Agilent ParBERT 81250 Measurement Software

DUT Output Timing/Jitter Measurement User Guide

Agilent Technologies

Important Notice

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Contents

Introduction

Electrical/Optical Measurement Capabilities

The Agilent 81250 ParBERT Measurement Software provides the capability of not only measuring electrical inputs and outputs, it can also be used to test optical and optoelectrical devices.

For electrical measurements, the threshold is given in Volts.
For optical measurements, the threshold is given in optical power units (W or dBm).

Because the DUT Output Timing /Jitter Measurement is not related to the threshold, this measurement provides the capability to use optical and electrical ports simultaneously.

Measurement Overview

The DUT Output Timing/Jitter measurement allows you to set up and run a bit error rate (BER) and jitter measurement for a device under test (DUT) with several output ports and terminals. It analyzes the jitter, separates the random jitter and deterministic jitter components, and estimates the total jitter.

Timing Measurement Characteristics

The sampling point is swept automatically within a 1.5 clock period to generate a “bathtub” curve. The resulting graph is centered around the optimum sampling point of the port. In addition, the results are available in a tabular view. If a clock signal is defined, the software measures also the data to clock alignment and displays the absolute delay.

Jitter Measurement Characteristics

The jitter is calculated as the derivative of the bit error rate (dBER/dt). Its peak-to-peak, RMS, and mean values are part of the result table. The jitter can also be displayed graphically. A dedicated Gaussian marker allows to investigate the jitter graph in detail and to measure the contribution of certain sections or jitter peaks to the overall results.

Fast Total Jitter Measurement Characteristics

This measurement is an alternative to the standard jitter measurement. It can be used to measure the total jitter at very low bit error ratios.

Whereas usual jitter measurements at a BER around 10^{-12} can take days (due to the huge number of bits that has to be compared for each measurement point), the Fast Total Jitter measurement can, for example, determine the total jitter at a BER of 10^{-12} in less than 20 minutes (at a data rate of 10 Gbit/s).

General

You can set the signal parameters, the values to be displayed and the output format according to your needs. For each measurement, you can define several ports with several terminals. For each port, you can define an individual clock signal.

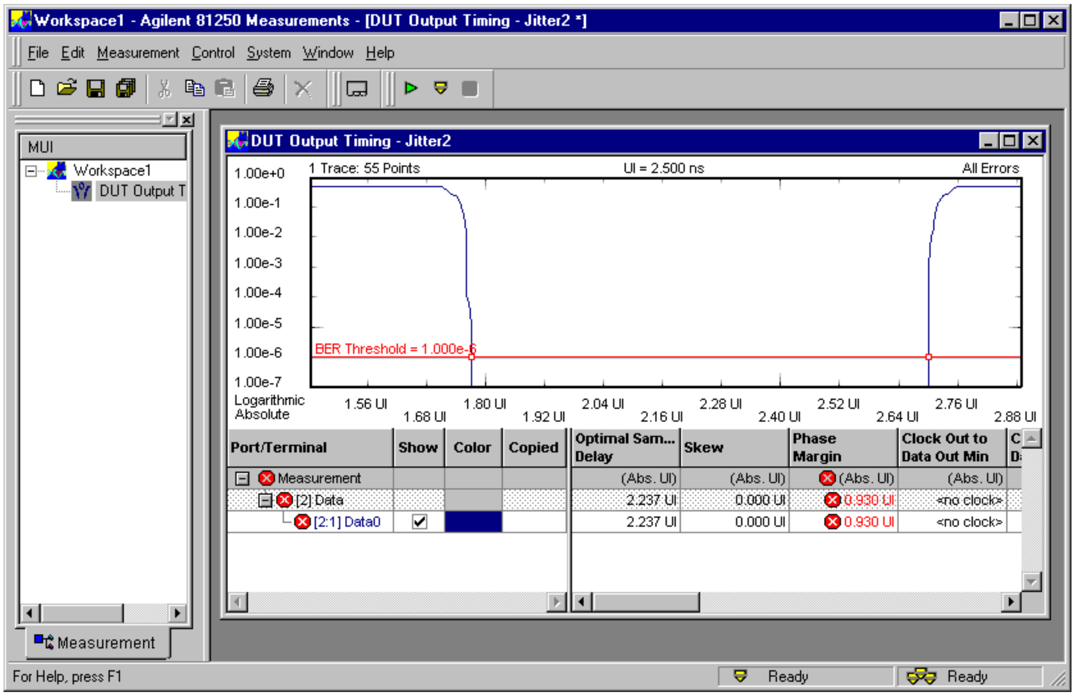
This document provides the following information:

- For a quick start, read the example session given in *"Example of a DUT Output Timing Measurement" on page 9*.
- *"Basics of the DUT Output Timing/Jitter Measurement" on page 21* provides detailed information on the prerequisites and the parameters shown on the result screen.
- *"Setting the Properties of a DUT Output Timing Measurement" on page 47* shows how to specify the input parameters and the graphical display of the measurement.

NOTE

It is assumed that you are familiar with the general characteristics and features of the *Agilent 81250 Measurement Software*. The general capabilities and operating principles are documented in the *Agilent 81250 ParBERT Measurements Framework User Guide*.

The following illustration shows the result of a typical DUT output timing measurement:



Example of a DUT Output Timing Measurement

This chapter shows how to set up and use the DUT output timing measurement.

This requires the following steps:

1. Set up the system with the *Agilent 81250 User Software*.

   See *"Setting Up and Connecting the DUT" on page 10*.

2. Set up a bit error measurement with the *Agilent 81250 User Software*.

   See *"Preparing the Measurement" on page 11*.

3. With the *Agilent 81250 Measurement Software*, create a new workspace and measurement and execute the measurement.

   See *"Executing the DUT Output Timing Measurement" on page 13*.

4. Change the measurement properties and the graphical display.

   See *"Changing the DUT Output Timing Parameters" on page 15*.

For this example, we use the following hardware components:

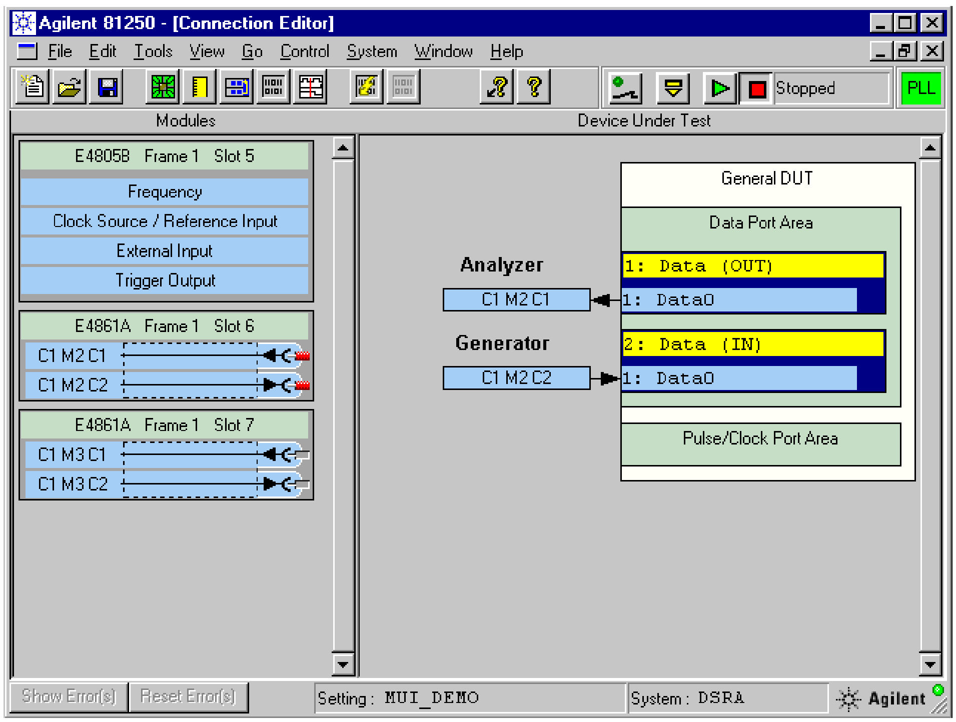
- E4861A 2.7 Gbit/s data generator/analyzer module
- E4862A generator frontend
- E4863A analyzer frontend

Setting Up and Connecting the DUT

Use the *Agilent 81250 User Software* to create a model of the hardware. For a detailed description of the *Agilent 81250 User Software*, refer to the *Agilent 81250 ParBERT System User Guide*.

1 Create a DUT output port and a DUT input port.

2 Connect the analyzer to the electrical output port and the generator to the electrical input port.



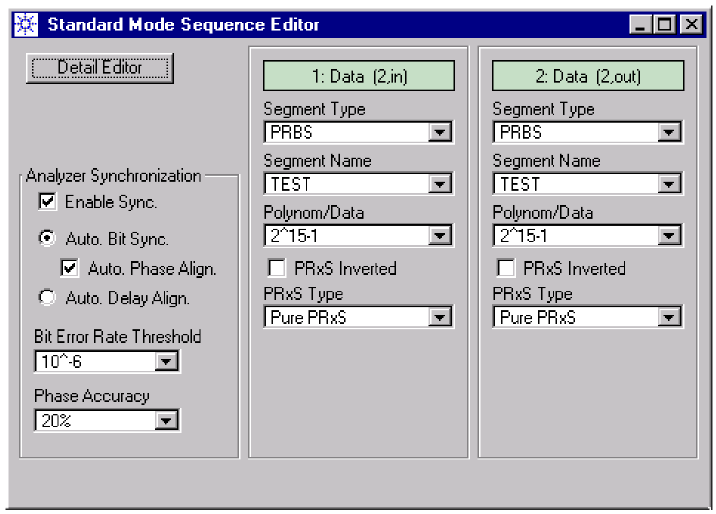
NOTE The other analyzer and generator modules shown in the figure are not required for this example.

3 Using a shielded cable, connect the analyzer physically with the generator. This cable will be the device under test.

Preparing the Measurement

Use the *Agilent 81250 User Software* to set up a bit error rate (BER) test:

1 Create the test sequence with the *Standard Mode Sequence Editor*. We use the same PRBS segment for the generator and the analyzer.

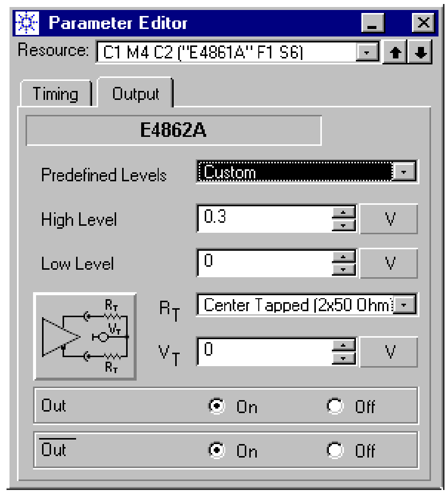


- Enable *Analyzer Synchronization*.

  Automatic Bit Synchronization will adjust the sampling point of the analyzer until the specified bit error rate is met. *Automatic Phase Alignment* will finally position the analyzer sampling point at the optimum.

  Automatic Delay Alignment requires that you specify a suitable analyzer start delay.

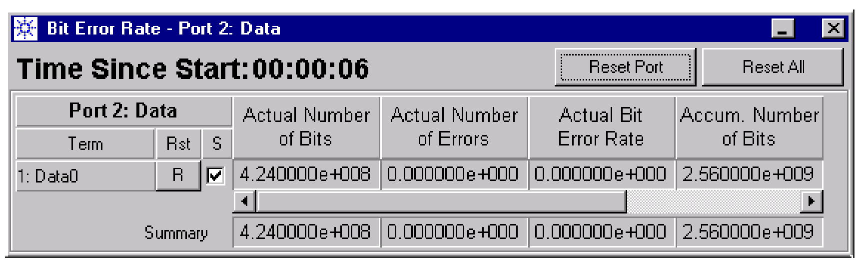
2 Edit the generator and analyzer properties with the *Parameter Editor*.



Choose suitable voltage levels and switch the generator and analyzer on.

3 Open the *Bit Error Rate* window and run the test.

The analyzer is automatically synchronized with the generator and the bit error rate is zero.



4 Stop the Bit Error Rate (BER) test in the *Agilent 81250 User Software*.

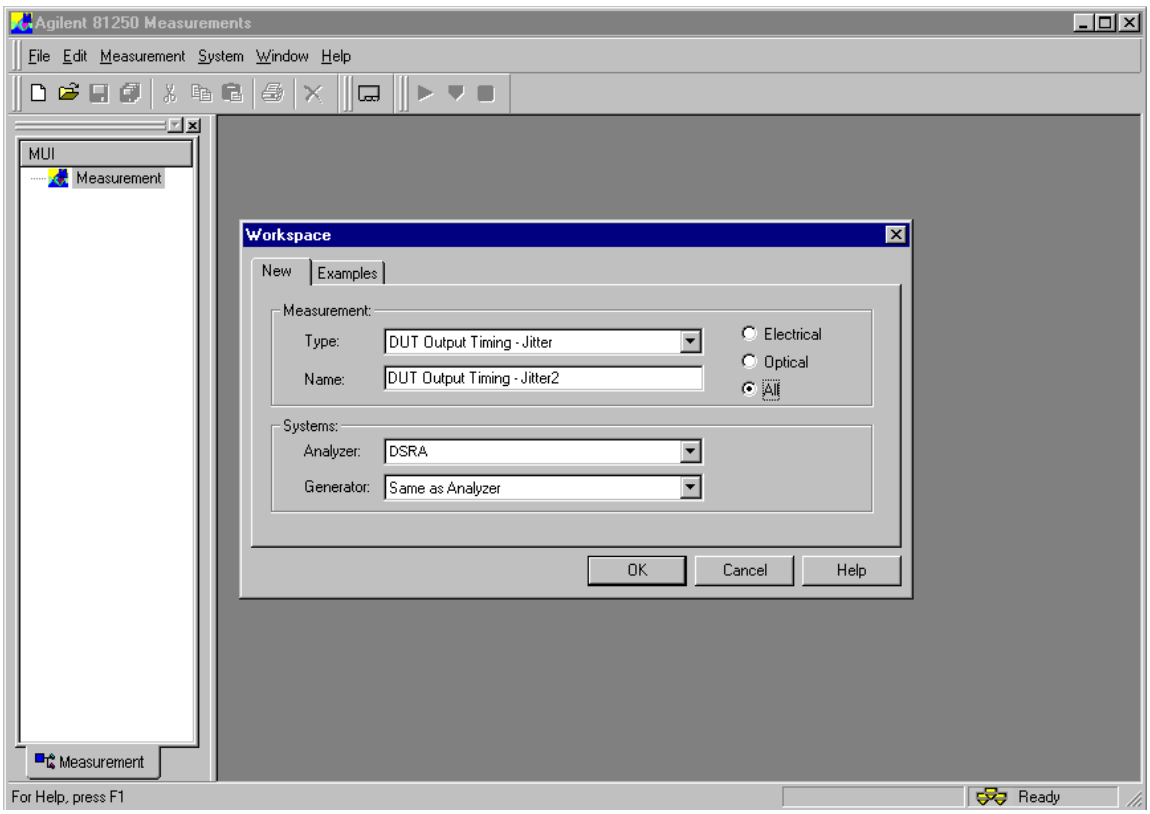
5 Save the setting under the name *MUI_DEMO*.

Once you have saved the setting, you may terminate the *Agilent 81250 User Software* if you wish to do so.

