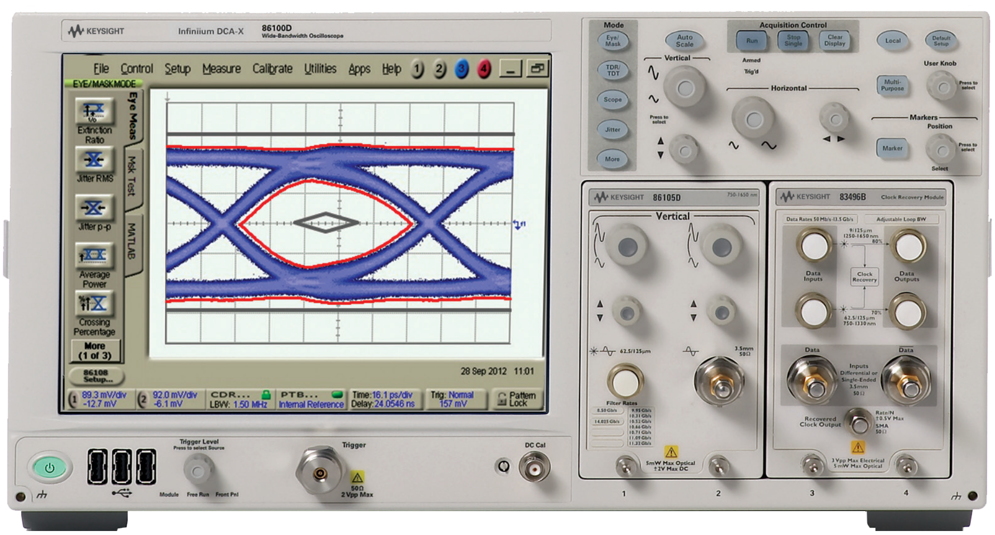
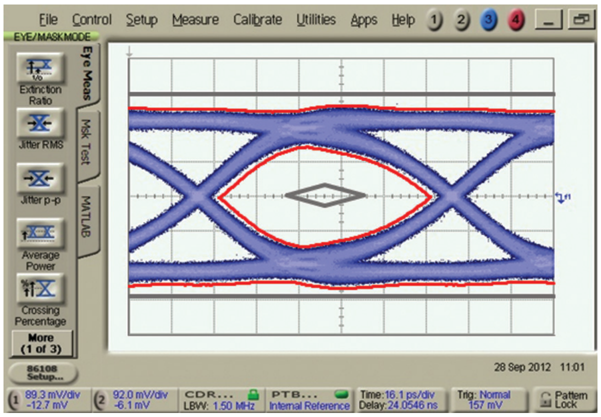
Keysight Technologies
Jitter Measurements on Long Patterns Using 86100DU-401 Advanced Waveform Analysis

Application Note



KEYSIGHT
TECHNOLOGIES

Introduction



Today's devices are characterized using a variety of test patterns. A commonly used test sequence for jitter and eye analysis is the Psuedo-Random Binary Sequence (PRBS) having 2^31-1 bits in length. Why test using PRBS-31? PRBS patterns are easy and inexpensive for devices to generate using hardware, and a long pattern like PRBS-31 (2^31-1 bits, or 2,147,483,647 bits) includes bit sequences that effectively stress baseline wander and clock wander in devices.

Total Jitter (TJ) on a PRBS-31 signal can be measured directly using a Bit Error Ratio Tester (BERT), but in order to achieve reasonable confidence in the result, test times can be long. PRBS-31 patterns are too long for jitter analysis tools that analyze every edge in a pattern and then estimate TJ based on random jitter (RJ) and deterministic jitter (DJ) measurements.

As an alternative to using long patterns, some Implementation Agreements such as the Optical Internetworking Forum - Common Electrical Interface (CEI) 2.0 developed short stress patterns (SSP) that ensure similar stress levels as PRBS31, but have pattern lengths that are short enough for today's jitter analysis tools.[1] However, since these SSP are memory based patterns (software), many of today's devices do not have the ability to generate such SSP.

The 86100D DCA-X Wide-Bandwidth Oscilloscope with Option 200 Enhanced Jitter Analysis is well known for its speed and accuracy. Its speed comes from the fact that, while in Jitter Mode, the DCA targets over 99% of its samples in the crossing region where jitter information resides (it does not waste time taking many samples where there is no jitter information). Accurate jitter analysis algorithms were developed using traceable amounts of jitter generated by a precision jitter transmitter,[2] and are documented in Application Note 86100C-1.[3] However, like most jitter analysis tools, detailed jitter analysis on every edge of the pattern is limited to patterns that are 2^16 bits in length or less.

To overcome pattern length limitations found in many of today's jitter analysis tools, Keysight Technologies, Inc. developed a Microsoft Office Excel-based application called 86100DU Option 401 Advanced Waveform Analysis. Option 401 controls an 86100D DCA-X mainframe and provides:

- Compliant jitter measurements (RJ/DJ/TJ, J2, J9) on long patterns, such as PRBS31 or live traffic
- BER contour mask testing on high-speed electrical, or optical, designs.

Jitter measurements without pattern length limitations

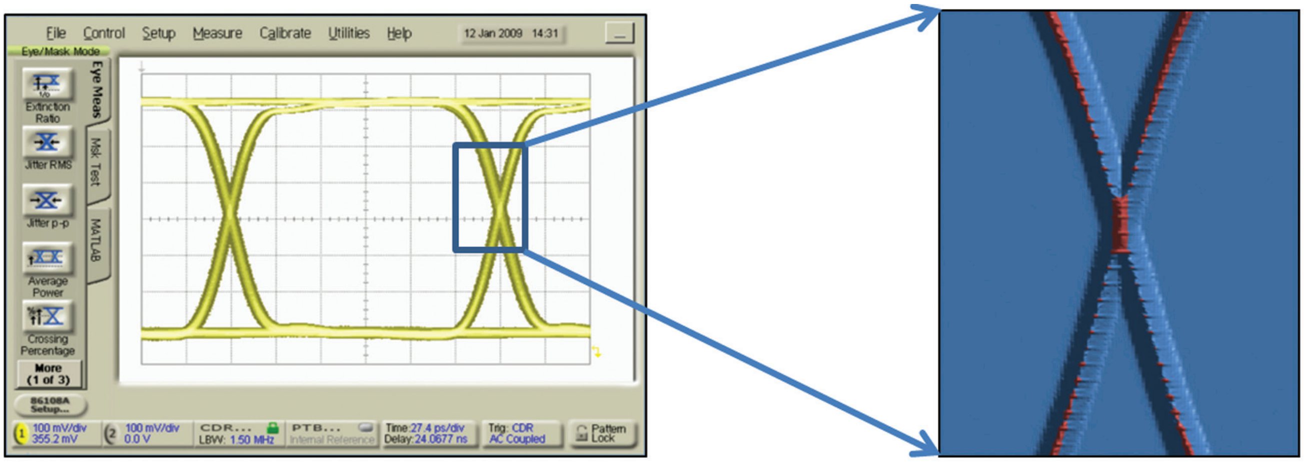


Figure 1 – The 3D Color Grade Scale (CGS) database in Eye/Mask mode creates a PDF of the incoming signal.

86100DU-401 Advanced Eye Analysis starts out by making very efficient use of data acquired using the 86100D's Eye/Mask mode. Eye/Mask mode does not have any pattern length limitations and saves precision measurement samples in a three-dimensional (3D) color-grade scale (CGS) database. Each sample acquired in Eye/Mask mode is assigned to a CGS database location that records time, amplitude, and a count of the number of samples for each bin location. The CGS database is essentially a probability density function (PDF) of the signal.

Efficient Use of Data

The ITU-T defines jitter as "a measure of the short term time variations of the significant instances of a digital signal from their ideal positions in time." In an eye diagram, jitter information resides in the crossing region of the eye. As a result, valid jitter information can be obtained from the inside and outside of each edge of the eye.

