ADSANTEC

FemtoScope 1000, 2000 and 3000-Series, PC-Wide-Bandwidth Oscilloscopes

5, 16 or 25 GHz, one, two or four channels

Data Sheet

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

***FemtoScope* 3254:**	25 GHz bandwidth, 4 channels with internal trigger
***FemtoScope* 3164:**	16 GHz bandwidth, 4 channels with internal trigger
***FemtoScope* 3054:**	5 GHz bandwidth, 4 channels with internal trigger
***FemtoScope* 2162:**	16 GHz bandwidth, 2 channels with internal trigger
***FemtoScope* 2052:**	5 GHz bandwidth, 2 channels with internal trigger
***FemtoScope* 1161:**	16 GHz bandwidth, 1 channel with internal trigger
***FemtoScope* 1051:**	5 GHz bandwidth, 1 channel with internal trigger

Table of Contents

Oscilloscopes 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 PC oscilloscopes.

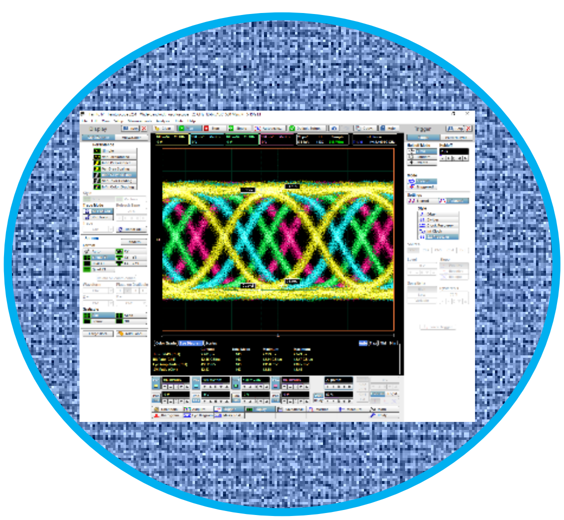
These one-, two- or four-channel instruments, having a bandwidth of 5 GHz, 16 GHz or 25 GHz and internal triggering for all models, provide the acquisition, display, measurement and analysis of complex waveforms in the range from picoseconds to hundreds of seconds.

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.

Features

- 1, 2 or 4 channels configuration.
- The industry's widest 5 GHz, 16 GHz or 25 GHz PC oscilloscope bandwidths available to match your measurement applications,
- The industry's lowest 1.2 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 PC oscilloscope.
- 10 ps/div fastest time base scale.
- Up to ±2 ps delta time measurement accuracy.
- Up to 18 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 or LAN connection.
- Less than 15 W, 22 W or 33 W power consumption depending on amount of channels.
- Less than 370 g, 790 g. or 1.52 kg weight depending on amount of channels.



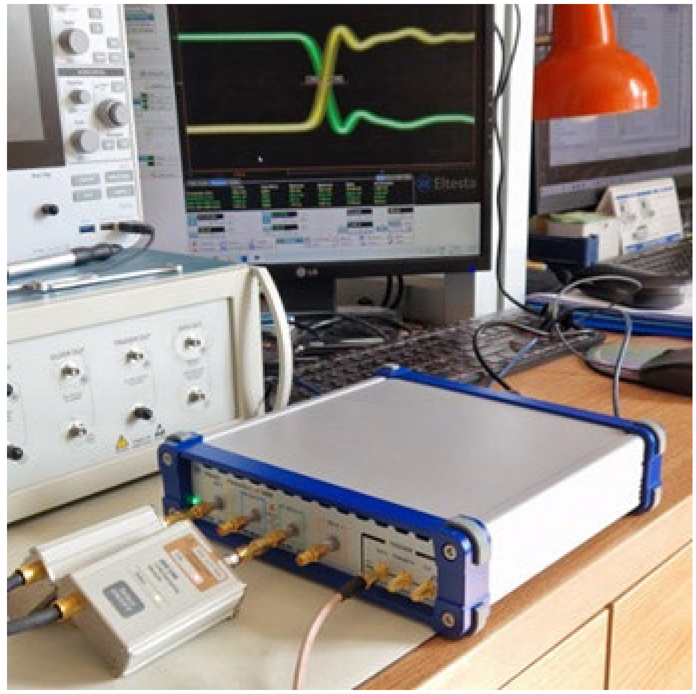


Figure 1. The *FemtoScope* 3254 measures differential TDT response with Tektronix 80E10B TDR/Sampler having its own 7 ps rise time.

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 (Figure 2).

For 25-GHz model Acquisition Board includes four mezzanines with ultra-wideband track-and-hold amplifiers.

12-bit ADCs with 500 MSa/s sampling rate, high-speed trigger circuitry and timing interpolator with sub-picosecond resolution also are key parts of the instruments.

A state-of-the-art microprocessor, FPGA and precision clock oscillator provide structure flexibility, fast acquisition speed and effective interaction with PC.

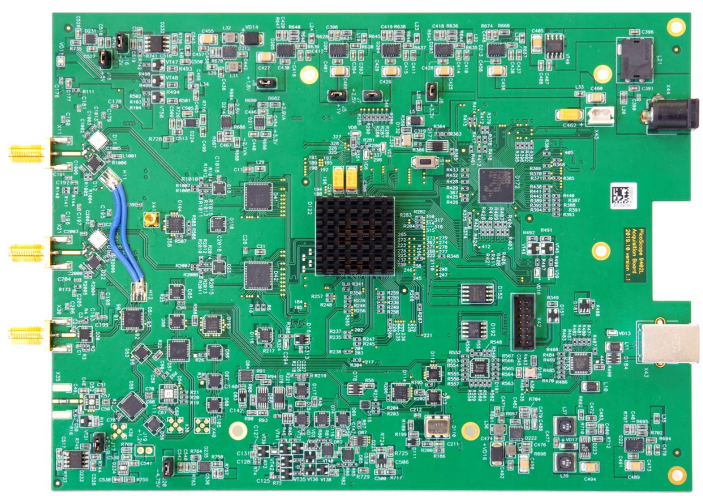


Figure 2. Acquisition Board of the *FemtoScope* 2052 oscilloscope.

ADSANTEC Near-Real-Time *FemtoScope*-Series Oscillosope Portfolio

Specifcations	*FemtoScope* 1051	*FemtoScope* 1162	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Model							
Channels	1		2		4		
Bandwidth	DC to 5 GHz	DC to 16 GHz	DC to 5 GHz	DC to 16 GHz	DC to 5 GHz	DC to 16 GHz	DC to 25 GHz
Vertical scale	10 mV/div to 250 mV/div						10 mV/div to 250 mV/div
DC gain accuracy	±1.5% of Full Scale, max, ±1% of Full Scale, max				±1% of Full Scale, max, ±0.5% of Full Scale, typ		±2% of Full Scale, max, ±1.5% of Full Scale, typ
DC offset range	±1 V						±800 mV
RMS Noise	1.6 mV typ, 1.8 mV max	2.2 mV typ, 2.4 mV max	1.6 mV typ, 1.8 mV max	2.2 mV typ, 2.4 mV max	1.6 mV typ, 1.8 mV max	2.2 mV typ, 2.4 mV max	2.9 mV typ, 3.1 mV max
Input Impedance	50 Ω ± 1.5 Ω						
Real time base 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	50 ps/div to 5 us/div	10 ps/div to 5 us/div	50 ps/div to 5 us/div	10 ps/div to 5 us/div	
Real time sample rate	500 MSa/s max						
Equivalent time sample rate	1 TSa/s max	5 TSa/s max	1 TSa/s max	5 TSa/s max	1 TSa/s max	5 TSa/s max	
Time base clock accuracy	± 0.5 ppm		± 5 ppm				± 0.5 ppm
Delta time measurement accuracy	± (2 ppm * reading + 0.1% * screen width + 5 ps)		± (15 ppm * reading + 0.1% * screen width + 5 ps)		± (15 ppm * reading + 0.1% * screen width + 2 ps)		± (2 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	Internal	Internal or Prescaled	Internal, External Direct or Prescaled
Trigger Style	Direct, Divided, Internal Clock		Direct, Divided, Clock Recovery Internal Clock	Direct, Divided, Clock Recovery Prescaled, Internal Clock	Direct, Divided, Clock Recovery Internal Clock	Direct, Divided, Clock Recovery Prescaled, Internal Clock	Direct, Divided, Clock Recovery, Prescaled, Internal Clock
Direct Trigger Bandwidth	DC to 2.5 GHz						
Divided Trigger Bandwidth	DC to 6 GHz typ						
Prescaled Trigger Bandwidth	N/A		N/A	1 GHz to 16 GHz	N/A	1 GHz to 16 GHz	1 GHz to 18 GHz
Clock Recovery Data Rate	N/A		6.5 MSa/s to 5 GSa/s	6.5 MSa/s to 11.3 GSa/s	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		

Bandwidth

The *FemtoScope* Series oscilloscopes have one, two or four input channels with 5 GHz, 16 GHz or 25 GHz bandwidth (Figures 3-5) with 12-bit ADC, timing and display resolutions for accurately measuring and visualizing of high-speed waveforms.

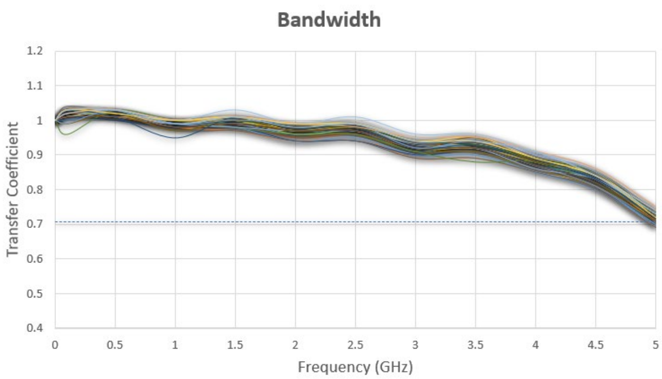


Figure 3. Frequency response of forty 5-GHz input channels (*FemtoScope* 3054).

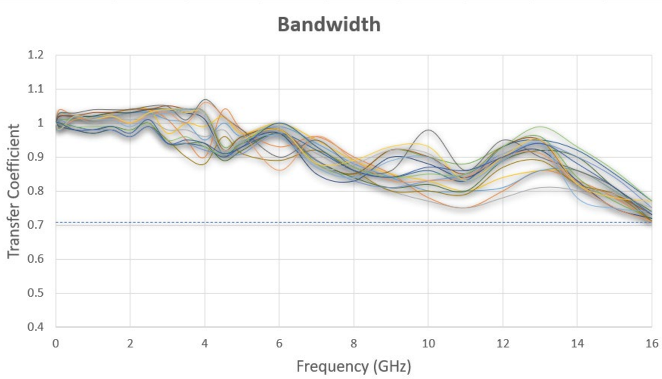


Figure 4. Frequency response of twenty 16-GHz input channels (*FemtoScope* 3164)

They are ideal for capturing pulse and step transitions down to 70, 22 or 14 ps respectively, impulses down to 140, 44 or 28 ps also clocks and data patterns up to 16 Gb/s. Most high-bandwidth applications involve repetitive signals or clock-related data streams that can be readily analyzed with these oscilloscopes by random equivalent-time sampling.

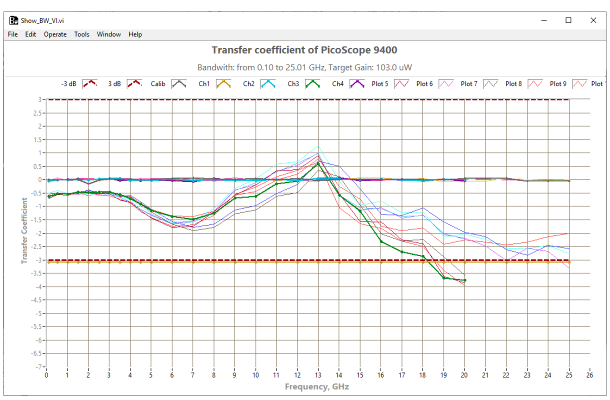


Figure 5. Frequency response of four input channels of the *FemtoScope* 3254. Response is made for both full (25 GHz) and narrow (18 GHz) bandwidth modes.

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. 5-GHz, 16-GHz and 25-GHz inputs also include wide-bandwidth symmetrical resistive voltage divider.

One half of the signal goes to the THA, the other to high frequency trigger comparator. The input impedance of the channel is (50 ± 1.5) Ω. With a maximum permissible input voltage of ±2 V for 5-GHz and 16-GHz channels, also ±1.5 V for 25-GHz channels, the dynamic range of the input signals is ±1 V for 5-GHz and 16-GHz channels, and ±800 mV for 25-GHz 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* 3054 and 3164 provide three bandwidths – full (5 GHz or 16 GHz), 500 MHz or 100 MHz.

The *FemtoScope* 3254 provide two bandwidths – full (25 GHz) and narrow (18 GHz).

Transient response

The transient response of oscilloscope is characterized by its rise time or fall time (transition durations), overshoot, undershoot, aberrations.

To test the transient response of an oscilloscope, an ideal pulse (flat baseline and topline, very small rise/fall times) is desirable for the input stimulus. A test pulse acceptable for testing most oscilloscopes has an overshoot, undershoot, and other aberrations less than one percent of the pulse amplitude and a rise time much smaller than that of the oscilloscope. For such wide-band oscilloscopes like *FemtoScopes* test pulse should be selected very carefully. Transient response characteristics of the instruments are shown in Figures 6-11.

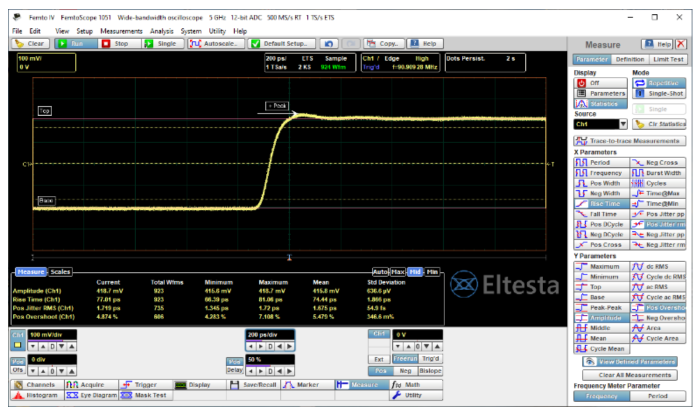


Figure 6. Transient response of 5-GHz *FemtoScope* 1051 shows less than **75 ps** transient response measured with Tektronix 1251 PPG (25 ps own rise time).

Figure 7. Transient response of the *FemtoScope* 3164 (16-GHz model) tested with 531-mV negative-going step at 100 mV/div vertical scale. Total measured fall time is **25 ps**, rms jitter is 1.221 ps, and negative overshoot is 2.92%. Signal source: Tektronix 1251 Pulse Pattern Generator.

