Eltesta

FemtoScope 1000/2000/3000 Series

5 and 16 GHz USB Wide-Bandwidth Oscilloscopes

Data Sheet

The capabilities of a Lab Oscilloscope for a Price of Miniature USB Oscilloscope

- *FemtoScope* 3164: 16 GHz bandwidth, 4 channels
- *FemtoScope* 2162: 16 GHz bandwidth, 2 channels
- *FemtoScope* 1161: 16 GHz bandwidth, 1 channel
- *FemtoScope* 3054: 5 GHz bandwidth, 4 channels
- *FemtoScope* 2052: 5 GHz bandwidth, 2 channels
- *FemtoScope* 1051: 5 GHz bandwidth, 1 channel

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Oscilloscope Overview

More recently, if you needed an oscilloscope with a bandwidth of more than 5 GHz, you had to accept the need for significant financial costs. The *FemtoScope* models set a new price/performance ratio standard for gigahertz frequency USB oscilloscopes.

These single-, dual- or four-channel instruments, having a bandwidth of 5 GHz or 16 GHz and triggering over the entire frequency range, provide the acquisition, display, measurement and analysis of complex waveforms in the range from picoseconds to hundreds of seconds.

These oscilloscopes are designed for engineers working both in research laboratories and in production workshops, and who, above all, need characteristics associated with flexible measurements of wide-bandwidth signals.

Being a direct alternative to traditional benchtop oscilloscopes, these instruments are portable, and maybe even miniature, and, what is extremely important, they have an incomparably lower cost. Economical prices make the *FemtoScope* Series preferred for teaching basic scientific and engineering measurements at lab stations in schools and universities. Features normally only found on much higher priced scopes equip the *FemtoScope* Series to be a powerful choice for R&D applications.

Figure 1. Three 16-GHz wide-bandwidth USB oscilloscopes *FemtoScope* 3164, *FemtoScopes* 2162 and *FemtoScope* 1161 capture rise times as fast as 16 ps (20%/80%) and 22 ps (10%/90%).

Features

- 1, 2 or 4 channels configuration.
- The industry's widest 5 GHz or 16 GHz USB oscilloscope bandwidths available to match your measurement application,
- The industry's lowest 1.5 ps rms intrinsic jitter for PC oscilloscope.
- 12-bit Analog-to-Digital Converter with 500 MSa/s real time sampling rate per channel.
- Up to ±1% of full scale DC gain accuracy.
- The industry's highest equivalent time sampling rate up to 5 TSA/s for USB oscilloscope.
- 10 ps/div fastest time base scale.
- Up to ±2 ps delta time measurement accuracy.
- Up to 16 GHz trigger bandwidth enables capture and analysis wide-bandwidth complex signals.
- Up to 11.3 Gb/s clock recovery trigger data rate.
- Powerful SW and flexible, simple and intuitive user interface with built-in OnLine Help and demo training signals.
- Color graded display, automatic measurements, eye diagrams, mask test, histograms, waveform mathematics, 7-digit built-in trigger frequency counter, spectrum analysis with FFT, autoscale, store waveforms and setups.
- USB connection.
- LAN connection (*FemtoScope* 3000 only).
- Less than 15 W, 22 W or 33 W power consumption.
- Less than 370 g, 790 g or 1.52 kg weight
- Less than 1.9 sq.dm., 3.4 sq.dm. or 5.69 sq.dm. footprint.
- Economical price starting from € 6 490.

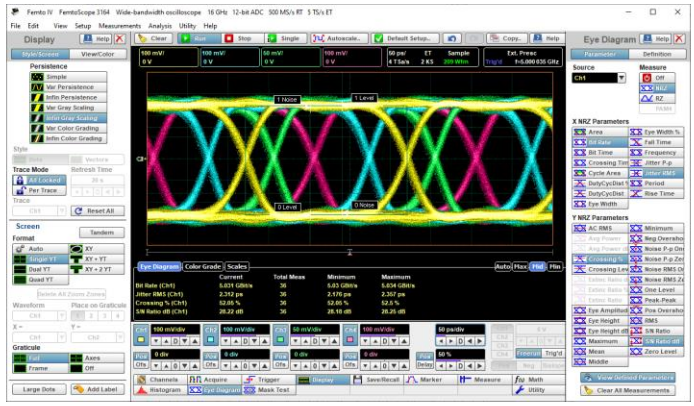


Figure 2. The *FemtoScope* 3164 provides best solutions for fast eye diagram measurements.

Overview of the *FemtoScope* Series Key Specifications

Model	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Input channels	1	2	4	1	2	4
Bandwidth	DC to 5 GHz			DC to 16 GHz		
Vertical scale	10 to 250 mV/div					
DC gain accuracy	±1.5% of full scale		±1% of full scale	±1.5% of full scale		±1% of full scale
DC offset range	-1 V to +1 V					
Input impedance	50 Ω					
Real TB range	10 ns/div to 1000 s/div					
Equivalent time base range	50 ps/div to 5 us/div			10 ps/div to 5 us/div		
Real time sampling rate	500 MSa/s max					
Equivalent time sampling rate	1 TSa/s max			5 TSa/s max		
Time base clock accuracy	± 0.5 ppm	± 5 ppm		± 0.5 ppm	± 5 ppm	
Delta time measurement accuracy	***FS* 1000:** ± (2 ppm * reading + 0.1% * screen width + 5 ps) ***FS* 2000:** ± (15 ppm * reading + 0.1% * screen width + 5 ps) ***FS* 3000:** ± (15 ppm * reading + 0.1% * screen width + 2 ps)					
ADC resolution	12 bits					
Record length	250 kSa max					
Trigger Source	Internal, External Direct				Internal, External Direct or Prescaled	
Trigger Style	Direct, Divided	Direct, Divided, Clock Recovery		Direct, Divided	Direct, Divided, Clock Recovery, Prescaled	
Direct Trigger Bandwidth	DC to 3 GHz					
Divided Trigger Bandwidth	DC to 6 GHz					
Prescaled Trigger Bandwidth	N/A				1 to 16 GHz	
Clock Recovery Data Rate	N/A	6.5 MSa/s to 5 GSa/s	6.5 MSa/s to 11.3 GSa/s	N/A	6.5 MSa/s to 5 GSa/s	6.5 MSa/s to 11.3 GSa/s
RMS trigger jitter	1.5 ps typ, 2 ps max		1.2 ps typ, 1.5 ps max	1.5 ps typ, 2 ps max		1.2 ps typ, 1.5 ps max

The *FemtoScope* USB oscilloscopes utilize modern hardware to perform many of the functions that traditional digitizers do with software on the CPU. Built as a single-board oscilloscope, they are controlled from a computer via USB interface. Acquisition Board includes ultra-wideband track-and-hold amplifiers, 12-bit ADCs with 500 MSa/s sampling rate, high-speed trigger circuity and timing interpolator with sub-picosecond resolution. A state-of-the-art microprocessor, FPGA and precision clock oscillator provide structure flexibility, fast acquisition speed and effective interaction with PC.

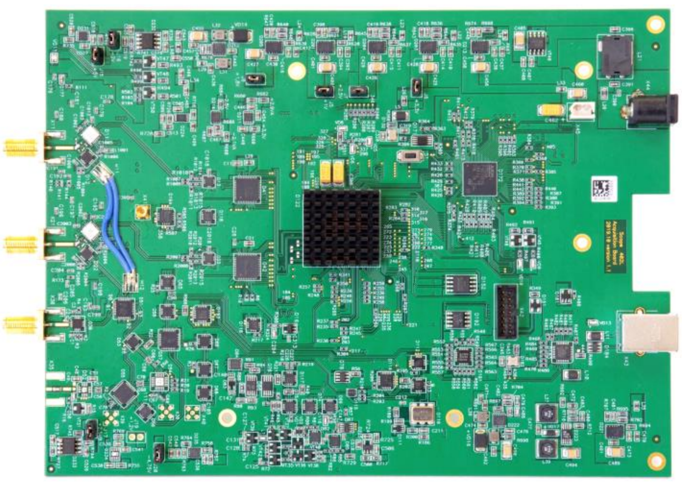


Figure 3. Acquisition Board of the *FemtoScope* 2052

Bandwidth and transient response

The *FemtoScope* Series USB oscilloscopes have one, two or four input channels to 5 GHz or 16 GHz bandwidth (Figures 4 and 5) with market-leading ADC, timing and display resolutions for accurately measuring and visualizing high-speed analog and data signals. They are ideal for capturing pulse and step transitions down to 70 or 22 ps, impulses down to 140 or 80 ps and clocks and data eyes to 5 or 11.3 Gb/s. Most high-bandwidth applications involve repetitive signals or clock-related data streams that can be readily analyzed with these oscilloscopes by equivalent-time sampling.

The heart of each of the channel is a wide-bandwidth track-and-hold amplifier, which stores the analog voltage at the channel input at a time determined by the arrival of a 500-MHz sampling pulse. The inputs include wide-bandwidth symmetrical resistive voltage divider. One half of the signal goes to the THA, the other to the trigger comparator. The input impedance of the channel is (50 ± 1.5) Ohms. With a maximum permissible input voltage of ±2 V, the dynamic range of the input signals is ±1 V.

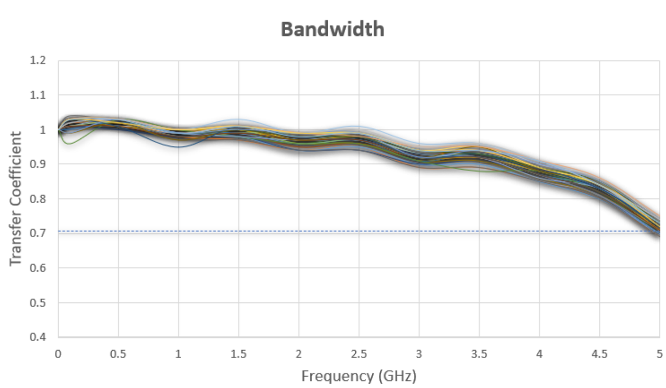


Figure 4. Frequency response of forty 5-GHz input channels.

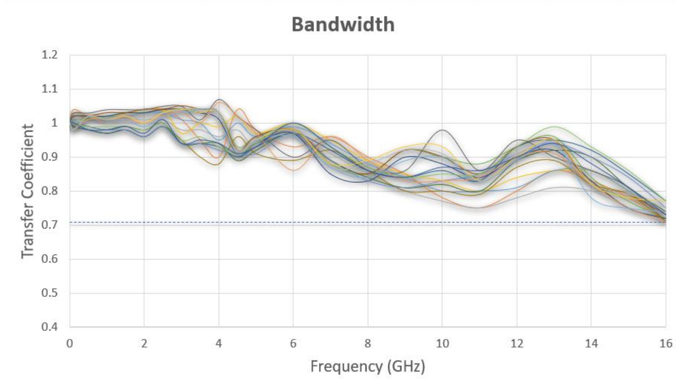


Figure 5. Frequency response of twenty 16-GHz input channels.

User-selectable hardware bandwidth-limiting reduces vertical noise. More bandwidth enhances quality of your measurements except when you want to limit noise level coming from additional bandwidth. However wide bandwidth may not be the best solution when you are making low-noise measurements as the additional bandwidth captures additional high-frequency noise along with high-frequency signal content.

The *FemtoScope* 1000 and 2000 provide two bandwidths – full and 500 MHz, while the *FemtoScope* 3000 provides three bandwidths – full, 500 MHz or 100 MHz.

Their transient response characteristics are shown in Figures 5-9.

Figure 5. Transient response of the *FemtoScope* 2162 tested with Keysight N2806A Calibration Generator. Total measured fall time is 23.71 ps, rms jitter is 1.256 ps, and negative overshot is 5.495%.

Figure 6. Transient response of the *FemtoScope* 1161 tested with 1.6 V step having 25 ps rise time. Response shows 31.8 ps rise time and 1.45 ps rms jitter.

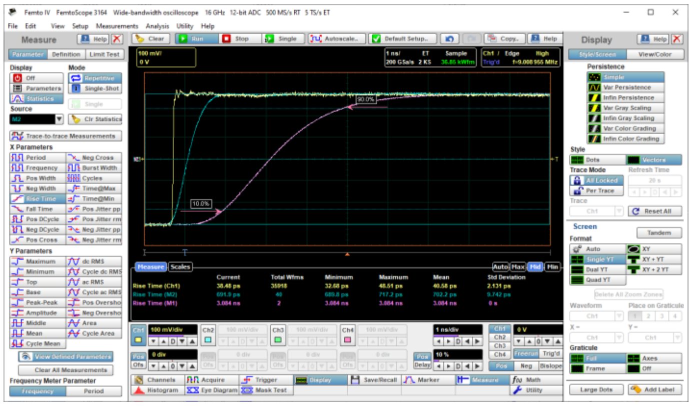


Figure 7. Comparative transient response of the *FemtoScope* 3164 made for three different bandwidths. Yellow shows 40.58 ps rise time acquired in full 16-GHz bandwidth, blue shows 702 ps rise time acquired in 500-MHz bandwidth and violet shows 3.084 ns rise time acquired in 100-MHz bandwidth.

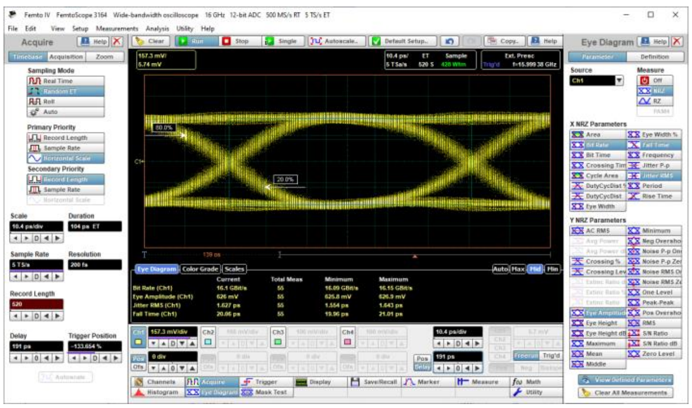


Figure 8. 16 Gb/s data rate and 600 mV amplitude eye diagram acquired with the *FemtoScope* 3164. Eye rms jitter = 1.643 ps. Eye fall time = 21.01 ps. Signal source: Anritsu MP1800A Signal Quality Analyzer.

