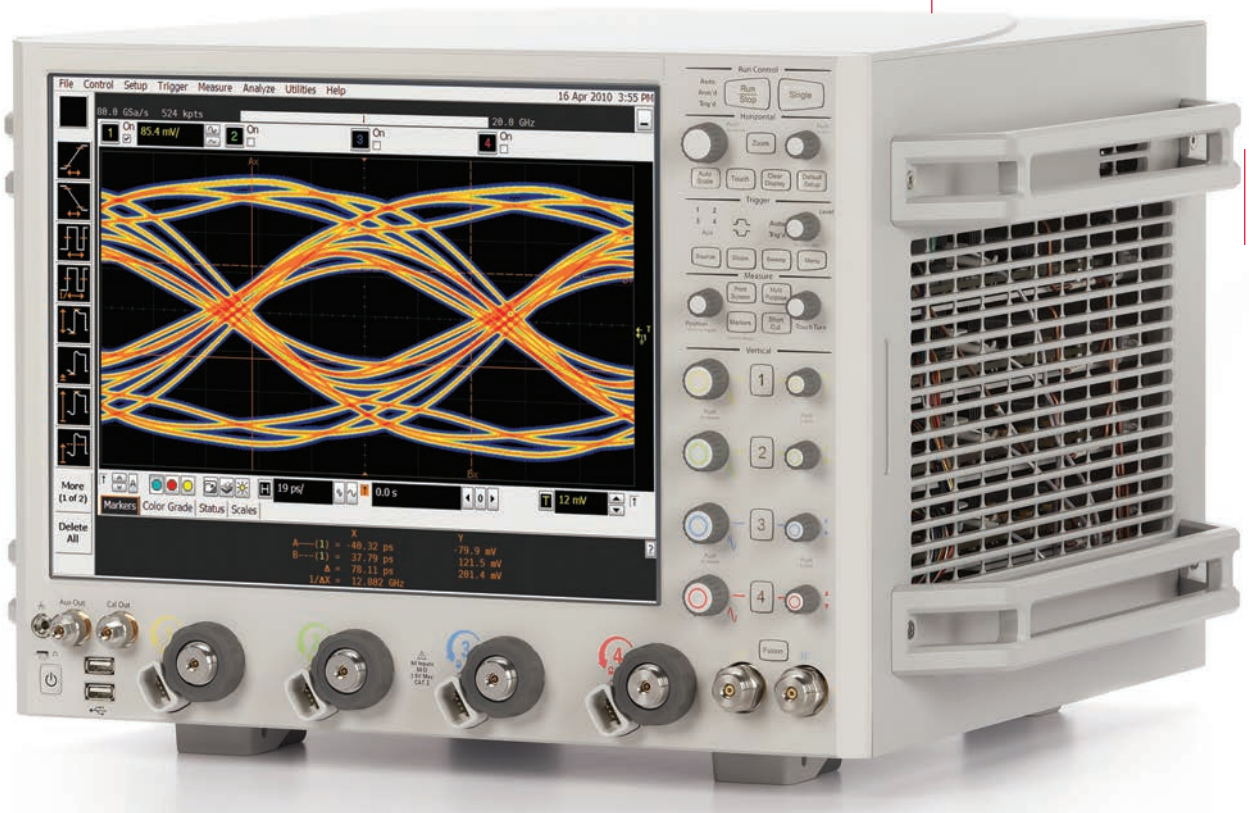
Keysight Technologies

EZJIT Complete Jitter and Vertical Noise Analysis Software for Infiniium Oscilloscopes

Data Sheet



KEYSIGHT TECHNOLOGIES

EZJIT Complete jitter and vertical noise analysis software for the 9000A, 9000 H-, 90000A, 90000 X-, and 90000 Q-Series Infiniium oscilloscopes adds advanced statistical analysis of high speed digital interfaces in the vertical (voltage) domain to the accurate horizontal (time) analysis capabilities provided by EZJIT and EZJIT Plus software. The result: the industry's most complete jitter and noise analysis software for real-time oscilloscopes.

Now for the first time, real time oscilloscopes can analyze both domains statistically with measured results that matter. Engineers who want to characterize a high speed transmitter or understand the full parameters of the waveform reaching a digital receiver will consider amplitude analysis as a new fundamental requirement in the complete consideration and evaluation of a high speed digital link.

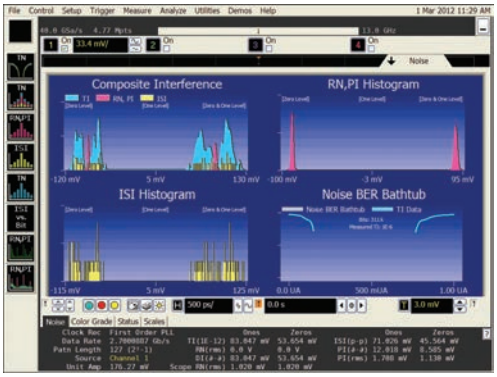


Figure 1. Vertical Noise Decomposition Graphs

EZJit Complete software includes all of the advanced jitter analysis features of EZJIT and EZJIT Plus and adds the following vertical noise analysis capabilities.

- Decomposition of Vertical Noise into constituent components:
  - Random Noise (RN)
  - Periodic Interference (PI)
  - Deterministic Interference (dual dirac model) (DI)
  - Data Dependent Interference, or Intersymbol Interference (ISI)
  - Aperiodic Bounded Uncorrelated Interference (ABUI)
- Estimation of Total Interference (TI) to a specified Bit Error Ratio
- Cumulative Average of High(One) and Low(Zero) levels
- Tabular Results of all measured quantities.
- Graphical Results of:
  - InterSymbol Interference per bit
  - RN/PI Histogram
  - Total (Composite) Interference Histogram
  - BathTub curve (Measured and Extrapolated)
  - Interference Frequency Spectrum
- Settable location in the UI for vertical analysis
- Scope noise compensation, choose between:
  - Measure noise directly
  - User input value
- Arbitrary or Periodic Data patterns
- Advanced spectral and tail fit algorithms for accurate RN, ABUI extraction in crosstalk environments
- Setup Wizard for robust setup

Choosing your Jitter Analysis Software for Infiniium Oscilloscopes

	EZJIT	EZJIT Plus	EZJIT Complete
Model number **Option number**	**E2681A** **002**	**N5400A** **004**	**N8813A** **057**
Advanced Clock Recovery	Requires Serial Data Analysis, option -003	Requires Serial Data Analysis, option -003	Requires Serial Data Analysis, option -003
Basic Jitter Views			
Jitter trend	●	●	●
Jitter histogram	●	●	●
Jitter spectrum	●	●	●
Multi-acquisition	●	●	●
Jitter Clock Measurements			
Period	●	●	●
Pulse width (+, –, both)	●	●	●
Frequency	●	●	●
Duty cycle (+, –)	●	●	●
Time-interval error	●	●	●
Cycle-cycle jitter	●	●	●
N-cycle jitter	●	●	●
Cycle-cycle +/– width	●	●	●
Cycle-cycle duty cycle	●	●	●
Jitter Data Measurements			
Time-interval error	●	●	●
Data rate	●	●	●
Unit interval	●	●	●
Delay/Edge Measurements			
Setup/hold	●	●	●
Phase	●	●	●
Rise/fall time	●	●	●
Jitter Separation			
Random jitter (RJ)		●	●
Deterministic jitter (DJ)		●	●
Data dependent jitter (DDJ)		●	●
Inter-symbol interference (ISI)		●	●
Duty cycle distortion (DCD)		●	●
Bounded uncorrelated jitter (BUJ)		●	●
Periodic jitter (PJ)		●	●
Aperiodic bounded uncorrelated jitter (ABUJ)		●	●
Total jitter (TJ) estimation		●	●
BER range		●	●
Max pattern length periodic mode		●	●
Max pattern length arbitrary mode		●	●

Choosing your Jitter Analysis Software for Infiniium Oscilloscopes *(Continued)*

	EZJIT	EZJIT Plus	EZJIT Complete
Model number **Option number**	**E2681A** **002**	**N5400A** **004**	**N8813A** **057**
Advanced Jitter Views			
Real-time Eye	**Requires Serial Data Analysis, option -003**	**Requires Serial Data Analysis, option -003**	**Requires Serial Data Analysis, option -003**
BER bathtub		●	●
DDJ vs bit		●	●
Composite histograms		●	●
TJ histogram		●	●
DDJ histogram		●	●
RJ/PJ histogram		●	●
RJ/PJ spectrum		●	●
Vertical Noise Analysis			
Vertical noise decomposition			●
Total interference estimation			●
Separate analysis of one and zero levels			●
Advanced noise views			●

EZJIT Complete: Advanced Jitter and Vertical Noise Separation and Analysis

Analyze your Eye Closure

As data rates increase, the vertical margin you have will be eroded because of channel effects (ISI) and differential noise mechanisms such as periodic interference and random noise. As a result, analysis of the complete eye with jitter measurements for the horizontal and noise measurements for the vertical is required. The results of such analysis can yield insight on debug tasks to pursue such as addressing channel loss or intra-pair skew resulting from common mode-to-differential mode conversion, and to establish system link budget/margins for your designs. Given a receiver's sensitivity, you can explore whether a transmitter's random noise component, δ_{RN}, with its BER multiplier (for instance, 14.3 for 10^{-12} BER) can be supported. With the vertical analysis complete, total confidence in the design is achieved.

