



# **PicoScope 9000 Series PC Sampling Oscilloscopes**

User's Guide



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# 1 Welcome

Thank you for buying a Pico Technology product!

The PicoScope 9000 Series of PC Sampling Oscilloscopes from Pico Technology is a range of wide-bandwidth compact units designed to replace traditional bench-top sampling oscilloscopes costing many times the price.



**PicoScope 9201**



**PicoScope 9211**

Here are some of the benefits provided by your new PicoScope 9000 Series PC Sampling Oscilloscope:

- **Portability:** Take the unit with you and plug it into any Windows PC.
- **Performance:** Electrical bandwidth 12 GHz or 8 GHz, 10 ps/div or faster time base with 5 TS/s maximum equivalent sampling rate (200 fs shortest sampling interval), up to 10 GHz trigger and fast USB 2.0 interface.
- **Powerful built-in measurement capabilities:** High-resolution cursors and automatic Pulse, NRZ- and RZ-eye pattern measurements with statistics, histograms, automated mask test with predefined standard and custom masks, waveform processing including FFT.
- **Applications:** Telecom Service and Manufacturing, Digital System Design, Semiconductor Characterization and Testing, High-Speed digital (pulse) measurements, TDR characterization of circuit boards, IC packages and cables.
- **Flexibility:** Use it as a sampling oscilloscope, spectrum analyzer, communications signal analyzer or time domain reflectometer.
- **Long-term support:** Software upgrades are available to download from our [website](#). You can also call our technical specialists for support. You can continue to use both of these services free of charge for the lifetime of the product.
- **Value for money:** You don't have to pay twice for all the features that you already have in your PC, as the PicoScope 9000 Series sampling scope unit contains the special hardware you need and nothing more.
- **Convenience:** The software makes full use of the large display, storage, user interface and networking built in to your PC.

## 2 Introduction

### 2.1 Overview

The **PicoScope 9000 Series** PC Sampling Oscilloscopes are high-bandwidth sampling oscilloscopes for use with personal computers. They are fully USB 2.0-capable and backwards-compatible with USB 1.1. You also can communicate with the PicoScope 9211 over the scope's built-in LAN interface.

With the PicoScope 9000 software, the PicoScope 9000 Series scopes can be used as a PC Sampling Oscilloscopes and PC Spectrum Analyzers.

For basic instructions on installing and using your oscilloscope, please refer to the printed **Quick Start Guide** supplied with the instrument.

### 2.2 Minimum PC requirements

For the PicoScope 9000 Series PC Sampling Oscilloscope to operate correctly, you must connect it to a computer with the minimum requirements to run Windows or the following (whichever is the higher specification):

<b>Processor</b>	Pentium-class processor or equivalent
<b>Memory</b>	256 MB
<b>Disk space</b>	Software occupies about 30 MB
<b>Operating system</b>	Microsoft Windows XP SP2 or Vista
<b>Ports</b>	USB 1.1 compliant port minimum. USB 2.0 compliant port recommended.

## 2.3 Safety information

We strongly recommend that you read the general safety information below before using your oscilloscope for the first time. If you use the oscilloscope in a manner contrary to these instructions, safety protection built in to the equipment may cease to function. This could cause damage to your computer or other equipment, or lead to injury to yourself and others.

### Maximum input range

The PicoScope 9000 PC Sampling Oscilloscopes are designed to measure voltages in the range stated in the [Specifications](#) table. The oscilloscope can withstand the maximum voltage range stated in the [Specifications](#) table, and operation with voltages exceeding this range may cause physical damage.

### Mains voltages

The PicoScope 9000 Series PC Sampling Oscilloscopes are designed for performing measurements on circuits that are not directly connected to the mains (line power).

Any attempt to connect the oscilloscope to mains (line) voltages will cause irreparable damage to the instrument, possible damage to other equipment, and a likelihood of personal injury or death.



**The PicoScope 9000 Series PC Sampling Oscilloscopes must not be directly connected to the mains (line power).**

**Failure to heed this warning may lead to injury or death.**

### Safety grounding

The PicoScope 9000 Series PC Sampling Oscilloscopes connect directly to the ground of your computer through the USB cable provided. This connection is intended only to minimise interference, and therefore you **must not** rely on it as a protective safety ground.

Do not connect the grounded connectors on the front panel to any source other than ground. If in doubt, use a meter to check that there is no significant AC or DC voltage between the oscilloscope's ground socket and point to which you intend to connect it. Failure to check may cause damage to your computer, or injury to yourself and others.

### Repairs

The oscilloscope contains no user-serviceable parts. Repair or calibration of the oscilloscope requires specialised test equipment and must only be performed by Pico Technology.

### Cooling fan

The unit contains a low-noise cooling fan that expels air through the holes in the back of the unit (shown in the Connections section). Do not block these holes, as this might cause the unit to overheat. Do not insert anything in the holes, as this could damage the unit or cause injury.

### Cleaning and decontamination

- Remove all connections from the unit
- Clean the external surfaces of the oscilloscope with a soft damp cloth. Do not use chemical cleaners.
- Make sure that the instrument is completely dry before using again.

## 2.4 Safety symbols

The following symbols appear on the front panel of the PicoScope 9000 Series PC Sampling Oscilloscope.

### Symbol 1: Caution: risk of electric shock



This symbol indicates that a safety hazard exists on the indicated connections if you do not take correct precautions. Ensure that you read in detail all safety documentation associated with the product before using it.

### Symbol 2: Equipotentiality



This symbol indicates that the indicated connectors are all at the same potential (i.e. are shorted together). You must therefore take necessary precautions to avoid applying a potential across the indicated terminals as this may result in a large current, causing damage to the product and connected equipment.

## 2.5 FCC notice

This equipment has been tested and found to comply with the limits for a **Class A digital device**, pursuant to **Part 15 of the FCC Rules**. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his or her own expense.

For safety and maintenance information see the [safety warning](#)<sup>4</sup>.

## 2.6 CE notice

The PicoScope 9000 Series PC Sampling Oscilloscopes meet the intent of the EMC directive **89/336/EEC** and are designed to the **EN61326-1 (1997) Class B Emissions and Immunity** standard.

The oscilloscopes also meet the intent of the **Low Voltage Directive** and are designed to the **BS EN 61010-1:2001 / IEC 61010-1:2001** (safety requirements for electrical equipment for measurement, control, and laboratory use) standard.

## 2.7 Legal information

The material contained in this release is licensed, not sold. Pico Technology grants a licence to the person who installs this software, subject to the conditions listed below.

### **Access**

The licensee agrees to allow access to this software only to persons who have been informed of these conditions and agree to abide by them.

### **Usage**

The software in this release is for use only with Pico products or with data collected using Pico products.

### **Copyright**

Pico Technology claims the copyright of, and retains the rights to, all material (software, documents etc) contained in this release. You may copy and distribute the entire release in its original state, but must not copy individual items within the release other than for backup purposes.

### **Liability**

Pico Technology and its agents shall not be liable for any loss, damage or injury, howsoever caused, related to the use of Pico Technology equipment or software, unless excluded by statute.

### **Fitness for purpose**

As no two applications are the same, Pico Technology cannot guarantee that its equipment or software is suitable for a given application. It is your responsibility, therefore, to ensure that the product is suitable for your application.

### **Mission-critical applications**

This software is intended for use on a computer that may be running other software products. For this reason, one of the conditions of the licence is that it excludes use in mission-critical applications, for example life support systems.

### **Viruses**

This software was continuously monitored for viruses during production, but you are responsible for virus-checking the software once it is installed.

### **Support**

If you are dissatisfied with the performance of this software, please contact our technical support staff, who will try to fix the problem within a reasonable time. If you are still dissatisfied, please return the product and software to your supplier within 28 days of purchase for a full refund.

### **Upgrades**

We provide upgrades, free of charge, from our web site at [www.picotech.com](http://www.picotech.com). We reserve the right to charge for updates or replacements sent out on physical media.

### **Trademarks**

*Windows* is a trademark or registered trademark of Microsoft Corporation. *Pico Technology* and *PicoScope* are internationally registered trademarks of Pico Technology.

## 2.8 Contact details

You can obtain technical assistance from Pico Technology at the following address:

**Address:** Pico Technology  
James House  
Colmworth Business Park  
Eaton Socon  
St. Neots  
PE19 8YP  
United Kingdom

Phone: +44 (0) 1480 396 395

Fax: +44 (0) 1480 396 296

**Email:**  
Technical Support: [support@picotech.com](mailto:support@picotech.com)  
Sales: [sales@picotech.com](mailto:sales@picotech.com)

**Web site:** [www.picotech.com](http://www.picotech.com)

## 3 Product Information

### 3.1 What do I get?

Your PicoScope 9000 Series PC Oscilloscope kit contains the following items:

Order No.	Quantity	Description
-	1	PicoScope 9201 PC Sampling Oscilloscope
-	1	PicoScope 9211 PC Sampling Oscilloscope
-	2	SMA connector saver (attached to oscilloscope)
DI053	1	PicoScope 9000 software CD
DO134	1	PicoScope PC Sampling Oscilloscopes Quick Start Guide
PS007	1	Universal power adaptor
MI106	1	USB cable
MI144	1	Carry case
MI193	1	UK mains lead (EU customers only)
MI194	1	EU mains lead (EU customers only)
MI195	1	US power cord (North American customers only)
MI197	4	Set of SMA connector dust caps (PicoScope 9201)
MI197	5	Set of SMA connector dust caps (PicoScope 9211)

Some product packs may contain additional items.

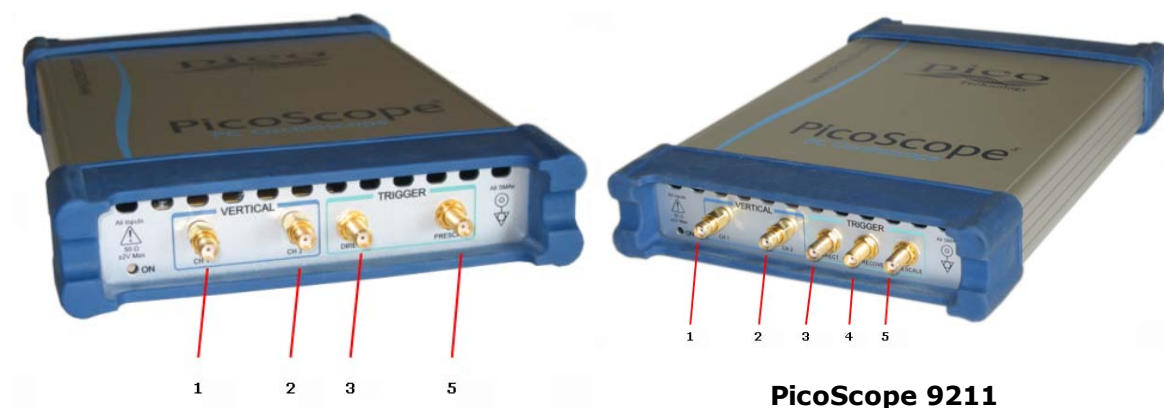
### 3.2 Connections

#### Standard oscilloscope connectors

The PicoScope 9000 Series PC Sampling Oscilloscopes have SMA oscilloscope connectors. The inputs have an impedance of 50  $\Omega$ , so they are compatible with low-impedance oscilloscope probes having different attenuations. If your probe has a BNC connector, use an SMA (m) - BNC (f) adaptor.

#### Connector diagrams

##### Front Panel

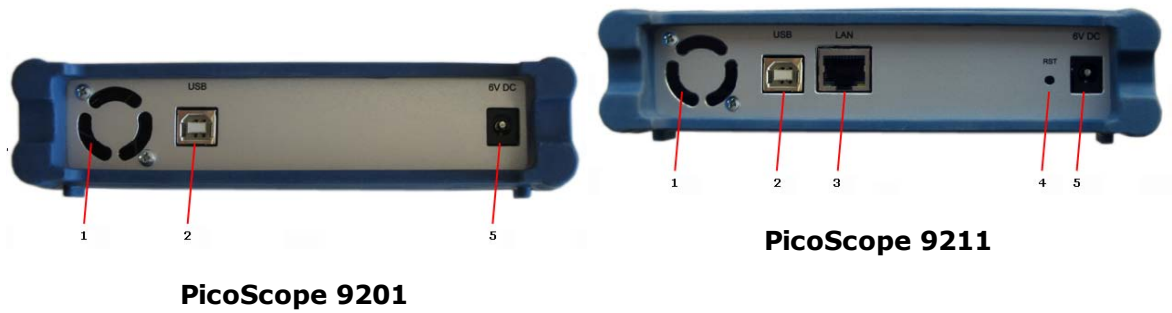


**PicoScope 9201**

**PicoScope 9211**

- 1. Input Channel 1**
- 2. Input Channel 2**
- 3. External Clock Recovery Trigger Input (PicoScope 9211 only)**
- 4. External Direct Trigger Input**
- 5. External Prescaled Trigger Input**

### Rear Panel



- 1. Cooling holes.** There is a low-noise fan inside the unit that blows air through these holes. Do not block the cooling holes or insert any objects through them, as this could damage the unit or cause injury.
- 2. USB 2.0 port**
- 3. LAN port (PicoScope 9211 only)**
- 4. LAN Reset Switch (PicoScope 9211 only)**
- 5. Power socket:** for use with the AC adaptor supplied with the unit



## 4 Specifications & Characteristics

The distinction between specifications, characteristics, typical performance, and nominal values is as follows.

**Specifications** describe guaranteed performance over the temperature range +15°C to + 25°C (unless otherwise noted) from the firmware calibration temperature. All specifications apply after the instrument's temperature has been stabilized after 1 hour of continuous operation. Unless otherwise noted, corrected limits are given when specifications are achieved using software processing.

Many performance parameters are enhanced through frequent, simple calibrations.

All specifications are subject to change without notice. Specifications are valid after a 1 hour warm-up period, and  $\pm 5^\circ\text{C}$  from the firmware calibration temperature.

**Characteristics** provide useful, but not guaranteed, information about the functions and performance of the instrument.

**Typical Performance**, where listed, is not guaranteed, but indicates the performance that most units will exhibit.

**Nominal Value** indicates the expected, but not guaranteed, value of the parameter.

**Factory Calibration Cycle.** For optimum performance, the instrument should have a complete verification of specifications once every 12 months.

### 4.1 Channels (Vertical)

#### Number of Channels

2 (simultaneous acquisition)

#### Bandwidth, 3dB Flatness

Full

*DC to 12 GHz*

Narrow

*DC to 8 GHz*

#### Rise Time, 10% to 90% calculated from $T_r = 0.35/BW$

Full Bandwidth

= 29.2 ps

Narrow Bandwidth

= 43.7 ps

#### RMS Noise, maximum

Full Bandwidth

< 2.5 mV

Narrow Bandwidth

< 2 mV

**Note:** Averaging reduces noise, until a system limitation of approximately 120  $\mu\text{V}$  RMS is reached.

#### Scale Factors (Sensitivity)

2 mV/div to 500 mV/div (full scale is 8 divisions)  
Adjustable in a 1-2-5-10 sequence.  
Also adjustable in 0.5% fine increments.

#### DC Difference Voltage Accuracy

$\pm 2\%$  of full vertical scale  $\pm 2$  mV

#### DC Offset Range

Adjustable from -1 V to 1 V in 25 mV increments (coarse). Also adjustable in fine increments of 1 mV.

<b>ADC</b>	16 bits
<b>Vertical Resolution</b>	125 $\mu$ V/LSB without averaging. Up to 16 bits with averaging.
<b>Maximum operating input voltage</b>	With Digital Feedback: 1 V p-p at $\pm 1$ V range. Without Digital Feedback: $\pm 300$ mV relative to channel offset.
<b>Maximum Safe Input Voltage</b>	16 dBm, or $\pm 2$ V (dc + peak ac)
<b>Nominal Input Impedance</b>	$(50 \pm 1) \Omega$
<b>Input connectors</b>	SMA (F)
<b>Deskew (The difference in delay between channels)</b>	Can be nulled out with 1-ps resolution to compensate for differences in input cables or probe length. Up to 100 ns of skew can be nulled out.
<b>Attenuation</b>	Attenuation factors may be entered to scale the oscilloscope for external attenuators connected to the channel inputs.
Range	0.00001:1 to 1,000,000:1
Units	Ratio or dB
Scale	Volt, Watt, Ampere, or Unknown
<b>Channel-to-channel isolation</b>	> 40 dB at rated bandwidth

## 4.2 Timebase (Horizontal)

<b>Timebases</b>	Main, Intensified, Delayed, or Dual Delayed
<b>Scale Factors</b>	Full scale is 10 divisions
Main Timebase	10 ps/div to 50 ms/div. Adjustable in a 1-2-5-10 sequence. Also adjustable in 0.1% fine increment.
Delayed Timebases	10 ps/div to current Main Timebase setting. Adjustable in a 1-2-5-10 sequence. Also adjustable in 0.1% fine increments.
<b>Delta Time Interval Accuracy</b>	$\pm 0.4\%$ of of Delta Time Interval $\pm 15$ ps $\pm 100$ ppm of Delay setting at a temperature within $\pm 3^\circ$ C of horizontal calibration temperature
<b>Typical Timing Accuracy</b>	The time base uses a series of near 4-ns blocks. Time base linearity and small discontinuities across these blocks contribute to the 15-ps accuracy specification.
<b>Variable Delay (Time offset relative to trigger)</b>	Up to 1000 screen widths of Delayed Timebase or 19.98 ms, whichever is smaller
<b>Minimum Delay (Minimum time offset relative to trigger)</b>	<40 ns
<b>Display Units</b>	Time or Bit Period
<b>Time Interval Resolution</b>	= (screen width) / (record length) or 200 fs, whichever is larger.

**Note:** The time interval resolution is the smallest time you can resolve between two points.

## 4.3 Trigger

### Trigger Sources

External Direct Trigger, External Prescaled Trigger, Internal Clock trigger (internally connected to direct trigger), Clock Recovery Trigger (PicoScope 9211 only).

### Trigger Modes

Triggered: causes the scope to trigger synchronously with the trigger input signal.  
Freerun: causes the scope to generate its own triggers.

### Trigger Holdoff

Adjustable from 5  $\mu$ s to 1 s in a 1-2-5-10 sequence, or in 8 ns increments.

### Internal Clock Repetition Rate

10  $\mu$ s to 2 ms in a 1-2-5-10 sequence, or in 125 ns increments.

## 4.4 Direct Trigger

### Direct Trigger Bandwidth and Sensitivity

100 mV p-p DC to 100 MHz. Increasing linearly from 100 mV p-p at 100 MHz to 400 mV p-p at 1 GHz.

### RMS Direct Trigger Jitter, maximum

Pulse Width: 500 ps @ 400 mV p-p  
3.5 ps + 20 ppm of delay setting

### Trigger Slope

**Note:** Measured at 1 GHz with the triggering level adjusted for optimum trigger.

Positive: triggers on rising edge.  
Negative: triggers on falling edge.

### Direct Trigger Level Range

-1 V to 1 V

### Direct Trigger Level Resolution

1 mV

### Direct Trigger Level Accuracy

$\pm(50 \text{ mV} + |0.1 \text{ of trigger level}|)$

### Direct Trigger Hysteresis

Normal: the trigger hysteresis is set so the instrument meets the trigger sensitivity specification.

High Sensitivity: hysteresis is turned off to allow a best sensitivity to high-frequency signals. This mode should not be used for noisy lower frequency signals that may mistrigger without hysteresis.

### Maximum Safe Direct Trigger Input Voltage

$\pm 2 \text{ V}$  (DC+peak AC)

### Direct Trigger Nominal Input Impedance

$(50 \pm 1) \Omega$

### Direct Trigger Coupling

DC coupled

### Direct Trigger Input Connector

SMA (F)

## 4.5 Prescaled Trigger

**Prescaled Trigger Bandwidth and Sensitivity**

200 mV p-p to 2 V p-p from 1 GHz to 8 GHz  
 300 mV p-p to 1 V p-p from 8 GHz to 10 GHz

**Prescaled Trigger RMS Jitter, maximum**

3.5 ps + 20 ppm of delay setting

**Prescaled Trigger input characteristics**

50 ohm, AC coupled, divide-by-sixteen prescaler ratio, fixed level zero volts.

**Prescaled Trigger Maximum Safe Input Voltage**

±2 V (DC+peak AC)

**Prescaled Trigger Input Connector**

SMA (F)

## 4.6 Clock Recovery Trigger (PicoScope 9211 only)

**Clock Recovery Trigger Data Rate and Sensitivity**

50 mV p-p typical from 12.3 Mb/s to 2.7 Gb/s Continuous Rate.

**Recovered Clock RMS Trigger Jitter, maximum**

1.0% of Unit Interval.

**Clock Recovery Trigger input characteristics**

50 ohm, AC coupled.

**Clock Recovery Trigger Maximum Safe Input Voltage**

±2 V (DC+peak AC)

**Clock Recovery Trigger Input Connector**

SMA (F)

## 4.7 Acquisition

**Number of Acquisition Channels**

2 (simultaneous acquisition)

**ADC Resolution**

16 bits

**Digitizing Rate**

DC to 200 kHz maximum. The signal is sampled and digitized at a rate dictated by the trigger repetition rate and the time base range. If data acquisition is not trigger-rate limited, the maximum sample rate is 100 kHz.

**Acquisition Modes**

Sample (normal), Average, Envelope.

**Average Modes**

Stable or Multiple

**Number of averages**

From 2 to 4096 in x2 sequence

**Envelope Modes**

Min, Max or both Min-Max values acquired over one or more acquisitions

**Data Record Length**

32 to 4096 points maximum per channel in x2 sequence

## 4.8 Display

### Display Resolution

Full: 800 points horizontally x 600 points vertically  
Data: 501 points horizontally x 257 points vertically

### Display Style

Dots

Vectors

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

Variable Gray Scaling: five levels of a single color that is varied in saturation and luminosity. Refresh time can be varied from 1 s to 100 s.

Infinite Gray Scaling

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 can be varied from 1 to 200 s.

Infinite color Grading

### Graticule

Full Grid, Axes with tick marks, Frame with tick marks, Off (no graticule)

### Screen

Single: all waveforms are superimposed and are eight divisions high

Dual: with two graticules, all waveforms can be four divisions high, displayed separately or superimposed

Quad: 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.

### Display Format

YT only, XY only, or both YT & XY

### Colors

You may choose a default color selection, or select your own color set. Different colors are used for displaying selected items: background, channels, functions, waveform memories, FFTs, TDR/TDTs, and histograms.

## 4.9 Save/Recall

### Management

Store and recall setups, waveforms, and screen images to any drive on your PC. Storage capacity is limited only by disk space.

### File extensions

Waveform files:

.wfm for binary format  
.txt for text format

Data base files: .cgs

Setup files: .set

### Operating System

Microsoft Windows® XP or Vista

### Waveform Save/Recall

Up to four waveforms may be stored into the waveform memories (M1-M4), and then recalled for display

### Save/Recall to 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 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.

### 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 1 kHz, duty cycle greater than 1%, amplitudes greater than 50 mV p-p (vertical) and 200 mV p-p (trigger). Autoscale is operative only for relatively stable input signals.

## 4.10 Marker

### Marker Type

X-Marker: vertical bars (measure time)

Y-Marker: horizontal bars (measure volts)

XY-Markers: waveform markers (x and +)

### Marker Measurements

Absolute, Delta, Volts, Time, Frequency, Slope (Volts/Time)

### Marker Modes

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.

## 4.11 Measure

**Automated Measurements**

Up to ten simultaneous measurements, or four statistics measurements, are supported at the same time

**Automatic Parametric**

39 automatic measurements available

**Amplitude Measurements**

Maximum, Minimum, Peak-Peak, Top, Base, Amplitude, Middle, Mean, DC RMS, AC RMS, Area, Cycle Middle, Cycle Mean, Cycle DC RMS, Cycle AC RMS, Cycle Area, Positive Overshoot, Negative Overshoot

**Timing Measurements**

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

**Dual-Channel Measurements**

Delay, Gain

**FFT Measurements**

FFT Magnitude, FFT Delta Magnitude, THD, FFT Frequency, FFT Delta Frequency

**Measurement Statistics**

Display 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**

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 vertical bars

**Measurement Mode**

Repetitive or Single-shot

## 4.12 Limit Test

**Limit Test**

Signals can be tested by up to ten automatic parametric measurements and compared to user-defined test boundaries. Failure tolerances can be selected independently for each of the parametric tests.

Limit test can be set to run continuously for a user-selected number of waveforms, or for a defined number of failures.

**On failure actions**

Beep, Save failed waveform to disk or Stop acquisition.

## 4.13 Mathematics

**Waveform Math**

Up to four math waveforms can be defined and displayed using math functions F1-F4.

**Math Operators**

Add, Subtract, Multiply, Divide, Invert, Absolute, Exponentiation (e), Exponentiation (10), Logarithm (e), Logarithm (10), Differentiate, Integrate, Inverse FFT, Linear Interpolation, Sin(x)/x Interpolation, Smoothing, Trend

**Operands**

Any channel, waveform memory, math function, spectrum, or constant can be selected as a source for one of two operands.

## 4.14 FFT

**FFT**

Up to two fast Fourier transforms can be run simultaneously

**Frequency Span**

Frequency Span = Sample Rate / 2  
= Record Length / (2 x Time Base Range)

**Frequency Resolution**

Frequency Resolution = Sample Rate / Record Length

**FFT Windows**

The built-in filters (Rectangular, Nicolson, Hanning, 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.

## 4.15 Zoom

**Zoom feature**

The zoom feature allows waveforms (memories, functions, and spectrums) to be expanded and positioned in both vertical and horizontal axes. Allows precise comparison and study of fine waveform detail without affecting ongoing acquisitions.

**Complex Scale**

You can select different Complex Scale: Magnitude, Phase, Magnitude + Phase, Real, Imaginary, and Real + Imaginary.

**Vertical expanding and positioning**

Zoom provides a vertical dynamic range of 10 million divisions or 1 million screens

**Horizontal expanding and positioning**

Zoom provides a horizontal dynamic range of 640 divisions or 64 screens

## 4.16 Histogram

**Histogram Axis**

Vertical, or Horizontal



**Histogram Measurement Set**

Both vertical and horizontal histograms, with periodically updated measurements, allow statistical distributions to be analysed over any region of the signal.

Scale, Offset, Hits in Box, Peak Hits, Pk-Pk, Median, Mean, Standard Deviation, Mean  $\pm$  1 Std Dev, Mean  $\pm$  2 Std Dev, Mean  $\pm$  3 Std Dev.

**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.

## 4.17 Eye-Diagram

**Eye Diagram**

The PicoScope 9000 can automatically characterise an NRZ and RZ eye pattern. Measurements are based upon statistical analysis of the waveform.

**NRZ Measurement Set**

AC RMS, Area, Bit Rate, Bit Time, Crossing %, Crossing Level, Crossing Time, Cycle Area, Duty Cycle Distortion (%), Extinction Ratio (dB, %, ratio), Eye Amplitude, Eye High, Eye Width (%), Fall Time, Frequency, Jitter (p-p, RMS), Max, Mean, Mid, Min, Negative Overshoot, Noise p-p (One, Zero), Noise RMS, One Level, Peak-Peak, Positive Overshoot, Period, Rise Time, RMS, Signal-to-Noise, Zero Level

**RZ Measurement Set**

AC RMS, Area, Bit Rate, Bit Time, Contrast Ratio (dB, %, ratio), Cycle Area, Eye Amplitude, Eye High, Eye Opening Factor, Eye Width (%), Fall Time, Jitter (p-p, RMS), Max, Mean, Mid, Min, RMS, Rise, Fall, Negative Crossing, Noise p-p (One, Zero), Noise RMS, One Level, Peak-Peak, Positive Crossing, Positive Duty Cycle, Pulse Width, Rise Time, RMS, Signal-to-Noise, Zero Level

## 4.18 Mask Test

**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

OC1/STMO, OC3/STM1, OC9/STM3, OC12/STM4, OC18/STM6, OC48/STM16, FEC2666, OC192/STM64, FEC1066, FEC1071, FEC4266, FEC4302

Fiber Channel	FC133, FC266, FC531, FC1063, FC2125, FC4250, 10GFC
Ethernet	GB Ethernet, 2XGB Ethernet, 10GB Ethernet, 10GBE Ethernet, 10XGB Ethernet
INFIBAND	
XAUI	
ITU G.703	DS1, DS2, 8 Mb, DS3, 140 Mb
ANSI T1/102	DS1, DS1C, DS2, DS3, STS1 Eye, STS1 Pulse, STS3

**Mask Margin**

Available for industry standard mask testing

**Automask Creation**

Masks are created automatically for single-valued voltage signals. Automask specifies both delta X and delta Y tolerances. The failure actions are identical to those of limit testing.

**Data collected during test**

Total number of waveforms examined, number of failed samples, number of hits within each polygon boundary

## 4.19 Environmental Conditions

**Temperature**

Operating: +5°C to +35°C for normal operation, +15°C to +30°C for quoted accuracy.  
Storage: -20°C to +50°C

**Humidity**

Operating: Up to 85 % relative humidity (non-condensing) at +25°C  
Storage: Up to 95 % relative humidity (non-condensing)

## 4.20 PC connection

**PC connection**

USB 2.0 (FS). Compatible with USB 1.1.  
LAN (PicoScope 9201 only).

## 4.21 Power Requirements

**Power supply voltage**

+6 V  $\pm$  5%

**Power supply current**

PicoScope 9201: 2.0 A max,  
PicoScope 9211: 2.2 A max.

**Protection**

Auto shutdown on excess or reverse voltage

**AC adaptor**

Universal adaptor supplied

## 4.22 Physical Characteristics

**Dimensions**

Width: 170 mm (6.7")  
Height: 40 mm (1.6")  
Depth: 255 mm (10.0")

**Net Weight**

PicoScope 9201: 1.1 kg,  
PicoScope 9211: 1.3 kg.

## 5 Menu

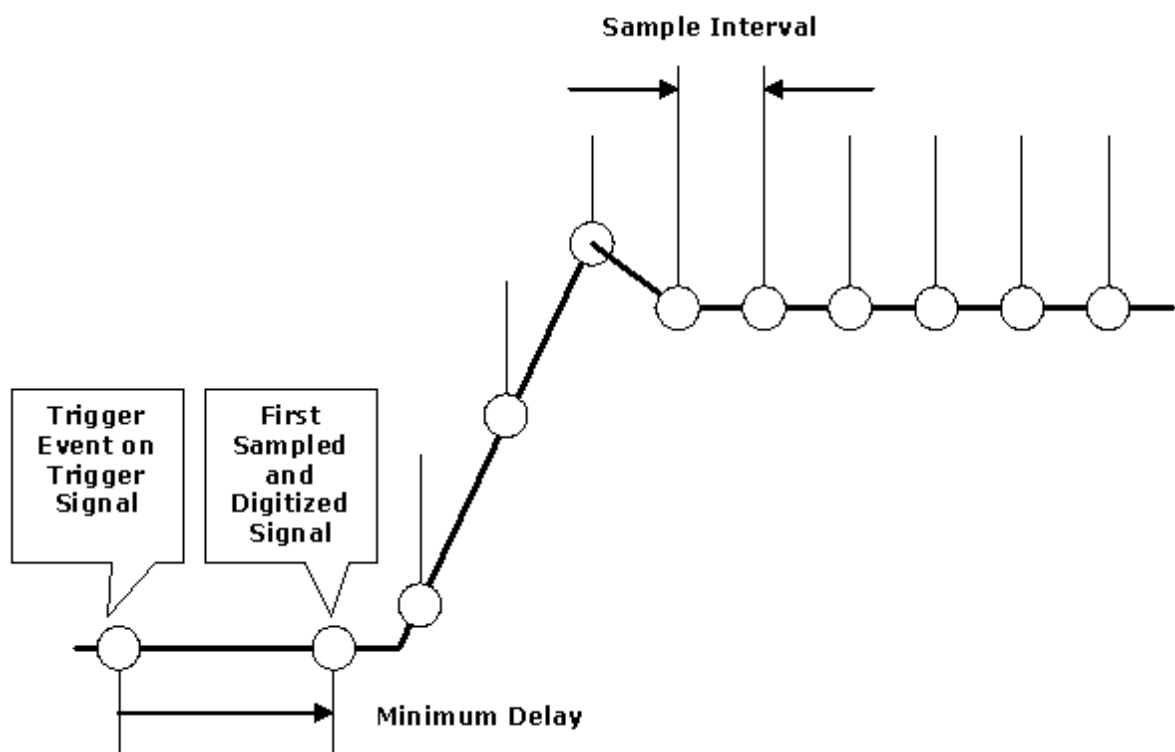
### 5.1 Acquisition Menu

#### Acquisition

Acquisition is a process of digitizing data points from a signal and assembling them into a trace record that is shown on the display. Once you have created a trace, acquisition of the signal is continuous and you see a live trace on the display.

#### How traces are acquired

The PicoScope 9000 uses a sequential sampling technique for acquiring waveforms. When the oscilloscope acquires trace records, it bases the sampling process on a trigger event that occurs on the trigger signal. The trigger signal is independent of the signal being acquired.



#### Acquisition of a Trace

When the trigger event is detected, the PicoScope 9000 waits a specified period of time before sampling and digitizing the first trace point. The time period is the horizontal position of the trace, which is set using the variables. After the first point is digitized, the PicoScope 9000 waits for another trigger event before sampling and digitizing the second point of the trace record. For the second point, the waiting time between the trigger event and the sampling and digitizing of the point is increased by the sample interval. The acquisition process continues until all the points in the trace are sampled and digitized. Points are acquired in order from left to right, and each point is sampled from a separate trigger event. When all the points in the trace record have been sampled and digitized, the trace is displayed.



For very slow trigger rates with traces that do not involve math functions or operations, a partial trace will be displayed even before all data points are accumulated.

A trace remains on the display until it is replaced by a more recent acquisition or until you clear the trace.

### **Determining the sample interval**

The sample interval is the time difference represented between successive points on the trace record. This is different from the sampling rate, which is the actual time that it takes to sample and digitize the successive points in the trace record. Since only one point is sampled and digitized after a trigger event, the sampling rate is much slower than the sample interval.

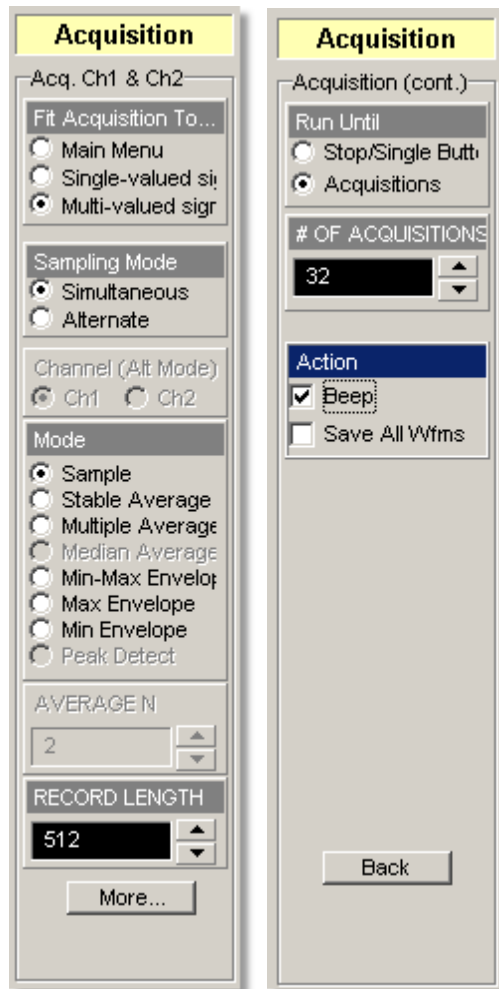
To compute the sample interval, divide the time period that the trace record displays by the number of points in the trace record. For example, if you are display a trace at 10 ns per division, and if the trace has 500 points (record length is equal to 512 points), the sample interval is 10 ns multiplied by 10 (divisions) and divided by 500 (points), or 200 ps.

All traces on the main or intensified time bases have the same record length and horizontal size. Similarly, all traces on delayed or dual delayed time bases share the same record length and horizontal size. This means that the PicoScope 9000 uses one sample interval for main or intensified traces and a different sample interval for delayed or dual delayed traces.

### **Equivalent sample rate**

The sample interval is 1 divided by the equivalent sample rate. The time duration of the data in a channel memory is the time between the sample points times the number of points. For example, if the equivalent sample rate is 100 GSa/s and the memory depth is 500 points/10 divisions, the time between the sample points is 10 ps. 10 ps times 500 points is 5 ns of waveform data stored in the channel memory. Because there are ten horizontal divisions on the display, set the time base to 500 ps/div to show the whole channel memory on the display.

$$\text{Time duration of the record} = \text{record length} / \text{equivalent sampling rate}$$



### Acquisition menu

The acquisition system of the PicoScope 9000 has several options for converting analogue data into digital form. The acquisition menu allows you to modify the way the instrument acquires the data from the input waveform by selecting the number of averages or envelopes, detection interval, and record length. Two types of waveforms can be selected for acquiring - single-valued waveforms or multi-valued waveforms.

### Acquisition readout and icons

The Acquisition readout at the top-left of the display shows the state of the acquisition system.





### Acquisition readout

It shows the following data:

- Equivalent sample rate for each of the channels
- If the **Average** mode is selected it shows the number of averages (**Avg N = XXX**)
- If the **Envelope** mode is selected it shows the number of acquisitions (**Env = XXX**)

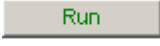
The Acquisition icon at the top right of the display shows the type of waveform that is selected for acquiring:


- The  icon shows acquisition for single-valued waveforms when digital feedback is used
- The  icon shows acquisition for multi-valued waveforms when digital feedback is not used

## System controls

You can control the acquisition process at any time by clicking on of the **System Controls** buttons **Run**, **Stop/Single** or **Clear Display**. For more details see [System Controls](#) <sup>[33]</sup>.

Using the **System Controls**, you control whether the oscilloscope is running or stopped.

The **Run** button  causes the instrument to resume acquiring data. If the instrument is stopped, it starts acquiring data on the next trigger event. If the instrument is already in the run mode, it continues to acquire data on successive trigger events.

The **Stop/Single** button  causes the instrument to stop acquiring data or to acquire a single waveform. You can stop acquisition if you want to freeze the displayed waveform(s) for closer analysis or measurement.

### 5.1.1 Fit Acquisition To...





The **Fit Acquisition To...** menu selects a mode of digital feedback.


#### Main Menu

The **Main Menu** mode selects digital feedback mode for all main menus excluding the following cases:


- NRZ or RZ measurement in the **Eye Diagram** menu is selected
- One of the standard masks for eye-diagram waveforms is selected in the **Mask Test** menu

When digital feedback mode is selected the  icon appears at the top right of the display. When digital feedback sampling loop mode is not selected the  icon appears at the top right of the display.

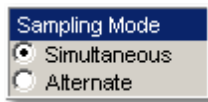
#### Single-valued signal

The **Single-valued signal** mode uses a digital feedback architecture that is the best choice for waveforms such as sine waves and pulses. When **Single-valued signal** mode is selected, the  icon appears at the top right of the display.

#### Multi-valued signal

The **Multi-valued signal** mode does not use the digital feedback architecture. This mode is the best choice for waveforms such as eye diagrams. When **Multi-valued** mode is selected, the  icon appears at the top right of the display.

### 5.1.2 Sampling Mode



The **Sampling Mode** menu selects how the signals will be acquired if more than one channel is selected. You can specify **Simultaneous** or **Alternate** mode.

#### Simultaneous

When more than one channel is selected, vertical acquisition is done simultaneously for both channels from a common strobe pulse. The **Simultaneous Sampling Mode** provides synchronous dual-channel acquisition with insignificant delay between channels. You can specify all functions for both channels equally from the **Acquisition** menu. Also, you cannot use the **DESKEW** variable from the **Channel** menu.

#### Alternate

When more than one channel is selected, the vertical acquisition switches sequentially through the selected channels. You can specify all functions for the selected channel from the **Acquisition** menu independently. For example, you can select the **Stable Average** mode for channel 1 and **Min-Max Envelope** mode for channel 2. Also, you can use the **DESKEW** variable from the **Channel** menu.

### 5.1.3 Channel (Alt Mode)

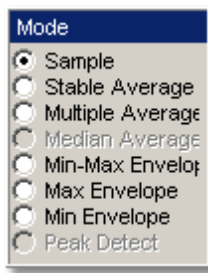


The **Channel (Alt Mode)** menu selects the waveform from one of the channels: **Ch1** or **Ch2**.

You can specify all functions for this selected channel from the **Acquisition** menu. The **Channel** menu can be active only when the **Alternate** mode is selected in the [Sampling Mode](#) menu.



### 5.1.4 Mode



The **Mode** option lets you choose how the oscilloscope will create points in the waveform record.

The PicoScope 9000 supports three basic acquisition modes. These are:

- **Sample** mode (default mode) - acquires one sample point per trigger and displays results without further processing
- **Average** mode - calculates the average values for each record point over many waveform records
- **Envelope** mode - uses the highest and lowest samples across several waveform records

When you select the **Average** mode you can enter the number of averages with the **AVERAGE N** variable. When you select the **Envelope** mode you can enter the number of acquisitions with the **ENVELOPE N** variable.

Acquisition modes do not affect the data sampling itself. However, they do affect the analysis of the sampling, and therefore the way the oscilloscope combines the samples into a data point value.

**Envelope** and **Average** modes operate after the oscilloscope has taken two or more acquisitions. For example, each **Average** mode averages the corresponding data points from two or more waveforms, not the waveform as a whole. **Envelope** mode builds an envelope from the peak minimum and maximum values of each point on a succession of waveforms.

#### Side effect of averaging and enveloping

Averaging improves the accuracy of some software measurements, because the measurements are taken from averaged data. However, some measurements can be adversely affected by averaging or enveloping. For example, if you take a rise time measurement of a signal with horizontal jitter, the averaged trace will indicate an inaccurately slow reading. Be cautious when taking software measurements of averaged or enveloped traces. Use statistical measurements on the unaveraged signal to take an accurate rise time measurement on a signal with jitter.

#### Sample acquisition mode

With the **Sample** radio button pressed, the oscilloscope saves one sample during each acquisition interval. Samples are accurately acquired at precisely and uniformly programmed intervals. When the record is full, the oscilloscope acquires new samples that overwrite the previously acquired waveforms. In the **Sample** mode, the sample interval varies with the time base settings.

At slower sweep speeds, the sample interval is often so large that the oscilloscope misses information between samples (for example, repetitive glitches). In the above waveform, the **Sample** mode misses a glitch in the first peak but happens to capture it in the second.

One drawback of the **Sample** mode is that it can be fooled by aliasing because the bandwidth of the data is proportional to the timebase scale settings. As the **Nyquist Theorem** predicts, the bandwidth of the data drops as you slow the timebase.

The default mode is **Sample**, which is useful for acquiring fast signals.

### Average mode

Pressing one of two Average radio buttons (**Stable Average** or **Multiple Average**) lets you acquire and display a waveform that is the combined result of several acquisitions. The oscilloscope acquires data as in the **Sample** mode and then averages it according to the number of averages that you specify. Each point in a record is numerically averaged with the same point in all other records. This reduces the random noise 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. The noise sources can average to zero over time while the underlying waveform is preserved. The effective resolution of the displayed waveform increases as more acquisitions are averaged together, provided that the input waveform is repetitive and has a stable trigger point. However, averaging reduces the throughput of the instrument. Also, the waveform is less responsive to changes, especially when you select a high number of averages. The vertical resolution can be improved to 16 bits by using averages.



Use the **Clear Display** button to reset the averaging process.



Note that averaging is particularly useful for single-valued waveforms, such as pulses. Multi-valued waveforms, such as eye-diagrams, are not improved with averaging because the eye “collapses” to the average value between logic level one and logic level zero.

Two **Average** modes are available in the PicoScope 9000:

- **Stable Average** mode.
- **Multiple Average** mode.

### Stable Average

Stable averaging lets you use the following algorithm:

$$A_n = A_{n-1} + \frac{x_n - A_{n-1}}{2^k}$$

where:

- $n$  - is the current acquisition's number
- $A_n$  - is the current acquisition's cumulative average
- $A_{n-1}$  - is the previous acquisition's cumulative average
- $x_n$  - is the newly acquired sample's value
- $k$  - is the number of averages

As the number of acquisitions increases, the number of averages  $k$  increases and the size of the correction term ( $2^{-k}$ ) decreases. Although the display becomes less noisy after each acquisition, the first acquisition has the greatest effect, and succeeding acquisitions have less effect as the correction term becomes smaller. For example, a change that occurs during the second acquisition shows up on the screen much sooner than one that occurs during the sixteenth. Whenever you adjust a control that affects the display, the scope starts a new averaging sequence to ensure that you will see the change immediately.

Stable averaging produces slightly less improvement—that is, a smaller signal-to-noise improvement ratio—than conventional averaging.

### Signal-to-Noise Improvement Ratio with Stable and Multiple Averaging

Selected Number of Averages	Signal-to-Noise Improvement Ratio			
	Stable Average		Multiply sampling	
	Numeric	dB	Numeric	dB
2	1.41	3.0	1.41	3.0
4	1.98	5.9	2.00	6.0
8	2.75	8.8	2.82	9.0
16	3.84	11.7	4.00	12.0
32	5.24	14.6	5.64	15.0
64	7.51	17.5	8.00	18.0
128	10.60	20.5	11.28	21.0
256	14.90	23.4	16.00	24.0
512			22.56	27.0

## Multiple Average

**Multiple** averaging lets you use the following algorithm:

$$A_i = \frac{\sum_{m=1}^N A_m}{N}$$

where:

$N$  - is the number of averages in every point

$A_m$  - is the acquired value of the waveform at point  $i$  during acquisition cycle  $m$

$A_i$  - is the averaged value of the waveform at point  $i$

When **Multiple** averaging is selected the oscilloscope works during the acquisition cycle as follows:

1. Operator selects the number of averages
2. The oscilloscope samples and digitizes  $N$  times the  $i$ th point of the waveform
3. Processor calculates new averaged value at point  $i$
4. This procedure repeats for every point of the waveform

Unlike the stable average mode, the multiple average mode is  $N$  times slower. However, every point of the waveform is displayed filtered from noise. The **Multiple Average** mode has the most effective Signal-to-Noise Improvement Ratio.

## Envelope Modes

Three **Envelope** modes are available in the PicoScope 9000:

- **Min-Max Envelope** mode
- **Max Envelope** mode
- **Min Envelope** mode

Clicking one of the envelope radio buttons (**Min-Max Envelope**, **Max Envelope** or **Min Envelope**) lets you acquire and display a waveform showing the extreme values of several acquisitions over a period of time. Thus, the oscilloscope detects peaks. You can specify a number of acquisitions over which to accumulate and display the min/max data. The oscilloscope compares the min/max values from the current acquisition with those stored from previous acquisitions up to the specified number of acquisitions. An enveloped waveform then shows the maximum excursions of the individual waveform records. This often results in a thicker waveform trace that shows the variations of the signal. Use this mode to reveal the noise band around the signal.

Because it degrades the timing information in the data by a factor of 2, **Envelope** mode is typically not suitable for FFT analysis. In addition, this mode can obscure the statistical distribution of the samples that occurred between the minimum and maximum values. However, you can create a display of this distribution by using the persistence display modes to view only peak values sampled over a period of time.



The **Envelope** mode requires a stable trigger for time correlation.

**Min-Max Envelope.** This radio button tells the oscilloscope to acquire and display the variation of both extremes - maximum and minimum.

**Max Envelope.** This radio button tells the oscilloscope to acquire and display the variation of maximum values.

**Min Envelope.** This radio button tells the oscilloscope to acquire and display the variation of minimum values.

### 5.1.5 AVERAGE N / ENVELOPE N



#### Number of Averages

The **AVERAGE N** variable changes the number of averages (records) when you select one of the two average radio buttons (**Stable Average** or **Multiple Average**). The number of averages can be specified from 2 to 4096 in multiples of two by one of these methods:

- By using the **AVERAGE N** spin box
- By using the [Pop-up Keypad](#)<sup>[375]</sup> for some specific settings

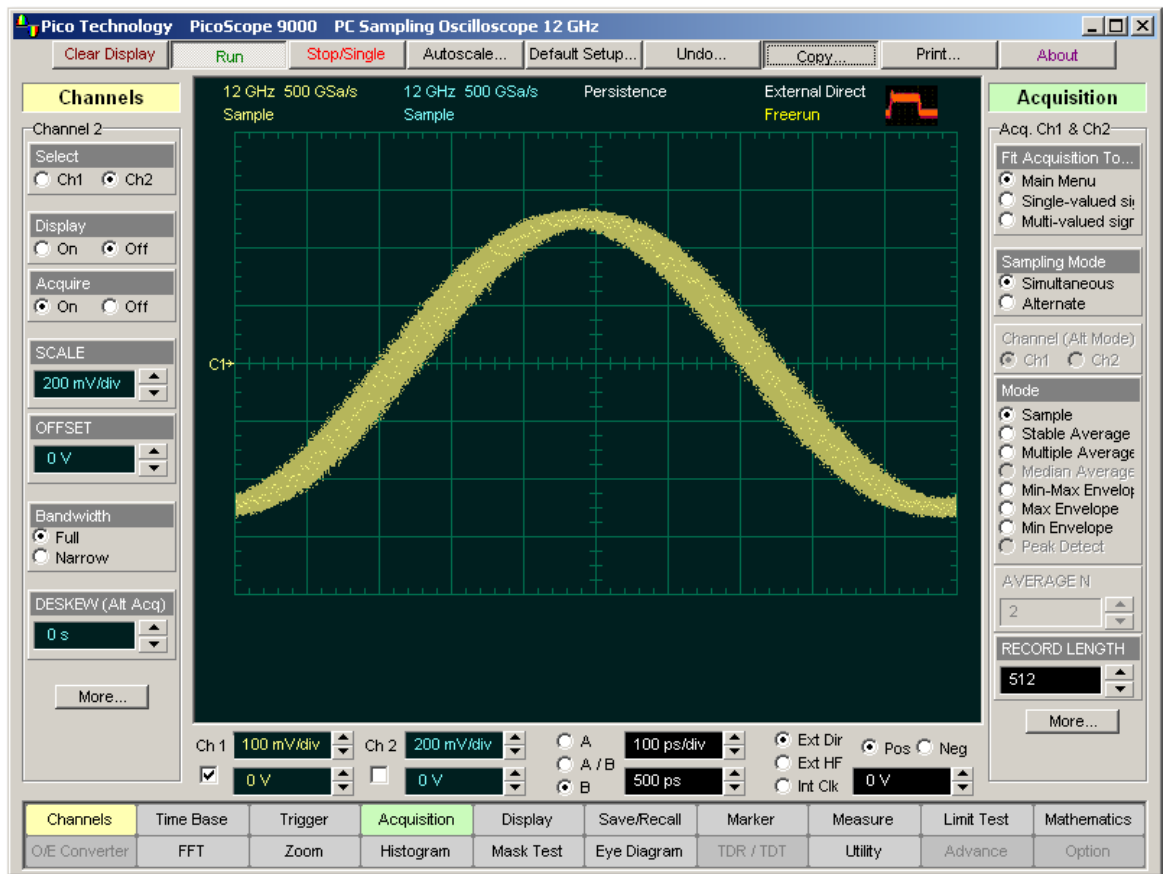


The waveform is less responsive to changes if a large number of averages is specified.

#### Number of Envelopes

The **ENVELOPE N** variable changes the number of acquisitions when you select one of the three envelope radio buttons (**Min-Max Envelope**, **Max Envelope** or **Min Envelope**). The number of acquisitions can be specified from 2 to 4096 in multiples of two or continuously using one of these methods:

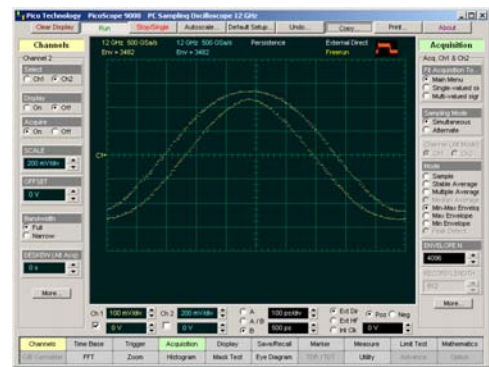
- By using the **ENVELOPE N** spin box
- By using the [Pop-up Keypad](#)<sup>[375]</sup> to enter specific settings



### Sample Acquisition Mode



Average Acquisition Mode



Min-Max Envelope Acquisition Mode

### 5.1.6 RECORD LENGTH



The number of samples that form a trace is called the record length (in points per waveform). For example, if the horizontal (timebase) scale is set up as 10 ns/div, the total displayed sweep time is 100 ns. The greater the amount of sampled data that is available for analysis or measurements, the greater the record length.

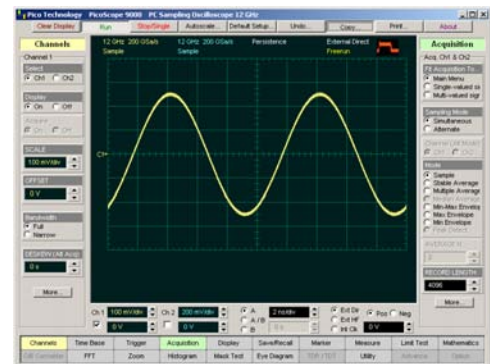
You can select record length with one of these methods:

- By using the **RECORD LENGTH** spin box
- By using the **Pop-up Keypad**<sup>[375]</sup> to enter specific settings

Record length can be selected from 32 to 4096 samples in multiples of two.



**Record length with 32 samples**



**Record length with 4096 samples**

Fast Fourier Transform algorithms require a record length that is a power of two. The 4096-point record length is provided as a convenience, and the visual truncation is a natural result.

When **Alternate Sampling Mode** is selected, the record length is set independently for each channel. Remember that equivalent sample rate and record length work together. If you combine a small record length memory depth with a high equivalent sample rate, you will have a very fast throughput (display update rate) but very little data in the channel memory. Because more data points need to be acquired, a waveform with a long record length takes longer to construct than one with a short record length. However, a long record length produces a waveform with higher horizontal resolution, and so a trade off exists between throughput and resolution.

You can set both the main record length and the delayed record length using the variables. All traces on the main timebase have the same record length. Delayed traces similarly share identical record lengths.



### 5.1.7 Run Until



The **Run Until** menu allows you to determine when the acquisition of data stops.

**Stop/Single Button.** You must press the **Stop/Single** key to stop the acquisition of data.

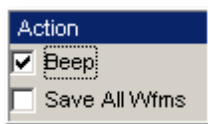
**Acquisitions.** After the number of acquisitions are met the acquisition is stopped. The number of acquisitions can be specified in the **# OF ACQUISITIONS** menu.

### 5.1.8 # OF ACQUISITIONS



Sets the number of acquisitions. After the selected number of acquisitions is met, the acquisition is stopped.

### 5.1.9 Action



The **Action** menu allows you to specify what the instrument does after acquisition is stopped. Two actions can be selected.

#### **Beep**

The **Beep** provides an audio tone.

#### **Save All Wfms**

Clicking **Save All Wfms** opens the **Windows Acquisition Limit Files** dialog box, which allows you to select the type of format you want to save the waveform as, and also to enter a key file name. You can select one of three types of waveform formats:

- Binary format with .wfm extension
- Text format with .txt extension
- Both formats with .wfm, and .txt extensions

After the **Run** key is pressed, the oscilloscope acquires the specified number of acquisitions. All of them will be saved into the memory.

## 5.2 Channels Menu

Channels



### WARNING!

The input circuits can be damaged by electrostatic discharge. Therefore, avoid applying static discharges to the front panel input connectors. Before connecting any coaxial cable to the connectors, momentarily short the centre and outer conductors of the cable together. Avoid touching the front panel input connectors without first touching the case of the instrument. Personnel should be properly grounded, and should touch the case of the instrument before touching any connector. Be sure that the instrument and PC are properly earth-grounded to prevent build-up of static charge.

Repair of damage due to misuse is not covered under the warranty!

**Channels**

Channel 1

Select

☒ Ch1 ☐ Ch2

Display

☒ On ☐ Off

Acquire

☒ On ☐ Off

SCALE

200 mV/div

OFFSET

0 V

Bandwidth

☒ Full ☐ Narrow

DESKEW (Alt Acq)

0 s

More...

**Channels**

Channel 1 (cont.)

External Scale

Attenuation Units

☐ Off ☒ Ratio ☐ Decibel

ATTENUATION

1:1

Scale

☒ Volt ☐ Watt ☐ Ampere ☐ Unknown

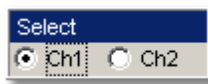
Back

The **Channels** menu allows you to set all controls for vertical setups of all live (channel) waveforms.

To display the **Channels** menu, click the **Channels** button of the main menu.

The controls for each channel are independent. When you select the **Channels** menu either the **SCALE**, **OFFSET**, **DESKEW**, or **ATTENUATION** control is highlighted in the same color as the selected channel, indicating that the function is active.

### 5.2.1 Channel Select

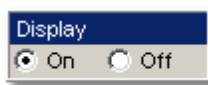


Many of the controls of the PicoScope 9000, especially the channel controls, operate on the selected channel. The instrument applies all actions that only affect one channel at a time, such as applying changes to the vertical control settings, to the selected channel.

Clicking the **Ch1** or the **Ch2** radio buttons:

- Toggles it between channels 1 and 2
- Assigns the function keys to the selected channel

### 5.2.2 Channel Display



There are two ways to add selected channels to the display and remove them again:

- Use the **On** or **Off** radio buttons on the **Channels/Display** menu
- Use the **Ch1** and **Ch2** check boxes in the **Permanent Controls Area**

Clicking the **On/Off** buttons:

- Turns the display for the selection on or off
- Changes the label from on to off or vice versa

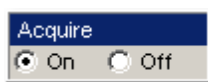
Turning the **Display** off does not turn off acquisition of the selected channels. To turn off acquisition of the selected channel, use the **Acquire** menu.

The **Display** turns on or off the display of the waveform for the chosen channel. When the channel display is on, a waveform is displayed for that channel, unless the offset is adjusted so the waveform is clipped off of the display.

When the channel display is off, the waveform display for that channel is turned off, but acquisition on that channel is not stopped. Turning a channel's display off also turns off the XY-markers while X- or Y-markers are available. Measurements, functions, FFTs, and histograms also are available to that channel.

Turning a channel off increases the display update rate for the remaining channel that is on.

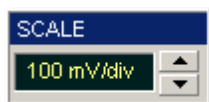
### 5.2.3 Channel Acquire



**On.** Turns on acquisition of the selected channel.

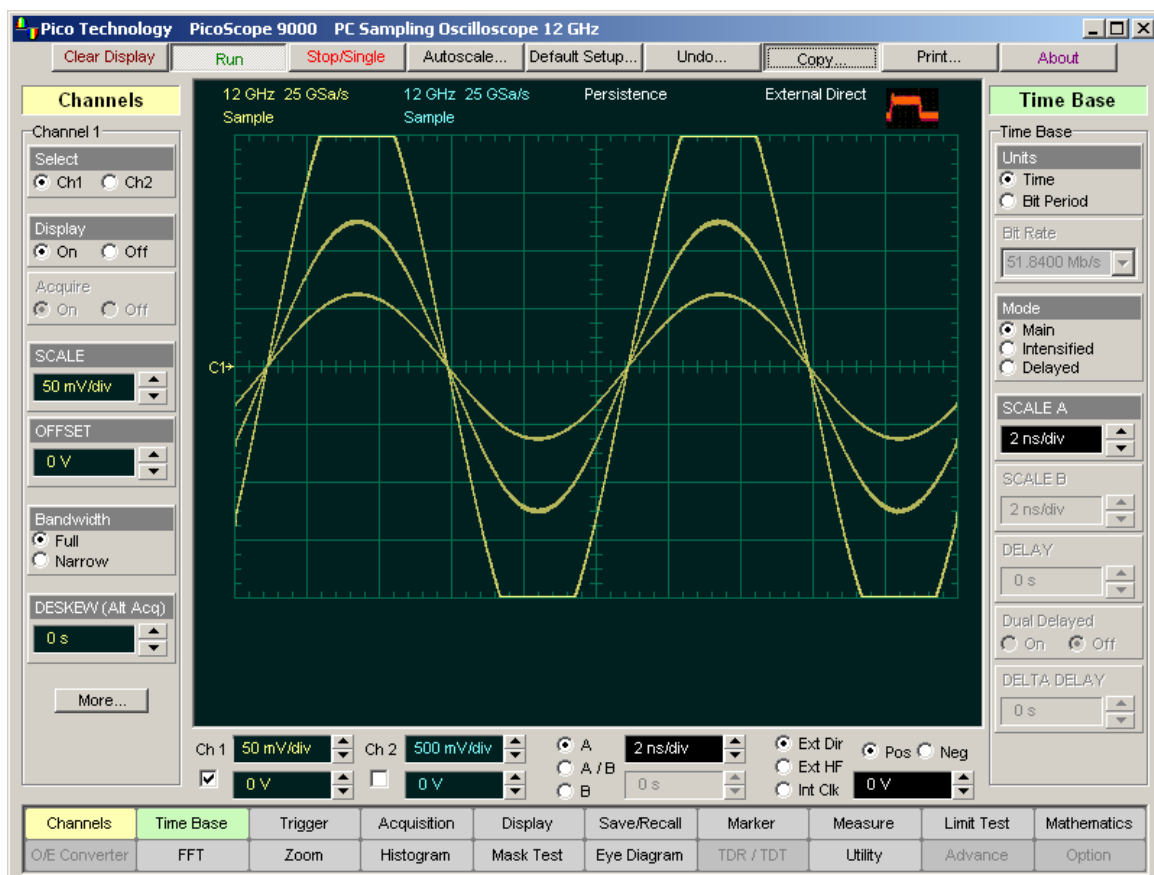
**Off.** Turns off acquisition of the selected channel.

### 5.2.4 Channel SCALE



The **SCALE** controls vertical scaling of the waveform. It determines the portion of the input signal presented to the acquisition system. Adjust the **SCALE** to control the portion of the vertical window displayed on screen. The vertical window is always centered around the offset value that is set.

As the numeric value of the scale is increased the displayed waveform decreases in size, and as numeric value of the scale is decreased, the waveform increases in size.



#### Vertical scaling of a waveform.



The channel **SCALE** does not affect the vertical acquisition window.



Only waveform traces from input channels can be vertically adjusted with the **SCALE** control. It does not affect waveforms saved in memories, or waveform functions.

You can set the vertical sensitivity of the selected channel in one of three ways:

- Use the **SCALE** spin box
- Use the **Ch1** and **Ch2** spin boxes in the **Permanent Controls** area
- Use the **Pop-up Keypad**<sup>[375]</sup> to enter specific settings

You can change the vertical scaling from 2 mV/div to 500 mV/div. If fine mode is off, the vertical scaling is in a 1-2-5-10 sequence. When fine mode is on, you can change the vertical scaling with a 0.5% increment or better.

The **SCALE** changes automatically if the attenuation factor is changed. The units the scale is displayed in depend on the unit of measure selected with the **Scale** menu. The choices for units are volts, watts, amperes, or unknown.

The **SCALE** changes automatically if the display graticule mode (single, dual or quad) or the attenuation factor is changed.

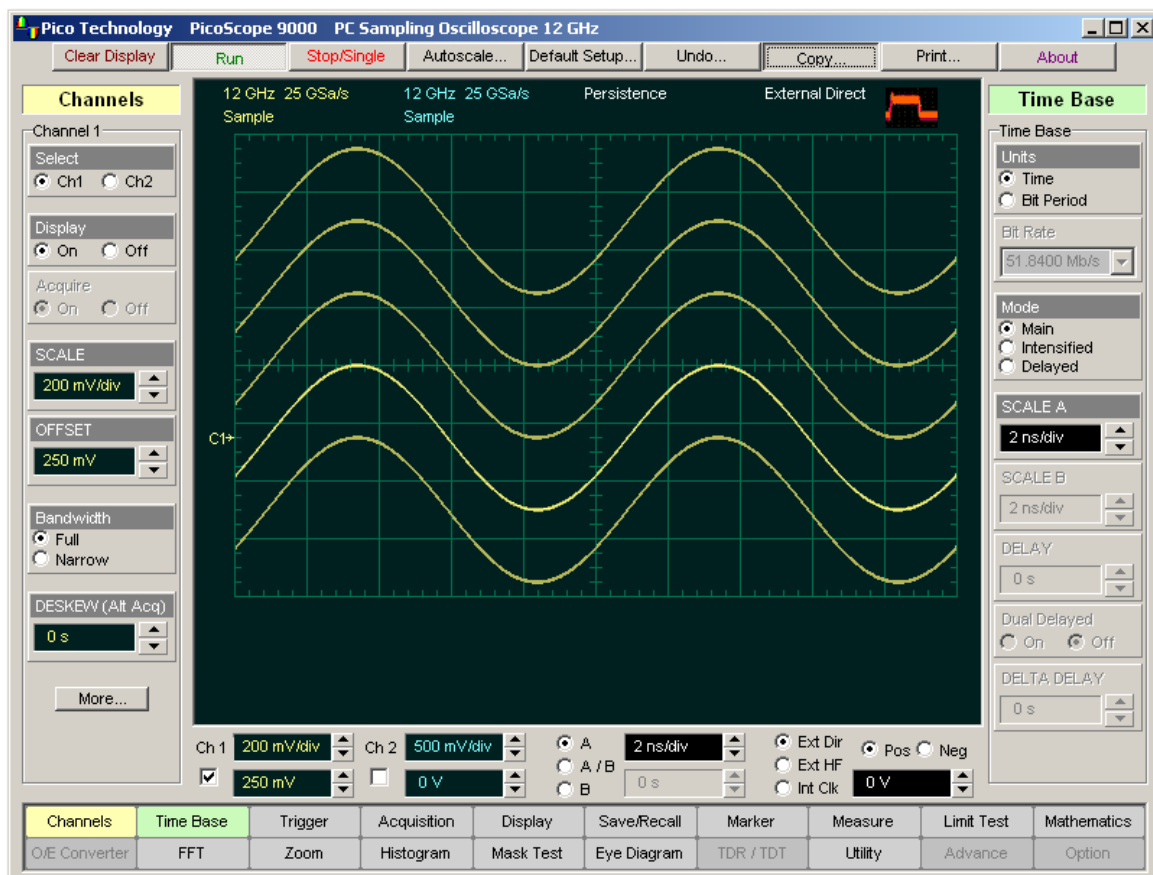
### 5.2.5 Channel OFFSET



The **OFFSET** variable changes the vertical position of a particular channel's waveform on the display screen without modifying the waveform itself. It determines the portion of the input signal presented to the acquisition system.

The advantage of digital offset is that it is calibrated. The offset voltage is the voltage at the centre of the graticule area, and the range of offset is  $\pm 1$  V. As you vary the offset, the middle voltage level moves relative to zero. This moves the vertical acquisition window up and down on the waveform. With input signals that are smaller than the window, the waveform appears to move in the window. Applying a negative offset moves the vertical range down relative to the DC level of the input signal, moving the waveform up on the display. Likewise, applying a positive offset moves the vertical range up, moving the waveform down on the display.

Set the vertical offset to display the features of interest on your waveform and avoid clipping.



**Sine-wave signal with different offsets**



Waveform data outside the vertical acquisition window is clipped: that is the data is limited to the minimum and/or maximum boundaries of the vertical acquisition window. This limiting can cause inaccuracies in amplitude-related measurements.



The **OFFSET** control affects the vertical acquisition window for selected input channel. It does not affect waveforms saved in memories, or waveform functions.

You can move the trace of the selected channel up or down in one of four ways:

- Use the **OFFSET** spin box
- Use the **Ch1** and **Ch2** offset spin boxes of the **Permanent Controls Area**
- Use the **Pop-up Keypad** <sup>[375]</sup> for some specific settings
- Use a channel **Ground Reference Indicator**

If fine mode is off, the offset can be changed in 25-mV steps. When fine mode is on, you can change the offset in 1-mV steps.

The **OFFSET** changes automatically if the attenuation factor is changed. The units the offset voltage is displayed in depend on the unit of measure selected with the **Scale** menu. The choices for units are volts, watts, amperes, or unknown.

The **OFFSET** changes automatically if the display graticule mode (single, dual or quad) or the attenuation factor is changed.



Each channel has a channel **Ground Reference Indicator** located to the left of the graticule area. The **Ground Reference Indicator** shows you where zero volts is for each channel.

### 5.2.6 Channel Bandwidth



**Bandwidth** is the range of frequencies that an oscilloscope can acquire and display accurately (that is, with less than 3 dB attenuation). You can use the **Bandwidth** function to select either full or narrow bandwidth.

The channel bandwidth setting affects the width of the sampling pulse used by the instrument. The wider bandwidth option allows the instrument to respond to fast changes in a waveform. The increased bandwidth thus yields the highest measurement fidelity.

The narrow bandwidth offers the best sensitivity by reducing the noise on the input waveform while still maintaining good frequency response. A lower sampler bandwidth is especially useful for low-level signals that cannot be averaged, such as an eye diagram. If you do not need wide bandwidth, use the narrow bandwidth to keep the signal-to-noise ratio at the best possible level. Narrow bandwidth removes high-frequency noise from a particular channel's waveform.

The **Bandwidth** does not affect the trigger signal.

**Full.** This button selects a 12-GHz bandwidth.

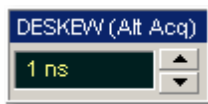
**Narrow.** This button selects an 8-GHz bandwidth.



**Channel 1 (yellow trace): full bandwidth 12 GHz**  
**Channel 2 (blue trace): narrow bandwidth 8 GHz**

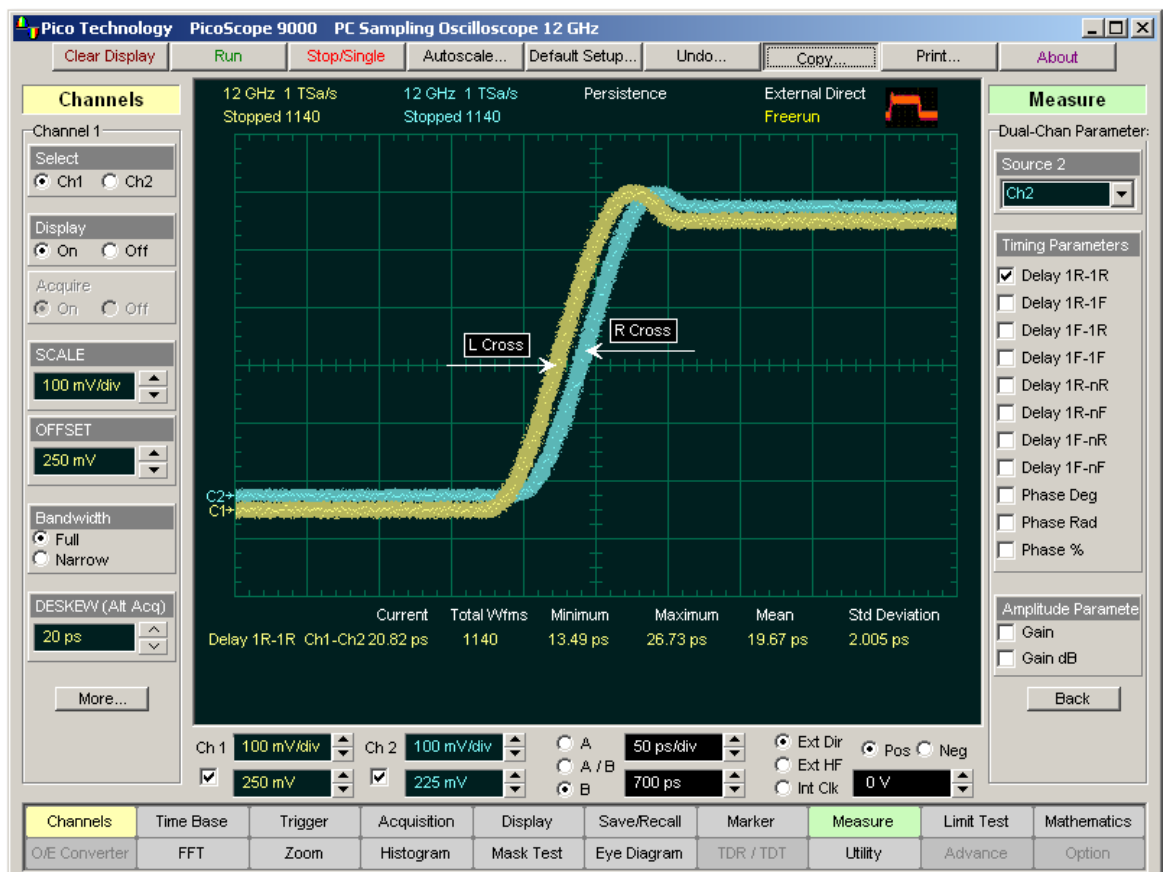


### 5.2.7 Channel DESKEW



The **DESKEW** variable adjusts the skew to change the horizontal position of one active channel with respect to another on the instrument display. The deskew function has a range of +100 ns. You can use the function to compensate the time offset between two channels, and also differences in cable or probe lengths. It also allows you to place the triggered edge at the centre of the display when you are using a power splitter connected between the channel and trigger inputs. Another use for deskew is when you are comparing the shapes of two waveforms rather than the actual timing difference between them: you can use the **DESKEW** to overlay one waveform on top of the other.

Use the **DESKEW** function only when the **Alternate Sampling Mode**<sup>[25]</sup> is selected in the **Acquisition**<sup>[20]</sup> menu.



**Two waveforms with entered deskew of 20 ps**

The **DESKEW** function allows you to set the horizontal position of a waveform in one of two ways:

- Use the **DESKEW** spin box
- Use the **Pop-up Keypad**<sup>[37]</sup> to enter specific settings

If fine mode is off, you can change the deskew value in 1 ns steps. When fine mode is on, you can change the deskew value in 1 ps steps.

### 5.2.8 Channel Input Impedance

The input channels of the PicoScope 9000 have 50-  $\Omega$  input impedance with DC input coupling. This is useful for connecting to probes or circuits that require a 50-  $\Omega$  termination. For example, you might choose an active probe to measure a very fast ECL or GaAs circuit. Such a probe usually has an amplifier near the tip of the probe, which drives the signal through a 50-  $\Omega$  cable. To minimize any waveform reflections, the scope input impedance must match the cable impedance as closely as possible so you would choose the 50-  $\Omega$  setting for that channel's input impedance.



#### CAUTION!

To avoid damage to the input of the scope, make sure you do not exceed the channel's maximum rated input voltage  $\pm 2$  V (DC + peak AC).

Using resistive divider probes you can increase input impedance up to 5 k  $\Omega$ , and using an active probe you can increase input impedance up to 10 M  $\Omega$ .

### 5.2.9 Channel Coupling

The samplers used in the PicoScope 9000 provide only straight-DC coupling to sampling circuits, with no protection. The PicoScope 9000 specifies a maximum vertical non-destructive range that limits signals to small level  $\pm 2$  V (DC + peak AC) or 16 dBm (See "[Channel \(Vertical\) Specification and Characteristics](#)"<sup>[10]</sup> for exact limits).



Do not exceed the limit, even momentarily, as the input channel may be damaged.



The PicoScope 9000 also specifies a maximum operating input voltage (dynamic range) that, if exceeded, could cause acquisition and measurement errors due to non-linearity. This limit is equal to 1 V p-p at  $\pm 1$  V range when digital feedback is used, and  $\pm 300$  mV relative to channel offset without digital feedback. Do not exceed this limit.

Also see "[Channel \(Vertical\) Specification and Characteristics](#)" for exact limits.

For removing the DC component of a particular channel's waveform to view AC waveforms with large DC offsets, use external wide-bandwidth HF blocking capacitors.

Use external attenuators if necessary to prevent exceeding the limits just described.

### 5.2.10 Channel External Scale

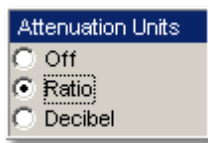
The **External Scale** functions allow you to set up a channel of the instrument to use external voltage attenuators or probes, current probes, and optical-to-electrical converters. Scaling is automatically adjusted to account and display information at the input side of an external device. For example, you may need to reduce the voltage level of a pulse generator that exceeds a channel's maximum input level. If you add a 20-dB attenuator, the voltage is reduced by a factor of 10:1. Although the voltage levels into the channel are within acceptable limits, your source measurements will be 1/10th of the actual source level. External scaling allows you to compensate for the 20 dB attenuation so your measurements reflect the source level prior to attenuation.

The measurement result reflects the actual value at the external device input. Once the number has been entered (1 is the default), the instrument then uses the total attenuation factor in scaling measurement results. Total attenuation is the product of the external attenuation multiplied by the hardware attenuation of the probe (or another external unit) or sampler.

When you enter attenuation, amplification, or conversion information with the **External Scale** menus, the channel settings change in the following ways:

- The unit values and amplitudes of the markers and vertical measurements reflect the signal at the input of a transducer, probe, attenuator, or amplifier. For example, you can connect an external device such as a photodiode to an electrical channel input and change the scale unit value to read watts, the unit value of the signal at the diode input.
- The maximum and minimum vertical scale settings change by a factor specified by the attenuation value entered.
- Offset minimum and maximum values change by a factor specified by the attenuation value entered.

### 5.2.11 Attenuation Units



You can enter attenuation or gain characteristics of an external device when configuring a channel for external scaling. The **Attenuation Units** function lets you select how you want the attenuation factor represented. Click the **Ratio** or **Decibel** radio buttons to choose either ratio or decibel. The formula for calculating decibels is:

$$20 \log(V_{out}/V_{in}) \text{ or } 10 \log(P_{out}/P_{in})$$

#### Decibels versus voltage ratio:

dB	Voltage Ratio
3 dB	1.41
6 dB	2.00
10 dB	3.16
20 dB	10
40 dB	100
60 dB	1000
120 dB	1 000 000
-80 dB	0.0001

Changing the channel attenuation factor does not attenuate the input signal; it only changes the database for generating prompts on the display and calculating the results of the automated waveform measurements. If the input signal must be attenuated, use external attenuators.



External gain is implied when you enter negative decibel values or ratios of less than 1:1 in the **ATTENUATION** variable. The default attenuation value is 1:1.

### 5.2.12 ATTENUATION



The **ATTENUATION** variable lets you select an attenuation that matches the device connected to the instrument. When the attenuation is set correctly, the instrument maintains the current scale factors if possible. All marker values and voltage, amperage or wattage measurements will reflect the actual signal at the input to the external device.

The channel attenuation factor is used to establish a database for:

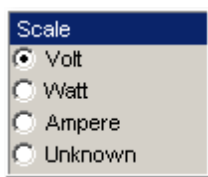
- Generating the vertical scale and offset prompts on the display
- Calculating the automated waveform measurements
- Y-marker levels
- Calculating functions

The attenuation factor can be adjusted from 0.0001:1 to 1000000:1 or from -80 dB to 120 dB.

The **ATTENUATION** function allows you to set attenuation of the selected channel in one of two ways:

- By using the **ATTENUATION** spin box
- By using the [Pop-up Keypad](#)<sup>[375]</sup> to enter specific settings

### 5.2.13 Scale



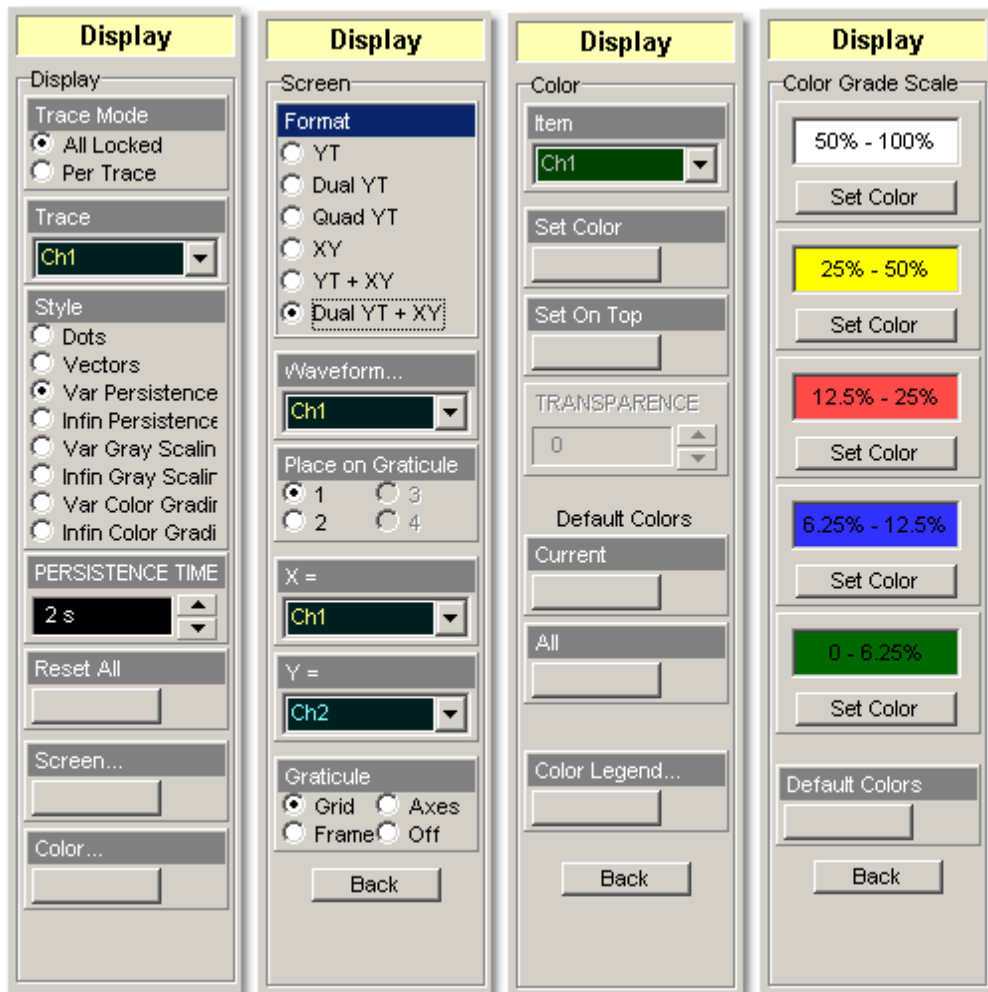
The (External) **Scale** function lets you select a unit of measure that is appended to the channel scale, offset and vertical measurement values. The units are **Volt**, **Watt**, **Ampere**, or **Unknown**.

Use **Volt** for voltage probes, **Ampere** for current probes, **Watt** for optical-to-electrical converters, and **Unknown** when there is no unit of measure or when the unit of measure is not one of the available choices.

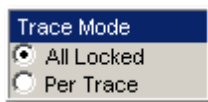
## 5.3 Display Menu



The **Display** menu controls most of the features that determine how the acquired data is displayed on the screen. You can configure the PicoScope 9000 for persistence or color-graded display style, select the graticule settings, define the waveform display area for single or multiple waveform displays, and you can change the color of most of the items that are displayed on the screen.



### 5.3.1 Trace Mode

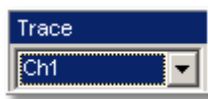


The PicoScope 9000 gives you the choice of constraining all input channels to the same display style, or setting these for each trace individually.

**All Locked.** Set the same display style for all traces.

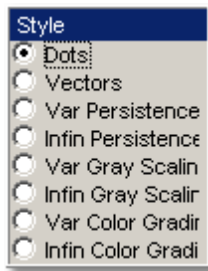
**Per Trace.** Set up traces individually.

### 5.3.2 Trace



Selects a trace to set **Display Style**. Is active only when **Per Trace** is selected from the **Trace Mode**.

### 5.3.3 Style



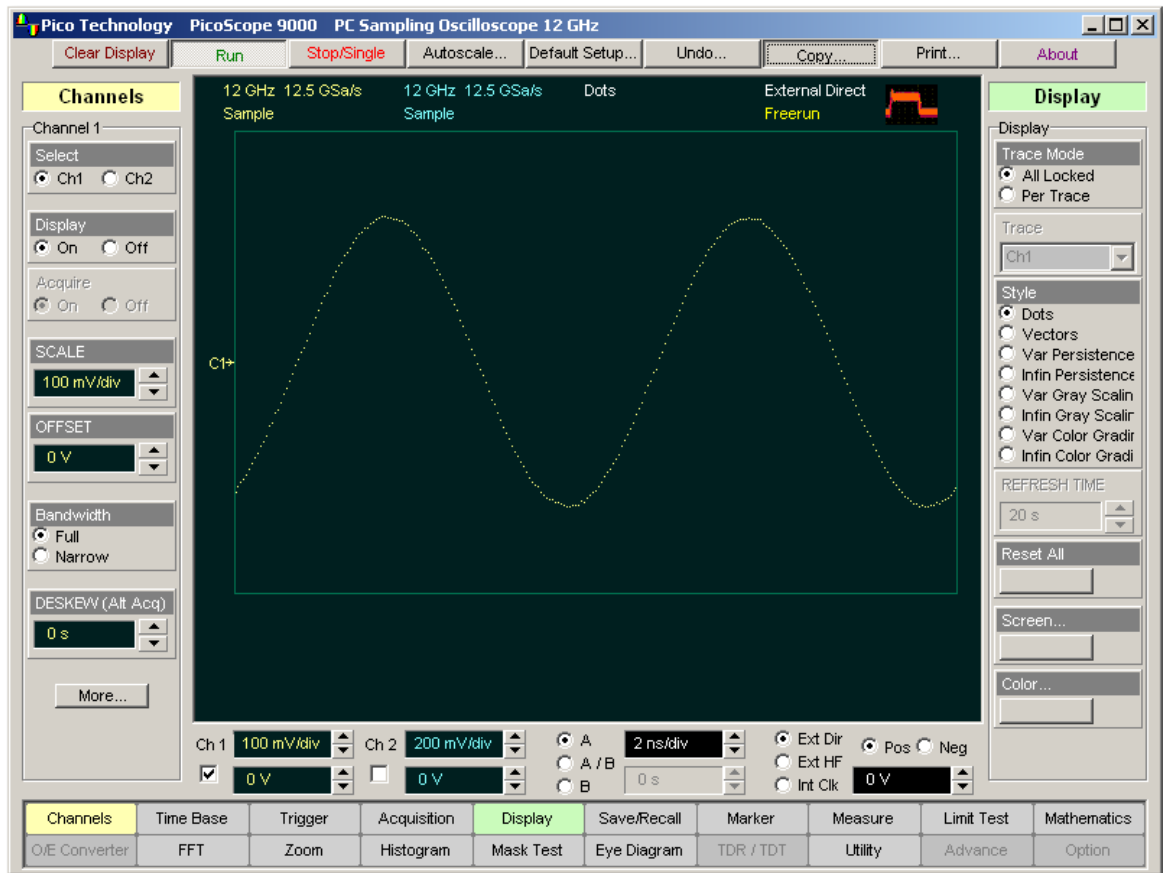
The **Style** menu determines how the data is displayed. There are eight choices for drawing waveforms:

- **Dots**
- **Vectors**
- **Variable Persistence**
- **Infinite Persistence**
- **Variable Gray Scaling**
- **Infinite Gray Scaling**
- **Variable color Grading**
- **Infinite color Grading**



## Dots display

The **Dots** style displays waveforms without persistence: each new waveform record replaces the previously acquired record for a channel. Data points are plotted on the display as fast as possible. When the waveform record length is small, the throughput of the instrument is fast enough that you can use the **Vector** style without noticing much decrease in throughput.



**Dot Display Style**

## Vector display

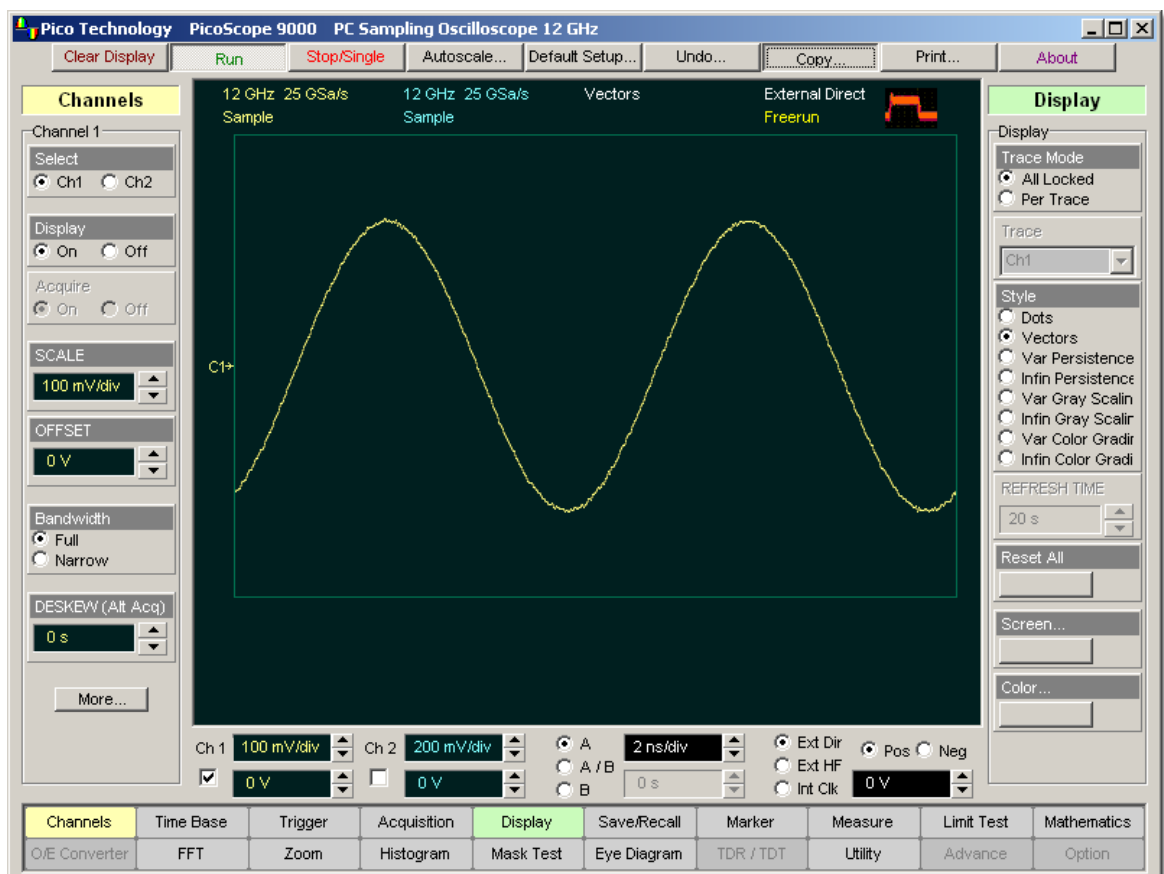
The **Vector** function draws a straight line through the data points on the display. This is also known as **Connect Waveform Dots**. The **Vector** style gives an analogue look to a digitized waveform and makes it possible to see steep edges on waveforms such as square waves. If you use the **Vector** style the approximate unaliased oscilloscope bandwidth is:

$$\text{Bandwidth} = \text{Equivalent Sample Rate} / 10.$$

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.



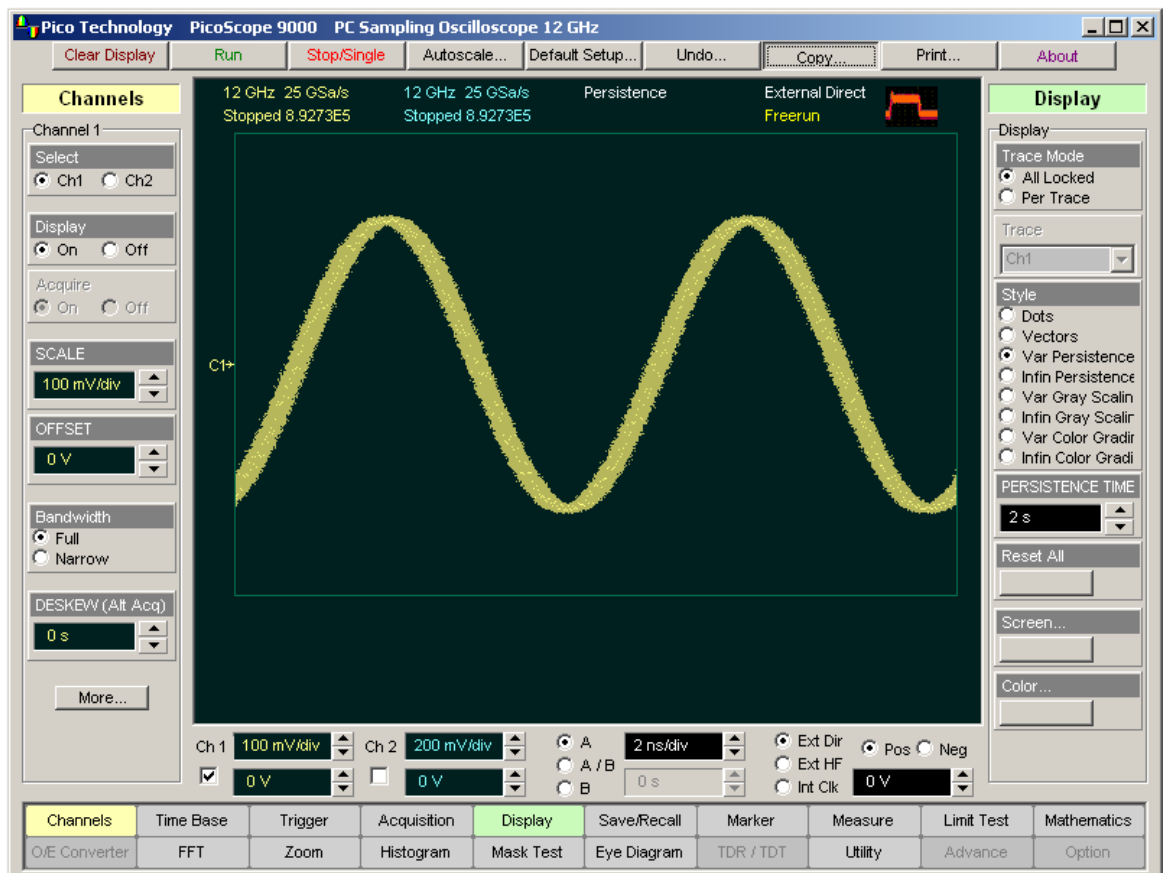
It is not recommended to view eye diagrams when **Vectors Style** is enabled. For this reason, do not use the **Vectors Style** in the **Eye Diagram** and **Mask Test** menus.



**Vector Display Style**

## Display Persistence

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. Acquisition memory is where the current waveform data is stored. Therefore, only the last acquired waveform is held in acquisition memory. Display memory is what is seen on the display graticule.



## Persistence Display Style

Persistence style applies to all waveforms. Use display persistence to control how waveform data ages. By adding persistence, you can see a visual history of a waveform's acquisitions over time. Setting the persistence to minimum allows for easiest viewing of variations in the acquired waveforms. Setting the persistence to infinite allows for a complete view of everything measured in the waveform. For example, you can see the accumulated peak-to-peak noise of a waveform over time, which may appear significantly different than in only one acquisition. You can see timing jitter, the variance of the waveform from the trigger event, by accumulating acquisitions on the display. By adding persistence, viewing a waveform's extremes over time is much easier.

You can have averaging and persistence on at the same time because when averaging is on, the averaging is done before the data is sent to the display. Use the [Acquisition](#) menu to control averaging.



Waveform persistence is used only in the **Display Area**.



Use waveform persistence in the **Eye Diagram** and **Mask Test** menus. The **Eye Diagram** and **Mask Test** measurement algorithms are based on the statistical accumulation of the data.

The PicoScope 9000 uses two persistence settings:

- **Variable Persistence**
- **Infinite Persistence**

### Variable Persistence

The **Variable Persistence** style accumulates the waveform-record points on screen and displays them for a specific time. The oldest waveform data continuously fades from the display as new waveform records are acquired.

By selecting the Variable Persistence display style, you can vary the persistence time from minimum of 100 ms to 20 s. When the persistence is set to minimum, all data points are kept on the display for 100 ms. After 100 ms all the previous data points are erased from the display, and new data points are written to the display. As you increase the persistence time, the previous data points are kept on the display depending on the persistence time you have selected. Therefore, the longer the persistence time, the longer each data point is left on the display before it is erased from the display. You can change the persistence time with the PERSISTENCE TIME variable.

A minimum persistence setting is used when the input signal is changing and you need immediate feedback. You can use the minimum persistence mode to view the fastest display update rate. For example, if you are rapidly probing a source, you may find that more persistence is useful for observing long-term changes in a signal or observing signals with low repetition rates. More persistence is useful when you are observing long-term changes in the signal or low signal repetition rates.



If you are adjusting the amplitude or frequency of a signal source, you may find that more persistence (variable or infinite) is useful for observing long-term changes in a signal or observing signals with low repetition rates. If you are adjusting signal parameters, such as scale or delay, you will find that minimum persistence is useful due to the fast update rate.

When the waveform acquisition is stopped, the last acquired data points are left on the display.

If one of the following is changed when the instrument is in the variable persistence mode, the displayed waveform is redrawn and any accumulated waveforms are cleared:

- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

### Infinite Persistence

When you select the **Infinite Persistence** display style, all the data points are kept on the display for an endless period of time, or until you change some control. Waveform data builds up as new data records are acquired. You can use infinite persistence for worst-case characterization of signal noise, jitter and drift, or to see a waveform's envelope, look for timing violations, and find infrequent events.

With infinite persistence, all sampled data points are left on the display until one of the following occurs:

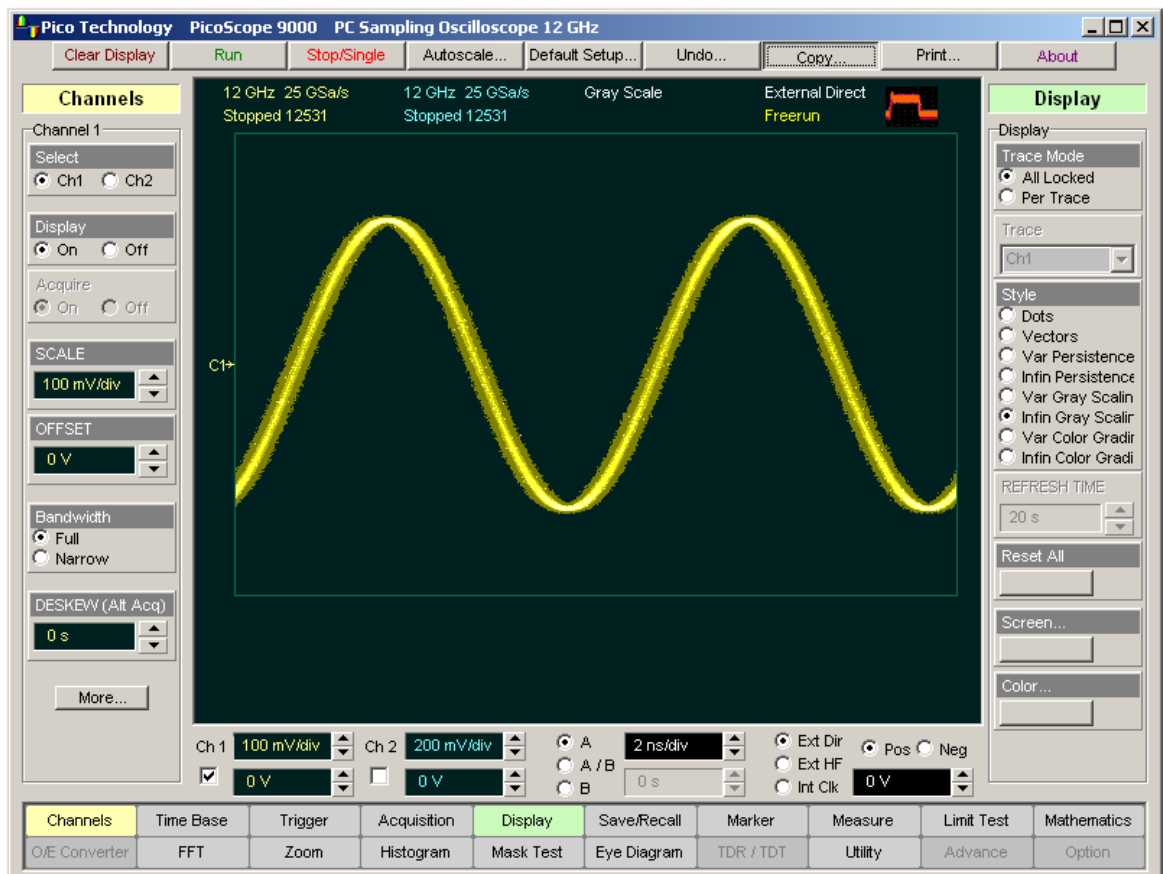
- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

## Gray Scaling

This mode is similar to persistence mode. The only difference is that the accumulated points are used are one color that is varied in saturation and luminosity levels (in other words, different shades of the same color). You can use the gray-scaling database with histograms, mask testing, statistical measurements, and eye diagrams. You can also use color grading to provide more visual information about the waveforms.

The **Gray Scaling** function uses the database in the size of the graticule area. Behind each pixel is a 16-bit counter. Each time a pixel is hit by data, the counter for that pixel is incremented. Each color used for the color grade mode represents a range of data counts. As the total count increases, the range of hits represented by each color also increases. The maximum count for each counter is 65,535.

There are five levels used in the gray-scaled mode. Each shade shows the number of hits per pixel over the graticule area, and represents a range of counts, which depends on the total number of hits. As the total count increases, the range of hits represented by each shade also increases. The shades are fixed and cannot be changed by the user.



### Gray-scaling display style

You can use the gray-scaling persistence style to display waveforms that use the instrument measurement database. This database consists of all data samples displayed on the screen. The measurement database provides the data for the construction of histograms and performing mask tests.

If the gray-scaling persistence style is left active for a long period of time, the waveform will become saturated with the shades that represent the highest density of data counts.



Use gray-scaling in the **Eye Diagram** and **Mask Test** menus. The **Eye Diagram** and **Mask Test** measurement algorithms are based on the statistical accumulation of the data that the **Gray Scaling** mode uses internally.

### Variable Gray Scaling

In the **Variable Gray Scaling** display style, the screen is not refreshed after every acquisition; instead, the screen is refreshed at a specified, user-selectable rate. You can vary the refresh time from minimum of 1 s to 200 s. You can change the refresh time with the REFRESH TIME variable.

If one of the following is changed when the instrument is in the Variable Gray Scaling display style, the displayed waveform is redrawn and any accumulated waveforms are cleared:

- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

### Infinite Gray Scaling

When you select the **Infinite Gray Scaling** display style, all the data points are kept on the display. With the **Infinite Gray Scaling** display style, all sampled data points are left on the display until one of the following occurs:


- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

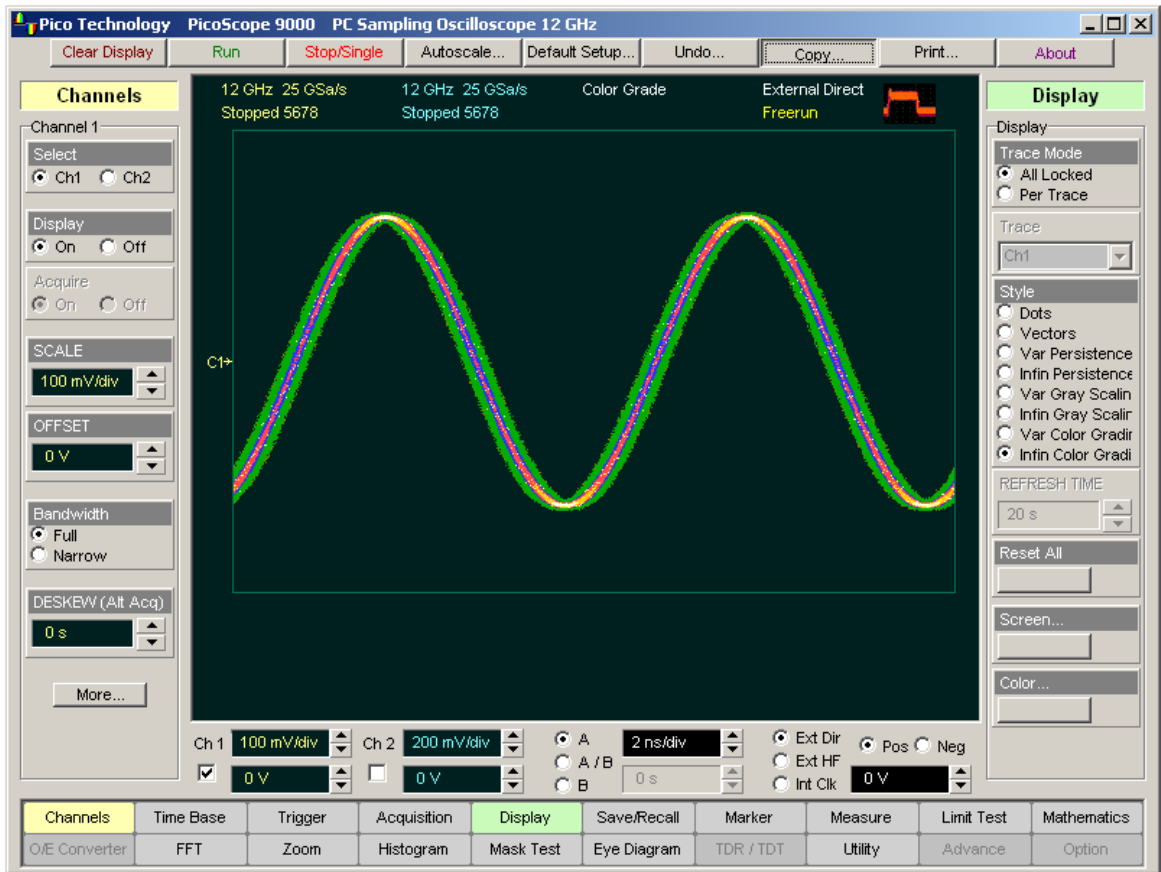
You can use infinite gray-scaling for worst-case characterization of signal noise, jitter and drift, or to see a waveform's envelope, look for timing violations, and find infrequent events.

### Color Grading

This mode is similar to persistence mode. The only difference is that the accumulated points are color-graded (shaded with different colors) to indicate the density of the points, and a color-graded database is built. You can use the color-graded database with histograms, mask testing, statistical measurements, and eye diagrams. You can also use color grading to provide more visual information about the waveforms.

The **Color Grading** function uses the database in the size of the graticule area. Behind each pixel is a 16-bit counter. Each time a pixel is hit by data, the counter for that pixel is incremented. Each color used for the color grade mode represents a range of data counts. As the total count increases, the range of hits represented by each color also increases. The maximum count for each counter is 65,535.

There are five colors used in the color-graded display. Each color shows the number of hits per pixel over the graticule area, and represents a range of counts, which depends on the total number of hits. As the total count increases, the range of hits represented by each color also increases. The colors can be changed from the [Color Grade](#)  menu.



### Color-Graded Display Style

You can use the color grade persistence mode to display waveforms that use the instrument measurement database. This database consists of all data samples displayed on the screen. The measurement database provides the data for the construction of histograms and performing mask tests.

If the color grade persistence style is left active for a long period of time, the waveform will become saturated with the color that represents the highest density of data counts. The **Color Grade Scale** menu displays the color levels and the range of counts the color represents. Click the **Color Grade Scale** button to view the color levels.



Use gray-scaling in the **Eye Diagram** and **Mask Test** menus. The **Eye Diagram** and **Mask Test** measurement algorithms are based on the statistical accumulation of the data that the **Gray Scaling** mode uses internally.

The PicoScope 9000 has two color-grading settings:

- **Variable Color Grading**
- **Infinite Color Grading**



### Variable Color Grading

In the **Variable Color Grading** display style the screen is not refreshed after every acquisition; instead, the screen is refreshed at a specified, user-selectable rate. You can vary the refresh time from minimum of 1 s to 200 s. You can change the refresh time with the **REFRESH TIME** variable.

If one of the following is changed when the instrument is in the Variable Color Grading display style, the displayed waveform is redrawn and any accumulated waveforms are cleared:

- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

### Infinite Color Grading

When you select the **Infinite Color Grading** display style, all the data points are kept on the display. With the **Infinite Color Grading** display style, all sampled data points are left on the display until one of the following occurs:

- **Clear Display** button is pressed
- An **Autoscale** button is executed
- A **Default Setup** button is executed
- The instrument is turned off

You can use infinite color grading for worst-case characterization of signal noise, jitter and drift, and to see a waveform's envelope, look for timing violations, and find infrequent events.

### 5.3.4 PERSISTENCE TIME / REFRESH TIME



#### PERSISTENCE TIME

The **PERSISTENCE TIME** variable works when the **Variable Persistence** display is selected in the [Style](#) <sup>49</sup> menu.

Persistence time is the amount of time for which a waveform sample appears on the display. In the **Variable Persistence** display style, a waveform sample point is displayed from 100 ms to 20 s. The default setting is 2 s.

This mode most closely simulates the phosphorescent persistence of an analog scope. Use variable persistence to view infrequent events and rapidly changing waveforms and watch the evolution of the waveform.

#### REFRESH TIME

The **REFRESH TIME** variable works with both the **Variable Gray Scaling** and the **Variable Color Grading** display styles.

Refresh time is a control of how often the screen is updated with new data. The range for refresh time is 1 to 200 s.

### 5.3.5 Reset All



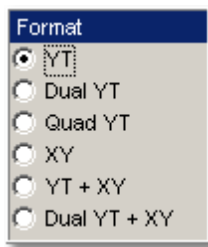
Click the **Reset All** button to return all traces setups to their default persistence settings.

### 5.3.6 Screen



The **Screen...** button gives you access to a second-level menu that allows you to define the display area in different ways.

## 5.3.6.1 Format



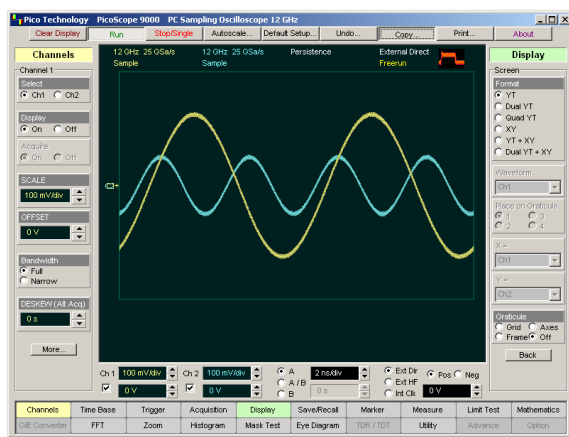
The **Format** menu determines how the instrument draws the waveforms on the display. Six formats are used in the PicoScope 9000.

**YT**

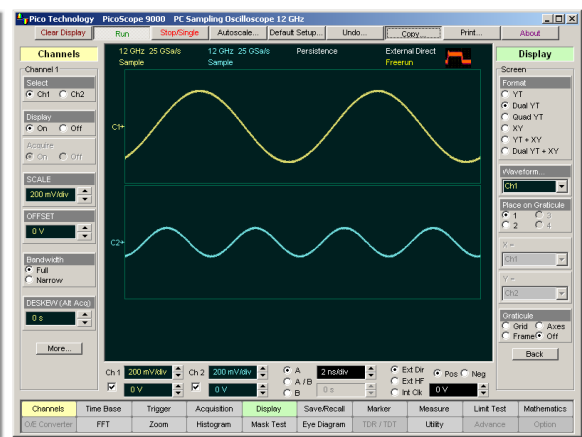
The **YT** format is the normal time (on the horizontal axis) versus voltage (on the vertical axis) format. The entire display area is one screen and any displayed waveforms are superimposed on top of each other.

**Dual YT**

The **Dual YT** format is the normal time (on the horizontal axis) versus voltage (on the vertical axis) format, but with the display area divided into two equal screens.



