

USER MANUAL



ML4015E User Manual

Connection | Installation | Calibration | Measurement | Troubleshooting

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General Safety Summary

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Only qualified personnel should perform service procedures.

While using this product, you may need to access other parts of the system. Read the General Safety Summary in other system manuals for warnings and cautions related to operating the system.

To Avoid Fire or Personal Injury

Use Proper Power Cord. Only use the power cord specified for this product and certified for the country of use.

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Do Not Operate Without Covers.

Do not operate this product with covers or panels removed.

Avoid Exposed Circuitry. Do not touch exposed connections and components when power is present.

Do Not Operate with Suspected Failures.

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Do Not Operate in Wet/Damp Conditions. Do Not Operate in an Explosive Atmosphere. Keep Product Surfaces Clean and Dry



Caution statements identify conditions or practices that could result in damage to this product or other property.

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INTRODUCTION

Acronym	Definition
BW	Bandwidth
NRZ	Non-Return to Zero
DUT	Device Under Test
SONET	Synchronous Optical Networking
SOC	System on a Chip
PCIe	Peripheral Component Interconnect Express
SATA	Serial Advanced Technology Attachment
PAM4	Pulse Amplitude Modulation
ORR	12G Wideband Optical Reference Receiver
Sim	Simulation
Conf	Configuration
PRD	Product Requirements Document
HW, FW, SW	Hardware, Firmware, Software
RF	Radio Frequency
Gbps	Gigabits per second
PC Mode	Pattern Capture Mode
GUI	Graphical User Interface
THD	Total Harmonic Distortions

Product Features

- Noise floor:
 - 5 μ W at 25 GHz bandwidth.
 - 6-7 μ W at 42 GHz bandwidth.
- Sensitivity level -11dBm for a 25.78 Gbps NRZ signal.
- Up to 50-70 MHz sampling rate.
- Supports 802.3 TDECQ measurements via SSPRQ patterns.
- Less than 10secs TDECQ on an SSPRQ pattern.
- Comprehensive eye mask library.
- Extensive library of built-in DSP filters.
- Brand new user interface.
- Precision TimeBase.
- Extremely low jitter.
- Optical bandwidth 25 / 40 GHz.
- Wavelengths between 1260 to 1650 nm single mode or 700 to 870 nm multimode.
- 32 GHz differential electrical sampler.
- Open Eye MSA support.
- 100G per wavelength and channel characterization.
- FPGA-based architecture enabling TDECQ measurements via capture of SSPRQ and PRBS16 patterns.
- An extensive library of built-in DSP filters such as Bessel-Thomson, CTLE, DFE, FFE, deembedding, and component emulation, all available free of charge in the standard GUI.
- Comprehensive eye mask library.
- Individual impulse response calibration performed at factory.
- Compact instrument footprint with a ruggedized enclosure and handle.
- Comprehensive set of APIs and associated sample scripts to accelerate automation development under Linux and Windows, supporting Python, LabView, Matlab, and C#.

Product Description

- Installation explains how to configure and install the instrument as well as how to install the included system software.
- Incoming Inspection provides a verification procedure for basic operation and functionality.
- Accessories and Options lists the instrument options available along with the standard/optional accessories for this product.

Overview

The **DSO** Digital Sampling Oscilloscope (DSO) is a fully integrated, ultra-compact Ethernet controlled instrument that automatically performs accurate eye diagram and pattern capture analysis to characterize the quality of transmitters and receivers, interconnecting with a specified input BW. It is operational under Windows and Linux.

The **DSO** implements a statistical under-sampling technique with comprehensive software libraries for eye measurement, jitter analysis and processing of NRZ data, thus enabling:

- Eye measurements with the following classes of operation:
 - Oscilloscope Measurements
 - NRZ Measurements
 - PAM4 Measurements
 - Multiple measurements
 - Mask Test
- Advanced pattern acquisition with pre-emphasis measurements.
- Jitter component decomposition
- Filtering
- De-Embedding
- Frequency domain plots

Key Features

- High-value instrument grade sampling scope optimized for high-speed data analysis.
- External reference clock input
- Single ended and differential electrical inputs supported.
- Eye capture, jitter, rise/fall, histogram, mask measurement, pattern capture, S21 Capture & frequency domain, all in a single instrument.
- Multiple modules can be controlled via fast Ethernet 100Base-T.
- The DSO tool can operate in a data acquisition only mode where the data is saved on multiple acquisitions for post processing.
- Supports high density parallel application with scalable concurrent testing.
- Ultra-compact form factor replaces conventional rack test solutions and solves impractical physical requirements of testing large lane counts. DSO can mount into the Verigy 93K.
- User friendly GUI enables zooming, markers, X/Y histograms, overlays, pre-emphasis with simultaneous measurement statistical captures.
- Load and analyze data that was previously captured in simulation mode.
- Capability to save statistical measurements, data files and configurations.
- Color graded display for visualizing jitter and noise distributions
- Standard stress masks selection for LRM precursor, LRM post-cursor, LRM symmetric and LRM Clean Eye.
- Mask user defined, auto-detect mask support.
- Percentage of failing points
- Save data and mask.
- Load mask file.

Scope Measurement Suite

- Mask margin, alternate mask margin rules available
- The mask margin (positive or negative) can be extracted for a defined number of points that fail, thus allowing for DUT quality assessment, control and binning
- The number of failed points for a region can be returned as well as the actual points that failed.
- Eye opening, eye height and width, eye amplitude, top, base, hi, lo, peak to peak, max, min
- Rise/ fall time, single edge measurement in pattern capture
- Total edge jitter
- Statistical histogram measurements
- Crossing point, crossing percentage
- Advanced pattern measurements:
 - Eye measurements on specific bits of the pattern

- Single edge measurement in pattern capture
- Pre-emphasis (positive and negative, height bandwidth)
- Jitter analysis
 - Deterministic jitter.
 - Random jitter.
- S-parameters & harmonic distortions

Target Applications

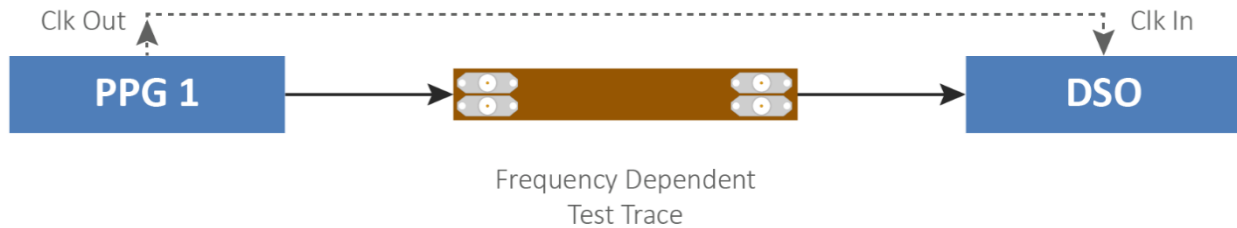


Figure 1: DSO Application

- Interconnect testing (SFP, SFP28, CFP, CFP2, CFP4, QSFP, QSFP28, ...)
- Backplane testing
- Interference and crosstalk testing
- Receiver jitter tolerance testing equalizer characterization
- Electro-optical module testing
- Electrical stressed eye testing for 100 Gbps Ethernet, MLD/CAUI application, OIF CEI- 28G-VSR, CPPI-4, CAUI-4, 32G Fiber Channel chip module (c2m)
- High speed SerDes testing & characterization.
- Handheld 10G test equipment for field Installation and maintenance
- Multi-port or line card system testing
- In-Situ testing of high port count systems
- Can be mounted in Automatic Test Equipment (ATE) or in socketed load board.
- Telecom equipment tests for installation and maintenance
- Fiber channel, Ethernet, PON, parallel optics, etc.
- High port count burn-in test
- Research and development applications