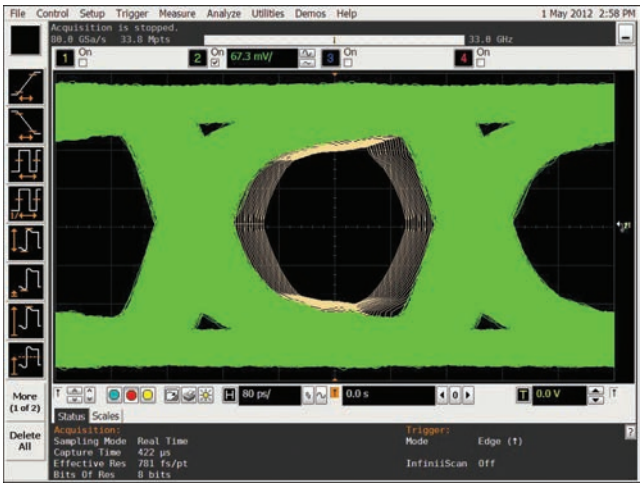


Figure 2. Eye showing BER contours from 10-1 to 10-21

Setting Up the Oscilloscope for Vertical Noise Analysis

Vertical Noise analysis software algorithms are very similar to the jitter algorithms found in EZJIT Plus. For this reason, and because the engineering tasks are related, the noise and jitter capabilities are merged together in one GUI and combined to constitute EZJIT Complete'. It is found in both analysis and measurement tabs in the infiniium oscilloscope control graphical user interface. Selecting either of these yields the entry dialog which allows manipulation of conditions for measurement, and also presents a setup wizard. The setup wizard is the best and most carefree way to ensure good measurements and is recommended.

Viewing the setup dialog one can see the close relationship jitter and noise measurement have. There is a common section that addresses the channel to be measured, the pattern type, whether it should be automatically evaluated, BER level, number of graphs to present for analysis insight, and graphical controls (such as Log/Linear format and Q vs BER scales. Additionally, there are common settings in clock recovery and thresholds. One cannot be too careful about Clock Recovery and it deserves special note. While the need for clock recovery should be obvious for jitter evaluation because jitter depends on comparison against an underlying time reference, noise evaluation requirement of clock recovery may not be so obvious. It is critical the vertical noise analysis software evaluates a vertical slice in the eye diagram and must have a clock reference to do so.

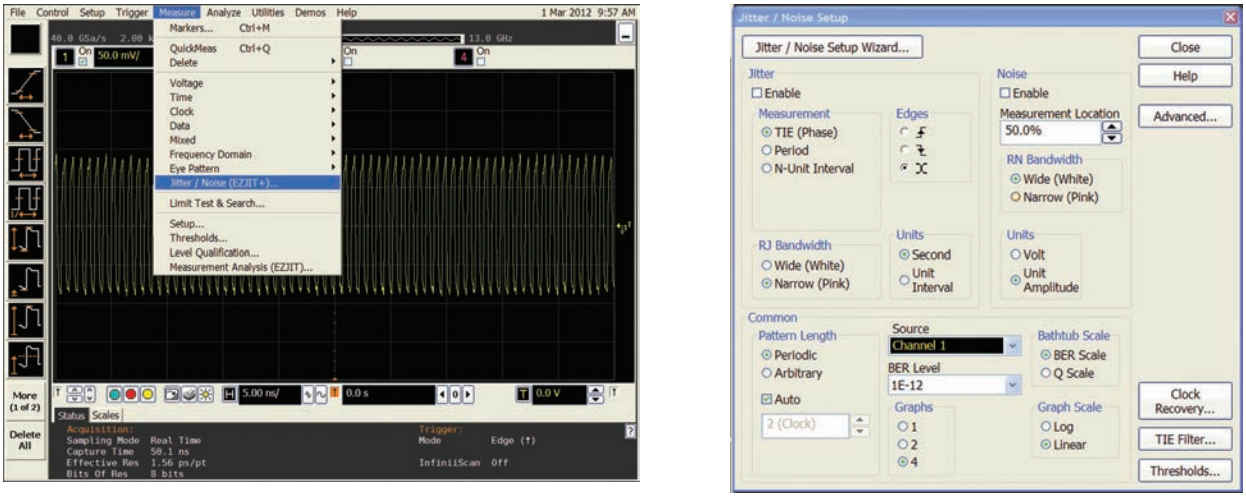


Figure 3. Jitter and Noise Measurement control dialog available from Analyze and Measurement Tabs and resulting setup control dialog

Use the Setup Wizard!

In all of Infiniium's measurement software, setup wizards guide users to the quickest way to achieve results and the vertical noise analysis software in EZJIT Complete is no exception. Use the Setup Wizard for bulletproof setup and results.

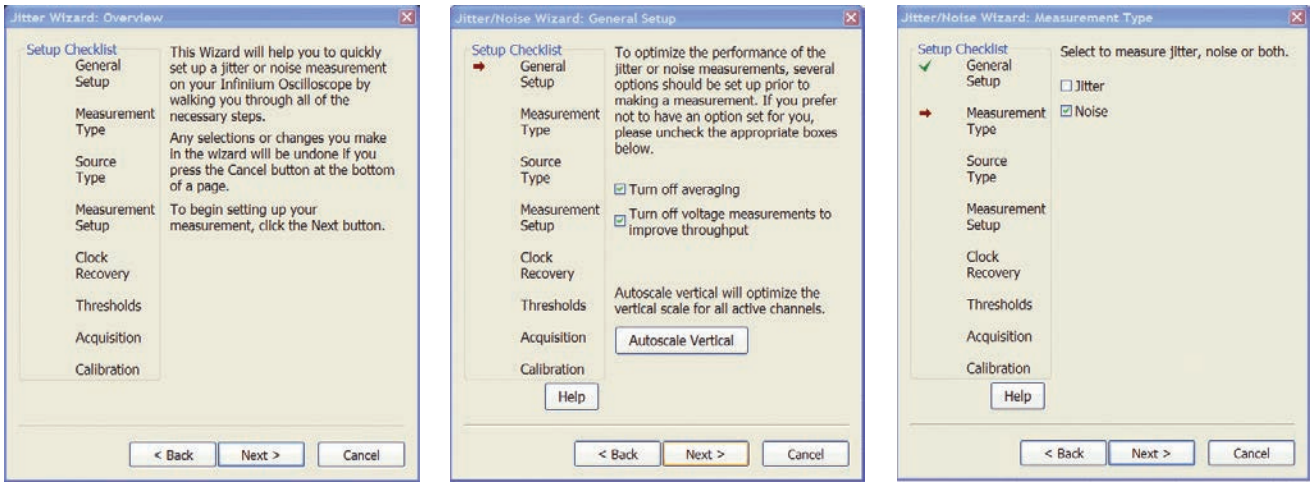


Figure 4. Jitter and Noise Wizard. The setup checklist is presented in the first wizard screen and the user can see where in the process they are every step of the way.

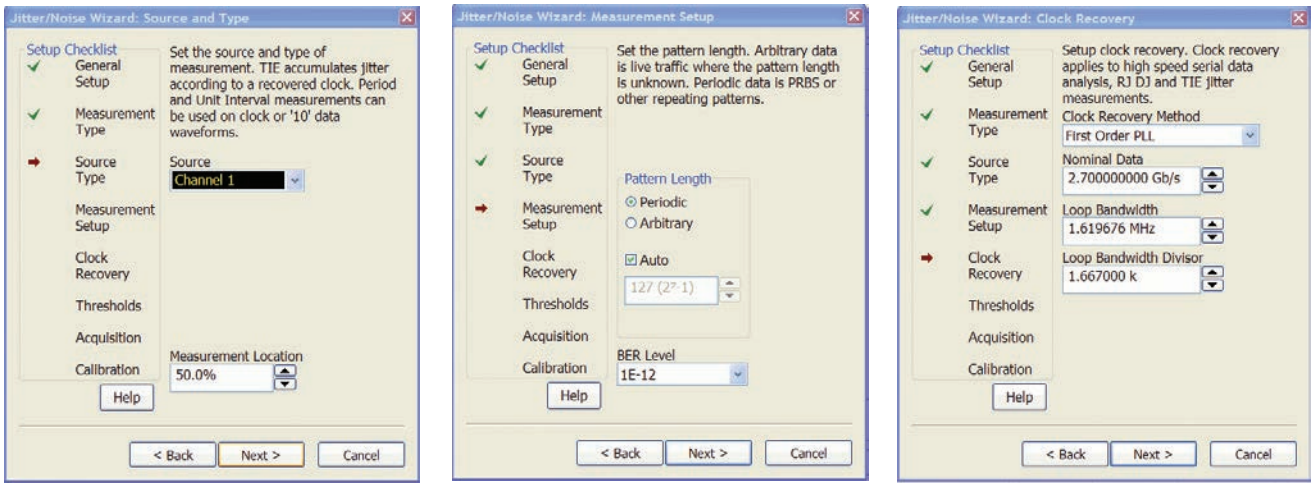


Figure 5. Jitter and Noise Wizard. Key parameters are selected. From the target and location in the unit interval, to whether periodic or arbitrary patterns are being analyzed, to clock recovery.