YT Display Format



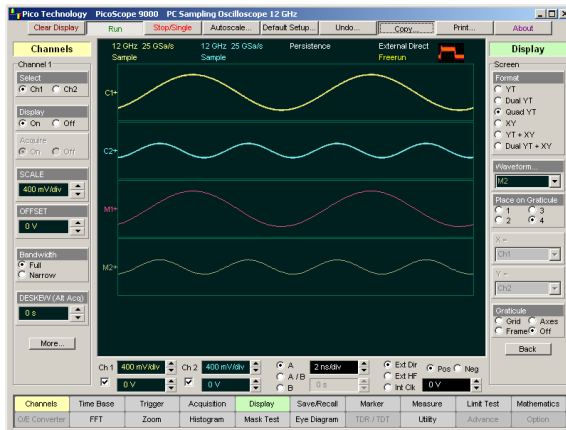
Dual YT Display Format

**Quad YT**

The **Quad YT** format is the normal time (on the horizontal axis) versus voltage (on the vertical axis) format, with the display area divided into four equal screens.

**XY**

The XY format displays voltages of two waveforms against each other, and draws the **Source 1** versus **Source 2** display of the two selected sources. **Source 1's** amplitude is plotted on the horizontal X axis and the **Source 2's** amplitude is plotted on the vertical Y axis.



Quad YT Display Format



XT Display Format

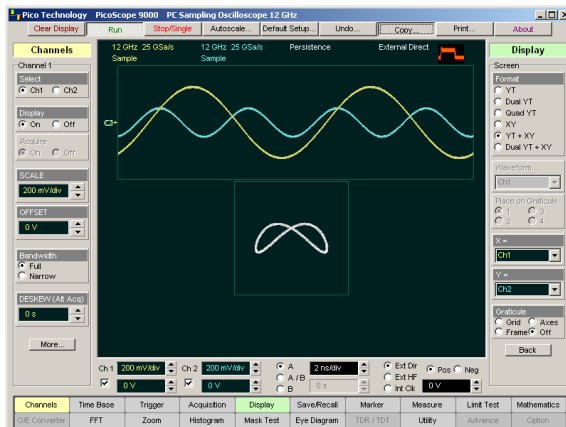
### YT+XY

The **YT + XY** format 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 one screen and any displayed waveforms are superimposed on top of each other.

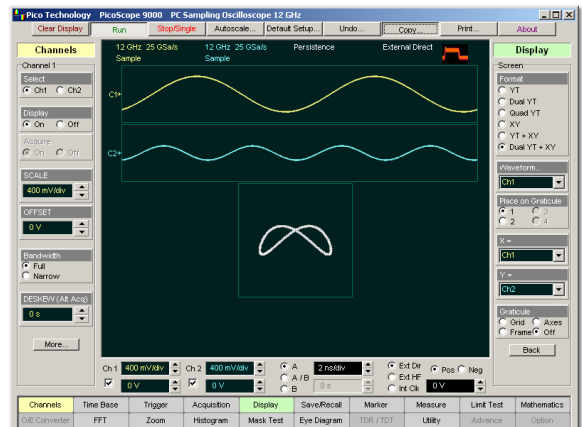
### Dual YT + XY

The **Dual YT + XY** format 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.

You can use the **XY** format to compare frequency and phase relationships between two signals. The **XY** format can also be used with transducers to display strain versus displacement, flow versus pressure, volts versus current, or voltage versus frequency.

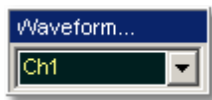


YT+XY Display Format



Dual YT+XY Display Format

## 5.3.6.2 Waveform



With the **Waveform** function you can set the waveform, which will be placed on the graticule, selected with the **Place on Graticule** menu.

The waveform source can be selected from:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4
- spectrums 1 and 2

Any waveform selected with the **Waveform** function is placed on the graticule chosen with the **Place on Graticule** menu.

## 5.3.6.3 Place on Graticule

**Place on Graticule**

With the **Place on Graticule** menu you can place a waveform, selected by the **Waveform** function, on any possible graticule.

You can place any waveform selected as source to any graticule. For example, you can place the **M1** waveform memory on the fourth graticule, or the **F1** function on the first graticule.

## 5.3.6.4 X= and Y=

**X=**

The **X=** control selects the waveform source related to the horizontal X axis. You can set the **X=** source to:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4
- spectrum 1 and 2

**Y=**

The **Y=** selects the waveform source related to the vertical Y axis. You can set the **Y=** source to:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4

- spectrum 1 and 2

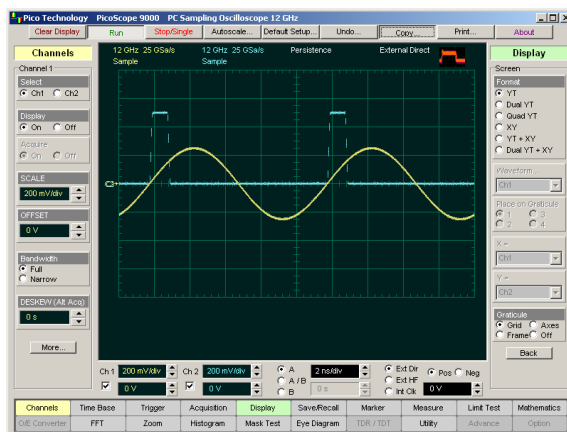
## 5.3.6.5 Graticule



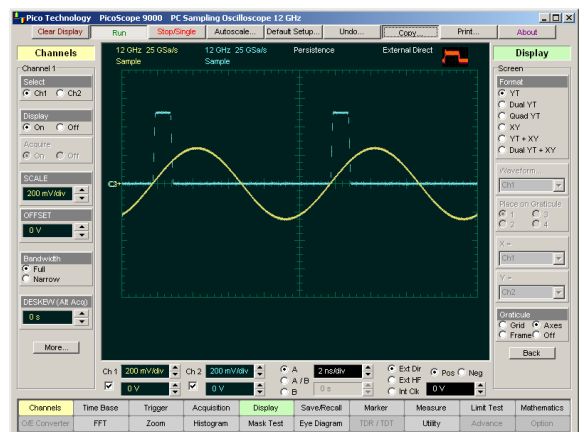
The PicoScope 9000 has a 10 by 8 display graticule grid, which you can turn on or off. The **Graticule** menu selection is:

- **Grid**
- **Axes**
- **Frame**
- **Off**

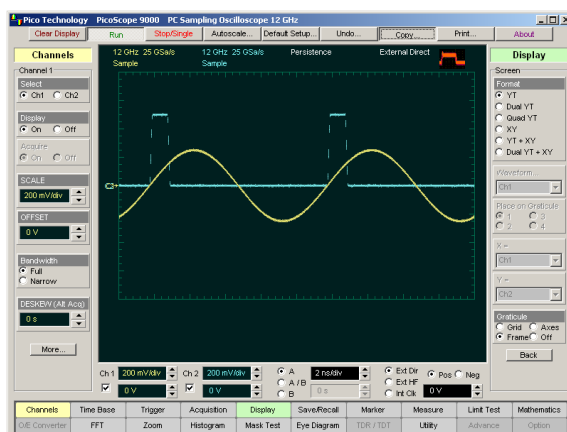
- Off.** Turns the background graticule off. The displayed waveforms and waveform information is not turned off.
- Frame.** Displays the outside border with a measurement scale. The measurement scale is incremented/decremented with major divisions and minor divisions based on the vertical and horizontal measurement settings.
- Axes.** Displays the outside border with a measurement scale and a measurement scale crossing at mid-screen.
- Grid.** The **Grid** background is complete graticule with ten horizontal major divisions and eight vertical major divisions. Vertically one minor division is one-quarter of a major division; and horizontally, one minor division is one-fifth of a major division.



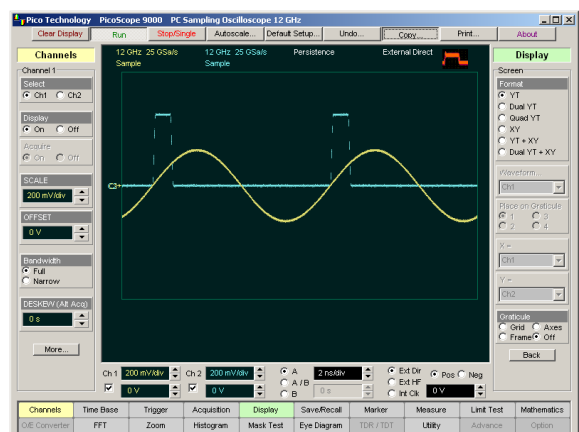
Grid Graticule



Axes Graticule



Frame Graticule



Graticule is off

### 5.3.7 Color



The **Color...** button gives you access to a second-level menu that allows you to define the display colors. You may modify the color of many items (display elements) that are displayed on the screen. For example, you can change the color of an input waveform channel for better visibility.

#### 5.3.7.1 Item



The **Item** allows you to choose from the list of display elements. You can modify the color of the channels, functions, display memories, spectrums, histogram, graticule, or screen. The color of the selected display element can be changed with the **Set Color** menu.

#### 5.3.7.2 Set Color



Clicking the **Set Color** button recalls the Windows **Color** Dialog:



**Windows Color Dialog**

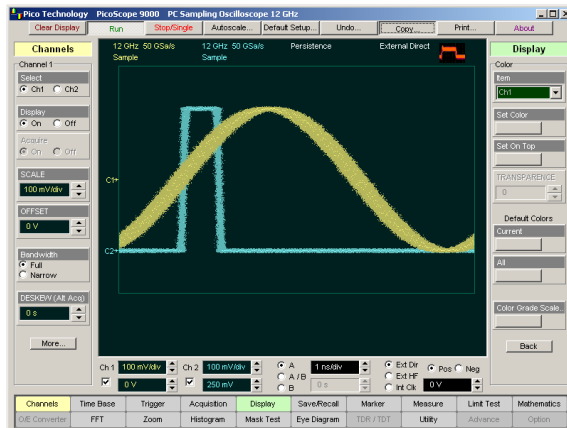
You can change the color of every item selected from the **Item** drop-down list box.



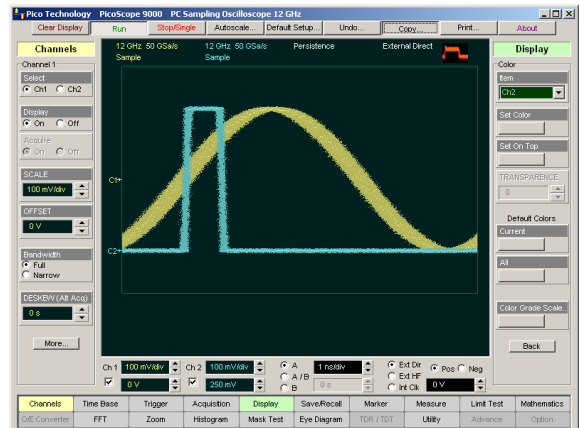
## 5.3.7.3 Set On Top



Click the **Set On Top** if you want to superimpose the display element selected from the **Item** list over all another display elements.



Channel 1 is superimposed on top



Channel 2 is superimposed on top

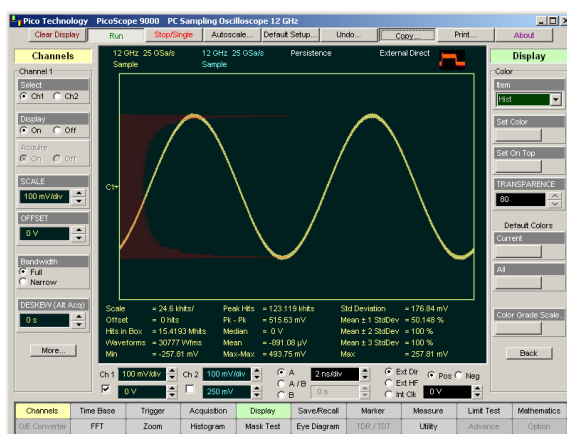
## 5.3.7.4 TRANSPARENCY



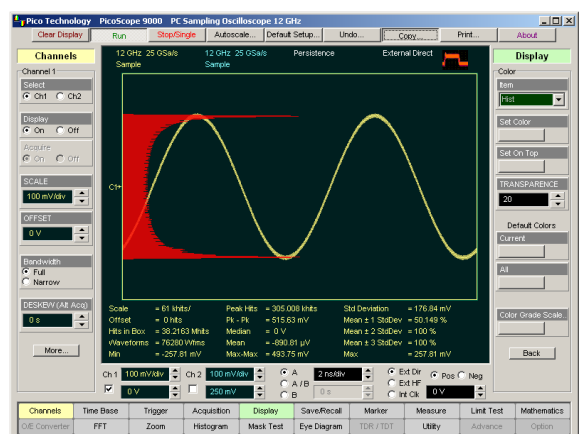
You can change the transparency of several display elements selected from the **Item** menu. They are:

- **Histogram**
- **Mask**

The **TRANSPARENCY** control increases or decreases the transparency effect.



A histogram with 80% transparency



A histogram with 20% transparency

## 5.3.7.5 Current



Clicking the **Current** button returns the selected display element to the factory default color.

## 5.3.7.6 All



Clicking the **All** returns all display elements to the factory default colors.

## 5.3.7.7 Color Grade Scale



Clicking the **Color Grade Scale...** button opens the **Color Grade Scale** menu with a list of five colors used in the color grade display.

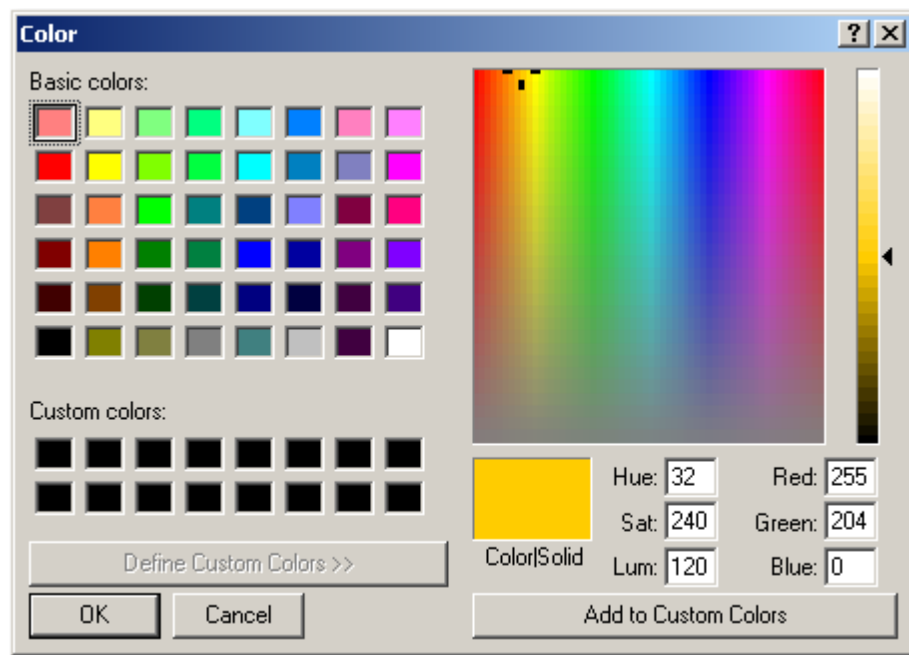
## 5.3.7.7.1 Color Grade Scale

The **Color Grade Scale** menu defines the five colors used in the color grade display. The algorithm used in the PicoScope 9000 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	<div>50% - 100%</div> <div>Set Color</div>
25% to 50%	Yellow	<div>25% - 50%</div> <div>Set Color</div>
12.5% to 25%	Rose	<div>12.5% - 25%</div> <div>Set Color</div>
6.25% to 12.5%	Light Blue	<div>6.25% - 12.5%</div> <div>Set Color</div>
0% to 6.25%	Green	<div>0 - 6.25%</div> <div>Set Color</div>

Click **Set Color** to recall the Windows **Color** Dialog:



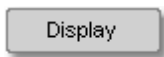
**Windows Color Dialog**

#### 5.3.7.7.2 Default Colors

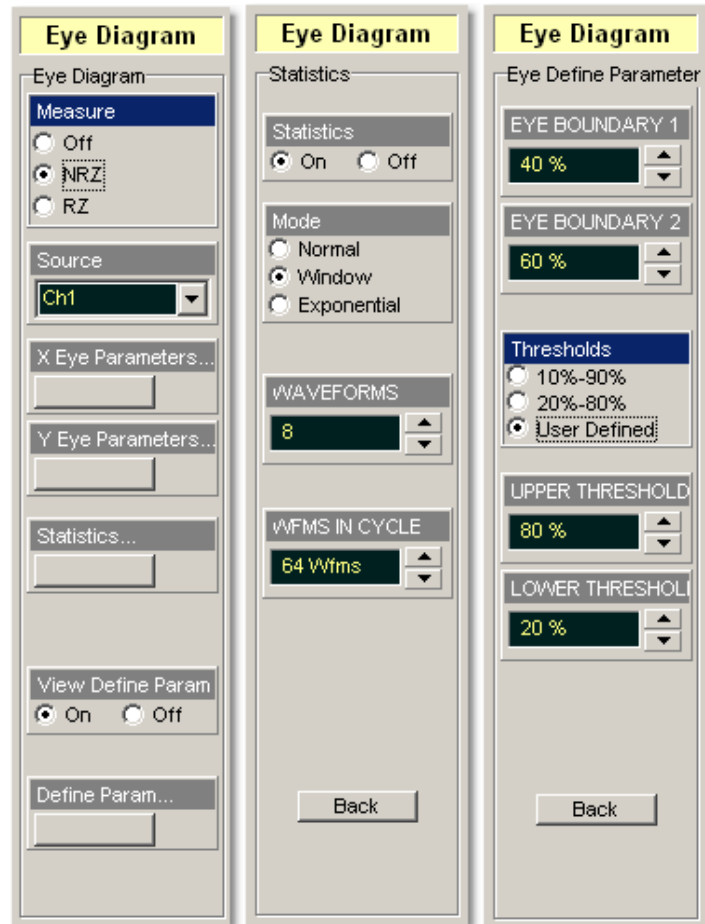


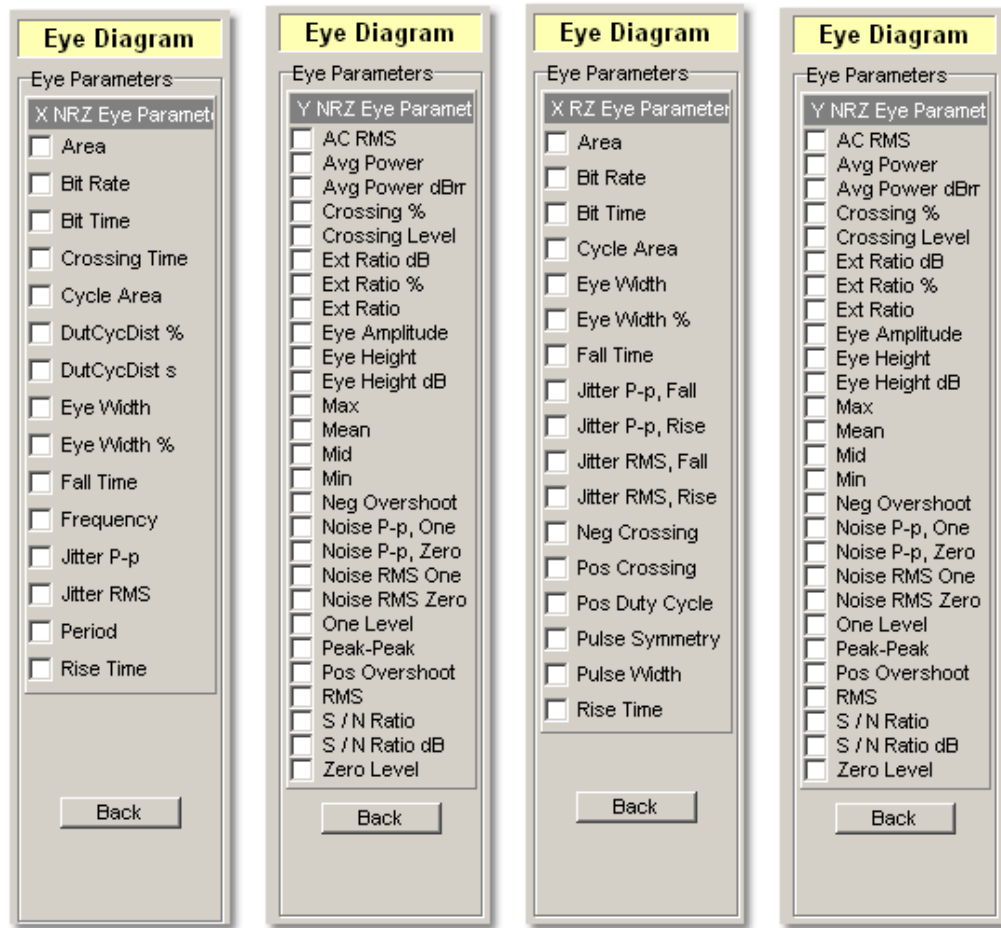
Clicking the **Default Colors** button returns all five colors used in the color-graded display to the factory default.

## 5.4 Eye Diagram Menu



The **Eye Diagram** menu allows you to perform eye diagram measurements.





**The Eye Diagram menu**



The measurement algorithms for **Eye Parameters** will only work when an eye diagram, and not a pulse, is present on the screen.

Eye measurements are based on statistical data that is acquired and stored in the measurement database. The algorithms are dependent upon histogram means calculated from the measurement database. Therefore, if you want to perform eye measurements, it is necessary that you first produce an eye diagram by triggering the instrument with a synchronous clock signal. Measurements made on a pulse waveform while in the **Eye Diagram** menu will fail.

Once the **Eye Diagram** measure menu has been selected, the measurement database is enabled. This database consists of all data samples displayed on the screen. The measurement database provides the data for the construction of histograms, generation of mask tests, and a visual representation of the eye via the color-graded display mode.



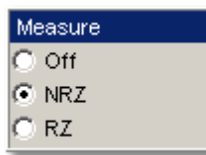
Once you are in the **Eye Diagram** menu, perform an **Autoscale**. This will ensure that an optimum eye diagram is displayed on the graticule. An optimum eye diagram consists of a full display of the eye in addition to portions of the waveform preceding and following the eye.

Data is acquired, histograms are built, and absolute maximum and minimum voltage/power levels as well as relative maximum (one) and minimum (zero) voltage/power levels are determined. The crossing points of the eye are located, the threshold levels are calculated, and then, depending on the specific measurement(s) activated, the requested parametric measurements are calculated.

Eye measurements are made in a fashion similar to many of the automatic measurements built into the instruments such as **Rise** and **Fall Time**, **Peak-Peak**, and **Frequency**. Up to four parametric measurements can be active whenever valid data exists. These measurements can include any of the eye measurements under the **X Eye Parameters...** and **Y Eye Parameters...** menus.

Eye measurements can be performed on a persistence or color-graded database.

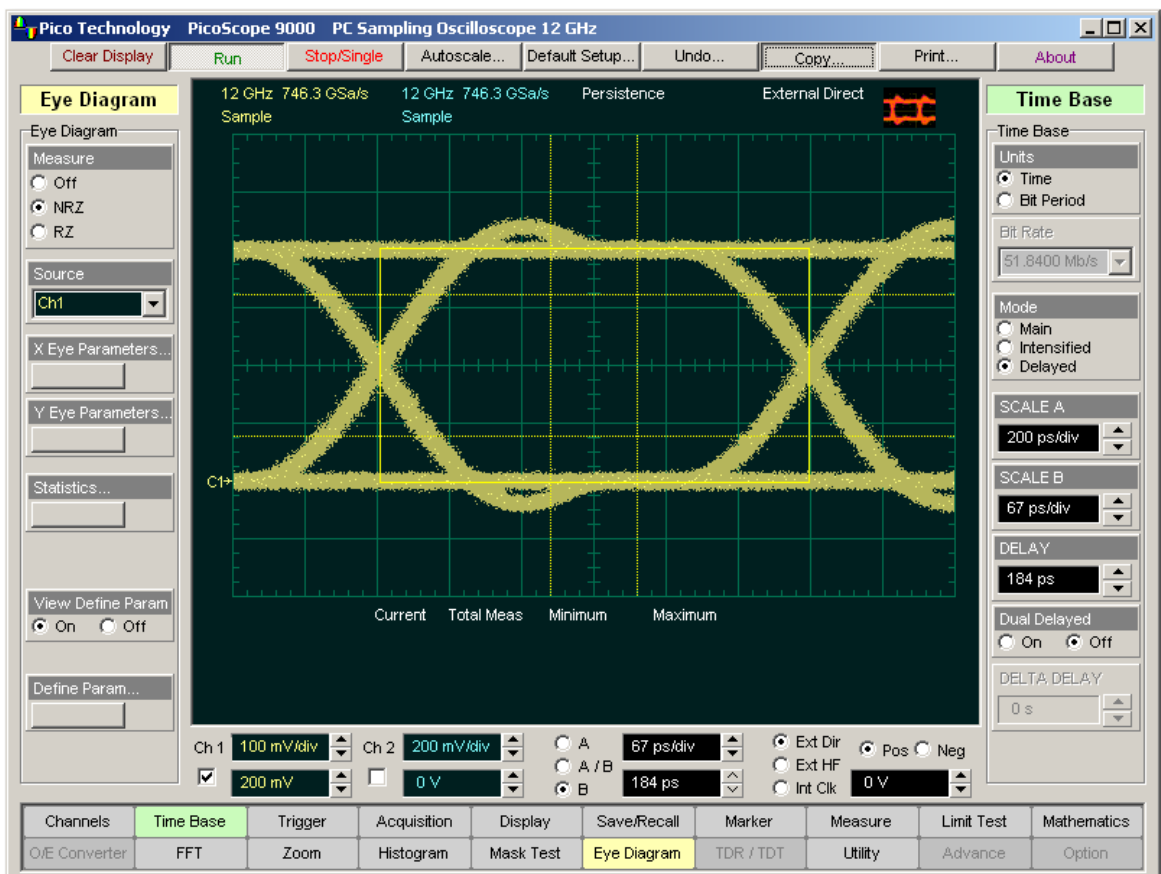
## 5.4.1 Measure

**NRZ**

Clicking the **NRZ** radio button in the **Measure** menu starts the instrument calculating the **One Level**, **Zero Level**, **Left Crossing** and **Right Crossing** for NRZ types of signal. After the calculations are finished the Eye Window, which has a red color, will appear.

**NRZ (Non-return to zero)**

A type of signal coding that ensures, in any one bit period, that the signal is turned on for the entire duration of a logical one pulse and turned off (or nearly off) for the entire duration of a logical zero pulse.



**The Levels, Crossings and Eye Boundaries of the NRZ Eye Window**



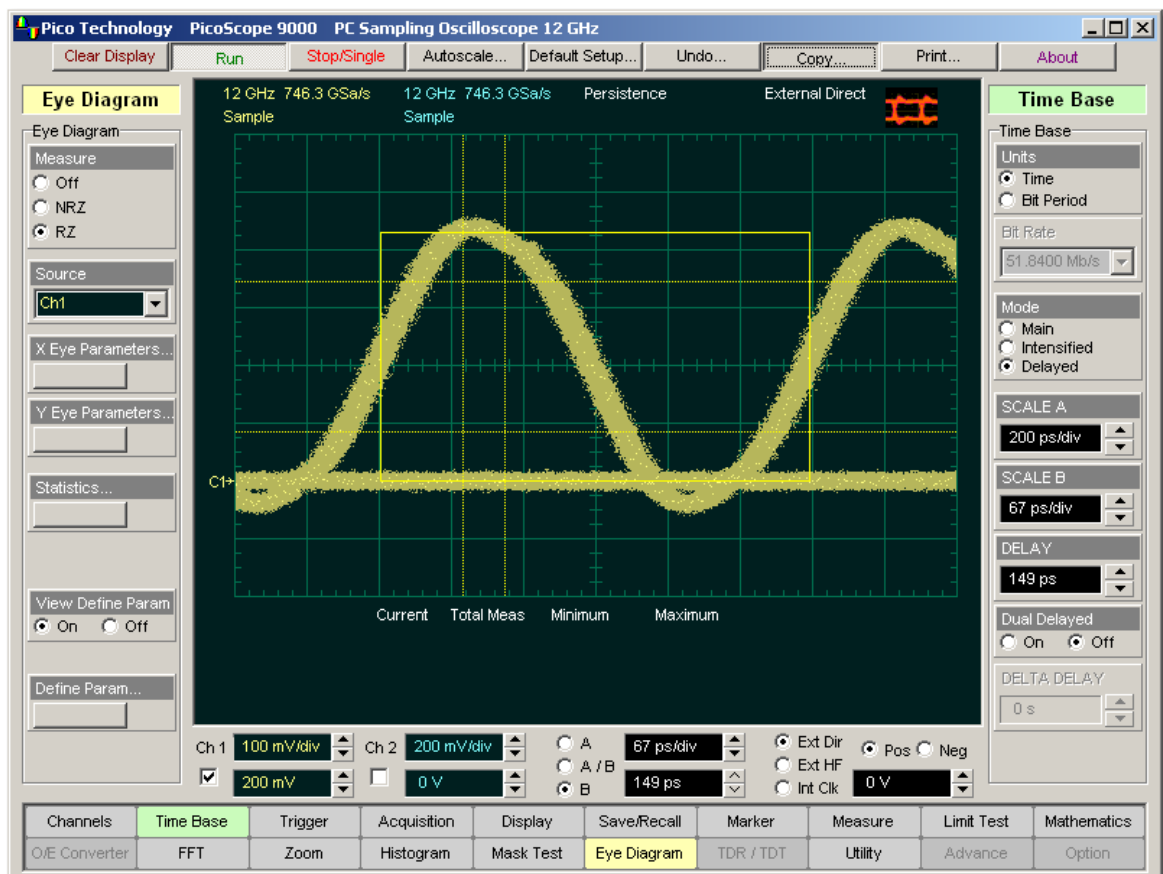
## RZ

Clicking the **RZ** radio button in the **Measure** menu starts the instrument calculating the **One Level**, **Zero Level**, **Left Crossing** and **Right Crossing** for RZ types of signal. After the calculations are finished the Eye Window, which has a red color, will appear.



### RZ (Return to zero)

A type of signal coding that ensures, in any one bit period, that the signal is turned on for the first half of a logical one pulse and turned off (or nearly off) for the second half of the logical one pulse. As with NRZ coding, the signal is turned off (or nearly off) for the entire duration of a logical zero pulse.



### The Levels, Crossings and Eye Boundaries of RZ Eye Window

## Off

Clicking the **Off** radio button stops running the test. The Eye Window, which has a red color, disappears.



The **Eye Boundaries** provide the time boundaries within which signal parameters for eye diagrams are measured.

## Measurements Results

The instrument displays the results of eye diagram measurements in the **Measurement Area** of the GUI. These values are displayed on tabs.

	Current	Total Meas	Minimum	Maximum
Bit Rate (Ch1)	2.508 GBit/s	2063	2.507 GBit/s	2.508 GBit/s
Eye Width (Ch1)	365.7 ps	1867	365.6 ps	366.6 ps
Crossing % (Ch1)	50.02 %	1346	49.99 %	50.03 %
Eye Height (Ch1)	353.4 mV	1136	353.3 mV	353.4 mV

### An example of the Eye Diagram Measure tab

The tabs only appear as the selected measurements are performed. For example, if you perform a **Bit Rate** measurement on channel 1, only this tab will appear on the display.

The measurement database and the graticule display will clear when you perform the following events:

- Switch between operating modes in the **Display** menu
- Change vertical and horizontal scale and position
- Click on the **Clear Display** button

The **Eye Diagram Measure tab** displays a maximum of four measurements at one time. The measurements are listed in the order in which they were performed.

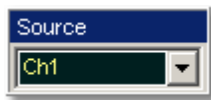
The **Measure tab** displays the following measurement statistics for each measurement:

- **Current:** the current value measured in the measurement database
- **Total Meas:** the total number of acquired measurement cycles
- **Minimum:** the minimum current value measured in the measurement database
- **Maximum:** the maximum current value measured in the measurement database



The measurement statistics reported will vary depending on the mode of operation selected.

#### 5.4.2 Source



The **Source** control selects the source you are measuring. The measurement read-outs of parameters will have the same color as the selected source.

#### 5.4.3 X Eye Parameters



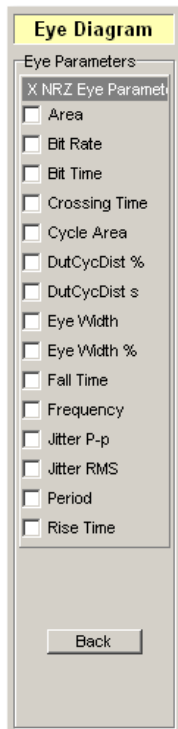
Click the **X Eye Parameters...** button to open the list of NRZ or RZ eye parameters and select any of the eye parameters for measurements.

#### 5.4.4 Y Eye Parameters

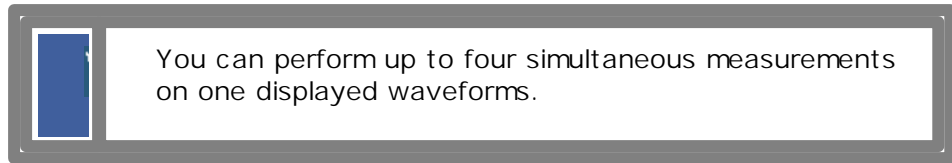


Clicking the **Y Eye Parameters...** button opens the list of NRZ or RZ eye parameters to select any of the eye parameters for measurements.

### 5.4.5 X NRZ Eye Parameters



The list of **X NRZ Eye Parameters** includes fifteen eye parameters.



The measurement algorithms for **X NRZ Eye Parameters** will only work when an NRZ eye diagram, and not an RZ eye diagram or a pulse, is present on the screen. Eye measurements are based on statistical data that is acquired and stored in the measurement database. The algorithms are dependent upon histogram means calculated from the measurement database. Therefore, if you want to perform eye measurements, it is necessary that you first produce an eye diagram by triggering the instrument with a synchronous clock signal. Measurements made on an RZ eye diagram or a pulse waveform while in the **X NRZ Eye Parameters** menu will fail.

## 5.4.5.1 NRZ Area

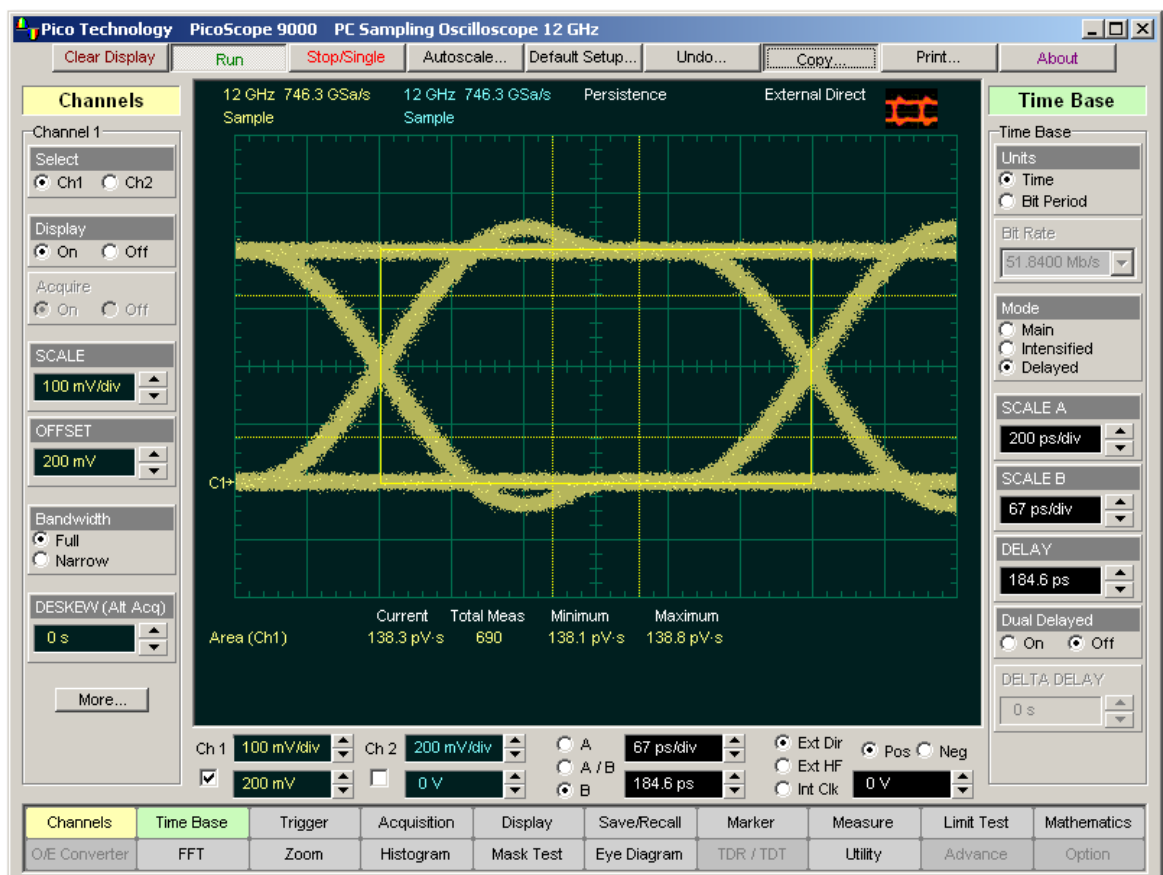


**NRZ Area** is a measure of the area under the curve for the NRZ waveform within the full display window. The area measured above ground is positive; the area measured below ground is negative.

The **NRZ Area** is determined as follows:

$$NRZ\_Area = \frac{\Delta t}{N} \sum_{n=1}^N VertPos(s_n)$$

over all  $N$  samples  $s_{1...N}$  in the measured region (full display window) of duration  $\Delta t$ .



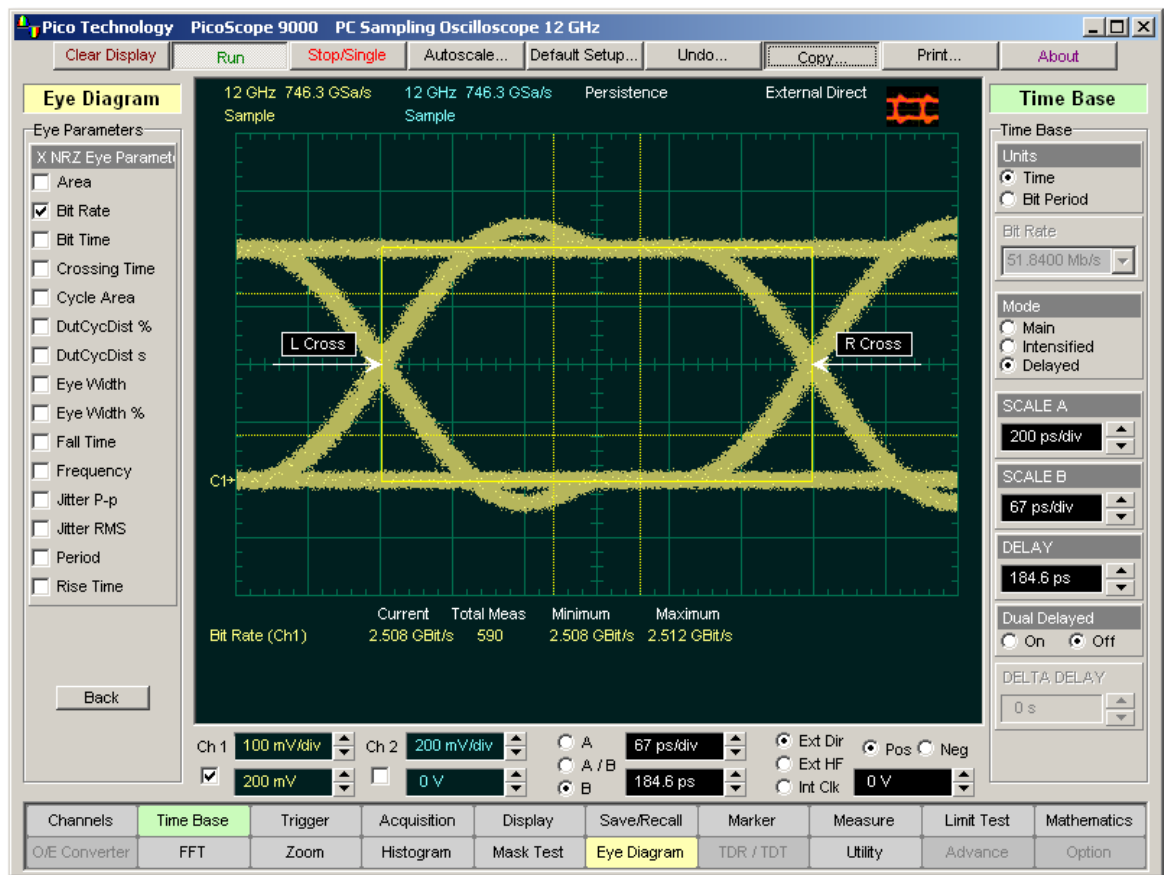
### NRZ Area definition

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.5.2 NRZ Bit Rate

☒ Bit Rate

**NRZ Bit Rate** is the inverse of bit time (1/bit time). The bit time is a measure of the horizontal opening of an eye diagram at the crossing points of the eye.



### NRZ Bit Rate definition

To compute bit time (bit period), the crossing points of the eye are first located. Then a vertically thin measurement window is placed horizontally through the crossing points. The data within this measurement window is analysed. This measurement window is created to be extremely small so that the width of the crossing points is not affected by the rise time and fall time of the waveform.

Once the bit period has been determined, the inverse value is calculated to determine the bit rate.

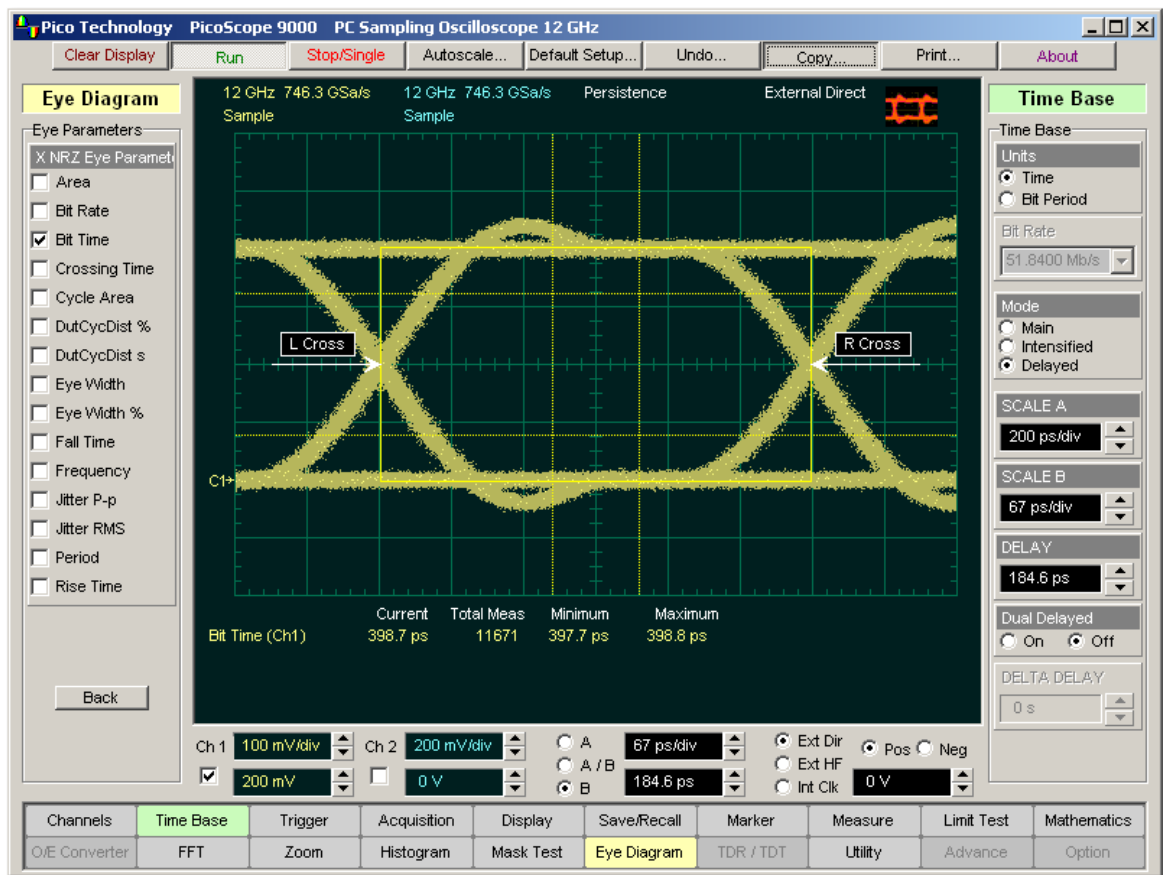
$$\text{NRZ Bit Rate} = 1 / \text{Bit Time}$$

Also see [NRZ Bit Time](#)<sup>[80]</sup>.

## 5.4.5.3 NRZ Bit Time



**NRZ Bit Time** is a measure of the horizontal opening of an eye diagram at the crossing points of the eye.



## NRZ Bit Time definition

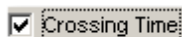
**NRZ Bit Time** can be determined as:

$$NRZ \text{ Bit Time} = T_{cross2} - T_{cross1}$$

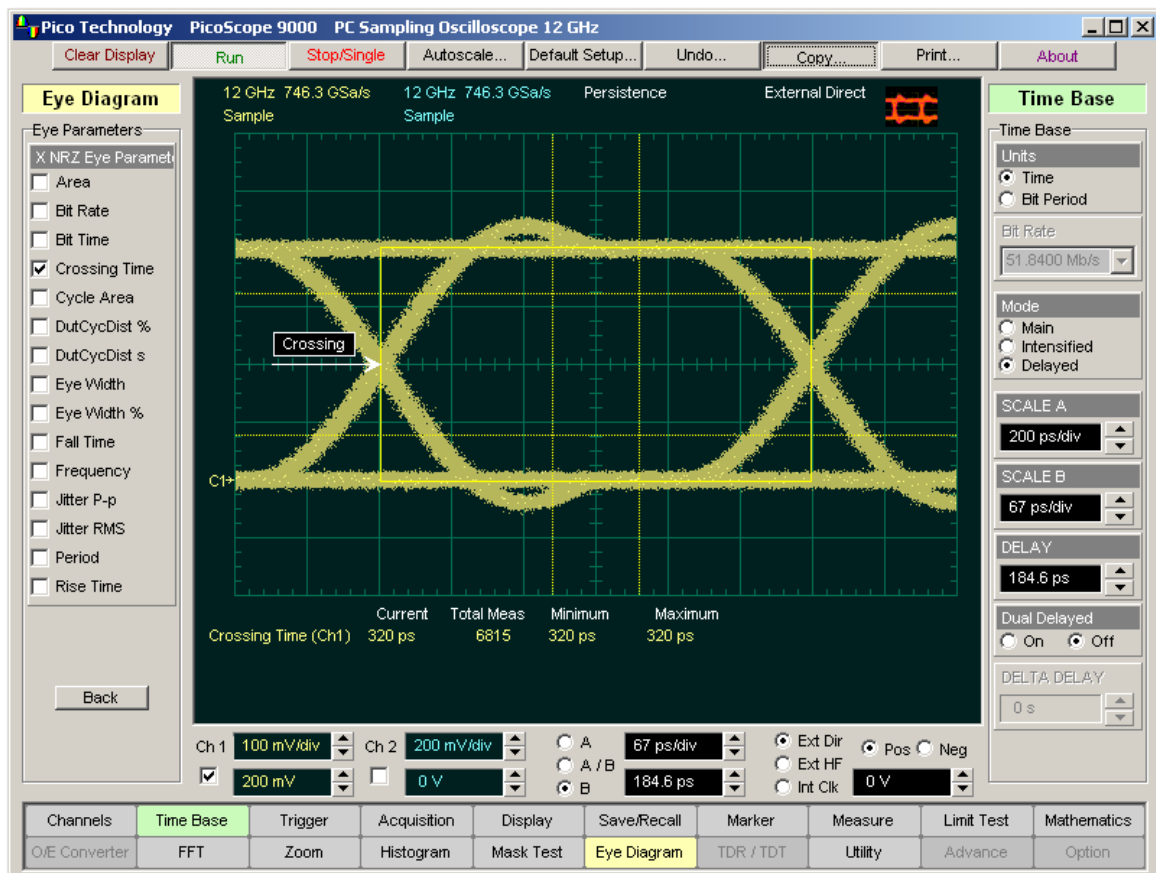
Where  $T_{cross2}$  and  $T_{cross1}$  are the mean of the histogram of the two consecutive eye crossings (**Right Crossing** and **Left Crossing**).

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.5.4 NRZ Crossing Time



**NRZ Crossing Time** is a measure of the horizontal position of the leftmost eye crossing.



### NRZ Crossing Time definition.

Data is sampled on a horizontal slice at the eye crossing, and the mean of the horizontal histogram returns the crossing time.

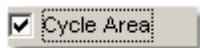
**NRZ Crossing Time** can be determined as:

$$NRZ\ Crossing\ Time = T_{cross1} + T_{delay}$$

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.



## 5.4.5.5 NRZ Cycle Area

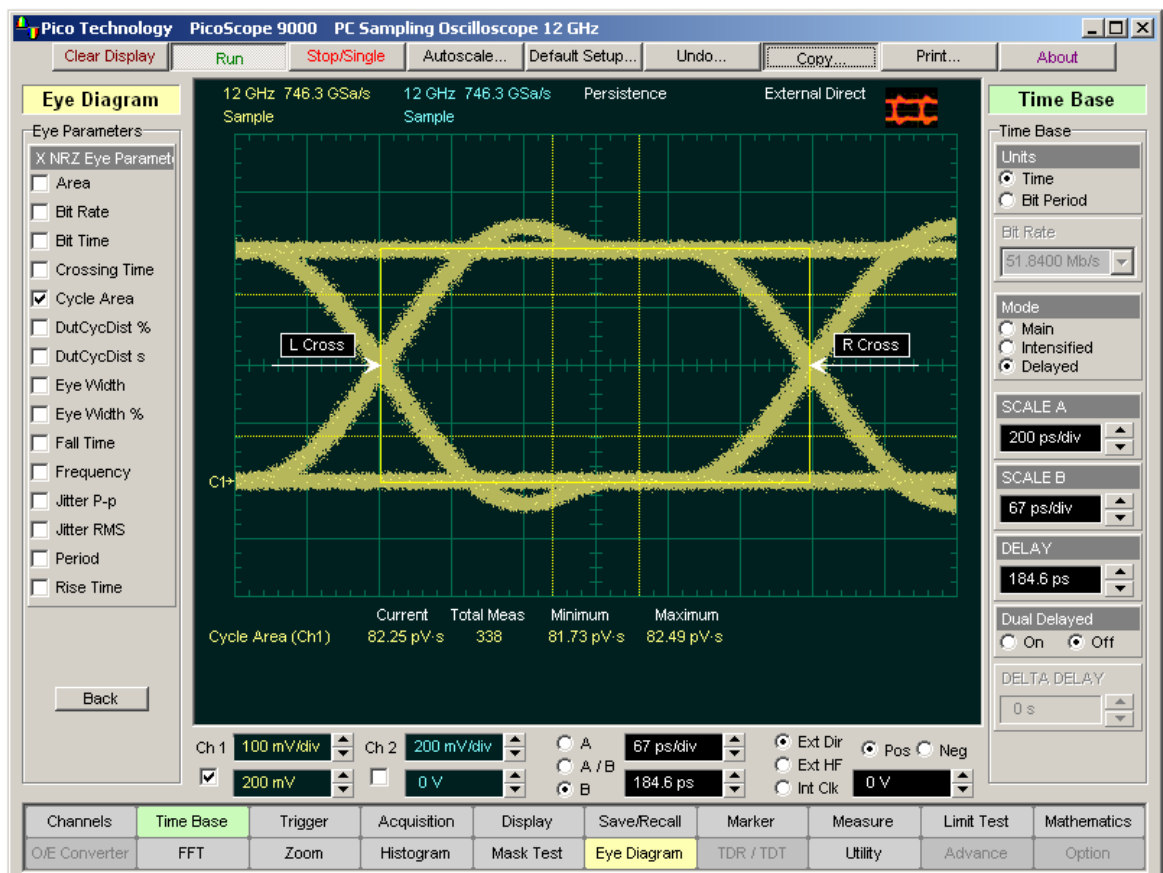


**NRZ Cycle Area** is a measure of the area under the curve for the first NRZ bit time within the measurement region. Area measured above ground is positive; area measured below ground is negative.

The **NRZ Cycle Area** is determined as follows:

$$NRZ\_CycleArea = \frac{\Delta t}{N} \sum_{n=1}^N VertPos(s_n)$$

over all  $N$  samples  $S_1...N$  within the measured region (eye window) of duration  $\Delta t$  between **Left Crossings** and **Right Crossings**. Neither slope nor direction is settable.



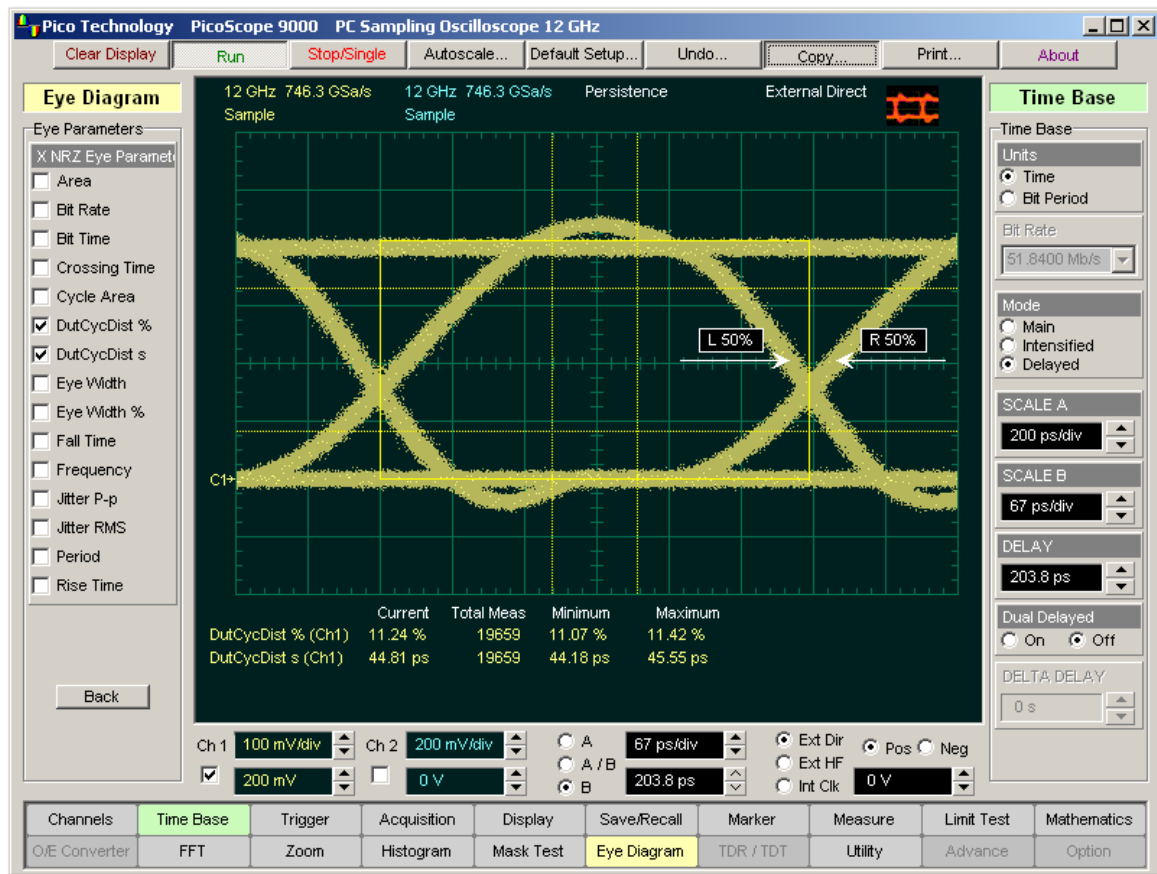
## NRZ Cycle Area definition

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.5.6 NRZ Duty Cycle Distortion % and NRZ Duty Cycle Distortion s

- ☒ DutCycDist %
- ☒ DutCycDist s

**NRZ Duty Cycle Distortion** is a measure of the time between the falling edge and the rising edge of the eye pattern at the middle threshold (50% level).



### Measurement of Duty Cycle Distortion. NRZ eye diagram has significant distortion.

The instrument constructs a histogram that records the time at which the rising edge and falling edge cross the middle threshold. If the falling edge and the rising edge intersect precisely at the middle thresholds, there is no duty cycle distortion. **NRZ Duty Cycle Distortion** is measured by histogram analysis at the crossing points and middle threshold.



The algorithm for calculating **NRZ Duty Cycle Distortion** is dependent upon the edge that crosses the threshold first. Therefore, the falling edge may occur prior to the rising edge. Ideally, both the rising and falling edges intersect precisely at the 50% threshold level. That results in no duty cycle distortion.

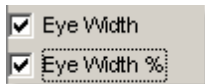
**NRZ Duty Cycle Distortion** can be displayed in two formats: time or percent. In the time format (**DutCycDis s**), the actual time between the median falling edge and the median rising edge at the middle thresholds is determined. In the percentage format (**DutCycDis %**), the time difference is determined as a percentage of the full bit time.

The **NRZ Duty Cycle Distortion** is determined as follows:

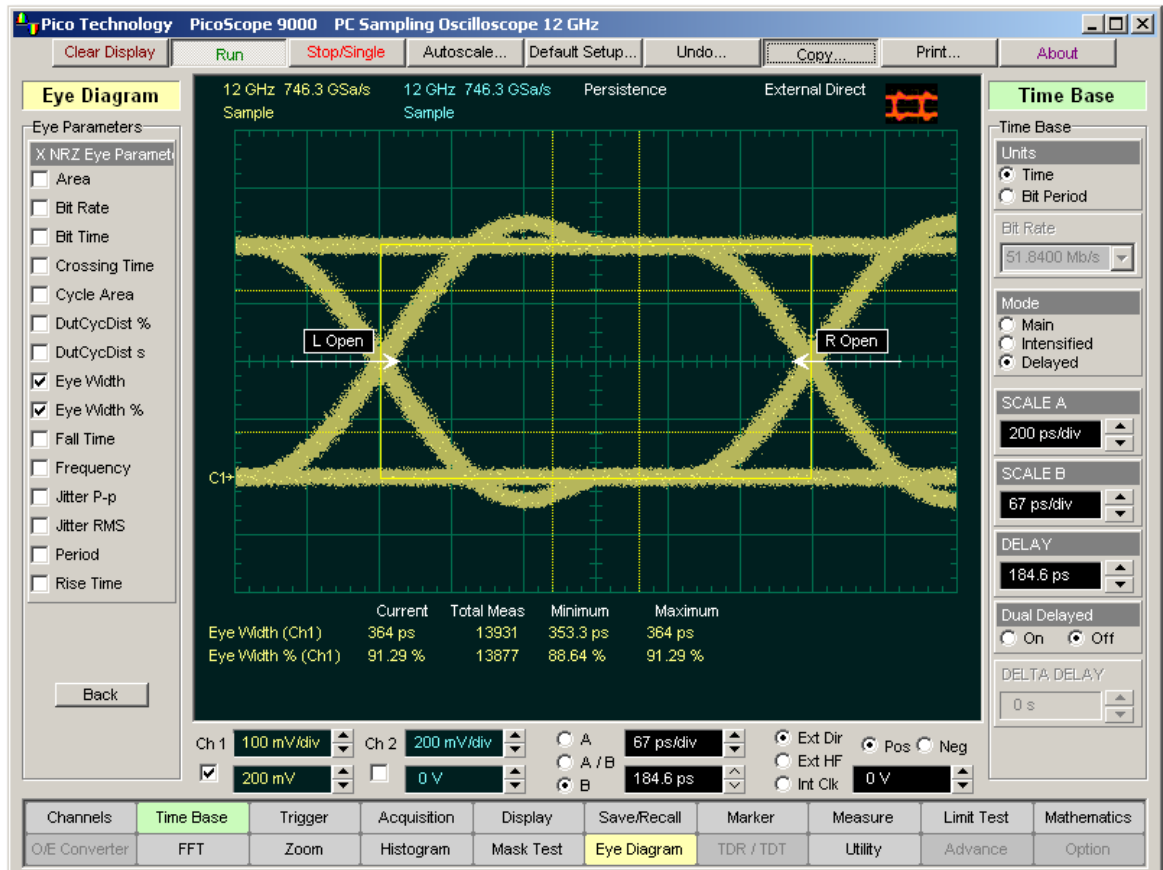
$$NRZ\_DutyCycleDistortion = Trise_{50\text{ percent}} - Tfall_{50\text{ percent}}$$

$$NRZ\_DutyCycleDistortion = \frac{Trise_{50\text{ percent}} - Tfall_{50\text{ percent}}}{BitPeriod}$$

## 5.4.5.7 NRZ Eye Width and NRZ Eye Width %



**NRZ Eye Width** is a measure of the horizontal opening of an eye diagram. Ideally, the eye width would be measured between the crossing points of the eye. A horizontal time histogram is constructed to determine the mean location at the crossing points, as well as statistical distribution of the crossing points. As would be expected, noise and jitter will cause a large variance in the location of the crossing points and result in the closure of the eye.

**NRZ Eye Width definition**

The eye width is determined using the time difference between the 3 (standard deviation) points of the crossing point histograms (**Eye Width** measurement).

$$NRZ\_EyeWidth = (T_{cross2} - 3\sigma_{cross2}) - (T_{cross1} - 3\sigma_{cross1})$$

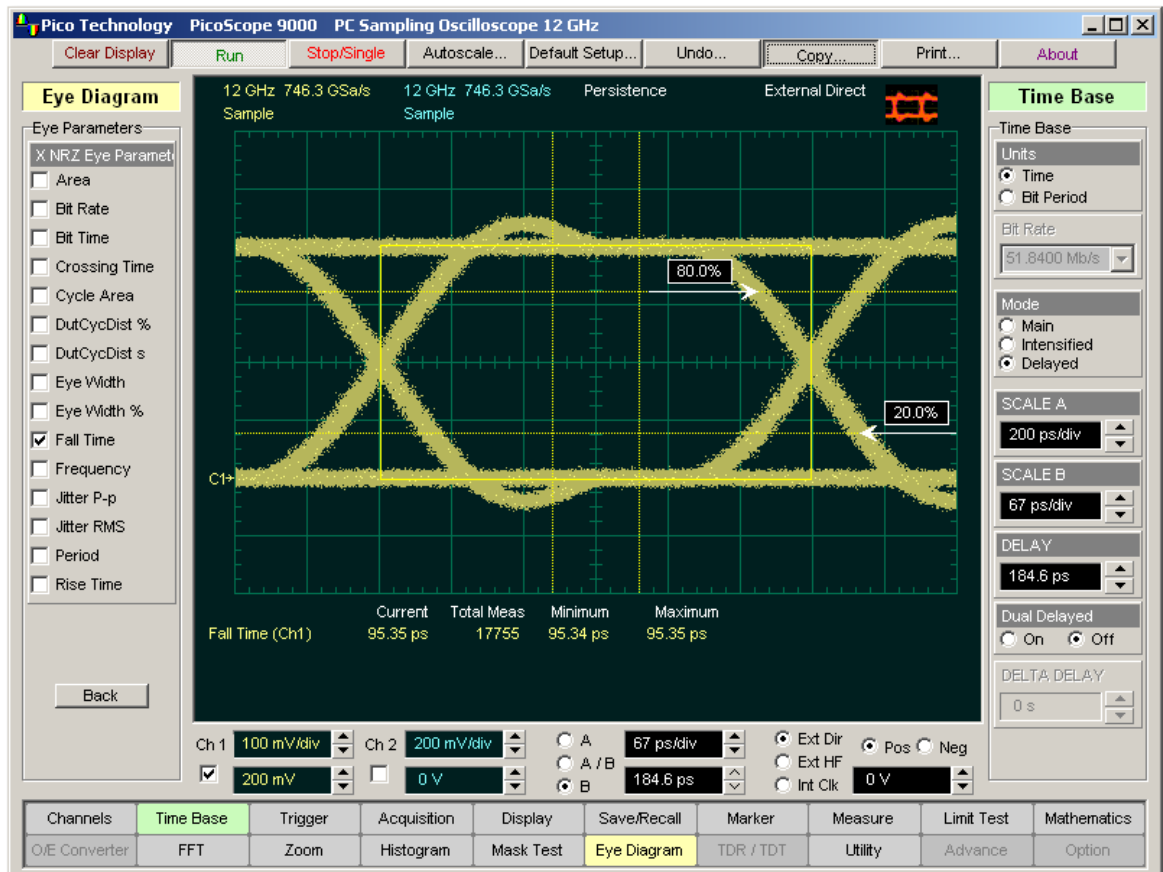
You can choose to view eye width as a ratio of the time difference between the 3 points of the crossing point histograms relative to the time between adjacent crossing points (bit period). The eye width can then be expressed in percent of the bit period (**Eye Width %** measurement).

$$NRZ\_EyeWidth\_ \% = \frac{(T_{cross2} - 3\sigma_{cross2}) - (T_{cross1} - 3\sigma_{cross1})}{T_{cross2} - T_{cross1}}$$

## 5.4.5.8 NRZ Fall Time

☒ Fall Time

**NRZ Fall Time** is a measure of the mean transition time of the data on the downward slope of an eye diagram. The data crosses through the following three thresholds: the upper, middle, and lower thresholds, as well as through the eye crossing points.



### NRZ Fall Time definition

A histogram is first constructed to find the mean location of the crossing points relative to the one level and zero level. Histograms are then constructed at each of the three threshold levels (for example, the 10%, 50%, and 90% points on the transition). The instrument analyses each histogram to determine the histogram mean at which the data crosses the separate threshold levels.

Once the scanning of the waveform is complete, and the instrument has identified the mean location for each threshold crossed, then fall time can be computed.

$$\text{NRZ Fall Time} = (\text{Time at the Lower Threshold Crossing}) - (\text{Time at the Upper Threshold Crossing})$$

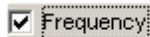
The instrument has two standard threshold levels for which fall time may be measured. The default setting is between the 20% and 80% points on the transition, and the second is between the 10% and 90% points on the transition. The 20% to 80% transition is recommended for devices with significant pulse distortion. Also, user defined threshold levels can be selected. You can define the threshold settings that you want by going to the [Define Parameters/Thresholds](#) <sup>[160]</sup> menu.



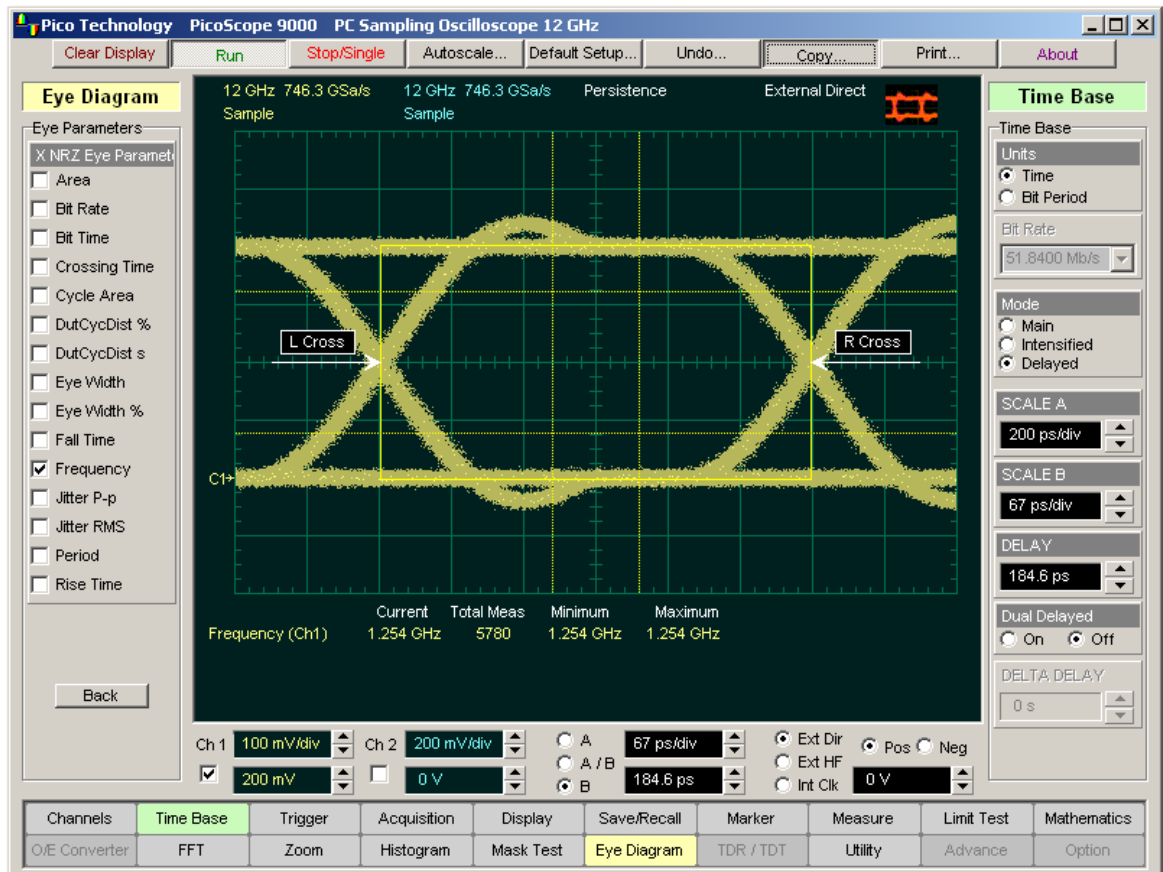
If the fall time relative to the time per division is a small value, the data acquired at the threshold levels on the falling edge will not yield accurate measurement results. (The falling edge will appear very steep on the display screen.)

If the falling edge of your eye diagram is steep, increase the timebase (horizontal scale) on the display so that the falling edge covers at least half a graticule division. The instrument will be able to discern the data at the threshold levels, producing more accurate results.

## 5.4.5.9 NRZ Frequency



**NRZ Frequency** is defined as half of the inverse of the time interval between two consecutive eye crossing points (i.e. the reciprocal of the **Period**). It would be the frequency of a digital signal of a 0-1-0-1... stream.



## NRZ Frequency definition

The **NRZ Frequency** is determined as follows:

$$NRZ\_Frequency = \frac{1}{2(T_{cross2} - T_{cross1})}$$

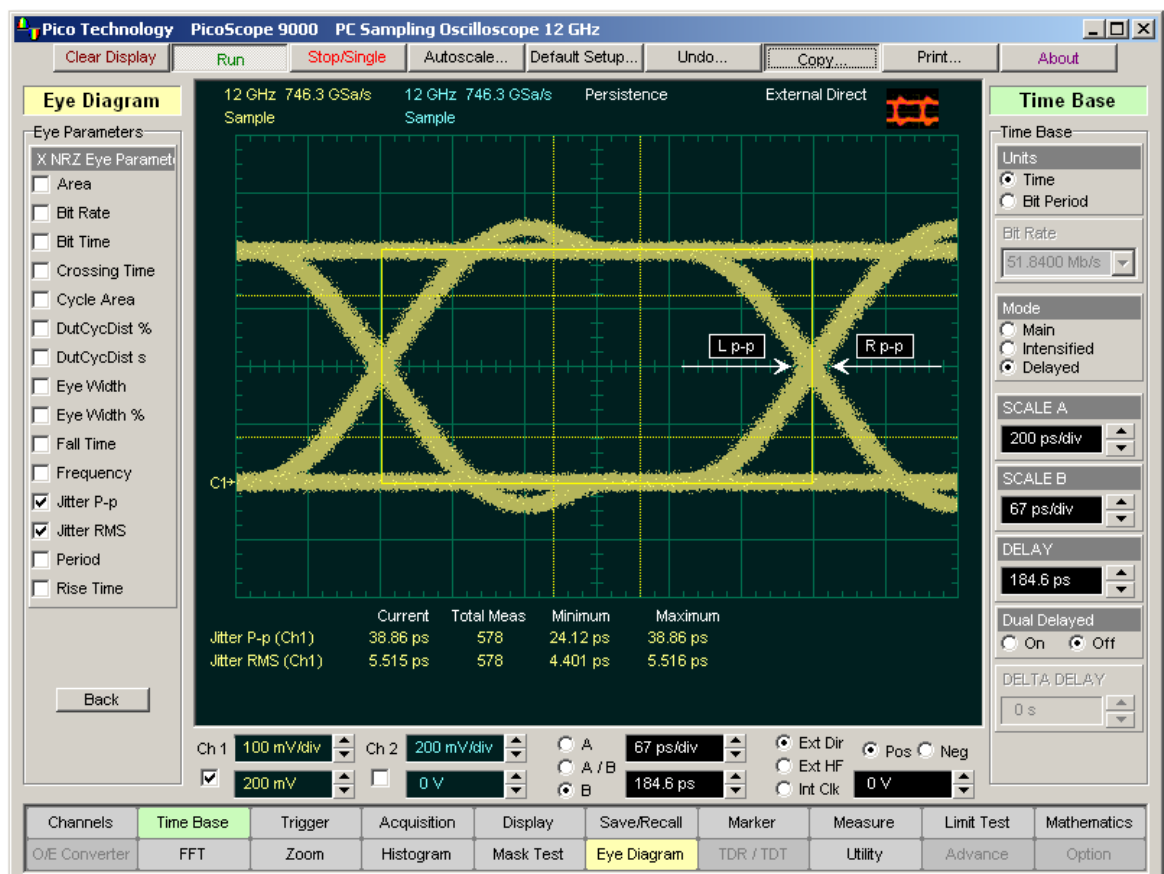
where  $T_{cross1}$  and  $T_{cross2}$  are the means of the histograms of the two crossings.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.5.10 NRZ Jitter p-p and NRZ Jitter RMS

- ☒ Jitter P-p  
☒ Jitter RMS

**NRZ Jitter** is a measurement of the time variance of the crossing points. Horizontal time histograms are constructed to determine the location of the crossing points. An iterative process is used to narrow the histogram window to precisely determine the crossing points and the variance. The measurement window is kept extremely small so that the width of the crossing points is not influenced by the rise time and fall time of the waveform. The amount of jitter on the waveform is directly related to the width of the crossing points.

**NRZ Jitter definition**

**NRZ Jitter** can be displayed in one of two formats: peak-to-peak (**NRZ Jitter p-p** measurement) or RMS (**NRZ Jitter RMS** measurement). Both values are based on the standard deviation of the crossing point position.

**NRZ Jitter peak-to peak** is equal to the full width of the histogram at the eye crossing point:

$$NRZ\ Jitter\ p-p = 6\sigma\ (crossing)$$

**NRZ Jitter RMS** is defined as one standard deviation from the histogram mean at the eye crossing point:

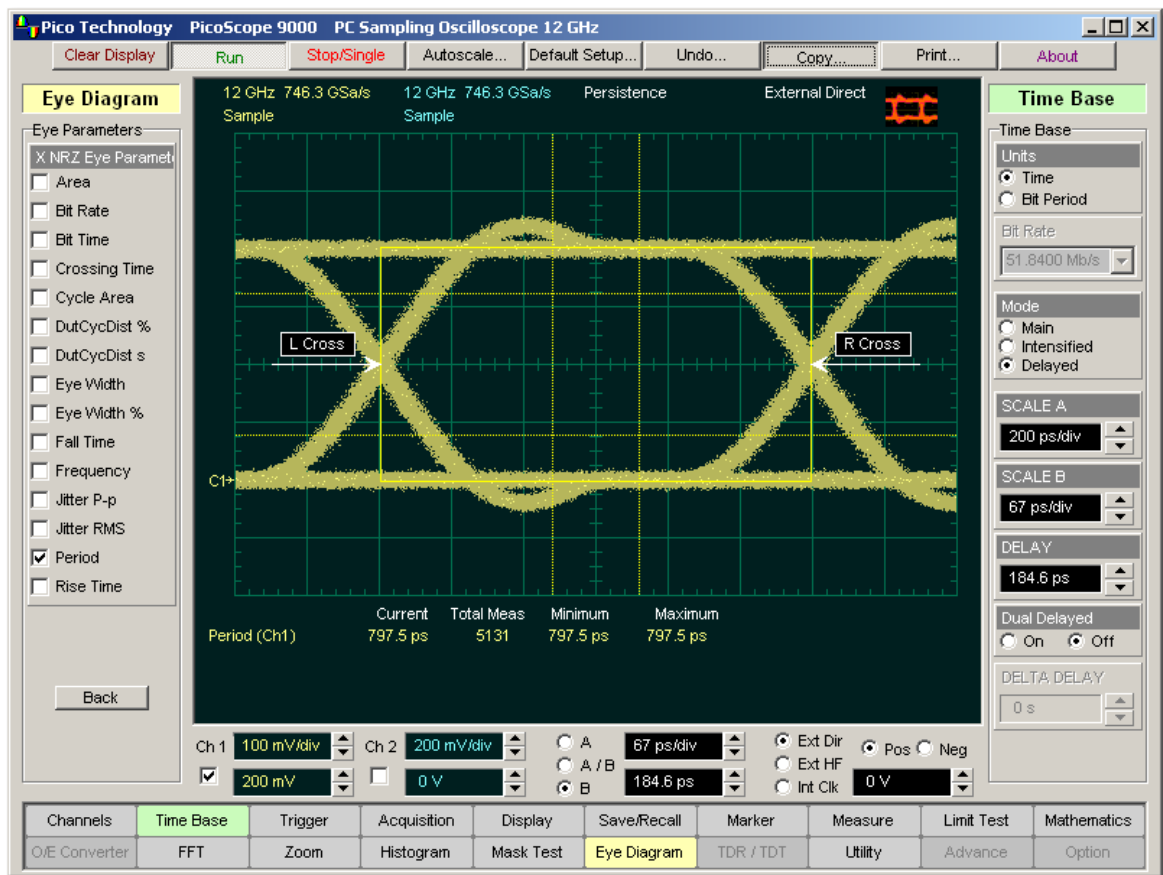
$$NRZ\ Jitter\ RMS = 1\sigma\ (crossing)$$



## 5.4.5.11 NRZ Period



**NRZ Period** is twice the time interval between two consecutive eye-crossing points. It would be the period of a digital signal of a 0-1-0-1... stream.

**NRZ Period definition**

**NRZ Period** can be defined as:

$$NRZ\_Period = 2(T_{cross2} - T_{cross1}) = 2(NRZ\_BitTime)$$

where  $T_{cross1}$  and  $T_{cross2}$  are the means of the histograms of the two crossings of the eye diagram (**Right Crossing** and **Left Crossing**).

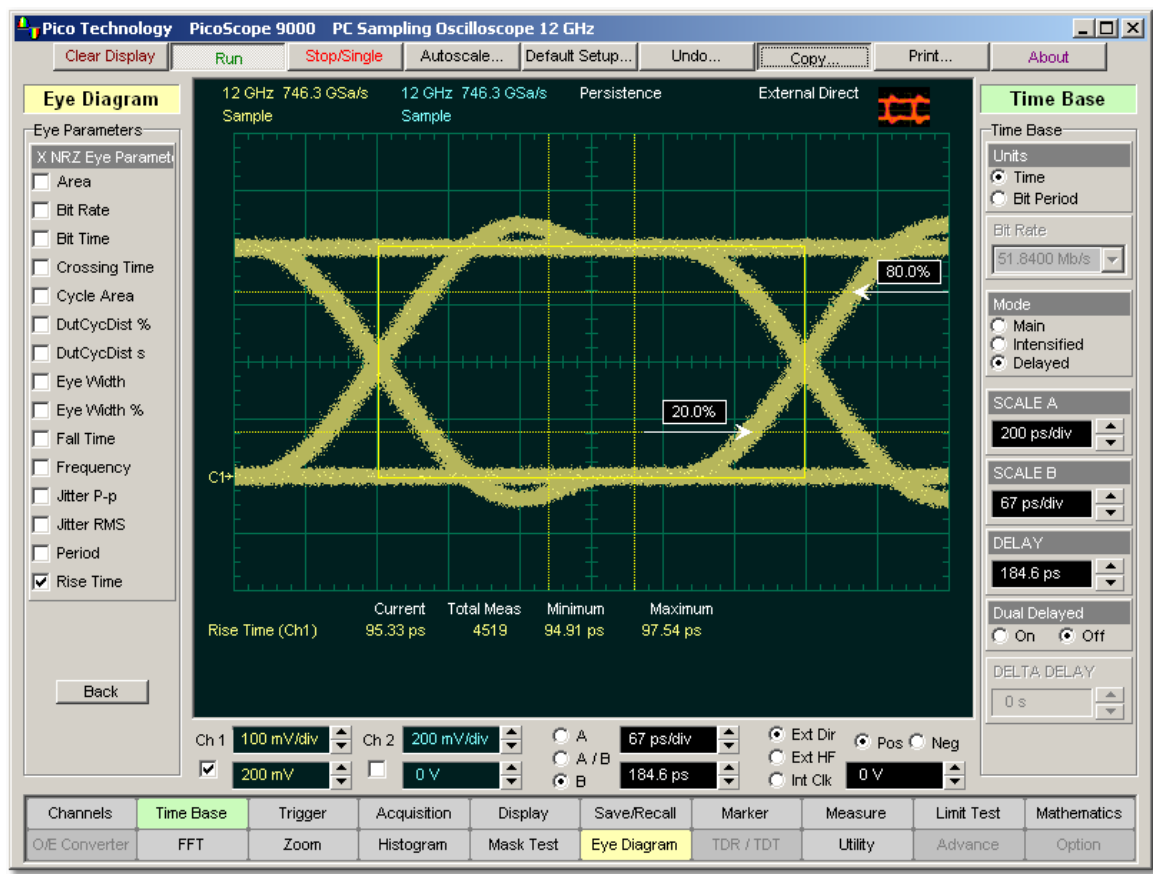
This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

Also see [NRZ Bit Time](#) <sup>[80]</sup>.

## 5.4.5.12 NRZ Rise Time

☒ Rise Time

**NRZ Rise Time** is a measure of the mean transition time of the data on the upward slope of an eye diagram. The data crosses the lower, middle, and upper thresholds, as well as the eye crossing points.



### NRZ Rise Time definition

A histogram is first constructed to find the mean location of the crossing points relative to the one level and zero level. Histograms are then constructed at each of the three threshold levels (for example, the 10%, 50%, and 90% points on the transition). The instrument analyses each histogram to determine the histogram mean at which the data crosses the separate threshold levels.

Once the scanning of the waveform is complete, and the instrument has identified the mean location for each threshold crossed, then rise time can be computed.

$$\text{NRZ Rise Time} = (\text{Time at the Upper Threshold Crossing}) - (\text{Time at the Lower Threshold Crossing})$$

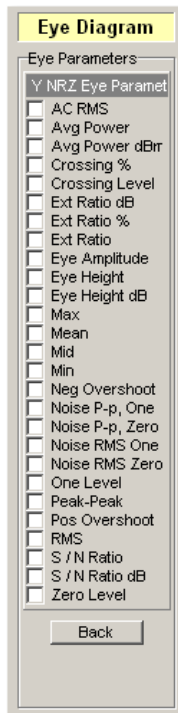
The instrument has two standard threshold levels for which fall time may be measured. The default setting is from the 10% to the 90% point on the transition, and the second is from the 20% to the 80% point on the transition. The 20% to 80% transition is recommended for devices with significant pulse distortion. Also, user defined threshold levels can be selected. You can define the threshold settings that you want by going to the [Define Parameters/Thresholds](#) <sup>160</sup> menu.



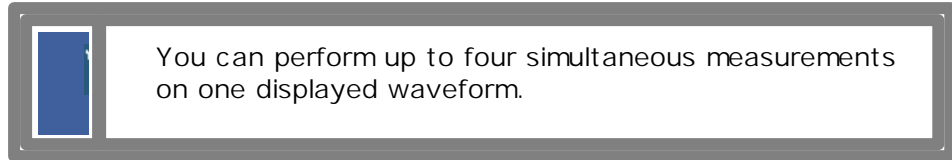
If the rise time relative to the time per division is a small value, the data acquired at the threshold levels on the falling edge will not yield accurate measurement results. (The rising edge will appear very steep on the display screen.)

If the rising edge of your eye diagram is steep, increase the timebase (horizontal scale) on the display so that the rising edge covers at least half a graticule division. The instrument will be able to discern the data at the threshold levels, producing more accurate results.

#### 5.4.6 Y NRZ Eye Parameters



The list of **Y NRZ Eye Parameters** includes twenty-seven eye parameters. Two of the them (**Avg Power** and **Avg Power dBm**) can be used in optical models only.

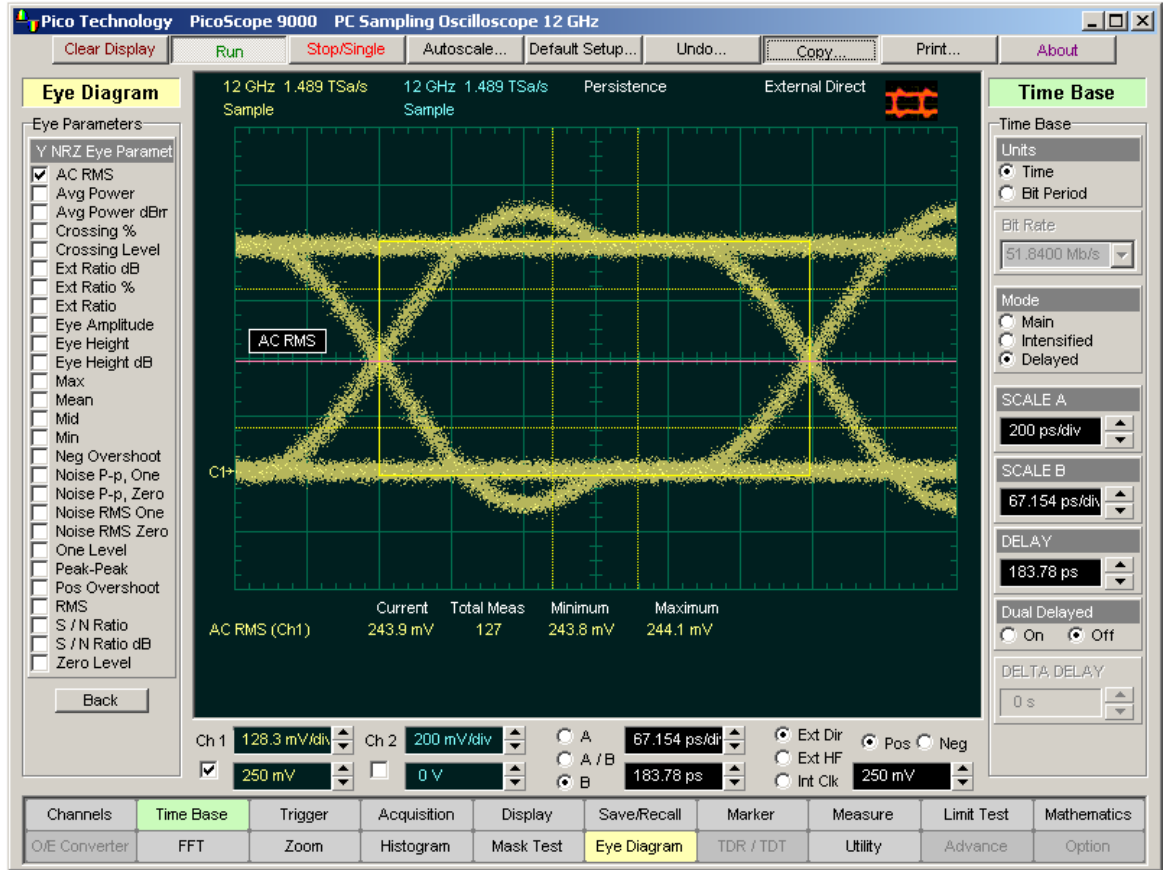


The measurement algorithms for **Y NRZ Eye Parameters** will only work when an NRZ eye diagram, and not an RZ eye diagram or a pulse, is present on the screen. Eye measurements are based on statistical data that is acquired and stored in the measurement database. The algorithms are dependent upon histogram means calculated from the measurement database. Therefore, if you want to perform eye measurements, it is necessary that you first produce an eye diagram by triggering the instrument with a synchronous clock signal. Measurements made on an RZ eye diagram or a pulse waveform while in the **X NRZ Eye Parameters** menu will fail.

## 5.4.6.1 NRZ AC RMS



**NRZ AC RMS** is a measure of the root mean square amplitude, minus the DC component, of the selected waveform.

**NRZ AC RMS definition**

The **NRZ AC RMS** is defined as follows:

$$NRZ\_AC\_RMS = \sqrt{\frac{\sum_{i=1}^N \langle [VertPos(s_i) - mean[VertPos(s)]]^2 \rangle}{N}}$$

where  $s$  is the set of  $N$  samples  $s_{1...N}$  within the measured region.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.2 NRZ Crossing % and NRZ Crossing Level



**NRZ Crossing** percentage is a measure of the location of the eye crossing points relative to the separation between the **One Level** ( $V_{one}$ ) and the **Zero Level** ( $V_{zero}$ ).

Typically, it is desirable to have the crossing points located midway between  $V_{one}$  and  $V_{zero}$ . In this case the crossing percentage would be 50% according to the following formula:

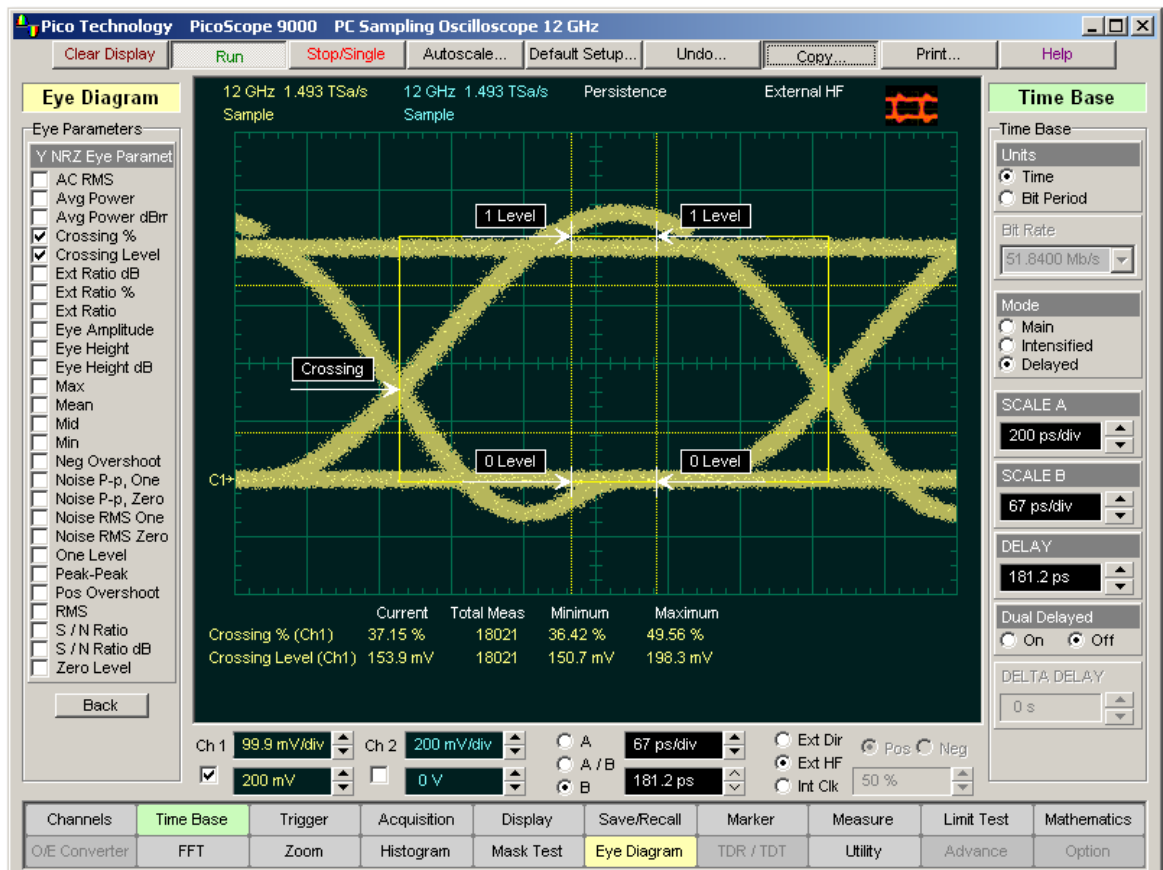
$$NRZ \text{ Crossing percentage} = 100 (V_{cross} - V_{zero}) / (V_{one} - V_{zero})$$

**NRZ Crossing Level** is the mean signal level at the eye crossing point:

$$NRZ \text{ Crossing Level} = \text{mean}[VertPos(s)]$$

where  $s$  is the set of samples in a vertical slice at the eye crossing point.

$V_{cross}$  is the more prevalent vertical location or amplitude of the crossing points. A horizontal histogram over the entire display is used to determine the time location of the crossing points. Narrow vertical histograms are then used to determine the vertical location of  $V_{cross}$ . The mean derived from the horizontal and vertical histogram results in  $V_{cross}$ .



**Example of eye diagram with low Crossing Level value**

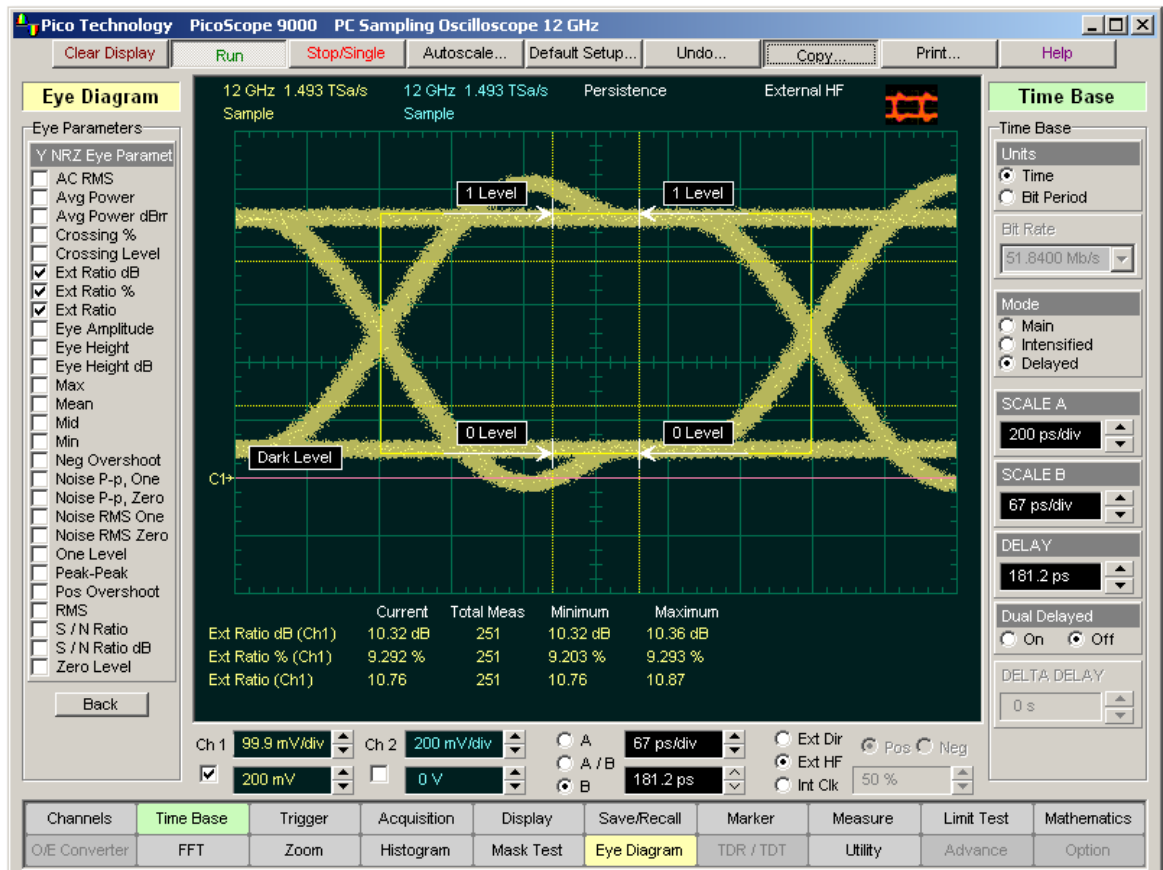


*Vone* and *Vzero* are calculated from a histogram using data within the eye window. These measurements are made in the central of the bit period (within **Eye Boundaries**). The default value is 20% of the NRZ bit time.

## 5.4.6.3 NRZ Extinction Ratio dB, NRZ Extinction Ratio % and NRZ Extinction Ratio



**NRZ Extinction Ratio** for an eye diagram is simply the ratio of the logic “high” level (*Vone* or *Pone*) to the logic “low” level (*Vzero* or *Pzero*). A very high extinction ratio typically implies that the logic low level is very small. In the case of an optical transmitter, the logic low level would approach a condition where the laser is nearly turned off.

**NRZ Extinction Ratio definition**

The accuracy of the extinction ratio can be dominated by the accuracy with which the low level was measured. This in turn can be significantly affected by any noise generated by the measurement system such as external converters, DC offsets, or electrical offsets in the instrument electronics. When these offsets occur, they add to the incoming signal. This will change the values of the one and zero levels. When the extinction ratio measurement is computed, the result may appear much smaller or larger than the true value, depending on the value of the offset.

To minimize extinction ratio measurement errors due to offsets, an extinction ratio calibration is recommended. This procedure allows the instrument to identify any internal signals present and remove them during the extinction ratio calculations. After the calibration is performed, a more accurate extinction ratio measurement can be executed.

Thus the extinction ratio measurements can be defined in one of the three following formats:



$$NRZ\_ExtinctionRatio(dB) = 10 \log_{10} \left( \frac{V_{one} - V_{dark}}{V_{zero} - V_{dark}} \right)$$

$$NRZ\_ExtinctionRatio(\%) = \frac{V_{one} - V_{dark}}{V_{zero} - V_{dark}} \times 100$$

$$NRZ\_ExtinctionRatio = \frac{V_{one} - V_{dark}}{V_{zero} - V_{dark}}$$

*Vone* (or *Pone*) and *Vzero* (*Pzero*) are determined from vertical histograms of the eye window. The histogram is typically bimodal, and *Vone* and *Vzero* correspond to the two means of the histogram. Histograms are constructed using the sampled portions of the eye diagram within the central 20% of the bit period (between the **Eye Boundaries**). One histogram is composed of data points from only the upper half of the eye diagram (one level). The second histogram is composed of data points from the lower half of the eye (zero level). The instrument analyses the histograms and determines the histogram means.



The vertical scale setting affects the magnitude of the offset.

For best accuracy, perform the extinction ratio calibration at the vertical scale at which you will make your measurement. You can then adjust the vertical scale between and up to the next closest scale value in the 1-2-5 sequence. For example, if you set the vertical scale to 50 mV and then performed an extinction ratio calibration, you can adjust the scale between and up to 20 mV and 100 mV. If you exceed those upper and lower values, the instrument will recommend that you perform another extinction ratio calibration at the new value. This recommendation is to ensure best measurement accuracy. You will still get valid measurement results without a new extinction ratio calibration, but with potentially lower precision.

Since the extinction ratio measurement is based on the histogram means of the one and zero levels, noise on the waveform typically does not have a significant effect on the accuracy of the measurement.

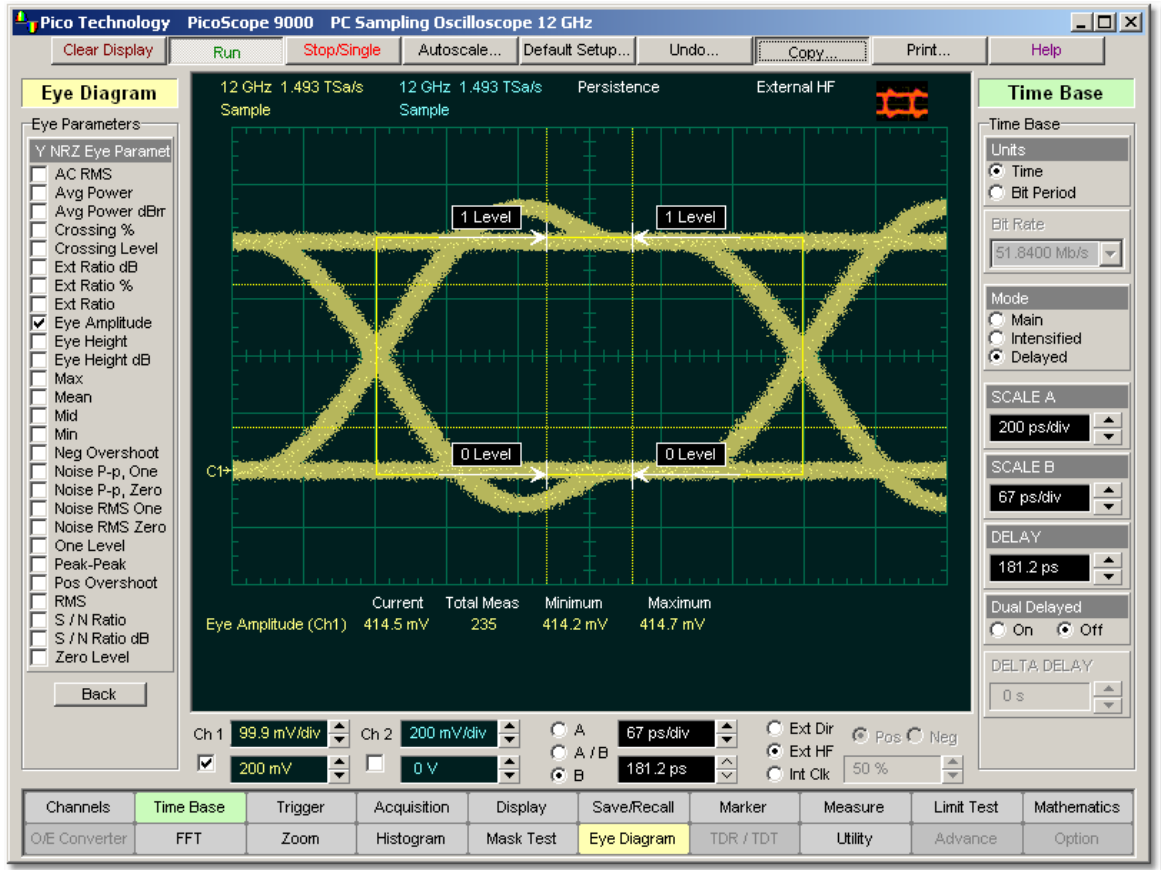


*Vone* and *Vzero* are calculated from a histogram using data within the eye window. These measurements are made in the central of the bit period (within **Eye Boundaries**). The default value is 20% of the NRZ bit time.

## 5.4.6.4 NRZ Eye Amplitude

☒ Eye Amplitude

**NRZ Eye Amplitude** is the difference between the logic 1 level and the logic 0 level histogram mean values of an eye diagram.



## NRZ Eye Amplitude definition

$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the centre of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from the upper and lower halves of the eye diagram. The instrument analyses the histogram and determines the mean values of the logic 1 and logic 0 levels.

The eye amplitude is determined as follows:

$$\text{NRZ Eye Amplitude} = \text{One Level} - \text{Zero Level}$$

## 5.4.6.5 NRZ Eye Height and NRZ Eye Height dB

☒ Eye Height ☒ Eye Height dB

**NRZ Eye Height** is a measurement of the vertical opening of an eye diagram. An ideal eye opening would be measured from the one level to the zero level. However, noise on the eye will cause the eye to close. The eye height measurement determines eye closure due to noise.

**NRZ Eye Height definition**

Similarly to the extinction ratio measurements, a vertical histogram is calculated on the data.  $V_{one}$  and the high-level distribution are determined, and similar patterns are determined for the low levels. The  $V_{one}$  and  $V_{zero}$  levels are the relative means of the histograms. The noise is measured through the histograms as three standard deviations ( $\sigma$ ) from both the one level and zero level into the eye opening.

The eye height can be defined in one of the two following formats:

$$NRZ\_EyeHeight = (V_{one} - 3\sigma_{one}) - (V_{zero} + 3\sigma_{zero})$$

$$NRZ\_EyeHeight(dB) = -10 \log_{10} \frac{(V_{zero} + 3\sigma_{zero})}{(V_{one} - 3\sigma_{one})}$$

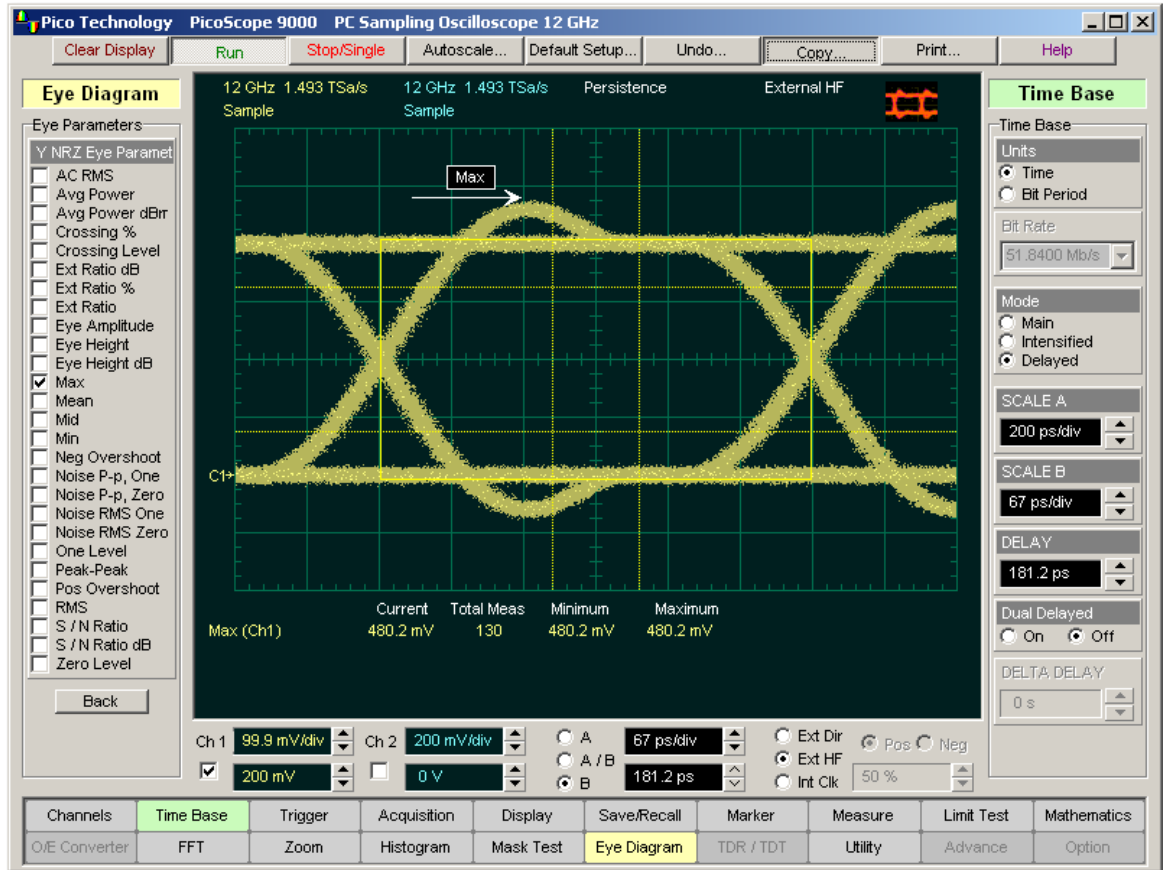


$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

## 5.4.6.6 NRZ Max



**NRZ Max** is a measure of the maximum vertical value of the waveform that is sampled within the eye window.



### NRZ Maximum definition

The NRZ maximum eye amplitude is determined as follows:

$$NRZ\ Maximum = \max[VertPos(s)]$$

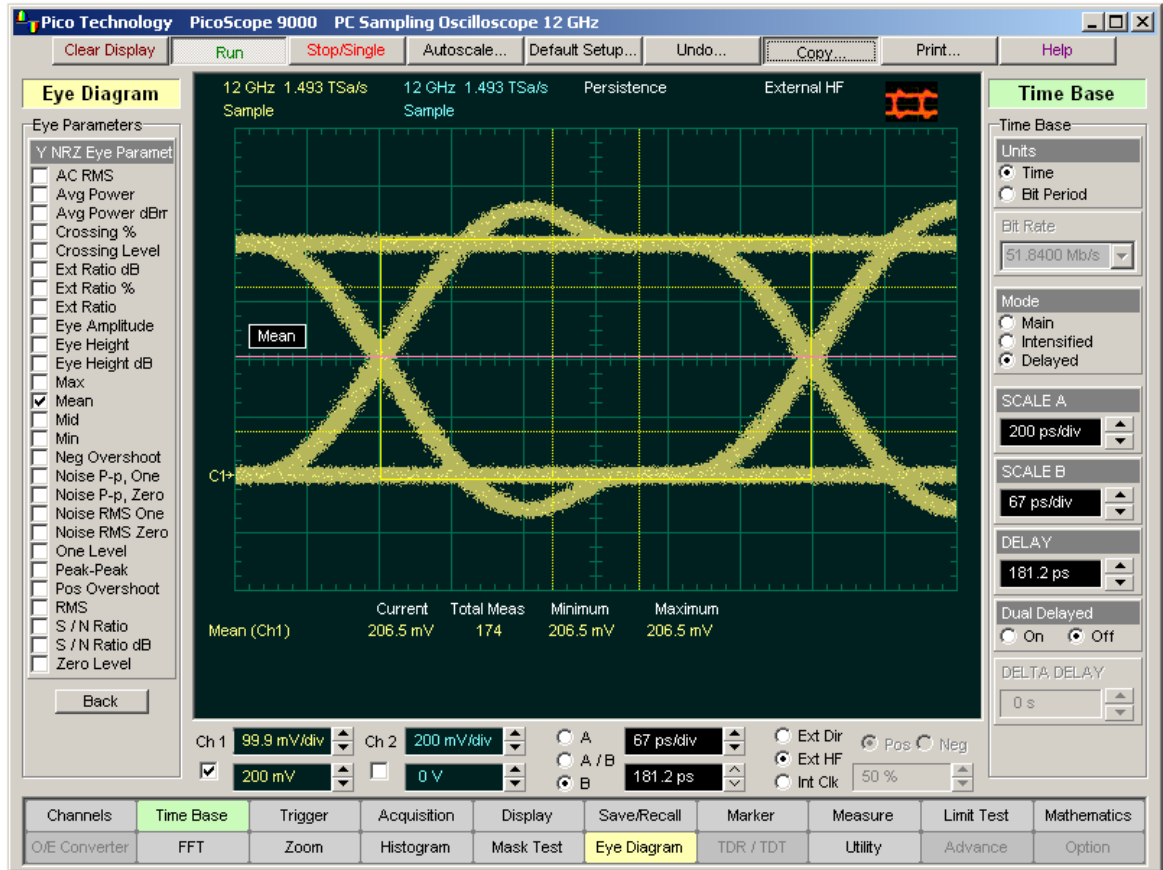
where  $s$  is the set of samples within the eye window.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.7 NRZ Mean



**NRZ Mean** is a measure of the arithmetic mean of the selected waveform within the eye window.

**NRZ Mean definition**

The NRZ mean is determined as follows:

$$NRZ\_Mean = mean[VertPos(s)] = \frac{1}{N} \sum_{i=1}^N VertPos(s_i)$$

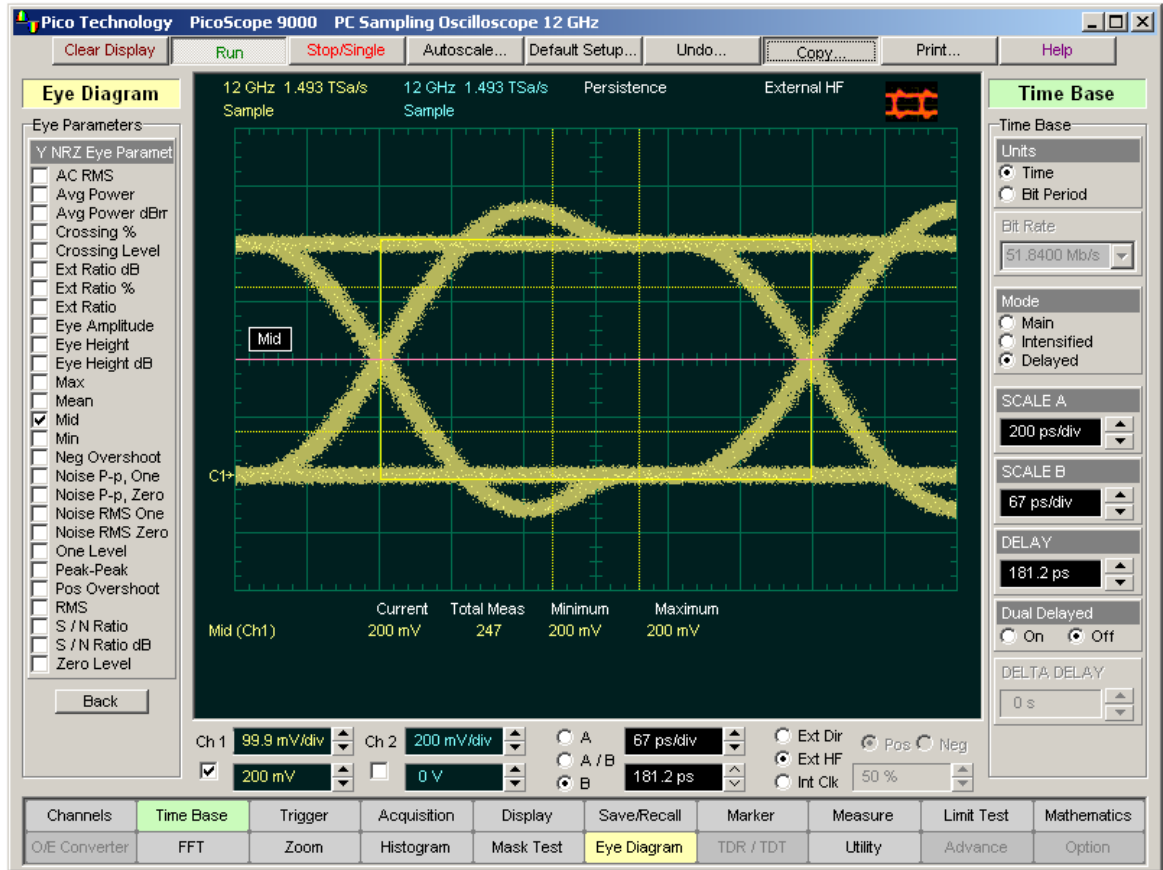
over all samples  $s_{1...N}$  within the eye window.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.8 NRZ Mid



**NRZ Mid** is a measure of the middle level between the Max and Min vertical values of the eye window.



### NRZ Middle definition

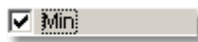
The NRZ middle is determined as follows:

$$NRZ\ Mid = (Max + Min) / 2$$

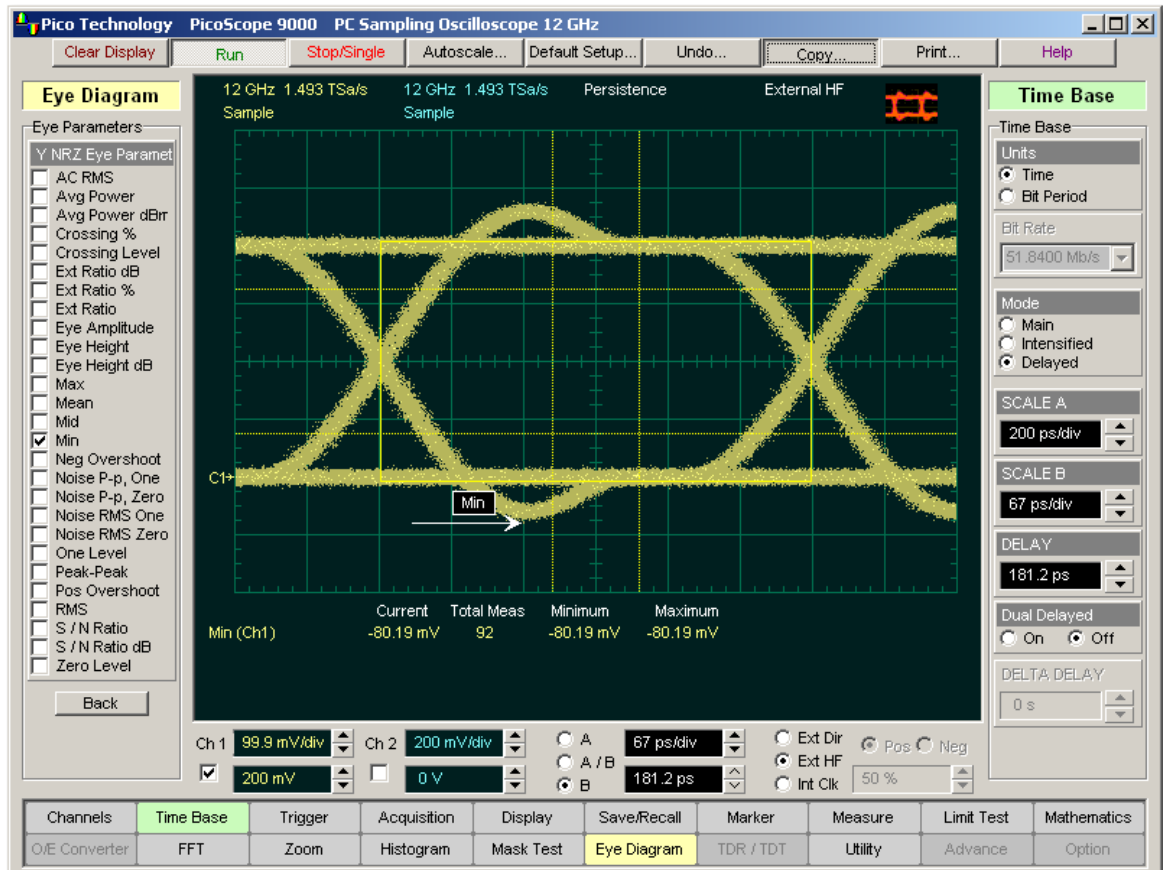
where *Max* and *Min* are the maximum and minimum measurements. See also [NRZ Max](#) [107] and [NRZ Min](#) [104].