Figure 8 shows comparative transient response of the *FemtoScope* 3164 made at 600 mV step amplitude for three different bandwidths – 16 GHz, 500 MHz and 100 MHz. Yellow trace shows 40.58 ps rise time acquired in full 16-GHz bandwidth. Blue trace shows 702 ps rise time acquired in 500-MHz bandwidth, Violet trace shows 3.084 ns rise time acquired in 100-MHz bandwidth.

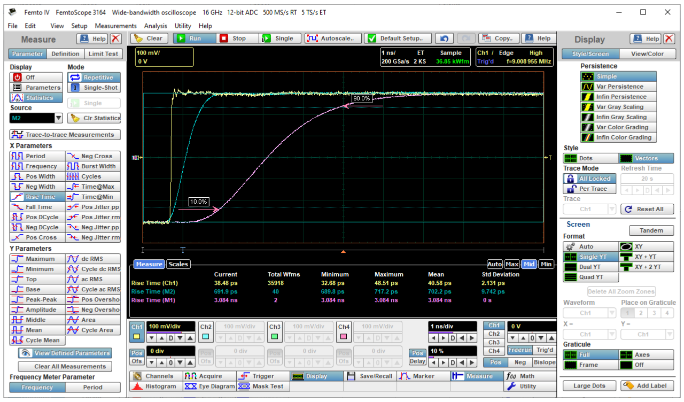


Figure 8. Comparative transient response of the *FemtoScope* 3164 made for three different bandwidths at 600 mV step amplitude.
Signal source: Tektronix PPG1251 Pulse Pattern Generator.

In full bandwidth mode, the instruments provide typical rms noise level less than 1.6 mV for 5 GHz bandwidth, 2.2 mV for 16 GHz bandwidth and 2.9 mV for 25 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 9 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* 3054 provides typical rms noise less than 0.45 mV. Narrow bandwidth setting can also be used as an anti-alias filter.

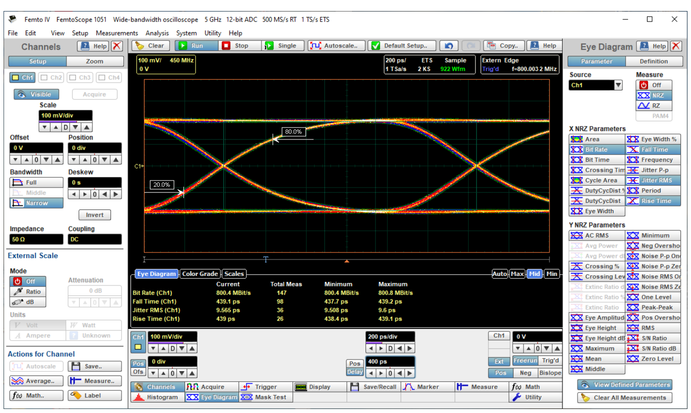


Figure 9. 800 Mb/s wide opened eye diagram acquired in narrow bandwidth mode with the *FemtoScope* 1051 shows good response characteristics.

The *FemtoScope* 3254 having 25-GHz bandwidth channels is a powerful instrument designed specifically to give you the highest accuracy and measurement speed for characterizing tele- and data communications waveforms. They effectively can be used for research and design or production test to provide the right answers. The frequency response of these models has been carefully designed in order to provide the best time domain response possible. Minimal aberrations in the pulse response allow the design engineer to see eye diagram measurements indicative of the device-under-test, not the test equipment.

The *FemtoScope* 3254 with its four 25-GHz channels provides own risetime of 14 ps. In pair with Tektronix 80E10B sampler/TDR module having its own 7 ps step rise time, they show common transient response faster 15 ps (see Figure 10). The lower 18-GHz bandwidth mode of the *FemtoScope* 3254 provides better oscilloscope noise performance for accurate measurement of low-level signals (Figure 11).

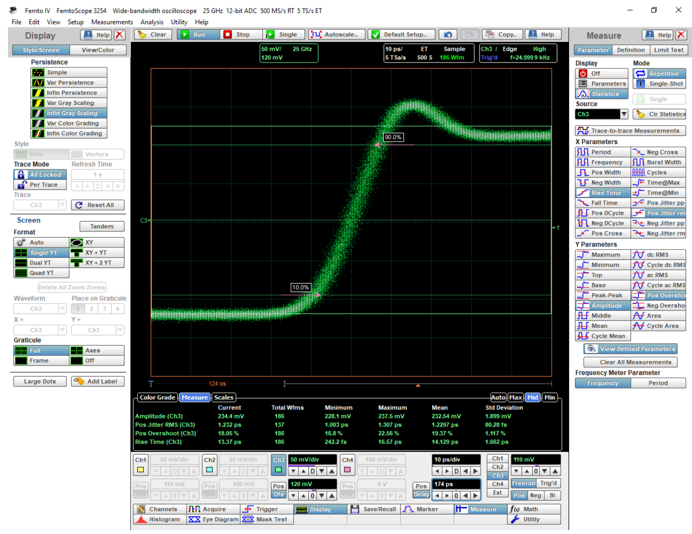


Figure 10. Transient response of the *FemtoScope* 3254 (25-GHz model) tested with 250-mV positive-going step at 50 mV/div vertical scale and 10 ps/div horizontal scale. Total measured rise time is **14.129 ps**, rms jitter is 1.2297 ps, and positive overshot is 19.37%. Signal source: Tektronix 80E10B sampler/TDR module with 7 ps own rise time.

Figure 11. Transient responses made on two channels the *FemtoScope* 3254. Step amplitude is 230 mV for both channels. Channel 1 has 25 GHz bandwidth, while channel 2 has 18 GHz (narrow bandwidth mode). Channel 1 total measured rise time is **14.34 ps**, 0.934 ps rms jitter, and 17.08% overshot. Channel 2 total measured rise time is **16.33 ps**, 1.1367 ps rms jitter, and 12.53% overshot. Signal source: two Tektronix 80E10B sampler/TDR modules having two positive steps with 7 ps own rise time.

Wide-bandwidth Oscilloscopes for Serial Data Analysis

The *FemtoScope* oscilloscopes show the eye diagrams, histograms, also provide mask test. All this helps you to perform correct Serial Data Measurements.

Having the right amount of oscilloscope bandwidth ensures more accurate measurements. If you have too much bandwidth, oscilloscope noise becomes a contributor in your measurement. With too little bandwidth, rise times are improperly depicted (see Figures 12-14).

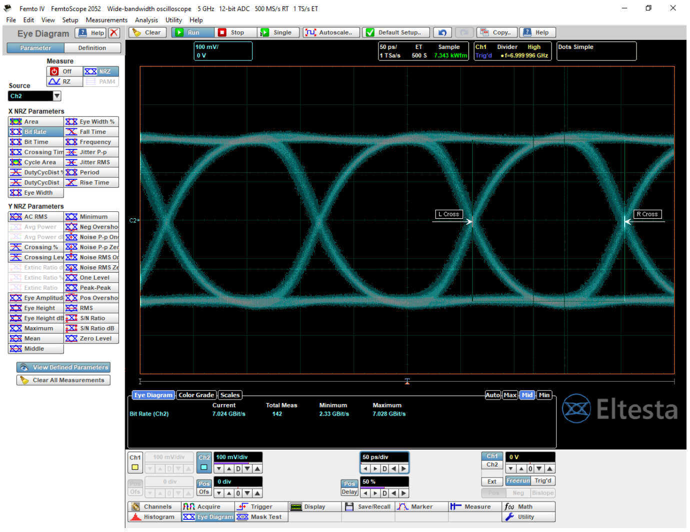


Figure 12. The *FemtoScope* 2052 with 5-GHz bandwidth captures only the fundamental frequency of a 7-Gbps PRBS signal.

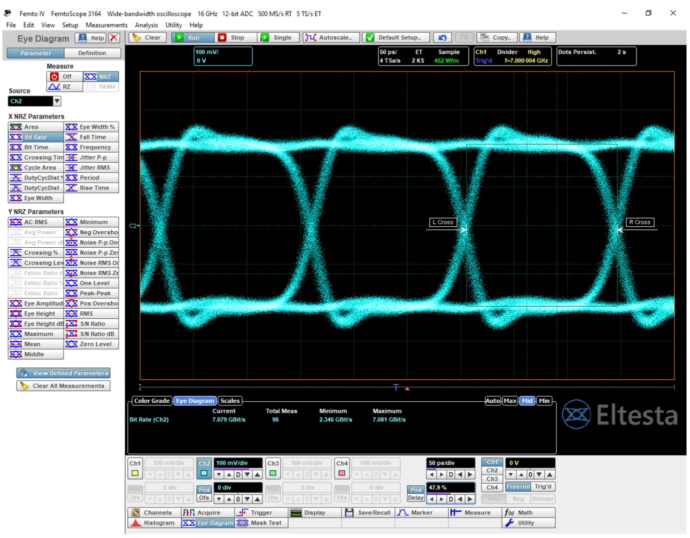


Figure 13. The *FemtoScope* 3164 with 16-GHz bandwidth sees the 3rd harmonic of a 7-Gbps PRBS signal.

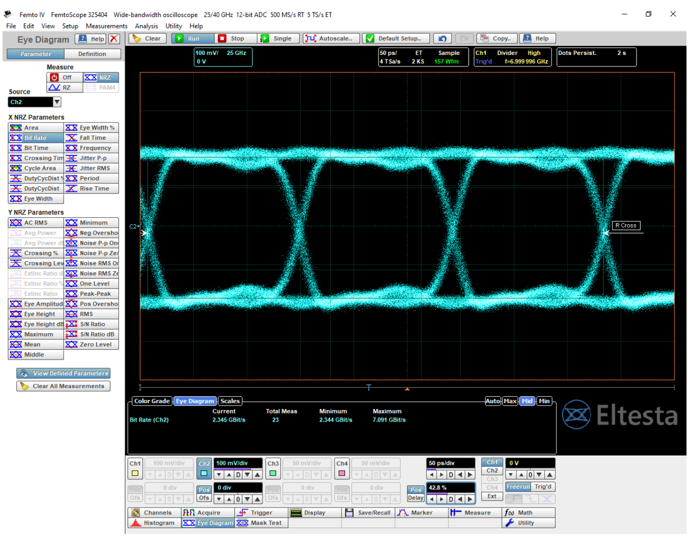


Figure 14. The *FemtoScope* 3254 with 25-GHz bandwidth (channel 2) sees up to the 5th harmonic of the 7-Gbps PRBS signal.

Use the charts below to find the correct oscilloscope bandwidth for the standard you are measuring.

Recommended Data Rate Configuration for 5-GHz *FemtoScope* 1051/2052/3054 oscilloscopes

Standard	Bit Rate	Recommended bandwidth
SONET/SDH, OC1/STMO	51.84 Mb/s	150 MHz
Fibre Channel, FC133	132.8 Mb/s	400 MHz
Ethernet, 100BASE-BX/LX10	125 Mb/s	400 MHz
SONET/SDH, OC3/STM1	155.52 Mb/s	500 MHz
Fibre Channel, FC266	265.6 Mb/s	800 MHz
SONET/SDH, OC9/STM3	466.56 Mb/s	2 GHz
Fibre Channel, FC531 I	531.35 Mb/s	2 GHz
SONET/SDH, OC12/STM4	622.08 Mb/s	2 GHz
SONET/SDH, OC18/STM6	933.12 Mb/s	3 GHz
Fibre Channel, FC1063 Electrical	1.0625 Gb/s	3 GHz
SONET/SDH, OC24/STM8	1.2442 Gb/s	4 GHz
Ethernet, 1.25 Gb/s	1.25 Gb/s	4 GHz
RapidIO, Serial Level 1, 1.	1.25 Gb/s	4 GHz
Serial ATA	1.5 Gb/s	5 GHz

Recommended Data Rate Configuration for 16-GHz *FemtoScope* 1161/2162/3164 oscilloscopes

Standard	Bit Rate	Recommended bandwidth
Fibre Channel, FC2125	2.1231 Gb/s	7 GHz
Ethernet, 2XGB Ethernet	2.5 Gb/s	8 GHz
SONET/SDH, OC48/STM16	2.48832 Gb/s	8 GHz
SONET/SDH, FEC 2666	2.6666 Gb/s	8 GHz
Infiniband, 2.5G	2.5 Gb/s	8 GHz
RapidIO, Serial Level 1, 2.5G	2.5 Gb/s	8 GHz
PCI Express, R1.0a 2.5G	2.5 Gb/s	8 GHz
Serial ATA, Ext Length, 3.0G	3 Gb/s	9 GHz
Ethernet, 3.125 Gb/s	3.125 Gb/s	10 GHz
XAUI, 3.125 Gb/s	3.125 Gb/s	10 GHz
RapidIO, Serial Level 1, 3.125G	3.125 Gb/s	10 GHz
Fibre Channel, FC4250	4.25 Gb/s	13 GHz
Infiniband, 5.0G	5 Gb/s	15 GHz
PCI Express, R2.0	5 Gb/s	15 GHz

Recommended Data Rate Configuration for 25-GHz *FemtoScope* 3254 oscilloscope

Standard	Bit Rate	Recommended bandwidth
SONET/SDH, OC192/STM64	9.95328 Gb/s	25 GHz
Ethernet, 10Gb	9.953 Gb/s	25 GHz
Ethernet 10GbE	10.3125 Gb/s	25 GHz
SONET/SDH FEC1066	10.664 Gb/s	25 GHz

Vertical channels

The *FemtoScope*-Series enables users to make wideband measurements up to 25 GHz frequency range (Figure 15). You can analyze wide-bandwidth signals by using the *FemtoScope*-Series with other types of measurement instruments like sine-, pulse-, pattern- or arbitrary-waveform signal sources.

4 channels	***FemtoScope* 3054**	***FemtoScope* 3164**	***FemtoScope* 3254**
2 channels	***FemtoScope* 2052**	***FemtoScope* 2162**	
1 channel	***FemtoScope* 1051**	***FemtoScope* 1162**	
Bandwidth	**5 GHz**	**16 GHz**	**25 GHz**

Figure 15. Distribution the *FemtoScope* models by bandwidth and amount of channels.

Providing up to 12 bits of vertical resolution even in single-shot acquisitions the *FemtoScope* allows to control vertical sensitivity from 10 mV/div to 250 mV/div for 5- and 16-GHz models, and to 200 mV/div for 25-GHz model.

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, also ±1 V DC offset, 5-GHz and 16-GHz oscilloscopes provide wide input dynamic range between -1 V and +1 V.

Figure 16 shows the *FemtoScope* 1051 with input pulse having 1.9 V amplitude symmetrical to zero on 250 mV/div vertical scale. With rise time faster than 10 ns it has very small ringing within ±1 %.

Figure 17 shows the *FemtoScope* 3254 with fast pulse having 1.4 V amplitude symmetrical to zero on 200 mV/div vertical scale. With rise time closed to 26 ps it has small ringing less than ±3.6%.

Figure 16. The *FemtoScope* 1051 (5 GHz bandwidth): measures symmetrical to zero pulse having less than 10 ns rise time and 1.9 V amplitude. The test shows ringing less than ±1 % on vertical scale 250 mV/div.

