# Techniques to Reduce Manufacturing Cost-of-Test of Optical Transmitters, Flex DCA Interface

## Application Note
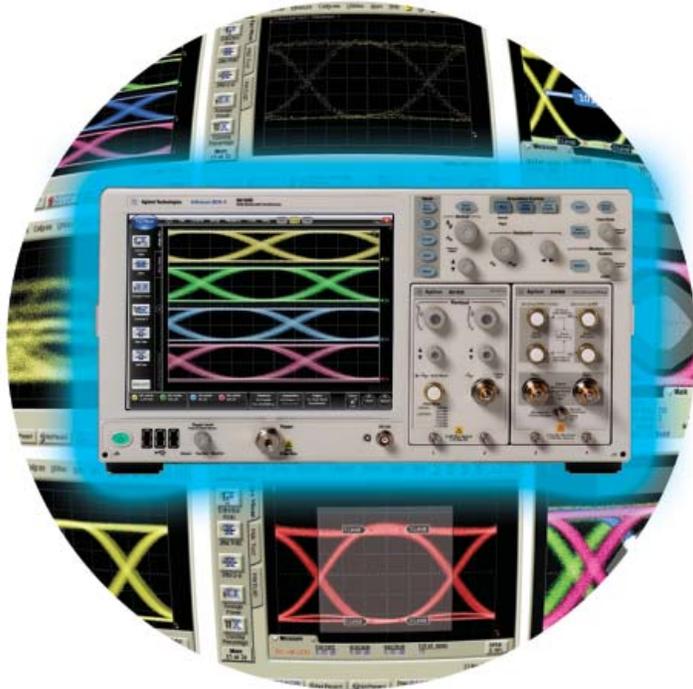
## Introduction

Manufacturers of optical transceivers are faced with increasing challenges to their businesses, particularly how to reduce product costs. Pressures to reduce costs as data rates rise means manufacturing engineering managers and their engineers must be more creative in how to reduce costs before their competitors do. Traditional methods of eliminating tests or trying to make tests run faster may not be feasible, may not yield the intended benefit or may provide results that don't agree well with their customer's measurements. The use of parallel testing has enabled some improvements, but challenges in capturing and organizing measurement results for multiple channels have precluded the fully desired improvements.

Agilent continues innovating test methodologies to assist manufacturing engineers in meeting or beating cost-of-test reduction goals. This application note describes several techniques that Agilent has created and improved to remotely program the DCA mainframes, to choose the appropriate tests, and to objectively determine just how much testing is required. Improvements in test station throughput of 2X to 17X can be achieved by applying these techniques, resulting in a cost of test of a few cents per transmitter.

## Agilent Technologies

# Common Transceiver Types and Manufacturing Flows

The number of communications standards and transceiver types has proliferated during the last decade creating more complexity for the typical manufacturing test facility. Mass market and other high volume transceivers typically have fewer tests and less temperature cycling. More complex transceivers at higher data rates have more extensive tuning, temperature cycling and challenges to meet high desired yields.

The current standards, packages and typical channel characteristics are summarized in the table below. The least complex transceivers follow a test flow similar to Figure 1, where the transceivers that do not pass the first test are re-worked and re-tested. The most complex transceivers follow a test flow similar to Figure 2, where two or three temperature levels are common to assure the transceivers will work in demanding networks and environments.

## Characteristics for common optical communications standards

| Standards | Package types | Channel rates, Gb/s | Optical transmitters per device | Manufacturing test flow |
|---|---|---|---|---|
| • Fibre Channel to 4X<br>• SONET/SDH to OC-48<br>• Gigabit Ethernet<br>• Wireless CPRI<br>• Passive Optical Network | SFP, SFF and PON | 0.155 to 6.25 | 1 | Figure 1 |
| • Fibre Channel to 16X<br>• 10G and 40G Ethernet | SFP+ and XFP | 1 to 14 | 1 | Figure 1 or Figure 2 |
| • 10G, 40G and 100G Ethernet<br>• SONET OC-192 | QSFP and CFP | 10 to 26 | 4, 8, 12 | Figure 2 |
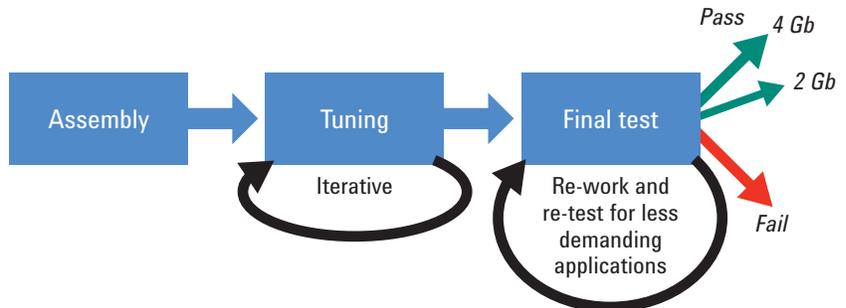


*Figure 1. Typical manufacturing flow for simpler and less expensive devices.*
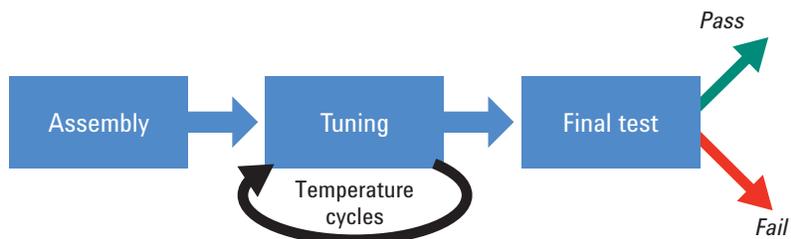


*Figure 2. Typical manufacturing flow for more complex devices.*

2

# Innovations to Reduce Cost of Test

The ultimate goal of Agilent's approach is to provide a sufficiently accurate answer, very quickly, which is enabled by these recently introduced capabilities:

- *Parallel characterization* of multiple devices, or characterization of parallel optics

- *Improved autoscale performance:* Several enhancements, including entering the data rate, cut autoscale time by 50% (available in Flex DCA version A.01.60 and later). See page 4.

- *Multi-channel autoscale:* Align more than one eye so the developer and operator can quickly display and measure multiple eyes and obtain measurements on transceivers (available in Flex DCA version A.01.60 and later). See page 4.

- *Eye Tuning:* Fast and intuitive tool to allow the operator to quickly tune laser parameters for optimal eye (available in firmware version A.09.01 and later). See page 7.

- *Rapid Eye:* New technique that improves acquisition speed by 1.3X to 5X and improves measurement accuracy (available in Flex DCA version A.01.60 and later). See page 9.

- *Faster eye mask testing:* Auto mask margins, choosing just enough samples and appropriate order of test commands improves mask test times by 3X to 5X (available in firmware version A.08.00 and later). See page 16.

- *Just enough test:* Use mask margin uncertainty to optimize sample size (acquisitions) for the required accuracy (available in Flex DCA version A.01.60 and later). See page 18.

- *Use the SCPI recorder:* This quickly shows the user the appropriate remote command while exercising the desired commands from the front panel (available in Flex DCA version A.01.60 and later). See page 23.