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.9 NRZ Min



**NRZ Min** is a measure of the minimum vertical value of the selected waveform of the eye window.



### NRZ Minimum definition

The NRZ minimum eye amplitude is determined as follows:

$$NRZ\ Minimum = \max[VertPos(s)]$$

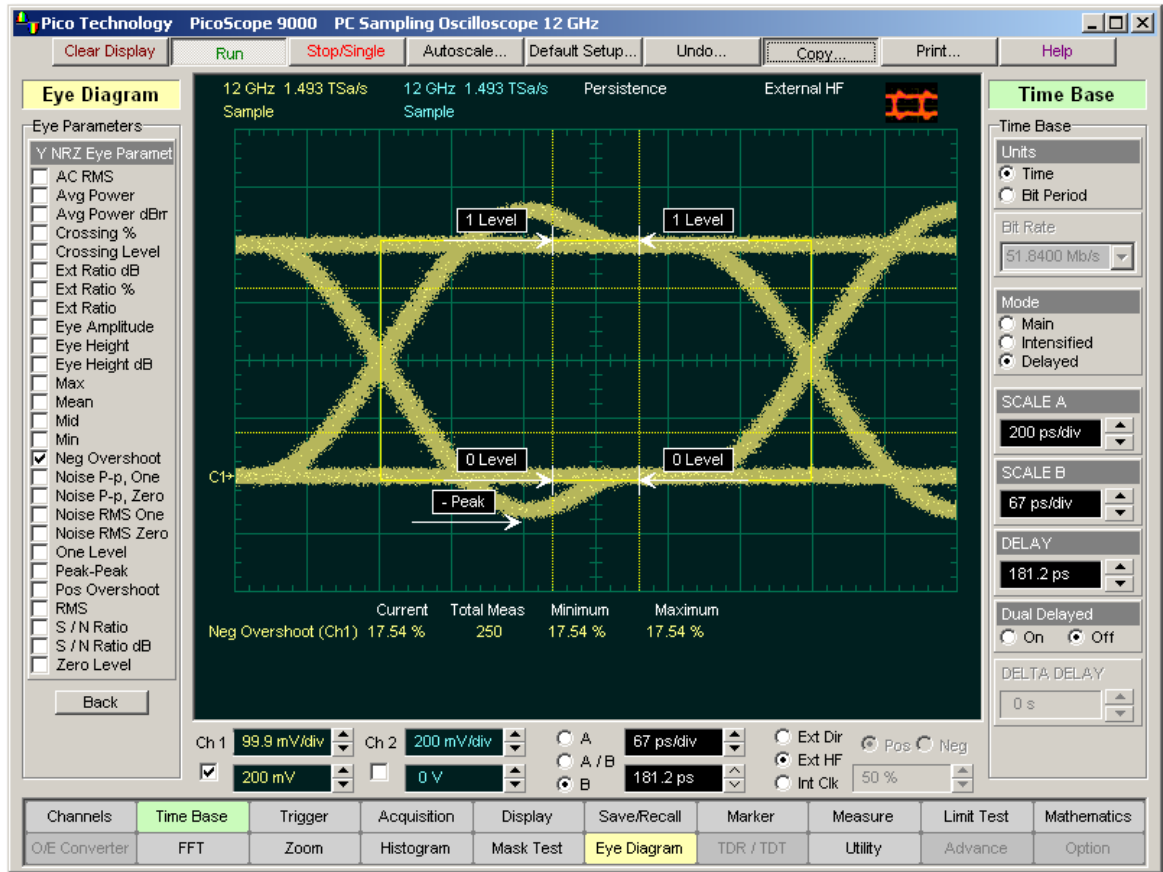
where  $s$  is the set of samples within the eye window.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.10 NRZ Negative Overshoot




**NRZ Negative Overshoot** is a measure of the ratio of the minimum value of the measured signal to its amplitude, expressed as a percentage. The waveform is scanned for the minimum value within the eye window, while the amplitude is measured in the **Eye Aperture**.

**NRZ Negative Overshoot definition**

The NRZ Negative Overshoot is determined as follows:

$$NRZ\_NegativeOvershoot = \frac{V_{zero} - V_{min}}{V_{one} - V_{zero}} \times 100$$

where  $V_{min}$  is the signal minimum, and  $V_{one}$  and  $V_{zero}$  are the logical 1 and 0 levels.



$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

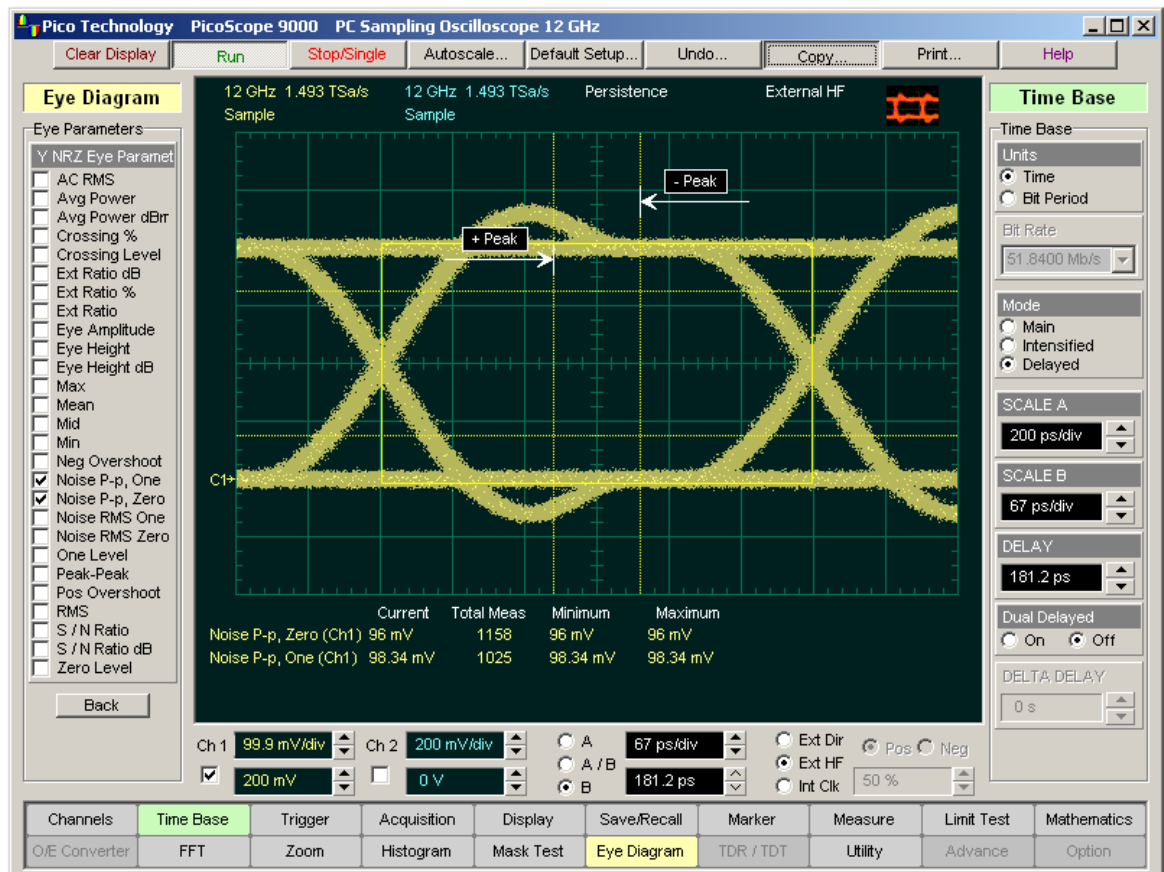


## 5.4.6.11 NRZ Noise P-p, One and NRZ Noise P-p, Zero

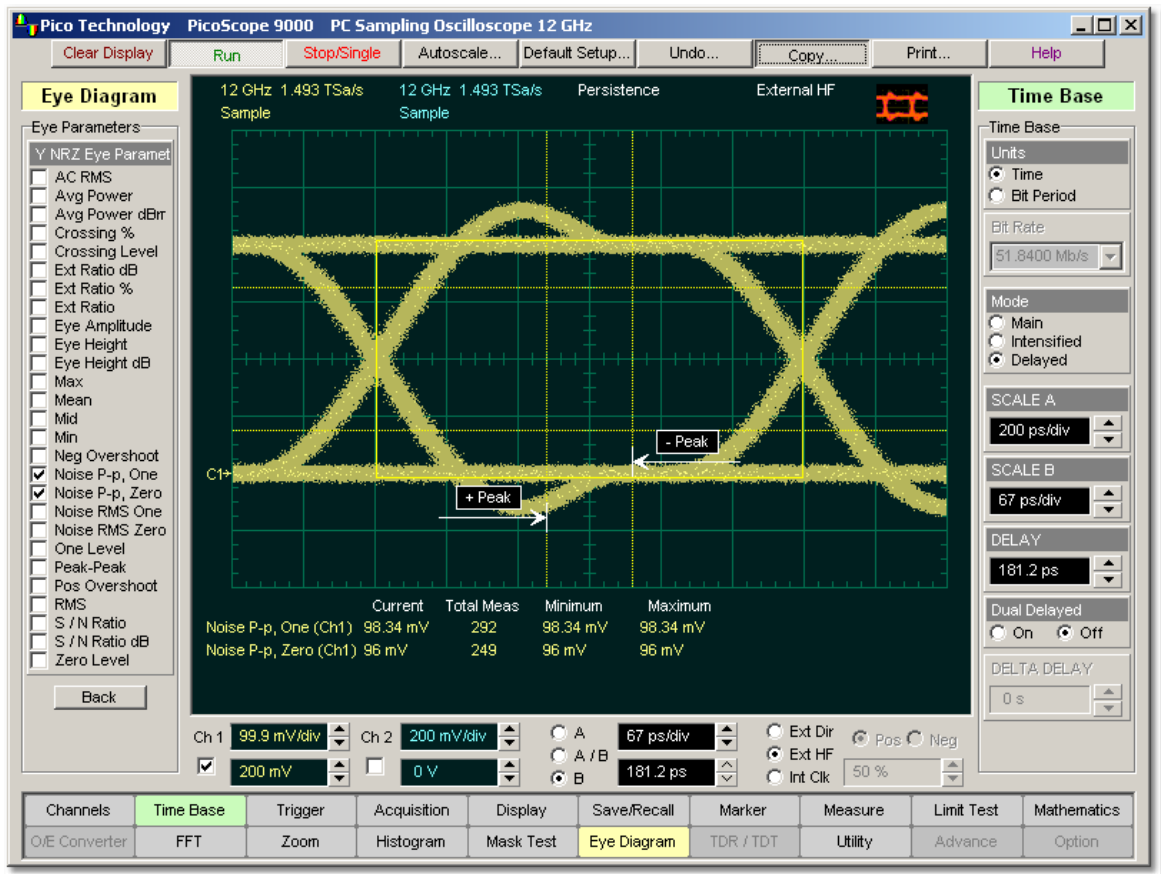
☒ Noise P-p, One    ☒ Noise P-p, Zero

**NRZ Noise P-p, One** is a measurement of the maximum range of the amplitude variance sampled within a fixed-width vertical slice located at the center of the **Eye Aperture** at the **One Level**.

**NRZ Noise P-p, Zero** is a measurement of the maximum range of the amplitude variance sampled within a fixed-width vertical slice located at the center of the **Eye Aperture** at the **Zero Level**.



**NRZ Noise P-p, One definition**



### NRZ Noise P-p, Zero definition

The **NRZ Noise P-p, One** is determined as follows:

$$NRZ \text{ Noise } P-p, \text{ One} = \text{One } P-p$$

The **NRZ Noise P-p, Zero** is determined as follows:

$$NRZ \text{ Noise } P-p, \text{ Zero} = \text{Zero } P-p$$



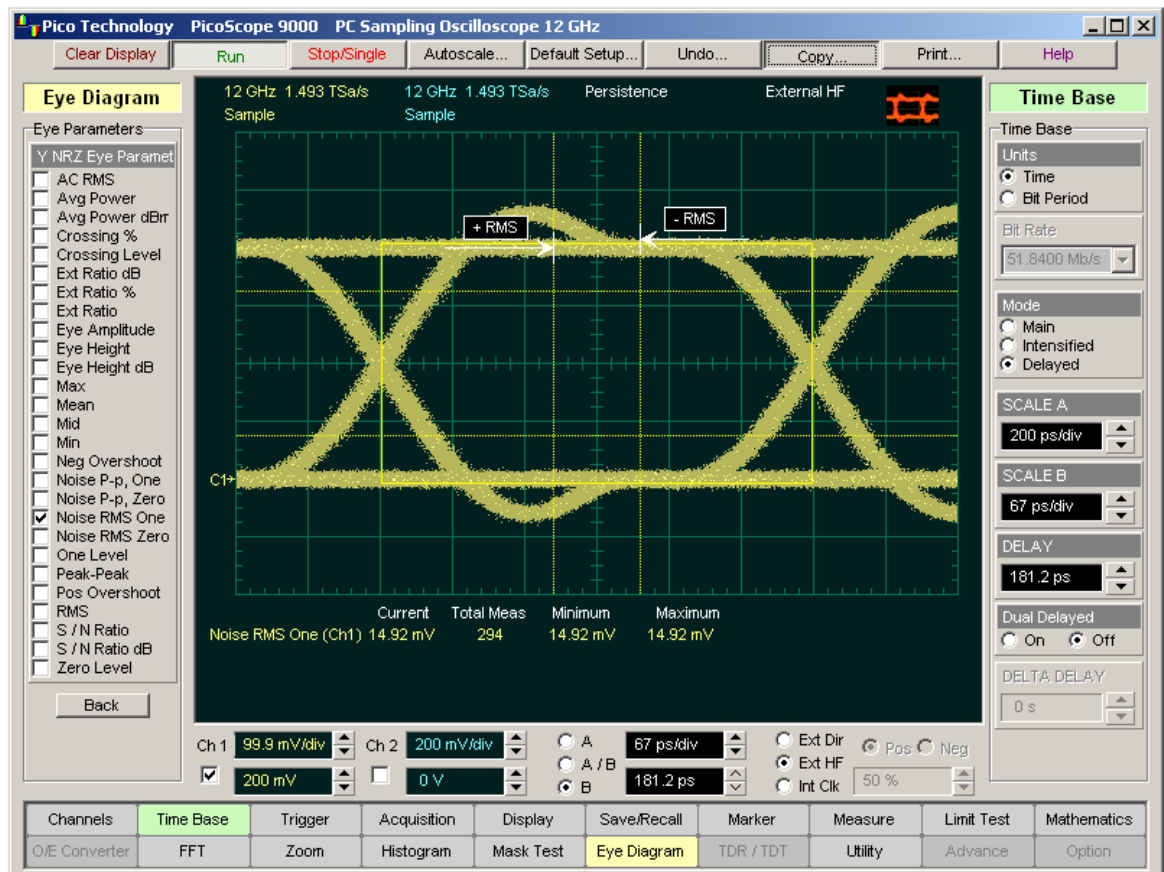
$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

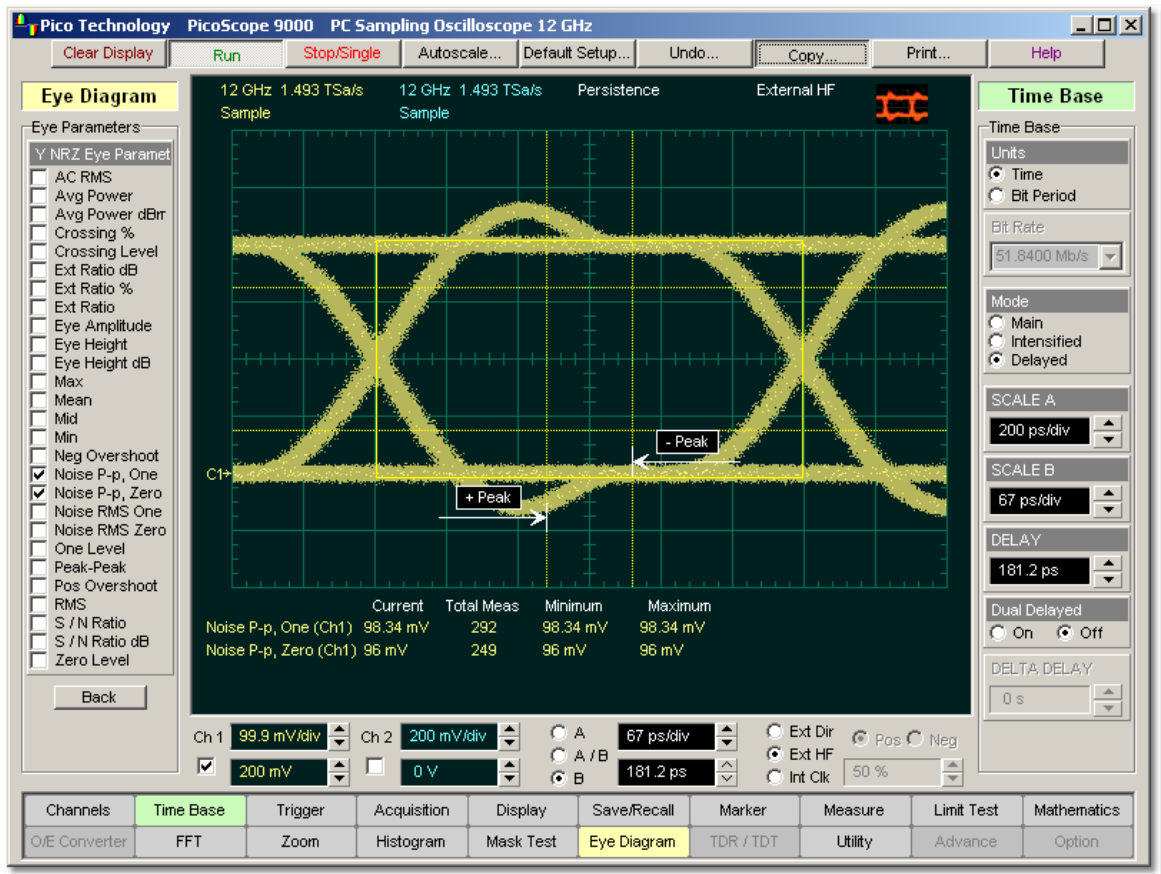
## 5.4.6.12 NRZ Noise RMS, One and NRZ Noise RMS Zero

☒ Noise RMS One ☒ Noise RMS Zero

**NRZ Noise RMS** is a measurement of the unit standard deviation of the amplitude variance sampled within a fixed-width vertical slice located at the center of the **Eye Aperture** at the **High** (logical 1) or **Low** (logical 0) levels.



**NRZ Noise RMS, One definition**



### NRZ Noise RMS, Zero definition

$$NRZ\ RMS = High\ \sigma$$

$$NRZ\ RMS = Low\ \sigma$$

The **Eye Aperture** is adjustable and defaults to 20% of the NRZ bit time. This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

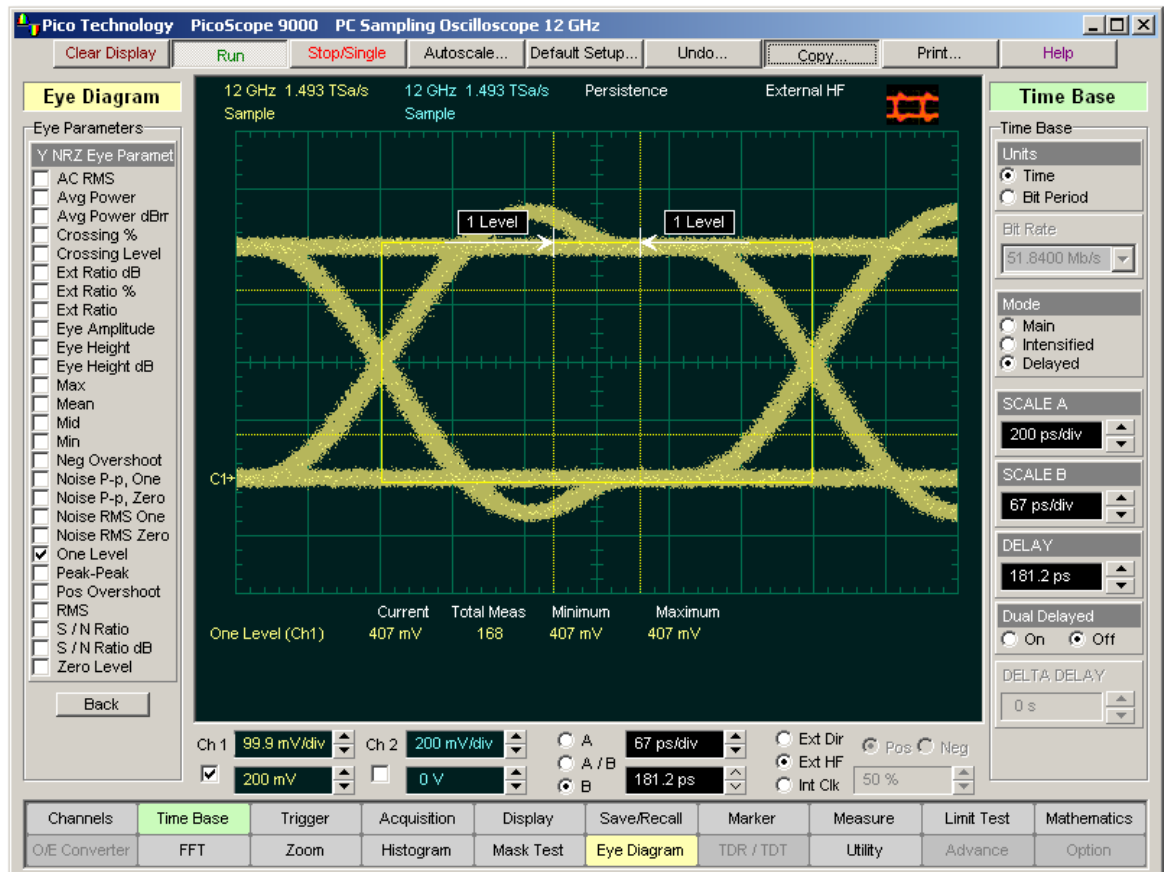


*Vone* and *Vzero* are calculated from a histogram using data within the eye window. These measurements are made in the central of the bit period (within **Eye Boundaries**). The default value is 20% of the NRZ bit time.

## 5.4.6.13 NRZ One Level



**NRZ One Level** is a measure of the mean value of the logical 1 of an eye diagram.



### NRZ One Level definition



$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from only the upper half of the eye diagram. The instrument analyses the histogram and determines histogram mean.

The **One Level** is determined as follows:

$$NRZ\ One\ Level = Histogram\ Mean$$

All data at the zero level is disregarded.

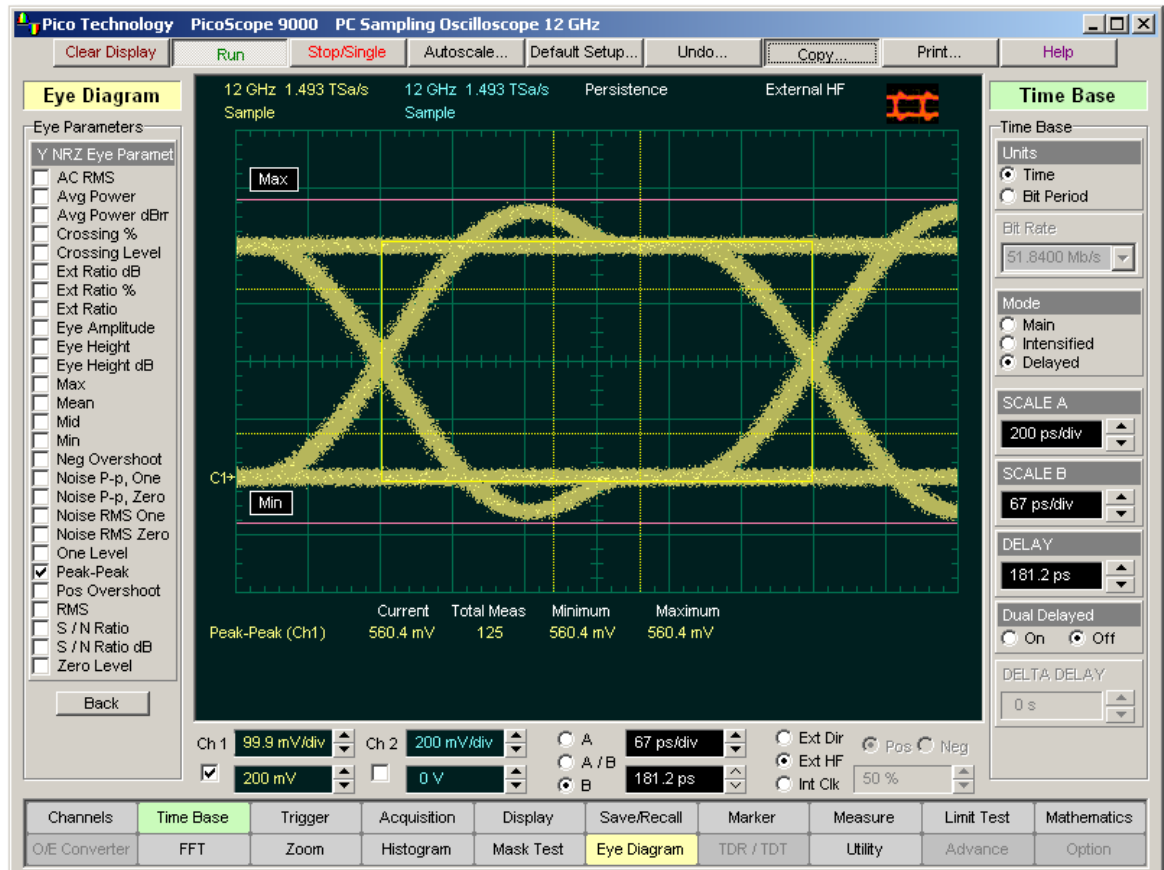


The standard deviation that is reported on the instrument display as part of the measurement results is derived from the statistical analysis of the one level measurement result. It is not the same as the standard deviation derived from the histogram analysis of the signal.

## 5.4.6.14 NRZ Peak-Peak

☒ Peak-Peak

**NRZ Peak-Peak** is a measure of the difference between the **Max** and **Min** vertical values of the selected waveform within the eye window.

**NRZ Peak-Peak definition**

The **NRZ Peak-Peak** is determined as follows:

$$NRZ\ Peak-Peak = Max - Min$$

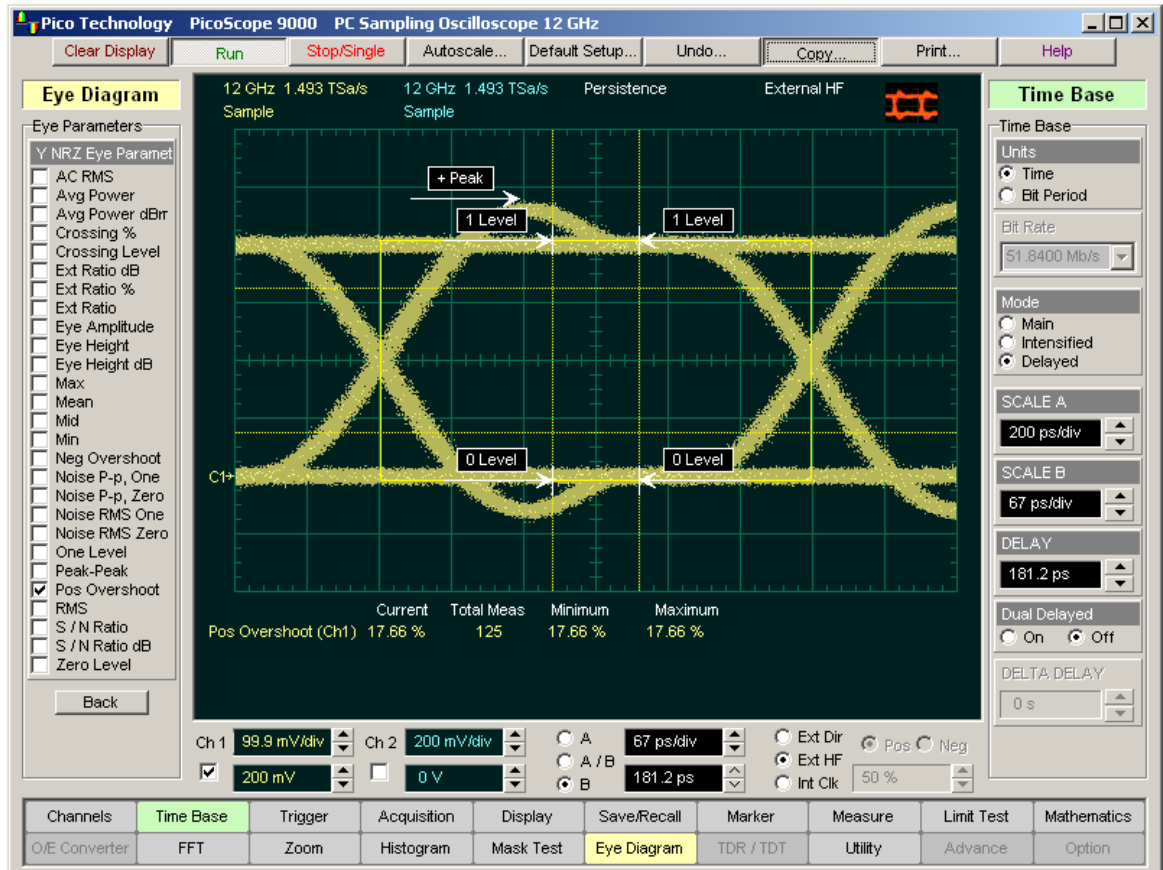
where *Max* and *Min* are the maximum and minimum measurements. See also [NRZ Max](#) [10f] and [NRZ Min](#) [10d].

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.6.15 NRZ Positive Overshoot

☒ Pos Overshoot

**NRZ Positive Overshoot** is a measure of the ratio of the maximum value of the measured signal to its amplitude, expressed as a percentage. The waveform is scanned for the maximum value within the eye window, while the amplitude is measured in the **Eye Aperture**.



## NRZ Positive Overshoot definition

The **NRZ Positive Overshoot** is determined as follows:

$$NRZ\_PositiveOvershoot = \frac{V_{max} - V_{one}}{V_{one} - V_{zero}} \times 100$$

where  $V_{max}$  is the signal maximum, and  $V_{one}$  and  $V_{zero}$  are the logical 1 and 0 levels.

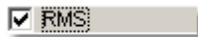


$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

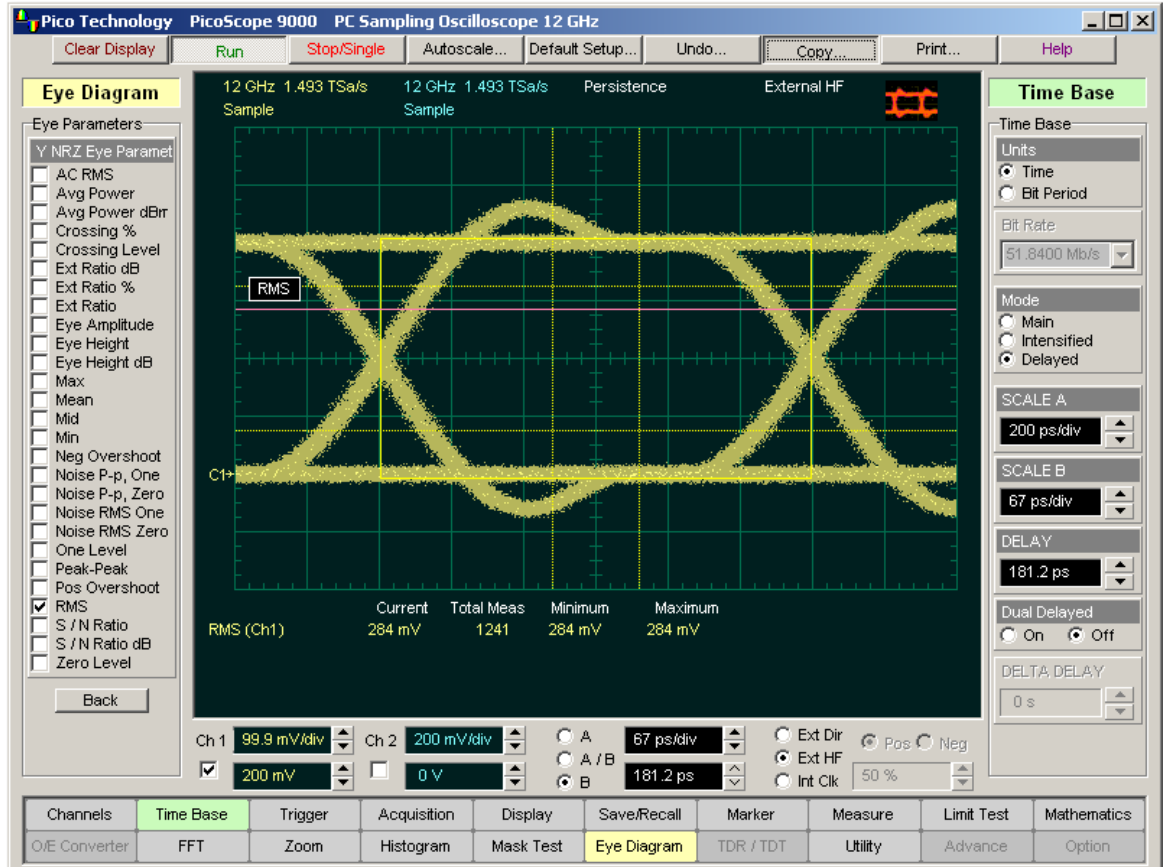
When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.



## 5.4.6.16 NRZ RMS



**NRZ RMS** is a measure of the true root mean square amplitude of the selected waveform within the eye window.

**NRZ RMS definition**

The **RZ RMS** is determined as follows:

$$NRZ\_RMS = \sqrt{\frac{\sum_{n=1}^N [VertPos(s_n)]^2}{N}}$$

over all  $N$  samples within the measured region; i.e., one standard deviation of the amplitude, i.e., RMS amplitude.

When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

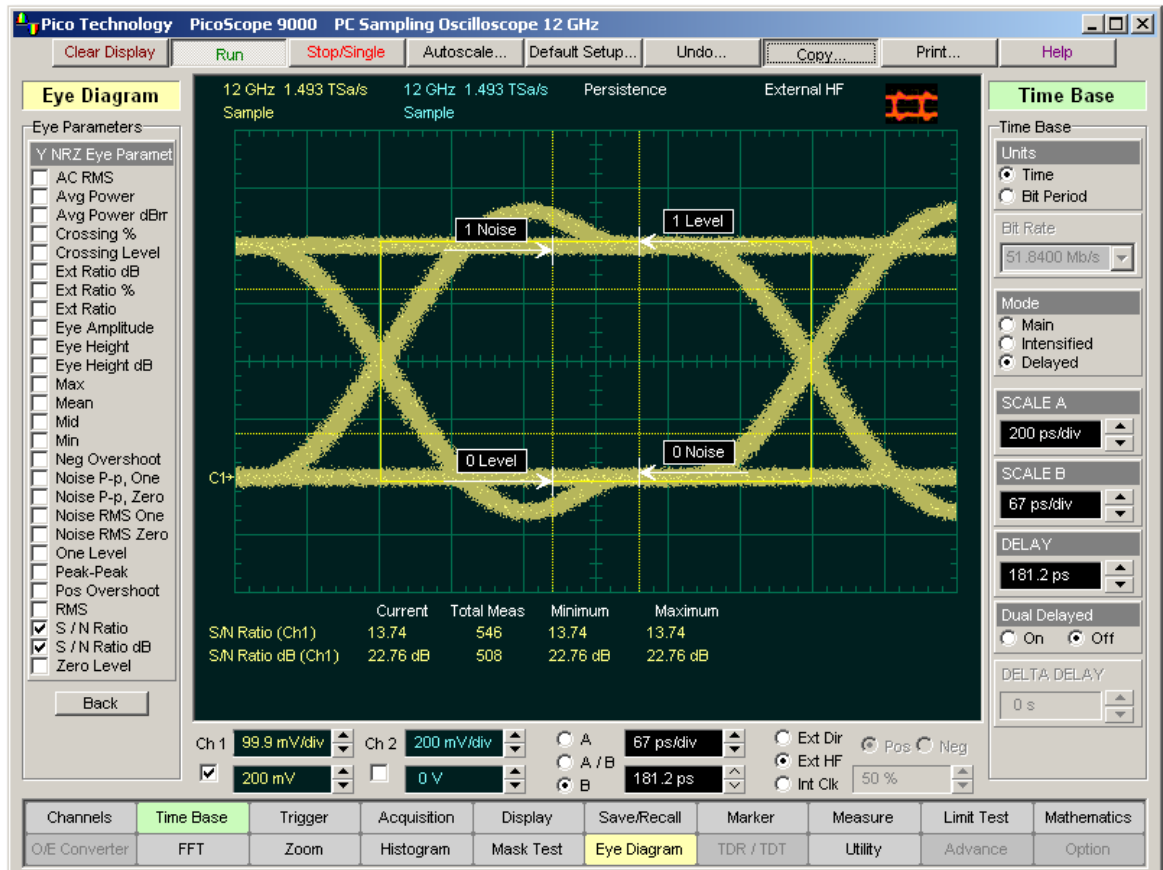


$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

## 5.4.6.17 NRZ S/N Ratio and NRZ S/N Ratio dB

☒ S / N Ratio    ☒ S / N Ratio dB

**NRZ Signal to Noise** is a ratio of the signal difference between one level and zero level relative to the noise present at both levels. Signal to Noise is similar in construction to a Q-factor measurement. However, noise levels contributed by the instrument cannot be removed, and therefore a slightly pessimistic Q-factor measurement may result.



## NRZ Signal to Noise Ratio definition

$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

To define the signal, histograms are constructed using the sampled portions of the eye diagram within the eye window boundaries. One histogram is composed of data points from only the upper half of the eye diagram (one level). The second histogram is composed of data points from the lower half of the eye (zero level). The instrument analyses the histograms and determines the histogram means and standard deviations. The noise is defined as  $1\sigma$  (standard deviation) of the histogram at the one and zero levels.

The RZ Signal to Noise is determined as follows:

$$NRZ\_Signal-to-Noise\_Ratio = \frac{V_{one} - V_{zero}}{\sigma_{one} + \sigma_{zero}}$$

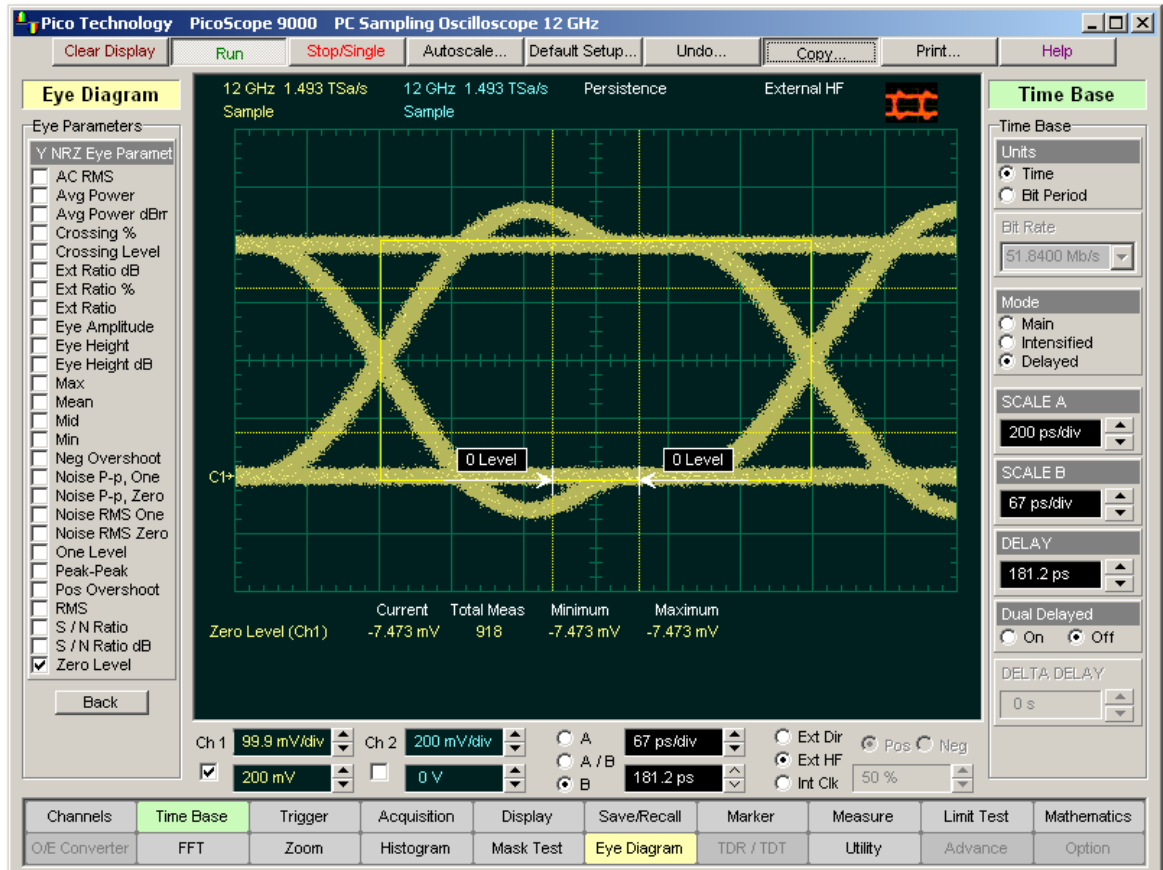


This measurement does not remove the effect of noise generated by the instrument. If the noise on the signal being tested is of a magnitude similar to that of the instrument or smaller, the signal-to-noise measurement error will be significant.

## 5.4.6.18 NRZ Zero Level

☒ Zero Level

**NRZ Zero Level** is a measure of the mean value of the logical 0 of an eye diagram.



### NRZ Zero Level definition



$V_{one}$  and  $V_{zero}$  are calculated from a histogram using data within the eye window. These measurements are made in the center of the bit period (within the **Eye Boundaries**). The default value is 20% of the NRZ bit time.

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from only the lower half of the eye diagram. The instrument analyses the histogram and determines histogram mean.

The **RZ Zero Level** is determined as follows:

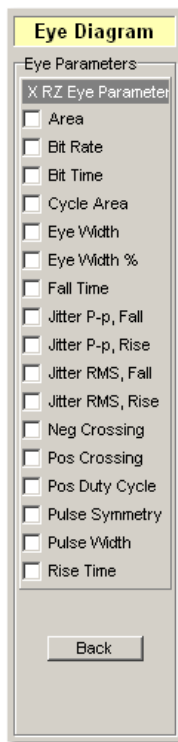
$$NRZ \text{ Zero Level} = \text{Histogram Mean}$$

All data at the one level is disregarded.

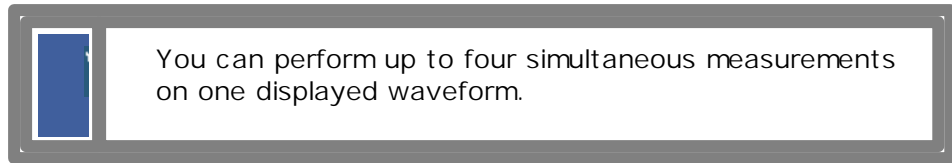


The standard deviation that is reported on the instrument display as part of the measure results is derived from the statistical analysis of the zero level measurement result. It is not the same as the standard deviation derived from the histogram analysis of the signal.

### 5.4.7 X RZ Eye Parameters

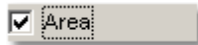


The list of **X RZ Eye Parameters** includes seventeen eye parameters.



The measurement algorithms for **X RZ Eye Parameters** will only work when an RZ eye diagram, and not an NRZ eye diagram or a pulse, is present on the screen. Eye measurements are based on statistical data that is acquired and stored in the measurement database. The algorithms are dependent upon histogram means calculated from the measurement database. Therefore, if you want to perform eye measurements, you must first produce an eye diagram by triggering the instrument with a synchronous clock signal. Measurements made on an NRZ eye diagram or a pulse waveform while in the **X RZ Eye Parameters** menu will fail.

## 5.4.7.1 RZ Area

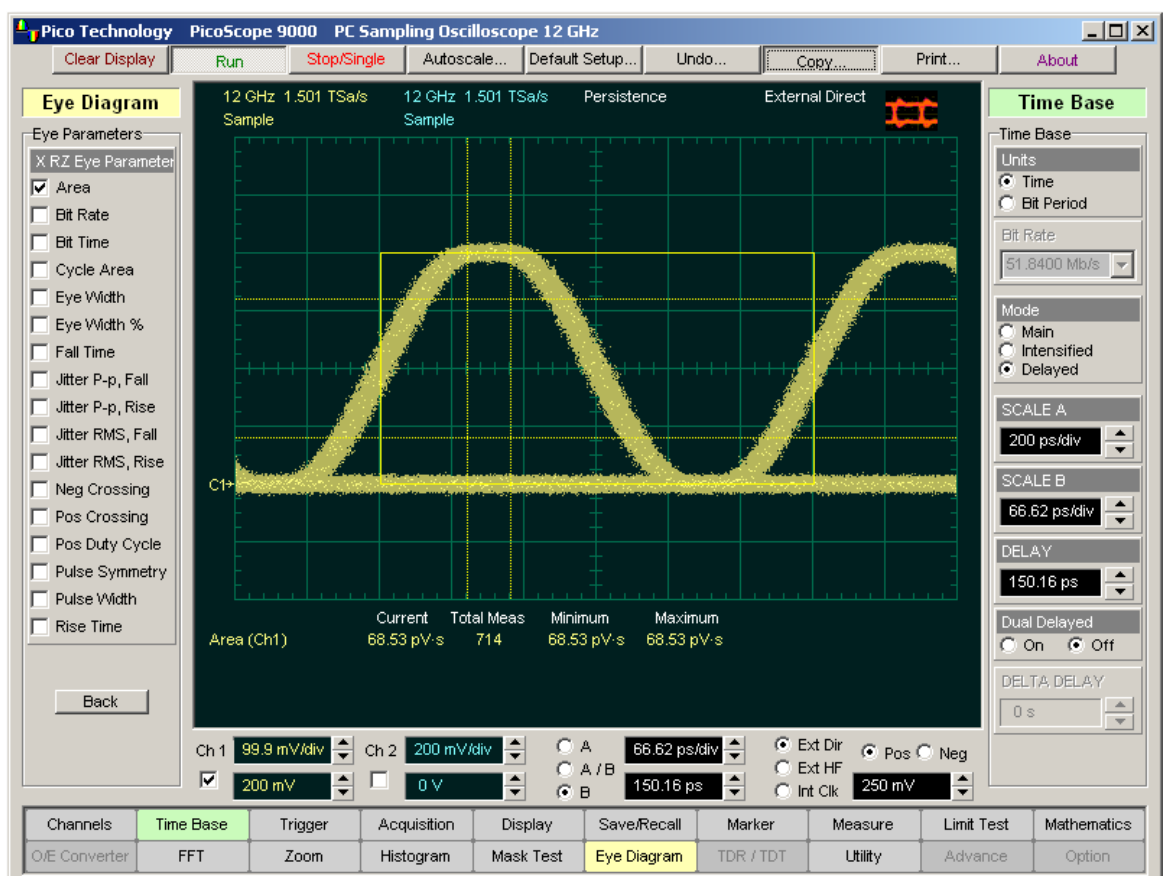


**RZ Area** is a measure of the area under the curve for the RZ waveform within the full display window. Area measured above ground is positive; area measured below ground is negative.

The **RZ Area** is determined as follows:

$$RZ\_Area = \frac{\Delta t}{N} \sum_{n=1}^N VertPos(s_n)$$

over all  $N$  samples  $s_{1...N}$  within the measured region (full display window) of duration  $\Delta t$ .



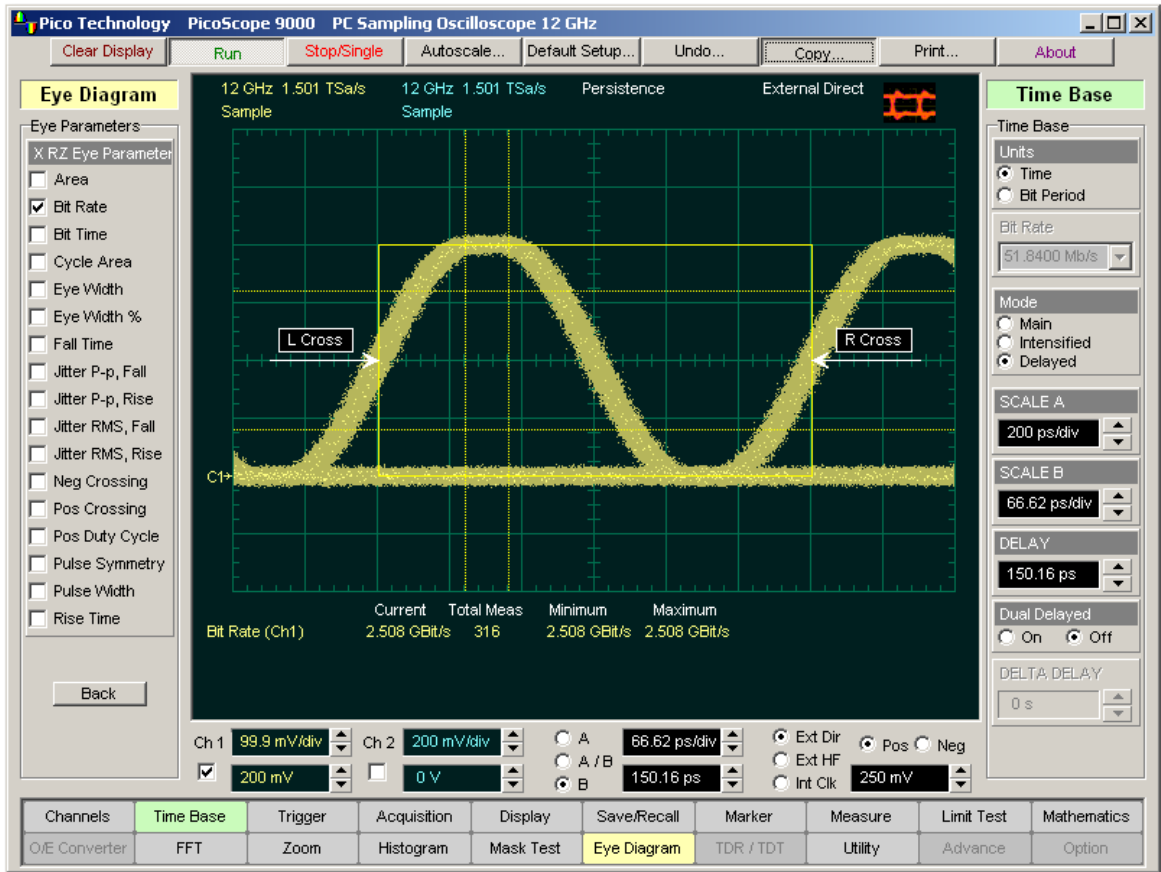
### RZ Area definition

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.2 RZ Bit Rate



The **RZ Bit Rate** is a measure of the inverse of the bit time (1/bit time or 1/period) of the RZ eye rising edges. The bit time is a measure of the time between the 50% rising edges of two consecutive eyes.

**RZ Bit Rate definition**

To compute bit time (period), the 50% heights of consecutive eyes are first determined. Then a vertically thin measurement window is placed horizontally through the 50% levels. The data within this measurement window is analysed. The measurement window is created to be extremely small so that the measurement is not affected by the Bit Rate or rise time of the waveforms.

Once the bit period has been determined, the inverse value is calculated to determine the RZ bit rate:

$$RZ\_BitRate = \frac{1}{RZ\_BitTime} = \frac{1}{2(T_{RightCross} - T_{LeftCross})}$$

where  $T_{RightCross}$  and  $T_{LeftCross}$  are the mean of the histogram of the two consecutive crossings on the rising slope at the mid-reference level.

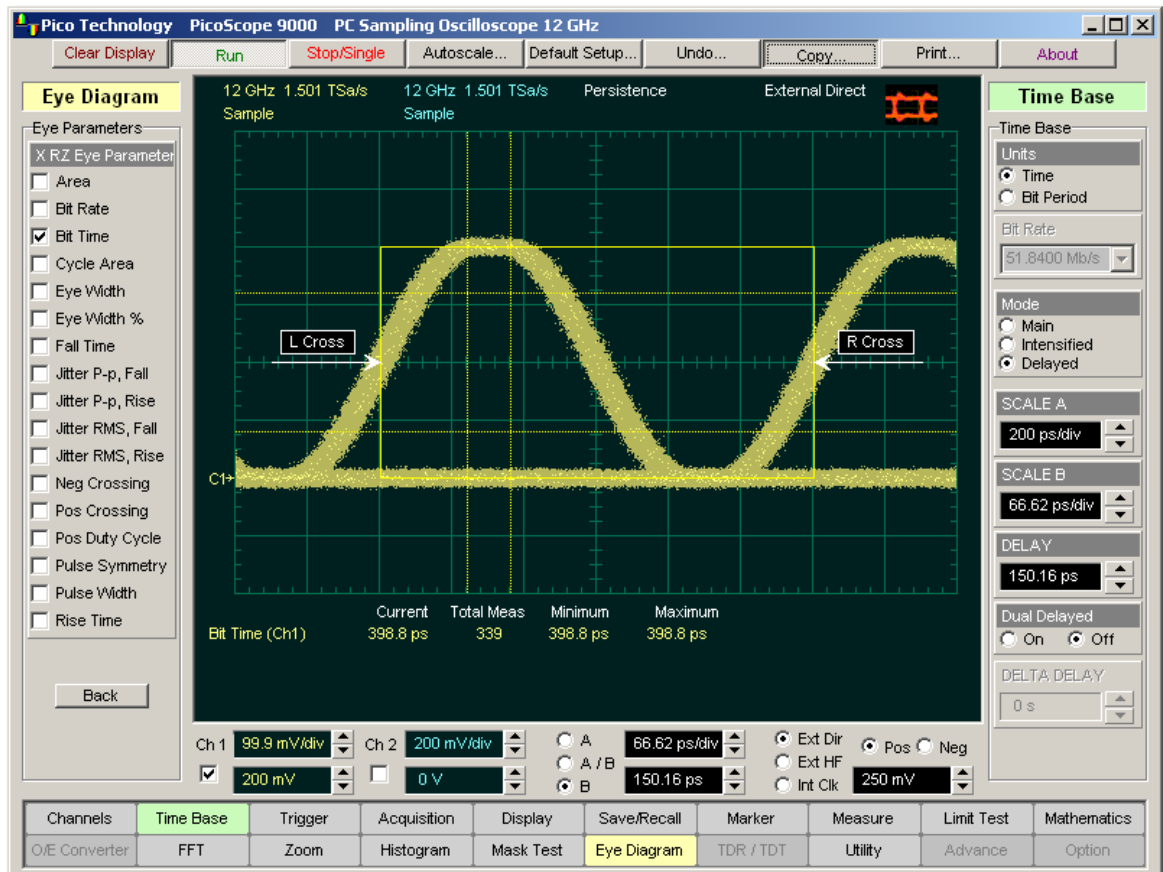
See also [RZ Bit Time](#) <sup>[122]</sup>.



## 5.4.7.3 RZ Bit Time

☒ Bit Time

The **RZ Bit Time** is a measure of the time interval between two consecutive rising edges. The crossing times are computed as the mean of the histogram of the data slice at the mid-reference level.

**RZ Bit Time definition**

The **RZ Bit Time** is determined as follows:

$$RZ\_BitTime = T_{RightCross} - T_{LeftCross}$$

where  $T_{RightCross}$  and  $T_{LeftCross}$  are the mean of the histogram of the two consecutive crossings on the rising slope at the mid-reference level.

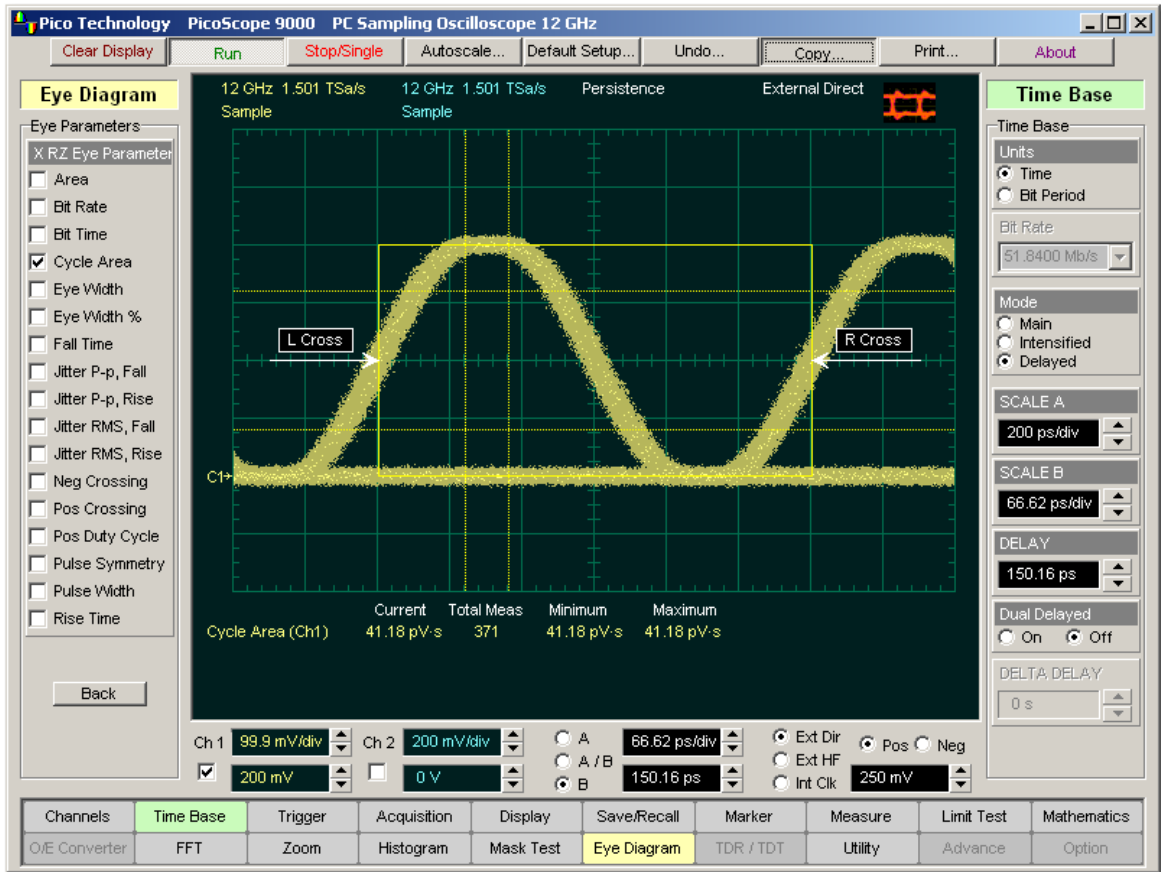
This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

**RZ Bit Time** also is called **RZ Bit Period**.

## 5.4.7.4 RZ Cycle Area



**RZ Cycle Area** is a measure of the area under the curve for the RZ waveform within the eye window. Area measured above ground is positive; area measured below ground is negative.

**RZ Cycle Area definition**

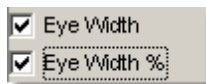
The **RZ Cycle Area** is determined as follows:

$$RZ\_CycleArea = \frac{\Delta t}{N} \sum_{n=1}^N VertPos(s_n)$$

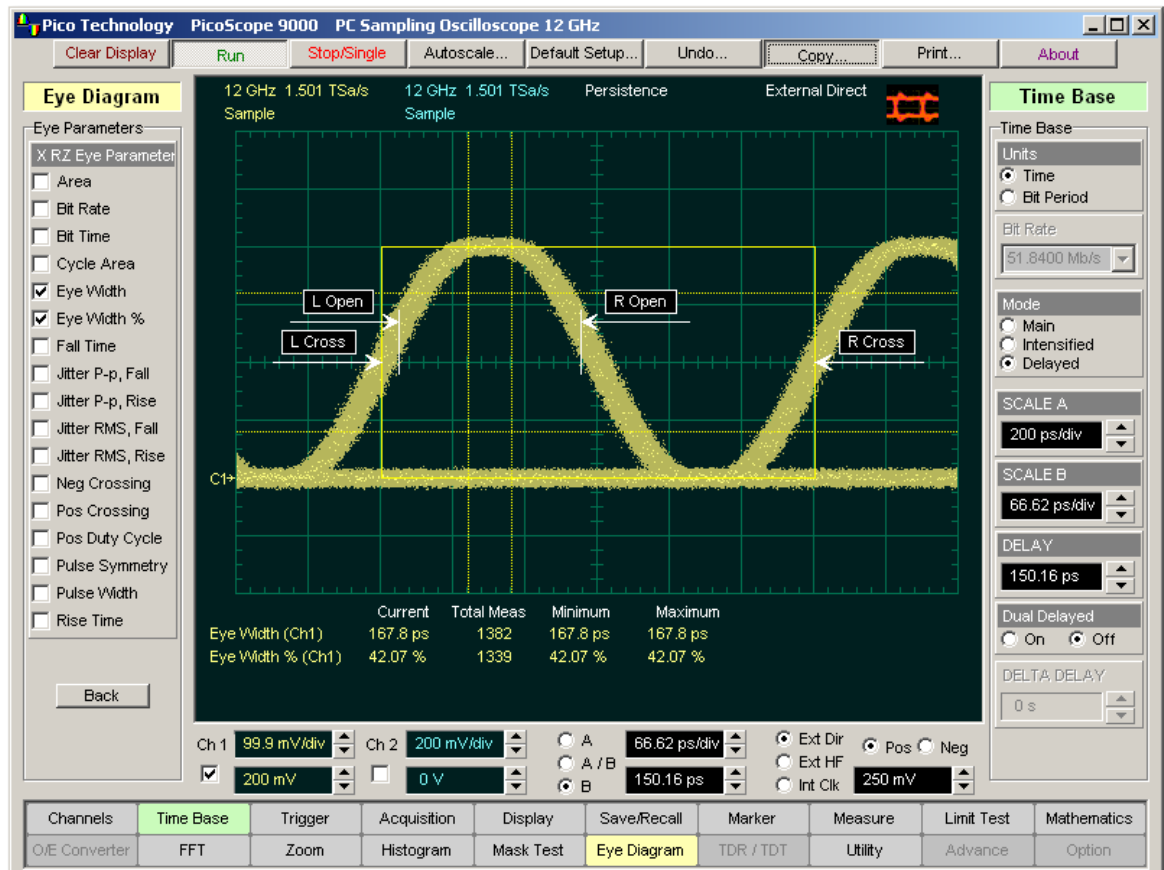
over all  $N$  samples  $s_{1...N}$  in the measured region (eye window) of duration  $\Delta t$  between two consecutive edges of the rising slope at the **Mid** reference level.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.5 RZ Eye Width and RZ Eye Width %



**RZ Eye Width** is a measure of the horizontal opening of an RZ eye diagram. The amount of jitter or noise that may appear on the waveform is measured to determine the actual horizontal opening of the eye.

**RZ Eye Width definition**

To compute eye width, the 50% height of the eye is first determined. Then a vertically thin measurement window is placed horizontally through the 50% levels, and the data within this measurement window is analysed. This measurement window is created to be extremely small so that the measurement is not affected by the rise time and fall time of the waveform.

The RZ eye width is determined using the time difference between the 3 (standard deviation) points of the 50% level histograms.

$$RZ\_EyeWidth = (T_{Fall50\%} - 3\sigma) - (T_{Rise50\%} - 3\sigma)$$

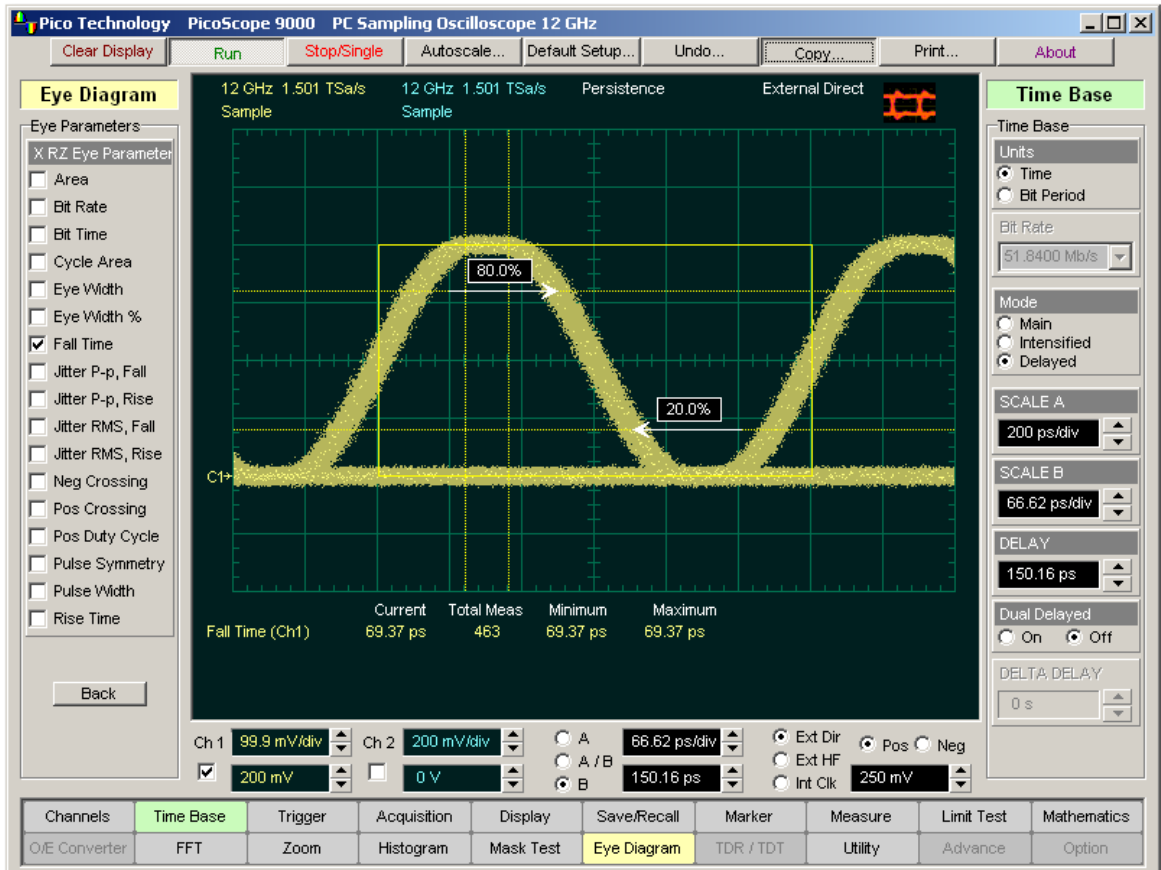
The RZ eye width can also be expressed as the ratio of the 3 (standard deviation) time difference between edges to the bit time (bit period) of the eye pulses:

$$RZ\_EyeWidth\_ \% = \frac{(T_{Fall50\%} - 3\sigma) - (T_{Rise50\%} + 3\sigma)}{BitTime}$$

## 5.4.7.6 RZ Fall Time

☒ Fall Time

**RZ Fall Time** is a measure of the mean transition time of the data on the downward slope of an RZ eye diagram. The data crosses through the following three thresholds: the upper, middle, and lower thresholds.



### RZ Fall Time definition

A histogram is first constructed to find the mean locations of the eye one level and zero level. Histograms are then constructed at each of the three threshold levels (for example, the 20%, 50%, and 80% points on the transition). The instrument analyses each histogram to determine the histogram mean at which the data crosses the separate threshold levels. Once the scanning of the waveform is complete, and the instrument has identified the mean location for each threshold crossed, then fall time can be computed.

$$\text{RZ Fall Time} = (\text{Time at the Lower Threshold Crossing}) - (\text{Time at the Upper Threshold Crossing})$$

The default setting for the threshold levels is the 20% to 80% points on the transition. These levels give more consistent results for eyes with distortion at the top or bottom. You can define the threshold settings that you want in the [Define Parameters](#) <sup>[159]</sup> menu.



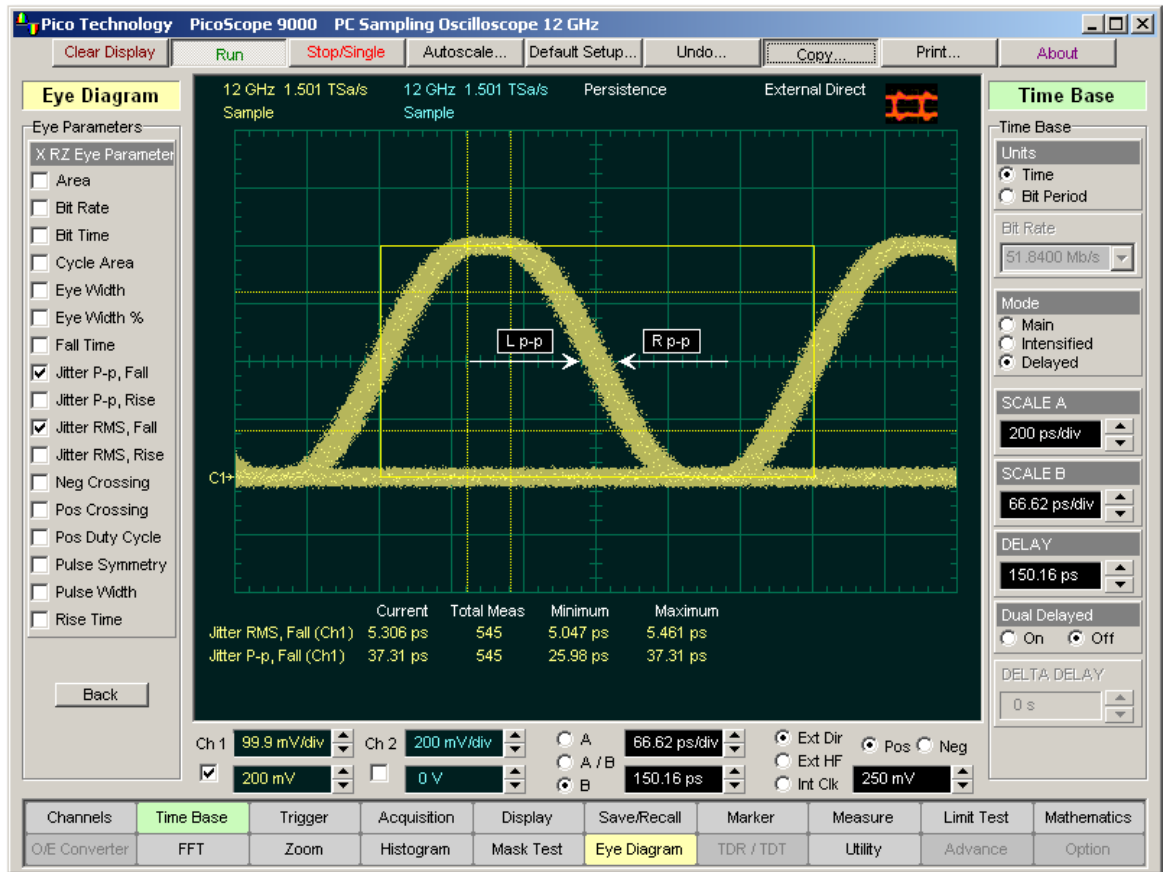
If the fall time relative to the time/division is a small value, the data acquired at the threshold levels on the falling edge will not yield accurate measurement results. (The falling edge will appear very steep on the display screen.)

If the falling edge of your eye diagram is steep, increase the timebase (horizontal scale) on the display so that the falling edge covers at least half a graticule division. The instrument will be able to discern the data at the threshold levels, producing more accurate results.

## 5.4.7.7 RZ Jitter P-p, Fall and RZ Jitter RMS, Fall



**RZ Jitter P-p, Fall** and **RZ Jitter RMS, Fall** are the measures of signal instability relative to its ideal position in time.

**RZ Jitter P-p, Fall and RZ Jitter RMS, Fall definition**

To compute jitter peak-to-peak, the standard deviation is measured at a 50% level of the first measurable falling edge. The measurement window is kept extremely small so that the width at the 50% level is not influenced by the slope of the waveform. The histograms are then analysed to determine the amount of RMS jitter, which is defined as 1 (standard deviation) from the histogram mean.

The RZ peak-to-peak jitter is the full width of the histogram at the eye 50% level:

$$RZ \text{ Jitter } P\text{-}p, \text{ Fall} = 6\sigma \text{ (crossing)}$$

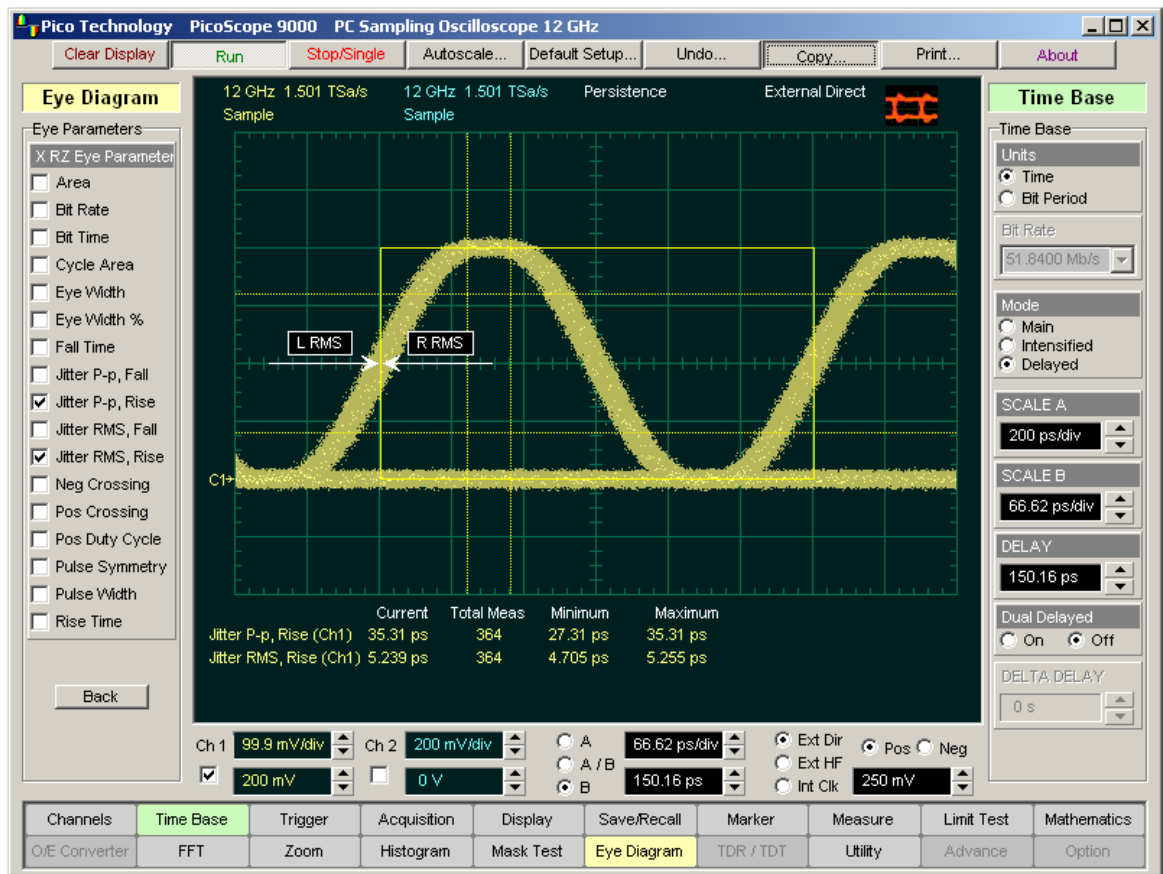
The RZ RMS jitter is defined as one standard deviation from the histogram mean at the eye crossing point:

$$RZ \text{ Jitter } RMS, \text{ Fall} = 1\sigma \text{ (crossing)}$$

## 5.4.7.8 RZ Jitter P-p, Rise and RZ Jitter RMS, Rise



**RZ Jitter P-p, Rise** and **RZ Jitter RMS, Rise** are the measures of signal instability relative to its ideal position in time.

**RZ Jitter P-p, Rise and RZ Jitter RMS, Rise definition**

To compute jitter peak-to-peak, the standard deviation is measured at a 50% level of the left measurable rising edge. The measurement window is kept extremely small so that the width at the 50% level is not influenced by the slope of the waveform. The histograms are then analysed to determine the amount of RMS jitter, which is defined as 1  $\sigma$  (standard deviation) from the histogram mean.

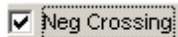
The RZ peak-to-peak jitter is the full width of the histogram at the eye 50% level:

$$RZ \text{ Jitter } P\text{-}p, \text{ Rise} = 6\sigma \text{ (crossing)}$$

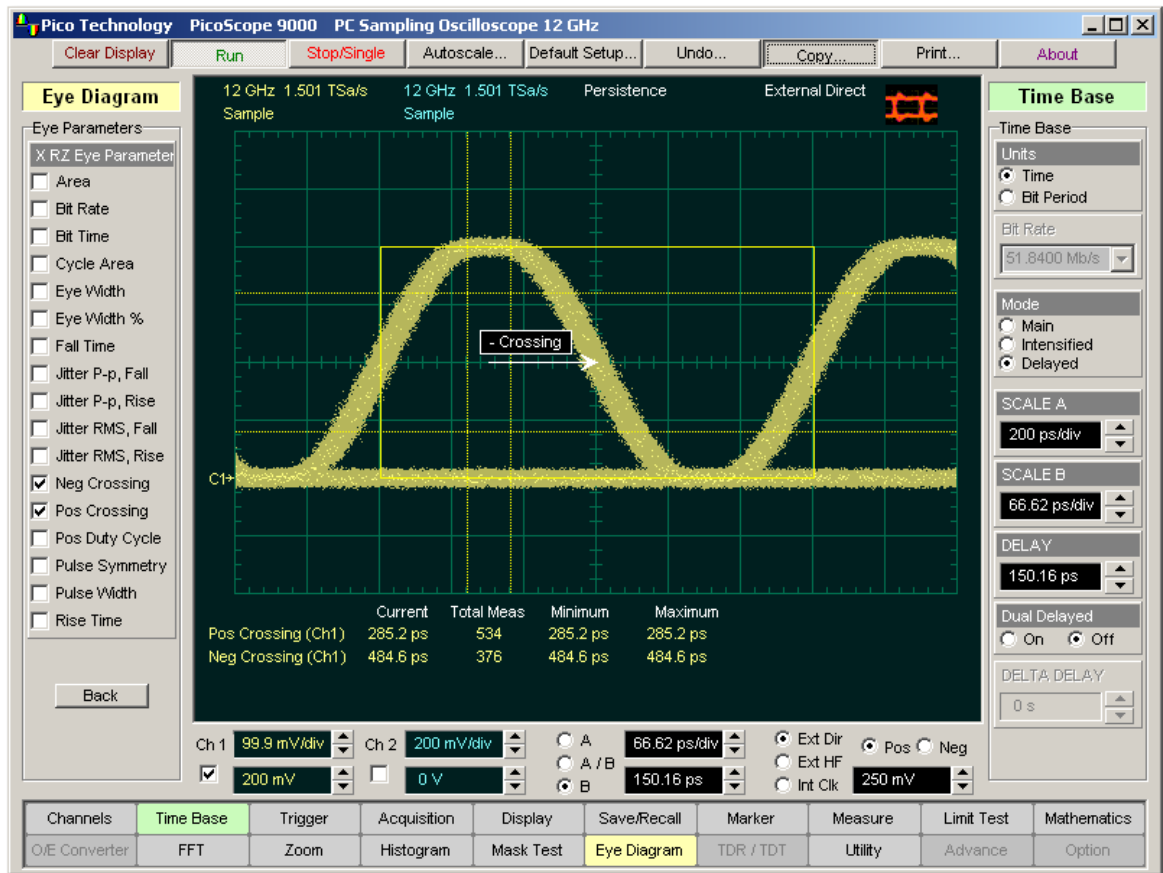
The RZ RMS jitter is defined as one standard deviation from the histogram mean at the eye crossing point:

$$RZ \text{ Jitter } RMS, \text{ Rise} = 1\sigma \text{ (crossing)}$$

## 5.4.7.9 RZ Negative Crossing



**RZ Negative Crossing** is a measure of the time of a negative crossing, defined as the mean of the histogram of the data sampled at the 50% reference level.



### RZ Negative Crossing definition

The **RZ Negative Crossing** is determined as follows:

$$RZ \text{ Negative Crossing} = T_{CrossNeg}$$

where  $T_{CrossNeg}$  is the mean of the histogram of a negative crossing.

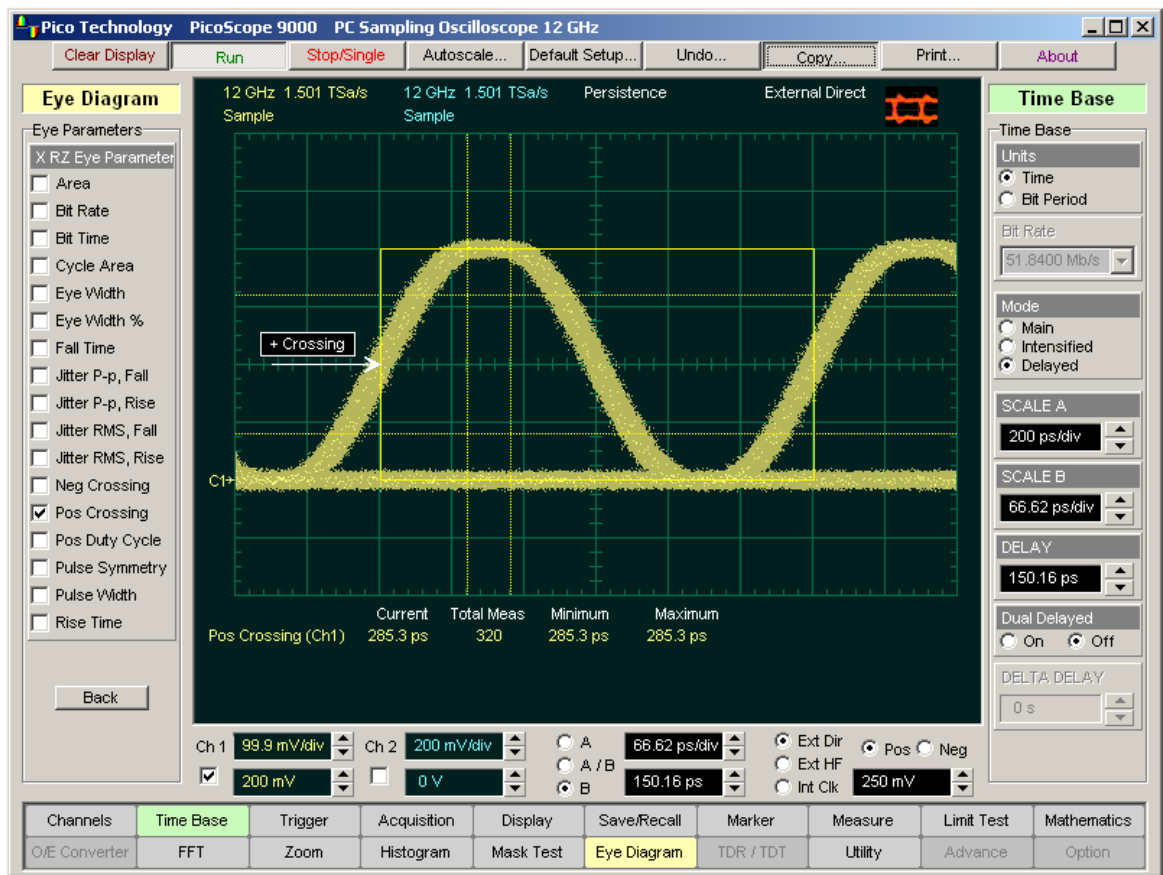
This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.



## 5.4.7.10 RZ Positive Crossing

☒ Pos Crossing

**RZ Positive Crossing** is a measure of the time of a left positive crossing, defined as the mean of the histogram of the data sampled at the 50% reference level.

**RZ Positive Crossing definition**

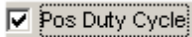
The **RZ Positive Crossing** is determined as follows:

$$RZ \text{ Positive Crossing} = T_{CrossPos}$$

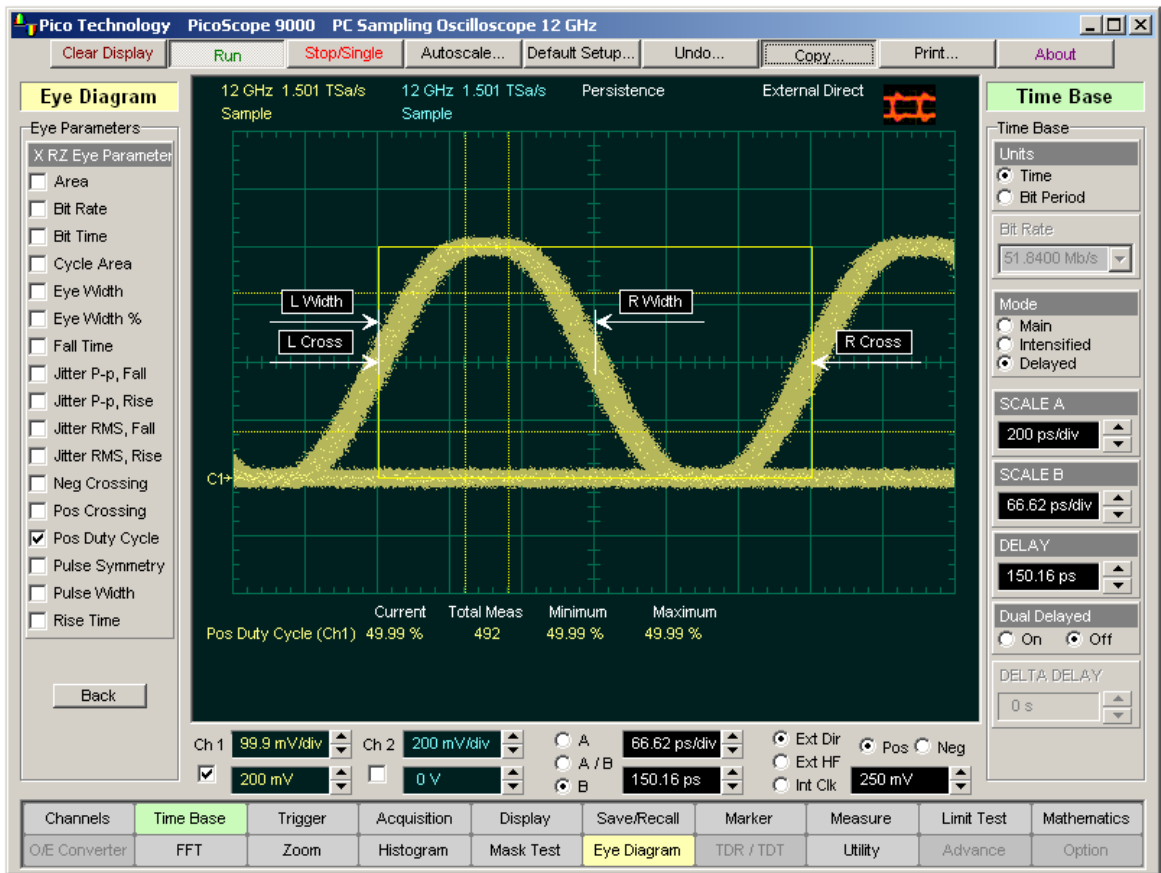
where  $T_{CrossPos}$  is the mean of the histogram of a positive crossing.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.11 RZ Positive Duty Cycle



**RZ Positive Duty Cycle** is a measure of the ratio of the RZ positive pulse width to the RZ bit time.

**RZ Positive Duty Cycle definition**

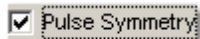
The RZ Positive Duty Cycle is determined as follows:

$$RZ\_DutyCycle = \frac{T_{Fall50\%} - T1_{Rise50\%}}{T2_{Rise50\%} - T1_{Rise50\%}} = \frac{RZ\_PositivePulseWidth}{RZ\_BitTime}$$

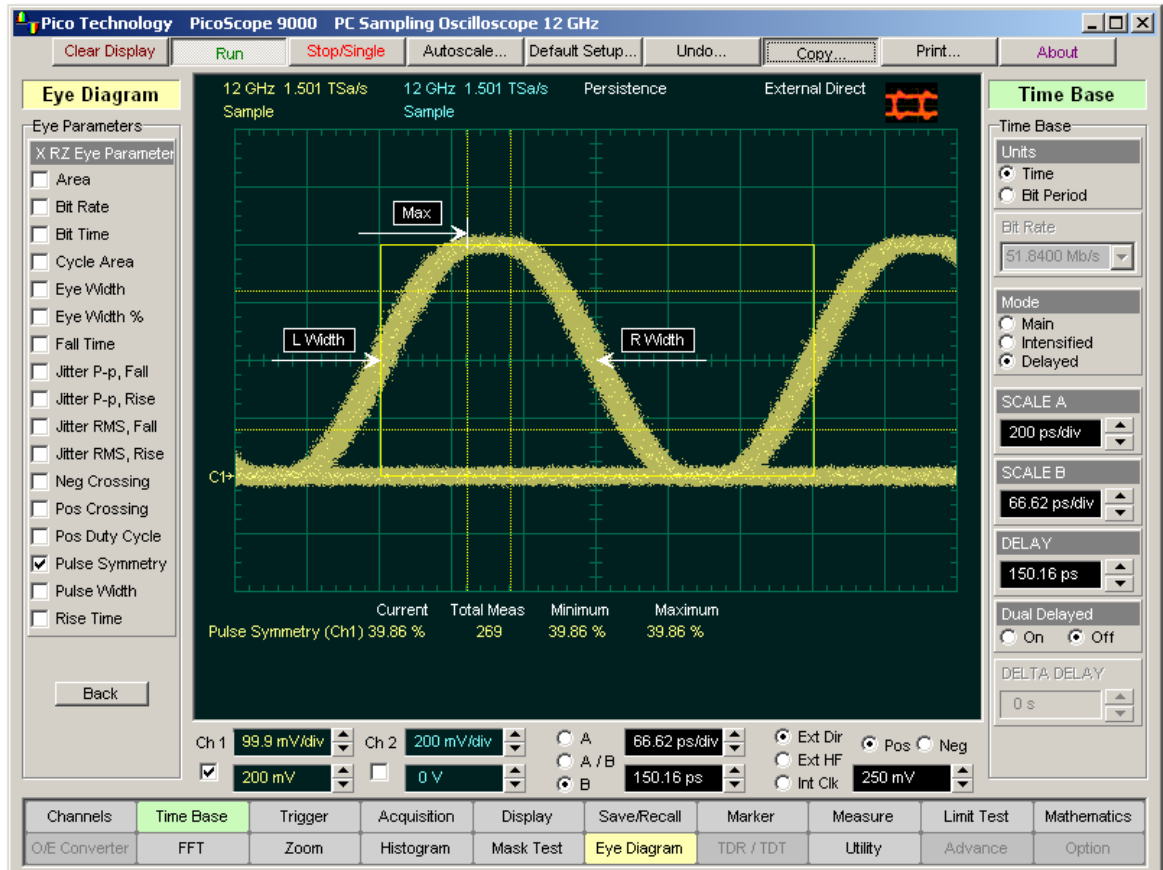
Where  $T1_{Rise50\%}$ ,  $T1_{Fall50\%}$  and  $T2_{Rise50\%}$  are the mean of the histogram of the first three consecutive crossings at the 50% reference level.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.12 RZ Pulse Symmetry



**RZ Pulse Symmetry** measures to what extent the RZ pulse is symmetrical around the peak at the 50% reference level. The pulse peak is the center of the interval, sized to **Eye Aperture**, which yields the maximum mean vertical value.

**RZ Pulse Symmetry definition**

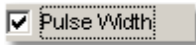
The **RZ Pulse Symmetry (%)** is determined as follows:

$$RZ\_PulseSymmetry, \% = 100 \frac{T_{Peak} - T_{Rise50\%}}{T_{Fall50\%} - T_{Rise50\%}}$$

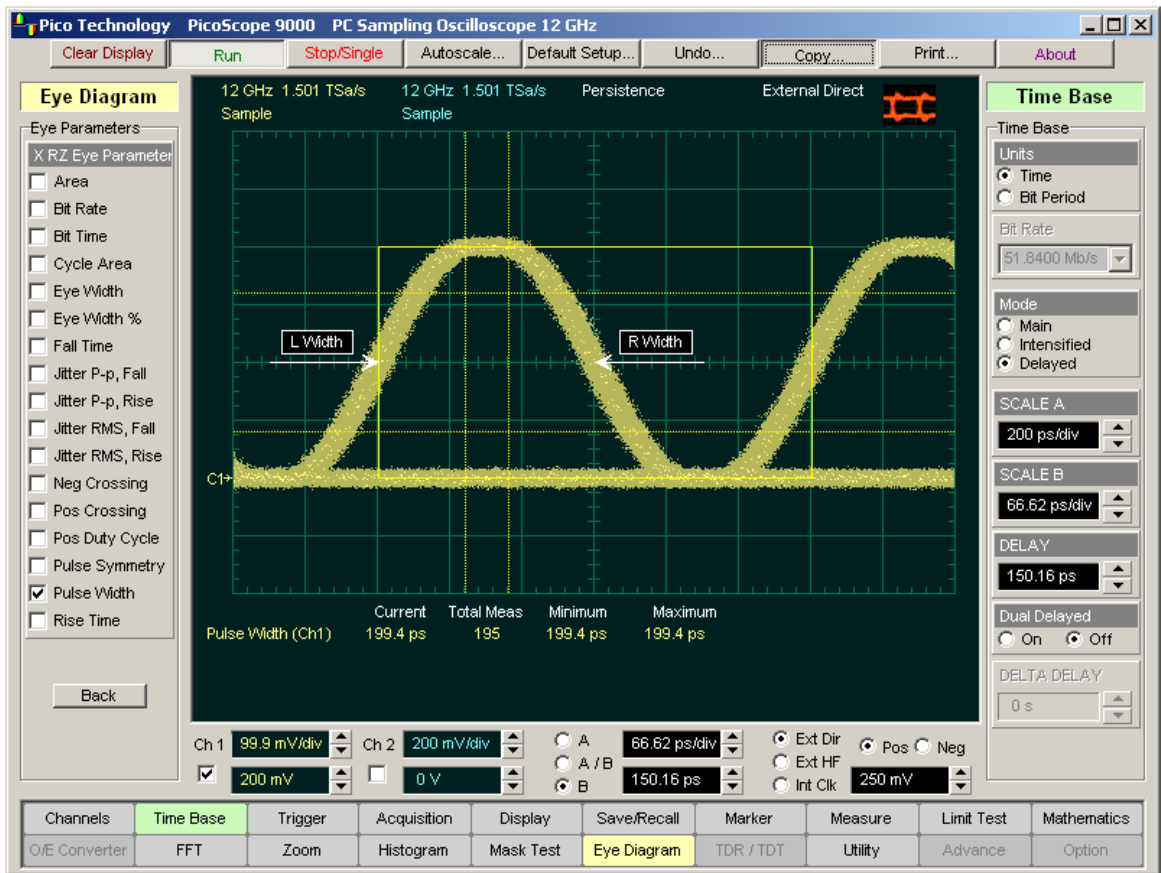
where  $T_{Rise50\%}$  and  $T_{Fall50\%}$  are the time crossings of the RZ pulse of the 50% reference level, and  $T_{Peak}$  is the time coordinate of the pulse peak.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.13 RZ Pulse Width



**RZ Pulse Width** is the time measured between histogram means of the 50% rising and 50% falling edges of an RZ eye diagram.



### RZ Pulse Width definition

The pulse width is determined as follows:

$$RZ \text{ Pulse Width} = T_{Fall50\%} - T_{Rise50\%}$$

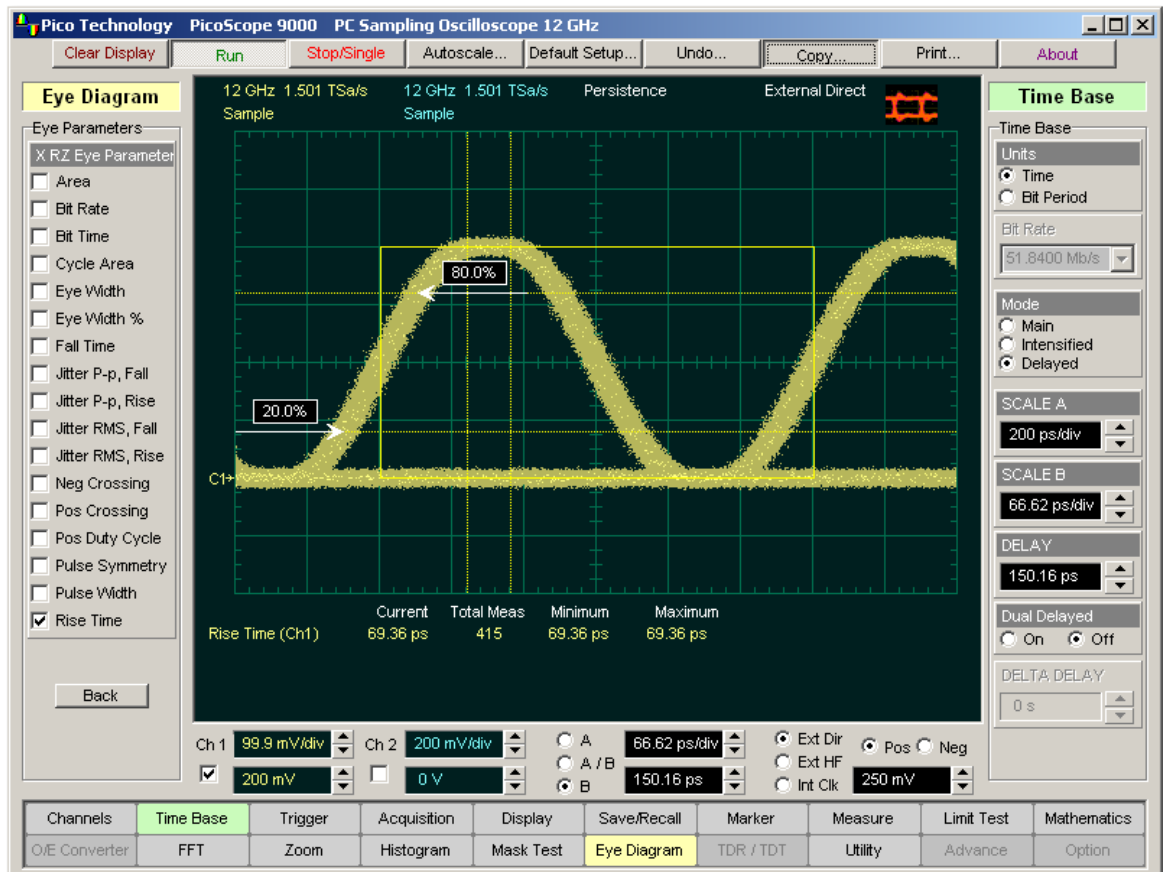
where  $T_{Fall50\%}$  and  $T_{Rise50\%}$  are the time crossings of the RZ pulse at the 50% reference level.

This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.

## 5.4.7.14 RZ Rise Time



**RZ Rise Time** is a measure of the mean transition time of the data on the upward slope of an RZ eye diagram. The data crosses through the lower, middle, and upper thresholds.

**RZ Rise Time definition**

A histogram is first constructed to find the mean locations of the eye one level and zero level. Histograms are then constructed at each of the three threshold levels (for example, the 20%, 50%, and 80% points on the transition). The instrument analyses each histogram to determine the histogram mean at which the data crosses the separate threshold levels. Once the scanning of the waveform is complete, and the instrument has identified the mean location for each threshold crossed, then fall time can be computed:

$$\text{RZ Rise Time} = (\text{Time at the Upper Threshold Crossing}) - (\text{Time at the Lower Threshold Crossing})$$

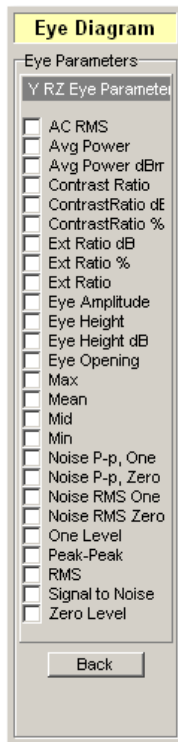
The default setting for the threshold levels is between the 20% and 80% points on the transition. These levels give more consistent results for eyes with distortion at the top or bottom. You can define the threshold settings that you want in the [Define Parameters](#) <sup>159</sup> menu.



If the rise time relative to the time per division is a small value, the data acquired at the threshold levels on the falling edge will not yield accurate measurement results. (The rising edge will appear very steep on the display screen.)

If the rising edge of your eye diagram is steep, increase the timebase (horizontal scale) on the display so that the rising edge covers at least half a graticule division. The instrument will be able to discern the data at the threshold levels, producing more accurate results.

## 5.4.8 Y RZ Eye Parameters



The list of **Y RZ Eye Parameters** includes twenty-six eye parameters. Two of the them (**Avg Power** and **Avg Power dBm**) can be used in optical models only.

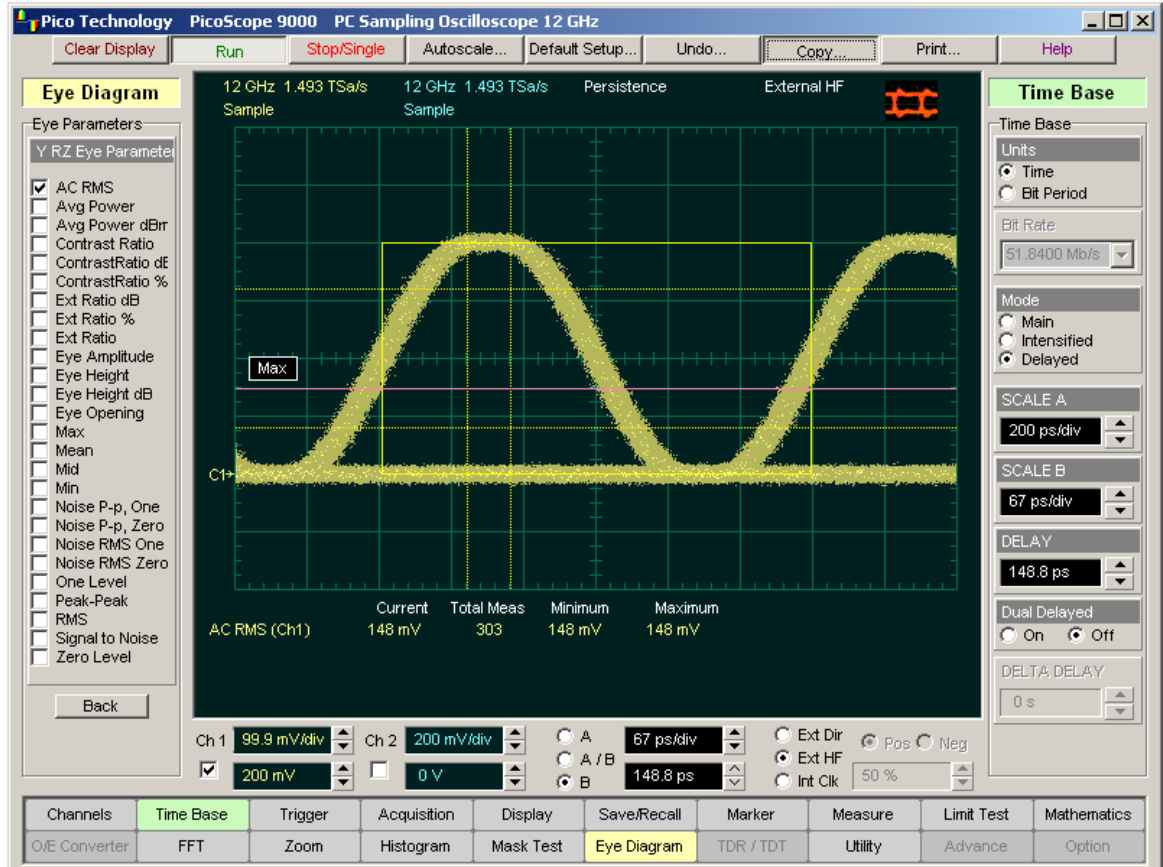
You can perform up to four simultaneous measurements on one displayed waveforms.

The measurement algorithms for **Y RZ Eye Parameters** will only work when an RZ eye diagram, and not an NRZ eye diagram or a pulse, is present on the screen. Eye measurements are based on statistical data that is acquired and stored in the measurement database. The algorithms depend upon histogram means calculated from the measurement database. Therefore, if you want to perform eye measurements, it is necessary that you first produce an eye diagram by triggering the instrument with a synchronous clock signal. Measurements made on NRZ eye diagram or a pulse waveform while in the **X RZ Eye Parameters** menu will fail.

## 5.4.8.1 RZ AC RMS



**RZ AC RMS** is a measure of the root mean square amplitude, minus the DC component, of the waveform within the eye window.

**RZ AC RMS definition**

The **RZ AC RMS** is determined as follows:

$$RZ\_AC\_RMS = \sqrt{\frac{\sum_{i=1}^N \langle (VertPos(s_i) - mean[VertPos(s)])^2 \rangle}{N}}$$

where  $S$  is the set of  $N$  samples  $s_{1...N}$  within the measured region.

