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Jitter Decomposition Measurement

Advanced Feature for Oscilloscopes

Application Note

May, 2026

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1. Document Overview

This document is designed to introduce the jitter decomposition measurement feature of RIGOL's oscilloscopes. The contents include:

- Basic concepts of jitter decomposition and jitter components;
- How to use the jitter decomposition feature on the oscilloscope;
- Test procedures for the typical application scenarios.

This document is intended for engineering technicians who need to perform high-speed serial digital signal jitter analysis on an oscilloscope.

This document has relevance with the following documents: *Clock Recovery Application Note*, *Jitter Decomposition – RJ Bandwidth Mode Selection*, and *Jitter Decomposition – How to Configure ISI Filter Coefficients*. To download these manuals, log in to the official website of RIGOL (www.rigol.com).

2. Jitter Feature Working Principle

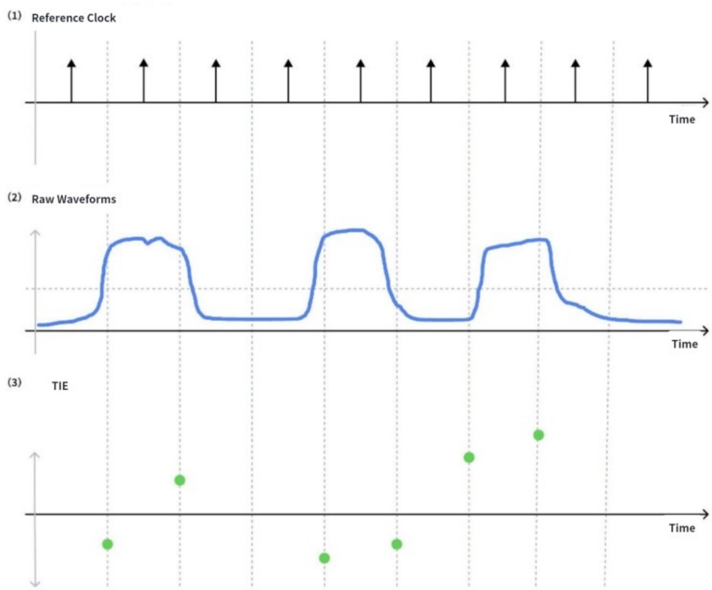
The jitter decomposition feature of the oscilloscope is mainly used in the comprehensive analysis of jitter for the high-speed serial digital signal. It is the fundamental tool in the high-speed interface design and validation process.

This feature enables the oscilloscope to make an in-depth statistical analysis of the signal. The total jitter (TJ) can be accurately separated into two core components: random jitter (RJ) and deterministic jitter (DJ). DJ can be further quantified into typical components such as Periodic Jitter (PJ), Duty Cycle Distortion (DCD), and Inter-Symbol Interference (ISI).

Presented in multi-dimensional analysis views such as jitter histogram, bathtub curve, and jitter spectrum, this feature allows engineers to quickly assess the sufficiency of timing margins and accurately locate the underlying jitter sources, including clock degradation, power integrity issues, crosstalk, and signal integrity degradation. In addition, this feature is based on industry-standard statistical models such as the Dual-Dirac model, which can effectively estimate peak-to-peak jitter at a very low bit error ratio (BER), significantly reducing the test costs for a long duration of a large volume of data acquisition required for traditional direct measurements, and greatly improving R&D validation efficiency.

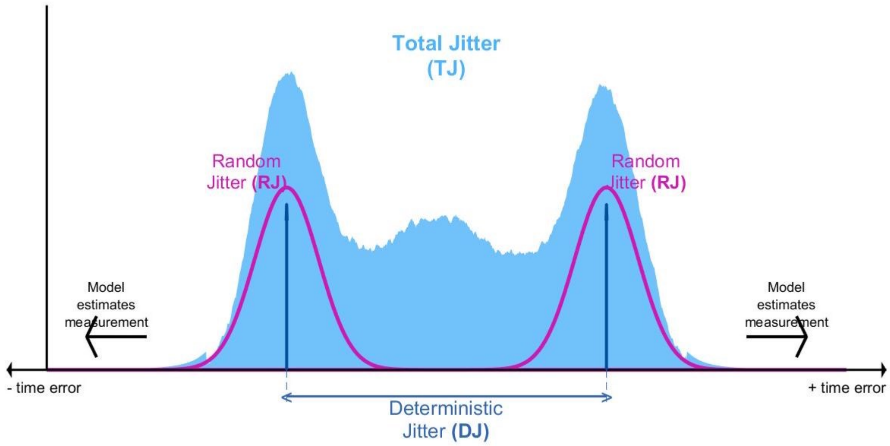
2.1 Time Interval Error (TIE)

TIE (Time Interval Error) represents the variation of each valid edge of the clock from the ideal position. The ideal time reference is a constant frequency ideal clock signal that best fits the measured waveform in its frequency and phase.



2.2 Dual-Dirac Model

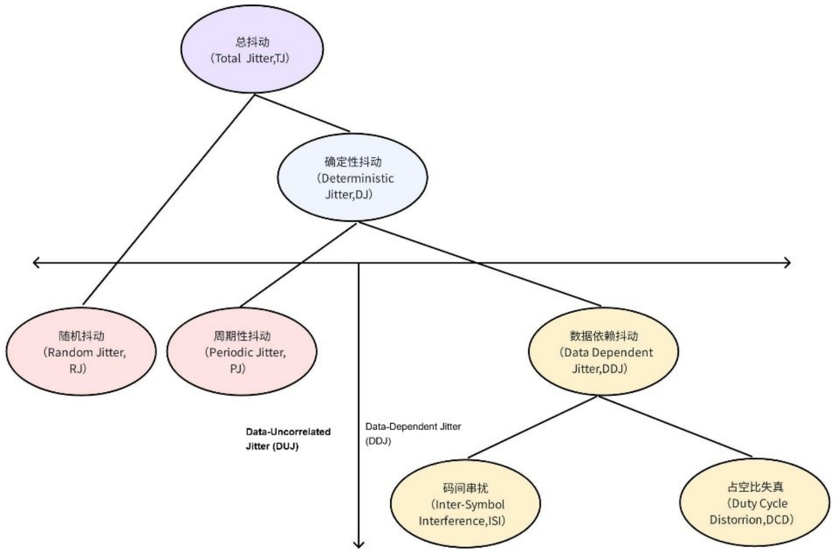
The Dual-Dirac model is a popular mathematical model that describes TIE probability density function. According to this model, Total Jitter (TJ) is decomposed into two fundamental components: Random Jitter (RJ) and Deterministic Jitter (DJ). In this model, RJ is assumed to follow a Gaussian distribution, while DJ is simplified into two discrete Dirac delta functions (representing a bimodal distribution). Through the convolution of their respective PDFs, the resulting model highly correlates with the actually measured TJ histogram, particularly in the low-probability regions (i.e., the distribution tails). The figure below illustrates the effectiveness of the Dual-Dirac model in tail fitting within these low-probability regions. In this model, RJ is assumed to follow a Gaussian distribution, while DJ is simplified into two discrete Dirac delta functions (representing a bimodal distribution). Through the convolution of their respective PDFs, the resulting model highly correlates with the actually measured TJ histogram, particularly in the low-probability regions (i.e., distribution tails). The figure below illustrates the effectiveness of the Dual-Dirac model in tail fitting within these low-probability regions.