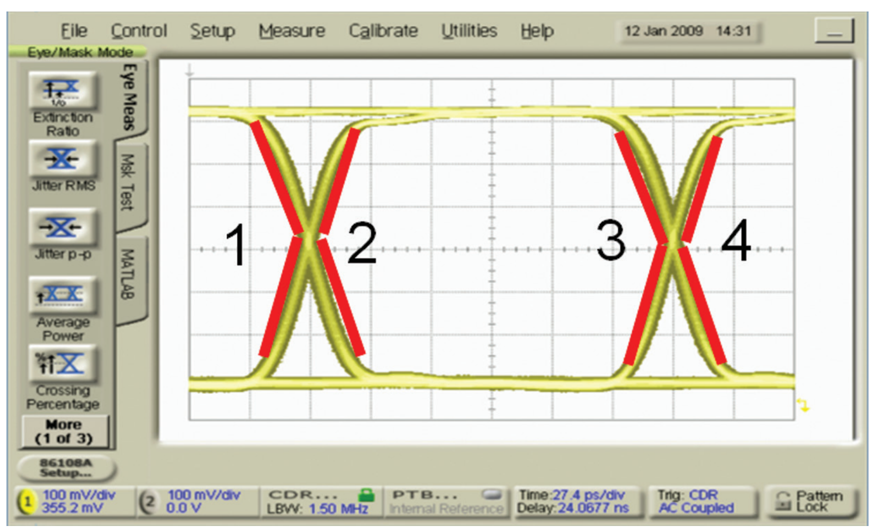


Figure 2 – Eye diagram showing edges containing jitter information.

Section 1: 86100DU-401 Advanced Eye Analysis – Measurement Methodology

Efficient Use of Data

Additionally, multiple rows in the CGS database can also be used by the jitter algorithms; the analysis does not need to be constrained to the 50% crossing point. Instead, Option 401 analyzes the eye diagram to determine:

1. CGS locations (rows of data) containing jitter information only (horizontal arrows in Figure 3).
2. CGS locations (columns of data) containing amplitude information only (vertical arrows in Figure 3).
3. CGS locations where samples are influenced by both timing and amplitude effects (diagonal arrows).

Advanced Eye performs a statistical analysis on the measured data set. Using multiple rows of data increases the sample size used for the analysis thereby allowing the measurement to be performed more quickly, and with greater accuracy.

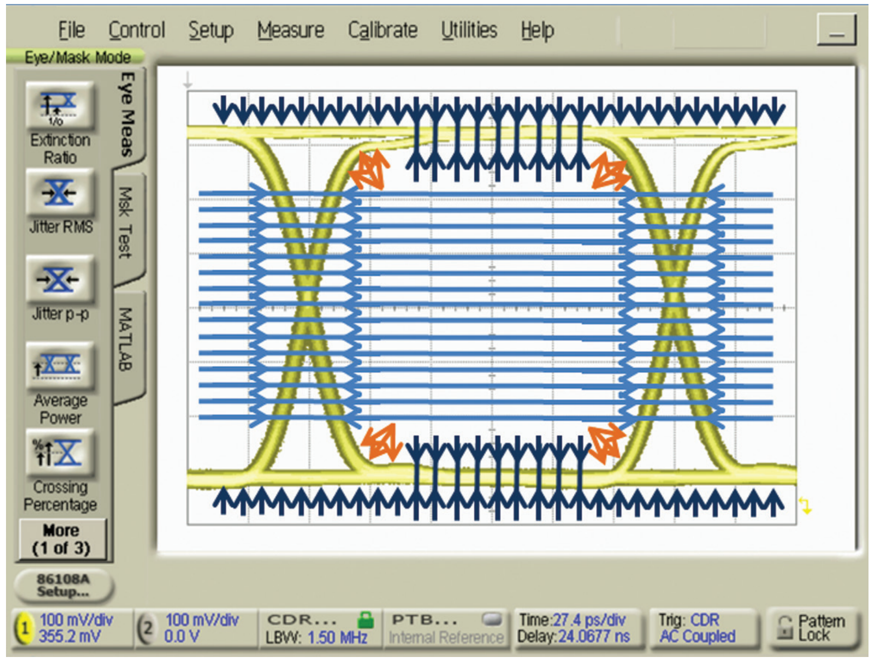


Figure 3 – Eye diagram showing CGS data that contains jitter information only (horizontal arrows), amplitude information only (vertical arrows), and samples heavily influenced by both jitter and amplitude effects (diagonal arrows).

Note – The actual database contains significantly more lines of resolution.

The Q-Scale and Total Jitter/Interference

After the data has been acquired, the PDF is integrated and converted into a Cumulative Distribution Function (CDF). The data is then analyzed using a Q-scale (see Keysight White Paper 5989-3206EN[4] for more information on the Q-scale). By definition, Deterministic Jitter (DJ) has a bounded probability, meaning its probability of introducing jitter into the system goes to zero at some point. The point below the lowest DJ probability is where the data on the Q-scale becomes linear (a straight line) and the inverse slope of the line in this linear region defines the random jitter (RJ) on the signal.

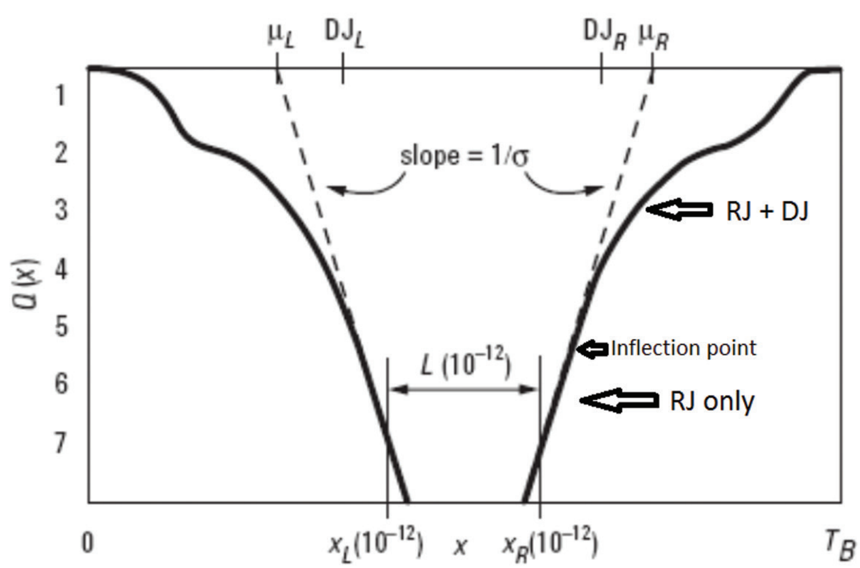


Figure 4 – When plotted on a Q-scale, the data will be a straight line when it is dominated by random jitter effects.

The Q-Scale and Total Jitter/Interference

As seen in Figure 5, this point can change depending on PRBS pattern length – the longer the PRBS sequence, the lower the inflection point on the Q-scale.

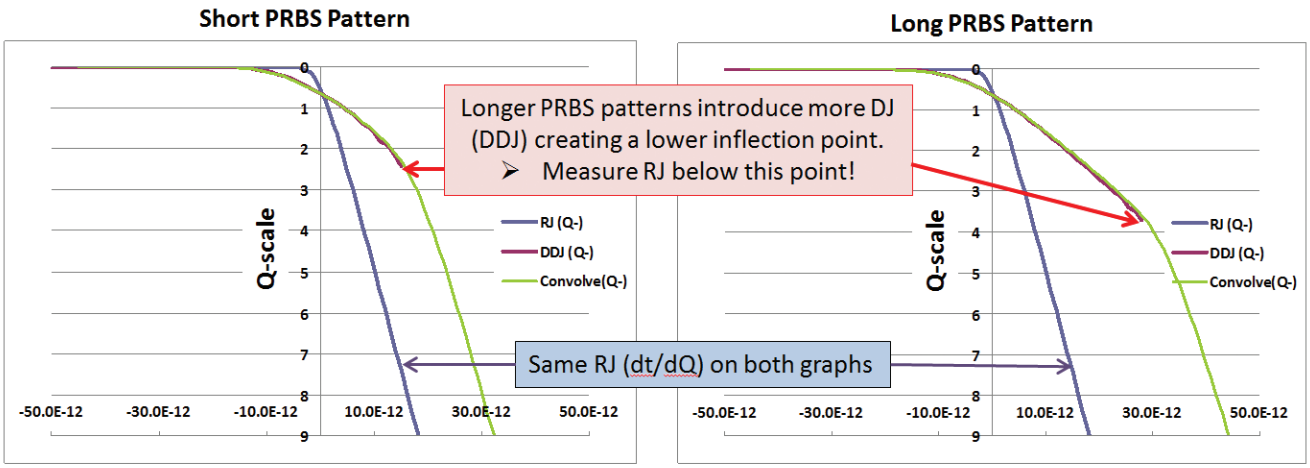


Figure 5 – Increasing PRBS pattern length increases DDJ and lowers the inflection point on a Q-scale plot.