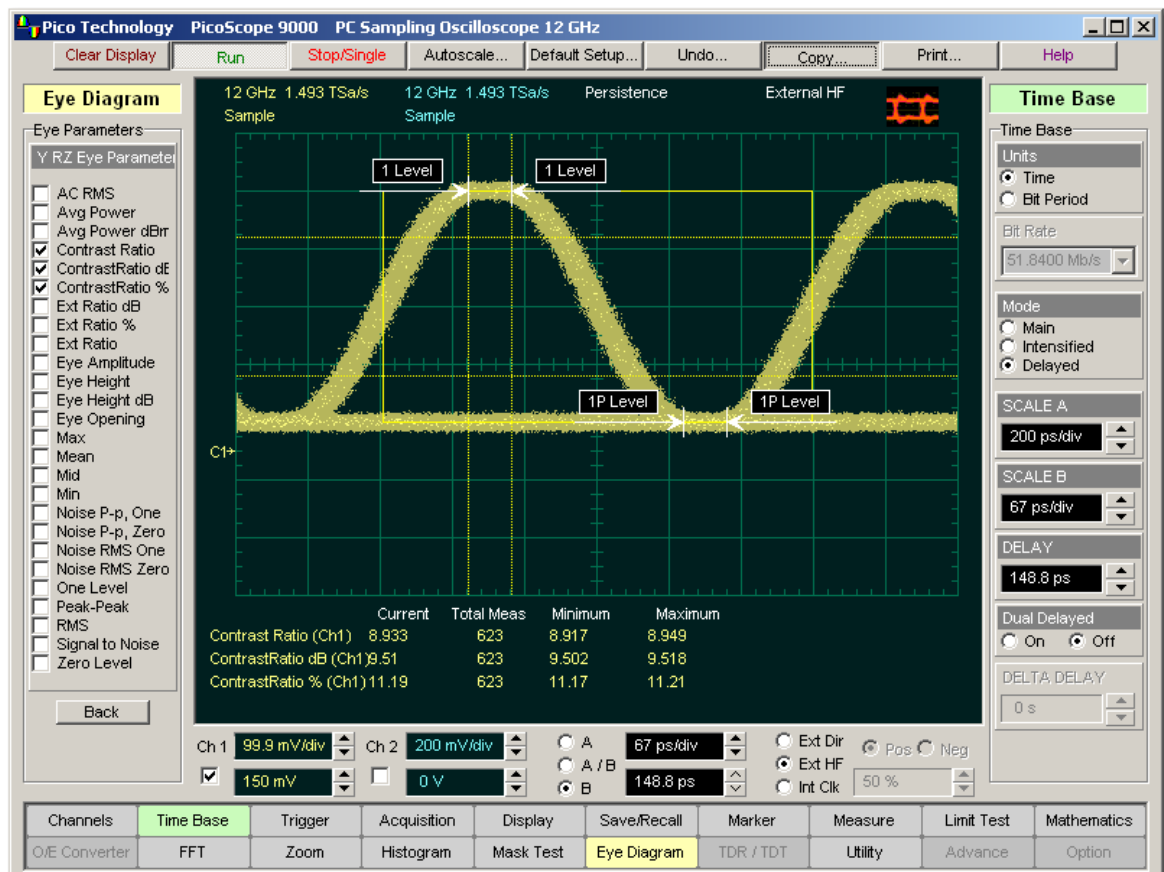
This measurement requires the use of a waveform database. When this measurement is turned on, it will automatically set the measurement system to use a waveform database if available.



## 5.4.8.2 RZ Contrast Ratio, RZ Contrast Ratio dB and RZ Contrast Ratio %

☒ Contrast Ratio    ☒ ContrastRatio dB    ☒ ContrastRatio %

**RZ Contrast Ratio** is a measure of the ratio of the one level at the centre of the eye diagram to the one level (after removal of the zero level contribution) found midway between eye diagram peaks. This measurement indicates how well the logic 1 levels return to the logic zero level. Like the RZ extinction ratio measurement, contrast ratio relies on determining and removing the dark level components from the measurement calculation. In order to perform an accurate contrast ratio measurement, you should first perform an extinction ratio calibration in order to minimize the dark level contribution.

**RZ Contrast Ratio definition**

**RZ Contrast Ratio** also is called **RZ Suppression Ratio**.

**RZ Contrast Ratio** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the Bit Time, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

Histograms are constructed using the sampled portions of the eye diagram within the eye window boundaries, and within equivalent eye window boundaries positioned between eye diagram peaks. The one level histogram mean is composed of data points taken from the upper half of the eye window located within the eye diagram, the zero level histogram is composed of data points taken from the lower half of the eye window located within the eye diagram, and the remaining histogram is composed of data points taken from the eye window located between peaks. The instrument analyses the histogram data, removes the zero level data from the between peaks histogram, then determines the ratio of the one level mean and the one level mean between peaks.

The accuracy of the contrast ratio measurement can be affected by offsets, including the dark level, generated within the instrument electronics, typically following the photodiode. When these offsets occur, they add to the incoming signal. This will change the values of the one and zero levels. When the contrast ratio measurement is computed, the result may appear much smaller or larger than the true value, depending on the value of the offset. To minimize contrast ratio measurement errors due to offsets, an extinction ratio calibration is recommended. This procedure allows the instrument to identify any internal signals present and remove them during the contrast ratio calculations. After the calibration is performed, a more accurate contrast ratio measurement can be executed.

With a valid extinction ratio calibration, the contrast ratio measurement can be computed and displayed in one of the three following formats:

$$NRZ\_ContrastRatio = \frac{OneLevel - DarkLevel}{OneLevel(between\_peaks) - DarkLevel}$$

$$NRZ\_ContrastRatio(dB) = 10 \log_{10} \left[ \frac{OneLevel - DarkLevel}{OneLevel(between\_peaks) - DarkLevel} \right]$$

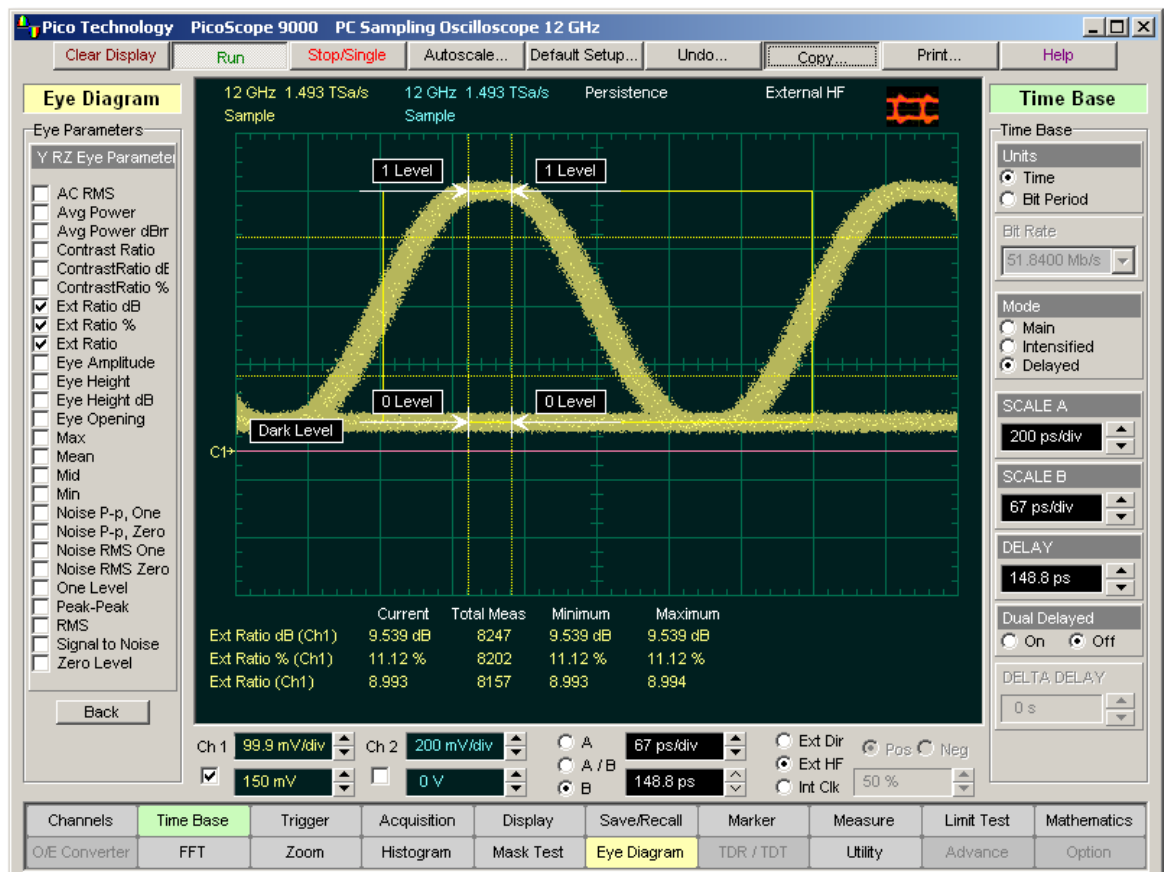
$$NRZ\_ContrastRatio(\%) = \frac{OneLevel(between\_peaks) - DarkLevel}{OneLevel - DarkLevel} \times 100$$

where: *One Level* = One level histogram mean at eye window, *One Level (between peaks)* = Histogram mean calculated from subtraction of zero level histogram from the between peaks histogram.

## 5.4.8.3 RZ Extinction Ratio dB, RZ Extinction Ratio % and RZ Extinction Ratio



**RZ Extinction Ratio** is a measure of the ratio of the one level and the zero level of an RZ eye diagram. The accuracy of this measurement relies on determining and removing the dark level components from the measurement calculation. In order to perform an accurate extinction ratio measurement, you should first perform an extinction ratio calibration in order to minimize the dark level contribution.

**RZ Extinction Ratio definition**

**RZ Extinction Ratio** measurement is made in a section of the eye referred to as **the Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

Histograms are constructed using the sampled portions of the eye diagram within the eye window boundaries. One histogram is composed of data points from only the upper half of the eye diagram (one level), and the second histogram is composed of data points from the lower half of the eye (zero level). The instrument analyses the histograms and determines the histogram means.

The accuracy of the extinction ratio measurement can be affected by offsets, including the dark level, generated within the instrument electronics, typically following the photodiode. When these offsets occur, they add to the incoming signal. This will change the values of the one and zero levels. When the extinction ratio measurement is computed, the result may appear much smaller or larger than the true value, depending on the value of the offset. To minimize extinction ratio measurement errors due to offsets, an extinction ratio calibration is recommended. This procedure allows the instrument to identify any internal signals present and remove them during the extinction ratio calculations. After the calibration is performed, a more accurate extinction ratio measurement can be executed.

With a valid extinction ratio calibration, the extinction ratio measurement is computed and can be displayed in one of the three following formats:

$$RZ\_ExtinctionRatio(dB) = 10 \log_{10} \left[ \frac{OneLevel(eye\_center) - DarkLevel}{ZeroLevel(eye\_center) - DarkLevel} \right]$$

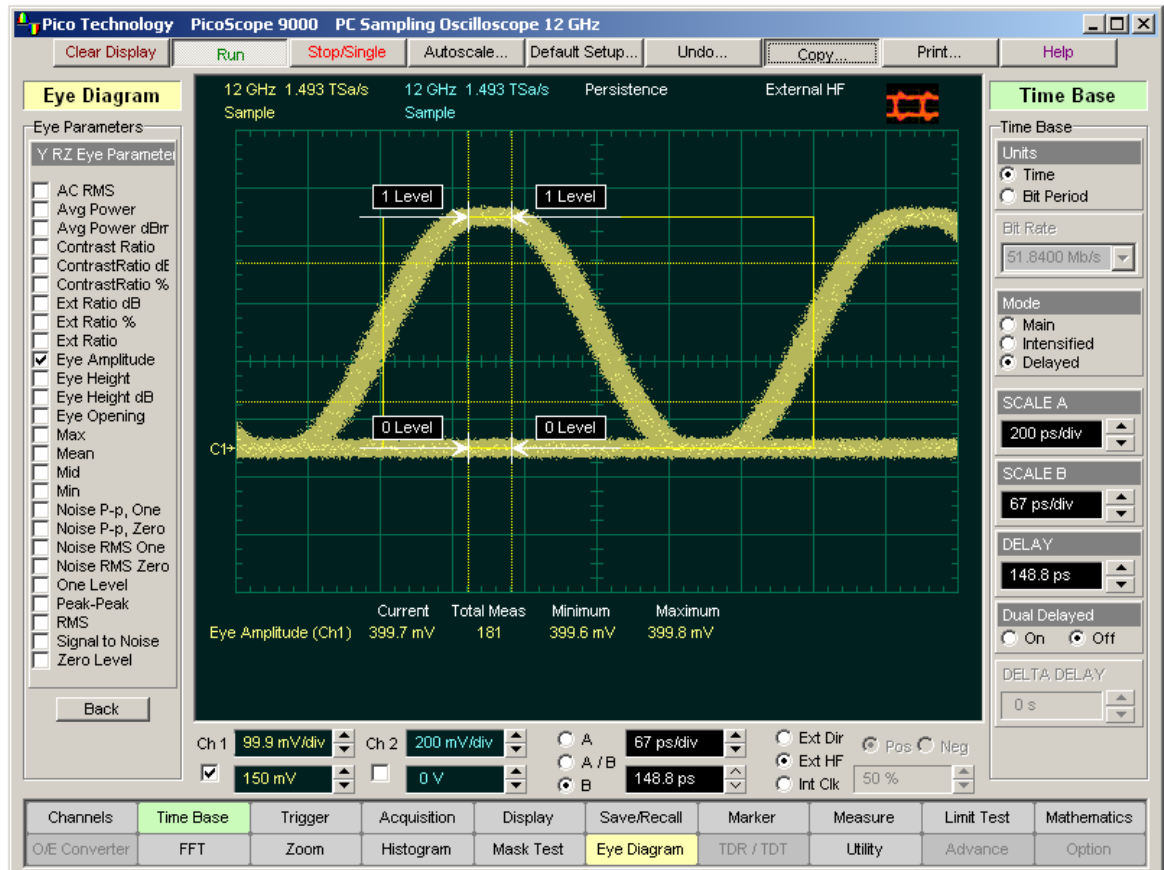
$$RZ\_ExtinctionRatio(\%) = \frac{ZeroLevel(eye\_center) - DarkLevel}{OneLevel(eye\_center) - DarkLevel} \times 100$$

$$RZ\_ExtinctionRatio = \frac{OneLevel(eye\_center) - DarkLevel}{ZeroLevel(eye\_center) - DarkLevel}$$

## 5.4.8.4 RZ Eye Amplitude

☒ Eye Amplitude

**RZ Eye Amplitude** is a measure of the difference between the logic 1 level and the logic 0 level histogram mean values of an RZ eye diagram. It differs from eye height in that it does not account for the noise on the signal.



### RZ Eye Amplitude definition

**RZ Eye Amplitude** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from the upper and lower halves of the eye diagram. The instrument analyses the histogram and determines the mean values of the logic 1 and logic 0 levels.

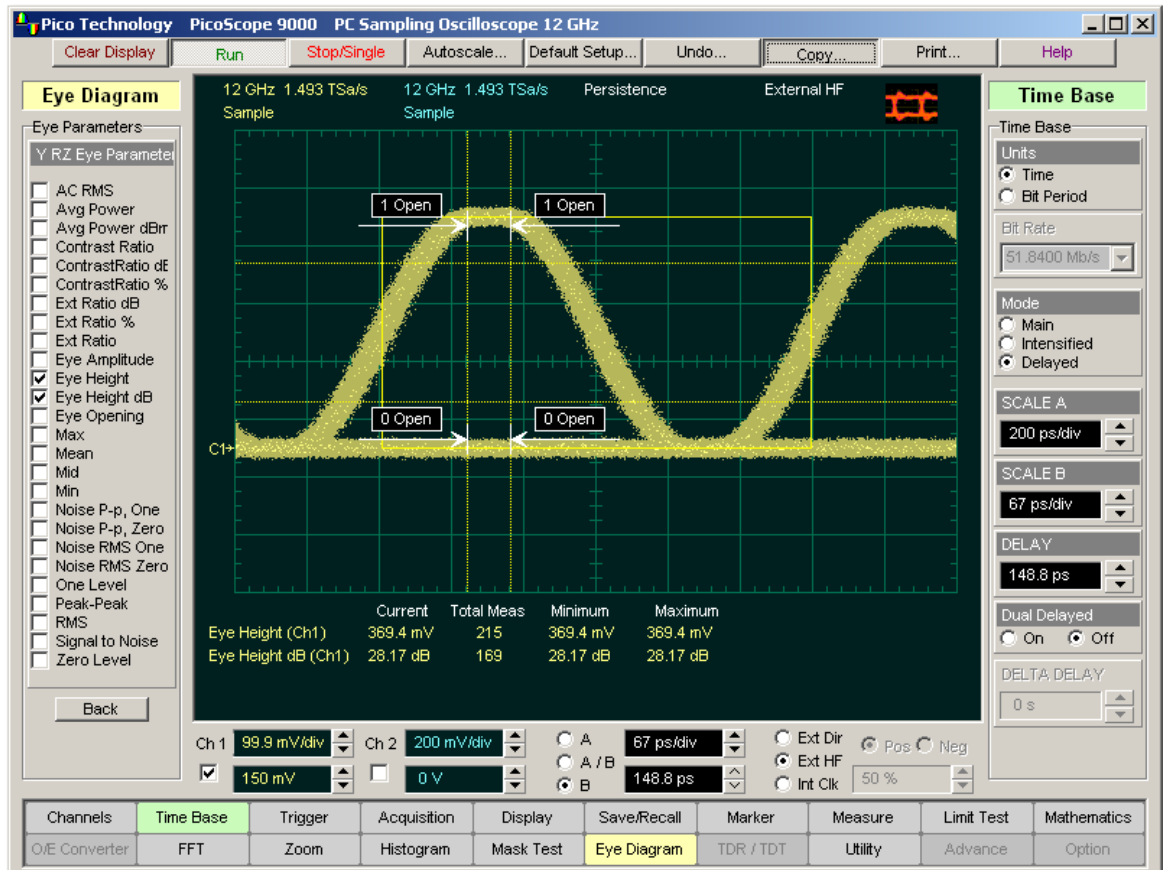
The eye amplitude is determined as follows:

$$\text{RZ Eye Amplitude} = \text{One Level} - \text{Zero Level}$$

## 5.4.8.5 RZ Eye Height and RZ Eye Height dB

☒ Eye Height ☒ Eye Height dB

**RZ Eye Height** is a measure of the vertical opening of an RZ eye diagram. An ideal eye opening would be measured from the one level to the zero level, but noise on the eye causes the eye to close. The eye height measurement determines eye closure due to noise.

**RZ Eye High definition**

**RZ Eye High** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

In order to make an accurate RZ eye height measurement, histograms are constructed to characterize both the one and zero levels and their noise levels within the eye window boundaries. The one and zero levels are the relative means of the histograms. The noise is measured through the histograms as three standard deviations ( $\sigma$ ) from both the one level and zero level into the eye opening.

The eye height is determined as follows:

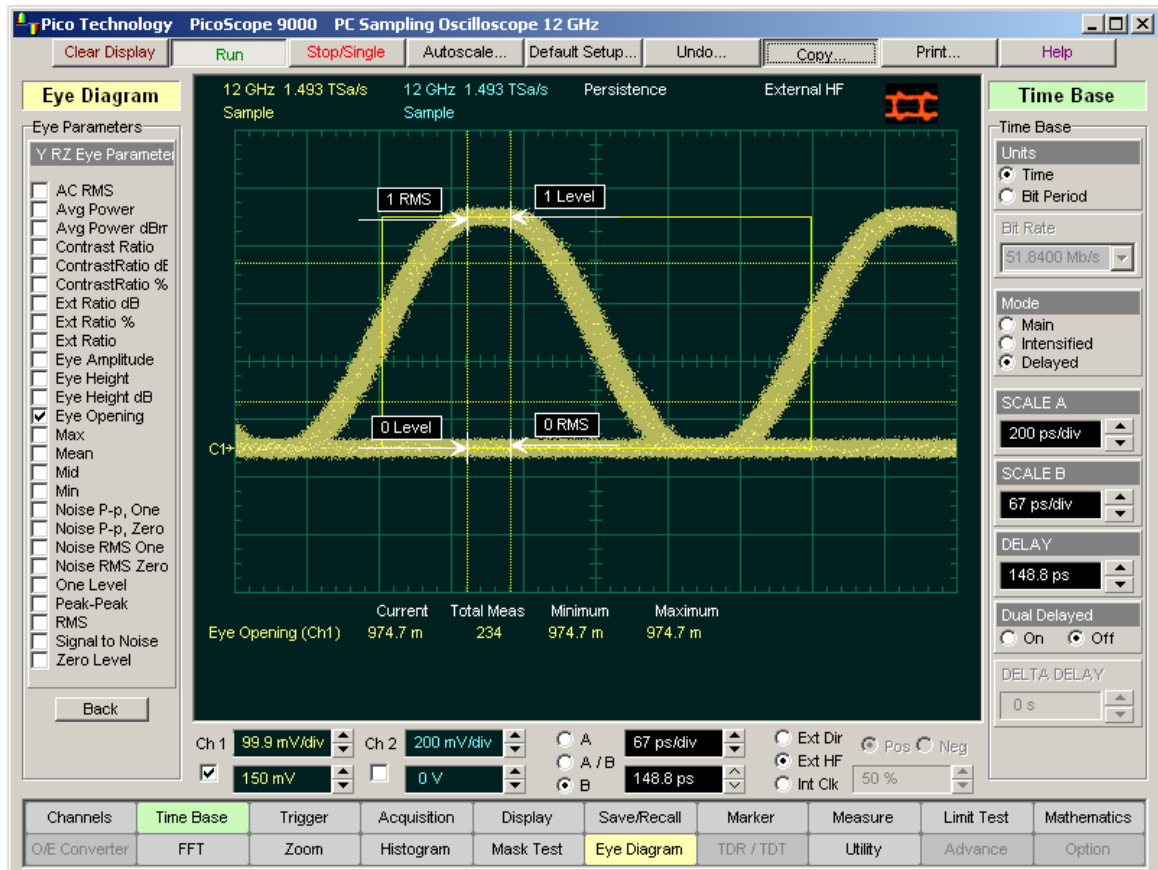
$$RZ\_EyeHeight = (OneLevel - 3\sigma_{one}) - (ZeroLevel + 3\sigma_{zero})$$

$$RZ\_EyeHeight(dB) = -10 \log_{10} \frac{(ZeroLevel + 3\sigma_{zero})}{(OneLevel - 3\sigma_{one})}$$

## 5.4.8.6 RZ Eye Opening

☒ Eye Opening

**RZ Eye Opening Factor** is similar to eye height. It measures the actual eye opening relative to an ideal noise-free eye. While the eye height measurement uses 3  $\sigma$  for the noise contribution, the eye opening measurement uses 1  $\sigma$ .

**RZ Eye Opening Factor definition**

The **RZ Eye Opening Factor** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

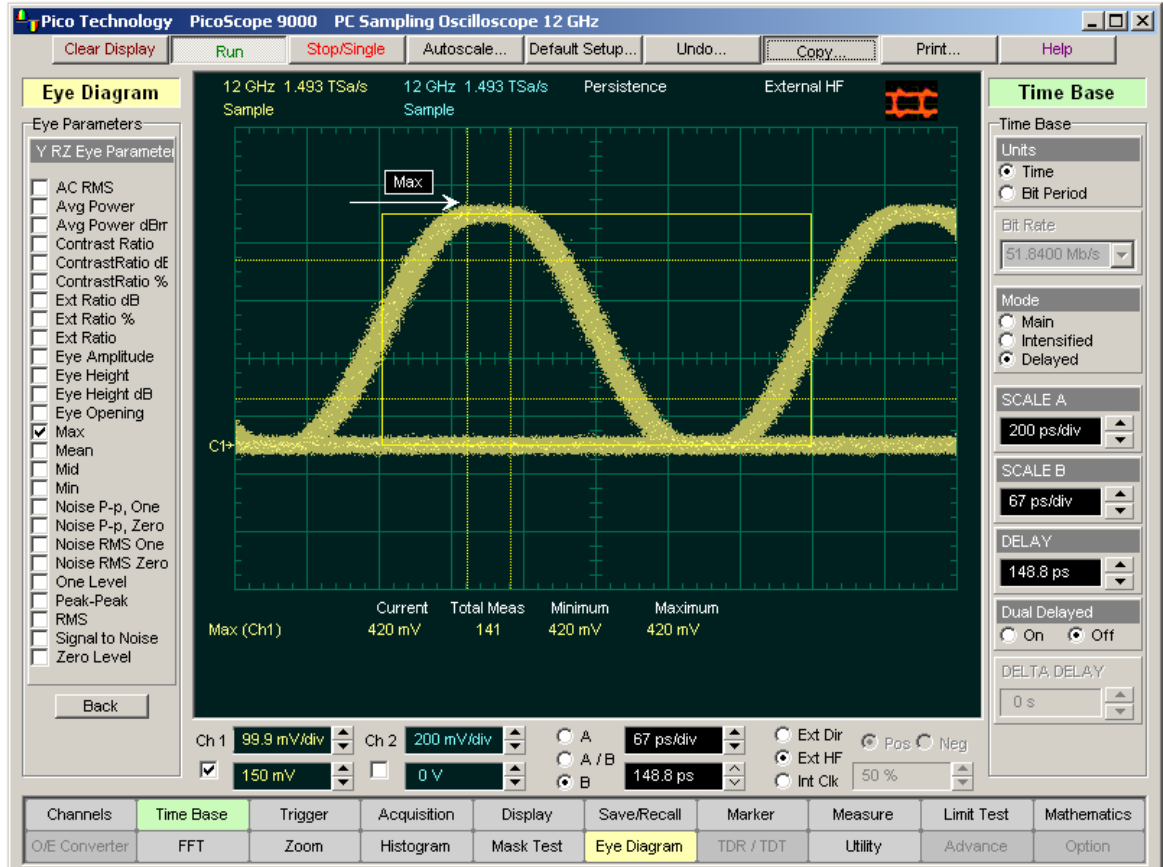
The eye opening factor is determined as follows:

$$RZ\_EyeOpeningFactor = - \frac{(OneLevel - \sigma_{one}) - (ZeroLevel + \sigma_{zero})}{OneLevel - ZeroLevel}$$

## 5.4.8.7 RZ Max



**RZ Max** is a measure of the maximum vertical value of the waveform that is sampled within the eye window.

**RZ Maximum definition**

The RZ maximum eye amplitude is determined as follows:

$$RZ\ Maximum = \max[VertPos(s)]$$

where  $s$  is the set of samples within the eye window.

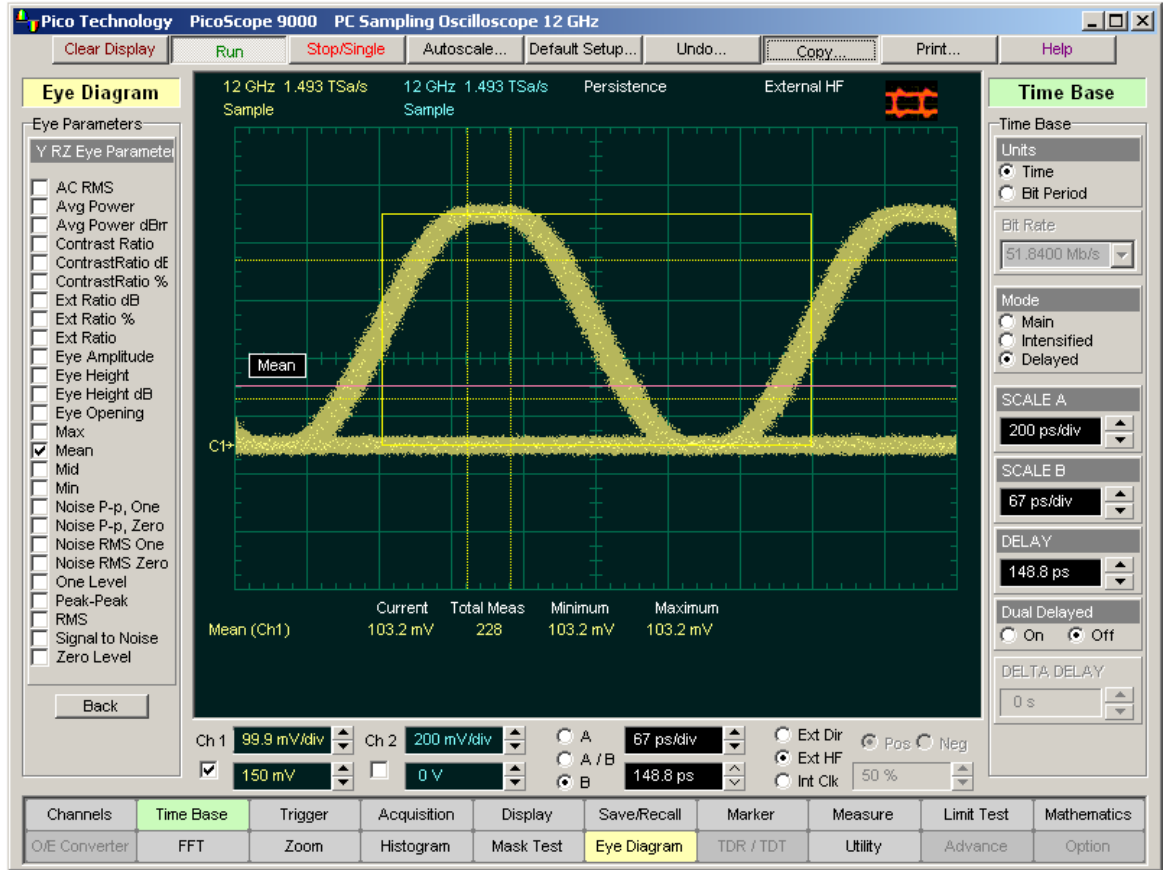
When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.



## 5.4.8.8 RZ Mean



**RZ Mean** is a measure of the arithmetic mean of the waveform that is sampled within the eye window.

**RZ Mean definition**

The **RZ Mean** is determined as follows:

$$RZ\_Mean = mean[VertPos(s)] = \frac{1}{N} \sum_{i=1}^N VertPos(s_i)$$

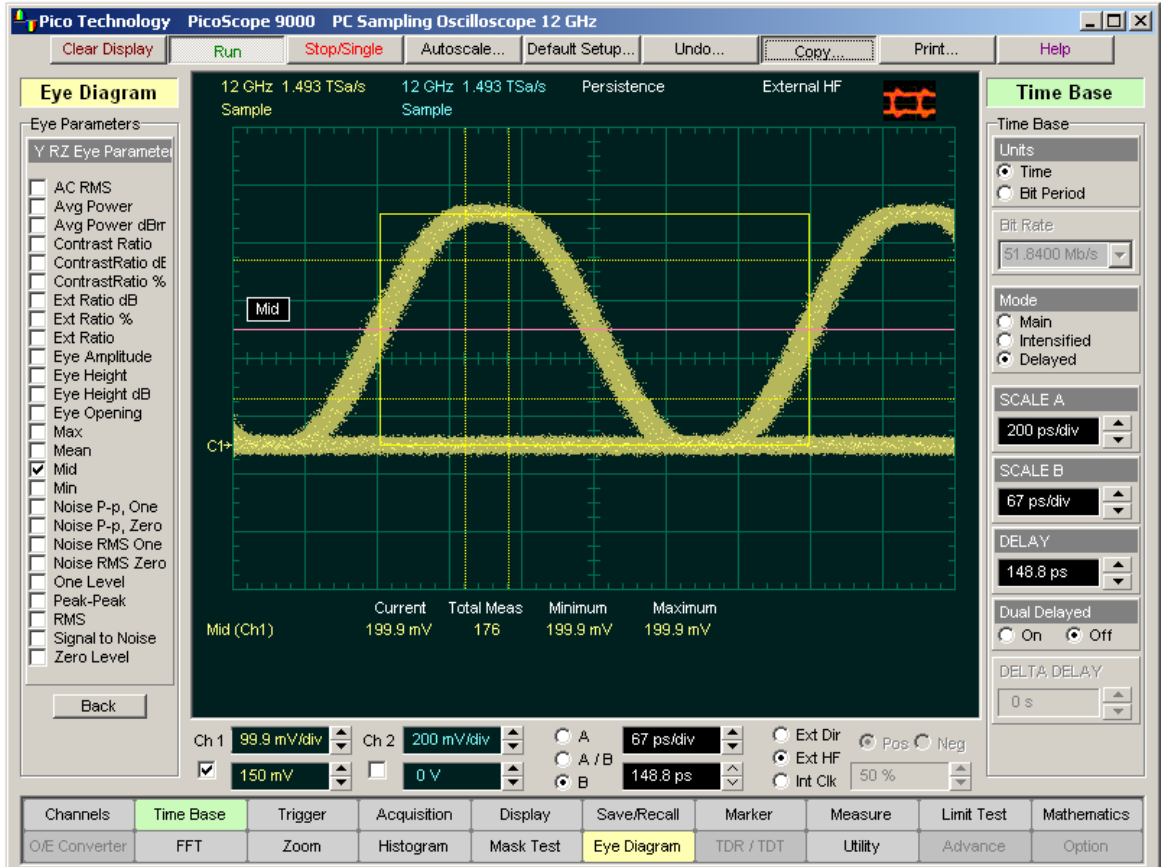
over all samples  $s_{i...N}$  within the eye window.

When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.

## 5.4.8.9 RZ Mid



**RZ Mid** is a measure of the middle level between the **Max** and **Min** vertical values of the waveform that is sampled within the eye window.

**RZ Mid definition**

The **RZ Mid** is determined as follows:

$$RZ\ Mid = (Max + Min) / 2$$

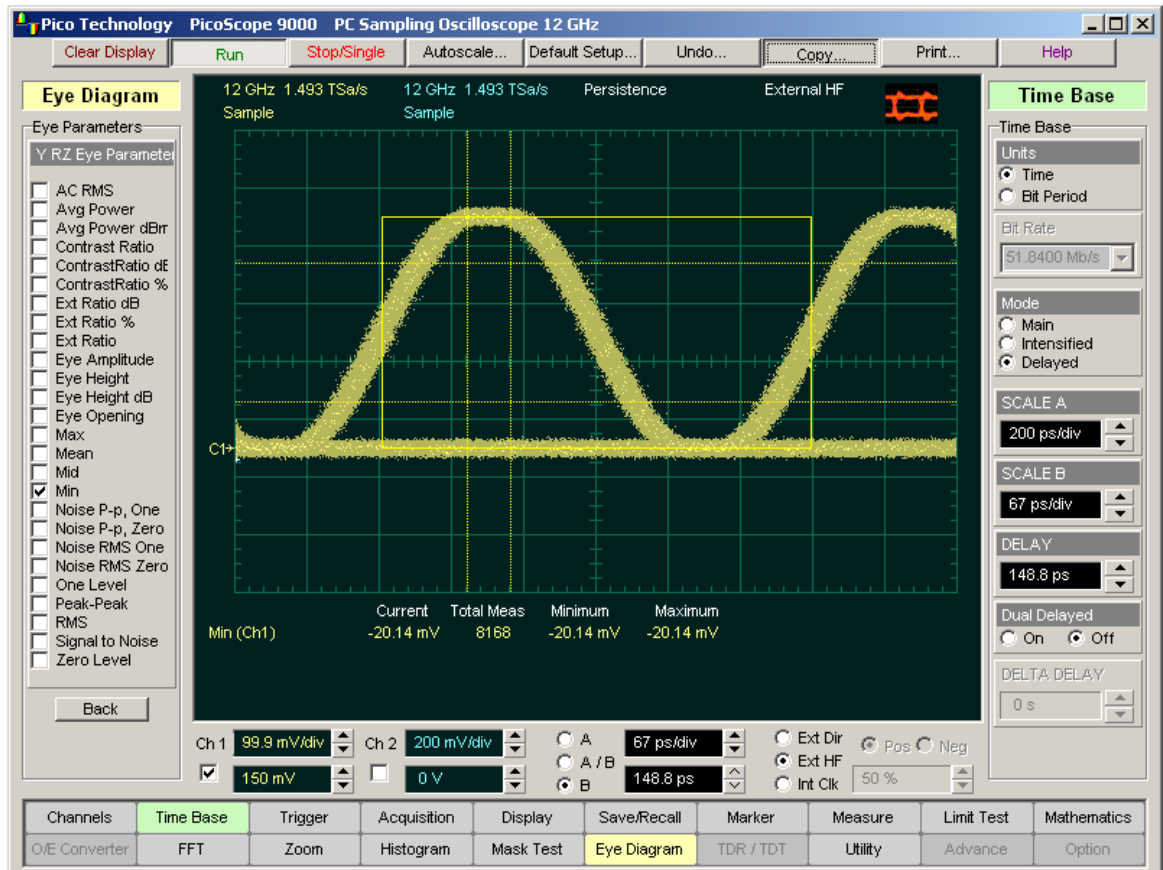
where *Max* and *Min* are the maximum and minimum measurements.

When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.

## 5.4.8.10 RZ Min



**RZ Min** is a measure of the minimum vertical value of the waveform that is sampled within the eye window.

**RZ Min definition**

The RZ minimum eye amplitude is determined as follows:

$$RZ\ Minimum = \max[VertPos(s)]$$

where  $s$  is the set of samples in the measured region. Minimum has no settable references.

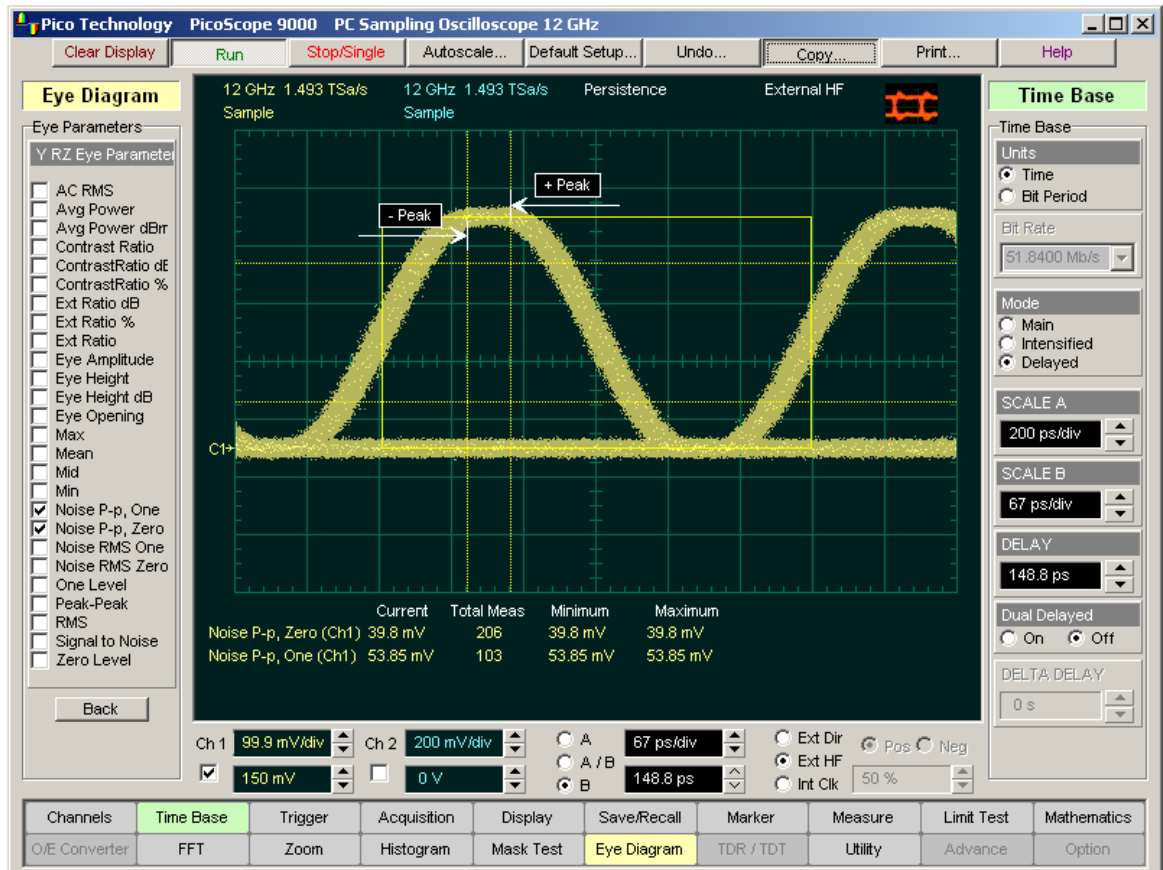
When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.

## 5.4.8.11 RZ Noise P-p, One and RZ Noise P-p, Zero

☒ Noise P-p, One    ☒ Noise P-p, Zero

**RZ Noise P-p, One** is a measure of the maximum range of the data distribution sampled within a fixed **RZ Eye Boundaries** slice located at the center of the **Eye Aperture** at the **One Level**.

**RZ Noise P-p, Zero** is a measure of the maximum range of the data distribution sampled within a fixed **RZ Eye Boundaries** slice located at the center of the **Eye Aperture** at the **Zero Level**.



**RZ Noise P-p, One and RZ Noise P-p, Zero definition**

The **RZ Noise P-p** is determined as follows:

$$RZ\_Noise, P-p = \max[VertPos(s)] - \min[VertPos(s)]$$

where  $s$  is the set of samples within a fixed width vertical slice located at the center of the eye aperture at either the **High** or the **Low** level (settable: **RZ Noise P-p, One**, and **RZ Noise P-p, Zero**).

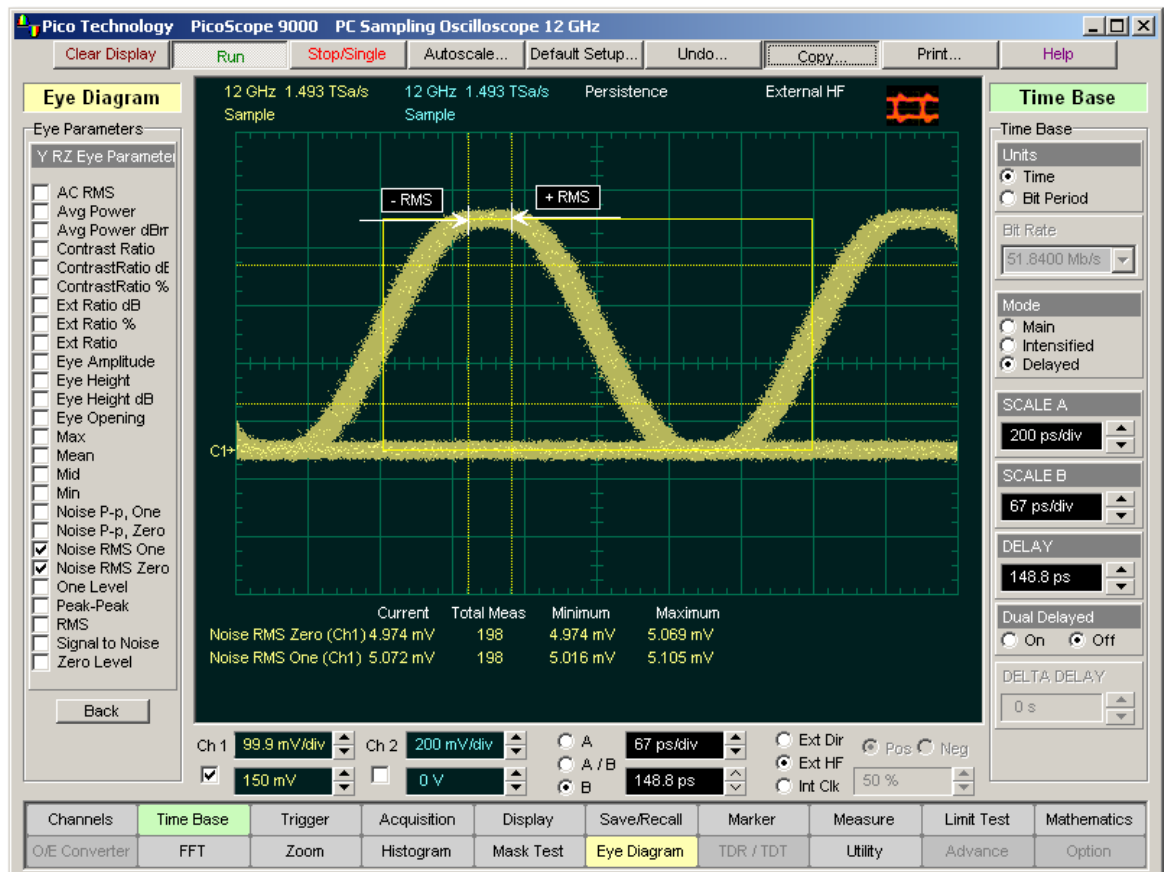
The **RZ Noise P-p, One** and **RZ Noise P-p, Zero** measurements are made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

This measurement requires the use of a waveform database. When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.

## 5.4.8.12 RZ Noise RMS, One and RZ Noise RMS Zero



**NRZ Noise RMS** is a measurement of the single standard deviation of the data distribution sampled within a fixed-width vertical slice located at the center of the **Eye Aperture** at the **High** (logical 1) or **Low** (logical 0) levels.



### RZ Noise RMS, One and RZ Noise RMS, Zero definition

The **RZ Noise RMS** is determined as follows:

$$RZ\ RMS = High\ \sigma$$

$$RZ\ RMS = Low\ \sigma$$

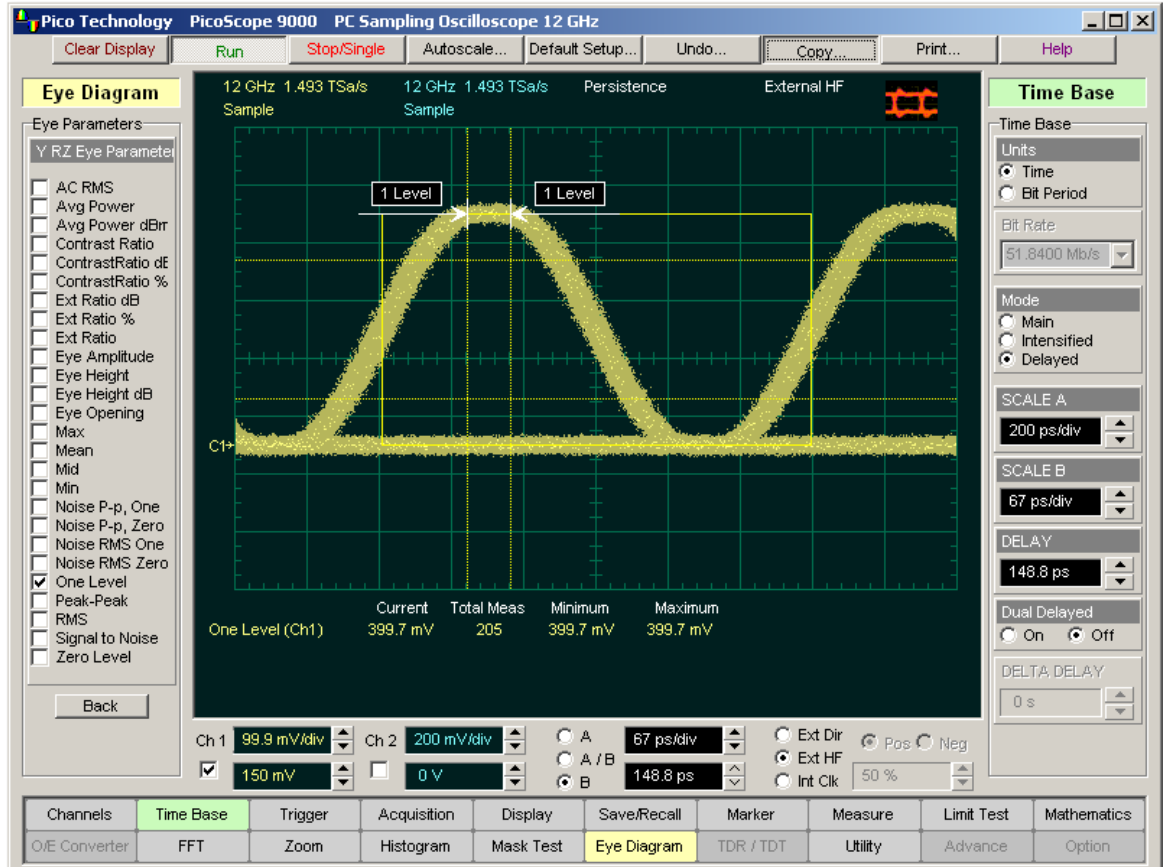
The **Eye Aperture** is adjustable and defaults to 5% of the RZ pulse width. The **High** or **Low** selection for noise control in the **Measurement Setup** dialog instructs the measurement to be performed on the logical 1 or 0 levels.

This measurement requires the use of a waveform database. When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.

## 5.4.8.13 RZ One Level



**RZ One Level** is a measure of the mean value found at the peak of the eye diagram logical 1.



### RZ One Level definition

The **RZ One Level** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from only the upper half of the eye diagram. The instrument analyses the histogram and determines the histogram mean.

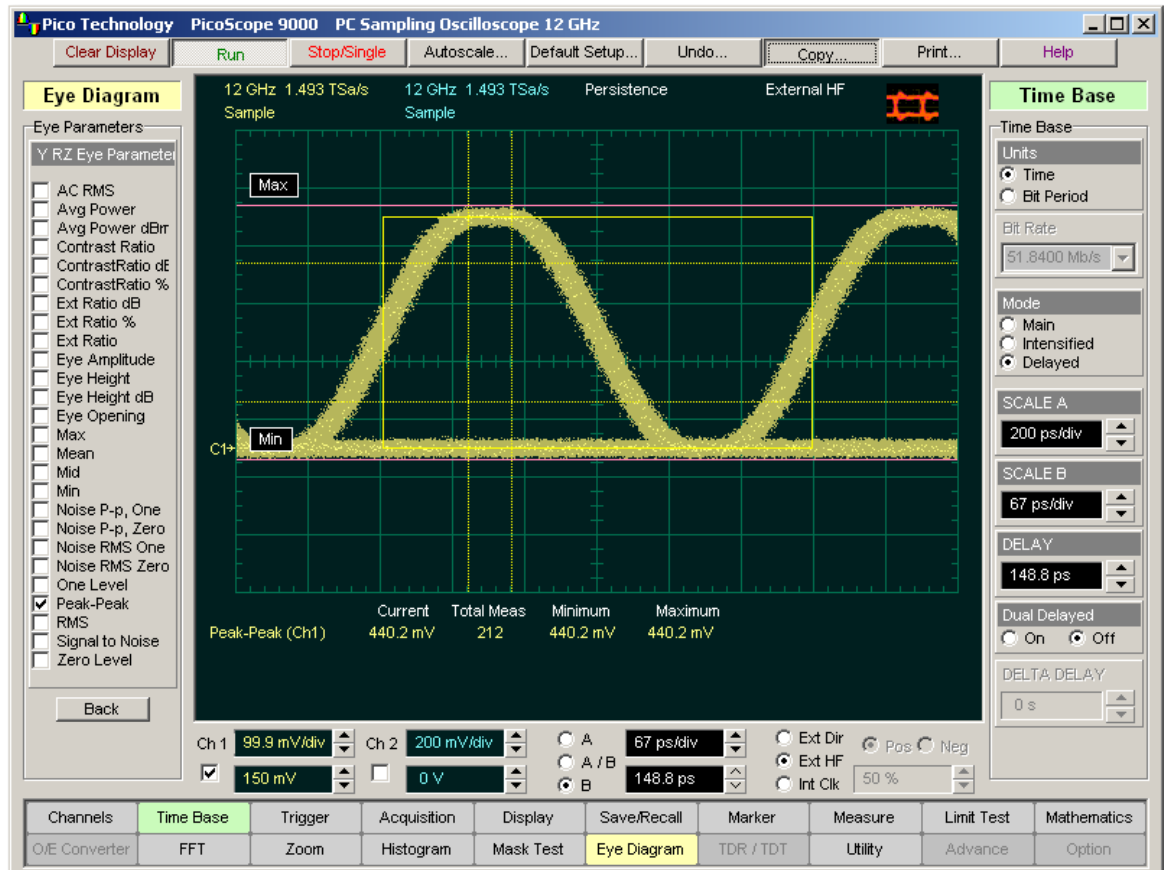
The **RZ One Level** is determined as follows:

$$RZ\ One\ Level = Histogram\ Mean$$

## 5.4.8.14 RZ Peak-Peak

☒ Peak-Peak

**RZ Peak-Peak** is a measure of the difference between the maximum and minimum vertical values of the waveform.

**RZ Peak-Peak definition**

The **RZ Peak-Peak** is determined as follows:

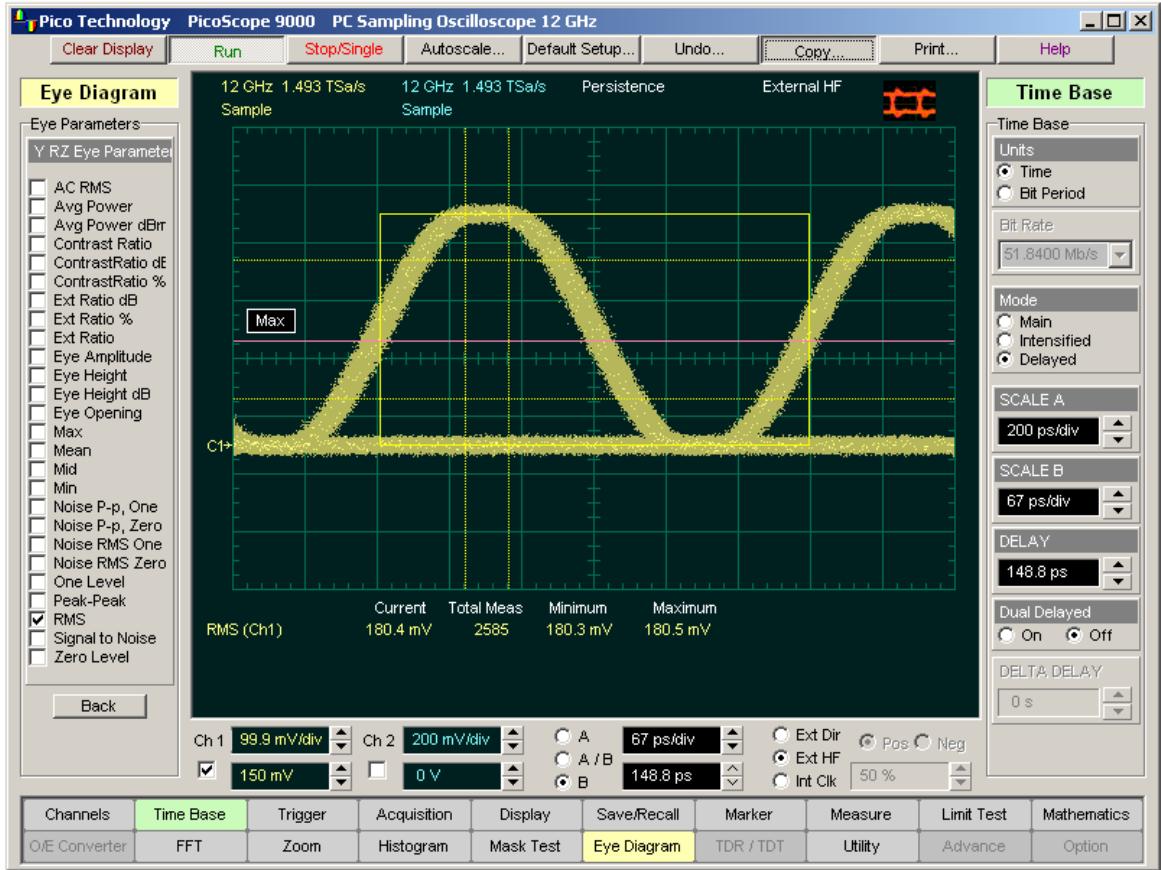
$$RZ \text{ Peak-Peak} = Max - Min$$

where *Max* and *Min* are the maximum and minimum measurements.

## 5.4.8.15 RZ RMS



**RZ RMS** is a measure of the true root mean square of the waveform that is sampled within the eye window.

**RZ RMS definition**

The **RZ RMS** is determined as follows:

$$RZ\_RMS = \sqrt{\frac{\sum_{n=1}^N [VertPos(s_n)]^2}{N}}$$

which is the RMS amplitude over all N samples  $s_{1...N}$  within the measured region (eye window); or one standard deviation of the amplitude.

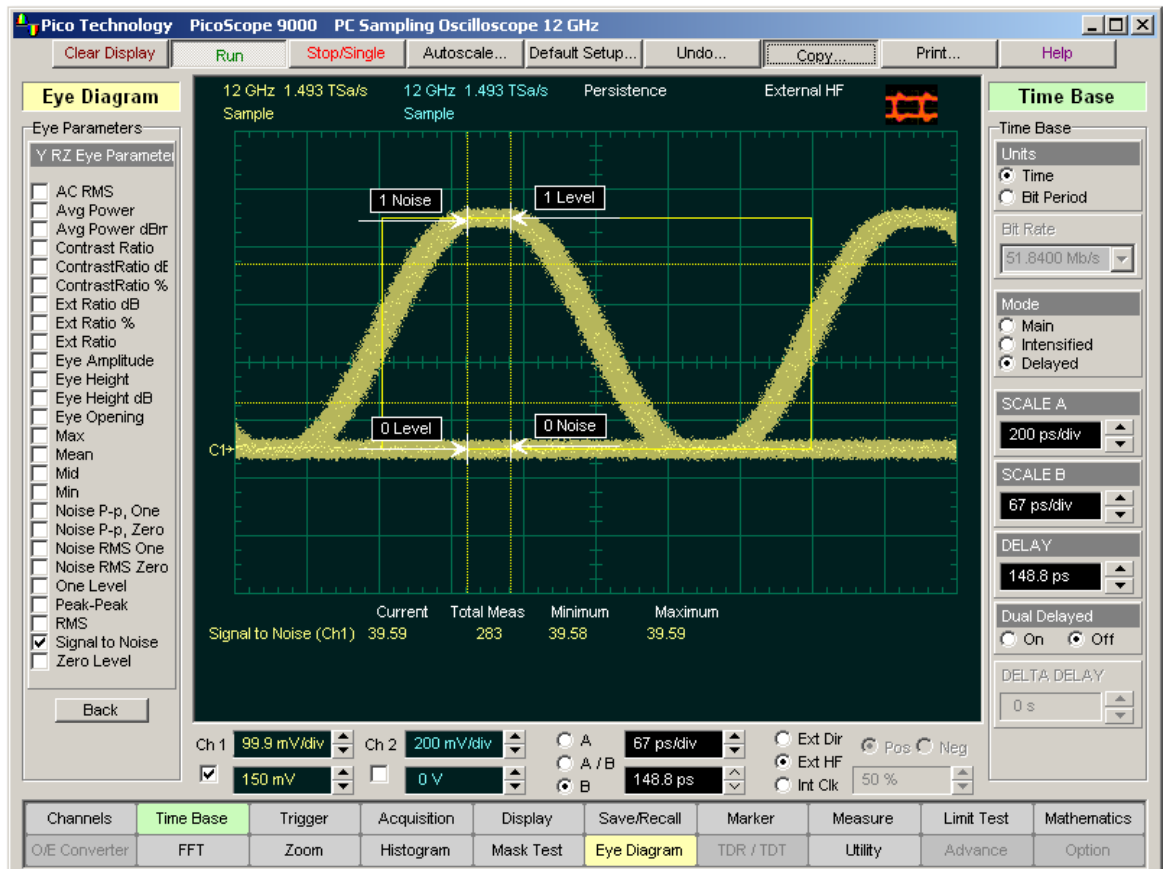
When this measurement is turned on, it automatically sets the measurement system to use a waveform database if available.



## 5.4.8.16 RZ Signal to Noise



**RZ Signal to Noise** is a measure of the ratio of the signal difference between one level and zero level relative to the noise present at both levels. Signal-to-noise is similar in construction to a Q-factor measurement. However, noise levels contributed by the instrument cannot be removed, therefore a slightly pessimistic **Q-factor** measurement may result.

**RZ Signal to Noise definition**

**RZ Signal to Noise ratio** is computed as:

$$RZ\_Signal\_to\_Noise\_Ratio = \frac{OneLevel - ZeroLevel}{\sigma_{one} + \sigma_{zero}}$$

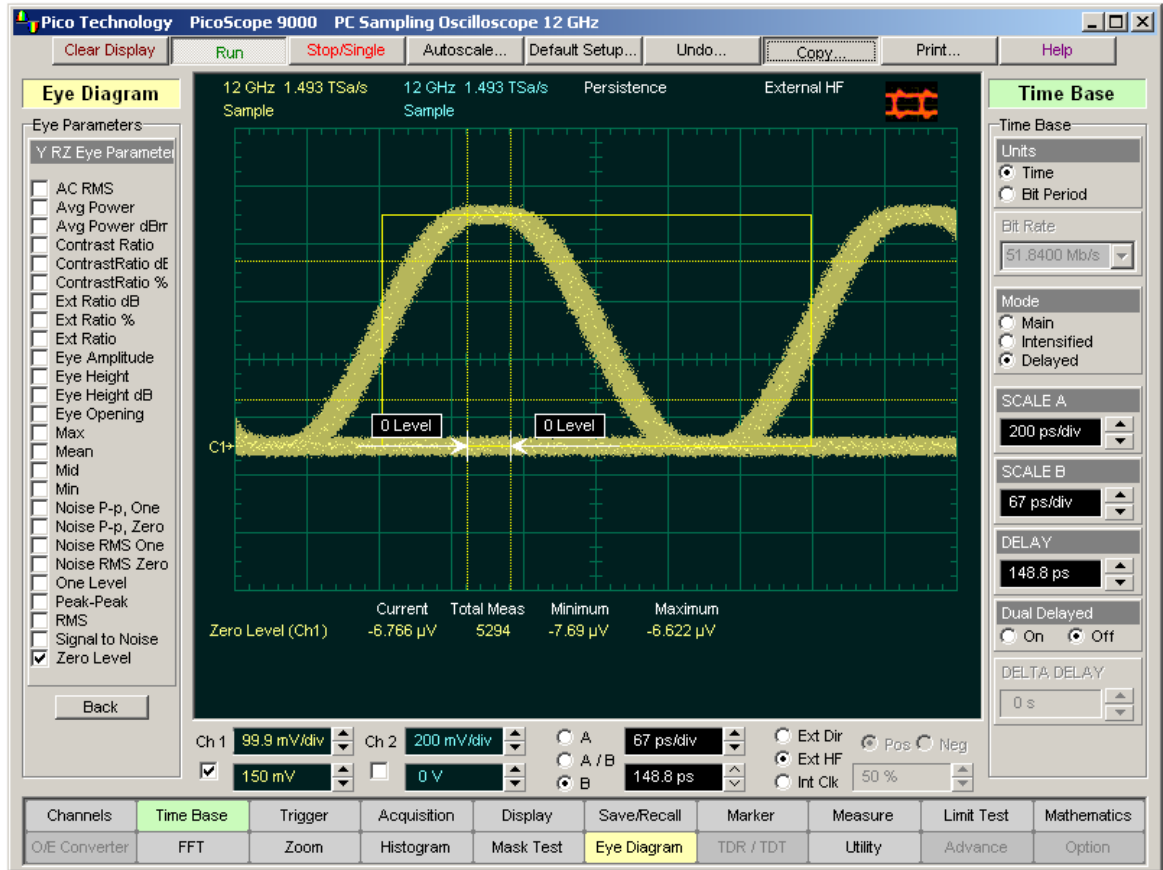
The **RZ One Level** and **Zero Level** measurements are made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

To define the signal, histograms are constructed using the sampled portions of the eye diagram within the eye window boundaries. One histogram is composed of data points from only the upper half of the eye diagram (one level), and the second histogram is composed of data points from the lower half of the eye (zero level). The instrument analyses the histograms and determines the histogram means and standard deviations. The noise is defined as 1 (standard deviation) from the histogram means for the one and zero levels.

## 5.4.8.17 RZ Zero Level



**RZ Zero Level** is a measure of the mean value of the logical 0 at a time position found directly below the peak of the eye diagram logical 1.

**RZ Zero Level definition**

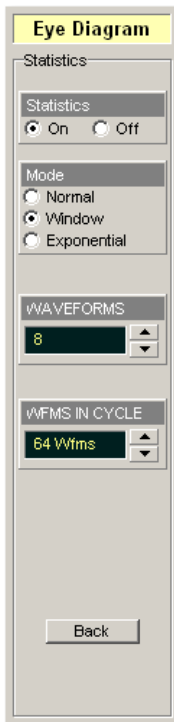
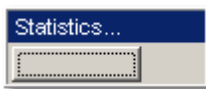
The **RZ Zero Level** measurement is made in a section of the eye referred to as the **Eye Boundaries**, and at the centre of the zero level between pulses. The default value for **RZ Eye Boundaries** is the central 5% p-p of the **Bit Time**, or 47.5% (**Eye Boundary 1**) and 52.5% (**Eye Boundary 2**).

A histogram is constructed using the sampled portion of the eye diagram within the eye window. This histogram is composed of data points from only the upper half of the eye diagram. The instrument analyses the histogram and determines the histogram mean.

The **RZ Zero Level** is determined as follows:

$$RZ\ Zero\ Level = Histogram\ Mean$$

## 5.4.9 Statistics



Click the **Statistics...** menu to open an eye diagram calculation statistical menu.

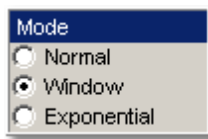
## 5.4.9.1 Statistics



**On.** Turns on statistical calculation of the eye diagram.

**Off.** Turns off statistical calculation of the eye diagram.

## 5.4.9.2 Mode



The **Mode...** menu defines one of three modes for statistical calculations.

**Normal.** Each of the acquired waveforms has equal influence on the eye diagram statistics. The **WAVEFORMS**<sup>[157]</sup> and **WEIGHT**<sup>[157]</sup> variables are not active in this mode.

**Window.** Only the last specified number of acquired waveforms will have equal influence on the eye diagram statistics. The **WAVEFORMS**<sup>[157]</sup> variable specifies the number of these influenced waveforms.

**Exponential.** Each of the acquired waveforms has a weighted influence on the result of the eye diagram statistics. The **WEIGHT**<sup>[157]</sup> variable specifies the degree of this influence.

## 5.4.9.3 WAVEFORMS &amp; WEIGHT

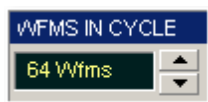


The **WAVEFORMS** variable specifies the number of influenced waveforms when the **Window** is selected in the **Mode**<sup>[157]</sup> menu. **WAVEFORMS** can be varied from 8 to 8192 in multiples of two.



The **WEIGHT** variable specifies the degree of influence of the latest acquired waveform against more remote waveforms. The **WEIGHT** variable is active when **Exponential** is selected in the **Mode**<sup>[157]</sup> menu. **WEIGHT** can be varied from 8 to 8192 in multiples of two.

## 5.4.9.4 WFMS IN CYCLE



The **WFMS IN CYCLE** variable determines how many acquired waveforms will be used for the one-measurement cycle in eye diagram calculations.

The **WFMS IN CYCLE** variable can be selected from 64 to 1024 waveforms per one-measurement cycle.

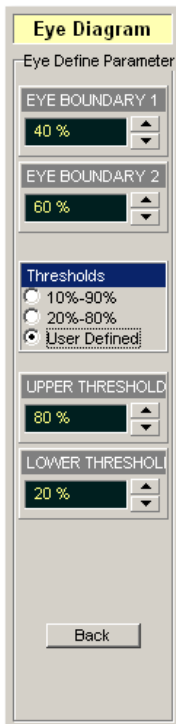
## 5.4.10 View Define Parameters



Setting **View Define Param** to **On** gives you a visual indicator of the calculation of the **Eye Window** placement. The **Eye Window** is red.

Setting the control to **Off** makes the **Eye Window** disappear.

### 5.4.11 Define Parameters



The **Define Param...** menu sets the measurement points (boundaries and thresholds) where the automatic measurements are made. The menu influences the measurement algorithm by allowing you to use the standard measurement points, or customize the measurements with user-defined selections.

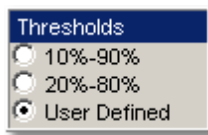
#### 5.4.11.1 EYE BOUNDARY 1 & EYE BOUNDARY 2



The **EYE BOUNDARY 1** (left boundary) and the **EYE BOUNDARY 2** (right boundary) variables set the time for the eye boundaries. These settings determine what horizontal portion of the eye will be used to generate histograms for eye diagram amplitude measurements. Both boundaries directly determine **One Level** and **Zero Level** values. You can use the instrument's default values of 40% and 60% for NRZ eye diagrams, and 47.5% and 52.5% for RZ eye diagrams, or you can enter the values you want for the boundaries.

**EYE BOUNDARY 1** allows you to set the percentage time for the left eye boundary, while **EYE BOUNDARY 2** allows you to set the percentage time for the right eye boundary.

## 5.4.11.2 Thresholds



The **Thresholds** menu sets the upper, middle, and lower measurement points that the eye diagram measurements use for calculating the timing measurement results. For example, rise time is measured from the lower threshold to the upper threshold, while a RZ Pulse Width measurement is made between two middle thresholds.

Thresholds are not visible.

The three threshold choices are the standard measurement points:

- **10%-90%**
- **20%-80%**
- **User Defined**

The **UPPER THRESHOLD** and **LOWER THRESHOLD** variables are displayed when **User Defined** is selected. **Middle** threshold is fixed at the 50% level.

**10%-90% and 20%-80%**

These are two standard pulse measurement thresholds for all measurements. These standard thresholds are calculated as a percentage of the **One-Zero Level** value, while the **One Level** and **Zero Level** values are calculated from the eye diagram that is on the display.

**10%-90%** means: Lower threshold = 10%, Upper threshold = 90%. Use these thresholds for typical eye diagrams.

**20%-80%** means: Lower threshold = 20%, Upper threshold = 80%. Use these thresholds for eye diagrams with excessive ringing or overshoot.

Make sure that the eye diagram is expanded vertically and horizontally so that the instrument can accurately determine the **One Level** and **Zero Level** values of the eye. However, if too much of the **One Level** and **Zero Level** of the eye diagram is on the display, it may reduce the repeatability of your measurements. A good rule of thumb is to have two divisions of **One Level** and two divisions of **Zero Level**.

**User Defined**

You can use the **User Defined** setting to define thresholds for eye diagrams at the positions you want.

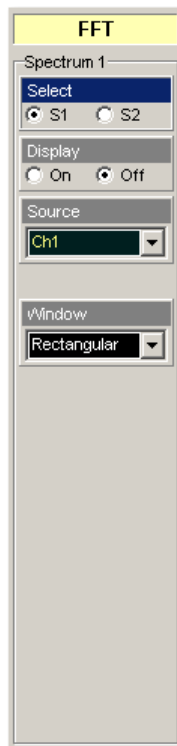
## 5.4.11.3 UPPER THRESHOLD &amp; LOWER THRESHOLD



The **UPPER THRESHOLD** and **LOWER THRESHOLD** variables are displayed only when **User Define** option of the [Thresholds](#) <sup>[160]</sup> menu is selected.

**UPPER THRESHOLD** can be set from 55% to 95%, while the **LOWER THRESHOLD** can be set from 5% to 45%.

## 5.5 FFT Menu



The **FFT** menu allows you to control the operation of the FFT, including spectrum selection and display, and also a choice of six FFT windowing functions. Two signal spectrums can be active simultaneously.

Refer to the [Zoom](#) <sup>366</sup> menu for formatting a spectrum with different complex scales, and also for scaling and positioning it.



### 5.5.1 FFT Basics

The PicoScope 9000 displays and measures signals in the time domain where the vertical axis is amplitude and the horizontal axis is time. This is the best way to view most waveforms. However, there are times when you want to know the frequency content of a waveform.



In 1807 the French mathematician Jean Baptiste Fourier developed the Fourier series and Fourier transform to solve thermodynamics problems. Using the Fourier series, any periodic waveform can be constructed by adding a DC term to a series of sine and cosine terms. You can use the Fourier transform to mathematically relate the time domain and the frequency domain.

The Discrete Fourier Transform (DFT) is used to convert sampled time domain waveform data into the frequency domain. However, the DFT is slow because it requires a large number of calculations. This led to the development of the Fast Fourier Transform (FFT), which runs faster than the DFT on digital computers.

When an FFT, or fast Fourier transform, is added to an instrument, signals can also be displayed in the frequency domain. The frequency domain allows you to see the frequency content of a signal. FFT functionality added to an instrument allows you to analyse a signal from two different, but complementary points of view: the frequency domain and the time domain. The FFT process mathematically converts the standard (in this case repetitive) time-domain signal into its frequency components, providing spectrum analysis capabilities. Being able to quickly look at a signal's frequency components and spectrum shape is a powerful research and analysis tool.

FFT is an excellent troubleshooting aid for:

- finding cross-talk problems
- finding distortion problems in analog waveforms caused by non-linear amplifiers
- adjusting filter circuits designed to filter out certain harmonics in a waveform
- testing impulse responses of systems
- identifying and locating noise and interference sources

The FFT display shows the amplitude for each frequency component in your waveform on the vertical axis, and frequency on the horizontal axis. The figure below illustrates what an FFT does. The FFT transforms a time record of  $N$  samples into a frequency record of  $N$  points from 0 Hz to  $F_s$ , where  $F_s$  is the sampling frequency. The resolution or the spacing between the points in the frequency record is  $F_s/N$ .



### The 1-GHz sine-wave signal shown in both the Time Domain and the Frequency Domain

The frequency  $F_s/2$  is a unique frequency referred to as the Nyquist frequency. At the Nyquist frequency there are exactly two samples on every cycle of the input signal. Signals above the Nyquist frequency become aliased, which means that they appear as signals of a lower frequency, because there are not enough sample points on each cycle of the signal to determine the correct frequency.

It turns out that the points above  $F_s/2$  are mirror images of the points below  $F_s/2$ . They are not displayed because they do not provide any additional information. Therefore,  $N$  time samples results in  $N/2$  displayed frequency points.

You can use the FFT capability to display both the magnitude and the phase, or the real and the imaginary parts of the frequency components of the signal, using a linear or decibel vertical scale.



Use the **Zoom** <sup>366</sup> menu for further magnification and spanning of the FFT, and for selecting the Complex Scale of the display.

You can perform an FFT on any waveform. The record length of the waveform can be up to 4096 points. Because the PicoScope 9000 performs FFT calculations on a complex trace record, you should use the shortest record length that provides adequate resolution, as FFT waveforms update slowly at long record length.

The PicoScope 9000 offers a choice of six FFT windowing functions, which modify the time-domain data to minimize "leakage" of energy across frequency components.

The five automated measurements FFT Magnitude, FFT Delta Magnitude, THD (Total Harmonic Distortion), FFT Frequency, and FFT Delta Frequency are intended for FFT waveforms. You can also use the markers to make magnitude and phase measurements on frequency domain traces.



Use the [Measure](#)<sup>[241]</sup> and [Marker](#)<sup>[187]</sup> menus for further spectral measurements of FFT waveforms.

## FFT Resolution

### Amplitude Resolution

Amplitude resolution is influenced by the windowing function used and the vertical adjustment of the time domain waveform. For maximum amplitude resolution, the time domain waveform should be adjusted so that it is centred vertically on the graticule and is tall as possible without going beyond the graticule, above or below.

### Frequency Range and Resolution

The range and resolution of the frequency spectrum displayed by the PicoScope 9000 are determined by the sample rate and record length. The sample interval is determined by the time base and record length. You can increase the record length for better FFT resolution but all points must be on the display for them to be included in the FFT calculation. The FFT calculation time will also increase because more waveform samples must be processed.

The FFT's resolution is expressed as follows:

$$\text{FFT Resolution} = \text{Equivalent Sample Rate} / \text{Record Length}$$

The FFT frequency range before scaling will be from 0 Hz to one half of the sample rate. Ensure that the sample rate is at least twice the highest anticipated frequency component of the waveform source you are measuring. Otherwise, the measurement results will exhibit aliasing and any measurements will be inaccurate.

The FFT's frequency range is expressed as follows:

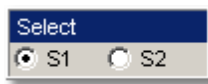
$$\text{FFT Frequency Range} = \text{Equivalent Sample Rate} / 2$$

### FFT Aliasing

Aliasing occurs when the input signal includes components at frequencies higher than the Nyquist frequency. These frequency components appear in the FFT waveform display as peaks at lower frequency. The higher-frequency components are reflected around the Nyquist frequency. For example, a frequency component 1 GHz above the Nyquist frequency will appear as a peak 1 GHz below the Nyquist frequency in the FFT waveform display.

You can eliminate aliasing by setting the equivalent sampling rate to be at least twice the highest frequency in the input signal. Increasing the record length or decreasing the timebase scale will increase the equivalent sampling rate.

## 5.5.2 Select



The **Select** menu allows you to select either FFT **S1** or **S2**.

Clicking the **S1** / **S2** radio buttons:

- selects FFTs S1 or S2, and
- assigns the function softkeys to the selected FFT

## 5.5.3 Display



The **Display** function turns the FFT functions on or off. When FFT is on, a new waveform is displayed on the screen corresponding to the FFT magnitude function. This FFT waveform is displayed in the color used to represent the **S1** spectrum.

## 5.5.4 Source

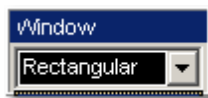


The **Source** function determines which signals the instrument uses to generate the FFT function.

As source of the FFT function, you can select any of the following:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4

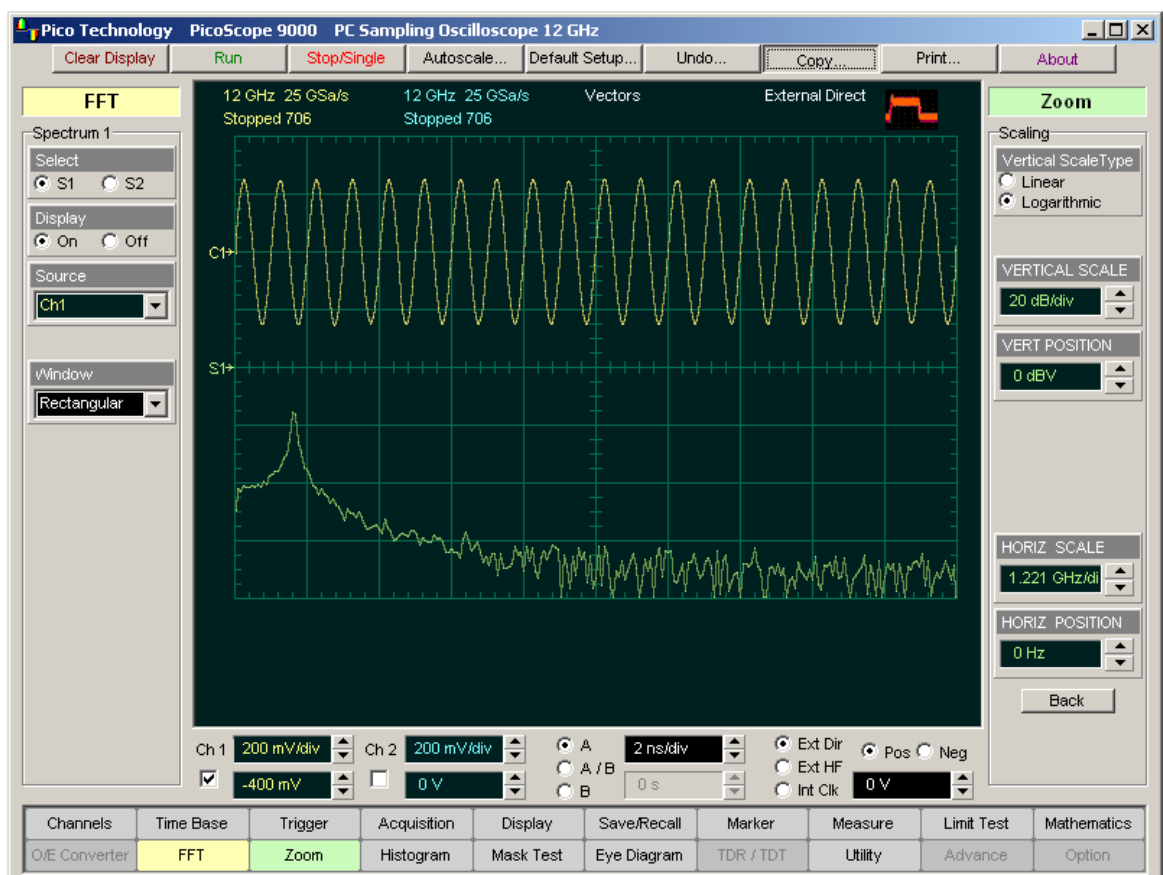
### 5.5.5 FFT Window



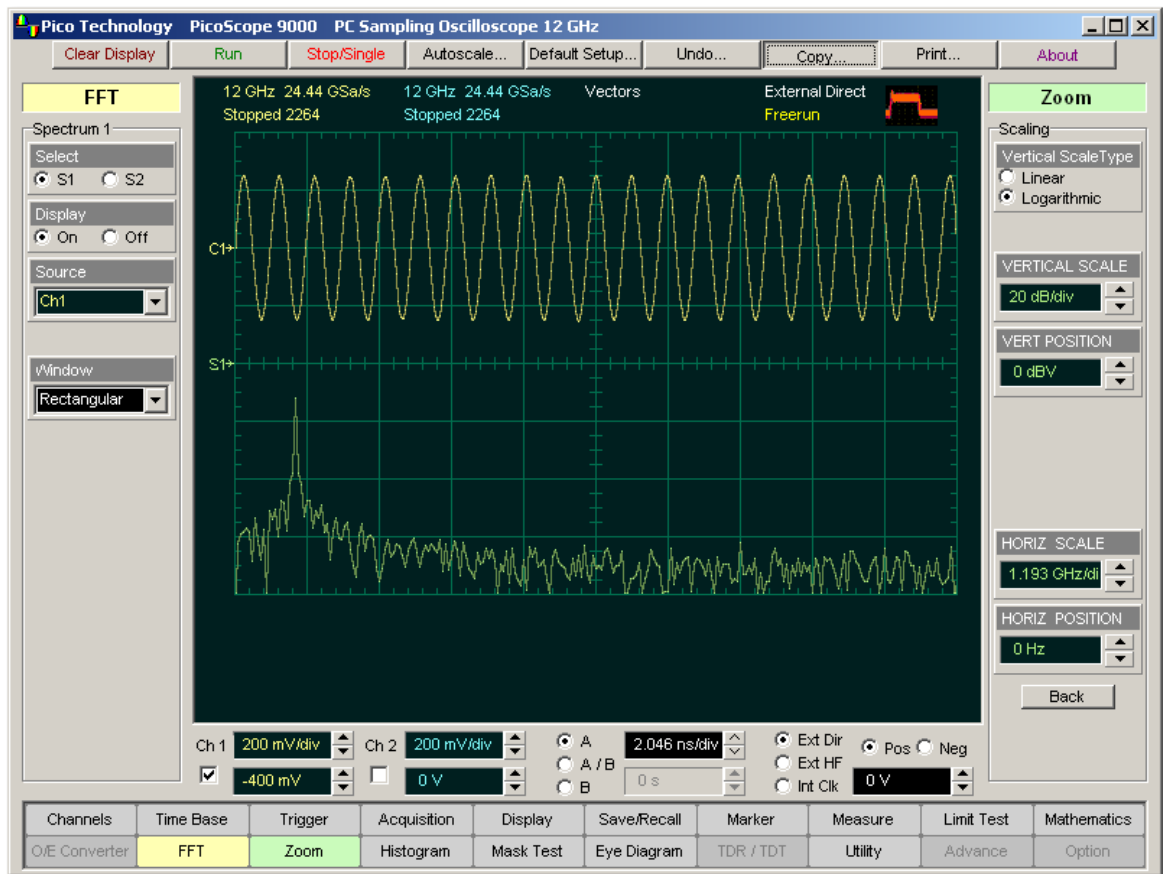
#### FFT Window

Windowing is a technique that compensates for some of the limitations of FFT analysis. The FFT operation assumes the time record repeats infinitely. Unless there are an integral number of cycles of the sampled waveform in the record, a discontinuity is created as the end of the record.

A pure sine wave transforms into a single spectral component, but a discontinuity in the time domain causes a frequency-domain widening or spreading out of the waveform, referred to as "spectral leakage". Two figures below show a sine wave FFT with and without leakage.



**FFT with leakage**

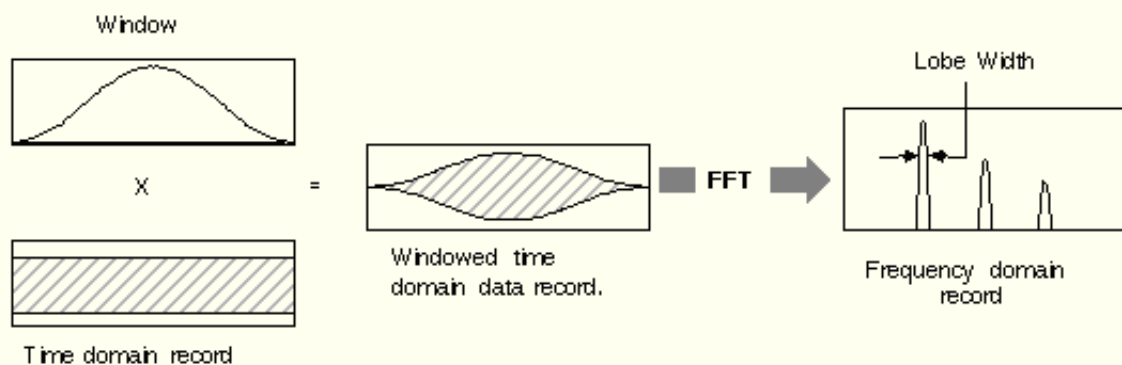


### FFT having small amount of leakage

A solution to the leakage problem is to force the waveform to zero at the beginning and end of the time record so that no transient is present when the time record is replicated. This is done by multiplying the time record by a window function, which produces its own effect in the frequency domain. However, the effect produced by the window function is a big improvement over using no window function at all.

### Windowing Process

The process of windowing the data is shown below. The FFT time domain record is multiplied point by point with the FFT window. When the Hanning or Blackman/Harris window is used, the data point amplitudes taper to zero at the end of the record.



### Multiplying the time domain data record by a window



When using windows, be sure that the most interesting parts of the signal in the time domain record are positioned in the centre of the window so the tapering does not cause significant errors.

### Types of FFT Window



The window type defines the bandwidth and shape of the equivalent filter associated with the FFT processing. The PicoScope 9000 provides a rectangular FFT window, which does not taper the time domain data, and five tapering FFT windows of different shapes.

The six supported FFT window functions are:

- **Rectangular** window,
- **Hamming** window,
- **Hann** window,
- **Flattop** window,
- **Blackman-Harris** window,
- **Kaiser-Bessel** window.



Remember that windows work by weighting points in the middle of the waveform record higher than those at the ends of the record.

Each time-domain FFT windowing function corresponds to a filter in the frequency domain. Each frequency domain filter has a high central lobe, or passband, whose width determines how well adjacent frequency components can be resolved. The height of the side lobes surrounding the central lobe determines how much leakage can occur.

### Equations for the FFT Windows

Four windows used in the PicoScope 9000 (**Hamming**, **Hann**, **Flattop**, and **Blackman-Harris**) are derived from a cosine series. The window type is obtained by substituting the correct coefficients for the cosine terms into the following equation:

$$f_n = \sum_{i=0}^m \left\langle a_i \cos\left[\frac{2\pi}{N} \left(n - \frac{N-1}{2}\right)\right] \right\rangle$$

where:  $n$  is the window data area,  $a$  is the array of window coefficients,  $N$  is the window length,  $m$  is the window order,  $i$  is the index to the window coefficient array, and  $n$  is the index to the window data array.  $n = 0$  to  $N-1$ .

The table of correction coefficients for different FFT windows indicates the values to substitute into equation to obtain the various windows.

**Correction coefficients for different FFT windows**

<b>Coefficients</b>	<b>Rectangular</b>	<b>Hamming</b>	<b>Hann</b>	<b>Flat</b>	<b>Blackman-Harris</b>	<b>Kaiser-Bessel</b>
M	0	1	1	2	3	3
a0	1.0	0.543478	0.5	0.281	0.35875	0.40243
a1	0.0	0.456522	0.5	0.521	0.48829	0.49804
a2	0.0	0.0	0.0	0.198	0.14128	0.09831
a3	0.0	0.0	0.0	0.0	0.01168	0.00122
Highest side lobe	-13 dB	-43 dB	-32 dB		-94 dB	-69 dB
3 dB Bandwidth in bins	0.89	1.3	1.44		1.92	1.72
Scallop loss	3.96 dB	1.78 dB	1.42 dB		0.81 dB	1.02 dB
Zero Phase Reference	50%	50%	50%		50%	50%

For the Rectangular window:  $n = 1$ .

The best window for a given application depends on various factors. Most measurements require the use of a window such as the **Hanning** or **Flat** windows, which are the appropriate windows for typical frequency analysis measurements. Choosing between different windows involves a trade-off between frequency resolution and amplitude accuracy.

For harmonic analysis of continuous-time signals, the best window choice depends on the signal characteristics and on the particular characteristics that are of most interest. The use of **Blackman-Harris**, **Kaiser-Bessel**, **Hanning** or **Hamming** windows typically makes harmonics observation easier.

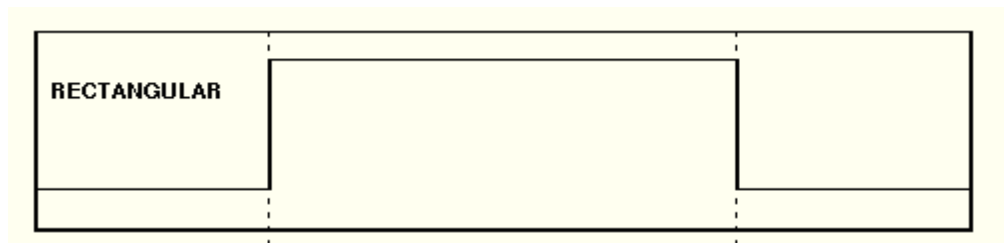
The rectangular window can be typically used for impulse response testing since the beginning points are usually zero and the data tapers to zero at the end of the record. The beginning points are zero because the impulse is normally placed in the centre of the time-domain record at the zero-phase reference point. Other windows can be used if desired. If phase is not important, the impulse can be placed at the beginning of the record. For this case, the window must be **Rectangular**.



## 5.5.5.1 Rectangular Window



The rectangular window (also referred to as the Uniform window) is essentially no window because the samples are left unchanged. All points in the record are multiplied by 1. In the frequency domain, the filter shape is  $\sin(x)/x$ .

**Time-domain characteristics for rectangular window**

The rectangular window is useful for transient signals and signals where there are an integral number of cycles in the time record. It is the best window to use when you want to examine the frequency spectrum of a non-repetitive signal. Also, it can be typically used for impulse response testing since the beginning points are usually zero and the data tapers to zero at the end of the record. The beginning points are zero because the impulse is normally placed in the centre of the time domain record at the zero phase reference point. Other windows can be used if desired. If phase is not important, the impulse can be placed at the beginning of the record. For this case, the window must be rectangular.

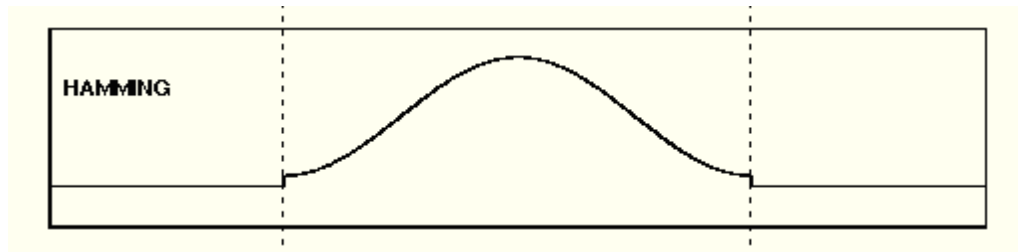
The rectangular window generally gives the best frequency resolution because it results in the narrowest lobe width in the FFT output record. It gains frequency resolution at the expense of amplitude accuracy if the frequency of the signal being observed has a non-integer number of cycles in the FFT time record. Signals not in this class show varying amounts of spectral leakage and scallop loss, which can be corrected by using one of the other windows.

Although the rectangular window has the potential for severe leakage problems, in some cases the waveform data in the time record has the same value at both ends of the record, thereby eliminating the transient introduced by the FFT. Such waveforms are called self-windowing. Waveforms such as sine bursts, impulses and decaying sinusoids can all be self-windowing.

## 5.5.5.2 Hamming Window



The **Hamming** window is a bell-shaped window. It has lower side lobes adjacent to the main lobe than, for example, the **Hann** window.

**Time-domain characteristics for Hamming window**

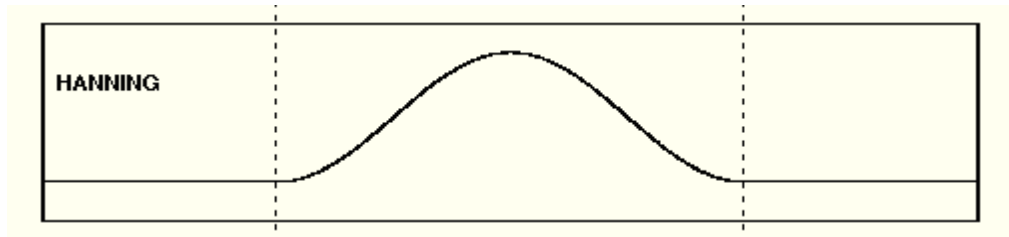
The **Hamming** window tapers the data to smaller values, but not to zero. It decreases the amount of energy spillover into adjacent frequency bins, increasing the amount of amplitude accuracy at the expense of decreasing the frequency.

Use the **Hamming** window for resolving frequencies that are very close to the same value with somewhat improved amplitude accuracy over the rectangular window.

## 5.5.5.3 Hann Window



The **Hann** (or **Hanning**, or **cosine**) window is bell-shaped window, and it looks like the first half of a sine wave. The **Hann** window multiplies the points in the centre of the record by 1 and multiplies the points at the start and the end of the record by zero. It decreases the amount of energy spillover into adjacent frequency bins, increasing the amount of amplitude accuracy at the expense of decreasing the frequency resolution because of wider lobe widths. The shape of **Hann** window is a compromise between amplitude accuracy and frequency resolution.



**Time domain characteristics for Hann window**

The **Hann** window is useful for frequency resolution and general-purpose use. Even though the overall shape of the time-domain signal has changed, the frequency content remains basically the same. The spectral line associated with the sinusoid spreads out a small amount in the frequency domain. It is good for resolving two frequencies that are close together or for making frequency measurements. The **Hann** window also improves amplitude accuracy.

The **Hann** window, compared to other common windows, provides good frequency resolution at the expense of somewhat less amplitude accuracy.

#### 5.5.5.4 Flattop Window



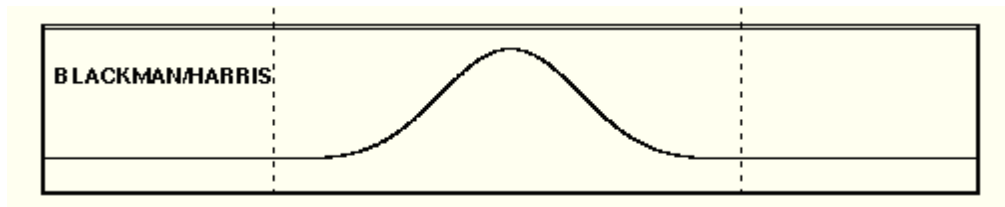
The **Flattop** window has fatter (and flatter) characteristic in the frequency domain. The flatter top on the spectral line in the frequency domain produces improved amplitude accuracy, but at the expense of poorer frequency resolution when compared with the **Hann** window.

The flattop window is the best window for making accurate amplitude measurements or frequency peaks.

## 5.5.5.5 Blackman-Harris Window



A **Blackman-Harris** window is a bell-shaped window. It reduces the leakage to a minimum, has the widest pass band (lowest frequency resolution) and lowest side lobes. It decreases the amount of energy spillover into adjacent frequency bins, increasing the amount of amplitude accuracy at the expense of decreasing the frequency resolution because of wider lobe widths.

**Time domain characteristics for Blackman-Harris window**

The **Blackman-Harris** window is the best window for measuring the amplitude of frequencies but worst at resolving frequencies. This window is especially good for viewing a broad spectrum.

#### 5.5.5.6 Kaiser-Bessel Window

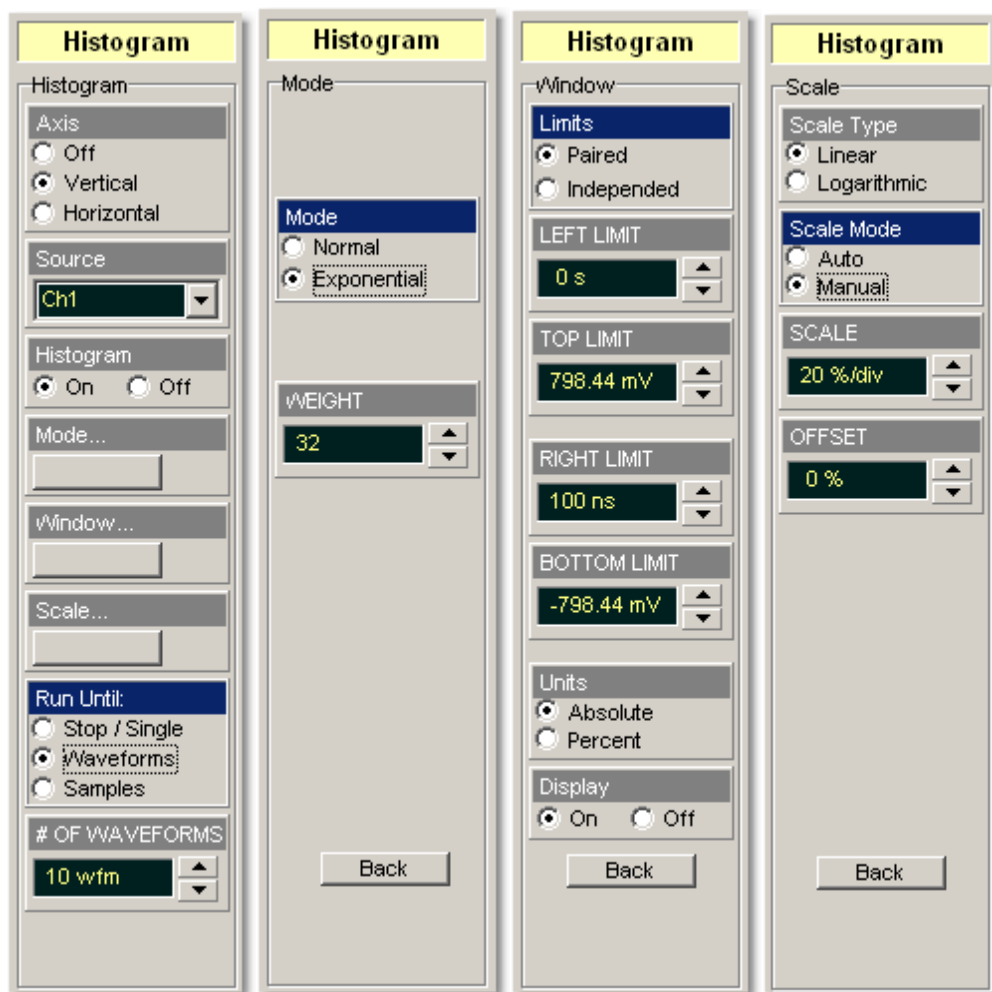


This window has resolution bandwidths and scallop losses close to the Blackman-Harris window. Choose the **Kaiser-Bessel** window to view the signal characteristics you are interested in.

## 5.6 Histogram Menu

Histogram

A histogram is a probability distribution that shows the distribution of acquired data from a source within a user-definable histogram window. The information gathered by the histogram is used to perform statistical analysis on the source. You can display the histogram either vertically for voltage measurements or horizontally for timing measurements.



**The Histogram menu**

Histograms are derived from the instrument measurement database. The measurement database consists of all data samples displayed on the display graticule. Every time a display sample point is acquired on a display coordinate, the counter for that coordinate is incremented. As the total count increases, the range of hits also increases. The maximum count for each counter is 63,488. If the histogram is left on for a very long time, the database will become saturated.

The two most common uses for histograms are measuring and characterizing noise or jitter on displayed waveforms. 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. 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.

When the histogram is turned on, the instrument begins to build its measurement database. Then the following events occur:

- The histogram is displayed as a series of lines on the display graticule
- The histogram data is analysed
- The results of the histogram are displayed on the **Measurement Area** of the display

The histogram is displayed as a series of horizontal or vertical lines (depending on the axis selected in the **Axis** menu). Each line is the width of one pixel on the display graticule. Each line is carefully positioned on the display graticule within the histogram window and appears above the waveforms. Therefore, the source waveform may not be viewed through the histogram waveform.

The measurement database continues to build until the instrument stops acquiring data or the histogram.



The measurement database is active in the persistence display style or color-graded display style.



To avoid erroneous data, reset the measurement database by pressing the **Clear Display** button. Changing the vertical scale, offset, time base scale, delay, and trigger settings will not reset the measurement database.

### Histogram measurement results

You will see the histogram statistics listed in the **Measurement Area** of the **GUI**. These values are displayed on tabs.

Scale	= 6.17 khits/	Peak Hits	= 30.843 khits	Std Deviation	= 176.99 mV
Offset	= 0 hits	Pk - Pk	= 515.63 mV	Mean $\pm$ 1 StdDev	= 50.281 %
Hits in Box	= 2.01753 Mhits	Median	= 0 V	Mean $\pm$ 2 StdDev	= 100 %
Waveforms	= 4027 Wfms	Mean	= 578.5 $\mu$ V	Mean $\pm$ 3 StdDev	= 100 %
Min	= -257.81 mV	Max-Max	= 496.88 mV	Max	= 257.81 mV

### An example of the Histogram Measure tab

The tabs only appear as the one of the histogram measurements is performed. For example, if you performed a vertical histogram measurement on the channel 1, only this tab will appear on the display.

The measurement database and the graticule display will clear when you perform the following actions:

- Switch between operating modes in the **Display** menu
- Change vertical and horizontal scale and position
- Click on the **Clear Display** button

The **Measure tab** displays the following measurement statistics for each measurement:

- **Scale.** Lists the display scale in hits per division or dB per division.
- **Offset.** Lists the offset in hits or dB. Offset is the number of hits or dB at the bottom of the display, as opposed to the centre of the display.
- **Hits in Box.** The total number of samples included in the histogram box.



- **Waveforms.** The number of waveforms that have contributed to the histogram.
- **Peak Hits.** The number of hits in the histogram's greatest peak.
- **Pk – Pk.** The width of histogram. For horizontal histograms, width is the difference time between the first and last pixel columns that contains data. For vertical histograms, width is the difference in time between the first and last pixel rows that contain data.
- **Median.** 50% of the histogram samples are above the median and 50% are below the median.
- **Mean.** Mean is the average value of all the points in the histogram.
- **StdDev.** The standard deviation ( ) value of the histogram.
- **Mean ± 1 StdDev.** The percentage of points that are within ± 1 of the mean value.
- **Mean ± 2 StdDev.** The percentage of points that are within ± 2 of the mean value.
- **Mean ± 3 StdDev.** The percentage of points that are within ± 3 of the mean value.
- **Min.** Min is the minimum value of all the points in the histogram.
- **Max.** Max is the maximum value of all the points in the histogram.
- **Max-Max.** The width between the vertical histogram's greatest peak.



The measurement statistics reported will vary depending on the mode of operation selected.

### Mean and Standard Deviation

The PicoScope 9000 calculates the mean and standard deviation automatically. It does not rely on the assumption that the data is of a particular distribution to determine the sample mean or standard deviation. The microprocessor-controlled acquisition allows the oscilloscope to store and display every data point. Therefore, the sample mean and standard deviation are easily computed by the microprocessor using the following equations respectively:

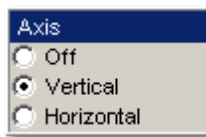
$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

$$S = \frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}$$

where:  $\bar{X}$  - mean,  $S$  - standard deviation,  $n$  - number of samples, and  $X_i$  - value of each sample.

The mean for time histogram is the time from the trigger point (without taking into account minimum delay) to the sample average. The mean for voltage histograms is the average voltage with respect to the ground reference.

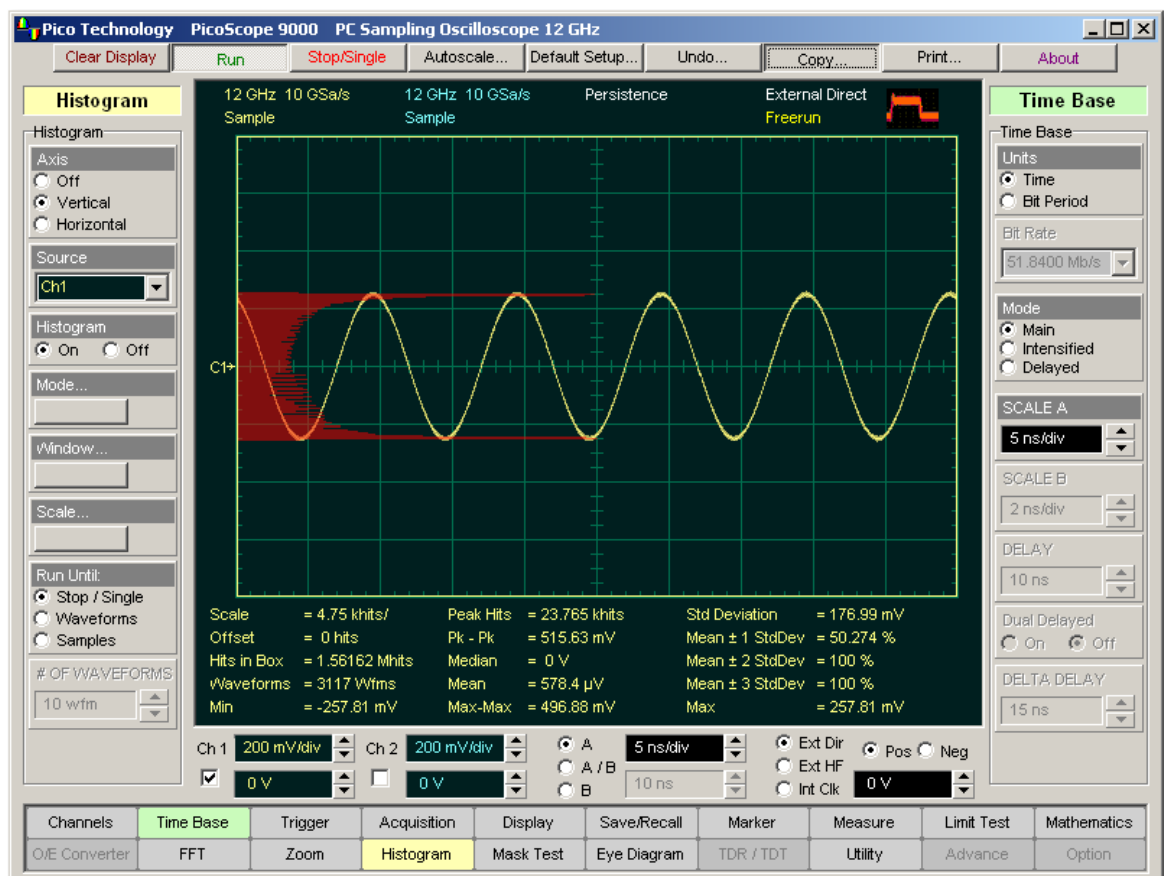
## 5.6.1 Axis



The **Axis** function turns the display of the histogram off or orients the histogram vertically or horizontally.

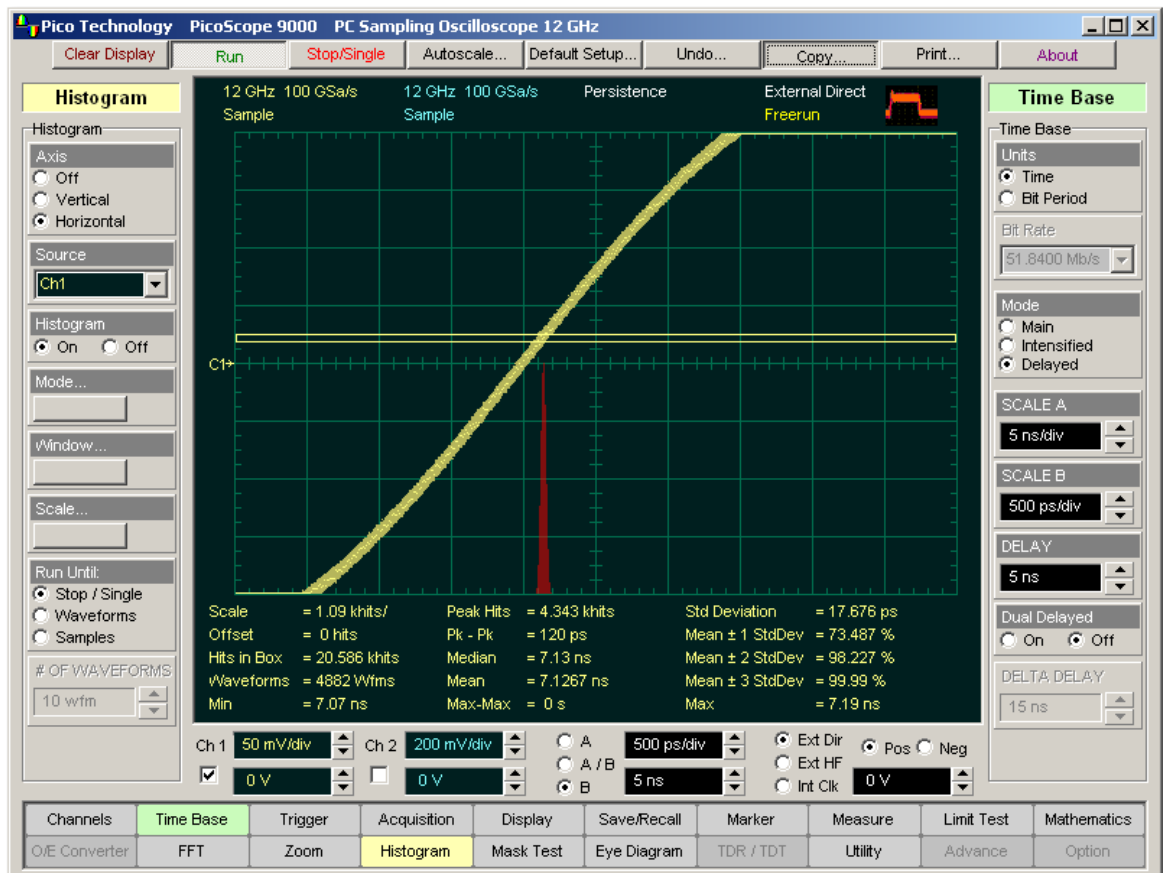
**Off.** Removes the histogram and histogram value from display.

**Vertical.** Places the histogram at the left side of the graticule, which allows for voltage measurements.



An example of the vertical histogram display

**Horizontal.** Places the histogram at the bottom of the graticule area, which allows for timing measurements.



**An example of the horizontal histogram display**

## 5.6.2 Source

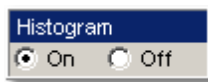


Histogram measurements can be made on only one source at a time. Select the source you want to measure using the **Source** menu. Be aware that even if the display shows only the most recent acquisitions, the measurement database keeps track of all display coordinates hit while the measurement database is building.

