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Eye Diagram Measurement

Advanced Feature for Oscilloscopes

Application Note

May, 2026

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E-mail: service@rigol.com

Website: www.rigol.com

Contents

1 Document Overview

This document is designed to introduce eye diagram feature of RIGOL's oscilloscopes. The contents include:

- Basic concepts of eye diagram measurement items;
- How to use the eye diagram feature on the oscilloscope;
- Test procedures for the typical application scenarios.

For details about the clock recovery feature of the oscilloscope and RIGOL DG4000 series function/arbitrary waveform generator mentioned in this manual, download *Clock Recovery Application Note* and the relevant manuals of the DG4000 series oscilloscope from the official website of RIGOL (www.rigol.com).

2 Eye Diagram

The eye diagram is formed by the cumulative superposition of individual bits from an acquired serial signal. Its resulting shape resembles a human eye, hence the name.

The eye diagram provides comprehensive information. It visualizes the impact of inter-symbol interference (ISI) and noise, revealing the overall characteristics of the digital signal, easy for you to effectively assess system performance.

Therefore, eye diagram analysis is critical in analyzing the high-speed interconnected system signal integrity. By observing the eye diagram, engineers can optimize the receiver equalization (RX EQ) settings to minimize ISI and enhance the transmission performance of the system.

3 Working Principle of Eye Diagram

3.1 Eye Diagram Analysis

The eye diagram plotting principle is as follows:

1. Before plotting the eye diagram, clock recovery must first be performed on the waveform. The information obtained for eye diagram plotting includes:

- Unit Interval (UI) / Symbol Rate of the Signal under Test
- Number of recovered clock cycles (Clk_num) / Positions of recovered clock edges / Attributes of recovered clock edges.

2. The sampled waveform data is then separated into several slices, with a time span of ± 1 UI, with "position of the recovered clock edge at the center of the cycle" as the center.

- A total of Clk_num waveform slices are obtained, each with a length of 2 UIs. The horizontal midpoint of each slice, i.e., the "position of the recovered clock edge at the center of the cycle" corresponds to the horizontal midpoint of a single UI.
- The first and last slices may be incomplete, but this will not affect the final

presentation of the eye diagram.

3. The horizontal range of the eye diagram is fixed to be 2 UIs (modification of the horizontal range is not supported in this version), while the vertical range matches the vertical scale of the original waveform. The aforementioned each waveform slice is then superimposed onto the eye diagram waveform using color-graded persistence.

- The horizontal width of each waveform slice is 2 UIs, consistent with the horizontal range of the eye diagram.
- The horizontal midpoint of each slice, i.e., the "position of the recovered clock edge at the center of the cycle" corresponds to the horizontal midpoint of the eye diagram.
- The counters for the corresponding pixels in the color-graded persistence database are updated based on the position of each sampling point of each waveform slice. All the waveform slices are superimposed to the eye diagram waveform in the form of color-graded persistence.

4. By analyzing the superimposed eye diagram waveforms, you can get the eye diagram measurement results.

3.2 Eye Mask Analysis

An eye mask is a pre-defined graphical boundary for the eye diagram, which is used to determine whether the generated eye diagram of the signal under test is outside a predetermined range, thereby quickly determining whether the signal under test meets the specific standard.

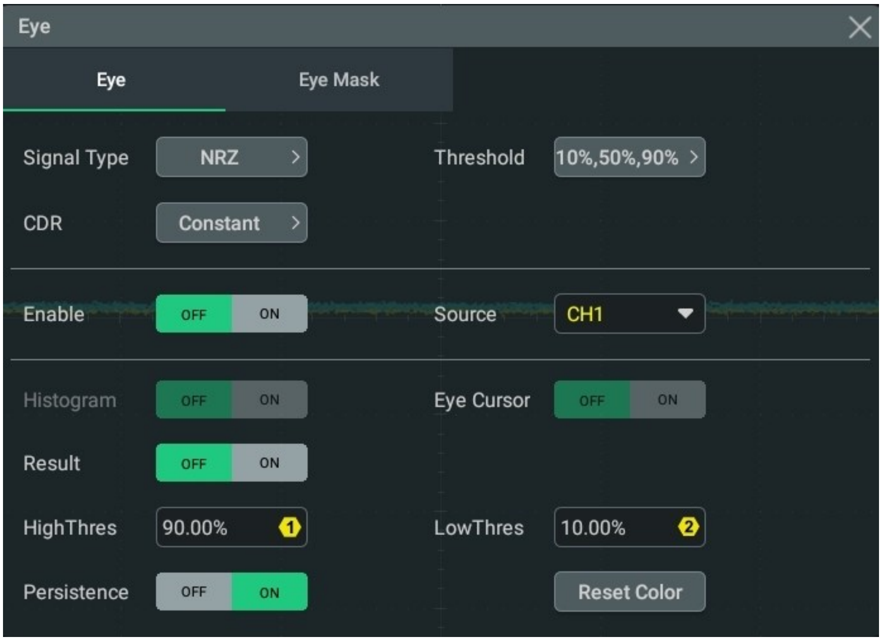
The eye mask analysis feature enables visual testing of various eye diagram parameters.

4 Eye Diagram Feature and Operation

Click or tap the function navigation icon at the lower-left corner of the screen to open the function navigation. Then, click or tap the **Eye** icon to enter the eye diagram measurement setting menu. For the detailed configurations of the clock recovery parameters related to the eye diagram, refer to descriptions in *Clock Recovery Application Note*.

4.1 Eye Diagram Configuration

The eye diagram interface is shown in the figure below.



You can configure the following parameters:

- **Signal Type**

  Click or tap this button to enter the signal type interface. Click or tap the drop-down button of **SIGNAL** to select "NRZ", "PAM3", or "PAM4". In this configuration, select NRZ. For setting methods, refer to *Clock Recovery Application Note*.

- **Threshold Settings**

  Click or tap **Threshold** to open the threshold settings interface. For the threshold settings, refer to descriptions in *Clock Recovery Application Note*.

- **CDR (Clock and Data Recovery)**

  Click or tap this button to open the clock recovery interface. For details about the settings of CDR, refer to descriptions in *Clock Recovery Application Note*.

- **Enable or Disable the Eye Diagram**

  OFF: disables the eye diagram.

  ON: enables the eye diagram.