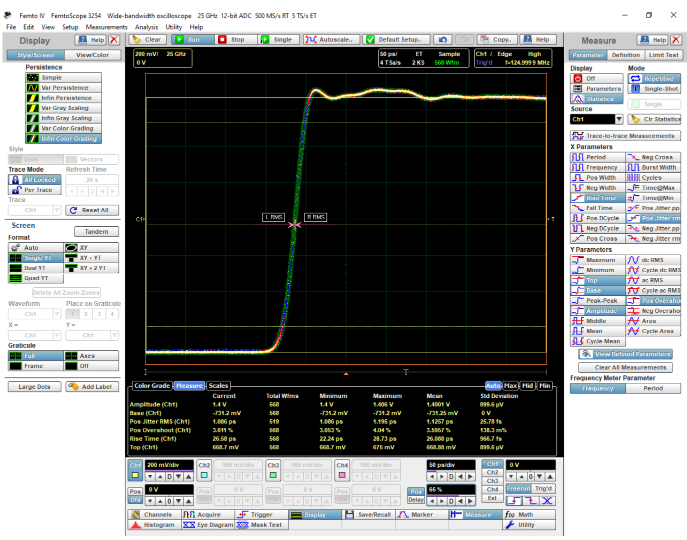


Figure 17. The *FemtoScope* 3254 (25 GHz bandwidth): measures very fast symmetrical to zero pulse having 26.088 ps rise time and 1.4 V amplitude. The test shows ringing less than ±3.6% on vertical scale 200 mV/div.

With 50 Ω channel input impedance 5- and 16-GHz oscilloscopes used standard SMA female connector providing ±2 V (DC + peak AC) maximum input voltage. While 25-GHz channels used 2.92 mm (K) female, compatible with SMA and PC3.5 connectors. Maximum input voltage for 25-GHz channel is ±1.5 V.

More wider oscilloscope bandwidth allows signal rise times to be more accurately depicted. At the same time the oscilloscope noise floor directly impacts the y-axis voltage placement of each signal data point. The *FemtoScope*-Series combines these characteristics with low trigger jitter (closed to 1 ps RMS). This ensures the lowest possible contribution to jitter measurements, allowing you to resolve low frequency jitter components in different type of measurement.

Figure 18 shows RMS noise level for 5-GHz *FemtoScope* 2052. Channel 1 has full 5 GHz bandwidth mode, while Channel 2 has middle 500 MHz bandwidth mode.

Figure 18. The *FemtoScope* 2052 (5 GHz bandwidth) shows 1.591 mV rms noise (channel 1 in full 5 GHz bandwidth mode), and 0.61 mV rms noise (channel 2 in middle 500 MHz bandwidth mode).

Figure 19 shows RMS noise level for 16-GHz *FemtoScope* 3164. Channels 1 and 4 having full 16 GHz bandwidth mode, Channel 2 has middle 500 MHz bandwidth mode, while Channel 3 has narrow 100 MHz bandwidth mode. RMS noise figures show how noise level depends on bandwidth value.

Figure 19. The *FemtoScope* 3164 (16 GHz bandwidth) shows 2.17 mV rms noise (channel 1) and 2.21 mV rms noise (channel 4), both in full 16 GHz bandwidth mode. Channel 2 shows 0.65 mV rms noise in middle 500 MHz bandwidth mode, and channel 3 shows 0.48 mV rms noise in narrow 100 MHz bandwidth mode.

Probes

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).

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.

Figure 20 demonstrate how the oscilloscope acquires two 5-ns single shot pulse at 500 MSa/s sampling rate

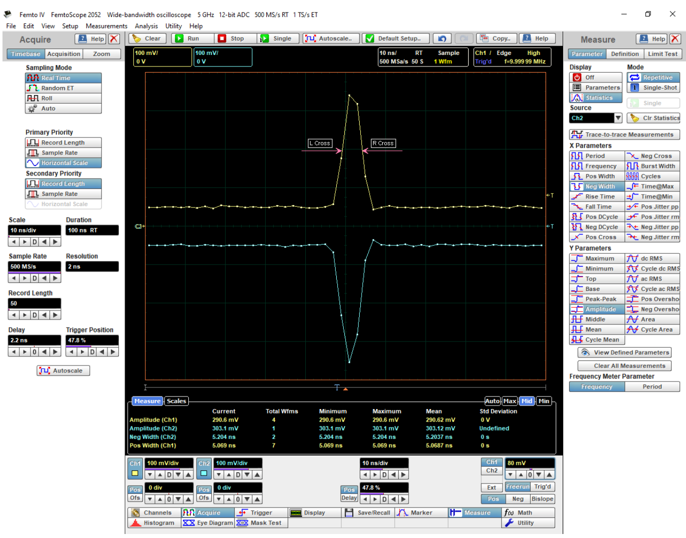


Figure 20. The *FemtoScope* 2052 acquired two singe shot pulses having 5 ns width. Independent acquisition was done on 500 MSa/s sampling rate per channel.

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. On Figure 21 the *FemtoScope* 1051 shows 0.63 ppm timing accuracy.

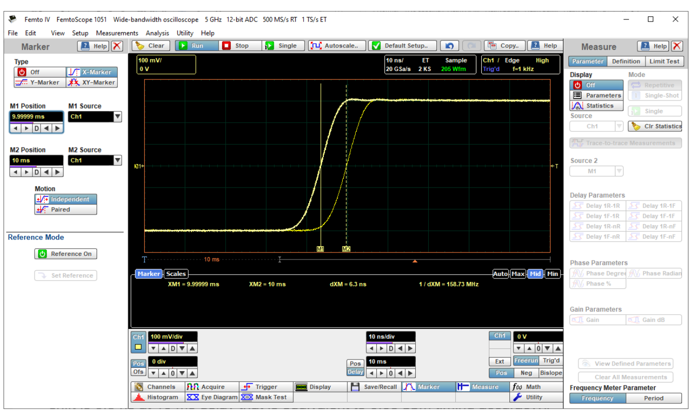


Figure 21. The *FemtoScope* 1051 demonstrates real time base accuracy. Timing shift is 6.3 ns at 10 ms delay that is equivalent to 0.63 ppm timing accuracy.

At the same time stability of real-time clock that can be estimated as a „long-time" jitter is also critical for deep-memory applications. Measurement of jitter is necessary for ensuring high-speed system reliability. The lower jitter value, the better you'll be able to characterize your device. *FemtoScopes* achieve both time accuracy and low jitter specifications.

Figure 22 demonstrates 716 ps rms jitter measured at 100 ms horizontal delay with the *FemtoScope* 1051. This is equivalent to 7.16 ppb real-time rms jitter.

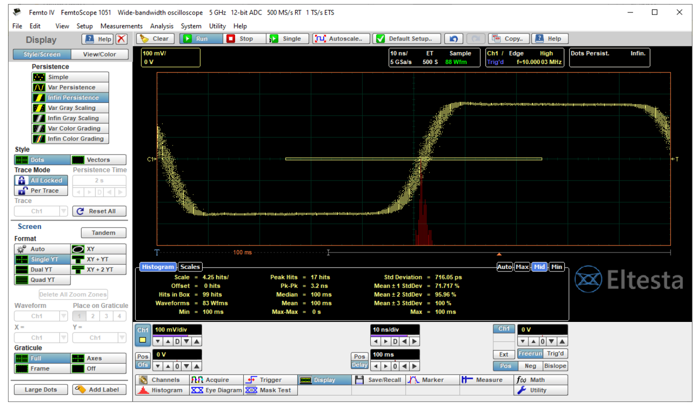


Figure 22. The *FemtoScope* 1051 measures real-time base long jitter from a stable 10 MHz clock source. RMS jitter value shows 716 ps at 100 ms horizontal delay that is equivalent to 7.16 ppb real-time rms jitter.

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 16-GHz and 25-GHz models have 0.2 ps timing resolution that is equivalent to 5 TSa/s equivalent-time sampling rate. For 5-GHz models these two values 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 to call it 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-diagram.

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.

Figures 23 and 24 demonstrate how the accuracy of horizontal scale can be tested with 1-GHz and 10-GHz sinewave clock. For better preciseness the oscilloscopes used averaging.

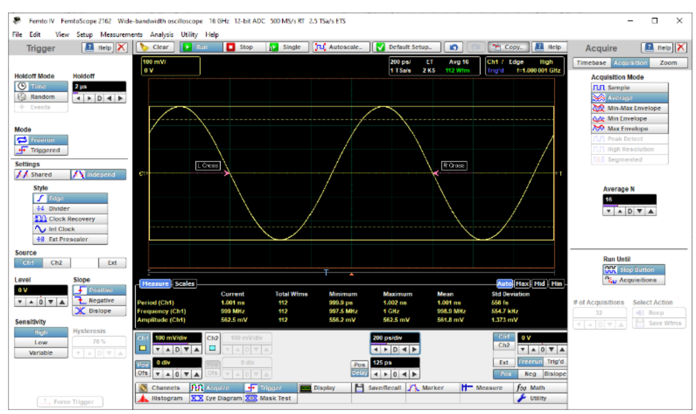


Figure 23. The *FemtoScope* 2162 tests accuracy of 200 ps/div horizontal scale with 1 GHz sinewave (1 ns period). Mean value of measured period is 1.001 ns that is equivalent to +0.1% accuracy.

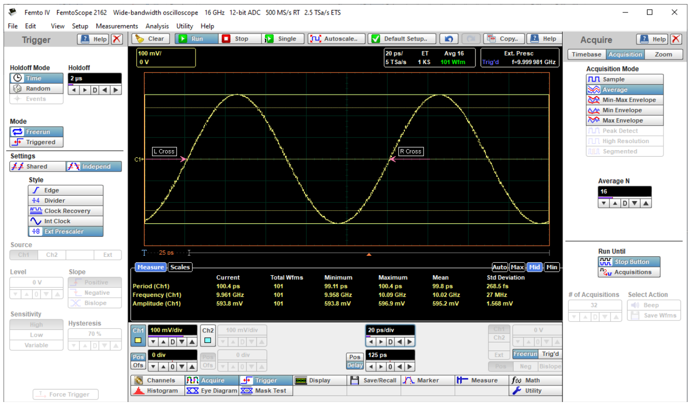


Figure 24. The *FemtoScope* 2162 tests accuracy of 20 ps/div horizontal scale with 10 GHz sinewave (100 ps period). Mean value of measured period is 99.8 ps that is equivalent to -0.2% accuracy.

The time base of the *FemtoScopes* should have its ability to make accurate, reliable delta-time measurements. Depending on the model time base system has maximum from ±2 ps to ±5 ps of delta-time error. Most of this error comes from discontinuity between clock period and duration of timing interpolator. This discontinuity may appear every 2 ns, and should be carefully calibrated and tested.

The trend function is an effective method of precise picosecond time base test. In the example on Figure 25, the oscilloscope measures the period of 21-GHz sinewave signal (dark green) used to test the time base. The trend function of the measured period (light-green) is the mathematical trend 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 time base at various horizontal points of the scale every 47.6 ps (1/21 GHz).

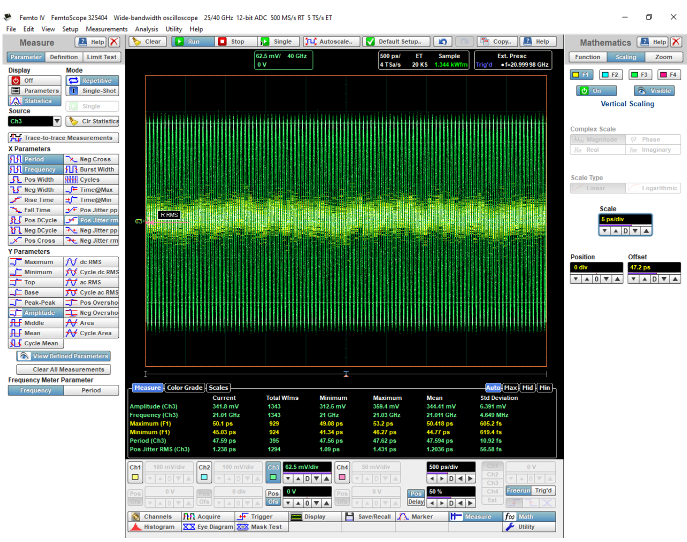


Figure 25. Trend of period measures nonlinearity of the *FemtoScope* 3254 time base with 21-GHz sinewave (period 47.619 ps). Maximum trend of period is 50.418.3 ps (+2.799 ps). Minimum trend of period is 44.77 ps (-2.849 ps). Peak-peak nonlinearity is less than 5.7 ps pk-pk at 5 ns timing window.

In conclusion, we mention the Roll mode that displays the waveform moving across the screen from right to left. Roll mode is available at the time base 100 ms/div or slower. It works at sample rates up to 62.5 kSa/s with a maximum record length of 62.5 Kpts.

Acquisition

Several acquisition modes let you choose how the oscilloscope will create points in the waveform record.

The Average calculates the average values for each record point over many waveform records. It is available in real- and equivalent-time modes.

The *FemtoScopes* use so-called stable averaging. It reduces the random noise and jitter of a displayed waveform and provides a cleaner display, improves resolution of the displayed waveform, and increases measurement repeatability, all due to a more stable displayed waveform.

Figure 26 shows speed limit signal averaged by the *FemtoScope* 3254. With selected number of averaging equal to 16 the level of RMS jitter is 387.1 fs and decreased approximately in 4 times compare with non-averaged mode.

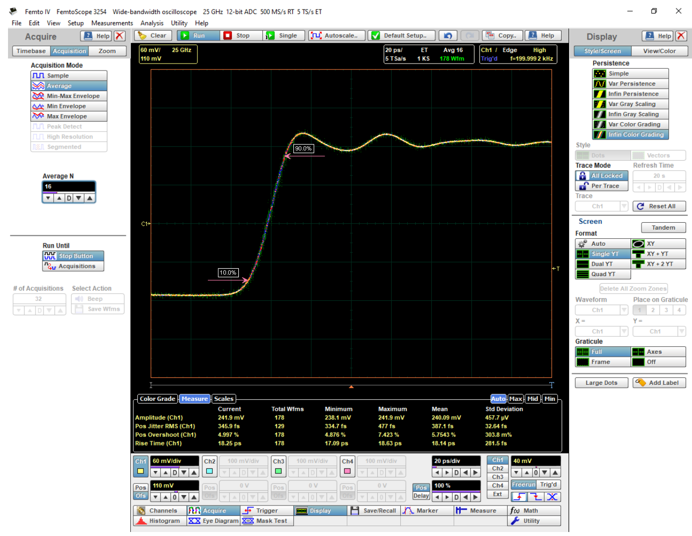


Figure 26. The *FemtoScope* 3254 shows fast transient response in average mode. Positive-going step has 18.14 ps total measured rise time and 0.3871 fs rms jitter (both with averaging). Number of averages = 4.
Signal source: Tektronix 80E10B sampler/TDR module.