Use the Setup Wizard! *(Continued)*

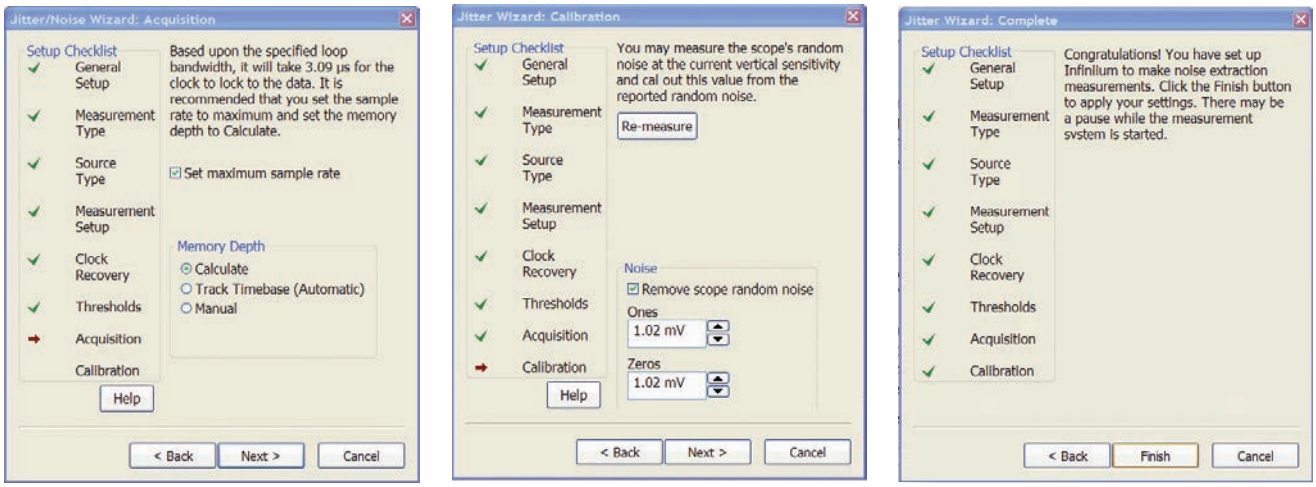


Figure 6. Jitter and Noise Wizard. Selecting 'Calculate' memory depth assures appropriate acquisition depth (memory) for highest accuracy. The Calibration tab will activate scope to measure its own noise and the check box selection of 'Remove scope random noise' will perform a root sum square subtraction of the scope's random noise from all subsequent calculations of random noise.

The jitter wizard guides you through the setup process, from General Setup to the Calibration where the oscilloscope's contribution to noise is subtracted. The default values in the wizard the optimize accuracy and robustness of the measurement.

Viewing and Analyzing Vertical Noise

Analysis of your signal is portrayed in graphical and tabular forms. The graphical portrayals provide the most immediate insight while the tabular provide the numeric evaluation you need for evaluating your target.

When analyzing vertical noise, four graphs will be presented as the standard configuration. These are shown below. These are considered to provide the most insight immediately, but the user also has more options available.

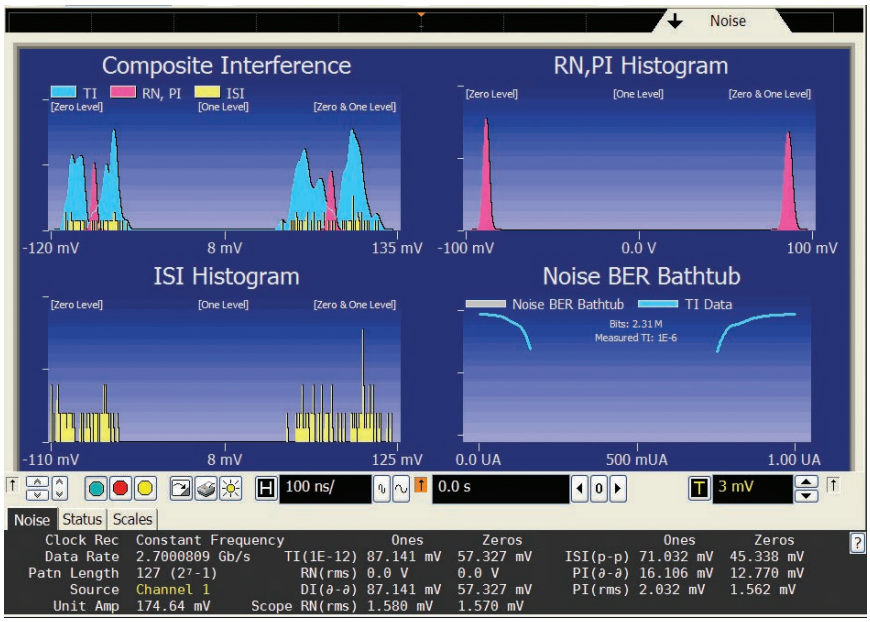


Figure 7. Standard graphical portrayal of vertical noise decomposition. From top to right: composite interference histogram, random and periodic histogram, intersymbol interference histogram, and bathtub plot.

Other Views

In addition to the vertical noise histograms and bathtub plots are other graphical portrayals that can give you the information you need to act. These are noise spectrum, threshold spectrum and ISI vs Bit. The noise spectrum and threshold spectrum will show periodic and random components vs frequency. The advantage of viewing the noise spectrum plot is to understand the noise contribution frequencies. For instance, if there is power supply radiation source or grounding issue on one side of a differential pair it will show up as common and differential noise and will be immediately clear on the plot. The threshold plot (not shown) shows the calculated threshold vs frequency that the vertical noise decomposition software uses to discern between a periodic noise component and random noise.

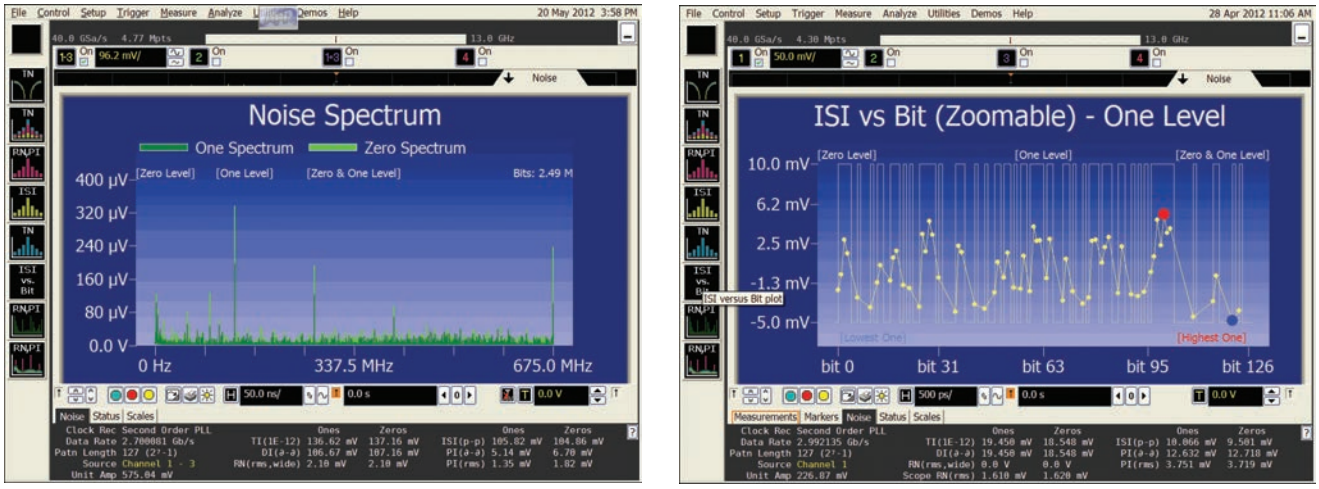


Figure 8. Spectrum portrayal of the vertical noise and pattern dependent noise (ISI) in ISI vs Bit plots. By selecting on the plot labels, the user can select between analyzing zeroes, ones, or both simultaneously.

Analysis of Ones, Zeroes, or both Ones and Zeroes

The vertical noise decomposition software will default to the four-graph view seen in Figure 7, however two other choices are available to you. These are two-graph and one-graph formats for better focused viewing. The selection is available in the entry screen shown in Figure 3.