- **Source**

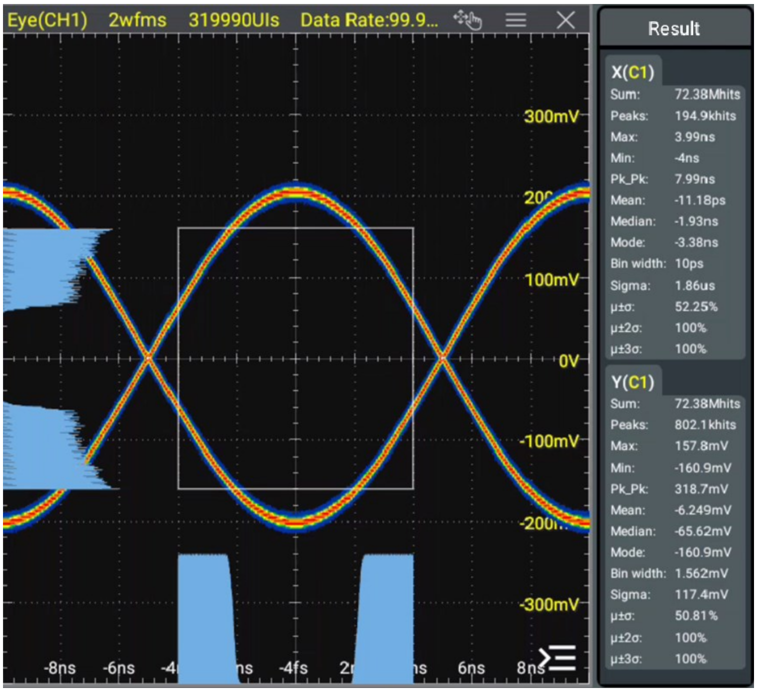
  Selects the channel of the oscilloscope to which the signal is connected for eye diagram analysis.

  The MATH channels are also available for you to choose as the source of the eye diagram analysis. When the MATH channel is selected, a maximum sampling points of 1M is allowed to be acquired.

- **Histogram**

  When the eye diagram is enabled, you can also enable the Histogram measurement. For detailed operation, refer to descriptions in "Histogram Analysis" section of the user guide of the oscilloscopes.

The range of the histogram measurements can be adjusted by scaling the rectangular box. The histogram measurements in the X-axis and Y-axis are displayed in the results window at the right section of the screen.



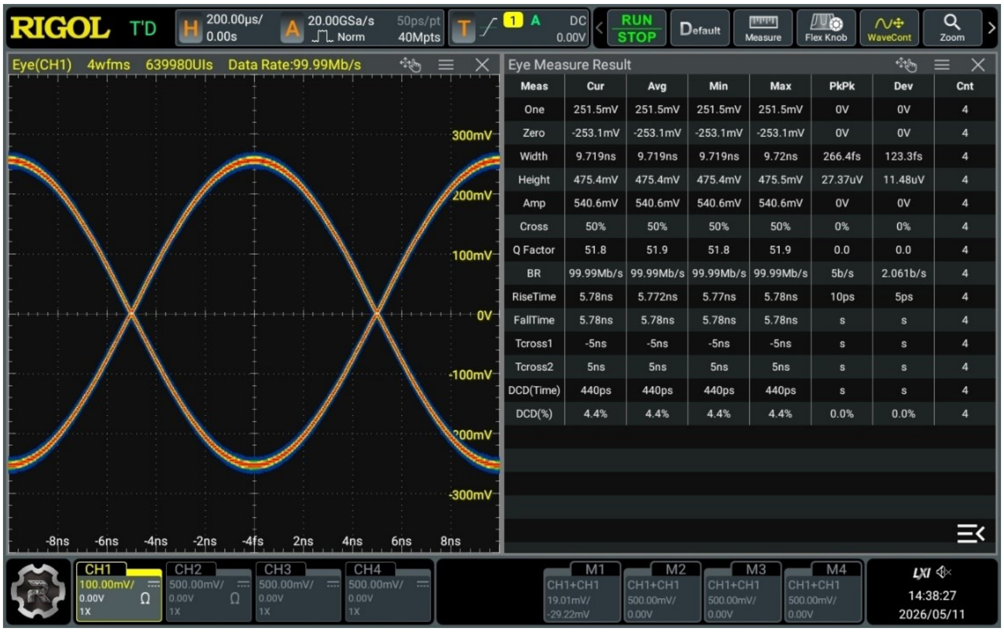
- Sum: indicates the sum of all bins (buckets) in the histogram.
- Peaks: indicates the maximum number of hits in any single bin.
- Max: indicates the value that corresponds to the maximum bin that has any hits.
- Min: indicates the value that corresponds to the minimum bin that has any hits.
- Pk_Pk: indicates the Delta between the max. value and the min. value.
- Mean: indicates the average value of the histogram.
- Median: indicates the median value of the histogram.
- Mode: indicates the mode value of the histogram.
- Bin width: indicates the width of each bin (bucket) in the histogram.
- Sigma: indicates the standard deviation of the histogram.
- XScale: indicates the horizontal scale of the histogram. It is 100 times the value of Bin width.
- μ ± σ: indicates the proportion of the number of frequencies or counts of the histogram hits that lie within one standard deviation of the mean to the total number of histogram hits. μ indicates the mean value in normal distribution. It is the average of the numbers. σ indicates the standard deviation in the normal distribution.
- μ±2σ: indicates the proportion of the number of frequencies or counts of the histogram hits that lie within two standard deviations of the mean to the total

number of histogram hits. μ indicates the mean value in normal distribution. It is the average of the numbers. σ indicates the standard deviation in the normal distribution.

- μ ± 3σ: indicates the proportion of the number of frequencies or counts of the histogram hits that lie within three standard deviations of the mean to the total number of histogram hits. μ indicates the mean value in normal distribution. It is the average of the numbers. σ indicates the standard deviation in the normal distribution.

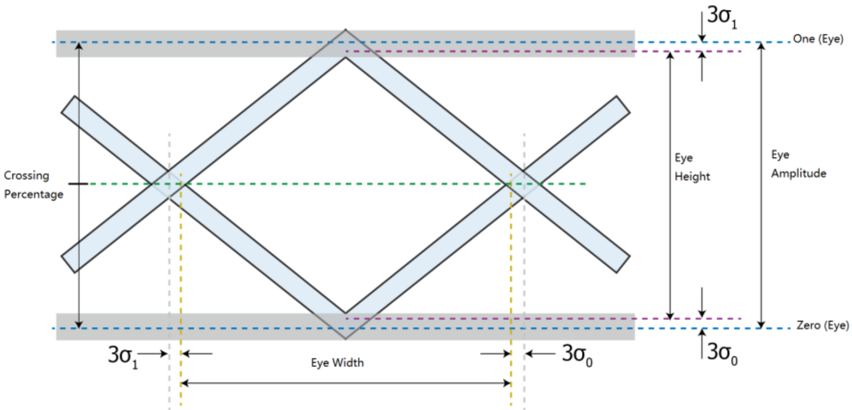
- **Measurement Result**

Enable the display of the measurement result, and the eye measurement result window is displayed on the screen.



- One: indicates "1" level.
- Zero: indicates "0" level.
- Width: indicates the width of an eye diagram.
- Height: indicates the height of an eye diagram.
- Amp: indicates the amplitude of an eye diagram.
- Cross: indicates the crossing percentage of an eye diagram.
- Q Factor: indicates the Q factor.
- BR: indicates the bit rate.
- RiseTime: indicates the rising time.
- FallTime: indicates the falling time.
- Tcross1: indicates the level position 1 of the middle value.
- Tcross2: indicates the level position 2 of the middle value.
- DCD(Time): indicates the duty cycle distortion time.

- DCD(%): indicates the duty cycle percentage.



- **High Threshold and Low Threshold**

  When you modify the high threshold and low threshold, the rising time and falling time of the eye measurement result will change with the threshold range modification.