Product Software

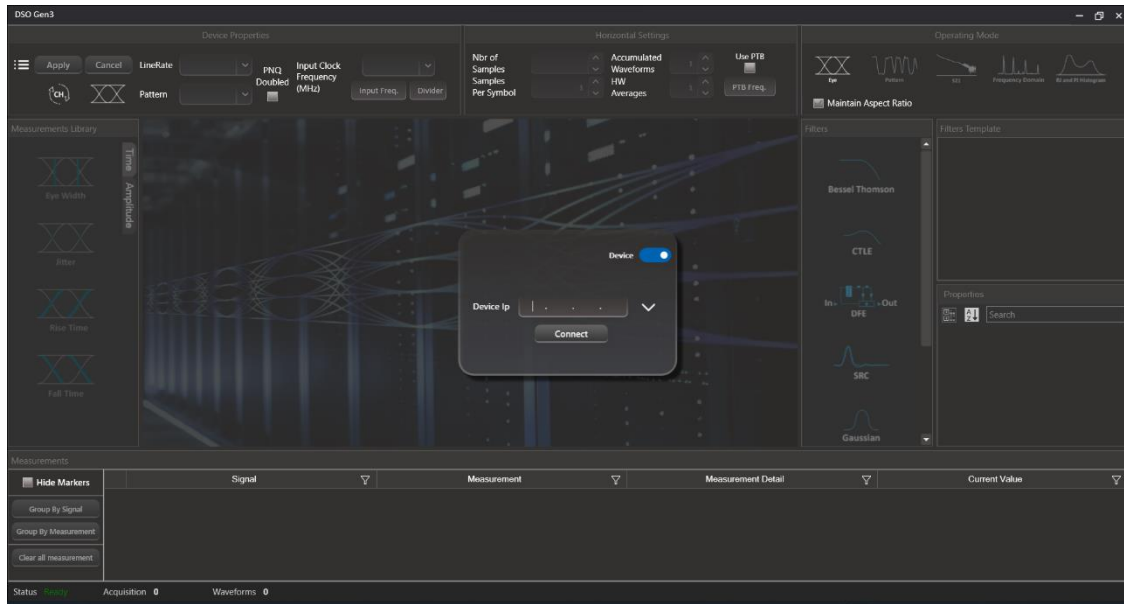


Figure 2: DSO GUI

Minimum PC Requirements

The Windows PC properties for the MultiLane software must meet the following specifications:

- Windows 7 or greater
- Minimum 4 GB RAM
- 1 Ethernet card to establish connection with the device.
- USB connector
- Pentium 4 processor 2.0 GHz or greater
- .NET Framework 4.0

NOTE: It is recommended to connect the DSO via Ethernet to a single PC only, preventing conflict from multiple user commands.

Installation

This section address installation and bring-up of the instrument, addressing the following topics:

- System start-up
- Connection guide

System Start-up

To use the **DSO** under Windows XP, Windows 7 and Vista, it is important that the correct start-up sequence is followed:

- Ensure [Microsoft .NET Framework 4.0](#) is installed
- Install the DSO GUI software.
- Connect the power cable to the power jack and field it with a 12 V/ 3 A supply.
- Note power plug is already included in the package accessories.
- Communication through USB to the instrument is required to configure its own IP **only**.
- Install the USB driver to the PC
- Change the IP of the DSO to fit in the network range by and using the software DSO Conf
- Communication through Ethernet port is required for data acquisition.
- Connect the PC to the DSO through an Ethernet cable, no driver required.
- Now the DSO is powered up, having the right IP, the Ethernet cable links the instrument to the PC with the GUI correctly installed.
- To open the GUI, double click on the software icon located in the Desktop directory.
- To characterize the signals fielding the instrument, check the Data and Connection configuration.

NOTE: *This release supports Ethernet connection for the software applications, and the USB port is used only to configure the device IP Address (note that the IP should be in the same range of the network)*

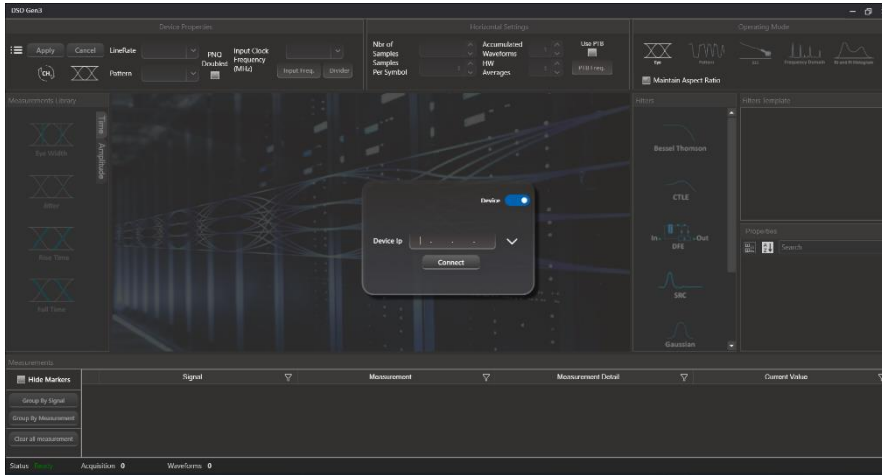
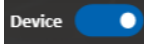
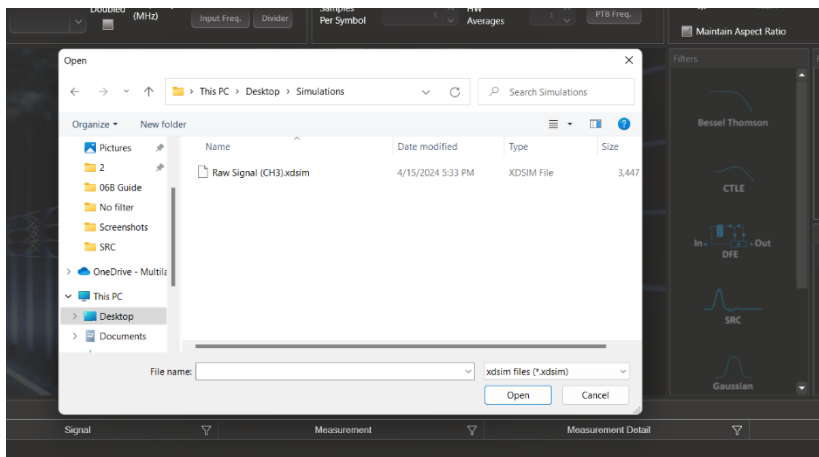


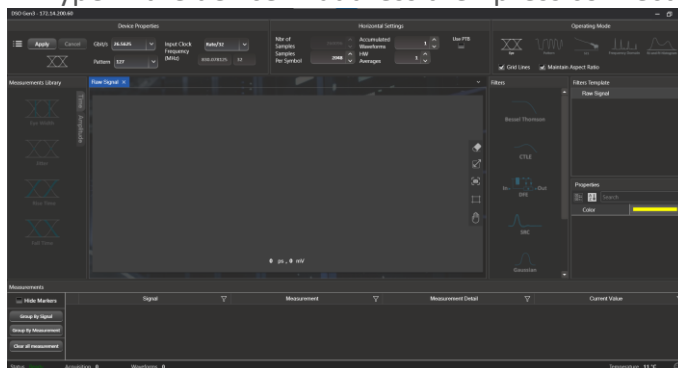
Figure 3: GUI

- Open DSO Gen3 Gui after installation
- The “Connect to DSO” window will popup.
- Click on the  Button if you want to load a simulation.