You can set the histogram source:

- Channel
- Function
- Waveform memory
- Spectrum

## 5.6.3 Histogram



The **Histogram** turns on or off the display a histogram.

**On.** Turns on the display of a histogram.

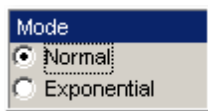
**Off.** Turns off the display of a histogram. Turning off a histogram does not turns off measurement process.

## 5.6.4 Mode



Clicking the **Mode...** menu opens a histogram calculation statistical menu.

## 5.6.4.1 Mode



The **Mode** menu defines one of two modes that determine an algorithm for statistical calculation.

**Normal.** When the **Normal** mode is selected, each of the acquired waveforms has equal influence on the result of the statistical calculations on the histogram. The **WEIGHT**<sup>[187]</sup> variable is not active in this mode.

**Exponential.** When the **Exponential** mode is selected, each of the acquired waveforms has a weighted influence on the result of statistical calculations on the eye diagram. The **WEIGHT**<sup>[187]</sup> variable specifies the degree of this influence.

## 5.6.4.2 WEIGHT



The **WEIGHT** variable specifies the degree of influence of the nearest acquired waveform against more remote waveforms. The **WEIGHT** variable is active when **Exponential** is selected in the **Mode**<sup>[187]</sup> menu. The **WEIGHT** can be varied from 8 to 8192 in multiples of two.

### 5.6.5 Window




Two common uses for histograms are measuring and characterizing noise or jitter on displayed waveforms.

Noise is measured by sizing the histogram window to a narrow portion of time and observing a vertical histogram that measures the noise on a flat section of a waveform.

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.

The histogram window determines which region of the database will be used to construct the histogram. The instrument will use only this region of the database to calculate the histogram results.

To define the histogram window, choose **Window...** from the **Histogram**  menu. The histogram **Window** menu gives you access to a second-level menu that allows you to select a region of the database to include in the histogram. Opening the **Window...** menu opens the histogram window markers. The markers consist of:

- Two solid vertical lines (the **LEFT LIMIT** and **RIGHT LIMIT** variables)
- Two solid horizontal lines (the **TOP LIMIT** and **BOTTOM LIMIT** variables)

You can then define the size of the histogram window within the horizontal and vertical scale limits of the instrument.

#### 5.6.5.1 Limits



The **Limits** menu defines a method of how the histogram window can be positioned with the **LEFT LIMIT**, **RIGHT LIMIT**, **TOP LIMIT** and **BOTTOM LIMIT** variables.

##### Paired

With the **Paired** method, the following conditions are used for positioning of the histogram window:

- The **LEFT LIMIT** variable changes the full histogram window to left or to right
- The **RIGHT LIMIT** variable changes the right limit of the histogram window to left or to right
- The **TOP LIMIT** variable changes the full histogram window up or down
- The **BOTTOM LIMIT** variable changes the bottom limit of the histogram window up or down

##### Independent

When the **Independent** is selected, each of the **LEFT LIMIT**, **RIGHT LIMIT**, **TOP LIMIT** and **BOTTOM LIMIT** variables changes the position of corresponding limit independently.

## 5.6.5.2 LEFT LIMIT, RIGHT LIMIT, TOP LIMIT and BOTTOM LIMIT



The **LEFT LIMIT**, **RIGHT LIMIT**, **TOP LIMIT** and **BOTTOM LIMIT** variables allow you to use the histogram limits to select a region of the database.

When the **Independent** mode in the [Limits](#)<sup>182</sup> menu is selected, the **TOP LIMIT** and **BOTTOM LIMIT** variables move the vertical histogram limits vertically across the display, while the **LEFT LIMIT** and **RIGHT LIMIT** variables move the horizontal histogram limits horizontally across the display.

When the **Paired** mode in the [Limits](#)<sup>182</sup> menu is selected, the **TOP LIMIT** variable moves the full histogram window up or down, and the **LEFT LIMIT** variable moves the full histogram window left or to right. At the same time the **BOTTOM LIMIT** variable moves the bottom limit of the histogram window up or down, while the **RIGHT LIMIT** variable moves the right limit of the histogram window left or to right.

Because the database that the histogram is derived from is limited to the size of the graticule area, placing the histogram limits beyond the graticule area results in a histogram of only the graticule area.

For jitter measurements you would position the **TOP LIMIT** and **BOTTOM LIMIT** histogram limits so that the histogram is built from a very narrow horizontal slice of the graticule area. For noise measurements, you would position the **LEFT LIMIT** and **RIGHT LIMIT** histogram limits so that the histogram is built from a very narrow vertical slice of the graticule area.



The histogram window limits are only visible when the [Histogram](#)<sup>176</sup> menu is opened.

The default setup positions the histogram markers as follows:

- **LEFT LIMIT < RIGHT LIMIT**
- **BOTTOM LIMIT < TOP LIMIT**

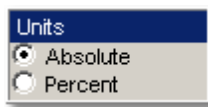
The values of **LEFT LIMIT** and **BOTTOM LIMIT** cannot be made greater than the values of **RIGHT LIMIT** and **TOP LIMIT** by repositioning the limits. The histogram window is always the area inside the boundaries of all of **LEFT LIMIT**, **RIGHT LIMIT**, **TOP LIMIT** and **BOTTOM LIMIT**, regardless of the limit values.

You can use the mouse to click and drag the histogram limits to new positions: click and hold the left mouse button while the mouse pointer is on one of the limits, then drag the marker to the position you want and release the mouse button. Clicking and dragging a limit makes it easy to quickly move the limit to the desired waveform event.



The values of the limits and the position arrows are dependent upon the vertical and horizontal scale settings.

## 5.6.5.3 Units



The **Units** function lets you select how you want the **LEFT LIMIT**, **RIGHT LIMIT**, **TOP LIMIT** and **BOTTOM LIMIT** variables represented.

**Absolute.** Represents all limits in current unit.

**Percent.** Represents all limits as percentages of the full vertical or horizontal scale.

## 5.6.5.4 Display



The **Display** menu is used to show histogram windows with both vertical and horizontal histogram limits.

Clicking the **On / Off** radio buttons:

- Turns the display of the selection on or off.

## 5.6.6 Scale



Histograms are derived from the instrument measurement database. The histogram values correspond to a row or column in the database. The database that is used to construct the histogram is dependent upon the selected source. The instrument converts the row and column numbers to time (seconds) and amplitude (volts) values using the scaling values of the selected the database source. Therefore, the histogram results from each source vary depending on the scaling of the source.

Histograms are displayed as a series of lines (vertical or horizontal). The length of each line represents the frequency or number of hits of data on that row (or column) of the display. Zero hits correspond to the left edge of the graticule (vertical histogram), or the bottom edge of the graticule (horizontal histograms).

The histogram **Scale** menu gives you access to a second-level menu that allows you to set the scale of the histogram.

## 5.6.6.1 Scale Type

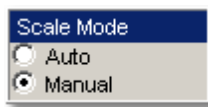


The **Scale Type** menu defines how to display histogram data. Two options can be set from the **Scale Type** menu: **Linear** and **Logarithmic**.

**Linear.** Sets the display of the histogram results to the number of hits per division.

**Logarithmic.** Sets the display of the histogram results to dB.

## 5.6.6.2 Scale Mode



The **Scale Mode** menu determines how much of the histogram is displayed on the screen.

**Auto**

If the **Axis** menu is set to **Horizontal**, the **Auto** sets the base of the histogram to the bottom of the graticule area and displays the histogram using half of the graticule height.

If the **Axis** menu is set to **Vertical**, the **Auto** sets the base of the histogram to the left edge of the graticule area and displays the histogram using half of the graticule width.

**Manual**

**Manual** lets you window in on the histogram by allowing you to change the scale and offset settings. Depending on the setting of the [Scale Type](#)<sup>[184]</sup> menu, the scale value is in either percent of a division or dB. By changing the scale, you can zoom in or out on the histogram. Offset allows you to pan across the histogram by moving the base of the histogram. Depending on the setting of the [Scale Type](#)<sup>[184]</sup> menu, the offset value is also in either percent of peak or dB per division.

## 5.6.6.3 SCALE

**Linear scale**

For the linear scale type, the scale is the percentage of the peak per division. For example, on a horizontal histogram, 20% places one-fifth of the histogram in each of eight divisions with the top of the peak (100%) at the middle of the display.

**Logarithmic scale**

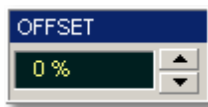
For the log scale type, the scale is in decibels per division. The histogram is plotted according to the following formula:

$$dB = 20 \log_{10} \frac{X}{Peak}$$

where:  $X$  is the number of hits in a histogram row for vertical histograms, or the number of hits in a histogram column for horizontal histograms,  $Peak$  is the number of hits in the largest histogram column or row, and  $dB$  is the log value that gets plotted.



## 5.6.6.4 OFFSET

**Linear offset**

For the linear scale type, the offset is the percentage of the peak at the left edge or lower edge of the display. For example, on a horizontal histogram, an offset of 20% places 20% of the peak at the lower edge of the display. Therefore, 20% of the histogram will be below the display and the other 80% of the histogram will be above the lower edge of the display (displayed on the screen).

**Logarithmic offset**

For the log scale type, the offset is in decibels at the left edge or lower edge of the display. The histogram is plotted according to the following formula:

$$dB = 20 \log_{10} \frac{X}{Peak}$$

where:  $X$  is the number of hits per row for vertical histograms, or the number of hits per column for horizontal histograms,  $Peak$  is the number of hits in the peak, and  $dB$  is the log value that gets plotted.

This means 0 dB is at the peak of the histogram and the offset can only contain negative values. For example, with a horizontal histogram, an offset of -20 dB places 10% or  $10^{\frac{-20}{20}}$  of the peak at the lower edge of the display.

## 5.6.7 Run Until



The **Run Until** menu allows you to determine when the acquisition of data stops.

**Stop / Single.** You must press the **Stop/Single** key to stop the acquisition of data.

**Waveforms.** After the number of waveforms is reached, acquisition stops.

**Samples.** After the number of samples is reached, acquisition stops.

## 5.6.8 # OF WAVEFORMS and # OF SAMPLES



**# OF WAVEFORMS.** Sets the number of waveforms. After the selected number of waveforms is reached, acquisition stops.

**# OF SAMPLES.** Sets the number of samples. After the selected number of samples is reached, acquisition stops.

## 5.7 Marker Menu



Markers are movable lines on the display. You set their value by positioning them on the display. Their actual value, however, comes from internal data, so they are more precise than graticules. They use numeric readouts to present results.

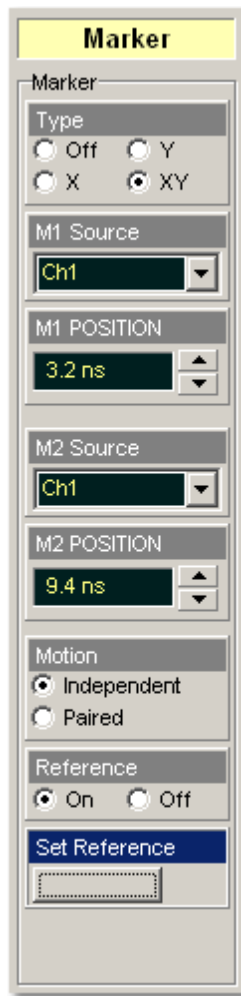
Markers can be positioned on either:

- a selected waveform source (input channel, waveform memory, function or spectrum)
- independently anywhere on the display graticule

Markers allow you to make:

- absolute vertical measurements (voltage, spectrum magnitude, spectrum phase, rho, ohms)
- ratiometric vertical measurements
- absolute horizontal measurements (timing, bit period, frequency, distance)
- ratiometric horizontal measurements

The markers are display-limited, so you cannot move them off screen. Also, if you resize waveforms, the markers do not track. That is, a marker stays at its screen position, ignoring changes to horizontal and vertical scale and position.



The **Marker** menu allows you to turn on and position calibrated colored markers on the display. For example, you can use the **M1 POSITION** (solid line) control to move the **X1** marker horizontal position. The position value of the marker will be displayed in the Measurement Area of the display.

However, it can be changed to a different color in the display menu. You can use the markers to make custom measurements or to use as visual reference point on the display.

### Marker measurement results

The **Measurement Area** of the GUI displays the values of the marker positions and measurements on tabs. The marker position readout is based on the units of the source waveform. The marker resolution is limited to the resolution of the display. As you move a marker, its position is displayed in the **Measurement Area**. The horizontal value (X-axis) is the time delay from the left border of the display graticule and the vertical position (Y-axis) is measured with respect to the corresponding source ground.

The following information is displayed for the selected source or waveform:

- **XM1.** Position of the **M1** marker (solid line). The X-axis units may be displayed in seconds, Hz, bits, meters or feet.
- **YM1.** Position of the **M1** marker (solid line). The Y-axis units depend upon the channel input, and may be displayed in volts, watts, amperes, phase degrees, rho, ohms.
- **M2.** Position of the **M2** marker (dashed line). The X-axis units may be displayed in seconds, Hz, bits, meters or feet.
- **YM2.** Position of the **M2** marker (dashed line). The Y-axis units depend upon the channel input; and may be displayed in volts, watts, amperes, phase degrees, rho, ohms.
- **dXM.** The difference between the **M1** and **M2** marker values, if both markers are turned on. **dXM** is calculated as follows:

Where **XM2** represents the dashed line marker, and **XM1** represents the solid line marker.

If **XM1** is more positive than **XM2**, **dXM** will be a negative number, which can result in negative time interval measurements.

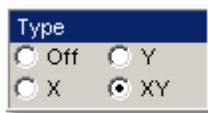
- The instrument will also calculate and display the **1/dXM** frequency value when both X-axis markers are turned on. If **XM1** is more positive than **XM2**, **1/dMX** will display a negative frequency.

- **YM1.** Position of the **M1** marker (solid line). The Y-axis units depend upon the channel input, and may be displayed in volts, watts, amperes, phase degrees, [rho](#)<sup>406</sup>, ohms.

Where **YM2** represents the dashed line marker, and **YM1** represents the solid line marker.

If **YM1** is more positive than **YM2**, **dYM** will be a negative number.

### 5.7.1 Type



There are three types of markers:

- **X**-markers (manual markers)
- **Y**-markers (manual markers)
- **XY**-markers (waveform markers)

Click the button for the marker type that you need.

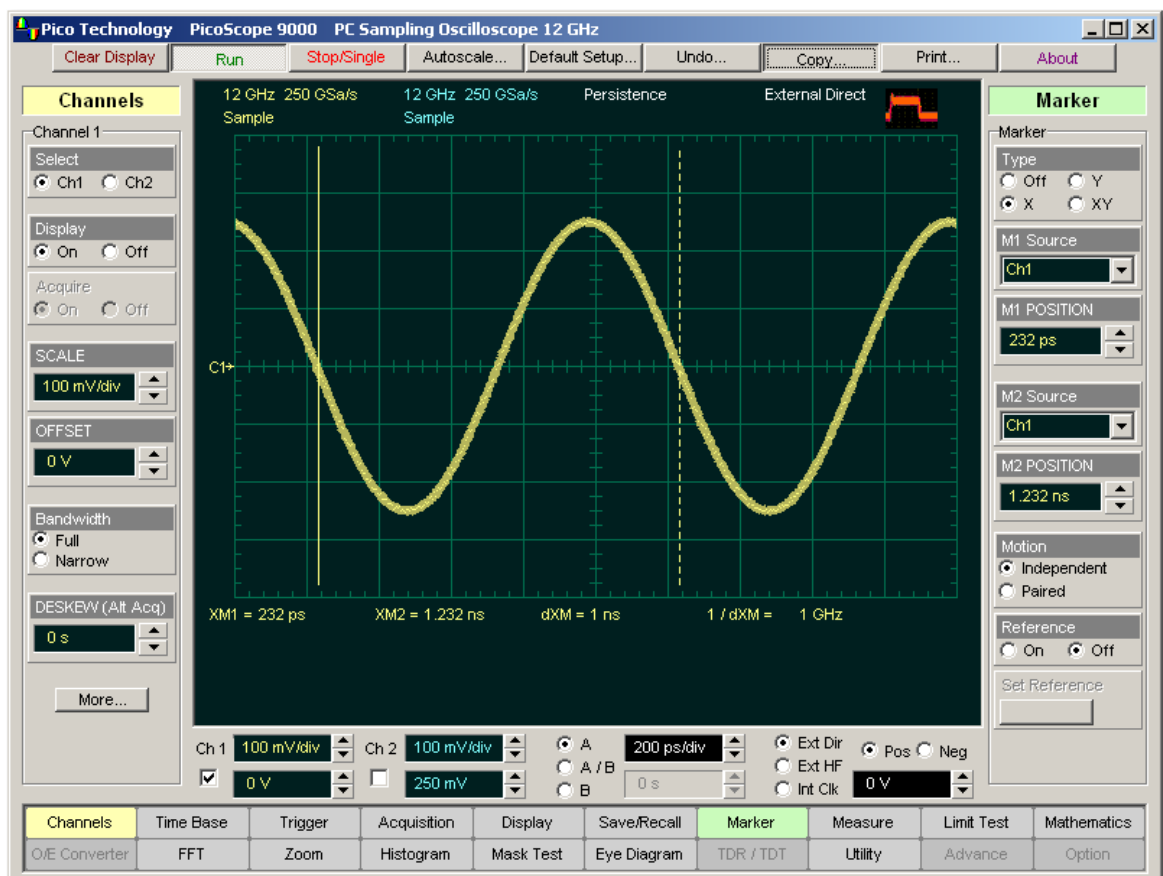
#### Off

Removes the markers and marker value from display.

#### X Markers

The **X** manual markers (**XM1** and **XM2** markers) are two vertical lines you can move horizontally. The **XM1** is displayed as a solid line, and the **XM2** is displayed as dashed line.

You can position the **X**-markers anywhere on the display, which allows you to make custom measurements. The **X**-markers track the time values as the timebase scale is changed, which allows you to make accurate delay measurements. The position readout is based on the scale factors of the source waveform. Marker resolution is limited to the pixel resolution of the display.

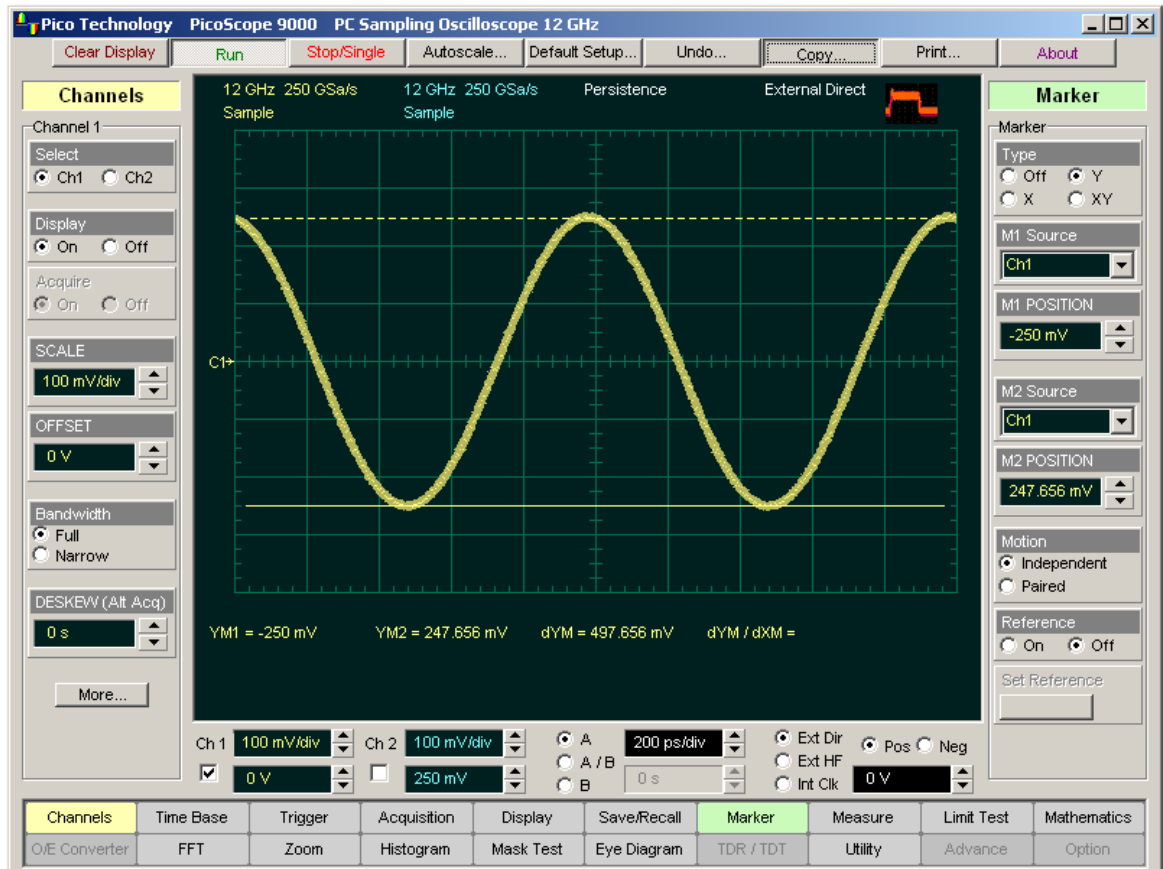


**Period measurement with the X Markers**

## Y Markers

The **Y** manual markers (**YM1** and **YM2** markers) are two horizontal lines you can move vertically. The **YM1** is displayed as a solid line, and the **YM2** is displayed as a dashed line.

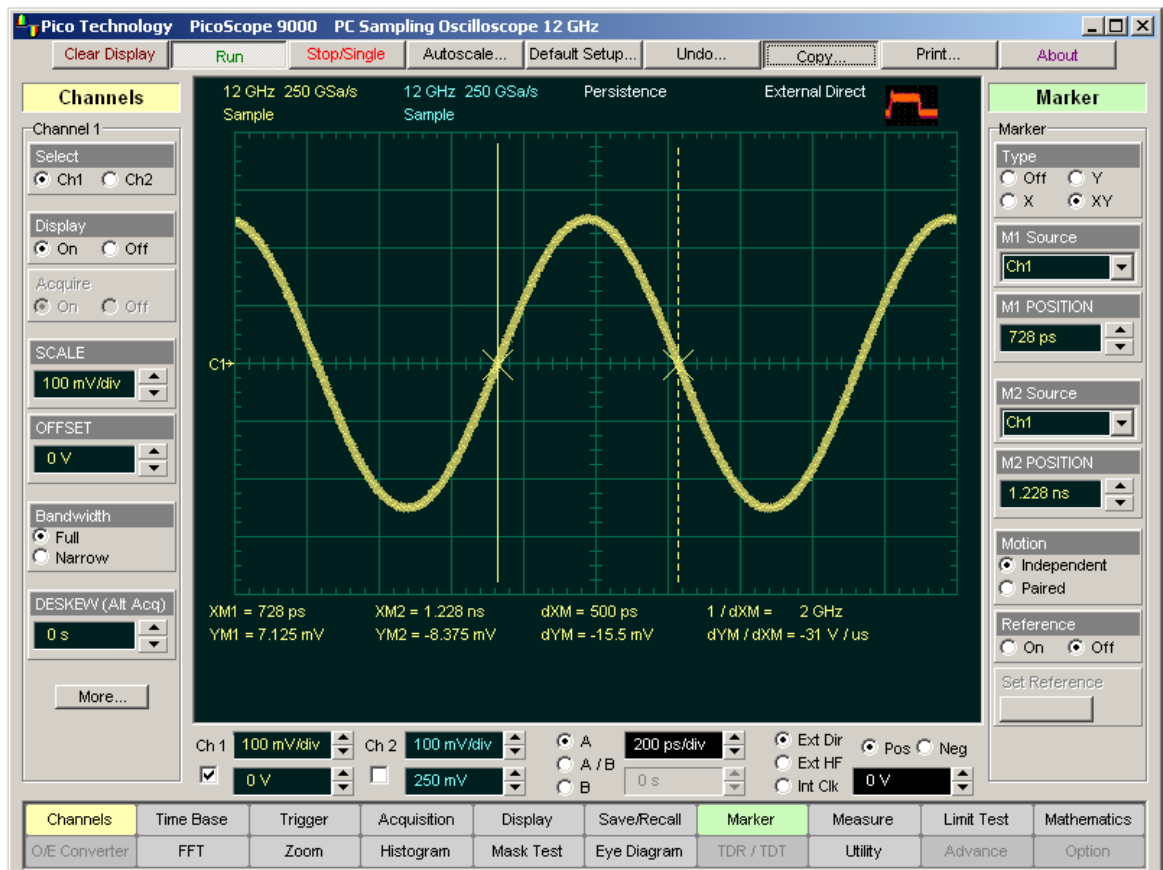
You can position the **Y**-markers anywhere on the display, which allows you to make custom measurements. The **Y**-markers track the voltage values as the vertical scale is changed, which allows you to make accurate voltage measurements. The position readout is based on the scale factors of the source waveform. Marker resolution is limited to the pixel resolution of the display.



**Amplitude measurement with the Y Markers**

## XY Markers

The **XYM1** and **XYM2** are two waveform markers. Their displays are: **+** and **X**. Each marker is in effect, both a horizontal and vertical marker. Neither of these markers can be moved off the waveform. The **XY**-markers track the waveform data in memory rather than on the displayed waveform. Because the waveform data in memory has a much greater resolution than the display, the measurements you make with the **XY**-markers are much more precise than measurements made with the manual markers. The **XY**-markers track the time as changes of the source signal. This allows you to make accurate delay measurements without having both markers on the display.



**Customized measurement with the Y Markers**

### 5.7.2 M1 Source and M2 Source



You may set the source for each marker:

- Channels 1 and 2
- Functions 1 through 4
- Waveform memories 1 through 4
- Spectra 1 and 2

For example, you could set the **M1 Source** to a waveform on channel 1, and the **M2 Source** to a waveform in memory **M1**. The scale used to position each marker on the display is based on the scale of the waveform source to which the marker is tied.



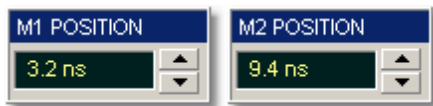
You cannot select a marker source that is turned off.



When you are placing markers on a waveform, make sure the source is set to that waveform.



### 5.7.3 M1 POSITION and M2 POSITION



You can use different methods to control the positions of the markers:

- Use the spin box
- Use the mouse to click and drag markers to a new position
- Use the keyboard
- Use the [Pop-up Keypad](#)<sup>[375]</sup> for quickly entering numeric data using the mouse

#### Manual X Markers

The **M1 POSITION** variable moves the **XM1** marker horizontally, and the **M2 POSITION** variable moves the **XM2** marker horizontally. The position of each marker is displayed, in the same color as the markers.

You can make timing measurements using **X** markers on the signal. The difference between the marker's positions is the timing measurement or **dXM**:

$$dXM = XM2 - XM1$$

If **XM1** is more positive than **XM2**, **dXM** will be a negative number, which can result in negative time interval measurements. Also notice the **1/dXM** value. If you are measuring the period of a signal with the **X**-markers, then **1/dXM** is the frequency of the signal. You can also make a channel-to-channel skew measurement by placing the **XM1** marker on one channel and the **XM2** marker on another channel.

#### Manual Y Markers

The **M1 POSITION** variable moves the **YM1** marker vertically, and the **M2 POSITION** variable moves the **YM2** marker vertically. The position of each marker is displayed, in the same color as the markers.

You can make voltage measurements on the signal by placing the **Y**-markers on the signal.

The difference between the markers is the voltage measurement or **dYM**:

$$dYM = YM2 - YM1$$

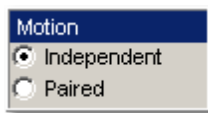
If **YM1** is more positive than **YM2**, **dYM** will be a negative number. You can also make a channel-to-channel voltage measurement by placing the **YM1** marker on one channel and the **YM2** marker on another channel.

#### Waveform XY Markers

The **X** marker is controlled by the **M1 POSITION** variable and the **+** marker is controlled by the **M2 POSITION** variable. The position of each marker is displayed, in the same color as the markers.

Each **XY** marker has an **YM** position and **XM** position. Vertical measurements are made with the **YM** positions, and **dYM** is the difference between the **YM** positions (see  $dYM = YM2 - YM1$ ). Timing measurements are made with the **XM** positions, and **dXM** is the difference between the **XM** positions (see  $dXM = XM2 - XM1$ ). Notice **1/dXM**. If you are using the markers to measure the period of a signal, then **1/dXM** is the frequency of the signal. Also notice **dYM/dXM**. If you are measuring such parameters as the rise or fall of an impulse with the **XY** markers, then **dYM/dXM** is the slope of the signal.

### 5.7.4 Motion



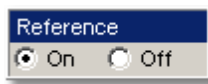
There are two options for the way in which PicoScope 9000 moves the markers:

- Independent
- Paired

**Independent.** When **Independent** motion is selected you can move each marker independently. The **M1 POSITION**<sup>[194]</sup> variable moves the **XM1**, or the **YM1**, or the **XYM1** marker. The **M2 POSITION**<sup>[194]</sup> variable moves the **XM2**, or the **YM2**, or the **XYM2** marker.

**Paired.** When **Paired** motion is selected you can move both markers with the **M1 POSITION**<sup>[194]</sup> variable simultaneously, while the difference between markers can be moved with the **M2 POSITION**<sup>[194]</sup> variable.

### 5.7.5 Reference



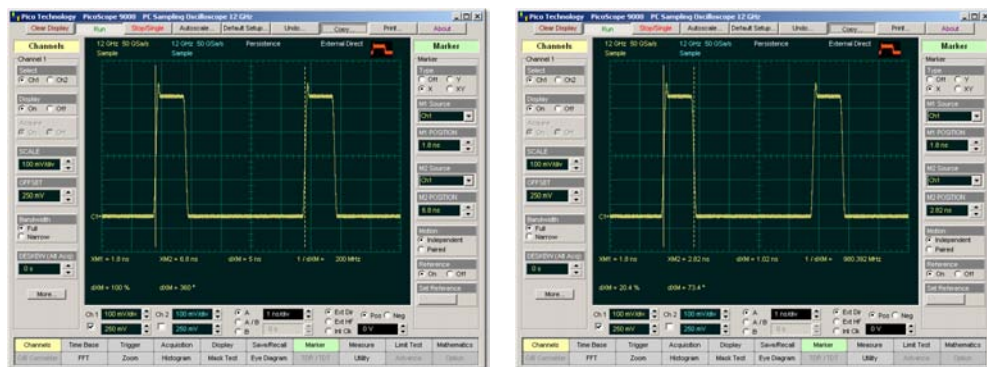
The **Marker** menu provides ratiometric measurements. These measurements give results in such ratiometric units as %, dB, and Degrees.

Ratiometric measurements require a reference for comparison.

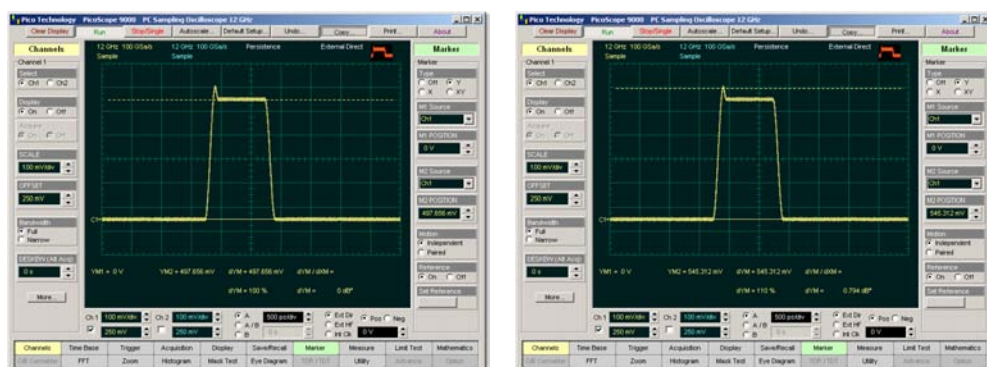
The user can set the reference:

1. First adjust the markers to a predetermined positional difference representing an absolute reference or position the markers on a reference waveform to define a specific parameter such as peak-to-peak voltage or period.
2. Then clicking the **Set Reference** button the ratiometric values for the reference in the Marker Measure tab becomes 100 %, 0 dB or 360°. These values are displayed, in the same color as the markers. When you change position of any marker, the results will be displayed in ratiometric values.

Click the **On** button to select ratiometric measurements.



**Ratiometric Measurement of Duty Cycle with X Markers**



**Ratiometric Measurement of Overshoot with Y Markers**

### 5.7.6 Set Reference



Clicking the **Set Reference** button sets the ratiometric values for the reference. As an example, they can be 100 %, 0 dB or 360°. These values are displayed, in the same color as the markers. When you begin to change the position of any marker, the results will be displayed in ratiometric values.

## 5.8 Main Menu

Channels	Time Base	Trigger	Acquisition	Display	Save/Recall	Marker	Measure	Limit Test	Mathematics
O/E Converter	FFT	Zoom	Histogram	Mask Test	Eye Diagram	TDR / TDT	Utility	Advance	Option

The **Main Menu** buttons are located at the bottom of the instrument display.

The **Main Menu** is used to:

- Set up the oscilloscope operating modes ([Channels](#)<sup>[35]</sup>, [Time Base](#)<sup>[343]</sup>, [Trigger](#)<sup>[354]</sup>, [Acquisition](#)<sup>[20]</sup>, [Display](#)<sup>[47]</sup> and [Zoom](#)<sup>[366]</sup> Menus)
- Set up and execute waveform measurements ([Marker](#)<sup>[187]</sup>, [Measure](#)<sup>[241]</sup>, **Limit Test**, [Histogram](#)<sup>[176]</sup>, [Eye Diagram](#)<sup>[70]</sup> and [Mask Test](#)<sup>[199]</sup> Menus)
- Control file management tasks ([Save/Recall](#)<sup>[316]</sup> Menu)
- Perform waveform analysis ([Mathematics](#)<sup>[234]</sup> and [FFT](#)<sup>[161]</sup> Menus)
- Set up and execute instrument calibration, and to use a demo mode (**Utility** Menu)

## 5.9 Mask Test

### Mask Test

There are industry standards that define the parameters for electrical and optical waveforms. Mask testing is a process you can use to verify that the displayed waveform complies with an industry standard waveform shape.

A mask is a template that consists of numbered, shaded regions on the instrument display screen. The input waveform must then remain outside these regions in order to comply with the industry standard. Any acquired data point that falls inside a mask margin appears in red.

The instrument has been designed to perform communication industry mask testing to a variety of test standards. Mask testing may be performed by a following simple procedure. This procedure loads one of several mask templates, automatically aligns the mask to the present waveform, and then determines the waveform's compliance to the mask. The size of the mask or the portion of the mask can be increased or decreased in a linear fashion to determine the waveform's margin of compliance. Both the user defined and standard (factory-installed) masks can be stored to disk for rapid switching between instrument setups. Mask testing can also activate a variety of actions upon determining a test failure.

The image displays five panels of the Mask Test menu interface, each with a yellow header and a 'Back' button at the bottom.

- Panel 1: Mask Test**
  - Mask Test
  - Create Mask... (button)
  - Erase Mask (button)
  - Compare with: ☒ Ch1 ☐ Ch2
  - Test: ☒ On ☐ Off
  - Run Until/Action... (button)
- Panel 2: Mask Test**
  - Create Mask
  - Standard Mask... (button)
  - Automask... (button)
  - Edit Mask... (button)
  - Recall User Mask (button)
  - Save User Mask (button)
  - Save Mask As Std (button)
- Panel 3: Mask Test**
  - Automask
  - Source: Ch1 (dropdown)
  - Units: ☒ Division ☐ Current
  - DELTA X: 0.2 div (spinners)
  - DELTA Y: 0.25 div (spinners)
  - Build Automask (button)
- Panel 4: Mask Test**
  - Edit Mask
  - Add Point (button)
  - Delete Point (button)
  - Add Polygon (button)
  - Delete Polygon (button)
  - Delete Mask (button)
- Panel 5: Mask Test**
  - Run Until/Action
  - Run Until: ☐ Stop / Single ☒ Failed Wfms ☐ Failed Samples ☐ Waveforms ☐ Samples
  - # OF FAILED WFM: 1000 Wfm (spinners)
  - Select Action: ☒ Beep ☐ Save

### 5.9.1 Create Mask



Clicking the **Create Mask...** button opens the mask selection menu. You can select from:

- industry-standard electrical masks
- industry-standard optical masks
- automasks
- new user-defined masks
- stored user-defined mask

Also you can edit any mask, and save it to a memory.

#### 5.9.1.1 Standard Mask



**Standard Masks...** allows you to select from a variety of standard telecommunication masks. Clicking the **Standard Masks...** button opens the **Standard Masks Dialog**.

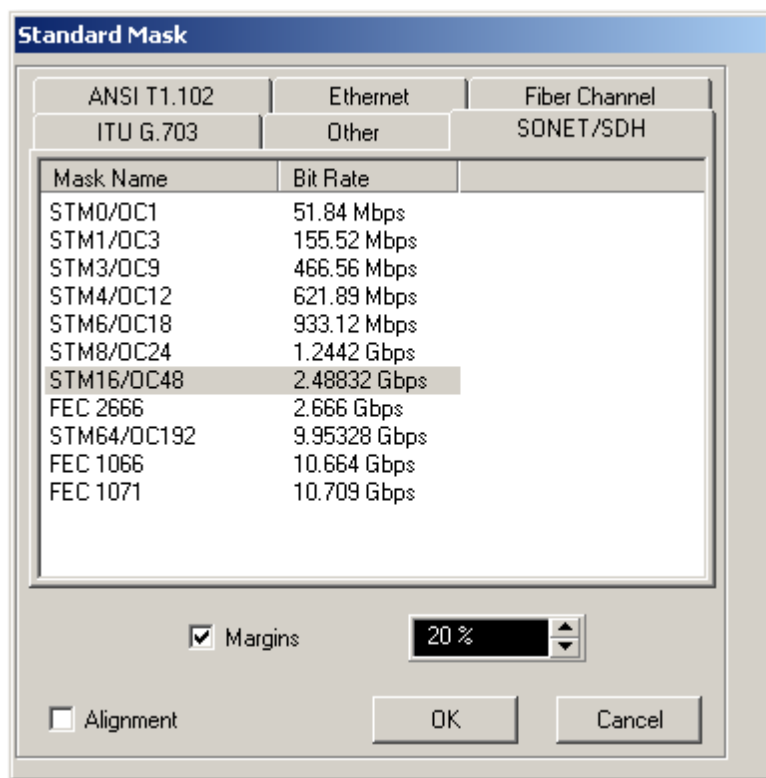
Choose a standard to access a list of masks used for optical or electrical waveforms. The PicoScope 9000 supports several standards for datacomms and telecomms masks. They are:

- SONET/SDH
- Fiber Channel
- Ethernet
- ITU G.703
- ANSI T1.102
- Other Masks

## 5.9.1.1.1 SONET/SDH Masks

SONET/SDH

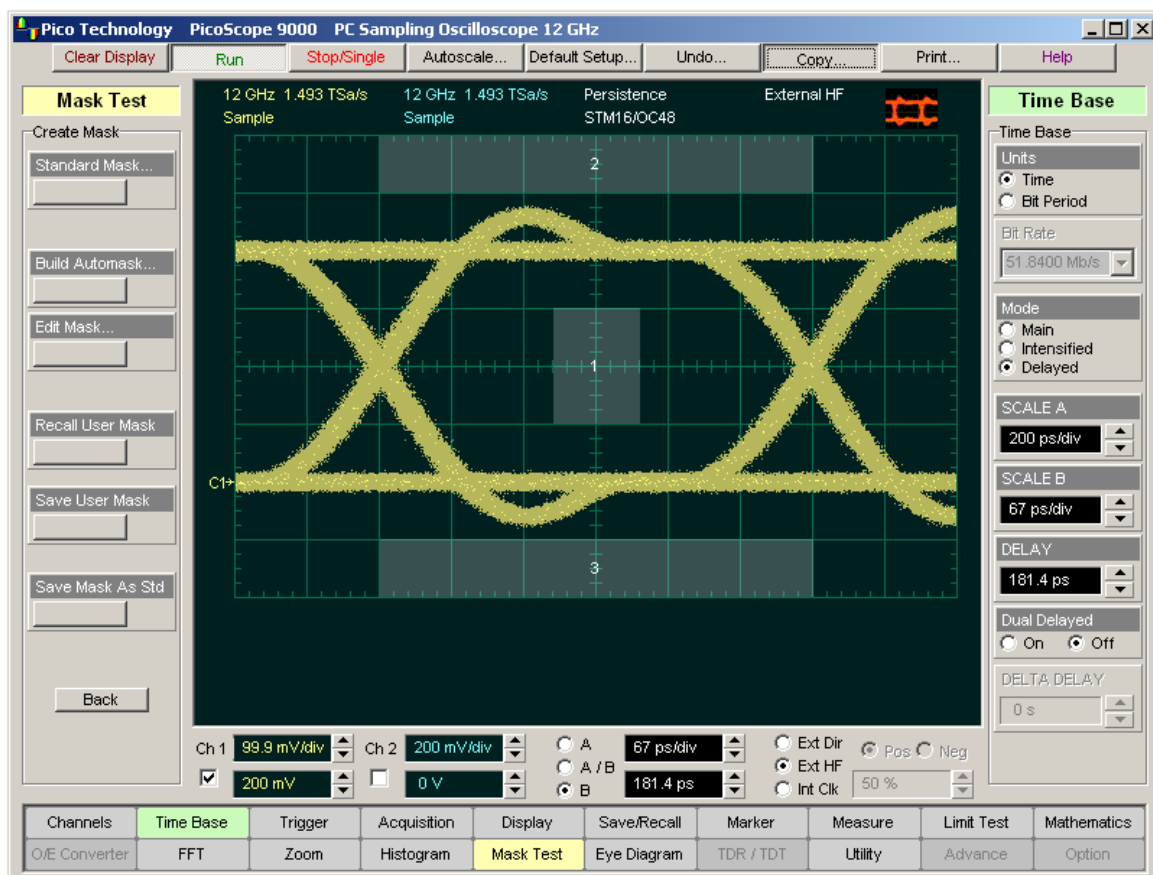
Clicking the **SONET/SDH tab** opens the list of industry-standard masks.



### The list of industry-standard SONET/SDH masks

Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above. An example eye-diagram with the **OS48/STM16** industry-standard mask is shown below.





**An example of eye-diagram with the OS48/STM16 SONET/SDH mask**

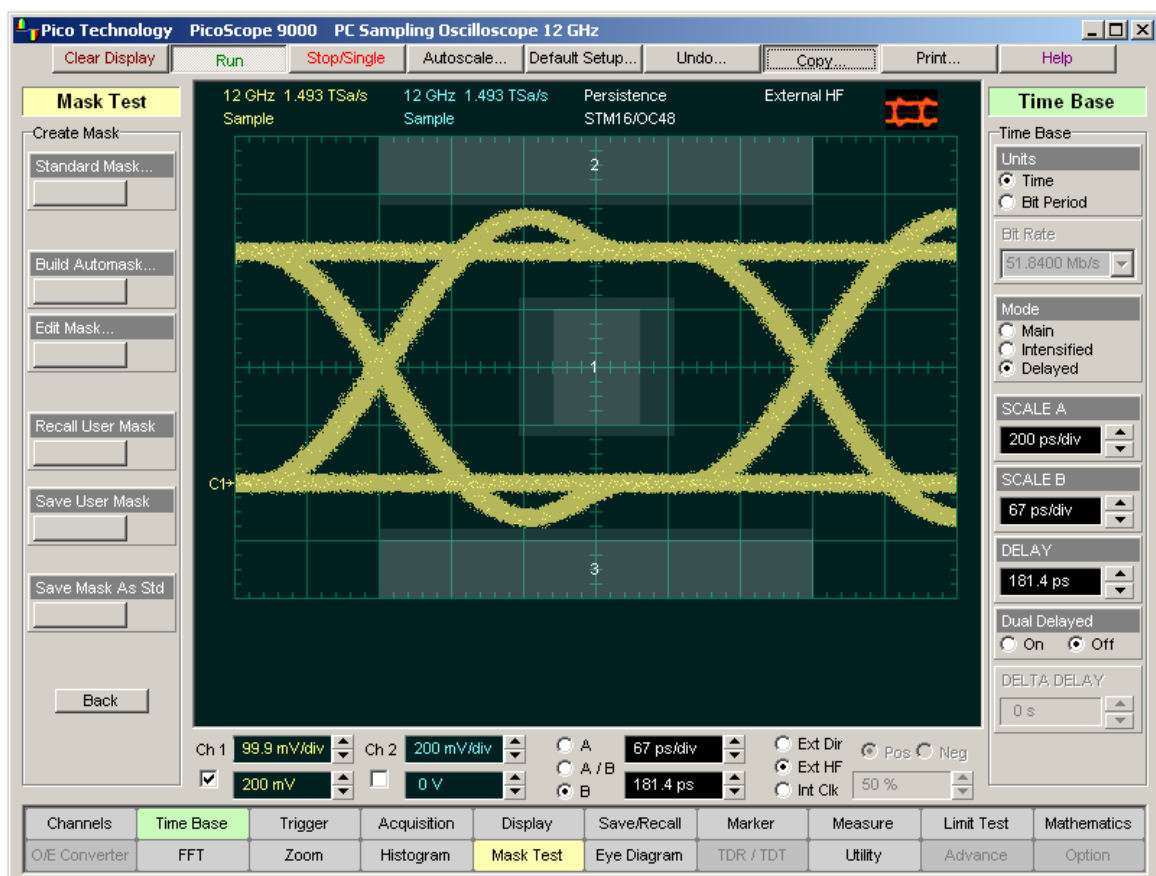
## 5.9.1.1.2 Mask Margins



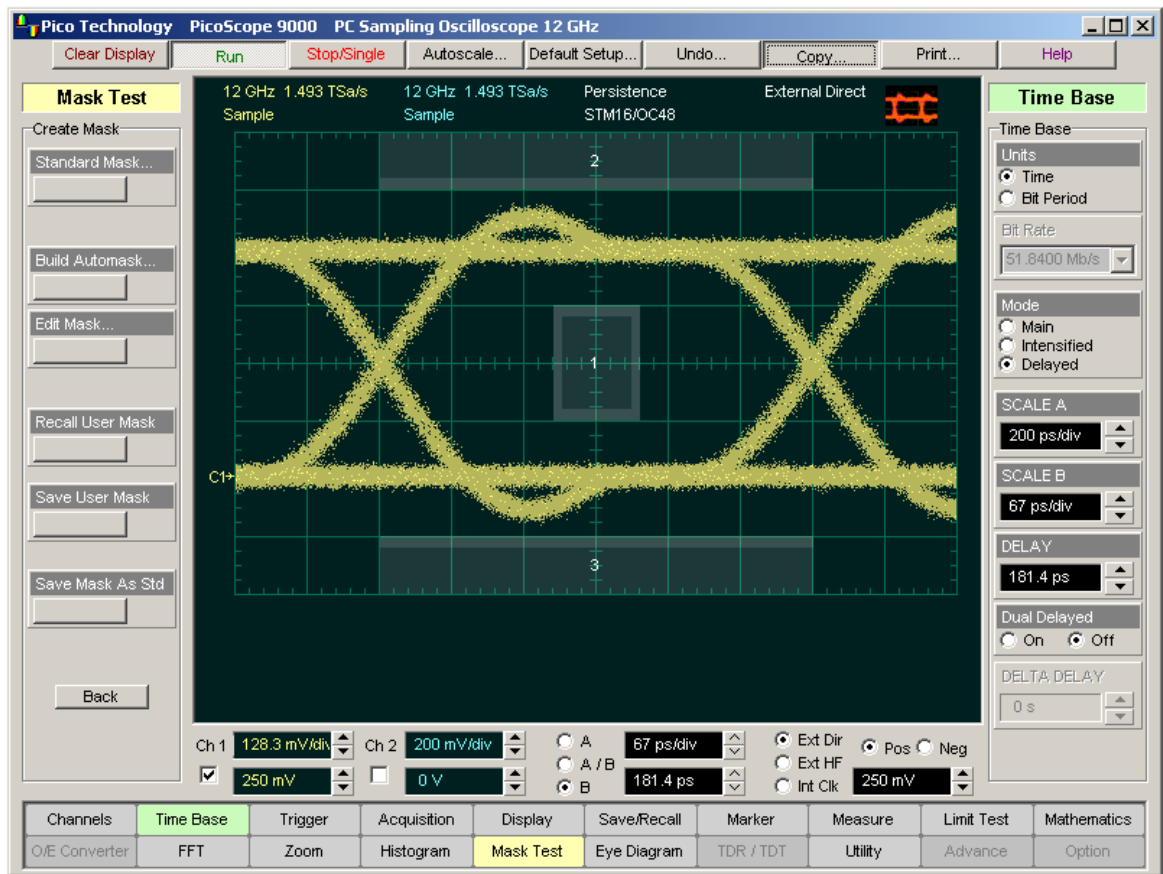
The **Margins** option is a part of each opened list of industry-standard masks. Mask margins are used to determine the margin of compliance for a standard mask. The operator can use both positive mask margins and negative mask margins. Positive mask margins determine how much larger you will be able to make the mask before violations will occur, while negative mask margins determine how much smaller you have to make the mask before violations no longer occur. You can then use this information to determine by what margin the waveform begins to fail to comply with industry standards.

To turn on the mask margins, check the **Margins** check box located on each opened list of industry-standard masks. After mask margins are enabled, use the arrows to adjust the percentage of margin you want, or use the [Pop-up Keypad](#)<sup>[376]</sup> for quickly entering numeric data. You can enter a value between -99% and +99%. For example, if you want to verify that the waveform can comply with a standard mask with a 20% margin, set the margin value to 20%. You can then increase the size of the margin by increasing the percentage until violations occur.

The instrument displays the mask margins in a different color than the mask. As with a mask, any acquired data point that falls inside a mask margin appears in red. Two examples of positive and negative are shown on figures below. Notice that positive margins appear outside the mask regions, while negative margins appear inside the mask regions.



**An example of eye-diagram with positive mask margins (+20%)**




**An example of eye-diagram with negative mask margins (-20%)**

#### 5.9.1.1.3 Alignment

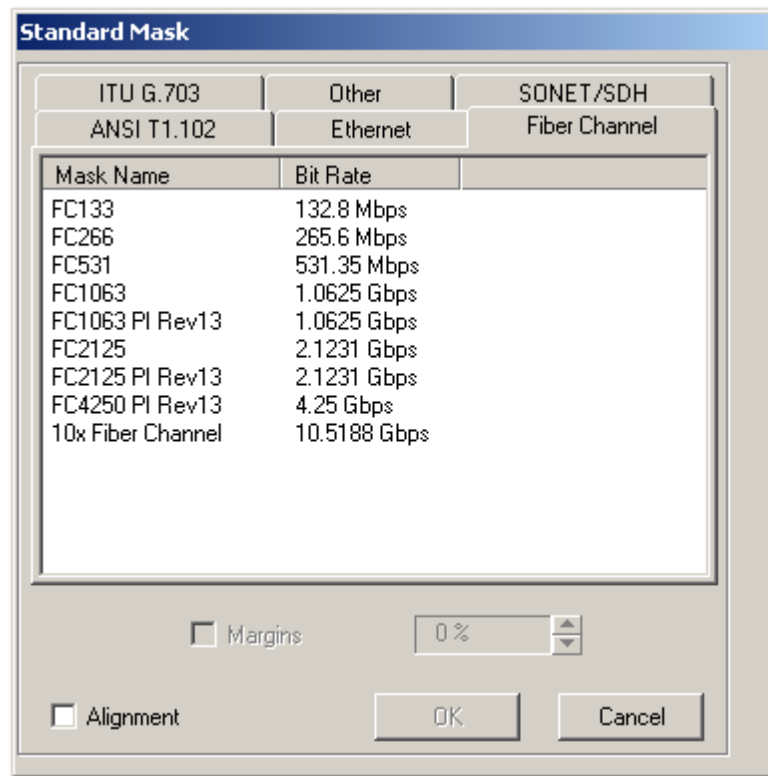


The instrument can align the **Time Base Scale** to a selected industry-standard mask. To turn on the alignment option, check the **Alignment** check box located on each opened list of industry-standard masks.

## 5.9.1.1.4 Fiber Channel Masks

A rectangular button with the text "Fiber Channel" in a sans-serif font.

Clicking the **Fiber Channel** tab opens the list of industry-standard masks. Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above.

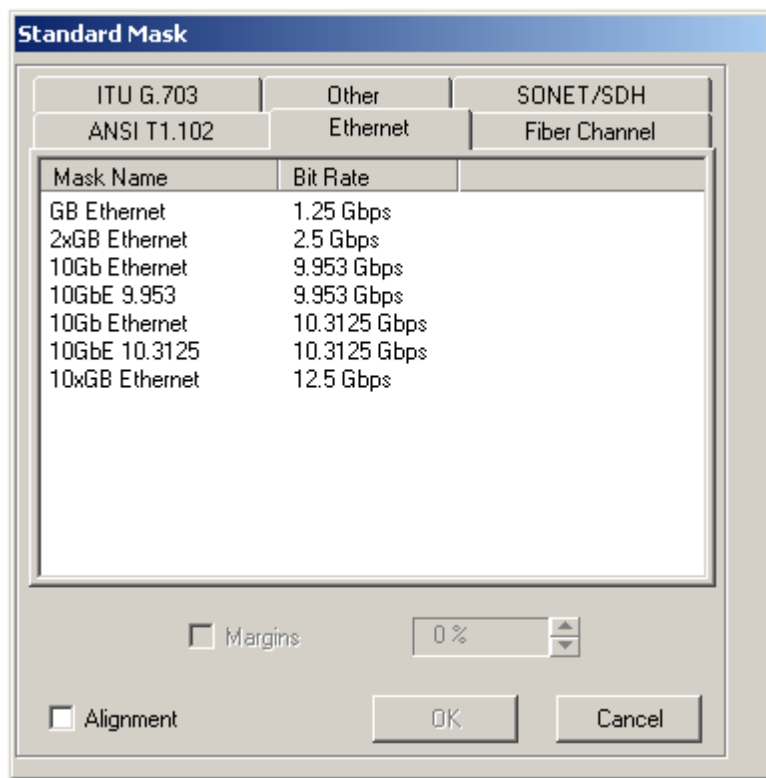


**The list of industry-standard Fiber Channel masks**

## 5.9.1.1.5 Ethernet Masks

A rectangular button with the word "Ethernet" in a sans-serif font.

Clicking the **Ethernet** tab opens the list of industry-standard masks. Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above.

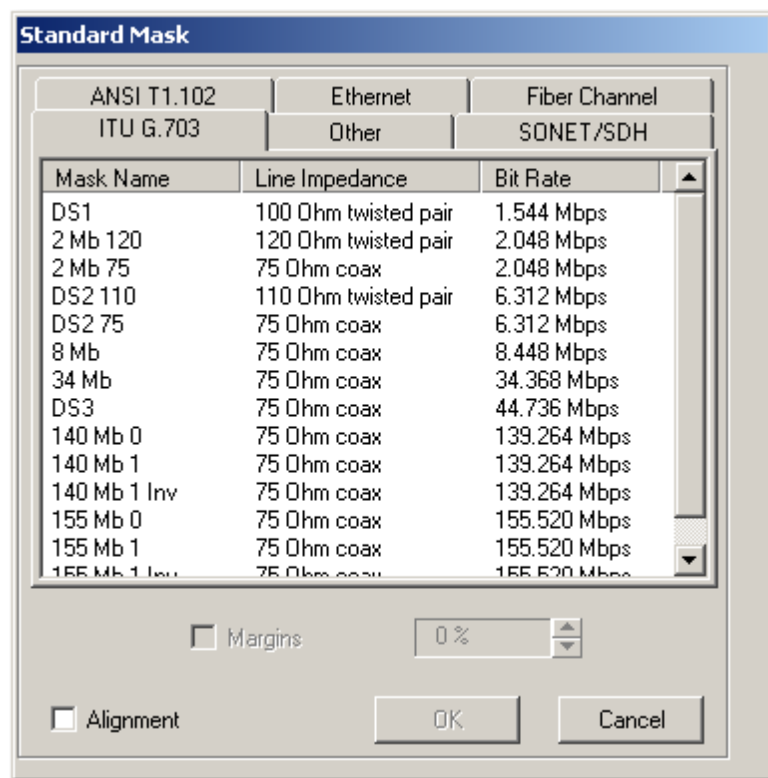


**The list of industry-standard Ethernet masks**

## 5.9.1.1.6 ITU G.703 Masks

## ITU G.703

Clicking the **ITU G.703** tab opens the list of industry-standard electrical masks. Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above.

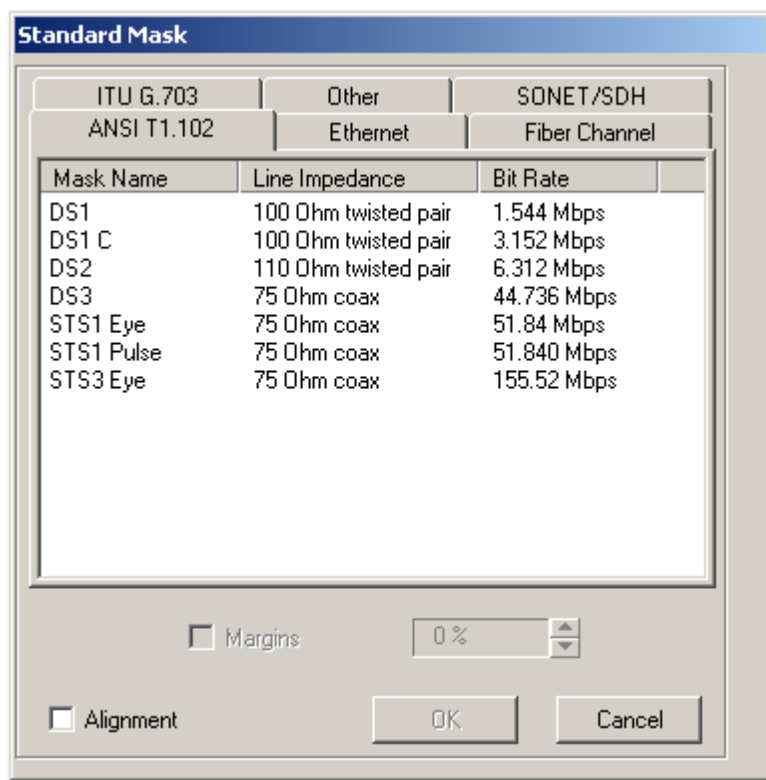


**The list of industry-standard electrical ITU G.703 masks**

## 5.9.1.1.7 ANSI T1.102 Masks

## ANSI T1.102

Clicking the **ANSI T1.102** tab opens the list of industry-standard electrical masks. Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above.

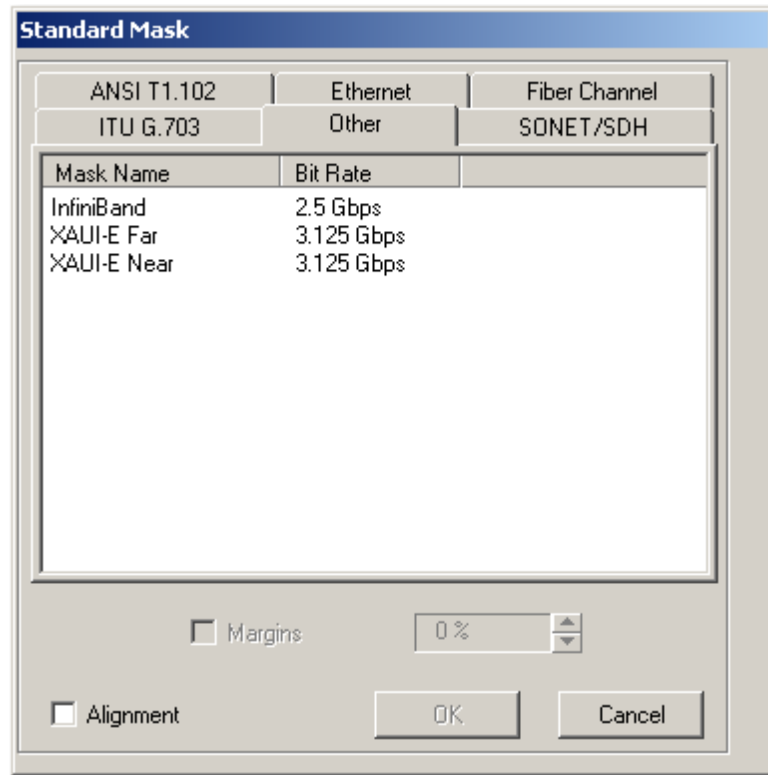


**The list of industry-standard electrical ANSI T1.102 masks.**

## 5.9.1.1.8 Other Masks

Other

Clicking **Other** opens the list of two additional industry-standard. Any of these masks may be recalled from memory and used to test a waveform to a specific industry standard listed above.



**The list of other industry-standard masks**



#### 5.9.1.2 User-defined Masks

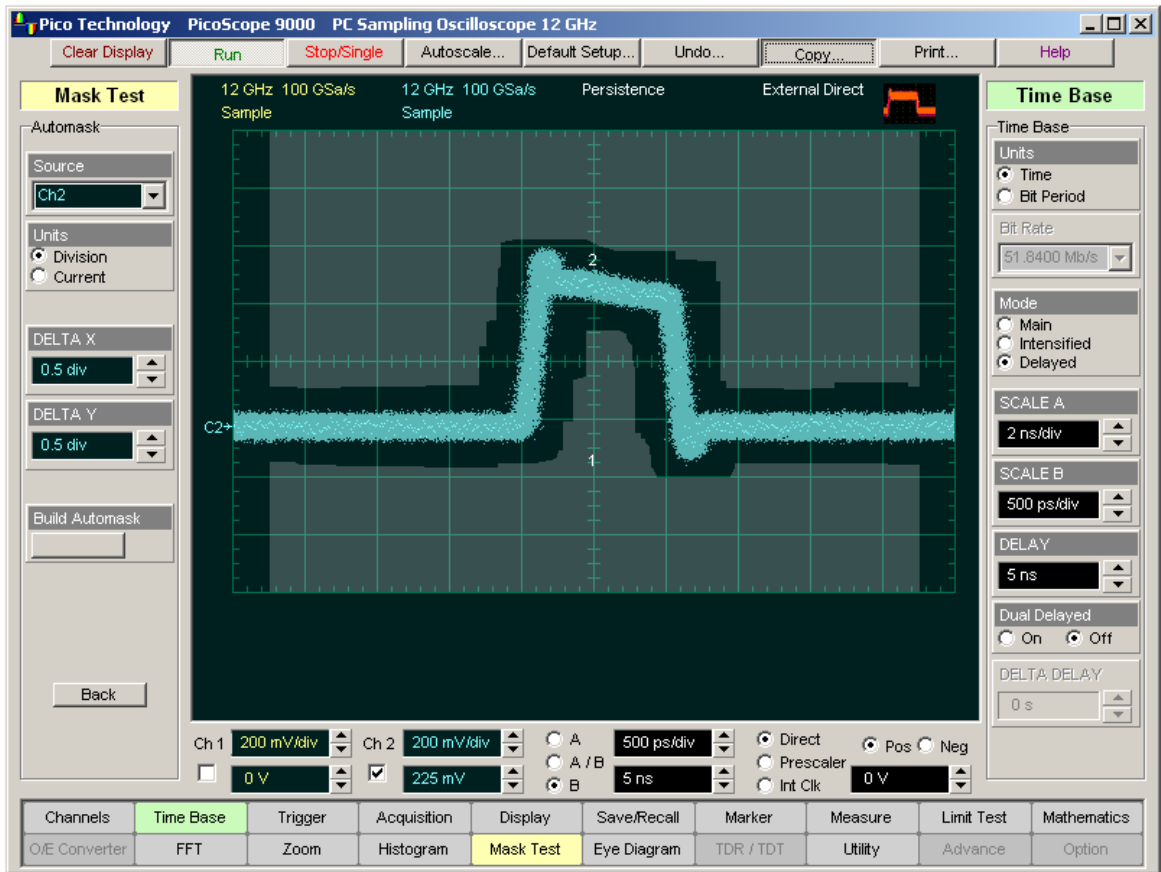
The **Mask Test** menu contains a mask-editing feature that allows you to create your own masks. These masks may be created using one of three methods:

- By using a reference waveform method (**Automask**). Masks are constructed by adding a **DELTA X** and **DELTA Y** tolerance around a reference waveform. This method is simple to use, though not as flexible as the polygon method.
- By using a polygon method for creating a unique new mask. Using this method, polygons are created to mask off failure regions of the graticule. Up to eight polygons can be positioned in the graticule area, each with 3 to 512 sides. Very complex masks can be constructed by placing polygons within polygons. Similar to margin testing discussed above, this method allows testing of waveform failure rates to varying tolerances, because failures are listed individually for each polygon.
- By using a polygon method for modifying an existing mask. This method involves the use of a reference waveform.

## 5.9.1.3 Automask

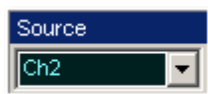


Clicking the **Automask...** button opens a menu for using the reference waveform method. An example of the method for a noisy impulse is shown in the figure below.



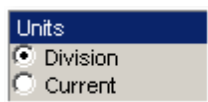
**An example of Automask for a noisy impulse**

## 5.9.1.3.1 Source



The **Source** function selects the channel, function, memory, or spectrum that the mask is scaled to.

## 5.9.1.3.2 Units



The **Units** function allows you to define **DELTA X** and **DELTA Y** in divisions or current source settings. Current is typically in volts and seconds or other appropriate units for the source.

## 5.9.1.3.3 DELTA X



The **DELTA X** variable defines the horizontal tolerance around the edges of the reference waveform.

## 5.9.1.3.4 DELTA Y



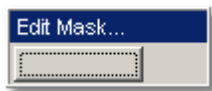
The **DELTA Y** variable defines the vertical tolerance around the edges of the reference waveform.

## 5.9.1.3.5 Build Automask



Clicking the **Build Automask** button builds a mask with the new values of the [DELTA X](#) [212] and [DELTA Y](#) [212] variables.

## 5.9.1.4 Edit Mask



The **Edit Mask...** function gives you access to a second-level menu that allows you to construct a new mask, or edit an existing one, using the polygon method. The procedure of editing a mask function brings up a set of brief instructions on how to construct a mask.

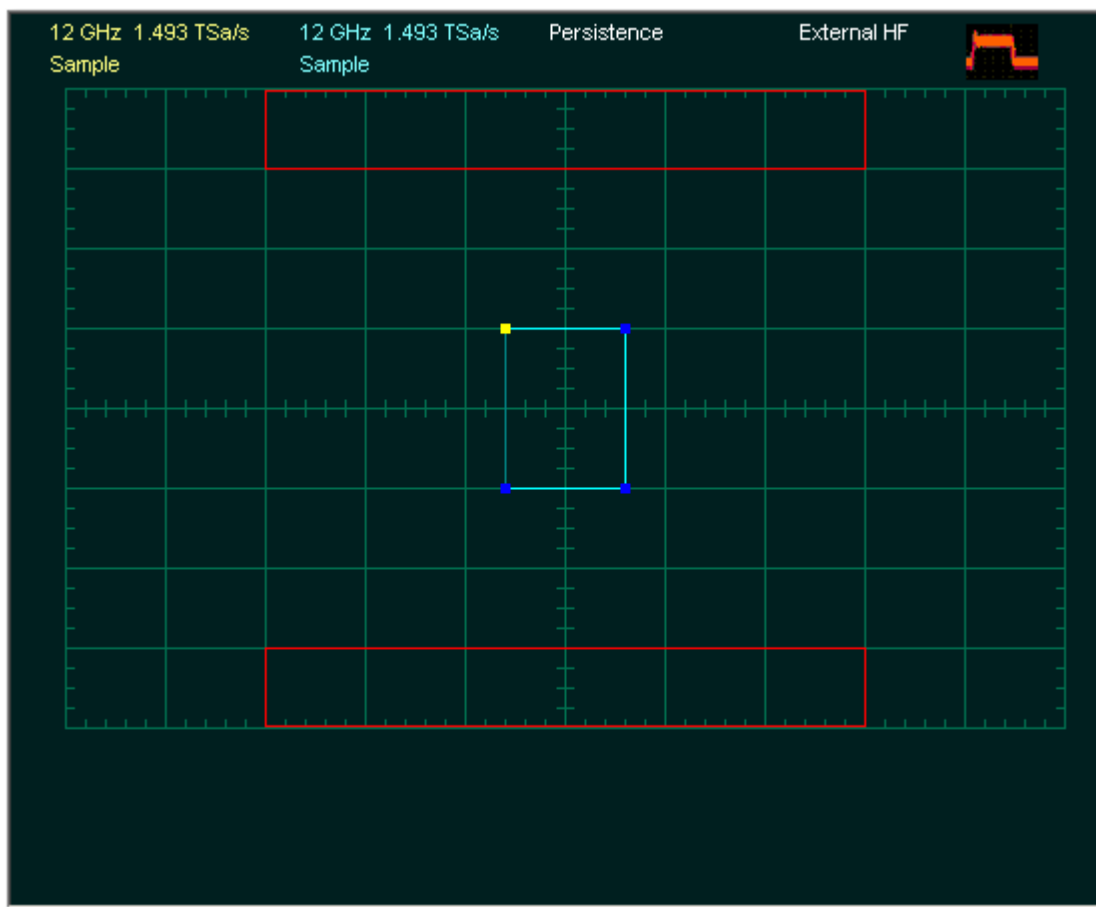
**Mask editing procedure**

The following is a simple editing procedure of editing the **OC48/STM16** standard mask into a user-defined mask.

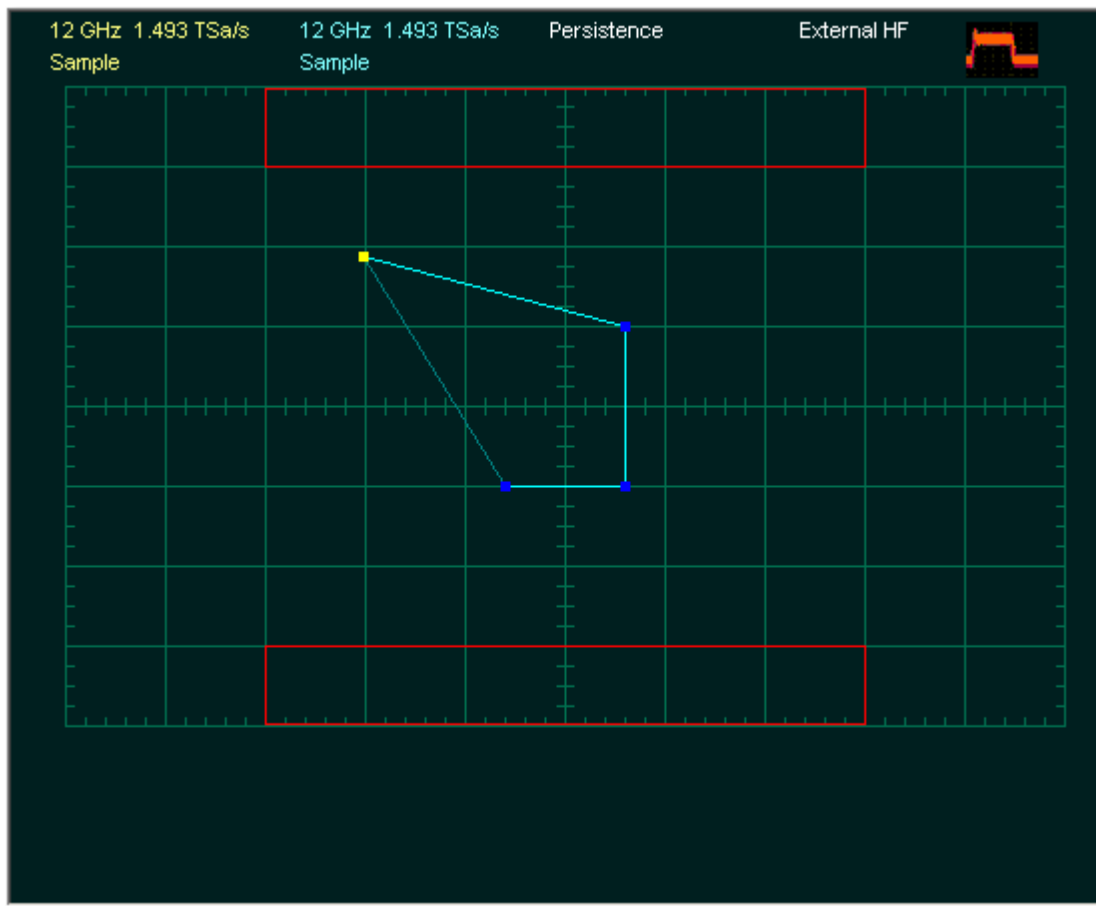
1. Select the **OC48/STM16** standard mask from **Mask Test / Create Mask... / Standard Mask / SONET/SDH / OC48/STM16**.



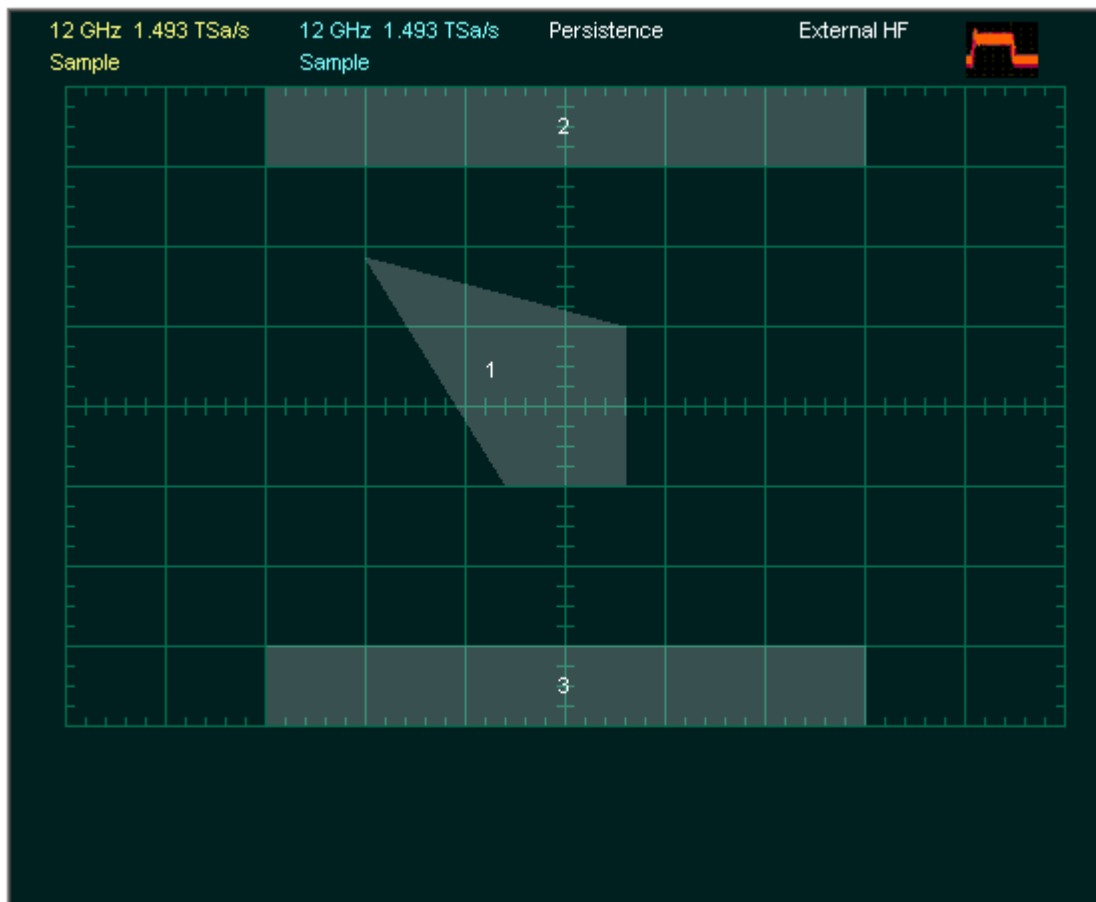
2. Click **Edit Mask...** Click a polygon to select it, and click again on a vertex of the polygon. Note the square points on the selected polygon, which are yellow when selected, otherwise blue. The vertical and horizontal coordinates of the selected point will appear in the Status Area of the GUI.



3. Click and hold the left mouse button on the selected point, then drag the mouse to move the point to the desired position. Release the mouse button when finished.



4. Click the **Back** button. The scope returns to the high-level menu, and mask gets a new shape.

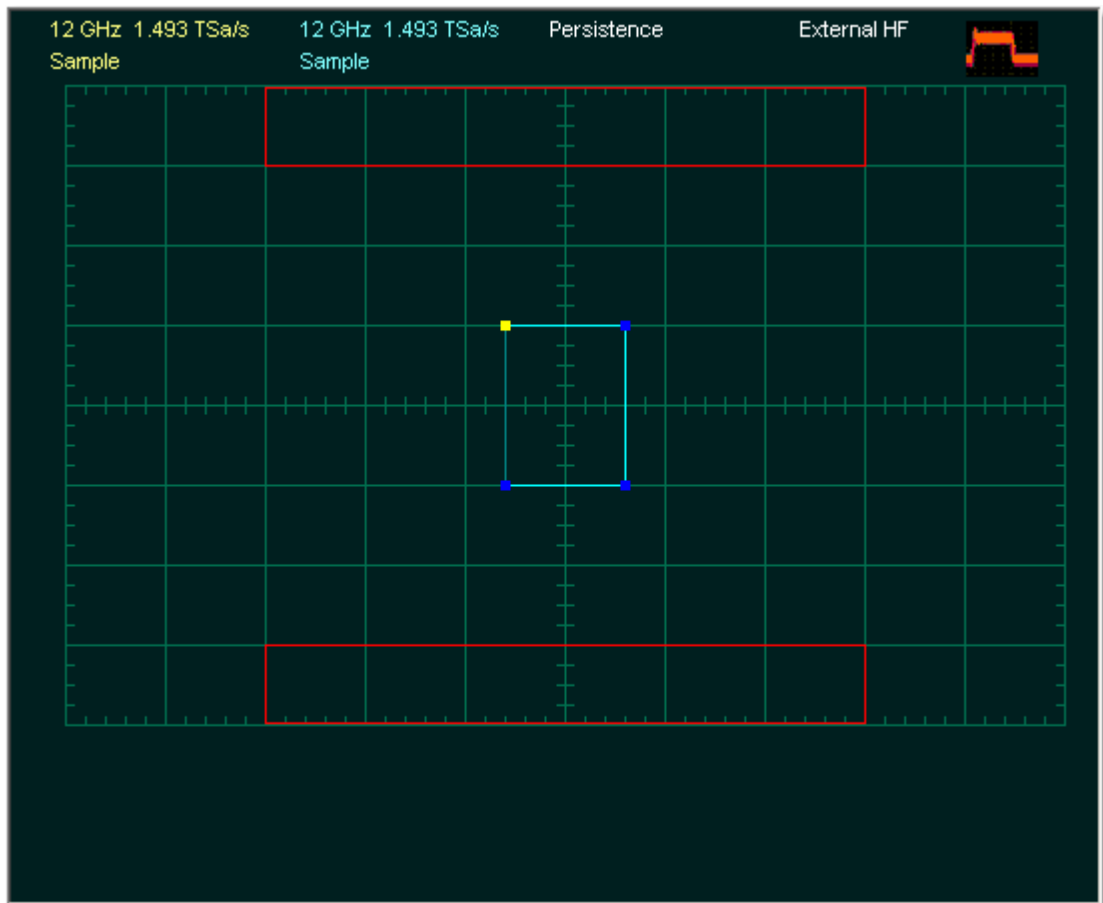


## 5.9.1.4.1 Add Point



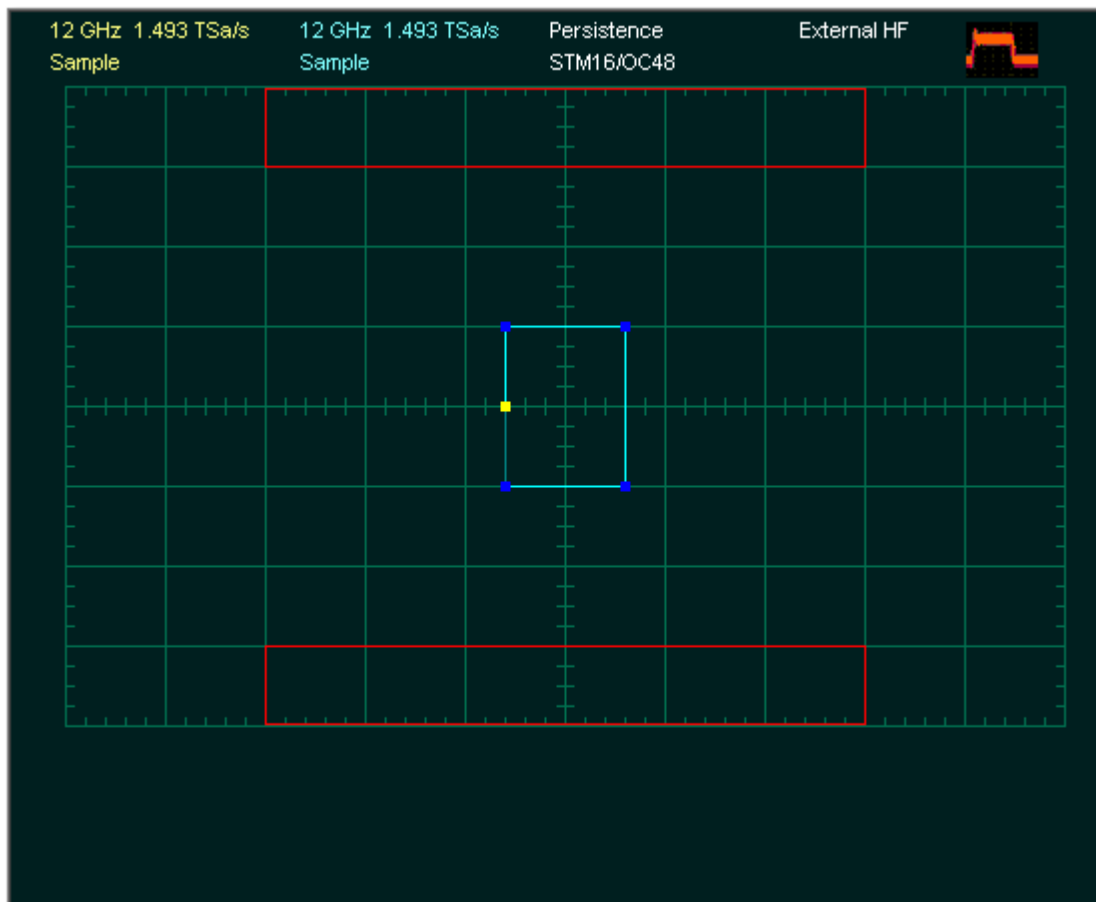
The **Add Point** function adds a point on the selected polygon in a **Mask**.

1. Click **Edit Mask**. Click on the polygon that you want to edit, and then click on a vertex of the polygon.

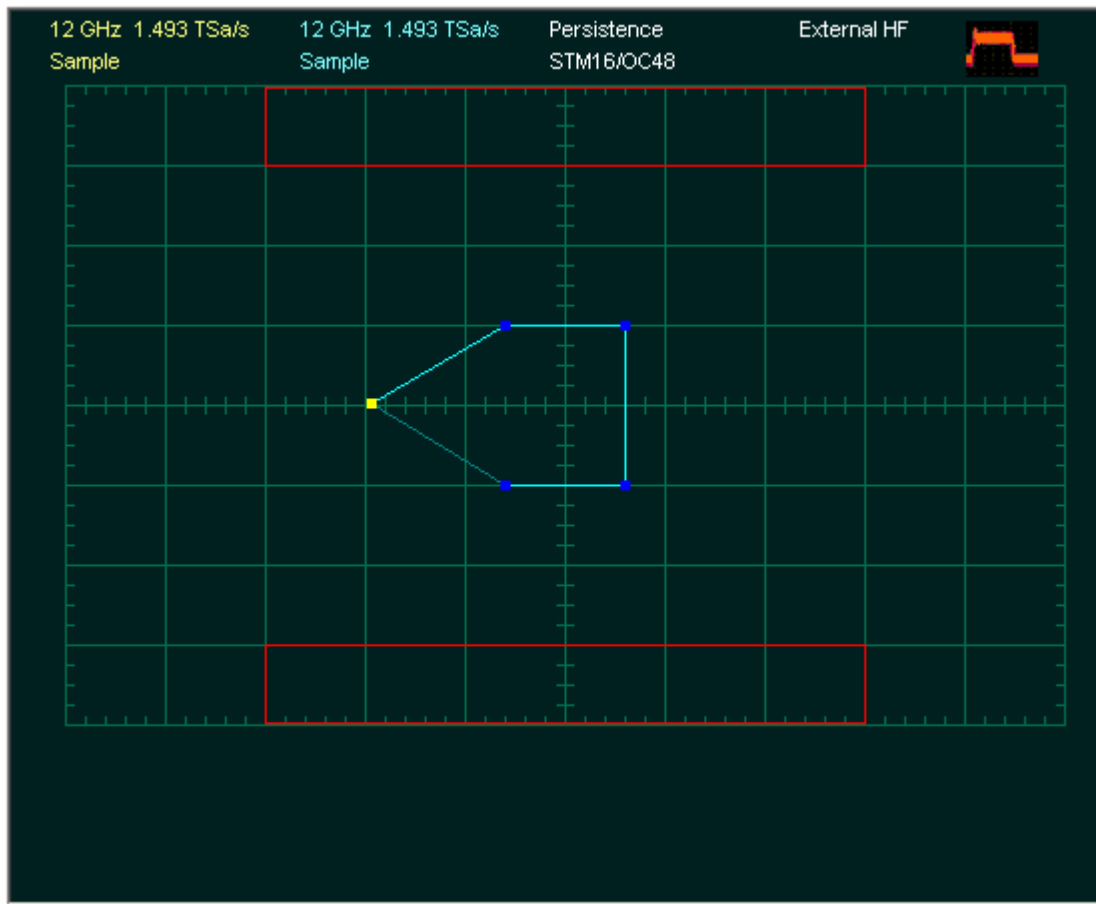




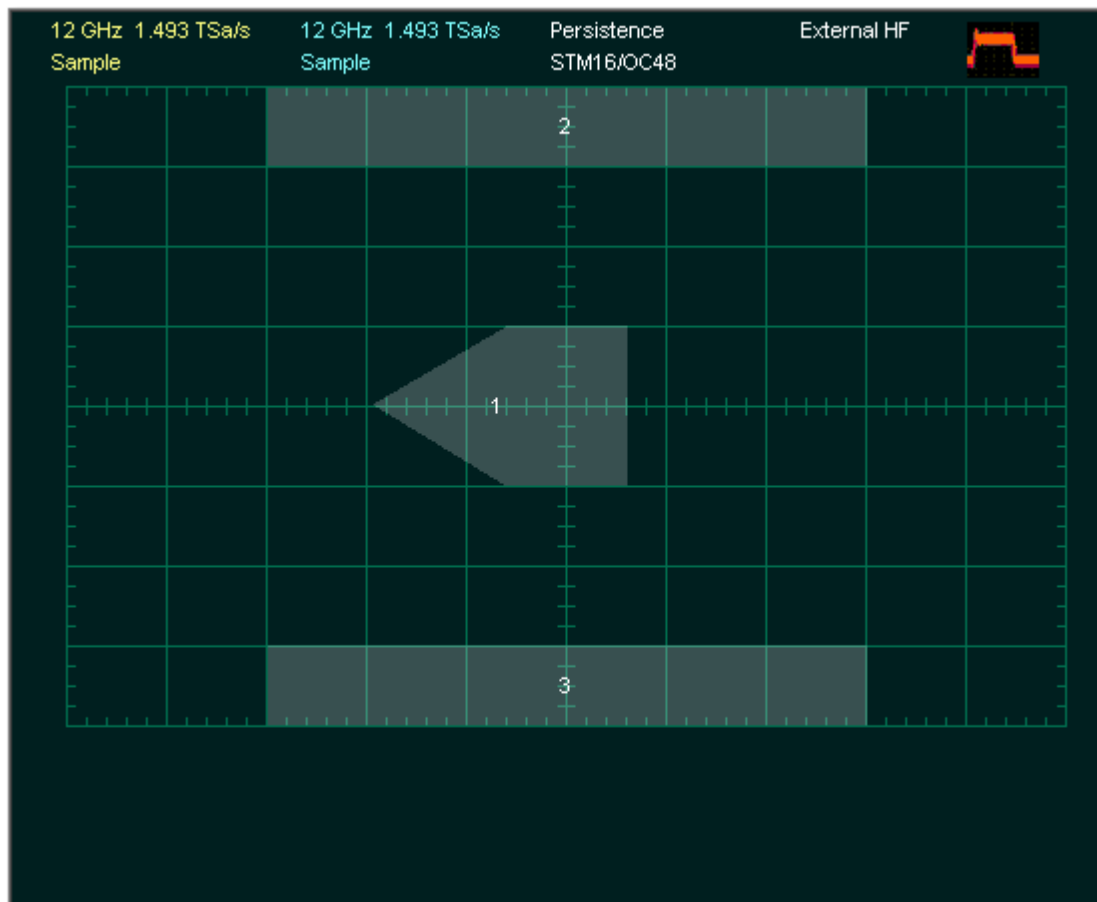
2. Click **Add Point**. A new point, highlighted in yellow, will appear counter-clockwise of the selected point. You can continue to edit this point.



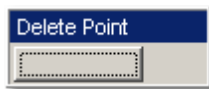
3. Click and hold the left mouse button on the new point, then drag the mouse to move it to the desired position. The vertical and horizontal coordinates of the new point change in the **Status Area** of the **GUI** when moving. Release the mouse button when finished.



4. Click the **Back** button. The scope returns to the high-level menu, and mask gets a new point.



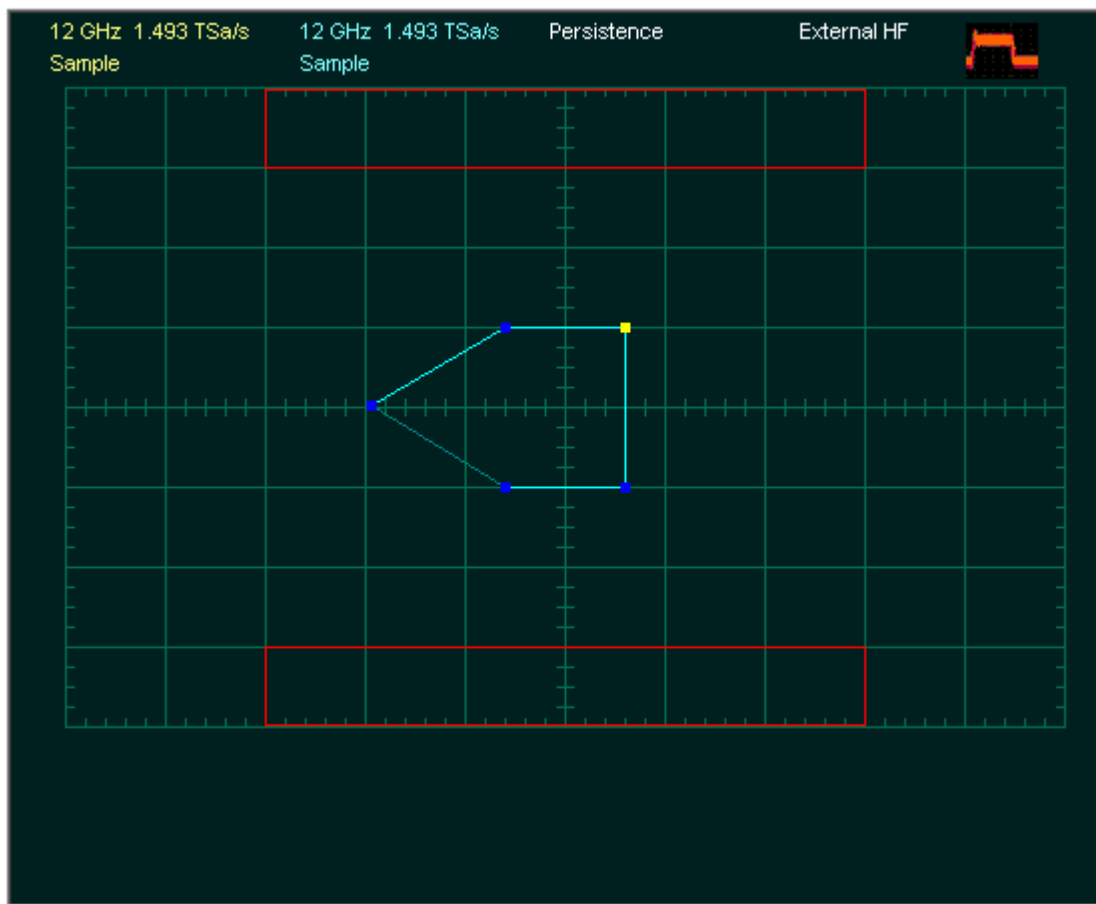
## 5.9.1.4.2 Delete Point



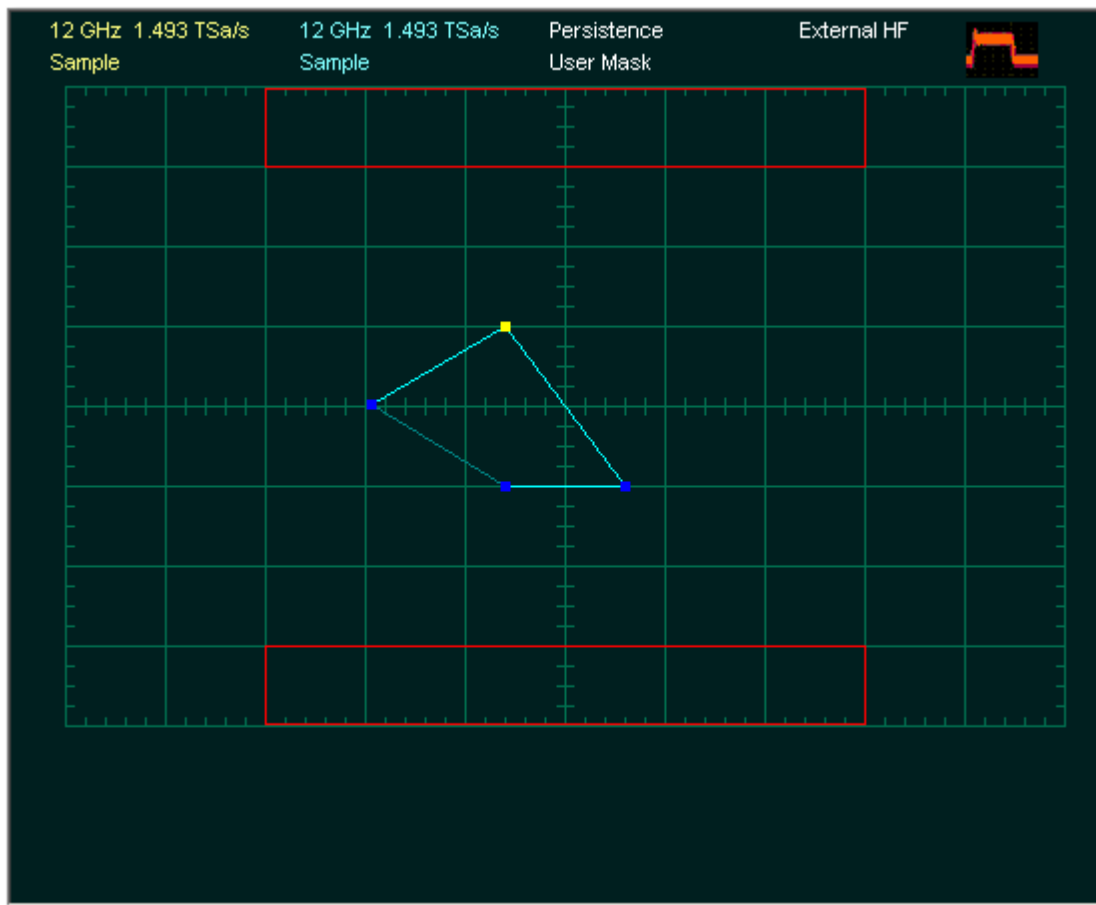
The **Delete Point** function deletes a point on a polygon of a **Mask**.

To delete a point:

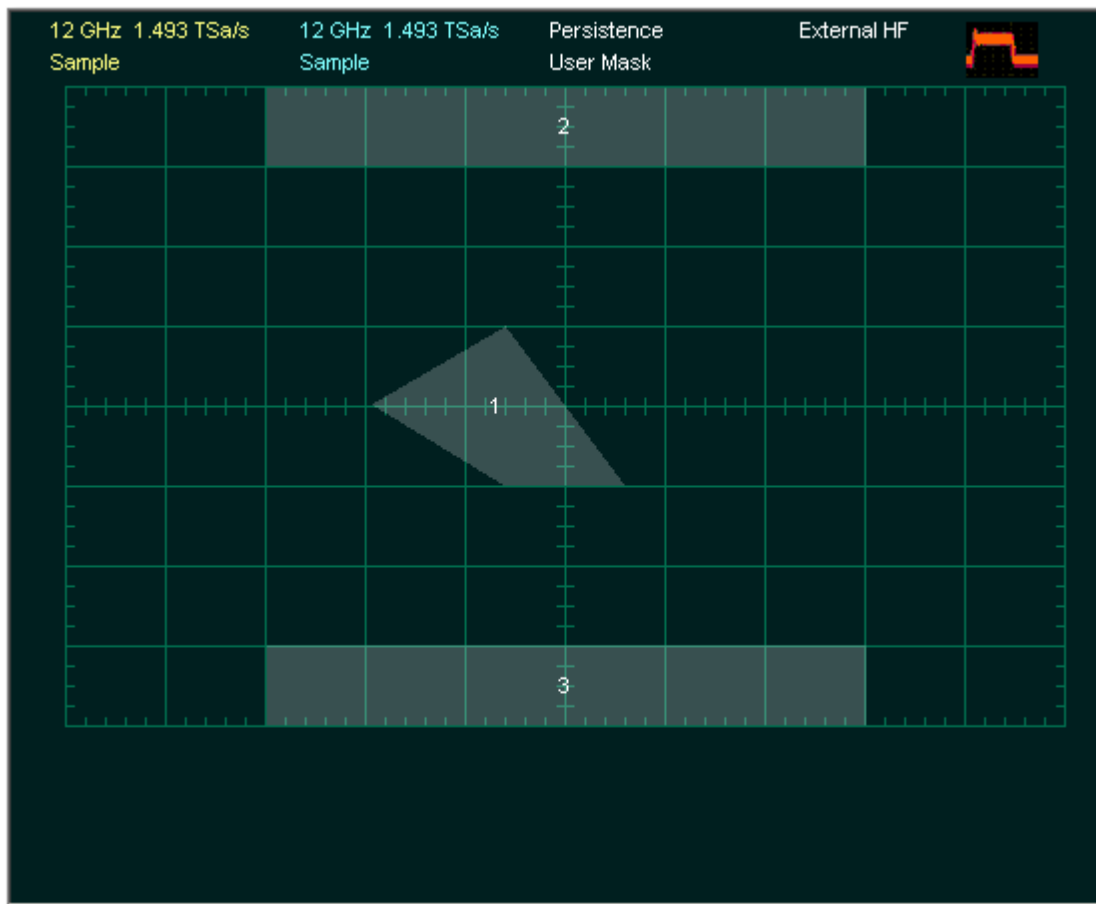
1. Click **Edit Mask**. Click on the polygon you want to use, and then click on the vertex you want delete. The selected point is highlighted in yellow. The vertical and horizontal coordinates of the selected point appear on the **Status Area** of the **GUI**.



2. Click the **Delete Point** button. The point will be deleted.



3. Click the **Back** button. The scope returns to high-level menu, and the mask gets a new shape without the deleted point.



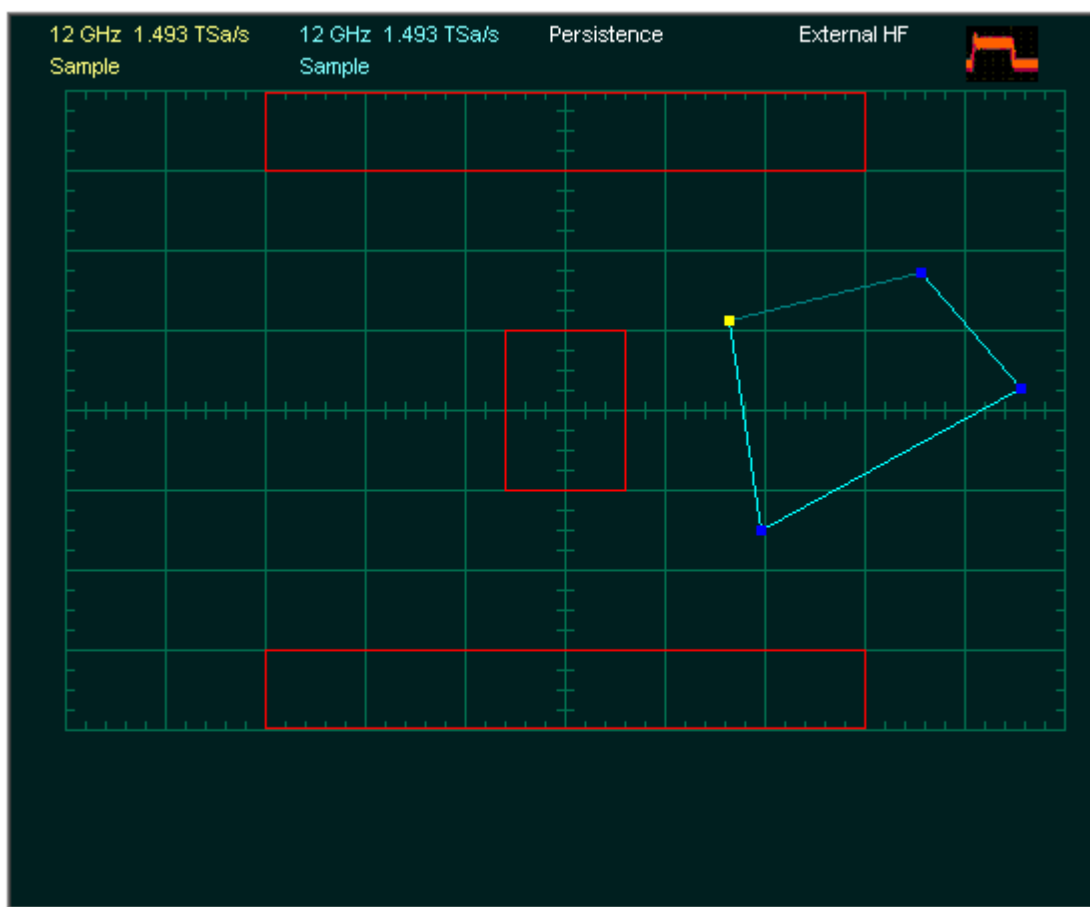
## 5.9.1.4.3 Add Polygon



The **Add Polygon** function allows you to select one of the eight polygons that you want to create.

**To add a polygon**

1. Click the **Edit Mask** button, and then the **Add Polygon** button. To create the first point of the new polygon, click on the waveform area of the screen. Move the mouse to the second point of the new polygon, then click again. Continue for all new points. You will see lines connecting all the points of the polygon. To finish the construction, right-click anywhere on the display. The polygon is now built, and the mouse is free.

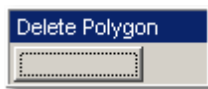


2. Click the **Back** button. The scope returns to the high-level menu, and the mask gets a new polygon.





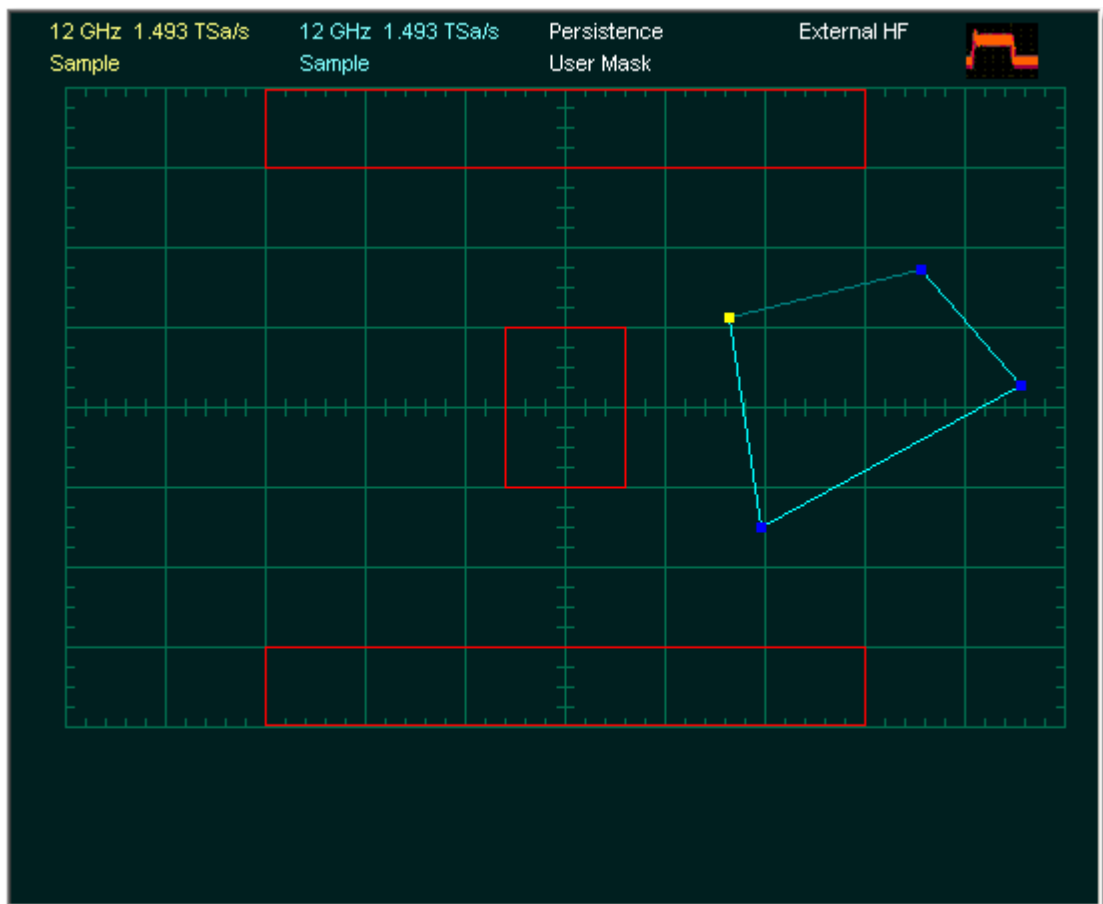
## 5.9.1.4.4 Delete Polygon



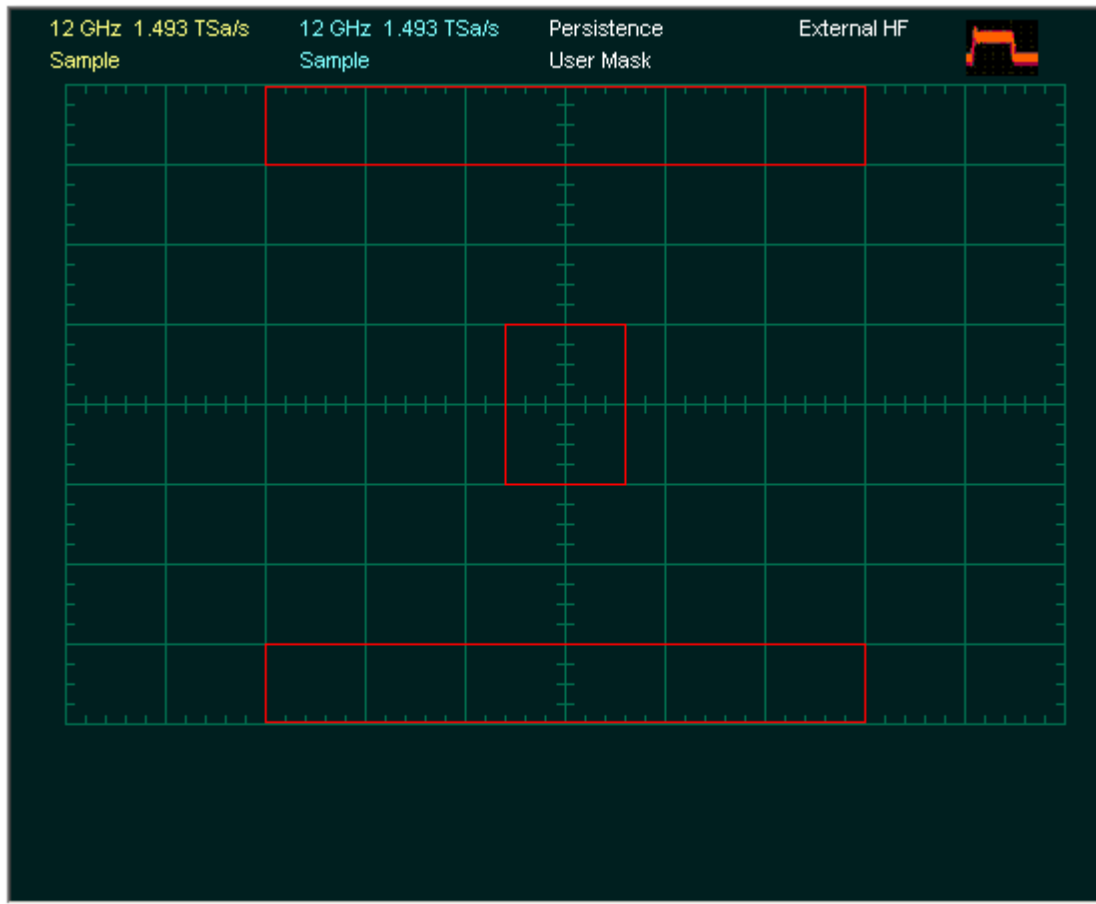
The **Delete Polygon** function allows you to delete one of the eight polygons.

**To delete the polygon**

1. Click the **Edit Mask** button. Click on any vertex of the polygon you want to delete.



2. Click the **Delete Polygon** button. You will see the mask without the deleted polygon.



3. Click the **Back** button. The scope returns to high-level menu, and mask gets a new form without deleted polygon.



## 5.9.1.4.5 Delete Mask



The **Delete Mask** function allows you to delete the mask that you are editing.

**To delete a mask**

1. Click the **Edit Mask** button.
2. Click the **Delete Mask** button. You will see the screen without the deleted mask.

## 5.9.1.5 Recall User Mask



Clicking the **Recall User Mask** button recalls the **Windows Recall Mask Dialog**. You can recall a saved mask from any drive on the computer. Saved masks have the extension .pcm.

## 5.9.1.6 Save User Mask

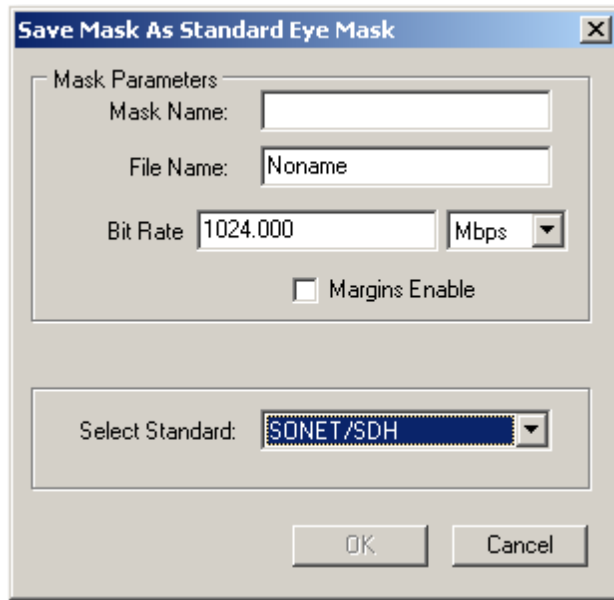


Clicking the **Save User Mask** button recalls the Windows **Save Mask As Dialog**. You can save the mask to any drive on the computer. Saved masks have the extension .pcm.