- *Quickly capture screen image of individual devices:* When testing multiple devices in parallel, enables developer or operator to save individual channel screen captures for use in test reports and for end customer (available in Flex DCA version A.01.60 and later). See page 27.

- *Improved parallel testing:* The combination of the above innovations greatly reduces test times on multiple DUT's while maintaining accuracy.

- Please refer to Appendix A for earlier features that also enable lower cost-of-test.

Implementing these innovations in your production line can improve by 2X to 10X the number of units tested per station per year, and result in a 2X to 5X improvement in the cost-of-test per transmitter. The contribution of the 86100D to the cost of producing a transmitter can be as low as one or two cents.

The Digital Communications Analyzer (DCA) has two user interfaces, the common interface of the 86100A, B, C and D and the new Flex DCA, which has some differences in dialogue boxes, features and remote commands. This document covers the Flex DCA interface. For the common DCA interface, please refer to the companion Application Note.

# Save Time When You Align Multiple Channels

Each time a new device under test is started or large changes in the measured parameters occur, autoscale is performed to optimally display an eye-diagram and obtain the most accurate results. While this is quick when measuring one channel, users can benefit from an even quicker autoscale for improved cost of test. With the introduction of the 86115D multi-channel optical reference receivers, users can now measure four optical channels with one mainframe. When measuring four channels *individually*, the total time of autoscale during the test sequence can be almost four times as long as when measuring four channels in *parallel*. This section addresses improvements in autoscale speed.

The user would like to autoscale all channels at once, but rarely are the eye crossing points aligned between channels, as shown in Figure 4a. Therefore one or two of the eyes are skewed where key measurements are not able to be done. The user can change the horizontal scale to include two eyes, which spreads the acquired samples over more unit intervals while the measurements are still based on the statistics of one UI.

A more effective approach is to adjust the delay between the multiple channels, which is accomplished through the mainframe software. You enable the software delay capability using the dialogue in Figure 3, resulting in eyes aligned as shown in Figure 4b. A quick method to adjust the skew between channels is to click **Align Channels During Auto Scale**. If you prefer manual adjustments, look at the eyes displayed on the screen to find which channel is aligned to the center of the screen. Next increase or decrease the Horizontal Adjustment, Software Delay for each of the other channels so the eye crossings for all eyes are aligned. This adjustment is required only the first time that a new physical configuration is used; if optical cables are not changed, the skew values will be valid when testing subsequent devices. An even quicker method of de-skewing the channels is covered in the later section on the new Rapid Eye feature.

The autoscale capability works well whether the channels are aligned or not aligned; the time to autoscale is slightly longer when channels are aligned. This is because the default acquisition period is based on the time base settings and covers about 1.6UI if displaying one eye. For the eyes on channels that have been aligned, the mainframe needs to take additional samples to the right or left of the eye that is fully on screen to capture samples for the adjusted eye.

# Save Time When You Align Multiple Channels
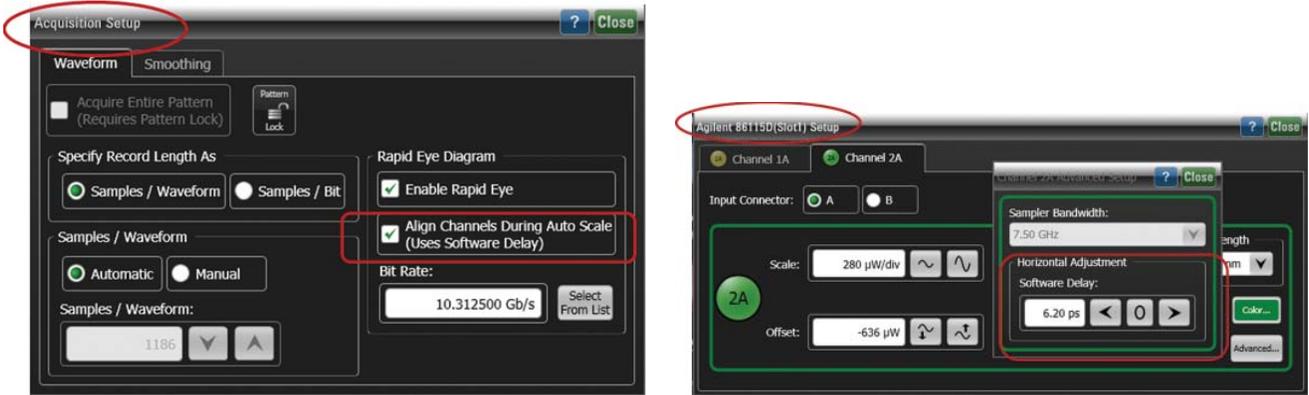


Figure 3. Dialogue boxes for software delay of channels. Dialogue to select Auto or Manual is on the left. Manual adjustment dialogue is on the right.
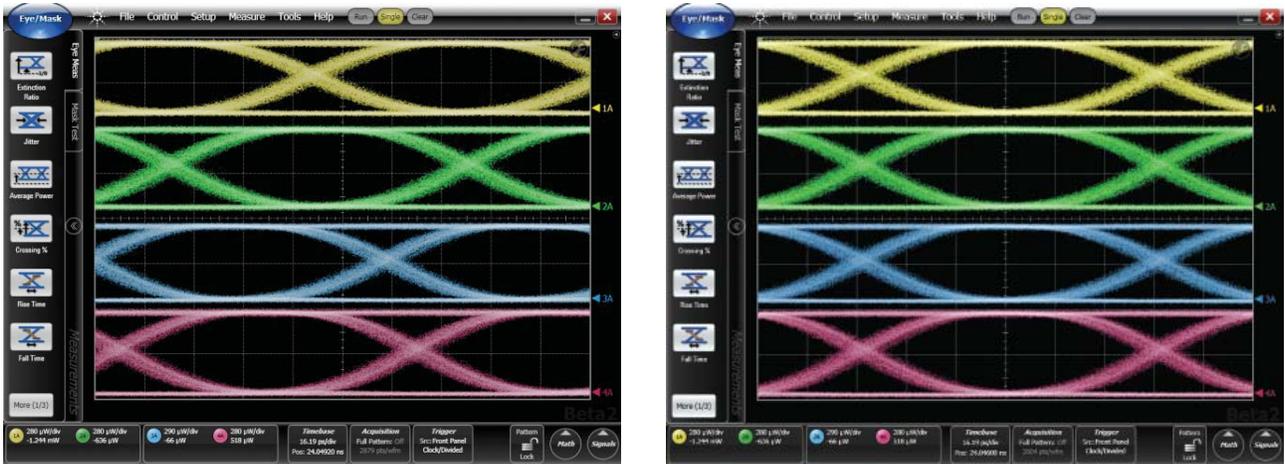


Figure 4a and b. Typical eye diagrams where eyes are not aligned and are aligned.