Executing the DUT Output Timing Measurement

Use the *Agilent 81250 Measurement Software* to set up the DUT output timing measurement:

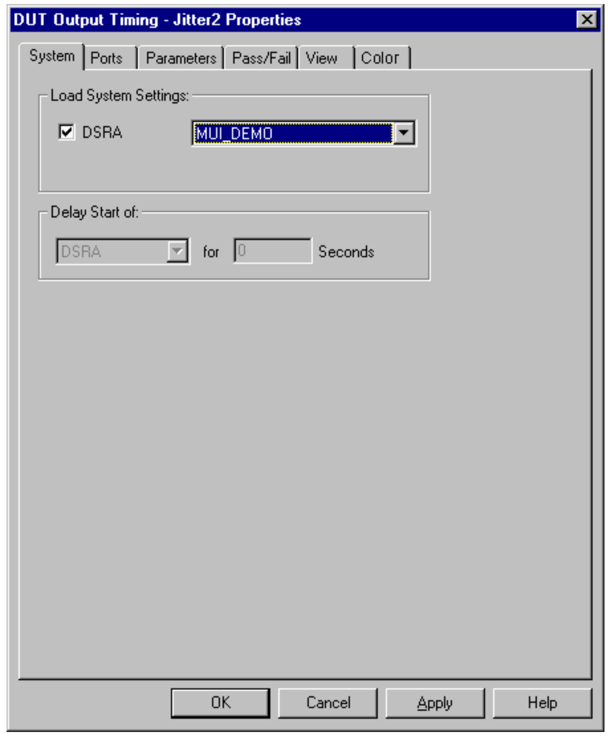
1 Start the *Agilent 81250 Measurement Software* and select the measurement type *DUT Output Timing/Jitter* for the system DSRA.



NOTE Each time you open the Workspace dialog box, your last settings are displayed.

2 Select the saved setting *MUI_DEMO* for the measurement.

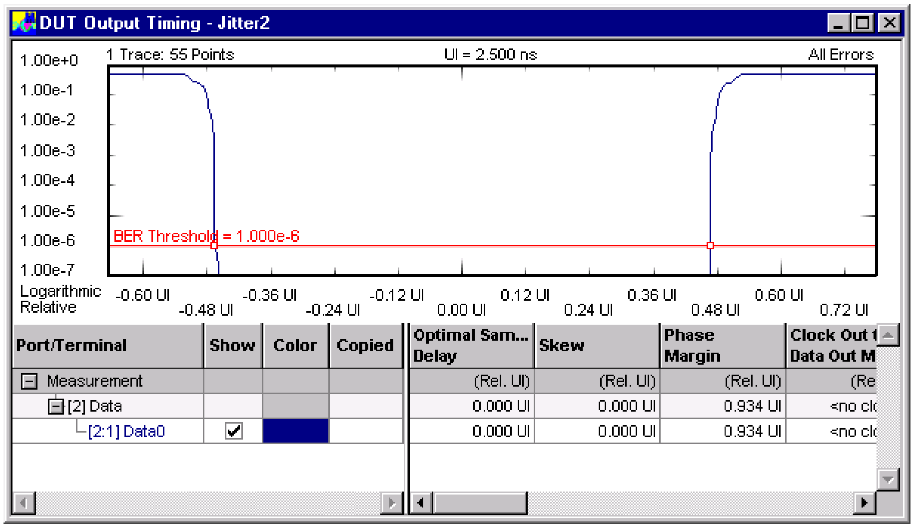
For the moment, there is no need to change the other parameters and options.



3 In the *Properties* dialog, click *OK*.

4 In the tool bar, click the *Run* button to load the parameters to the firmware and execute the measurement.

The measurement software runs the measurement and displays the results. The following illustration shows the bathtub curve of the measured bit error rate and—in the tabular view—the calculated results for the *Optimal Sampling Delay*, the *Skew* and the *Phase Margin*.



On this screen, you can modify the graphical display of the results to improve the result evaluation.

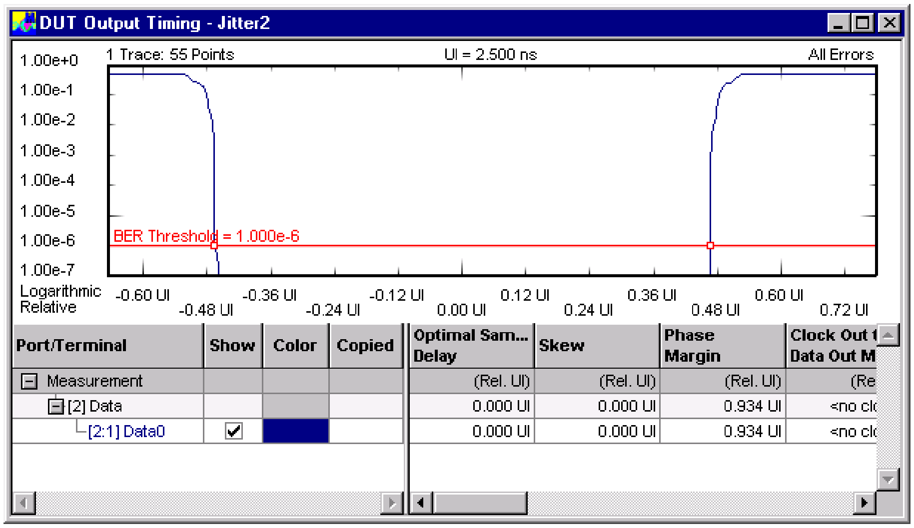
Changing the DUT Output Timing Parameters

After a measurement has been run, you can change the measurement parameters:

- Some of the modifications will change the result display without rerunning the measurement. For examples, refer to *"Changing the Graphical Display of the Results" on page 16*.
- Some of the modifications require to repeat the measurement. For an example, refer to *"Changing the Measurement Parameters" on page 20*.

The following sections show some typical modifications of the measurement and the graphical display of the results.

The original graph of the measurement looks as follows:



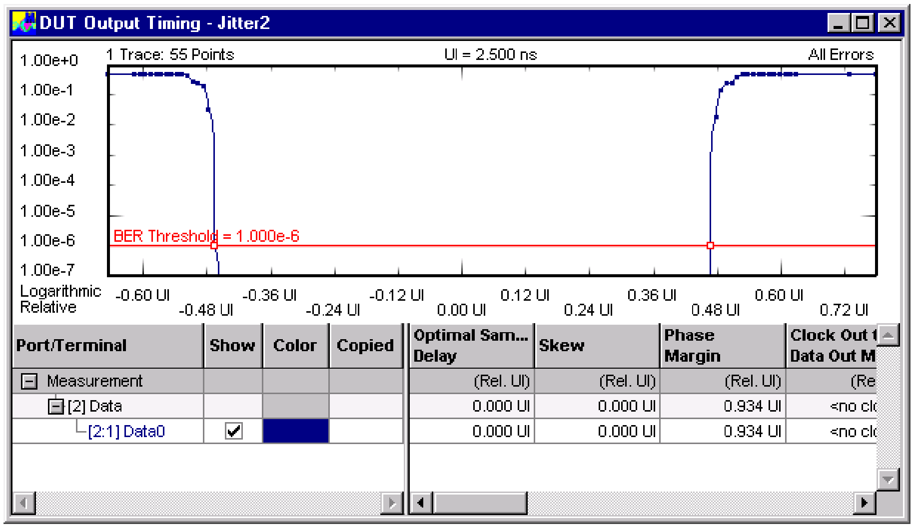
Changing the Graphical Display of the Results

You can modify the graphical display of the results at any time without rerunning the measurement to analyze the results with different criteria.

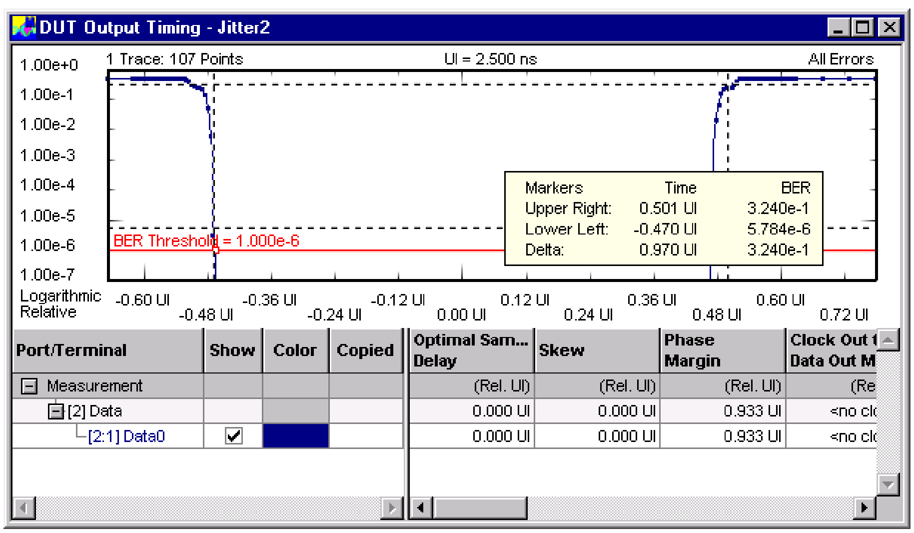
The measurement software allows you to modify the graphical output in two ways:

- You can set the parameters on the *View* page of the *Properties* dialog.
- You can change the graphical display via the measurement's context menu at any time when the results are available (refer to *How to Change Measurement Properties after Running* in the *Framework User Guide*).

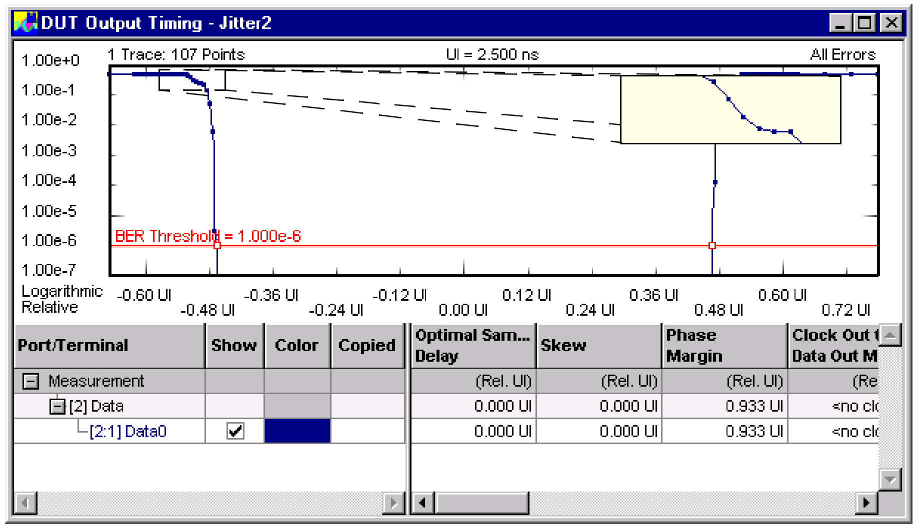
Measured Points If you want to see the points that have actually been measured, choose *View Options – Show Measured Points* from the context menu.



Markers To analyze the results, you can switch on markers (context menu *Display Options – Show Markers*).



Zoom To view details of the results, you can zoom an area of the graph (context menu *Display Options – Show Zoom Graph*).



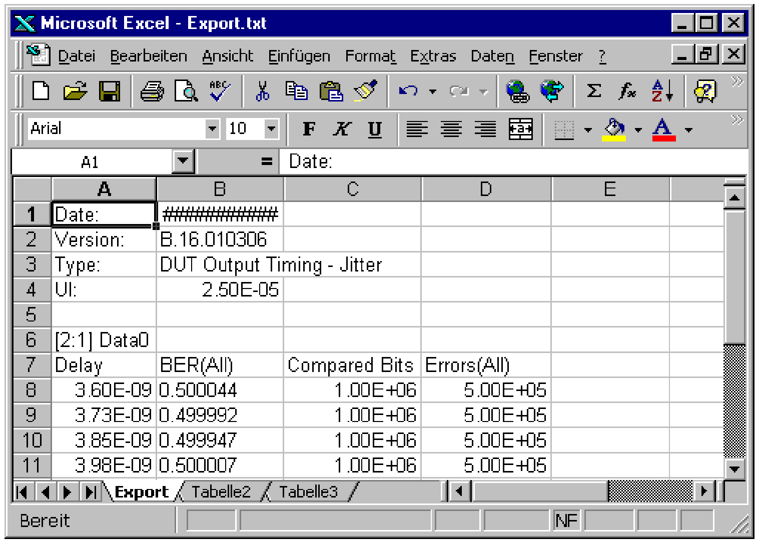
Exporting result data If you want to use the measurement results with other applications, you can export the data to a file via *Measurement – Export Result Data*.

The contents of the resulting file looks as follows:

```
Date:,03/12/01 12:38:46 PM
Version:,B.16.010306
Type:,DUT Output Timing - Jitter
UI:,2.5000E-009

[2:1] Data0,,,,
Delay,BER(All),Compared Bits,Errors(All),
3.604310E-009,5.000440E-001,1.000000E+006,5.000440E+005,
3.729310E-009,4.999920E-001,1.000000E+006,4.999920E+005,
3.854310E-009,4.999470E-001,1.000000E+006,4.999470E+005,
3.979310E-009,5.000070E-001,1.000000E+006,5.000070E+005,
4.104310E-009,4.999690E-001,1.000000E+006,4.999690E+005,
4.121552E-009,5.000010E-001,1.000000E+006,5.000010E+005,
...
```

This file can be imported into a Microsoft Excel sheet, for example. For more information, refer to *How to Export Measurement Results* in the *MUI Framework User Guide*.



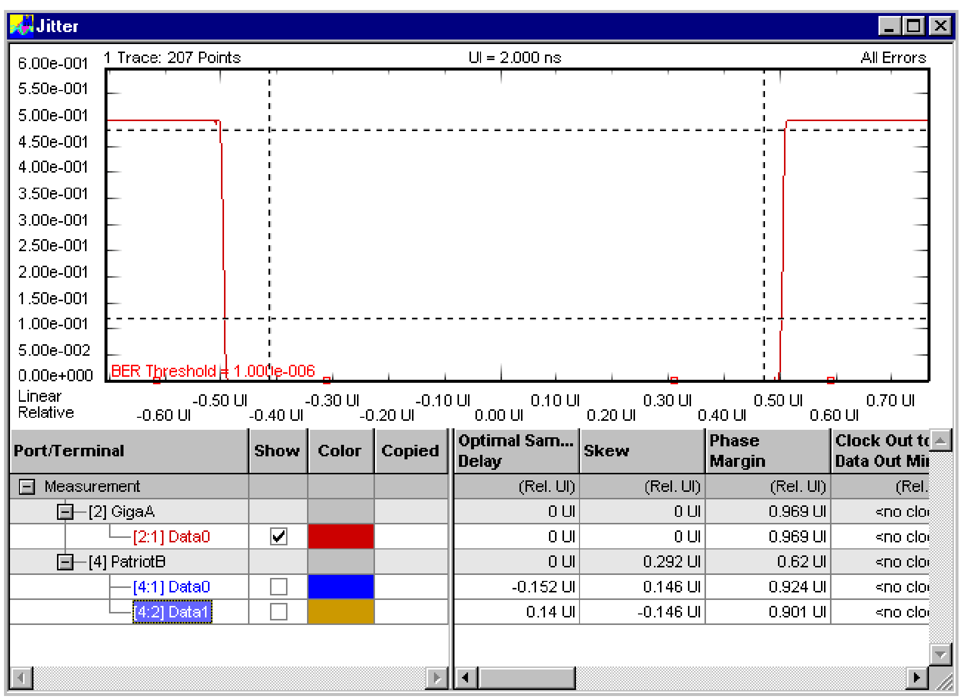
Changing the Display Units

If desired, you can:

- Switch from logarithmic to linear display (context menu *View Settings – Linear Scale*)

  and

- Change the timebase from unit intervals to seconds (context menu *View Settings – Seconds*).