## 5.9.1.7 Save Mask as Std

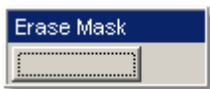


Clicking the **Save Mask as Std** button recalls the Windows **Save Mask As Standard Eye Mask** dialog.

**Windows Save Mask As Standard Eye Mask Dialog**

To save the mask as a standard mask, enter all needed information in the dialog, then click **OK**.

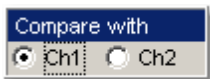
## 5.9.2 Erase Mask



The **Erase Mask** function located on the first page of the **Mask Test** menu allows you to erase the mask that is under test.

To erase the mask click the **Erase Mask** button. You will see the screen without the deleted mask.

## 5.9.3 Compare with



The **Compare with** menu determines which waveform the masks are compared against. You can select from channel 1 or channel 2.

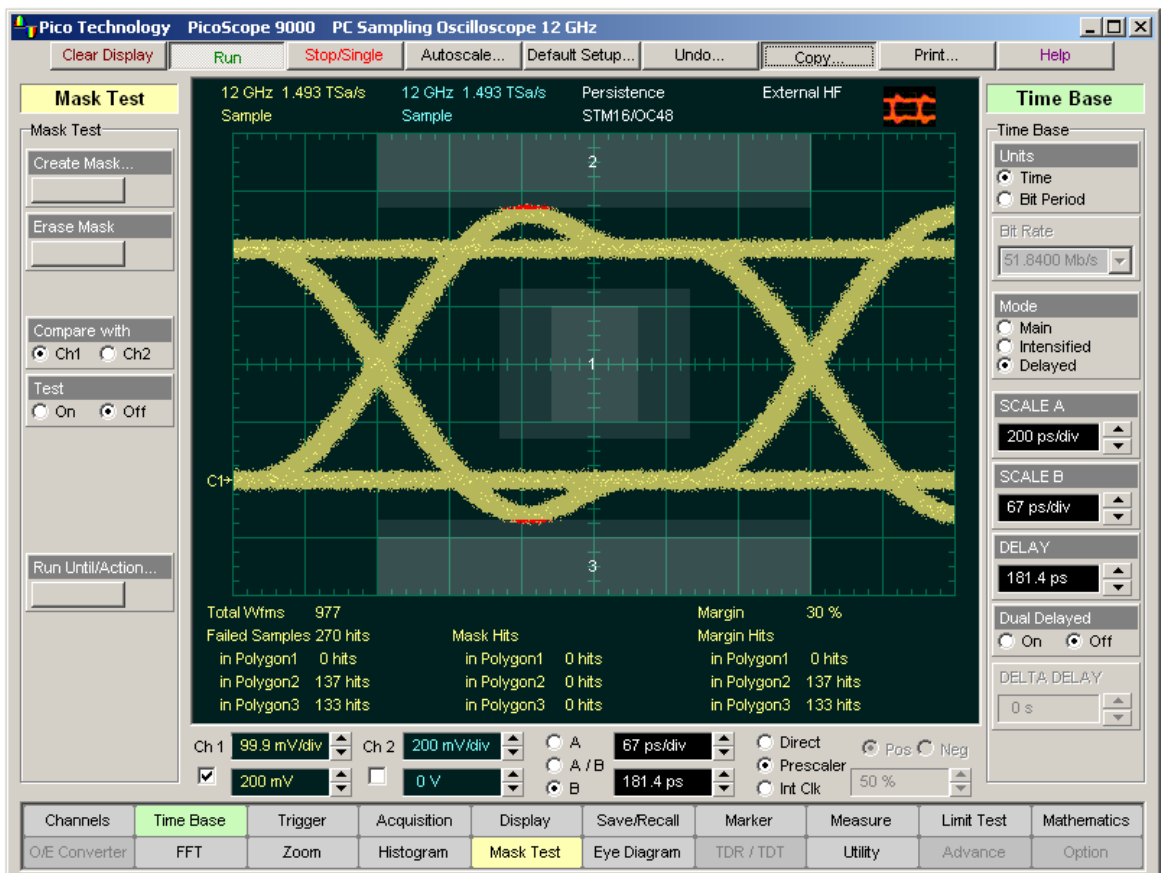
## 5.9.4 Test



After selecting a mask, you can enable mask counting and see the results of the count. To enable mask counting, click the **On** button in the **Test** menu.

If mask testing is on, you can read the results listed in the **Measurement Area** of the **GUI**. These values are displayed on tabs. Notice that any acquired data point that falls inside a mask or a mask margin appears in red.

The **Mask Test** tab displays the relevant test results.



An example of Mask Test

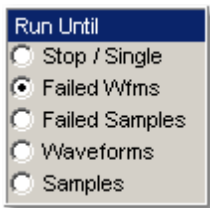
### 5.9.5 Run Until/Action



The **Run Until/Action...** button gives you access to a second-level menu that allows you to specify the following functions:

- When the instrument should stop running the mask test
- What the instrument does with the test data after each failure of the mask test, or after the mask test is complete

#### 5.9.5.1 Run Until



The five choices are:

- Run the test until the **Stop/Single** button is pressed
- Run until a set number of failed waveforms occur
- Run until a set number of failed samples occur
- Run until a set number of waveforms occur
- Run until a set number of samples occur

#### Stop/Single

The **Stop/Single** function runs a mask test until the **Stop/Single** button is pressed. Use the **Stop/Single** mode when you want the mask test to run continually and not stop after a fixed number of failures or acquisitions. For example, you may want the mask test to run overnight and not be limited by a number of failures or acquisitions.

#### Failed Wfms

The **Failed Wfms** function runs the mask test until a set number of failed waveforms are acquired. When the **Failed Wfm** is selected you can set the number of failures from the **# OF FAILED WFM**<sup>[233]</sup> variable.

#### Failed Samples

The **Failed Samples** function runs the mask test until a set number of failed samples are acquired. When the **Failed Samples** is selected you can set the number of failed samples from the **# OF FAILED SMPL**<sup>[233]</sup> variable.

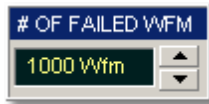
#### Waveforms

The **Waveforms** function runs the mask test until a set number of waveforms are acquired. When the **Waveforms** is selected you can set the number of waveforms from the **# OF WAVEFORMS**<sup>[233]</sup> variable.

#### Samples

The **Samples** function runs the mask test until a set number of samples are acquired. When the **Samples** is selected you can set the number of samples from the **# OF SAMPLES**<sup>[233]</sup> variable.

## 5.9.5.2 # OF FAILED WFM, # OF FAILED SMPL, # OF WAVEFORMS and # OF SAMPLES



When the **Failed Wfms** option on the **Run Until** menu is selected, the **# OF FAILED WFM** variable sets the number of failed waveforms. After this number is reached, acquisition stops.

When the **Failed Samples** option on the **Run Until** menu is selected, the **# OF FAILED SMPL** variable sets the number of failed samples. After this number is reached, acquisition stops.

When the **Waveforms** option on the **Run Until** menu is selected, the **# OF WAVEFORMS** variable sets the number of waveforms. After this number is reached, acquisition stops.

When the **Samples** option of the **Run Until** menu is selected, the **# OF SAMPLES** variable sets the number of samples. After this number is reached, acquisition stops.

## 5.9.5.3 Select Action



One of two actions can be selected.

**Beep**

**Beep** produces an audio tone when any failure occurs.

**Save**

**Save** recalls the Windows **Save Waveform As Dialog** that allows you to select the type of format you want to save the waveform as. You can select one of three types of waveform formats:

- Binary format with .wfm extension
- Text format with .txt extension
- Both formats with .wfm, and .txt extensions

When a mask test is started, all waveforms that have data points sampled in the mask regions and margin regions (failures) are stored into the memory in the directory **Mask Test Files**.



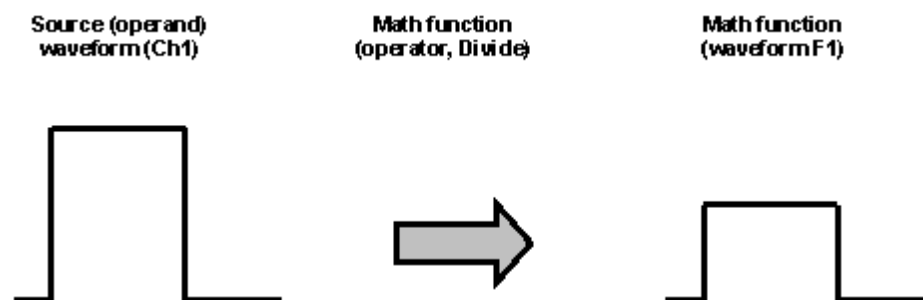
## 5.10 Mathematics Menu

Mathematics

### Waveform analysis

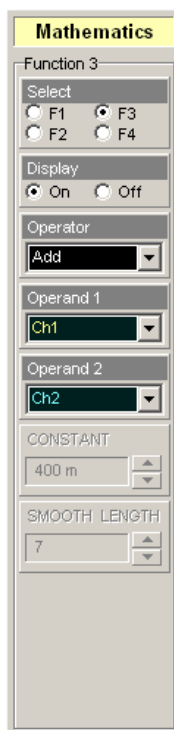
Once you have acquired or taken measurements on waveforms, the oscilloscope can mathematically combine them to create a waveform that supports your data-analysis task. For example, you can define math waveforms mathematically (+, -, x, /). You can also differentiate or integrate a single waveform.

The PicoScope 9000 supports mathematical combination and functional transformation of the waveforms that it acquires. The figure below shows this concept.



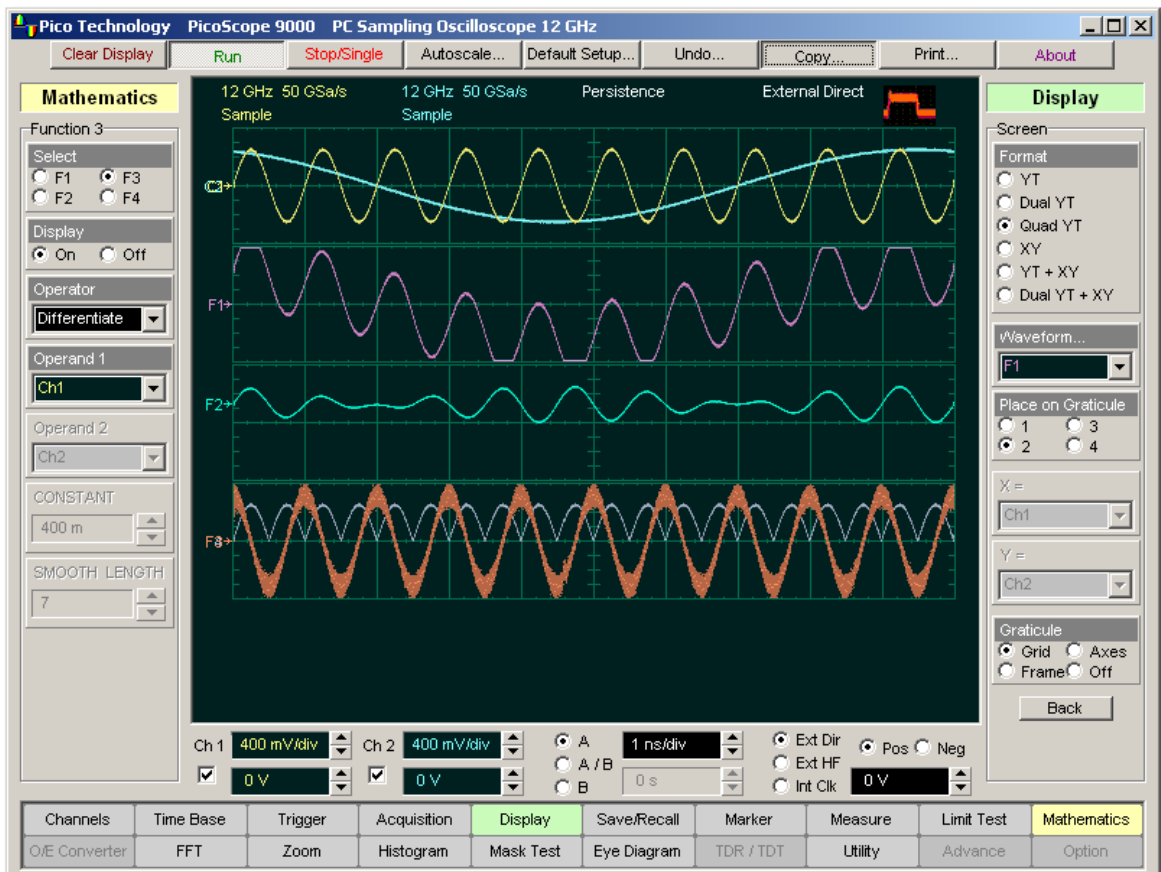
**Functional transformation of an acquired waveform**

Create math waveforms to support the analysis of your channel and reference waveforms. By combining and transforming source waveforms and other data into math waveforms, you can derive the data view that your application requires.



### The Mathematics Menu

The **Mathematics** menu allows you to define up to four functions. Each function consists of a math operator and either one or two operands. A function is calculated on data adjusted by the calibration factor from a selected source(s), and a new waveform (called a function) is generated by the computation. You can place markers on functions, make measurements on functions, or store functions to waveform memories.



**An example of GUI with two channel waveforms and four Math Functions: Ch1: 1-GHz sine-wave; Ch2: 100-MHz sine-wave; F1: Addition (Ch1+Ch2); F2: Multiplication (Ch1xCh2); F3: Differentiate (F1); F4: Absolute (Ch1).**

You can use the waveform math function capabilities to perform math operations on one or two source waveforms. For example, you can subtract channel two from channel one to make a differential measurement. Or, if one channel is measuring current and another channel is measuring voltage, you can use a function to multiply the two channels together and display the instantaneous power as a third waveform. This new waveform can then be measured with markers, or automatic measurements, such as **Peak-Peak** or **AC RMS**.

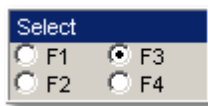
You can define up to four functions and, in most cases, a function may be used as a source for another function, so the PicoScope 9000 can perform more complex math operations. Select the function you want to define: F1 to F4. Select the operator and source(s) you want to use in the function. If the sources you have selected are active, the scope is triggered, and you will see the display update as you configure the function.

When a function is calculated, it can be displayed on the screen, evaluated with the PicoScope 9000 measurement features, stored in memory or to disk, or used as the source for another function. All math operators, such as invert, subtract, multiply, and divide, are post-processing algorithms so functions are calculated only after their sources have been acquired. All waveform math functions operate on waveform data, which is on the display.



Math operators allow vertical and horizontal scaling of the displayed function. See the [Zoom](#) <sup>368</sup> menu for details.

### 5.10.1 Select



The **Select** menu allows you to select function F1 to F4.

Clicking the F1 - F4 options:

- selects one of the functions
- assigns the function soft keys to the selected function

### 5.10.2 Display



Clicking the **On** / **Off** options:

- turns the display for the selection on or off
- changes the label from on to off or vice versa



You can display all four functions on the screen at the same time.

### 5.10.3 Operator



You can select any of the math functions as a math operator to act on the operand or operands. To see the resultant waveform click the **Operator** drop-down list box and then select a function.

A waveform math operator is a math function that requires either one or two sources. The operators that involve two waveform sources are: **Add**, **Subtract**, **Multiply**, and **Divide**.

The operators that involve one waveform source are: **Invert**, **Absolute**, **Exponent (e)**, **Exponent (10)**, **Logarithm (e)**, **Logarithm (10)**, **Differentiate**, **Integrate**, **Inverse FFT**, **Int(erpolation) Linear**, **Int(erpolation) Sin(x)/x**, **Smoothing** and **Trend**.

#### Descriptions of all the math operators

##### Add

Adds, point by point, operand 1 and operand 2 voltage values. You can use **Add** to look at the common-mode component of differential waveforms.

##### Subtract

Subtracts, point by point, operand 2 from operand 1. You can use **Subtract** to make a differential measurement or to compare two waveforms.

##### Multiply

Multiplies, point by point, operand 1 and operand 2. Use **Multiply** to make electrical power measurements.

##### Divide

Divides, point by point, operand 1 by operand 2 voltage values. You can use **Divide** to measure the ratio of any two signals, for example the output voltage divided by the input voltage of an amplifier circuit.

##### Invert

Inverts the voltage values, point by point, of the waveform on operand 1. You can use **Invert** to compare the input and output of an inverting amplifier.

##### Absolute

The **Absolute** value function makes positive all vertical values of the waveform data points on operand 1. The results provide the vertical plot data for a waveform. The horizontal scale is not changed.

##### Exponent (e)

The natural logarithm base **e** is raised to an exponent equal to the vertical value of a waveform data point of operand 1. **Exponent (e)** exponentiates each point of the waveform. The results provide the vertical plot data for a waveform. The horizontal scale is not changed.

**Exponent (10)**

The base 10 is raised to an exponent equal to the vertical value of a waveform data point of operand 1. **Exponent (10)** exponentiates each point of the waveform. The results provide the vertical plot data for a waveform. The horizontal scale is not changed.

**Logarithm (e)**

Takes the natural logarithm (base *e*) of the vertical value of each waveform data points of operand 1. The natural logarithm results provide the vertical plot data for a waveform. The horizontal scale is not changed.

**Logarithm (10)**

The **Logarithm (10)** function converts the absolute vertical values in the waveform record to common logarithms of base 10 of operand 1. The results provide the vertical plot data for a waveform. The horizontal scale is not changed.

**Differentiate**

Calculates the discrete derivative of the vertical value of the waveform data points of operand 1. You can use **Differentiate** to measure the instantaneous slope of a waveform. The horizontal scale is not changed. This may be used to measure, for example, the slew rate of an operational amplifier.

**Integrate**

Calculates the integral of the vertical values of the waveform data points of operand 1. The results provide the vertical plot data for a waveform. The horizontal scale is not changed. This function can be used to calculate the energy of a pulse in volt-seconds or measure the area under a waveform.

**Inverse FFT**

Calculates the time-domain function from its frequency-domain data (spectrum).

**Linear Interpolation**

Draws a line between consecutive waveform data points. It gives an analog look to a digitized waveform. For example, you can see steep edges on waveforms, such as square waves.

**Sin(x)/x Interpolation**

Uses a  $\sin(x)/x$  digital filter that improves the reconstruction of the waveform. The reconstruction is done by adding data points between the acquired data points. This function improves accuracy of measurements. It is important for waveforms that can be bandlimited to  $\frac{1}{4}$  of the current equivalent sample rate.

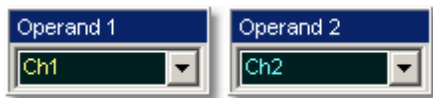
**Smoothing**

This allows reduction of unwanted noise and jitter on the signal with a simple, moving-average filter. N-point smoothing can be done with up to a 51-point filter. The number of points N can be selected by the **SMOOTH LENGTH** <sup>[240]</sup> variable.

**Trend**

Trend represents the evolution of timing parameters as line graphs whose vertical axes are the value of the parameter, and horizontal axes the order in which the values were acquired. The information obtained from applying timing parameters can then be analysed using the trend.

#### 5.10.4 Operand 1 & Operand 2



The instrument performs math functions on the source(s) (operands) you select. The math operator is performed either on operand 1, or on operand 1 and operand 2. The number of operands used depends on the math operator you select. For example, **Add** requires two operands while **Invert** requires only one operand.

The Operand 1 or Operand 2 menus let you select from:

- channels
- functions
- waveform memories
- spectrums
- constants

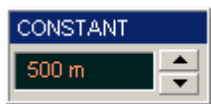
You should be aware of some conditions of the math function menu:

- If the operand waveforms have different record length, the function uses the shortest record length. The instrument finds the nearest point in the longer waveform record that corresponds to the current point in the shorter record. It then performs math functions on those points and skips non-corresponding points in the longer record.
- If two operands have the same timebase scale, the resulting function has the same timebase scale, which results in the proper time scale for the function.
- If two operands have different horizontal scale settings (possibly when using a waveform memory as an operand) the resulting function has the same horizontal scale as operand 1.
- Constant operands have the same time scale as the associated waveform operand.
- You can use each function as an operand for another function. This allows you to construct equations with a large number of operators and operands.



If you select a math operator that uses more than one operand, select the source 2 from the **Operand 2** drop down list box. When the **Constant** option is selected in the **Operand 2** drop-down list box the **CONSTANT**<sup>239</sup> variable becomes active.

#### 5.10.5 Constant



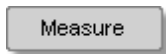
You can use the **CONSTANT** variable to control the value of operand 2 from -100 million to 100 million.

### 5.10.6 SMOOTH LENGTH



The **SMOOTH LENGTH** variable defines the number of points  $N$  in the moving-average filter used for the smoothing operator.  $N$ -point smoothing can be selected from 3 up to 51 points.

## 5.11 Measure Menu



With automatic measurements, you just press a few buttons and the sampling oscilloscope does the calculations for you. Because these measurements use the waveform record points directly, they are more accurate than markers or graticules.

Measurements cover voltage, timing, and **FFT**. Amplitude measurements are made on vertical parameters, typically voltage. They include such parameters as **Maximum**, **Peak-Peak**, **Middle**, and **RMS**. Timing measurements are made on horizontal parameters, typically seconds or hertz. They include such parameters as **Period**, **Width** and **Rise Time**. **FFT** measurements are made on both vertical and horizontal parameters, typically volts and hertz. They include such parameters as **FFT Magnitude** and **FFT Frequency**. Measurements made on two channels can include amplitude and timing parameters.

Each measurement relates to the source that was active when you selected that measurement. It remains displayed until you remove it. If you turn off the source that was selected for a measurement, only the last measured result will be displayed.

The PicoScope 9000 makes measurements after every trigger event, always maintaining continuity between the measurement results and the display. This makes sure that no aberration in the waveform under observation is missed.

You can set measurement markers (thresholds and margins) on the display as defined parameters to track the measurement results. This helps you verify that the oscilloscope is measuring the correct phenomena and to aid in windowing the waveform properly for measurement.



Measure	Measure	Measure	Measure	Measure
<b>Measure</b> Display <input type="radio"/> Off <input type="radio"/> Parameters <input checked="" type="radio"/> Statistics Source Ch1 X Parameters... Y Parameters... Dual-Chan Param... Define Param... View Define Param <input checked="" type="radio"/> On <input type="radio"/> Off Mode <input type="radio"/> Repetitive <input checked="" type="radio"/> Single-shot Single	<b>Measure</b> X Parameters Timing Parameters <input type="checkbox"/> Period <input type="checkbox"/> Frequency <input type="checkbox"/> Pos Width <input type="checkbox"/> Neg Width <input type="checkbox"/> Rise Time <input type="checkbox"/> Fall Time <input type="checkbox"/> Pos Duty Cycle <input type="checkbox"/> Neg Duty Cycle <input type="checkbox"/> Pos Crossing <input type="checkbox"/> Neg Crossing <input type="checkbox"/> Burst Width <input type="checkbox"/> Cycles <input type="checkbox"/> Time@Maximum <input type="checkbox"/> Time@Minimum <input type="checkbox"/> Pos Jitter p-p <input type="checkbox"/> Pos Jitter RMS <input type="checkbox"/> Neg Jitter p-p <input type="checkbox"/> Neg Jitter RMS Back	<b>Measure</b> Y Parameters Amplitude Parameter <input type="checkbox"/> Maximum <input type="checkbox"/> Minimum <input type="checkbox"/> Peak-Peak <input type="checkbox"/> Top <input type="checkbox"/> Base <input type="checkbox"/> Amplitude <input type="checkbox"/> Middle <input type="checkbox"/> Mean <input type="checkbox"/> dc RMS <input type="checkbox"/> ac RMS <input type="checkbox"/> Area <input type="checkbox"/> Cycle Mean <input type="checkbox"/> Cycle dc RMS <input type="checkbox"/> Cycle ac RMS <input type="checkbox"/> Cycle Area <input type="checkbox"/> Pos Overshoot <input type="checkbox"/> Neg Overshoot Back	<b>Measure</b> Dual-Chan Parameter: Source 2 Ch2 Timing Parameters <input checked="" type="checkbox"/> Delay 1R-1R <input type="checkbox"/> Delay 1R-1F <input type="checkbox"/> Delay 1F-1R <input type="checkbox"/> Delay 1F-1F <input type="checkbox"/> Delay 1R-nR <input type="checkbox"/> Delay 1R-nF <input type="checkbox"/> Delay 1F-nR <input type="checkbox"/> Delay 1F-nF <input type="checkbox"/> Phase Deg <input type="checkbox"/> Phase Rad <input type="checkbox"/> Phase % Amplitude Parameter <input checked="" type="checkbox"/> Gain <input type="checkbox"/> Gain dB Back	<b>Measure</b> FFT Parameters FFT Freq Parameter <input type="checkbox"/> FFT Freq <input type="checkbox"/> FFT dFreq FFT Magnitude Para <input type="checkbox"/> FFT Magnit <input type="checkbox"/> FFT dMagnit <input type="checkbox"/> THD PEAK LEFT 1 PEAK RIGHT 3 Back
<b>Measure</b> Define Param... Statistics... Method <input type="radio"/> Histogram <input type="radio"/> Min / Max <input type="radio"/> User Defined TOP 400 mV BASE -400 mV Thresholds <input checked="" type="radio"/> 10%-50%-90% <input type="radio"/> 20%-50%-80% <input type="radio"/> User Defined Defined Thresholds Margins... Back	<b>Measure</b> Define Thresholds Units <input checked="" type="radio"/> Percent <input type="radio"/> Vertical Unit <input type="radio"/> Division UPPER THRESHOLD 90 % MIDDLE THRESHOLD 50 % LOWER THRESHOLD 10 % Back	<b>Measure</b> Statistics Mode <input type="radio"/> Normal <input checked="" type="radio"/> Window <input type="radio"/> Exponential #WAVEFORMS 8 Back	<b>Measure</b> Margins Mode <input type="radio"/> Waveform <input checked="" type="radio"/> Marker LEFT MARGIN 0 s Left Threshold <input type="radio"/> Upper <input checked="" type="radio"/> Middle <input type="radio"/> Lower RIGHT MARGIN 50 ns Right Threshold <input type="radio"/> Upper <input checked="" type="radio"/> Middle <input type="radio"/> Lower Back	<b>Measure</b> FFT Define Param. Method <input checked="" type="radio"/> Harmonic <input type="radio"/> Peak LEFT MARGIN 122.07 kHz RIGHT MARGIN 488.28 MHz PEAK LEVEL -20 dB PEAK LEFT 1 PEAK RIGHT 3 Back

## Measurement Results

The measurement readouts appear in the **Measurement Area** of the screen. These values are displayed on tabs. The readouts are continuously updated as the oscilloscope acquires new data or as you change settings. You can display as many as ten measurements of parameters, continuously updated, and as many as four statistics measurements at any one time.

Frequency (Ch1)	100.1 MHz	Period (Ch2)	1.997 ns
Rise Time (Ch1)	2.907 ns	Pos Width (Ch2)	996.5 ps
Amplitude (Ch1)	988 mV	Cycles (Ch2)	24
Peak-Peak (Ch1)	1.003 V	Amplitude (Ch2)	999.3 mV
Top (Ch1)	493.5 mV	Base (Ch2)	5.718 mV

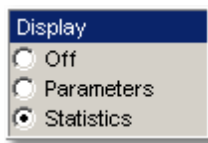
**Measure tab with the results of ten automated parameter measurements**

	Current	Total Wfms	Minimum	Maximum	Mean	Std Deviation
Frequency (Ch1)	100.1 MHz	58578	100.1 MHz	100.2 MHz	100.1 MHz	9.178 kHz
Peak-Peak (Ch1)	1.002 V	58578	999.9 mV	1.006 V	1.003 V	834.5 $\mu$ V
Amplitude (Ch2)	998.7 mV	4322	998.1 mV	999.9 mV	999 mV	245.3 $\mu$ V
Pos Width (Ch2)	996.4 ps	4074	996.2 ps	996.6 ps	996.4 ps	51.85 fs

**Measure tab with the results of four statistics measurements**

When the instrument cannot make the requested measurement, an error message **"Undefined"** is displayed instead of measurement results. Usually, this is because there are not enough sample points, there is no edge on the display, or the specified channel is turned off.

## 5.11.1 Display



Two types of measurements are used in the PicoScope 9000:

- Measurements of parameters (**Parameters**)
- Statistics measurements (**Statistics**)

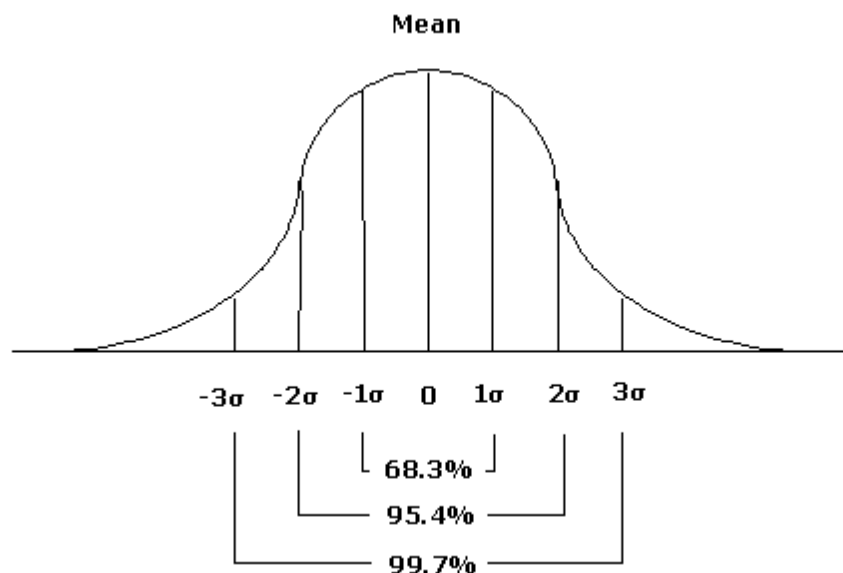
Click on the option for the type of measurement that you require. **Off** removes the measurement results and markers from the display.

**Statistics**

The **Statistics** function calculates the minimum, maximum, mean and standard deviation of the automatic measurement results. The current value and amount of measurements are also displayed.

When you turn **Statistics** on, the minimum, maximum, mean and standard deviation values start to accumulate at the same time. All results are continuously updated; the mean, standard deviation results are also calculated and continuously updated. Minimum and maximum are the absolute extremes of the automatic measurements. Mean and standard deviation calculate the mean and standard deviation of the automatic measurement results. Mean is the statistical average of all results for a particular measurement. Standard deviation measures the dispersion of those measurement results.

The figure below shows the mean and standard deviation more graphically. Standard deviation is represented by the Greek letter sigma ( $\sigma$ ). For a Gaussian distribution, two sigma ( $\pm 1$  from the mean) is where 68.3 percent of the data points reside. Four sigma ( $\pm 2$  from the mean) is where 95.4 percent of the data points reside. Six sigma ( $\pm 3$  from the mean) is where 99.7 percent of the data points reside.



**Standard deviation of a Gaussian distribution**

The mean is calculated as follows:

$$\sigma = \frac{\sum_{i=1}^n (X_i - \bar{X})^2}{N-1},$$

where:  $\mu$  - mean,  $N$  – the number of taken measurements,  $X_i$  - measurement  $i$ -th result.

The standard deviation is calculated as follows:

$$\mu = \frac{\sum_{i=1}^n X_i}{N},$$

where:  $\sigma$  - mean,  $N$  – the number of taken measurements,  $X_i$  - measurement  $i$ -th result,  $\bar{X}$  - the mean.

Click the **Define Param...** button and open the **Statistics...** menu for some statistics options.

### 5.11.2 Source



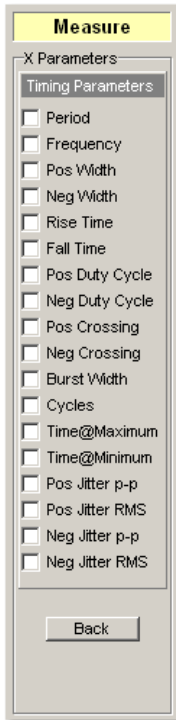
The **Source** drop-down list box selects the source you are measuring.

You can select as the source:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4
- spectrums 1 and 2

The measurement readouts of each parameter will have the same color as the selected source.

## 5.11.3 X Parameters...



Clicking the **X Parameters...** button opens the list of timing parameters. The list includes eighteen timing parameters used for pulse measurements. Once the **Top** and **Base** calculation area is completed, most of the amplitude measurements can be made.



You can continuously update as many as ten parameter measurements, and as many as four statistics measurements at any one time.

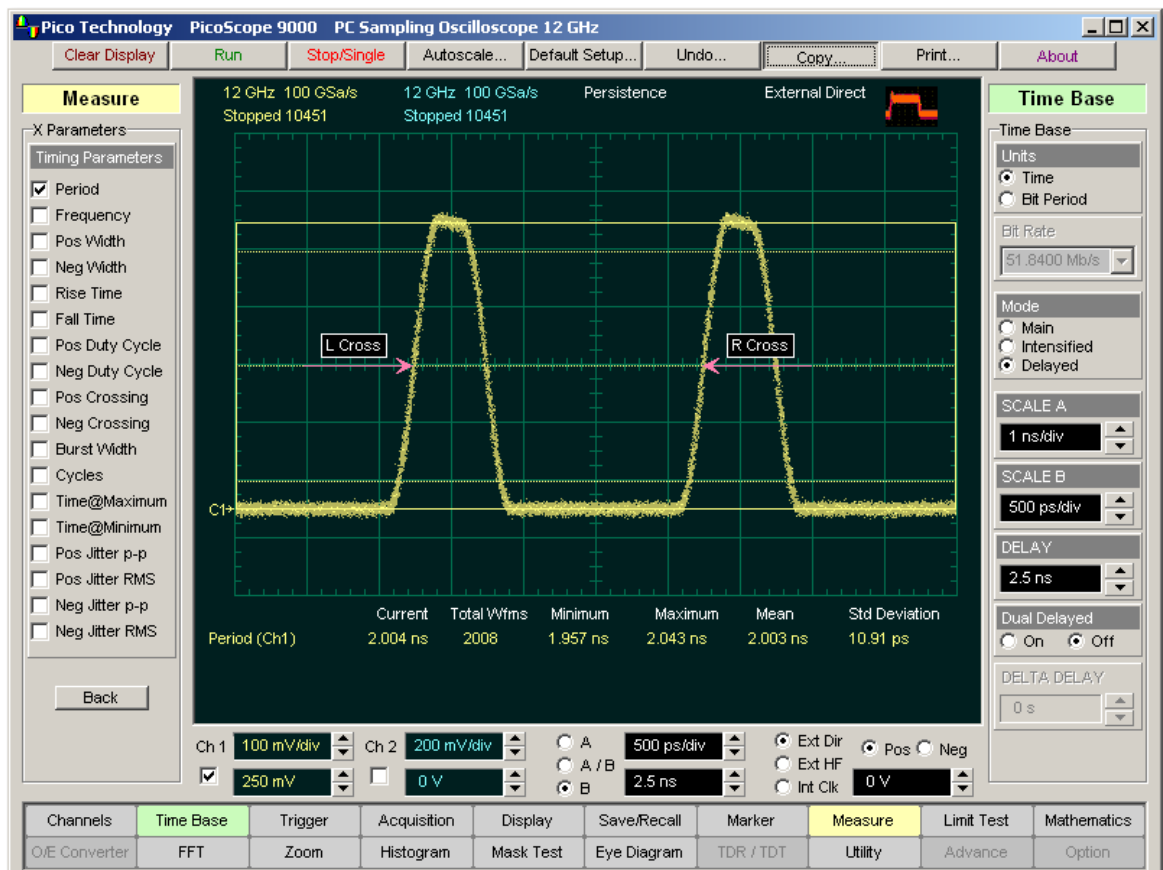


The pulse measurement algorithms for **X Parameters** will only work when a single-valued signal is used, and no NRZ eye diagram or RZ eye diagram is present on the screen. Measurements made on both NRZ and RZ eye diagrams will fail.

## 5.11.3.1 Period



**Period** is a measure of the time between the mid-threshold crossings of two consecutive edges of the same polarity. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



### Period definition

Because the detected edges can be either rising or falling, the period is determined as follows:

$$\text{Period} = T_{\text{cross}3} - T_{\text{cross}1}$$

where  $T_{\text{cross}3}$  and  $T_{\text{cross}1}$  are the times of the first two consecutive crossings on the same slope at the mid-reference level.

If more than one period can be found within the margins, the scope measures the average period.



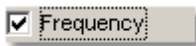
The **Margins...** <sup>307</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of period value will be performed only inside these margins.



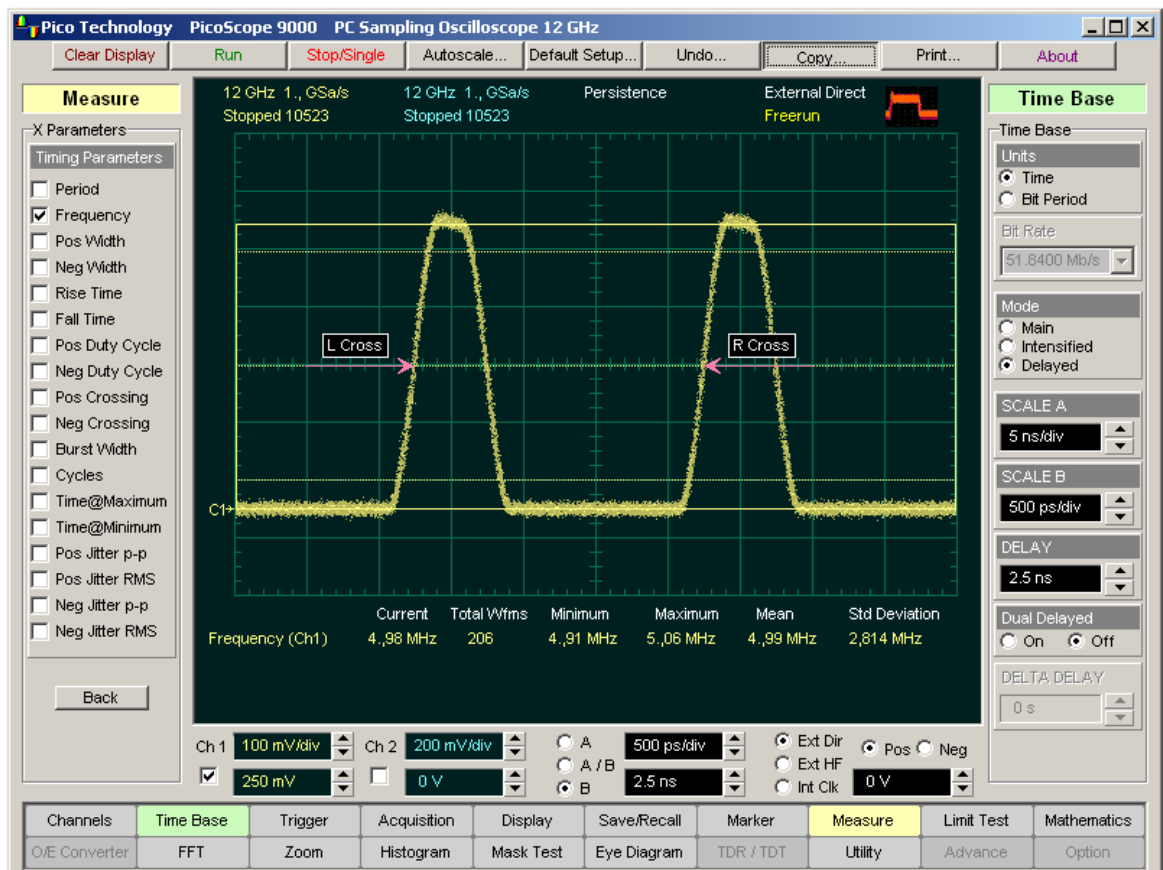
Period value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.



## 5.11.3.2 Frequency



**Frequency** is defined as the inverse of the period (1/period). Period is a measure of the time between the mid-threshold crossings of two consecutive edges of the same polarity. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



## Frequency definition

Because the detected edges can be either rising or falling, the frequency is determined as follows:

$$\text{Frequency} = 1/\text{Period} = 1/(\text{Tcross3} - \text{Tcross1})$$

where  $\text{Tcross3}$  and  $\text{Tcross1}$  are the times of the first two consecutive crossings on the same slope at the mid-reference level.

If more than one period can be found within the margins, the scope measures the average frequency value.

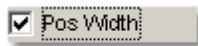


The **Margins...** <sup>307</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of frequency value will be performed only inside these margins.

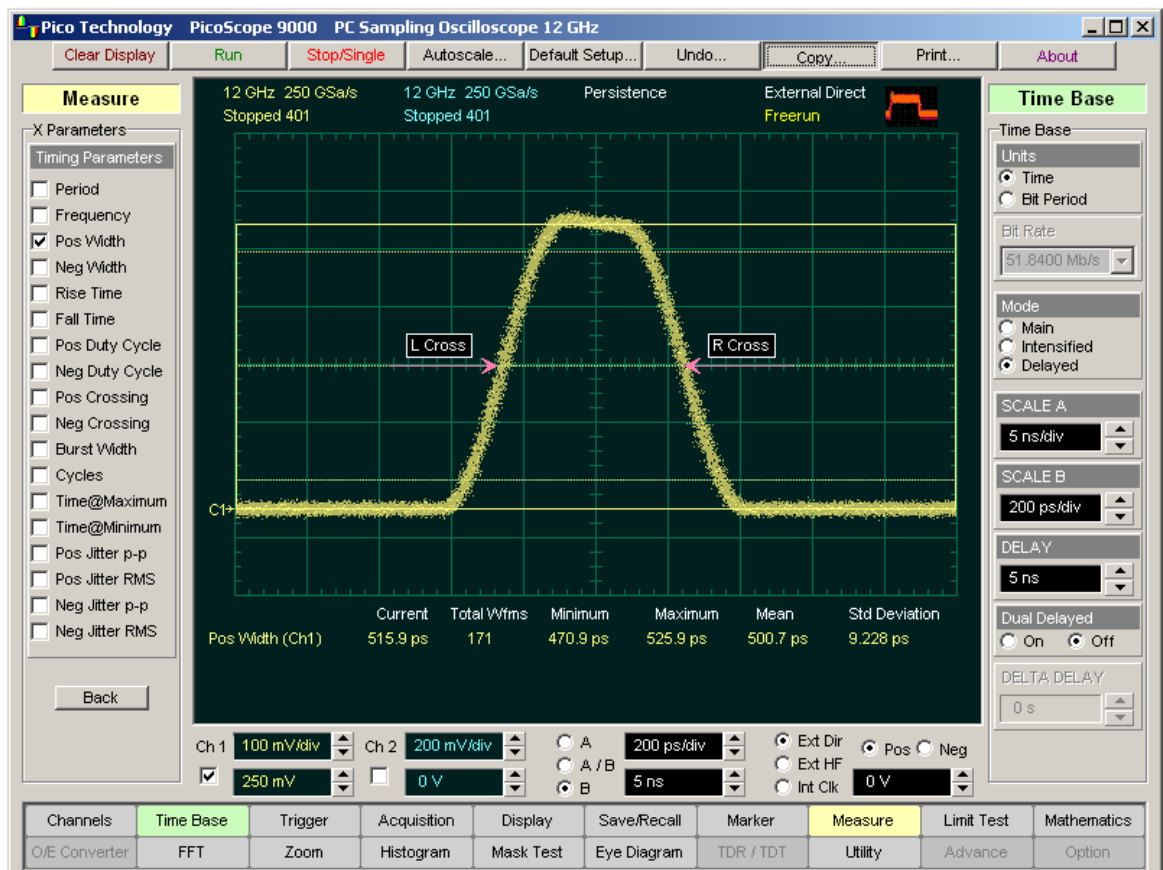


Frequency value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.3 Positive Width



**Positive Width** is a measure of the time from the mid-threshold of the first rising edge to the mid-threshold of the next falling edge. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).

**Positive Width definition**

Positive pulse width is determined as follows:

$$\text{Positive Width} = T_{\text{cross2}} - T_{\text{cross1}}$$

where  $T_{\text{cross1}}$  and  $T_{\text{cross2}}$  are the two consecutive horizontal crossings on the first positive pulse.

If more than one positive pulse width can be found within the margins, the scope measures the average value of the positive pulse width.



The **Margins...** <sup>307</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of positive pulse width value will be performed only inside these margins.

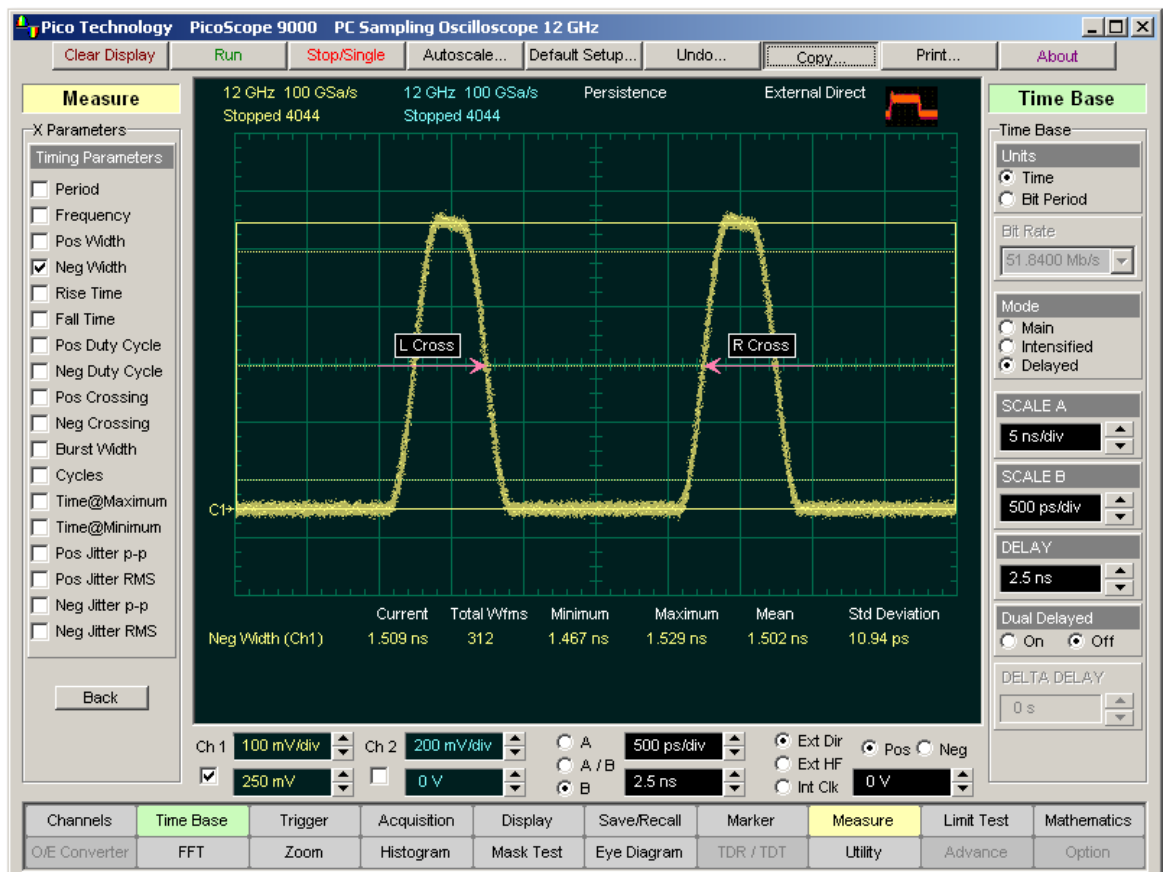


Positive pulse width value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.4 Negative Width



**Neg Width (Negative Pulse Width)** is a measure of the time from the mid-threshold of the first falling edge to the mid-threshold of the next rising edge. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



### Negative Width definition

Negative pulse width is determined as follows:

$$\text{Negative Width} = T_{\text{cross2}} - T_{\text{cross1}}$$

where  $T_{\text{cross1}}$  and  $T_{\text{cross2}}$  are the two consecutive horizontal crossings on the first negative pulse.

If more than one negative pulse width can be found within the margins, the scope measures the average value of the negative pulse width.



The **Margins...** <sup>307</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of negative pulse width value will be performed only inside these margins.



Negative pulse width value is affected by the [Define Param...](#)<sup>300</sup> menu. In the [Defined Thresholds](#)<sup>305</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.5 Rise Time



**Rise Time** is a measure of the time at the upper threshold minus the time at the lower threshold on the edge you are measuring on. It is a measure of the transition time of the data on the positive (rising) edge of a waveform. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



### Rise Time definition

Rise Time is determined as follows:

$$\text{Rise Time} = T_{\text{crossUT}} - T_{\text{crossLT}}$$

where  $T_{\text{crossUT}}$  is the time of crossing with the upper threshold, and  $T_{\text{crossLT}}$  is the time of crossing with the lower threshold.

If more than one rise time can be found within the margins, the scope measures the average value of rise time.

The rise time will not be measured until the rising edge completes the transition through all three levels.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of rise time value will be performed only inside these margins.



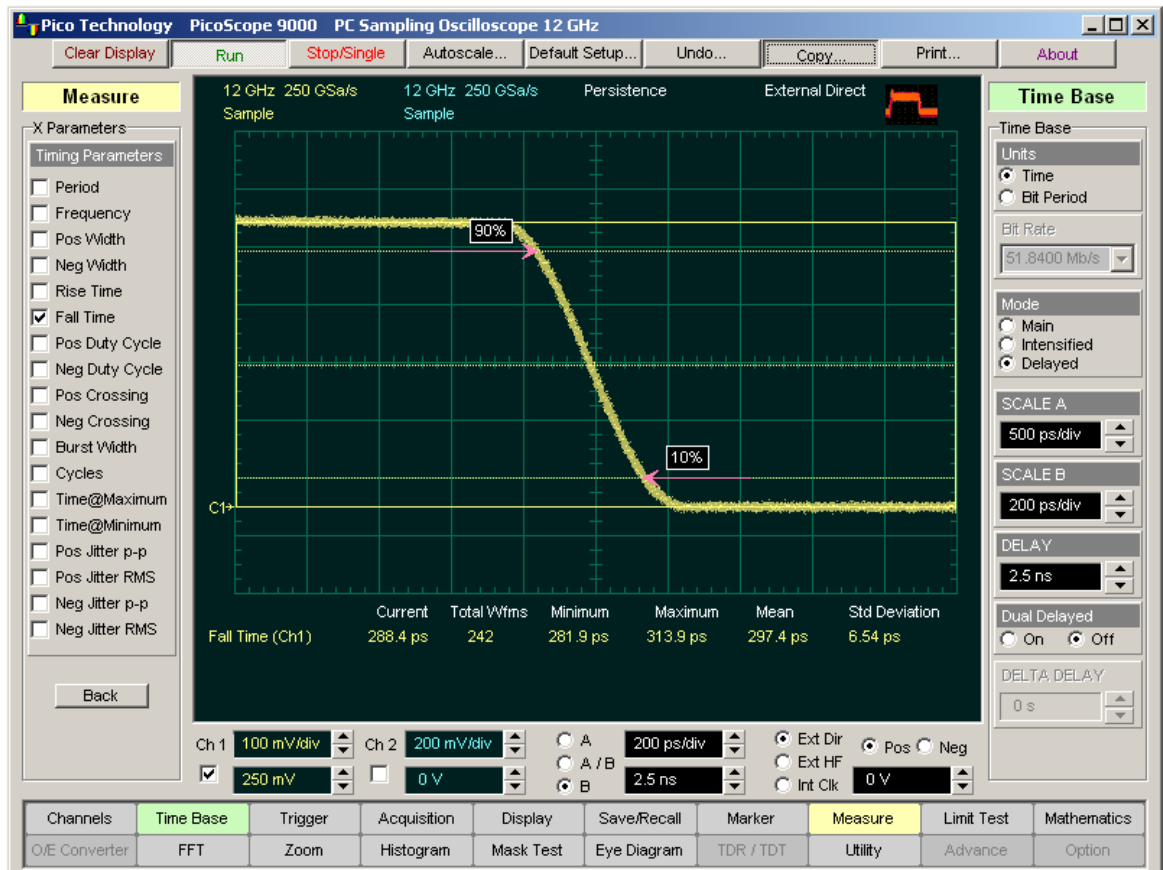
Rise time value is affected by the **Define Param...** <sup>[300]</sup> menu. In the **Defined Thresholds** <sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.



## 5.11.3.6 Fall Time



**Fall time** is a measure of the time at the lower threshold minus the time at the upper threshold on the edge you are measuring on. It is a measure of the transition time of the data on the negative (falling) edge of a waveform. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



## Fall Time definition

Fall Time is determined as follows:

$$\text{Fall Time} = T_{\text{crossLT}} - T_{\text{crossUT}}$$

where  $T_{\text{crossUT}}$  is the time of crossing with the upper threshold, and  $T_{\text{crossLT}}$  is the time of crossing with the lower threshold.

If more than one fall time can be found within the margins, the scope measures the average value of rise time.

The fall time will not be measured until the falling edge completes the transition through all three levels.

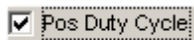


The **Margins...** <sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of fall time value will be performed only inside these margins.

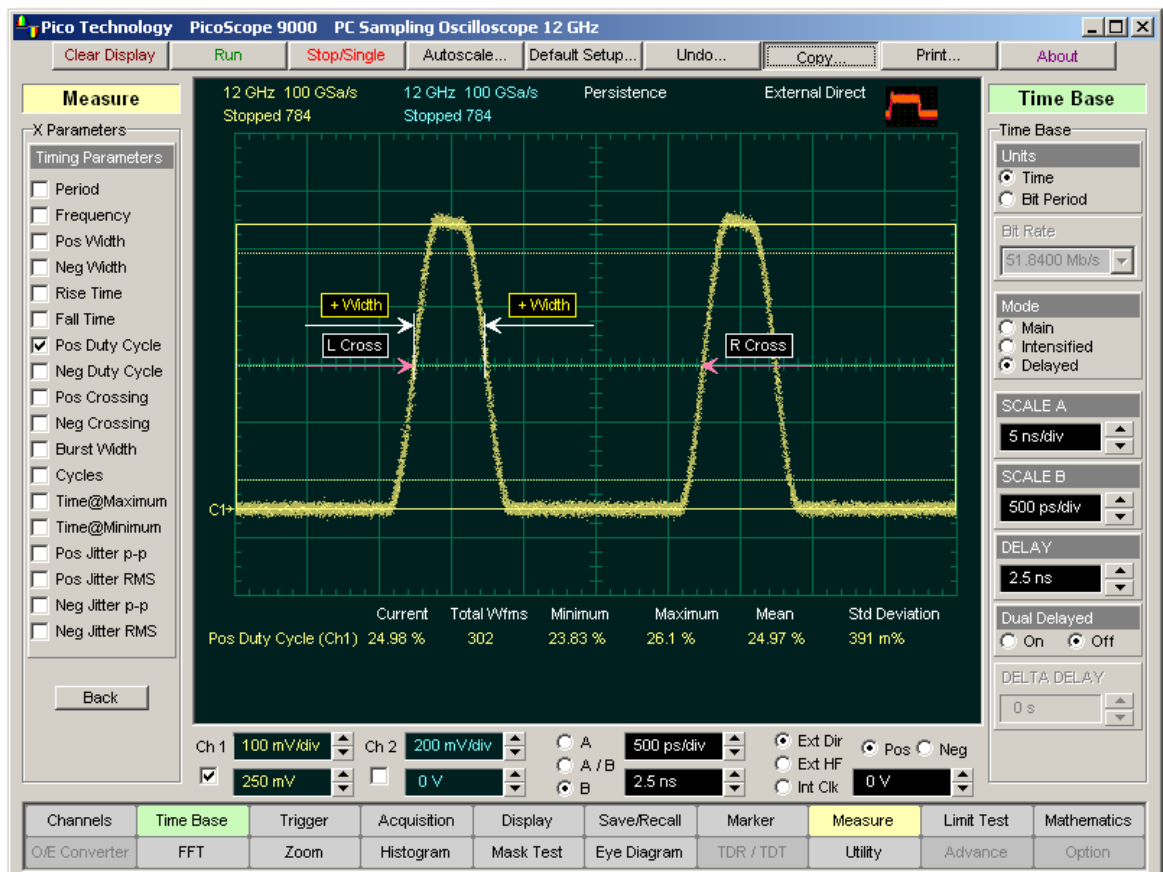


Fall time value is affected by the **Define Param...** <sup>[300]</sup> menu. In the **Defined Thresholds** <sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.7 Positive Duty Cycle



**Positive Duty Cycle** is defined as the ratio of the positive pulse width to the period. This is the percentage of the period that the positive pulse width occupies. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



## Positive Duty Cycle definition

**Positive Duty Cycle** is determined as follows:

$$\text{Positive Duty Cycle} = (\text{Positive Width} / \text{Period}) * (100\%)$$

If more than one positive duty cycle can be found within the margins, the scope measures the average value of all positive duty cycles.

The positive duty cycle will not be measured until the period and positive pulse width complete the transition through all three levels.

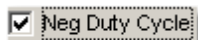


The **Margins...** menu sets the margin markers to see where scope is making the automatic measurement. All calculations of positive duty cycle value will be performed only inside these margins.

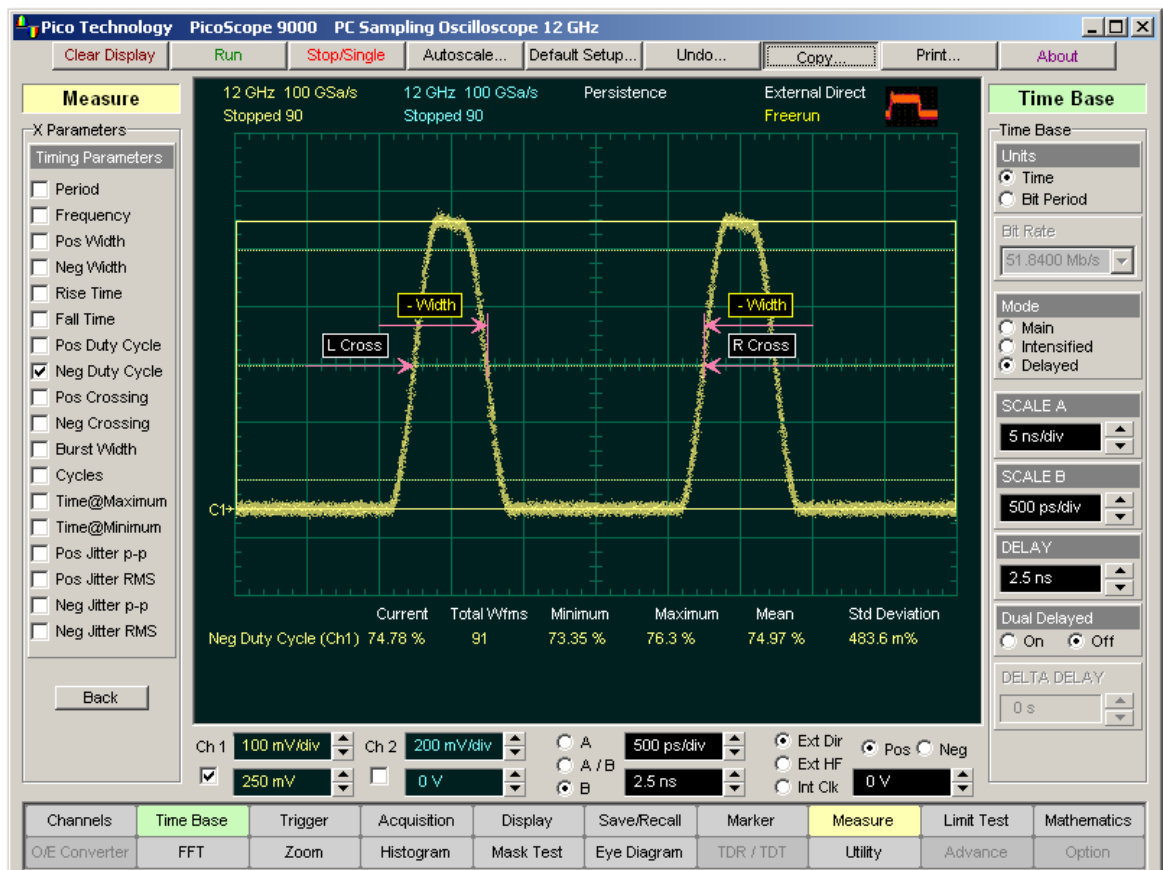


Positive duty cycle value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.8 Negative Duty Cycle



**Negative Duty Cycle** is defined as the ratio of the negative pulse width to the period. This is the percentage of the period that the negative pulse width occupies. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).



### Negative Duty Cycle definition

**Negative Duty Cycle** is determined as follows:

$$\text{Negative Duty Cycle} = (\text{Negative Width} / \text{Period}) * (100\%)$$

If more than one negative duty cycle can be found within the margins, the scope measures the average value of all negative duty cycles.

The negative duty cycle will not be measured until the period and negative pulse width completes the transition through all three levels.

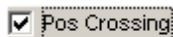


The **Margins...** <sup>307</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of negative duty cycle value will be performed only inside these margins.

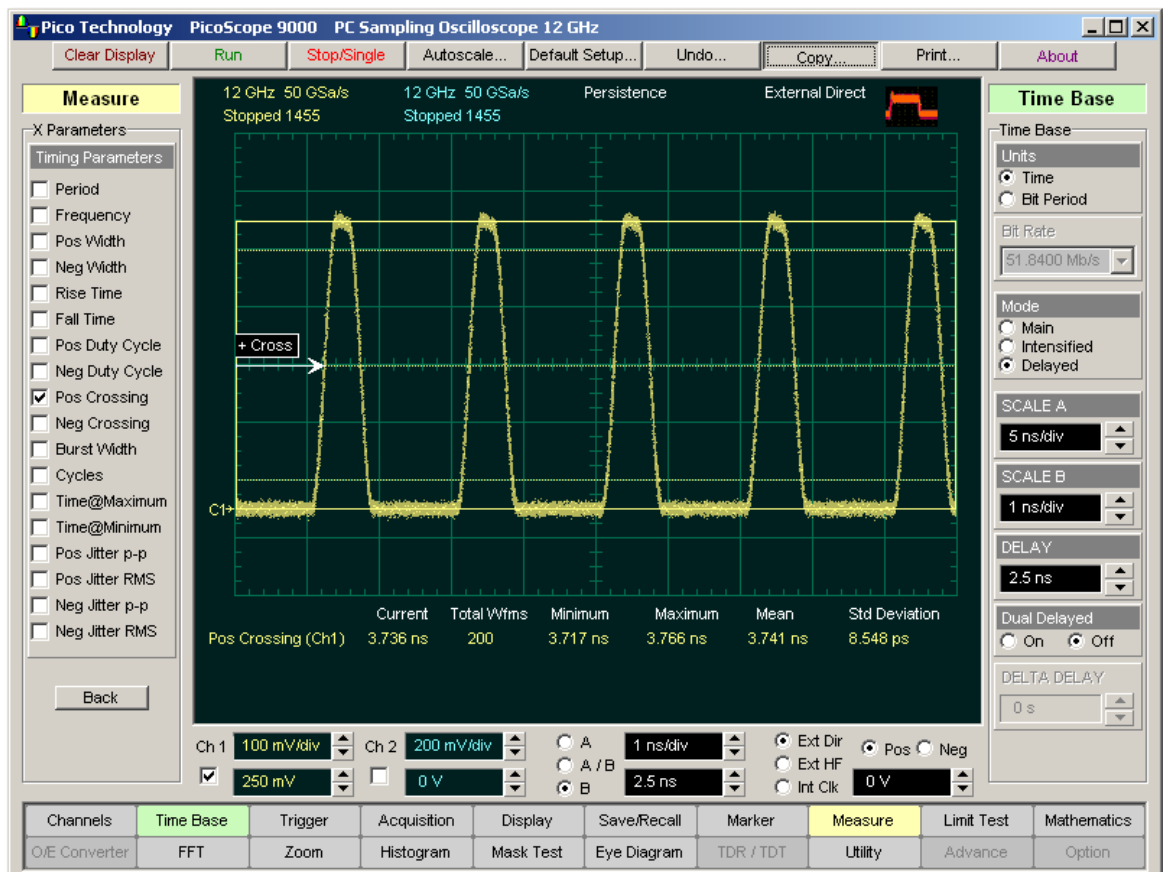


Negative duty cycle value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.9 Positive Crossing



**Positive Crossing** is defined as the time of the first positive crossing of the data sampled at the mid-reference level in the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).

**Positive Crossing definition**

Positive crossing is determined as follows:

$$\text{Positive Crossing} = T_{\text{cross}}$$

where  $T_{\text{cross}}$  is the horizontal coordinate of the first positive crossing.

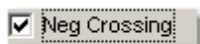


The **Margins...**<sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of positive crossing value will be performed only inside these margins.

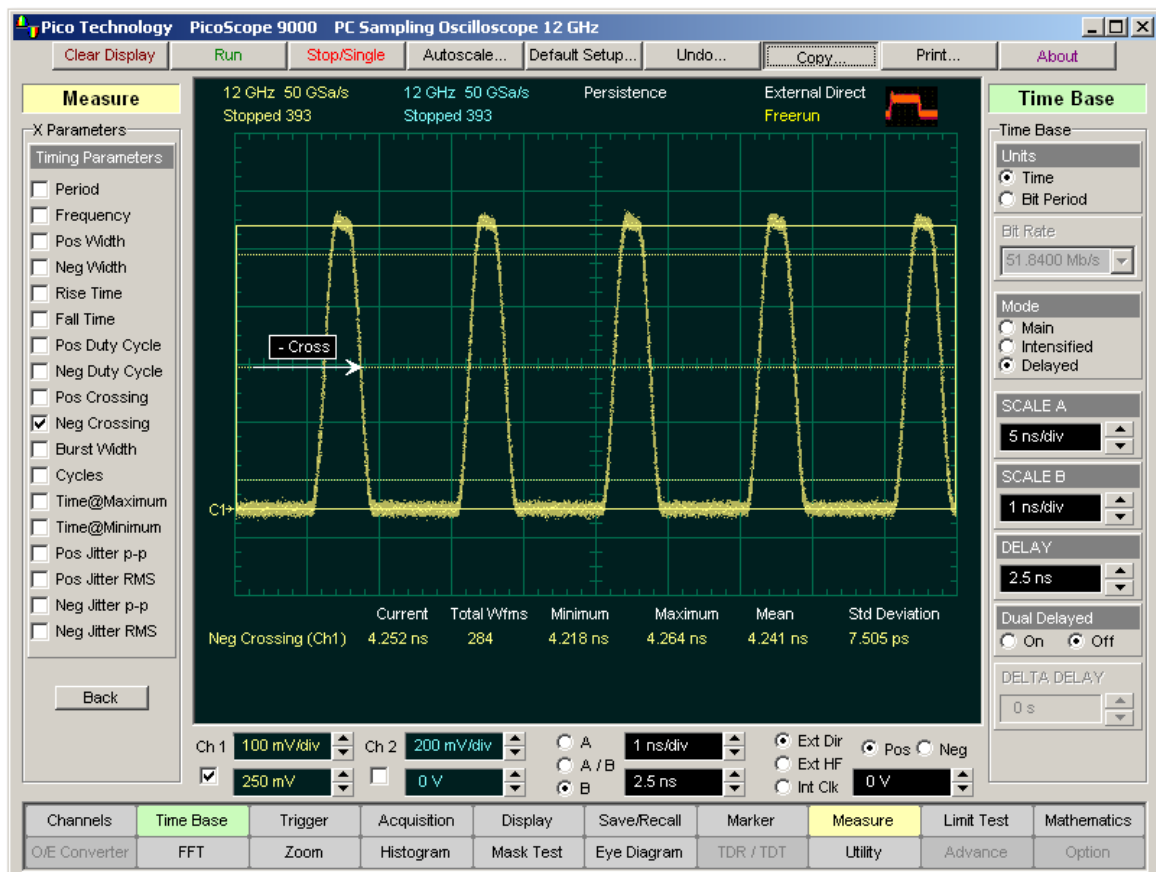


Positive crossing value is affected by the **Define Param...**<sup>[300]</sup> menu. In the **Defined Thresholds**<sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.10 Negative Crossing



**Negative Crossing** is defined as the time of the first negative crossing of the data sampled at the mid-reference level in the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the display (right margin).



### Negative Crossing definition

Negative crossing is determined as follows:

$$\text{Negative Crossing} = T_{\text{cross}}$$

where  $T_{\text{cross}}$  is the horizontal coordinate of the first negative crossing.



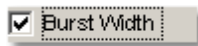
The **Margins...** <sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of negative crossing value will be performed only inside these margins.



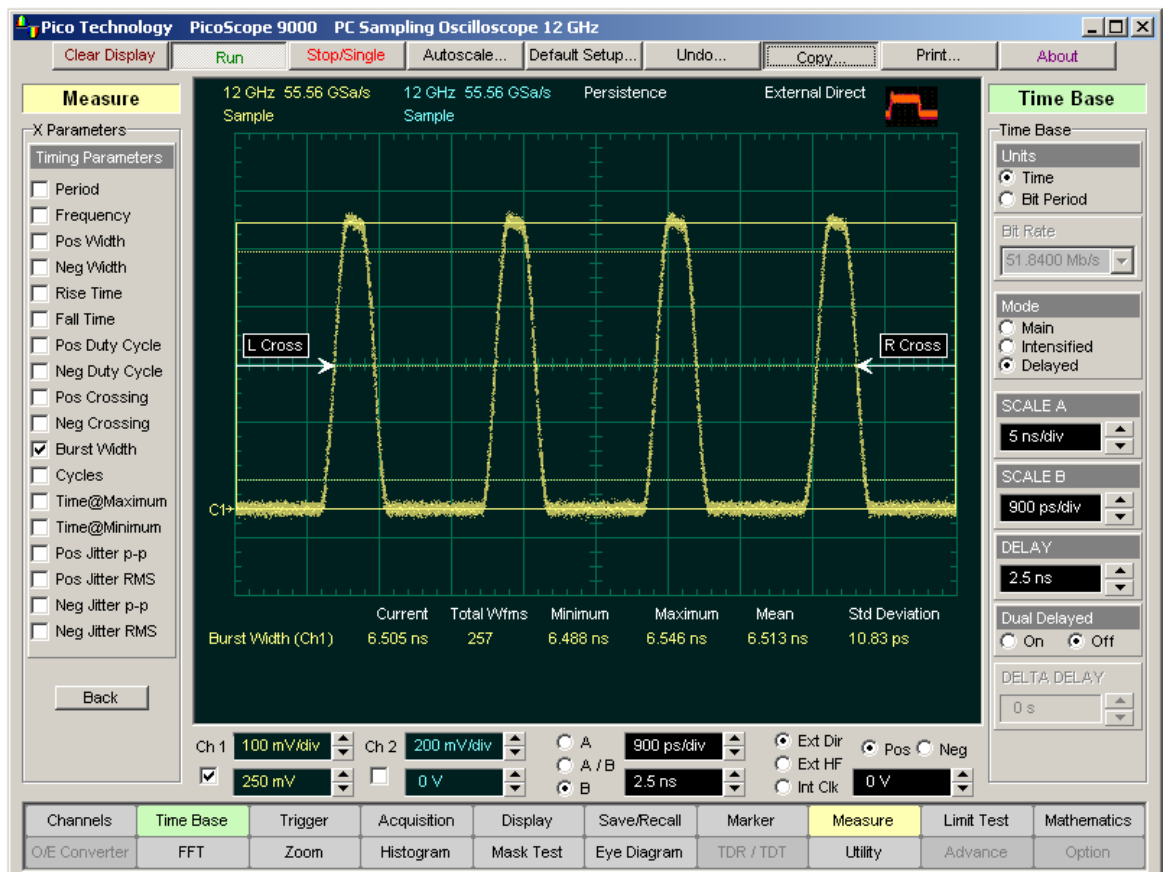
Negative crossing value is affected by the **Define Param...** <sup>[300]</sup> menu. In the **Defined Thresholds** <sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.



## 5.11.3.11 Burst Width



**Burst Width** is defined as the time between the first and last crossings, either positive or negative, of the waveform at the mid-reference level in the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the display (right margin).



Burst Width definition

Burst width is determined as follows:

$$\text{Positive Width} = T_{\text{crossL}} - T_{\text{crossF}}$$

where  $T_{\text{crossL}}$  is the horizontal coordinate of the last crossing, and  $T_{\text{crossF}}$  is the horizontal coordinate of the first crossing.



The **Margins...**<sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of burst width value will be performed only inside these margins.

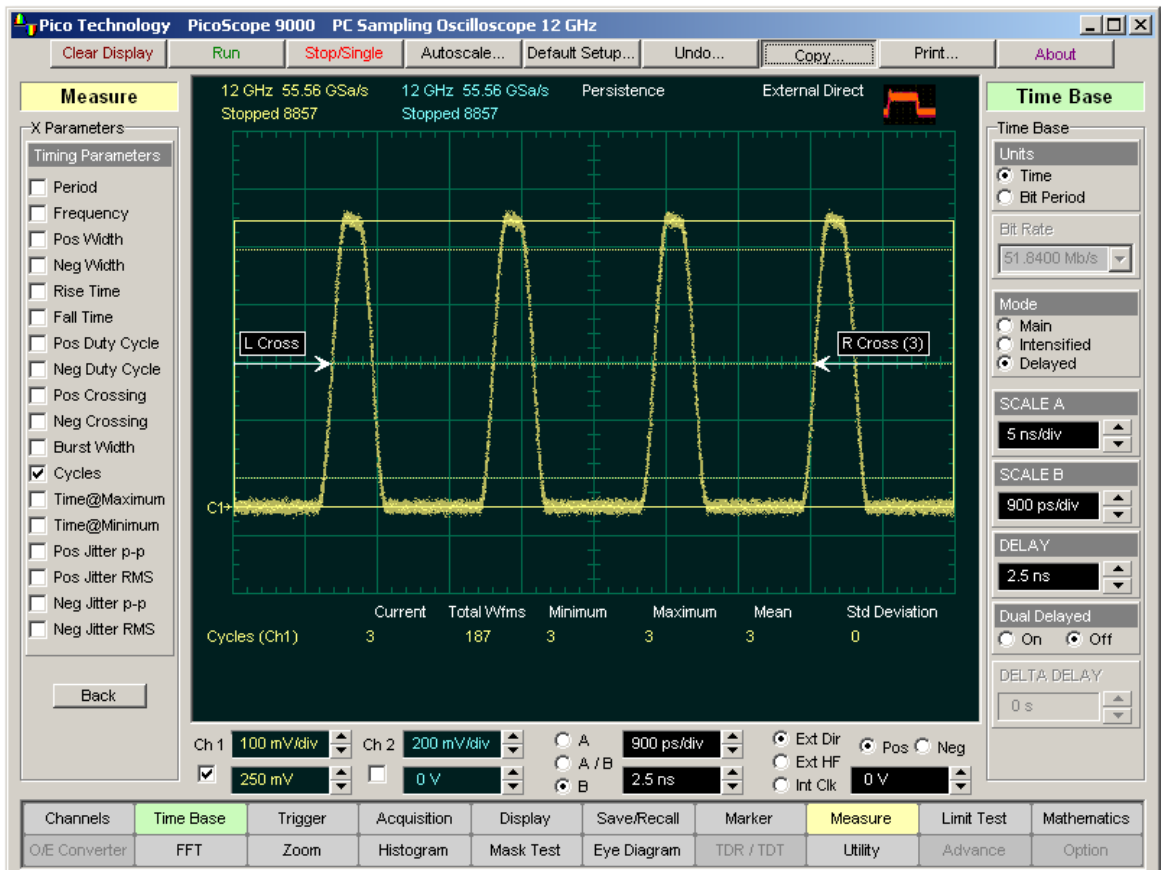


Burst width value is affected by the **Define Param...**<sup>[307]</sup> menu. In the **Defined Thresholds**<sup>[308]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.12 Cycle



**Cycles** is defined as the number of cycles of a periodic waveform between the mid-threshold crossings of two consecutive first and last edges of the same polarity. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin). The detected edges can be either rising or falling.



## Cycle definition

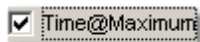


The **Margins...** <sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of cycles value will be performed only inside these margins.



Cycles value is affected by the **Define Param...** <sup>[300]</sup> menu. In the **Defined Thresholds** <sup>[305]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.3.13 Time@Maximum



**Time@Maximum** is a measure of the time of the first occurrence of the first data sample with the maximum signal level. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the display (right margin).

**Time@Maximum** is position-independent. Therefore, the instrument uses the entire waveform on the display graticule to determine the maximum signal level.

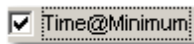


## Time@Maximum definition



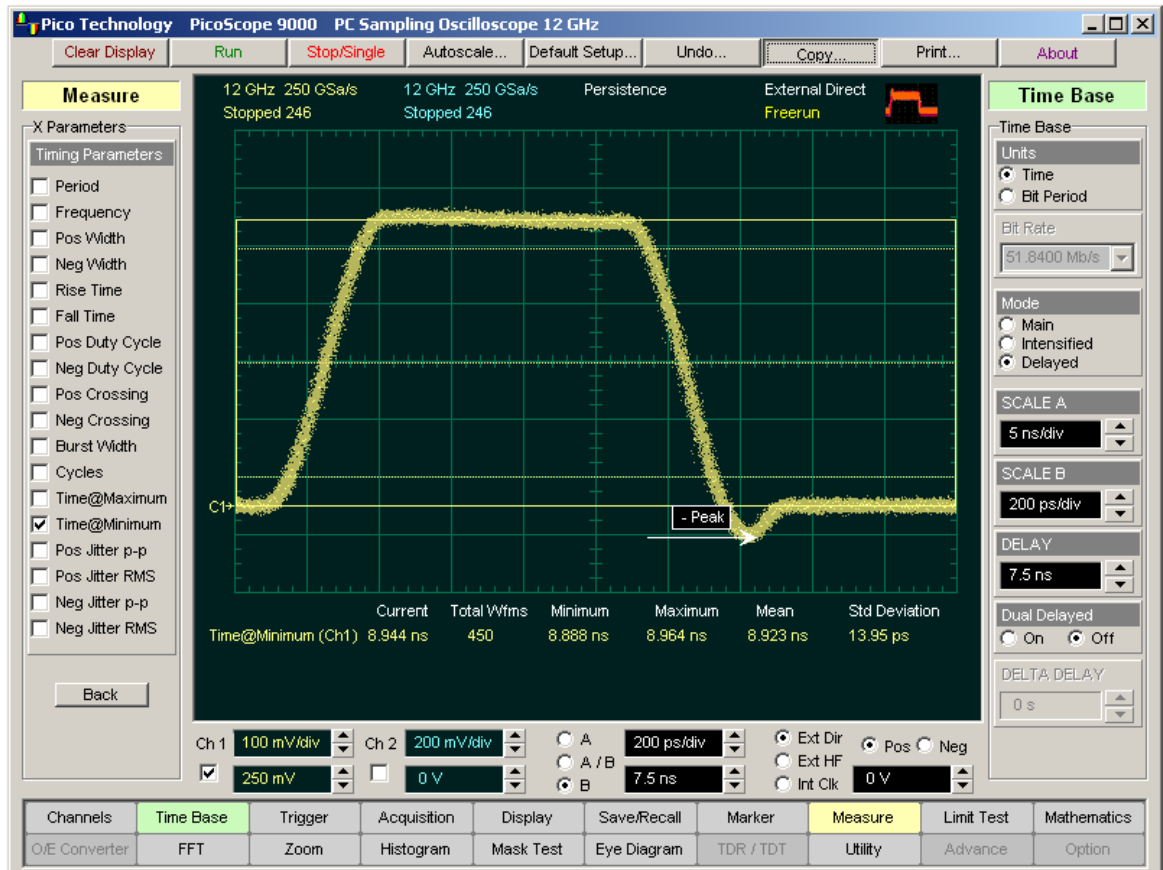
The **Margins...** <sup>307</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of Time@Maximum value will be performed only inside these margins.

## 5.11.3.14 Time@Minimum



**Time@Minimum** is a measure of the time of the first occurrence of the first data sample with the minimum signal level. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the display (right margin).

**Time@Minimum** is position-independent. Therefore, the instrument uses the entire waveform on the display graticule to determine the minimum signal level.



## Time@Minimum definition



The **Margins...** <sup>307</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Time@Minimum** value will be performed only inside these margins.

## 5.11.3.15 Positive Jitter p-p



**Positive Jitter p-p** is a measure of peak-peak time variations of the rising edges of a pulse waveform at the middle threshold.



### Positive Jitter p-p definition

**Positive Jitter p-p** is determined as follows:

*Positive Jitter p-p = Full width of the Horizontal Histogram in the Middle Threshold*



The **Margins...** <sup>307</sup> menu sets the margin markers to see where the scope is making the automatic measurement. All calculations of **Positive jitter p-p** will be performed only inside these margins.

## 5.11.3.16 Positive Jitter RMS



**Positive Jitter RMS** is a measure of rms time variations of the rising edges of a pulse waveform at the middle threshold.



### Positive Jitter RMS definition

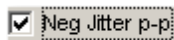
**Positive Jitter RMS** is determined as follows:

*Positive Jitter RMS = 1 $\sigma$  (standard deviation) of the Horizontal Histogram in the Middle Threshold*

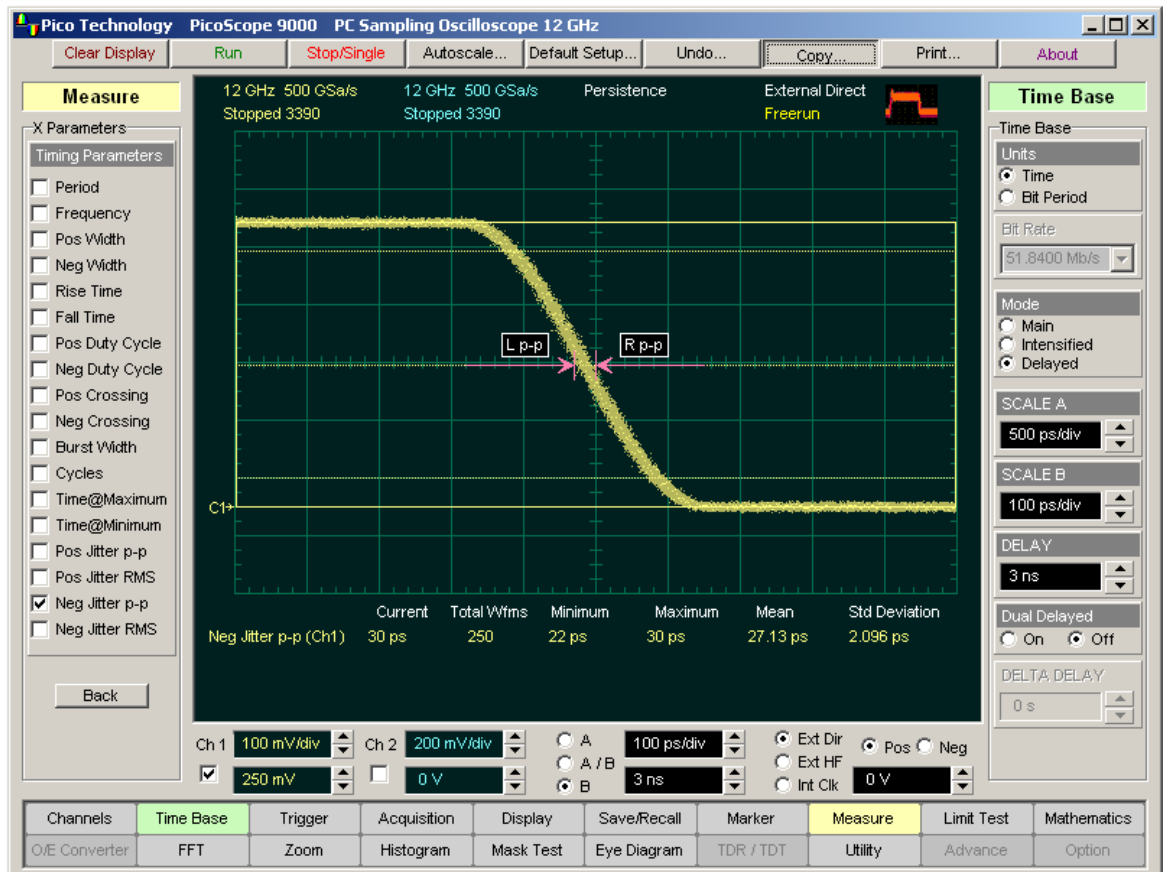


The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of **Positive jitter RMS** will be performed only inside these margins.

## 5.11.3.17 Negative Jitter p-p



**Negative Jitter p-p** is a measure of the peak-peak time variations of the falling edges of a pulse waveform at the middle threshold.



### Negative Jitter p-p definition

**Negative Jitter p-p** is determined as follows:

*Negative Jitter p-p = Full width of the Horizontal Histogram in the Middle Threshold*



The **Margins...** <sup>(307)</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of **Negative jitter p-p** will be performed only inside these margins.

## 5.11.3.18 Negative Jitter RMS



**Negative Jitter RMS** is a measure of the rms time variations of the falling edges of a pulse waveform at the middle threshold.

**Negative Jitter RMS definition**

**Negative Jitter RMS** is determined as follows:

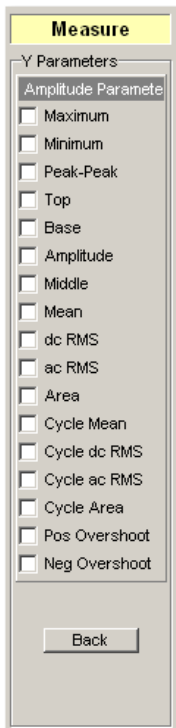
*Negative Jitter RMS =  $1\sigma$  (standard deviation) of the Horizontal Histogram in the Middle Threshold*



The **Margins...** <sup>307</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of **Negative jitter RMS** will be performed only inside these margins.



## 5.11.4 Y Parameters...



Clicking the **Y Parameters...** button opens the list of amplitude parameters. The list includes seventeen amplitude parameters for pulse measurements. Once the **Top** and **Base** calculation area is completed, most of the amplitude measurements can be made.



You can continuously update as many as ten measurement parameters, and as many as four statistics measurements at any one time.



The pulse measurement algorithms for **X Parameters** will only work when a single-valued signal is used, and no NRZ eye diagram or RZ eye diagram is present on the screen. Measurements made on both NRZ and RZ eye diagrams will fail.

## 5.11.4.1 Maximum



**Maximum** is the voltage (or power) of the absolute maximum level of the measurement region. The maximum level is taken directly from the histogram data. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



## Maximum definition



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of maximum value will be performed only inside these margins.

## 5.11.4.2 Minimum



**Minimum** is the voltage (or power) of the absolute minimum level of the measurement region. The minimum level is taken directly from the histogram data. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).

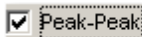


## Minimum definition



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of minimum value will be performed only inside these margins.

## 5.11.4.3 Peak-Peak



**Peak-Peak** is a measure of the difference between **Maximum** and **Minimum** of a displayed waveform. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



### Peak-Peak definition

**Peak-Peak** is determined as follows:

$$\text{Peak-Peak} = \text{Maximum} - \text{Minimum}$$

where *Maximum* is the voltage (or power) of the absolute maximum value of the waveform, and *Minimum* is the voltage (or power) of the absolute minimum value of the waveform.



The **Margins...** <sup>307</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of peak-peak value will be performed only inside these margins.

## 5.11.4.4 Top



**Top** is the voltage of the statistical maximum level. Use the [Method](#)<sup>[303]</sup> and [Thresholds](#)<sup>[304]</sup> menus to customize the measurement threshold levels. **Top** may be equal to **Maximum** for many waveforms, such as triangle waveforms. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



## Top definition



The [Margins...](#)<sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Top** value will be performed only inside these margins.

## 5.11.4.5 Base



**Base** is the voltage of the statistical minimum level. Use the [Method](#)<sup>[303]</sup> and [Thresholds](#)<sup>[304]</sup> menus to customise the measurement threshold levels. **Base** may be equal to **Minimum** for many waveforms, such as triangle waveforms. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



## Base definition



The [Margins...](#)<sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Base** value will be performed only inside these margins.

## 5.11.4.6 Amplitude



**Amplitude** is a measure of the difference between the **Top** and **Base** of a displayed pulse waveform. Use the [Method](#) <sup>[303]</sup> and [Thresholds](#) <sup>[304]</sup> menus to customize the measurement threshold levels. **Amplitude** may be equal to **Peak-Peak** for many waveforms, such as triangle waveforms. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).

**Amplitude definition**

**Amplitude** is determined as follows:

$$\text{Amplitude} = \text{Top} - \text{Base}$$

where *Top* is the statistical maximum level, and *Base* is the statistical minimum level.



**Top** may be less than or equal to the maximum value of the waveform, while **Base** may be greater than or equal to the minimum value of the waveform.



The [Margins...](#) <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of amplitude value will be performed only inside these margins.

## 5.11.4.7 Middle



**Middle** is the computation of the middle point between the maximum and minimum amplitude peaks of the waveform over the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



### Middle definition

**Middle** is determined as follows:

$$\text{Middle} = (\text{Maximum} - \text{Minimum}) / 2$$

where *Maximum* is the voltage (or power) of the absolute maximum value of the waveform, and *Minimum* the voltage (or power) of the absolute minimum value of the waveform.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of middle value will be performed only inside these margins.



## 5.11.4.8 Mean



**Mean** is the average mean of all the waveform data over the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin).



## Mean definition

**Mean** is determined as follows:

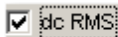
$$Mean = \frac{1}{n} \sum_{i=1}^N V(i)$$

where  $n$  is the number of waveform points on screen and not the memory depth,  $V(i)$  is the voltage at the  $i$ -th point on screen.

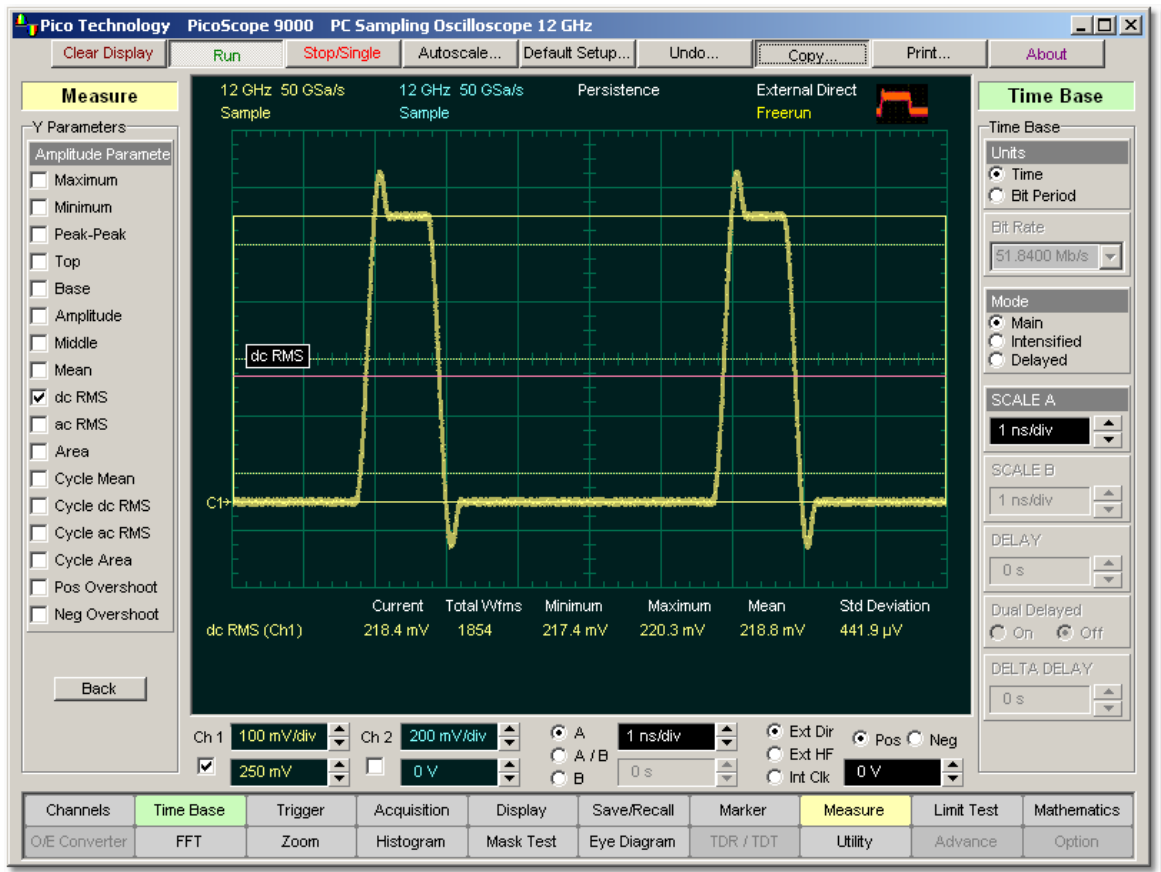


The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of mean value will be performed only inside these margins.

## 5.11.4.9 dc RMS



**dc RMS** is the root-mean-square voltage of the waveform over the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either ac or dc RMS measurements.

**dc RMS definition**

**dc RMS** measurement is determined as follows:

$$dcRMS = \sqrt{\frac{\sum_{i=1}^n [V(i)]^2}{n}}$$

where:  $n$  is the number of waveform points on screen and not the memory depth, and  $V(i)$  is the voltage at the  $i$ -th point on screen.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **dc RMS** value will be performed only inside these margins.

## 5.11.4.10 ac RMS



**ac RMS** is the root-mean-square voltage of the waveform less the mean value over the measurement region. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either ac or dc RMS measurements.

**ac RMS definition.**

The **ac RMS** measurement is determined as follows:

$$acRMS = \sqrt{\frac{\sum_{i=1}^N [V(i) - Mean]^2}{n}}$$

where:  $n$  is the number of waveform points on screen and not the memory depth,  $V(i)$  is the voltage at the  $i$ -th point on screen, and  $Mean$  is an average mean voltage.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **ac RMS** value will be performed only inside these margins.

## 5.11.4.11 Area



**Area** is the area under the curve of the waveform within the measurement region in vertical units multiplied by horizontal units, such as volt-seconds or watt-seconds. Area measured above ground is positive; area measured below ground is negative.



## Area definition

Area is determined as followed:

If  $Start=End$  then return the (interpolated) value at  $Start$ .

Otherwise,


$$Area = \int_{Start}^{End} Waveform(t) dt$$

In practice the PicoScope 9000 uses the following algorithm:

$$Area = \frac{\Delta t}{N} \sum_{i=1}^N V(i)$$

where:  $N$  is the number of waveform points on screen and not the memory depth,  $V(i)$  is the voltage at the  $i$ -th point on screen, and  $\Delta t$  is the measured region duration.

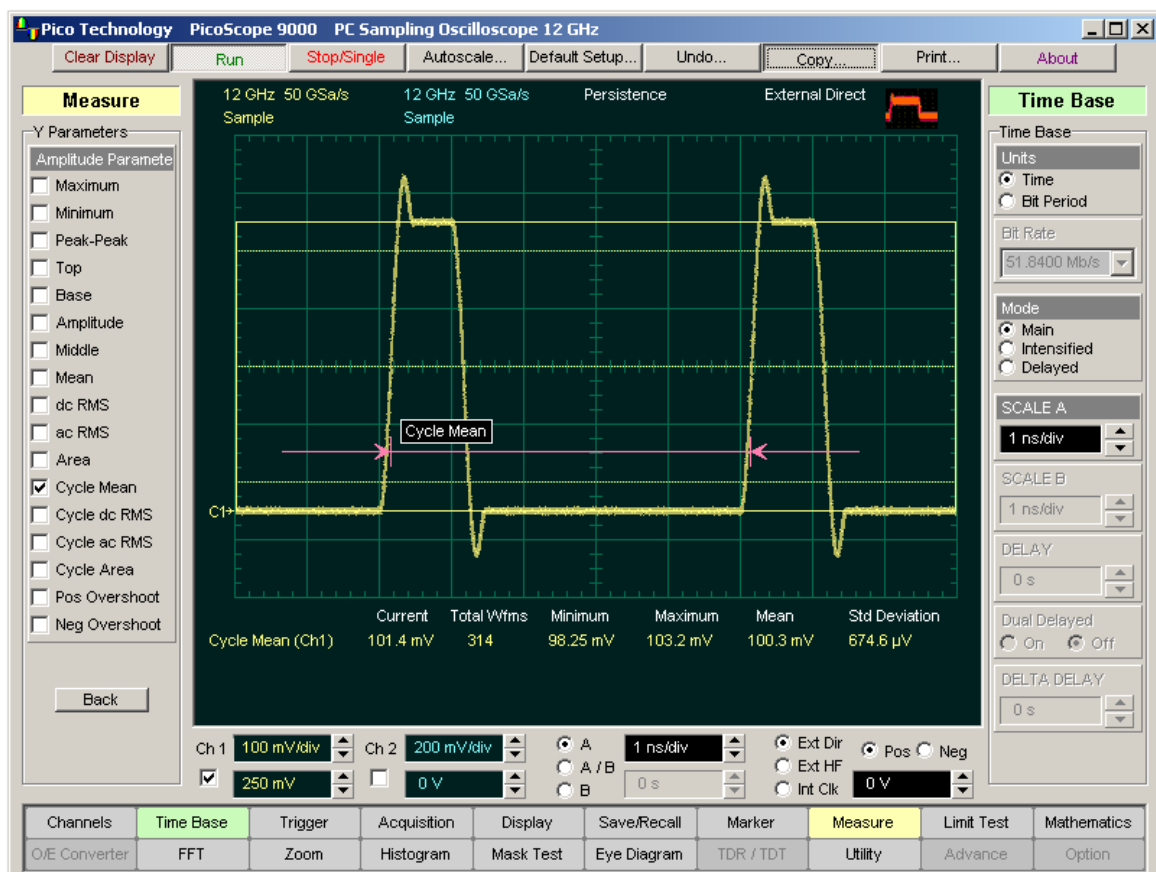


The **Margins...**  menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of area value will be performed only inside these margins.

## 5.11.4.12 Cycle Mean



**Cycle Mean** is the averaged mean of all the waveform data of one cycle of the signal over the measurement region. The average of the data values is taken of an integral number of periods. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). See also **Mean**.



## Cycle Mean definition

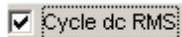


You can customize this measurement to be made either on one waveform cycle or across all data on the display. The [Margins...](#)<sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Cycle Mean** value will be performed only inside these margins.



Cycle Mean value is affected by the [Define Param...](#)<sup>[308]</sup> menu. In the [Defined Thresholds](#)<sup>[309]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.4.13 Cycle dc RMS



**Cycle dc RMS** is the averaged root-mean-square voltage of one cycle of the waveform value over the measurement region. The average of the data values is taken of an integral number of periods. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either cycle ac or dc RMS measurements. See also [dc RMS](#) <sup>[283]</sup>.



## Cycle dc RMS definition



You can customize this measurement to be made either on one waveform cycle or across all data on the display. The [Margins...](#) <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Cycle dc RMS** value will be performed only inside these margins.

## 5.11.4.14 Cycle ac RMS



**Cycle ac RMS** is the averaged root-mean-square voltage of one cycle of the waveform less the cycle mean value over the measurement region. The average of the data values is taken of an integral number of periods. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either ac or dc RMS measurements. See also [ac RMS](#) <sup>[284]</sup>.



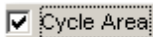
## Cycle as RMS definition



You can customize this measurement to be made either on one waveform cycle or across all data on the display. The [Margins...](#) <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Cycle ac RMS** value will be performed only inside these margins.



## 5.11.4.15 Cycle Area



**Cycle Area** is the averaged area under the curve for one cycle the waveform within the measurement region in vertical units multiplied by horizontal units, such as volt-seconds or watt-seconds. The average of the data values is taken over an integral number of periods. Area measured above ground is positive; area measured below ground is negative. See also [Area](#) <sup>[285]</sup>.

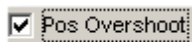


## Cycle Area definition

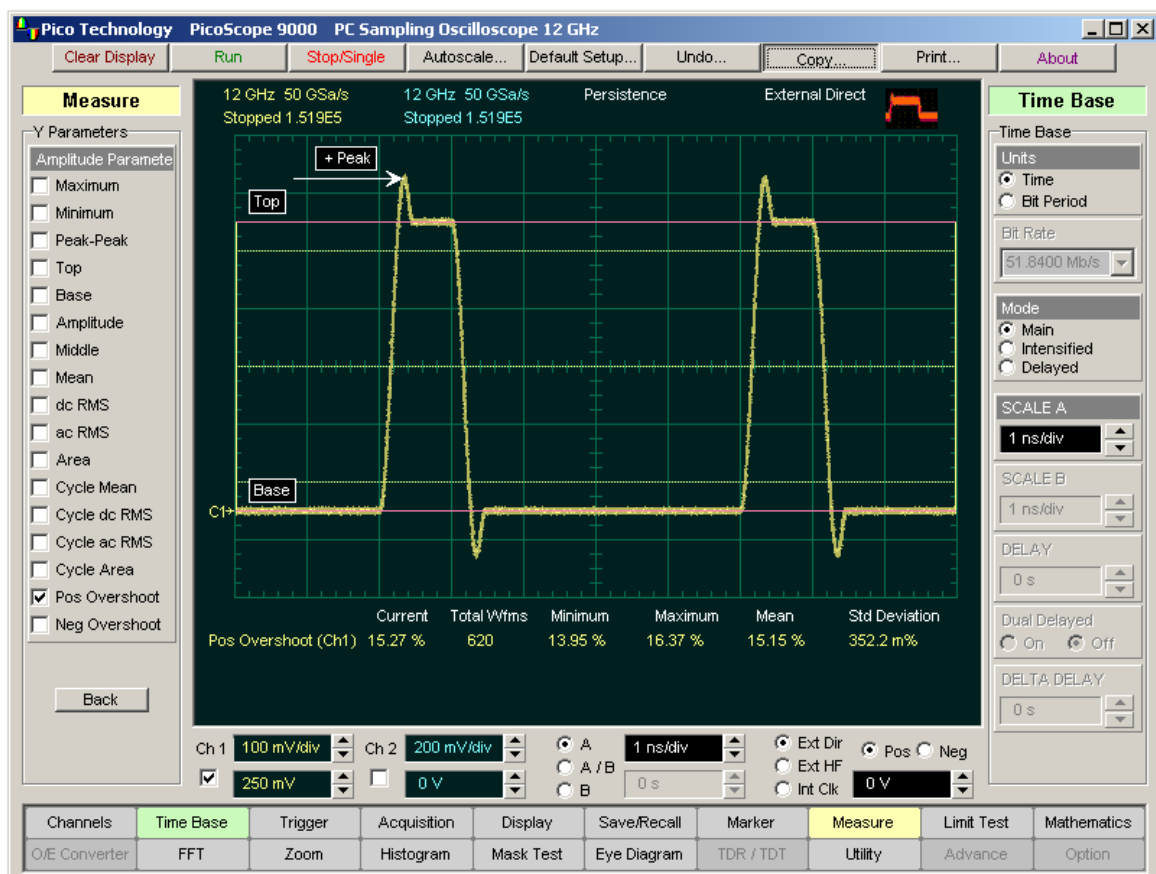


The [Margins...](#) <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of cycle area value will be performed only inside these margins.

## 5.11.4.16 Positive Overshoot



**Positive Overshoot** is defined as a maximum distortion that follows a positive waveform edge transition. This distortion occurs after the edge crosses through the waveform threshold levels. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either positive and negative overshoot measurements.



## Positive Overshoot definition

## Positive Overshoot definition

Positive overshoot, determined when the waveform edge is rising (upward slope), is computed as follows:

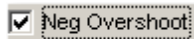
$$\text{Positive Overshoot} = [(Maximum - Top) / Amplitude] \times 100\%$$

where: *Maximum* is the signal maximum, *Top* is the signal top value, and *Amplitude* is the signal amplitude.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Positive Overshoot** value will be performed only inside these margins.

## 5.11.4.17 Negative Overshoot



**Negative Overshoot** is defined as a maximum distortion that follows a negative waveform edge transition. This distortion occurs after the edge crosses through the waveform threshold levels. The PicoScope 9000 starts the measurement on the first left-most portion of the measurement region (left margin) and stops the measurement on the right-most portion of the display (right margin). The instrument can make either positive and negative overshoot measurements.



### Negative Overshoot definition

**Negative Overshoot**, determined if the waveform edge is falling, is computed as follows:

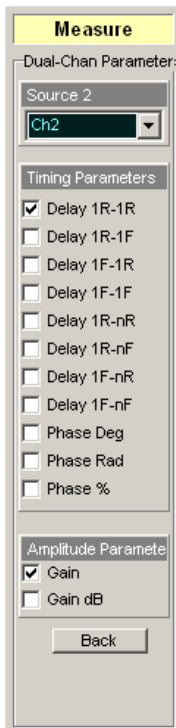
$$\text{Negative Overshoot} = [(Base - Minimum) / Amplitude] \times 100\%$$

where: *Minimum* is the signal minimum, *Base* is the signal base value, and *Amplitude* is the signal amplitude.



The **Margins...** <sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Negative Overshoot** value will be performed only inside these margins.

### 5.11.5 Dual-Channel Parameters



Clicking the **Dual Channel Parameters...** button opens the list of parameters that can be measured with two sources.

You can select as one of the sources:

- channels 1 and 2
- functions 1 through 4
- waveform memories 1 through 4
- spectrums 1 and 2

The list includes eight delay parameters, three phase parameters, and two gain parameters.



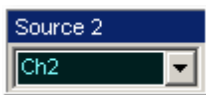
You can continuously update as many as ten measurement parameters, and as many as four statistics measurements at any one time.



The pulse measurement algorithms for **X Parameters** will only work when a single-valued signal is used, and no NRZ eye diagram or RZ eye diagram is present on the screen. Measurements made on NRZ and RZ eye diagrams will fail.

When the **Dual Channel Parameters...** menu is selected, the **Source** drop-down list box located on the first page of the **Measure**<sup>[24†]</sup> menu selects the reference source, while the **Source 2** drop-down list box located on the **Dual Channel Parameters** menu page selects the second source.

#### 5.11.5.1 Source 2



When the **Dual-Chan Parameters...** menu is selected, the **Source** drop-down list box located on the first page of the **Measure**<sup>[24†]</sup> menu selects the reference source, while the **Source 2** drop-down list box located on the **Dual-Chan Parameters** menu page selects the second source.

## 5.11.5.2 Delay

- ☐ Delay 1R-1R
- ☐ Delay 1R-1F
- ☐ Delay 1F-1R
- ☐ Delay 1F-1F
- ☐ Delay 1R-nR
- ☐ Delay 1R-nF
- ☐ Delay 1F-nR
- ☐ Delay 1F-nF

**Delay** is defined as a time interval between the crossings of the two mid-reference levels on the two sources of the measurement. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).

**Delay** is determined as follows:

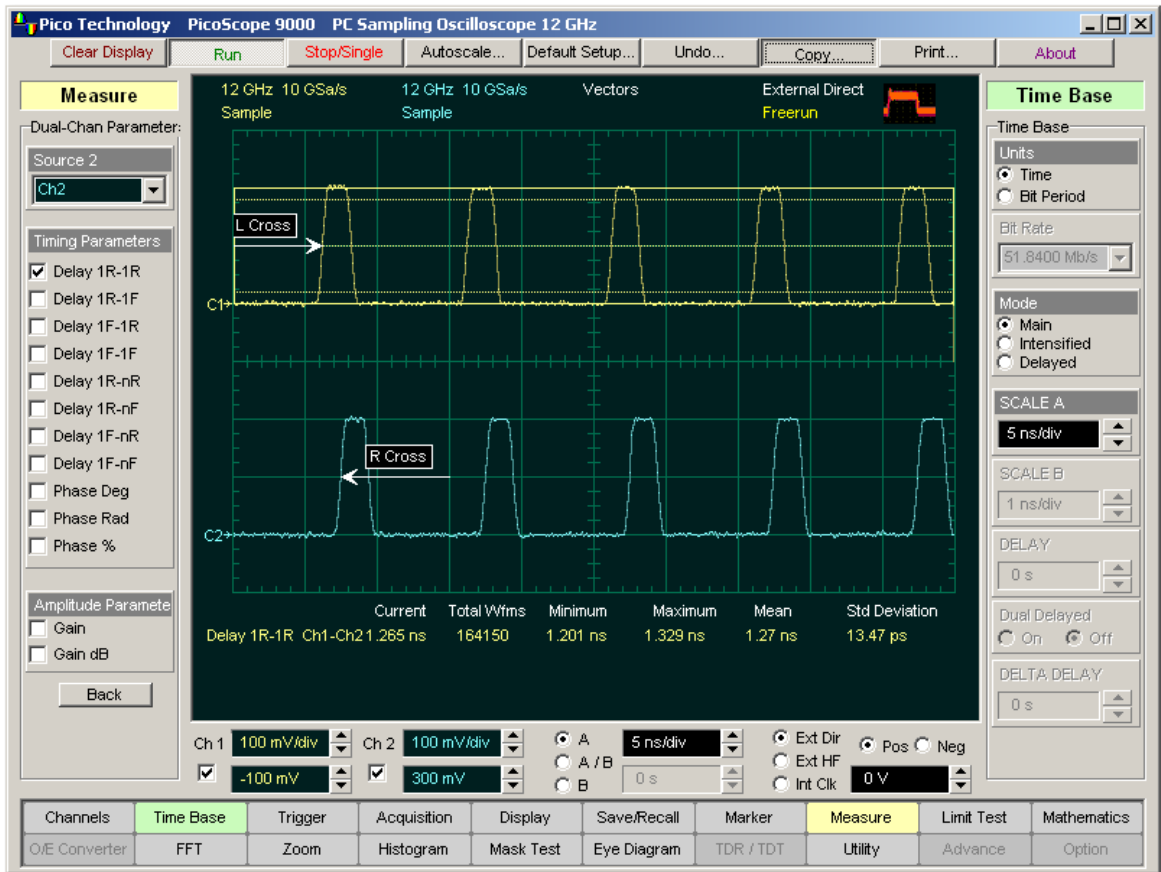
$$\text{Delay} = T_{\text{cross2}} - T_{\text{cross1}}$$

where:  $T_{\text{cross2}}$  is a horizontal crossing on the rising or falling edge of the second source, and  $T_{\text{cross1}}$  is a horizontal crossing on the rising or falling edge of the first (reference) source.

The delay will not be measured until the rising and falling edges on both sources complete the transition through all three levels.

You can select one of the eight delay options:

- ☒ Delay 1R-1R **Delay 1R-1R** is the delay between the first rising edge on the reference source and the first rising edge on the second source.
- ☒ Delay 1R-1F **Delay 1R-1F** is the delay between the first rising edge on the reference source and the first falling edge on the second source.
- ☒ Delay 1F-1R **Delay 1F-1R** is the delay between the first falling edge on the reference source and the first rising edge on the second source.
- ☒ Delay 1F-1F **Delay 1F-1F** is the delay between the first falling edge on the reference source and the first falling edge on the second source.
- ☒ Delay 1R-nR **Delay 1R-nR** is the delay between the first rising edge on the reference source and the last rising edge on the second source.
- ☒ Delay 1R-nF **Delay 1R-nF** is the delay between the first rising edge on the reference source and the last falling edge on the second source.
- ☒ Delay 1F-nR **Delay 1F-nR** is the delay between the first falling edge on the reference source and the last rising edge on the second source.
- ☒ Delay 1F-nF **Delay 1F-nF** is the delay between the first falling edge on the reference source and the last falling edge on the second source.