2.3 Jitter Model

The Dual-Dirac model is a fundamental tool in jitter analysis. By leveraging statistical modeling, it extrapolates the peak-to-peak jitter at extremely low Bit Error Ratio (BER), thereby reducing the time costs for the traditional direct measurements. In addition to quickly estimating total jitter (TJ), jitter decomposition is also useful for engineers to identify specific sources and causes of jitter.

The hierarchical classification of jitter is shown in the following figure.



In more refined jitter analysis models, deterministic jitter (DJ) is often further decomposed into the following key components:

- PJ (Periodic Jitter):
  Stems from periodic modulating signals caused by internal or external system

interference (e.g., switching power supply noise).

- DDJ (Data-Dependent Jitter): Jitter components that are highly correlated with the data bit sequence and its historical states.
- ISI (Inter-Symbol Interference): Primarily caused by bandwidth limitations or reflections within the transmission channel, resulting in mutual interference between adjacent data symbols.
- DCD (Duty Cycle Distortion): Jitter caused by unequal propagation delays between the rising and falling edges of a signal (i.e., pulse width asymmetry).

2.4 Jitter Theory

2.4.1 Periodic and Non-Periodic (Arbitrary) Modes

The jitter decomposition software supports jitter analysis of various types of clock waveforms and Non-Return-to-Zero (NRZ) serial data waveforms, independent of specific binary data patterns. For clock signals, the software treats them as data waveforms with an alternating "1/0" data pattern. Depending on the type of data pattern specified by the user, jitter decomposition software uses two targeted analysis algorithms:

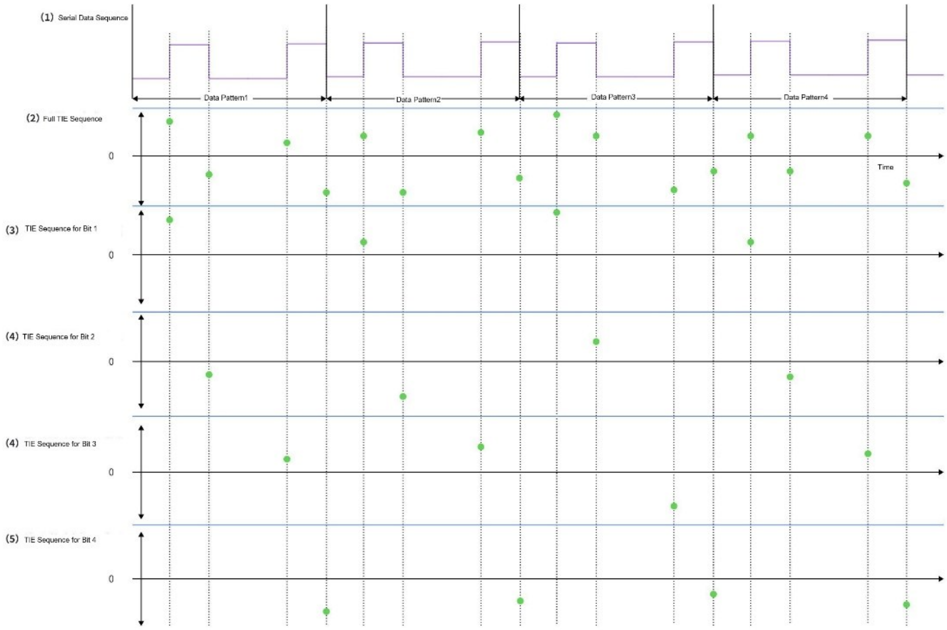
- Periodic Mode
    - Features: Designed for loop-repeating data patterns, with extremely high computing efficiency, analysis speed faster than non-periodic mode.
    - Limitation: Limited to max. pattern length, restricted to periodic patterns within a limited length.
    - Application Scenarios: Applicable to waveforms with high repeatability and fixed pattern, such as protocol-specific synchronization sequences or simple test stimulus signals.
- Non-Periodic (Arbitrary) Mode
    - Features: Able to process arbitrary random data patterns, capable of dealing with more complex and irregular signal characteristics.
    - Benefits: Although requiring a relatively longer computation time, it delivers more comprehensive and universally applicable analysis results.
    - Application Scenarios: Widely used for complex data flow analysis in real-world conditions, such as random business data in high-speed data communication links and storage systems.

2.4.2 Separate DDJ from RJ and PJ

2.4.2.1 Periodic Mode

In Periodic mode, the software extracts data-dependent jitter (DDJ) by averaging the TIE measurements at specific bit positions over multiple pattern cycles. The process flow is as follows:

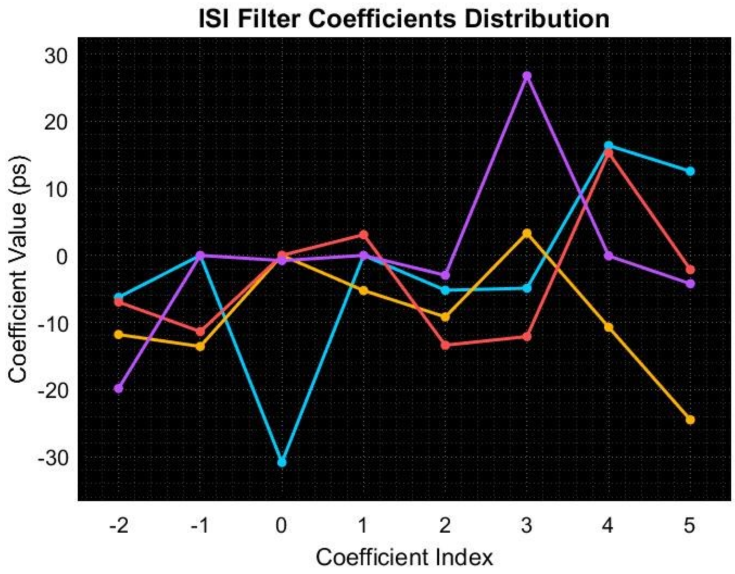
1. **TIE Extraction and Pattern Recognition**
   First, the software extracts the logical bit stream from the acquired source waveform and identifies its repeating Pattern Length. Then calculate the full-waveform TIE record and map each individual TIE measurement to its corresponding bit position in the logical bit stream.
2. **Subsampling and Decimation**
   The original TIE trend is decimated into multiple subsampled TIE sequences, with each sequence corresponding to a specific bit position within the pattern. Relationship between Decimation Strategy and RJ Bandwidth is as follows: The number of samples skipped during the decimation process depends on the Random Jitter (RJ) bandwidth mode configured by the user.
   - Narrow/Pink Mode: employs a maximized decimation ratio, retaining fewer samples (optimized for low-frequency RJ). For guidance on selecting the RJ bandwidth, please refer to *Jitter Decomposition -- RJ Bandwidth Mode Selection*.
   - Wide/White Mode: employs a minimized decimation ratio, retaining more samples (optimized for broadband RJ).
3. **Frequency Domain Transformation and DDJ Separation**
   The software calculates the mean value of each subsampled TIE sequence; this mean value represents the Data-Dependent Jitter (DDJ) at that specific logical bit position. Through this step, the deterministic DDJ component is accurately quantified and can subsequently be subtracted from the total TIE record, enabling precise separation from Random Jitter (RJ) and Periodic Jitter (PJ).