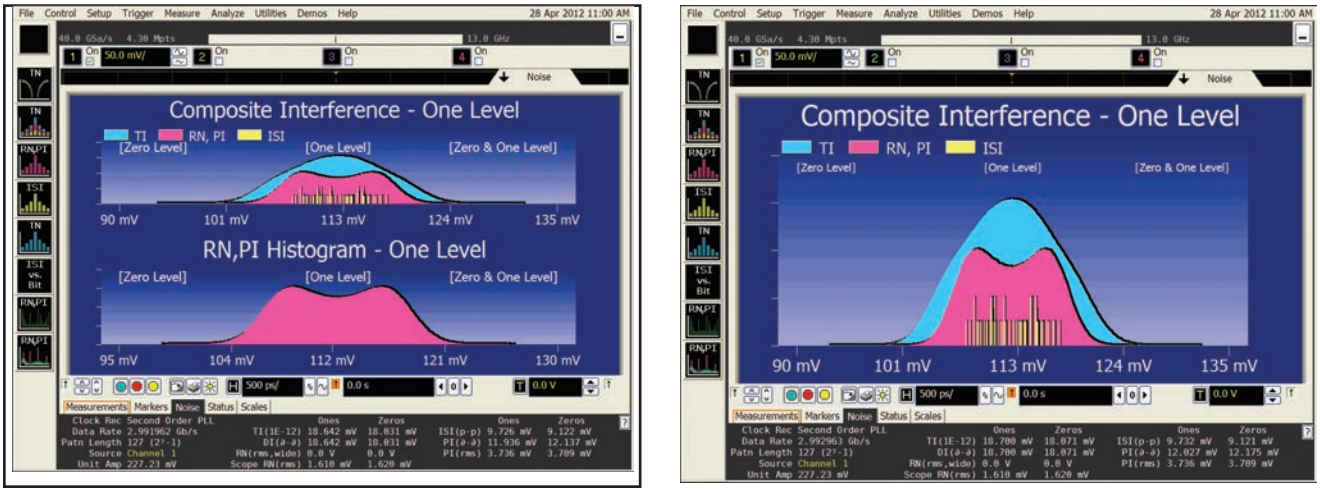


Figure 9. The EZJIT Complete entry screen allows selection of 4, 2 or 1 graph formats.

Analysis of Ones, Zeroes, or both Ones and Zeroes

Close analysis of the the four-graph view seen in Figure 7, will reveal that the plot is rendering both One and Zero analysis on each of the graphs shown. In those graphs, if you should want to examine the 'One' histograms or 'Zero' histograms in greater detail, you can click on the '[One Level]' or '[Zero Level]' labels. When you do so, the graph will rescale and show the side selected (One or Zero). This is depicted in Figure 10.

Tabular results

Finally, the measured results are available in tabular form or over remote user interface. The results are available now in their own results tab at the bottom of the infiniium screen under 'Noise'.

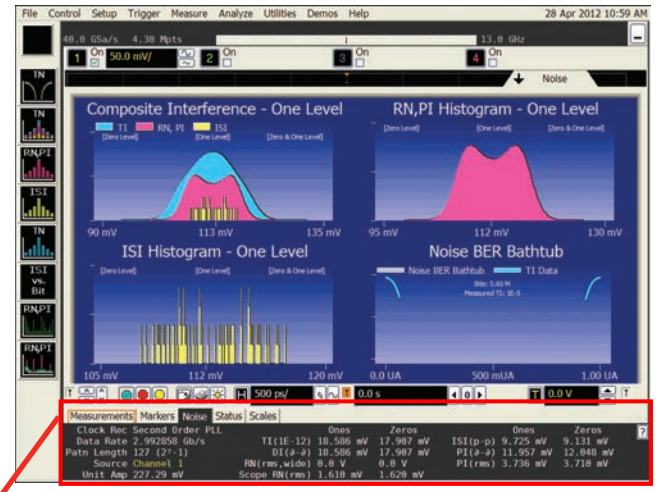


Figure 10. Focus on just the Ones, or the Zeroes or both: Analysis for Ones is shown here.

Measurements | Markers | Noise | Status | Scales

		Ones	Zeros		Ones	Zeros
Clock Rec	Second Order PLL					
Data Rate	2.993028 Gb/s	TI(1E-12)	19.403 mV	19.143 mV	ISI(p-p)	10.087 mV	9.522 mV
Patn Length	127 (2^7-1)	DI(∂-∂)	19.403 mV	19.143 mV	PI(∂-∂)	12.760 mV	12.985 mV
Source	Channel 1	RN(rms,wide)	0.0 V	0.0 V	PI(rms)	3.742 mV	3.722 mV
Unit Amp	226.85 mV	Scope RN(rms)	1.610 mV	1.620 mV			

Figure 11. New Noise tab displaying all the values associated with vertical decomposition.

Other Analyses Enabled

Fixed Level Analysis: if your device is fixed at a high or a low, you can still analyze the system noise. In this case, you do not have a signal to perform first or second order recovery from data, so you can use an explicit clock and adjust threshold and hysteresis settings in the wizard.

Sweep the Eye: To comprehend vertical performance throughout the eye, the user can sweep the measurement location in the eye and performing noise analysis at each vertical solutions. With similar measurements of jitter at different horizontal thresholds the results can be processed externally to render a complete contour around the eye opening. This would be done to evaluate the statistical eye contour, or to measure over a specific range given assumptions of the behavior of the system receiver. An example of this is shown in Figure 2.

Separate jitter on periodic and arbitrary patterns

Typically, jitter separation is performed on repetitive waveforms that are designed to stress the data transmission link and the receiver's clock recovery circuitry. However, many embedded designs using multi-vendor chipsets are limited to testing live traffic with additional align characters and packet frames that may not be repetitive. EZJIT Plus allows designers to choose between periodic and arbitrary data modes when analyzing jitter for compliance. In the arbitrary data mode, the ISI Filter shows victim-aggressor relationships between each rising and falling edge that are N-edges apart in the captured waveform. By setting the filter wide enough to capture all significant relationships, designers can quickly analyze ISI problems and accurately separate RJ/DJ parameters to provide a TJ estimation at low BER.

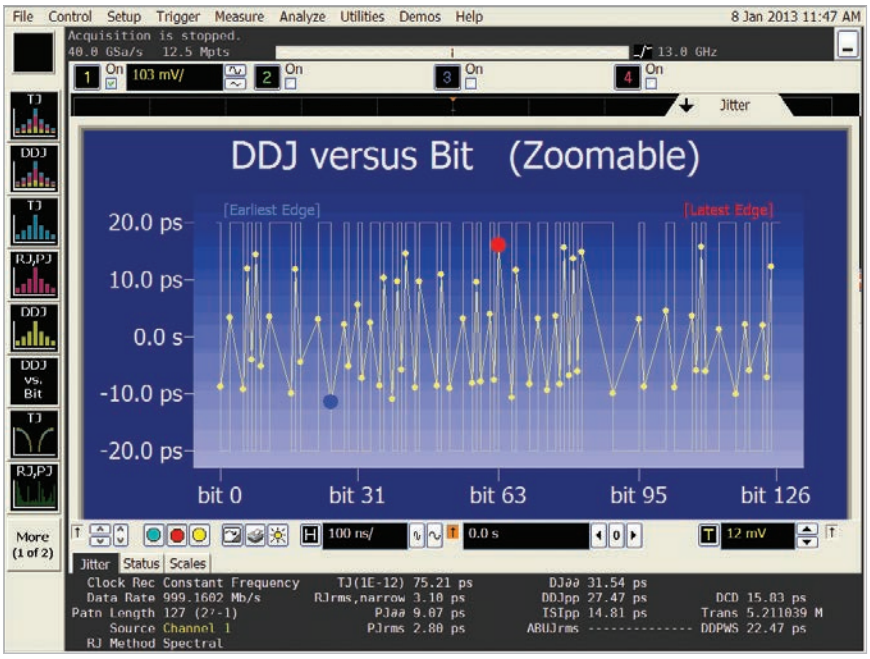


Figure 12. DDJ vs. Bit chart

Easy-to-use Jitter Separation Wizard

The easy-to-use wizard built into EZJIT Plus makes setting up advanced jitter separation simple. Walk through the measurement setup step-by-step to set critical parameters such as thresholds, vertical scaling, and clock recovery. The result: fast and accurate separation of signal jitter into components and flexible jitter views to provide critical insight.