# Take Advantage of Even Faster Autoscale

Previously the autoscale function determined the bit rate of the incoming data stream and performed the autoscale, which takes a little time. The autoscale functionality in the Flex DCA interface has been significantly enhanced and provides the improvements shown in the next table.

|  | Classic DCA autoscale | Flex DCA autoscale | Speed improvement |
|---|---|---|---|
| One channel | 1.6 sec | 1.0 sec | 1.6X |
| Two channels | 2.2 sec | 1.2 sec | 2.2X |
| Four channels | 2.8 sec | 1.3 sec | 2.2X |

### Remote commands for autoscale (firmware A.01.02 or later)

For autoscale          :SYSTem:AUToscale
                       *OPC?

# Save Time When You Tune Lasers

Many lasers require some tuning during the test sequence to achieve a targeted extinction ratio or to optimize the eye shape; this tuning can be one of the more time-consuming tasks during manufacturing test. Earlier test methods have depended upon the DCA being in infinite persistence mode. Infinite persistence allows samples to continuously contribute to the displayed eye. In an infinite persistence mode, as a laser bias is adjusted, the displayed eye consists of samples from the old and the new bias settings leading to incorrect measurement results.

The typical measurement that may be displayed is shown in Figure 5, which has earlier samples that are displayed and may detract from the current tuned position. The user can remedy this effect by regularly pushing Clear Display, but this adds time to the test sequence.
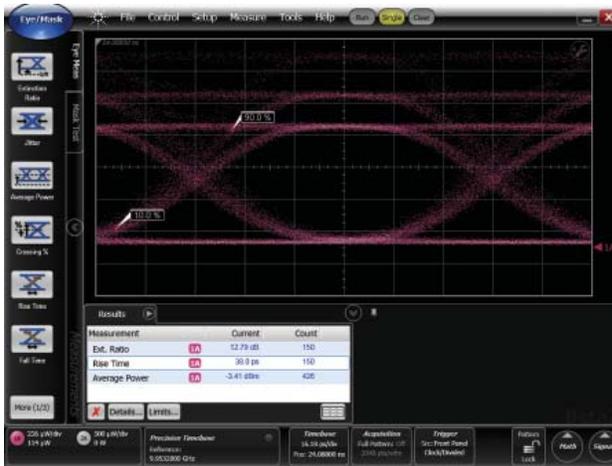


Figure 5. Typical eye display when tuning a laser.

A special "Eye Tuning" mode helps the user to more quickly tune the lasers by displaying the eye with the most recently taken samples. As the user changes the laser bias, earlier samples fade from the display providing the user a more real-time update of their device performance. To enable Eye Tuning, click **Setup and Display**, then select Eye Tuning as shown in the dialogue box in Figure 6.



Figure 6. Display dialogue box to enable Eye Tuning mode.

# Save Time When You Tune Lasers

Eye Tuning also reduces the number of samples required to provide eye measurement results and therefore provides very quick measurement updates, which are especially important for quickly determining key parameters such as extinction ratio and average power. By implementing Eye Tuning, the operator can experience laser tuning times improving by 2-3X.
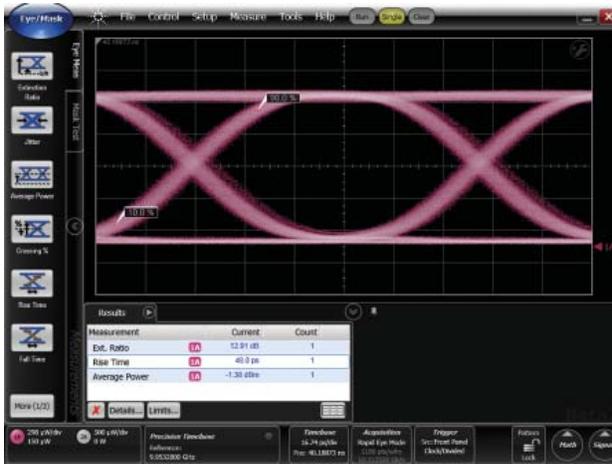


*Figure 7. Typical eye display with Eye Tuning enabled and measurement results to optimize.*

Measurement stability is impacted by the amount of data displayed. More data yields higher stability at the cost of longer test times. Measurements like extinction ratio typically required very small databases. If the user would like to change the response speed to tuning changes (rate of decay for the old samples), change the record length by altering the points per waveform in the Acquisition dialogue or by using remote commands. The default value for the automatic value of points per waveform provides the recommended value.

---

### Remote command for Eye Tuning (firmware A.01.60 or later)

Turn on Eye Tuning · :DISPlay:ETUNing ON

Adjust Record Length for
desired decay rate · :DISPlay:ETUNing:COUNt 50000

---

# Save Acquisition Time with Rapid Eye

**Previous acquisition technique**

Most key parameters for transceivers are based on measuring the eye diagram. Test instrumentation typically uses only samples from one unit interval (UI) for eye analysis; Figure 8b shows an example where only 25% of the acquired samples are actually being used for analysis. The other 75% of the samples are visible but are not used in the measurement process. This results in a low efficiency of samples being used and slower measurements. Figure 8a shows a typical eye diagram where 62% of the acquired samples are used.

The eye diagrams in Figures 8a and 8b have the same number of acquired samples; therefore the time to acquire both is identical. However, the measurements of Figure 8a are based on a sample size that is 2.5X of the sample size of Figure 8b. Often a user may consider an instrument with a higher advertised sampling rate; however the more important measure is how fast the acquired samples for the measurements are turned into reported measurement results. This leads to the concept of improving effective sample rate through efficient use of acquired data.
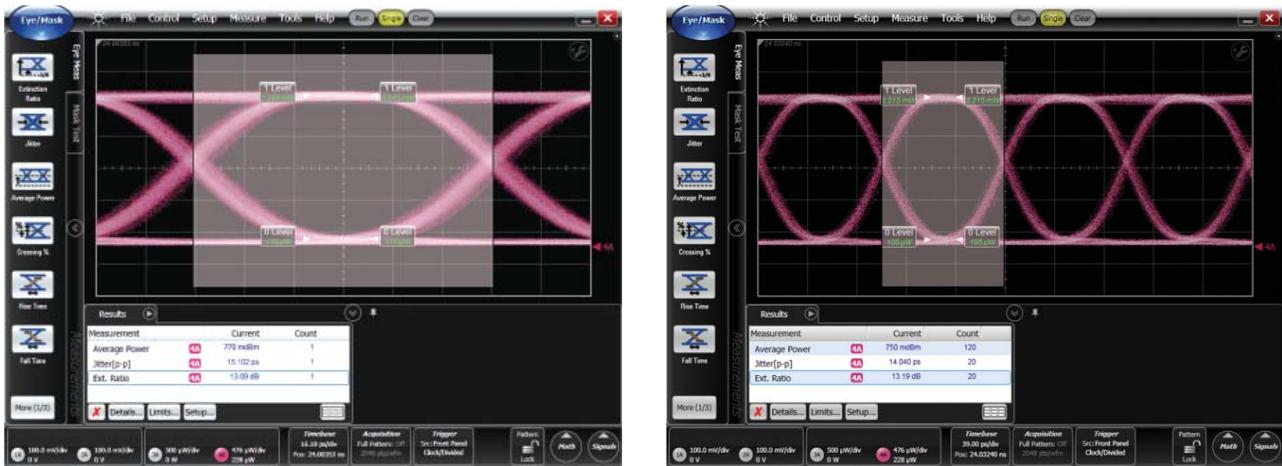


*Figure 8a and b. Eye diagrams showing the typical region of samples used to calculate measurement results without Rapid Eye.*

# Save Acquisition Time with Rapid Eye

## Rapid Eye technique

Let's start by describing a numerical example. The user allows the DCA to choose the number of samples which we will assume to be 4000 samples per waveform without Rapid Eye; those 4000 samples are used to create the one unit interval eye and the regions to the left and right of the one unit interval. Recalling from the section above that not all acquired samples are used, 2500 samples (62.5% of 4000) are used for the one unit interval eye and measurements; the other 1500 samples are unused for the measurement results. Therefore we should be able to obtain equivalent measurement results by acquiring only 2500 samples.