• This window will popup, Navigate and choose the file you want to simulate.

- To connect to your device, Keep the switch in device mode.
- Type in the device IP address then press connect.



NOTE: Any data file that has already been saved using the **DSO** software can be loaded.

DSO Configuration

Connection Configuration

Change the configuration as needed:

- The default display name of the target DSO can be edited as preferred.
- The IP of the DSO connected by writing it next to “IP” label.

Data Configuration

The DSO has 3 SMA inputs (two for the differential data RF Input + and RF Input –, and one for the Clock input).

External Clock Operation

Clock Input in normal mode ranges between 5 and 525 MHz (710 MHz for certain models):

- Choose the Normal Operation radio button to use the onboard timing generator.
- Enter the target line rate less Line Rate (Gbps) into the **Gbit Rate** field or choose a Gbps value, example: 10.709, 10.625, 10.3125, 9.95328, 8.5, 6.25, 4.25 and 3.125, 25.78125, 26.5625, 53.125, 106.25
- Specify the number of packets; it can be 4, 8, 16, 32, 64, 128, 256 or 512

Each packet consists of 512 sample points per UI, which are duplicated when drawing the eye.

Eg: 256 packets correspond to 131072 points per pattern, and 262144 points per eye (131072 for each of the 2 UIs displayed in eye mode).

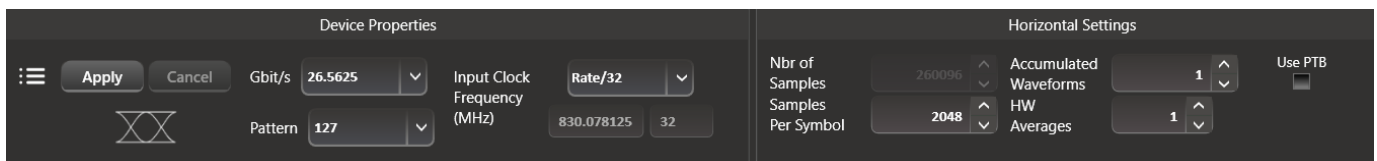
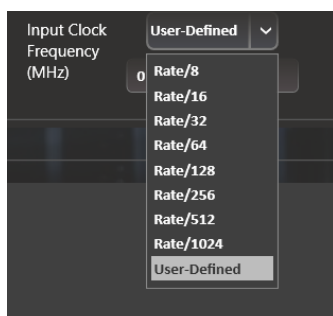



Figure 4. DSO Configuration

- Enter the percentage level of rising and falling times in the **NRZ Thresholds** field.
- Enter the **External Reference Clock Frequency** in MHz or as a factor of the bit rate.



- Clock rate can vary from 50 MHz to (525/710) MHz, with an amplitude range from 0.05 to 1.5 Vpp
- Typically, this will be rate / 8,16,32,64,... 1024, but can be any other rate as well.
- Enter the **Pattern Length** of the data feeding the DSO to capture the full pattern
Note: Incorrect pattern length would still display the eye capture, however full pattern capture is required for certain features of the software such as Jitter Decomposition, PTB and Filters.

E.G.: Pattern Length = 127 for PRBS-7, The Pattern length of PN(n) is $(2^n) - 1$.

- To get wander correction, check the box then choose between the 3 frequencies, 1024 or 2048 or 4096 Hz.
- To retrieve the last configuration, disconnect from here  then reconnect.
- To capture more points for sharper measurements, accumulate the number of points from all the acquisitions by entering the total number of points to persist in the accumulate field. This will set the number of points filling the entire eye diagram. For both UI's, half this number of points will be displayed in the pattern diagram. Accumulation works in infinite persistence mode, and unless the points are cleared or the connection is reset, all acquisitions will take part in the accumulated result with equal amounts of points randomly selected from each acquisition.

	PRBS	Pattern	Samples Per Symbol
ML4015E	PRBS7	127	4095
ML4015E-E	PRBS9	511	1800
ML4015E-2X	PRBS11	2047	400
ML4015F	PRBS13	8191	100
ML4015F-2X	PRBS15	32767	28
	PRBS16	65535	12

PS:

- All ML4015 in this table follow the same configuration.
- Always click on “PNQ Doubled” when the Pattern is doubled.

DSO Menu

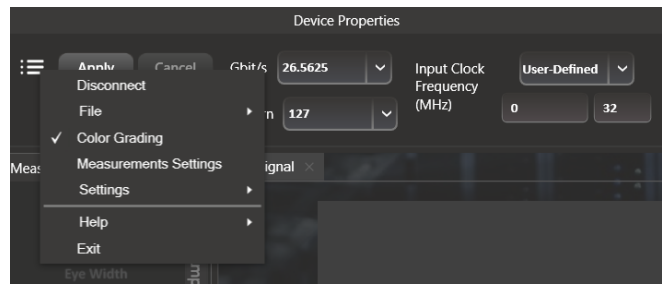


Figure 6: DSO menu bar

File Menu

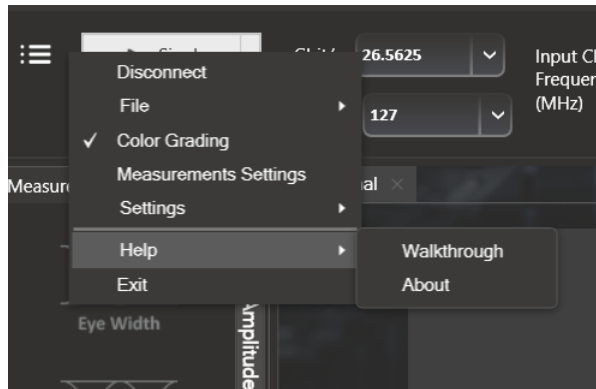
Save: after clicking on this icon, a save window appears, enabling you to save configurations, data and measurements files for each acquisition.

In the case of being connected to multiple DSOs, there are check boxes next to each DSO, check the one related to the needed DSO and save preferences. Each checked DSO has a separate folder. If the 3 options Conf, Data and Measurements are checked; in this folder 3 kinds of files will be found.

Conf: select to save the configuration file.

Data: select to save the data file.

Measurements: select to save the statistical measurements files.



The version for this software can be found after selecting the “**About**” under “**help**” menu option.

Zooming can be done by clicking on the graph and dragging, which would draw a dotted window. When the mouse is released, the graph will zoom to display only the content within the drawn box. This method of zooming may alter aspect ratio of the graph if the drawn box is of disproportional dimensions.

Zooming also can be done using the mouse wheel when the Ctrl button is held. This method will maintain the original aspect ratio of the graph.

In order to go back to the initial view, right click on the graph, and choose “**Undo All Zoom/Plan**”

Panning

The position of the graph in the display window can be panned by dragging the graph with the mouse while the Ctrl key is held.

Copy, Save, Undo Zoom and Print a Graph

Right clicking the graph exposes these features:

Copy: copy the present graph as an image into clipboard.

Save Image As: save the present graph in the desired location.

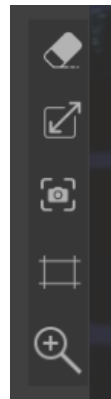
Page Setup: view page information for printing.

Print: print the graph.

Show point values: display the coordinates of points when hovering over them in the graph.

Un-Zoom: undo the last zooming performed.

Undo All Zoom/ Plan: undo/reset all zoom actions.



