1. How are the PicoScope 9000 Series Sampling Oscilloscopes different from normal digital storage oscilloscopes?

Digital storage oscilloscopes (DSOs) work by sampling the input signal at regular intervals. The samples are then reconstructed to draw a picture of the signal, as illustrated in Fig. 1. The samples must be taken frequently enough to capture the fastest variations in the signal. This technique is called *real-time sampling*.

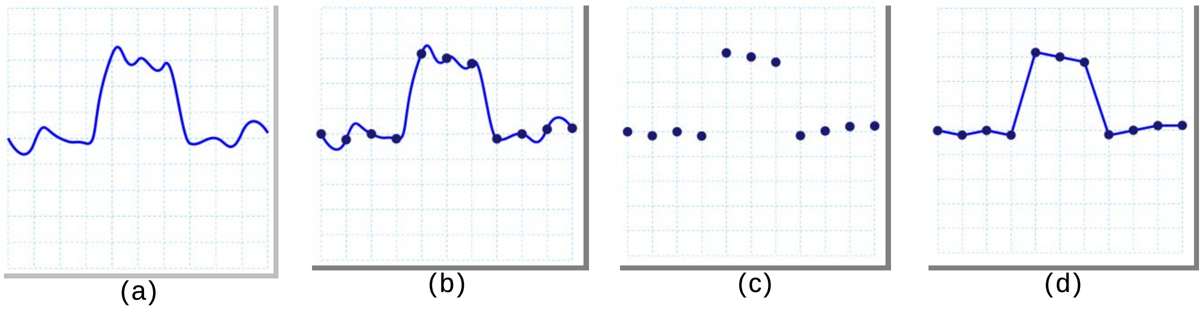


Fig. 1 – Real-time sampling. (a) Original signal. (b) Scope samples signal at regular intervals. (c) Samples are stored in memory. (d) Scope draws approximation of signal using stored samples.

A *sampling oscilloscope* is a special type of oscilloscope that uses a technique called *sequential time sampling*. This type of sampling is best suited to repetitive waveforms or those that are derived from a regular clock, such as serial data streams, clock waveforms and pulses in digital circuits, semiconductor test patterns, and amplifier pulse-response and rise-time tests. Signals like these tend to have very high bandwidths or high data rates. A sampling scope captures just one sample from one trigger event, typically a single cycle of the waveform or clock, and then repeats the process over a large number of cycles, varying the timing of the sample by a small increment from one sample to the next. The resulting collection of samples is then assembled into a picture of a typical cycle.

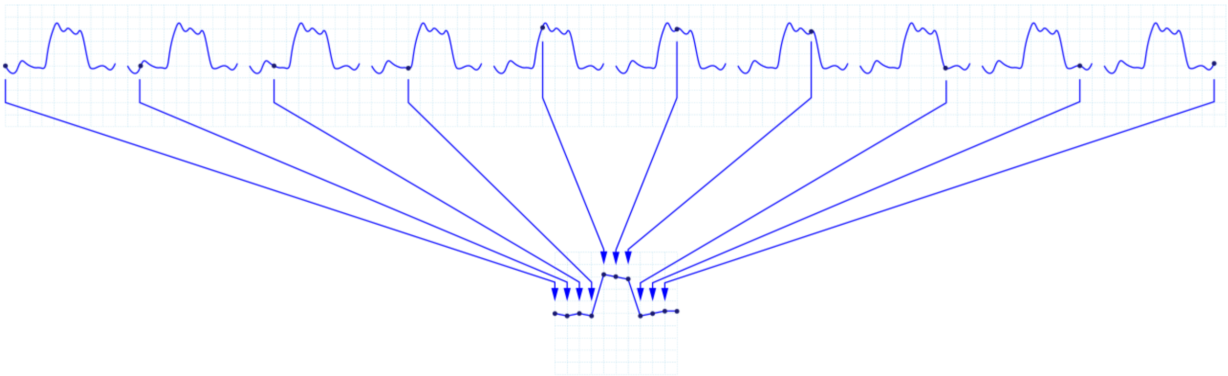


Fig. 2 – Sequential time sampling. One sample is taken from each triggered event in a sequence. The samples are assembled to form a composite waveform.

The advantage of a sampling scope is that even with input signals in the gigahertz range, the output of the sampler is at a much lower frequency, typically in the audio frequency band. This allows high-fidelity, low-frequency amplifiers and ADCs to be used to capture the signal. For example, the PicoScope 9300 Series can capture waveforms up to 20 GHz with high precision (16-bit resolution before scaling and processing). A real-time DSO that could capture a single cycle of the same 20 GHz waveform would be prohibitively expensive. For example the 20 GHz Agilent DSOX92004A, with a real-time sampling rate of 80 GS/s, has a base price of $177,000 — almost 12 times the price of the PicoScope 9301 while yielding only 4 samples per cycle. The PicoScope 9300 Series, sampling at an effective rate of 15 THz, would yield 750 samples per cycle of the same waveform.