- **Eye Cursor Measurement**

  When the eye diagram is enabled, you can also enable the eye cursor measurement. It supports two pairs of cursors (AX/BX/AY/BY). The cursor measurement results are displayed at the right section of the screen.

  For details about how to use the cursor measurement, refer to descriptions in "Cursor Measurement" section of the user guide of the oscilloscopes.

- AX: indicates the X value at Cursor A.
- AY: indicates the Y value at Cursor A.
- BX: indicates the X value at Cursor B.
- BY: indicates the Y value at Cursor B.
- ΔX: indicates the horizontal spacing between Cursor A and Cursor B.
- ΔY: indicates the vertical spacing between Cursor A and Cursor B.

- 1/ΔX: indicates the reciprocal of the horizontal spacing between Cursor A and Cursor B.

- **Persistence**

  OFF: disables waveform persistence, and displays only the eye diagram generated from the current single acquisition.

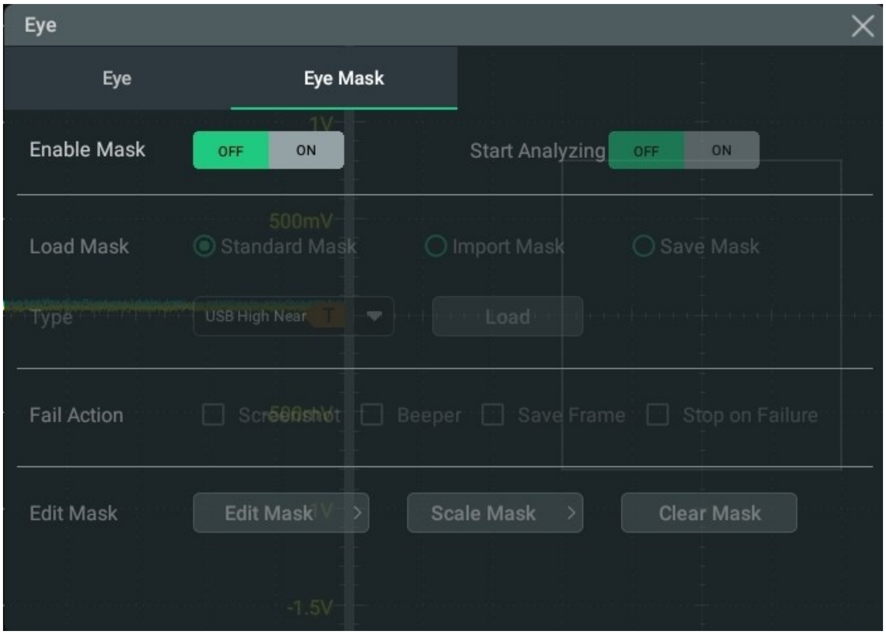
  ON: enables waveform persistence, and continuously superimposes all subsequently captured waveforms onto the same eye diagram display.

- **Reset Color**

  Click or tap this menu to clear the accumulated color-graded persistence data and measurement results, and reset the eye diagram display to its initial state.

4.2 Eye Mask Configuration

The eye mask menu is shown in the following figure. Only when the eye diagram is enabled, can you configure the parameters for the eye mask.



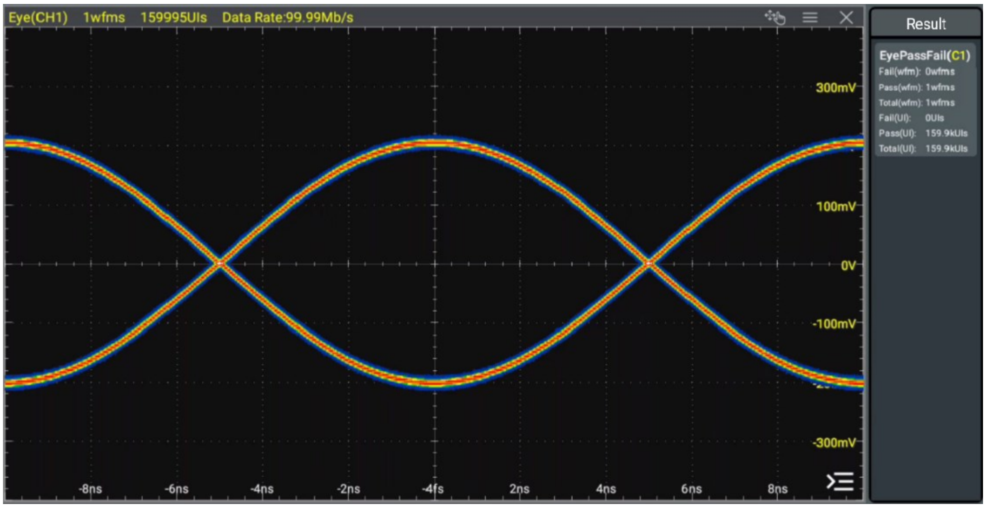
- **Enable or Disable the Eye Mask**

  OFF: disables the eye mask.

  ON: enables the eye mask.

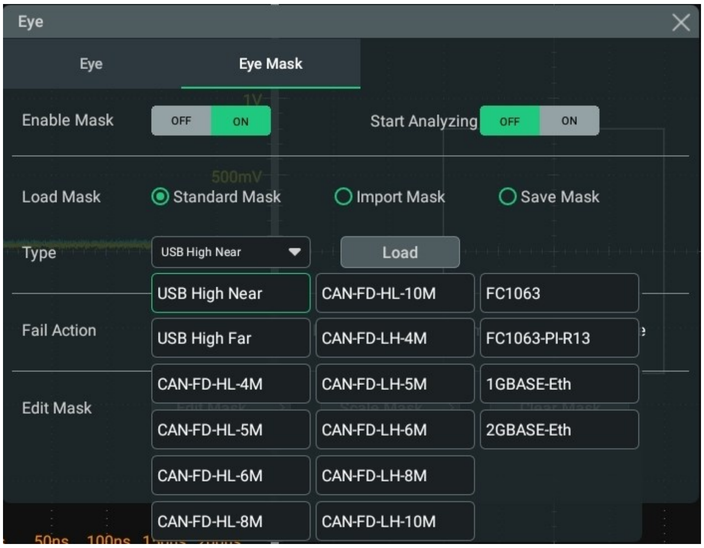
- **Start Analyzing**

  When you enable starting analyzing, the eye mask testing is launched. The eye mask test results will be displayed at the right section of the screen. When no mask is loaded, the result shows "pass" by default.



- **Load Mask**

  Standard Mask: when you select "Standard Mask", click or tap the drop-down button of **Type** to select the desired standard mask.



  Import Mask: loads the user-defined eye mask.

  Save Mask: saves the user-defined eye mask to the specified path.

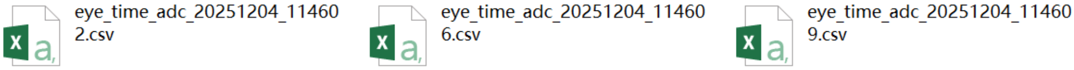
- **Fail Action**

  Sets the action taken after the eye mask test is failed.

  Screenshot: default action. When the eye mask test fails, the oscilloscope stops acquiring data and captures the screenshot. The saved the screenshot file will be saved to the local path of the oscilloscope.