Operating Modes

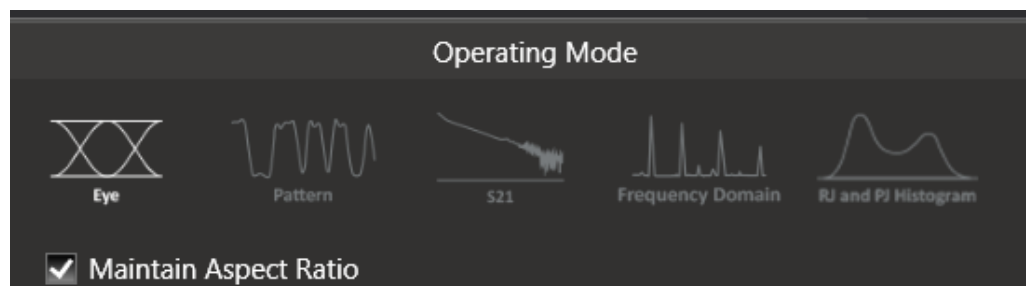



Figure 7: Supported DSO GUI Operating Modes

Selecting **Operating Modes** in upper right corner allows navigation between:

- Eye Measurement Mode:
 - Oscilloscope Measurements
 - Multiple measurements
 - NRZ Measurements
 - PAM4 Measurements
 - Mask Test
- Pattern Capture Mode includes jitter decomposition.
- S-Parameter Mode
- Frequency Domain Mode

Eye Measurement Mode

Regardless of hardware or simulation mode, it is possible to draw the eye and capture measurements after filling the configuration window and connecting to the instrument.

In Eye Mode, in order to draw the eye diagram, click on the **Start Data Acquisition** button 

Check the **Check All** button to view all the eye measurements down the screen for one time or select the needed measurement only by pressing on the desired icons. Use the second option to reduce measurement operation time.

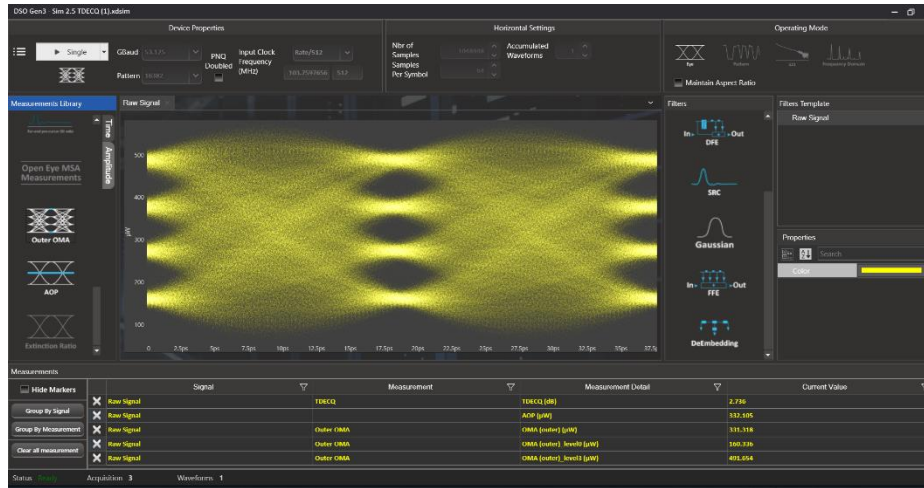
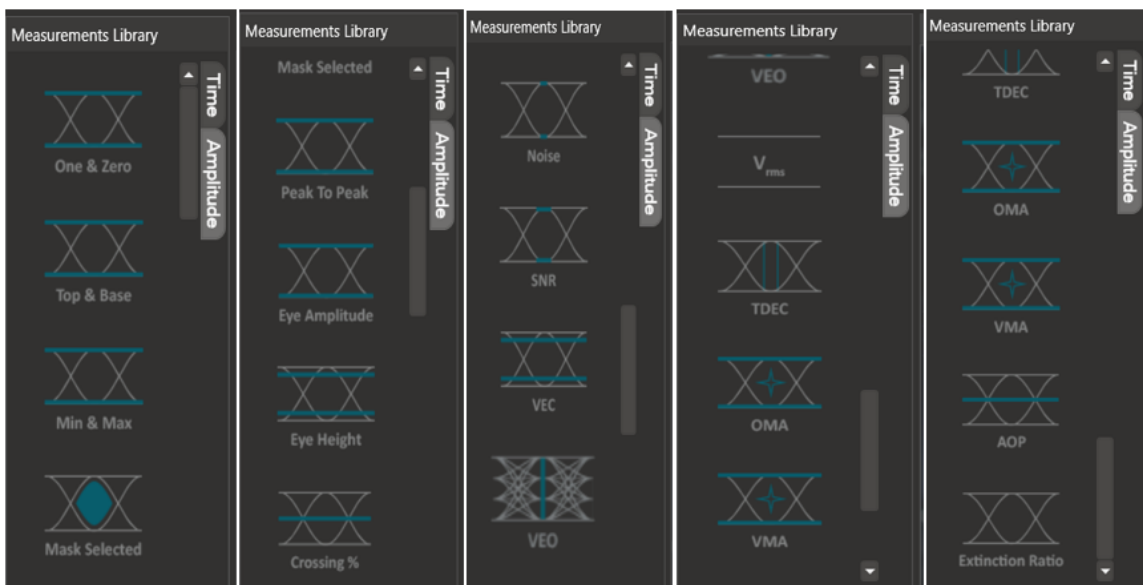


Figure 8: Measurements Mode



Status Bar

Number of Samples

The status bar displays the number of kilo-samples captured in the Eye mode. '1K Samples' is equivalent to 1000 sample points in the Eye graph, including accumulated point when applicable.

Operation Status

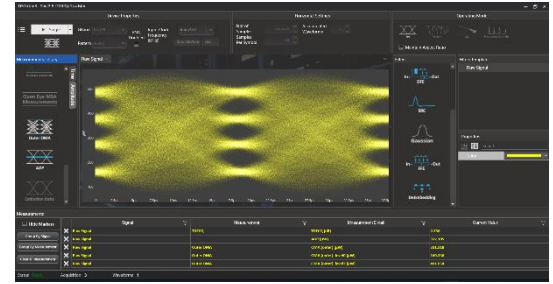
Operation Status	Status Description
Gathering Data	Acquiring data (reading from hardware)
Saving Data	Saving data in the data file
Error Connecting to DSO	A connection between SW and HW cannot be established
Error Applying Wander Compensation on DSO	Wander cannot be applied because an eye cannot be detected at the first place
Saving Results	Saving acquired data points and statistical measurements into their file
Displaying Results	Showing the statistical measurements and refreshing the graph
Acquisition Finished	Acquiring data and sampling is finished

Table 1: Operation Status Messages

Oscilloscope Measurements

While capturing the eye, a user can perform measurements by simply clicking the corresponding buttons: Top, Base, Min, Max, Fall time, Rise time, Peak to Peak, Eye Amplitude, Eye Height, Eye Width, Jitter, and the crossing percentage. The **Check All** text box can be selected to capture all the measurements in one action.

When multiple DSOs are connected, and after drawing all the eyes or patterns, the measurements are displayed for all DSOs down the screen in the tables.