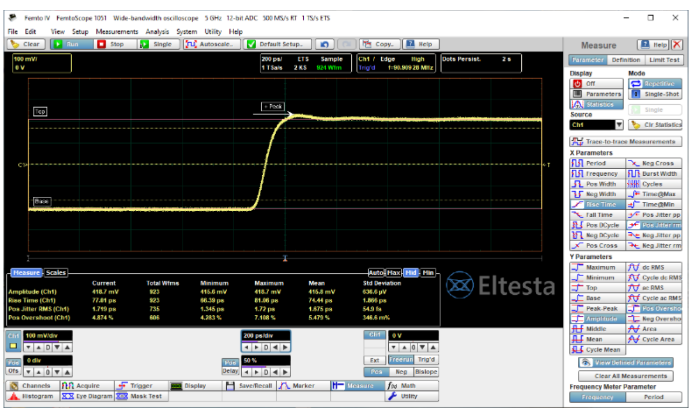


Figure 9. Transient response of 5-GHz *FemtoScope* 1051 shows less than 75 ps total rise time measured from Tektronix 1251 PPG (25 ps own rise time).

In full bandwidth mode, the instruments provide typical rms noise level less than 1.6 mV (for 5 GHz bandwidth) and 2.2 mV (for 16 GHz bandwidth). In 500 MHz mode, the THA operates in the “transparency” mode, providing 500 MHz bandwidth with less than 0.65 mV typical rms noise. This opens possibility to perform more sensitive measurements. Figure 10 shows wide opened 800 Mb/s eye diagram acquired in 500 MHz bandwidth mode that demonstrates extremely good response characteristics. In 100 MHz bandwidth mode, the *FemtoScope* 3000s provide typical rms noise less than 0.45 mV.

Narrow bandwidth setting can also be used as an anti-alias filter.

Figure 10. 800 Mb/s wide opened eye diagram acquired in narrow bandwidth mode with the *FemtoScope* 1051 shows good response characteristics.

Vertical channels and probes

Providing up to 12 bits of vertical resolution the *FemtoScope* allow to control vertical sensitivity between 10 mV/div and 250 mV/div. Full scale is defined as 8 vertical divisions, and further zooming may increase sensitivity in 100 times. With ±1.5% or even ±1% DC gain accuracy for the *FemtoScope* 3000s, also ±1 V DC offset the scopes provide wide input dynamic range between -1 V and +1 V.

Figure 11 shows 1.9 V amplitude pulse symmetrical to zero. With rise time faster than 10 ns it has very small ringing within ±1 %.

With 50 Ω channel input impedance all the oscilloscopes used standard SMA female connector providing ±2 V (DC + peak AC) maximum input voltage.

You can use wide range of high-bandwidth low-impedance probes. The PicoConnect 900 family of high performance, ultra-low capacitance passive probes tailored to low invasive probing of high speed data lines out to 18 Gb/s (9 GHz). They are ideal companions for the *FemtoScope* Series, allowing cost-effective fingertip browsing of fast signals.

Two series are available: RF, microwave and pulse probes for broadband signals up to 5 GHz (10 Gb/s), and Gigabit probes for data streams such as USB 2, HDMI 1, Ethernet, PCIe and SATA up to 9 GHz (18 Gb/s).

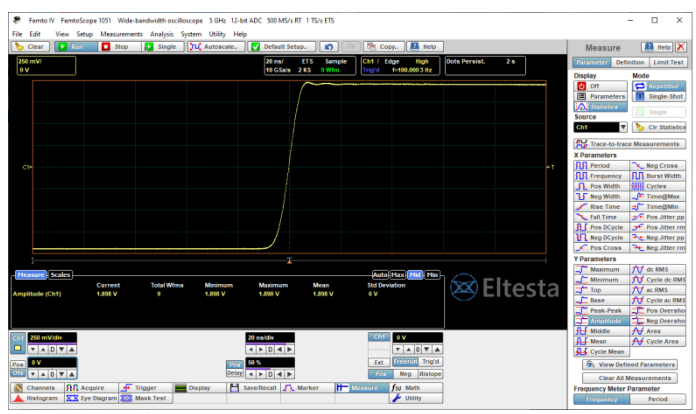


Figure 11. Symmetrical to zero pulse having less than 10 ns rise time and 1.9 V amplitude shows ringing less than ±1 % on the *FemtoScope* 1051.

Acquisition and time base

The *FemtoScope* oscilloscopes used real-time, equivalent-time and roll sampling modes.

Real-time sampling mode is designed with a high enough sampling rate to capture a transient, non-repetitive signal with the instrument’s specified analog bandwidth up to 200 MHz. According to Nyquist’s sampling theorem, for accurate capture and display of the signal the scope's sampling rate must be at least twice the signal bandwidth. Typical high-bandwidth real-time oscilloscopes exceed this sampling rate by perhaps a factor of two, achieving up to four samples per cycle, or three samples in a minimum-width impulse.

Several acquisition modes let you choose how the oscilloscope will create points in the waveform record. Average calculates the average values for each record point over many waveform records. It is available in in real- and equivalent-time modes. Min-Max, Min and Max Envelope use the highest and lowest samples across several waveform records. These are also available in real- and equivalent-time modes. Peak Detect mode alternates between saving the highest sample in one acquisition interval and the lowest sample in the next acquisition interval. It is available in real-time only. High Resolution mode averages all samples taken during an acquisition interval to create a record point. This average results in a higher-resolution, lower-bandwidth waveform that works with real-time mode.

Time scale accuracy is critical, especially when you need deep-memory applications. In real-time acquisition the *FemtoScope* used stable internal 500 MHz clock that allows 10 ns/div faster time base scale (Fig 12).

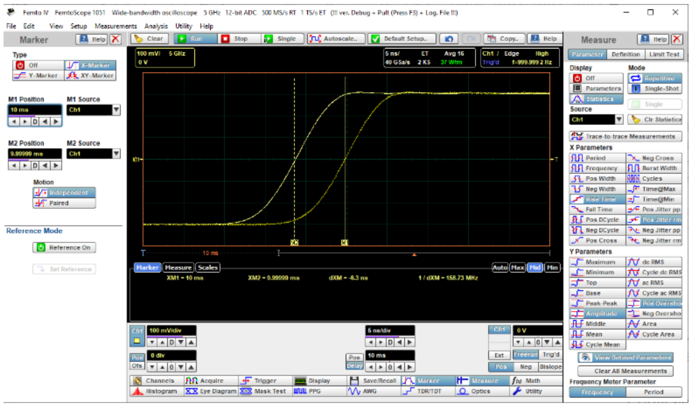


Figure 12. The *FemtoScope* 1051 demonstrates real time base accuracy. Timing shift is 6.3 ns at 10 ms delay that is equivalent to 0.63 ppm timing accuracy.

Stability of real-time clock can be estimated as a „long-time" jitter. Figure 13 demonstrates 716 ps rms jitter measured at 100 ms horizontal delay. This is equivalent to 7.16 ppb real-time rms jitter.

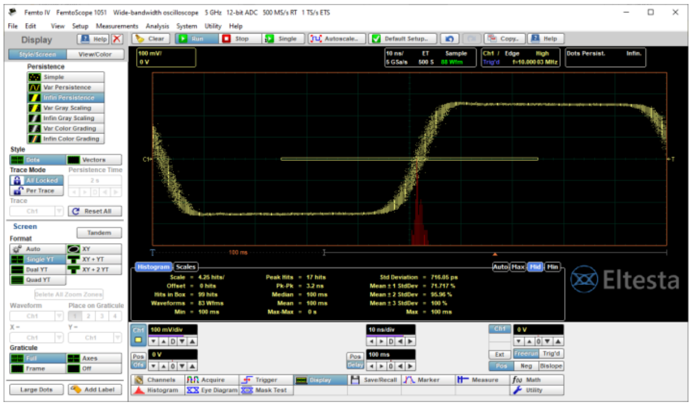


Figure 13. The FemtoScope 1051 measures real-time base long jitter from a stable 10 MHz clock source. RMS jitter value shows 716 ps at 100 ms horizontal delay that is equivalent to 7.16 ppb real-time rms jitter

For signals close to or above Nyquist limit, the *FemtoScopes* can be switched into equivalent-time sampling mode. In this mode the scope acquires as many samples as it can for each of many trigger events, each trigger contributing more and more samples and detail in a reconstructed waveform. Critical to alignment of these samples is a separate and precise measurement of time between each trigger and the next occurring sample clock. After a large number of trigger events the scope has enough samples to display the waveform with the desired time resolution. This is called the effective sampling resolution, which is many times higher than is possible in real-time mode. As an example the *FemtoScope* 2000s and 3000s have 0.2 ps timing resolution that is equivalent to 5 TSa/s equivalent-time sampling rate. For the *FemtoScope* 1000s these two figures are 1 ps and 1 TSa/s.

As this technique relies on a random relationship between trigger events and the sampling clock, it is more correctly called random equivalent-time sampling (or sometimes random interleaved sampling, RIS). It can be used for repetitive signals or for data pattern when you want to build an eye diagrams.

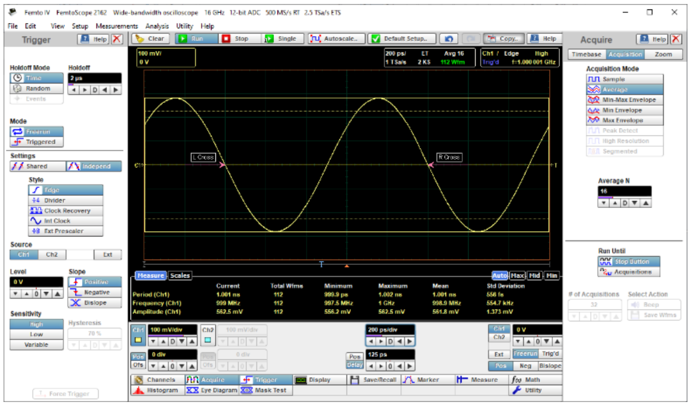


Figure 14. The *FemtoScope* 2162 tests accuracy of 200 ps/div horizontal scale with 1 GHz sinewave (1 ns period). Mean value of measured period is 1.001 ns

Equivalent-time sampling mode is the most actual for signal integrity measurements when you need very accurate results for such parameters as rise time or jitter. Precise picosecond time base and low intrinsic trigger jitter are necessary for ensuring high-speed test system reliability. With more lower the value, the better you'll be able to characterize your device. See Figures 14 and 15.

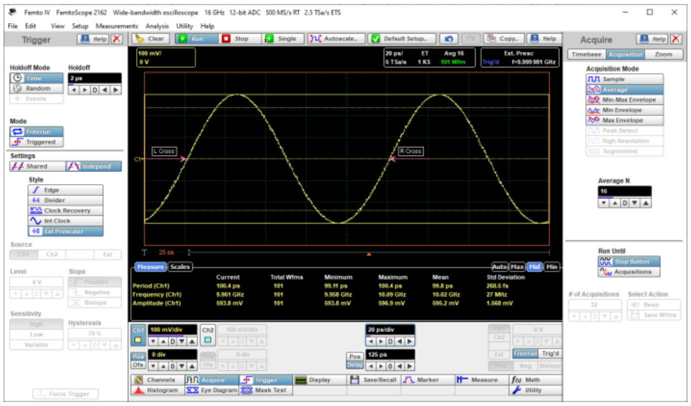


Figure 15. The *FemtoScope* 2162 tests accuracy of 20 ps/div horizontal scale with 10 GHz sinewave (100 ps period). Mean value of measured period is 99.8 ps.

Zoom

Due to the long memory, the zoom allows you to view and compare up to four vertically and horizontally enlarged waveform sections simultaneously. At the same time, it is possible to shift any of zoomed zones both vertically and horizontally (Fig. 16). The maximum vertical zoom is 100, and maximum horizontal zoom is 2048.

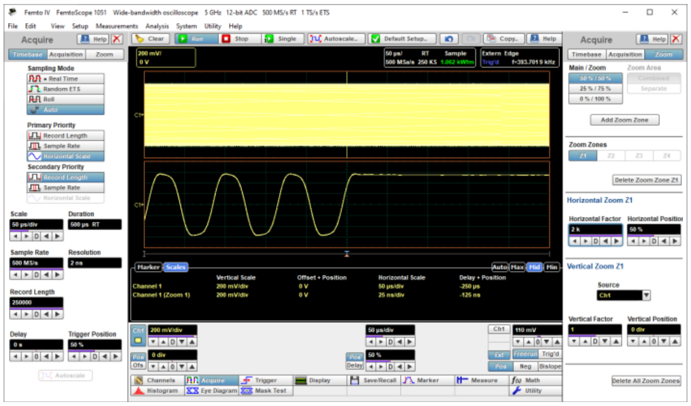


Figure 16. 50 Mb/s data pattern is acquired at 500 MSa/s sampling rate, 50 us/div time base and 250 KB record length (top). With 2K horizontal zoom you have possibility to measure the details of the waveform at 25 ns/div time base (bottom)

Trigger

One of the most important properties of wide-bandwidth oscilloscopes is their ability to provide extremely low-jitter trigger in wide frequency range. The difficulties in providing such properties were primarily associated with the following reasons.

First, the *FemtoScopes* are not a fully real-time oscilloscope that meets the Nyquist criterion in full bandwidth range. Therefore, the use of the so-called software trigger is not possible.

Secondly, the trigger electronics was not supposed to be designed as a custom IC, which would significantly increase the cost of development. As a result, the trigger was created on the basis of the fastest logic ICs having up to 10 GHz clock frequency and an output voltage slope of more than 4 V/ns.

All the models of the oscilloscopes provide full-function internal or external direct trigger up to 3 GHz. Input high-speed comparators allow you to adjust the trigger level and hysteresis, providing trigger sensitivity better than 70 mV. It is possible to select any of the trigger slope, as well as use the bi-slope trigger, which allows you to acquire the so-called pseudo-eye diagrams.

Figure 17. The FemtoScope 1051 surely triggers from 2.5 GHz sinewave with 1.62 ps rms jitter using internal trigger source

To expand the trigger frequency range up to 6 GHz, all the models provides a frequency divider mode. This mode is especially relevant for measurements on such popular clock ranges as 3.25 GHz and 5 GHz.