A further benefit is that every sample point in the sequential sampling process is timed from the trigger event, and therefore from the original signal, rather than derived from an internal oscillator. Sampling jitter is therefore vastly reduced compared to the single-trigger, clock-derived sampling of the real-time DSO counterpart.

2. Are the PicoScope 9000 Series Sampling Oscilloscopes digital signal analyzers (DSAs)?

Yes. Some manufacturers use that term for sampling scopes that are aimed at the digital signal market. We chose to call the PicoScope 9000 Series 'sampling oscilloscopes' because they are more versatile than purely digital instruments: they can also be used to analyze repetitive analog waveforms.

3. What is the difference between the real-time sampling rate of a DSO and the effective sampling rate of a sampling oscilloscope?

The real-time sampling rate of an oscilloscope is the rate at which its ADC can reliably sample the input waveform. If you wish to capture a single event such as a one-off glitch in a digital circuit, the oscilloscope has only one chance to acquire enough samples to represent the waveform accurately. In such cases, there is no substitute for an oscilloscope with a high real-time sampling rate. A common rule of thumb is that at least 10 samples are needed for each cycle of the waveform. For example, if the signal in question is a 2 GHz square wave, then a scope with a real-time sampling rate of at least 20 GS/s would be needed to capture a realistic-looking picture. For accurate analysis of the timing and shape of the waveform, as required in mask testing, several hundred samples are needed. This would entail a real-time sampling rate of 200 GS/s or more, which is beyond the capabilities of today's off-the-shelf instruments and, even if such a scope existed, it would be prohibitively expensive.

The effective sampling rate of a sampling oscilloscope is not a measure of the speed of its ADC; it is the accuracy with which it can reconstruct a waveform using its sampling and timing circuitry. PicoScope sampling oscilloscopes use dedicated hardware to provide sequential time sampling (STS). STS inserts a precisely defined delay between the trigger event and the sampling instant and then increments the delay by a small time difference from one trigger/sample pair to the next. This creates a sequence of samples at predictable, equally spaced and potentially very short intervals.

In STS mode, thanks to their highly accurate timing circuitry and low sampling jitter, the fastest PicoScope 9000 Series Sampling Oscilloscopes can achieve a timing resolution, also called *effective sampling interval*, as short as 64 femtoseconds (64×10^{-15} s). This can also be expressed as an *effective sampling rate* of 15 terasamples per second (15×10^{12} S/s).

The PicoScope 9000 Series provides an alternative sampling mode called equivalent-time sampling (ETS). ETS uses the random drift of the internal sampling clock with respect to the signal to create an unpredictable sampling delay. The oscilloscope measures the delay between the trigger and the internal clock for each sample and uses it to calculate the correct time coordinate of the sample. This method is also used in some real-time oscilloscopes to emulate a sampling oscilloscope. Its main advantage over ETS is its ability to capture pre-trigger as well as post-trigger data, but this is at the expense of the longer and less predictable time needed to accumulate the required number of samples. ETS mode on the PicoScope 9000 Series gives 4 ns timing resolution and therefore an effective sampling rate of 250 MS/s for repetitive signals.

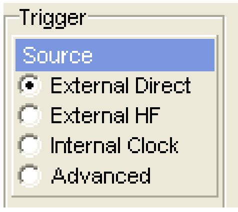
Many of today's DSOs list both real-time and effective (ETS) sampling rates in their specifications. When choosing an oscilloscope, you need to make sure that both sampling rates are adequate for your application.

4. Can I use the PicoScope 9000 Series Sampling Oscilloscopes in general test and measurement applications?

The PicoScope 9000 Series Sampling Oscilloscopes are not intended to replace the general-purpose oscilloscope on your workbench. The main differences between oscilloscopes in the PicoScope 9000 Series and a general-purpose scope are as follows:

- **SMA and 2.92 mm input connectors**. General-purpose scopes usually have BNC connectors on their inputs, but these connectors do not have a well-defined impedance above about 2 to 3 GHz. SMA connectors are better suited to high-frequency signals and are widely used in microwave applications.
- **50 ohm inputs**. The PicoScope 9000 Series have low-impedance inputs that work well with low-impedance probes and active probes. The low input impedance is necessary to ensure that we receive the signal that we wish to measure, rather than reflecting a significant proportion of it back to the source. Most instruments designed for signals above about 500 MHz have input and output impedances of 50 Ω. High-impedance passive probes are not suitable for use with these instruments.
- **±2 volt safe input range**. The sensitive, high–bandwidth input circuitry of the PicoScope 9000 Series does not allow the same wide range of input voltages as found on general-purpose scopes. If your signal is larger than ±1 volt (the maximum measuring range) then you must use an external attenuator. You must also be aware that sampling oscilloscope inputs are susceptible to electrostatic discharge (ESD) damage. A DSO typically includes switched but slower attenuators and amplifiers to achieve greater dynamic range (at the expense of fidelity and bandwidth), and these make it less susceptible to ESD.
- **Unique DSO capability.** The PicoScope 9000 Series scopes are optimized for use as sequential sampling and random equivalent time oscilloscopes. Their design is focused on achieving very high effective sampling rates and very low sampling jitter. However, uniquely among sampling scopes, they can also operate in a real-time mode with trigger and sampling modes similar to a DSO and a transient sampling rate of 1 MHz. This allows convenient probing of LF signals into the tens of megahertz without the need for a separate trigger.
- **Dedicated software**. The software supplied with the PicoScope 9000 Series is designed to work only with sampling oscilloscopes. It provides advanced display features such as eye diagrams and histograms, and specialised measurements and industry-standard mask tests that do not apply to real-time oscilloscopes. This software is very different from PicoScope 6, our general-purpose oscilloscope software, in both appearance and function.

5. What is the difference between direct and prescaled trigger on a sampling oscilloscope and the trigger or external trigger on a DSO?



A sampling oscilloscope requires a separate trigger input, either from an external clock signal or derived from the data signal by a clock recovery module. PicoScope 9000 Series oscilloscopes have two trigger inputs. The Direct Trigger is a full-function trigger input with a bandwidth of 1 to 2.5 GHz, and is applied directly to the trigger circuitry. This input allows variable slope, hysteresis and trigger level. The HF (Prescaled) Trigger input passes through an internal frequency divider before being applied to the trigger circuitry. This input has a higher bandwidth, from 10 to 14 GHz, but lacks the adjustments available on the Direct Trigger input.

Many DSOs have an external trigger input but, in contrast to sampling oscilloscopes, in many cases they can also trigger on the input signal itself without the need for a separate trigger signal.

6. What is the histogram function for?

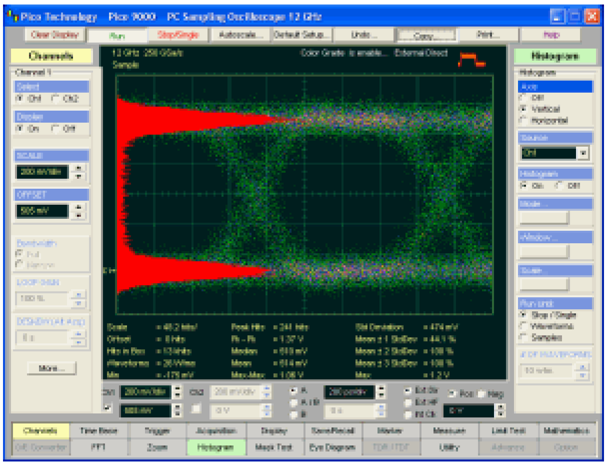


Fig. 3 – Histogram. A vertical histogram shows the signal density as a function of voltage, and helps to visualise noise.

The PicoScope 9000 Series Sampling Oscilloscopes can collect large numbers of waveforms and perform statistical analysis on them. The results of the analysis can be displayed as histograms against voltage (vertical histograms) or time (horizontal histograms). A vertical histogram shows how much time the signal spends at each voltage level, and is useful for visualising RMS noise and noise margins; while a horizontal histogram shows how much time is spent at each time interval and indicates RMS jitter and timing margins. Histograms help you to visualize the quality of your signal, but if you prefer you can also get statistics in numerical form by using the built-in statistics functions. The histogram analysis is performed on the area defined by a box drawn around the waveform, allowing statistical focus on a narrow time slice, a narrow voltage slice (or threshold) through to the entire displayed waveform.

7. Prices starting from less than $10,000? What's the catch?

There are no hidden extra costs. When you buy a PicoScope 9000 Series Sampling Oscilloscope, you get a complete system: the front-end hardware to plug into your USB port, a mains power adapter, and Windows-based software for your PC. You just provide the computer. You also get valuable extra services: free, time-unlimited support from our technical specialists, and free software updates for as long as we continue to support the product.

Of course, every lab needs more than just a scope. You will need cables, connectors, and possibly coaxial dividers and attenuators, but these are all application-specific and you are likely to have them on your shelf anyway.