Three types of Envelope mode (Min-Max, Min and Max) use the highest and lowest samples across several waveform records. These are also available in real- and equivalent-time modes. Envelope mode help to see the rise time of a radar burst. You need to add a rise time measurement to an envelope function that provides an AM demodulation of a burst (Figure 27).

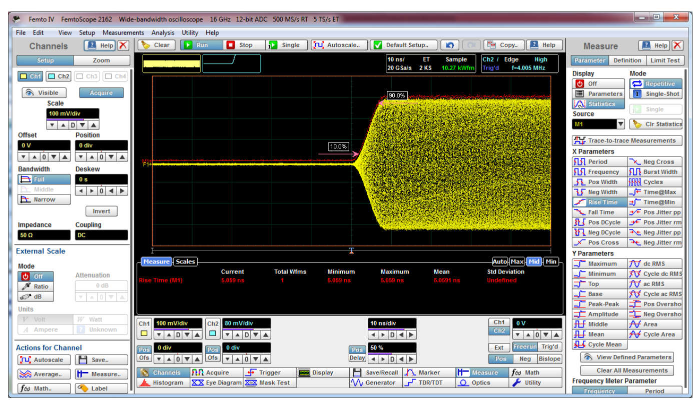


Figure 27. Envelope mode of the *FemtoScope* 2162 (red trace) helps to detect of a 1-GHz AM burst (yellow trace). Measured rise time of detected burst is 5.091 ns.

Min-Max Envelope helps to measure peak-peak jitter of enough complicated waveforms like distorted pulses. Figure 28 shows how the *FemtoScope* 3164 measures 13.25 ps peak-peak jitter of fast pulse having distortions on the top.

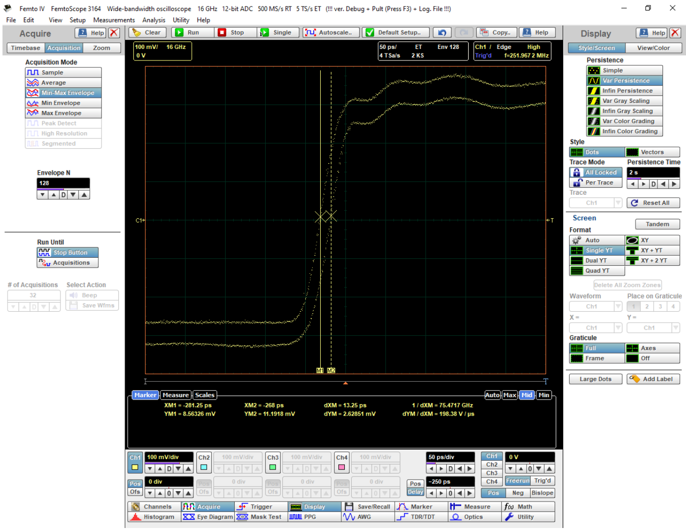


Figure 28. Min-Max Envelope helps to measure 13.25 ps peak-peak jitter of enough fast and distorted waveform.

To build more confidence in your designs, sometimes you need to look into more signal detail than you can see with the standard 12-bit vertical resolution of the *FemtoScope*-Series. High-resolution mode offers additional resolution and insight into the signal, without requiring a repetitive signal.

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.

The table below indicates a comparison of the typical noise floor between the sample (normal) and high-resolution mode. It shows that you can obtain up to 16 significant bits with High Resolution mode when ≥ 1 µs/div at 500 MSa/s.

Main relations for the *FemtoScopes* in High Resolution mode

Resolution	Maximum Sampling Rate	Bandwidth	RMS Noise Level
Sample Mode			
12 bits	500 MS/s	220 MHz	2.4 mV
High Resolution Mode			
12.5 bits	250 MS/s	110 MHz	1.60 mV
13 bits	125 MS/s	55 MHz	1.10 mV
13.5 bits	62.5 MS/s	27.5 MHz	0.74 mV
14 bits	31.25 MS/s	13.8 MHz	0.50 mV
14.5 bits	15.625 MS/s	6.9 MHz	0.36 mV
15 bits	7.81 MS/s	3.4 MHz	0.30 mV
15.5 bits	3.91 MS/s	1.7 MHz	0.23 mV
16 bits	1.95 MS/s	0.85 MHz	0.12 mV

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.

Zoom

Up to 250 KB memory you can capture long, non-repeating or repetitive signals, maintain high sample rate, and quickly zoom in on areas of interest.

Zoom is not a special mode. That means it's always available to help you find details buried in complex signals, discover anomalies, correlate high-speed digital control signals with slower analog signals and capture infrequent events.

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 (Figure 29). The maximum vertical zoom is 100, and maximum horizontal zoom is 2048.

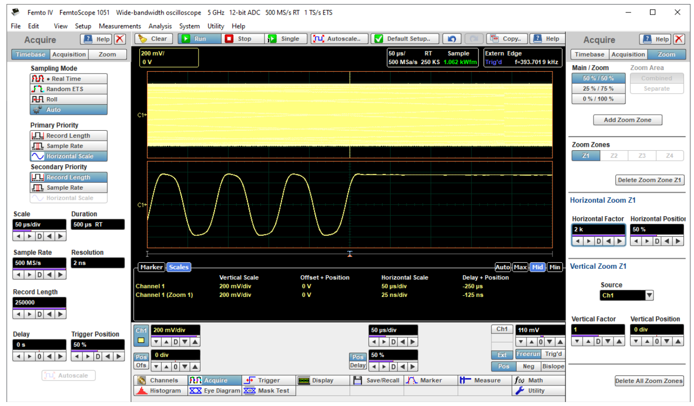


Figure 29. 50 Mb/s data pattern is acquired at 500 MSa/s sampling rate, 50 us/div time base and 250 KB record length (top). With 2K horizontal zoom you have possibility to measure the details of the waveform at 25 ns/div time base (bottom)

Trigger

One of the most important properties of wide-bandwidth oscilloscopes is their ability to provide sensitive and 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 edge trigger up to 2.5 GHz, and divided trigger up to 6 GHz. Input high-speed comparators allow you to adjust the trigger level and hysteresis, providing trigger sensitivity for edge trigger better than 30 mV p-p at 100 MHz and better than 50 mV pp at 2.5 GHz with RMS jitter less than 1.5 ps (Figures 30, 31). Typical trigger sensitivity for divided is better than 70 mV p-p at 6 GHz (Figure 32). It is possible to select any trigger slope, as well as use the bi-slope trigger, which allows you to acquire the so-called pseudo-eye diagrams.

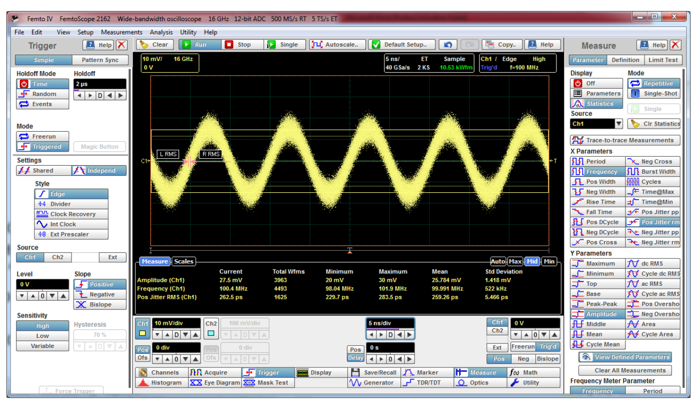


Figure 30. The *FemtoScope* 2162 provides internal edge trigger from 100-MHz sinewave with 30 mV p-p amplitude.

To expand the trigger frequency range up to 6 GHz, all the models provide a frequency divided mode. In this mode circuitry includes a low-jitter, high-speed frequency divider with division factor of 4. The divided signal is applied to the existing trigger circuitry. Slope, trigger level and hysteresis controls function as in Edge style of trigger thus it will operate correctly on a sine wave input down to DC.

This mode is especially relevant for measurements on such popular clock ranges as 3.25 GHz and 5 GHz.

Figure 31. The *FemtoScope* 3164 surely provides internal edge trigger from 2.5 GHz sinewave with 1.2426 ps rms jitter.

Figure 32. The *FemtoScope* 3164 used internal divided trigger from 6 GHz sinewave with 1.3427 ps rms jitter.

And, finally, all 16-GHz and 25-GHz models have external prescaled trigger. 16-GHz models (*FemtoScope* 2162/3164) provide 16 GHz prescaled trigger bandwidth. 25-GHz model *FemtoScope* 3254 provides 18 GHz prescaled trigger bandwidth.

Prescaled style of trigger is realized by using high-frequency prescaler with fixed /8 division factor, as well as a small additive phase noise, which helps to achieve a low trigger jitter level (Figures 33, 34).

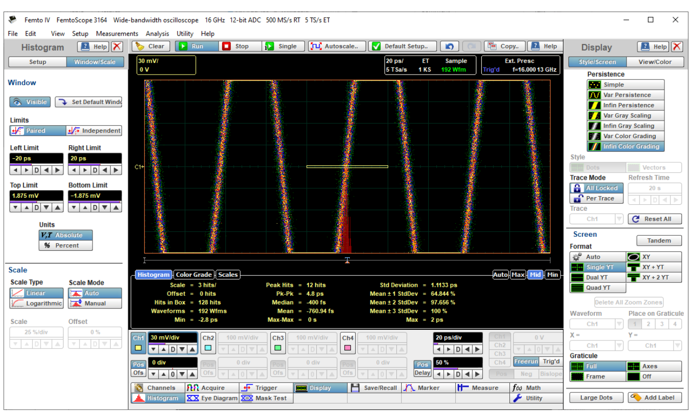


Figure 33. The *FemtoScope* 3164 provides external prescaled trigger from 16 GHz sinewave with 1.1133 ps rms jitter.

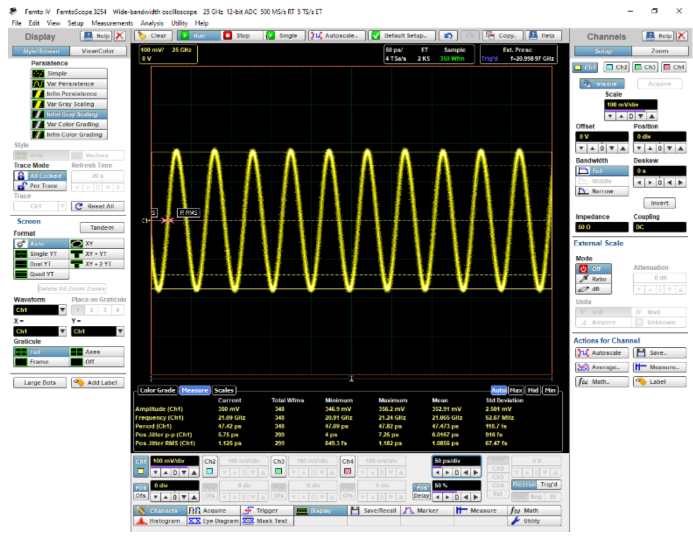


Figure 34. The *FemtoScope* 3254 shows external prescaled trigger from 21 GHz (typical value) sinewave with 1.0856 ps RMS jitter.

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 35 shows how the *FemtoScope* 3164 used internal trigger from a short pulse having less than 87 ps pulse width. Such pulses are the shortest in a 12 Gb/s data pattern.

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

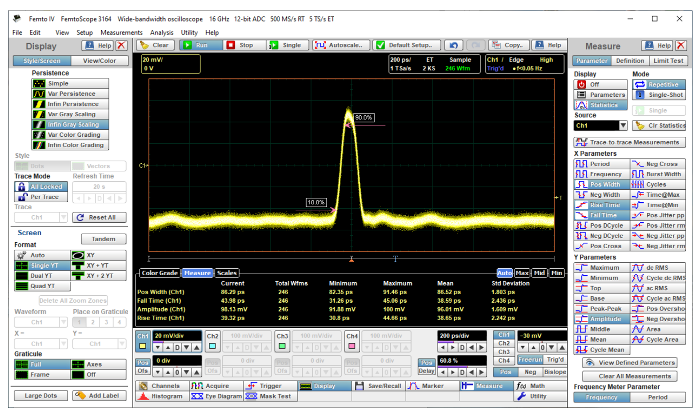


Figure 36. The *FemtoScope* 3164 demonstrates internal edge trigger from 86.52 ps pulse having 96.01 mV amplitude at enough low repetition rate.

Clock recovery trigger

The Clock recovery trigger derives a timing reference directly from the NRZ waveform to be measured. The clock recovery trigger covers the most popular electrical standards used today from 6.5 Mb/s to 11.3 Gb/s bit rates

The *FemtoScope* oscilloscopes provide both internal and external 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, 3164 and 3254 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 37 shows an eye diagram of 8-Gb/s data pattern acquired with internal clock recovery trigger.

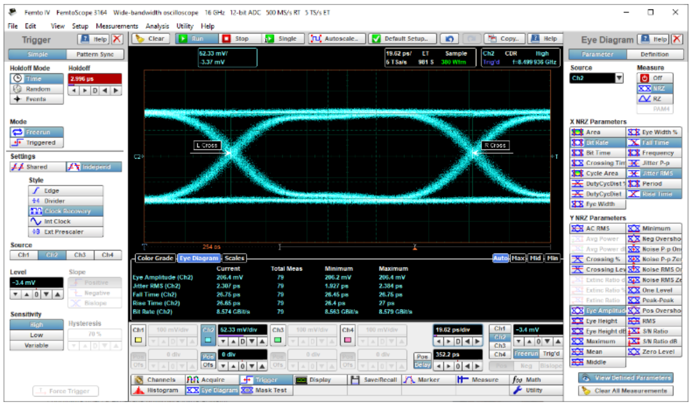


Figure 37. The *FemtoScope* 3164 acquires 8.5 Gb/s eye diagram with internal clock recovery trigger.

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 edge (up to 2.5 GHz), internal or external divided (up to 6 GHz), internal or external clock recovery (up to 11.3 Gb/s) and external prescaled (up to 18 GHz guaranteed).

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 38). 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 38. 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 8388607 (2^{23}–1). Use manual entry when you do not have any information about data pattern length.

The *FemtoScope* used 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 of 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.

Use the Eye Line mode to average eye diagrams and to view specific bit trajectories (see Figure 39).

The number of averages can be set from the Average N of the Acquisition Mode menu.

Eye Line mode used the pattern lock feature to establish a pattern sync trigger and then to use 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 39. The *FemtoScope* 3164 demonstrates averaged 2.5 Gb/s eye diagram by using Eye Line mode. Eye RMS Jitter = 1.96 ps. Scan Bits = 32. Clearly noticeable influence of data dependent jitter.

Display

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

The Persistence function determines how long a data point is kept on the display before being erased. Normally, a waveform is displayed only for one trigger event. When the next trigger event occurs, the previous waveform is erased and the newly acquired waveform is drawn on the display. Persistence is a display memory function; therefore acquired waveforms are written only to display memory.