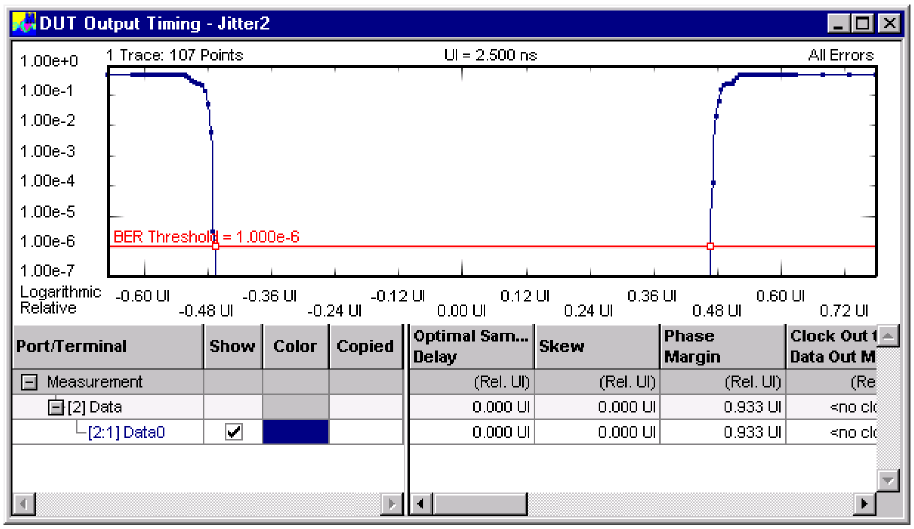
Changing the Measurement Parameters

The settings on the *System*, *Ports* and *Parameters* pages affect the measurement results and changes on these pages require to repeat the measurement.

Changing the Measurement Resolution

If the resolution is not high enough, change the parameter *Resolution* on the *Parameters* page of the *Properties* dialog from 0.01 to 0.005 and run the measurement again.

The resulting graph shows 107 instead of 55 measured points.



Basics of the DUT Output Timing/Jitter Measurement

In this chapter you find the following information:

- For the prerequisites to be met to run the measurement, refer to *"Prerequisites for Output Timing Measurements" on page 21*.
- For the definitions of the measurement results, refer to *"DUT Output Timing/Jitter Measurement Results" on page 22*.
- For an introduction to the Fast Total Jitter measurement, refer to *"Explanation of the Fast Total Jitter Measurement" on page 31*.

Prerequisites for Output Timing Measurements

In order to perform DUT output timing measurements, the following prerequisites have to be met in addition to the global ones (see *Prerequisites* in the *Framework User Guide*):

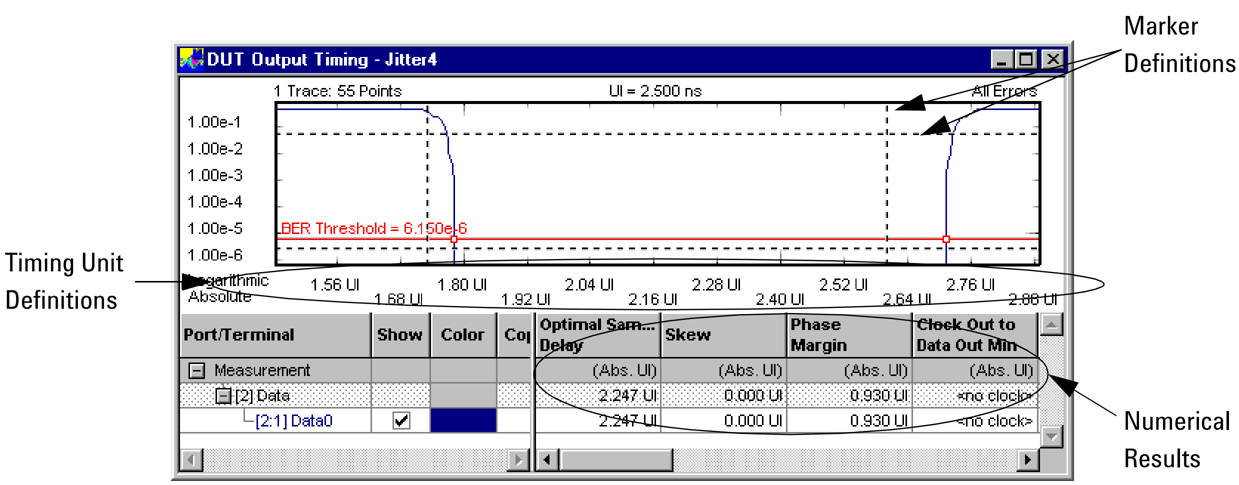
- The analyzers must be synchronized to the incoming data stream
  - either manually (specify a valid start delay)

    or
  - by automatic analyzer sampling point adjustment (*Automatic Bit Synchronization* or *Automatic Delay Alignment*).
- If automatic analyzer sampling point adjustment is used, the phase verniers of the analyzers have to be in zero position.

DUT Output Timing/Jitter Measurement Results

The ParBERT measurement software performs a measurement and returns the results in a graphical and in a tabular form. The following sections provide the definitions of measured parameters, of timing unit parameters, and of markers.

The following figure shows a typical result display of an output timing measurement.



The graph shows either the bath tub curve as illustrated in the figure above, or, if selected, the jitter distribution vs. time.

NOTE Under certain circumstances, some numerical results are not available. This is indicated by <*invalid*>, <*not applicable*>, or <*no clock*> in the numerical results table below the measurement graphic.

- <*invalid*> indicates that the value could not be calculated. This is the case, for example, for phase margin, when the BER threshold is set to high values and does not intersect with the bathtub curve.
- <*not applicable*> indicates that the value could be calculated, however is not shown because quality criteria are not met. This is the case, for example, for RJ/DJ results, when the r^2 value of one or both edges is <0.75. Even though RJ/DJ values can be calculated in this case, they are not shown because confidence in the results is too low.

- <*no clock*> indicates that certain values can only be calculated when a clock terminal is defined. Refer to *"How to Set Up a Clock Terminal for a Port" on page 52* for details.

For details see:

- *"Explanation of the Graphical Displays" on page 23*
- *"Explanation of the Numerical Results" on page 25*
- *"Explanation of the Fast Total Jitter Measurement" on page 30*
- *"Timing Unit Definitions" on page 36*
- *"Marker Definitions" on page 39*

Explanation of the Graphical Displays

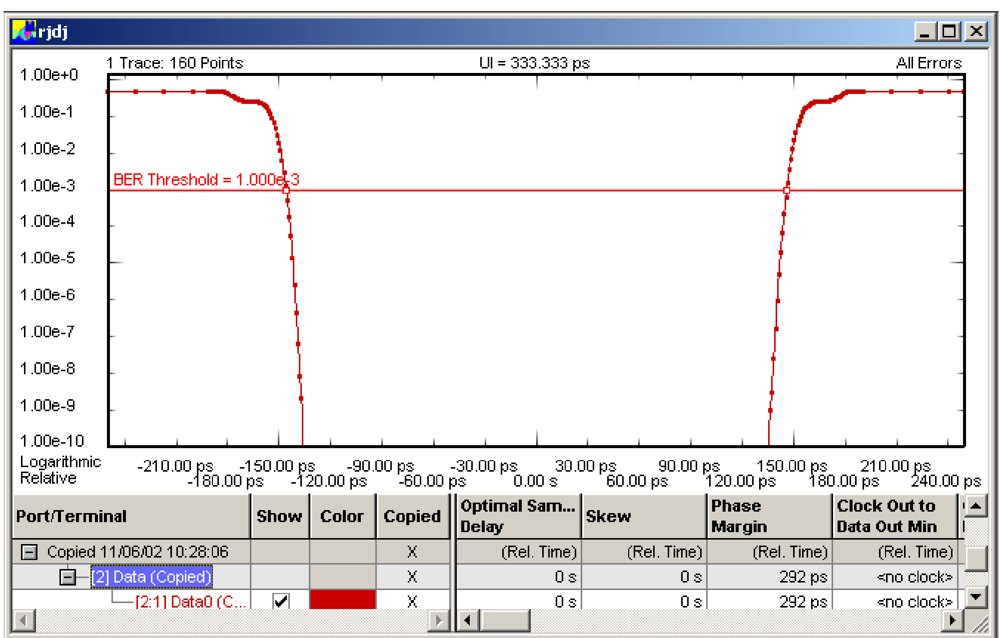
The standard measurement provides two views of the results:

- The BER graph
- The jitter histogram

These views are described in the following sections. The Fast Total Jitter measurement has its own display (see *"Explanation of the Fast Total Jitter Measurement" on page 30*).

The Bit Error Rate Graph

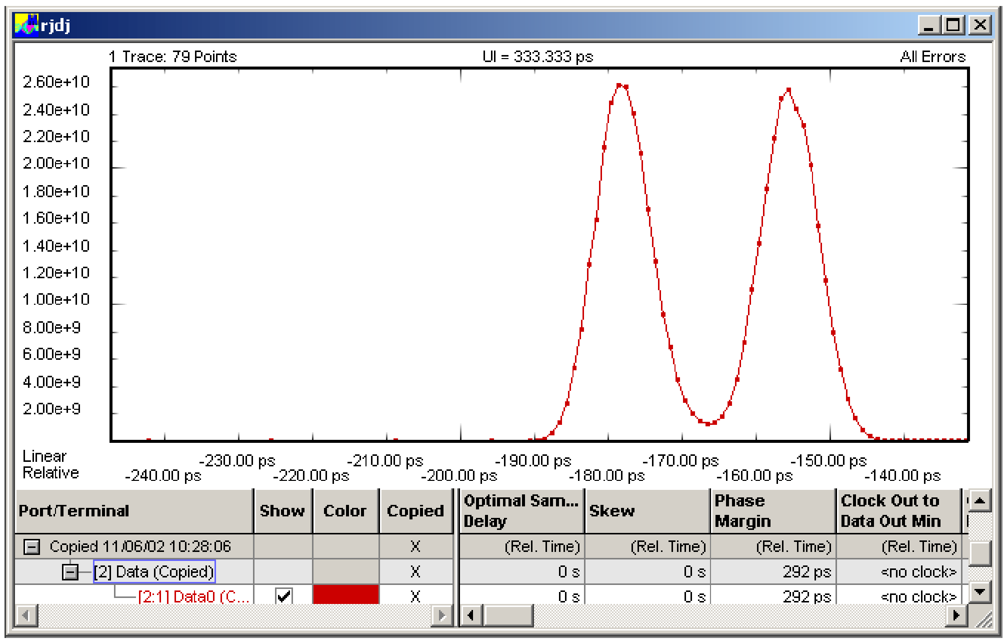
The BER graph (the "bathtub") shows the BER vs. the sampling delay.



The BER graph can be viewed in either linear or logarithmic view. The logarithmic view is shown in the figure above.

The Jitter Histogram

The jitter histogram can be enabled from the *View* tab of the *Properties* dialog. The DUT output timing/jitter measurement calculates the jitter histogram as the linear derivative of the measured bit error rate (jitter = dBER/dt).



NOTE Because the right-hand slope of the tub does not provide additional information on the jitter, the measurement's graphical jitter display shows only the portion at the left-hand side of the optimum sampling point.

The jitter histogram allows you to inspect the jitter components visually:

- Random Jitter (RJ)
- Deterministic Jitter (DJ)
- Estimated Total Jitter (TJ)

"Jitter Measurement Results" on page 28 describes how these components are calculated.

A Gaussian marker is available in this view to help analyze the jitter components. See *"The Gaussian Marker" on page 42* for details.

Explanation of the Numerical Results

The measurement provides numerical results for:

- Output timing parameters
- Jitter parameters
- Fast total jitter measurement parameters

Output Timing Measurement Results

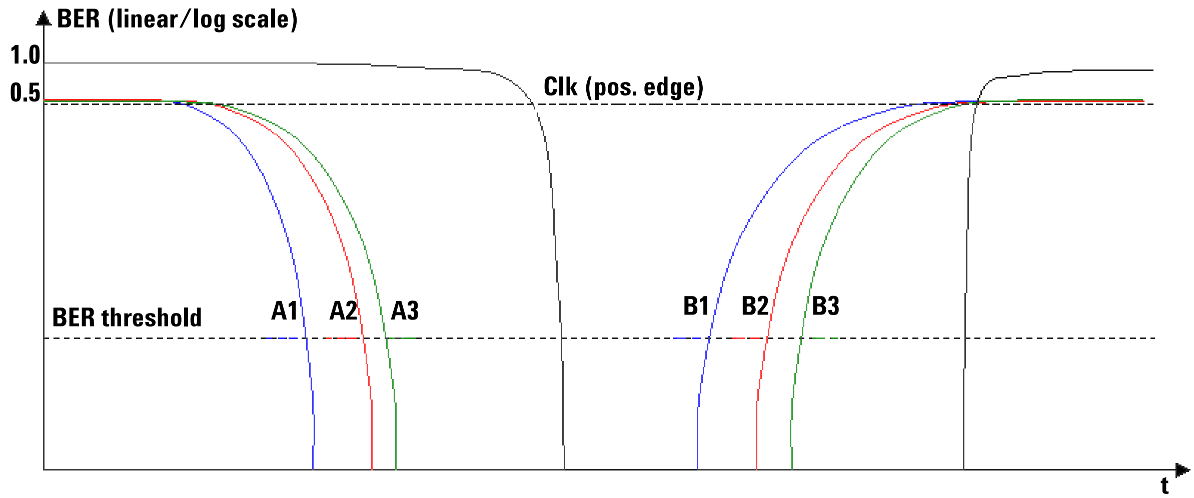
The output timing measurement parameters are defined in the following table.

NOTE The output timing measurement results are related to the BER threshold. They change when you change the BER threshold.

Parameter	Description	
	Terminal	**Port**
Optimum Sample Point Delay	The average of the left (A_i) and right (B_i) bathtub/BER threshold intersections.	The average of the maximum left (Amax) and minimum right (Bmin) bathtub/BER threshold intersections of all terminals in the port.
	Note: The average optimum sample point of all terminals in a port is not the same value as the optimum sample point of the port.	
Skew	The time difference between its optimum sample point and the average of the optimum sample points of all terminals in the port.	The time difference between the maximum and the minimum optimum sample point of all terminals in the port.
	Note: The sum (and thus, the average) of all terminal skews in a port is zero, and not the same value as the skew of a port.	
Phase Margin	The period of time where the bit error rate is lower than the BER threshold.	The period of time where the bit error rate of all its terminals are lower than the BER threshold.
Min Clock Out to Data Out	The time difference between the left bathtub/BER threshold intersection (A_i) and the clock edge.	The time difference between the maximum of all left bathtub/BER threshold intersections in the port and the clock edge.
Max Clock Out to Data Out	The time difference between the right bathtub/BER threshold intersection (B_i) and the clock edge.	The time difference between the maximum of all right bathtub/BER threshold intersections in the port and the clock edge.

The following illustration shows an example for one port with three terminals.

NOTE This graphical view is not available in the measurement software.