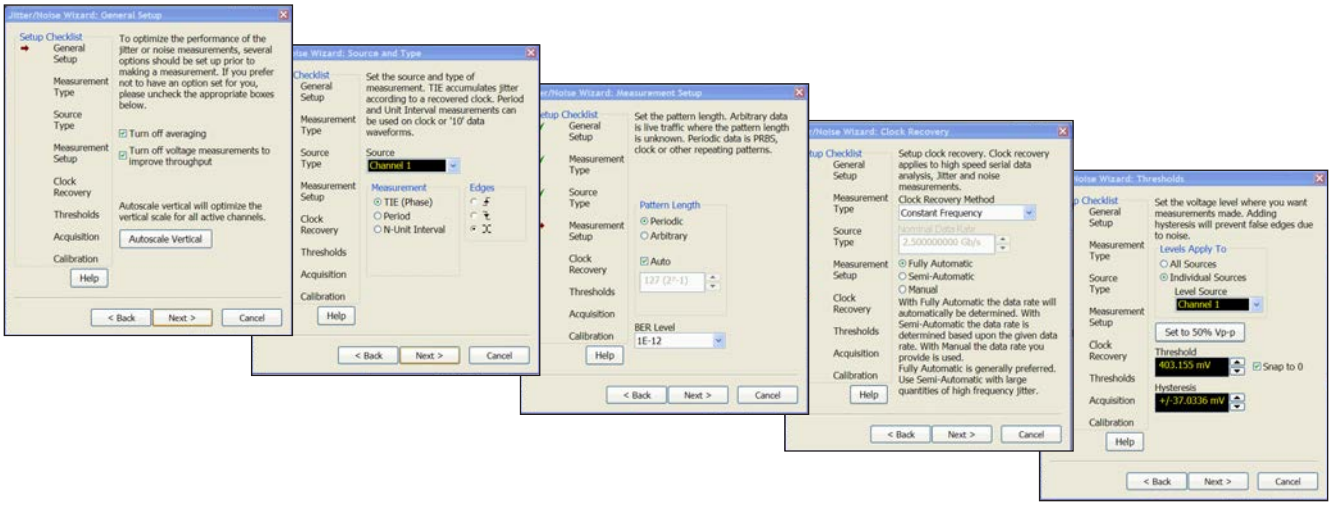


Figure 13. RJ/DJ Wizard allows user selection of data pattern type, TJ BER calculation level, clock recovery type and jitter measurement threshold.

Accurate Random Jitter Separation using Spectral and Tail Fit Algorithms

The Problem:

Common spectral algorithm for RJ extraction over-reports RJ.

Why?

Any Aperiodic Bounded Uncorrelated Jitter (ABUJ) on the signal is factored into RJ. A common source of ABUJ is crosstalk from adjacent signals.

How does this affect me?

First, the RJ measurement can be inaccurate. Second, when measuring Total Jitter (TJ) vs. BER, TJ can be dramatically overestimated due to the RJ multiplier. For example, TJ = DJ + 14*RJ for a BER of 10^-12. This means the scope will provide an unfairly negative report of the overall jitter performance of your serial data link.

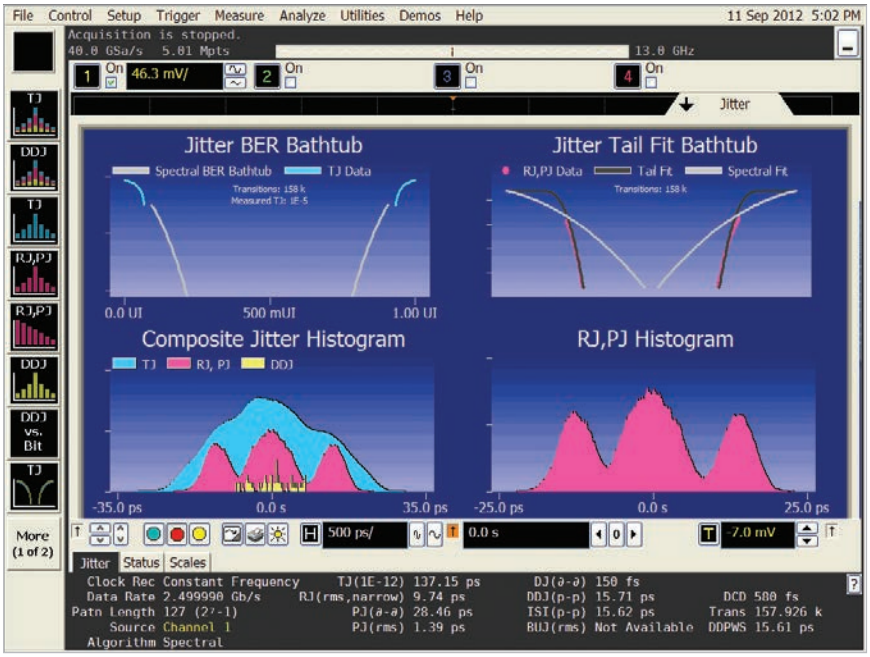


Figure 14. Jitter separation with artificially extreme crosstalk using spectral algorithm for RJ extraction. Notice the discontinuity in the BER bathtub.

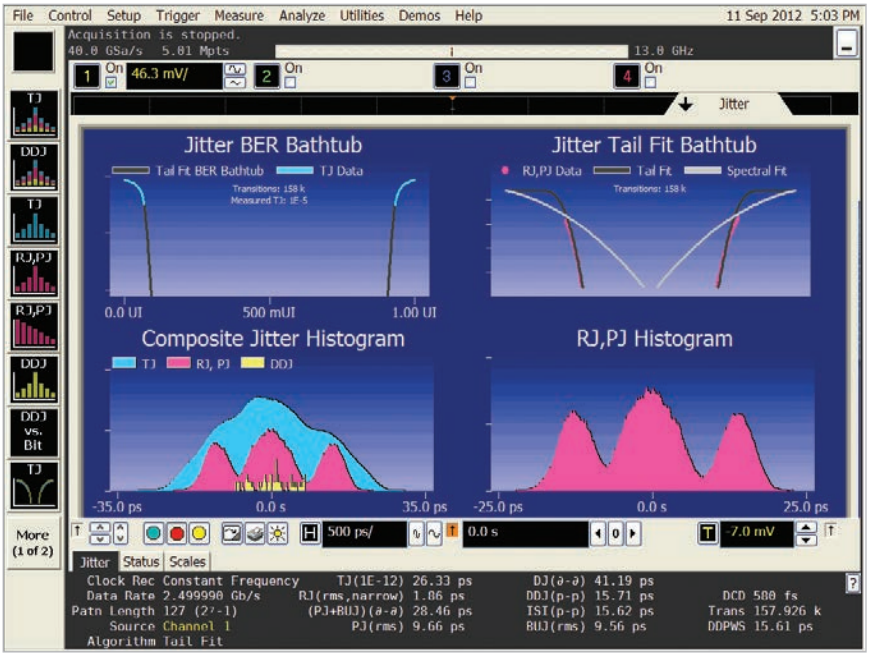


Figure 15. Jitter separation with artificially extreme crosstalk using tail fit algorithm for RJ extraction. Notice the good fit to the BER bathtub and dramatically lower RJ and TJ results.

The Solution:

EZJIT Complete provides two distinct algorithms for RJ extraction to ensure you achieve accurate measurements under all signal conditions.

The Tail Fit algorithm accurately extracts RJ, even in extreme ABUJ/crosstalk environments, by fitting directly to the tail of the RJ,PJ histogram.

Figures 14 and 15 contrast the two algorithms in a contrived jitter measurement with extreme crosstalk. You can see the tail fit algorithm in Figure 5 provides a much better fit to the BER bathtub curve in the upper left and reports significantly lower RJ and TJ.

Jitter Separation and Total Jitter Estimation at Low BER

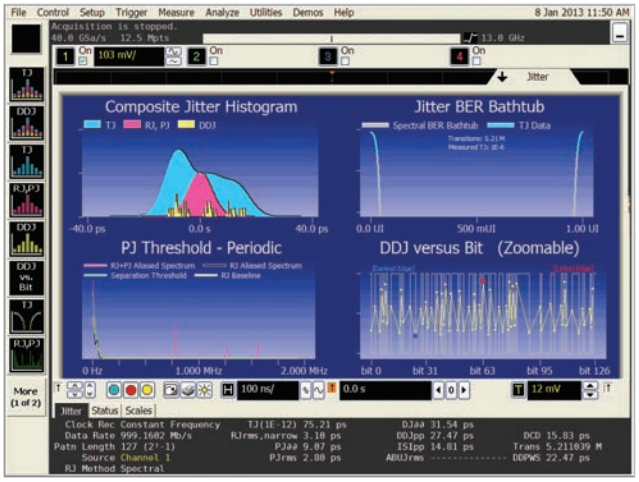


Figure 16.

4-in-1 jitter measurement results display allow for multiple views of jitter populations and distributions, data-dependent jitter versus bit in repetitive patterns, as well as the bathtub curve plot, which measures eye-opening vs. bit error rate.