The *FemtoScopes* used two persistence settings: Variable Persistence or Infinite Persistence. In variable persistence mode, the oscilloscope updates the display of newly collected waveforms in 0.1 s to 20 s.

In “gray scaling” mode (Figure 40), the oscilloscope uses five different degrees of intensity of the same color. 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.

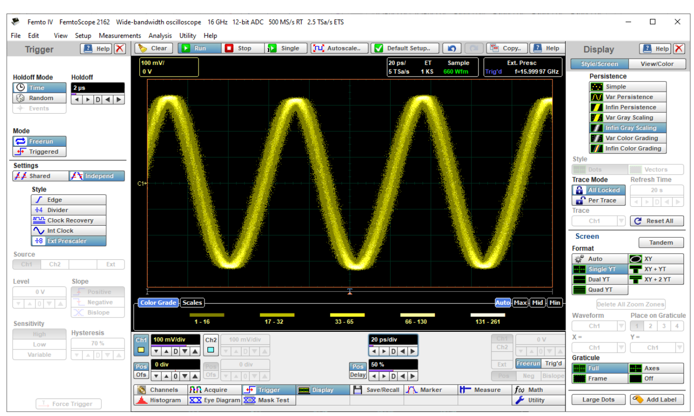


Figure 40. The *FemtoScope* 2162 shows a 16-GHz sinewave in “grey-scaling” format.

In the "color grading" format (Figure 41) 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.

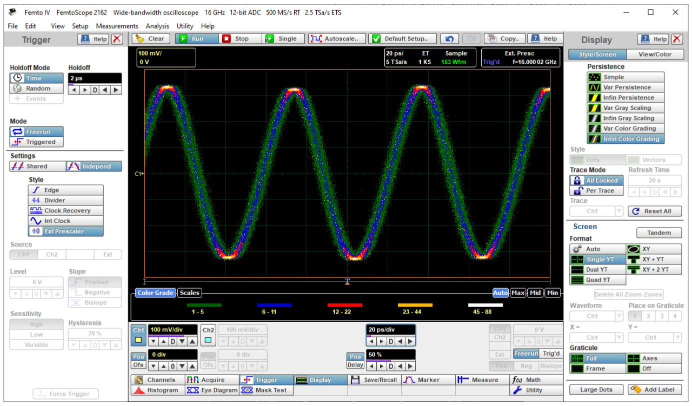


Figure 41. The *FemtoScope* 2162 shows 16-GHz sinewave in "color-grading" format

The Style menu determines how waveform dots are displayed. There are two choices: Dots or Vectors. The Dots style displays waveforms with dots. The Vector style draws a straight line through the data points on the display. This is also known as Connect Waveform Dots. The Vector style gives an analog look to a digitized waveform and makes it possible to see steep edges on waveforms such as square waves.

If you use the Vector style the approximate unaliased oscilloscope bandwidth is:

Bandwidth = Effective Sample Rate / 10

In this configuration, a waveform can alias if its highest frequency component exceeds 1/10 the sample rate. On waveforms where there are only a few dots representing the acquired data points, such as when the record length is small, you may find it easier to have a sense of what the waveform looks like.

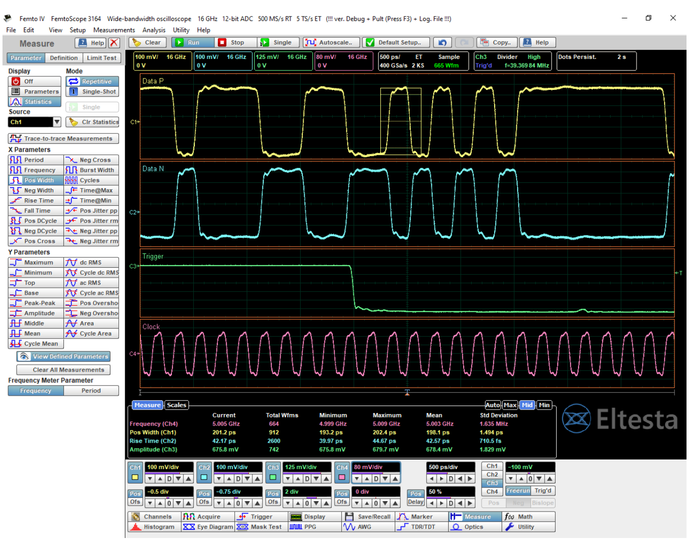


Figure 42. The *FemtoScope* 3164 works with four graticules. Channel 1 shows PRBS waveform, Channel 2 shows inverse PRBS waveform, Channel 3 shows pattern waveform, and Channel 4 shows 5-GHz clock.

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 (Figure 42). Moreover, any of the signals can be moved to any of the graticule

For phase measurements, XY display formats are used (see Figure 43). 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 phase differences between two signals, 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 (Figure 44).

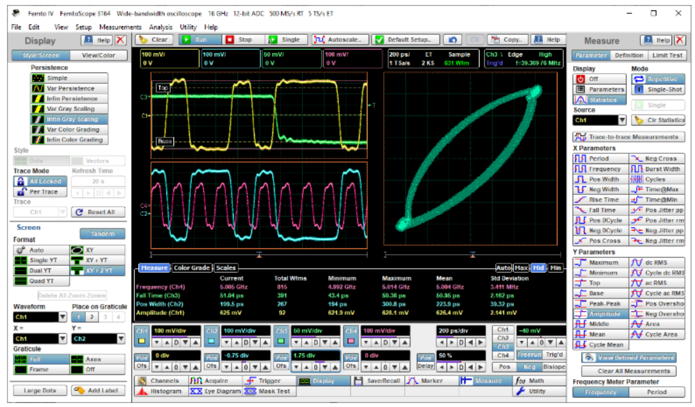


Figure 43. The XY and YT display format.

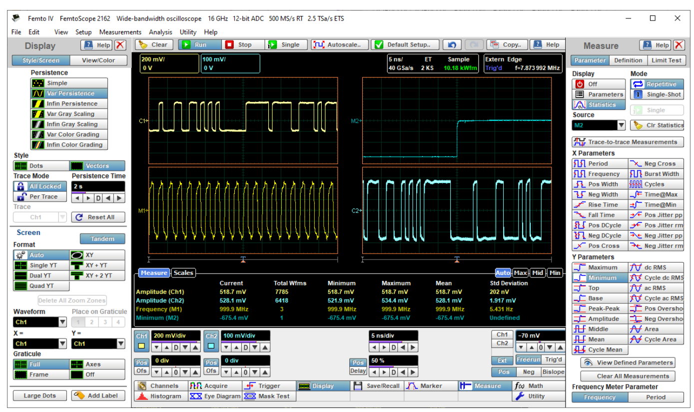


Figure 44. "Tandem" display format.

You to define the display colors and transparency of many display elements. For example, you can change the color of an input waveform channel for better visibility (Figure 45).

The color palette defines the five colors used in the color grade display (see chart below). The algorithm used in the *FemtoScope*-Series depends on the maximum number of hits for any pixel in the display. An example of the assignment of colors is shown in the table below. Maximum in the table represents the maximum number of hits in any bin, which for this algorithm must be at least 16.

A sample assignment of colors to hit density

Hit density	Default color	Color
50% to 100%	White	50% – 100%
25% to 50%	Yellow	25% – 50%
12.5% to 25%	Rose	12.5% – 25%
6.25% to 12.5%	Light Blue	6.25% – 12.5%

0% to 6.25%	Green	0% – 6.25%

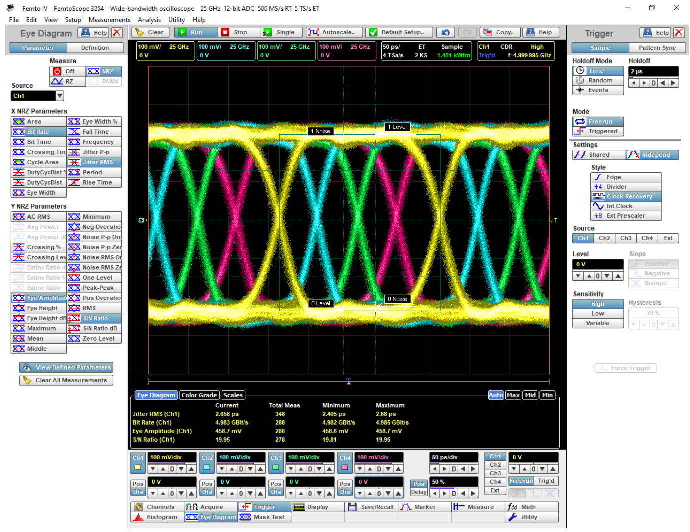


Figure 45. FemtoScope 3254 displays four eye diagrams having different colors.

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. Its allow you to quickly make detailed measurements on the waveform.

Marker measurements track waveforms or automatic measurement selections. Markers may manually or automatically be placed showing horizontal and Vertical readouts.

The coordinates of the marker are displayed based on vertical and horizontal scale, which makes marker measurements more accurate than quick 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.

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 (Figure 46).

Figure 46. The *FemtoScope* 1161 makes ratiometric measurements. 1-V pulse is used as a reference. Two Y-markers measure 1.27% peak-peak ringing on the top of pulse.

Automatic measurements

The *FemtoScope* oscilloscopes provide a wide range of automatic measurements (see example on Figure 47). Automatic measurements are the essential tool of an oscilloscope.

To make quick and efficient measurements, the *FemtoScopes* provide 53 types of powerful automatic measurements and can display up to 10 at a time. This gives you quick access to powerful functions. Measurements can be gated by auto select, main window, zoom window, or cursors, and include full statistics.

They are separated into four categories: amplitude, time, inter-channel and spectral measurements.

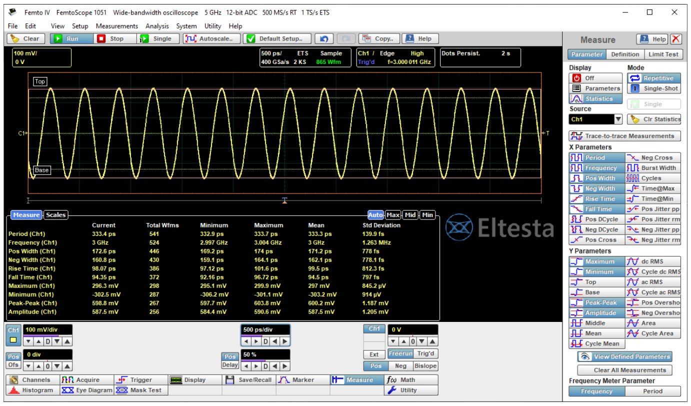


Figure 47. Up to ten individual measurements can be displayed on the screen simultaneously. The *FemtoScope* 1051 measures parameters of 3-GHz sinewave.

Each of the measurement can be performed on live signals, saved waveforms or math functions. Up to 10 measurements continuously updated with statistics (Figure 48). With statistical measurements, the oscilloscope measures the minimum, maximum, average and current values, as well as the standard deviation.

You can store several waveforms in the scope's non-volatile reference waveform memory locations, and then compare these reference waveforms with live waveforms and perform post - measurements of stored data.

	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 48. Snapshot tab with the results of ten measurements with full statistic

Amplitude measurements include 17 following parameters (Figure 49): 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, and Cycle Area.

18 timing measurements include 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, and Negative Jitter RMS.

Inter-channel measurements are those performed on two signals. These include delay (8 options), phase, and gain.

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

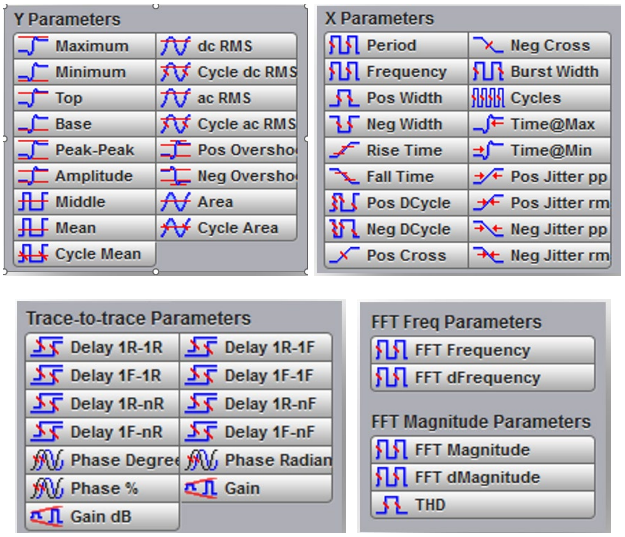


Figure 49. Four categories of measurement selection menu: amplitude, time, inter-channel and spectral measurements.

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 *FemtoScopes* used 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 (Figures 50 and 51).

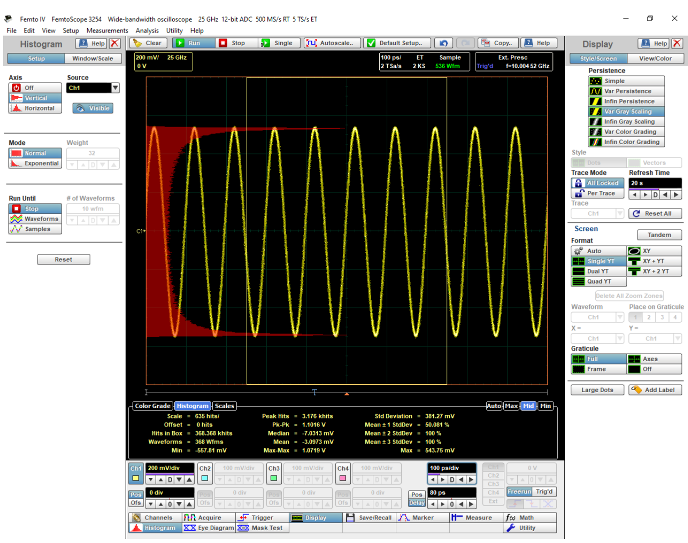


Figure 50: The *FemtoScope* 3254 measures vertical histogram of 10-GHz sinewave having 1.0719 V amplitude (Max-Max value).

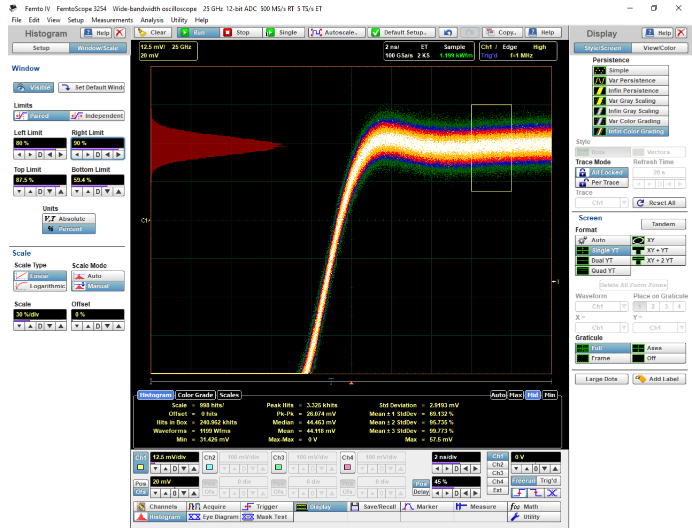


Figure 51. Vertical waveform histogram of the *FemtoScope* 3254 reveals Gaussian noise with standard deviation of 2.9193 mV.
Noise is measured by sizing the histogram window to a narrow portion of time and observing a vertical histogram that measures the noise on an edge.