After the data is acquired, a statistical fit is applied to determine the RJ (the inverse slope of the line). Knowing the eye opening, the inverse slope of the line (dt/dQ), and Q, the software determines DJ at the transition density (TD) of the pattern (TD = 0.5 for PRBS patterns). Finally, Total Jitter (TJ) can be found at any desired probability using:

$$TJ\ (@\ BER) = 2Q{*}RJ + DJ \qquad \text{Equation 1}$$

A similar approach is used to measure random noise (RN), deterministic interference (DI), and Total Interference (TI) at a specified BER.

$$TI\ (@\ BER) = 2Q{*}RN + DI \qquad \text{Equation 2}$$

BER Contours

Sampling scopes, due to their unmatched signal fidelity, continue to be the de facto standard for mask testing. Mask margin (expressed as a %) is calculated by expanding traditional mask vertices until a mask violation occurs or it exceeds a mask hit ratio (see Figure 6b). However, some Implementation Agreements like CEI 2.0 and XFP MSA specify an eye mask test based on a BER such as 1E-12. While these masks can be modified and run using traditional scope-based mask testing, Option 401 performs mask testing based on BER contour masks.

BER-based masks use a statistical approach to mask testing, which prevents data outliers, commonly caused by random jitter/noise or low-probability DJ, from reducing mask margins and increasing measurement variability (compared to the traditional mask testing approach).

Section 1: 86100DU-401 Advanced Eye Analysis – Measurement Methodology

BER Contours

Based on a user-specified BER, the Advanced Eye Analysis software uses the TJ and TI information to compute lines of constant BER and plot them on the eye diagram (note that a combination of both TJ and TI values is used in order to compute BER contours along the inside corners of the eye diagram). The eye contour is compared to the BER mask, and a pass/fail determination is reported. So long as the calculated eye contour does not encroach upon the mask, a PASS is reported; that is, the signal will operate to that BER level or better. Not only does the BER-based (statistical) approach to mask testing improve measurement repeatability, but the test can also be completed with far fewer samples compared to traditional mask test methods, thereby saving test time.

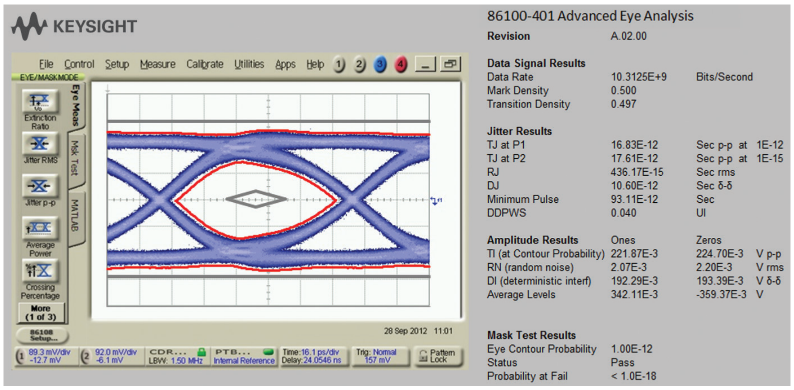


Figure 6a Eye diagram showing BER contour lines (red lines) and BER-based mask (grey lines).

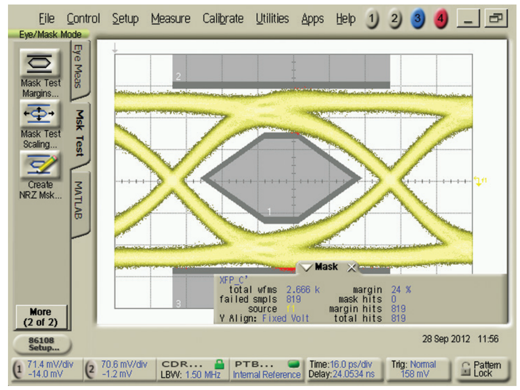


Figure 6b - Right: Traditional eye mask testing expands a mask to determine mask margin.

The "Long Pattern" Challenge

When measuring random jitter in the presence of low probability deterministic jitter, the challenge is to make certain that a sufficient sample size has been acquired so as to ensure that analysis is being performed in the linear region (see Figure 5). If not, the statistical fit used to determine RJ can be negatively influenced by a small amount of low-probability DJ.

In other words, if the statistical fit is performed on a region of the data that is non-linear on the Q-scale, RJ will be over-reported and TJ results will be too high. To mitigate this issue, Option 401 employs a proprietary "filtered Q-scale" technique making the measurement less susceptible to extremely low-probability DJ samples.

Progress Chart – How long does a measurement take?

Option 401 also divides each measurement into several sub-measurements and reports TJ and TI results on a progress chart (similar to a strip chart). The progress chart not only provides users with preliminary jitter results and feedback on measurement progress, but it can also be used to determine whether a sufficient sample size has been acquired to yield an accurate result.

If results from three or more consecutive measurements converge upon a single TJ value (indicated by a flat line on the graph), it indicates that the measured values of RJ and DJ (used to calculate TJ) have stabilized – see Figure 7. Additional data acquisition will have limited benefits and simply increase test time.

Section 1: 86100DU-401 Advanced Eye Analysis – Measurement Methodology

Progress Chart – How long does a measurement take?

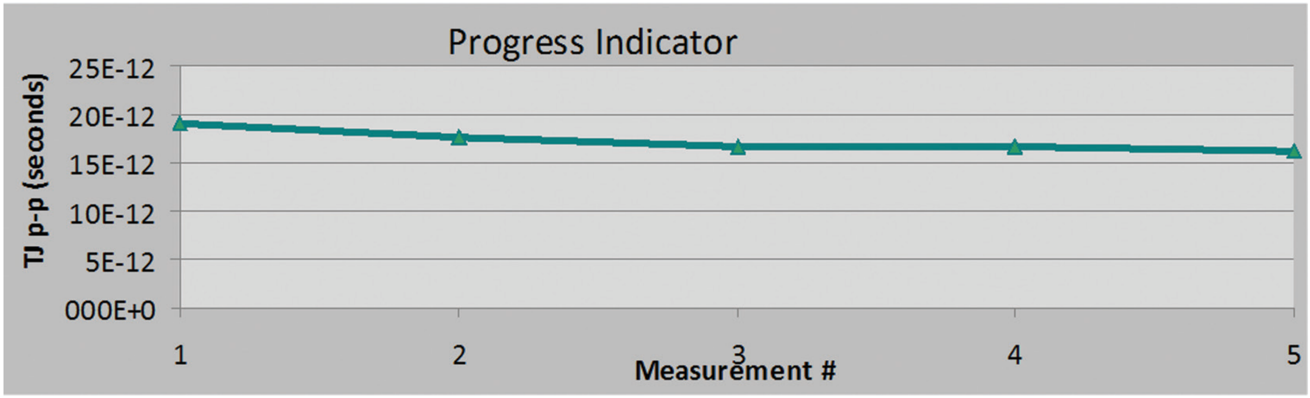


Figure 7 – Progress Chart indicating good stabilization of total jitter results.

However, should the Progress Chart not converge for three or more consecutive measurements, it is an indication that the measurement time (or number of samples) should be increased – see Figure 8.

