What is the difference between an equivalent time sampling oscilloscope and a real-time oscilloscope?

Application Note 1608

In the past, deciding between an equivalent time sampling oscilloscope and a real time oscilloscope was a matter of determining your bandwidth requirements; but with today's high performance instruments that distinction isn't as clear. This document will discuss how each type of scope samples the incoming waveform and explain the trigger requirements. A summary detailing the advantages of each scope is provided at the end.

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Real-time oscilloscope

Real-time oscilloscope as an ADC

A real-time oscilloscope, sometimes called a "single-shot" scope, captures an entire waveform on each trigger event. Put another way, this means that a large number of data points are captured in one continuous record. To better understand this type of data acquisition, imagine it as an extremely fast analog-to-digital converter (ADC) in which the sample rate determines the sample spacing and the memory depth determines the number of points that will be displayed. In order to capture any waveform, the ADC sampling rate needs to be significantly faster than the frequency of the incoming waveform. This sample rate, which can be as fast as 40 GSa/s, determines the bandwidth which currently extends to 13 GHz.

Triggering the real-time oscilloscope

The real-time scope can be triggered on a feature of the data itself, and often a trigger will occur when the incoming waveform's amplitude reaches a certain threshold. It is at this point that the scope starts converting the analog waveform to digital data points at a rate asynchronous and very much unrelated to the input waveform's data rate. That conversion rate, known as the sampling rate, is typically derived from an internal clock signal. The scope samples the amplitude of the input waveform, stores that value in memory, and continues to the next sample as illustrated in Figure 1. The trigger's main job is to provide a horizontal time reference point for the incoming data.

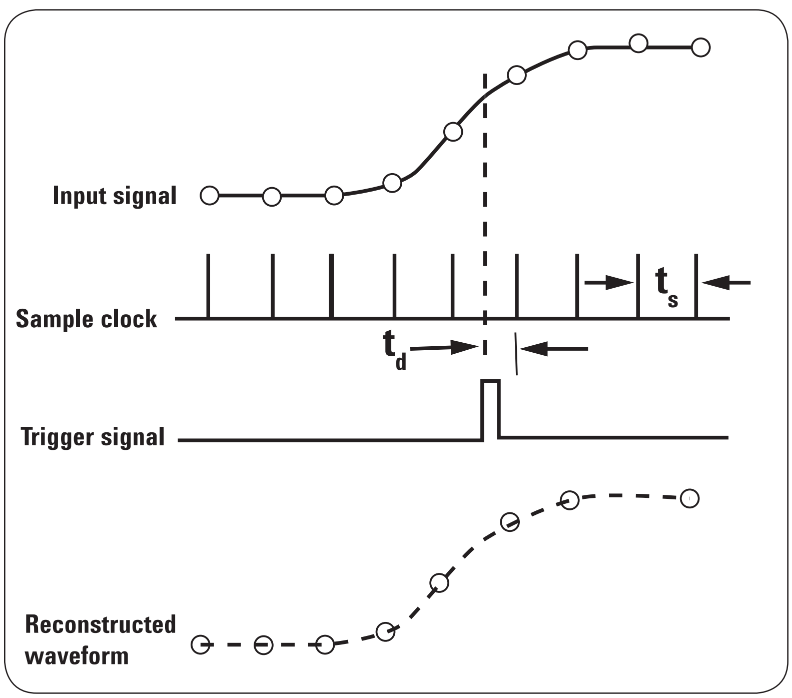


Figure 1 – Waveform acquisition using a real-time oscilloscope

Equivalent time sampling oscilloscope

One sample per cycle

An equivalent time sampling oscilloscope, sometimes simply called a "sampling scope," measures only the instantaneous amplitude of the waveform at the sampling instant. In contrast to the real-time scope, the input signal is only sampled once per trigger. The next time the scope is triggered, a small delay is added and another sample is taken. The intended number of samples determines the resulting number of cycles needed to reproduce the waveform. The measurement bandwidth is determined by the frequency response of the sampler which currently can extend beyond 70 GHz.

Sampling methodology

The triggering and subsequent sampling of an equivalent time sampling oscilloscope is different from a real-time oscilloscope in some very tangible ways. Most importantly, the equivalent time sampling scope needs an explicit trigger in order to operate, and this trigger needs to be synchronous with the input data. Typically this trigger is provided by the user but, in some cases, the trigger can be obtained using a hardware clock recovery module. The sampling works as follows: A trigger event initiates the acquisition of the first sample, then the scope rearms and waits for another trigger event. The rearm time is approximately 25 µs. The next trigger event initiates the second acquisition and adds a precise incremental delay before sampling the second data point. This incremental delay time is determined by the time base setting and the number of sample points. This process, which is illustrated in Figure 2, is repeated until the entire waveform is acquired.