The following table explains the parameters displayed in the numerical view and the calculation algorithms:

Result	Optimal Sample Point Delay	Skew	Phase Margin	Min Clock Out to Data Out	Max Clock Out to Data Out
Port 123	(A3 + B1)/2 $(B_i min + A_i max)/2$	$^1/_2 \cdot ((A3 + B3) – (A1 + B1))$ $^1/_2 \cdot ((A_i + B_i)max – (A_i + B_i)min)$	B1 – A3 $B_i min – A_i max$	A3 – Clk $A_i max$ – Clk	B1 – Clk $B_i min$ – Clk
Terminal 1	(A1 + B1)/2	Av – (A1 + B1)/2	B1 – A1	A1 – Clk	B1 – Clk
Terminal 2	(A2 + B2)/2	Av – (A2 + B2)/2	B2 – A2	A2 – Clk	B2 – Clk
Terminal 3	(A3 + B3)/2	Av – (A3 + B3)/2	B3 – A3	A3 – Clk	B3 – Clk
Clock					

For the definitions you have to consider the following:

- The A_i and B_i values are the left and right intersections of the bathtub curves with the BER threshold. Obviously, they change with the BER threshold, so all values that have A_i or B_i in their definition change with the BER threshold.
- Av is the average, calculated as Av = (A1+A2+A3+B1+B2+B3)/6
- The sum of all terminal skews is zero.
- A *Port* row shows the overall values for the related port.

Jitter Measurement Results

The jitter measurement parameters are defined in the following table.

NOTE All jitter measurement parameters (except the *Total Jitter RMS* and *Total Jitter Mean*) change with the BER threshold.

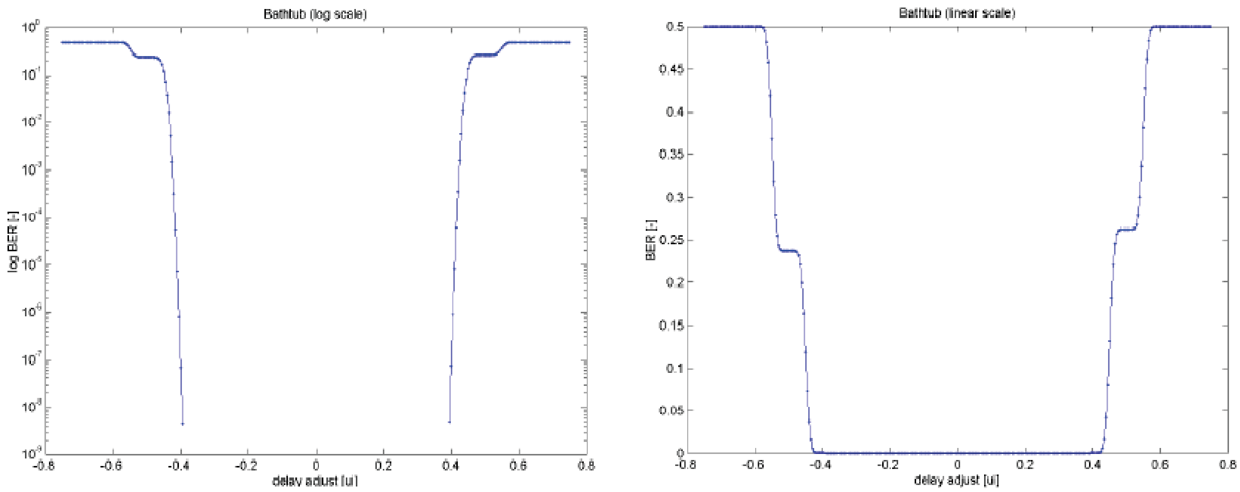
Jitter values are only defined for terminals, not for ports.

Parameter	Description
Total Jitter RMS	The average of the left and right jitter histogram root mean squared values.
Total Jitter Peak-Peak	Peak to peak value for total jitter. Calculated as the pulse period (unit interval) minus the phase margin.
Total Jitter Mean	Mean value for total jitter. Calculated as the weighted average of the left edge jitter histogram.
Random Jitter RMS	The total jitter component with Gaussian distribution. After transforming a contiguous range of measured points into Q space and performing a linear regression, it is calculated as the mean of the sigmas of the two straight lines.The contiguous range is limited by the the *BER Threshold* and the *Min. BER for RJ/DJ Separation* threshold.
Deterministic Jitter	The total jitter component with non-Gaussian distribution. After transforming a contiguous range of measured points into Q space and performing a linear regression, it is calculated as the period minus the difference between the means of the two straight lines.
Estimated Total Jitter	A forecast of the expected jitter for very low bit error rates. After extrapolating the measured BER curves, it is calculated as the period minus the expected width of the eye opening.
R^2 value	The R^2 values are calculated for both slopes of the bathtub curve. They are a measure of how well the transformed points between *BER Threshold* and *Min. BER for RJ/DJ Separation* fit to the linear regression. They have to be greater than 0.75 for the RJ, DJ, and estimated TJ values to be applicable.
No. of points	This is the number of points that has been measured between the *BER Threshold* and the *Min. BER for RJ/DJ Separation* threshold. It is displayed for both slopes. This number has to be greater than 2 for the RJ, DJ, and estimated TJ values to be applicable.

How RJ/DJ Separation Works

To understand the RJ and DJ results, it is helpful to first understand how the software generates the results:

1 The bathtub curve is measured.



2 All measurement points that have BER between the *BER Threshold* and *Minimum BER for RJ/DJ Separation* are transformed into Q-space.

   The Q-factor describes the signal-to-noise ratio at the decision circuit. It is described under *Explanation of the Q-Factor Results* in the *Output Level Measurement Guide*.

3 Linear regression is performed for both the left and right edges.

4 The mean and sigma are calculated for both lines:

   – RJ is calculated as the mean of the two sigmas.

   – DJ is calculated as the period minus the difference of the two means.

5 The *Estimated Total Jitter* is calculated:

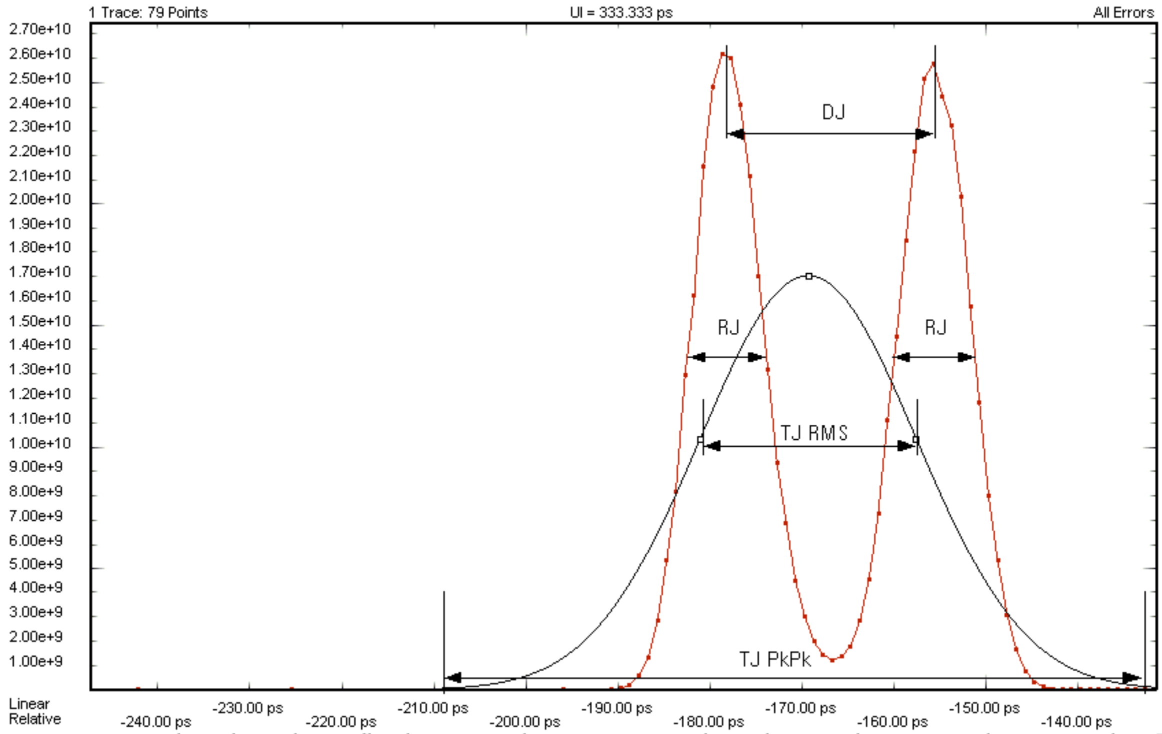
   – Linear regression is used to extrapolate the bathtub curve to lower BER values.

   – The intersections of the resulting lines with the *Residual BER for RJ/DJ Separation* are located.

   – The eye opening is calculated.

   The *Estimated Total Jitter* is the period minus the width of the eye opening.

The illustration below shows a jitter curve where both RJ and DJ are present. It also shows how the *Total Jitter peak-to-peak* and *Total Jitter RMS* are calculated.

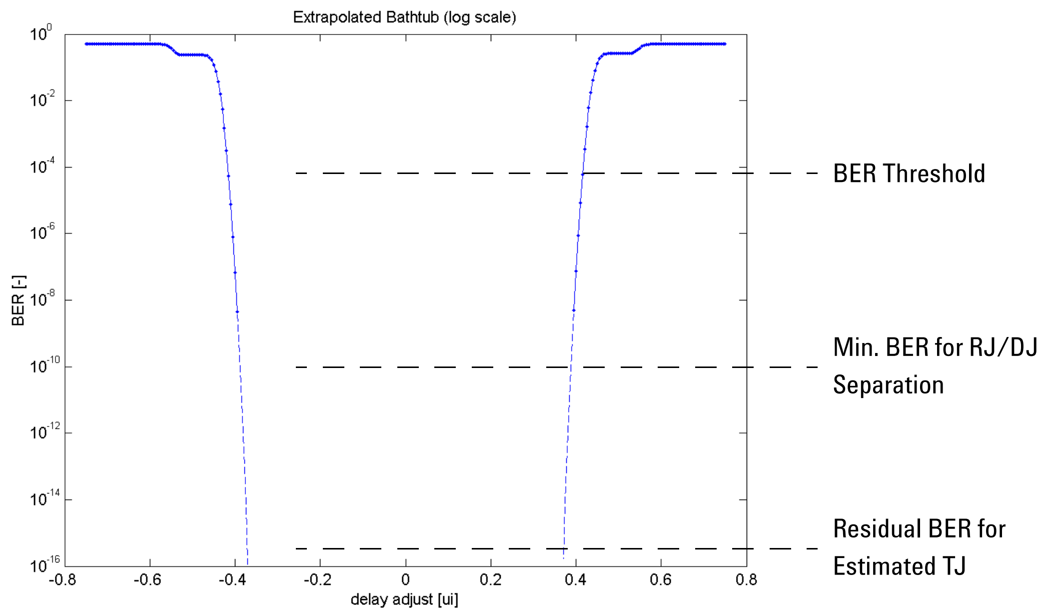


Calculating the Estimated Total Jitter

The *Estimated Total Jitter* allows you to predict the jitter expected for very low bit error rates that would take a long time to measure. It is obtained by extrapolating the measured BER curves.

The TJ is estimated by extending the BER curves (based on the points detected between the *BER Threshold* and the *Minimum BER for RJ/DJ Separation*) to the *Residual BER for RJ/DJ Separation* level. The estimated TJ is the period minus the width of the measured eye.

NOTE The following graphic is not available from the measurement software. It is inserted here to show how the TJ period is calculated.



Explanation of the Fast Total Jitter Measurement

The Fast Total Jitter measurement is an optimized method to determine the total jitter for devices that generate a very low error density (BER well below 10^{-10}).

To *measure* (not estimate) the total jitter for a device with a BER of 10^{-12} with conventional methods, one usually needs to compare more than 10^{12} bits for each sample point. To measure a full eye opening this way with appropriate timely resolution takes time (maybe days or weeks, depending on the data rate), and the probability of seeing one or no error in 10^{12} bits is not higher than 37 percent.

If one would compare 10^{13} bits for the same device, the probability of seeing ten errors is even lower (12 %), but the probability of observing no error is almost zero.

The Fast Total Jitter measurement implements a method that reduces the measurement time considerably and provides a higher accuracy. It is based on statistical and probability calculations.

The measurement can be enabled from the *Parameters* tab of the *Properties* dialog.

Basics of the Fast Total Jitter Measurement

The method was presented at the DesignCon 2005 and is described in *"Total Jitter Measurement at Low Probability Levels, using Optimized BERT Scan Method"*, included as "5989-2933EN.pdf".

We will not go into the details but provide an introduction.

The Uncertainty Band

Quite often, we do not need to measure the exact BER, but can stop the measurement if we are sure that the BER is above or below a threshold. In a jitter tolerance test, for example, we need just to assure that the device under test operates with a BER better than let us say 10^{-12}; whether the true BER is 1.1×10^{-13} or 2.7×10^{-15} is irrelevant.

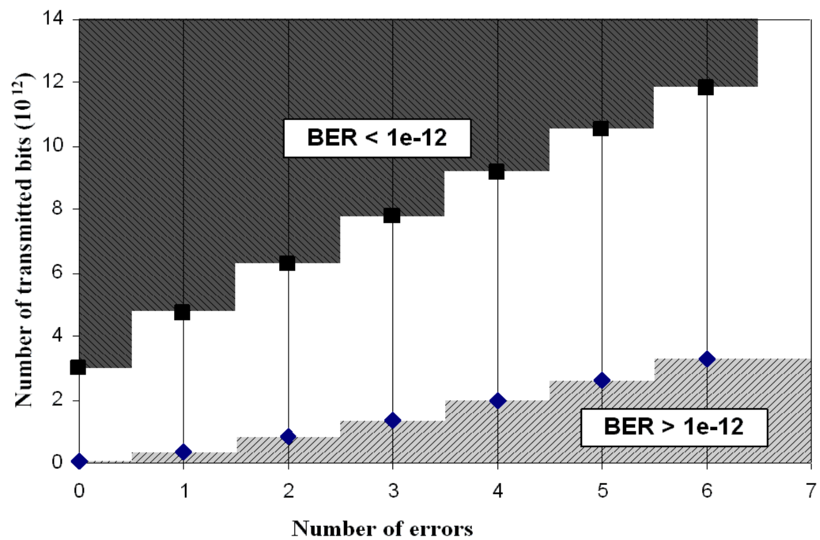
To abort the measurement for a single point and proceed to the next, we need two limits that tell us whether the BER is above or below the given threshold.

These limits have been calculated from the error probability density functions applicable to BER measurements. The equations were solved for a level of confidence of 95 %. The calculations have led to the following table:

95% confidence level lower limits, BER > 10^{-12}		95% confidence level upper limits, BER < 10^{-12}	
Min number of errors	Max number of compared bits ($\times 10^{12}$)	Max number of errors	Min number of compared bits ($\times 10^{12}$)
1	0.05129	0	2.996
2	0.3554	1	4.744
3	0.8117	2	6.296
4	1.366	3	7.754
5	1.970	4	9.154
6	2.613	5	10.51
7	3.285	6	11.84

The BER threshold of 10^{-12} and hence the setting of the multiplication factor to 10^{12} is just an example—by changing the exponent, the table applies analog to other thresholds.

The following figure shows a plot of this table.