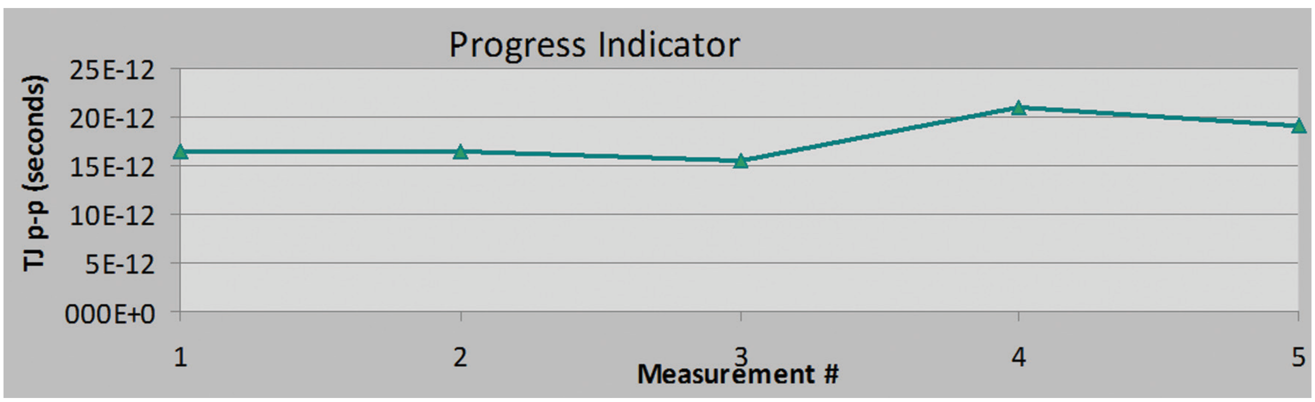


Figure 8 – Progress Chart indicating additional measurement time (more samples) is required to yield an accurate result.

Increased jitter accuracy using Option 200/300 Enhanced Jitter and Amplitude Analysis

The CGS database from Eye/Mask mode contains all types of random and deterministic jitter. As mentioned earlier, Option 401 separates random jitter from deterministic jitter using a statistical fit on low-probability jitter. However, given that long patterns such as PRBS-31 can generate low-probability deterministic jitter that appears to be random, accurate RJ measurements can be very challenging when using "fitting" techniques (often referred to as "tail-fit" algorithms).

Option 401 also allows users to leverage the strengths of 86100D-200/300 Enhanced Jitter and Amplitude Analysis software (Jitter Mode) to yield faster, more accurate jitter measurements. Due to its targeted sampling technique, Jitter Mode only needs to separate RJ from the presence of periodic jitter (PJ). It does not have to separate RJ in the presence of other significant DJ components such as Data Dependent Jitter (DDJ) and Duty Cycle Distortion (DCD). As a result, the measurement quickly converges to an accurate RJ result when analyzing patterns that are 2^16 bits in length or shorter.

Option 200 Enhanced Jitter Analysis and Option 401 Advanced Eye Analysis complement each other in a two-step procedure:

1. Configure the DUT to transmit a short pattern such as PRBS7
   – Use Option 200/300 to measure random jitter and noise (RJ and RN).
2. Prompt the user to change the DUT and have it transmit a longer pattern such as PRBS31
   – Use Option 401 to measure deterministic jitter and interference (DJ and DI).

Option 401 automatically controls both steps and then calculates TJ/TI based on the two measurements. As an alternative to using Jitter Mode to measure RJ, users also have a choice of using RJ results acquired by other means (for example, using a spectrum analyzer measurement of a clock signal).

When RJ is measured using the method outlined in Step 1 (or spectrum analyzer), the RJ value determines the slope of line on the Q-scale for the measurement performed in Step 2. Strictly speaking, RJ should not change if only the pattern has changed. However, due to amplitude noise on the signal (from the DUT and the oscilloscope) in combination with a slower slew rate on some edges of the new pattern, some AM to PM conversion can occur, which may increase RJ slightly.[5] How significant of an increase in RJ depends on the amount of noise in the system and the number of new bits that have slower slew rates. Since sampling scopes have extremely low noise samplers, normally this increase in RJ is negligible compared to other sources of measurement error (other sources include the error in fitting a model to low-probability data and the impact of non-ideal clock recovery designs).

Section 2: 86100DU-401 Advanced Eye Analysis – The Graphical User Interface (GUI)

The User Interface – An Overview

86100DU-401 Advanced Eye Analysis is a Microsoft Office Excel workbook that controls an 86100D DCA-X via LAN or GPIB. The workbook sheet labeled "GUI" configures the instrument, starts the measurement, and automatically transfers data acquired by the 86100D to the workbook for processing.

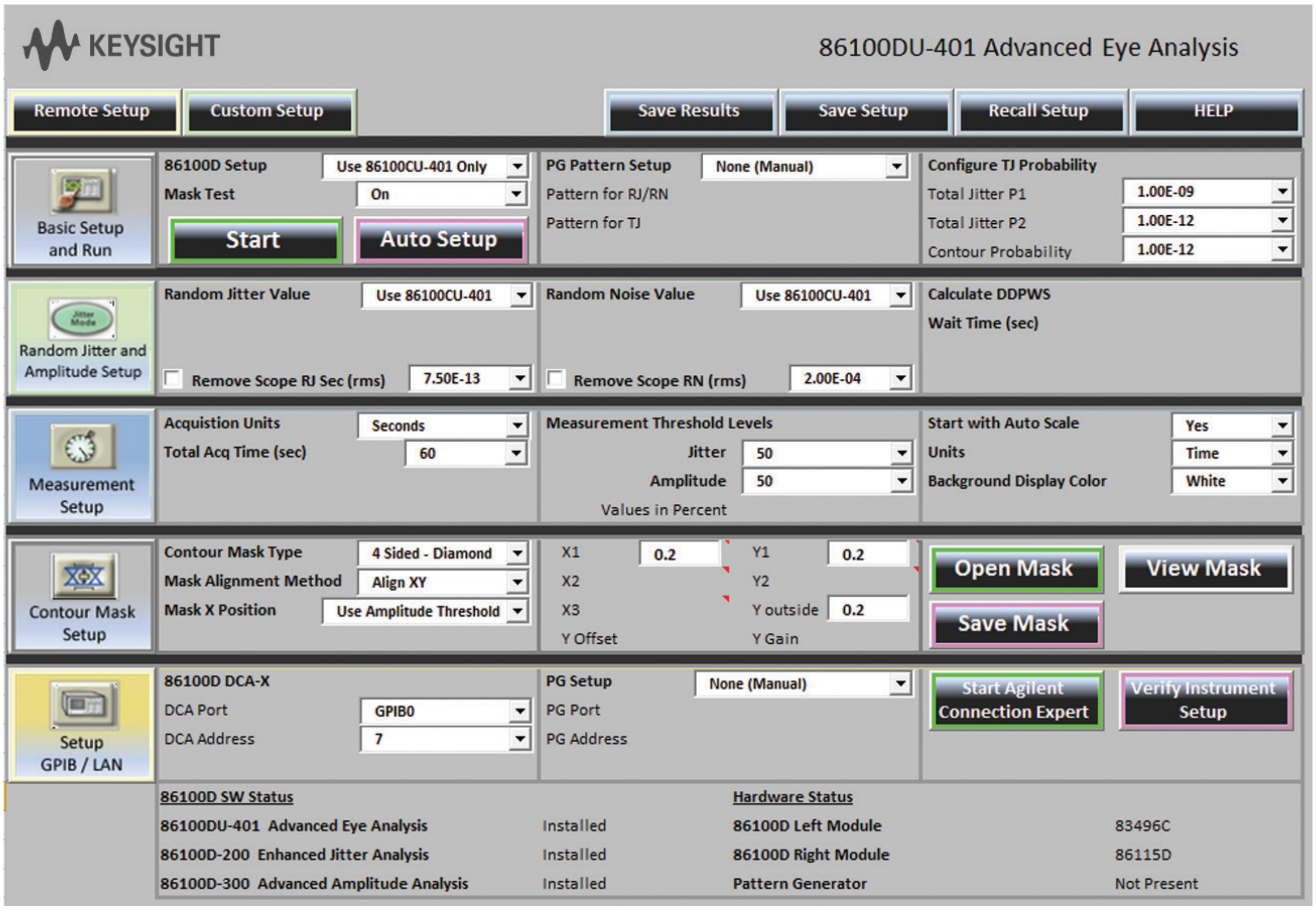


Figure 9 – 86100DU-401 Advanced Eye Analysis "GUI" page is used for setting up jitter and mask measurements.

