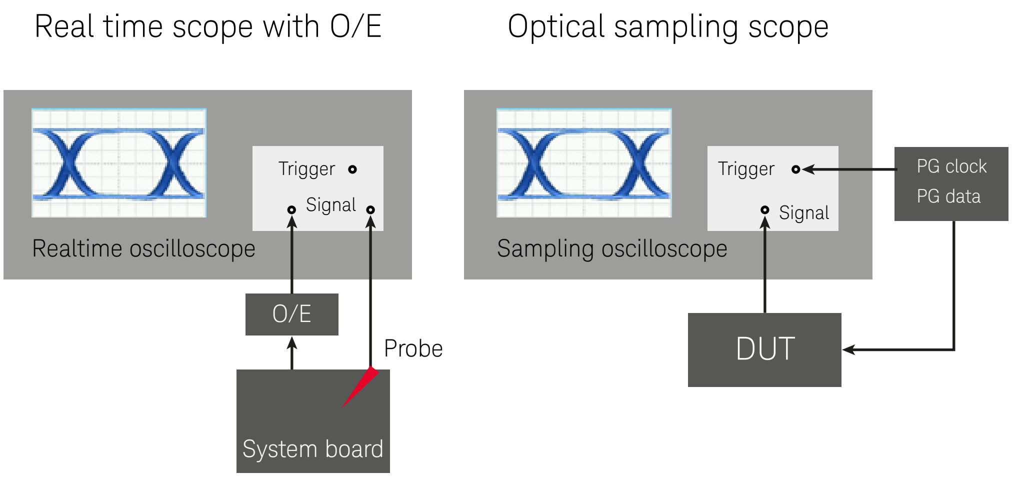


Figure 4. When to use real-time scope vs sampling scope for optical measurement?

Noise Floor

If you have had a chance to fiddle with the vertical scale setting on a real-time oscilloscope and a sampling oscilloscope, you may have noticed that the inherent noise floor of the real- time oscilloscope increases as the vertical scale gets larger. On the other hand, the sampling oscilloscope's noise floor stays unaffected by vertical scale changes.

Here in the example, the displayed noise on a real-time oscilloscope with the N7004A O/E converter is compared to a sampling oscilloscope in the same bandwidth. Notice that the real-time oscilloscope noise grows as you switch to higher watt/div settings, while the sampling oscilloscope noise remains constant.

To maximize the SNR with a real-time oscilloscope, it is important to note that you must set the vertical scale as low as possible while fitting most of the signal contents on screen.

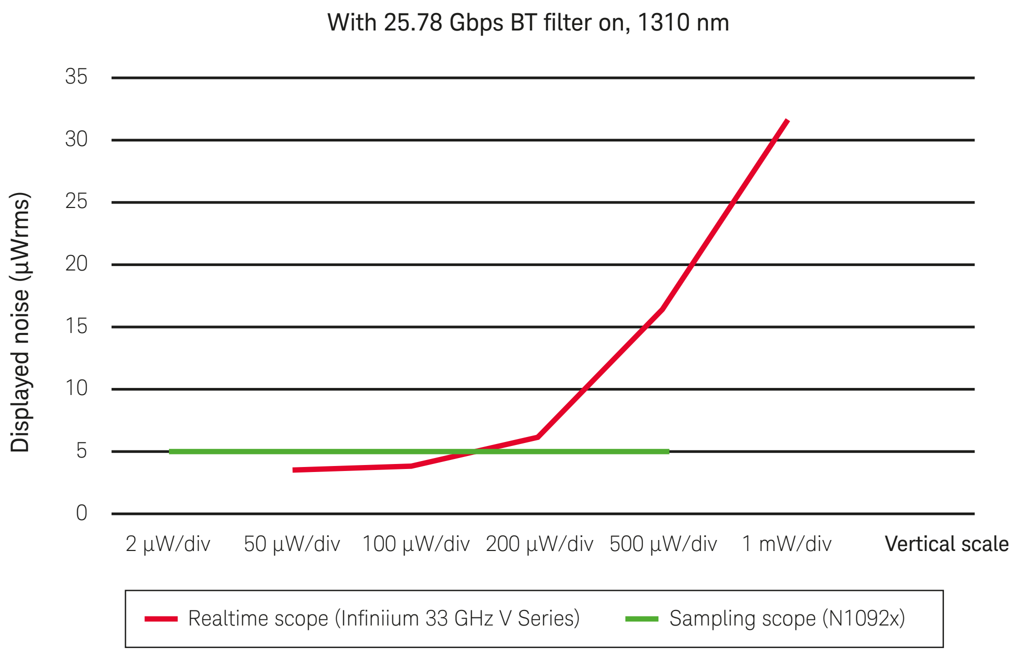


Figure 5. Sampling oscilloscope noise remains constant over vertical scale change.