The DCA software enhancement called Rapid Eye collects and analyzes samples from two or more unit intervals, and the samples are used to create one unit interval. Rapid Eye detects the user timebase settings and calculates how many samples are needed; in this example, Rapid Eye chooses 2500 samples per waveform. The shaded areas of Figure 9 show the samples that are measured over two eyes and consolidated into one unit interval. When Rapid Eye is turned on, 1250 samples are taken from each of two eyes and used to create one unit interval which provides a more accurate view of the eye particularly if adjacent eyes are not symmetrical. This technique forms the basis of improving measurement times by 1.6X (the inverse of 62.5%).



Acquired samples        Displayed samples
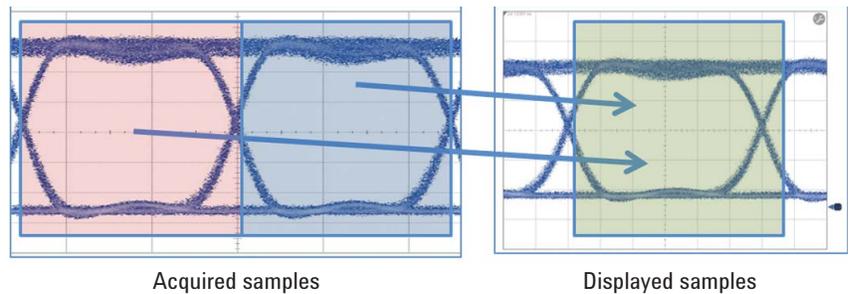
*Figure 9. Rapid Eye example demonstrating samples from two eyes being used in the measurement of one unit interval.*

# Save Acquisition Time with Rapid Eye

**Rapid Eye technique (continued)**

Recall from Figure 8 that 37.5% of the acquired samples to the far left and far right of the eye transitions were not used to determine measurement statistics without Rapid Eye. As shown in Figure 10, Rapid Eye uses acquired samples from two adjacent eyes to complete the left and right edges of the displayed eye. Continuing our numerical example, a portion of the 2500 acquired samples is re-used to display the areas to the left and right of the unit interval. A key result is that construction and display of the left and right edges of the display are achieved without having to acquire data in addition to the 2500 samples used to construct the central UI display. This concept can be extended to any user-defined timebase when eye diagrams are being displayed.



Acquired samples        Displayed samples
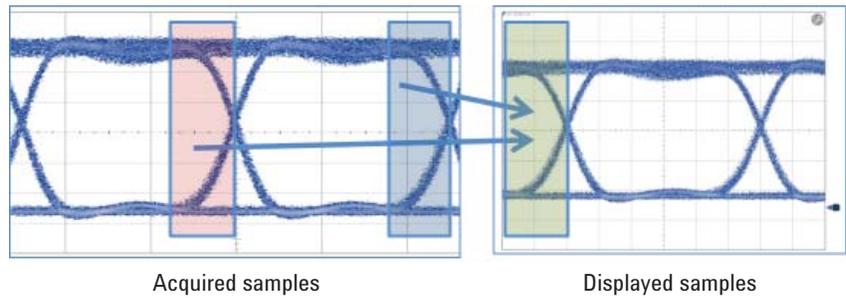
*Figure 10. More effectively using the acquired samples to quickly create and display the eye diagram.*

Figure 11a shows the samples acquired to show one waveform of 4000 points without Rapid Eye. Figure 11b shows the eye when Rapid Eye is enabled; for this eye, 2500 samples were acquired and 4000 are displayed (1500 are re-used). Note that the eyes are identical and although not seen, the time required to obtain the eye of Figure 11b was 1.6X faster than the time to acquire the eye in Figure 11a. The user can still choose to change the timebase settings to view a narrow portion of the unit interval. When changing the time base to view more unit intervals, note that each eye will be identical.
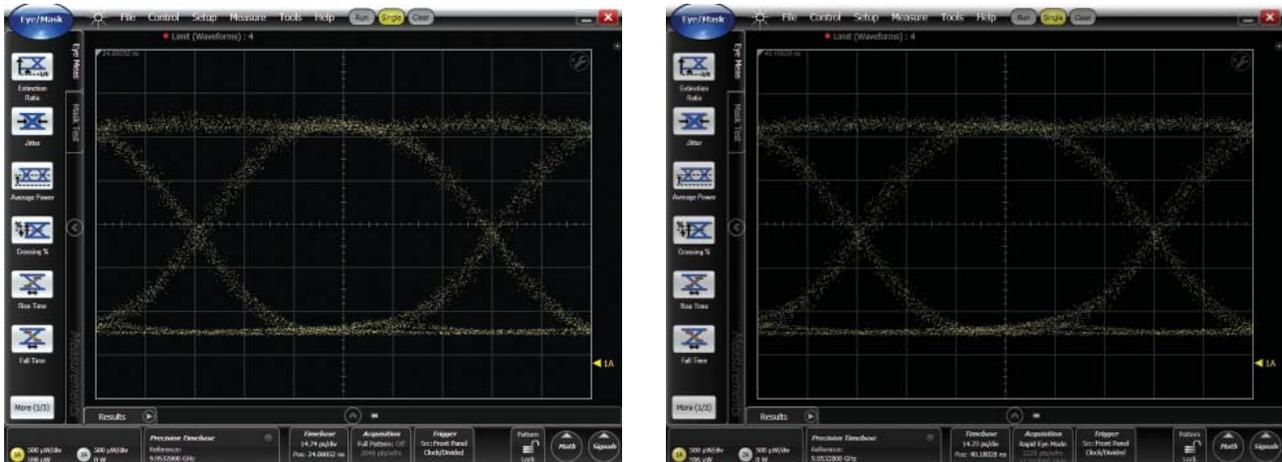


*Figure 11a and b. Acquired samples for one waveform without and with Rapid Eye.*

# Save Acquisition Time with Rapid Eye

## Non-symmetrical bits in the data stream

As the data rates increase in standards like Ethernet, designers often choose to multiplex two or more lower rate data streams into one higher rate stream. Aligning the transition edges for each channel of the multiplexer is very challenging and transceiver designs can suffer from poorer performance because the non-aligned edges produce higher jitter or more closed eyes. The multiplexer may align one channel of the incoming data stream on the clock rising edge and the other channel on the clock falling edge; if the rising and falling edges do not exactly align with the bit period, then the adjacent eyes will not be symmetrical. Let's explore how Rapid Eye provides the designer with insights into potential improvements.