2.4.2.2 Non-Periodic Mode

In non-periodic mode, due to the absence of a fixed repeating pattern, it is unable to simply average TIE values at specific bit positions. Instead, the jitter decomposition software employs a model-based estimation approach, utilizing an ISI filter to infer DDJ from adjacent data bits.

- Core Principle: Aggressor-Victim Model
  The algorithm is based on the physical model of Inter-Symbol Interference (ISI), assuming that the energy carried by adjacent signal transitions (edges) perturbs the timing of the current transition.
  - Victim: The current signal edge under test.
  - Aggressor: The adjacent signal edges occurring before (pre-cursor or lead) or after (post-cursor or lag) the current edge.
- Non-linear ISI Filter Design
  To account for the asymmetries between rising and falling edge characteristics (non-linear effects), the filter incorporates four independent sets of weighting coefficients, corresponding to four distinct transition combinations:
  - Rising Victim – Rising Aggressor
  - Rising Victim – Falling Aggressor
  - Falling Victim – Rising Aggressor
  - Falling Victim – Falling Aggressor
- **Algorithm Optimization and Coefficient Calculation**
  The user only needs to specify the number of pre-cursor (lead) and post-cursor (lag) bits (number of Taps) included in the filter. The software automatically leverages the Least Mean Squares (LMS) algorithm to compute the optimal filter coefficients, minimizing the mean squared error between the measured total jitter (TIE sequence) and the model-predicted DDJ. The following figure shows an example of an 8-tap ISI filter.



For the setting of the ISI filter coefficient, please refer to *Jitter Decomposition – How to Configure ISI Filter Coefficients*.

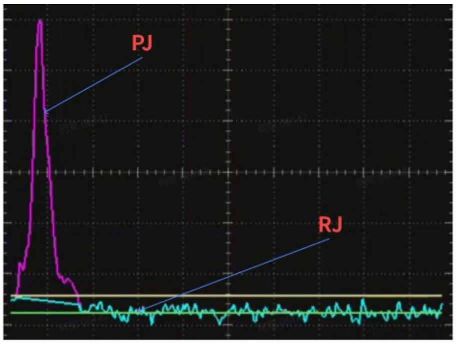
2.5 Separate PJ from RJ

2.5.1 Periodic Mode

In periodic mode, after subtracting the Data-Dependent Jitter (DDJ) component from the Total Jitter (TJ) spectrum, the remaining spectrum consists of random jitter (RJ) and periodic jitter (PJ). The steps to separate these two components are as follows:

1. Calculate Power Spectral Density (PSD): Calculates the power spectral density of the residual RJ/PJ spectrum.
2. Generate APSD (Averaged Power Spectral Density): Average the currently acquired spectrum and history spectrum to generate the APSD. This step effectively reduces the random noise floor and highlights the periodic component.
3. Remove PJ Components: Within the APSD, any spectral peaks (spurs) with an amplitude that are significantly above the noise floor are identified as potential Periodic Jitter (PJ) and removed.
4. Calculate RJ RMS: Calculate the root mean square (RMS) value of Random Jitter (RJ) by integrating (combining) the remaining background spectrum components after the PJ has been removed.

As shown in the following figure, spectral components with amplitudes significantly exceeding the APSD noise floor are eliminated from the TJ spectrum. The RMS value for RJ is then calculated based on the remaining spectrum components.



2.5.2 Non-Periodic Mode

Similar to the periodic mode, DDJ is first subtracted from the TJ in the time domain to generate a TIE sequence that contains only RJ and PJ. The subsequent process is more complex:

Spectrum Preprocessing: Segmentation and Decimation

Before calculating PSD, the TIE sequence is preprocessed differently based on the RJ bandwidth mode selected by the user:

- Narrow/Pink Mode: Decimates the TIE sequence to focus on low-frequency components.

- Wide/White Mode: Segments the TIE sequence to cover wideband components.

Address the "Hole Modulation" Effect

In arbitrary data mode, due to the irregular nature of the data stream, TIE values exist only at signal transitions (edges). The absence of transitions results in data 'holes' within the TIE record. This non-uniform sampling (or gating effect) results in spectrum modulation:

- Phenomenon: The PJ component of a single frequency no longer manifests itself in the spectrum as a single line, but is split into multiple spurs (main peak + modulation sidebands).
- Challenge: These PJ spurious signal amplitudes modulated by data mode can be very small and it is difficult to simply distinguish it from RJ noise floor by the amplitude threshold.

Iterative Deduction Algorithm

To address these issues, the jitter decomposition employs a model-based iterative subtraction method.

1. Modelling Prediction: The algorithm calculates (predicts) the locations and amplitudes of the modulation spurs of the PJ generated in the spectrum based on the known serial data mode.
2. Iterative Subtraction: Subtracts each of these predicted PJ components, including the main peak and the sidebands, from the original RJ/PJ spectrum.
3. Iterative Convergence: Repeats the process until a significant periodic component is no longer present in the spectrum.
4. Calculate RJ: Integrates the remaining clean background PSD to compute the Root Mean Square (RMS) value of the Random Jitter (RJ).

2.6 Apply the Dual Dirac Model to PJ and DJ

The jitter decomposition software determines DJ and PJ parameters by fitting the Dual-Dirac model to the measured jitter histogram. Although common fitting methods typically require both Gaussian Component (RJ) and Bimodal Component (DJ) to be solved iteratively, jitter decomposition employs a more efficient strategy:

- Employ known RJ: As the algorithm accurately calculated the Random Jitter (RJ) component in the previous phase, the software will take it as a known condition in the model.
- Solve Bimodal Width: The algorithm only needs to focus on solving the spacing (i.e., width) between the peaks of bimodal distribution. It adjusts the width of the peaks of the bimodal distribution until the nth percentile of the Dual-Dirac model precisely coincides with the corresponding percentile in the measured histogram.
- To achieve the best fit accuracy under different test time and data volume, the jitter decomposition software employs a strategy to dynamically adjust the