Finally the *FemtoScope* 2162 and 3164 provide external prescaled trigger within full 16-GHz bandwidth. This trigger is realized by using high-frequency divider with fixed /8 division factor, as well as a small additive phase noise, which helps to achieve a low trigger jitter level (Fig. 18).

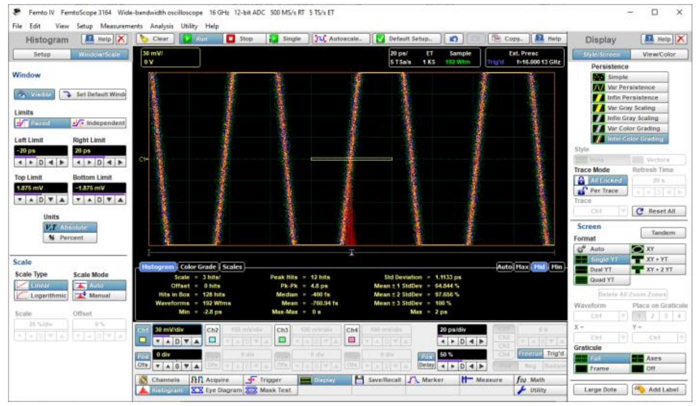


Figure 18. The *FemtoScope* 3164 provides external prescaled trigger from 16 GHz sinewave with 1.11 ps rms jitter.

A distinctive feature of all the *FemtoScope* models is their ability to trigger from extremely short pulses. This is important both when you acquire simple pulse waveforms and when you want to analyse fast data patterns.

Figure 19 shows how the *FemtoScope* 1161 internally triggers with a short pulse having less than 81 ps width. Such pulses are the shortest in a 12.5 Gb/s data pattern.

Basically you can trigger your oscilloscope from 30 mV signal at 100 MHz to 70 mV signal at 6 GHz.

Figure 19. The *FemtoScope* 1161 demonstrates internal direct trigger from 81-ps pulse having 400 mV amplitude and 781 MHz frequency

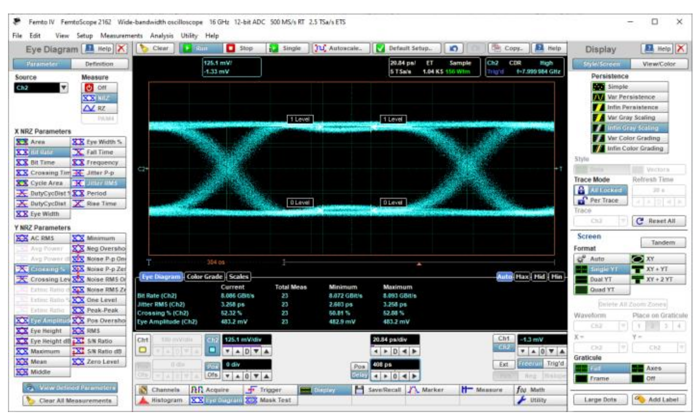


Figure 20. The *FemtoScope* 2162 acquires 8 Gb/s eye diagram with clock recovery trigger

Clock recovery trigger

The *FemtoScope* 2000s and 3000s oscilloscopes provide clock recovery trigger. This trigger mode is necessary when you need to display an eye diagram based on the clock recovered from input data pattern. The *FemtoScope* 2052 and 3054 allow you to recover clock for up to 5 Gb/s data rate, while the *FemtoScope* 2162 and 3164 provide this style of trigger up to 11.3 Gb/s, thereby ensuring the overlap of the most popular clock frequencies of data- and telecommunication standards. Figure 20 shows an eye diagram of 8-Gb/s data pattern acquired with clock recovery trigger.

Pattern Sync trigger

Pattern Sync trigger is the ability of the *FemtoScope* to internally generate and lock onto a right pattern trigger. The pattern trigger is derived from the supplied clock by automatically detecting all of the following parameters: data rate, pattern length and trigger divide ratio.

The *FemtoScope* can generate a pattern trigger from any of trigger source: internal or external (up to 6 GHz), clock recovery (up to 11.3 Gb/s) and external prescaled (up to 16 GHz).

When Pattern Lock is switched to Auto Detect the oscilloscope automatically detects data rate, pattern length, and trigger divide ratio and generates the pattern trigger (Figure 21). To get correct pattern lock you need to, check the Pattern Length List. The pattern length you want to detect can be added to this list if necessary.

Figure 21. The *FemtoScope* 3164 used Pattern Lock trigger to generate pattern trigger from 2.5 GHz clock. Eye RMS Jitter = 2.64 ps.

The oscilloscope also can manually detect data rate, pattern length, and trigger divide ratio and generates the pattern trigger. Enter the length of the test pattern in bits, which can be any value between 7 and 8 388 607 (223–1). Use manual entry when you do not have any information about data pattern length.

The FemtoScope uses an internal frequency counter that constantly measures the data rate taking into account the trigger divide ratio.

You can use Start Bit control to specify the starting bit location for the scan. When Auto Detect is selected in the Pattern Lock menu, Start Bit specifies an offset in data bits from the pattern trigger. Because the internally generated pattern trigger is synchronized to an unknown bit number in the data pattern, Start Bit does not specify an absolute bit in the data pattern. You can use this feature to step the triggering through each bit of a pattern when Eye Line mode is off. This is a relative setting from an arbitrary reference pattern bit.

Eye Line mode is used to average eye diagrams and to view specific bit trajectories. The number of averages can be set from the Average N of the Acquisition Mode menu (Figure 22).

Eye Line mode uses the pattern lock feature to establish a pattern sync trigger and then uses that trigger to walk through each bit of the data pattern. For eye diagrams, this allows high and low values to be separated before being averaged together. Without Eye Line mode, averaging an eye diagram would result in highs from one bit being averaged with lows of another bit which results in an erroneous value between the two levels.

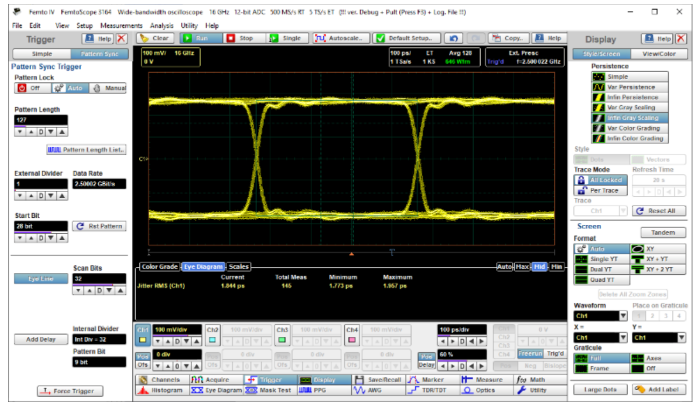


Figure 22. *FemtoScope* 3164 demonstrates the same average 2.5 Gb/s eye diagram by using Eye Line mode. Eye RMS Jitter = 1.96 ps. Clearly noticeable influence of data dependent jitter.

Display

Display options include such functions as persistence, ”gray scaling" and “color grading”, various screen and graticule formats, as well as color adjustment.

In persistence mode, the oscilloscope updates the display of newly collected waveforms in 0.1 to 20 s. In “gray scaling” mode (Fig. 23), the oscilloscope uses five different degrees of intensity of the same color.

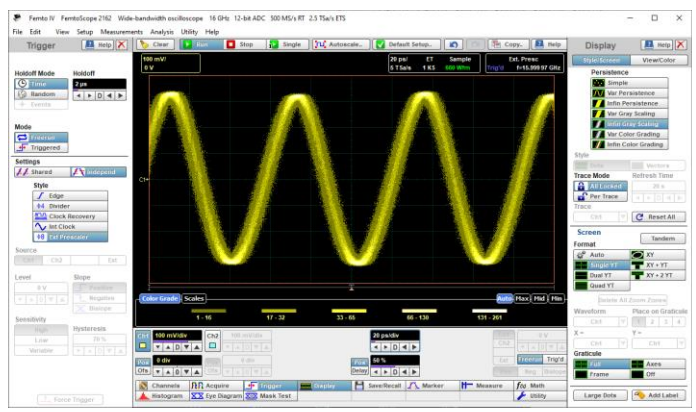


Figure 23. The *FemtoScope* displayed a 16-GHz sinewave in “grey-scaling” format.

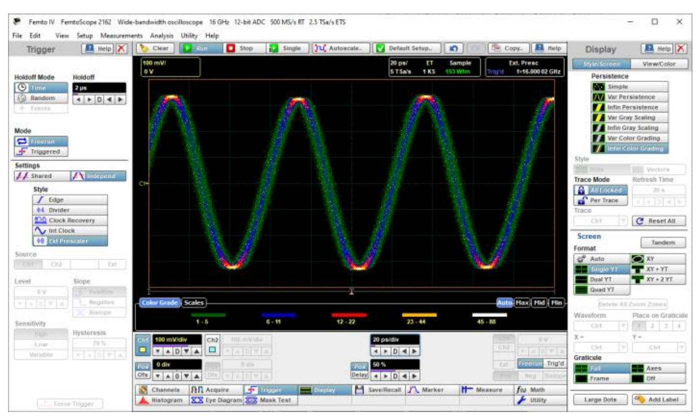


Figure 24. The *FemtoScope* displayed a 16-GHz sinewave in “color-grading” format.

Different color intensities depend on the number of hit points. The intensity accumulates between their possible minimum and maximum values. The maximum hit values automatically get the highest brightness, and the minimum hit values get the lowest brightness. Refresh time can be selected from 1 to 200 s.

In the “color grading” format (Fig. 24) the display is formed by accumulated dots having different colors. The color indicates the density of the hits points on the waveform. The “color grading” format is useful when you work with histograms, eye diagrams, masks, that is, with statistical measurements. It is also used when necessary to obtain as much visual information about the signal. Refresh time here also can be selected from 1 to 200 s.

The display function determines how many independent graticules can be used when displaying information - one when all information is displayed on one combined graticule, two when all information is displayed on two identical graticules, or four when all information is displayed on four identical graticules. Moreover, any of the signals can be moved to any of the screens (Fig. 25).

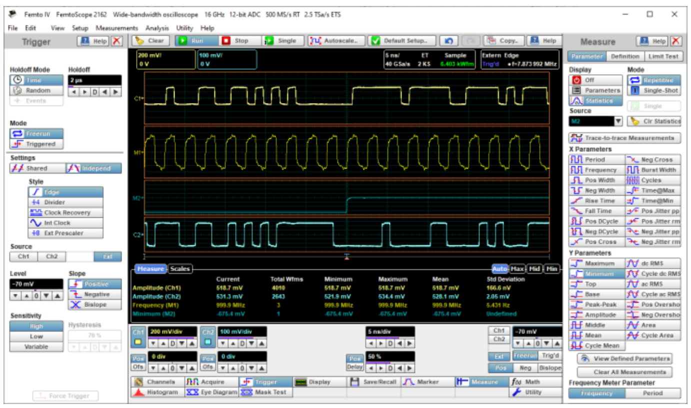


Figure 25. Display with four-graticules.

For phase measurements, XY display formats are used. In the XY format, the horizontal axis is the voltage axis of one of the signal sources, while the vertical axis is the voltage axis of another signal source. The XY & YT format displays waveforms of both formats - YT and XY. The YT format is located at the top of the screen, and the XY format is at the bottom.

The XY format is used to compare frequencies and or phase differences between two signals, and also to display the mutual dependence of two quantities, for example, current on voltage or voltage on frequency.

We also note such an interesting format as “tandem”, in which the screen is divided into several scales not only vertically, but also horizontally (Fig. 26).

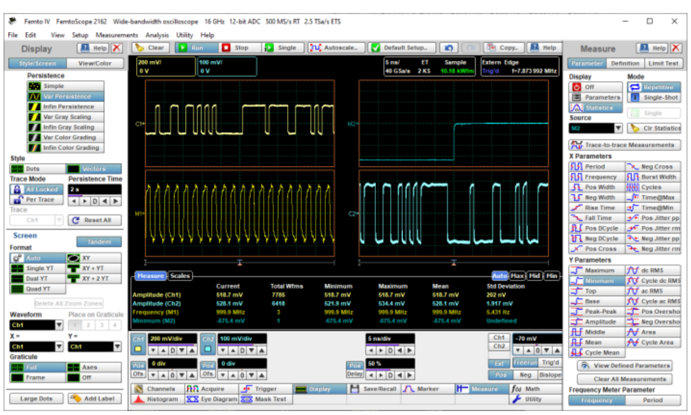


Figure 26. “Tandem” display format.

Markers

Markers are vertical or horizontal lines moved around the screen, as well as the crosshairs of these lines with signals. Markers allow custom measurements of waveform parameters, since the marker can be installed at any point on the screen. They allow you to quickly make detailed measurements on the waveform.

The coordinates of the marker are displayed based on vertical and horizontal scale, which makes marker measurements more accurate than graticule measurements. Two Y-markers measure the absolute vertical value and the vertical difference (voltage). Two X-markers measure the absolute horizontal value (time), the difference in horizontal values (time), as well as its equivalent frequency. Two XY-markers combine the marker with the waveform, which makes measurements more accurate, and also allows you to measure the slope between the two points of intersection of the markers with the waveform.

Figure 27. Ratiometric measurements. 1-V pulse is used as a reference. Two Y-markers measure 1.27% peak-peak ringing on the top of pulse.

Whether you’re measuring voltage, time or frequency, the set of X- and Y-markers support precise user-defined measurement. The best resolution with marker measurements is as follows: voltage - 80 uV, time - 0.1 ps.

Ratiometric measurements with a reference marker allow you to measure the phase in degrees and percent, as well as the ratio in decibels.

Automatic measurements

The *FemtoScope* oscilloscopes provide a wide range of automatic measurements. More than 50 types of typical automatic oscilloscope measurements give you quick access to powerful functions. They are separated into four categories: amplitude, time, inter-channel and spectral measurements.

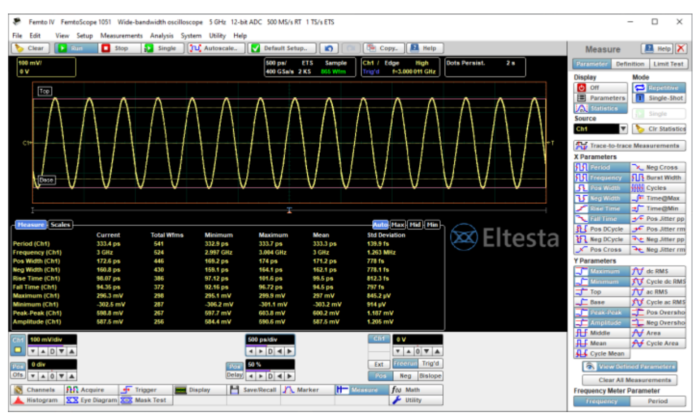


Figure 28. Up to ten individual measurements can be displayed on the screen simultaneously.