1. Basic Setup and Run

a. "86100D Setup" – Configure which software analysis tools to use. It's recommended to use 86100D-200/300 when available.

b. "Start" button – Click Start to begin an Advanced Eye Analysis measurement. To cancel a measurement, repeatedly press the Escape (Esc) key.

c. "Auto Setup" button – Click Auto Setup and the application queries the 86100D for available software options and hardware, and then configures Option 401 for optimal accuracy.

d. "PG Pattern Setup" – Configure a Pattern Generator (PG) and PG patterns (optional). When configured, Option 401 will automatically control the PG during the measurement.

e "Configure TJ Probability" – Configure user-specified jitter and BER contour probabilities. These values may also be changed after the data has been acquired. The results will automatically be updated whenever a change is made.

Section 2: 86100DU-401 Advanced Eye Analysis – The Graphical User Interface (GUI)

The User Interface – An Overview

2. Random Jitter and Amplitude Setup

a. "Random Jitter Value" – Configure the RJ analysis method to use (86100D-200 recommended, if available). "Manual" allows users to enter in RJ values measured using a Spectrum Analyzer, for example. .

b. "Remove Scope RJ" – Allows users to Root Sum Square (RSS) out a user-specified value from the jitter results (example – remove intrinsic jitter generated by the test equipment).

c. "Random Noise Value" – Configure the RN analysis method to use (86100D-300 recommended, if available).

d. "Remove Scope RN" – Allows users to RSS out user-specified value from the amplitude results (example – remove intrinsic noise generated by the test equipment; measure using Vrms (AC)).

e. "Calculate DDPWS" – Calculated using DDJ vs. Bit information when 86100D-200 is enabled.

f. "Wait Time" – Determines how long to wait for Jitter Mode to run after valid RJ/RN results are reported.

3. Measurement Setup

a. "Measurement Units" – Configure seconds or samples. "Single Capture" is used for demo purposes.

b. "Total Acq Time/Samples" – Specifies how long (or how many samples to acquire) in Eye/Mask mode.

c. "Measurement Threshold Levels"

   i. Jitter – Specify the percentage of eye amplitude where deterministic jitter (DJ) is measured.

   ii. Amplitude – Specify the percentage of Unit Interval (UI) where the Deterministic Interference (DI) is measured.

d. "Start with Autoscale" – This setting allows users to continue the Eye/Mask mode measurement without clearing data that has already been acquired.

e. "Units" – Choose to display measured jitter results in units of Time (seconds) or Unit Intervals (UI). DDPWS (if enabled) is always displayed in terms of UI. Amplitude Results are always reported in terms of Volts (V) or Watts(W), based on the units selected on the 86100D channel setup.

f. "Background Display Color" – Select the background color (black or white) for the 86100D screen capture displayed on the Results sheet.

Section 2: 86100DU-401 Advanced Eye Analysis – The Graphical User Interface (GUI)

The User Interface – An Overview

4. Contour Mask Setup

a. "Contour Mask Type" – Select the type of BER contour mask based on shape and number of vertices.

b. "Mask Alignment Method" – Select to align the mask to X-axis only (fixed voltage mask) or to both the X-axis (time) and the Y-axis (amplitude).

c. "Mask X Position" – Defines the mask's location along the X-axis.

d. "Polygon Shape Area" – Defines BER contour-based mask.

e. "Open Mask" – Opens saved mask.

f. "View Mask" – The mask is displayed in the Excel workbook. Changes are updated as you enter new values into the Mask Polygon Shape Area.

5. Setup GPIB/LAN

a. "DCA Port" – This is the address of the GPIB or LAN port where the 86100D is located. If the application is installed on the 86100D itself, this field should be set to TCPIP0.

b. "DCA Address" – GPIB address of the DCA when using GPIB (default is 7). If using TCPIP (LAN), enter the host name of the DCA. If the application is installed on the 86100D, this field should be set to "localhost."

c. "PG Setup" – If you are controlling your device manually or through another program, select None (Manual) for this field. Otherwise, for automatic control of a PG, select the Keysight model number.

d. "Start Keysight Connection Expert" – If experiencing communication issues, this button opens the connection expert where you can view the GPIB/LAN settings for your 86100D and/or PG.

e. "Verify Instrument Setup" – Click this button after making all your selections on the worksheet to display the 86100D software and hardware status.

Section 3: 86100DU-401 Advanced Eye Analysis – Installation and Setup

This section provides step-by-step instructions on how to install and configure the application in preparation for a measurement. For detailed setup instructions, complete with video clips, please refer to the 86100DU-401 online HELP file (included with the Advanced Eye Analysis download).

A. Initial Installation and Setup

– Software Prerequisites for your PC (or your 86100D DCA-X mainframe):
  – Microsoft Office Excel 2007/2010 (user supplied)
  – Keysight IO Libraries Suite 15.0 (or later)

a. Install the "Advanced Eye Analysis" Application
   Download and install the 86100DU-401 application onto your PC. The application is available for download from www.keysight.com/find/eye (click the "Trials and Licenses" tab).
   Note – you may also install MS Excel (not included) and the application on your 86100D.

b. Install Software License
   Install the 86100DU-401 software license onto your 86100D mainframe. If you have not yet purchased Option 401, a 30-day trial license may be generated from www.keysight.com/find/eye.

c. Connect Hardware
   Connect your PC to the 86100D DCA-X mainframe using a Keysight 82357B USB-GPIB Adapter. Alternatively, a LAN connection may also be used.

d. Setup GPIB/LAN Connection
   i. Open the application and click on the <Setup GPIB/LAN> button to raise the shade that hides the input fields. Enter the DCA Port/Address information. If you do not know this information, click the <Start Keysight Connection Expert> button, locate the DCA, and take note of the Port/Address information. See Appendix A for detailed LAN setup instructions.

Figure 10 – Use the Keysight Connection Expert to locate DCA Port/Address information.

   ii. To verify that the application is connected to the 86100D, click the <Verify Instrument Setup> button. If a valid connection exists, the 86100D SW Option and module HW information will be updated with data that reflects your setup.

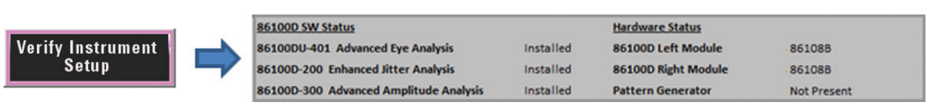


Figure 11 – Press the "Verify Instrument Setup" button to check the communication link between the 86100DU-401 application and your 86100D mainframe.

Section 3: 86100DU-401 Advanced Eye Analysis – The Graphical User Interface (GUI)

e. Setup the "Advanced Eye Analysis" Application (for optimal measurement accuracy)
   i. Click the <Basic Setup and Run> button to open the shade (if not already open).
   ii. Click the <Auto Setup> button. This will determine which 86100D software options are available to the application and optimize the measurement setup accordingly. (If 86100D-200/300 are available, it will use them.)

Figure 12 – The <Auto Setup> button optimizes measurement accuracy based on available 86100D options.

   iii. Mask Test = On (optional)
   iv. Click the <Measurement Setup> button to open the shade (if not already open).
   v. Total Acq Time = 120 seconds.

Note - Measurement time will vary depending on the DUT and pattern length. You can adjust (increase/decrease) the test time based on Progress Chart flatness.

B. Programming 86100DU-401 Advanced Eye Analysis

Option 401 is ActiveX-aware and may be controlled via a remote program. Programming examples are available upon request (contact your local Keysight Applications Engineer).

Section 4: 86100DU-401 Advanced Eye Analysis – Measurement Example

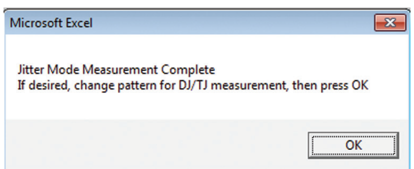
The following section outlines basic operation of Keysight 86100DU-401 Advanced Eye Analysis and includes step-by-step instructions on how to perform a measurement that leverages the 86100D-200/300 Enhanced Jitter and Amplitude Analysis feature (best accuracy).