Beeper: when the eye mask test fails, the oscilloscope beeps on failure.

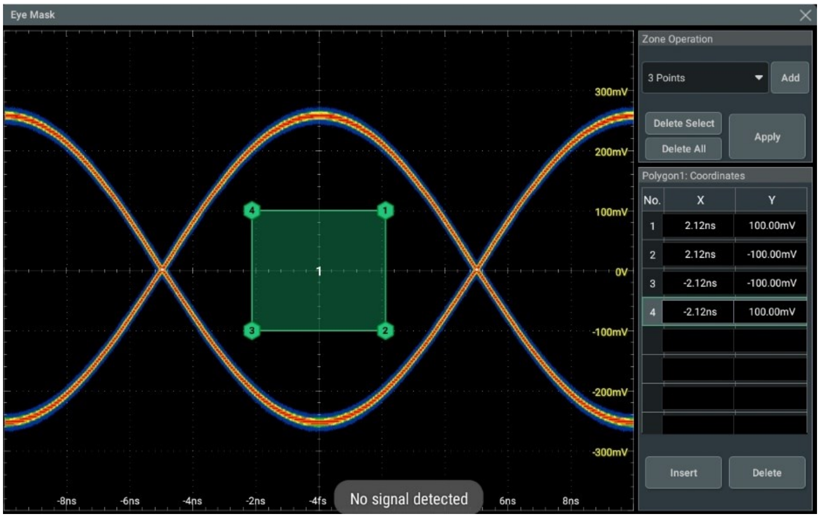
Save Frame: when a mask test failure occurs, the oscilloscope saves the raw ADC data of the current waveform to its local path. For the saved "*.csv" file, its first column lists the data of X-axis; and the second column lists the data of Y-axis.



Stop on Failure: the oscilloscope stops running immediately when the eye mask test failure is detected.

- **Edit Mask**

Click or tap this menu to enter the following interface. You can self-define the eye mask.



Set the number of points to generate a user-defined shape as the eye mask.

Add: adds the user-defined shape to the eye mask window. Multiple shapes are supported to be added.

Delete Select: deletes the selected eye mask.

Delete All: deletes all the eye masks created.

Apply: applies the mask editing operation. After completing editing the mask, only when you click or tap **Apply**, can your editing operation be applied to the eye diagram.

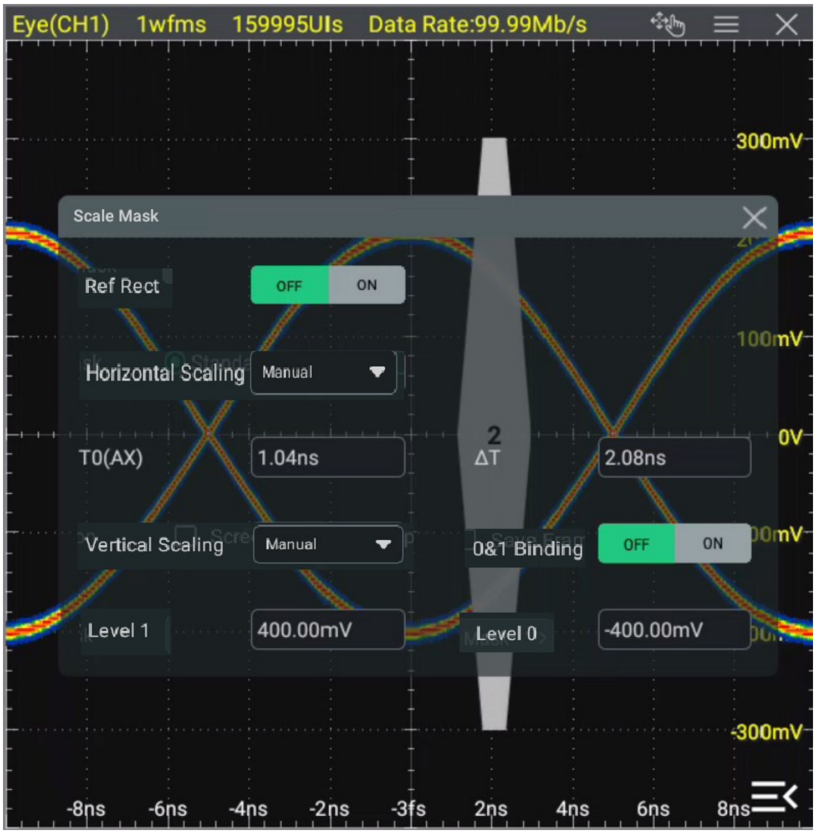
No.: indicates the point No. of the selected shape. You can modify the X-axis value and Y-axis value of each point manually.

Insert: inserts one coordinate into the currently selected eye mask shape.

Delete: deletes one coordinate from the currently selected eye mask shape.

- **Scale Mask**

After loading the mask, click or tap **Scale Mask**, then the Scale Mask interface is displayed.



Ref Rect: enables or disables the reference rectangle.

Horizontal Scaling: adjusts the eye mask horizontally. When it is set to Manual, you can drag the left boundary of the rectangle. When it is set to Auto, the left boundary of the rectangle cannot be dragged. Its left boundary is located at the crossing point of the eye diagram.

T0(AX): indicates the X-axis coordinate of the left boundary of the reference rectangle.

ΔT: indicates the width of the horizontal coordinate of the reference rectangle.

Vertical Scaling: adjusts the eye mask vertically. When it is set to Manual, you can drag the top and bottom boundaries of the rectangle. When it is set to Auto, you cannot drag the top and bottom boundaries of the rectangle. Its top boundary is located at Level 1; and its bottom boundary is located at Level 0.

Level 1: voltage position of the top boundary of the rectangle.

Level 0: voltage position of the bottom boundary of the rectangle.

0&1 Binding: when it is enabled, the difference between Level 1 and Level 0 of the reference rectangle remains unchanged.

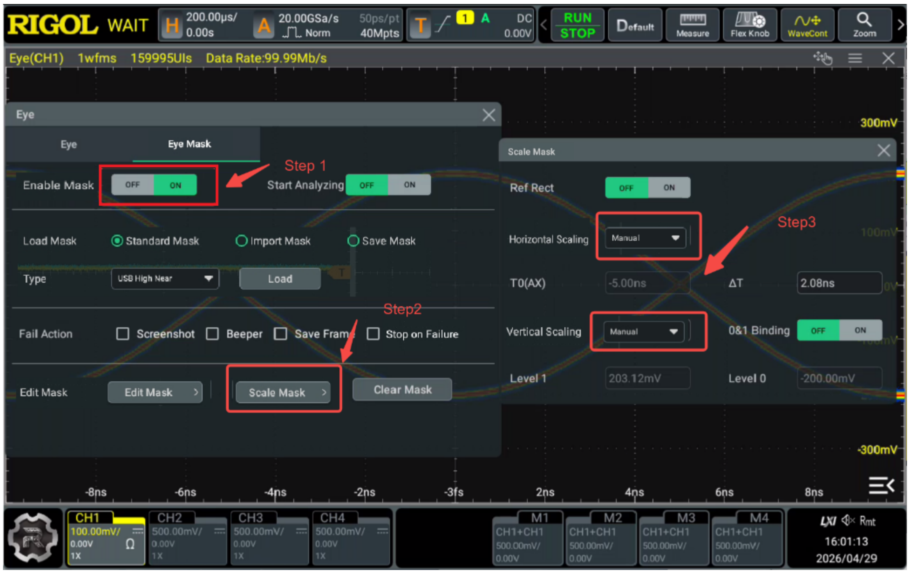
- **Clear Mask**

  Deletes all the existing eye masks.