Consider the example of a 2:1 multiplexer combining two 5.15 Gb/s data streams into one 10 Gb Ethernet stream. This multiplexer has the two streams being combined at different times relative to the bit period, by about 7%. Refer to Figure 12 which shows two adjacent eyes. The measurements for extinction ratio and jitter may be very similar for the left and right eyes. The mask margins for the left and right eyes will be quite different, with the left one reporting a more optimistic value and the right one reporting a more pessimistic value. If the designer were viewing only the left eye on the screen and recorded the measurement statistics, he may think the design is performing better than it will perform when installed in the network.
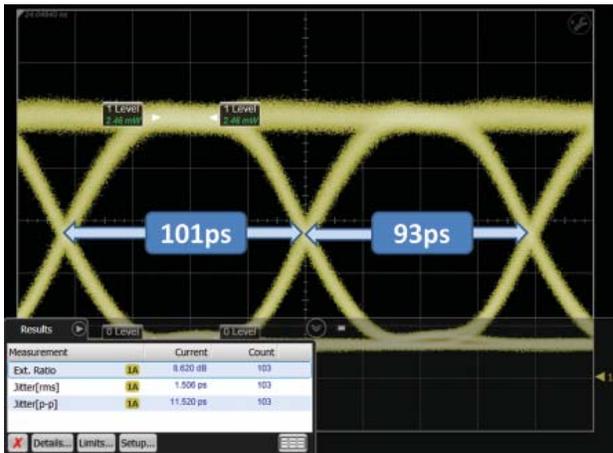


*Figure 12. Eye and measurements for a multiplexer with non-symmetrical data streams and bit periods.*

# Save Acquisition Time with Rapid Eye

The receiver at the other end of the deployed network will be trying to interpret the transmitted bits and could suffer from increased bit errors because the designer did not validate the transmitter with the full eye diagram from the multiplexed data stream, which is shown in Figure 13; these eyes were measured with Rapid Eye enabled. The eyes now have equal unit intervals, but note the increased width in the eye transitions which increases the jitter; depending on the particular transmitter, mask margin may be higher or lower than the values reported for the eyes with different bit periods. Jitter and mask margin can determine the difference between a high yield and a low yield on the manufacturing line. The reason the Rapid Eye representation is more correct is that the aggregate eye, composed of bits from both legs of the multiplexer, is being displayed and measured.
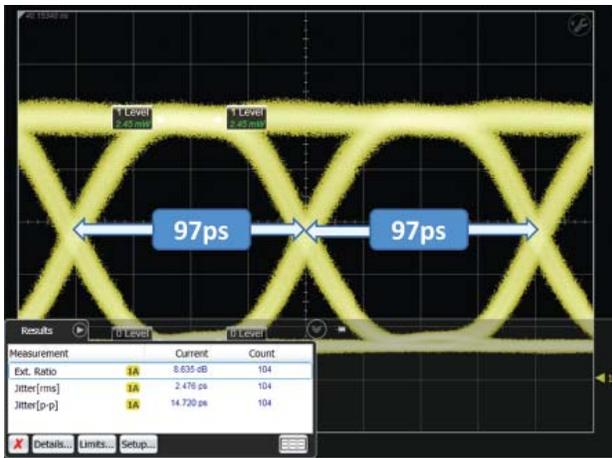


*Figure 13. Measurement of the same multiplexer using Rapid Eye, demonstrating more complete characterization of the eye and the same bit periods.*

The DCA provides powerful capability to determine not only the measured parameters of the eye, but also to trouble shoot where the source of errors may be. If the user is viewing more than one eye with Rapid Eye enabled, the displayed eyes will be replicates of each other and will report results that are representative of how the device will behave in operation. However, the device performance may not be sufficient to meet your customer requirements so viewing without Rapid Eye shows which transitions may be contributing to poorer performance.

# Save Acquisition Time with Rapid Eye

## Setting up Rapid Eye

Like most DCA features, Rapid Eye is enabled through a simple dialogue box with a few clicks as shown in Figure 14. The user selects the bit rate from the list or enters the bit rate to at least four significant digits, and can also choose Optimize Channel Skew during autoscale with one more click. After making the choices, click **Close**. The recommended number of unit intervals is 2, the default value. (Adjusting the number of unit intervals is only accomplished through remote commands, listed in the box at the end of this section).

Let's distinguish between the UI setting in Rapid Eye and the mainframe time base settings. The time base settings control how many eyes or how much of an eye is displayed on the screen. After autoscale, 1.6 unit intervals are displayed on the screen and one eye is displayed over six divisions. For 10 Gb Ethernet with a bit period of about 97 ps, the time per division is about 16 ps. Rapid Eye has acquired samples over two bit periods, or over 194 ps. The user can decrease the time per division to see more detail or increase the time per division to see more eyes; at any time base setting, the complete or fractional eyes are identical to what was observed with one eye. The Rapid Eye view is representative of the overall DUT performance in the network.

For multi-channel measurements, particularly for extinction ratio and mask margin, the channels need to be aligned to bring the eyes fully on screen. A common approach has been to use more eyes on screen. Rapid Eye provides software delay of channels which is much faster than using manual alignment adjustments. Recall from the earlier discussion that taking samples for three complete eyes requires more acquisition time to obtain the additional samples for the aligned channels. Choosing Align Channels During Autoscale aligns the eyes for each channel as shown in Figure 14.
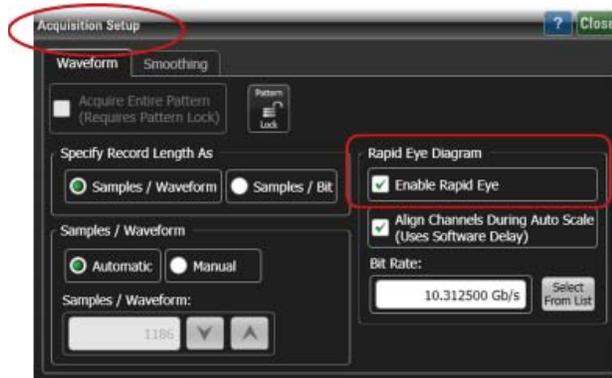


*Figure 14. Acquisition dialogue box to enable Rapid Eye.*

## Remote commands for Rapid Eye (firmware A.01.60 or later)

| | |
|---|---|
| Turn on Eye Mode | :System:MODE EYE |
| Set the Bit Rate | :TIMebase:BRATe 10.3125e9 |
| Turn on Rapid Eye | :ACQuire:REYE ON |
| Turn on Channel De-skew | :ACQuire:REYE:ASKew ON |
| Autoscale the channels | :AUToscale<br>*OPC? |

# Save Acquisition Time with Rapid Eye

**Benefits of Rapid Eye**

Recall the earlier discussion of multi-channel autoscale, where eye alignment provides the ability to quickly measure all channels and may be slightly longer when acquiring the samples. For autoscale, enabling Rapid Eye not only removes the additional slight delay, but improves the overall autoscale by as much as 5X as shown in the table below.