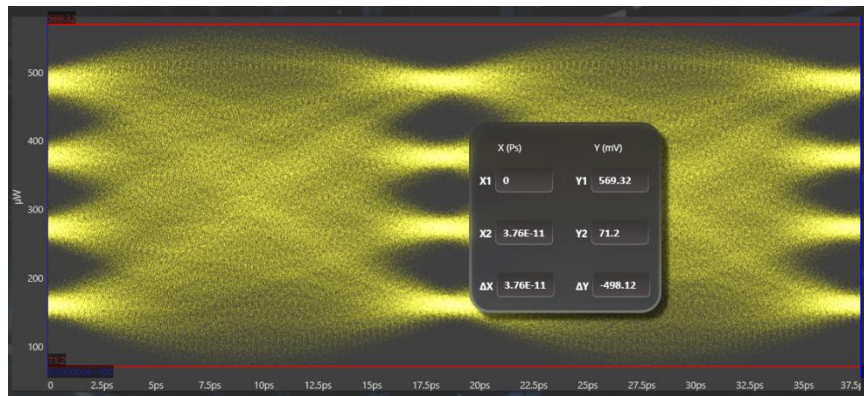


Markers

This feature by default is off; in order to use it, switch it to on by choosing the **On** radio button, under the **Markers** group box.

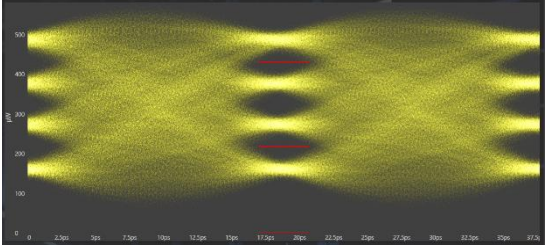
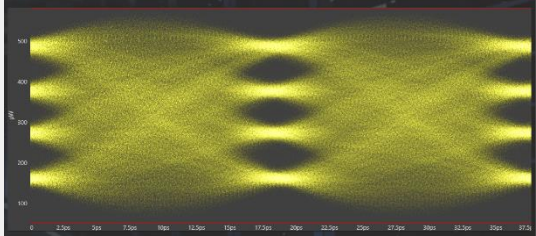
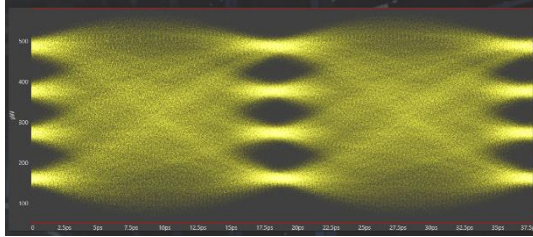
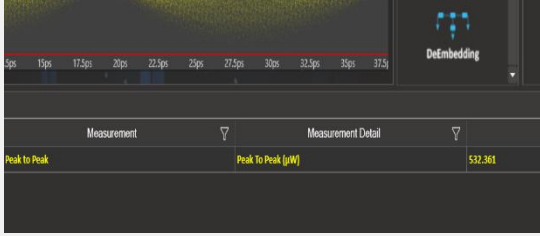
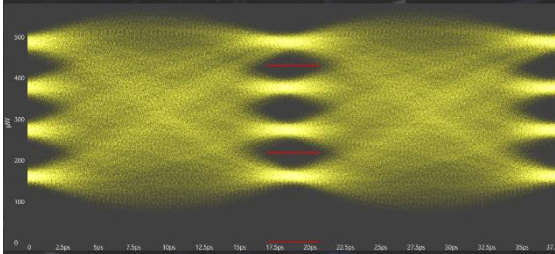
A pair of movable markers in both X-axis and Y-axis is displayed. The horizontal and vertical markers help bound the measurement region by giving the difference between the 2 horizontal and vertical markers.

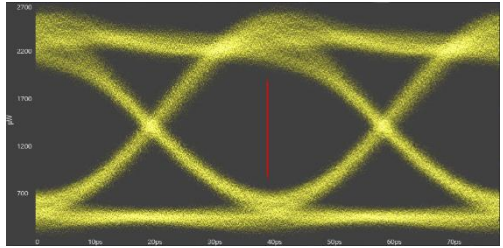
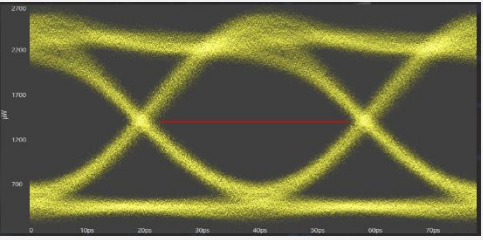
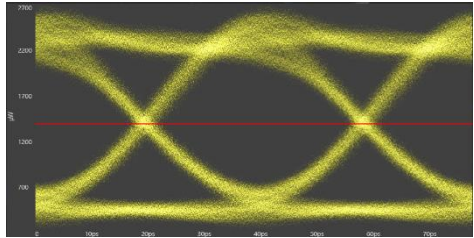
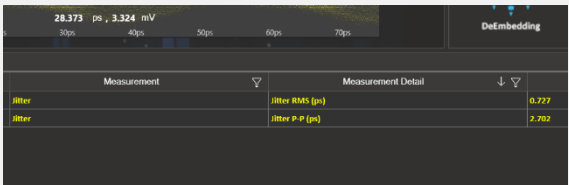
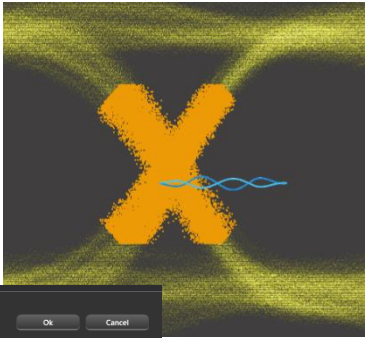

The results are displayed at the top of the graph. Picosecond or UI is the unit of the X axis; mV is the unit of the Y axis.

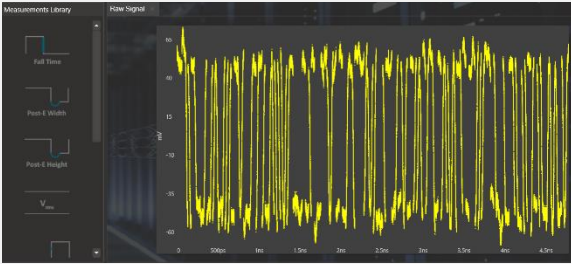
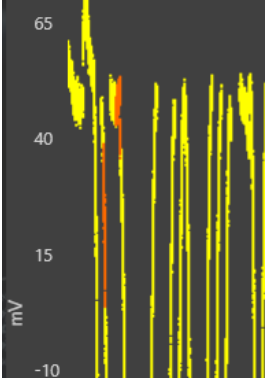
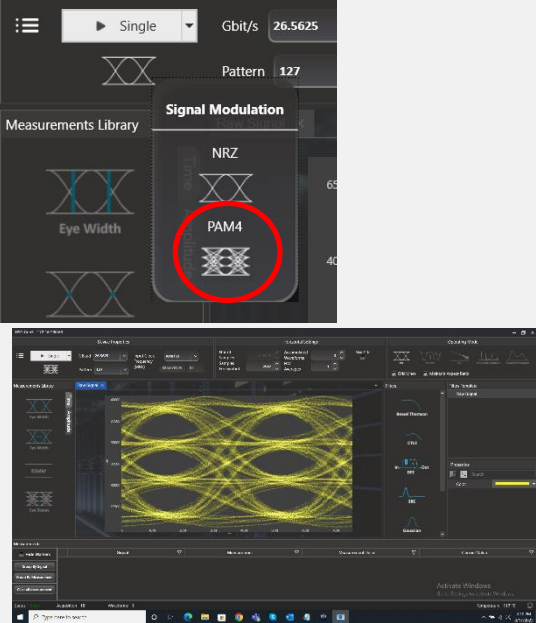
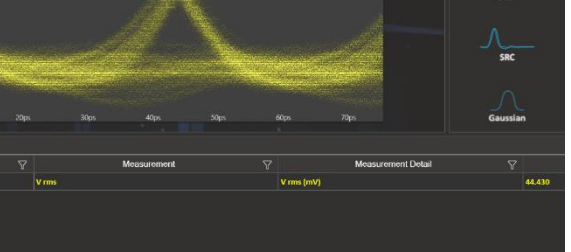