Each of the measurement can be performed on live signals, saved waveforms or math functions. Up to 10 measurements continuously updated with statistics (Fig.29). With statistical measurements, the oscilloscope measures the minimum, maximum, average and current values, as well as the standard deviation.

	Current	Total Wfms	Minimum	Maximum	Mean	Std Deviation
Period (Ch1)	333.4 ps	541	332.9 ps	333.7 ps	333.3 ps	139.9 fs
Frequency (Ch1)	3 GHz	524	2.997 GHz	3.004 GHz	3 GHz	1.263 MHz
Pos Width (Ch1)	172.6 ps	446	169.2 ps	174 ps	171.2 ps	778 fs
Neg Width (Ch1)	160.8 ps	430	159.1 ps	164.1 ps	162.1 ps	778.1 fs
Rise Time (Ch1)	98.07 ps	386	97.12 ps	101.6 ps	99.5 ps	812.3 fs
Fall Time (Ch1)	94.35 ps	372	92.16 ps	96.72 ps	94.5 ps	797 fs
Maximum (Ch1)	296.3 mV	298	295.1 mV	299.9 mV	297 mV	845.2 µV
Minimum (Ch1)	-302.5 mV	287	-306.2 mV	-301.1 mV	-303.2 mV	914 µV
Peak-Peak (Ch1)	598.8 mV	267	597.7 mV	603.8 mV	600.2 mV	1.187 mV
Amplitude (Ch1)	587.5 mV	256	584.4 mV	590.6 mV	587.5 mV	1.205 mV

Figure 29. Snapshot tab with the results of ten measurements with full statistic

Amplitude measurements include 17 parameters such as maximum, minimum, top, base, peak-peak, amplitude, middle, mean, cycle mean, rms, etc.

18 timing measurements include period, frequency, positive or negative pulse width, rise or fall time, duty cycle, etc.

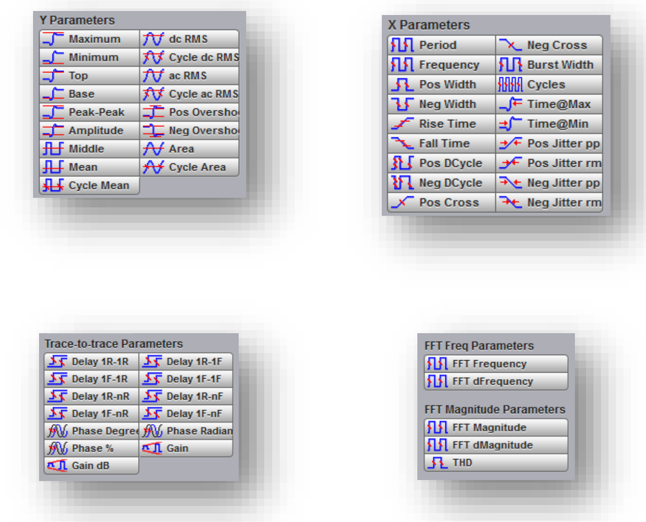


Figure 30. Measurement selection menu

Inter-channel measurements are those performed on two signals. These include delay, phase, and gain.

Spectral measurements are performed with FFT and include FFT magnitude and delta magnitude, total harmonic distortion, FFT frequency and delta frequency.

All measurement algorithms are based on several auxiliary parameters such as top and base vertical levels, threshold values, as well as horizontal margins.

The statistical top and base levels can be determined by a histogram, set by the minimum and maximum of the waveform, or selected by the operator. Thresholds are used when measuring rise and fall time or pulse width, they can be set as a percentage of the amplitude, units of the vertical scale or in divisions. Standard thresholds are 10% -50% -90% and 20% -50% -80%. Measurements can be gated with the margins defined by arbitrary horizontal markers inside which measurements are taken.

Histogram

Histograms are a statistical representation of a signal or its measurement results. The *FemtoScope* oscilloscopes use two types of histograms - vertical and horizontal. You can turn on the histogram to live signals, saved waveforms or math functions. Color grade display usually used with histogram on a waveform to add statistical view.

A vertical histogram is a probabilistic distribution of data collected about a signal along a vertical axis within a given histogram window. The information collected by such a histogram is used in the statistical analysis of the signal source. A vertical histogram is the most acceptable way to measure the noise characteristics of the waveforms (Fig. 31). Noise is measured by sizing the histogram window to a narrow portion of time and observing a vertical histogram that measures the noise on an edge.

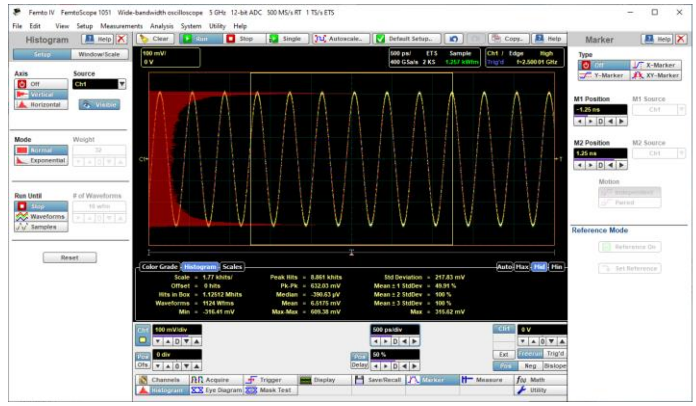


Figure 31: Vertical histogram of 2.5-GHz sinewave measures 609.38 mV amplitude (Max-Max value).

The parameters of both the vertical and horizontal histograms include the display scale in hits per division or dB per division, the offset in hits or dB (the number of hits or dB at the bottom of the display, as opposed to the center of the display), the total number of samples included in the histogram box, the number of waveforms that have contributed to the histogram, the number of hits in the histogram's greatest peak, the width, median and mean of histogram, the standard deviation (σ) value of the histogram, also the percentage of points that are within ± 1σ, ± 2σ and ± 3σ of the mean value, etc.

The most common use for horizontal histogram is measuring and characterizing timing jitter on displayed waveforms (Fig 32). Jitter is measured by sizing the histogram window to a narrow portion of voltage and observing a horizontal histogram that measures the jitter on an edge.

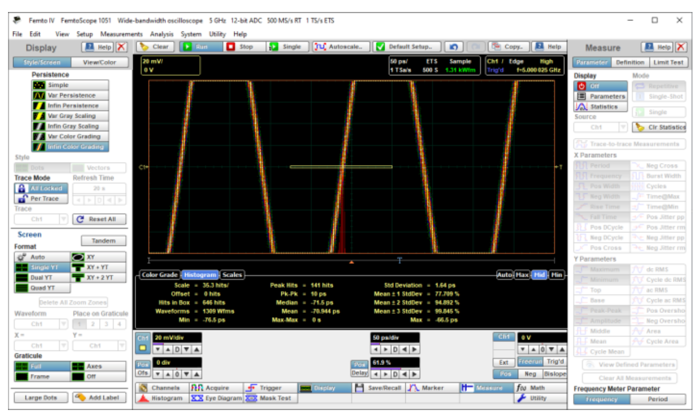


Figure 32. Horizontal histogram measures 1.64 ps rms jitter of 5-GHz sinewave (Std Deviation value).

Eye Diagram

An eye diagram is an effective graphical method for evaluating the quality of a digital pattern. The results of its measurements are integral characteristics that describe the quality of the data channel and its ability to reproduce waveforms in undistorted form. Eye diagram helps to visualize signal integrity.

The relationship between the required oscilloscope bandwidth and the maximum data rate is known. To acquire the third harmonic of the stream, this ratio is 1.8, and for the fifth harmonic it is already 3.

Following these relationships 16-GHz *Femtoscope* will acquire the third harmonic of the 8.8 Gb/s data pattern and the fifth harmonic of the 5.3 Gb/s data pattern. At the same time 5-GHz *Femtoscope* will acquire the third harmonic of the 2.5 Gb/s data pattern and the fifth harmonic of the 1.7 Gb/s data pattern.

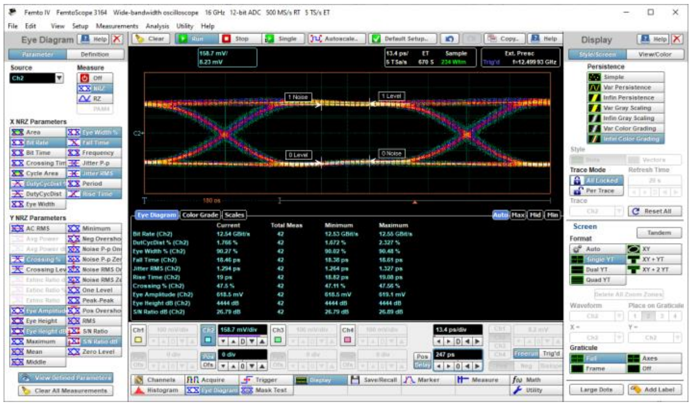


Figure 33. The FemtoScope 3164 acquire and measures 10 parameters of 12.5 Gb/s NRZ eye diagram.

In general, eye diagrams are multilevel waveforms. The *FemtoScopes* measures two-level eye diagrams, such as NRZ ("No return to zero") or RZ ("Return to zero").

A high-quality eye diagram on the *FemtoScope* screen can be obtained in two ways.

The first method is available when measuring data pattern is fed to the channel input, and it is also selected as the synchronization source. "Clock recovery" should be selected as the trigger style. With this method, the data rate range reaches 11.3 Gb/s for the *FemtoScope* 2162 or 3164, and 5 Gb/s for the *FemtoScope* 2052 or 3054.

The second way is that the measuring data pattern is fed to the input of the channel, and the clock signal used as a trigger source is supplied to another channel or to the input of any of external trigger input. In principle, the second method does not need to use clock recovery style.

You can reach data rate up to 16 Gb/s for the *FemtoScope* 2162 or 3164, and 6 Gb/s for other four models.

In order to make the correct measurements, the eye diagram is automatically autoscaled so that its vertical size is four large divisions, its horizontal size is six large divisions (Fig. 34).

Figure 34. Disclosed 2.5 Gb/s eye diagram acquired with the *FemtoScope* 1051.

If, after autoscaling, the eye is fully open and takes a shape that is close to rectangular - the signal transmission channel is ideal. When the level of noise and jitter increases, rise and fall time becomes longer, other types of distortion become more visible, the "eye" hides. With the eye completely closed, distinguishing between pattern bits becomes difficult.

Eye-diagram measurements include such parameters as eye height, eye width, jitter rms, crossing percentage, Q factor, and duty-cycle distortion. Totally the *FemtoScope* can measure 27 vertical and 15 horizontal parameters of NRZ eye diagram, ten of them can be measured simultaneously.

The *FemtoScope* also allows you to measure 26 vertical and 17 horizontal parameters of the RZ eye diagram.

Mask Test

This test is used when it is necessary to control the shape of the measured waveform. Such waveforms can be quite complex as, and example, eye diagrams, and the number of possible waveform anomalies can be significant, which makes it difficult to perform standard measurements.

Mask test is widely used in production, in the control of quality, as well as in its testing for compliance with the requirements of standards. It is useful when you need to validate the stability of your electronic components and systems.

The test works on a good / bad basis.

Masks are geometric templates that show acceptable areas of the screen into which testing waveform should not fall. The *FemtoScope* uses three types of masks - standard, automatic and arbitrary.

The shape of standard masks depends on the type of standard and its data rate. The oscilloscopes will allow to analyze standard masks of the following international standards - SONET / SDH, Ethernet, RapidIO, G.984.2, Fiber Channel, ITU G.703, PCI Express, ANSI T1.102, InfiniBand, Serial ATA and XAUI. The shape of standard masks is usually a quad or hexagon. There are options for editing standard masks (Fig. 35).

Depending on bandwidth specifications the *FemtoScope* provide up to 161 types of standard masks.

The principle of mask test is to determine if the waveform hits the mask, which violates the boundaries of the mask. Such a hit detects the exceeding the specified limits. This is fixed by changing the color of the waveform to red, which indicates an error in its shape.

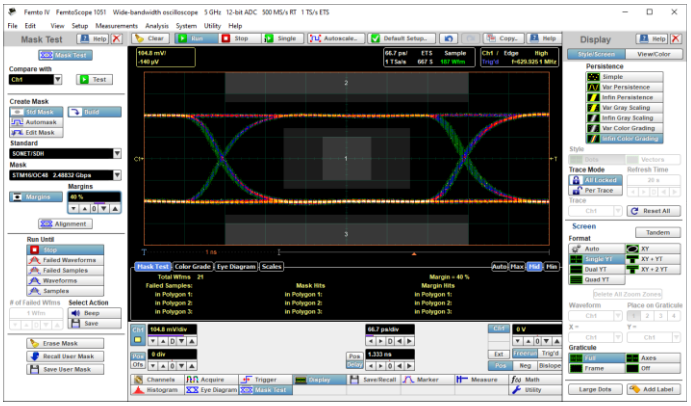


Figure 35. The *FemtoScope* 1051 makes 2.5 Gb/s SONET/SDH standard mask test.

Statistical test results include information about errors registered within standard templates, registered within additional margins, as well as full error information.

Other commonly used is an automask. An automatic mask is constructed according to the shape of tested waveform by adding to it certain preset tolerances vertically and horizontally.

Figure 36 shows an automatic mask constructed for a short 80-ps pulse. The mask consists of two patterns that seamlessly repeat the waveform on both sides of it. Figure also shows an automask test under the influence of noise. Acquired points on a pulse that go beyond tolerances are marked in red. In this example, horizontal tolerance limit is ±5 ps.

The last is arbitrary type of mask. It can be created directly by the user. Moreover, the number of templates can be up to eight, and their shape can be freely edited and saved.