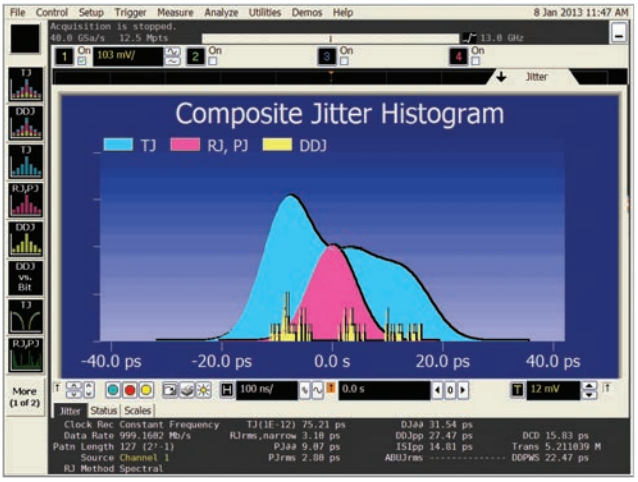


Figure 17.

Composite histogram displays relative contributions of data-dependent jitter, total jitter as well as random and periodic jitter. Total jitter is a convolution of the data-dependent jitter probability density function (PDF) and the random/periodic jitter PDF.

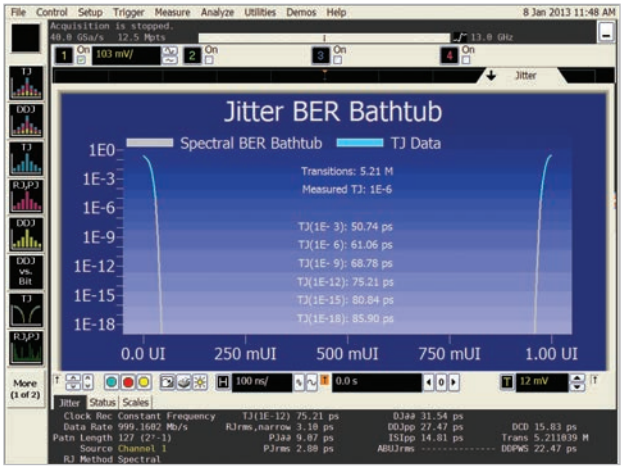


Figure 18.

Simplified display leverages existing measurement results tabs and measurement toolbars, integrating the EZJIT Plus measurement capability into the Infiniium display window. When the RJ/DJ graphical display window is minimized to view the voltage vs. time waveform under test, the jitter separation results are still visible in the jitter measurement results tab.

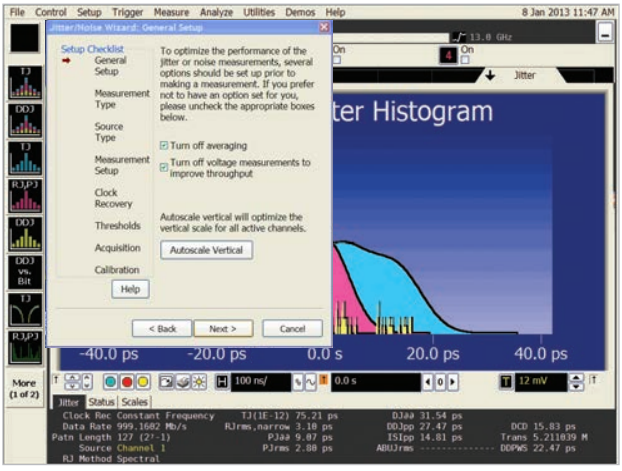
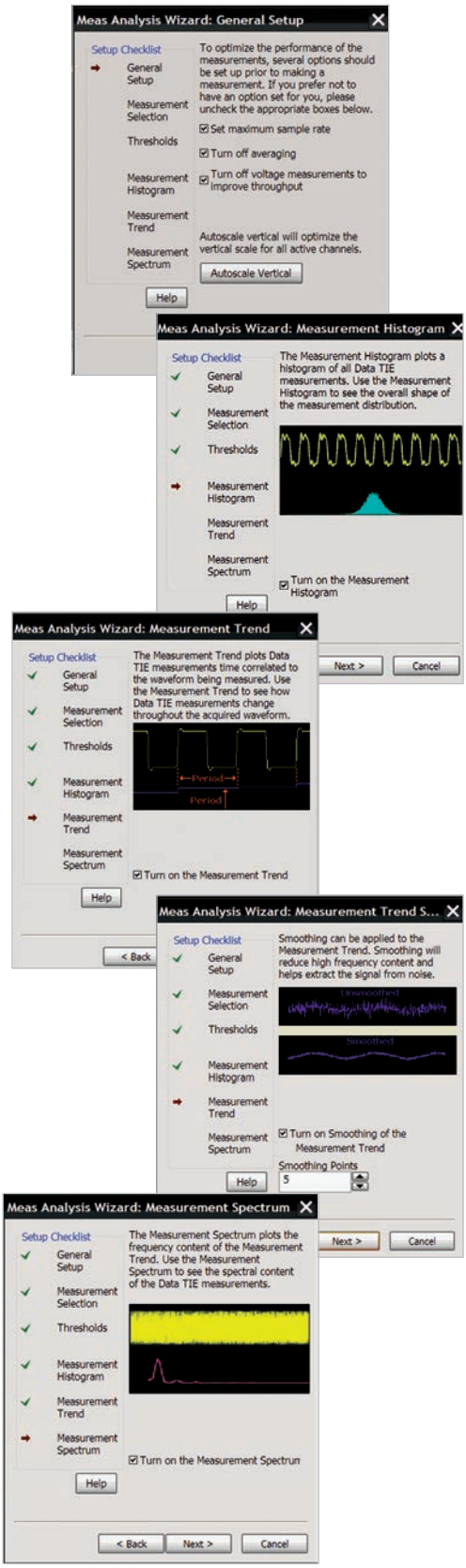


Figure 19.

A step-by-step wizard simplifies complex jitter measurement setups and allows for complete user control over important parameters such as the measurement threshold voltage and clock recovery method.

EZJIT: Essential Jitter Analysis Tools

Included with EZJIT Plus



Jitter analysis made easy

A wizard in the EZJIT jitter analysis software helps you quickly set up the Infiniium oscilloscopes and begin taking measurements. With time-correlated jitter trend and signal waveform displays, the relationships between jitter and signal conditions are more clearly visible. Intuitive displays and clear labeling of information make it easy to comprehend measurement results.

Figure 20. The setup wizard prompts you to select measurement thresholds, histogram, jitter trend, and/or spectrum displays.

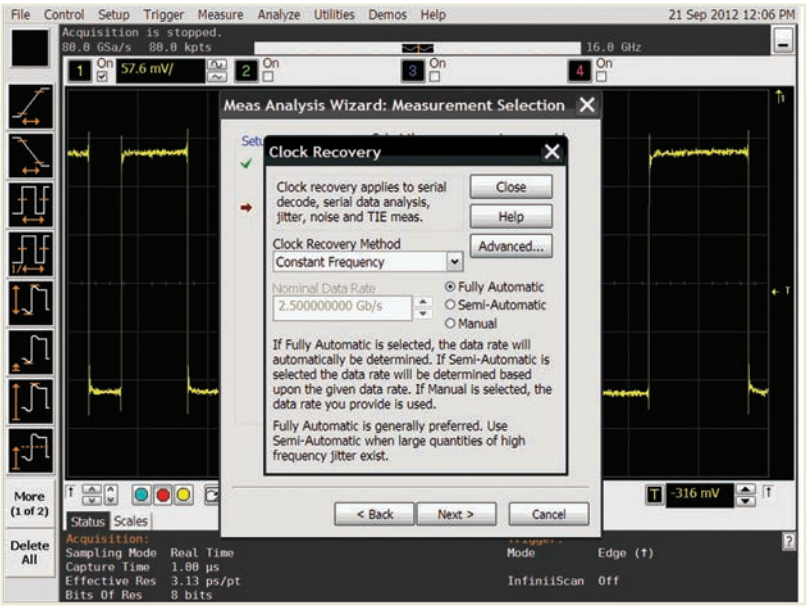


Figure 21. The EZJIT wizard simplifies jitter measurement setup, such as advanced clock recovery, shown here.