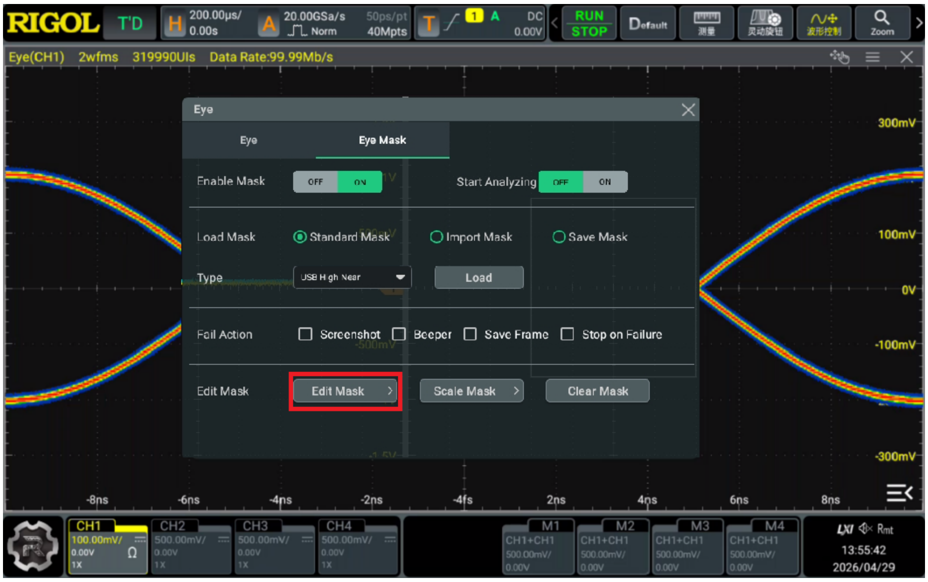
4.3 Eye Mask Operation

4.3.1 Use the Eye Mask (Save the Absolute-Coordinate Mask File)

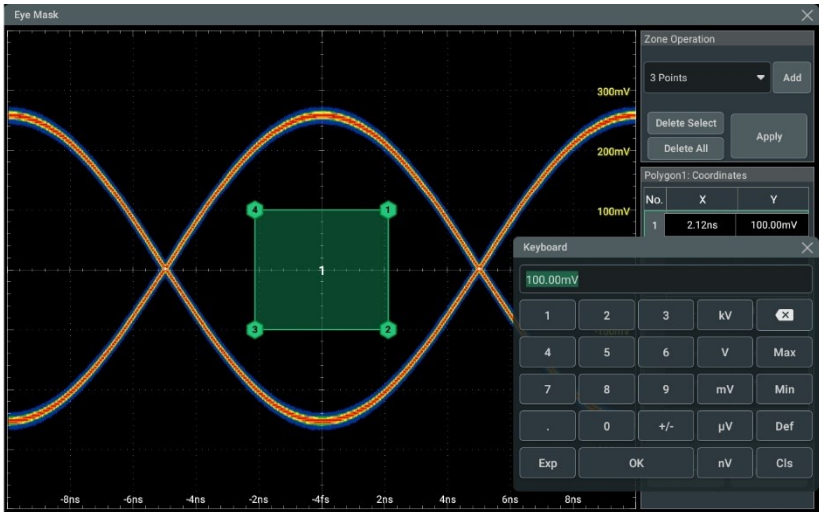
Step 1: Enable mask. Click or tap **Scale Mask** to enter the mask scaling interface. Set both **Horizontal Scaling** and **Vertical Scaling** to "Manual". Then close the interface.



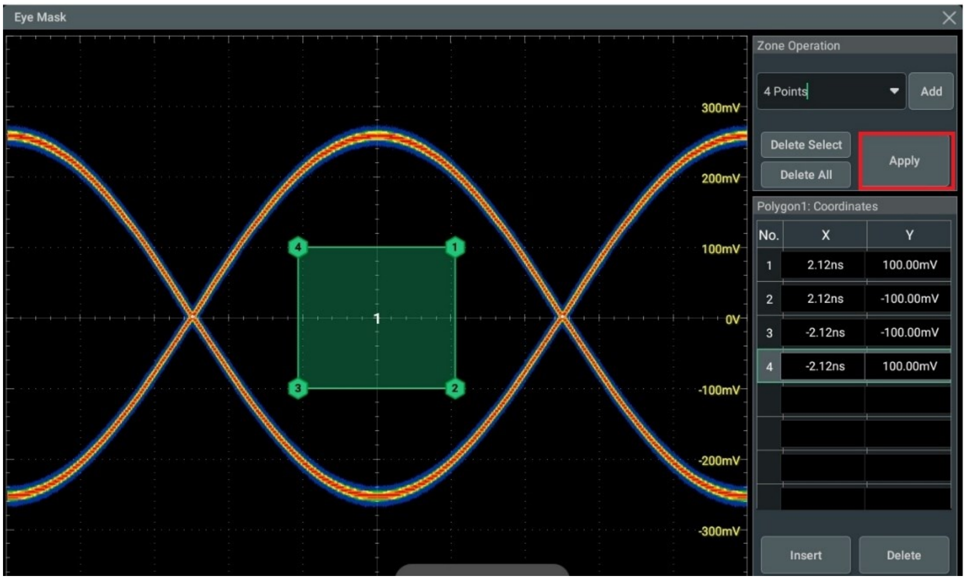
Step 2: Click or tap **Edit Mask** to enter the mask editing interface. Select the desired number of points to form a polygon. Click or tap **Add**. Then a polygon is formed. Click or tap the coordinate of each point of the polygon to edit it. After completing the editing, click or tap **Apply** to apply the editing. Then exit the mask editing interface.