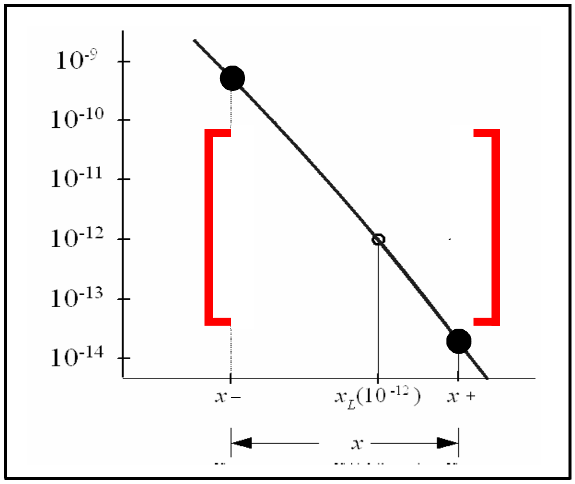
Note that there is a gap where the BER is so close to 10^{-12} that we cannot decide. For example, if we compared 3×10^{12} bits and got two errors (a measured BER of 0.667×10^{-12}), we are in the "uncertain" white area on the graph.

In such a case, we need to transmit more bits until the number of bits either reaches the upper limit (6.296×10^{12}), or until we see more errors. If the actual BER is very close to 10^{-12}, however, we are unable to apply a lower or upper limit to the BER, no matter how many bits we transmit. Whether such a test fails or passes depends entirely on the application.

The Bracketing Approach

Once we are able to decide for a measured point whether its BER is above or below the BER threshold, we can determine the total jitter at the intersection of the BER threshold with the bathtub curve.

Since we are unable to find a single point on the slope where the BER is exactly 10^{-12}, we search for an interval that brackets the point at which the BER is equal to 10^{-12}. This is illustrated for the left-hand slope in the following figure.



We do not need to know the exact BER values at x+ and x-. It is sufficient to assure that BER(x-) is greater than 10^{-12} and BER(x+) is lower than 10^{-12} at a confidence level of 95 %.

The algorithm then assumes that x_L (for the left-hand slope of the bathtub curve) is in the middle of the bracketing interval. After repeating the procedure to determine x_R (for the right-hand slope), it calculates the total jitter peak-to-peak like in the standard timing/jitter measurement.

Measurement Duration

The duration of a Fast Total Jitter measurement depends on:

- the BER threshold
- the bit rate
- the sample delay step size
- the contribution of random jitter
- the contribution of deterministic jitter

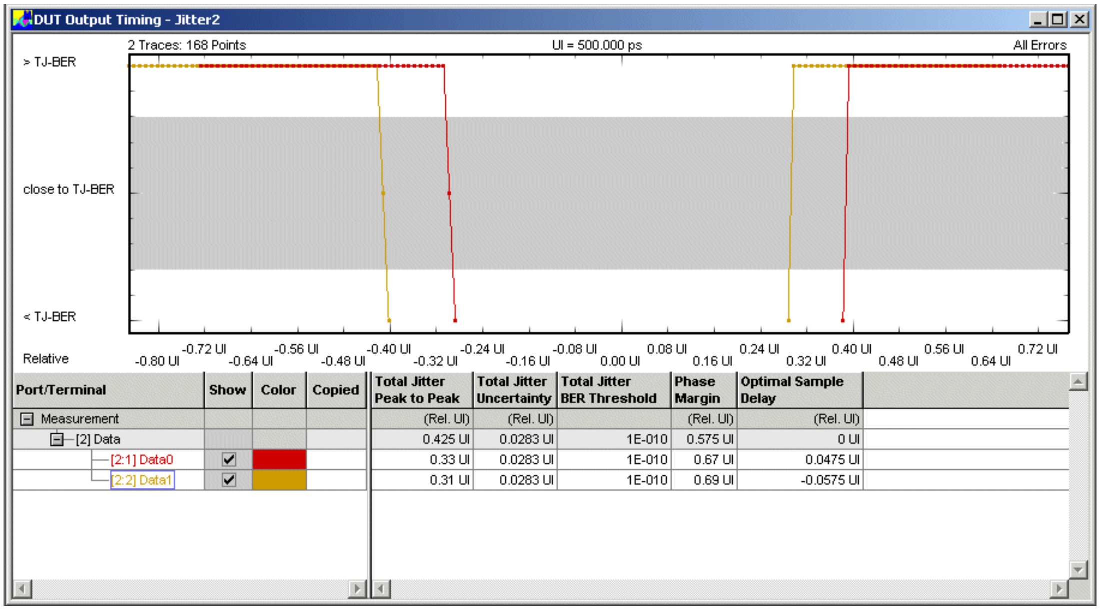
Compared to a conservative bathtub measurement, the Fast Total Jitter measurement can reduce the measurement time by more than a factor of 40.

Typical test times are approximately 20 minutes at 10 Gbit/s and slightly more than one hour at 2.5 Gbit/s for a measurement at the 10^{-12} BER threshold with an overall confidence level better than 90%.

Fast Total Jitter Measurement Result Display

After running the Fast Total Jitter measurement, you can inspect the results.

In the example below, the display of measured points was enabled.



The result graph shows you the points in time that have been investigated and whether the actual BER at these points was higher or lower than the BER threshold specified for the measurement. The grey area in the middle indicates the uncertainty band (see *"Basics of the Fast Total Jitter Measurement" on page 32*).

NOTE The test will fail, if the BER floor is not well below the BER threshold specified for the measurement.

Markers / Zoom Like for the standard Output Timing measurement, a zoom window and markers are available that provide additional and detailed information.

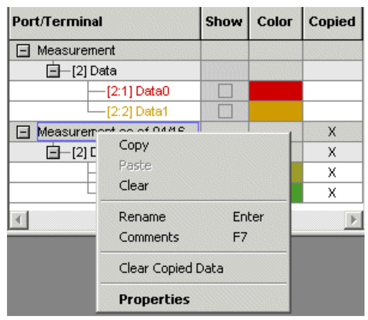
Time Scale You can also switch between relative and absolute time scale and the display of unit intervals (UI) or seconds (see *"Timing Unit Definitions" on page 37*).

Copy and Paste In addition, it is possible to copy and paste the results. This allows you to run a new measurement (Fast Total Jitter or standard Output Timing) and to compare the new results with the previous ones.

Present and copied results of the same kind of measurement can be displayed simultaneously. Results of different kinds of measurements can be displayed alternatively.

Comments / Rename

From the context menu of the numerical result table you can add a comment to every measurement or port.



Copied measurements, ports, and terminals can be renamed to support easy distinction.

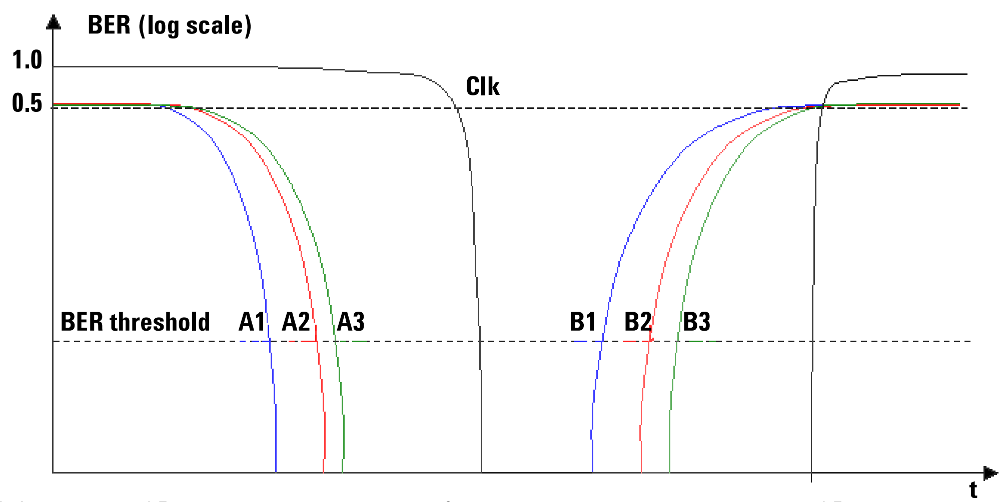
Fast Total Jitter Measurement Results

The Fast Total Jitter measurement result parameters are summarized in the following table.

Parameter	Description
Phase Margin	For a terminal: The period of time where the bit error rate is lower than the *Total Jitter BER Threshold*. For a port: The period of time where the bit error rates of all port terminals are lower than the *Total Jitter BER Threshold*.
Total Jitter Peak-Peak	Peak-to-peak value of the total jitter. Calculated as the pulse period (unit interval) minus the *Phase Margin* at the *Total Jitter BER Threshold*. For a port, the *Phase Margin* of the port is used.
Total Jitter Uncertainty	The maximum of the uncertainties of both slopes. Measured as the time between a point with a BER greater than the specified *Total Jitter BER Threshold* and the next point with a BER less than the specified *Total Jitter BER Threshold* (left slope) and vice versa (right slope). For a port: The maximum uncertainty of all terminals.
Total Jitter BER Threshold	The BER threshold specified for the measurement.
Optimal Sample Point Delay	For a terminal: The average of the left (A_i) and right (B_i) bathtub/BER threshold intersections. For a port: The average of the maximum left (A_{max}) and minimum right (B_{min}) bathtub/BER threshold intersections of all terminals in the port.

Timing Unit Definitions

The timing unit specifies the timebase for the measurements. It is possible to switch between the unit interval (UI) or seconds for the time scale. The timebase is set on the *View* page of the *Properties* dialog box (refer to *"How to Specify the Graphical Display" on page 60*).



Time	relative	–1.5 ns	0 ns	+1.5 ns
	absolute	54.2 ns	55.7 ns	57.2 ns
Unit interval	relative	–0.75 UI	0 UI	+0.75 UI
	absolute	27.1 UI	27.85 UI	28.6 UI

The Unit Interval

Unit interval values are a convenient way to express time values in a dimensionless form. In order to convert a time value to a unit interval value, divide it by the pulse period (which is the inverse of the clock frequency).

Example At 100 MHz, the pulse period is $1/100 \times 10^{-6} = 1 \times 10^{-8}$ s = 10 ns; this is the unit interval (UI). For example, a value—in fact, any parameter that is specified in time units—of 37 ns is equivalent to
37 ns / 10 ns = 3.7 UI (express time values are expressed as multiples of the unit interval).

Measurements at Different Frequencies

This makes it easy to analyze measurements at different frequencies: If the measured phase margin is 8 ns at 100 MHz (1 UI = 10 ns), and 4 ns at 200 MHz (1 UI = 5 ns): The phase margin is 0.8 UI (or 80% of the unit interval) in both cases, and it is immediately obvious that it does not depend on the system frequency.

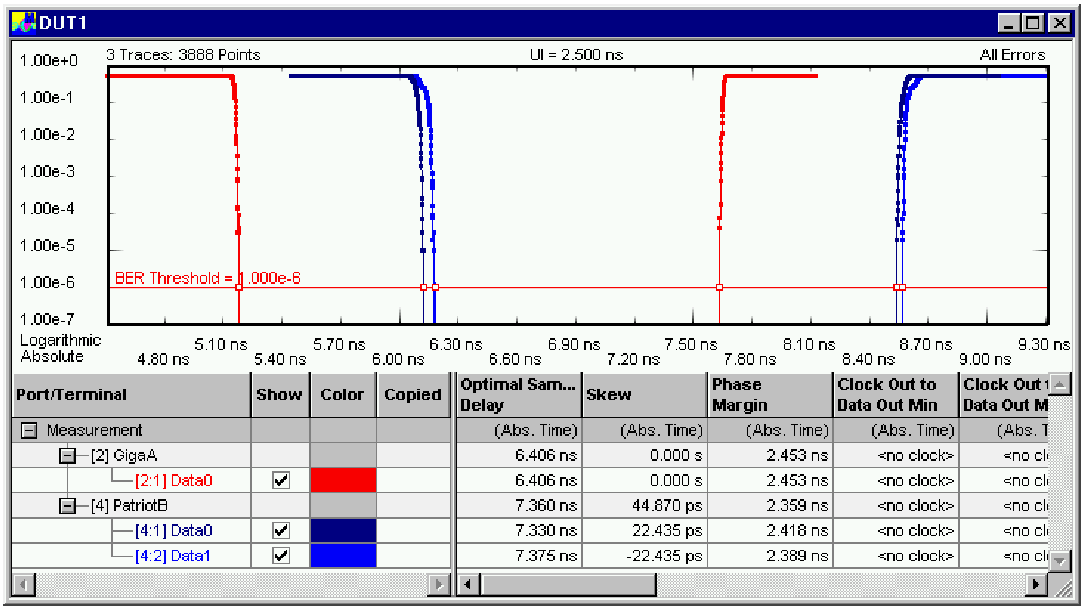
The same is true for the delay resolution parameter in the DUT output timing and eye opening measurement: If you specify the delay resolution as 0.01 UI, the MUI will always measure 150 points across the bathtub, no matter what system frequency you choose (only if edge optimization is switched off, of course). However, if you specify the resolution in time, the number of measured points will change inversely proportional to the system frequency (doubling the frequency results in half the number of measured points).

Absolute/Relative Timing

It is best to explain absolute/relative timing via an example. Imagine an 81250 hardware setup: The signal leaves the generator frontend, travels through a cable, the DUT, another cable, and finally reaches the analyzer frontend.

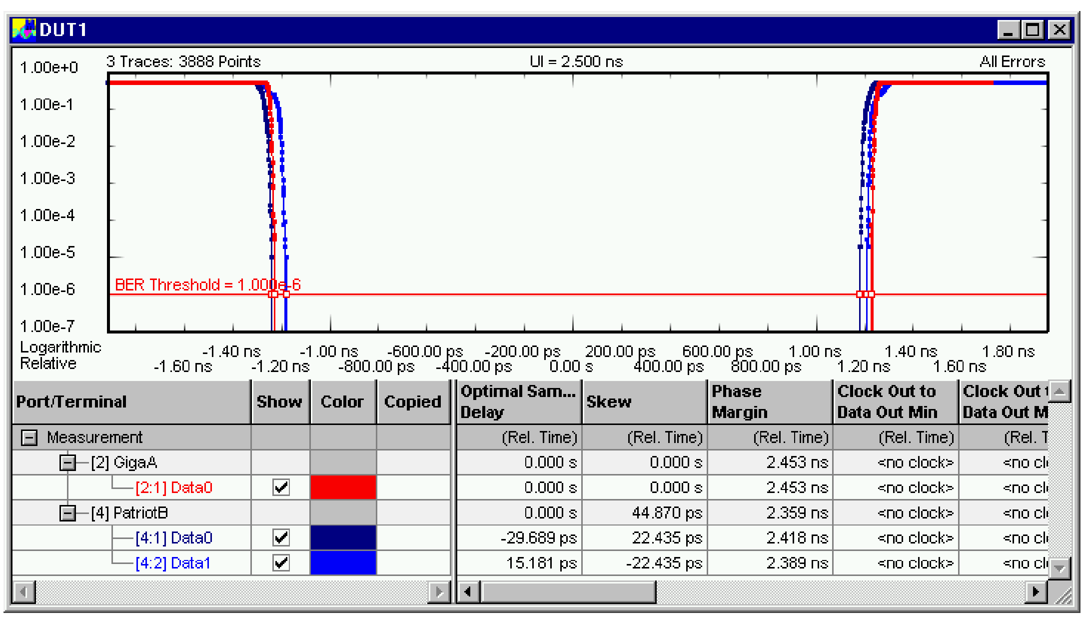
This travel takes some time, and the delay is visible if you use absolute timing display. So, in absolute timing mode, the timing at the receiver is expressed relative to the generator timing. This is useful if you are interested in the amount of delay that is introduced by a DUT, or similar (using the 81250's cable deskew feature, you can even compensate for cable delays).