A. Set up the 86100D DCA-X Mainframe

a. Configure the measurement channel (for example, set up a differential signal), clock recovery (if required), and enable the precision timebase (if available), as appropriate.
b. Ensure an eye diagram of your signal can be displayed on the 86100D DCA-X mainframe.

B. Making Measurements

a. Step 1 - Measure RJ and RN using a short pattern
   i. Configure your device (DUT) to transmit a PRBS7.
   ii. In the Option 401 application, click the <Start> button.
   The application will launch Jitter Mode and make a jitter measurement on the short pattern. When complete, the application will pause and prompt the user to change the pattern (if desired).

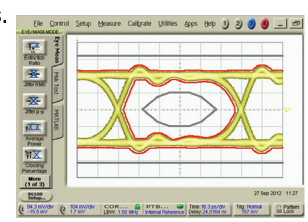


b. Step 2 - Measure DJ and DI using a long pattern

   i. When prompted by Option 401, configure your device (DUT) to transmit a long pattern, such as PRBS31.
   The application will switch the DCA to Eye/Mask mode and continue the measurement. It will acquire data for the time/samples specified in the <Measurement Setup> section of the application.
   ii. Click on the <Results> tab. The Progress Chart will provide updated jitter information with each sub-measurement. Users should expect to see the results converge (stabilize) over several measurements. If not, increase the test time (or number of samples).
   For Progress Chart examples, see Figures 7 and 8 above.

C. Analyzing the Results

a. View Results - Click on the <Results> tab to view the Option 401 measurement results.
   i. Eye/Mask Screen Capture
      – A screen capture of the eye diagram is displayed.
      – BER contour lines are overlaid on the eye diagram.
      – If Mask Testing = Yes, the BER based mask will be displayed on the eye diagram



   ii. Progress Indicator
      Examine the progress indicator. Ideally the TJ/TI results will have converged towards a stable value for several consecutive measurements. If not, increase measurement time (or samples) so as to acquire more data for the analysis. If it remained stable for more than three consecutive measurements, you try reducing measurement time or acquire fewer samples. For Progress Chart examples, see Figures 7 and 8 above.

III Data Signal Results
- – Data Rate
- – Mark Density
- – Transition Density

Data Signal Results		
Data Rate	10.3125E+9	Bits/Second
Mark Density	0.501	
Transition Density	0.495	

IV Jitter Results
- – TJ is calculated at two user-specified probabilities
- – RJ – Random Jitter
- – DJ – Deterministic Jitter
- – Minimum Pulse Width (if Option 200 is used and DDWPS setup = Yes)
- – DDPWS (if Option 200 is used and DDWPS setup = Yes)

  Note – Change "Units" from sec to UI in the Measurement Setup section of the GUI tab

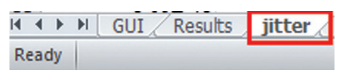
Jitter Results			
TJ at P1	9.57E-12	Sec p-p at	1E-12
TJ at P2	10.38E-12	Sec p-p at	1E-15
RJ	452.81E-15	Sec rms	
DJ	3.11E-12	Sec δ-δ	
Minimum Pulse	94.77E-12	Sec	
DDPWS	0.023	UI	

V. Amplitude Results - for Zero and One levels
- – TI (at user-specified contour probability)
- – RN – Random Noise
- – DI – Deterministic Interference

Amplitude Results	Ones	Zeros	
TI (at Contour Probability)	112.38E-3	108.66E-3	V p-p
RN (random noise)	3.10E-3	2.67E-3	V rms
DI (deterministic interf)	68.13E-3	70.61E-3	V δ-δ
Average Levels	387.07E-3	-406.22E-3	V

VI. Mask Test Results (if Mask Test setup = yes)
- – Eye Contour Probability (user-specified)
- – Pass/Fail Status
- – Probability at Fail – If a mask failure occurred, it reports the probability at the point where the contour line hit the mask.

Mask Test Results	
Eye Contour Probability	1.00E-12
Status	Pass
Probability at Fail	< 1.0E-18



b. Review Jitter Mode Results - When Option 401 is configured, to leverage Option 200/300 for RJ and RN measurements (Step 1 above). The <jitter> tab does not appear unless Option 401 is configured to use Option 200/300. A complete set of Jitter Mode results are exported from the DCA and saved on the workbook's <jitter> tab.

D. Compare jitter results measured using PRBS7 vs. PRBS15 vs. PRBS31.

An informative experiment is to compare how much added DJ is introduced as the PRBS pattern is increased from PRBS7 > PRBS15 > PRBS31. For comparison purposes, measurements were made on a 10.3125 Gb/s signal using both 86100DU-Option 401 and 86100D-200 Enhanced Jitter Analysis software (Option 401 measured DJ and 86100D-200 was used to measure RJ).

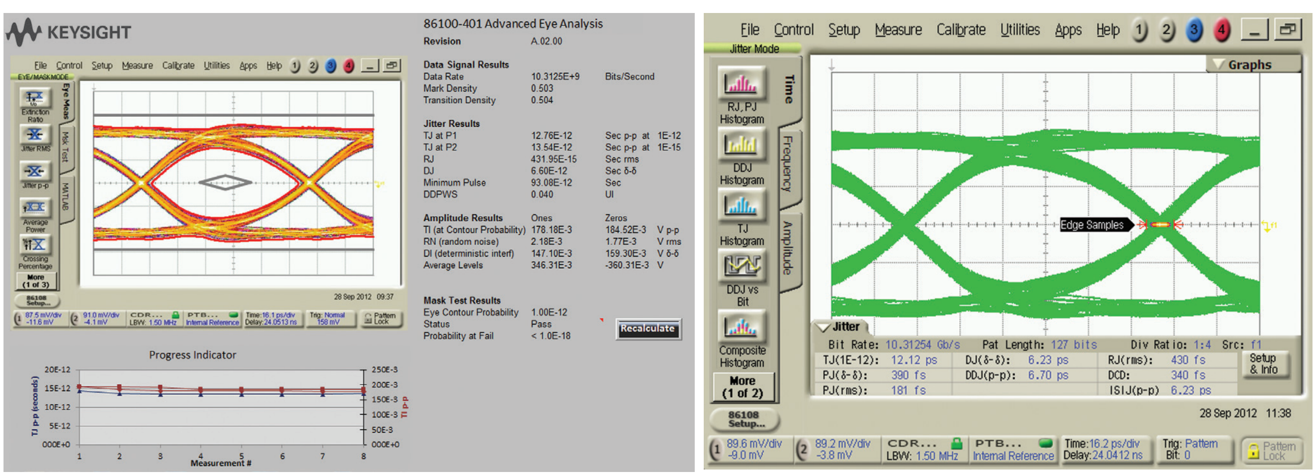


Figure 14 - Measurement performed using a PRBS7 pattern for both RJ and DJ measurements (Steps 1 and 2).
TJ @ 1E-12 = 12.76 ps p-p (Option 401) / 12.12 ps p-p (Option 200 only).

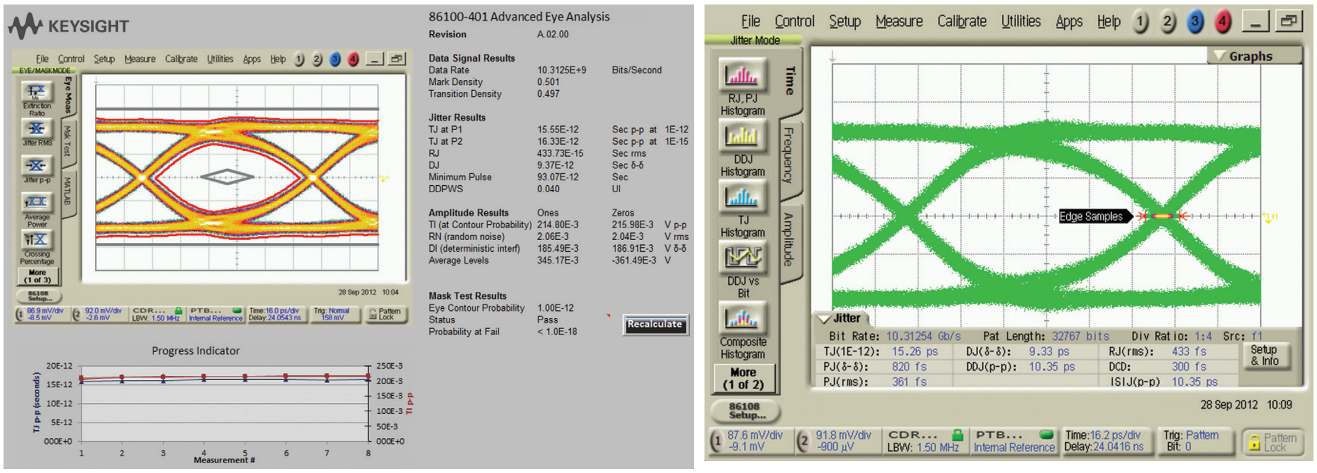


Figure 15 - Jitter results using a PRBS-15 pattern (PRBS7 pattern used for RJ measurement in Step 1).
TJ @ 1E-12 = 15.55 ps p-p (Option 401) / 15.26 ps p-p (Option 200).