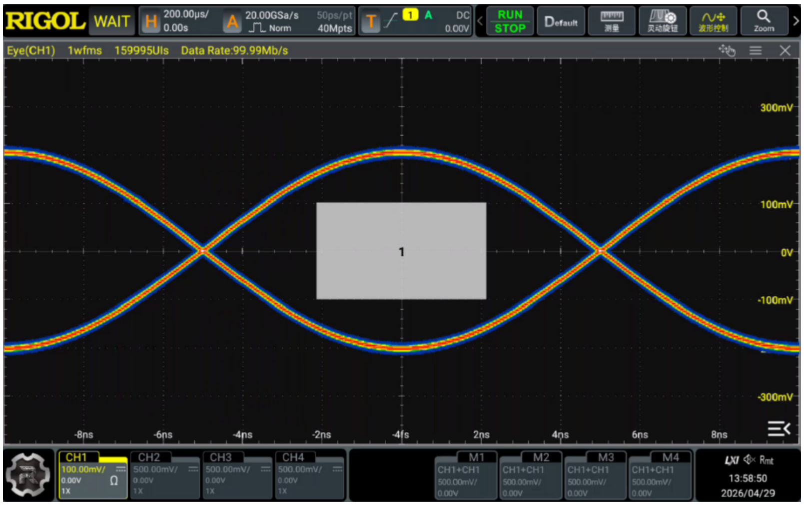

RIGOL
Eye(CH1) 2wfms 319990UIs Data Rate:99.99Mb/s
Eye
Eye Mask
Enable Mask
Start Analyzing
Load Mask
Standard Mask
Import Mask
Save Mask
Type
Load
Fail Action
Screenshot
Beeper
Save Frame
Stop on Failure
Edit Mask
Scale Mask
Clear Mask


Eye Mask
Zone Operation
Step1
3 Points
Add
Step2
8 Points
9 Points
10 Points
11 Points
12 Points
4 Points
5 Points
6 Points
7 Points
Insert
Delete

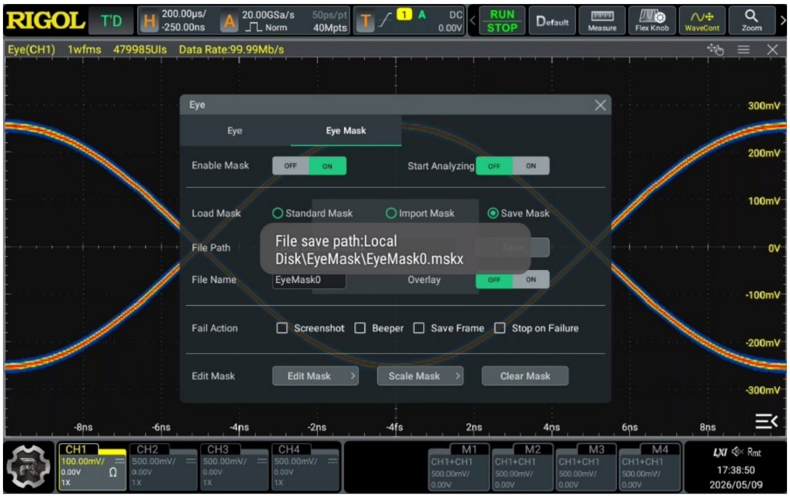


For example, set the Y-axis to 100 mV and -100 mV respectively. After completing the editing, click or tap **Apply** to apply the editing of the eye mask to the eye diagram, as shown in the figure below.

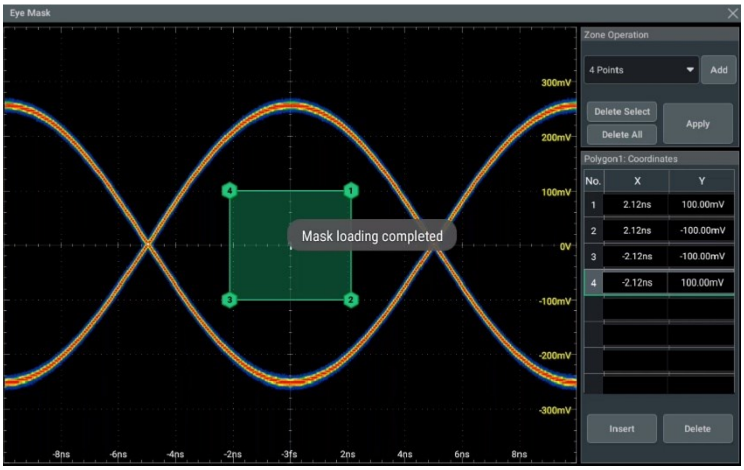




Step 3: Click or tap **Save Mask**, then the file path and file name menus are displayed. You can select the desired path and set the filename to save the mask file.



Step 4: To use the user-defined saved mask, click or tap **Import Mask** to import the user-defined mask file from the specified path. Then click or tap **Load** to load the file. Then a prompt message "Mask loading completed" is displayed. After that, click or tap **Edit Mask**, you will see the coordinates are not changed.

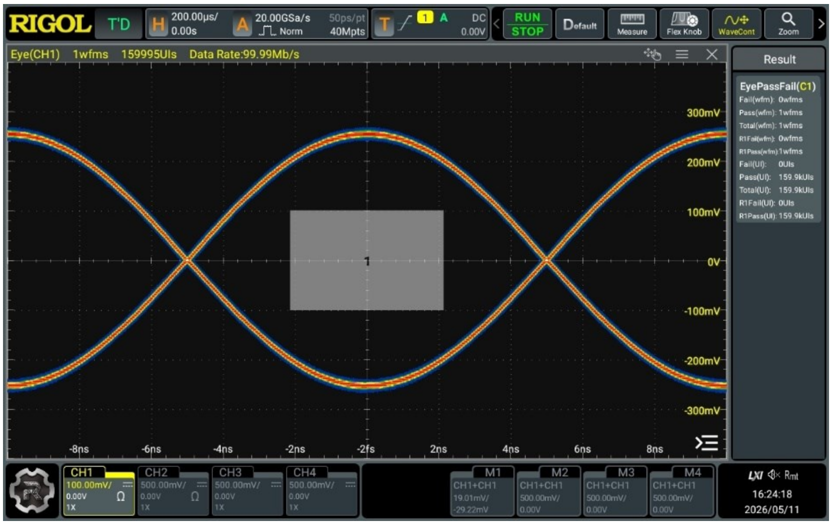


4.3.2 Eye Mask Analysis Results

The statistics items of the eye mask results are displayed at the right section of the screen.

- Fail(wfm): The total number of waveforms that hit all the eye mask regions.
- Pass(wfm): The total number of waveforms that did not hit the eye mask regions.
- Total(wfm): The total number of waveforms that hit the mask. It's the addition result of both failed waveforms and passed waveforms.
- R1Fail(UI): The number of data points or waveforms that hit Mask Region 1 (R1 specified in R1Fail indicates the first mask, here it refers to Mask Region 1).
- R1Pass(UI): The total number of waveforms that did not hit Mask Region 1.

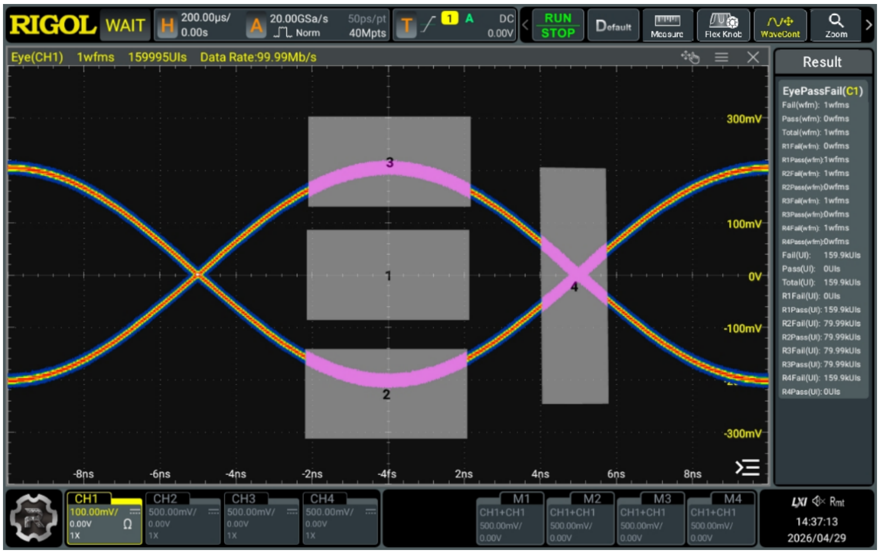
In the following figure, the waveforms do not hit the eye mask. Thus, the failed results show 0.