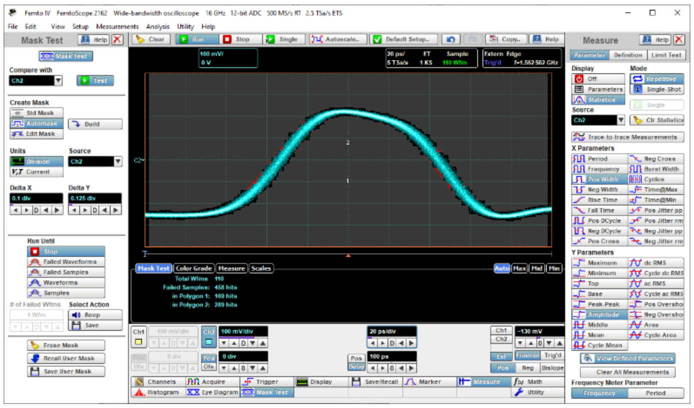


Figure 36. An example of 80-ps pulse automask performed by the *FemtoScope* 2162.

Mathematics

Based on the data on acquired waveform, the *FemtoScope* allows the simultaneous calculation of up to four mathematical functions. Any mathematical function can be selected as an operator for one or two operands (sources). For example, inversion is a one-operand function, while addition is a two-operand function. Live waveforms, stored waveforms, or other mathematical functions can be selected as an operand.

The oscilloscopes used several categories of mathematical functions. These are arithmetic (12 functions), algebraic (14 functions), trigonometric (12 functions), spectral (6 functions), logical (7 functions), etc. It is also possible to use the formula editor.

Arithmetic functions include such functions as addition, subtraction, multiplication, division, absolute value, inversion, half-sum, scaling, etc. (Fig. 37).

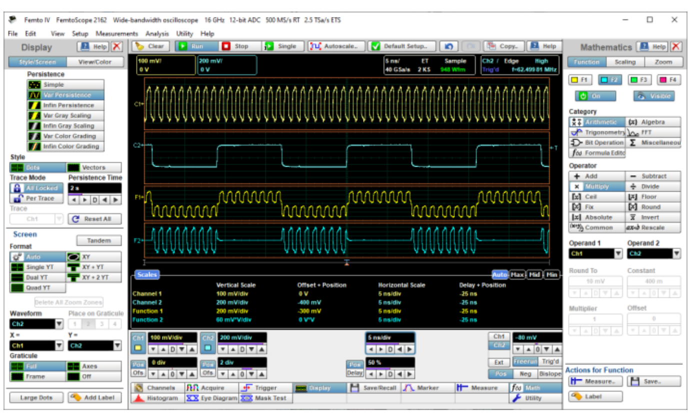


Figure 37. Example of arithmetic functions (from top to bottom): a) channel1, b) channel 2, c) a sum channel 1 + channel 2, d) multiplication channel 1 x channel 2.

Algebraic functions include functions such as the exponent on the base e, 10 or on an arbitrary base, the logarithm, differentiation, integration, square, cube, square root, etc. (Fig. 38).

Trigonometric functions include functions such as sine, cosine, tangent, cotangent, arcsine, arccosine, arctangent, arc tangent, hyperbolic tangent and hyperbolic cotangent.

FFT includes FFT magnitude and phase, the real and imaginary parts, also the inverse FFT (Fig. 39).

To compensate for the inherent limitations of the FFT, the operator must use the FFT windows. The type of window determines the bandwidth and slope of the corresponding mathematical filter. The oscilloscope supports six types of FFT windows. A rectangular FFT window does not change the signal data acquired in the time domain. Other five FFT windows have different filter characteristics in the time domain. They are Hamming window, Hanning window, flat window, Blackman-Harris window and Kaiser-Bessel window.

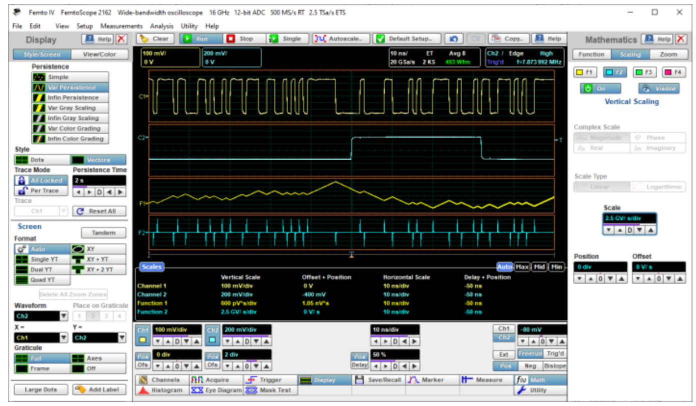


Figure 38. Example of algebraic functions (from top to bottom): a) channel1 (data pattern), b) channel 2 (clock), c) integral of channel 1 d) differential of channel 1

Logical functions include such functions as AND, AND-NOT, OR, OR-NOT, exclusive OR, exclusive OR-NOT, and also NOT.

In real time, when relation between sampling rate and the input frequency may significantly decrease, aliasing distortions occur. To avoid such distortions the oscilloscopes provide linear or Sin (x) / x interpolation functions. The Sin (x)/x interpolation function effectively restores the shape of the input signal.

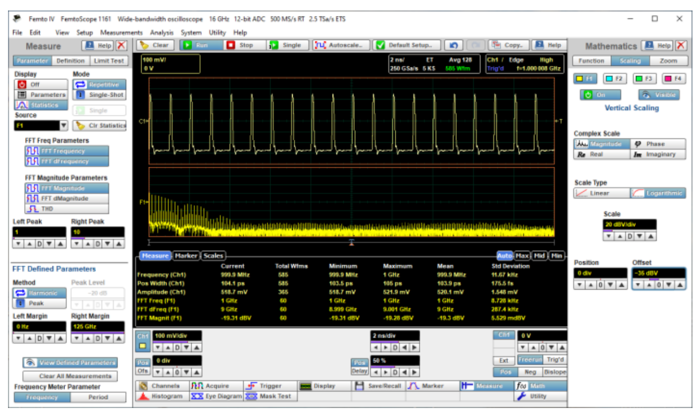


Figure 39. The FemtoScope 1161 performs Fast Fourier Transform with 1 GHz waveform having 100 ps pulse width. The first measured FFT harmonic is 1 GHz at -19.21 dBV magnitude

The oscilloscopes used trend as a mathematical function that shows the nature of the variation in the signal parameter over time. The vertical axis shows the value of the selected parameter, and the horizontal axis shows the period of the signal for which this parameter was calculated.

In the example on Fig. 40, the oscilloscope measures the period of the harmonic signal used to calibrate the sweep (purple). The trend function of the measured period (blue) is the mathematical function of this signal. Amplitude measurements of the trend function show the evolution of the change in the period value, i.e. show the magnitude of the non-linearity of the sweep at various horizontal points of the scale.

Figure 40. Trend of period measures nonlinearity of oscilloscope time base with 10-GHz sinewave. Maximum trend of period = 102.3 ps. Minimum trend of period = 98.98 ps. Peak-peak nonlinearity is within ±2.3 ps at 5 ns timing window.

Frequency counter

A dedicated frequency counter shows signal frequency (or period) at all times, regardless of measurement and time base settings, with a 7 digits resolution. For *FemtoScope* 2162 and 3164 maximum frequency is 16 GHz, for other four models it is 6 GHz.

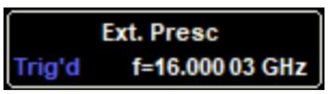


Figure 41. Frequency counter measurement results

Connectivity

Built-in USB device ports make PC connectivity easy for all models of the oscilloscopes. To provide a confident connectivity you need USB cable and external AC/DC power adapter (no power is used from the USB connection). Both parts are included in the oscilloscope kit.

The *FemtoScope* 3000 used both USB and LAN ports.

Figure 42. Rear panel of the *Femtoscope* 1000 with USB connector.

Figure 43. Rear panel of the *Femtoscope* 2000 with USB connector.

Figure 44. Rear panel of the *Femtoscope* 3000 with USB and LAN connectors.

Software

The *FemtoScope* oscilloscopes used *Femto IV* Software that is common for all models of the series.

Femto IV Software has friendly user interface that easy lets you control, visualize, measure and analyze waveforms acquired by the *FemtoScope*-Series oscilloscope.

Portability

Weighing less than 370 g with a 1.9 sq.dm small footprint, the *FemtoScope* 1000 Series USB oscilloscopes can go anywhere with ease. You can just put it in the pocket of your jacket or in a small briefcase

The *FemtoScope* 2000 Series USB oscilloscopes deliver the performance and features you expect in a big scope. 16 GHz bandwidth on two channels, less than 2 ps rms jitter, 8 Gb/s clock recovery trigger are now available with portable enclosure having less than 790 g weight and 3.4 sq.dm small footprint.

Standard accessories

Your *FemtoScope* Series oscilloscope kit contains the following items:

- *FemtoScope* USB Wide-Bandwidth Oscilloscope.
  Specified from FS1051, FS1161, FS2051, FS2162, FS3054 or FS3164.
- *Femto IV* software (supplied on a USB stick and also available as a free download from www.eltesta.com).
- *FemtoScope* 1000/2000/3000 Series User's Guide (supplied on a USB stick and also available as a free download from www.eltesta.com).
- 12 VDC power supply with specified localized IEC mains lead.
- 80 cm precision cable, 2 pcs.
- USB cable, 1.8 m.
- LAN cable, 1 m (*FemtoScope* 3000 only)
- SMA / PC3.5 / 2.92 wrench.

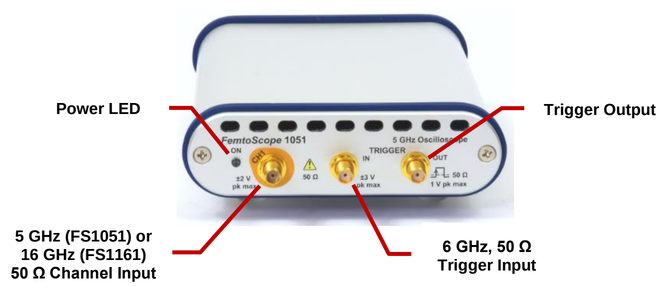
Price

Economical price makes *FemtoScope* 1000, 2000 and 3000 Series ideal as production facilities, for engineering laboratories, and for teaching basic scientific and measurements at schools and universities.

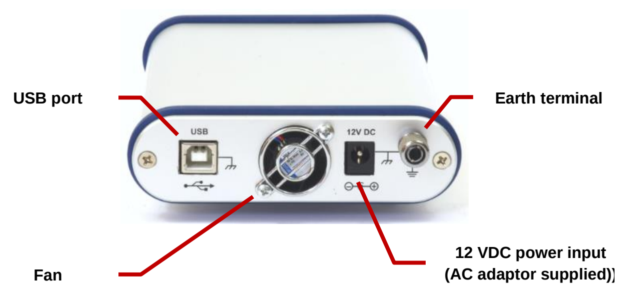
Ordering information at 11th of May 2020	Price
***FemtoScope* 1051**: 1 channel, 5 GHz bandwidth, 6 GHz trigger	€ 6 490
***FemtoScope* 1161:** 1 channel, 16 GHz bandwidth, 6 GHz trigger	€ 8 990
***FemtoScope* 2052:** 2 channels, 5 GHz bandwidth, 6 GHz trigger	€ 8 990
***FemtoScope* 2162:** 2 channels, 16 GHz bandwidth, 16 GHz trigger	€ 11 990
***FemtoScope* 3054**: 4 channels, 5 GHz bandwidth, 6 GHz trigger	€ 10 990
***FemtoScope* 3164:** 4 channels, 16 GHz bandwidth, 16 GHz trigger	€ 15 590

Inputs, Outputs and Indicators

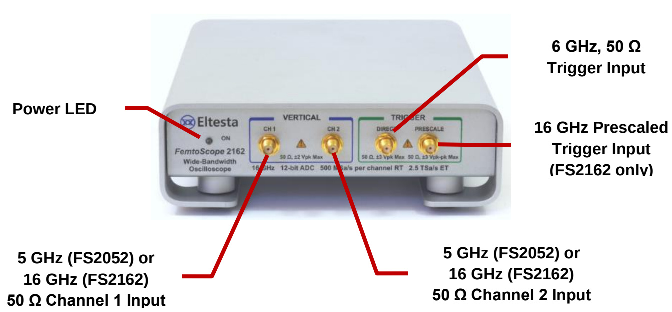
FemtoScope 1000 front panel



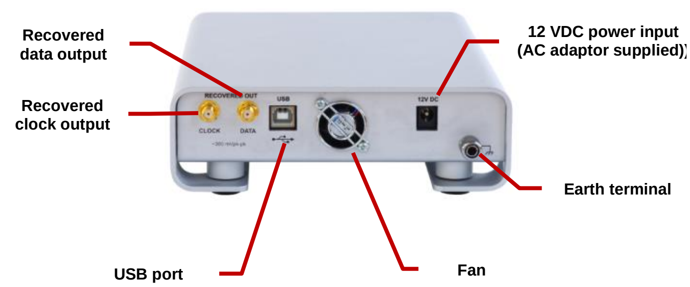
FemtoScope 1000 rear panel



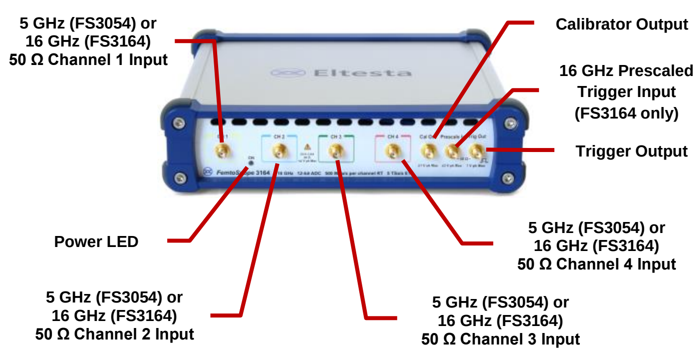
FemtoScope 2000 front panel



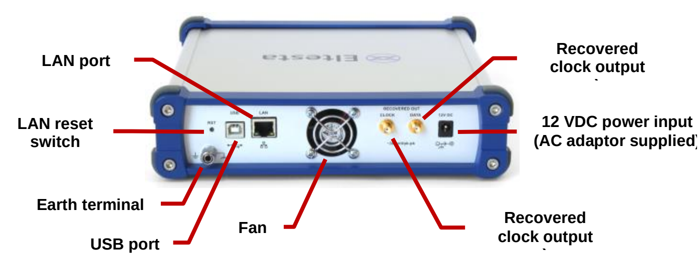
FemtoScope 2000 Series rear panel



FemtoScope 3000 front panel



FemtoScope 3000 rear panel



Power LED: Green under normal operation.