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 (Figures 52, 53). 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.

Horizontal histograms, which are useful for evaluating signal jitter, sample the waveform within a specified region, sort the values into time bins and plot the accumulated bin values versus time.

Horizontal histogram places the histogram at the bottom of the graticule area, which allows for timing measurements. You can select the source you want to measure using the Source menu. Be aware that even if the display shows only the most recent acquisitions, the measurement database keeps track of all display coordinates hit while the measurement database is building.

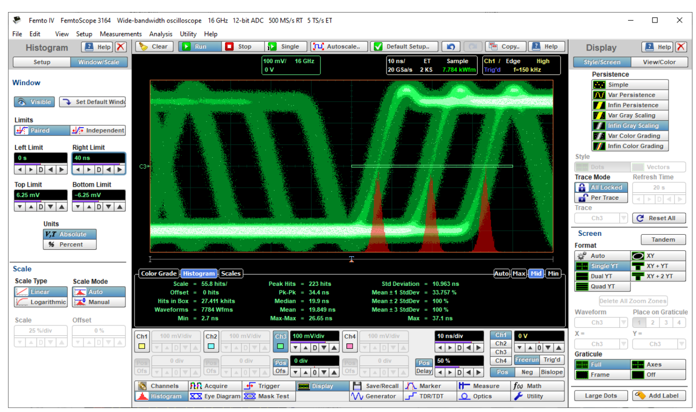


Figure 52. Grey scaling and histogram on a jittery clock edge.

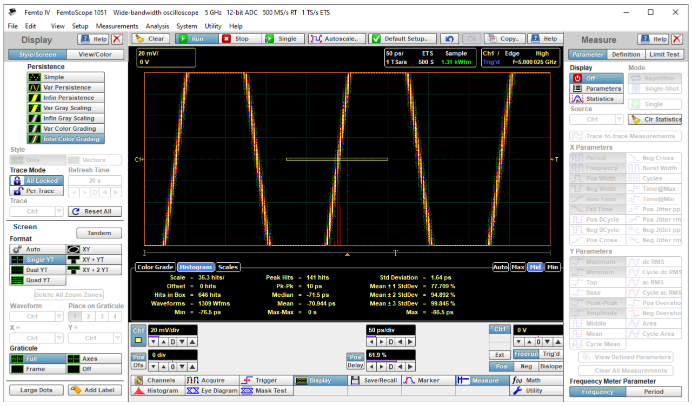


Figure 53. The *FemtoScope* 1051 measures rms jitter of 5-GHz sinewave by using horizontal histogram. Std Deviation value is 1.64 ps.

Eye Diagram

Eye diagram measurement is a serious choicy from a large selection of analysis applications performing by *FemtoScope* oscilloscopes.

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. ADSANTEC *FemtoScope* oscilloscopes provide eye diagram measurements to make general testing of communications designs and systems even easier.

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 1.5 or more, and for the fifth harmonic it is already more than 2.5. Following these relationships 16-GHz *FemtoScope* will acquire the third harmonic of the 10.66 Gb/s data pattern and the fifth harmonic of the 6.4 Gb/s data pattern. The relationships between oscilloscope bandwidth and possible pattern data rate are shown in table below.

The relationships between oscilloscope bandwidth and pattern data rate

Oscilloscope bandwidth	Maximum data rate to acquire the third harmonic	Maximum data rate to acquire the fifth harmonic
5 GHz	3.33 Gb/s	2 Gb/s
16 GHz	10.66 Gb/s	6.4 Gb/s
25 GHz	16.66 Gb/s	10 Gb/s

In general, eye diagrams are multilevel waveforms. The *FemtoScope* measures two-level eye diagrams, such as NRZ ("No return to zero") or RZ ("Return to zero"). It also measures four-level PAM4 eye-diagrams.

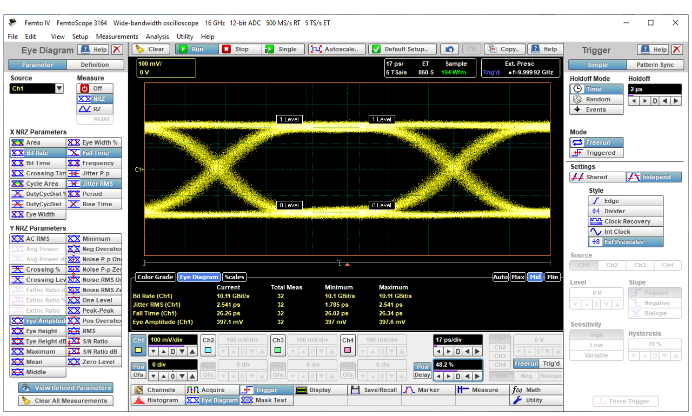


Figure 54. The *FemtoScope* 3164 measures 10-Gb/s eye diagram having 397 mV eye amplitude. Eye fall time is 26.34 ps max, and rms jitter is 1.765 ps min.

Eye-diagram measurements include such important types as eye height, eye width, eye jitter p-p or rms, crossing % (percentage), and duty-cycle distortion. Software quickly provides information and shows you any signal anomalies. Eye diagram might be the only way to visualize what the input signal looks like from your receiver's perspective. You can combine eye diagram analysis with histogram measurements to get further insight into your design.

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.

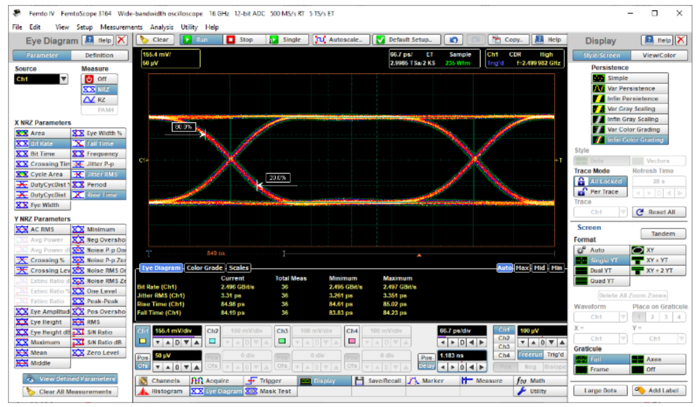


Figure 55. Disclosed eye diagram measurement of a clean 2,5-Gbps PRBS waveform. The histogram measured about 3.3 ps rms jitter.

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 *FemtoScopes* 2162/3164/3254, and 5 Gb/s for the *FemtoScopes* 2052/3054.

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* 3254, up to 11 Gb/s for the *FemtoScopes* 2162/3164, and 6 Gb/s for the *FemtoScopes* 2052/3054.

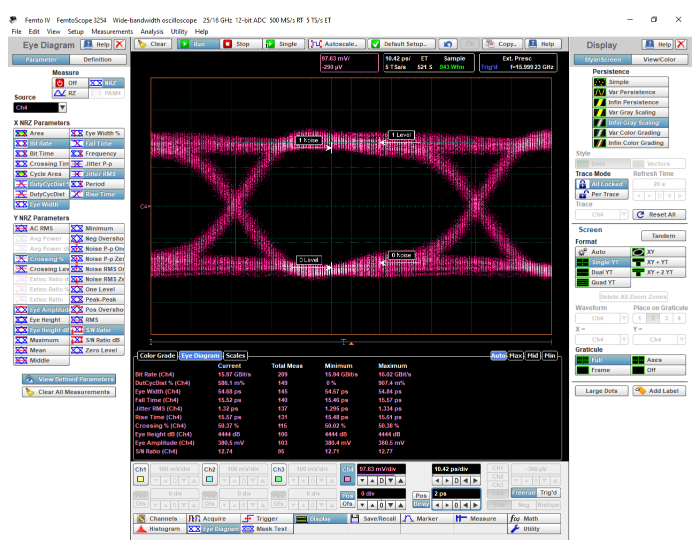


Figure 55. The *FemtoScope* 3254 tests ten parameters of 20-Gb/s eye diagram having 400-mV eye amplitude, 15.57 ps eye fall time and 1.334 ps rms jitter.

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. If, after autoscaling, the eye is fully opened 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.

PAM4 measurements

Pulse Amplitude Modulation 4-level (PAM4) is a multilevel signal modulation format used to transmit signal. Each signal level can represent 2 bits of logic information. PAM4 is a branch of the pulse amplitude modulation technology, which is a mainstream signal transmission technology following non-return-to-zero (NRZ)

Compare with 2-level NRZ waveforms PAM4 has some of the advantages and disadvantages. They are:

Used in up to 400 gigabit Ethernet.
Can pull twice the signal vs NRZ.
Operates on four levels vs two levels in NRZ
Has a throughput of 2 bit per Unit Interval (UI).
SNR is worse than NRZ at -9.54 dB.
Reflections are 3x worse.
More expensive equipment required.

With the *FemtoScopes* you can perform 48 different electrical and optical measurements on PAM4 waveforms (see Figure 56).

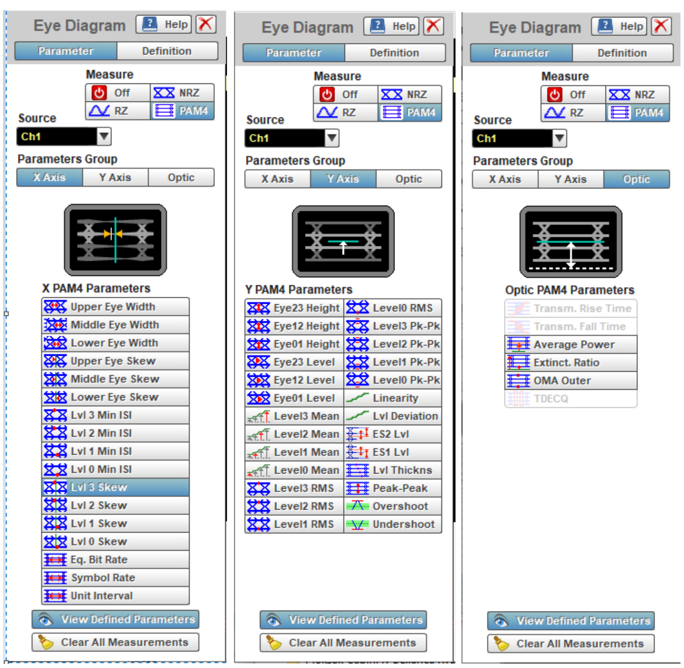


Figure 56. Three categories of PAM4 measurement selection menu: level (17 measurements), time (26 measurements), and optic (5 measurements).

Several examples of PAM4 measurements are described below.

PAM4 Levels RMS measure the RMS amplitude all four levels (0, 1, 2, 3) of a PAM4 signal. The PAM Levels measure all four levels of a PAM4 signal displayed as a single-valued waveform. The PAM Linearity measures the linearity RLM (Ratio Level Mismatch) of all four amplitude levels (0, 1, 2, 3) of a PAM4 signal. Linearity is a measure of the variance in amplitude separation (distribution) between the different PAM4 levels.

The PAM Level Skews measurement measures the skew (seconds or UI) of each level (0, 1, 2, 3) of a PAM4 eye diagram relative to the average center time of all levels. The PAM Eye Widths measurement measures the eye width (horizontal opening) for each of three eyes of a PAM4 signal.

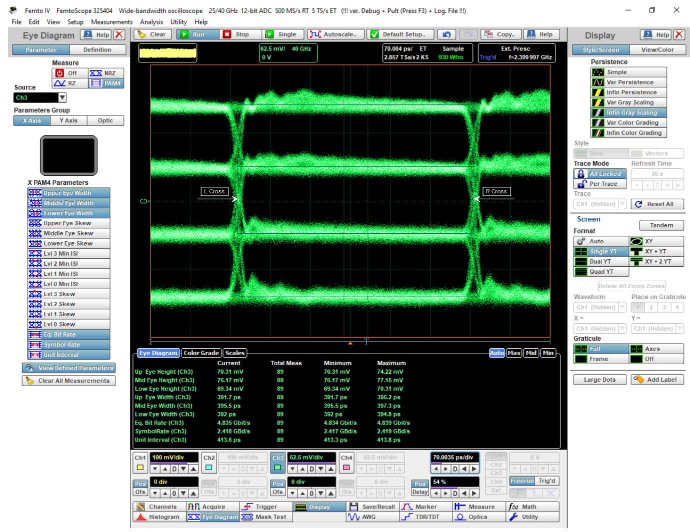


Figure 57. The *FemtoScope 3254* measures 9 parameters of 2.4-GBd PAM4 waveform. With unit interval 413.6 ps it has 4.836 Gbit/s equivalent bit rate.

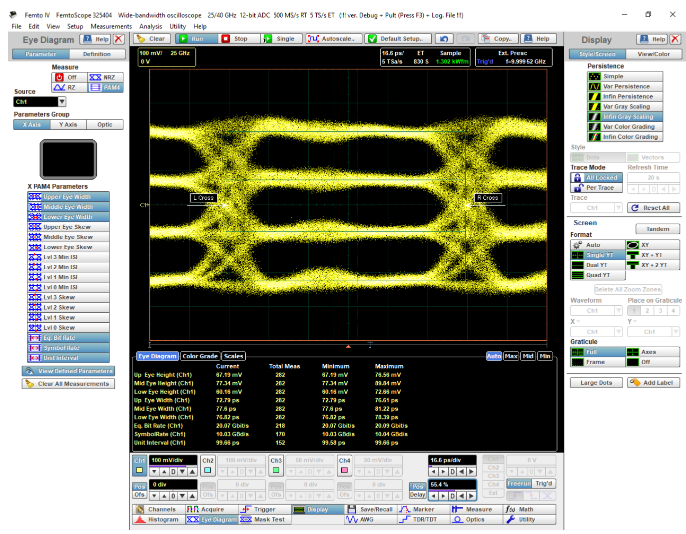


Figure 58. The *FemtoScope 3254* measures the same 9 parameters of 10-GBd PAM4 waveform. With unit interval 99.68 ps it has 20.07 Gbit/s equivalent bit rate.