In the following figure, only the upper region of the waveforms hit the mask region. Thus, the failed results equal to the passed results.

In the following figure, the upper and lower part of the waveforms both hit the eye mask region. Thus, all the waveforms (or UIs) failed. Thus, in this figure, all the waveforms (or UIs) failed; and the passed waveforms (or UIs) = 0.

For the scenarios where two and more eye masks exist, R(n)Fail(UI) and R(n)Pass(UI), respectively, represent the statistics of the waveform UIs that hit and do not hit the nth eye mask. Fail and Pass results are the overall statistics for all the waveforms (UIs) that hit and do not hit all the eye masks.


RIGOL
WAIT
H 200.00μs/ 0.00s
A 20.00GSa/s Norm
50ps/pt 40Mpts
T
DC 0.00V
RUN STOP
Default
Measure
Flex Knob
WaveCont
Zoom
Eye(CH1) 1wfms 159995UIs Data Rate:99.99Mb/s
300mV
100mV
0V
-100mV
-300mV
-8ns
-6ns
-4ns
-2ns
-4fs
2ns
4ns
6ns
8ns
1
2
3
4
Result
EyePassFail(C1)
Fail(wfm): 1wfms
Pass(wfm): 0wfms
Total(wfm): 1wfms
R1Fail(wfm): 0wfms
R1Pass(wfm):1wfms
R2Fail(wfm): 1wfms
R2Pass(wfm):0wfms
R3Fail(wfm): 1wfms
R3Pass(wfm):0wfms
R4Fail(wfm): 1wfms
R4Pass(wfm):0wfms
Fail(UI): 159.9kUIs
Pass(UI): 0UIs
Total(UI): 159.9kUIs
R1Fail(UI): 0UIs
R1Pass(UI): 159.9kUIs
R2Fail(UI): 79.99kUIs
R2Pass(UI): 79.99kUIs
R3Fail(UI): 79.99kUIs
R3Pass(UI): 79.99kUIs
R4Fail(UI): 159.9kUIs
R4Pass(UI): 0UIs
CH1 100.00mV/ 0.00V 1X
CH2 500.00mV/ 0.00V 1X
CH3 500.00mV/ 0.00V 1X
CH4 500.00mV/ 0.00V 1X
M1 CH1+CH1 500.00mV/ 0.00V
M2 CH1+CH1 500.00mV/ 0.00V
M3 CH1+CH1 500.00mV/ 0.00V
M4 CH1+CH1 500.00mV/ 0.00V
LXI Rmt
14:37:13
2026/04/29

5 Typical Application

When using eye diagram of the oscilloscope, we recommend you to make the waveform amplitude take up the whole screen as much as possible. Set the memory depth to Auto, adjust the time base and sample rate to make the memory depth greater than or equal to 1M. Set the bandwidth limit as required.

The following typical application scenario takes RIGOL DG4000 Function/Arbitrary Waveform Generator to generate the specified signal and perform the eye diagram test on the oscilloscope. To obtain any information about DG4000, download the DG4000 manuals from the official website of RIGOL.

5.1 Clock Signal

5.1.1 Test Procedures

Step 1: Input the clock signal under test to CH1 of the oscilloscope.

Step 2: In the "Horizontal" system menu, set the memory depth to Auto, and the sample rate is automatically set to a fixed value 20 GSa/s. Adjust the time base to make its memory depth to 40 Mpts.

Step 3: In the "Vertical" system menu, set the vertical scale of CH1 to 100 mV (make the signal amplitude take up the whole display area).

Step 4: In the eye diagram interface, set **Signal Type** to NRZ.

Step 5: Click or tap **Threshold** to select 10%, 50%, 90% of top, base. Set **Level Setting** to Default.

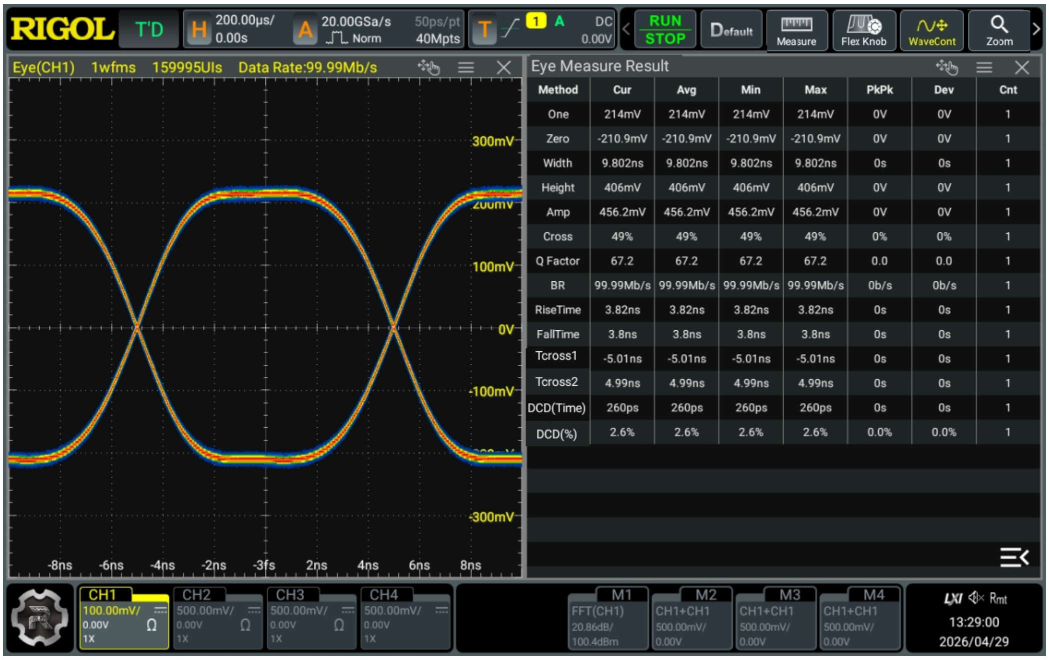
Step 6: Click or tap **CDR** to enter the CDR interface. Click or tap the drop-down button of **CDR Method** to select **Constant Frequency**. Set **Data Rate Method** to Auto. Click or tap **Advanced Setting** to enter the advanced setting interface. Click or tap to select "Both" for **Edge Direction**.

Step 7: In the eye diagram interface, click or tap **Source** to select CH1. Then enable the display of the eye diagram measurement result.

Step 8: Enable the eye diagram measurement, and you will see the measurement results.