In the following illustration for the absolute timing, the signal of GigaA is the original signal and the signals of PatriotB show the delay introduced by the DUT:



Sometimes however, you are not really interested in this absolute delay. In manufacturing for example, engineers work DUT-centered, that is, they are not interested in the generator/DUT/analyzer system timing, only DUT timing matters. This is what the relative timing mode is for: It compensates for all initial delays, and displays all timing information relative to the optimum sample point of the DUT (or, in terms of the 81250, the optimum sample point of the port).

In the following illustration for the absolute timing, the signal of GigaA is the original signal and the signals of PatriotB are displayed relative to the signal of GigaA:



If you make use of the auto bit synchronization feature (which is always the case if independent/asynchronous generator and analyzer systems are involved), the absolute timing information is not available anyway. The measurement software will automatically detect if absolute display is possible or not, and prompt you for action (absolute display is disabled in this case).

NOTE The absolute/relative setting does not affect any result parameter other than the optimum sampling point. Switching between unit interval and seconds changes all values that are expressed in a unit of time (skew, jitter, etc.).

Marker Definitions

Markers make the analysis and tracing of the results more comfortable. Markers can be switched on or off at any time when results are available in the graphical view. For the DUT output timing/jitter measurement, the software provides two types of markers:

- Two linear markers, if the bath tub curve is present.

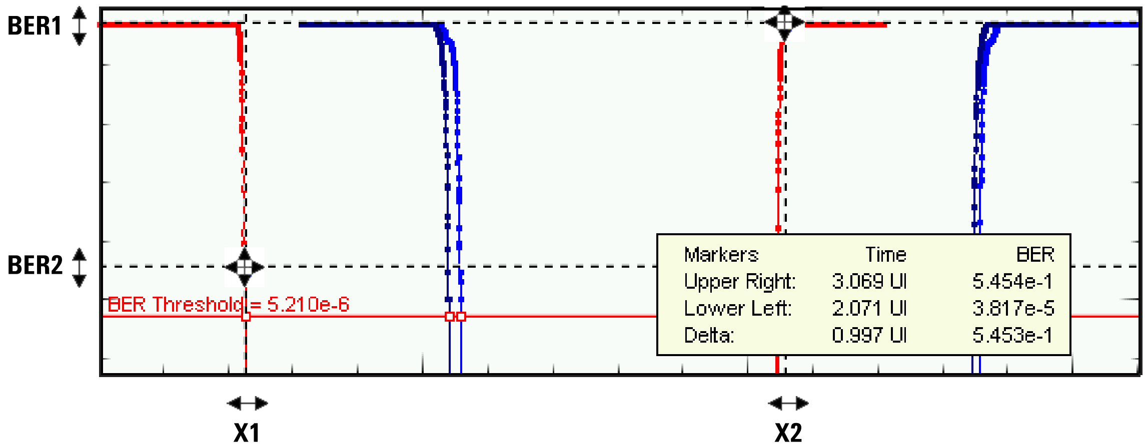
  See *"Linear Markers" on page 41*.
- A Gaussian marker, if the jitter distribution is displayed.

  See *"The Gaussian Marker" on page 42*.

Linear Markers

The following illustration shows the definitions for the markers and the values that can be derived from the marker position.

For more information, refer to *How to Change Measurement Properties after Running* in the *Framework User Guide*.



The following values are displayed for the current marker positions:

Value	Description
X1	Sample point delay related to the position of marker 1
X2	Sample point delay related to the position of marker 2
X2 – X1	Delta between the two marker positions
BER1	Bit error rate related to the position of marker 1
BER2	Bit error rate related to the position of marker 2
BER1 – BER2	Delta of the bit error rate between the two marker positions

The markers can be moved via the mouse to keep track of the data.

The Gaussian Marker

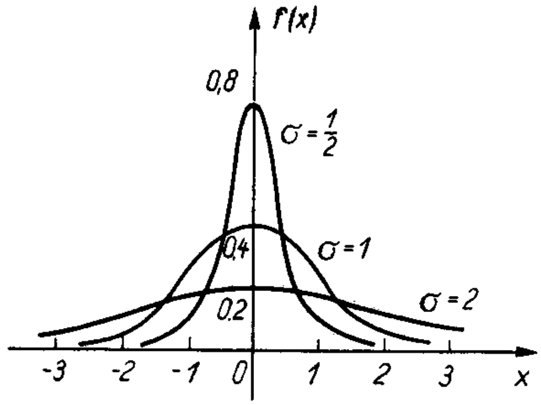
A Gaussian marker is available when the jitter graph is displayed. It is most useful, if deterministic jitter is present. In this case, the jitter graph shows more than one peak (see also *"Calculating the Estimated Total Jitter" on page 30*).

The jitter values Mean, RMS, and Peak-Peak refer to the whole jitter. The Gaussian marker now allows to measure the normal distribution of individual jitter peaks. You can thus determine how parts of the jitter histogram contribute to the overall jitter values.

The distribution of random values is called normal, if it can be described by the following formula:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

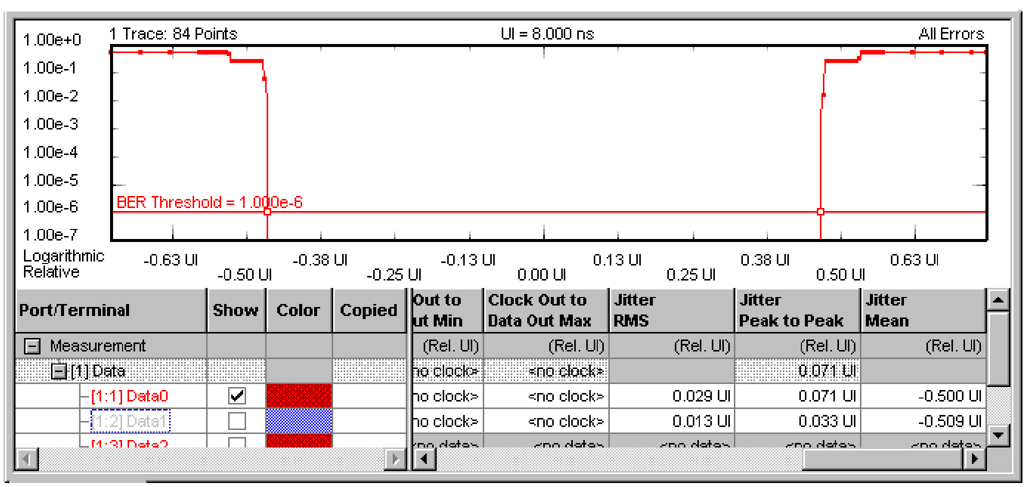
This formula describes a bell-shaped Gauss curve. If μ is zero and σ varied, you would get the curves illustrated in the figure below:



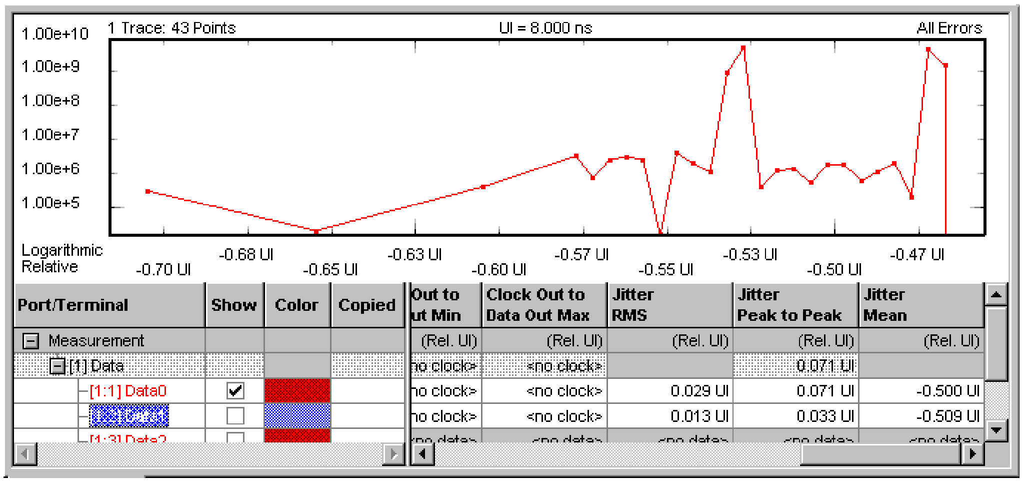
The height of a normal distribution can be specified in terms of two parameters: μ and σ. The parameter μ is the mean, the parameter σ is the standard deviation.

The Gaussian marker shows such a curve. Position, height, and width of this curve can be changed with the mouse, and the actual parameter values are displayed.

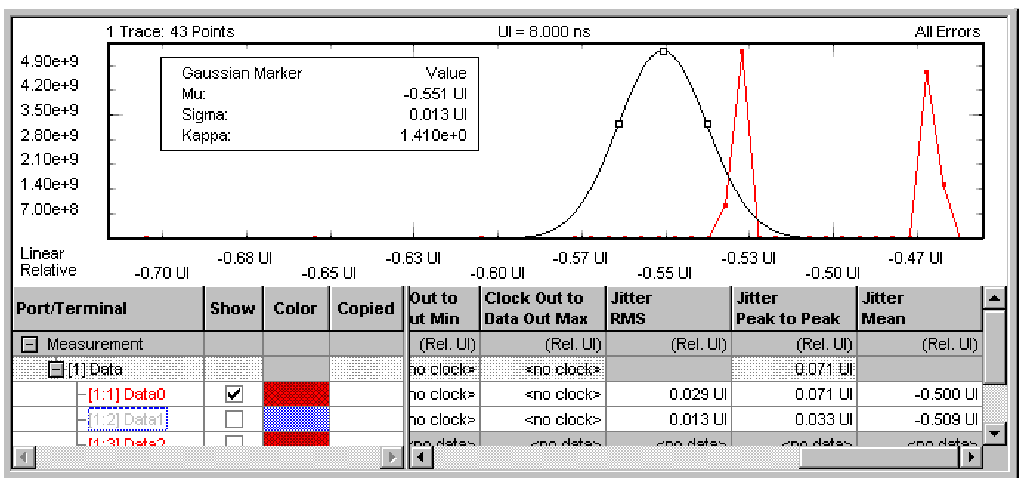
You may have measured a bathtub curve like the one shown below:



As the bathtub borders are not uniform (both have two edges), the linear derivative (the jitter) will show two peaks:



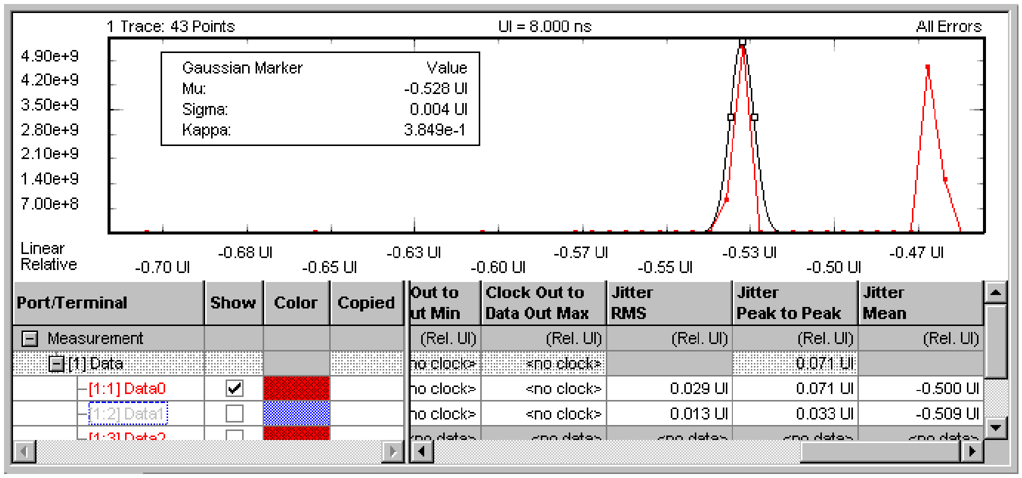
If you switch to linear scale and enable the marker, you can see its bell shape.



The marker has three handles that can be dragged with the mouse:

- Use the right or left handle to adjust the width.
- Use the middle handle to position the marker on the time scale and to adjust its height.

You can adjust the marker to your needs.

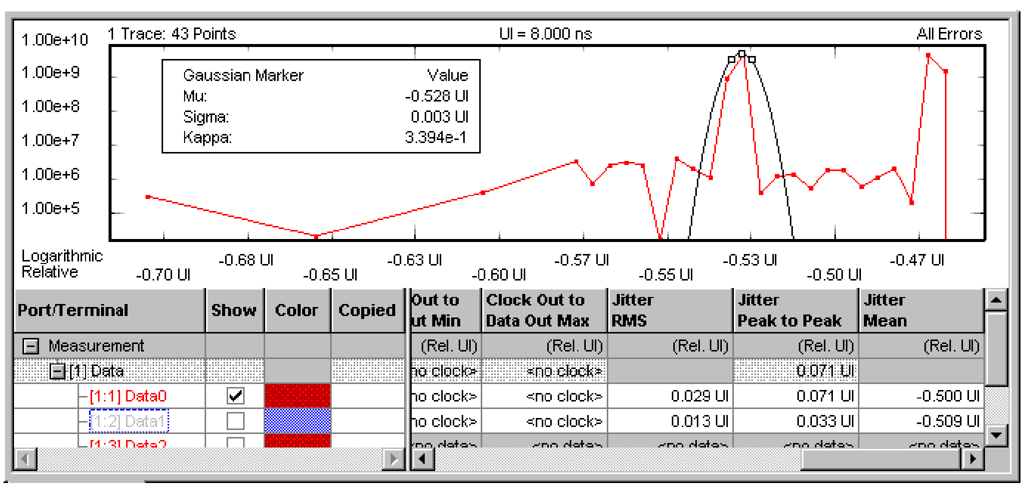


The marker readout provides the following information:

Parameter	Symbol	Meaning
Mu	μ	Mean. The position of the marker center on the time scale.
Sigma	σ	Standard deviation. The RMS value of the marked area.
Kappa	κ	Linear scaling factor.

You can hence measure the random jitter distribution of each peak as well as the distance between the peaks, which means the deterministic jitter.

You can also use the marker with logarithmic scale. In this case, it appears as a parabolic curve.



Setting the Properties of a DUT Output Timing Measurement

Before you can run a DUT Output Timing measurement you have to set the required parameters on the measurement's property pages:

- *"How to Set Up the System to be Used" on page 48*
- *"How to Select the Ports to be Measured" on page 50*
- *"How to Specify the Measurement Parameters" on page 54*
- *"How to Set Pass/Fail Criteria" on page 56*
- *"How to Specify the Graphical Display" on page 60*

When you create a new measurement the *Properties* dialog box will be displayed automatically. To change the parameters later on, select the measurement and choose *Measurement – Properties* from the menu bar.

If you change the measurement settings after the measurement has been run, please note:

- Changes on the *View* and *Pass/Fail* pages have only an impact on the display of the results. There is no need to repeat the measurement.
- Changes on the *System*, *Ports,* and *Parameters* pages take only effect if you rerun the measurement. To remind you that the present results have not been obtained with the modified settings and that you should repeat the measurement, the result display shows a yellow bar.

NOTE All time-related entries understand both time and unit interval notation, regardless of the UI/time selection made in the *View* tab of the *Properties* dialog box. You can enter **17 s**, **5 ns** or **0.01 UI** at any time. On run, the MUI will automatically convert all entries to time values, using the current unit interval. So, the UI is handy if you want to set values independently from the system frequency.

All voltage-related entries understand **23 mV**, **0.01 V**, and so forth.

All dimensionless quantities understand decimal notations (**10000000**, **0.0003**, for example) and scientific/engineering notation (**1e9**, **1.7e-3**, for example).