CH1, CH2, CH3, CH4: Channel 1-4 Inputs.

The *FemtoScope* 1000s have one input channel, the *FemtoScope* 2000s have two input channels and the *FemtoScope* 3000s have four input channels. All channels also are an internal trigger input.

The *FemtoScope* 1051, 2052 and 3054 have 5 GHz bandwidth, while the *FemtoScope* 1161, 2162 and 3164 have 16 GHz bandwidth.

TRIGGER IN (*FemtoScope* 1000s) or **DIECT TRIGGER** (*FemtoScope* 2000s)**:** DC to 6 GHz external trigger input.

TRIGGER OUT (*FemtoScope* 1000s and 3000s)**:** Can be used to synchronize an external device to the oscilloscope rising edge.

PRESCALE TRIGGER (*FemtoScope* 2162 and 3164 only)**:** 1 GHz to 16 GHz external prescaled trigger input.

Cal Out (*FemtoScope* 3000s)**:** Can be used for probe calibration.

USB: The USB 2.0 port is used to connect the oscilloscope to the PC.

Fan: Low-noise fan inside the unit which blows air through the holes on the back and front panels.

12 VDC input: Use only the earthed mains adaptor supplied with the oscilloscope.

Earth terminal: For unit grounding.

RECOVERED CLOCK OUT (*FemtoScope* 2000s and 3000s)**:** Recovered clock from the currently selected trigger source and the built-in clock recovery module (optional).

RECOVERED DATA OUT (*FemtoScope* 2000s and 3000s)**:** Recovered data from the currently selected trigger source and the built-in clock recovery module (optional).

LAN: LAN port.

RST: LAN Reset Switch.

Specifications and Characteristics

Vertical	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Input channels	1	2	4	1	2	4
	All channels are identical and digitized simultaneously.					
Analog bandwidth, –3 dB flatness	These specifications are valid after a 30-minute warm-up period and ±2 °C from firmware calibration temperature.					
Full bandwidth *	DC to 5 GHz			DC to 16 GHz		
Middle bandwidth, typical	N/A		DC to 500 MHz	N/A		DC to 500 MHz
Narrow bandwidth, typical	DC to 500 MHz		DC to 100 MHz	DC to 500 MHz		DC to 100 MHz
Passband flatness (full BW)	±1 dB to 3 GHz			±1 dB to 5 GHz		
Calculated rise time (Tr), typical	Calculated from the bandwidth: 10% to 90%: calculated from Tr = 0.35/BW. 20% to 80%: calculated from Tr = 0.25/BW.					
Full bandwidth	10% to 90%: ≤ 70 ps, 20% to 80%: ≤ 50 ps.			10% to 90%: ≤ 21.9 ps, 20% to 80%: ≤ 15.6 ps.		
Middle bandwidth	N/A		10% to 90%: ≤700 ps 20% to 80%: ≤500 ps	N/A		10% to 90%: ≤700 ps 20% to 80%: ≤500 ps
Narrow bandwidth	10% to 90%: ≤ 700 ps 20% to 80%: ≤ 500 ps		10% to 90%: ≤3.5 ns 20% to 80%: ≤2.5 ns	10% to 90%: ≤ 700 ps 20% to 80%: ≤ 500 ps		10% to 90%: ≤3.5 ns 20% to 80%: ≤2.5 ns
Step response, typical						
Full bandwidth				N/A		
Overshoot	< 8%					
Ringing	±6% to 3 ns, ±4% from 3 ns to 10 ns, ±3% from 10 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.					
Middle bandwidth	N/A			N/A		
Overshoot			< 6%			< 6%
Ringing			±4% to 10 ns, ±3% from 10 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.			±4% to 10 ns, ±3% from 10 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.
Narrow bandwidth						
Overshoot	< 6%		< 5%	< 6%		< 5%
Ringing	±4% to 10 ns, ±3% from 10 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.		±5% to 20 ns, ±3% from 20 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.	±4% to 10 ns, ±3% from 10 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.		±5% to 20 ns, ±3% from 20 ns to 100 ns, ±2% from 100 ns to 400 ns, ±1% after 400 ns.
RMS noise						
Full bandwidth *	1.8 mV, maximum. 1.6 mV, typical.			2.4 mV, maximum. 2.2 mV, typical.		
Middle bandwidth	N/A		0.8 mV, maximum. 0.65 mV, typical.	N/A		0.8 mV, maximum. 0.65 mV, typical.
Narrow bandwidth	0.8 mV, maximum. 0.65 mV, typical.		0.6 mV, maximum. 0.45 mV, typical.	0.8 mV, maximum. 0.65 mV, typical.		0.8 mV, maximum. 0.65 mV, typical.
Scale factors (sensitivity)	10 mV/div to 250 mV/div. Full scale is 8 vertical divisions. Adjustable in a 10-12.5-15-20-25-30-40-50-60-80-100-125-150-200-250 mV/div sequence. Also adjustable in 1% fine increments or better. With manual or calculator data entry the increment is 0.1 mV/div.					
DC gain accuracy *	±1.5% of full scale, maximum. ±1% of full scale, typical.		±1% of full scale, maximum. ±0.5% of full scale, typical.	±1.5% of full scale, maximum. ±1% of full scale, typical.		±1% of full scale, maximum. ±0.5% of full scale, typical.

***** Specifications marked with (*****) are checked in the Performance Verification.

Vertical (continued)	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Position range	±4 divisions from center screen					
DC offset range	Adjustable from –1 V to +1 V in 10 mV increments (coarse). Also adjustable in fine increments of 2 mV. With manual or calculator data entry the increment is 0.01 mV for offset between –99.9 and 99.9 mV, and 0.1 mV for offset between –999.9 and 999.9 mV. Referenced to the center of display graticule.					
DC offset accuracy *	±1.5 mV ± 1.5% of offset setting, maximum. ±1 mV ± 1% of offset setting, typical.			±1 mV ± 1% of offset setting, maximum. ±0.5 mV ± 0.5% of offset setting, typical.		
Operating input voltage	±1 V					
Vertical Zoom and Position	For all input channels, waveform memories, or functions.					
Vertical factor	0.01 to 100.					
Vertical position	±800 division maximum of zoomed waveform.					
Channel-to-channel crosstalk (channel isolation)	≥50 dB (316:1) for input frequency DC to 1 GHz. ≥40 dB (100:1) for input frequency >1 GHz to 3 GHz. ≥36 dB (63:1) for input frequency >3 GHz to ≤5 GHz			≥50 dB (316:1) for input frequency DC to 1 GHz. ≥40 dB (100:1) for input frequency >1 GHz to 3 GHz. ≥36 dB (63:1) for input frequency >3 GHz to ≤16 GHz.		
Delay between channels	N/A	≤ 10 ps typical at full bandwidth, equivalent time.		N/A	≤ 10 ps typical at full bandwidth, equivalent time.	
ADC resolution	12 bits					
Hardware vertical resolution	0.5 mV / LSB without averaging.					
Input impedance *	50 Ω ± 1.5 Ω maximum. 50 Ω ± 1 Ω typical					
Input match	Reflections for 70 ps rise time: 10% or less.			Reflections for 50 ps rise time: 10% or less.		
Input coupling	DC					
Maximum safe input voltage	±2 V (DC + peak AC)					
Input connector	SMA female					
Attenuation	Attenuation factors may be entered to scale the oscilloscope for external attenuators connected to the channel inputs.					
Range	0.0001:1 to 1 000 000:1					
Units	Ratio or dB					
Scale	Volt, Watt, Ampere, or Unknown.					

Horizontal	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Time base	Internal time base common to all input channels.					
Time base range	Full horizontal scale is 10 divisions.					
Real time sampling	10 ns/div to 1000 s/div.					
Random equivalent time sampling	50 ps/div to 5 µs/div.			10 ps/div to 5 µs/div.		
Roll	100 ms/div to 1000 s/div.					
Segmented	Total number of segments: 2 to 1024. Dead time between segments: 3 µs.					
Horizontal zoom and position	For all input channels, waveform memories, or functions					
Horizontal factor	From 1 to 2000.					
Horizontal position	From 0% to 100% non-zoomed waveform.					
Time base clock accuracy	@ 25 °C ± 3 °C					
Frequency	500 MHz					
Initial set tolerance	± 0.5 ppm	± 5 ppm		± 0.5 ppm	± 5 ppm	
Overall frequency stability * (over operating temperature range)	± 2 ppm	± 15 ppm		± 2 ppm	± 15 ppm	
Aging	± 3 ppm	± 7 ppm		± 3 ppm	± 7 ppm	

Hirizontal (continued)	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Time base resolution	1.0 ps			0.2 ps		
	At random equivalent time sampling					
Delta time measurement accuracy *	***FemtoScope* 1000:** ± (2 ppm * reading + 0.1% * screen width + 5 ps). ***FemtoScope* 2000:** ± (15 ppm * reading + 0.1% * screen width + 5 ps). ***FemtoScope* 3000:** ± (15 ppm * reading + 0.1% * screen width + 2 ps).					
Pre-trigger delay	Record length / current sampling rate maximum at zero variable delay time					
Post-trigger delay	0 to 4.28 s. Coarse increment is one horizontal scale division, fine increment is 0.1 horizontal scale divisions, manual or calculator increment is 0.01 horizontal scale divisions.					
Channel deskew range	±50 ns range. Coarse increment is 100 ps, fine increment is 10 ps. With manual or calculator data entry the increment is four significant digits or 1 ps.					

Acquisition	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Sampling modes						
Real time	Captures all of the sample points used to reconstruct a waveform during a single trigger event					
Equivalent time	Acquires sample points over several trigger events, requiring the input waveform to be repetitive					
Roll	Acquisition data will be displayed in a rolling fashion starting from the right side of the display and continuing to the left side of the display (while the acquisition is running)					
Segmented	Segmented memory optimizes available memory for data streams that have long dead times between activity. Number of segments: up to 1024. Segments stamped with absolute and delta times.					
Maximum sampling rate						
Real time sampling	500 MS/s per channel simultaneously					
Equivalent time sampling	Up to 1 TS/s or 1.0 ps trigger placement resolution			Up to 5 TS/s or 0.2 ps trigger placement resolution		
Record length						
Real time sampling	50 S/ch to 250 kS/ch for one channel, to 125 kS/ch for two channels, to 50 kS/ch for three and four channels.					
Equivalent time sampling	500 S/ch to 250 kS/ch for one channel, to 125 kS/ch for two channels, to 50 kS/ch for three and four channels.					
Duration at highest sample rate	0.5 ms for one channel, 0.25 ms for two channels, 0.125 ms for three and four channels.					
Acquisition modes						
Sample (normal)	Acquires first sample in decimation interval and displays results without further processing.					
Average	Average value of samples in decimation interval. Number of waveforms for average: 2 to 4096.					
Envelope	Envelope of acquired waveforms. Minimum, Maximum or both Minimum and Maximum values acquired over one or more acquisitions. Number of acquisitions is from 2 to 4096 in ×2 sequence and continuously.					
Peak detect	Largest and smallest sample in decimation interval. Minimum pulse width: 1/(sampling rate) or 2 ns @ 50 μs/div or faster for single channel.					
High resolution	Averages all samples taken during an acquisition interval to create a record point. This average results in a higher-resolution, lower-bandwidth waveform. Resolution can be expanded to 12.5 bits or more, up to 16 bits.					

Trigger	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Trigger sources	Internal Direct or Divided, External Direct or Divided.	Internal Direct, Divided or Clock Recovery. Internal Direct, Divided or Clock Recovery.	Internal Direct, Divided or Clock Recovery. External Direct, Divided or Clock Recovery.	Internal Direct or Divided, External Direct or Divided.	Internal Direct, Divided or Clock Recovery.External Direct, Divided, Clock Recovery or Prescaled	Internal Direct, Divided or Clock Recovery. External Prescaled.
Trigger mode						
Freerun	Triggers automatically but not synchronized to the input in absence of trigger event.					
Normal (triggered)	Requires trigger event for oscilloscope to trigger.					
Single	Software button that triggers only once on a trigger event. Not suitable for random equivalent-time sampling					
Pattern Lock	The oscilloscopes internally generate and lock onto a pattern with (2^15)-1 max length up to maximum specified trigger frequency.					
Eye Line	This mode is used to view averaged eye diagrams as well as a pattern's Uis.					