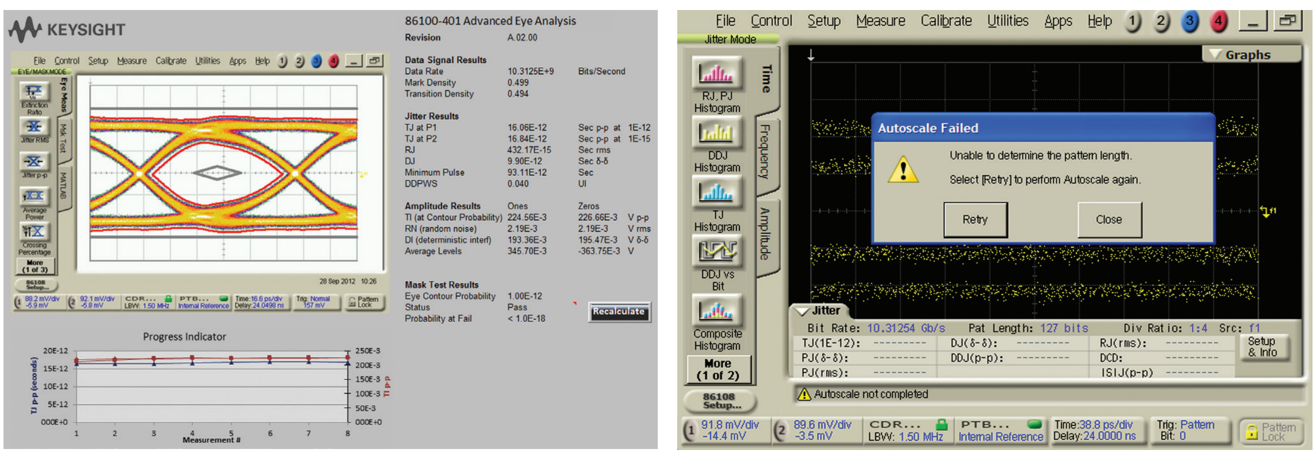


Figure 16 - Jitter results using a PRBS-31 pattern (PRBS7 pattern used for RJ measurement in Step 1).
TJ @ 1E-12 = 16.06 ps p-p (Option 401) / Exceeds pattern length limitation (Option 200).

Table 1. Jitter measurements comparison between 86100DU-401 and 86100D-Option 200.

Jitter Parameter	PRBS7		PRBS15		PRBS31	
	Option 401	Option 200	Option 401	Option 200	Option 401	Option 200
TJ (@ 1E-12)ps pp	12.76	12.12	15.55	15.26	16.06	N/A
RJ fs rms*	432	430	434	433	432	N/A
DJ ps δδ	6.60	6.32	9.37	9.33	9.90	N/A

* All RJ measurements were performed using 86100D-200 on a PRBS7 pattrern.

Deterministic Jitter (DJ) was measured on PRBS-7 and PRBS-15 patterns using both Eye/Mask mode data (Option 401) and Jitter Mode (Option 200). As seen in Table 1, the results correlate very well. DJ was also measured on a PRBS-31 pattern (it exceeds the max pattern length of 2^16 bits for Option 200), and as expected, the DJ increased with increased PRBS pattern length. In all cases, RJ was measured using 86100D-200 on a PRBS-7 pattern for optimal RJ accuracy.

Resultant TJ @ 1E-12 increased by ~ 3.3 ps p-p (from 12.76 ps to 16.06 ps) when the pattern used to measure DJ was changed from PRBS-7 to PRBS-31.

Section 5: Conclusion

Many of today's jitter analysis tools, such as 86100D-200 Enhanced Jitter Analysis software, analyze every edge in the pattern and accurately separate jitter into constituent components. However, for extremely long patterns such as PRBS-31, it is impractical to analyze every edge in the pattern. Why? In order to gather a sufficient number of samples to characterize every edge of a PRBS-31 pattern, today's solutions either run out of memory (real-time scopes), do not acquire data quickly enough (equivalent-time sampling scopes), and/or do not have adequate error detector (ED) delay line accuracy or phase margin performance to make an accurate analysis (BERTs).

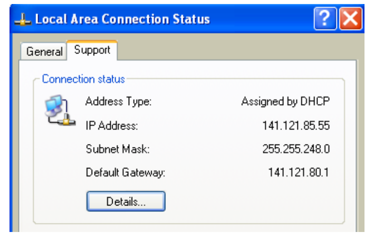
On today's standards that specify use of long patterns such as PRBS-31, measurement tools that estimate total jitter must change their measurement algorithms accordingly. 86100DU-401 Advanced Eye Analysis software overcomes the aforementioned limitations and provides the ability to:

- Measure jitter on any pattern, including PRBS-31 and live traffic
  - Random Jitter (RJ), Deterministic Jitter (DJ), Total Jitter (TJ)
  - J2 and J9 Jitter
- Perform BER contour-based mask testing

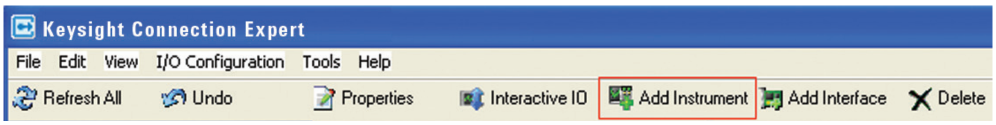
86100D-200/300 Enhanced Jitter and Amplitude Analysis software enhances Option 401 measurement accuracy when using long patterns to characterize today's high-speed devices.

Appendix A – Setting up a LAN connection between your PC and 86100D

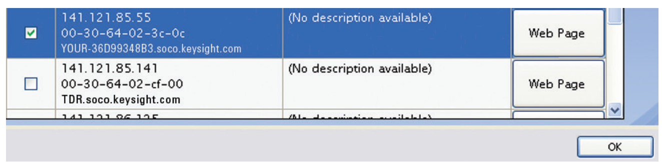
1. Connect a LAN cable to your equipment (recommend DHCP enabled). To find the IP Address assigned to the instrument:
    a. Click Start -> Accessories -> Communications -> Network Connections.
    b. Double-click "Local Area Connection."
    c. Click the "Support" tab.
    d. Record the IP Address. (eg:141.121.85.55)



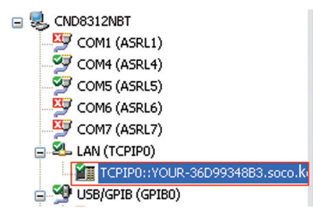
2. Use Keysight IO Connection Expert to find the Hostname:
    a. Click "Add Instrument."



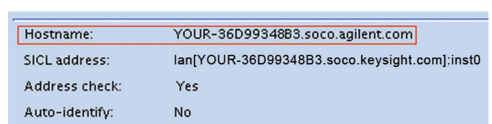
    b. Click "Auto Find."
    c. Locate the IP Address of the instrument from step 1(d) above.
    d. Enable the "Select" box.
    e. Click "OK."