| Autoscale | Standard acquisition | With Rapid Eye | Speed improvement |
|---|---|---|---|
| Four channels, one at a time | 1.0 x 4 = 4.0 sec | 0.7 x 4 = 2.8 sec | 1.4X |
| Four channels, two at a time | 1.2 x 2 = 2.4 sec | 1.0 x 2 = 2.0 sec | 1.2X |
| Four channels, simultaneously | 1.3 sec | 1.1 sec | 1.2X |
| Overall improvement | 3.1X | 2.5X | 3.6X |

Many users have defaulted to acquiring one million samples to make their measurements, perhaps from earlier legacy needs or to incorporate a very conservative test scheme to make sure their devices work very well. Making more efficient use of the acquired samples, Rapid Eye yields significantly faster measurements. The methodology shown in Figure 9 and Figure 10 provides the speed improvement here. Let's compare acquisition times for a different number of optical channels when repeating the autoscale times as above and capturing one million samples on typical eye diagrams that have been aligned. Times and improvements are shown in the table below, highlighting the 3X to 5X improvement. For typical test plans that include several measurement stages, such as tuning or thermal cycling, the corresponding 2X to 3X improvement in cost of test is significant.

| Acquiring 1 M samples | Standard acquisition | With Rapid Eye | Speed improvement |
|---|---|---|---|
| Four channels, one at a time | 30 x 4 = 120 sec | 19 x 4 = 78 sec | 1.5X |
| Four channels, two at a time | 32 x 2 = 64 sec | 20 x 2 = 40 sec | 1.6X |
| Four channels, simultaneously | 35 sec | 23 sec | 1.5X |
| Overall improvement | 3.4X | 3.4X | 5.2X |

# Save Time with Faster Eye Mask Testing

The eye mask is one of the most important characteristics of eye quality, and designers and manufacturing engineers need to consider the trade-offs between speed, accuracy and uncertainty. The fastest result is with the minimum number of samples to build the eye diagram but the repeatability is poor and uncertainty is high. To be thorough in measurements, many users choose one million samples which provide somewhat more repeatable measurements with increased time and cost. Wouldn't you like to know if a reduced number of samples are enough to meet your requirements? Let's explore these topics in depth.

## What to view

The user may want to see as much detail in the eye as possible; if so, the mask measurement table can be minimized. Otherwise the user can choose two levels of detail for the mask measurement table as shown in Figure 15.
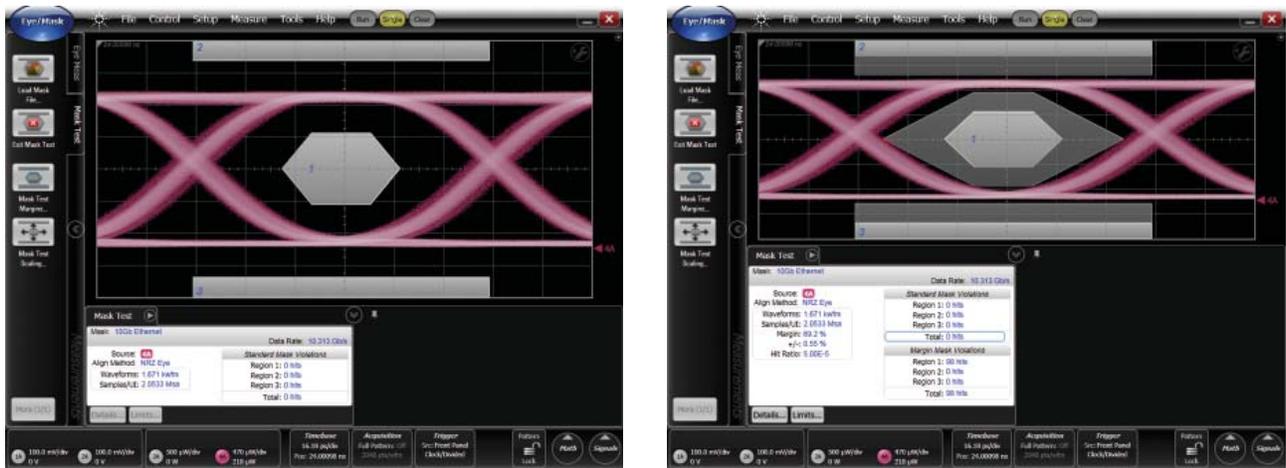


*Figure 15. Levels of detail for mask testing.*

## Hit Ratio

Nearly all high-volume manufacturing facilities use process control. The manufacturing engineer can use the data collected to determine not only that the devices pass specifications, but also by how much they pass and how consistent they are. Mask margin provides a key metric of how well in control are the devices and manufacturing techniques.

Having a higher mask margin provides better system performance and commands a price premium to customers that benefit from the higher eye quality. For many years, designers and manufacturing engineers were faced with transceiver test failures when a single sample out of hundreds of thousands violated the mask, even if the sample is a clear outlier. The standards committees chose a Hit Ratio metric which standardized how many hits are allowable. For example, the hit ratio is set at 1 hit in 20,000 samples for IEEE 802.3ba.

# Save Time with Faster Eye Mask Testing

The DCA calculates the mask margin based on the chosen Hit Ratio, which establishes the number of allowable mask violations; example calculations are shown in Appendix C. The dialogue box is chosen by clicking the **Mask Test** tab, clicking **Mask Test Margins**, completing the Target Hit Ratio and selecting **Margins On**. These are all shown in Figure 16.



*Figure 16. Mask Test Margins dialog box to enable mask margins and Hit Ratio.*

Mask margins are quickly calculated once the samples are acquired. More samples will improve the uncertainty but reaches diminishing returns quickly on clean eyes at high optical powers and less quickly on poor eyes with higher noise. Designers and manufacturing engineers can use the new DCA capability within Flex DCA that calculates the uncertainty of the mask margin measurement and choose how many samples are appropriate for that type of transceiver; see Figure 17.



*Figure 17. Typical eye diagram with mask margin.*

17

# Save Time By Choosing Just Enough Test Data



If the production batch of transceivers proves to have a mask margin much greater than what is needed by the customer, then fewer samples can be acquired. If the production batch is very close to specification and care must be used to assure that transceivers pass incoming inspection at the customer facility, then more samples are acquired.

Choosing the number of samples is quick and easy using the Flex DCA interface, which can be downloaded from **www.agilent.com** and is included with the 86100D DCA-X mainframe, and can be used with the 86100C DCA-J mainframe when connected to a computer. Flex DCA is a second user interface with new features, an even more intuitive user interface and additional remote control capability. The test developer uses the Flex DCA interface to obtain and analyze a new metric: mask margin uncertainty which is shown here.

While taking samples using the Flex DCA interface, observe the ±% result until the desired uncertainty is achieved, then choose that number of samples, or a few more to be conservative. The uncertainty calculation predicts the range of mask margin values with confidence of 1 in 10^6. If the optical signal is noisy, then the number of acquired samples for the desired mask margin may increase.