5.1.2 Measurement Result

The following figure shows the eye diagram measurement of a 50 MHz clock signal.



5.2 NRZ Data Signal

5.2.1 Test Procedures

Step 1: Import the CSV file into DG4000 to generate a 50 MHz PRBS7 signal.

Step 2: In the "Horizontal" system menu, set the memory depth to Auto, and the sample rate is automatically set to a fixed value 20 GSa/s. Adjust the time base to make its memory depth to 40 Mpts.

Step 3: In the "Vertical" system menu, set the vertical scale of CH1 to 200 mV (make the signal amplitude take up the whole display area).

Step 4: In the eye diagram interface, set **Signal Type** to NRZ.

Step 5: Click or tap the "Threshold" menu to enter the threshold setting interface. Click or tap the drop-down button of **Threshold** to select "threshold+/-hysteresis". Click or tap **AutoSet**.

Step 6: Click or tap **CDR** to enter the CDR interface. Click or tap the drop-down button of **CDR Method** to select "**First Order PLL"**. Set **Data Rate** to 50Mb/s. Click or tap **Advanced Setting** to enter the advanced setting interface. Set **PLL Settling Time** to 5.00T; set **PLL Idle Clock** to 80. Click or tap to select **Both** for **Edge Direction**.

Step 7: In the eye diagram interface, click or tap **Source** to select CH1. Then enable the display of the eye diagram measurement result.

Step 8: Enable the eye diagram measurement, and you will see the measurement results.

5.2.2 Measurement Result

The following figure shows the eye diagram measurement results of the 50 MHz PRBS7 signal generated from DG4000.

Method	Cur	Avg	Min	Max	PkPk	Dev	Cnt
One	496.8mV	496.8mV	496.8mV	496.8mV	0V	0V	1
Zero	-506.2mV	-506.2mV	-506.2mV	-506.2mV	0V	0V	1
Width	19.72ns	19.72ns	19.72ns	19.72ns	0s	0s	1
Height	877.1mV	877.1mV	877.1mV	877.1mV	0V	0V	1
Amp	1.121V	1.121V	1.121V	1.121V	0V	0V	1
Cross	51%	51%	51%	51%	0%	0%	1
Q Factor	23.9	23.9	23.9	23.9	0.0	0.0	1
BR	49.99Mb/s	49.99Mb/s	49.99Mb/s	49.99Mb/s	0b/s	0b/s	1
RiseTime	5.88ns	5.88ns	5.88ns	5.88ns	0s	0s	1
FallTime	6ns	6ns	6ns	6ns	0s	0s	1
Tcross1	-10ns	-10ns	-10ns	-10ns	0s	0s	1
Tcross2	10ns	10ns	10ns	10ns	0s	0s	1
DCD(Time)	180ps	180ps	180ps	180ps	0s	0s	1
DCD(%)	0.9%	0.9%	0.9%	0.9%	0.0%	0.0%	1

5.3 PAM3 Data Signal

5.3.1 Test Procedures

Step 1: Import the CSV file into DG4000 to generate a 100 MHz PAM3 signal.

Step 2: In the "Horizontal" system menu, set the memory depth to Auto, and the sample rate is automatically set to a fixed value 20 GSa/s. Adjust the time base to make its memory depth to 40 Mpts.

Step 3: In the "Vertical" system menu, set the vertical scale of CH1 to 200 mV (make the signal amplitude take up the whole display area).

Step 4: In the eye diagram interface, set **Signal Type** to PAM3.

Step 5: Click or tap **Threshold** to enter the threshold setting interface. Click or tap the drop-down button of **Threshold** to select 50% of levels. Set **Level Setting** to PAM Auto Level.

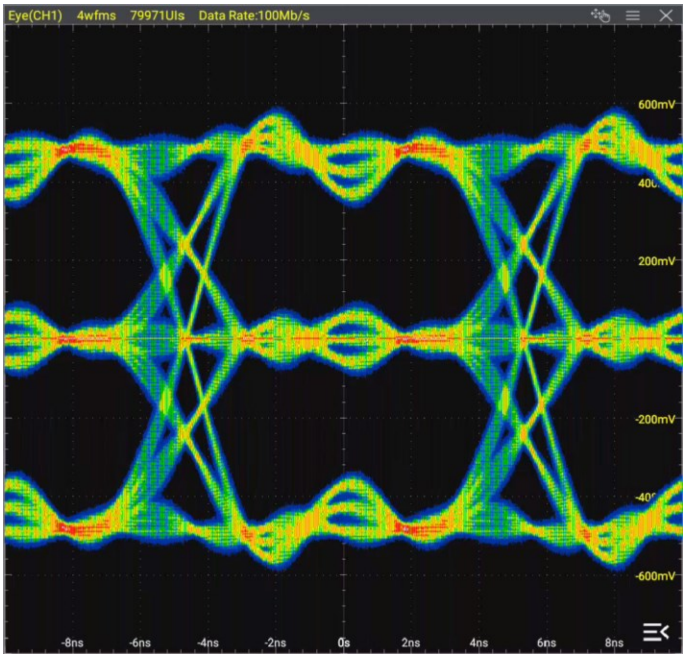
Step 6: Click or tap **CDR** to enter the CDR interface. Click or tap the drop-down button of **CDR Method** to select **Constant Frequency**. Set **Symbol Rate** to "100MBd". Set **Data Rate Method** to Semi-Auto. Click or tap **Advanced Setting** to enter the advanced setting interface. Click or tap to select "Both" for **Edge Direction**.

Step 7: In the eye diagram interface, click or tap **Source** to select CH1. The measurement result of the PAM signal is currently unavailable. Thus, no measurement result display operation is available.

Step 8: Enable the eye diagram, and you will see the eye diagram plot.

5.3.2 Measurement Result

The following figure shows the eye diagram of the 100 MHz PAM3 signal generated from DG4000.



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HEADQUARTER

RIGOL TECHNOLOGIES CO., LTD.
No.8 Keling Road, New District,
Suzhou,JiangSu, P.R.China
Tel: +86-400620002
Email: info-cn@rigol.com

EUROPE

RIGOL TECHNOLOGIES EU GmbH
Friedrichshafener Str. 5
82205 Gilching
Germany
Tel: +49(0)8105-27292-21
Email: info-europe@rigol.com

NORTH AMERICA

RIGOL TECHNOLOGIES, USA INC.
10220 SW Nimbus Ave.
Suite K-7
Portland, OR 97223
Tel: +1-877-4-**RIGOL**-1
Email: sales@rigol.com

JAPAN

RIGOL JAPAN CO., LTD.
5F,3-45-6,Minamiotsuka, Toshima-Ku,
Tokyo,170-0005,Japan
Tel: +81-3-6262-8932
Fax: +81-3-6262-8933
Email: info.jp@rigol.com

KOREA

RIGOL KOREA CO,. LTD.
5F, 222, Gonghang-daero,
Gangseo-gu, Seoul, Republic of Korea
Tel: +82-2-6953-4466
Fax: +82-2-6953-4422
Email: info.kr@rigol.com

For Assistance in Other Countries

Email: info.int@rigol.com