**Example of Delay measurement between the first rising edge on the reference source and the first rising edge on the second source**

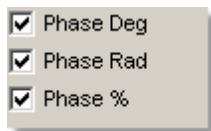


The [Margins...](#)<sup>[307]</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Delay** value will be performed only inside these margins.



The **Delay** value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[308]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.

## 5.11.5.3 Phase



**Phase** is the amount by which a waveform leads or lags another in time. It is defined between the first rising edge on the reference source and the first rising edge on the second source. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).

**Phase** is determined as follows:

$$PhaseDeg = \frac{T_{cross2} - T_{cross1}}{Period} * 360^\circ$$

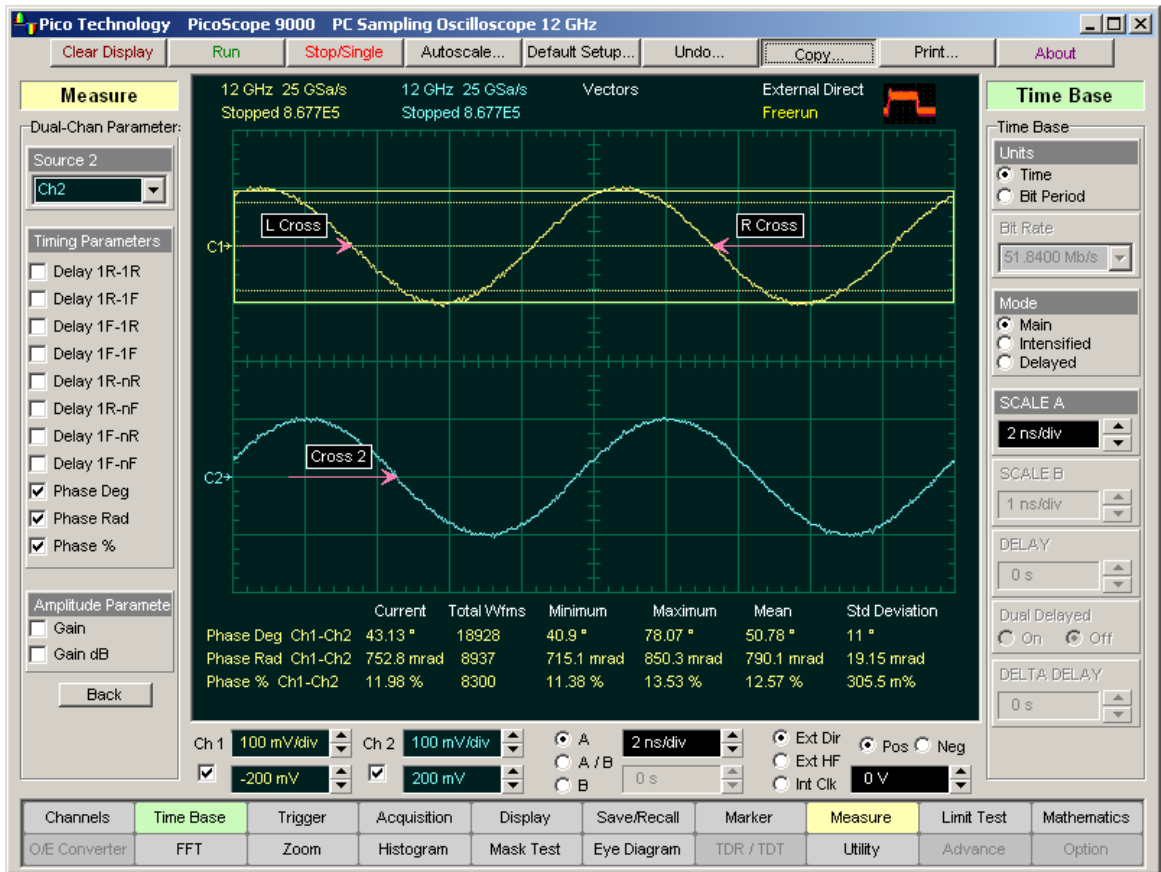
$$PhaseRad = \frac{T_{cross2} - T_{cross1}}{Period} * 2\pi$$

$$PhaseRad = \frac{T_{cross2} - T_{cross1}}{Period} * 100\%$$

where: *Tcross2* - is a horizontal crossing on the first rising edge of the second source, *Tcross1* is a horizontal crossing on the first rising edge of the first (reference) source, and *Period* is a period value.

You can select one of three phase options:

- ☒ **Phase Deg** is a phase expressed in degrees, where 360° constitutes one waveform cycle
- ☒ **Phase Rad** is a phase expressed in radians, where one waveform cycle (360°) corresponds to 2π radians
- ☒ **Phase %** is a phase expressed as a percentage of one waveform cycle



### Example of phase measurement between two sine-wave signals



Both the first (reference) and the second sources should have an equal period value when the phase measurements are performed.



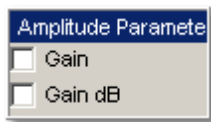
The [Margins...](#)<sup>[307]</sup> menu sets the margin markers to see where scope is making the automatic measurement. All calculations of the **Phase** value will be performed only inside these margins.



Phase value is affected by the [Define Param...](#)<sup>[300]</sup> menu. In the [Defined Thresholds](#)<sup>[306]</sup> menu you can redefine the mid-threshold setting from 50% to any other level you want.



## 5.11.5.4 Gain



**Gain** is the amplitude gain between two selected waveforms. The PicoScope 9000 starts the measurement on the first edge on the left-most portion of the measurement region (left margin) and stops the measurement on the last edge on the right-most portion of the measurement region (right margin).

Gain is determined as follows:

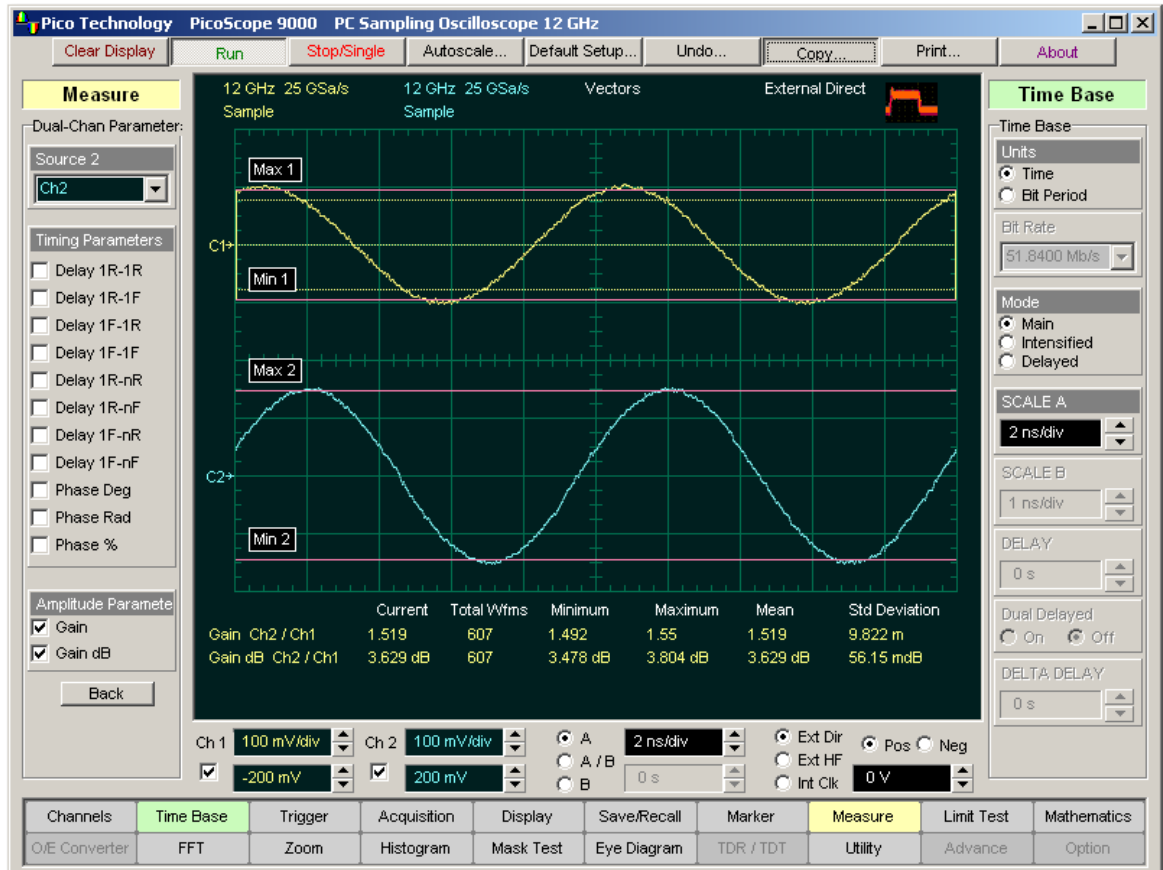
$$Gain = \frac{Amplitude2}{Amplitude1}$$

$$Gain\_dB = 20 \log_{10} \left( \frac{Amplitude2}{Amplitude1} \right)$$

where: *Amplitude1* is the amplitude measurements of the first (reference) source, and *Amplitude2* is the amplitude measurements of the second source.

You can select one of two gain options:

- ☒ **Gain** is a gain expressed as an amplitude gain between the amplitudes of two waveforms.
- ☒ **Gain dB** is a gain expressed in decibels.

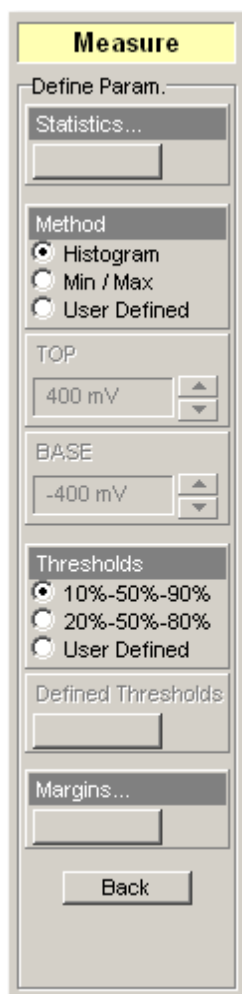
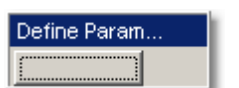


**Example of gain measurement between two sine-wave signals**



The **Margins...** <sup>307</sup> menu sets the margin markers to show where the scope is making the automatic measurement. All calculations of the **Gain** value will be performed only inside these margins.

## 5.11.6 Define Parameters

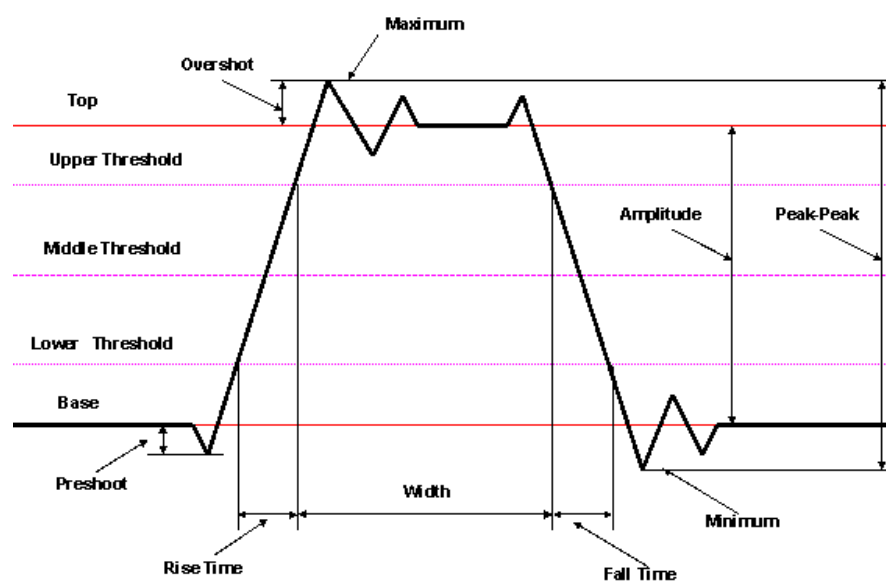


The **Define Parameters** menu sets the measurement points (thresholds and margins) where the automatic measurements are made. These measurement points can be set to the same points for all waveforms (channel waveforms, function waveforms, and waveform memories) or can be set differently for each individual waveform. The menu influences the measurement algorithm by allowing you to use the standard IEEE measurement points, or customize the measurements with the user-defined selections. The **Define Param...** menu also includes the [Statistics...](#) menu for some statistics options.

The **Define Parameters** menu is different when you work in time domain with signals or in the frequency domain with spectrums.

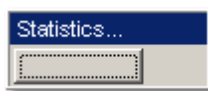
**Standard IEEE measurement points**

The waveform drawing below shows some of the standard measurement points, thresholds, and parameters.



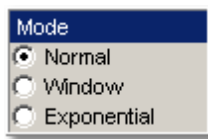
**Standard IEEE measurement points**

## 5.11.6.1 Statistics...



The **Statistics...** menu includes modes and variables that determine the algorithm for a statistical measurement calculation. The **Statistics...** menu is active only when the **Statistics** mode of the [Display](#)<sup>47</sup> menu is selected.

## 5.11.6.1.1 Mode



The **Mode** menu defines one of three modes that determine the algorithm for statistical measurement calculations.

**Normal.** Each of the acquired waveforms has an equal influence on the result of the statistical measurement calculation. The [WAVEFORMS](#)<sup>[302]</sup>/[WEIGHT](#)<sup>[302]</sup> variables are not active in this mode.

**Window.** Only a limited number of the recently acquired waveforms have an equal influence on the result of statistical measurement calculations. The [WAVEFORMS](#)<sup>[302]</sup> variable specifies the number of recently acquired waveforms used for statistical measurement calculations. Use the **Window** mode when measuring a waveform that is rapidly drifting.

**Exponential.** Each of the acquired waveforms has a weighted influence on the result of statistical calculations on eye diagrams. Each subsequently acquired waveform has a greater influence than the preceding acquired waveforms. The [WEIGHT](#)<sup>[302]</sup> variable specifies the degree of this influence. Use the **Exponential** mode when measuring a waveform that is slowly drifting.

## 5.11.6.1.2 WAVEFORMS



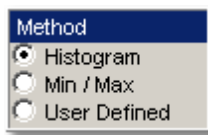
The **WAVEFORMS** variable specifies the number of recently acquired waveforms used for statistical measurement calculations. The variable is active when **Window** is selected in the [Mode](#)<sup>[302]</sup> menu. It can be varied from 8 to 8192 in multiples of two.

## 5.11.6.1.3 WEIGHT



The **WEIGHT** variable specifies the degree of influence of each recently acquired waveform against more remote waveforms. The variable is active when **Exponential** is selected in the [Mode](#)<sup>[302]</sup> menu. **WEIGHT** can be varied from 8 to 8192 in multiples of two.

## 5.11.6.2 Method



The **Method** menu sets the **Top** and **Base** vertical reference thresholds for amplitude measurements. It also sets the values from which the upper, middle and lower thresholds are calculated. The **Top** and **Base** variables are displayed when the **User Defined** method is selected. The three selections under the **Method** menu allow the user to choose the method for determining the **Top** and **Base** of the waveform.

**Histogram.** The instrument calculates the top and base using the IEEE standards with a voltage histogram of the waveform that is on the display. The instrument finds the most prevalent top and base voltage values. Make sure there is enough of the signal displayed on the screen so that the instrument can accurately determine the top and base values of the waveform. However, if too much of the top and base of the waveform are on the display, it may reduce the number of sample points on the edge of interest, which may reduce the repeatability of your measurements. A good rule of thumb is to have two divisions of top and two divisions of base.

**Min / Max.** The absolute maximum (positive peak) of the targeted waveform is used as the **Top**, and the absolute minimum (negative peak) of the targeted waveform is used as the **Base**.

**User Defined.** This method lets you set the top and base to a specific voltage value. The upper, middle and lower thresholds are then calculated from the voltage values you select.

The **User Defined** simplifies the threshold detection algorithm. The result is that the measurement throughput of the instrument is increased, because the instrument does not have to calculate the top and base values. After you selected the **User Defined** method, the **Top** and **Base** variables becomes active.

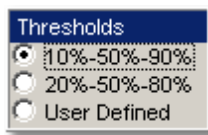
## 5.11.6.3 TOP and BASE



The **TOP** and **BASE** variables let you set the top and base to a specific voltage value. As an example, for a 200 mV/div vertical scale you can set the top and base voltage values from -798 mV to 798 mV in 25 mV (coarse) or 1.56 mV (fine) increments determined by the voltage range you are in.

Note that the top value cannot be less than base value.

## 5.11.6.4 Thresholds



The **Thresholds** menu sets the measurement points that the automatic measurements use for calculating the timing measurement results. The threshold points are upper, middle, and lower. For example, rise time is measured from the lower threshold to the upper threshold, while a width measurement is made between two middle thresholds.

The three threshold choices are the standard IEEE measurement points:

- **10%-50%-90%**
- **20%-50%-80%**
- **User Defined**

By default, the PicoScope 9000 uses the IEEE thresholds of 10, 50 and 90 percent for pulse measurements. A rising or falling edge is only recognized after passing through all three thresholds. You can specify your own thresholds rather than using the IEEE standard 10, 50, and 90 percent levels, but this can dramatically change measurement results. Note how the rise and fall times will be faster for the same waveform using the 80%, 20% criteria instead of the 90%, 10% criteria. You may rely on the scope to automatically set top and base or redefine those levels yourself and use units of voltage instead of percent.

The **UPPER THRESHOLD**, **MIDDLE THRESHOLD**, and **LOWER THRESHOLD** variables are displayed only when the **User Defined** is selected in the **Thresholds** menu.

**10%-50%-90% and 20%-50%-80%**

These are two IEEE standard pulse measurement thresholds for all measurements. These standard thresholds are calculated as a percentage of the top-base values, and the top-base values are calculated from the waveform that is on the display.

**10%-50%-90%** means: Lower threshold = 10 %, Middle threshold = 50 %, Upper threshold = 90 %.

**20%-50%-80%** means: Lower threshold = 20 %, Middle threshold = 50 %, Upper threshold = 80 %.

Make sure that the waveform is expanded vertically and horizontally so that the instrument can accurately determine the top and base values of the waveform. However, if too much of the top and base of the waveform is on the display, it may reduce the repeatability of your measurements. A good rule of thumb is to have two divisions of top and two divisions of base.

**User Defined**

For waveform records or portions of waveform records on which you want to make custom measurements or define thresholds in units of volts, percents or divisions, you can use the **User Defined** setting. By using units of Volts, you can fix the thresholds and compare different waveform records using exactly the same, fixed threshold points.

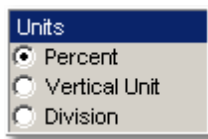
## 5.11.6.5 Defined Thresholds...

The "Measure" dialog box is shown with the "Define Thresholds" tab selected. The "Units" section has three radio buttons: "Percent" (selected), "Vertical Unit", and "Division". Below this are three threshold settings, each with a text box and up/down arrows: "UPPER THRESHOLD" is set to "90 %", "MIDDLE THRESHOLD" is set to "50 %", and "LOWER THRESHOLD" is set to "10 %". At the bottom of the dialog is a "Back" button.

Clicking the **Defined Thresholds...** button opens the second-level menu that allows you select defined threshold options.



## 5.11.6.5.1 Units



You can set the unit of measure for upper, middle, and lower thresholds to **Percent**, **Vertical Unit** or **Division**.

**Percent.** This is calculated from the top-base values, and you can set the maximum percentage up to 200% in 1% (coarse) or 0.1% (fine) increments.

**Volt.** This lets you set the thresholds to particular voltage values regardless of the top-base values. For example, for a vertical scale of 200 mV/div you can set the voltage values from -797 mV to 797 mV in approximately 25 mV (coarse) or 1.56 mV (fine) increments determined by the voltage range you are in. Setting **Units** to **Volt** simplifies the threshold detection algorithm. The result is that the measurement throughput of the instrument is increased, because the instrument does not have to calculate the voltage thresholds.

**Division.** This lets you set the thresholds to particular voltage values regardless of the top-base values. For example, you can set the voltage values from -3.97 to 3.97 divisions in 125 milli-divisions (coarse) or 7.8 milli-divisions (fine) increments.

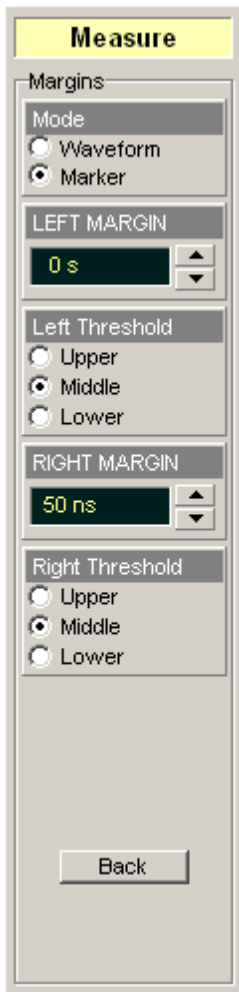
## 5.11.6.5.2 UPPER, MIDDLE and LOWER THRESHOLD



The **UPPER THRESHOLD**, **MIDDLE THRESHOLD**, and **LOWER THRESHOLD** variables are displayed only when **User Defined** is selected in the [Thresholds](#) <sup>304</sup> menu. All variables can be selected for the either **Percent**, **Volt** or **Division**.

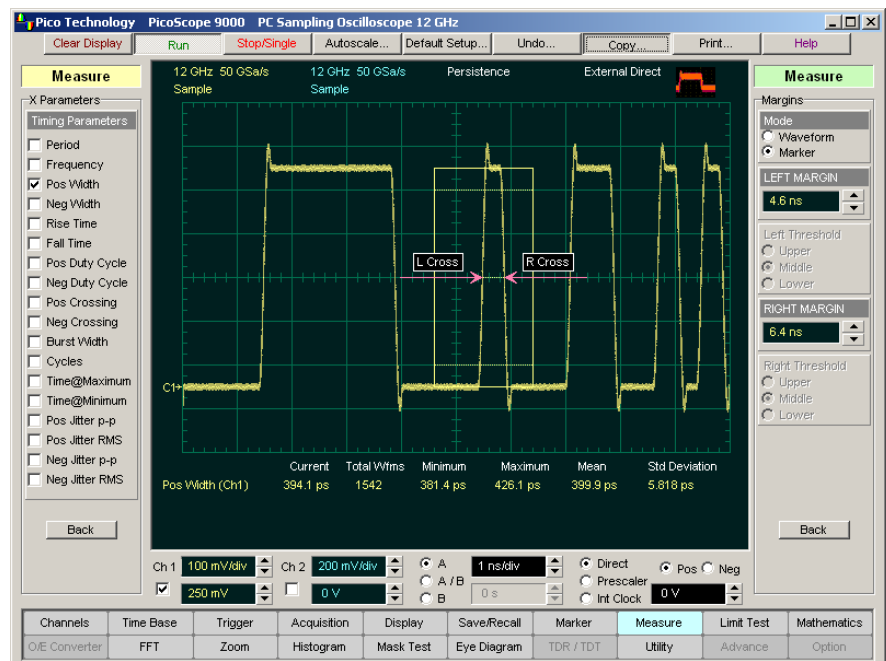
The upper threshold value is always greater than the value of the middle threshold, and the middle threshold value is always greater than the value of the lower threshold. The instrument will not allow a threshold to cross over the adjacent threshold.

## 5.11.6.6 Margins...



The **Margins...** menu sets left and right horizontal margins that the automatic measurements use for calculating measurement results. All calculations of measuring parameters can be performed only inside these margins.

The figure below demonstrates how correctly positioned margins can provide enough complicated user-defined horizontal measurements.



**Correct position of both margins provides width measurement of second short pulse**

## 5.11.6.6.1 Mode



Two modes are used to set the margins:

- **Waveform**
- **Marker**

**Waveform.** Provides automatic setting of the left and right margins on any of the rising or falling edges of the selected waveform. The **LEFT MARGIN** and **RIGHT MARGIN** variables provide positioning of both margins into any upper, middle or lower threshold with any rising or falling edge of the waveform.

**Marker.** Provides manual setting of the left and right margins with the **LEFT MARGIN** and **RIGHT MARGIN** variables.

## 5.11.6.6.2 LEFT MARGIN and RIGHT MARGIN

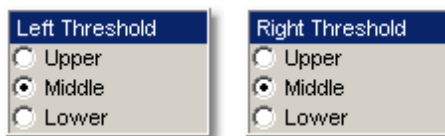


You can set the left and right margins with the [LEFT MARGIN](#)<sup>[308]</sup> and [RIGHT MARGIN](#)<sup>[308]</sup> variables.

When the **Waveform** is selected in the **Mode** menu, both variables automatically set margins on any rising or falling edge of selected waveform. With the [LEFT MARGIN](#)<sup>[308]</sup> marker or [RIGHT MARGIN](#)<sup>[308]</sup> marker you can move the left and right margins from the 1st rising (edge) up to the 256th falling (edge).

Both variables set the margins at any point of the display manually when **Marker** is selected in the [Mode](#)<sup>[307]</sup> menu.

## 5.11.6.6.3 Left Threshold and Right Threshold



The **LEFT THRESHOLD** and **RIGHT THRESHOLD** variables select crossing points on the edge of the selected waveform. Both variables can be used only when **Waveform** is selected in the [Mode](#)<sup>[307]</sup> menu.

**Upper.** A margin will be placed on the upper threshold.

**Lower.** A margin will be placed on the lower threshold.

**Middle.** A margin will be placed on the middle threshold.

You can change values of upper, lower, and middle thresholds from the [Defined Thresholds...](#)<sup>[305]</sup> menu.

### 5.11.7 FFT Parameters

You can use automated measurements to measure FFT waveforms. To take automated measurements with FFT waveforms, select one of the spectrums in the **Source** on the first page of the [Measure](#) <sup>[24†]</sup> menu.

After one of the spectrum waveforms is selected you can perform up to five FFT measurements. They are:

- **FFT Frequency**
- **FFT delta Frequency**
- **FFT Magnitude**
- **FFT delta Magnitude**
- **Total Harmonic Distortion**



You can continuously update as many as ten measurement parameters, and as many as four statistics measurements at any one time.



The algorithms for FFT measurements will only work when a spectrum waveform is used. Measurements made on a single-valued signal, NRZ or RZ eye diagrams, will fail.



**Aliasing.** When using FFTs, make sure you avoid signal aliasing. Aliasing occurs when there are insufficient samples on each cycle of the input signal to reconstruct the signal. It occurs whenever the frequency of the input signal is greater than the Nyquist frequency, which is the sample frequency divided by 2. When a signal is aliased, it shows up in the FFT spectrum as a signal of a lower frequency. Because the frequency span goes from 0 to the Nyquist frequency, the best way to prevent aliasing is to make sure that the frequency span is greater than all the frequencies present in the input signal. Keep in mind that most periodic signals that are not sine waves have frequency components much higher than the fundamental frequency of the signal. Those components may also cause aliasing.

## 5.11.7.1 FFT Frequency



The **FFT Frequency** measures the frequency value of a peak in the FFT spectrum as defined by the [Define param...](#)<sup>[300]</sup> menu.

When **Harmonic** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among other peaks and located within the margins limited by the [LEFT MARGIN](#)<sup>[308]</sup> and [RIGHT MARGIN](#)<sup>[308]</sup> variables.

When the **Peak** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the [PEAK LEVEL](#)<sup>[313]</sup> variable.

You can choose a peak by using the **PEAK 1** variable in the [Define param...](#)<sup>[300]</sup> menu.

## 5.11.7.2 FFT Delta Frequency



The **FFT Delta Frequency** measures the frequency difference between two peaks in the FFT spectrum as defined by peak numbers the [Define param...](#)<sup>[300]</sup> menu.

When the **Harmonic** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among other peaks and located within the margins limited by the [LEFT MARGIN](#)<sup>[308]</sup> and [RIGHT MARGIN](#)<sup>[308]</sup> variables.

When the **Peak** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the [PEAK LEVEL](#)<sup>[313]</sup> variable.

You can choose a peak by using the **PEAK 1** and **PEAK 2** variables in the [Define param...](#)<sup>[300]</sup> menu.

## 5.11.7.3 FFT Magnitude



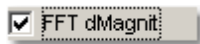
The **FFT Magnitude** measures the magnitude value of a peak in the FFT spectrum as defined by the [Define param...](#)<sup>[300]</sup> menu.

When the **Harmonic** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among another peaks and located within the margins limited by the [LEFT MARGIN](#)<sup>[308]</sup> and [RIGHT MARGIN](#)<sup>[308]</sup> variables.

When the **Peak** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the [PEAK LEVEL](#)<sup>[313]</sup> variable.

You can choose a peak by using the **PEAK 1** variable in the [Define param...](#)<sup>[300]</sup> menu.

## 5.11.7.4 FFT Delta Magnitude



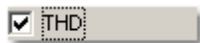
The **FFT Delta Magnitude** measures the magnitude difference between two peaks in the FFT spectrum as defined by peak numbers the [Define param...](#)<sup>[300]</sup> menu.

When the **Harmonic** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among another peaks and located within the margins limited by the [LEFT MARGIN](#)<sup>[308]</sup> and [RIGHT MARGIN](#)<sup>[308]</sup> variables.

When the **Peak** is selected in the [Method](#)<sup>[303]</sup> menu a peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the [PEAK LEVEL](#)<sup>[313]</sup> variable.

You can choose a peak by using the **PEAK 1** and **PEAK 2** variables in the [Define param...](#)<sup>[300]</sup> menu.

## 5.11.7.5 Total Harmonic Distortion



**THD** is a ratio, expressed as a percentage, of the rms level of the measured signal, with the fundamental harmonic removed, to the rms level of the the fundamental harmonic.

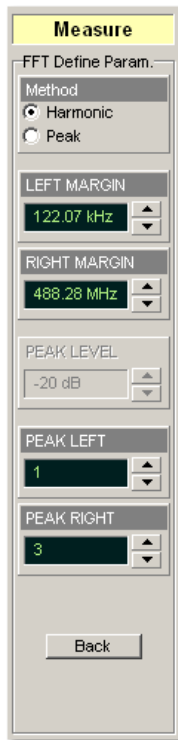
Total harmonic distortion is determined as follows:

$$THD = \sqrt{\frac{\sum_{n=2}^N U_n^2}{U_1^2}} \cdot 100\%$$

where:  $U_n$  - is an amplitude of the  $n$ -th harmonic, and  $U_1$  - is an amplitude of the fundamental harmonic.

THD is a measure of signal purity, used to characterize linearity in electronic circuits and components. A high-purity sine wave, one with low harmonic content, is input to the device under test. An analysis of the frequency content of the output from that device will reveal non-linear operation in the form of increased harmonic levels.

## 5.11.8 FFT Define Parameters

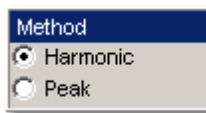


The **Define Param...**<sup>[300]</sup> menu is changed when the spectrum waveform for FFT measurement is selected.

To select defined parameters for FFT measurements do as follows:

- Select one of the spectrums in the **Source** on the first page of the **Measure**<sup>[24]</sup> menu.
- Click **Define Param...**<sup>[300]</sup>

## 5.11.8.1 Method



Two modes are used to define FFT peaks:

- **Harmonic**
- **Peak**

**Harmonic.** A peak 1 is defined as a peak having maximum amplitude among other peaks and located within the margins limited by the **LEFT MARGIN**<sup>[308]</sup> and **RIGHT MARGIN**<sup>[308]</sup> variables. *F1* is a fundamental frequency of a peak 1.

A frequency of *n*-th harmonics is calculated as follows:

$$F_n = n * F_1$$

**Peak.** A peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the **PEAK LEVEL**<sup>[313]</sup> variable.

## 5.11.8.2 LEFT MARGIN and RIGHT MARGIN



**LEFT MARGIN** and **RIGHT MARGIN** variables limit a horizontal (spectrum) window used for a peak 1 definition. When **Harmonic** is selected in the **Method**<sup>[313]</sup> menu a peak 1 is defined as a peak having maximum amplitude among other peaks and located within the margins limited by the **LEFT MARGIN** and **RIGHT MARGIN** variables.

## 5.11.8.3 PEAK LEVEL



The **PEAK LEVEL** defines the threshold that an FFT peak must cross to be considered a peak. The default peak level is -20 dBmV.

## 5.11.8.4 PEAK LEFT and PEAK RIGHT



**PEAK LEFT** defines which of the peaks, counting from the left of the display, you want to start making FFT measurements on. When **Harmonic** is selected in the **Method**<sup>[313]</sup> menu a peak 1 is defined as a peak having maximum amplitude among other peaks and located within the margins limited by the **LEFT MARGIN**<sup>[313]</sup> and **RIGHT MARGIN**<sup>[313]</sup> variables. When **Peak** is selected in the **Method**<sup>[313]</sup> menu, a peak 1 is defined as a peak having maximum amplitude among all peaks exceeding the value of the **PEAK LEVEL**<sup>[313]</sup> variable.

**PEAK RIGHT** defines the second peak used for the FFT measurements.



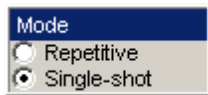
## 5.11.9 View Define Parameters



The markers can be used to give you a visual indicator of where you are manually setting the thresholds and margins. To use the markers to show the settings, use the **View Define Param** menu.

Clicking the **On / Off** options turns the display for the selection on or off.

## 5.11.10 Mode



Two modes are available for extracting parameters:

- **Repetitive**
- **Single-shot**

**Repetitive.** This mode dynamically extracts the same number of parameters, based on successive acquisition sequences, and updates the measurements approximately every 100 ms (except at very slow repetition rates).

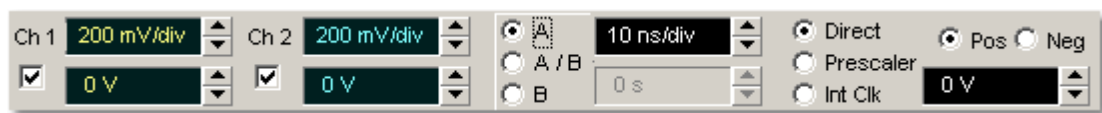
**Single-shot.** Extracts up to ten measuring parameters and up to four statistical parameters, based on the last acquisition, and displays the result.

## 5.11.11 Single



Clicking the **Single** button provides single-shot measurement of selected parameters.

## 5.12 Permanent Controls



The **Permanent Controls** are located at the bottom of the display area. They are permanent because they are the most common function that affect the waveform display. They include the channel, timebase and trigger toolbars.

The **Permanent Controls** are:

- The **Channel 1** and **Channel 2** on/off check boxes, scale, and offset settings
- The time base modes, the **A** and **B** time base scales, and delay settings
- Trigger source, slope, and level settings

Clicking the right mouse button on a selected variable displays a [pop-up numeric keypad](#)<sup>[375]</sup> allowing you to set a precise value.

Each channel has a check box allowing you to turn that channel on or off, and a set of controls allowing you to change the vertical scaling or offset. Only channels that are on are shown in matching colors.

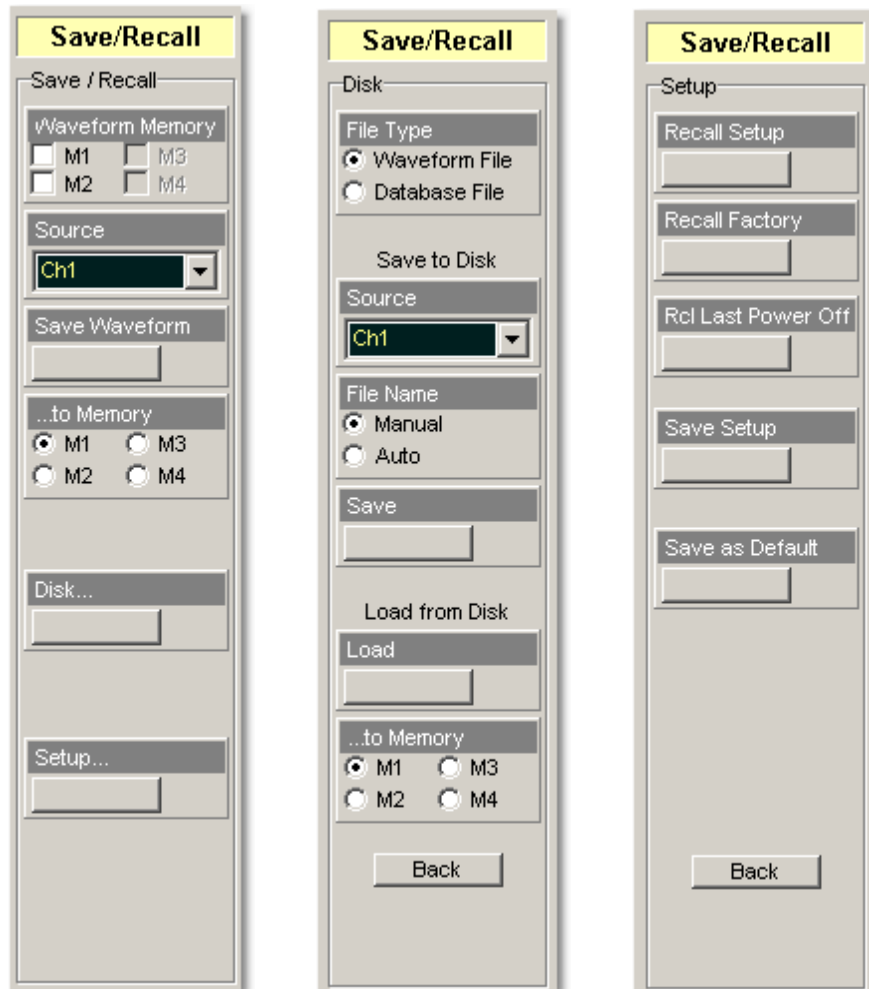
The right-hand side of the permanent controls contains a limited number of trigger controls. You can choose between **Direct**, **Prescaler** and **Int Clk** source, and between **Positive** and **Negative** trigger slope. You can set a particular trigger level.

## 5.13 Save/Recall Menu

Save/Recall

You can use any drive on the PicoScope 9000's PC for the following save/recall tasks:

- To save or recall your acquired waveforms to or from the **M1 - M4** waveform memories
- To save your acquired waveforms to a drive
- To load your saved waveforms from a drive to the **M1 - M4** display memories
- To save current front-panel setups for later recall



### 5.13.1 Waveform Memory



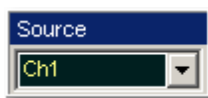
The instrument allows you to save your acquired waveforms to any of the instrument's internal drives. You can recall these waveforms at a later time and display them on the instrument's display screen.

The **Waveform Memory** allows you to save or recall a waveform into one of the waveform memories (**M1 – M4**), intended for display. When you recall a waveform from memory, it is displayed in the default color for that memory number. However, you can change the default color in the [Display/Color](#)<sup>[65]</sup> menu. The default colors are:

- **M1**: red
- **M2**: yellow-gray
- **M3**: violet
- **M4**: gray

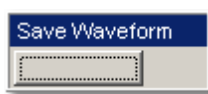
The waveform memories are non-volatile so the data is not lost if you turn off the power, or set the instrument to the default settings. The **M1 - M4** memories contain a single waveform record, including the horizontal and vertical scaling parameters. Therefore you can make parametric measurements on stored waveforms or use them as operands in a function. You can also recall the waveform for future comparison or analysis, save it to disk, or load it from a disk.

### 5.13.2 Source (Waveform Memory)



The **Source** menu allows you to choose the source of the waveform you intend to save into one of the waveform memories (**M1 – M4**). You can choose between channels, functions, spectrums, and memories as the waveform sources.

### 5.13.3 Save Waveform



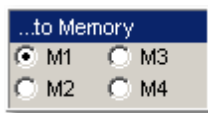
Clicking the **Save Waveform** button copies the selected waveform to one of the selected waveform memories (**M1 – M4**).

**Save Waveform** saves only the current acquired data from the signal. Therefore, the recalled waveform will be displayed as a single trace. This method of saving the waveform is not the preferred process if you want to save a waveform that is using the measurement database (for example, saving a persistence or color-graded trace, or an eye diagram), and you want to recall the entire waveform.



Make sure the waveform to be saved exists; that is, your source must be a channel, an active math waveform, or an active waveform memory. Display the waveform in the timebase with which you want to save it.

## 5.13.4 ...to Memory



Clicking **...to Memory** selects which of the available waveform memory locations the instrument saves the waveform to. When a waveform is saved to a memory, it overwrites any data that was previously stored in that memory. If the **Waveform Memory** menu for that memory is on, then the display is also updated.

## 5.13.5 Disk...

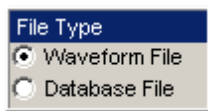


The **Disk** menu allows you to save your acquired waveform or database as arbitrary file to a disk, in either internal format or text format. You can load these waveforms at a later time into the waveform memory (**M1 – M4**), and display them on the instrument's display screen. A database also can be loaded and displayed, but not via the waveform memory (**M1 – M4**).

Save/recall capability is helpful when you want to:

- Recall a waveform for further evaluation or comparison with other waveforms.
- Extend the waveform-carrying capacity of the oscilloscope. The PicoScope 9000 supports two channels, four waveform memories, four math functions, and two spectrums.

## 5.13.5.1 File Type



The **File Type** menu selects how waveforms are stored to disk. Two options are available:

- **Waveform File**
- **Database File**

**Waveform File**

The **Waveform File** is used for storing the last record of the waveform data acquired by the instrument after the **Save** button was pressed. You can save acquired waveforms to a file, so that you can recall them at a later time and display them on the instrument's screen, and perform different measurements.

**Database File**

The **Database File** is used for storing the multiple-waveform database acquired by the instrument between clicking the **Save** button and later clicking any another control. The **Database File** is useful for such database signals as eye diagrams, and the pulse waveforms for noise and jitter measurements with histograms. A histogram can also be saved with this mode. You can recall saved database files at a later time, display them on the instrument's screen with different display styles, and perform histogram measurements and mask tests.

## 5.13.5.2 Source



The **Source** menu allows you to choose the source of the waveform you intend to save to disk. You can choose between channels, functions, spectrums and memories as the waveform source.

## 5.13.5.3 File Name



The **File Name** menu sets how the oscilloscope creates the name of the file. The PicoScope 9000 uses two modes:

- **Manual**
- **Auto**

**Manual**

You enter the file name from the keyboard of the PC.

**Auto**

In this mode full information the file name consists of a base name, a file number, and one underline between them. The length of file name is unlimited, while the file number must have five digits. The last digit in the file name is sequential. For example, the instrument can assign the file name **abc\_XXXXX.cgs** where **XXXXX** is a number from 1 to 99999. Each time you save a waveform, the number in the file name is automatically incremented by one or by whatever is necessary to reach the next unused number. This ensures that the waveform will always be saved to a new file and protects you from inadvertently overwriting an existing file.

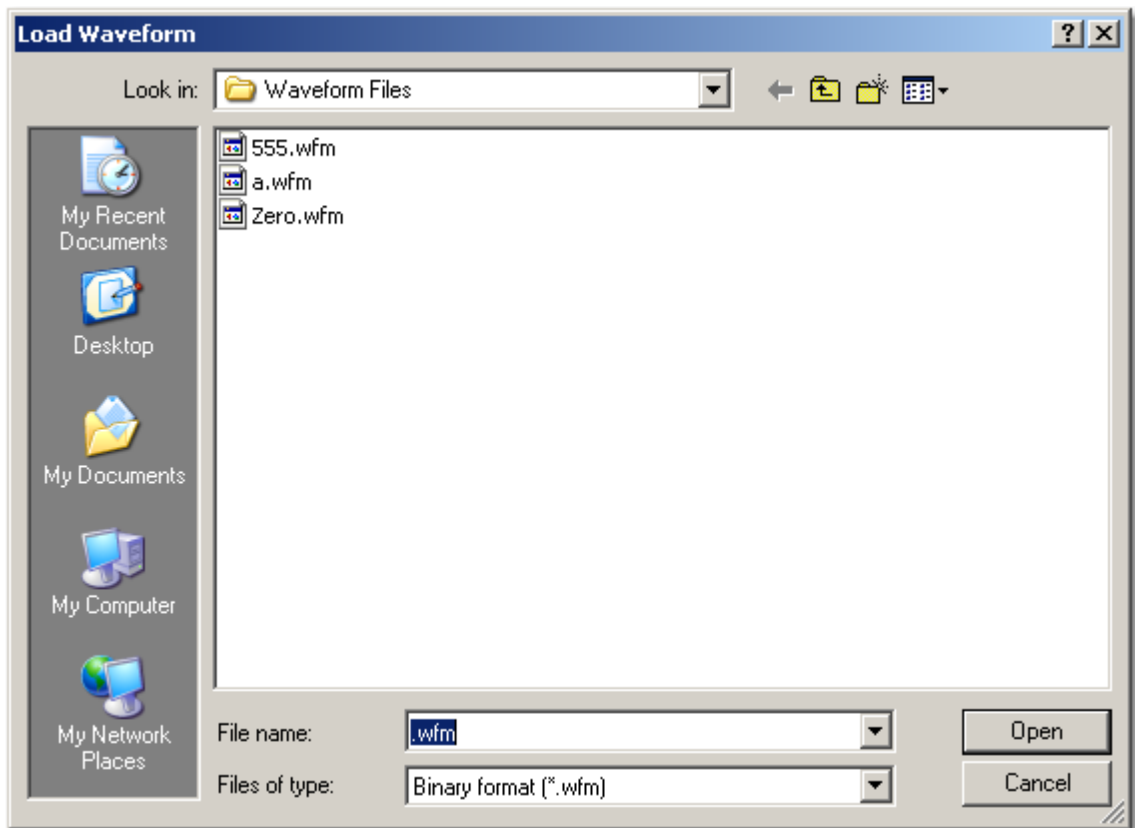
## 5.13.5.4 Save



The **Save** button stores the selected waveform to a disk. Clicking the **Save** button performs one of the following:

**1. Waveform File is selected in the File Type <sup>[319]</sup> menu, while **Manual** is selected in the File Name <sup>[319]</sup> menu.**

Clicking the **Save** button opens the Windows **Load Waveform** dialog box, which allows you select the type of format you want to save the waveform as.



**Windows Load Waveform dialog box**

You can select one of three types of waveform format:

- Binary format with **.wfm** extension
- Text format with **.txt** extension
- Both formats with **.wfm**, and **.txt** extensions

The **Waveform Files** dialog box also allows you to create subdirectories, rename waveform files, or overwrite existing waveform files.

The **Save** feature saves only the current acquired data from the signal. Therefore, the recalled waveform will be displayed as a single trace. This method of saving the waveform is not the preferred process if you want to save a waveform that is using the measurement database (for example, saving persistence or color-graded traces, or eye diagrams), and you want to recall the entire waveform.





Remember to always copy important settings and waveforms to a removable disk. If your original files are damaged or lost, you can restore the files from the backup disk.

### Binary format

The binary format files (**.wfm** extension) stored using the internal format contain the vertical and horizontal scaling parameters of the original waveform. Therefore, when you recall a waveform into a waveform memory, you can still perform automatic measurements and use the markers. Because the internal format is binary, you cannot directly display its contents in a word processing or plotting program. However, you can convert the binary format file to a text file (**.txt**) for use in a spreadsheet or word processing program, by recalling a **.wfm** waveform and saving it in the text format.

### Text format

The text format (**.txt**) is an ASCII text file format that uses alphanumeric characters to represent the voltage values of a waveform. This file format consists of a file header, which describes format (**.txt**) waveform horizontal and vertical scaling information and scope information. The header is followed by data, which consists of Y values separated by a carriage return and line feed. Text format files use 4 to 5 times more disk space than internal format files.

The text files are a convenient method for transferring waveforms to other software applications. You can import this file format into many spreadsheet or word processing programs.

### Both

The **Both** uses both internal and text formats. Two files are needed when you save waveform in both formats.



Ensure your waveform files have the file name extension **.wfm** or **.txt**. If you specify a different extension, the instrument automatically corrects the extension.



Make sure the waveform to be saved exists; that is, your source must be a channel, an active math waveform, or an active waveform memory. Display the waveform in the timebase with which you want to save it.



Enter a useful comment in the file name about each waveform you save. Write the comment so that it explains the purpose of the saved file when that file is later accessed.

**2. Waveform File is selected in the [File Type](#) <sup>319</sup> menu, while Auto is selected in the [File Name](#) <sup>319</sup> menu.**

Clicking the **Save** button stores your acquired waveforms, automatically incrementing a new number in a previous file name with its selected format(s).

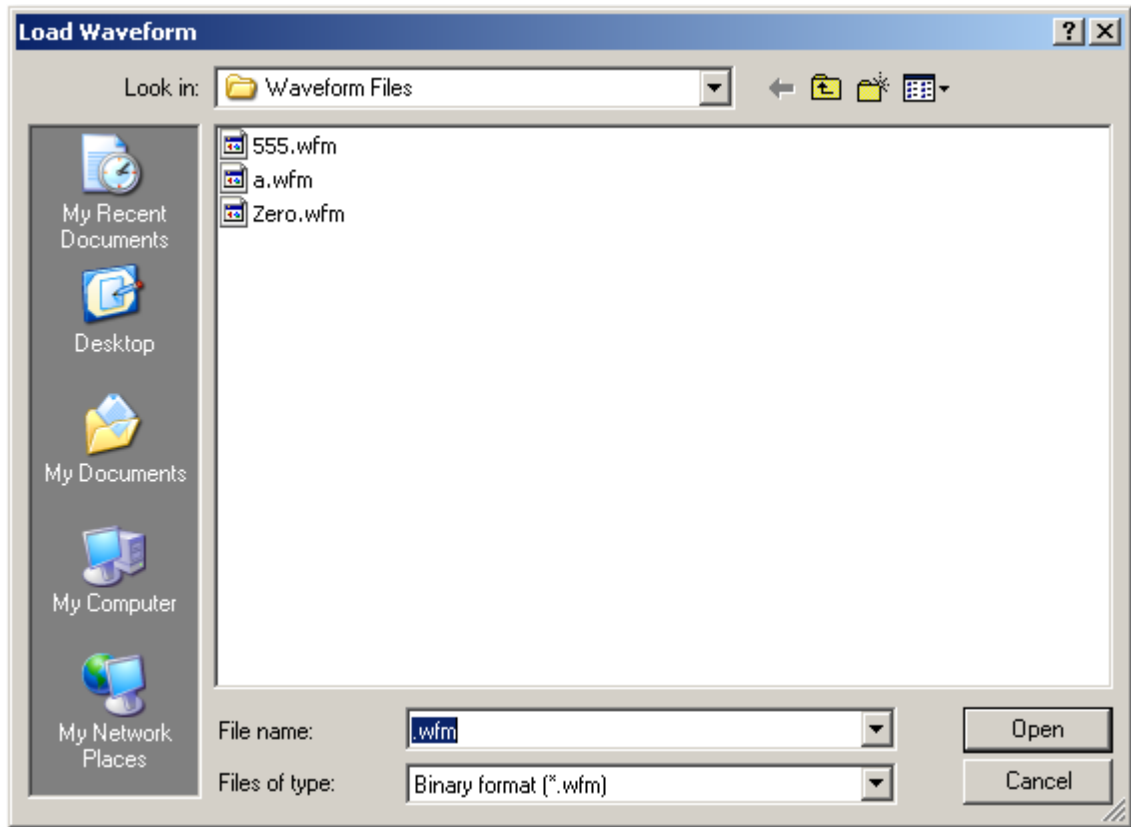
**3. Database File is selected in the [File Type](#) <sup>319</sup> menu.**

Clicking the **Save** button opens Windows Load Waveform dialog box, which allows you to select a file name. Only **.cgs** file extension can be use in this case.

## 5.13.5.5 Load



The **Load** button loads the selected file from a disk into one of the memories **M1 - M4**. Clicking the **Load** button opens the Windows **Load Waveform** dialog box and allows you to select which subdirectory, waveform, and file format you want to recall.



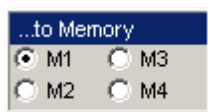
**Windows Waveform Files dialog box**

You can select one of three types of waveform formats:

- Binary format with **.wfm** extension
- Text format with **.txt** extension
- Both formats with **.wfm**, and **.txt** extensions

You can also specify in the **...to Memory** menu to which one of the four waveform memories **M1 - M4** you want to load the file.

## 5.13.5.6 ...to Memory



The **...to Memory** menu selects which of the available memory locations the instrument loads the saved file into.

### 5.13.6 Setup...



To save a current setup for later use, you can use any drive available to the PicoScope 9000's PC. When you save a setup, all of PicoScope 9000's settings, including measurements, markers, horizontal and vertical control settings, trigger configuration, color scheme, and math functions, are saved.

The **Setup...** menu allows you to save and recall setups. You can use the setup memories when you want to:

- Save a series of setups to help automate a procedure. You can later recall a sequence of saved setups when you perform the procedure (for production test environments).
- Save and recall a setup that optimises the instrument for displaying and analysing certain signals.
- Compare waveforms by using more than one setup.
- Set the instrument to its default settings. These settings set the instrument to a known operating condition.
- Export a setup for sharing with a second instrument.

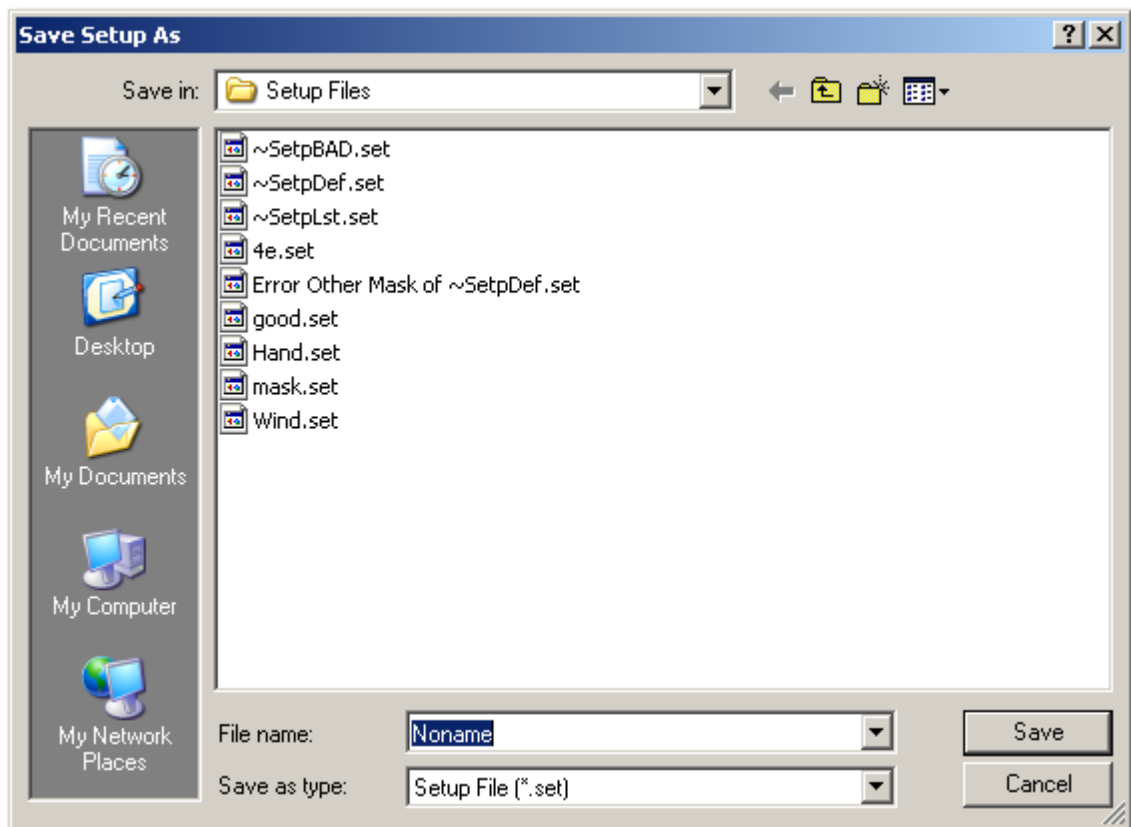
The number of setups you can save is limited only by the available space on the selected drive. Each setup uses approximately 30 kbytes of disk space.

## 5.13.6.1 Recall Setup



You can recall a setup that you have previously saved on any drive of your PC.

The **Recall Setup** button sets up the front panel by recalling a front-panel setup from a selected setup memory. Use the standard Windows **Save Setup As** dialog box. The dialog box opens and allows you to select which subdirectory and setup you want to recall. Because recalling a setup will overwrite the instrument's existing configuration, you may want to save the existing setup first.



**Windows Setup Files dialog box**



Remember that the PicoScope 9000 uses the file extension **.set** for setup files.

Recalling a setup replaces the current setup with the recalled setup. If you do not want to lose your current setup, save it to its own setup file for later recall before you recall the new setup.



Remember to always copy important settings and waveforms to an external drive. If your original files are damaged or lost, you can restore the files from the backup drive.

## 5.13.6.2 Initialization

Initialization allows you to return the instrument to one of its default settings. The default settings place the instrument in a known operating condition. This known operating condition is used as a starting point in the service procedures. You may find it helpful to use this known operating condition when someone else has used the scope before you, or as a starting point when setting up the instrument to view signals.

Three initialization settings are:

- **Factory**
- **Last Power Off**
- **Default**

## 5.13.6.3 Recall Factory



Clicking the **Recall Factory** button returns the instrument to the manufacturer's default setting. This places the oscilloscope in a known operating condition. You may find it helpful to use the default factory settings when initially setting up the instrument to view signals, or someone else has used the scope before you. You may also use the default settings to troubleshoot unexpected instrument behaviour.

**Default Factory Setup**

Channels	
<b>Select</b>	Ch1
<b>Display</b>	On (for both channels)
<b>SCALE</b>	200mV/div (for both channels)
<b>OFFSET</b>	0 V (for both channels)
<b>Bandwidth</b>	Full (for both channels)
<b>DESKEW</b>	0 s (for both channels)
<b>Attenuation Units</b>	Off (for both channels)
Timebase	
<b>Units</b>	Time
<b>Mode</b>	Main
<b>SCALE A</b>	10 ns/div
TRIGGER	
<b>Source</b>	External Direct
<b>Mode</b>	Freerun
<b>LEVEL</b>	0 V
<b>Slope</b>	Positive
<b>HOLDOFF</b>	10 us
<b>Hysteresis</b>	Normal
<b>Attenuation Units</b>	Off
ACQUISITION	
<b>Fit Acquisition To...</b>	Single-valued signal
<b>Sampling Mode</b>	Simultaneous
<b>Mode</b>	Sample
<b>RECORD LENGTH</b>	512 points (for both channels)

**DISPLAY**

<b>Trace Mode</b>	All Locked
<b>Style</b>	Variable Persistence
<b>PERSISTENCE TIME</b>	2 s
<b>Format</b>	YT
<b>Graticule</b>	Grid
<b>Default Colors</b>	Default colors legend

**SAVE/RECALL**

<b>...to Memory</b>	M1
<b>Disk</b>	
<b>File Type</b>	Waveform File
<b>File Name</b>	Manual
<b>...to Memory</b>	M1

**MARKER**

<b>Type</b>	Off
-------------	-----

**MEASURE**

<b>Display</b>	Off
<b>Define Parameter</b>	
<b>Method</b>	Histogram
<b>Thresholds</b>	10%-50%-90%
<b>Margins</b>	
<b>Mode</b>	Marker
<b>LEFT MARGIN</b>	0 s
<b>RIGHT MARGIN</b>	100 s
<b>Left Threshold</b>	Middle
<b>Right Threshold</b>	Middle

**LIMIT TEST**

Off

**MATHEMATICS**

<b>Select</b>	F1
<b>Display</b>	Off
<b>Operator</b>	Add
<b>Operand 1</b>	Ch1
<b>Operand 2</b>	Ch2

**FFT**

<b>Select</b>	S1
<b>Display</b>	Off
<b>Source</b>	Ch1
<b>Window</b>	Rectangular

**ZOOM**

Off

**HISTOGRAM**

<b>Axis</b>	Off
<b>Source</b>	Ch1

**MASK TEST**

<b>Compare with</b>	Ch1
---------------------	-----

**EYE DIAGRAM**

<b>Measure</b>	Off
<b>Source</b>	Ch1
<b>Define Parameter</b>	
<b>EYE BOUNDARY 1</b>	40%
<b>EYE BOUNDARY 2</b>	60%
<b>Thresholds</b>	20%-80%

## 5.13.6.4 Recall Power Off



Clicking the **Recall Power Off** button returns the instrument to the last setting before the power supply was last switched off.



## 5.13.6.5 Save Setup



The **Save Setup** button stores the present front-panel setup to a selected setup memory. To save a current setup for later use, you can use any available drive. Use the standard Windows **Setup Files** dialog box. You can create subdirectories; new setup files, or overwrite existing setup files from this dialog box. The PicoScope 9000 uses the file extension **.set** for setup files.



Enter a useful comment about each setup you save. Write the comment so that it explains the purpose of the saved file when that file is later accessed.

When you save a setup, all settings, including measurements, markers, horizontal and vertical control settings, trigger configuration, color scheme, and math functions, are saved to the disk file you have selected. The number of setups you can save is limited only by the available space on the drive. Each setup uses approximately 30 kbytes of disk space.



Ensure your setup files have the extension **.set**.

If you do not specify an extension, the oscilloscope supplies one automatically.

If you use a different extension, the instrument may not recognize the file as a setup file, therefore you may have trouble saving or finding the setup file.

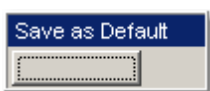
To recall a setup you have previously saved, use the **Recall Setup** button in the same menu.

Try to use the **Save Setup** button to save important setups.



Remember always to copy important settings and waveforms to an external disk. If your original files are damaged or lost, you can restore the files from the backup disk.

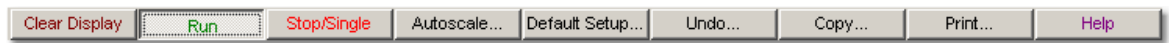
## 5.13.6.6 Save as Default



Clicking the **Save as Default** button stores the present front-panel setup as the default setup.

You can recall the saved default setup by clicking the **Default Setup** button in the [System Controls](#) <sup>[33]</sup> area.

## 5.14 System Controls



Using the **System Controls**, you control whether the oscilloscope is running or stopped; other buttons allow you to reset the oscilloscope to its default setup, automatically configure the oscilloscope for the current signals (**Autoscale**), or erase the waveforms from the display.

The **System Controls** are:

- The [Clear Display](#)<sup>[332]</sup> button
- The [Run](#)<sup>[333]</sup> button
- The [Stop/Single](#)<sup>[334]</sup> button
- The [Autoscale](#)<sup>[335]</sup> button
- The [Default Setup](#)<sup>[337]</sup> button
- The [Undo](#)<sup>[338]</sup> button
- The [Copy](#)<sup>[339]</sup> button
- The [Print](#)<sup>[341]</sup> button
- The [Help](#)<sup>[342]</sup> button

### 5.14.1 Clear Display



Clicking the **Clear Display** button erases all channel waveform data from the graticule area. The following occurs when the display graticule is cleared:

- All channel waveform data is erased from the graticule area.
- Functions, spectrums and waveform memories are not erased from the display graticule when the clear display feature is executed.
- All associated measurements and measurement statistics are reset (averaging, color-grading, mask test data, limit test data, and histogram results), if enabled.

#### **When the instrument is running**

If the instrument is running and is receiving triggers, new waveform data is displayed on the next acquisition, averaging is reset; and persistence and color-grading, histograms, the mask testing database and all measurements are recalculated.

#### **When the instrument is stopped**

If the instrument is stopped, the display remains cleared of waveform data until the trigger circuit is rearmed and the instrument is triggered. Then the new data is displayed and measurements are recalculated.

### 5.14.2 Run



The **Run** button causes the instrument to resume acquiring data. If the instrument is stopped, it starts acquiring data on the next trigger event. If the instrument is already in the run mode, it continues to acquire data on successive trigger events.

If pressing the **Run** button does not cause waveform data to display on the screen, try the following:

- Make sure a signal is connected to one of the channel and the display for that channel is turned on.
- Make sure the offset does not have the trace clipped off the display.
- Check the trigger setup conditions to make sure the trigger conditions are valid for the signal.
- Set the trigger mode to **Freerun**. **Freerun** forces the instrument to trigger, which may allow you to see enough of the signal so that you can set up the front panel properly.
- Click the **Autoscale** button.

### 5.14.3 Stop/Single

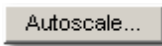


The **Stop/Single** button causes the oscilloscope to stop acquiring data or to perform a single waveform acquisition. You can stop acquisition if you want to freeze the displayed waveform(s) for closer analysis or measurement.

Each subsequent press of the **Stop/Single** button rearms the trigger circuit. A complete acquisition cycle is performed, and any measurements are recalculated.

If all of the channels are turned off or if a trigger event is not found, the instrument will not acquire any data.

#### 5.14.4 Autoscale



Adjusting an oscilloscope to display a stable trace of usable size and amplitude can be a time-consuming process. The **Autoscale** feature of the PicoScope 9000 can quickly give you a stable, meaningful trace display.

The **Autoscale** button causes the instrument to quickly analyse any waveforms connected to the trigger and channel inputs. Then, it sets up the vertical, horizontal, and trigger controls to best display that signal.

When you click the **Autoscale** button, you tell the PicoScope 9000 to examine the signal and adjust the following controls for optimum display:

- Vertical scale and offset
- Timebase scale and delay
- Trigger level, if appropriate to that trigger source

The PicoScope 9000 must have an available trigger source and input. For example, if you are using the DIRECT TRIGGER INPUT, and **Direct** is selected in the **Trigger Source**<sup>[358]</sup> menu, the trigger signal must be connected to this trigger input. **Autoscale** can then set the trigger level. If you are using the **PRESCALE TRIGGER INPUT**, and the **Prescaler** is selected in the **Trigger Source**<sup>[358]</sup> menu, the trigger signal must be connected to this trigger input.

When **Direct** is selected in the **Trigger Source**<sup>[358]</sup> menu the **Autoscale** function can find repetitive signals with:

- Frequency greater than 1 kHz
- Duty cycle greater than 1%
- Vertical amplitude greater than 50 mV p-p
- Trigger amplitude as it is specified

When **Prescaler** is selected in the **Trigger Source**<sup>[358]</sup> menu, the **Autoscale** function can find repetitive signals having trigger frequency and amplitude as they are specified.

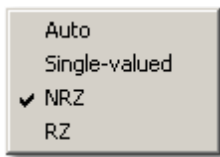
**Autoscale** is operative only for relatively stable input signals. **Autoscale** looks for signals on both channels, even if they are turned off. It also searches for a trigger signal on the trigger inputs.

If the **Autoscale** button is pressed unintentionally, use the **Undo** button to return the instrument to the settings that existed before.

When the **Autoscale** is selected, the following controls are set:

- **Time Base Mode: Delayed (B)**
- **SCALE B:** to best display the waveform
- **Trigger.**
  - If the **Direct Trigger Source** is selected: **Freerun Mode, Positive Slope, Trigger LEVEL** to 50% amplitude point of the trigger waveform, **Normal Hysteresis, HOLDOFF** with minimum value;
  - If the **Prescaler Trigger Source** is selected: to best display waveforms
- Vertical **OFFSET:** to best display waveforms on active channels
- Vertical **SCALE:** to best display waveforms on active channels

### Autoscale options



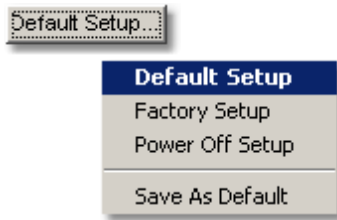
To perform autoscale, right-click the **Autoscale** button to get the four autoscale options. Select one of them, and then the scope will perform an optional **Autoscale**.

The four **Autoscale** options are:

- **Auto**
- **Single-valued**
- **NRZ**
- **RZ**

- |                       |   |
|-----------------------|---|
| <b>Auto.</b>          | Optimizes the autoscale algorithm for such waveforms as sine waves or pulses, for all main menus excluding the following cases: <ul style="list-style-type: none"><li>• Either <b>NRZ</b> or <b>RZ</b> is selected in the <a href="#">Eye Diagram/Measure</a><sup>[73]</sup> menu</li><li>• One of the standard masks for eye-diagram waveforms is selected in the <a href="#">Mask Test</a><sup>[199]</sup> menu</li></ul> |
| <b>Single-valued.</b> | Optimizes the autoscale algorithm for such waveforms as sine waves and pulses.  |
| <b>NRZ.</b>           | Optimizes the autoscale algorithm for such waveforms as <b>NRZ</b> eye-diagrams.  |
| <b>RZ.</b>            | Optimizes the autoscale algorithm for such waveforms as <b>RZ</b> eye-diagrams  |

#### 5.14.5 Default Setup



The **Default Setup** button returns the instrument to its default settings. This places the oscilloscope in a known operating condition. You may find it helpful to use this known operating condition when someone else has used the oscilloscope before you. If you accidentally press the **Default Setup** button, use the **Undo** button to return the oscilloscope to the operating condition it was in before **Default Setup** was pressed.

Right-click on the button to get four options:

- **Default Setup.** Returns the instrument to its default settings.
- **Factory Setup.** Returns the instrument to default setting of the manufacturer.
- **Power Off Setup.** Returns the instrument to the last setting before switching off the power supply.
- **Save As Default.** Stores the present front-panel setup as default setup.



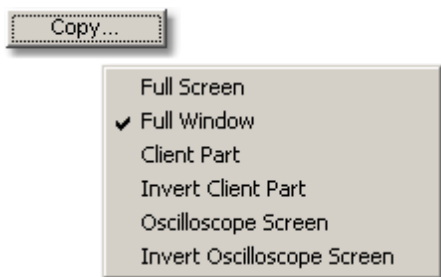
#### 5.14.6 Undo



You may find situations where you have unintentionally selected an unnecessary control. When this happens, you can use the **Undo** button to return the oscilloscope to the previous settings. The depth of undo steps can be up to 100.

If you later decide you didn't want to undo an action, right-click the button and select **Redo**.

## 5.14.7 Copy

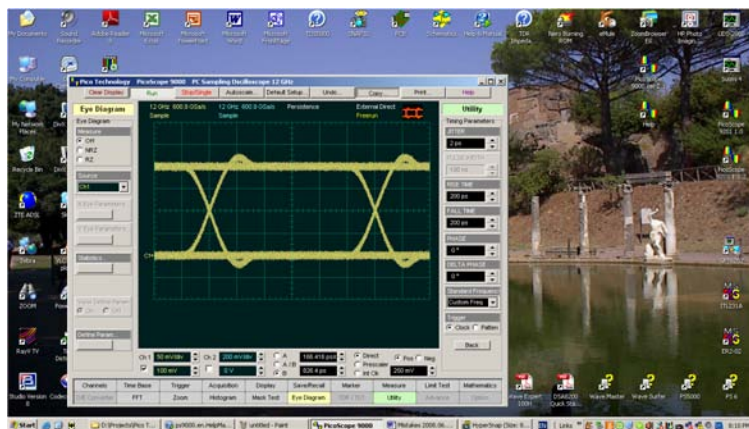


Clicking the **Copy** button copies different programming windows into the **Windows Clipboard**. From there, you can paste copied information into such **Windows** programs as **Word**, **Corel Draw**, **Paint Brush**, **Photoshop** and so on.

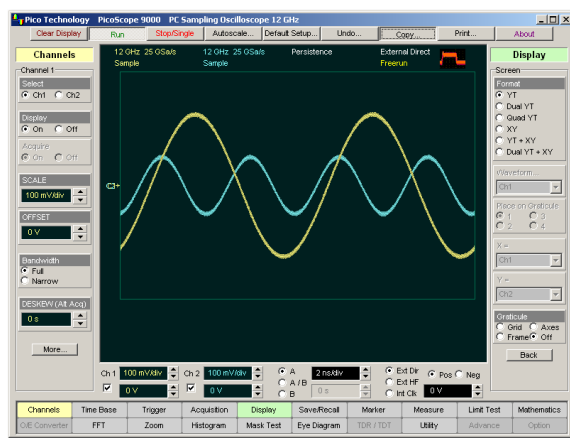
Use the **Copy** function when preparing documentation based on usage of the PicoScope 9000.

Right-click the button to get six options:

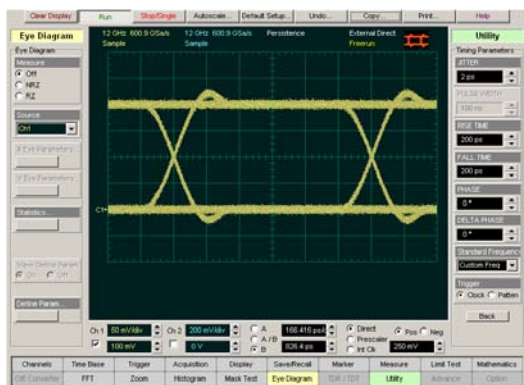
- **Full Screen**
- **Full Window**
- **Client Part**
- **Invert Client Part**
- **Oscilloscope Screen**
- **Invert Oscilloscope Screen**



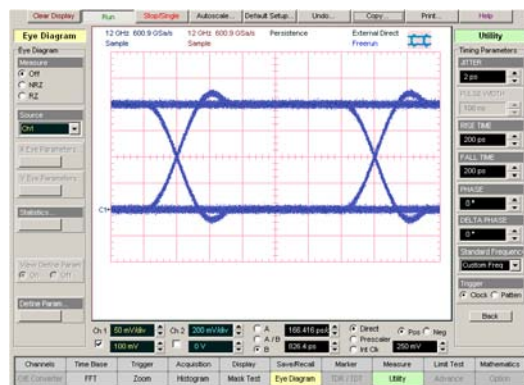
**Full Screen Copy**



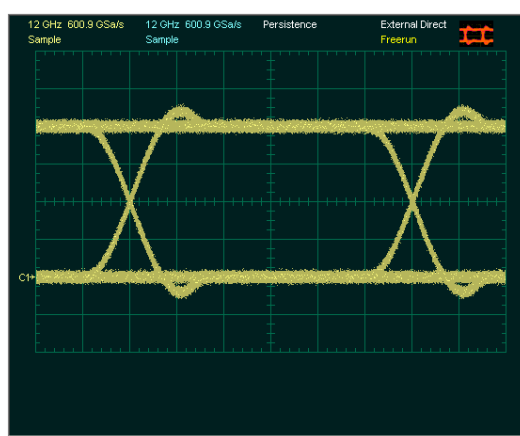
**Full Window Copy**



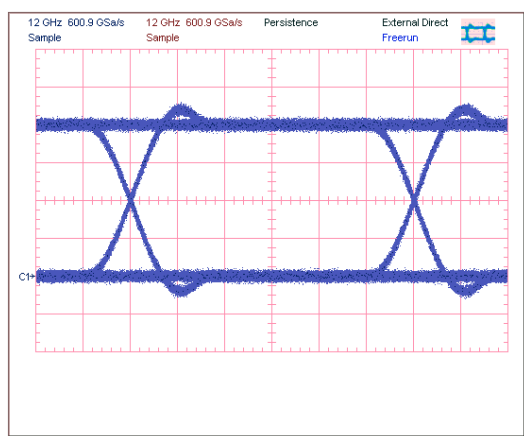
Client Part Copy



Invert Client Part Copy



Oscilloscope Screen Copy



Invert Oscilloscope Screen Copy

#### 5.14.8 Print



To print, you must first have installed and configured a printer.


To print a hardcopy, click the **Print** button.

Right-click the button, and then select the **Printer Setup**. It opens the standard Windows **Print Setup** dialog box, which allows you select printer options.

## 5.14.9 Help



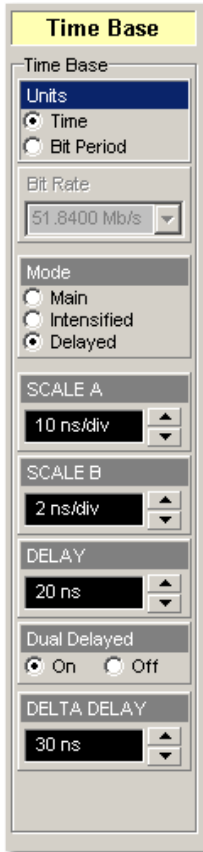
The **Help** button has two functions:

- Click it to activate the context-sensitive built-in information system on the instrument. This changes the pointer into a context-sensitive help icon, like this:  
. You can then click any control to open the manual at the relevant page.
- Right-click it to open the **PicoScope 9000 Help** manual, or the **About...** and **Instrument Info** windows.

## 5.15 Time Base Menu



The **Time Base** menu allows you to control the horizontal display through the **Main**, **Intensified**, **Delayed** or **Dual Delayed** timebases and through the **TIME/DIV** and **DELAY** functions.



The common timebase parameters specify a common horizontal acquisition window that is applied to both channels in parallel. These parameters are:

- The **trigger** signal that you input, and set the trigger system to recognize, determines the point relative to the input waveform that triggers the oscilloscope.
- The **horizontal position** you set determines the horizontal delay from the trigger point to the first sample point in the acquisition window.
- The **horizontal scale** you set, and the requirement that all waveforms fit within the 10 horizontal-division display, determines the horizontal duration of the window relative to any waveform, allowing you to scale it to contain a waveform edge, a cycle, or several cycles.
- The **record length** (along with the horizontal scale) you set for the 10-division window determines the sample interval (horizontal point spacing or resolution) on the waveform.

The **Time Base Scale**, **Record Length**, **Sample Interval** and **Resolution** are related to each other and specify the horizontal acquisition window. Relations between these horizontal elements are as follows:

$$\text{Time Duration (seconds)} = 10 \text{ div (window size)} \times \text{Time Base Scale (sec/div)}$$

$$\text{Time Duration (seconds)} = \text{Sample Interval (seconds/sample)} \times \text{Record Length (samples)}$$

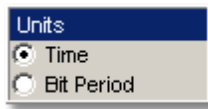
$$\text{Sample Interval (seconds/sample)} = \text{Resolution (sec/sample)} = 1 / \text{Sample Rate (samples/sec)}$$

These elements in formulas behave as follows:

- If **Record Length** or **Time Duration** vary, **Sample Interval** varies to accommodate them, up to the highest sample rate (lower sample interval or highest resolution).
- If you set a faster **Time Base Scale** setting, decreasing **Time Duration**, and the **Sample Interval** reaches its lower limit, the horizontal scale becomes limited to a setting compatible with the record length and the lower limit of the sample interval.
- If you attempt to set a longer **Record Length** and the **Sample Interval** reaches its lower limit, **Time Duration** remains constant and the record length becomes limited. The equation becomes:

$$\text{Maximum Record Length} = \text{Time Duration} / \text{Min Sample Interval}$$

### 5.15.1 Units



The **Units** function lets you set the instrument timebase in basic time units or in bit period (data rate) units. Bit period units provide an easy and intuitive way to display digital communication signals. Instead of having to compute the time interval required to display two bits or eyes, you can simply set the scale to two bits.

#### **Time (Basic time units)**

Allows you to set the scale units to seconds per division (*s/div*) and the position units to seconds (*s*). The default value for basic time units is 10 ns/div.

#### **Bit Period (Bit units)**

Allows you to select from a list of standard optical and digital telecommunications rates. When selected, the timebase scale units are set to bits per division and the delay units to bits. In this mode, the instrument internally performs the calculation to convert the number of bits displayed on the screen to the time per division. For example, if you wanted to convert *x* bits per division to time per division, you would have to compute the following:

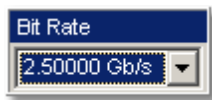
$$Y \text{ bits/screen}$$

$$\text{Bit period} = 1 / \text{bit rate}$$

$$\text{Time/screen} = -Y \text{ bits/screen} \times (\text{bit period})$$

$$\text{Time/division} = 0.1 \text{ time/screen}$$

### 5.15.2 Bit Rate



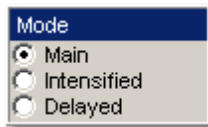
The **Bit Rate** allows the time base to be configured for a variety of standard optical and electrical telecommunications rates. If you are measuring a signal with one of these standard rates, the scale and delay functions will coincide with this rate.

The following bit rates are standard selections when you select **Bit Period** <sup>[344]</sup> as the horizontal (time base) scale units.

Bit Rate	Standard
1.544 Mbit/s	DS1
2.048 Mbit/s	PDH 2.048 Mb
3.152 Mbit/s	DS1C
6.312 Mbit/s	DS2
8.448 Mbit/s	PDH 8.448 Mb
34.368 Mbit/s	PDH 34.4 Mb
44.736 Mbit/s	DS3
51.84 Mbit/s	STM0/OC1
125.0 Mbit/s	FDDI
132.813 Mbit/s	FC133
139.264 Mbit/s	DS4/PDH 139 Mb
155.52 Mbit/s	STM1/OC3
265.625 Mbit/s	FC266
466.56 Mbit/s	OC9
531.25 Mbit/s	FC531
622.08 Mbit/s	STM4/OC12
933.12 Mbit/s	OC18
1.0625 Gbit/s	FC1063
1.24416 Gbit/s	OC24
1.250 Gbit/s	Gb Ethernet
1.86624 Gbit/s	OC36
2.12500 Gbit/s	
2.48832 Gbit/s	STM16/OC48
2.5000 Gbit/s	2XGb Ethernet/Infiniband
2.66606 Gbit/s	FEC 2666
3.1250 Gbit/s	XAUI
3.1870 Gbit/s	FC3187
3.3200 Gbit/s	12x Parallel Optics
9.95328 Gbit/s	STM64/OC192
10.3125 Gbit/s	10Gb Ethernet
10.51875 Gbit/s	10GFC
10.6642 Gbit/s	FEC 1066
10.709 Gbit/s	FEC 1071
11.0975 Gbit/s	
12.2495 Gbit/s	STM-64/OC-192 SuperFEC
19.90656 Gbit/s	STM-128/OC-384
39.81312 Gbit/s	STM-256/OC-768
42.65691 Gbit/s	FEC 4266
43.01841 Gbit/s	FEC 4302



### 5.15.3 Time Base Mode

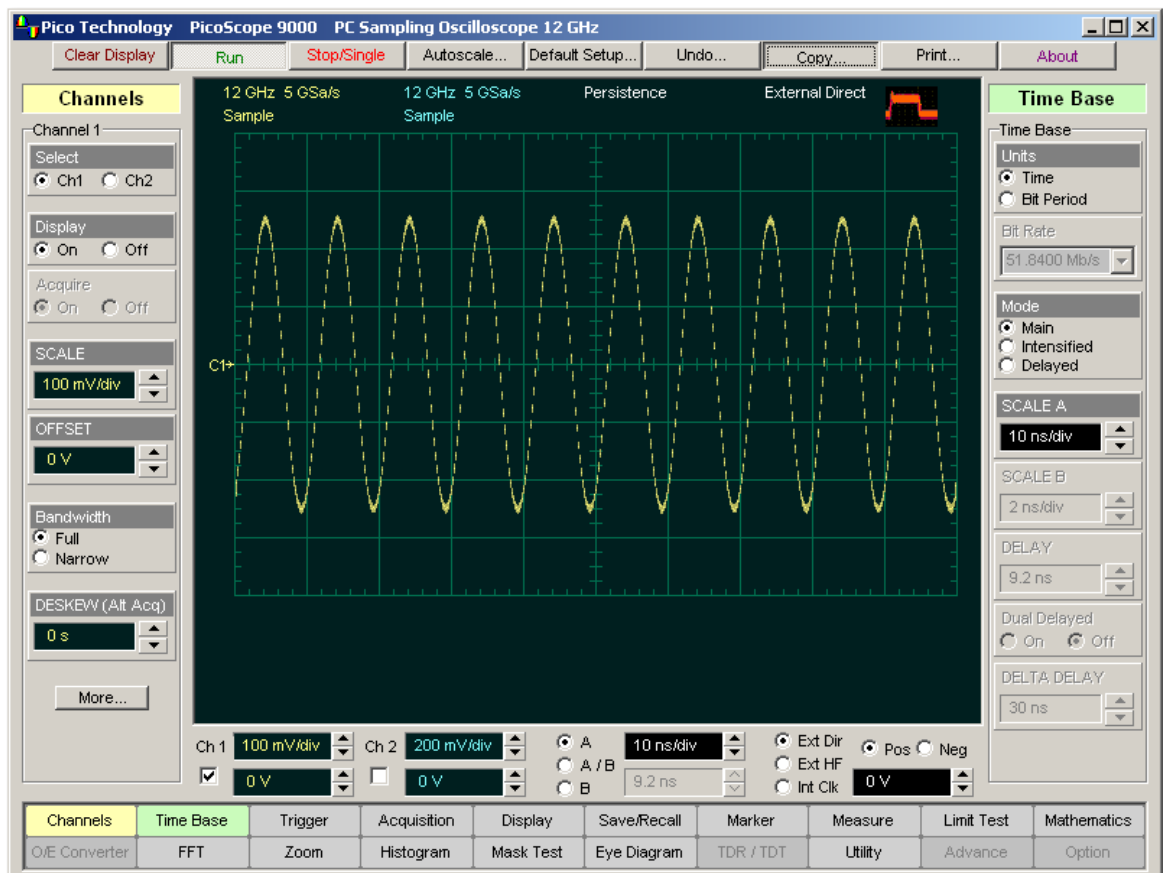


The **Mode** menu provides **Main**, **Intensified**, **Delayed**, or **Dual Delayed** timebase modes using time windowing.

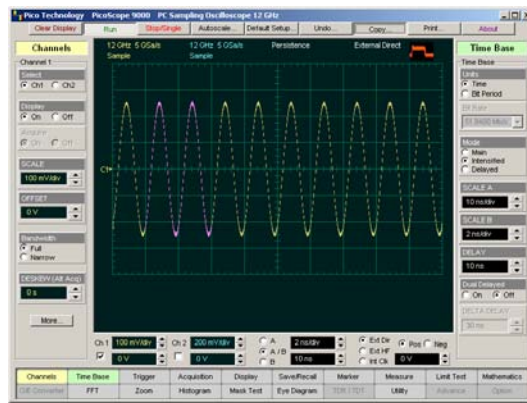
The **Time Base** windowing function is similar to the delayed or dual delayed sweep on traditional oscilloscopes because it turns on an expanded time base. This expanded time base allows you to pinpoint and to horizontally expand a portion (or two portions) of the signal for a more detailed or high-resolution analysis. It can also help you to make custom automatic measurements. Automatic measurements are made on the first occurrence of the event on the display. The windowing feature allows you to isolate individual events on the display for the automatic measurements.

Windowing includes several steps:

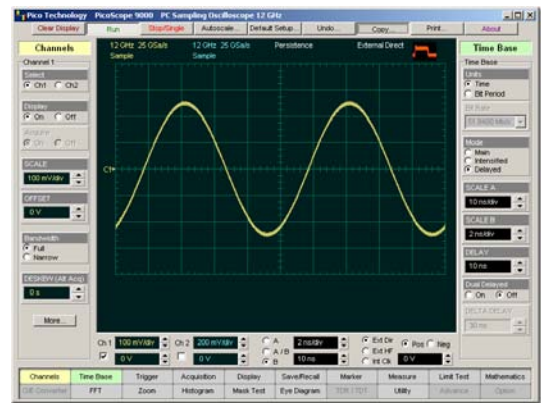
- Select main time base scale (**SCALE A**).
- Select one or two intensified time bases. Select the dimension (**SCALE B**) and position (**DELAY**) of the delayed time base or the **Dual Delayed** time base (**DELTA DELAY**) on the main time base trace.
- Click the **Delayed** or **Dual Delayed** timebase (**Delayed** or **Dual Delayed/On**).



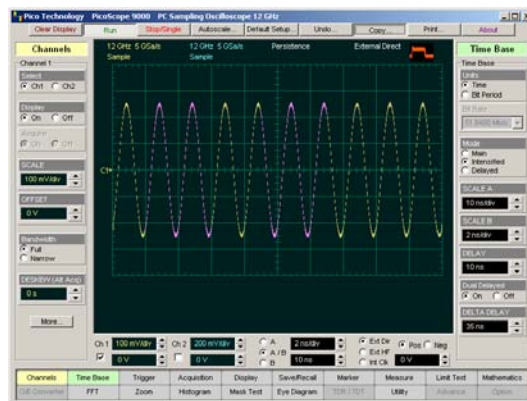
**Main Time Base Mode**



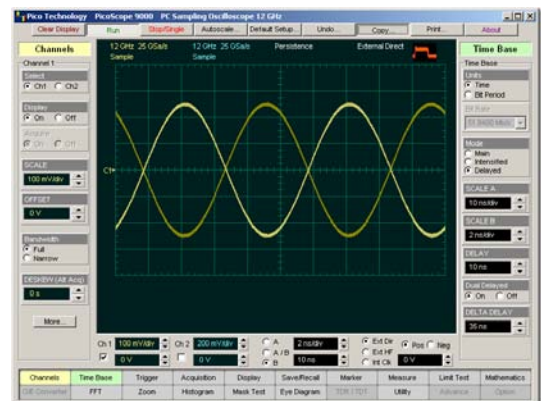
Intensified Time Base Mode



Delayed Time Base Mode



Intensified Time Base Mode

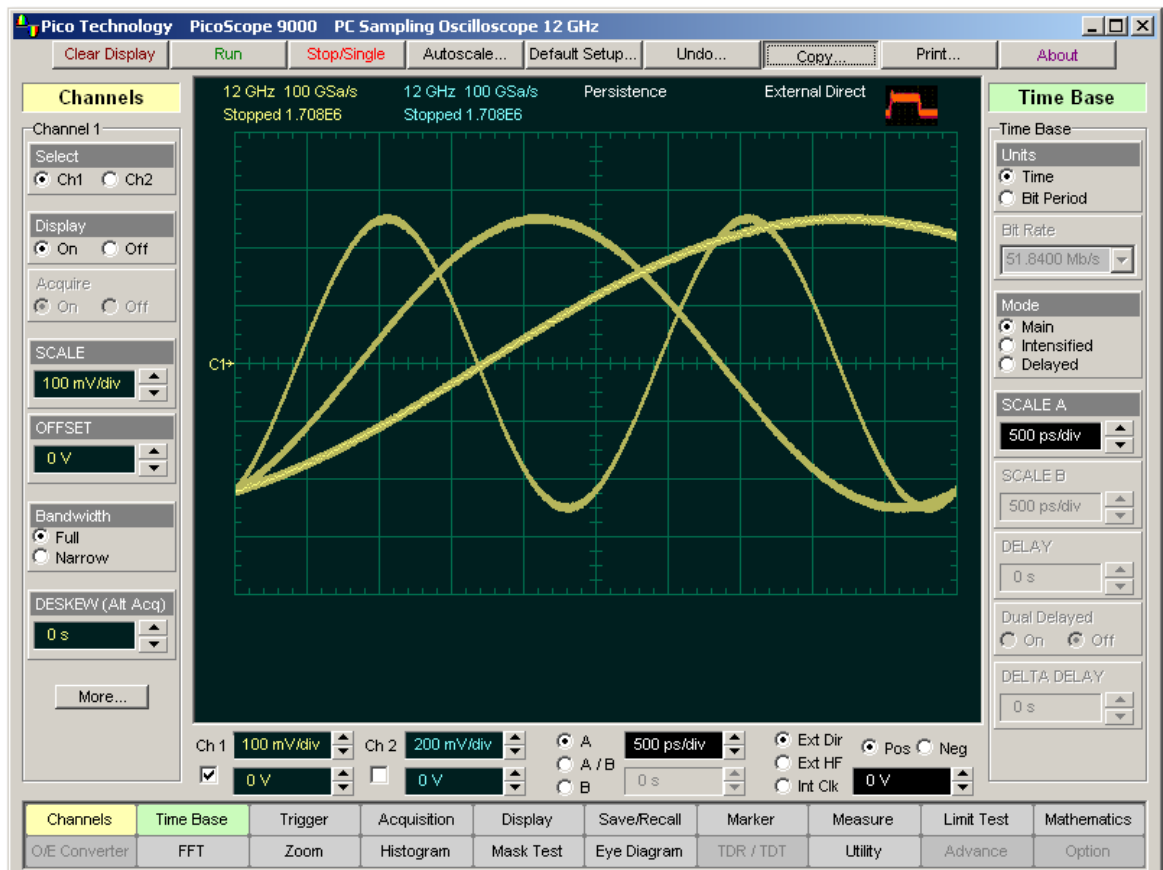


Dual Delayed Time Base Mode

## 5.15.4 SCALE A



The **SCALE A** function is similar to the time/div knob of the main timebase on a traditional oscilloscope. (Division in this instance equals 1/10 of the horizontal axis.) Adjusting the horizontal (timebase) scale control expands and compresses the displayed waveform horizontally.



### Horizontal scaling of a waveform

**SCALE A** controls horizontal scaling of the waveform. You can set the main timebase scale from 10 ps/div to 2 ms/div in one of three ways:

- By using the **SCALE A** spin box
- By using the corresponding spin box in the [Permanent Controls Area](#) <sup>[315]</sup>
- By using the [Pop-up Keypad](#) <sup>[375]</sup> to quickly enter numeric data for the timebase scale using the mouse.

If fine mode is off, the main timebase scaling is in a 1-2-5-10 sequence. When fine mode is on, you can adjust the main timebase scaling in 0.1% increments or smaller.

### 5.15.5 SCALE B



The **SCALE B** function is similar to the time/div knob of the delayed timebase on a traditional oscilloscope. Adjusting the delayed timebase scale control expands and compresses the displayed waveform horizontally.

**SCALE B** allows you to simultaneously control the time scale of both delayed timebases from 10 ps/div to 2 ms/div in one of three ways:

- By using the **SCALE B** spin box
- By using corresponding spin box in the [Permanent Controls Area](#)<sup>[315]</sup>
- By using the [Pop-up Keypad](#)<sup>[375]</sup> to quickly enter numeric data using the mouse.

If fine mode is off, the main timebase scaling is in a 1-2-5-10 sequence. When fine mode is on, you can adjust the main timebase scaling in 0.1% increments or smaller.

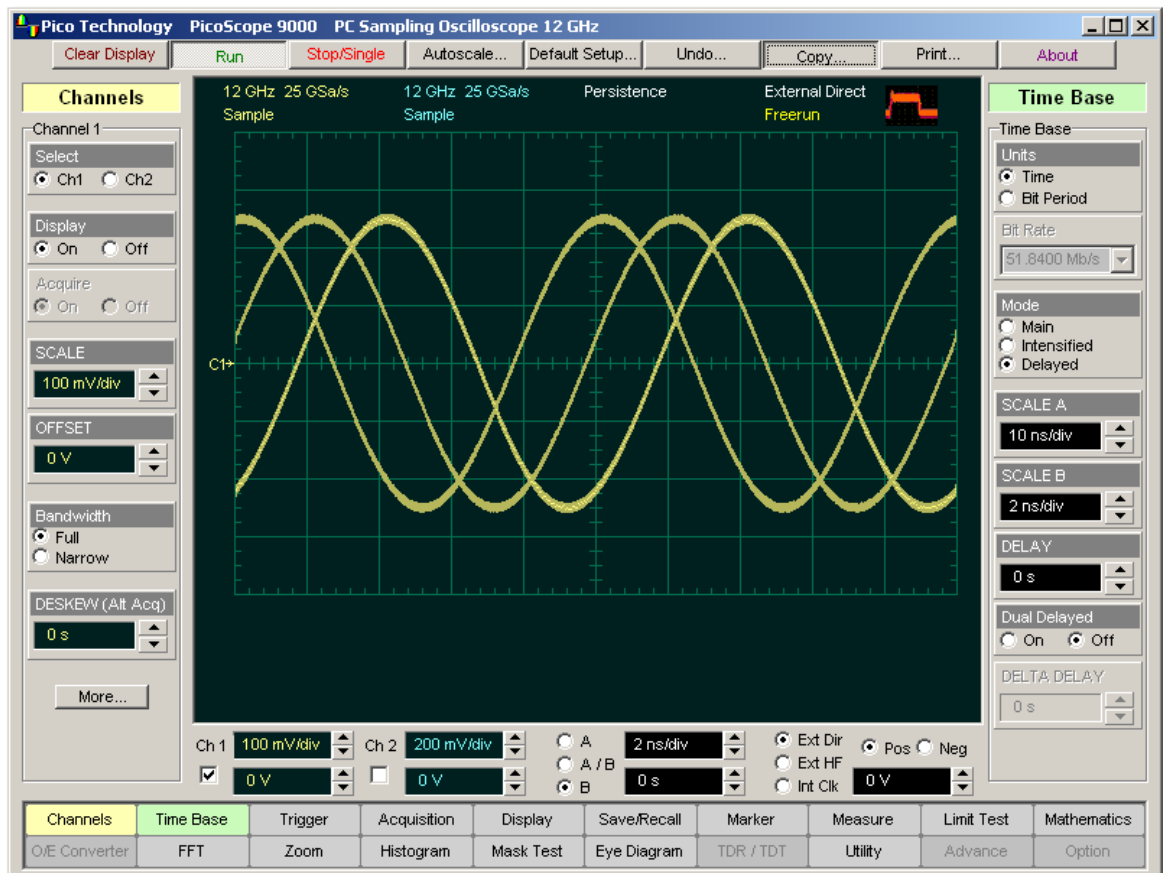


The **SCALE B** value cannot exceed the [SCALE A](#)<sup>[348]</sup> value.

## 5.15.6 DELAY



The **DELAY** function is similar to the delay knob of the delayed timebase on a traditional oscilloscope. **DELAY** is a post-trigger function, because it controls the delay from the trigger. The maximum post-trigger delay varies with the sweep speed, and the minimum delay (zero delay value) is limited by the propagation delay of the trigger path. The advantage of digital delay is that it is calibrated. Adjusting the delay moves the position of the input waveform horizontally. As the delay increases, the waveform moves to the left of the display graticule. As the delay decreases, the waveform moves to the right of the graticule.



**Delay of a waveform**

The **DELAY** spin-box allows you to simultaneously control the position of both delayed timebases from 0 up to maximum value of 10 divisions of main timebase in one of three ways:

- By using the **DELAY** spin box
- By using corresponding spin box in the [Permanent Controls Area](#) <sup>[315]</sup>
- By using the [Pop-up Keypad](#) <sup>[375]</sup> for some specific settings.

If fine mode is off, the delay can be changed in a sequence of 0.5 major divisions of the main timebase. When fine mode is on, you can change delay in a sequence of 0.001 major divisions of main timebase.

The possible maximum value of **DELAY** can be calculated from the following condition:

$$\text{Maximum Delay} + 10 \times \text{SCALE B} = 10 \times \text{SCALE A}$$

### 5.15.7 Dual Delayed



This function expands and displays the intensified portion of the waveform. The amount of expansion depends on the [SCALE B](#)<sup>[349]</sup> setting. The position of the first delayed timebase depends on the [DELAY](#)<sup>[350]</sup> setting, and the position of the second delayed timebase depends on both the [DELAY](#)<sup>[350]</sup> and [DELTA DELAY](#)<sup>[353]</sup> settings.

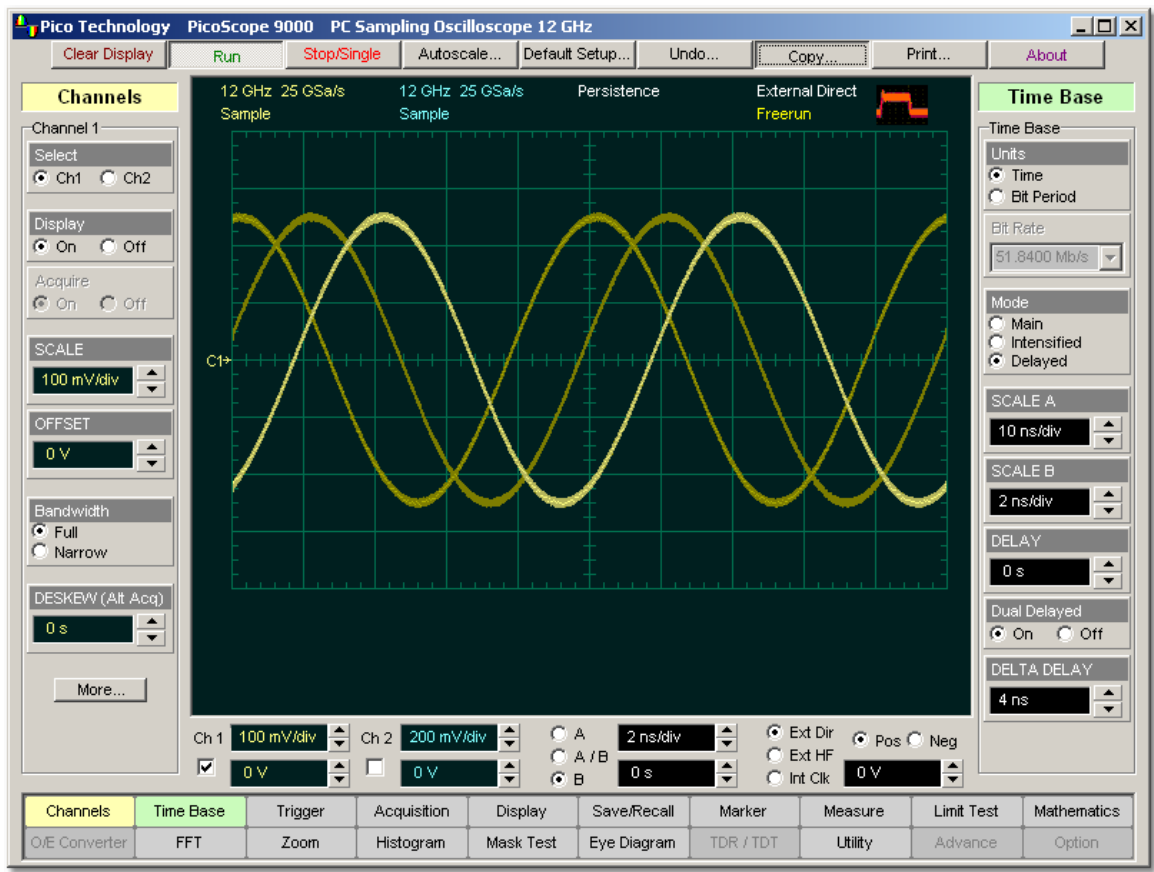
Click the **On** option to select the delayed timebase. The following conditions are then available:

- If **Off** is selected, the timebase is equivalent to **Delayed Time Base**
- If **On** is selected, the timebase is equivalent to **Dual Delayed Time Base**

## 5.15.8 DELTA DELAY



The **DELTA DELAY** function is similar to the delta delay knob of the dual delayed timebase on a traditional oscilloscope.



### Dual Delay of a waveform

The **DELTA DELAY** spin-box allows you to vary the position of the second delayed timebase relative to the position of the first delayed time base from 0 up to a maximum value of 10 divisions of the main timebase, in one of three ways:

- By using the **DELTA DELAY** spin box
- By using the corresponding spin box in the [Permanent Controls Area](#) <sup>[315]</sup>
- By using the [Pop-up Keypad](#) <sup>[375]</sup>

If fine mode is off, delta delay can be changed in a sequence of 0.5 major divisions of the main timebase. When fine mode is on, you can change the delay in a sequence of 0.001 major divisions of the main timebase.

The possible maximum value of the **DELTA DELAY** variable can be calculated from the following condition:

$$\text{Maximum delay} + \text{Maximum delta delay} + 10 \times \text{SCALE B} = 10 \times \text{SCALE A}$$



## 5.16 Trigger Menu



The scope trigger circuitry helps you locate the waveform you want to view. The oscilloscope uses a reference signal to determine precisely when to acquire data from the signal. The data can then be displayed as a function of time (relative to the reference signal). This reference signal is commonly referred to as a trigger.

The trigger event, when synchronized to the input signal, also defines the horizontal acquisition window. By choosing the trigger event and adjusting the horizontal position (delay between trigger event and the horizontal reference point) you control the location in the data stream (the input signal) from which the waveform record is taken.



## Types of trigger

There are several different types of trigger used in digitizing oscilloscopes. The PicoScope 9000 uses three of them:

- Edge trigger
- Prescaled trigger
- Clock recovery trigger

## Edge trigger

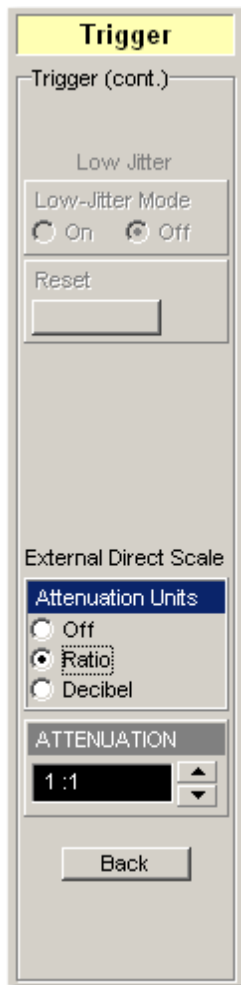
Edge trigger is the traditional and most often used type. It identifies a trigger condition by looking for the slope (rising or falling) and voltage level (trigger level) on the source you select. When the trigger edge crosses a predefined threshold, the oscilloscope begins to sample and acquire data from the signal. By acquiring data from the input signal, the oscilloscope can reconstruct the waveform and display it on the display screen.

## Prescaled trigger

Prescaled trigger extends direct triggering to signals up to 10 GHz. In this mode, there is no control over the trigger level or slope. The input circuitry includes a low-jitter high-speed 1:16 frequency divider. The divided signal is applied to the existing trigger circuitry. The trigger input is AC-coupled to the divider. The input threshold of the divider is set for maximum sensitivity and bandwidth, and it will operate correctly on a sine wave input from 1 GHz to 10 GHz. Square wave triggers, or other sharp-edged transitions, will function down to DC.

## Clock recovery trigger

This optional type is needed in cases where direct or prescaled trigger signals are not available. 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 lines used today from 12 Mb/s to 2.7 Gb/s bit rates.



The screenshot shows the 'Trigger' menu in a software interface. At the top is a yellow header with the word 'Trigger'. Below it is a section labeled 'Trigger (cont.)'. Inside this section, there is a 'Low Jitter' label, followed by a 'Low-Jitter Mode' section with two radio buttons: 'On' and 'Off', where 'Off' is selected. Below that is a 'Reset' button. Further down is an 'External Direct Scale' section with a sub-section 'Attenuation Units' containing three radio buttons: 'Off', 'Ratio' (which is selected and has a dotted border), and 'Decibel'. Below this is an 'ATTENUATION' section with a digital display showing '1 : 1' and two small up/down arrow buttons. At the bottom of the menu is a 'Back' button.

### External trigger inputs

Three external trigger inputs (one optional) are placed on the front panel:

- **DIRECT TRIGGER INPUT** SMA female. This input is used for edge triggering. PicoScope 9000 provides a 0 to 1 GHz direct trigger bandwidth.
- **PRESCALE TRIGGER INPUT** SMA female. This input is used for prescaled triggering. PicoScope 9000 provides 1 GHz to 10 GHz trigger bandwidth.
- **CLOCK RECOVERY TRIGGER INPUT** SMA female. This input is used for clock recovery triggering. PicoScope 9000 provides triggering on 12 Mb/s to 2.7 Gb/s bit rates.



When using a given trigger source, you should disconnect any other trigger source from the front panel to ensure specified performance.

## Triggering process

Oscilloscopes respond to trigger signals in different ways, depending on their architecture. The PicoScope 9000 uses digital sampling oscilloscope technology to acquire and display wide-bandwidth waveforms. This type of instrument employs a triggering scheme referred to as equivalent time sampling. The trigger circuit and sampler circuits operate in parallel. The sampler samples the input signal at a specific rate. The trigger circuit operates independently of the sampler circuit, and a trigger event does not have to occur at the same time as a sample point. Because the instrument knows when the trigger event happened in relation to the sampled data, it knows where to place the sampled data on the display.

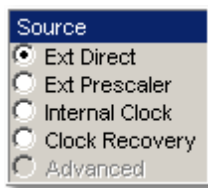
The triggering scheme is based up the following characteristics:

- An external trigger signal is required. The instrument does not have the ability to synchronize directly to the signal being measured.
- The instrument must be armed and an input channel must be turned on in order to respond to a trigger. Typically the instrument will be armed if it is placed in the **Run** mode. The instrument also becomes armed if it is in **Single** acquisition mode. The single acquisition mode occurs after the instrument is placed into **Stop** mode. Click the **Stop/Single** button repeatedly to toggle the instrument modes between stop and single acquisition.
- A significant time delay occurs between the time the instrument responds to a trigger and when the instrument is armed and able to respond to another trigger. This delay is called the rearm or setup and hold time, and is on the order of 5  $\mu$ s. Therefore, many trigger events can occur and are not responded to by the instrument while the rearming process takes place.
- A displayed waveform consists of several sampled points. A trigger event (edge) is required for each sampled point. For example, if the number of points making up a waveform trace is 512, then the instrument would have to respond to at least 512 trigger edges.
- A minimum time delay occurs between the time a trigger is received and when the data is actually sampled. This delay is on the order of 40 ns. Therefore, the signal at the trigger point (time 0) is usually not seen unless the data is delayed (through cable lengths or delay lines) relative to the trigger signal. The delay between the trigger event and the sample point can be longer than 40 ns. You can change the amount of delay in the [Time Base](#)<sup>[343]</sup> menu. Upon the next trigger event, a sample point is acquired at a small time increment in addition to the initial delay of 40 ns. Each additional trigger event yields sample points delayed by sequentially greater amounts of time. Therefore, after many triggers, the input waveform is reconstructed on the display screen.

The types of signals that can be viewed with these triggering requirements are divided into the following categories:

- Signals that are repetitive. The displayed waveforms are constructed from samples taken over multiple repetitions of the waveform. A trigger signal synchronous with the data is needed to control the timing of the sampling process.
- Signals that are not repetitive but are synchronous with a trigger signal. The primary example of a non-repetitive signal is the measurement of digital data streams or eye-diagrams with the oscilloscope triggered by a synchronous clock signal.

## 5.16.1 Source



The source provides the signal that the trigger system monitors. The **Source** function displays a list of the available trigger sources. There are four sources that the PicoScope 9000 can use for a trigger:

- **External Direct**
- **External Prescaler**
- **Internal Clock**
- **Clock Recovery (PicoScope 9201 only).**

**External Direct**

Connect an external trigger source to the **DIRECT TRIGGER INPUT** SMA female. The **External Direct** trigger source is an edge trigger. Use this mode when the trigger signal is in the frequency range DC to 1 GHz.



The **DIRECT TRIGGER INPUT** female connector is a DC-coupled input with 50- input impedance.

**CAUTION!**

To avoid damage to the **DIRECT TRIGGER INPUT** of the scope, make sure you do not exceed the maximum rated input voltage  $\pm 2$  V (DC + peak AC).

Using resistive divider probes you can increase the input impedance up to 5 kilohms, and using an active probe you can increase the input impedance up to 10 megaohms.

**External Prescaler**

Connect an external trigger source to the **PRESCALE TRIGGER INPUT** SMA female. The **External Prescaler** trigger source is a prescaled trigger. Use it when the trigger signal is in the frequency range 1 GHz to 10 GHz.

**Internal Clock**

With the **Internal Clock** source you can trigger the instrument from the precise internal clock. The frequency of the internal clock can be changed by the **INTERNAL RATE** control. Use this source as a TDR clock rate.



Changing trigger sources while the instrument is running causes newly acquired data to overwrite existing waveforms that are on the display. However, if the instrument is stopped, changing the trigger sources does not change the display until the instrument starts running again.

**Clock Recovery (PicoScope 9201 only).**

Connect an external trigger source to the **CLOCK RECOVERY TRIGGER INPUT** SMA female when the **Clock Recovery** trigger source is selected. This trigger source is a clock recovery trigger. Use it when the trigger signal is an NRZ data pattern with any data rate between 12.3 Gb/s and 2.7 Gb/s.

### 5.16.2 INTERNAL RATE



The **INTERNAL RATE** spin-box allows you to vary the repetition rate of the internal clock from 16 ns us to 2 ms. If fine mode is off, the repetition rate can be set to 16 ns, 24 ns, 32 ns, 40 ns, 80 ns, 160 ns or 200 ns, and then changed in a 1-2-5 sequence. When fine mode is on, you can change the repetition rate in 8 ns increments.