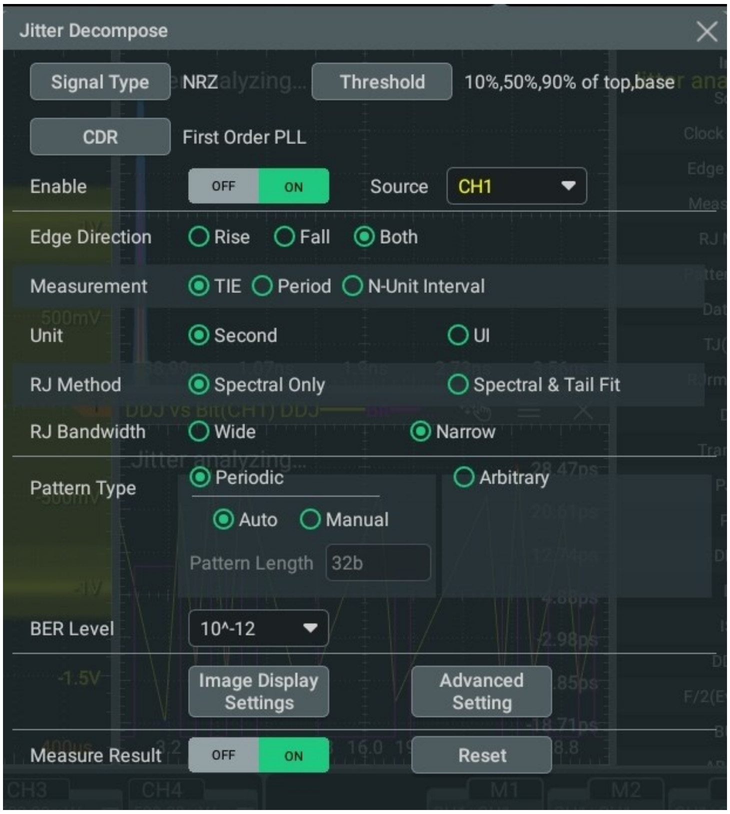
position of the fit points:

- PJ Fit Strategy:
  The percentile chosen for fitting is not fixed. It is progressive, with an initial setting of about 0.1%. With the cumulative number of acquisitions increases, the percentile is automatically reduced and gradually moves toward the "tails" of the distribution, thus employing more statistical data to improve accuracy.
- DJ Fit Strategy:
  DJ fitting also adopts the progressive strategy, but its starting position of the percentile range is dynamically calculated:
  - The range is from 0.1% to 0.1%/nEdges. Where, nEdges indicates the number of edges in the data mode.
  - Note: The selection of the starting point depends on the convolution effect of the histogram. When the RJ/PJ histogram is convolved with the DDJ histogram to produce the aggregate total-jitter (TJ) histogram, the distribution features are partially compressed (i.e., the distribution is smoothed). The jitter decomposition software automatically optimizes the initial fitting point depending on the extent to which it is compressed.

3. Jitter Decomposition Feature

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 **Jitter Decompose** icon to enter the jitter decomposition setting menu. In the jitter decomposition configuration settings, clock recovery feature is also involved. For the detailed configurations of the clock recovery parameters related to the jitter decomposition, refer to descriptions in *Clock Recovery Application Note*.

3.1 Jitter Decomposition Configuration for NRZ Signals



The jitter decomposition interface is shown above. 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 Jitter Decomposition**

  OFF: disables the jitter decomposition.

  ON: enables the jitter decomposition.

- **Source**

  Selects the channel of the oscilloscope to which the signal is connected for jitter decomposition analysis.

- **Edge Direction**

  Rise: only measures the rising edge of the signal under test for jitter decomposition.

  Fall: only measures falling edge of the signal under test for jitter decomposition.

  Both: measures both the rising and falling edges of the signal under test for jitter decomposition.

- **Measurement**

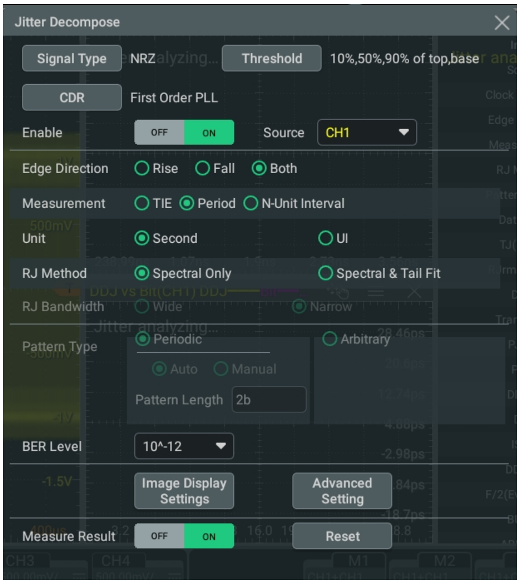
  TIE: Time difference between each signal transition and ideal time reference.

  Periodic Jitter: Analyzes the time error between one cycle of a clock signal and the standard cycle.

  N-Unit Interval: Analyzes the time error between the N UIs of the clock signal and the standard N UIs, where periodic jitter can be considered as a special case when N is equal to 2.

  When you select N-Unit Interval, you can set the number of UIs.

  The **RJ Bandwidth** and **Pattern Type** are not available to set if you select "Period" or "N-Unit Interval".

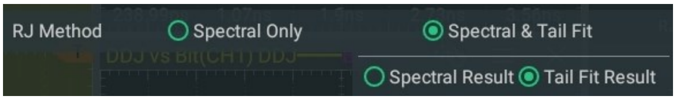


- **Unit**

Second: The measurement results of the jitter decomposition are presented in time, expressed in second.

UI: The measurement results of the jitter decomposition are presented as multiples of the single unit interval (UI) of the signal under test, such as 0.01UI.

- **RJ Calculation Method**



Spectral Only: RJ is calculated from the spectral only.

Spectral and Tail Fit: RJ is computed using a hybrid approach that integrates frequency-domain analysis with statistical-domain tail fitting.

When you select "Spectral & Tail Fit", you can also select to display "Spectral Result" or "Tail Fit Result" for the jitter decomposition measurement results.

- **RJ Bandwidth**

Wide: The entire spectrum can be considered relatively flat.

Narrow: The entire spectrum can be considered extremely uneven.

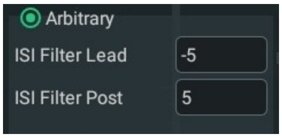
- **Pattern Type**

Periodic: employs the periodic type when the signal under test is periodic.

Auto: Jitter decomposition automatically detects the periodic data pattern of the signal under test and displays it in the input field of Pattern Length. You are not allowed to modify the pattern length at this time.

Manual: modifies the pattern length manually for the signal under test.

Arbitrary: employs the arbitrary type when the signal under test is non-periodic.



ISI Lead: sets the lead factor for the ISI filter.

ISI Lag: sets the lag factor for the ISI filter.

- **BER**

  Selects the bit error rate used for jitter decomposition. The lower the BER, the larger the equivalent total jitter TJ (BER), the more sensitive it is to the random jitter (RJ). Therefore, the jitter decomposition results (especially TJ) for the same eye diagram can be different for different target BERs.