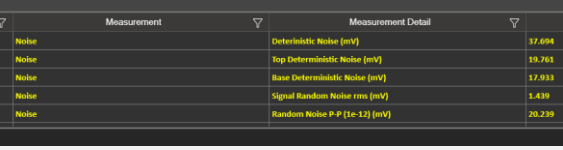
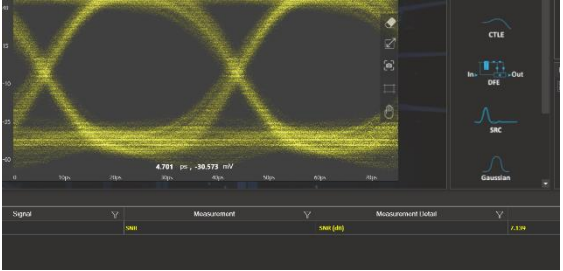
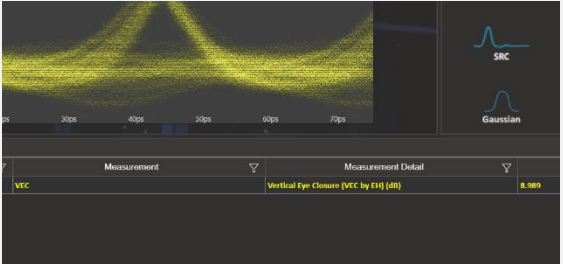
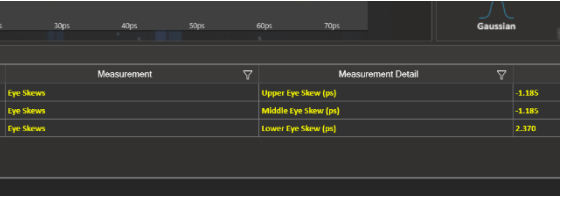
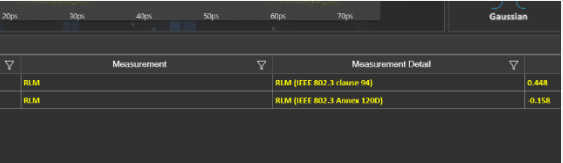
- First select the marker to be moved; it should be highlighted in yellow.
- Drag the markers to the required location.
- The marker values displayed in the textboxes bottom left can be used to manually specify the marker positions.
- Markers help verify horizontal and vertical measurements, such as jitter, eye width, eye height, and mask margins. They can be dragged manually to view the delta or difference between 2 markers.

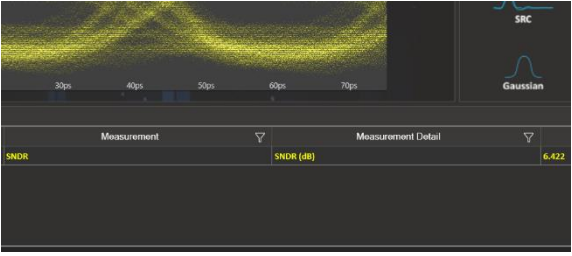
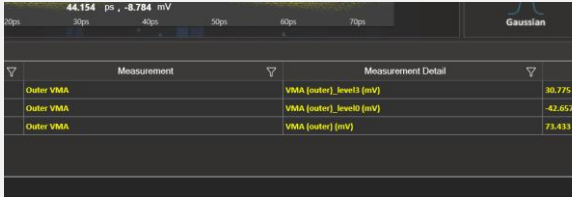
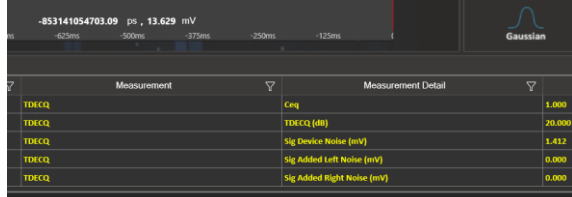
Measurements

Measurement	Description	Screenshot
One and Zero Levels	The average y-values at 20% around center of the eye	
Min	The minimum sample value.	
Max	The maximum sample value.	
Peak to Peak	The difference between the max and the min eye sample values, here max is the value of the sample point with the highest amplitude and min is the value of the sample point with the lowest amplitude.	
Eye Amplitude	The difference between one level and zero level of an eye.	

Measurement	Description	Screenshot
Eye Height	Eye Height is the vertical opening of the eye measured as the difference between the -3 sigma value of the high samples within the NRZ window and the +3 sigma values of the low samples within the NRZ window.	
Eye Width	The time between the latest possible occurrences of one eye crossing to the earliest possible occurrence of the next crossing.	
Crossing Percentage	The amplitude of the crossing level relative to the low and high levels. (The value of the crossing percentage is displayed in the bottom of the screen.)	
Jitter	The jitter measurement allows to calculate the total jitter, the jitter peak-to-peak and the jitter rms in ps.	
Mask Margin	<p>The Switch to Mask Mode button, located between the Eye and Pattern buttons, is used to find the maximum mask margin that results in no more than a specified number or ratio of failing points. The figure below shows an example of where the user wants to determine the maximum mask margin available for the highest number of failing points, but no more than 25.</p> <p>The answer in this example is +13% for 8 points. Setting the margin below this level would result in less failing points in total. Setting the margin above this level would result in fewer failing points.</p> <p>The DSO has the following standard masks: 100Gbase-SR, LR, STM-1, STM-4, STM-16, Gb Ethernet, Fiber Channel (1x), Fiber Channel (2x, 4x), Fiber Channel (8x), Fiber Channel (10x), 10 Gb Ethernet, and user defined masks. New masks are continuously added. Recent additions are QDR & FDR.</p>	 

<p>Pattern Capture Mode</p>	<p>Pattern Capture mode enables the raw bit sequence captured by the DSO to be captured. In order to see the behavior of a specified sequence of bits, zoom in and out by scrolling the mouse wheel, or using the cursor to specify the region to be zoomed in upon. Pattern rise/fall times pre-emphasis, post-emphasis, PRBS validity and VMA (voltage modulation amplitude) can be measured in this mode. Note, Pattern Capture mode needs to be able to show the full pattern for certain features of the software to work, such as:</p>	
<p>VMA</p>	<p>The voltage modulation amplitude of a pattern displayed in mV.</p>	
<p>PAM4</p>	<p>Pulse-amplitude modulation (PAM4) is a form of signal modulation where the message information is encoded to one of 4 amplitude levels. Unlike NRZ which varies between 2 amplitude levels indicating zero and one, PAM 4 varies between 4 amplitude levels where one symbol corresponds to a value in the range zero to three. This leads to double the bit rate for the same baud rate as NRZ.</p> <p>To unlock the PAM4 measurement library, choose PAM4 as the signal type.</p>	
<p>Voltage RMS</p>	<p>The voltage RMS measurement can be captured without Pattern or Eye Lock, and can be used to determine noise floor, which is then entered in the Configuration/Advanced Menu for De-Embedding the intrinsic noise from the setup.</p> <p>Some of the measurements (Min, Max, One, Zero, Peak to Peak, Eye Amplitude, Eye Height, Eye Width, Eye Height BER, Eye Width BER and VEC) are applicable in PAM4 mode.</p>	