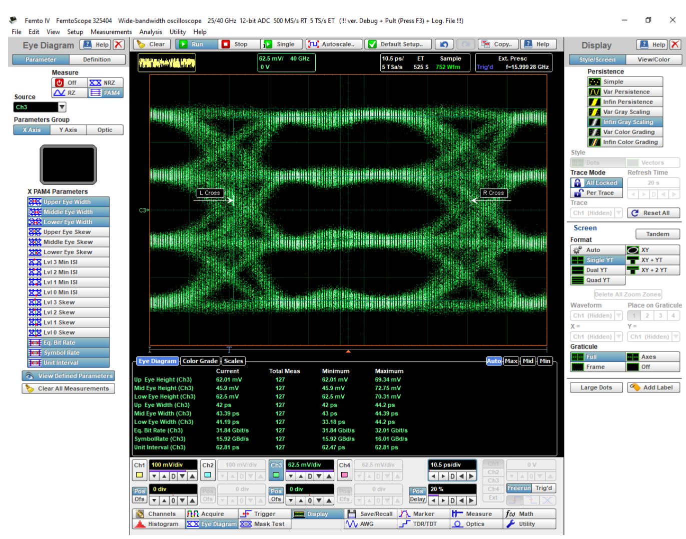


Figure 59. The *FemtoScope 3254* measures 9 parameters of 16-GBd PAM4 waveform. With unit interval 62.81 ps it has 31.84 Gbit/s equivalent bit rate.

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 (Figure 60).

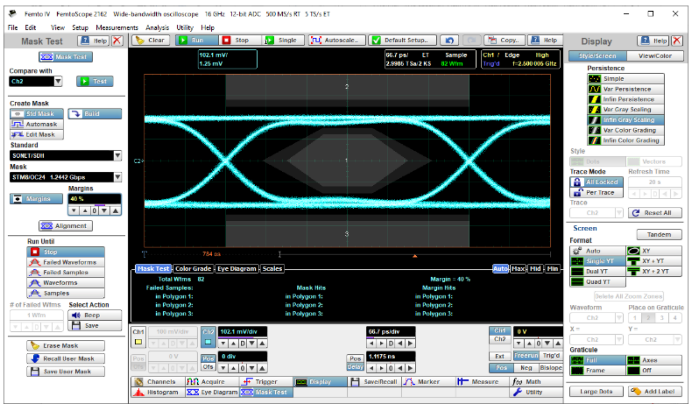


Figure 60. The *FemtoScope* 2162 makes 2.5 Gb/s SONET/SDH standard mask test.

Depending on bandwidth specifications the *FemtoScope* provides 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 61).

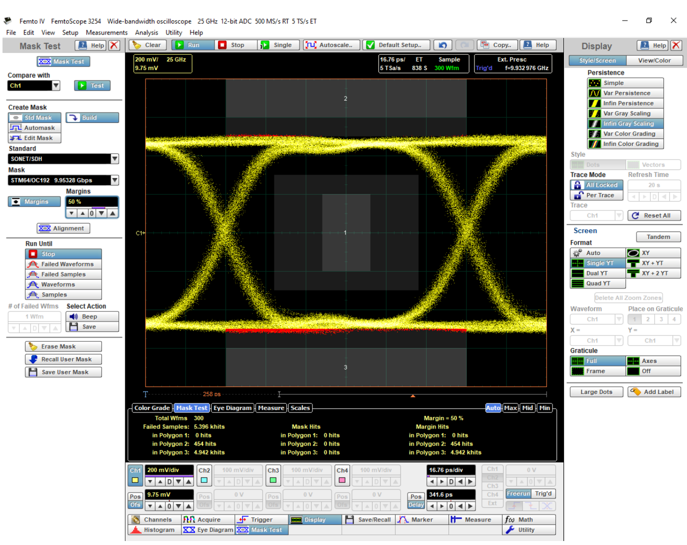


Figure 61. The *FemtoScope* 3254 performs 9.95 Gb/s SONET/SDH mask test.

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 62 shows an automatic mask constructed for a short 90-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 ±2 ps.

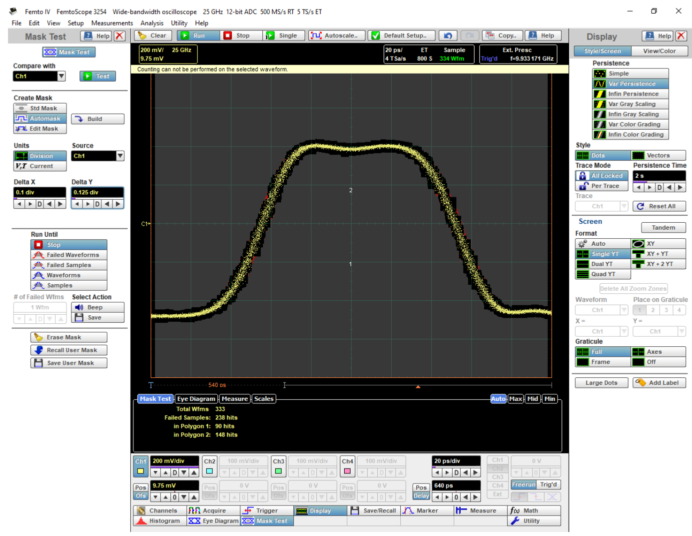


Figure 62. An example of 90-ps pulse automask performed by the *FemtoScope* 3254.

The last is arbitrary type of mask (Figure 63). 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.

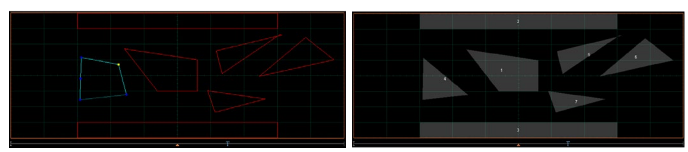


Figure 63. An example of arbitrary polygons building.

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, stored, 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. (Figure 64).

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. (Figure 65).

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

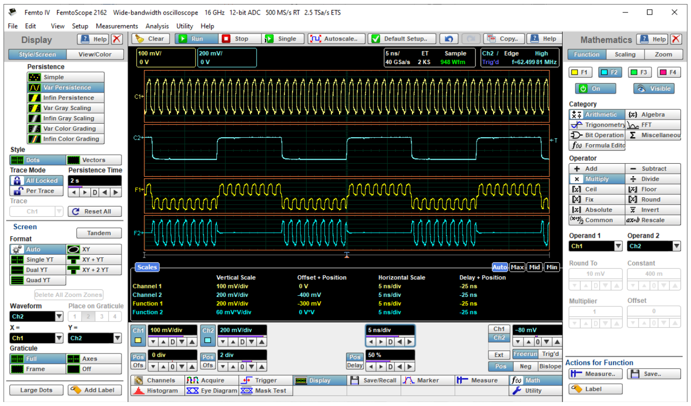


Figure 64. Example of arithmetic functions (from top to bottom): a) channel1, b) channel 2, c) a sum channel 1 + channel 2, d) multiplication channel 1 x channel 2.

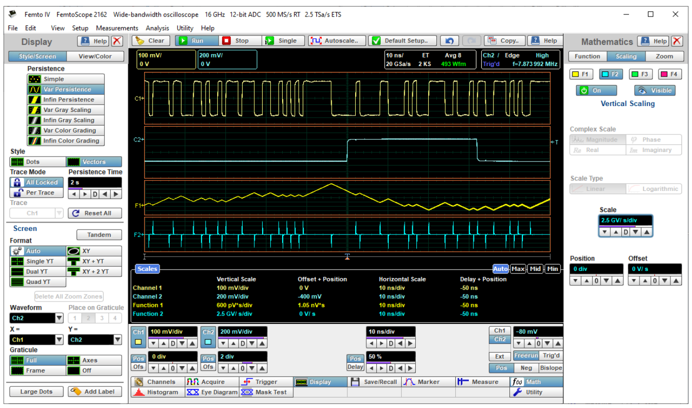


Figure 65. Example of algebraic functions (from top to bottom): a) channel1 (data pattern), b) channel 2 (clock), c) integral of channel 1 d) differential of channel 1

FFT includes FFT magnitude and phase, the real and imaginary parts, also the inverse FFT (Figure 66).

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.

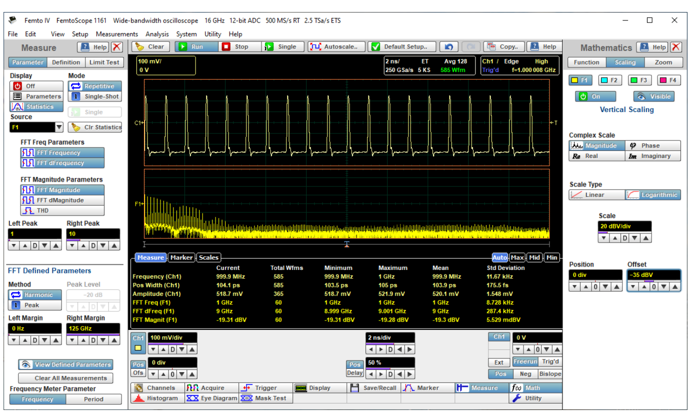


Figure 67. The *FemtoScope* 1161 makes FFT with 1 GHz signal having 100 ps pulse width. The first measured FFT harmonic is 1 GHz at -19.21 dBV magnitude

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 oscilloscope provides linear or Sin(x)/x interpolation functions. The Sin(x)/x interpolation function effectively restores the shape of the input signal.

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 Figure 67, 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.

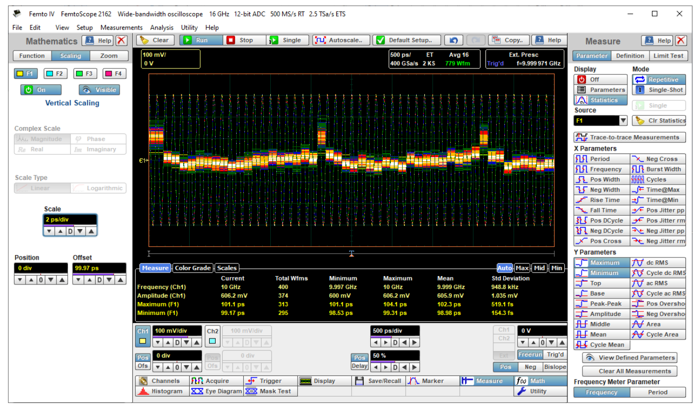


Figure 67. Trend of period measures nonlinearity of oscilloscope time base with 10-GHz sinewave. Maximum trend of period = 102.3 ps. Minimum trend of period = 98.98 ps. Peak-peak nonlinearity is within ±2.3 ps at 5 ns timing window.

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. Maximum counter frequency depends on maximum trigger frequency value and can be up to 18 GHz.

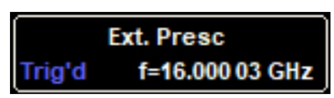


Figure 68. Frequency counter measurement results

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 also used both USB and LAN ports.

Figure 69. Rear panel of the *FemtoScope* 1000 with USB connector.

Figure 70. Rear panel of the *FemtoScope* 2000 with USB connector.

Figure 71. 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

Figure 72. Front panel of miniature 16-GHz *FemtoScope* 1161

Figure 73. The *FemtoScope* 2000 can be simply transported in hand. 16-GHz *FemtoScope* 1161

The *FemtoScope* 2000 Series USB oscilloscopes deliver the performance and features you expect in a big scope.

16 GHz oscilloscope bandwidth on two channels, with less than 2 ps rms jitter, 11.3 Gb/s clock recovery trigger are now available in portable enclosure having less than 790 g weight and 3.4 sq.dm small footprint.

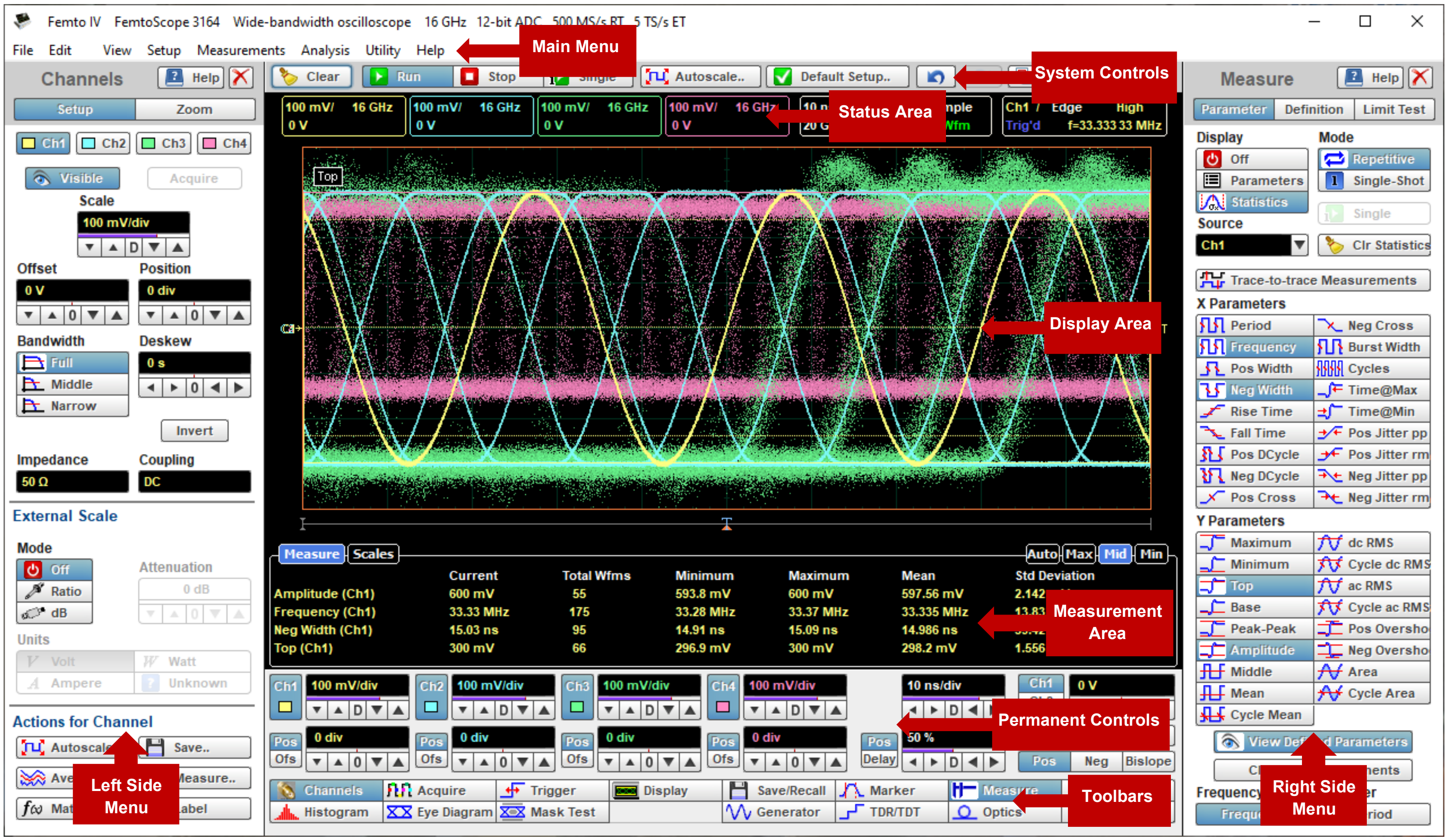
Standard accessories

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

- *FemtoScope* USB Wide-Bandwidth Oscilloscope. Specified from *FemtoScope* 1051, *FemtoScope* 1161, *FemtoScope* 2051, *FemtoScope* 2162, *FemtoScope* 3054, *FemtoScope* 3164, or *FemtoScope* 3254.
- *Femto IV* software (supplied on a USB stick and also available as a free download from www.ADSANTEC.com).
- *FemtoScope* 1000/2000/3000 Series User's Guide (supplied on a USB stick and also available as a free download from www.ADSANTEC.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.