- **Measurement Result**

  When the jitter decomposition feature is enabled, the **Measure Result** menu is automatically enabled.

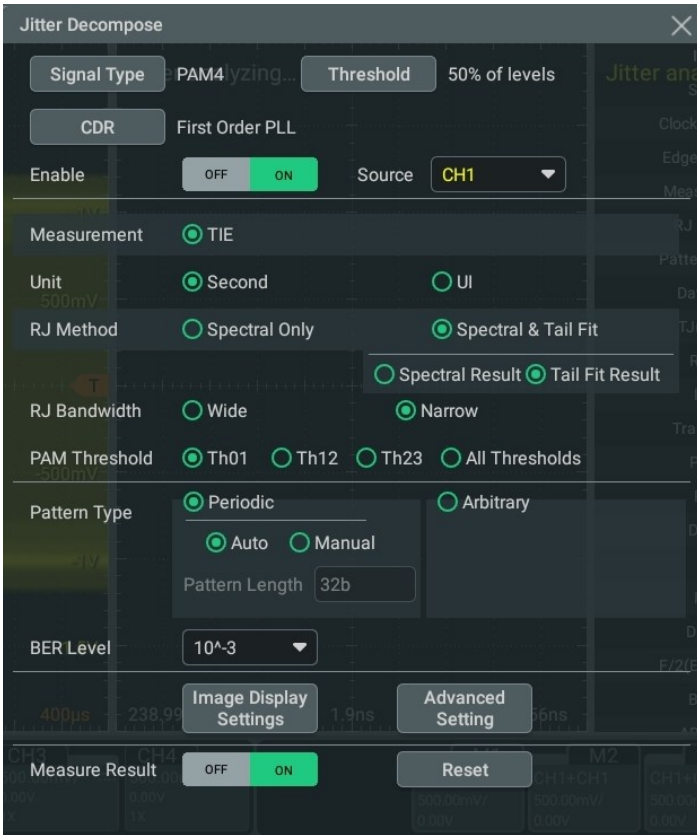
  OFF: disables the display of the measurement result window on the screen.

  ON: enables the display of the measurement result window on the screen.

- **Reset**

  Click or tap **Reset**, then the oscilloscope clears the accumulative results of the current measurement items and restarts the measurement.

3.2 Jitter Decomposition Configuration for PAM Signals



The PAM signal only supports the TIE measurement, but allows to select PAM threshold.

- **PAM Threshold**

  Th01: performs a jitter-decomposition measurement on the 0-to-1 transition edge of the PAM signal.

  Th12: performs a jitter-decomposition measurement on the 1-to-2 transition edge of the PAM signal.

  Th23: performs a jitter-decomposition measurement on the 2-to-3 transition edge of the PAM signal.

  All Thresholds: performs a jitter-decomposition measurement on all the edges of the PAM signal.

- **Display Threshold**

  When PAM Threshold is set to "All Thresholds", you can select which threshold you expect to display its image.

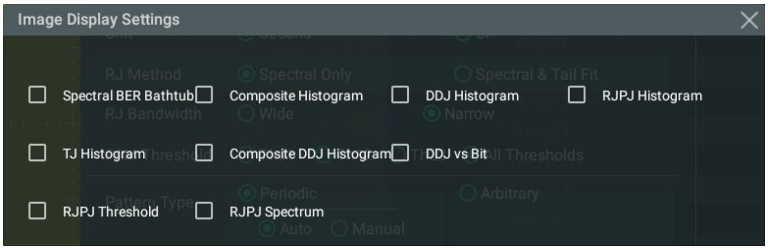
  Th01: displays the image of the 0-to-1 transition edge of the PAM signal.

  Th12: displays the image of the 1-to-2 transition edge of the PAM signal.

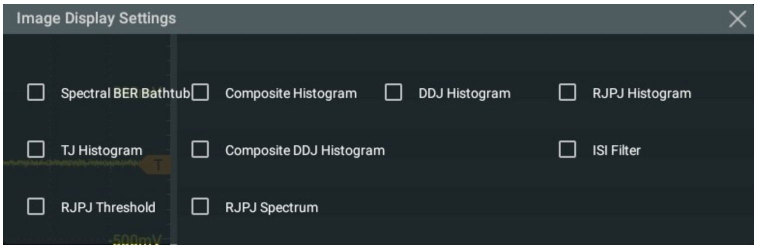
  Th23: displays the image of the 2-to-3 transition edge of the PAM signal.

3.3 Image Display Settings

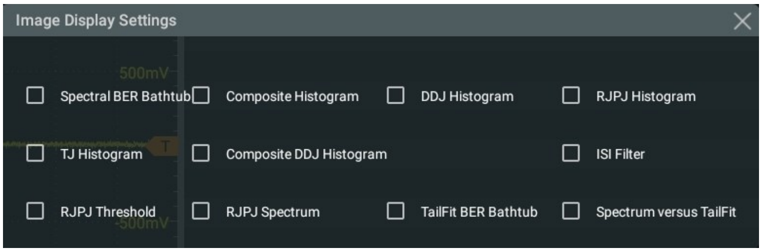
The available types of displayed images for the periodic mode are as follows:



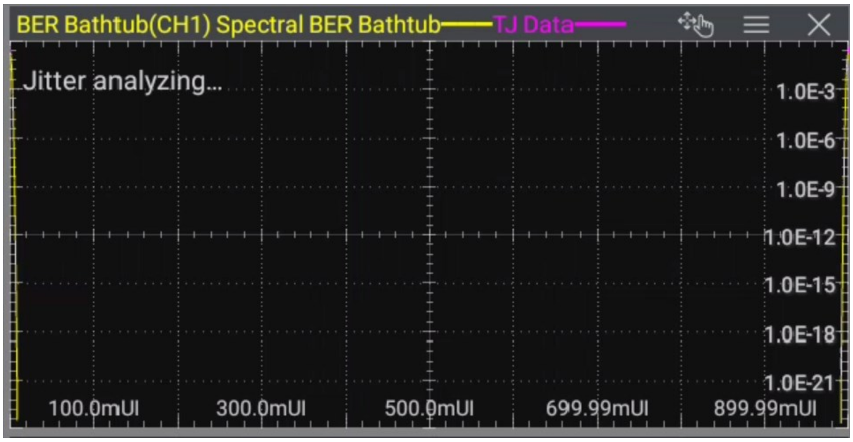
The available types of displayed images for the non-periodic mode (Arbitrary) are as follows:



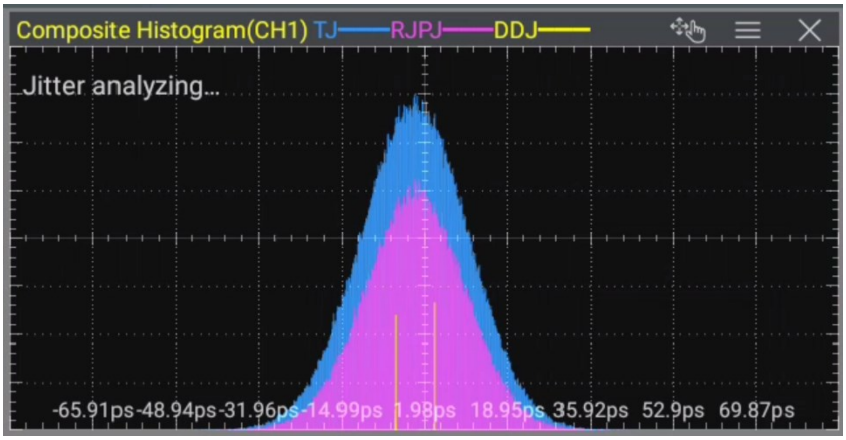
When you select "Spectral & Tail Fit" and select to display "Tail Fit Result" for the jitter decomposition measurement results, then the supported types of image to be displayed are as follows:



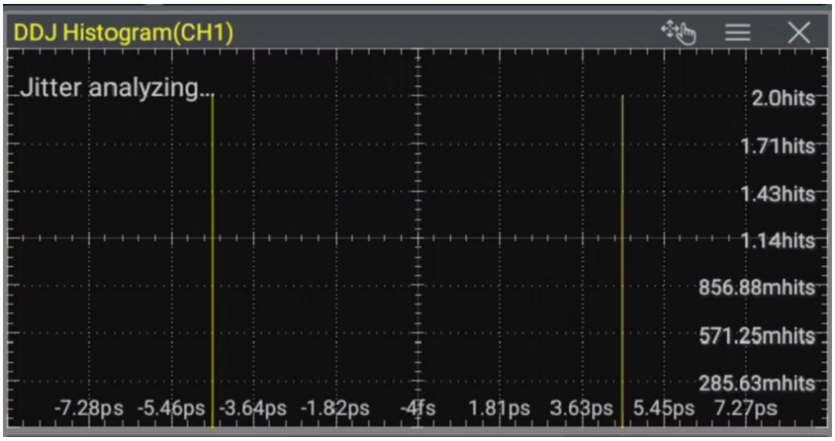
- **Spectral BER Bathtub:** The oscilloscope plots the spectral BER Bathtub curve for the jitter decomposition results.



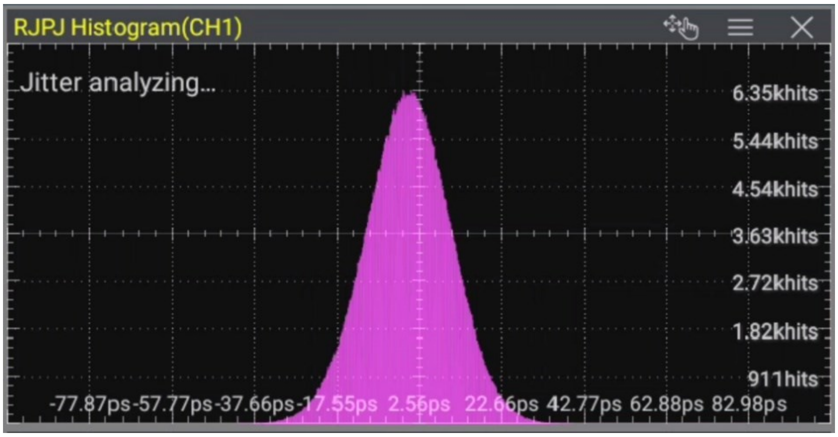
- **Composite Histogram:** The oscilloscope simultaneously plots the TJ Histogram, RJPJ Histogram, and DDJ Histogram in one graph.



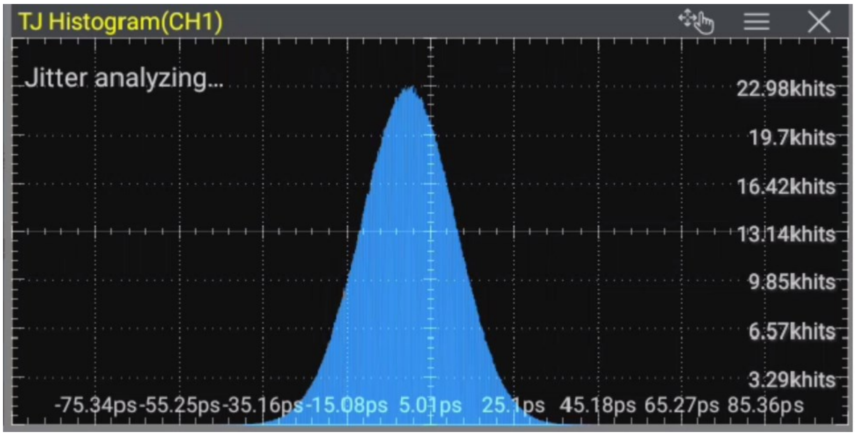
- **DDJ Histogram:** The oscilloscope plots the DDJ histogram of the jitter decomposition results.



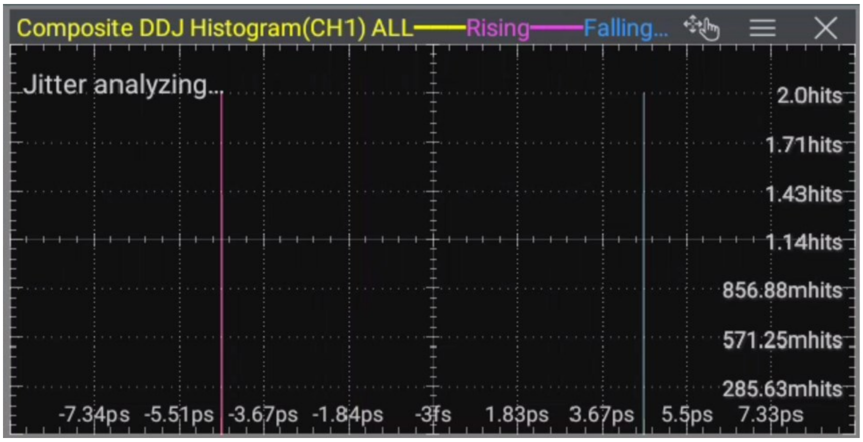
- **RJPJ Histogram:** The oscilloscope plots the RJPJ histogram of the jitter decomposition results.



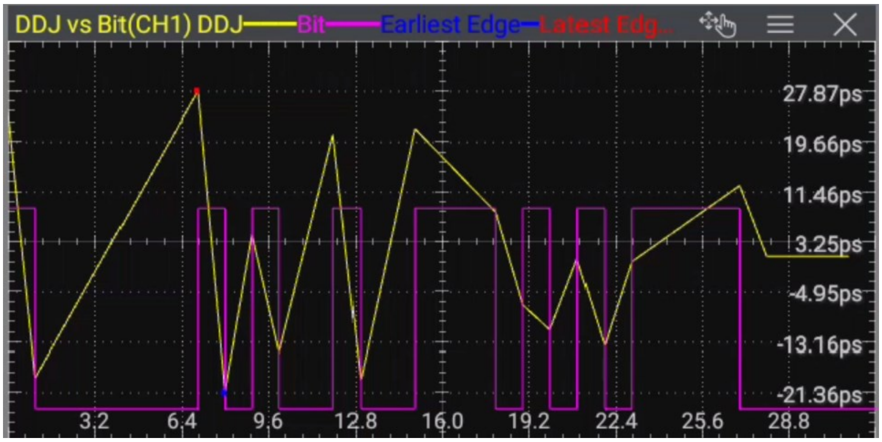
- **TJ Histogram:** The oscilloscope plots the TJ histogram of the jitter decomposition results.