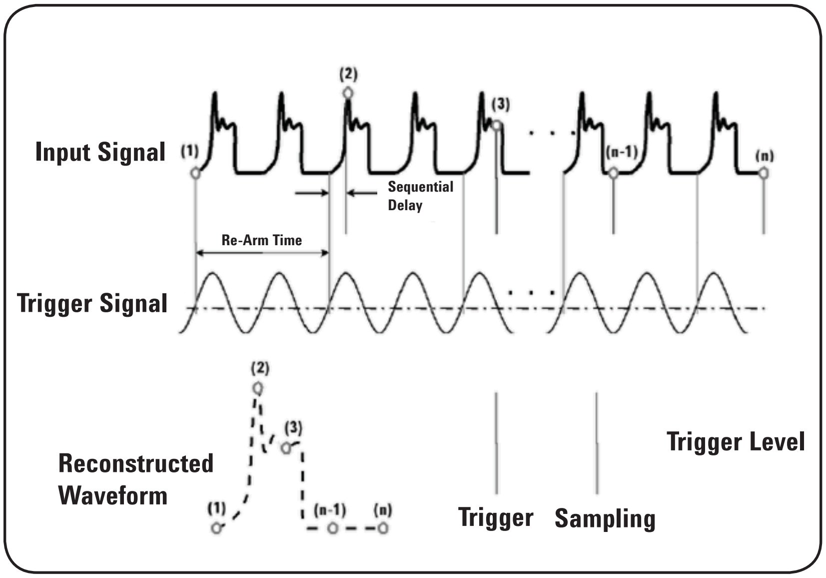


Figure 2 - Waveform acquisition using an equivalent time sampling oscilloscope

Equivalent time sampling oscilloscope (Continuation)

Triggering the equivalent time sampling scope

There are two ways to trigger an equivalent time sampling oscilloscope and each results in a different data viewing format; either a bit stream or an eye diagram. Viewing the individual bits in the signal allows the user to see the pattern dependencies in the system, but does not allow for high resolution with large numbers of bits. In order to view a bit stream, the trigger must only pulse once during the period of the input pattern and must be at the same relative location in the bit pattern for each event. The input signal is then sampled and upon the next trigger event, the incremental delay is added and the bit steam is sampled until the entire waveform is acquired. In order to view a bit stream on an equivalent time scope, you must have a repetitive waveform; otherwise a real-time scope is needed. The triggering process to display a bit stream waveform is shown in Figure 3.

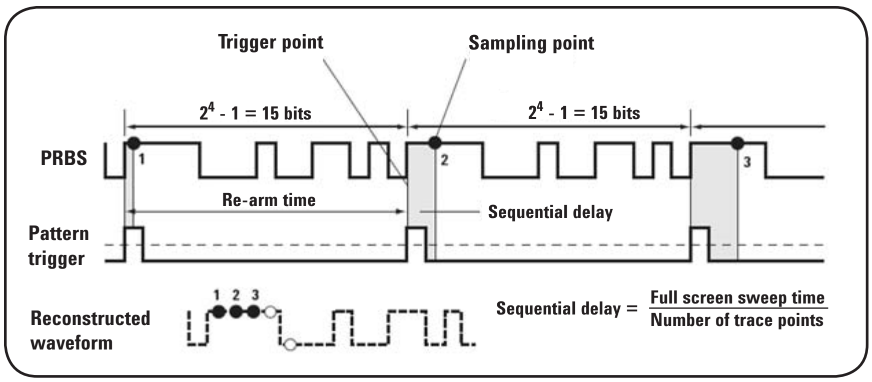


Figure 3 - Sampling Process for a Bit Steam Pattern Waveform

Eye diagram

Creating an eye diagram

The other viewing mode is the eye diagram. This mode does not require a repetitive waveform and can help to determine noise, jitter, distortion, and signal strength among many other measurements. It gives an overall statistical view of the system's performance as it looks at an overlay of every combination of bits in the bit steam. The triggering required for this mode is a synchronous clock signal. At each trigger event, allowing for rearm time, the scope samples the data and builds the combination of all possible 1 and 0 combinations across the screen. Full rate clocks as well as divided rate clocks can be used for the trigger, however if the length of the pattern is an even multiple of the clock divide ratio, the eye diagram will be missing combinations and will therefore be incomplete. In addition, if the data is used as its own trigger, the eye diagram may appear complete, but the scope is only triggered on rising edges of the data pattern. This should be avoided to make accurate eye diagram measurements. The triggering process to display an eye diagram is shown in Figure 4.