The *FemtoScope* User Interface

7 oscilloscope models	5, 16 or 25 GHz bandwidth	1, 2 or 4 channel configuration	Up to 18 GHz trigger	1.2 ps rms intrinsic jitter	Up to ±1% of full scale DC gain accuracy	10 ps/div fastest time base scale	Up to 5 TSA/s equivalent time sampling rate	11.3 Gb/s clock recovery



Color graded display	Automatic measurements	Eye diagrams	Mask test	Histograms	Waveform mathematics	Trigger frequency counter	Spectrum analysis with FFT	Autoscale	USB or LAN connection	Less 15, 22 or 33 W power consumption	Less than 0.37, 0.79 or 1.52 kg

Specifications and Characteristics

							
Vertical	***FemtoScope* 1051**	***FemtoScope* 1161**	***FemtoScope* 2052**	***FemtoScope* 2162**	***FemtoScope* 3054**	***FemtoScope* 3164**	***FemtoScope* 3254**
Input channels	One channel		Two channels		Four channels		
	All channels are 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	DC to 5 GHz	DC to 16 GHz	DC to 5 GHz	DC to 16 GHz	DC to 25 GHz
Middle bandwidth, typical	N/A	N/A	N/A	N/A	DC to 500 MHz	DC to 500 MHz	N/A
Narrow bandwidth typical	DC to 500 MHz	DC to 500 MHz	DC to 500 MHz	DC to 500 MHz	DC to 100 MHz	DC to 100 MHz	DC to 18 GHz
Passband flatness (full bandwidth)	±1 dB to 3 GHz	±1 dB to 5 GHz	±1 dB to 3 GHz	±1 dB to 5 GHz	±1 dB to 3 GHz	±1 dB to 5 GHz	±1 dB to 4 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	≤ 21.9 ps	≤ 70 ps	≤ 21.9 ps	≤ 70 ps	≤ 21.9 ps	≤14 ps
20% to 80%	≤ 50 ps	≤ 15.6 ps	≤ 50 ps	≤ 15.6 ps	≤ 50 ps	≤ 15.6 ps	≤10 ps
Middle bandwidth							
10% to 90%	N/A	N/A	N/A	N/A	≤ 700 ps	≤ 700 ps	N/A
20% to 80%	N/A	N/A	N/A	N/A	≤ 500 ps	≤ 500 ps	N/A
Narrow bandwidth							
10% to 90%	≤ 700 ps	≤ 700 ps	≤ 700 ps	≤ 700 ps	≤ 3.5 ns	≤ 3.5 ns	≤19.5 ps
20% to 80%	≤ 500 ps	≤ 500 ps	≤ 500 ps	≤ 500 ps	≤ 2.5 ns	≤ 2.5 ns	≤13.9 ps
Step response, typ.							
Full bandwidth		N/A		N/A		N/A	N/A
Overshoot	< 8%		< 8%		< 8%		
Ringing	±6% to 3 ns, ±4%, 3-10 ns, ±3%, 10-100 ns ±2%, 100-400 ns ±1%, > 400 ns.		±6% to 3 ns, ±4%, 3-10 ns, ±3%, 10-100 ns ±2%, 100-400 ns ±1%, > 400 ns.		±6% to 3 ns, ±4%, 3-10 ns, ±3%, 10-100 ns ±2%, 0.1-0.4 us ±1%, >0.4 us.		
Middle bandwidth	N/A						
Overshoot					< 6%		
Ringing					±4% to 10 ns, ±3%, 10-100 ns ±2%, 100-400 ns, ±1%, >400 ns		
Narrow bandwidth							
Overshoot	< 6%				< 5%		
Ringing	±4% to 10 ns, ±3%, 10-100 ns, ±2%, 100-400 ns, ±1%, > 400 ns.				±5% to 20 ns, ±3%, 20-100 ns, ±2% 0.1- 0.4 us, ±1%, >0.4 us.		
RMS noise							
Full bandwidth *	1.8 mV, max. 1.6 mV, typ.	2.4 mV, max. 2.2 mV, typ.	1.8 mV, max. 1.6 mV, typ.	2.4 mV, max. 2.2 mV, typ.	1.8 mV, max. 1.6 mV, typ.	2.4 mV, max. 2.2 mV, typ.	3.1 mV, max. 2.9 mV, typ.
Middle bandwidth	N/A				0.8 mV, max. 0.65 mV, typ.	0.8 mV, max. 0.65 mV, typ.	N/A
Narrow bandwidth	0.8 mV, max. 0.65 mV, typ.				0.6 mV, max. 0.45 mV, typ.	0.6 mV, max. 0.45 mV, typ.	2.7 mV, max. 2.5 mV, typ.

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

Vertical (continued)	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Scale factors							
Sensitivity	10 mV/div to 250 mV/div						10 to 200 mV/div
Full scale	8 vertical divisions.						
Coarse adjustment	10-12.5-15-20-25-30-40-50-60-80-100-125-150-200-250 mV/div						10-12.5-15-20-25-30-40-50-60-80-100-125-150-200 mV/div
Fine adjustment	In 1% fine increments or better						
Manual or calculator	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		±2% of full scale, maximum. ±1.5% of full scale, typical.
Position range	±4 divisions from center screen						
DC offset range							
Coarse adjustment	From –1 V to +1 V						From –800 mV to +800 mV
Coarse increment	10 mV						
Fine increment	2 mV						
Manual or calculator	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.						
Reference	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		±2 mV ± 2% of offset setting, maximum. ±1 mV ± 1% of offset setting, typical.
Operating input voltage	±1 V						±800 mV
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 (isolation)							
DC to 1 GHz.	≥50 dB (316:1)						
>1 GHz to 3 GHz	≥40 dB (100:1)						
>3 GHz to ≤5 GHz	≥36 dB (63:1)						≥40 dB (100:1)
>5 GHz to ≤16 GHz		≥36 dB (63:1)		≥36 dB (63:1)		≥36 dB (63:1)	≥40 dB (100:1)
>16 GHz to ≤25GHz							≥36 dB (63:1)
Delay between channels	N/A	N/A	≤ 10 ps typical at full bandwidth, equivalent time				
ADC resolution	12 bits						
Hardware vertical resolution	0.5 mV / LSB without averaging						0.4 mV / LSB w/o average
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	Reflections for 70 ps rise time: 10% or less	Reflections for 50 ps rise time: 10% or less	Reflections for 70 ps rise time: 10% or less	Reflections for 50 ps rise time: 10% or less	Reflections for 20 ps rise time: 10% or less

Vertical (continued)	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Input coupling	**DC**						
Maximum safe input voltage	**±2 V (DC + peak AC)**						**±1.5 V (DC + peak AC)**
Input connector	**SMA female**						**2.92 mm (K) female, compatible with SMA**
Attenuation	**Attenuation factors may be entered to scale the oscilloscope for external attenuators connected to the channel inpu**						
Range	**0.0001:1 to 1 000 000:1**						
Units	**Ratio or dB**						
Scale	**Volt, Watt, Ampere, or Unknown.**						

Horizontal	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Time base	**Internal time base common to all input channels.**						
Time base range	**Internal time base common to all input channels.**						
Real time sampling	**Full horizontal scale is 10 divisions.**						
Random equivalent time sampling	**50 ps/div to 5 µs/div.**	**10 ps/div to 5 µs/div.**	**50 ps/div to 5 µs/div.**	**10 ps/div to 5 µs/div.**	**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**
Overall frequency stability over operating temperature range *	**± 2 ppm**		**± 15 ppm**				**± 2 ppm**
Aging	**± 3 ppm**		**± 7 ppm**				**± 3 ppm**
Time base resolution	**1.0 ps**	**0.2 ps**	**1.0 ps**	**0.2 ps**	**1.0 ps**	**0.2 ps**	
	All at random equivalent time sampling						
Delta time measurement accuracy *	**± (2 ppm * reading + 0.1% * screen width + 5 ps).**		**± (15 ppm * reading + 0.1% * screen width + 5 ps).**		**± (15 ppm * reading + 0.1% * screen width + 2 ps)**		**± (0.5 ppm * reading + 0.1% x 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	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
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.						
Max sampling rate							
Real time sampling	500 MS/s per channel simultaneously						
Equivalent time sampling	Up to 1 TS/s or 1 ps trigger placement resolution	Up to 5 TS/s or 0.2 ps trigger placement resolution	Up to 1 TS/s or 1 ps trigger placement resolution	Up to 5 TS/s or 0.2 ps trigger placement resolution	Up to 1 TS/s or 1 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 (continued)	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
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	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Trigger sources	Internal Direct or Divided, External Direct or Divided.		Internal Direct, Divided or Clock Recovery. External Direct, Divided or Clock Recovery.	Internal Direct, Divided or Clock Recovery. External Direct, Divided, Clock Recovery or Prescaled	Internal (Ch1-Ch4) Direct, Divided or Clock Recovery.	Internal (Ch1-Ch4) Direct, Divided or Clock Recovery. External Prescaled	Internal (Ch1-Ch4) Direct, Divided or Clock Recovery. External Direct, Divided, Clock Recovery or 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)	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
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	*FemtoScope* 1051	*FemtoScop e* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Trigger style							
Edge (Direct)							
Divided							
Clock recovery	N/A		6.5 Mb/s to 5 Gb/s	6.5 Mb/s to 11.3 Gb/s	6.5 Mb/s to 5 Gb/s	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							
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 2.5 GHz. 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 2.5 GHz. 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 100 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 11.3 Gb/s with optimum triggering level						
Edge and Divided	2 ps + 0.1 ppm of delay, max. 1.5 ps + 0.1 ppm of delay, typ.		2 ps + 0.1 ppm of delay, max. 1.5 ps + 0.1 ppm of delay, typ.		1.5 ps + 0.1 ppm of delay, maximum. 1.2 ps + 0.1 ppm of delay, typical.		
Clock recovery	N/A		2.5 ps + 1.0% of unit interval + 0.1 ppm of delay, maximum. 2 ps + 1.0% of unit interval + 0.1 ppm of delay, typical.				
External trigger Input impedance *	50 Ω ± 1.5 Ω maximum. 50 Ω ± 1 Ω, typical		50 Ω ± 1.5 Ω maximum. 50 Ω ± 1 Ω, typical		N/A		50 Ω ± 3 Ω maximum. 50 Ω ± 1 Ω, typical
External trigger maximum safe input voltage	±3 V (DC+peak AC)		±3 V (DC+peak AC)		N/A		±3 V (DC+peak AC)
External trigger input coupling	DC		DC		N/A		DC
External trigger input connector	SMA female		SMA female		N/A		SMA female

External Prescaled Trigger	*FemtoScope* 1051	*FemtoScope* 1161	*FemtoScope* 2052	*FemtoScope* 2162	*FemtoScope* 3054	*FemtoScope* 3164	*FemtoScope* 3254
Prescaled trigger input coupling	N/A			50 Ω, AC coupled, fixed level zero volts	N/A	50 Ω, AC coupled, fixed level zero volts	
Prescaled trigger bandwidth and sensitivity *	N/A			200 mV p-p, 1 to 16 GHz (sine wave input)	N/A	200 mV p-p, 1 to 16 GHz (sine wave input)	200 mV p-p, 1 to 18 GHz (sine wave input)
Prescaled RMS trigger jitter *	N/A			1.5 ps max, 1.2 ps typ. For trigger input slope >5 V/ns.	N/A	1.5 ps maximum, 1.2 ps typical. For trigger input slope > 5 V/ns	
Prescaler ratio	N/A			Divided by 8, fixed	N/A	Divided by 8, fixed	
Prescaled trigger maximum safe input voltage	N/A			±3 V (DC + peak AC)	N/A	±3 V (DC + peak AC)	
Prescaled trigger input connector	N/A			SMA female	N/A	SMA female	

Display	*FemtoScope* 1000 / 2000 / 3000
Persistence	
Simple	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.
Color	You may choose a default color selection, or select your own color set. Different colors are used for display-ing 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	*FemtoScope* 1000 / 2000 / 3000
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 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	*FemtoScope* 1000 / 2000 / 3000
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	*FemtoScope* 1000 / 2000 / 3000
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.

Frequency Counter	*FemtoScope* 1051 / 1161 / 2052 / 3054	*FemtoScope* 2162 / 3164 / 3254
Counter	**Built-in frequency counter**	
Source	**Internal or External**	**Internal, External or External Prescaled.**
Resolution	**7 digits**	
Maximum frequency, guaranteed	**6 GHz**	**Internal or External Direct: 6 GHz.** **External Prescaled (*FemtoScope* 2162/3164): 16 GHz.** **External Prescaled (*FemtoScope* 3254): 18 GHz.**
Measurement	**Frequency, period**	
Time reference	**500 MHz oscillator. Internal 250 MHz reference clock for the *FemtoScope* 3254**	

Mathematics	*FemtoScope* 1000 / 2000 / 3000
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 Real, 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	*FemtoScope* 1000 / 2000 / 3000
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	*FemtoScope* 1000 / 2000 / 3000
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	*FemtoScope* 1000 / 2000 / 3000
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)**
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), 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),**
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)**

Mask Test (continued)	*FemtoScope* 1000 / 2000 / 3000
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), 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), R2.0 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	Total number of waveforms examined, number of failed samples, number of hits within each polygon boundary

System	*FemtoScope* 1000 / 2000 / 3000
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	LAN

Calibrator Output	*FemtoScope* 3054 and *FemtoScope* 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	*FemtoScope* 1000 / 3000
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	*FemtoScope* 2052 / 3054	*FemtoScope* 2162 / 3164 / 3254
Data Rate	6.5 Mb/s to 5 Gb/s	6.5 Mb/s to 11.3 Gb/s
Eye amplitude	250 mV p-p typical	
Eye rise/fall time	20%–80%: 70 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	
Output coupling	AC-coupled	
Output connections	SMA female	

Recovered Clock Output	*FemtoScope* 2052 / 3054	*FemtoScope* 2162 / 3164 / 3254
Output frequency	Half rate clock output, 3.25 MHz to 2.5 GHz	Half 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	

General	*FemtoScope* 1000	*FemtoScope* 2000	*FemtoScope* 3000
Power requirements			
Power supply voltage	+12 V ± 5%		
Power supply current	1.3 A max	1.8 A max	2.8 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			
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		

ADSANTEC

www.ADSANTEC.com

ADSANTEC, 2025, September 6, 2025
FemtoScope 1000, 2000 & 3000 Specifications v1.6.

2790 Skypark Dr., STE. 112, Torrance, CA 90505, USA
Phone: 1-310-530-9400
e-mail: sales@ADSANTEC.com