Benefits of Integrated O/E Solution

The Keysight N7004A is the first fully-integrated optical-to-electrical converter solution for Infiniium real-time oscilloscopes. A full suite of optical measurement software is built into the Infiniium baseline software v 05.70 or higher and is offered at no additional cost. The N7004A comes in a compact form factor that is plugged directly into the AutoProbe II probe interface of the Infiniium oscilloscope.

The integrated solution provides unparalleled convenience and performance benefits over the off-the-shelf O/E product commonly available in the market. Some of the key benefits include the followings.

- Plug-on module with auto configuration and auto power from the oscilloscope
- DSP corrected frequency response
- Superior signal integrity
- Optical measurements in watt
- Integrated optical measurements including built-in extinction ratio measurement with dark calibration

Figure 6. N7004A O/E converter delivers integrated solution benefits.

In Summary

Real time

- R&D
- System level (electrical > optical)
- Flexible triggering and powerful analysis
- Debugging and troubleshooting

Sampling

- Manufacturing > R&D
- Component level (optical)
- Cost effective
- Compliance test

Figure 7. Positioning real time vs sampling scope for optical measurement.

The real-time oscilloscope is essentially an R&D tool for system level testing. It gives flexible triggering features and powerful analysis. The real-time oscilloscope also is a great debugging or troubleshooting tool and is also excellent for when you want trigger on hard-to-find signal events. However, it is somewhat expensive compared to the sampling oscilloscope and is not optimized for component level testing in manufacturing environment.

The sampling oscilloscope based O/E solution is a cost-efficient method well suited for component level testing such as testing optical transceivers in the manufacturing environment. If your application includes a repetitive waveform that requires lower noise, jitter and a higher dynamic range, a sampling oscilloscope is a good choice.

www.axiestandard.org

AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. The business that became Keysight was a founding member of the AXIe consortium. ATCA®, AdvancedTCA®, and the ATCA logo are registered US trademarks of the PCI Industrial Computer Manufacturers Group.

www.lxistandard.org

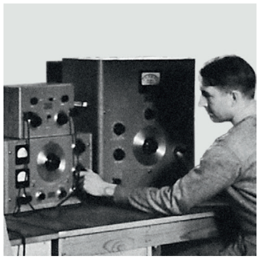
LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. The business that became Keysight was a founding member of the LXI consortium.

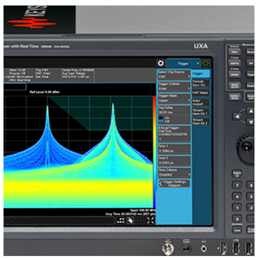
www.pxisa.org

PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.

Evolving Since 1939

Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology.
From Hewlett-Packard to Agilent to Keysight.





myKeysight

myKeysight
www.keysight.com/find/mykeysight
A personalized view into the information most relevant to you.

www.keysight.com/find/emt_product_registration
Register your products to get up-to-date product information and find warranty information.

KEYSIGHT SERVICES
Accelerate Technology Adoption. Lower costs.

Keysight Services
www.keysight.com/find/service
Keysight Services can help from acquisition to renewal across your instrument's lifecycle. Our comprehensive service offerings—one-stop calibration, repair, asset management, technology refresh, consulting, training and more—helps you improve product quality and lower costs.

Keysight Assurance Plans
www.keysight.com/find/AssurancePlans
Up to ten years of protection and no budgetary surprises to ensure your instruments are operating to specification, so you can rely on accurate measurements.

Keysight Channel Partners
www.keysight.com/find/channelpartners
Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 11 2626
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-9-7-17)

DEKRA Certified
ISO9001 Quality Management System

www.keysight.com/go/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2015
Quality Management System

Published in USA, December 1, 2017
5992-2416EN
www.keysight.com

KEYSIGHT TECHNOLOGIES