Real-time eyes

It is important to note that an eye diagram may also be viewed with newer real-time oscilloscopes. These "real-time eyes" or "single-shot" eye diagrams are constructed using a software recovered clock or an external explicit clock provided by the user. The real-time scope slices the single long capture waveform at times equal to the recovered clock cycle and overlays these bits to recreate the eye diagram.

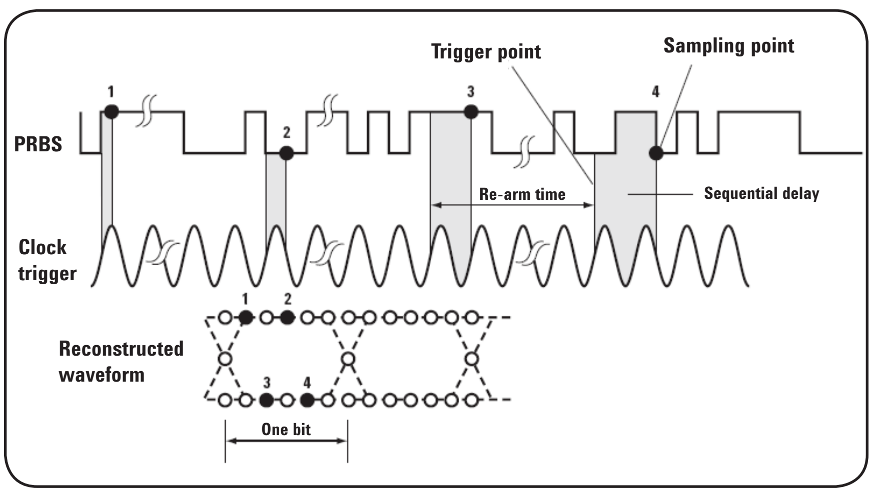
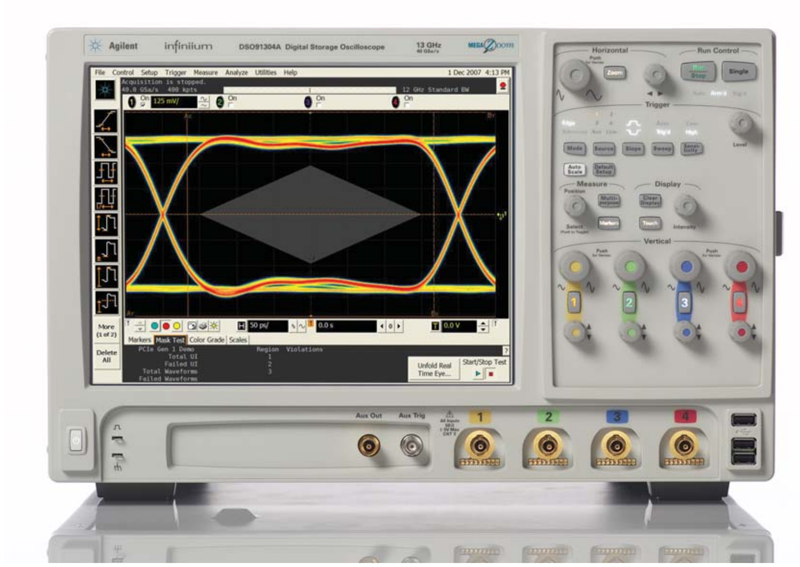