Extensive parametric analysis

EZJIT jitter analysis software can analyze the time variability of any of the following fundamental parametric measurements:

Single-source
- Period
- Frequency
- Positive pulse width
- Negative pulse width
- Duty cycle
- Rise time
- Fall time

Dual-source
- Setup time
- Hold time
- Phase

Clock
- Time-interval error (TIE)
- N - Period Jitter
- Period to Period Jitter
- Pos width to Pos width jitter
- Neg width to Neg width jitter
- Cycle-to-cycle duty cycle

Data
- Time interval error (TIE)
- Data rate
- Unit interval
- n - UI jitter
- UI - UI jitter
- Clock Recovery Rate

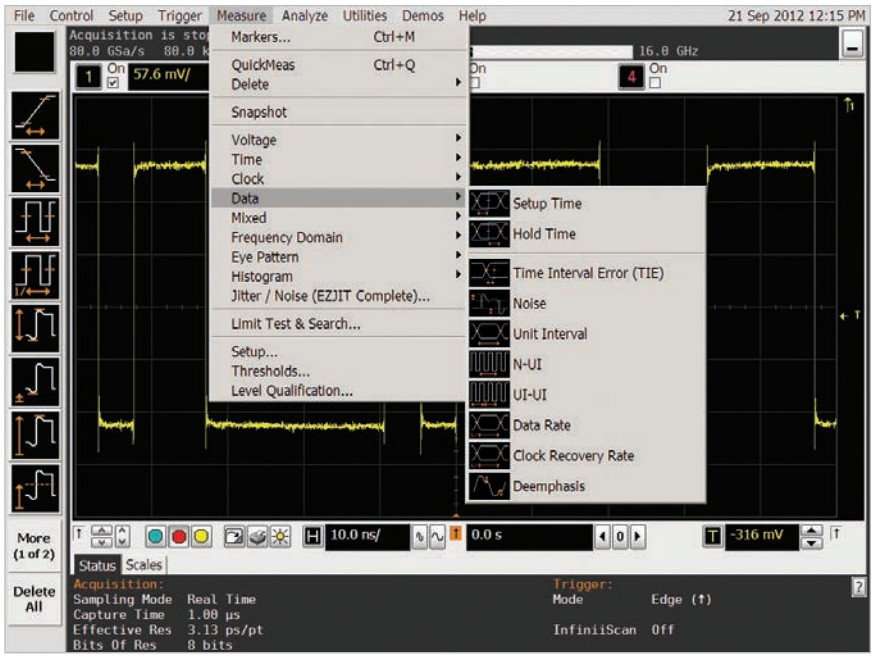


Figure 22. Extensive parametric analysis provides insight into data jitter components.

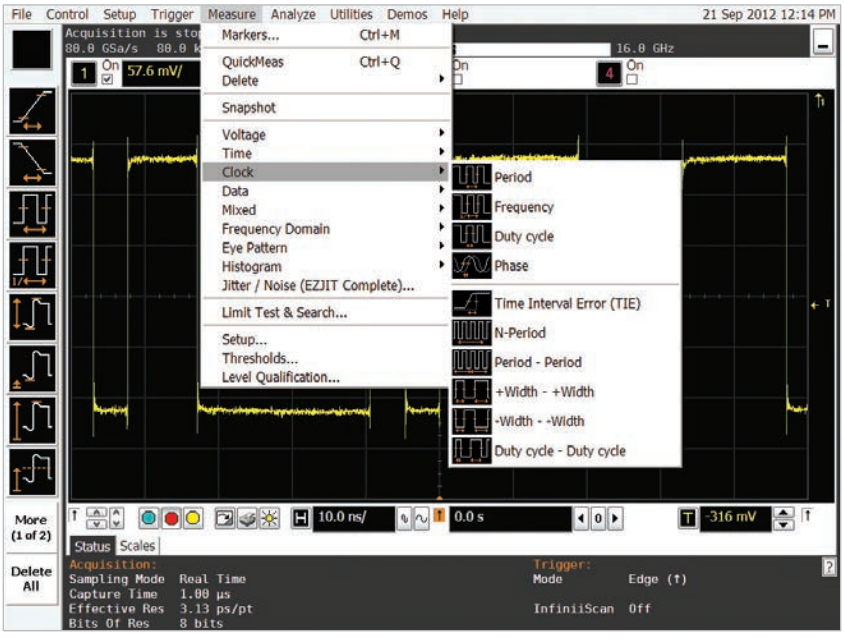


Figure 23. Clock jitter measurements provides insight into clock jitter components.

Real-time trend, histogram, and spectrum displays

Measurement data can be viewed as a trend display (Figure 24), showing a time plot of the measurement time-correlated with the signal waveform data. This makes it easy to understand relationships between jitter and signal conditions, such as intersymbol interference (ISI).

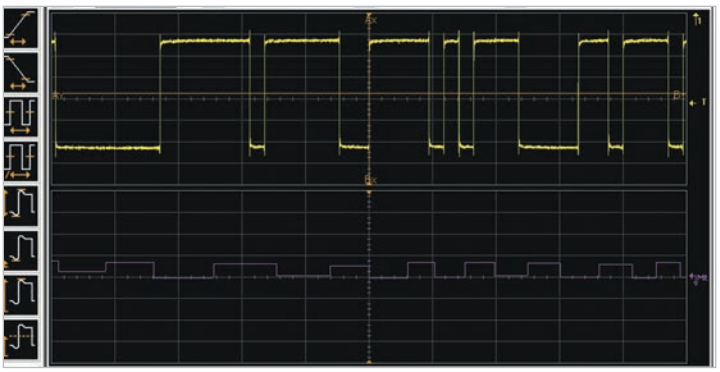


Figure 24. A trend display, showing a time plot of the measurement time-correlated with the signal waveform data, makes it easy to understand relationships between jitter and signal conditions.

The histogram display (Figure 25) plots the relative occurrence of values for the measured parameter. The histogram provides insight into the statistical nature of the jitter.

For example, the histogram shown in Figure 25 appears as two gaussian distributions. The peak-to-peak jitter between the gaussians indicates significant deterministic jitter in the signal, while the gaussians show the spread of random jitter.

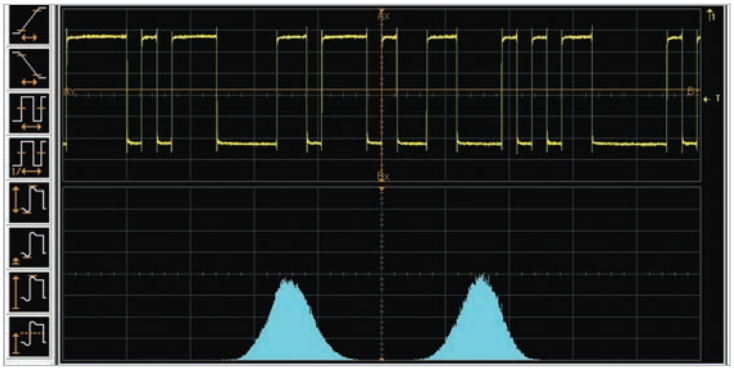


Figure 25. A histogram display plots the relative occurrence of values for the measured parameter, providing insight into the statistical nature of the jitter.

The spectrum display (Figure 26) shows the spectral content of the jitter. The spectrum display can be useful for identifying sources of jitter by their frequency components. For example, if you suspect a switching power supply with a switching frequency of 33-KHz is injecting jitter, you can test your theory by examining the jitter spectrum for a peak at 33-KHz.

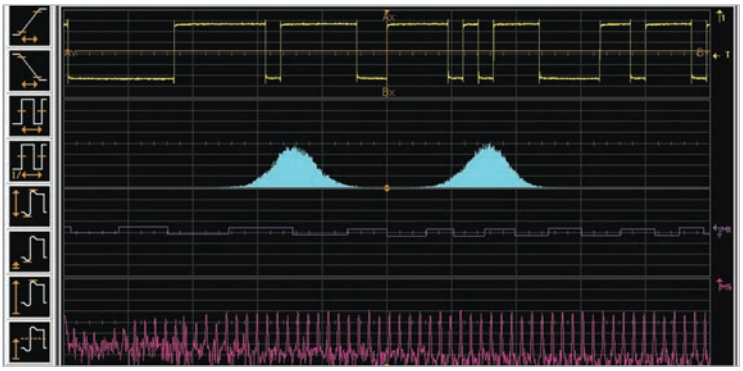


Figure 26. A spectrum display shows the spectral content of the jitter, useful for identifying sources of jitter by their frequency components.

Flexible clock recovery

You can choose constant-frequency or phase-locked loop (PLL) clock recovery as well as use an explicit clock on another input channel to time the data transition. With PLL clock recovery, the data rate and loop bandwidth are adjustable.

Many standards allow the use of spread-spectrum clocking to avoid concentrating EMI and RFI at specific frequencies. Spread-spectrum clocking is simply FM modulation of the clock frequency, usually at some frequency well below the clock frequency. The bandwidth of the PLL in the receiver hardware allows it to track the slow change in the clock frequency while allowing faster changes to be measured.

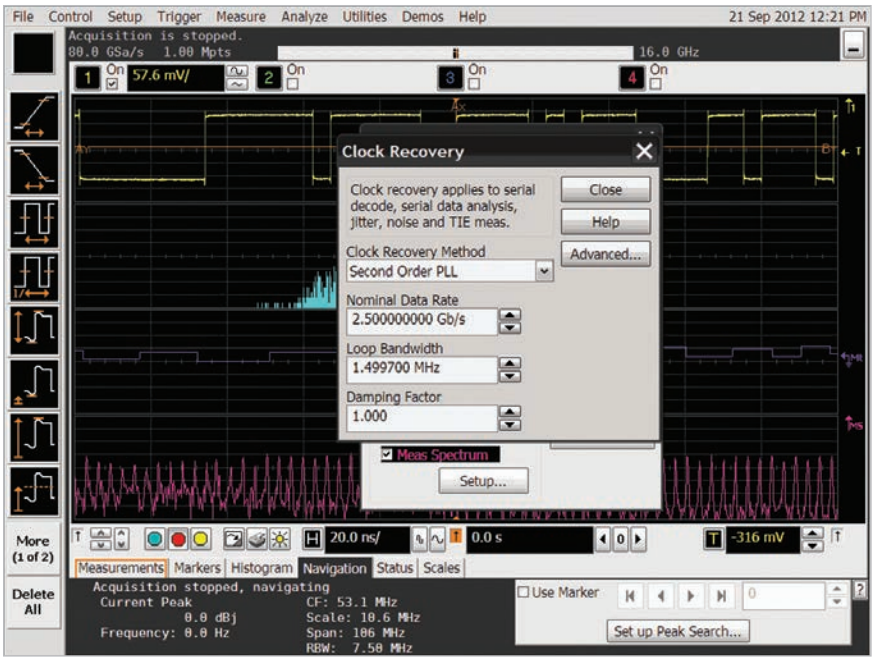


Figure 27. You can choose constant-frequency or phase-locked loop (PLL) clock recovery. With PLL clock recovery, the data rate, loop bandwidth and damping factor are adjustable.