<p>Noise</p>	<p>This library is a consolidation of all vertical noise measurements including rms and deterministic noise. For an optical DUT signal this will be depicted in Watts.</p>	 <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th></th> </tr> </thead> <tbody> <tr> <td>Noise</td> <td>Deterministic Noise (mV)</td> <td>37.694</td> </tr> <tr> <td>Noise</td> <td>Top Deterministic Noise (mV)</td> <td>19.761</td> </tr> <tr> <td>Noise</td> <td>Base Deterministic Noise (mV)</td> <td>17.933</td> </tr> <tr> <td>Noise</td> <td>Signal Random Noise rms (mV)</td> <td>1.439</td> </tr> <tr> <td>Noise</td> <td>Random Noise P-P [1σ-1σ] (mV)</td> <td>20.239</td> </tr> </tbody> </table>	Measurement	Measurement Detail		Noise	Deterministic Noise (mV)	37.694	Noise	Top Deterministic Noise (mV)	19.761	Noise	Base Deterministic Noise (mV)	17.933	Noise	Signal Random Noise rms (mV)	1.439	Noise	Random Noise P-P [1σ-1σ] (mV)	20.239
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<p>SNR</p>	<p>The signal to noise is a ratio of the signal difference between one level and zero level relative to the noise present at both levels.</p>																			
<p>VEC</p>	<p>VEC = Vertical Eye Closure in dB.</p> <p>Calculated in NRZ as:</p> $20 \times \log \left(\frac{\text{Eye amplitude}}{\text{Eye height}} \right)$ <p>Calculated in PAM 4 as:</p> $20 \times \log \left[\text{Max} \left(\frac{AV_{upp}}{V_{upp}}, \frac{AV_{mid}}{V_{mid}}, \frac{AV_{low}}{V_{low}} \right) \right]$ <p>Note: AV is the eye amplitude and V is the eye height in PAM4 mode.</p>	 <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th></th> </tr> </thead> <tbody> <tr> <td>VEC</td> <td>Vertical Eye Closure [VEC by E1] (dB)</td> <td>8.989</td> </tr> </tbody> </table>	Measurement	Measurement Detail		VEC	Vertical Eye Closure [VEC by E1] (dB)	8.989												
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<p>Eye Skews</p>	<p>Ratio Level Mismatch is a measure of linearity in a PAM4 signal. This measurement is defined by the IEEE as a metric to compare the consistency of the three eye openings of a PAM4 signal. Please refer to the 120D-6 IEEE annex for the relevant equation.</p>	 <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th></th> </tr> </thead> <tbody> <tr> <td>Eye Skews</td> <td>Upper Eye Skew (ps)</td> <td>-1.185</td> </tr> <tr> <td>Eye Skews</td> <td>Middle Eye Skew (ps)</td> <td>-1.185</td> </tr> <tr> <td>Eye Skews</td> <td>Lower Eye Skew (ps)</td> <td>2.370</td> </tr> </tbody> </table>	Measurement	Measurement Detail		Eye Skews	Upper Eye Skew (ps)	-1.185	Eye Skews	Middle Eye Skew (ps)	-1.185	Eye Skews	Lower Eye Skew (ps)	2.370						
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<p>SNDR</p>	<p>Signal-to-Noise Distortion Ratio in dB. SNDR is defined by:</p> $10 \times \log_{10} \left(\frac{P_{max}^2}{\sigma_e^2 + \sigma_n^2} \right)$ <p>where P_{max} is the maximum value of $P(k)$ which is the linear fit pulse response, σ_e is the standard deviation of the error $e(k)$ and σ_n is the RMS deviation from the mean voltage at a fixed point in a run of at least 8 consecutive identical levels.</p>	 <p>The screenshot shows an eye diagram with a signal-to-noise ratio measurement. The measurement table is as follows:</p> <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>SNDR</td> <td>SNDR (dB)</td> <td>6.422</td> </tr> </tbody> </table>	Measurement	Measurement Detail	Value	SNDR	SNDR (dB)	6.422												
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<p>Outer VMA</p>	<p>Outer VMA" likely refers to "Vertical Mask Alignment".</p> <p>A feature used to analyze the quality of digital signals by comparing them to defined voltage masks. This helps identify issues like timing jitter and amplitude variations in signals. It's useful for measuring signals like PRBS in digital communication systems.</p>	 <p>The screenshot shows an eye diagram with three VMA measurements. The measurement table is as follows:</p> <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Outer VMA</td> <td>VMA (outer_level3) (mV)</td> <td>30.775</td> </tr> <tr> <td>Outer VMA</td> <td>VMA (outer_level0) (mV)</td> <td>-42.657</td> </tr> <tr> <td>Outer VMA</td> <td>VMA (outer) (mV)</td> <td>73.433</td> </tr> </tbody> </table>	Measurement	Measurement Detail	Value	Outer VMA	VMA (outer_level3) (mV)	30.775	Outer VMA	VMA (outer_level0) (mV)	-42.657	Outer VMA	VMA (outer) (mV)	73.433						
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<p>TDECQ</p>	<p>Transmitter and Dispersion Eye Closure for Quaternary.</p> <p>Details</p>	 <p>The screenshot shows an eye diagram with several TDECQ measurements. The measurement table is as follows:</p> <table border="1"> <thead> <tr> <th>Measurement</th> <th>Measurement Detail</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>TDECQ</td> <td>Cdq</td> <td>1.000</td> </tr> <tr> <td>TDECQ</td> <td>TDECQ (dB)</td> <td>20.000</td> </tr> <tr> <td>TDECQ</td> <td>Sig Device Noise (mV)</td> <td>1.412</td> </tr> <tr> <td>TDECQ</td> <td>Sig Added Left Noise (mV)</td> <td>0.000</td> </tr> <tr> <td>TDECQ</td> <td>Sig Added Right Noise (mV)</td> <td>0.000</td> </tr> </tbody> </table>	Measurement	Measurement Detail	Value	TDECQ	Cdq	1.000	TDECQ	TDECQ (dB)	20.000	TDECQ	Sig Device Noise (mV)	1.412	TDECQ	Sig Added Left Noise (mV)	0.000	TDECQ	Sig Added Right Noise (mV)	0.000
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Multiple Measurements

The multiple measurements give the user the ability to view the different measurements: Top, Base, Min, Max, Fall/ Rise time, Peak to Peak, Eye Amplitude, Eye Height, Eye Width, Jitter, and the crossing percentage for a number of measurements specified in the repetitive box or for an undetermined number. Use the **Check All** text box to display all the measurements.

Statistics

To enable repetitive data acquisition, and statistics measurements, the repetitive mode needs to be checked or the numbers of acquisition in the counter box needs to be increased, then the statistical measurements are shown and the following is displayed: Current value, average minimum, maximum and the standard deviation of each measurement.

Filters

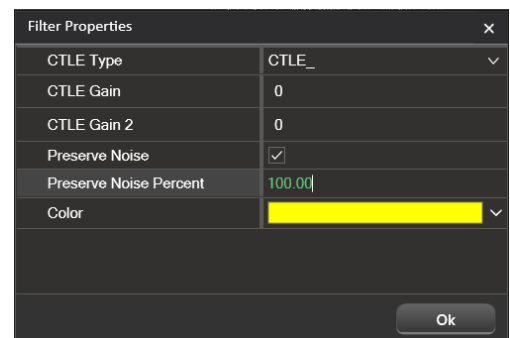
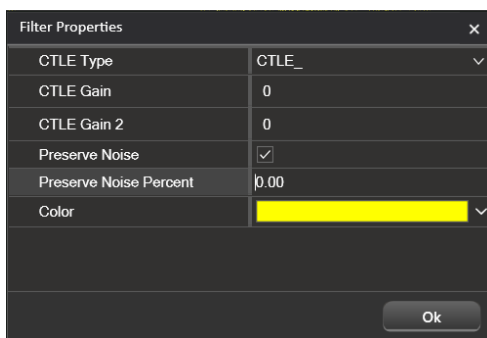
The DSO GUI platform comes equipped with useful filters that offer a variety of signal processing techniques including cleaning the signal, de-embedding and discovering the optimal taps for improving an NRZ or PAM4 signal. The filtering GUI can be used to adaptively detect the minimum number of FFE or DFE taps required to reach a target Eye Height or SNR.