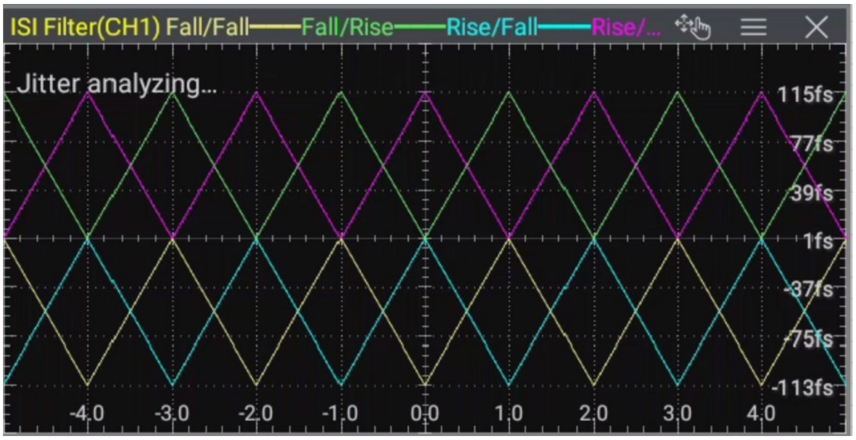
- **Composite DDJ Histogram:** The oscilloscope plots the rising edge, falling edge, and both edges of the DDJ histogram of the jitter decomposition results.



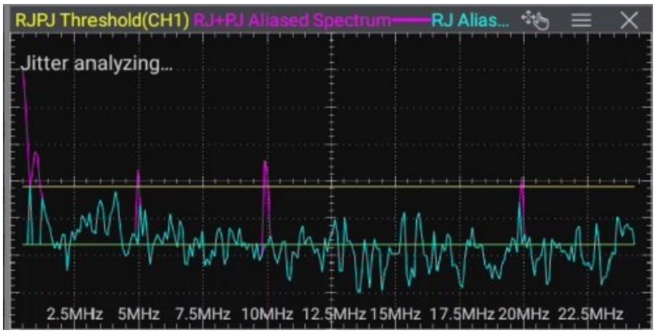
- **DDJ vs Bit:** The oscilloscope plots the DDJ size for each bit position of the jitter decomposition result.



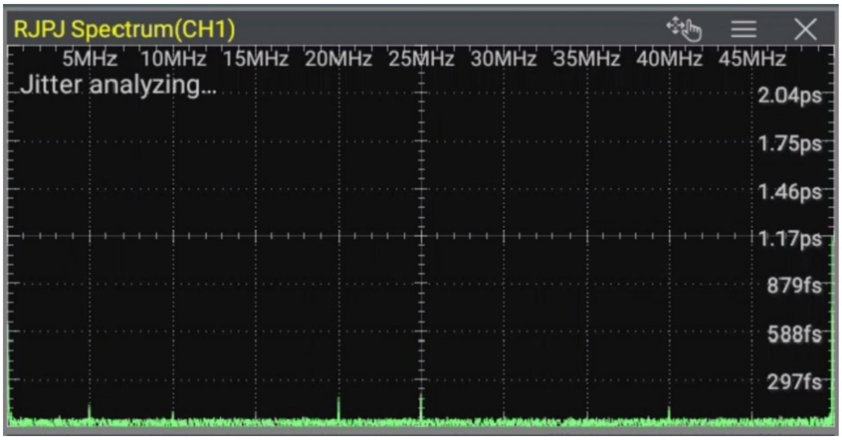
- **ISI Filter:** The oscilloscope plots the magnitudes of the tap coefficients, which quantify the mutual interference between different symbols (bits/bauds).



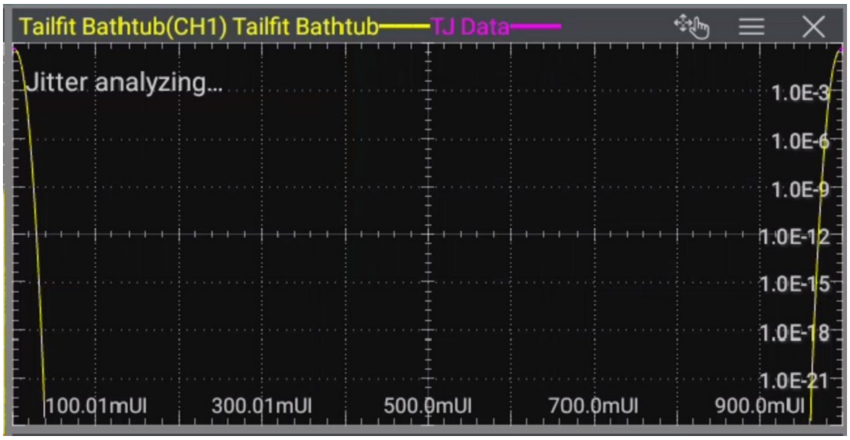
- **RJPJ Threshold**: The oscilloscope plots the jitter characteristics measured at different thresholds (level thresholds).



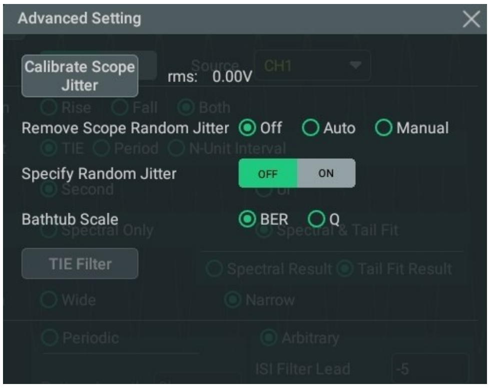
- **RJPJ Spectrum:** The oscilloscope plots the RJPJ histogram of the jitter decomposition results.



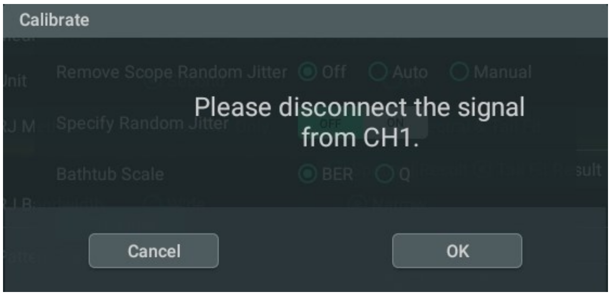
- **TailFit BER Bathtub:** The oscilloscope plots the TailFit BER Bathtub curve for the jitter decomposition results.