Deep memory captures low-frequency jitter

Deep memory is especially valuable for jitter analysis. The optional 2 Gpts memory on the Keysight Technologies, Inc. 90000 X-Series and 90000 Q-Series is helpful in measuring low frequency jitter. At a sample rate of 80 GSa/s and incoming data rate of 2.5 Gb/s, 2 Gpts allows you to capture jitter frequency components down to 40Hz. Comparably in the 90000A, 9000A, and 9000 H-Series, the 40 GSa/s sample rate and optional 1 Gpts memory allows you to capture jitter frequency components as low as 40 Hz.

In some cases, measuring low-frequency jitter is not required; for example, the clock recovery PLL in most serial data receivers can reject jitter very effectively at moderately low frequencies. But sometimes an event occurring at a low repetition rate can cause bursts of jitter or noise with higher frequencies that the PLL cannot reject.

An example is shown in Figure 28. The upper yellow trace is a serial data signal. The middle green trace shows an uncorrelated aggressor signal that is causing short-term bursts of jitter in the data signal. The lower purple trace, showing a jitter trend signal derived from the serial data signal, plots the timing of each edge in the data stream compared to the "ideal" recovered clock. You can see a burst of timing errors that coincides with each transition in the middle green signal.

Further jitter analysis support

For additional jitter analysis features, including Rj/Dj separation, bathtub curve generation, and ABUJ extraction, Keysight offers the N5400A EZJIT Plus jitter analysis software.

For even deeper insight, apply the same deep analysis and component separation to the vertical noise affecting your signal using Keysight's N8813A EZJIT Complete software.

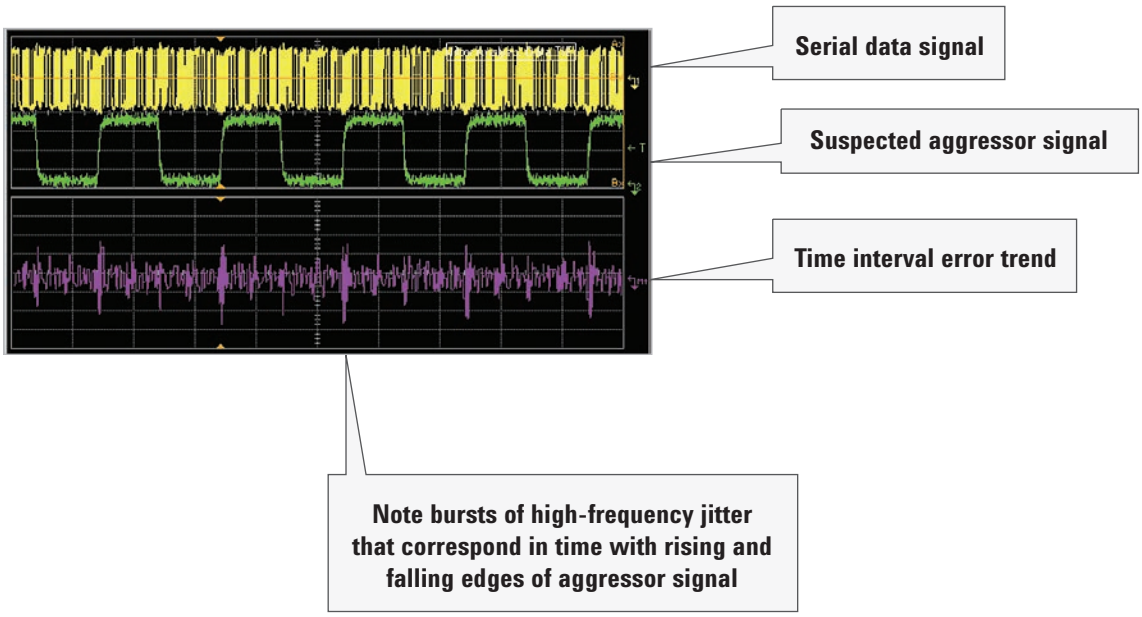


Figure 28. The clock recovery PLL in most serial data receivers can reject jitter at low frequencies. However, sometimes events occurring at low frequencies (middle green trace) can cause bursts of jitter that contain higher frequencies that the PLL cannot reject (lower purple trace).

Oscilloscope compatibility

Oscilloscopes	Software revision
90000 Q-Series	3.5 or higher
90000 X-Series	3.0 or higher
90000 Series	2.1 or higher
9000 Series	2.0 or higher
9000 H-Series	–
90008 Series Oscilloscopes/Digitizers	All

Ordering information

To order the EZJIT jitter analysis software with an oscilloscope, please order the option indicated in the table:

Oscilloscope	Option number			Description
	EZJIT	EZJIT Plus	EZJIT Complete	
DSO9000 Series DSO9000 H-Series DSO90000 Series DSO90000 X-Series DSO90000 Q-Series	002	004	057	EZJIT, EZJIT Plus, and EZJIT Complete jitter analysis software for Infiniium DSO90000 oscilloscopes (installed)

To order the EZJIT jitter analysis software for an existing oscilloscope, please order the following:

Model number	Description
E2681A	After-purchase EZJIT jitter analysis software for Infiniium oscilloscopes
N5400A	After-purchase EZJIT Plus jitter analysis software for Infiniium oscilloscopes
N5401A	After-purchase EZJIT Plus upgrade from existing EZJIT installation for oscilloscopes
N8813A	After-purchase EZJIT Complete upgrade from existing EZJIT Plus installation for oscilloscopes

Other Measurement Software for High Speed Digital Data Analysis

Infiniium Real-Time Oscilloscopes		
Model Number	**Title**	**Description**
N5461A	Equalization	Select from CTLE, FFE and DFE equalization types and various clock topologies to understand what equalization will do to a signal, or to model voltage eye internal to receiver device.
N2809A & N2807A	Precision Probe Software and Hardware Kit	Measure and remove effects of cable and switch paths in front of the oscilloscope, measure and ac calibrate probes for greatest accuracy and bandwidth.
N5465A	InfiniiSim Waveform Transformation Toolset	Creates transfer functions for implementing De-Embedding of Fixtures and cables, Embedding, general simulation, removing probe loading and changing observation point of measurement.
E2688A	Serial Data Analysis	Create eye diagrams of total captured waveform or of particular filtered portions of it (i.e bit sequence dependence). Includes standard masks and 8b/10b protocol analysis.
Sampling Oscilloscopes: 86100D Series Digital Communication Analyzer		
86100D-300	Advanced Amplitude Analysis	Infiniium DCA software option that performs the highest accuracy amplitude analysis available.
86100D-200	Advanced Jitter Analysis	Jitter Decomposition using dual dirac technique. Predict total jitter to low BERs
86100D-201	Advanced Jitter Analysis	Equalize signals using software CTLE and FFE/LFE models.
86100D-202	Enhanced Impedance and S-Parameter SW	Single-ended and differential S-parameter measurements.
86100D-300	Advanced Amplitude Analysis	Infiniium DCA software option that performs the highest accuracy amplitude analysis available.
86100DU-401	Advanced Eye Analysis	Jitter and amplitude/noise analysis on long patterns such as PRBS31. Eye contour and eye/mask testing.
86100D-SIM	InfiniiSim-DCA	Creates transfer functions used to de-embed/embed fixtures and cables, general simulation, removing probe loading and changing observation point of measurement.

Related Literature

Publication title	Publication type	Publication number
Infiniium DSO90000 and DSA90000 Series Oscilloscopes	Data Sheet	5989-7819EN
Infiniium 90000 X Series	Data Sheet	5990-5271EN
Infiniium 90000 Q Series	Data Sheet	5990-5299EN
Information on Jitter Measurement	White Paper	5989-5483EN
86100D Wide-Bandwidth Oscilloscop Mainframe and Modules	Data Sheet	5990-5822EN
86100C Jitter/Amplitude	Product Note	5989-1146EN

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(BP-07-10-14)

KEYSIGHT TECHNOLOGIES

Published in USA, August 2, 2014
5991-0523EN
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