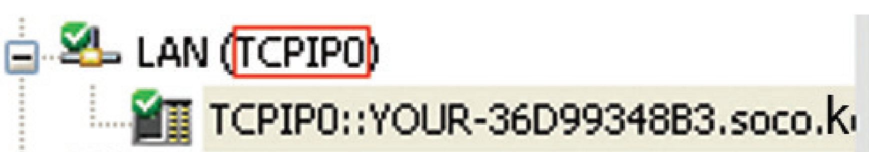
    f. The <hostname> will be displayed on the right hand side of the Keysight IO display.
        – Highlight and Copy (or write down) the hostname.



    g. The <hostname> will be displayed on the right hand side of the Keysight IO display.
        – Highlight and Copy (or write down) the hostname

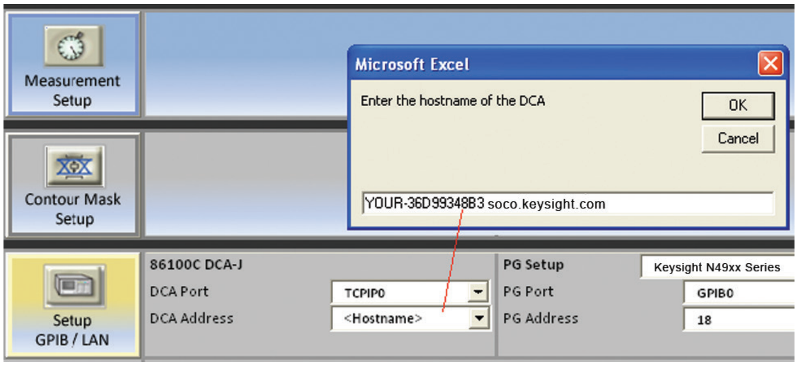


3. Open 86100DU-401 Advanced Eye Analysis and set up the Port/Address info.
    a. Unhide the Setup GPIB/LAN area.
    b. Configure the DCA (or PG) Port = TCPIP0 (or whatever LAN port was assigned to the instrument)

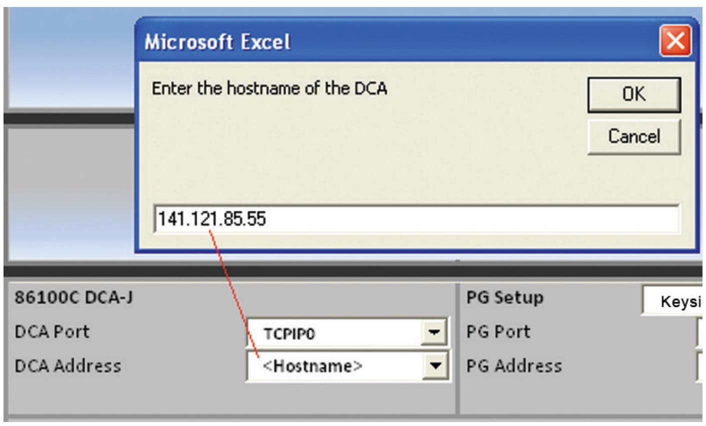


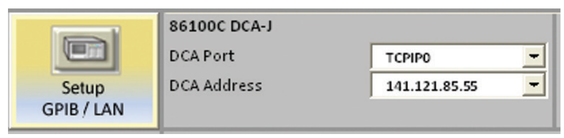
    c. For DCA (or PG) Address, select <Hostname>, and paste the hostname as identified in Step xx above.

Appendix A – Setting up a LAN connection between your PC and 86100D



Alternatively, you can enter the IP address located in step 1(d) above





d. Click <OK>.

e. Click "Verify Instrument Setup."

The application will report the configured instruments and their options.

86100D SW Status		Hardware Status	
86100DU-401 Advanced Eye Analysis	Installed	86100D Left Module	83496C
86100D-200 Enhanced Jitter Analysis	Installed	86100D Right Module	86115D
86100D-300 Advanced Amplitude Analysis	Installed	Pattern Generator	Not Present

You are now ready to start making measurements.

References

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   http://www.oiforum.com/public/documents/OIF_WP_CEI_Short_Stress_Patterns.pdf

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   http://literature.cdn.keysight.com/litweb/pdf/5989-3204EN.pdf

3. "Precision Jitter Analysis Using the Keysight 86100C DCA-J," Application Note 86100C-1, literature number 5989-1146EN

4. "Jitter Analysis: The dual-Dirac Model, RJ/DJ, and Q-Scale," White Paper, literature number 5989-3206EN

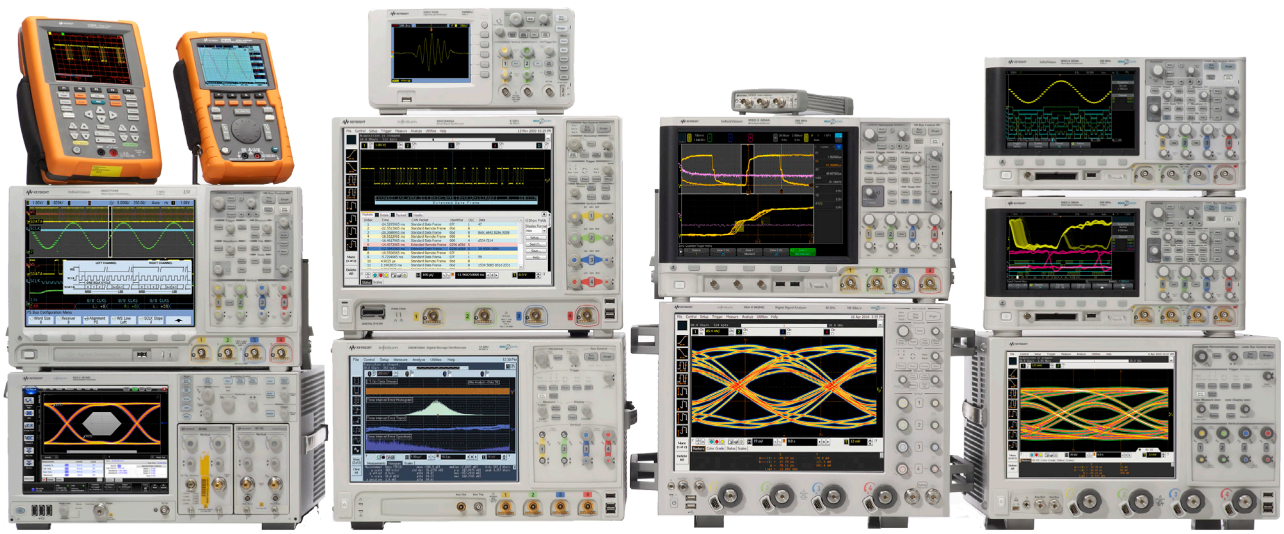
5. "Random Noise Contribution to Timing Jitter—Theory and Practice," Maxim Application Note 3631.
   http://pdfserv.maximintegrated.com/en/an/AN3631.pdf

6. Keysight data sheet for 86100DU-401 Advanced Eye Analysis Software, literature number 5990-3818EN
   http://literature.cdn.keysight.com/litweb/pdf/5990-3818EN.pdf

7. Infiniium DCA-X Keysight 86100D Wide-Bandwidth Oscilloscope Mainframe and Modules, Technical Specification, literature number 5990-5824EN.
   http://literature. cdn.keysight.com/litweb/pdf/5990-5824EN.pdf

8. Optical Internetworking Forum, Common Electrical I/O -- Electrical and Jitter Interoperability agreements for 6 G + bps, 11 G + bps and 25 G + bps I/O, Implementation Agreement # OIF-CEI-03.0

Publication title	Publication type	Publication number
Precision Jitter Transmitter	White Paper	5989-3204EN.
Precision Jitter Analysis Using the Keysight 86100C DCA-J	Application note	5989-1146EN
Jitter Analysis: The dual-Dirac Model, RJ/DJ, and Q-Scale,	White Paper	5989-3206EN
86100DU-401 Advanced Eye Analysis Software	Data sheet	5990-3818EN
Infiniium DCA-X Keysight 86100D Wide-Bandwidth Oscilloscope Mainframe and Modules	Technical Specification	5990-5824EN



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Published in USA, August 2, 2014
5991-1284EN
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