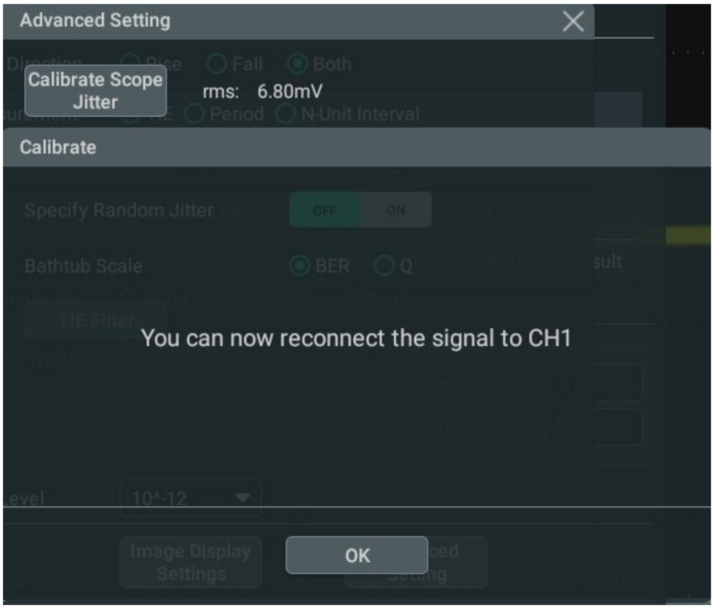
3.4 Advanced Setting



The advanced setting interface is shown above. When the jitter decomposition is set to OFF, the **Calibrate Scope Jitter** menu is available to operate. Click or tap this menu to calibrate the oscilloscope jitter. Then the following interface is displayed. Disconnect the signal as required, leaving only the noise floor signal. Click or tap **OK**.



A pop-up window appears. Reconnect the signal to CH1. At this time, the RMS value of the noise floor updates.



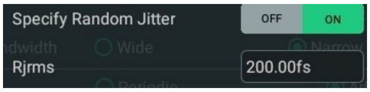
- **Remove Scope Random Jitter**

  Off: no calculation on the oscilloscope random jitter is performed for the jitter decomposition.

  Auto: automatically calculates the oscilloscope random jitter and removes it from the jitter decomposition measurement results.

  Manual: manually inputs the value of "Scope RJrms" and remove it from the jitter decomposition measurement.

- **Specify Random Jitter**



  OFF: does not specify the random jitter.

  ON: inputs the random jitter value manually.

- **Bathtub Scale**

  You can choose to plot a BER-scale bathtub curve or a Q-scale bathtub curve when you select to plot a bathtub curve.

- **TIE Filter**: not available currently.

4. Typical Application

When using the oscilloscope to perform the jitter decomposition measurement, make the following configurations: set the sample rate to 20 GSa/s; adjust the time base to make the oscilloscope's memory depth greater than 32 Mpts; and set the bandwidth limit as required.

4.1 Clock Signal

4.1.1 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 200 μs to make its memory depth to 40 Mpts.

Step 3: In the "Vertical" system menu, adjust the vertical scale to make the signal amplitude take up the whole display area; set the bandwidth limit to 3G;

Step 4: In the jitter decomposition 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 "Rise" for **Edge Direction**.

Step 7: In the jitter decomposition interface, click or tap the drop-down button of **Source** to select CH1. Click or tap to select "Both" for **Edge Direction**. Set measurement type to Periodic. Set **Unit** to Second. Click or tap to select Spectral Only for **RJ Method**. Click or tap the drop-down button of **BER Level** to select 1e-12. Click or tap to select the desired image display for **Image Display Settings** according to actual needs (here we take "Composite Histogram" as an example). Keep **Advanced Setting** configurations remain default.

Step 8: Enable the jitter decomposition measurement, and you will see the measurement results.

4.1.2 Measurement Result

The following figure shows the jitter decomposition measurement results of a 50 MHz clock signal.

4.2 NRZ Data Signal

4.2.1 Test Procedures

Step 1: Output a NRZ data signal whose pattern length is 32 bits with the signal generator.

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 20 Mpts.

Step 3: In the "Vertical" system menu, set the vertical scale of CH1 to make its signal amplitude take up the whole display area; set the bandwidth limit to a proper value.

Step 4: In the jitter decomposition 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 **"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 jitter decomposition interface, click or tap the drop-down button of **Source** to select CH1. Set measurement type to TIE. Set **Unit** to Second. Click or tap to select "Spectral Only" for **RJ Method**. Click or tap to select "Wide" for **RJ Bandwidth**. Click or tap to select "Periodic" for **Pattern Type**. Click or tap the drop-down button of **BER Level** to select 1e-12. Click or tap to select the desired image display for **Image Display Settings** according to actual needs. Here, for better demonstration, we only check the "Composite Histogram" and "DDJ vs Bit". Keep **Advanced Setting** configurations remain default.

Step 8: Enable the jitter decomposition measurement, and you will see the measurement results.

4.2.2 Measurement Result

The following figure shows the jitter decomposition measurement results of the NRZ signal.

4.3 PAM4 Data Signal

4.3.1 Test Procedures

Step 1: Input the PAM4 signal 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 an appropriate value.

Step 3: In the "Vertical" system menu, set the vertical scale of CH1 to make its signal amplitude take up the whole display area; set the bandwidth limit to a proper value.

Step 4: In the jitter decomposition interface, set "Signal Type" to PAM4.

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 a desired symbol rate. 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 jitter decomposition interface, click or tap the drop-down button of **Source** to select CH1. By default, the edge direction is Both. Set measurement type to TIE. Set **Unit** to Second. Click or tap to select "Spectral Only" for **RJ Method**. Click or tap to select "Wide" for **RJ Bandwidth**. Click or tap to select "Th01" for **PAM**

Threshold. Click or tap to select "Periodic", "Auto" for **Pattern Type**. Click or tap the drop-down button of **BER Level** to select 1e-3. Click or tap to select the desired image display for **Image Display Settings** according to actual needs. Here, for better demonstration, we only check the "Composite Histogram" and "DDJ vs Bit". Keep **Advanced Setting** configurations remain default.

Step 8: Enable the jitter decomposition measurement, and you will see the measurement results.

4.3.2 Measurement Result

The following figure shows the jitter decomposition measurement results of the PAM4 signal.

5. Appendix

Abbreviations

Abbreviations	Full Name
BER	Bit Error Ratio
CDR	Clock Data Recovery
Erf/Erfc	Error function or Gauss error function
NRZ	Non-return-to-zero Code
RMS	Root Mean Square
UI	Unit Interval
TIE	Time Interval Error
TJ	Total Jitter
RJ	Random Jitter
DJ	Deterministic Jitter
PJ	Periodic Jitter
DDJ	Data-Dependent Jitter
DCD	Duty Cycle Distortion
ISI	Inter-Symbol Interference

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