Figure 18a shows typical mask margin percentage and uncertainty for a clean eye. If the desired mask margin is 35%, the manufacturing engineer could choose 200 to 250 K samples rather than the more commonly-used 1 M samples. Figure 18b shows smaller mask margin for a more noisy eye. The uncertainty window is wider and becomes more consistent at larger samples. If the mask margin is 5%, the engineer could again choose 200 to 250 K samples. If the mask margin is 10%, then 800 K samples is more appropriate.
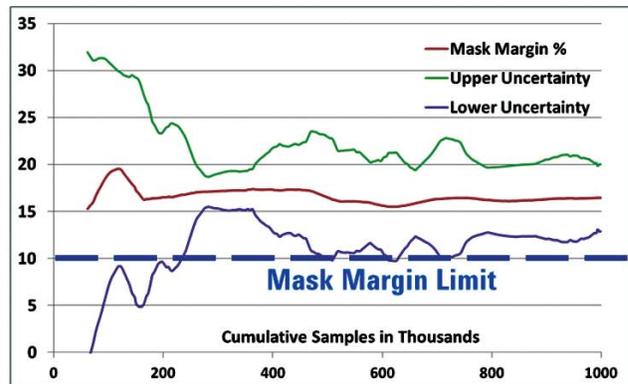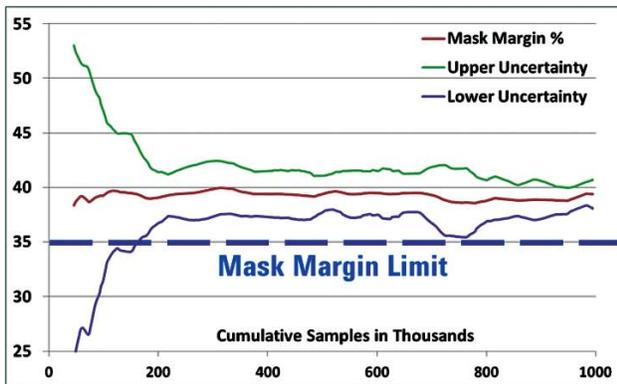


*Figure 18a and b. Typical mask margins and limits for less noisy and more noisy eyes.*

# Save Time By Choosing Just Enough Test Data

Most modern transceivers have higher optical power and will be more similar to Figure 18a. This example reduces the number of samples required and nets a 5X improvement in the test time to acquire the samples, which greatly reduces cost of test when compared to traditional approaches. When running the same test plan to complete four channels simultaneously and combining with the reduced number of samples plus Rapid Eye, the improvement is an impressive 17X improvement in test time.

|  | 1 M samples, no Rapid Eye | 300 K samples with Rapid Eye | Overall improvement |
|---|---|---|---|
| Four channels, one at a time | 30 x 4 = 120 sec | 6.2 x 4 = 24.8 sec | 4.8X |
| Four channels, two at a time | 32 x 2 = 64 sec | 6.3 x 2 = 12.6 sec | 5.1X |
| Four channels, simultaneously | 35 sec | 7.2 sec | 4.9X |
| Overall improvement | 3.4X | 3.4X | 17X |

## Remote commands to choose sample size

| | |
|---|---|
| Set the sample size at 300 K | :LTESt:ACQuire:CTYPe SAMPles |
| | :LTESt:ACQuire:CTYPe:SAMPles 3E5 |
| | :LTESt:ACQuire:STATe ON |
| Perform the measurements | :ACQuire:RUN |
| Complete the operation | *OPC? |

## Remote commands for Mask Testing (firmware A.01.60 or later)

| | |
|---|---|
| Choose the channel for mask test | :MTESt:SOURce CHAN1A |
| Choose the mask file | :MTESt:LOAD:FNAMe "filename" |
| Load the mask | :MTESt:LOAD |
| Choose mask auto margin | :MTESt:MARGin:METHod AUTO |
| Turn on mask auto margin | :MTESt:MARGin:STATe ON |
| Choose type of margin | :MTESt:MARGin:AUTo:METHod HRATio |
| Choose value of Hit Ratio | :MTESt:MARGin:AUTo:HRATio 5.0E-5 |
| Obtain the mask margin value | :MEASure:MTESt:MARGin? |

# Practical Strategies for Parallel Testing of Multiple Transceivers

Great improvements in cost of test are achieved by testing multiple transceivers in parallel, either several single channel transmitters at once or several channels on a multi-channel transmitter at once. Let's review how to set up a few common scenarios and the associated considerations. One consideration for all scenarios is to have the data being distributed to each device under test (DUT) be synchronous with the same clock. The signal that is triggering the DCA must be synchronous with the clock, and can be full rate or sub-rate.

## Scenario 1: Four optical transmitters with one channel each

Transceivers with one optical transmitter are still the highest volume and most common, such as Small Form Pluggables (SFP's) for Fibre Channel. Since the time to test the receiver section can be 2-3 times longer than the time for the transmitter section, all of the optical channels can be done at once and the receivers can be done at a separate station. The reference receivers are 86115D Option 002.
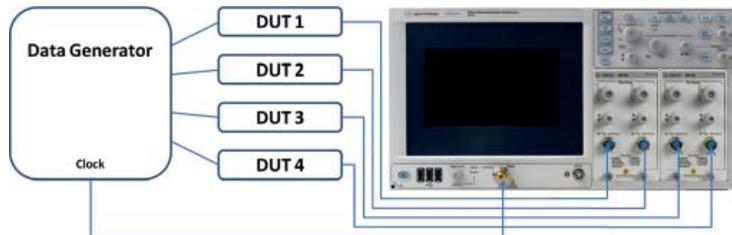


## Scenario 2: One optical transmitter with four channels

Transceivers with four optical transmitters are becoming more common. Therefore being able to connect all four channels and control the DUT one time and take all measurements in parallel improves the total required time in the test process. The reference receivers are 86115D Option 002. Note the use of one common clock as a reference for the data generators and the DCA.

# Practical Strategies for Parallel Testing of Multiple Transceivers

## Scenario 3: Multiple sets of four optical transmitters

Particularly for high volume production lines, operators can be installing units into the test fixture while another set is being tested under automatic control. By making all connections, including the optical fiber, the next set of transmitters can quickly start their testing.
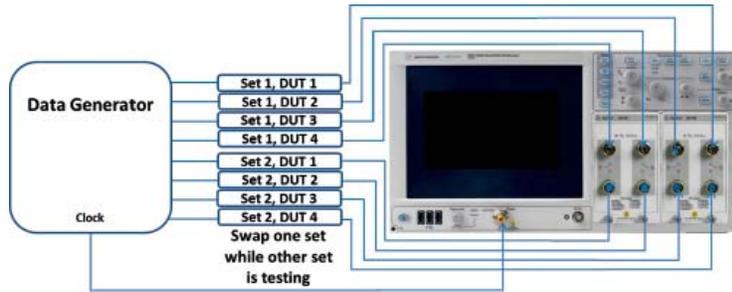