**INTERNAL RATE** is used only when the [Internal Clock](#)<sup>358</sup> source is selected.

### 5.16.3 Mode



The trigger modes control the behaviour of the instrument when not triggered. The **Mode** menu lets you select between **Freerun** and **Triggered** modes.

The **Mode** menu is active when the **External Direct**, **External HF** or **Clock Recovery** sources are selected in the [Source](#) <sup>[358]</sup> menu.

#### Freerun

With the **Freerun** mode, the trigger circuit is armed and the instrument waits for up to 400  $\mu$ s for a trigger occur. If a trigger does not occur within 400  $\mu$ s, the instrument triggers itself, and the data that is acquired with the trigger is displayed on the screen. Use the **Freerun** mode when you are unsure how to setup the trigger menu to trigger the instrument, or for DC trigger signals. This mode forces the instrument to trigger, giving you glimpses of the signal, which then allows you to set up the instrument to display the signal.

For waveforms whose period is greater than 400  $\mu$ s the **Freerun** mode should not be used, because the scope's 400- $\mu$ s timeout will always occur before your waveform trigger. For waveforms whose period is lower than 400  $\mu$ s, the **Freerun** mode works similarly to the **Triggered** mode.

Use **Freerun** triggering when you are not using an external trigger and you want to view the waveform for amplitude information only. **Freerun** triggering allows the instrument to trigger as soon as the instrument is armed, and is asynchronous to the data. You can also use **Freerun** triggering to view a signal without any timing information. It is an easy way to examine the amplitude of a signal.

#### Triggered

In **Triggered** mode, the instrument displays data only after all of the trigger conditions are met. **Triggered** mode keeps the instrument from triggering and displaying data on the screen before a specific trigger event occurs. Use **Triggered** mode to update the display only when a trigger event occurs or for waveforms that have a fundamental period of less than 400  $\mu$ s.

#### 5.16.4 LEVEL



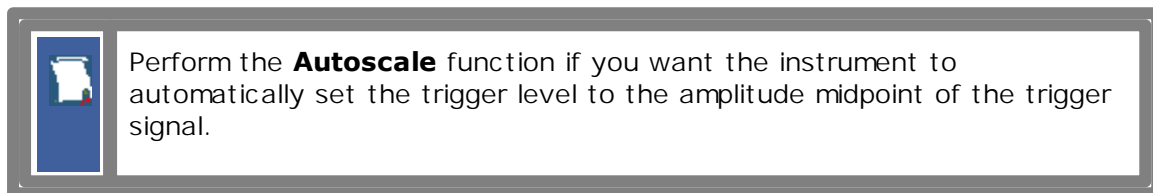
The **LEVEL** variable specifies the voltage threshold that a signal must cross in order for the instrument to trigger on that signal. When the input signal crosses this voltage level, the instrument triggers.

**LEVEL** is active only when **External Direct** is selected in the **Source**<sup>[358]</sup> menu.

You can select the trigger level in one of three ways:

- By using the **LEVEL** spin box
- By using trigger level spin boxes in the **Permanent Controls**<sup>[315]</sup> area.
- By using the **Pop-up Keypad**<sup>[375]</sup> to quickly enter numeric data using the mouse.

When the External Direct trigger source is selected, you can adjust the trigger level value between –1 V and 1 V in 10 mV steps (coarse increment) or 1 mV steps (fine increment).

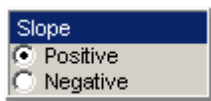


The trigger signal must be connected to the trigger input of the instrument. For example, if you are using the trigger input on the instrument front panel, the trigger signal must be connected to the front panel trigger input. **Autoscale** can then set the trigger level.

When direct (edge) trigger is in use, the trigger level setting also determines what the instrument uses as a reference to determine a high or low. A high is a voltage above the trigger level, and a low is a voltage below the trigger level.

**LEVEL** changes automatically if the attenuation factor is changed.

#### 5.16.5 Slope



The **Slope** menu specifies whether the instrument triggers on either the positive or negative edge of the signal. The **Slope** menu is active when the **External Direct** source is selected in the **Source**<sup>[358]</sup> menu.

**Positive.** Triggers on an edge that transitions through and above the trigger level.

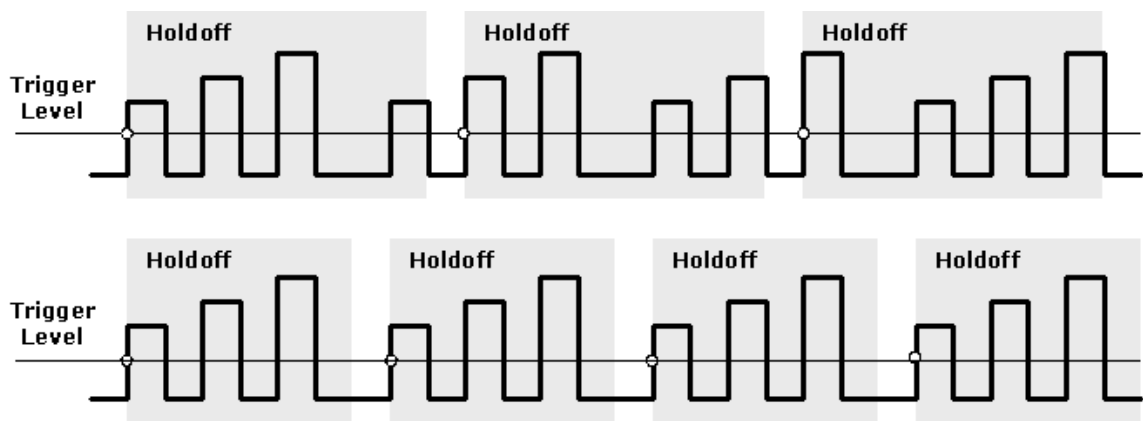
**Negative.** Triggers on an edge that transitions through and below the trigger level.



## 5.16.6 HOLDOFF



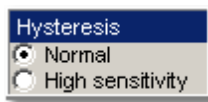
Trigger holdoff helps stabilize triggering. When you adjust the **HOLDOFF** control, the amount of time that the scope waits before re-arming the trigger circuitry also changes. Before re-arming, the trigger circuitry cannot recognize when the next trigger conditions are satisfied and so cannot generate the next trigger event. When the instrument is triggering on undesired trigger events, you adjust holdoff to obtain stable triggering. For example, if you have a burst of pulses and want to trigger on the first pulse in the burst, you can set the holdoff time to be slightly longer than the burst width.



The **HOLDOFF** spin-box allows you to change the holdoff time from 5  $\mu$ s to approximately 30.72 ms.

**HOLDOFF** is active when the **External Direct**, **External HF** or **Clock Recovery** sources are selected in the [Source](#) <sup>358</sup> menu.

### 5.16.7 Hysteresis



Trigger hysteresis helps to prevent false triggers from occurring on a falling edge due to noise when the rising edge is selected as the trigger edge (or on a rising edge when the falling edge is selected as the trigger edge).

The voltage through which the trigger signal must pass before the instrument is ready to accept another valid trigger is known as the arming voltage level. Hysteresis is the voltage difference between the arming level and the trigger threshold level.

The **Hysteresis** menu is active when **External Direct** is selected in the [Source](#) <sup>358</sup> menu.

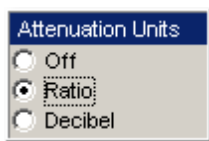
The trigger hysteresis can be set to two modes:

- **Normal.** Hysteresis is enabled. The trigger hysteresis is set so that the instrument meets the trigger sensitivity specification. The instrument will trigger if a trigger signal crosses both the arming voltage level and the trigger threshold voltage level. **Normal** mode provides good trigger performance while minimizing false triggers.
- **High sensitivity.** The trigger hysteresis is turned off to allow best sensitivity to high-frequency signals. This mode should not be used for noisy lower-frequency signals that may mistrigger without hysteresis, but can result in false triggers if there is significant noise on the trigger signal, or if the trigger signal is not monotonic in the region of the trigger threshold level.

### 5.16.8 External Direct Scale

The **External Direct Scale** functions can be used when the trigger signal level changes due to the use of an amplifier, attenuator or a probe. The attenuation factor can be entered either as a ratio or decibel value.

## 5.16.9 Attenuation Units



You can enter the attenuation or gain characteristics of an external device when configuring a trigger channel for external scaling. The **Attenuation Units** function lets you select how you want the probe attenuation factor represented. There are options for either decibel or ratio. The formula for calculating decibels is:

$$20\log(V_{out}/V_{in}) \text{ or } 10\log(P_{out}/P_{in})$$

**Decibel Versus Voltage Ratio:**

dB	Voltage Ratio
3 dB	1.41
6 dB	2.00
10 dB	3.16
20 dB	10
40 dB	100
60 dB	1000
120 dB	1 000 000
-80 dB	0.0001



Changing the attenuation factor does not attenuate the trigger signal; it only changes the database for generating prompts on the display. If the trigger signal must be attenuated, use external attenuators.



Gain is implied when you enter negative decibel values or ratios of less than 1:1 in the **ATTENUATION** variable. The default attenuation value is 1:1.

## 5.16.10 ATTENUATION

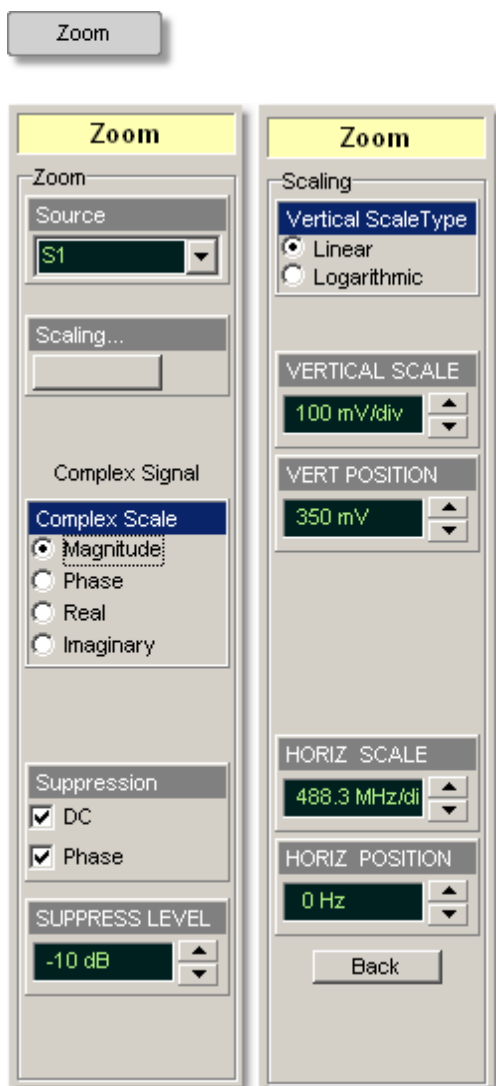


The **ATTENUATION** variable lets you select an amplification or attenuation that matches the device connected to the trigger input of the instrument. When the attenuation is set correctly, the instrument maintains the trigger level if possible. For example, if you want to trigger the scope with a 0 to 5 V trigger source, you can attenuate the source with a 20 dB pad to bring the level within external trigger limits. The pad lowers the source level to 0 to 0.5 V, but you can use external scaling to compensate for the 20 dB pad. This allows you to view the trigger source voltage in the trigger level spin-box as though no attenuation were present. Because of this scaling feature, you can set the scope to trigger at the precise source level you want without calculating the drop across the pad.

The trigger level attenuation factor is used to establish a database for generating the **LEVEL** prompts on the display.

The attenuation factor is from 0.000,1:1 to 1,000,000:1 or from -80 dB to 120 dB.

## 5.17 Zoom Menu



In addition to channel scaling and a delayed timebase, the PicoScope 9000 includes graphical zoom capability for rescaling the vertical and horizontal components of waveforms simultaneously. You can use the **Zoom** menu to change the vertical and horizontal scales and positions for waveform memories, or waveform math functions and spectrums that are currently displayed. Also the instrument will convert your time domain waveform into a frequency domain spectrum using an FFT, similar to the way that an RF spectrum analyzer displays in different complex scales.

## 5.17.1 Source



The **Source** menu selects the source trace for displaying with different complex scales, and for vertical and horizontal scaling and positioning.

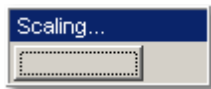
You may set the source to:

- spectrums 1 and 2
- functions 1 through 4
- waveform memories 1 through 4



Live waveforms from channels cannot be selected as sources in the **Zoom** menu.

## 5.17.2 Scaling



Clicking the **Scaling...** button opens a second-level menu that let you control vertical and horizontal magnification and positioning without affecting the channels and timebase scaling controls.

## 5.17.2.1 Vertical Scale Type



The **Vertical Scale Type** menu allows you to set the scale of the vertical display. Vertical units can be either linear or logarithmic.

**Linear.** Sets the display to the current source value. Usually this is volts, but it may also be watts or amperes.

**Logarithmic.** Sets the display of the results to dB. Use the **VERT POSITION** <sup>368</sup> to set what vertical position in the magnitude spectrum will be zero dB. The following equation applies:

$$dB = 20 \log_{10} \left( \frac{|X|}{X_{ref}} \right)$$

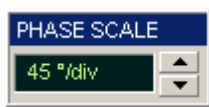
where:  $X$  is a complex data point in the spectrum, and  $X_{ref}$  is the reference value equal to 1 V.

## 5.17.2.2 VERTICAL SCALE

**Magnitude**

The **VERTICAL SCALE** function uses software expansion to set the vertical scaling of the selected waveform. It does not affect the hardware settings in the instrument, only the appearance of the waveform.

The scaling units are mV per division or dB per division. For example, if the vertical scale is set to 10 dB/div, and a peak is two divisions high, you know that the amplitude of the frequency peak is 20 dB. When scaling is set to 0 dBV, the display is in decibels relative to a 1 V peak sine wave (0 dBV) into 50 ohms.

**Phase**

The **PHASE SCALE** function uses vertical software expansion to set the phase characteristic of the spectrum. It does not affect the hardware settings in the instrument, only the appearance of the phase waveform. You can change phase scale from 4.5°/div to 90°/div.

## 5.17.2.3 VERT POSITION



The **VERT POSITION** controls use software to move the selected waveform vertically on the screen. Vertical position is the value at the centre of the graticule area. If you adjust the vertical position so that a peak is at the vertical centre of the graticule area, then you know that the peak magnitude is the vertical position value. For example, if the peak of the spike is at the vertical centre of the graticule area and the vertical position is -20 dBV, then you know that the peak magnitude is -20 dBV.

## 5.17.2.4 HORIZ SCALE



The **HORIZ SCALE** control allows you to zoom in a portion of the waveform record. Horizontal zooming can be entered in steps of 1-2-4-8. Changing the horizontal magnification of an FFT waveform using the **HORIZ SCALE** changes the appearance of the trace, but does not increase the horizontal (frequency) resolution.

You can also change the frequency interval and frequency range by changing the record length and horizontal scale of the time-domain waveform. If the record length increases, frequency resolution improves. When the equivalent sample rate increases (due to a faster horizontal size setting), frequency interval and frequency range both increase, giving the FFT waveform a broader frequency range with less frequency resolution.

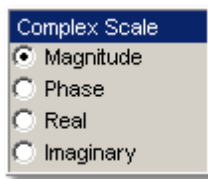
## 5.17.2.5 HORIZ POSITION



The **HORIZ POSITION** function allows you to move the horizontally expanded portion of the waveform record. The **HORIZ POSITION** variable uses software positioning.



## 5.17.3 Complex Scale

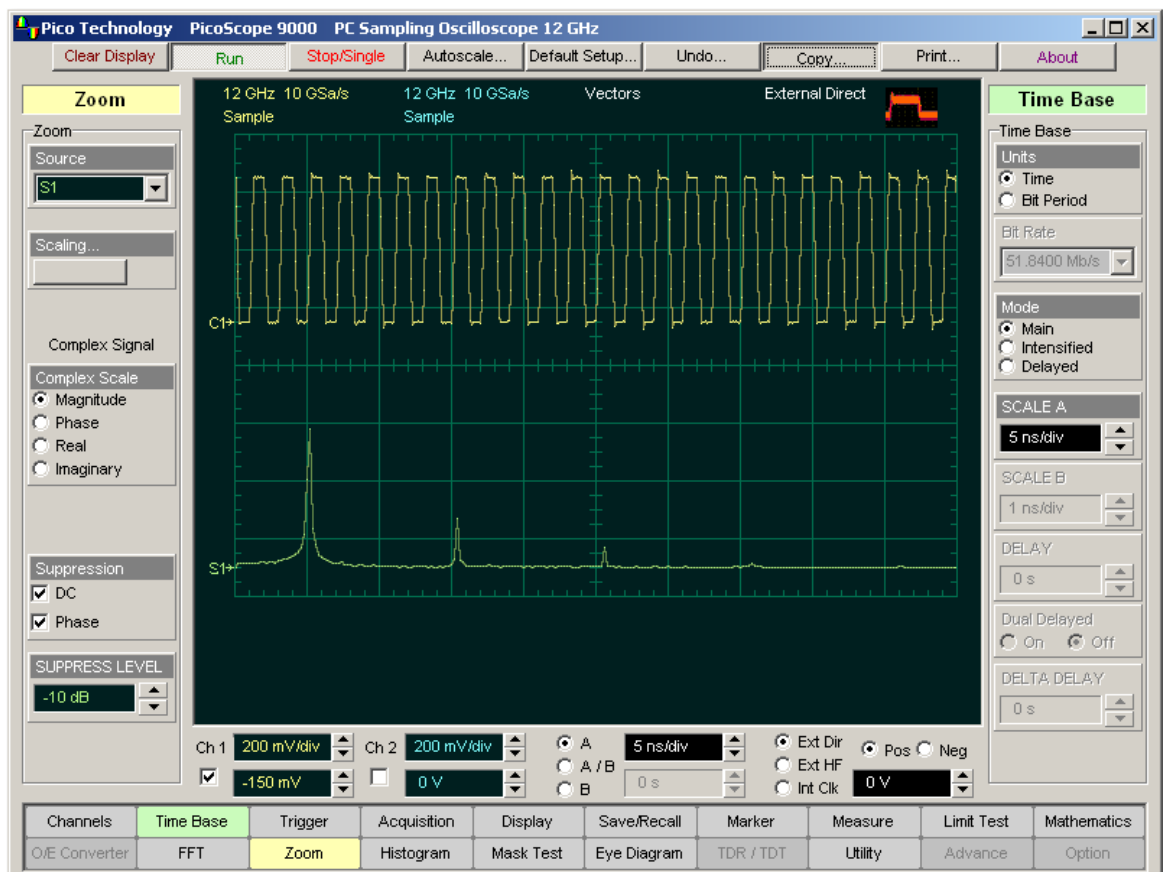


The **Complex Scale** menu selects the display format of a waveform that has a complex value. The options are:

- **Magnitude**
- **Phase**
- **Real**
- **Imaginary**

**Magnitude**

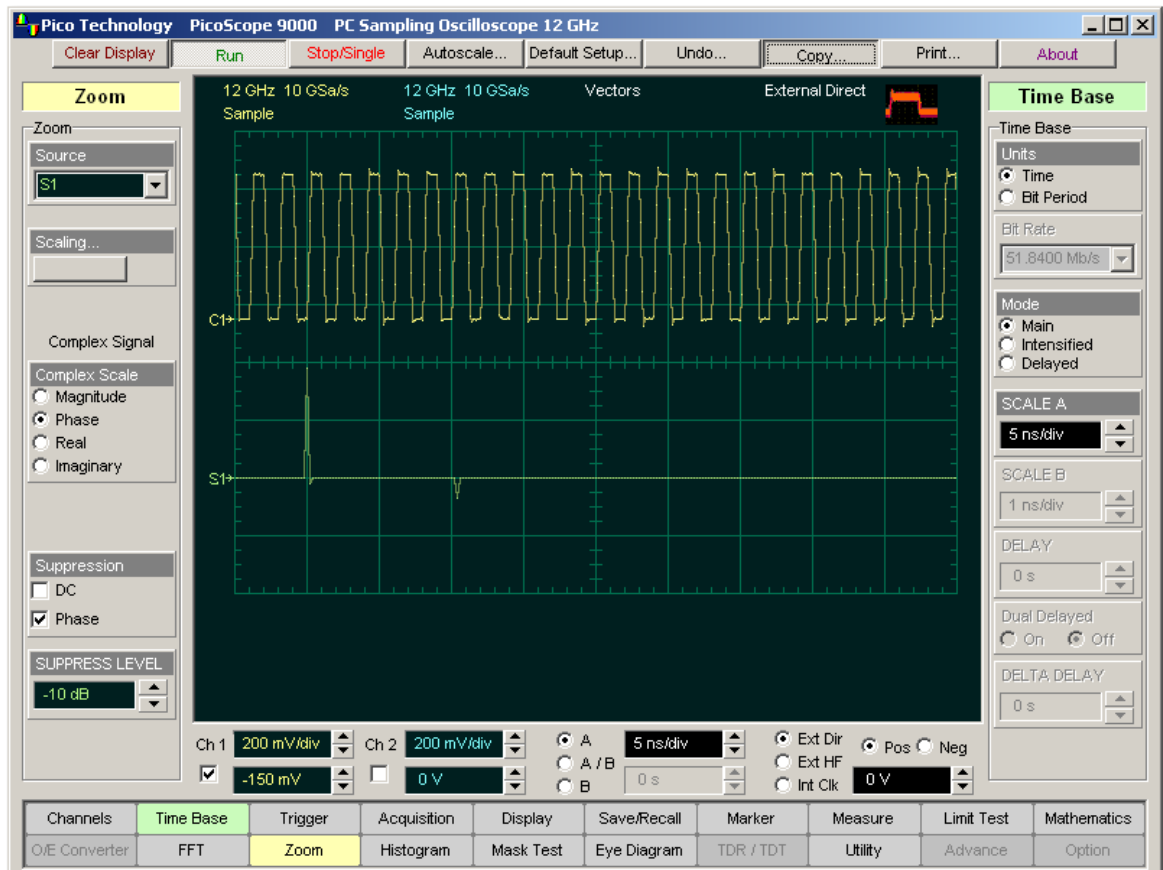
The peak signal amplitude is represented on a linear or logarithmic scale, in the same units as the input signal. You can choose to display data in dB or linear mode. You may display the real or imaginary parts of the spectral magnitude only. **VERT POSITION** control gives complete control over the vertical position of the spectrum.



**Spectrum Magnitude of 500-MHz pulse waveform**

## Phase

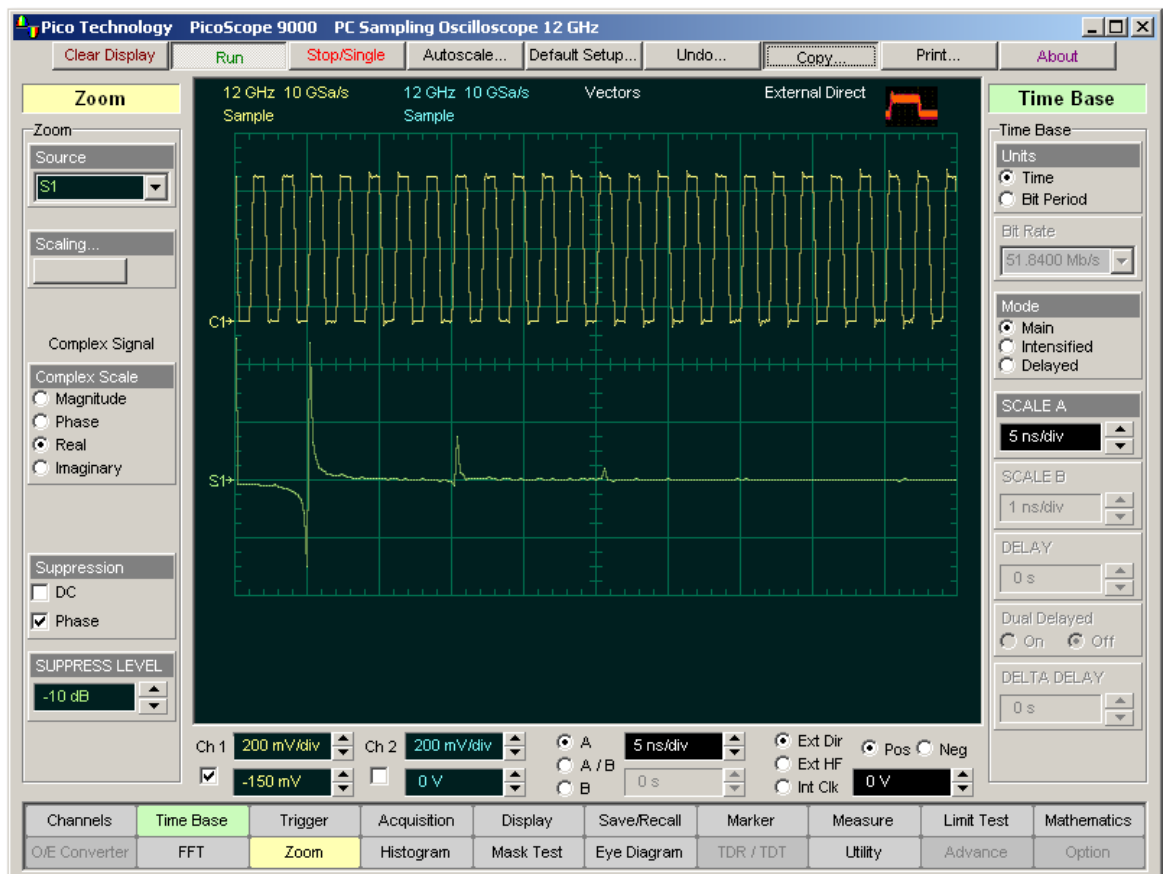
Phase is measured with respect to a cosine whose maximum occurs at the left-hand edge of the screen, at which point it is  $0^\circ$ . Similarly, a positive-going sine wave starting at the left-hand edge of the screen has a  $-90^\circ$  phase. You can display phase data as a function of frequency in degrees. You can zero the noise phase for magnitudes below a threshold level.



**Phase Spectrum of 500-MHz pulse waveform with deep suppression level**

## Real

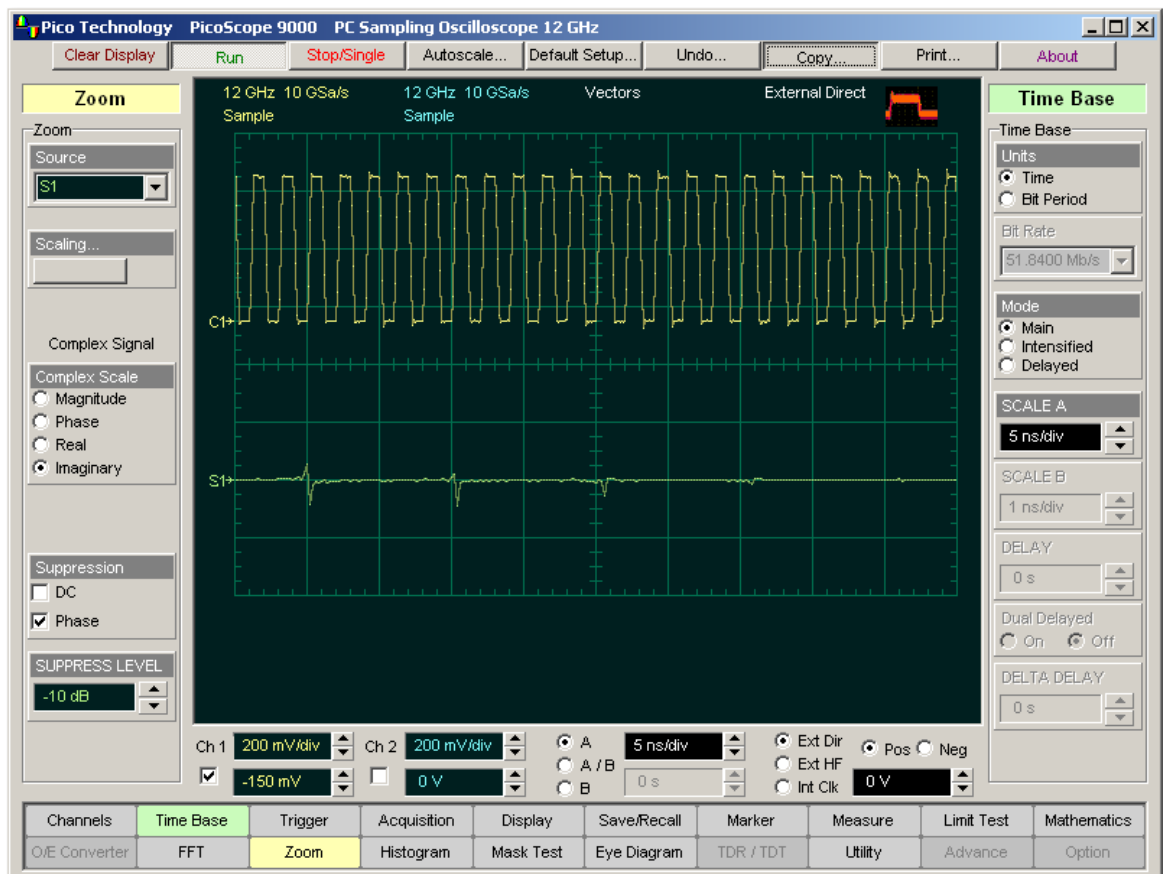
Displays the linear magnitude of the real part of the spectral magnitude only. This is useful if you process the spectrum off-line and transform it back into a time-domain trace. You could save the real spectrum into a waveform memory.



**Real part of the spectrum for 500-MHz pulse waveform**

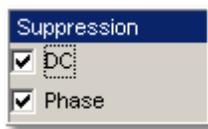
## Imaginary

Displays the linear magnitude of the imaginary part of the spectral magnitude only. This is useful if you process the spectrum off-line and transform it back into a time-domain trace. You could save the imaginary spectrum into a waveform memory.



**Imaginary part of the spectrum for 500-MHz pulse waveform**

#### 5.17.4 Suppression

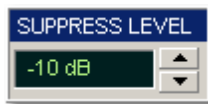


The **Suppression** mode allows you to reduce the DC components in your spectrum, and also to reduce the effect of noise in your phase FFT.

**DC.** Check the DC option to reduce the DC components in the FFT spectrum of the signal.

**Phase.** Your source waveform record may have a noise component with phase angles that randomly vary from - to + . This noise could make the phase display unusable. In such a case, use phase suppression to control the noise. Checking **Phase** reduces the effect of noise in your phase FFT.

#### 5.17.5 SUPPRESS LEVEL



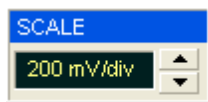
Your source waveform record may have a noise component with phase angles that randomly vary from - to + . This noise could make the phase display unusable. In such a case, use phase suppression to control the noise.

The **SUPPRESS LEVEL** control allows you to adjust the phase suppression level. You specify the phase suppression level in dB with respect to a peak having maximum amplitude among other peaks. If the magnitude of the frequency is greater than this threshold, then its phase angle will be displayed. FFT magnitudes below this level will have their phase set to zero.

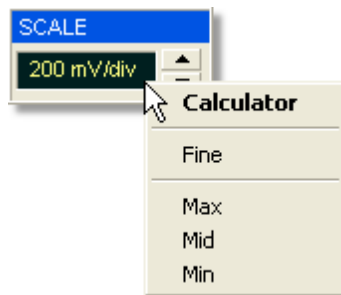
## 5.18 Pop-up keypad

The **Pop-up keypad** allows you to enter numeric values directly. You can use it with any numeric field in the PicoScope 9000 program: just right-click on the field and select **Calculator**. (You can also type variables directly into numeric fields: first type the number, then finish by typing a single letter - p,n,u,m,X,k,M,G,T. The meanings of these letters are explained below.)

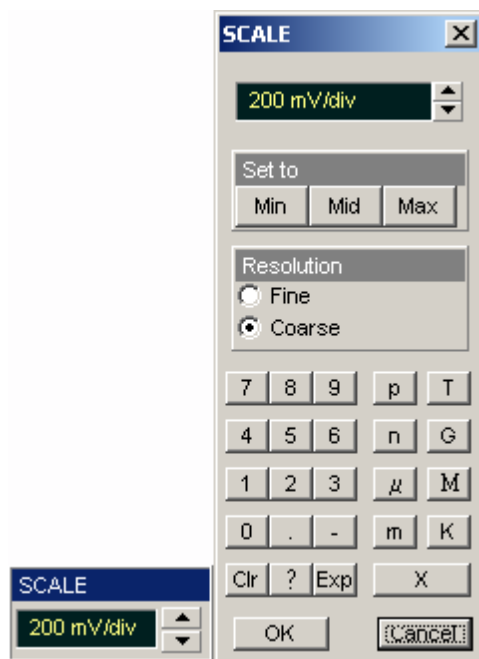
1. Choose the numeric field that you wish to edit:



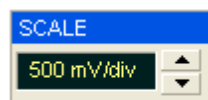
2. Right-click on the field to bring up the context menu:



3. Click the **Calculator** command to bring up the **Pop-up keypad**:



4. Enter the new value numerically by clicking the number keys, then click one of the multiplier buttons to complete the value. (The **X** button means a multiplier of 1.) Finally, click **OK** to update the numeric field:



## Special Key Definitions



**Min.** Enter the minimum value of selected variable.



**Mid.** Enter the middle value of selected variable.



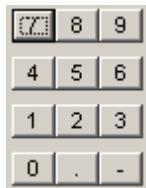
**Max.** Enter the maximum value of selected variable.



**Fine.** Enter the value of selected variable with fine resolution.



**Coarse.** Enter the value of selected variable with coarse resolution.



## Numeric value keypad

**Minus (-).** Changes the sign of the mantissa. Changes the sign of the exponent after you have pressed the exponent key.



## Dimension keypad

**p** (pico-suffix). Appends an exponent of  $10^{-12}$  to the number you have entered.

**n** (nano-suffix). Appends an exponent of  $10^{-9}$  to the number you have entered.

**u** (micro-suffix). Appends an exponent of  $10^{-6}$  to the number you have entered.

**m** (milli-suffix). Appends an exponent of  $10^{-3}$  to the number you have entered.

**K** (kilo-suffix). Appends an exponent of  $10^3$  to the number you have entered.

**M** (mega-suffix). Appends an exponent of  $10^6$  to the number you have entered.

**G** (giga-suffix). Appends an exponent of  $10^9$  to the number you have entered.

**T** (tera-suffix). Appends an exponent of  $10^{12}$  to the number you have entered.



**Clr** (Clear). Clears any numbers you have entered.



**Backspace.** Use the backspace key to erase the character to the left of the insertion point.



**Exp** (Exponent). The number you enter after pressing this key is an exponent of 10.

## 6 Glossary

### 6.1 A

#### **AC (Alternating Current)**

A signal in which the current and voltage vary in a repeating pattern over time.

#### **AC Coupling**

AC coupling removes the DC component of the waveform from the channel input or the trigger path. Only the AC portion of the waveform is displayed or used in the trigger path. You can use AC coupling to view an AC waveform with greater sensitivity or to trigger on an AC waveform that is riding on a DC waveform.

#### **Accuracy**

1. The closeness of the indicated value to the true value.
2. The percentage of error possible in transferring the signal through the vertical and horizontal channels.

#### **Acquisition**

Acquisition is the process of sampling an analog input waveform, digitising the samples and storing the samples in memory. The stored values represent the waveform record, which can be displayed as a waveform on the scope display, analysed, or transferred to a computer or a disk for further analysis. The trigger marks time in that process.

The Acquisition control allows you to define the way the instrument acquires data from the input waveform. You can set up the instrument to continuously acquire data, or you can acquire data in single cycles. Acquisition control also allows you to enable waveform averaging, enveloping, or peak detecting and record length (points per waveform).

#### **Acquisition Interval**

The time duration of the waveform record divided by the record length. The oscilloscope displays one data point for every acquisition interval.

#### **Acquisition System**

The acquisition system is a combination of hardware and firmware that converts an analog input waveform into discrete digital values and assembles the waveform samples into a waveform record.

#### **Acquisition Time**

In a sample-and-hold or track-and-hold circuit, the time required after the sample or track command for the output to slew through a full-scale voltage change and settle to its final value within a specified error band.

#### **AC RMS**

The AC RMS is a modified RMS (root-mean-square) measurement. It removes the DC component of the waveform from the calculation of the RMS voltage.

#### **ADC (Analog-to-Digital Converter)**

The ADC is the part of the hardware acquisition system in a sampling oscilloscope that converts the analog input waveform into discrete digital values, which make up the waveform record. Several characteristics of the ADC such as sample rate, resolution, accuracy, and linearity directly relate to the oscilloscope's performance.



**Alias**

Nyquist's sampling theorem says that a signal must be sampled at a minimum rate equal to twice the input signal frequency for accurate representation. Signals sampled at a rate lower than this minimum (the Nyquist Rate) will show up as low-frequency signals due to insufficient sample points. Such a signal is called an alias. The phenomenon is called aliasing.

**Alias frequency**

A false lower-frequency component that appears in analog data that is reconstructed from original data digitized at an insufficiently high sampling rate.

**Aliasing**

An invalid low-frequency waveform (a false representation of a signal), or an aliased waveform, may be displayed by a digitising scope if a high frequency waveform is sampled at too low a sample rate. The waveform displayed on the oscilloscope may have a lower frequency than the actual input signal.

Aliasing is a condition that occurs when an oscilloscope digitizes at an effective sampling rate that is too slow to reproduce the input signal. A waveform is aliased when it is sampled at a frequency that is less than two times the highest frequency component of the waveform. For the best waveform fidelity, the sample rate should be at least four times the highest frequency component of the waveform.

**Alternate Mode**

A display mode of operation in which the oscilloscope completes tracing one channel before beginning to trace another channel.

**Amplitude**

1. The magnitude of a quantity or strength of a signal. In electronics, amplitude usually refers to either voltage or power.
2. Amplitude is the amplitude of the waveform.
3. Amplitude = Top - Base where Top is the most prevalent point above the waveform midpoint and Base is the most prevalent point below the waveform midpoint.

**Analog-to-digital conversion**

The process that changes an analog signal into a digital magnitude value.

**AND**

Logical designation or circuit function meaning that all inputs must be in the TRUE state for a TRUE output.

**Annotations**

Lines displayed on screen to indicate measurement reference levels and points that an automatic measurement is using to derive the measurement value.

**Anti-alias filter**

A filter that attenuates noise and high-frequency components of an analog signal prior to its conversion into a digital value.

**Aperture Jitter**

In a sample-and-hold or ADC, the jitter between the time of the sample (or convert) command pulse and the time the input signal is actually sampled. This jitter is usually due to thermal noise.

**Aperture Uncertainty**

In a sample-and-hold or ADC, the total uncertainty in the time of the sample (or convert) command pulse and the time the input signal is actually sampled, due to all causes including noise, signal amplitude-dependent delay variation (as in a flash ADC), temperature, etc. Often used interchangeably with "aperture jitter," but "aperture uncertainty" is the more inclusive term.

**Area**

Measurement of the waveform area taken over the entire waveform or the gated region. Expressed in volt-seconds. Area above ground is positive; area below ground is negative.

**Attenuation**

Attenuation is the difference in a signal's voltage, current, or power when it goes through a probe or other attenuation device. When using a standard 10:1 probe on a scope, the input waveform will be reduced, or attenuated, by a factor of 10 in voltage or 20 dB. Probe attenuation may be set in the CHANNELS menu.

**Attenuation coefficient**

The rate of optical power loss with respect to distance; measured in decibels per kilometer (dB/km) at a specific wavelength.

**Auto**

Auto (or Freerun) is a trigger mode in which the trigger circuit is armed, and the instrument then waits for up to 400  $\mu$ s for a trigger to occur. If a trigger does not occur within 400  $\mu$ s, the instrument triggers itself, and the data that is acquired with the trigger is displayed on the screen.

**Automatic measurement**

An automatic measurement of a parameter and its numeric readout that the instrument takes and updates directly from a channel, math, or reference waveform in real time, without operator intervention.

**Autoprobe**

Autoprobe is an interface, which detects the some types of probe that are connected to a scope's input channels. Autoprobe automatically configures the vertical channel coupling and attenuation for the type of probe attached to the channel.

**Autoscale**

Autoscale (also Autoset) evaluates the input waveforms to a scope and adjusts the scope's controls to get a stable waveform display. Autoscale sets up front-panel controls based on the characteristics of the active waveform. In addition to turning on any channels that are sensed as active, trigger, horizontal, and vertical settings are adjusted automatically based on the input waveforms. A successful autoscale will set the volts/div, time/div, and trigger level to produce a coherent and stable waveform display.

**Autostore**

Autostore (see also Infinite Persistence) is a display mode in which acquired waveforms are displayed indefinitely.

**Average (Acquisition mode)**

In this mode, the oscilloscope acquires and displays a waveform that is the averaged result of several acquisitions. Averaging reduces the apparent noise. The oscilloscope acquires data as in the sample mode and then averages it according to a specified number of averages. You can use Averaging to eliminate random noise from a repetitive waveform.

**Average Optical Power (AOP)**

The time-averaged measurement of the optical power over a much longer time period than the bit rate of the signal.

**Averaging**

Mathematically smoothing the results of several measurements by adding them and dividing by the number of samples.

**6.2 B****Balanced**

A signal transmitted through a pair of wires, each having the same source impedance. Ground does not serve as a return path for the signal.

**Balanced sampling gate**

A type of sampling gate arranged so that strobe currents are balanced to minimise kick-out from the input connector of the sampler.

**Bandwidth or BW**

1. The bandwidth (BW) of the oscilloscope is the frequency range at which the channel-input circuits attenuate the waveform by 3 dB (70.7% of maximum). In modern specifications, bandwidth refers to the highest frequency signal the oscilloscope can acquire with no more than 3-dB (0.707) attenuation of the original (reference) signal. The PicoScope 9000 PC-Sampling Oscilloscope has a low-frequency response that extends to DC.
2. In normal use, the frequency range over which the gain of an amplifier or other circuit does not vary by more than 3 dB.
3. A range of frequencies over which a system works without degrading the original signal

**Bandwidth (Full or Narrow)**

When Narrow Bandwidth is enabled, the high-frequency noise of a waveform is reduced. When Narrow Bandwidth is enabled, it is easier to view on noisy waveforms.

**Bandwidth Limit or BW Limit**

The bandwidth limit is the instrument control that reduces the high frequency noise of a waveform by the use of a low-pass filter in the channel or trigger path of the instrument. Signals with high-frequency content may be distorted when the bandwidth is limited.

**Base**

Base is the statistically most prevalent voltage value below the waveform midpoint.

**Base-line drift**

Vertical movement of the entire trace under constant signal conditions and control settings.

**BER**

An acronym for Bit Error Ratio (or Rate). The principal measure of quality of a digital transmission system. BER is defined as:

$$BER = \text{Number of Errors} / \text{Total Number of Bits}$$

**BER floor**

A limiting of the bit-error-ratio in a digital system as a function of received power due to the presence of signal degradation mechanisms or noise.

**Bin**

Each frequency point represented in the frequency domain display of an FFT is called a bin.

**Binning**

A technique for combining points in a histogram to be compatible with the resolution of the display device.

**Blind Time**

In digital scopes, the blind time, or dead time, is the time from the end of one data acquisition to the beginning of the next acquisition. Better update rate in a scope means less dead time and less chance of missing a significant event.

**Bit**

One of the two numbers, 0 and 1, used to encode data. A bit is often represented by a high or low electrical voltage.

**Bit error**

An incorrect bit. Also known as a coding violation.

**Bit Error Rate**

Ratio of the number of bits of a message incorrectly received to the total number received.

**Bitmap or .bmp**

Bitmap, or .bmp, is a standard used for storing bit-mapped graphic files that can be imported into other Windows applications for documentation purposes.

**Blind Time**

In digital scopes, the blind time, or dead time, is the time from the end of one data acquisition to the beginning of the next acquisition. Better update rate in a scope means less dead time and less chance of missing a significant event.

**Blow-by**

A display aberration caused by signal-induced current through the sampling-gate shunt capacitance. The nature of the aberration depends on the circuit time constants.

**Bode plots**

The amplitude and phase plots as a function of frequency are known as Bode plots. The logarithmic amplitude thus defined is measured in dB.

**Brightness**

The value associated with a pixel that represents a gray value between black and white.

## 6.3 C

### **CCD**

Charge-Coupled Device. An integrated circuit that allows the transfer of a variable amount of charge through a series of cells; an analog shift register.

### **Channel**

A path through an arrangement of components (modules and electrical or optical cabling or both) along which signals can be sent. Also an input used for signal acquisition. The PicoScope 9000 PC Sampling Oscilloscope has two input channels.

### **Channel Ground Reference Indicator**

The indicator on the left side of the display that points to the position around which the waveform contracts or expands when vertical scale is changed. This position is ground when offset is set to 0 V; otherwise, it is ground plus offset.

### **Channel/probe deskew**

A relative time delay for each channel. The ability to adjust deskew lets you align signals to compensate for the fact that signals may come in from cables of differing length.

### **Chop Mode**

A display mode of operation in which small parts of each channel are traced so that more than one waveform can appear on the screen simultaneously.

### **Circuit Loading**

The unintentional interaction of the probe and oscilloscope with the circuit being tested, distorting the signal.

### **Coherency**

The optical power emitted from a laser diode after a specific current threshold is reached. Also known as Stimulated Emission.

### **Coherent display**

A display where the time sequence of signal events is preserved. A coherent display may be produced by either random or sequential sampling.

### **Color-Grading (Waveform Persistence)**

The color-graded persistence mode displays the sampled data points for an endless period of time. This persistence mode uses five color levels to represent the total number (density) of data counts acquired on a pixel (time and amplitude display coordinate) of the display graticule. Every time a display is acquired on a display coordinate, the counter for that coordinate is incremented. Each color used for the color grade mode represents a range of data counts. As the total count increases, the range of hits represented by each color also increases. If color grade is left on for a long time the waveform will become saturated with the color of highest hits.

You can use the color-graded persistence mode to display waveforms that use the instrument's measurement database. This database consists of all data samples displayed on the screen. The measurement database provides the data for the construction of histograms and the generation of mask tests.

### **Common Mode Range**

The maximum range (usually voltage) within which differential inputs can operate without a loss of accuracy.

### Common Mode Rejection Ratio

How well the common mode voltage is cancelled at different frequencies. 60 dB means that 1V of common mode voltage results in 1 mV at the oscilloscope input.

$$20 \times \log (1 \text{ V} / 1 \text{ mV}) = 60 \text{ dB}$$

### Common Mode Signal (Noise)

The signal (usually noise) that appears equally and in phase on each of the differential signal conductors to ground.

### Comparator

A circuit that compares two signals and changes a binary output when one signal exceeds the other.

### Compensation

Compensation is an adjustment process that maximizes the bandwidth of a probe by precisely adjusting the capacitor in the probe such that the input capacitance of the scope is canceled. Probe compensation is typically accomplished by connecting the probe to a calibrator waveform built in the scope and performing a simple adjustment to the probe to make sure the displayed square wave is as square and flat-topped as possible.

### Connect Dots

Connect dots is a display technique in which a straight line is drawn between two adjacent samples on the display (see [Vectors](#)<sup>[415]</sup>).

### Contrast Ratio

Contrast ratio is a measure of the RZ eye one level (at the eye window), to the one level found between eye diagram peaks.

### Conversion time

The time required from the moment a channel is interrogated to the moment that accurate data is available. Usually associated with DACs and ADCs.

### Convolution

The integration of the product of two functions in time. Convolution in the time domain is equivalent to multiplication in the frequency domain.

### Countdown

The process of dividing an input frequency by  $n$  to produce a lower-frequency output. Countdown is usually used in sampling oscilloscopes to generate a lower-frequency trigger signal by responding to every  $n$ th signal transition.  $N$  is an integer divisor that may or may not be constant.

### Counter

1. In software, a memory location used to store a count of certain occurrences.
2. In hardware, a circuit that counts events. See also event counter.

### Coupling

The method of connecting two circuits together. Circuits connected with a wire are directly coupled; circuits connected through a capacitor or a transformer are indirectly (or AC, frequency filtering) coupled.

**Crossing Percentage**

Crossing percentage is a measure of the amplitude of eye diagram crossing points relative to the one level and zero levels.

**Crossing Point**

The point in time, in an NRZ eye diagram, where the rising edge of a waveform intersects with the falling edge.

**Crosstalk**

1. A phenomenon in which one or more signals interfere with another signal.
2. Unwanted coupling of a signal from one channel to another.

**Cursors**

Cursors are two sets of horizontal and vertical markers in the waveform display area used for making custom voltage and time measurements. See [Markers](#) <sup>398</sup>.

**6.4 D****DAC**

Digital-to-analog converter.

**Dark Calibration**

Dark calibration (extinction ratio calibration) is a calibration that allows the instrument to identify internally generated offset (dark level) signals and remove them during the extinction ratio measurement calculations.

**Data acquisition (DAQ)**

Gathering information from sources such as sensors and transducers.

**Data Dependent Jitter**

Data-dependent jitter is pattern-related jitter caused by the combined effects of inter-symbol interference and duty cycle distortion.

**DC (Direct Current)**

A signal with a constant voltage and current.

**DC Coupling**

DC coupling passes both the AC and DC components of the waveform to the channel input or the trigger path. If a channel is DC-coupled, the DC component of the waveform can be quickly measured by noting the distance from the ground indicator.

**DC Level Shift**

A change in the nominal DC voltage level present in a circuit.

**DC Offset**

This term may imply that the shift is intentional, for example, adjustable by a control.

**DC Overload**

An overload signal of long duration compared to the normal input pulse width.

**DC RMS**

The DC RMS measurement is the typical method of making an rms (root-mean-square) voltage measurement.

**Dead Time**

In digital scopes, the dead time is the time from the end of one data acquisition to the rearm of the trigger circuitry for the next acquisition. Better update rate in a scope means less dead time and less chance of missing a significant event.

**Decibel (dB)**

A logarithmic measure of the ratio of two signal levels:

$$dB = 20 \log (Voltage_1 / Voltage_2) \text{ or } dB = 10 \log (Power_1 / Power_2)$$

Variants on the decibel (dB) used in spectrum-analysis and network-analysis measurements are:

dBmV	- absolute voltage level referred to 1 mV
dB $\mu$ V	- absolute voltage level referred to 1 $\mu$ V
dBm	- absolute power level referred to 1 mW
dBc	- level difference referred to a carrier level, c
dBc/Hz	- level difference referred to carrier level calculated for a measurement bandwidth of 1 Hz. (Spectrum and network analysis.)

**Delay**

Delay, or position, moves the waveform horizontally on the display. By adjusting the delay variable it is possible to view events that happen before (negative delay value) or after (positive delay value) the trigger point. Because the PicoScope 9000 is a sequential sampling oscilloscope, you can adjust the delay time only after (positive delay value) the trigger point.

**Delay By Events Triggering**

Delay by events triggering is a trigger mode in which the trigger circuitry arms on an edge from one of the channels, waits for a number of events on the selected channel, then triggers on an edge of the selected channel. Basically, the trigger criterion is two edge triggers separated by a selectable number of events.

**Delay By Time Triggering**

Delay by time triggering is a trigger mode in which the trigger circuitry arms on an edge of the selected channel, waits for a period of time, then triggers on an edge of the selected channel. Basically, the trigger criterion is two edge triggers separated by at least the selected period of time.

**Delay measurement**

A measurement of the time between the middle reference crossings of two different waveforms.

**Delayed Sweep**

Delayed sweep is a magnified portion of the main sweep. When delayed sweep is enabled, an expanded view of a selected portion of the waveform are displayed by the scope, allowing you to view and analyse the main sweep in more detail.

**Delay measurement**

A measurement of the time between the middle reference crossings of two different waveforms.

**Delay time**

The time between the trigger event and the acquisition of data. Also called Delta Time.



**Delta (Δ)**

Greek letter (uppercase) used to represent a finite change in a variable.

**Deterministic Jitter**

Deterministic jitter is data-related jitter. It is the combined effects of the data-dependent jitter, periodic jitter and bounded uncorrelated jitter components that are present on a signal. Deterministic jitter is bounded, meaning that measured values do not increase with longer measurement times.

**Differential Input**

A circuit with two inputs that is sensitive to the algebraic difference between the two.

**Differential Linearity**

A term often inappropriately used to mean differential non-linearity.

**Differential Output**

A circuit with two outputs supplying one normal and one complementary level of output signal.

**Differential Pulses**

Two opposite-polarity pulses coincident in time.

**Differential time domain reflectometry (TDR)**

A technique for determining the impedance of coupled transmission lines in which complementary steps are applied to the two sides of the line to be tested, and the timing and the amplitude of the reflected signals are to be measured.

**Differentiate (Signal Processing)**

The capability of an oscilloscope to display a derivative math waveform. The derivative math waveform indicates the instantaneous rate of change of the waveform acquired. One use of derivative waveforms is the measurement of amplifier slew rate.

**Digital Filtering**

The manipulation of digital data to both enhance desirable and to remove undesirable aspects of the data.

**Digital-to-analog conversion**

The process that changes discrete values into a voltage or current.

**Digitizing**

The process of converting a continuous analog signal such as a waveform to a set of discrete numbers representing the amplitude of the signal at specific points in time. Digitising comprises two steps: sampling and quantization.

**Display Update Rate**

In digital scopes, the number of trigger events that the scope can capture and display is referred to as its update rate. Unlike an analog scope, digital scopes require time to move the sampled data to memory, display the acquired data, do any post-processing math (such as Amplitude or Frequency measurements), and re-arm the trigger circuitry for the next acquisition. Technology advances have greatly improved the update rate in digital scopes. Better update rate in a scope means less dead time and less chance of missing a significant event.

**Display window**

The time window represented within the horizontal limits of the graticule.

**Dithering**

Typically used when averaging signals (which have low noise content) to improve vertical resolution and decrease the effects of an ADC's non-linearities. The technique applies different offsets to each incoming waveform to ensure the signal is not always digitized by the same portion of the ADC. The offsets must be subtracted from the recorded signals before being included in the summed average.

**Division**

Measurement markings on the graticule of the oscilloscope.

**Dragging**

The act of changing your selection either by clicking (with the mouse) or touching (on a touchscreen) a point on the screen and pulling across the screen while holding down the button (mouse) or maintaining contact with your finger (touchscreen).

**Duty Cycle**

Duty cycle is the average duration that a waveform remains above the mid-amplitude point as a percentage of the waveform period.

**Duty Cycle Distortion**

Duty Cycle Distortion (DCD) is caused by a different duration of 1's and 0's. It is a measure of the time separation between the rising edge and falling edge at the 50% level of an NRZ eye diagram (middle threshold). The duty cycle distortion is then the difference in time between the intersecting edges. The duty cycle distortion can also be viewed as a percentage of the time difference relative to the full bit period or the time between adjacent crossing points.

**Dynamic Range**

1. Dynamic Range specifies the amplitude (size) of a signal that can be input into the scope at a particular vertical scale without overdriving the front end, resulting in an inaccurate acquisition of data.
2. The ratio of the largest to smallest signal that can be accurately processed by a module.

## 6.5 E

**Earth Ground**

A conductor that will dissipate large electrical currents into the Earth.

**ECL**

Emitter-coupled logic, an unsaturated logic performed by emitter-coupled transistors. Usually, ECL logic 1 = -1.6 V and logic 0 = -0.8 V.

**Edge Triggering**

Edge triggering is the traditional scope-triggering mode. A trigger event is defined as a transitioning edge of a specified polarity (slope) crossing a specified voltage threshold (level).

**Effective Sample Rate**

In the equivalent-time sampling mode, a waveform record is built up by sequential or random repetitive samples taken from multiple trigger events. This process allows samples in the waveform record to be spaced more closely together for repetitive waveforms. As a result, the waveforms appear to have been sampled at a much higher rate, sometimes referred to as an effective sample rate. The effective sample rate is calculated by the formula:

$$\text{Effective sample rate} = \text{Record length} / \text{Time length of the record}$$

This is the same as  $1/(\text{time between the sample points})$ .

### **Electromagnetic compatibility (EMC)**

The ability of electronic equipment to operate in an intended electromagnetic environment without degradation caused by interference; and to operate in its electromagnetic environment without creating interference with other equipment.

### **EMI**

Electromagnetic interference caused by current or voltage induced into a signal conductor by an electromagnetic field.

### **Envelope**

An acquisition mode in which the oscilloscope acquires and displays a waveform that shows the signal's highest and lowest points acquired over many acquisitions.

### **Equivalent Time**

The time scale represented in the display of a sampling oscilloscope operating in the equivalent-time sampling mode.

### **Equivalent Time Sampling**

A sampling mode in which the oscilloscope constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. Thus, building the display takes longer than the time represented in the display.

In equivalent time sampling mode, a waveform record is built up by sequential or random repetitive samples taken from multiple trigger events. This process allows samples in the waveform record to be spaced more closely together for repetitive waveforms. As a result, the waveforms appear to have been sampled at a much higher rate, sometimes referred to as an effective sample rate.

In random equivalent-time sampling, an internal clock is used that runs asynchronously with respect to the input signal and the signal trigger. The oscilloscope takes samples continuously, independent of the trigger position, and displays them based on the time difference between the sample and the trigger. Although the samples are taken sequentially in time, they are random with respect to the trigger.

### **Error detection**

Checking for errors in data transmission. A calculation is made on the data being sent and the results are sent along with it. The receiving station then performs the same calculation and compares its results with those sent. Each data signal conforms to specific rules of construction so that departures from this construction in the received signals can be detected. Any data detected as being in error is either deleted from the data delivered to the destination, with or without an indication that such deletion has taken place, or delivered to the destination together with an indication that it is in error.

### **Error rate**

The ratio of the number of data units in error to the total number of data units.

**Extinction Ratio**

Extinction ratio is the ratio of the one level and the zero level of an eye diagram. This measurement is made in a section of the eye referred to as the eye window. Histograms are constructed using the sampled portions of the eye diagram within the eye window. One histogram is composed of data points from only the upper half of the eye diagram (one level). The second histogram is composed of data points from the lower half of the eye (zero level). The instrument analyses the histograms and determines the histogram means.

**Extrema**

The computation of a waveform envelope, by repeated comparison of successive waveforms, of all maximum points (roof) and all minimum points (floor). Whenever a given data point of the new waveform exceeds the corresponding maximum value in the roof record, it is used to replace the previous value. Whenever a given data point of the new waveform is smaller than the corresponding floor value, it is used to replace the previous value.

**Eye Diagram or Pattern**

Eye Diagrams are digital communication waveforms that consist of pseudo-random patterns of ones and zeros, which are best displayed as multivalued waveforms for analysis. Eye diagrams are multivalued waveforms because each point on the time axis has several voltage values associated with it. Single-valued waveforms, such as sine waves, square waves, and triangle waves, have a single voltage value associated with each point on the time axis. When analysing a digital communication waveform, single-valued displays are not very useful. By using infinite persistence feature, you can view eye diagrams.

**Eye Height**

Eye height is a measure of the vertical opening of an eye diagram.

**Eye Opening Factor**

Eye Opening Factor is a measure of the vertical opening of an RZ eye diagram. A noise contribution of 1 is subtracted from the logic mean levels.

**Eye Width**

Eye width is a measure of the horizontal opening of an eye diagram.

**Eye Window**

The eye window provides the time boundaries within which signal parameters for eye diagrams are measured.

**6.6 F****Fall Time**

1. Fall time is the time interval on a falling edge of a waveform between an upper threshold (usually the 90% point) and a lower threshold (usually the 10% point).
2. Fall time is a measure of the mean one level to zero level transition time of the data of an eye diagram. The data crosses through the upper, middle, and lower thresholds, as well as through the NRZ eye crossing points.

**False display**

A sampling display that allows faulty or ambiguous interpretation usually caused by insufficient sample density or improper triggering (also known as aliasing).

## Feedthrough

An unwanted signal that passes a closed gate or disabled input.

## FFT (Fast Fourier Transform)

The Fast Fourier Transform is a mathematical algorithm that takes the sample points of a waveform in the time domain and computes the frequency components.

The FFT function enables the oscilloscope to transform a waveform from a display of its amplitude against time to one that plots the amplitudes of the various discrete frequencies the waveform contains. Some uses for the FFT capability are measuring harmonic content and distortion in systems, analysing vibration, testing the impulse response of filters, and identifying noise sources in digital logic circuits.

## FFT Frequency Bins

A Fast Fourier Transform corresponds to analyzing the input signal with a bank of  $n/2$  filters, all having the same shape and width, and centered at  $n/2$  discrete frequencies. Each filter collects the signal energy that falls into the immediate neighborhood of its center frequency, and thus it can be said that there are  $n/2$  "frequency bins". The distance  $\Delta f$ , in Hz, between the center frequencies of two neighboring bins is always  $1/T$ , where  $T$  is the duration of the time-domain record in seconds. The nominal width of bin is equal to  $\Delta f$ .

## FFT Frequency Range

The range of frequencies computed and displayed in an FFT is 0 Hz to the Nyquist frequency.

## FFT Frequency Resolution

In a narrow sense, the frequency resolution is equal to the bin width,  $\Delta f$ . That is, if the input signal changes its frequency by  $\Delta f$ , the corresponding spectrum peak will be displaced by  $\Delta f$ . For smaller changes of frequency, only the shape of the peak will change. However, the effective frequency resolution (i.e., the ability to resolve two signals whose frequencies are almost the same) is further limited by the use of window functions. The ENBW value of all windows other than the rectangular is greater than  $\Delta f$  (i.e., greater than the bin width).

## FFT Number of Points

FFT is computed over the number of points (Transform Size) whose upper bound is the source number of points. FFT generates spectrums having  $n/2$  output points.

## FFT Phase

The time comparison in degrees or radians of a signal harmonic and the twiddle factor of the same frequency.

## FFT Windows

The FFT window can be set to rectangular, Hamming, Nicolson, Hanning, flattop, or Blackman-Harris. A rectangular window is useful for transient signals. Use the Hanning window for frequency resolution and general-purpose use. Use the flattop window for making accurate amplitude measurements of frequency peaks.

## Filter

An operation that selectively removes noise from a signal. Electronic filters include low-pass, band-pass, and high-pass types. Mathematical filters can operate on data to extract information and to enhance images.

**Fine**

Vernier, or fine control, allows a calibrated fine adjustment of a scaling factor such as the channel volts/div or the timebase time/div. For example, it is possible to set the V/div to 150 mV/div instead of the standard choices of 100, or 200 mV/div.

**Freerun**

Freerun is a trigger mode that will attempt to trigger the scope on the specified trigger conditions. If the trigger conditions are not met, a trigger will be forced, displaying the acquired data. This is a useful trigger mode to use if you are unsure about the exact trigger conditions, as it forces the scope to acquire and display a waveform, giving you a glimpse of the waveform. Caution should be used if the waveform is low-frequency as a free-running display may result even if the trigger conditions are valid. An alternative to the freerun trigger mode is the triggered, or normal, trigger mode, which requires that the trigger conditions be met before acquiring a waveform.

**Frequency**

The number of times a signal repeats in one second, measured in hertz (cycles per second). The frequency equals  $1/\text{period}$ .

**Frequency Bins**

The FFT algorithm takes a discrete source waveform, defined over  $N$  points, and computes  $N$  complex Fourier coefficients, which are interpreted as harmonic components of the input signal.

For a real source waveform (imaginary part equals 0), there are only  $N/2$  independent harmonic components.

**Frequency Domain**

Signals displayed with frequency along the X-axis and magnitude along the Y-axis.

**Frequency Range**

The range of frequencies computed and displayed is 0 Hz (displayed at the left-hand edge of the screen) to the Nyquist frequency (at the rightmost edge of the trace).

**Frequency Resolution**

In a simple sense, the frequency resolution is equal to the bin width  $\Delta f$ . That is, if the input signal changes its frequency by  $\Delta f$ , the corresponding spectrum peak will be displaced by  $\Delta f$ . For smaller changes of frequency, only the shape of the peak will change. However, the effective frequency resolution (that is, the ability to resolve two signals whose frequencies are almost the same) is further limited by the use of window functions.

**Frequency standard**

A precise frequency generator such as a rubidium, cesium, or hydrogen maser whose output is used as a frequency.

**Functions**

Functions are mathematical operations (such as Add, Subtract, and Multiply) that can be performed on input waveforms, stored waveform memories, or even other functions. There are four functions, F1 to F4, which can be set up in the [Mathematics](#)<sup>[234]</sup> menu. When the function is set up and turned on, a post-processing calculation is done and a new waveform is displayed.

## 6.7 G

### **Gated measurements**

A feature that lets you limit automated measurements to a specified portion of the waveform. You define the area of interest using measurement gates.

### **GIF**

GIF (Graphics Interchange Format) is a standard graphics format used to store bit-mapped graphic files that can be imported into other applications for documentation purposes.

### **Gigahertz (GHz)**

1,000,000,000 hertz; a unit of frequency.

### **Glitch**

A spike or short-time duration structural aberration on an otherwise smooth waveform that is normally characterized by more gradual amplitude changes. In digital electronics, where the circuit under test uses an internal clock, a glitch can be considered to be any pulse narrower than the clock width. Glitch is an intermittent error in a circuit.

### **Glitch**

A spike or short-time duration structural aberration on an otherwise smooth waveform that is normally characterized by more gradual amplitude changes. In digital electronics, where the circuit under test uses an internal clock, a glitch can be considered to be any pulse narrower than the clock width.

### **GPIB (General Purpose Interface Bus)**

GPIB (General Purpose Interface Bus), or IEEE 488 bus, is an interconnect bus and protocol that allows multiple test and measurement instruments to be linked together in a network under the control of a computer. GPIB transfers data and commands with eight parallel data lines and several control and handshake lines. Also called HP-IB.

### **Graphics Interchange format or .gif**

Graphics interchange format or .gif is a standard graphics format used to store bit mapped graphic files that can be imported into other applications for documentation purposes. You can save the .gif file to the internal hard disk or an external memory device. It is a compressed, 256-color file format.

### **Graticule or Grid**

The graticule, or grid, is the enclosed area where the waveform is displayed on a scope. Tick marks on the frame or axis of the graticule or horizontal and vertical lines within the graticule are a scaling aid for making visual measurements.

### **Gray Scale (Waveform Persistence)**

The gray-scale waveform persistence mode displays the sampled data points for an endless period of time. This persistence mode uses one hue that varies in saturation and luminosity to represent the number (density) of data counts acquired on a pixel (time and amplitude display coordinate) of the display graticule. Every time a display is acquired on a display coordinate, the counter for that coordinate is incremented. Each level of saturation and luminosity used for the gray-scale mode represents a range of data counts. The peak density of data counts is represented by the by the brightest regions of the waveform. You can use the gray-scale persistence mode to display waveforms that use the instrument's measurement database. This database consists of all data samples displayed on the screen. The measurement database provides the data for the construction of histograms and the generation of mask tests.

**Ground**

1. A conducting connection by which an electric circuit or equipment is connected to the earth to establish and maintain a reference voltage level.
2. The voltage reference point in a circuit.

**Ground Loop**

A circuit with multiple low-impedance paths connected to the same ground potential. A ground loop acts as a shorted transformer turn, which induces circulating ground currents. These currents produce slight changes in the ground potentials within the circuit.

## 6.8 H

**Harmonic distortion (HD)**

A form of distortion in analog circuits that generates harmonics (signals whose frequencies are integer multiples of the input signal). It is calculated as the ratio of a single harmonic to the level of the original signal. Harmonic distortion is related to total harmonic distortion (THD), the ratio of the sum of multiple harmonics to the level of the original signal.

**Hardcopy**

The ability to save an oscilloscope display in an electronic format usable by a printer.

**Hertz (Hz)**

The unit of frequency. One hertz is equal to one cycle per second.

**HF Reject**

HF Reject removes the high-frequency portion of the triggering signal. Thus, only low-frequency components are passed on to the triggering system to start an acquisition. High-frequency rejection attenuates signals above tens of kHz.

**HF Sync**

Reduces the trigger rate by including a frequency divider in the trigger path, enabling the input trigger rate to exceed the maximum for repetitive signals.

**High**

The value used as the 100% level in amplitude measurements, such as Peak and Overshoot.

**High-pass filter**

A circuit that attenuates low-frequency components in an analog signal.

**Histogram**

A graphical statistical representation of data such that the data is divided into intervals or bins. The intervals or bins are then plotted on a bar chart where the height is proportional to the number of data points contained in each interval or bin. The distribution of acquired data is displayed within a user-definable window.

**Holdoff by Events**

Selects a minimum number of events between triggers. An event is generated when the trigger source meets its trigger conditions. A trigger is generated when the trigger condition is met after the selected number of events from the last trigger. The hold-off by events is initialized and started on each trigger.



**Holdoff by Time**

Holdoff time is the amount of time that the scope waits before rearming the trigger circuitry. By using different holdoff times, complex waveform triggering can be stabilised.

**Horizontal Acquisition Window**

A common time window or range that is applied to all channels in parallel to determine the segment of an incoming signal that becomes the waveform record. The trigger and horizontal controls determine the duration of this window and its placement in the incoming signal.

**Horizontal bar cursors**

The two horizontal bars that you position to measure the voltage parameters of a waveform. The oscilloscope displays the value of the cursors with respect to ground and the voltage value between the bars.

**Horizontal Reference**

1. The trigger point corresponds to the horizontal reference point when the horizontal position is set to zero. Reference represents the point from which the delay offset is calculated.
2. The point about which waveforms are expanded or contracted horizontally when horizontal scale adjustments are made. The horizontal reference point remains anchored as the rest of the waveform grows or shrinks around it.

**Horizontal Scale**

Horizontal scale is an instrument control that controls the X-axis or time per division of displayed waveforms. Referred to as sweep speed in some instruments

## 6.9

## I

**IEEE-488.2 (See [GPIB](#) <sup>392</sup>)**

**Impulse**

An electromagnetic pulse of short duration--shorter than one cycle at the highest frequency being considered.

**Infinite Persistence**

Infinite persistence is a display mode in which acquired waveforms are displayed indefinitely. In the usual display modes, waveforms are overwritten with each acquisition, but when infinite persistence is selected, old waveforms are not erased and sample points accumulate on the display like a storage scope. You can use infinite persistence to measure worst-case timing jitter on a waveform. Other applications include display of eye diagrams (telecommunications) or detection of metastable states in logic designs.

**Initialization**

A process of setting the instrument to a completely known, default condition.

**Integral Linearity**

A term often used inappropriately to mean integral non-linearity.

**Integral Non-Linearity**

Deviation of ADC response from an appropriate straight-line fit. The specification is sometimes defined as maximum deviation, expressed as a fraction of full scale. More recent ADCs have a specification expressed as a percent of reading plus a constant.

**Integrate**

The capability of an oscilloscope to display an integral math waveform. The integral math waveform is computed from the acquired waveform. One use of integral waveforms is for measuring power and energy.

**Interleaved Clocking**

Supplying clock pulses of equal frequency to parallel circuits or instruments in order to increase the system sample rate. An example is the use of two transient recorders with inputs in parallel but complementary clocks to allow operation at twice the maximum rate of a single unit.

**Internal clock**

A trigger source that is synchronized to the internal clock, with a selectable repetition rate. It is most often used with TDR to synchronize the generation of TDR step pulses with subsequent acquisition.

**Interpolation (Signal Processing)**

Generally speaking, a "connect-the-dots" processing technique to estimate what a fast waveform looks like based on only a few sampled points. More specifically, Interpolation refers to the way the oscilloscope calculates values for record points when the oscilloscope cannot acquire all the points for a complete record with a single trigger event. That condition occurs when the oscilloscope is limited to real-time sampling and the timebase is set to a value that exceeds the effective sample rate of the oscilloscope. The oscilloscope can have two interpolation options: linear or  $\sin(x)/x$  interpolation.

Linear interpolation calculates record points in a straight-line fit between the actual values acquired.  $\sin(x)/x$  computes record points in a curve fit between the actual values acquired. It assumes all the interpolated points fall in their appropriate point in time on that curve.

**Integrate**

The capability of an oscilloscope to display an integral math waveform. The integral math waveform is computed from the acquired waveform.

**Interval Trigger**

Selects an interval between two edges of the same slope. The trigger can be generated on the second edge if it occurs within the selected interval or after the selected interval. The timing for the interval is initialized and restarted whenever the selected edge occurs.

**6.10 J****Jitter**

Jitter is any frequency- or phase-related spurious variation of a waveform from its ideal. It consists of short-term fluctuations in the output of a circuit or instrument that are independent of the input. It appears on a waveform edge before or after the trigger point as a wide, smeared edge.

1. Jitter is the measure of the time variances of the rising and falling edges of an eye diagram as these edges affect the crossing points of the eye.

2. Jitter is a measure of the time variances of the rising or falling edges of a pulse waveform at the middle threshold.

### **JPEG or .jpg**

The JPEG file format, or .jpg, is a graphics file format that can be imported into other applications for documentation purposes. It can be greatly compressed, but because this compression is lossy, it can result in reduced image quality. This format is a good choice where file size is a more important factor than image quality.

## **6.11 K**

### **Kick-out**

A signal, usually unwanted, from the internal circuitry that comes out of an input connector.

### **Kilohertz (kHz)**

1000 hertz; a unit of frequency.

## **6.12 L**

### **Leakage**

In the power spectrum of a sine wave with an integral number of periods in the (rectangular) time window (that is, where the source frequency equals one of the bin frequencies), the spectrum contains a sharp component whose value accurately reflects the source waveform's amplitude. For intermediate input frequencies this spectral component has a lower and broader peak.

The broadening of the base of the peak, stretching out into many neighboring bins, is termed *leakage*. It is due to the relatively high sidelobes of the filter associated with each frequency bin.

The filter sidelobes and the resulting leakage are reduced when one of the available window functions is applied. The best reduction is provided by the Blackman–Harris and Flattop windows. However, this reduction is offset by a broadening of the main lobe of the filter.

### **LF**

Low Frequency.

### **LF Rejection**

LF Rejection removes the low-frequency portion of the signal. Thus, only high-frequency components are passed on to the channel or triggering system for acquisition. Low-frequency rejection attenuates signals below the tens of kHz.

### **Limit Test**

Comparison of an input signal or math waveform to a template waveform. When performing a limit test, the oscilloscope looks for waveforms that fall outside the limits defined by the template waveform. The oscilloscope can be programmed to generate a hardcopy, beep, or stop and wait for input from an operator when it finds a waveform that exceeds the template limits.

### **Linear Interpolation**

Linear interpolation is another term for 'join the dots'. A straight line is drawn between two adjacent data points.

**Linearity**

The closeness of a device's response to a straight line.

**Lissajous**

A special case of an X-Y plot in which the waveforms applied to both axes are sinusoidal functions. For a stable display the waveforms must be related harmonics. Lissajous figures are useful for determining phase and harmonic relationships.

The X-Y plot can be selected in the **DISPLAY**  menu.

**Live Waveforms**

Waveforms that can update as the acquisition system acquires data. Channel waveforms are live waveforms; reference waveforms are not. Math waveforms are live if they contain live waveforms.

**Logical 1**

A signal level indicating the TRUE state; corresponds to the unit being set (i.e., if interrogated, the answer is yes).

**Logical 0**

A signal level indicating the FALSE state; corresponds to the unit NOT being set (i.e., if interrogated, the answer is no).

**Logic Triggering**

Logic triggering allows you to qualify the trigger event further than the standard edge trigger mode.

**Long-Term Stability**

Stability over a long time, such as several days or months.

**Loop gain**

The product of sampling efficiency, forward gain, and feedback attenuation in a sampling loop. Loop gain in a calibrated system is normally unity (1), but can go to values more or less than unity.

**Low**

The value used as the 0% level in amplitude measurements, such as Peak and Overshoot.

**Low-pass filter**

A circuit that attenuates the high-frequency components in an analog signal.

**Luminance**

The brightness or intensity of a color.

**Luminosity**

The relative brightness of a color. A 100% luminosity is the maximum color brightness. A 0% luminosity is pure black.

## 6.13 M

**Main Sweep**

When main sweep is enabled, all input channels will be displayed along a single common timebase. If delayed sweep is enabled, then the display shows an expanded view of a selected portion of the main sweep.

## Margin Measurements

A feature that lets you limit automated measurements to a specified portion of the waveform. You define the area of interest using the vertical cursors.

## Markers

On-screen markers that you can align with a waveform to take accurate measurements. Markers are two sets of horizontal, vertical, or waveform markers in the waveform display area used for making custom voltage and time measurements. Markers, or Cursors, can be placed anywhere on the displayed waveform and the scope will display the numerical position of the markers and the difference between the markers with units in volts and time for the time-domain display or dB and Hz for FFT functions.

## Mask

A form of waveshape limit test that defines a maximum deviation equal to a uniform tolerance on each measured point in a waveform. A mask template consists of numbered, shaded regions on the instrument display screen. The input waveform must remain within these regions in order to comply with industry standards. The waveforms that intrude into these regions are mask violations.

## Mask Test

A test process used to verify that waveforms generated by a test device conform to industry standards.

## Mathematics

The mathematics functions are mathematical operations (such as Add, Subtract, Multiply, and Integrate) that can be performed on input waveforms, stored waveform memories, or even other functions. There are four functions, F1 to F4, which can be set up in the **MATHEMATICS** <sup>[234]</sup> menu. When the function is set up and turned on, a post-processing calculation is done and the resulting waveform is displayed.

## Math Waveform

A waveform defined by a combination of one or more operands (channel waveforms, reference waveforms, and automatic measurement scalars). Math waveforms may also contain math operators and functions.

## Maximum

Amplitude (voltage) measurement of the maximum amplitude. Typically the most positive peak voltage.

## Maximum Input Voltage

The maximum voltage that can be applied to an input channel without damaging the input circuitry.

## Mean

Amplitude (voltage) measurement of the arithmetic mean over the entire waveform.

## Measurement statistics

The accumulation of a history of individual measurement readouts, showing the mean and standard deviation of a selected number of samples.

## Measurement updating

The process of automatically adjusting the measurement parameters to reflect changes in the waveform targeted by an automatic measurement.

**Median**

The data value of a waveform above and below which there are equal numbers of data points.

**Megahertz (MHz)**

1,000,000 hertz; a unit of frequency.

**Megasamples per second (MS/s)**

A sampling rate unit equal to one million samples per second.

**Memory**

Four Memories in an oscilloscope used to store waveforms or settings. You can use that waveform data later for processing. The oscilloscope saves the data even when the oscilloscope is turned off or unplugged.

**Memory Depth**

The number of waveform samples stored in the waveform memory. The greater the memory depth, the greater the amount of sampled data that is available for analysis or measurements. This is referred to as Record Length by some oscilloscope manufacturers.

**Microsecond**

A unit of time equivalent to 0.000 001 seconds.

**Millisecond (ms)**

A unit of time equivalent to 0.001 seconds.

**Minimum**

Amplitude (voltage) measurement of the minimum amplitude. Typically the most negative peak voltage.

**Monochrome**

An image represented by a single color. Often, a monochrome image is presented as white on a black background.

**Monotonic**

A function with a derivative that does not change sign.

**Multiple-Valued Waveform**

A method of representing a signal in which every horizontal acquisition point can have associated with it multiple amplitude values. An eye diagram is an example of a multiple-valued waveform. In contrast, a single-valued waveform is displayed by measuring and displaying one and only one amplitude value for each horizontal acquisition point.

**Multiplexer (MUX)**

A set of semiconductor or electromechanical switches arranged to direct one of many inputs to a single output.

**6.14 N****NAND**

An AND circuit, except with a complementary (negative true) output.

**Nanosecond (ns)**

A unit of time equivalent to 0.000 000 001 seconds.

**Negative duty cycle**

A timing measurement representing the ratio of the negative pulse width to the signal period expressed as a percentage.

**Negative overshoot measurement**

Amplitude (voltage) measurement.

**Negative width**

A timing measurement of the distance (time) between two amplitude points (the falling-edge middle reference point (default 50%) and the rising-edge middle reference point (default 50%) on a negative pulse.

**Noise**

An unwanted voltage or current in an electrical circuit.

**Noise distortion**

The nonlinear behavior that circuits or devices exhibit when driven with a broadband noise signal.

**Noise floor**

1. The level below which no information can be obtained from a signal. A signal that occurs below a noise floor is permanently lost.
2. The minimum discernible signal that can be detected by a receiver.

**Noise Reject**

Noise Reject is a trigger conditioning setting that makes the trigger circuitry less sensitive to noise. You can use noise reject when triggering on noisy waveforms minimise the possibility of false triggering. Basically, noise reject increases the trigger hysteresis band so that noise on a waveform will not generate a trigger.

**NOR**

An OR circuit, except with a complementary (negative true) output.

**Normalization**

Normalization is a TDR measurement technique that removes impedance discontinuities at the reference plane. Characteristic impedance measurements are more accurate after the discontinuities are removed. A waveform is derived in the normalization process and represents the systematic errors of the input signal. This waveform is subtracted from the waveform of the device under test. The subtracted result is then put through a digital filter to yield the response waveform.

**Normal Trigger Mode**

A mode in which the oscilloscope does not acquire a waveform record unless a valid trigger event occurs. It waits for a valid trigger event before acquiring waveform data. Normal trigger mode, or triggered, requires that the trigger conditions be met before the acquisition process terminates. If the trigger conditions are not met, new input data cannot be displayed. The normal or triggered mode is the desired mode of triggering when you know the trigger conditions and want a stable trigger. An alternative to the normal or triggered mode is the auto trigger mode, which will force a trigger after a period of time if trigger conditions are not met.

**NRZ**

(Non-return to zero) A type of signal coding that ensures that, in any one bit period, the signal is turned on for the entire duration of a logical one pulse and turned off (or nearly off) for the entire duration of a logical zero pulse.

**Number of Points**

The FFT is computed over the number of points (Transform Size) whose upper bounds are the source number of points, and by the maximum number of points selected in the menu. The FFT generates spectrums of N/2 output points.

**Nyquist Frequency**

The Nyquist frequency is equal to one half of the effective sampling frequency (after decimation):  $f \times N/2$ .

**Nyquist point**

The minimum sampling frequency as defined by the Nyquist Sampling Theorem, which requires that a signal be sampled at a minimum rate equal to twice the input signal frequency for faithful reproduction. Sampling below this frequency will lead to aliasing.

6.15 **O****Offset**

Offset moves the waveform vertically up or down on the Y-axis of the display. It is similar to the vertical position control on analog scopes. Offset is precisely calibrated on a digital scope. The offset voltage is the voltage at the centre of the graticule area.

**Offset null**

An adjustment to remove any unwanted DC offset that may be present in the sampler. Effectively zeroes the sampler so that an input signal with zero volts of amplitude delivers a zero volt output.

**OMA (Optical Modulation Amplitude)**

The difference between the average power levels of the logic 1 level, High, and the logic 0 level, Low, of the optical pulse signal. The levels are the Means of the logical levels sampled within an Aperture of the logical 1 and 0 regions of the pulse. The logical 1 and 0 time intervals are marked by the crossings of a reference level determined as the Average Optical Power (AOP) of the signal.

**One Level**

One level is a measure of the mean value of the logical 1 of an eye diagram.

**OR**

A logic circuit having the property that if at least one input is true, the output is true.

**Oscilloscope**

An instrument used to make voltage changes visible over time. The word oscilloscope comes from "oscillate," since oscilloscopes are often used to measure oscillating voltages.

**Overshoot**

Overshoot is a distortion that follows a waveform edge transition. This distortion occurs after the edge crosses through the waveform threshold levels,, and can occur on either the rising or falling edge.



**Overshoot, Negative**

A time-domain parameter in waveform measurements, equal to the base value of a waveform minus the minimum sample value, expressed as a percentage of the amplitude.

**Overshoot, Positive**

A time-domain parameter in waveform measurements, equal to the maximum sample value minus the top value, expressed as a percentage of the amplitude. The top value is the most probable state determined from a statistical distribution of data point values in the waveform.

**6.16 P****Pass/Fail Testing:**

Post-acquisition testing of a waveform against a reference mask or of waveform parameters against reference values.

**Pattern Dependency**

Pattern dependency is the behavior of a waveform as it is influenced by the preceding data pattern. For example, a logic level one that follows a logic level zero may have a different amplitude than a logic level one that follows a previously generated logic level one.

**Pattern Triggering**

Pattern triggering qualifies the trigger event by having the scope search for a pattern using the selected channel inputs. You can define the pattern as a combination of highs, lows, or don't care levels. Input channel voltages above the selected voltage level are highs while voltages below the selected voltage level are lows.

**Peak-to-Peak**

Amplitude (voltage) measurement of the absolute difference between the maximum and minimum amplitude.

**Peak Detect**

Peak detect is an acquisition mode that runs the sampler at a very high equivalent rate, even though the timebase setting would dictate a slower sampling rate. The oversampled data is processed so that a maximum and minimum pair is stored for each time bucket for display. Using this mode will ensure that very fast extremes of a waveform, such as glitches, will be captured and displayed.

**Period**

1. The amount of time it takes a wave to complete one cycle. Period equals  $1/\text{frequency}$ .
2. A full period is the time measured between the first and third 50% crossing points (medial points) of a cyclic waveform.

**Periodic Jitter**

Periodic Jitter is one component of Deterministic Jitter. Periodic Jitter is predictable and not data-related and often has Sinusoidal Jitter (SJ) as a component.

**Persistence**

Persistence is a display mode in which old waveform data is left on the display for a specified period of time. You can select persistence settings of variable, or infinite. There are different persistence modes available in the instrument: Variable, Infinite, Gray-Scaled and Color-Graded.

**Phase**

A timing measurement between two waveforms of the amount one leads or lags the other in time. Phase is expressed in degrees, where 360° comprise one complete cycle of one of the waveforms. Waveforms measured should be of the same frequency or one waveform should be a harmonic of the other.

**Pixel**

1. The fundamental picture element in a digital image.
2. The coordinate unit used to define the horizontal location of a pixel in an image. ("Pixel" is an acronym for "picture element.")

**Pigtail**

A fiber-optic cable that has a connector installed on one end.

**Pop-up menu**

A menu that displays when you right click an application element, such as a channel or its icon, a measurement or other readout. Usually provides quick access to settings related to the object clicked.

**Position**

Position moves the waveform horizontally on the display. Real-time digitizing scopes allow you to view events that happened before the trigger event. A negative position value is time before the trigger event, and a positive position value is time after the trigger event. Some scopes refer to position as delay.

In some scopes, position also refers to a control that moves the waveform vertically on the Y-axis of the display. In this series of scopes, however, vertical movement is controlled by the offset in the [Channel](#) <sup>35</sup> menu.

**Positive Duty Cycle**

A timing measurement of the ratio of the positive pulse width to the signal period, expressed as a percentage.

**Positive Overshoot**

Amplitude (voltage) measurement.

**Positive Width**

A timing measurement of the distance (time) between two amplitude points? the rising-edge middle reference point (default 50%) and the falling-edge middle reference point (default 50%)? on a positive pulse.

**Posttrigger**

The specified portion of the waveform record that contains data acquired after the trigger event.

**PRBS (Pseudo Random Binary Sequence)**

A repetitive, effectively random, digital signal pattern.

**Preshoot**

Preshoot is a distortion that precedes a waveform edge transition. This distortion occurs after the edge crosses through the waveform threshold levels, and can occur on either the rising or falling edge.

**Pretrigger**

The specified portion of the waveform record that contains data acquired before the trigger event.

**Pre-trigger Sampling**

A design concept used in transient recording in which a predetermined number of samples taken before a stop trigger are preserved.

**Probe**

An oscilloscope input device, usually having a pointed metal tip for making electrical contact with a circuit element and a flexible cable for transmitting the signal to the oscilloscope.

**Probe compensation**

Adjustment that improves low-frequency response of a probe.

**Pulse**

A common waveform shape that has a fast rising edge, a width, and a fast falling edge.

**Pulse Trigger**

Selects a pulse width, either maximum or minimum. The trigger is generated on the selected edge when the pulse width is either greater than or less than the selected width. The timing for the width is initialized and restarted on the edge opposite to the edge selected.

**Pulse Width**

Determines the duration between the Pulse Start (the 50% magnitude transition point, on the leading edge) and the Pulse Stop (medial point on the trailing edge) of a pulse waveform.

**6.17 Q****Q-factor**

Q-factor is a figure of merit for an eye diagram indicating the vertical eye opening relative to the noise at both the high and low logic levels.

**Quantizing**

The process of converting an analog input that has been sampled, such as a voltage, to a digital value.

**Quantizing error**

The inherent uncertainty in digitizing an analog value that is caused by the finite resolution of the conversion process. Increasing the resolution of an ADC reduces the uncertainty.

**6.18 R****RAM**

A memory in which each data address can either be written into or read from at any time.

**Random Jitter**

Random Jitter is jitter that is unpredictable and not data-related. Random jitter is unbounded, meaning that measured values increase with longer measurement times.

**Random Repetitive Sampling**

One method of Equivalent Time Sampling. Acting upon stable, repetitive signals, it represents the process of storing different full sampling sweeps in a DSO or digitizer system, where each sweep is slightly offset from the other to achieve a higher effective sampling rate than the single-shot rate. A major advantage of this technique is "pretrigger viewing".

**Range**

The maximum and minimum allowable full-scale signal (input or output) that yields a specified performance level.

**Real Time Sampling**

A sampling mode in which the oscilloscope collects as many samples as it can as the signal occurs. In real-time sampling mode, all the data points that make up a waveform come from a single trigger event unless you have enabled averaging. The real-time sampling mode is typically used on events that occur either once or infrequently - to capture single-shot or transient events.

**Recall Setup or Load Setup**

Recall Setup is a quick and easy way to reconfigure the scope to a previous configuration. The scope's configuration, or setup, includes timebase scale (s/div), position, vertical scale (V/div), offset, trigger source and level, as well as all the other settings.

**Reconstruction**

Reconstruction, sometimes called interpolation, fills in information between acquired sample points using digital signal processing techniques. 'Join the dots' involves a simple linear interpolation, while reconstruction usually refers to more advanced techniques such as sin x filters that will increase the resolution, accuracy and repeatability of time-interval measurements.

**Record Length**

Record length is the number of waveform samples stored in the waveform memory. The greater the memory depth, the greater the amount of sampled data that is available for analysis or measurements. Increasing the memory depth decreases the display update rate. This is called Memory Depth in this scope.

**Recovered Clock**

The process of extracting a clock signal from electrical digital communications signals. The resulting trigger signal is made available to the instrument. The recovered clock has a lower jitter modulation bandwidth than trigger from data signal.

**Reference memory**

Memory in an instrument used to store waveforms or settings. You can use that waveform data later for processing. The instrument saves the data even when the instrument is turned off or unplugged.

**Reference waveforms**

Waveforms that are static, not live (see live waveforms). Reference waveforms are channel or math waveforms that you save to references or to files in the instrument's file system. Once saved, they do not update.

**Reflection Coefficient (Rho)**

In time-domain reflectometry, the ratio of peak amplitude of a reflection to the incident step amplitude. The observed reflection coefficient may depend upon system rise time, losses in the transmission medium, and the nature of the discontinuity that produced the reflection.

**Repetitive Sampling**

Repetitive sampling is another term that is used to refer to equivalent time sampling. In the repetitive or equivalent-time sampling mode, a waveform record is built up by taken from multiple trigger events. This process allows samples in the waveform record to be spaced more closely together for repetitive waveforms. As a result, the waveforms appear to have been sampled at a much higher rate, sometimes referred to as the effective sampling rate.

The equivalent time sampling mode increases the effective bandwidth of the scope for repetitive waveforms that have a stable trigger. It can also be used with multivalued waveforms such as eye diagrams.

**Resolution**

The minimum measurable increment, such as one bit level of an ADC. Time resolution is determined by the sampler bandwidth and ADC sampling rate, which on a DSO is plus or minus one sampling interval.

**Responsivity**

The ratio of an optical detector's electrical output to its optical input, often as a function of optical wavelength.

**Rise Time**

1. Rise time is a measure of the transition time of a waveform as the rising edge passes through the lower (usually the 10% point), middle (usually the 50% point), and upper threshold (usually the 90% point) or logic levels.
2. Rise time is a measure of the mean transition time of the data on the upward slope of an eye diagram. The data crosses through the following thresholds: the lower, middle, and upper thresholds, as well as through the crossing points of NRZ eyes.

**RMS**

RMS is the root-mean-square (rms) of the voltage values of a waveform. The RMS value of an AC voltage equals the DC voltage that would cause the same heating in a resistive load.

**Roll or Scan Mode**

Roll or scan mode is a display mode available on some scopes that emulates a strip chart recorder, showing a continuously drawn waveform at slow sweep speeds. Waveforms can be displayed a slow sweeps but will be displayed only when the acquisition period has a full record, not point by point. The trigger activity light on the front panel will assist in showing the acquisition process.

**ROM**

Read-only memory is any type of memory that cannot be readily rewritten. The information is stored permanently and used repeatedly. Usually randomly accessible.

**Runt Pulse**

A runt pulse is a pulse in your waveform that is shorter than the other pulses in the waveform.

**RZ**

(Return to zero) A type of signal coding that ensures, in any one bit period, that the signal is turned on for the first half of a logical one pulse and turned off (or nearly off) for the second half of the logical one pulse. As with NRZ coding, the signal is turned off (or nearly off) for the entire duration of a logical zero pulse.

**6.19 S****Sample**

The oscilloscope creates a record point by saving the first sample during each acquisition interval. Sample mode is the default acquisition mode.

**Sample and hold (S/H)**

A circuit that acquires an analog voltage and stores it temporarily in a capacitor. This circuit is also referred to as a sample-and-hold amplifier (SHA).

**Sample interval**

The time interval between successive samples in a timebase. For real-time digitisers, the sample interval is the reciprocal of the sampling rate. For equivalent-time digitisers, the time interval between successive samples represents equivalent time, not real time.

**Sample Point**

An item of raw data from an ADC used to calculate a waveform point.

**Sampling Rate**

Sampling rate is the rate at which the acquisition system samples a waveform. In real-time mode, all samples in a given waveform record are taken from one trigger event and are evenly spaced in time at a distance of  $1/(\text{sample rate})$ . In equivalent-time mode, a waveform record is built up from multiple trigger events. This process allows samples in the waveform record to be spaced more closely together for repetitive waveforms. As a result, the waveforms appear to have been sampled at a much higher rate, sometimes referred to as an effective sample rate.

**Sampling**

The process of capturing an analog input, such as a voltage, at a discrete point in time and holding it constant so that it can be quantized for further processing or display. Two general methods of sampling are: real-time sampling and equivalent-time sampling.

**Sampling efficiency**

The percentage of signal voltage transferred across the sampling gate when the gates conduct.

**Sampling Frequency**

The clock rate at which samples are taken during the process of digitizing an analog signal in a DSO or digitizer.

**Sampling gate**

An electronic switch that briefly conducts a command to collect and store the instantaneous value of a signal (sometimes called sampling bridge).

### Sampling loop

The circuits that provide the main signal path through the input sampling gate, amplifiers, forward gain attenuator, memory gate, memory, feedback attenuator, and back to the sampling gate (also called feedback loop).

### Sampling Oscilloscope

An oscilloscope using sampling along with the means for building a coherent display of the samples taken.

### Saturation

The saturation of a color is the purity of the color or the absence of white. A 100% saturated color has no white component. A 0% saturated color is pure white.

### Save Setup

The scope's configuration, or setup, includes the timebase scale (s/div), position, vertical scale (V/div), offset, trigger source and level, as well as all the other settings.

Using setups makes it quick and easy to reconfigure the scope to a previous configuration.

### Scale (Vertical or Horizontal)

Vertical scale is an instrument control that controls the Y-axis or volts (or other unit) per division for the selected channel. This control allows you to adjust the sensitivity of the instrument. Horizontal scale is an instrument control that controls the X-axis or time per division of displayed waveforms. Horizontal scale is referred to as sweep speed in some instruments.

### Scan Mode

See [Roll or Scan mode](#) 

### Screen

The surface of the CRT or LCD upon which the visible pattern is produced - the display area.

### Screen Update Rate

The number of times per second that the screen information is renewed. The quicker the rate, the better the feel of the DSO controls.

### Sequential sampling

A sampling process where samples are taken at successively later times relative to the trigger recognition point.

### Sensitivity

1. The minimum signal input capable of causing an output signal with the desired characteristics.
2. The ratio of the magnitude of the instrument response to the input magnitude (e.g., a voltage ADC has a sensitivity that is usually measured in counts/mV). Often, sensitivity is referred to the input and is therefore stated as the inverse.

### Sequential equivalent-time sampling

A type of equivalent-time sampling in which one sample is taken per acquisition, with each sample skewed incrementally with respect to an external trigger event. This instrument acquires using sequential equivalent time sampling.

**Settling Time**

Settling time is the time it takes for a waveform to settle to within some user defined  $\pm$  percentage of its steady state value following a rising or falling edge.

**Shot Noise**

Noise caused by current fluctuations, due to the discrete nature of charge carriers and random emission of charged particles from an emitter. Many refer to shot noise loosely, when speaking of the mean square shot noise current (amperes) rather than a noise power (watts).

**Signal Generator**

A test device for injecting a signal into a circuit input; the circuit's output is then read by an oscilloscope.

**Signal Processing**

With respect to oscilloscopes, this refers to functions that are performed by signal processing hardware or software. For example, signal measurements (rise time, overshoot, period, etc.), FFTs, Integration and Differentiation functions are signal processing functions.

**Sine Wave**

A common curved wave shape that is mathematically defined (by the value of the sin function).

**Single Shot**

A signal measured by an oscilloscope that only occurs once (also called a transient event).

**Signal-to-Noise ratio (SNR)**

Signal-to-noise is a ratio of the signal difference between one level and zero level relative to the noise present at both levels. The ratio of total signal to noise expressed in decibels (dB). The larger the number, the better. SNR is calculated by:

$$SNR = 20 \log (Signal_{RMS} / Noise_{RMS})$$

A related unit is the signal-to-noise-and-distortion ratio (SINAD), the ratio of the input signal to the sum of noise and harmonics:

$$SINAD = 20 \log (Signal_{RMS} / (Noise + Harmonics)_{RMS})$$

**Significant Instant**

A significant instant is any convenient, easily identifiable point on a signal (for example, a point on either the rising or falling edge of a pulse).

**Simultaneous sample and hold**

A data-acquisition technique in which several sample-and-hold circuits sample several different analog channels simultaneously.

**Sine Wave**

A common curved wave shape that is mathematically defined (by the value of the sin function).



**Single**

In single trigger mode, the scope triggers once when the trigger conditions are met. Once the acquisition process is complete, the scope will display the acquired waveform and stop the acquisition process.

**Single Shot**

A signal, measured by an oscilloscope, that only occurs once (also called a transient event).

**Single-Valued Waveform**

A method of representing a signal in which every horizontal acquisition point has associated with it one and only one amplitude value. In contrast, an eye diagram is displayed by measuring and displaying multiple amplitude values for each horizontal acquisition point.

**Skew**

Skew changes the horizontal position of a waveform on the display independent of any other waveforms on the display. Skew is typically used for overlaying waveforms, or eliminating timing differences caused by different cable and probe lengths. The timebase position control moves all of the waveforms on the display at the same time, whereas skew moves individual waveforms.

**Slewing**

The causing of successive samples to be taken at different times than the trigger recognition point.

**Slope**

On a graph or an oscilloscope screen, the ratio of a vertical distance to a horizontal distance. A positive slope increases from left to right, while a negative slope decreases from left to right.

**Smoothing**

A process that reduces displayed noise by reducing the gain of the sampling loop. By oversampling the input signal, the sampling loop can maintain an apparent unity gain while reducing noise.

**SNR**

Signal-to-Noise Ratio (SNR) is the ratio of the magnitude of the signal to that of the noise.

**Source**

The source (input channel, math function, waveform memory, spectrum, or constant) used when performing tasks such as measurements, math, or mask tests.

**Square**

The process of multiplying a value by itself.

**Square Wave**

A common wave shape consisting of repeating square pulses.

**Standard Deviation**

Standard deviation is the measure of the dispersion or spread of the statistical average of all results for a particular measurement. Standard deviation is represented by the Greek letter sigma ( $\sigma$ ). In a Gaussian distribution, two sigma, or within  $\pm 1$  of the mean, is where 68.3 percent of the data points reside. Six sigma, or within  $\pm 3$  of the mean, is where 99.7 percent of the data points reside.

**State Triggering**

State triggering is an edge-qualified pattern trigger. A trigger event occurs if a specified pattern is present when an edge occurs on the designated clock waveform.

**State Qualified**

State-Qualified triggering generates a trigger when the trigger source meets its conditions during the selected pattern. A pattern is defined as a logical AND combination of trigger states. A trigger state is either high or low; high when a trigger source is greater than the trigger level, and low if it is less than the trigger level.

**Stimulated Emission**

The optical power emitted from a laser diode after a specific current threshold is reached. Also known as Coherency.

**Stop/Single**

In the Stop/Single mode, the scope triggers once when the trigger conditions are met. Once the acquisition process is complete, the scope will display the acquired waveform and stop the acquisition process. You can begin another acquisition by pressing the front-panel Run button.

**Stop Trigger**

A pulse that is used to stop a transient recording or similar sequence.

**Strobe**

A short duration pulse that operates the sampling gate.

**Strobe kick-out**

A fraction of the strobe signal coming out of the input connector.

**Summed, or Summation, Averaging**

The repeated addition, with equal weight, of successive waveforms divided by the total number of waveforms acquired.

**Sweep**

One horizontal pass of an oscilloscope's trace from left to right across the screen.

**Sweep Cycle Time**

The time required for making a complete sweep and preparing for the next sweep. It can be measured as the time from the start of one sweep to the start of the next sweep.

**Sweep Speed**

The rate at which the sweep moves across the display. The sweep speed is expressed in units of time per division, for example, 1 ns/div.

## 6.20 T

### **Test Template**

A general form of waveshape limit test, which defines an arbitrary limit (or non-uniform tolerance) on each measured point in a waveform.

### **Text Verbose**

An ASCII text file format that uses alphanumeric characters to represent the voltage values of a waveform. This format includes header information about the waveform and when it was acquired. The text file formats are a convenient method for transferring waveforms to other computer applications.

### **Threshold**

The voltage or current level at which a circuit will respond to a signal at its input. Also referred to as trigger level.

### **Throughput**

Throughput is the rate at which the scope can acquire, display, and make measurements on a waveform. The faster the throughput of a scope, the more waveforms per second that it can process. Faster throughput in a scope means less dead time and less chance of missing a significant event

### **TIFF or .tif**

TIFF, or .tif, is a high-quality graphics file format that can be imported into other applications for documentation purposes. Widely supported across platforms (PC, Mac, UNIX), its better quality makes it a format of choice for master copies, but results in larger file sizes.

### **Time Base**

Oscilloscope circuitry that controls the timing of the sweep. The timebase is set by the Time/div variable.

### **Time Base Accuracy**

The closeness of the indicated time value to the true value.

### **Time Base Range**

The range of values to which the horizontal deflection factor can be set.

### **Time domain**

Signals displayed with time on the X-axis and amplitude on the Y-axis. Instruments that display signals in this format are called time-domain instruments.

### **Time domain**

Signals displayed with time on the X-axis and amplitude on the Y-axis. Instruments that display signals in this format are called time-domain instruments.

### **Time Domain Network Analysis (TDNA)**

TDNA includes both time-domain reflectometry (TDR) and time-domain transmission (TDT) measurements. Imperfect connectors, cabling, and even the response of the instrument itself can introduce errors into TDR/TDT measurements. Understanding the effects of these errors, and more importantly, how to remove them, will result in more accurate and useful measurements.

**Time Domain Reflectometry (TDR)**

The technique of sending a pulse or step signal into a transmission line and analysing any reflections produced. TDR gives an intuitive measurement of any discontinuities in a circuit. It measures the location, electrical length, nature of circuit (resistive, capacitive, inductive), and amount of reflection from discontinuities.

**Time Domain Transmission (TDT)**

TDT is a measurement technique that measures both attenuation and propagation delay of your device under test. TDT requires that you connect an electrical channel to the output of your device under test. The instrument sends a fast step signal into your device. The output from the device is then sent into the electrical channel and back into the instrument.

**Time@Maximum**

Time@Maximum is a measure of the time of the first occurrence of the first data sample with the maximum signal level.

**Time@Minimum**

Time@Minimum is a measure of the time at which the first data sample with the minimum signal level first occurs.

**Time Qualified**

Time-Qualified triggering generates a trigger when the trigger source meets its trigger condition after entering or exiting the pattern. The trigger can occur even if the pattern disappears before the trigger meets its trigger conditions.

**Tolerance Mask**

A form of waveshape limit test that defines a maximum deviation equal to a uniform tolerance on each measured point in a waveform.

**Top**

Top is the statistically most prevalent voltage value above the waveform midpoint.

**Total harmonic distortion (THD)**

See [Harmonic Distortion](#) <sup>393</sup>

**Total Jitter**

Jitter is the measure of the time variances of the rising and falling edges of an eye diagram as these edges affect the crossing points of the eye. Total Jitter represents the combined effects of all components of jitter: Deterministic Jitter and Random Jitter.

**Trace**

The visible shapes drawn on the screen of an oscilloscope.

**Transient**

A signal, measured by an oscilloscope, that only occurs once (also called a single-shot event).

**Trend**

Plot of a parameter value or other characteristic of a measurement over a period of time.

**Trigger**

1. The circuit that initiates a horizontal sweep on an oscilloscope and determines the beginning point of the waveform.
2. The signal that tells the DSO to start capturing data.

**Trigger Coupling**

Describes the circuitry used to connect the trigger source to the trigger circuit. Several types of coupling are available: HF Reject, LF Reject, Noise Reject, AC, and DC. The different types of coupling provide improved triggering performance depending on the characteristics of the trigger source.

**Triggered**

The triggered, or normal, trigger mode requires that trigger conditions be met before the acquisition process terminates. If the trigger conditions are not met, the scope will not display any input waveforms. The normal or triggered mode is the desired mode of triggering when you want a stable trigger and know the trigger conditions. An alternative to the normal or triggered mode is the freerun (or auto) trigger mode, which will force a trigger after a period of time if trigger conditions are not met.

**Trigger Event**

A trigger event is the change, in the trigger source waveform, that meets your trigger condition and tells the acquisition system where the sampled data point corresponding to the trigger point is stored in the channel memory. The time at which the trigger event occurs is the time reference for the waveform and is, by definition, 0 seconds.

**Trigger Holdoff**

A control that inhibits the trigger circuit from looking for a trigger level for some specified time after the end of the waveform.

**Trigger Hysteresis**

Trigger Hysteresis is the difference between the arming voltage and the trigger level voltage. This defines the minimum peak-to-peak waveform voltage, which can cause a trigger. The waveform must cross both the arming level voltage and the trigger level voltage to generate a trigger event. Trigger Hysteresis helps to prevent false triggers from occurring on a falling edge due to noise when the rising edge is selected as the trigger edge (or on a rising edge when the falling edge is selected as the trigger edge).

**Trigger kick-out**

A signal from a trigger circuit that comes out of the trigger input connector.

**Trigger Level**

The voltage level that a trigger source signal must reach before the trigger circuit initiates a sweep.

**Trigger pick-off**

A circuit used to extract a portion of the input signal to trigger the timebase.

**Trigger recognition**

The process of responding to a suitable triggering signal.

**Trigger recognition point**

The time when trigger recognition occurs. Also, the point on a displayed waveform representing the instant of trigger recognition.

**Trigger Source**

The signal source used to trigger the scope. Usually one of the input channels or a dedicated input.

**TTL (Transistor-Transistor Logic)**

A class of logic circuitry with signal levels defined as follows: logical 0 = 0 to 0.8 V and logical 1 = 2.0 to 5.0 V.

## 6.21 U

**Update Rate**

Display Update Rate. In digital scopes, the number of trigger events that the scope can capture and display is referred to as its update rate. Unlike analog scopes, digital scopes require time to move the sampled data to memory, display the acquired data, do any post-processing math (such as Amplitude or Frequency measurements), and rearm the trigger circuitry for the next acquisition. Technology advances have greatly improved the update rate in digital scopes. Better update rate in a scope means less dead time and less chance of missing a significant event.

**Uptime**

The number of hours the instrument has been powered on.

## 6.22 V

**Variable Persistence**

The ability to set time parameters for the displaying of acquired data is a valuable analysis tool. Setting the time to a minimum allows you to view rapidly changing signals when you want immediate display feedback. Setting the time to infinite allows you to observe worst-case jitter of a signal, as the acquired waveforms are never erased – similar to a storage scope. Setting the persistence time to intermediate values allows you to observe long-term changes or trends.

**Vectors**

Vectors, or 'connect the dots', is a display technique in which a straight line is drawn between two adjacent samples on the display. It is a display feature and has no effect on the waveform data stored in the channel memory. This method is also called linear interpolation.

**Vernier**

Vernier, or fine control, allows a calibrated fine adjustment of a scaling factor such as the channel volts/div or the timebase time/div. For example, it is possible to set the mV/div to 150 mV/div instead of the standard choices of 100, or 200 mV/div by entering the desired value using the numeric keypad for the mV/div scale factor.

**Vertical bar markers**

You position the two vertical bars to measure a time parameter of a waveform record. The oscilloscope displays the value of the markers with respect to the trigger and the time difference between the bars.

**Vertical Accuracy**

The closeness of the indicated signal voltage to the true value.

**Vertical Resolution**

The number bits of bits used to digitise the input signal. A 14-bit digitiser can resolve a signal into 16,384 levels.

**Vertical Sensitivity**

The range of values to which the vertical deflection factor can be set.

**Volt**

The unit of electric potential difference.

**Voltage**

The difference in electric potential expressed in volts, between two points.

**6.23 W****Waveform**

A graphic representation of a voltage varying over time.

**Waveform database**

A collection of sequentially acquired waveforms.

**Waveform interval**

The time interval between record points as displayed.

**Waveform markers**

The marker mode that presents two cursors that you position to measure both the time and amplitude parameters of a waveform record. The instrument displays the times of both cursors with respect to the trigger and the time difference between the cursors. The instrument also displays the amplitude values of both cursors with respect to the waveform ground and between the cursors.

**Waveform Memory**

A waveform memory is a convenient, non-volatile, waveform storage area. It contains a single waveform record along with the vertical and horizontal scaling factors for that waveform.

**Waveform Point**

A digital value that represents the voltage of a signal at a specific point in time. Waveform points are calculated from sample points and stored in memory.

**Waveform Record**

The collection of acquired data in a waveform.

**Waveform types**

Waveform types of the source to be measured can be Pulse, NRZ, and RZ. Each waveform type has a measurement category (Amplitude, Timing, or Area) that can be selected.

**Window**

In general, the period of time acquired in a waveform is called a "window". In instruments with dual timebase architecture, a window refers to the magnified section of a lower resolution (main) waveform. The window waveform is acquired with a smaller equivalent time sample interval than the main waveform.

**Window Functions**

Used to modify the spectrum of a truncated waveform prior to Fourier analysis.

Alternately, window functions determine the selectivity (filter shape) in a Fourier transform spectrum analyzer.

**Windows OS**

The underlying operating system on which this instrument runs.

## 6.24 X

**XY Display Mode**

XY is a display mode that converts the scope from a volts versus time display to a volts versus volts display of two input channels, functions, or waveform memories. The XY display plots the voltage values of two inputs, with one input's voltage values displayed horizontally and the second input's voltage values plotted vertically. This is a useful display mode for evaluating phase relations between two waveforms.

**XY format**

A display format that compares the voltage level of two waveform records point by point. It is useful for studying phase relationships between two waveforms.

## 6.25 Y

**YT format**

The conventional oscilloscope display format. It shows the voltage of a waveform record (on the vertical axis) as it varies over time (on the horizontal axis).

## 6.26 Z

**Z-axis**

Another name for the brightness of the trace at a given location.

**Zero Level**

Zero Level is a measure of the mean value of the logical 0 of an eye diagram.

**Zero phase reference point**

The point in the time-domain record to which the phase values of the FFT are referenced.

**Zoom**

Zoom allows you to analyse your waveform in more detail by expanding the waveform display either horizontally.



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