Trigger (continued)	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Trigger holdoff mode	By Time, Random or by Events					
Trigger holdoff range						
Holdoff by time	Adjustable from 500 ns to 15 s in a 1-2-5-10 sequence or in 4 ns fine increments.					
Random	This mode varies the trigger holdoff from one acquisition to another by randomizing the time value between triggers. The randomized time can be between the values specified in the Min Holdoff and Max Holdoff.					
Internal or External Trigger	Internal and External Trigger				Internal Trigger only	
Trigger style						
Edge	Triggers on a rising and falling edge of any source within frequency range DC to 3 GHz.					
Divided	The trigger source is divided before being applied to the trigger system. Maximum trigger frequency 6 GHz					
Division factor	/2	/4		/2	/4	
Clock recovery	N/A	6.5 Mb/s to 5 Gb/s		N/A	6.5 Mb/s to 11.3 Gb/s	
Trigger level range	–1 V to 1 V in 10 mV increments (coarse). Also adjustable in fine increments of 1 mV.					
Trigger bandwidth and sensitivity	Internal and External trigger					
Low sensitivity (Edge trigger)	100 mV p-p DC to 100 MHz. Increasing linearly from 100 mV p-p at 100 MHz to 150 mV p-p at 3 GHz (*FemtoScope* 1000) and at 3 GHz typical, 2.5 GHz guaranteed (*FemtoScope* 2000/3000). Pulse Width: 80 ps @ 200 mV p-p typical.					
Low sensitivity (Divided trigger)	100 mV p-p DC to 100 MHz. Increasing linearly from 100 mV p-p at 100 MHz to 200 mV p-p at 6 GHz. Pulse Width: 80 ps @ 200 mV p-p typical.					
High sensitivity (Edge trigger) *	30 mV p-p DC to 100 MHz. Increasing linearly from 30 mV p-p at 100 MHz to 50 mV p-p at 3 GHz (*FemtoScope* 1000) and at 3 GHz typical, 2.5 GHz guaranteed (*FemtoScope* 2000/3000). Pulse Width: 80 ps @ 70 mV p-p typical.					
High sensitivity (Divided trigger) *	30 mV p-p DC to 100 MHz. Increasing linearly from 30 mV p-p at 100 MHz to 70 mV p-p at 6 GHz. Pulse Width: 80 ps @ 70 mV p-p typical.					
Edge trigger slope						
Positive	Triggers on rising edge.					
Negative	Triggers on falling edge.					
Bi-slope	Triggers on both edges of the signal.					
RMS trigger jitter *	Measured at 2.5 GHz or 5 Gb/s with optimum triggering level.					
Edge and Divided trigger	1.5 ps + 0.1 ppm of delay typical. 2 ps + 0.1 ppm of delay maximum		1.2 ps + 0.1 ppm of delay, typical. 1.5 ps + 0.1 ppm of delay, maximum	1.5 ps + 0.1 ppm of delay typical. 2 ps + 0.1 ppm of delay maximum		1.2 ps + 0.1 ppm of delay, typical. 1.5 ps + 0.1 ppm of delay, maximum
Clock recovery trigger	2 ps + 1.0% of unit interval + 0.1 ppm of delay, typical. 2.5 ps + 1.0% of unit interval + 0.1 ppm of delay, maximum.					
External direct trigger Input impedance *	50 Ω ± 1.5 Ω maximum. 50 Ω ± 1 Ω, typical				N/A	
External direct trigger maximum safe input voltage	±3 V (DC+peak AC)				N/A	
Trigger coupling	DC				N/A	
External direct trigger input connector	SMA female				N/A	
External Prescaled Trigger	N/A					
External prescaled trigger coupling					50 Ω, AC coupled, fixed level zero volts	
External prescaled trigger bandwidth and sensitivity *					200 mV p-p from 1 to 16 GHz (sine wave input)	
External prescaled RMS trigger jitter *					1.5 ps delay, 2 ps maximum. For trigger input slope > 5 V/ns.	1.2 ps delay, 1.5 ps maximum
Prescaler ratio					Divided by 8, fixed	
External prescaled trigger maximum safe input voltage					±3 V (DC + peak AC)	
External prescaled trigger input connector					SMA female	

Display	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Persistence						
Off	No persistence					
Variable Persistence	Time that each data point is retained on the display. Persistence time can be varied from 100 ms to 20 s.					
Infinite Persistence	In this mode, a waveform sample point is displayed forever.					
Variable Gray Scaling	Five levels of a single color that is varied in saturation and luminosity. Refresh time varied from 1 s to 200 s.					
Infinite Gray Scaling	In this mode, a waveform sample point displayed as five levels of a single color is displayed forever.					
Variable Color Grading	With Color Grading selected, historical timing information is represented by a temperature or spectral color scheme providing "z-axis" information about rapidly changing waveforms. Refresh time varied from 1 to 200 s					
Infinite Color Grading	In this mode, a waveform sample point displayed as a temperature or spectral color is displayed forever.					
Style						
Dots	Displays waveforms without persistence, each new waveform record replaces the previously acquired record for a channel.					
Vector	This function draws a straight line through the data points on the display. Not suited to multi-value signals such as a displayed eye diagram.					
Graticule	Full Grid, Axes with tick marks, Frame with tick marks, Off (no graticule).					
Format						
Auto	Automatically places, adds or deletes graticules as you select more or fewer waveforms to display.					
Single XT	All waveforms are superimposed and are eight divisions high.					
Dual YT	With two graticules, all waveforms can be four divisions high, displayed separately or superimposed.					
Quad YT	With four graticules, all waveforms can be two divisions high, displayed separately or superimposed. When you select dual or quad screen display, every waveform channel, memory and function can be placed on a specified graticule.					
XY	Displays voltages of two waveforms against each other. The amplitude of the first waveform is plotted on the horizontal X axis and the amplitude of the second waveform is is plotted on the vertical Y axis.					
XY & YT	Displays both XY and YT pictures. The YT format appears on the upper part of the screen, and the XY format on the lower part of the screen. The YT format display area is one screen and any displayed waveforms are superimposed.					
XY + 2YT	Displays both YT and XY pictures. The YT format appears on the upper part of the screen, and the XY format on the lower part of the screen. The YT format display area is divided into two equal screens.					
Tandem	Displays graticules to the left and to the right.					
Colors	You may choose a default color selection, or select your own color set. Different colors are used for displaying selected items: background, channels, functions, waveform memories, FFTs, TDR/TDTs, and histograms.					
Trace annotation	The instrument gives you the ability to add an identifying label, bearing your own text, to a waveform display. For each waveform, you can create multiple labels and turn them all on or all off. Also, you can position them on the waveform by dragging or by specifying an exact horizontal position.					

Save/Recall	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Management	Store and recall setups, waveforms and user mask files to any drive on your PC. Storage capacity is limited only by disk space.					
File extensions	Waveform files: .wfm for binary format, .txt for verbose format (text), .txty for Y values formats (text). Database files: .wdb. Setup files: .set. User mask files: .pcm.					
Operating system	Microsoft Windows® 7, 8 or 10, 32-bit or 64-bit					
Waveform save/recall	Up to four waveforms may be stored into the waveform memories (M1 to M4), and then recalled for display.					
Save to/recall from disk	You can save or recall your acquired waveforms to or from any drive on the PC. To save a waveform, use the standard Windows **Save As** dialog box. From this dialog box you can create subdirectories and waveform files, or overwrite existing waveform files. You can load, into one of the Waveform Memories, a file with a waveform you have previously saved and then recall it for display.					

Save/Recall (continued)	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Save/recall setups	The instrument can store complete setups in the memory and then recall them.					
Screen image	You can copy a screen image into the clipboard with the following formats: Full Screen, Full Window, Client Part, Invert Client Part, Oscilloscope Screen and Oscilloscope Screen.					
Autoscale	Pressing the Autoscale key automatically adjusts the vertical channels, the horizontal scale factors, and the trigger level for a display appropriate to the signals applied to the inputs. The Autoscale feature requires a repetitive signal with a frequency greater than 100 Hz, duty cycle greater than 0.2%, amplitudes greater than 100 mV p-p. Autoscale is operative only for relatively stable input signals.					

Marker	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Marker type	X-Marker: vertical bars (measure time). Y-Marker: horizontal bars (measure volts). XY-Markers: waveform markers.					
Marker measurements	Absolute, Delta, Volt, Time, Frequency, Slope.					
Marker motion	Independent: both markers can be adjusted independently. Paired: both markers can be adjusted together.					
Ratiometric measurements	Provide ratiometric measurements between measured and reference values. These measurements give results in such ratiometric units as %, dB, and degrees.					

Measure	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Automated measurements	Up to ten simultaneous measurements are supported at the same time.					
Automatic parametric	53 automatic measurements available.					
Amplitude measurements (17)	Maximum, Minimum, Top, Base, Peak-Peak, Amplitude, Middle, Mean, Cycle Mean, DC RMS, Cycle DC RMS, AC RMS, Cycle AC RMS, Positive Overshoot, Negative Overshoot, Area, Cycle Area.					
Timing measurements (18)	Period, Frequency, Positive Width, Negative Width, Rise Time, Fall Time, Positive Duty Cycle, Negative Duty Cycle, Positive Crossing, Negative Crossing, Burst Width, Cycles, Time at Maximum, Time at Minimum, Positive Jitter p-p, Positive Jitter RMS, Negative Jitter p-p, Negative Jitter RMS.					
Inter-signal measurements (13)	Delay (8 options), Phase Deg, Phase Rad, Phase %, Gain, Gain dB.					
FFT measurements (5)	FFT Magnitude, FFT Delta Magnitude, THD, FFT Frequency, FFT Delta Frequency.					
Measurement statistics	Displays current, minimum, maximum, mean and standard deviation on any displayed waveform measurements.					
Method of top-base definition	Histogram, Min/Max, or User-Defined (in absolute voltage).					
Thresholds	Upper, middle and lower horizontal bars settable in percentage, voltage or divisions. Standard thresholds are 10–50–90% or 20–50–80%.					
Margins	Any region of the waveform may be isolated for measurement using left and right margins (vertical bars).					
Measurement mode	Repetitive or Single-shot.					
Counter	Built-in frequency counter					
Source	Internal or External	Internal from any of two channels or External Direct	Internal from any of four channels	Internal or External	Internal from any of two channels, External Direct or External Prescaled.	Internal from any of four channels or External Prescaled.
Resolution	7 digits					
Maximum frequency	6 GHz				Internal or External Direct: 6 GHz. External Prescaled: 16 GHz.	
Measurement	Frequency, period					
Time reference	Internal 250 MHz reference clock					

Mathematics	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Waveform math	Up to four math waveforms can be defined and displayed using math functions F1 to F4					
Categories and math operators						
Arithmetic (12)	Add, Subtract, Multiply, Divide, Ceil, Floor, Fix, Round, Absolute, Invert, Common, Rescale.					
Algebra (14)	Exponentiation (e), Exponentiation (10), Exponentiation (a), Logarithm (e), Logarithm (10), Logarithm (a), Differentiate, Integrate, Square, Square Root, Cube, Power (a), Inverse, Square Root of the Sum.					
Trigonometry (12)	Sine, Cosine, Tangent, Cotangent, Arcsine, Arc cosine, Arctangent, Arc cotangent, Hyperbolic Sine, Hyperbolic Cosine, Hyperbolic Tangent, Hyperbolic Cotangent.					
FFT (6)	Complex FFT, FFT Magnitude, FFT Phase, FFT Realt, FFT Imaginary, Inverse FFT, FFT Group Delay.					
Bit Operator (7)	AND, NAND, OR, NOR, XOR, XNOR, NOT.					
Miscellaneous (4)	Trend, Linear Interpolation, Sin(x)/x Interpolation, Smoothing.					
Formula Editor	You can build math waveforms using the Formula Editor control window.					
FFT						
FFT frequency span	Frequency Span = Sample Rate / 2 = Record Length / (2 × Timebase Range)					
FFT frequency resolution	Frequency Resolution = Sample Rate / Record Length					
FFT windows	The built-in filters (Rectangular, Hamming, Hann, Flattop, Blackman–Harris and Kaiser–Bessel) allow optimization of frequency resolution, transients, and amplitude accuracy.					
FFT measurements	Marker measurements can be made on frequency, delta frequency, magnitude, and delta magnitude. Automated FFT Measurements include: FFT Magnitude, FFT Delta Magnitude, THD, FFT Frequency, and FFT Delta Frequency.					

Histogram	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Histogram axis	Vertical, or Horizontal. Both vertical and horizontal histograms, with periodically updated measurements, allow statistical distributions to be analyzed over any region of the signal.					
Histogram measurement set (15)	Scale, Offset, Hits in Box, Waveforms, Peak Hits, Pk-Pk, Median, Mean, Standard Deviation, Mean ± 1 Std Dev, Mean ± 2 Std Dev, Mean ± 3 Std Dev, Min, Max-Max, Max.					
Histogram window	The histogram window determines which part of the database is used to plot the histogram. You can set the size of the histogram window to be any size that you want within the horizontal and vertical scaling limits of the scope.					

Eye Diagram	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Eye diagram	The oscilloscope can automatically characterize an NRZ and RZ eye pattern. Measurements are based upon statistical analysis of the waveform.					
NRZ measurement set (42)	AC RMS, Area, Bit Rate, Bit Time, Crossing %, Crossing Level, Crossing Time, Cycle Area, Duty Cycle Distortion (%, s), Extinction Ratio (dB, %, ratio), Eye Amplitude, Eye High, Eye High dB, Eye Width (%, s), Fall Time, Frequency, Jitter (p-p, RMS), Max, Mean, Mid, Min, Negative Overshoot, Noise p-p (One, Zero), Noise RMS (One, Zero), One Level, Peak-Peak, Period, Positive Overshoot, Rise Time, RMS, Signal-to-Noise Ratio, Signal-to-Noise Ratio dB, Zero Level.					
RZ measurement set (43)	AC RMS, Area, Bit Rate, Bit Time, Contrast Ratio (dB, %, ratio), Cycle Area, Extinction Ratio (dB, %, ratio), Eye Amplitude, Eye High, Eye High dB, Eye Opening Factor, Eye Width (%, s), Fall Time, Jitter P-p (Fall, Rise), Jitter RMS (Fall, Rise), Max, Mean, Mid, Min, Negative Crossing, Noise P-p (One, Zero), Noise RMS (One, Zero), One Level, Peak-Peak, Positive Crossing, Positive Duty Cycle, Pulse Symmetry, Pulse Width, Rise Time, RMS, Signal-to-Noise, Zero Level.					