Figure 4 - Sampling Process for an Eye Diagram Waveform

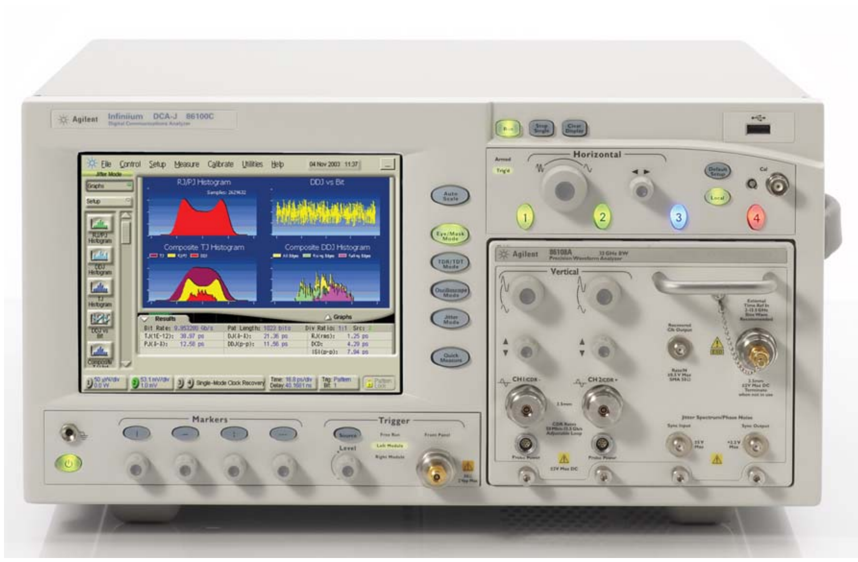
Advantages of Real-Time Scopes

- Able to display one-time transient events
- No explicit trigger needed
- Does not require a repetitive waveform
- Measures cycle to cycle jitter directly
- Large record lengths/ deep memory
- Great for troubleshooting scenarios



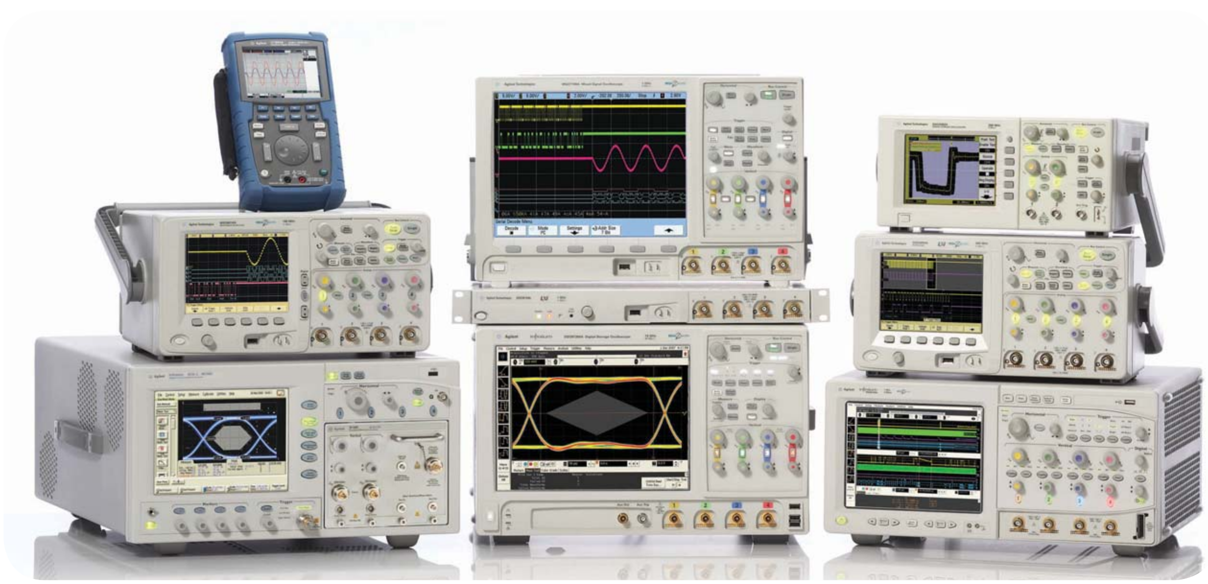
Advantages of Equivalent Time Sampling Scopes

- Lower sampling rate allows higher resolution ADC conversion
- Wider bandwidth
- Lower noise floor
- Lower intrinsic jitter
- Can include front end optical modules
- Can be used for TDR to obtain impedance and S-parameter measurements
- Can achieve solutions at a reduced cost



Related Literature

Publication Title	Publication Type	Publication Number
Picking the Optimal Oscilloscope for Serial Data Signal Integrity Validation and Debug	Application Note 1556	5989-2581EN
Triggering Wide-Bandwidth Sampling Oscilloscopes For Accurate Displays of High-Speed Digital Communications Waveforms	Product Note 86100-5	5989-2603EN
Loop Bandwidth and Clock Data Recovery (CDR) in Oscilloscope Measurements	Application Note 1304-6	5988-6682EN
Choosing an Oscilloscope with the Right Bandwidth for your Application	Application Note 1588	5989-5733EN
Precision Waveform Analysis for High-Speed Digital Communications Using the 86100C and 86108A	Application Note	5989-8362EN
Agilent Infiniium DSO/DSA90000A series	Data Sheet	5989-7819EN
Agilent 86100C Wide-Bandwidth Oscilloscope Mainframe and Modules	Data Sheet	5989-0278EN



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