How to Set Up the System to be Used

NOTE If you modify the parameters of this page, you have to rerun the measurement to update the results.

The *System* page of the *Properties* dialog box appears automatically if you have set up a new measurement. The *System* page shows one or two systems, depending on your selection when creating the measurement.

If you have already loaded a setting with the *Agilent 81250 User Software*, the name of this setting will be displayed, and it will be used by default.

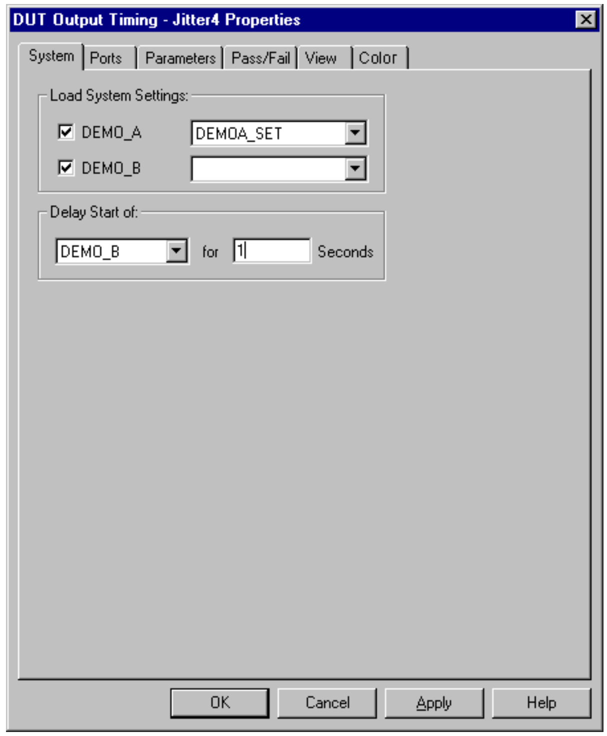
If no setting is indicated, or if the name of a different setting than required is displayed, you have to load one or two settings.

To load a setting:

1 Click the check box belonging to the system.

This activates the setting name field.

2 Choose a suitable setting from the drop-down list.



When you choose a new system setting, it will be downloaded to the firmware. You have to confirm this action before it will actually be performed.

NOTE On one system only one setting can be loaded at one time. The *Agilent 81250 User Software* and the *Agilent 81250 Measurement Software* therefore always refer to the same setting. If the *Agilent 81250 User Software* is active and you load a different setting from the *Agilent 81250 Measurement Software*, the *Agilent 81250 User Software* will be updated, and vice versa.

If you add or delete ports or terminals or change their connections with the *Agilent 81250 User Software*, then the *Agilent 81250 Measurement Software* will detect such changes when you attempt to run the measurement.

TIP If you have changed the current setting with the *Agilent 81250 User Software* and wish to keep your modifications, save the setting with the *Agilent 81250 User Software* before loading a different one. The *Agilent 81250 Measurement Software* does not save settings.

3 In case of two systems, you can specify a start delay for one of the systems.

This may be useful, for instance, to allow a PLL or clock recovery circuit in the DUT to lock onto the incoming data stream.

4 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

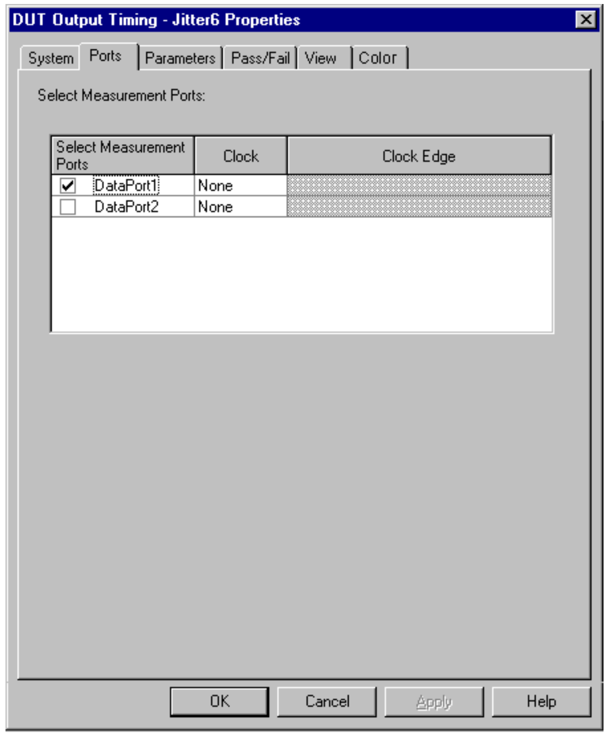
How to Select the Ports to be Measured

After you have specified the measurement system and the related system settings, you may wish to exclude one or several DUT output ports from the measurement.

NOTE When you modify the parameters on this page, you have to rerun the measurement to update the results.

How to Enable/Disable the Ports to be Measured

1 In the *Properties* dialog box, select the *Ports* tab.



The *Ports* page lists all the output ports of the device under test, as defined in the loaded setting. In case of two systems, this is the setting loaded on the analyzing system. By default, all these ports are enabled and will be measured.

The display is not automatically updated if you change the loaded setting by means of the *Agilent 81250 User Software*.

2 Disable the ports that shall not be measured.

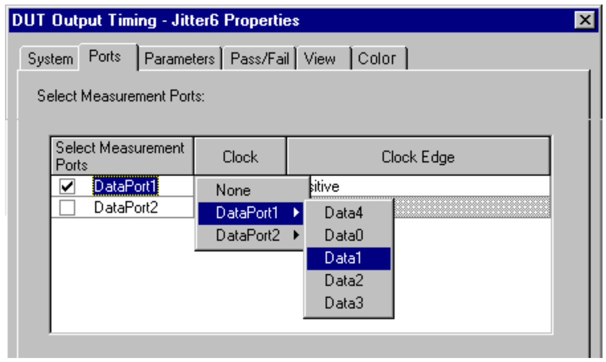
For example, in the figure above only *DataPort1* will be measured.

3 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

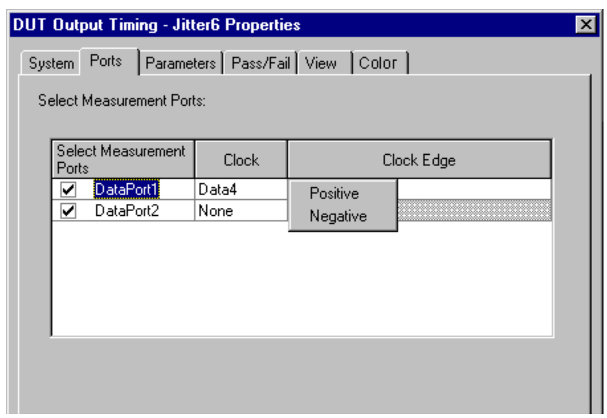
How to Set Up a Clock Terminal for a Port

1 In the *Properties* dialog box, select the *Ports* tab.

2 Select for each port if any of the terminals carries a clock signal.



3 Select for each clock signal whether the positive (rising) or negative (falling) edge is active. For a double pumped clock, you have to select both.

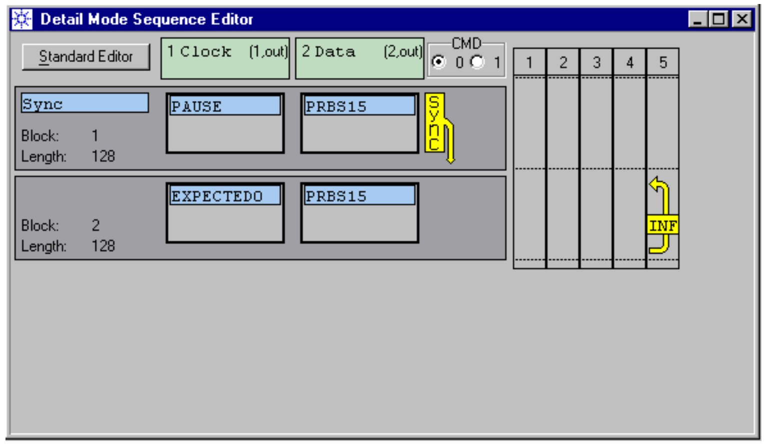


4 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

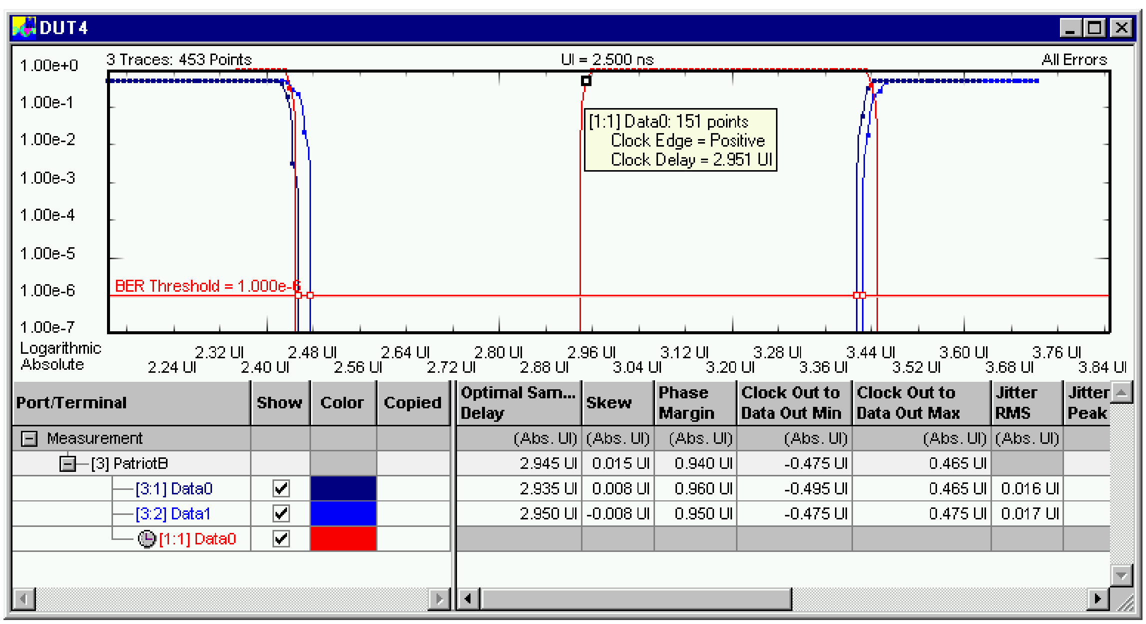
NOTE If your DUT requires a clock and you want to characterize the data/clock relation, consider the following:

- If the DUT loads/toggles on a positive or negative clock edge, set the analyzer terminal expected data to “expected zero”.
- If the DUT toggles on both edges (double pumped device), set the analyzer terminal expected data to a toggle pattern (0101).
- In the measurement software, select the respective clock edge (“Both” in case of the double pumped device) in the *Ports* page of the *Properties* dialog box.

- If your setup requires auto-synchronization, make sure that the clock analyzer does not take part in the synchronization (pause segment). This can not be done in the Standard Mode Sequence Editor.



The following illustration shows an example with a positive (rising) clock signal.

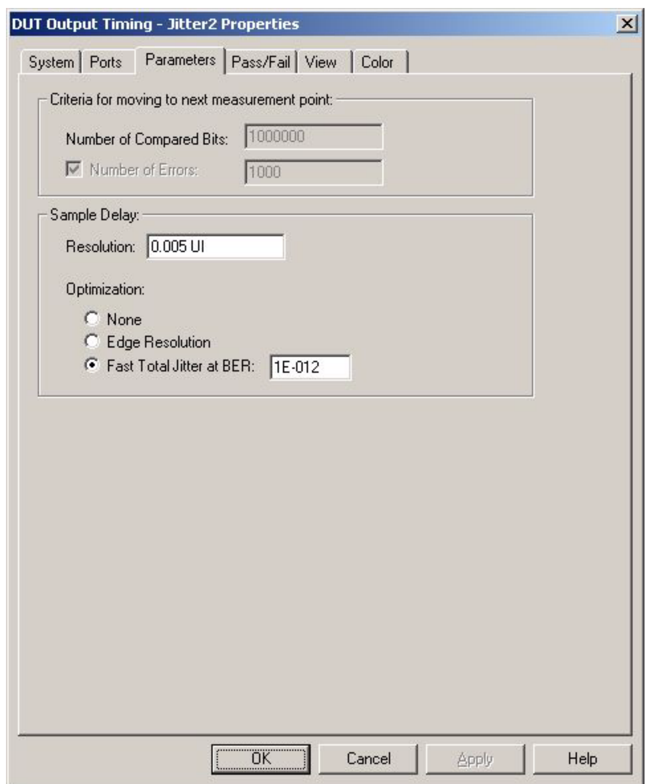


How to Specify the Measurement Parameters

The *Parameters* page of the *Properties* dialog box allows you to specify the parameters for a particular sample point and for the resolution of the sample delay.

NOTE When you modify the parameters on this page, you have to re-run the measurement to update the results.

1 In the *Properties* dialog, click the *Parameters* tab.



In this example, the Fast Total Jitter measurement was enabled.

2 Set the criteria for moving to the next sample point:

– *Number of Compared Bits*: After this amount of compared bits the measurement stops for the current measurement point and moves to the next one.

– *Number of Errors*: After this amount of errors the measurement stops for the current measurement point and moves to the next one. This allows you to speed up the measurement. You can switch off this option, if only the number of compared bits is important.

NOTE The measurement moves to the next sample point, when the first of the two criteria is reached.

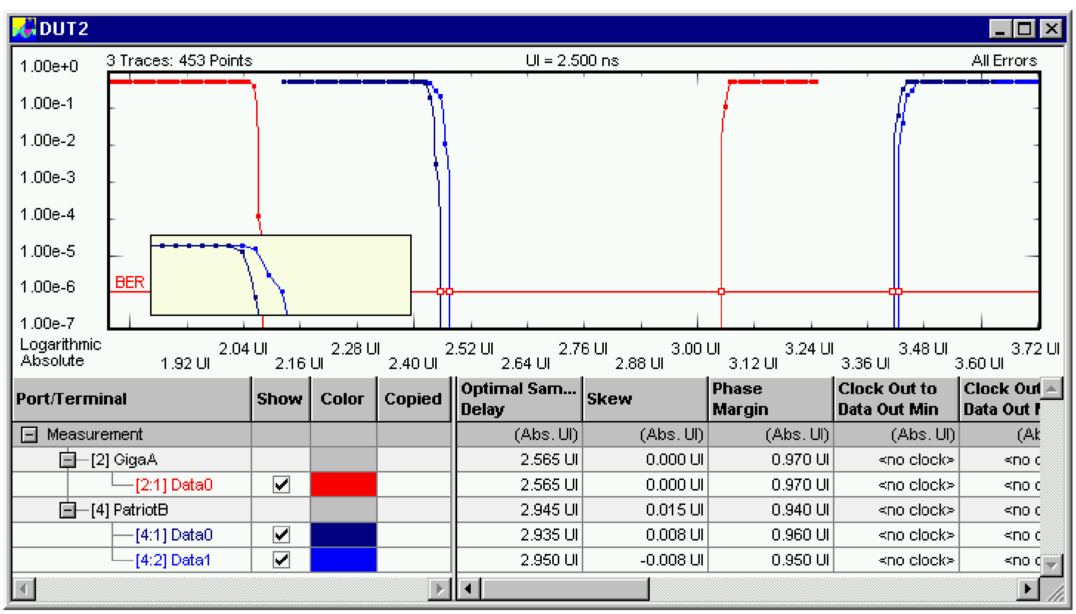
3 Set the criteria for the sample delay:

– *Resolution*: Specifies how many sample points are taken within a unit interval. You have to enter the resolution in UI or ps, ns, s, ... The timebase is set on the *View* page of the *Properties* dialog box (refer to *"How to Specify the Graphical Display" on page 60*).