Mask Test	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Mask test	Acquired signals are tested for fit outside areas defined by up to eight polygons. Any samples that fall within the polygon boundaries result in test failures. Masks can be loaded from disk, or created automatically or manually.					
Mask creation	You can create the following Mask: Standard predefined Mask, Automask, Mask saved on disk, Create new mask, Edit any mask.					
Standard mask	Standard predefined optical or standard electrical masks can be created.					
SONET/SDH (10)	OC1/STMO (51.84 Mb/s), OC3/STM1 (155.52 Mb/s), OC9/STM3 (466.56 Mb/s), OC12/STM4 (622.08 Mb/s), OC18/STM6 (933.12 Mb/s), OC24/STM8 (1.2442 Gb/s), OC48/STM16 (2.48832 Gb/s), FEC 2666 (2.6666 Gb/s) OC192/STM64 (9.95328 Gb/s), FEC1066 (10.664 Gb/s)					

Mask Test (continued)	*FS* 1051	*FS* 2052	*FS* 3054	*FS* 1161	*FS* 2162	*FS* 3164
Fibre Channel (31)	FC133 Electrical (132.8 Mb/s), FC133 Optical (132.8 Mb/s), FC266 Electrical (265.6 Mb/s), FC266 Optical (265.6 Mb/s), FC531 Electrical (531.35 Mb/s), FC531 Optical (531.35 Mb/s), FC1063 Electrical (1.0625 Gb/s), FC1063 Optical (1.0625 Gb/s), FC1063 Optical PI Rev13 (1.0625 Gb/s), FC1063E Abs Beta Rx.mask (1.0625 Gb/s), FC1063E Abs Beta Tx.mask (1.0625 Gb/s), FC1063E Abs Delta Rx.mask (1.0625 Gb/s), FC1063E Abs Delta Tx.mask (1.0625 Gb/s), FC1063E Abs Gamma Rx.mask (1.0625 Gb/s), FC1063E Abs Gamma Tx.mask (1.0625 Gb/s), FC2125 Optical (2.1231 Gb/s), FC2125 Optical PI Rev13 (2.1231 Gb/s), FC2125E Abs Beta Rx.mask (2.125 Gb/s), FC2125E Abs Beta Tx.mask (2.125 Gb/s), FC2125E Abs Delta Rx.mask (2.125 Gb/s), FC2125E Abs Delta Tx.mask (2.125 Gb/s), FC2125E Abs Gamma Rx.mask (2.125 Gb/s), FC2125E Abs Gamma Tx.mask (2.125 Gb/s).					
				FC4250 Optical PI Rev13 (4.25 Gb/s), FC4250E Abs Beta Rx.mask (4.25 Gb/s), FC4250E Abs Beta Tx.mask (4.25 Gb/s), FC4250E Abs Delta Rx.mask (4.25 Gb/s), FC4250E Abs Delta Tx.mask (4.25 Gb/s), FC4250E Abs Gamma Rx.mask (4.25 Gb/s), FC4250E Abs Gamma Tx.mask (4.25 Gb/s)		
Ethernet (11)	100BASE-BX10 (125 Mb/s), 100BASE-BX/LX10 (125 Mb/s), 1.25 Gb/s 1000Base-CX Absolute TP2 (1.25 Gb/s), 1.25 Gb/s 1000Base-CX Absolute TP3 (1.25 Gb/s), GB Ethernet (1.25 Gb/s), 2XGB Ethernet (2.5 Gb/s), 3.125 Gb/s 10GBase-CX4 Absolute TP2 (3.125 Gb/s).					
				10Gb Ethernet (9.953 Gb/s), 10GbE 9.953 (9.953 Gb/s), 10Gb Ethernet (10.3125 Gb/s), 10GbE 10.3125 (10.3125 Gb/s).		
Infiniband (16)	2.5G InfiniBand Cable mask (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 1 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 10 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 2 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 3 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 4 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 5 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 6 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 7 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 8 (2.5 Gb/s), 2.5G InfiniBand Driver Test Point 9 (2.5 Gb/s), 2.5G InfiniBand Receiver mask (2.5 Gb/s), InfiniBand (2.5 Gb/s).					
				5.0G InfiniBand Driver Test Point 1 (5 Gb/s), 5.0G InfiniBand Driver Test Point 6 (5 Gb/s), 5.0G InfiniBand Transmitter Pins (5 Gb/s)		
XAUI (4)	3.125 Gb/s XAUI Far End (3.125 Gb/s), 3.125 Gb/s XAUI Far End (3.125 Gb/s), XAUI-E Far (3.125 Gb/s), XAUI-E Near (3.125 Gb/s)					
ITU G.703 (14)	DS1, 100 Ω twisted pair (1.544 Mb/s), 2 Mb 120, 120 Ω twisted pair (2.048 Mb/s), 2 Mb 75, 75 Ω coax (2.048 Mb/s), DS2 110, 110 Ω twisted pair (6.312 Mb/s), DS2 75, 75 Ω coax (6.312 Mb/s), 8 Mb, 75 Ω coax (8.448 Mb/s), 34 Mb, 75 Ω coax (34.368 Mb/s), DS3, 75 Ω coax (44.736 Mb/s), 140 Mb 0, 75 Ω coax (139.264 Mb/s), 140 Mb 1, 75 Ω coax (139.264 Mb/s), 140 Mb 1 Inv, 75 Ω coax (139.264 Mb/s), 155 Mb 0, 75 Ω coax (155.520 Mb/s), 155 Mb 1, 75 Ω coax (155.520 Mb/s), 155 Mb 1 Inv, 75 Ω coax (155.520 Mb/s).					
ANSI T1/102 (7)	DS1, 100 Ω twisted pair, (1.544 Mb/s), DS1C, 100 Ω twisted pair, (3.152 Mb/s), DS2, 110 Ω twisted pair, (6.312 Mb/s), DS3, 75 Ω coax, (44.736 Mb/s), STS1 Eye, 75 Ω coax, (51.84 Mb/s), STS1 Pulse, 75 Ω coax, (51.84 Mb/s), STS3, 75 Ω coax, (155.520 Mb/s)					
RapidIO (9)	RapidIO Serial Level 1, 1.25G Rx (1.25 Gb/s), RapidIO Serial Level 1, 1.25G Tx LR (1.25 Gb/s), RapidIO Serial Level 1, 1.25G Tx SR (1.25 Gb/s), RapidIO Serial Level 1, 2.5G Rx (2.5 Gb/s), RapidIO Serial Level 1, 2.5G Tx LR (2.5 Gb/s), RapidIO Serial Level 1, 2.5G Tx SR (2.5 Gb/s), RapidIO Serial Level 1, 3.125G Rx (3.125 Gb/s), RapidIO Serial Level 1, 3.125G Tx LR (3.125 Gb/s), RapidIO Serial Level 1, 3.125G Tx SR (3.125 Gb/s)					
PCI Express (41)	R1.0a 2.5G Add-in Card Transmitter Non-Transition bit mask (2.5 Gb/s), R1.0a 2.5G Add-in Card Transmitter Transition bit mask (2.5 Gb/s), R1.0a 2.5G Exp.Card Host Non-Transition bit mask (2.5 Gb/s), R1.0a 2.5G Exp.Card Host Transition bit mask (2.5 Gb/s), R1.0a 2.5G Exp.Card Module Non-Transition bit mask (2.5 Gb/s), R1.0a 2.5G Exp.Card Module Transition bit mask (2.5 Gb/s), R1.0a 2.5G Exp.Card Transmitter Non-Transition bit mask (2.5 Gb/s),					

Mask Test (continued)	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
PCI Express (continued)	R1.0a 2.5G Exp.Card Transmitter Transition bit mask (2.5 Gb/s), R1.1 2.5G Add-in Card Transmitter Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Add-in Card Transmitter Transition bit mask (2.5 Gb/s), R1.1 2.5G Cable Receiver End Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Cable Receiver End Transition bit mask (2.5 Gb/s), R1.1 2.5G Cable Transmitter End Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Cable Transmitter End Transition bit mask (2.5 Gb/s), R1.1 2.5G Express Module System Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Express Module System Transition bit mask (2.5 Gb/s), R1.1 2.5G Express Module Transmitter Path Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Express Module Transmitter Path Transition bit mask (2.5 Gb/s), R1.1 2.5G Receiver mask (2.5 Gb/s), R1.1 2.5G System Board Transmitter Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G System Board Transmitter Transition bit mask (2.5 Gb/s), R1.1 2.5G Transmitter Non-Transition bit mask (2.5 Gb/s), R1.1 2.5G Transmitter Transition bit mask (2.5 Gb/s)					
				R2.0 5.0G Add-in Card 35 dB Transmitter Non-Transition bit mask (5 Gb/s), R2.0 5.0G Add-in Card 60 dB Transmitter Non-Transition bit mask (5 Gb/s), 2.0 5.0G Add-in Card 35 dB Transmitter Transition bit mask (5 Gb/s), R2.0 5.0G Add-in Card 60 dB Transmitter Transition bit mask (5 Gb/s), R2.0 5.0G Mobile Transmitter mask (5 Gb/s), R2.0 5.0G Receiver mask (5 Gb/s), R2.0 5.0G System Board Transmitter Non-Transition bit mask (5 Gb/s), R2.0 5.0G System Board Transmitter Transition bit mask (5 Gb/s), R2.0 5.0G Transmitter Non-Transition bit mask (5 Gb/s), R2.0 5.0G Transmitter Transition bit mask (5 Gb/s). R2.1 5.0G Transmitter Non-Transition bit mask (5 Gb/s), R2.1 5.0G Transmitter Transition bit mask (5 Gb/s)		
Serial ATA (24)	Ext Length, 1.5G 250 Cycle, Rx Mask (1.5 Gb/s), Ext Length, 1.5G 250 Cycle, Tx Mask (1.5 Gb/s), Ext Length, 1.5G 5 Cycle, Rx Mask (1.5 Gb/s), Ext Length, 1.5G 5 Cycle, Tx Mask (1.5 Gb/s), Gen1, 1.5G 250 Cycle, Rx Mask (1.5 Gb/s), Gen1, 1.5G 250 Cycle, Tx Mask (1.5 Gb/s), Gen1, 1.5G 5 Cycle, Rx Mask (1.5 Gb/s), Gen1, 1.5G 5 Cycle, Tx Mask (1.5 Gb/s), Gen1m, 1.5G 250 Cycle, Rx Mask (1.5 Gb/s), Gen1m, 1.5G 250 Cycle, Tx Mask (1.5 Gb/s), Gen1m, 1.5G 5 Cycle, Rx Mask (1.5 Gb/s), Gen1m, 1.5G 5 Cycle, Tx Mask (1.5 Gb/s), Ext Length, 3.0G 250 Cycle, Rx Mask (3 Gb/s), Ext Length, 3.0G 250 Cycle, Tx Mask (3 Gb/s), Ext Length, 3.0G 5 Cycle, Rx Mask (3 Gb/s), Ext Length, 3.0G 5 Cycle, Tx Mask (3 Gb/s), Gen1, 3.0G 250 Cycle, Rx Mask (3 Gb/s), Gen1, 3.0G 250 Cycle, Tx Mask (3 Gb/s), Gen1, 3.0G 5 Cycle, Rx Mask (3 Gb/s), Gen1, 3.0G 5 Cycle, Tx Mask (3 Gb/s), Gen1m, 3.0G 250 Cycle, Rx Mask (3 Gb/s), Gen1m, 3.0G 250 Cycle, Tx Mask (3 Gb/s), Gen1m, 3.0G 5 Cycle, Rx Mask (3 Gb/s), Gen1m, 3.0G 5 Cycle, Tx Mask (3 Gb/s).					
Mask margin	Available for industry-standard mask testing					
Automask creation	Masks are created automatically for single-valued voltage signals. Automask specifies both delta X and delta Y tolerances. The failure actions are identical to those of limit testing.					
Data collected during test	Total number of waveforms examined, number of failed samples, number of hits within each polygon boundary					

System requirements	***FS* 1051**	***FS* 2052**	***FS* 3054**	***FS* 1161**	***FS* 2162**	***FS* 3164**
Processor	Pentium-class processor or equivalent					
Memory	4 GB					
Disk space	Software occupies about 50 MB					
Operating system	Windows 7, Windows 8 or Windows 10. 32-bit and 64-bit versions					
PC connection port						
USB	USB 2.0 (high speed). Also compatible with USB 3.0					
LAN	N/A		LAN	N/A		LAN

Calibrator Output	*FS* 3054	*FS* 3164
Output mode	DC, 1 kHz square, Meander with frequency from 15.266 Hz to 500 kHz.	
Output DC level	Adjustable from –1 V to +1 V into 50 Ω. Coarse increment: 50 mV, fine increment: 1 mV.	
Output DC level accuracy	± 1 mV ± 0.5% of output DC level	
Output impedance	50 Ω nominal	
Rise/Fall time	150 ns, typical	
Output connectors	SMA female	

Trigger Output	*FS* 1051	*FS* 3054	*FS* 1161	*FS* 3164
Timing	Positive transition equivalent to acquisition trigger point.			
Low level	(–0.2 ± 0.1) V. Measured into 50 Ω.			
Amplitude	(900 ± 200) mV. Measured into 50 Ω.			
Rise time	10% to 90%: ≤ 0.45 ns. 20% to 80%: ≤ 0.3 ns.			
RMS jitter	2 ps or less.			
Output delay	(4 ± 1) ns			
Output coupling	DC-coupled			
Output connectors	SMA female			

Recovered Data Output	*FS* 2052	*FS* 3054	*FS* 2162	*FS* 3164
Data Rate	6.5 Mb/s to 5 Gb/s		6.5 Mb/s to 8 Gb/s	
Eye amplitude	250 mV p-p typical			
Eye rise/fall time	20%–80%: 75 ps, typical. Measured at 5-GHz channel.		20%–80%: 50 ps, typical. Measured at 16-GHz channel	
RMS jitter	2 ps +1% of UI, typical		2 ps +1% of UI, typical	
Output coupling	AC-coupled			
Output connections	SMA female			

Recovered Clock Output	*FS* 2052	*FS* 3054	*FS* 2162	*FS* 3164
Output frequency	Full rate clock output, 3.25 MHz to 2.5 GHz		Full rate clock output, 3.25 MHz to 5.65 GHz	
Output amplitude	250 mV p-p, typical			
Output coupling	AC-coupled			
Output connectors	SMA female			

System requirements	*FS* 1051	*FS 1161*	*FS* 2052	*FS* 2162	*FS* 3054	*FS* 3164
Power requirements						
Power supply voltage	+12 V ± 5%					
Power supply current	1.3 A max		1.8 A max		2.7 A max	
Protection	Auto shutdown on excess or reverse voltage					
AC-DC adaptor	Universal adaptor supplied					
Physical characteristics						
Dimensions						
Width	113.9 mm		160 mm		244 mm	
Height	33.5 mm w/o feet, 41.8 mm with feet		50 mm w/o feet, 54 mm with feet		64 mm	
Depth	162 mm (w/o connectors), 187 mm (with connectors)		210 mm (w/o connectors), 225 mm (with connectors)		233 mm	
Net weight	370 g		790 g		1.52 kg	
Environmental conditions						
Temperature	Normal: +5°C to +40°C. For quoted accuracy: +15°C to +25°C. Storage: –20°C to +50°C.					
Humidity	Operating: Up to 85 % relative humidity at +25°C. Storage: Up to 95 % relative humidity					

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Pico Technology is a UK-based manufacturer of high-precision PC-based oscilloscopes and automotive diagnostics equipment, founded in 1991. The product range includes the PicoScope line of PC-based oscilloscopes, data loggers, automotive equipment, and most recently, handheld USB-based oscilloscopes.

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