These filters can be applied to a DUT signal with or without introducing the **preserve noise** feature, which compensates for the filter side effect of reducing signal noise of adjacent measurement points.

Click on the Filters button after a successful signal acquisition.

Handling the preserve noise function:

When applying CTLE, Bessel-Thomson and De-Embedding filters, You can find in the middle a preserve noise checkbox.



- You have a range from 0% - 100%
- 100 keep all the noise.
- 0 remove all the noise (for deterministic data checking).
- Preserve noise is kept 100% by default.

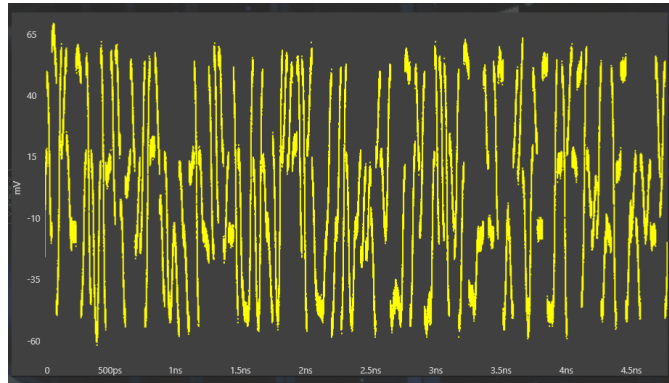


Figure 10: PAM4 pattern mode

Current List of Supported Filters:

- 1- Moving Average Filter for signal smoothing: User can specify window size.
- 2- 4th Order Bessel Thomson filter at frequency equal to 0.75 of the bit rate (order and cutoff are configurable).
- 3- CTLE filter: User can automatically or manually select the filter parameters. Adaptive CTLE can determine the CTLE for best Eye Height.
- 4- S2P/S4P De-Embedding: This filter simulates the inverse of a channel or DUT, where the channel's S2P or S4P file is loaded. Can also emulate channel insertion loss.
- 5- DFE: The Decision Feedback Equalizer (nonlinear adaptive equalizer) is based on the principle that once the decision circuit has determined the value of the current transmitted symbol; one can precisely remove the ISI contribution of that symbol to future received symbols. Optimal DFE parameters can be determined by the GUI, and it can also adaptively detect minimum taps required for a target Eye Height or SNR value.
- 6- FFE: With the Feed Forward Equalizer (linear equalizer), each value of the output sequence is a weighted sum of the most recent input values. Optimal FFE parameters can be determined by the software, and it can also adaptively detect minimum taps required for a target Eye Height or SNR value.
- 7- SIRC: Also referred to as SRC, stands for System Impulse Response Correction. It is the extracted time domain impulse response of a reference O/E which is converted into the frequency domain using an FFT. Either method will yield a 4th Order Bessel-Thompson roll-off as dictated by the IEEE 802.3bs/cd publication standards for both NRZ and PAM4 optical signals.

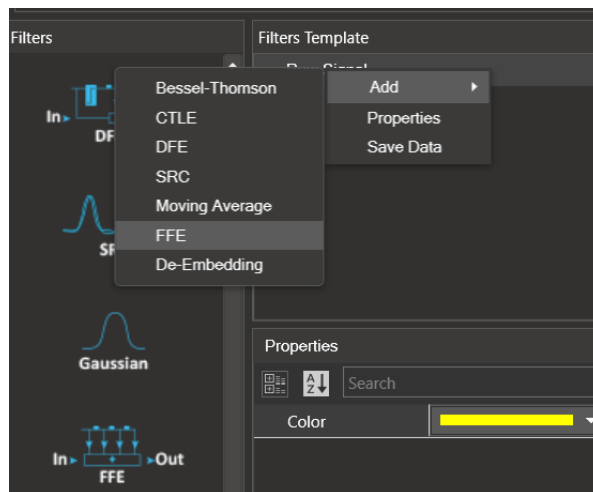
Filter Configuration Parameters follow:

FFE:

1. The tap delay is expressed as an integer fraction of the bit period.
2. Select the number of taps.
3. Tap coefficients: enter the different tap coefficients separated by commas, from tap 0 to tap N.
4. Normalize: This would normalize the filter taps ensuring unity gain. Note that if taps were generated automatically, they would already be normalized (sum = 1).

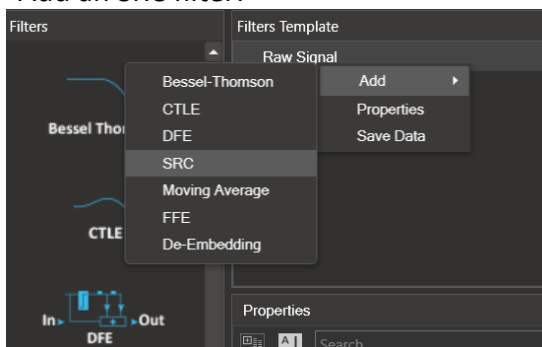
DFE:

1. With DFE, tap delay is always fixed to 1 tap per bit.
2. Tap coefficients: Enter the different tap coefficients separated by commas, ranging from tap 0 to tap N.
3. Delay value, given in picoseconds, allows users to change the decision point of the DFE slicer. This value must range from the negative bit period/2 ($-T_b/2$) to the positive bit period/2 ($+T_b/2$) of the DFE Filter; this delay defines a shift magnitude from the center of the unit interval.

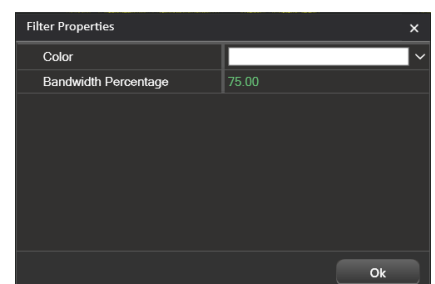


TDECQ:

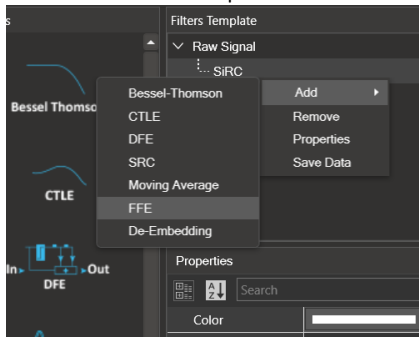
1. Switch the signal modulation from NRZ to pam4
2. Add an SRC filter:



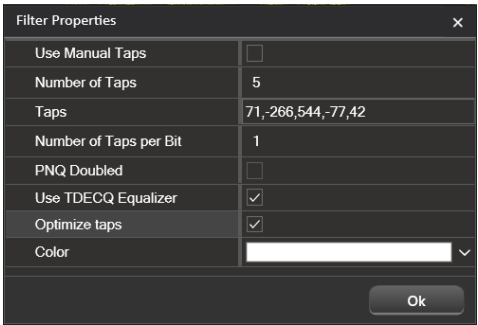
Right click on Raw
Add SRC filter
OK



3. Add FFE 5 taps



Right click SRC
 Add FFE
 5 taps
 Optimize
 Generate
 OK



4. Press on TDECQ