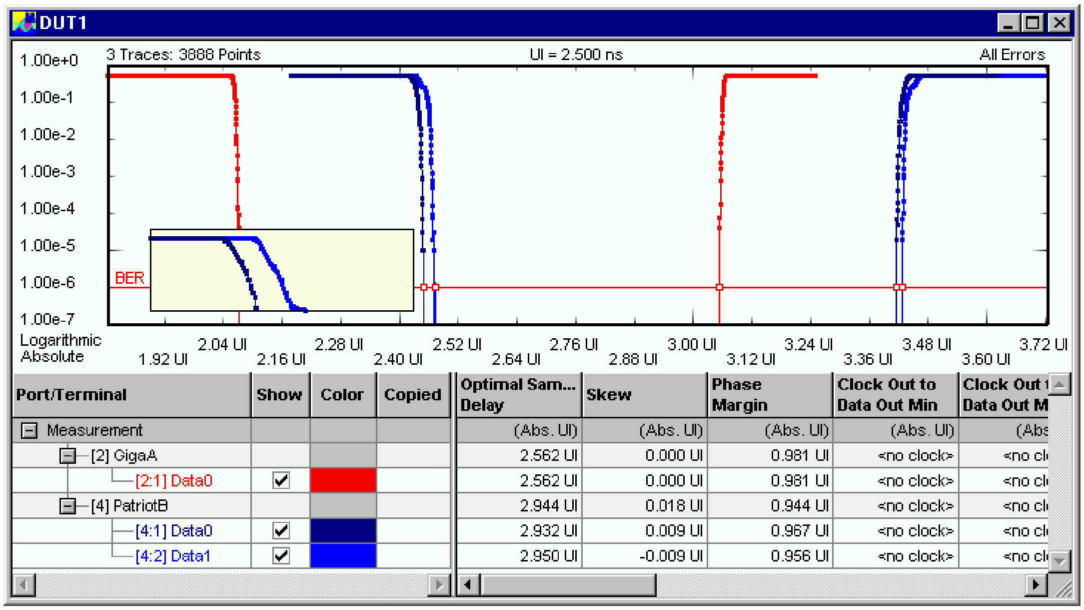
4 Set the criteria for the optimization:

– *Edge Resolution*: Turns the edge resolution optimization on or off. If this option is set to on, the MUI applies a lower resolution where the signal has no edges to generate a bathtub curve. If this option is disabled, a fixed step size is used.

The following illustration shows a diagram with default resolution and no edge resolution optimization:



The following illustration shows a diagram with high resolution and edge resolution optimization. For the areas of the diagram with edges more sample points are taken, this results in a much better display of the signal shape:



– *Fast Total Jitter at BER:* This enables or disables the Fast Total Jitter measurement. If you enable this measurement, enter the desired BER threshold. For more information refer to *"Explanation of the Fast Total Jitter Measurement" on page 31*.

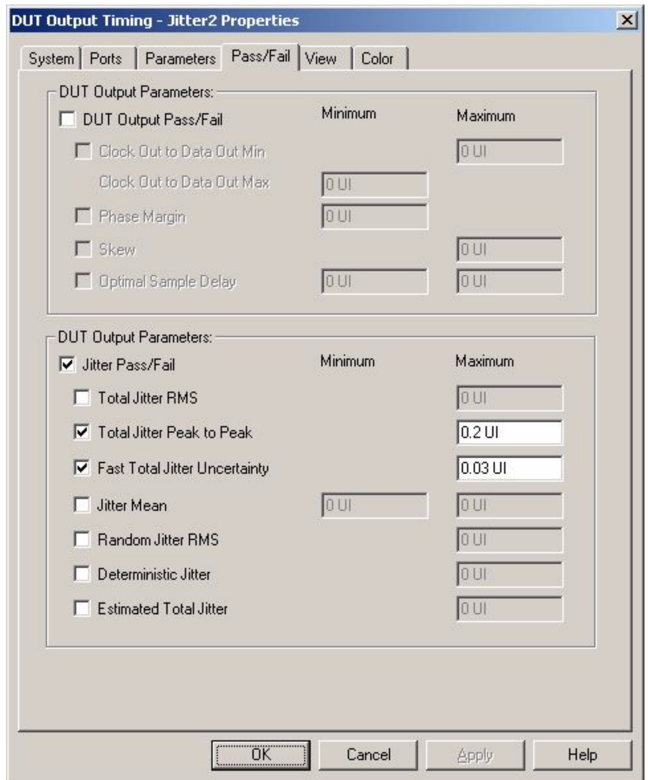
5 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

How to Set Pass/Fail Criteria

The *Pass/Fail* page of the *Properties* dialog box allows you to specify the criteria to decide whether the DUT passes or fails the test. You can change pass/fail criteria without rerunning a test. The software compares the criteria with results of a test.

NOTE The pass/fail criteria do not control measurement execution. The measurement run will be completed even if the measurement fails for one or more of the criteria.

1 In the *Properties* dialog box, select the *Pass/Fail* tab. By default, all criteria are disabled.



2 Click *DUT Output Pass/Fail* to select the following criteria for the pass or fail decision:

Criterion	Description
Clock Out to Data Out Min	This value is compared to the measured *Clock Out to Data Out Min* at the BER threshold. If the measurement result is less than the pass/fail value, the result passes the test. This value is only calculated if a clock signal is defined.
Clock Out to Data Out Max	This value is compared to the measured *Clock Out to Data Out Max* at the BER threshold. If the measurement result is higher than the pass/fail value, the result passes the test. This value is only calculated if a clock signal is defined.
Phase Margin	This value is compared to the measured *Phase Margin* at the BER threshold. If the measurement result is higher than the pass/fail value, the result passes the test.
Skew	This value is compared to the absolute *Skew* at the BER threshold. If the absolute value of the measurement result is less than the pass/fail value, the result passes the test.
Optimal Sample Delay (Minimum)	This value is compared to the measured *Optimal Sample Delay*. If the measured optimum sample delay is higher than the minimum optimum sample delay, the result passes the test.
Optimal Sample Delay (Maximum)	This value is compared to the measurement result of the *Optimal Sample Delay*. If the measured optimum sample delay is less than the maximum optimum sample delay, the result passes the test.

If the pass/fail value is equal to the measured result, the result fails the test.

3 Click *Jitter Pass/Fail* to select the following criteria for the pass or fail decision:

Criterion	Description
Total Jitter RMS	This value is compared to the *Total Jitter RMS*. If it is less than the *Total Jitter RMS*, the result passes the test.
Total Jitter Peak to Peak	This value is compared to the *Total Jitter Peak to Peak*. If it is less than the *Total Jitter Peak to Peak*, the result passes the test.
Fast Total Jitter Uncertainty (Maximum)	This value (only applicable to the Fast Total Jitter measurement) is compared to the measurement result of the *Total Jitter Uncertainty*. If the measured uncertainty is less than the allowed maximum, the result passes the test.
Jitter Mean (Minimum and Maximum)	These values are compared to the *Jitter Mean*. If it is within the defined range, the result passes the test.
Random Jitter RMS	This value is compared to the *Random Jitter RMS*. If it is less than the *Random Jitter RMS*, the result passes the test.
Deterministic Jitter	This value is compared to the *Deterministic Jitter*. If it is less than the *Deterministic Jitter*, the result passes the test.
Estimated Total Jitter	This value is compared to the *Estimated Total Jitter*. If the measurement's estimated total jitter is below this value, the result passes the test.

Each of the calculated values will be displayed in the tabular view in red if it fails the related criteria. The port will also turn to red, to indicate that one of its terminals failed. In addition, the symbol is displayed.

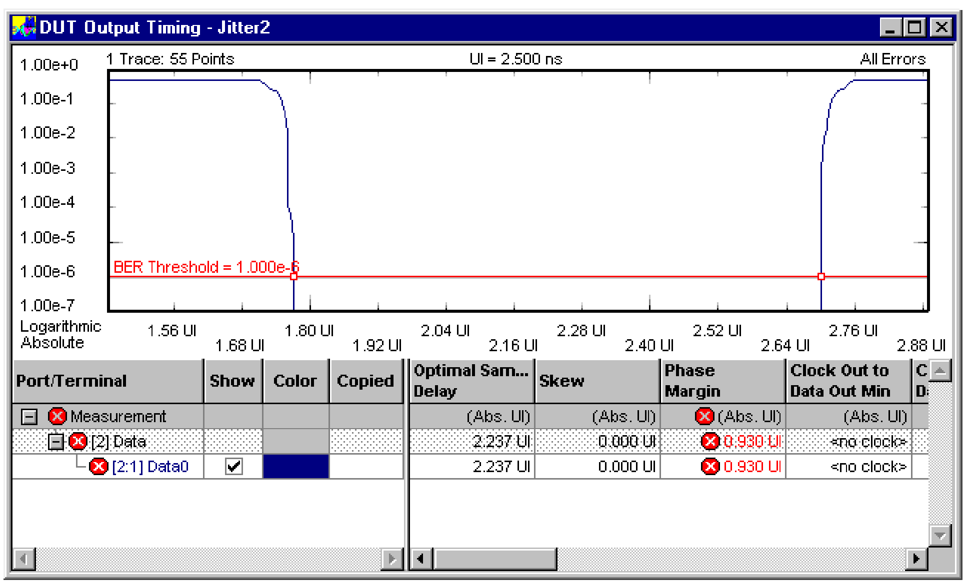
NOTE If the results of a Fast Total Jitter measurement are displayed, only the appropriate parameters are compared and flagged:

- Phase Margin
- Optimal Sample Delay
- Total Jitter Peak to Peak
- Fast Total Jitter Uncertainty

Other pass/fail limits may be enabled but are ignored.

4 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

The following illustration shows a DUT output timing measurement that has failed the criterion for the phase margin.

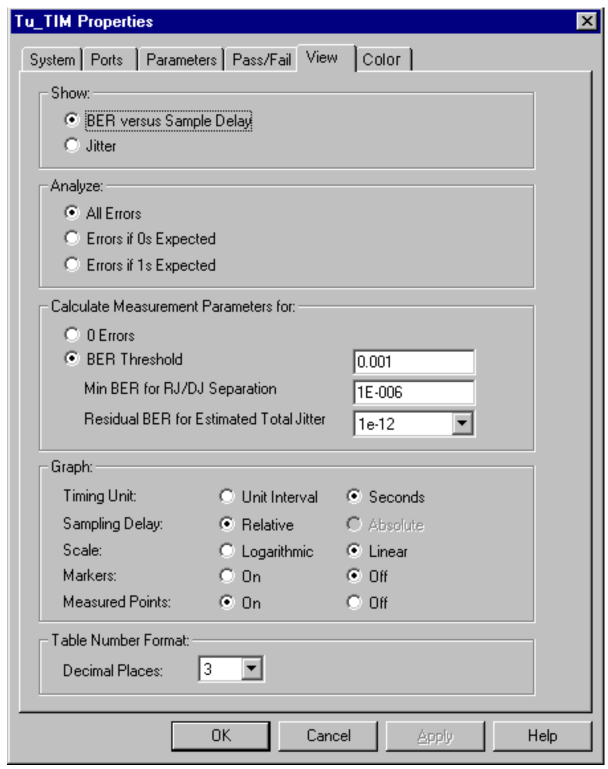


How to Specify the Graphical Display

The *View* page of the *Properties* dialog box allows you to modify the graphical display of the measurement results.

When you modify the parameters on this page, the results will be updated immediately.

1 In the *Properties* dialog box, select the *View* tab.



2 Select the following options for the graphical display:

Option	Description
Show	
BER versus Sample Delay	To display the bit error rate relative to the sample delay.
Jitter	To display the jitter (the linear derivative of the bit error rate)
Analyze	
All Errors	To calculate the BER values from all bits/errors.
Errors if 0s Expected	To calculate the BER values if “0” is expected, but “1” received.

Option	Description
Errors if 1s Expected	To calculate the BER values if “1” is expected, but “0” received.
Calculate Measurement Parameters for	
0 Errors	To calculate the parameters for 0 errors. If this is selected, RJ/DJ separation is not available.
BER Threshold	To calculate the parameters for the given BER threshold. This is the BER level for which output timing numerical values (phase margin, skew, etc.) are calculated. It is also the upper limit of the BER range for RJ/DJ separation. The BER threshold influences some of the parameters of the DUT output timing measurement. You can also drag and drop the horizontal BER threshold in the graphical display to change this value.
Min BER for RJ/DJ Separation	Lower limit of the BER range for RJ/DJ separation.
Residual BER for Estimated Total Jitter	BER level for which the estimated total jitter is calculated. See *“Calculating the Estimated Total Jitter” on page 30* for details on how it used.
Graph	
Timing Unit	Select *Unit Interval* or *Seconds* as time scale.
Sampling Delay	Select *Relative* to choose a timing relative to the optimum sample point; select *Absolute* to choose an absolute timing.
Scale	Select a *Logarithmic* or a *Linear* scale for the graphical display.
Markers	To switch the markers for the graphical display *On* or *Off*.
Measured Points	To switch the display of the measured points *On* or *Off*. The MUI uses linear interpolation for the graph.
Table Number Format	
Decimal Places	To select the number of *Decimal Places* to be displayed in the table view.

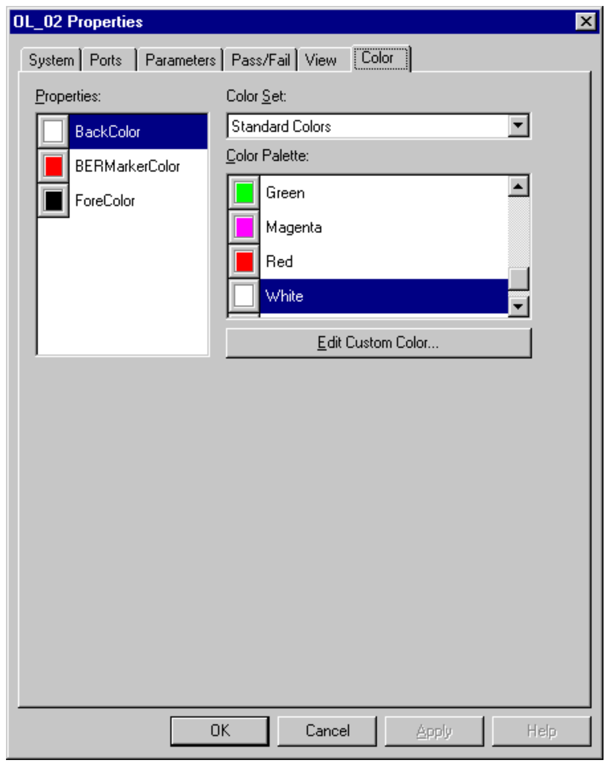
3 Click *Apply* to accept the modifications without leaving the *Properties* dialog box. Or click *OK* to accept the modifications and close the *Properties* dialog box.

For examples of the display settings, refer to *“Changing the Graphical Display of the Results” on page 16*.

How to Change the Colors of the Graph

This page of the *Properties* dialog enables you to customize the colors of the graphical display.

1 Click the *Colors* tab.



You can change:

- The background color of the graphs (default is white)
- The color of the *BER Threshold* indicator (default is red)
- The foreground color of the scales and frame of the graphs (default is black)

2 If you have made any changes, click *Apply*.

This updates the measurement window, and you can immediately check the result.

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