## Scenario 4: One optical transmitter with eight channels

While the volume is not as high, transceivers with many channels are challenging to test because of the desire to minimize the number of connects and disconnects. The 86115D Option 004 reference receivers are an excellent choice enabling the user to connect all optical ports and run the full suite of tests. The test station measures the first four channels, switches the internal switch to the other position, and measures the other four channels. Devices with 12 channels can be similarly tested with a second mainframe and another reference receiver, or with the addition of optical switches to the test station.
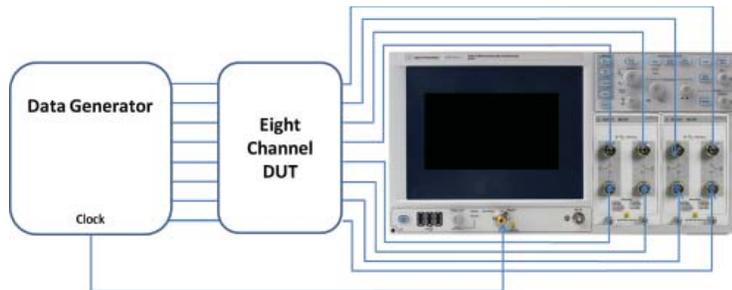
# Practical Strategies for Parallel Testing of Multiple Transceivers

## Scenario 5: Two optical transceivers

When the receiver tests have duration similar to the transmitter tests, or the receiver electrical tests are functional or with a few brief output waveform tests, then both the transmitter and receiver sections of the transceiver can be measured in parallel; this can also greatly reduce the test time. The measurement modules are one 86115D Option 002 and one 86112A. The data generator sends the desired pattern into the electrical input of the DUT. The optical output of the DUT can be split; one split is measured on the optical channel of the reference receiver and the other leg of the splitter is routed into the DUT optical receiver. The converted electrical channel from the DUT is then characterized using the electrical channel of the reference receiver.
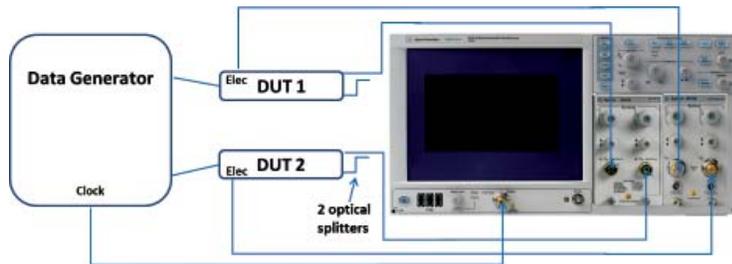


## Scenario 6: Very low jitter measurements with Precision Time Base

At data rates of 10 Gb/s and above, obtaining a high performance eye diagram and best jitter performance is often difficult because of large noise in the optical transmitter or the residual jitter of the test equipment. At 25 Gb/s, the challenges escalate. Choosing the 86115D Option 004 provides four optical channels; adding the 86107A Precision Time Base further decreases the intrinsic jitter of the measurement equipment and aids the user in quickly achieving the desired performance.

The set-up shown below provides the measurement solution for four channels at 25 Gb/s at 850 nm with very low jitter. The range of data rates for multi-mode measurements is extended on the 86115D through the use of System Impulse Response Correction (SIRC), a new and innovative technique that preserves measurement statistics and noise. For more detail on SIRC, please refer to the companion application note entitled *Techniques for Higher Accuracy Optical Measurements*.



22
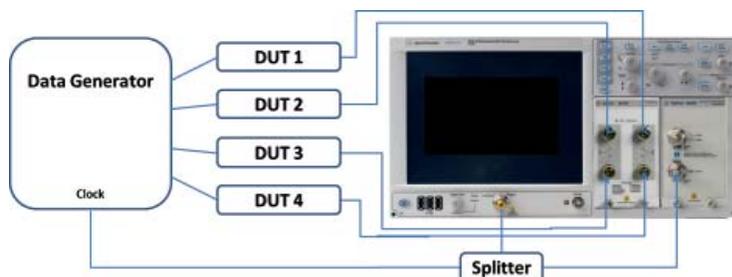
# Efficient Use of Remote Commands

Designing and troubleshooting manufacturing test software is often one of the longest tasks when setting up a new automated test system for new transmitter technologies. A strategic approach to control of the test instruments and their remote commands provides additional improvements in cost-of-test. The recommended typical remote commands for each of the cost-of-test enhancements are highlighted in summary boxes at the end of each major section of this Application Note. Using these will streamline your test development time. Appendix B includes a typical test script with SCPI commands to test four optical channels; the script includes the enhancements described in the previous sections.

Flex DCA also offers the SCPI Recorder feature, which provides the user a very quick method to obtain the desired remote command. At the top of the screen, click **Tools > SCPI Programming Tools > SCPI Recorder** as shown in Figure 19. Click **Start Rec** to enable recording of the commands. Use the mouse, touch screen and front panel buttons to select the desired controls in order of execution; you will see the appropriate commands listed in the dialogue box. Once done, click **Stop Rec**. You may Save the sequence as a SCPI file, and later use the same or other files by choosing the Load command.



Figure 19. Dialogue box for the SCPI Recorder (firmware A.01.60 or later).

## Typical test scenario

Let's consider the following test scenario:

- Four SFP+'s at 10 G rate

- No tuning (as in a final test scenario)

- No temperature cycling

- Measure extinction ratio, average power, total jitter and mask margin

- DCA-X mainframe and two 86115D Option 002 reference receivers

- Compare results when acquiring one million samples versus 300 K samples

When a test sequence is structured to autoscale, acquire samples and do measurements on one channel at a time rather than all channels in parallel, the elapsed test time is significantly longer than necessary. Test flows that take samples for multiple channels in parallel, then do measurements and turn on masks for each channel, yield greatly reduced measurement times.

# Efficient Use of Remote Commands

Let's start with the common approach of acquiring one million samples and completing measurements for each channel, which takes about 124 seconds as shown in the table below. We see a 2X to 3X speed improvement when acquiring samples for all channels at once, then completing the measurements. Choosing the Rapid Eye feature improves the speed by another 1.5X resulting in an overall 4X improvement in measurement speed.

| (# of samples noted) | With Rapid Eye off, 1 M | With Rapid Eye on, 1 M | Speed improvement |
|---|---|---|---|
| Four channels, one at a time | 136 | 84 | 1.6X |
| Four channels, in parallel | 44 | 32 | 1.4X |
| Speed improvement | 3.1X | 2.2X | 4.2X |

Please refer to the section entitled Save Time By Choosing Just Enough Test Data that demonstrates the advantage of acquiring fewer samples with a similar level of measurement accuracy. When combining the use of parallel channels with Rapid Eye with fewer samples, the end result is a full 8X improvement in your test times!!!

| (# of samples noted) | With Rapid Eye off, 1 M | With Rapid Eye on, 300 K | Speed improvement |
|---|---|---|---|
| Four channels, one at a time | 136 | 37 | 3.7X |
| Four channels, in parallel | 44 | 17 | 2.6X |
| Speed Improvement | 3.1X | 2.2X | 8X |

Each facility has a choice of interfaces between the test station and controlling computer, including LAN, USB and GPIB. Many test stations are connected to PC's using LAN, which can be quite congested with traffic. Creating typical test scripts and executing the scripts over a widely used LAN, a sparsely used LAN and a USB-to-GPIB adapter will help you choose which method is fastest for your manufacturing stations. The total test time is affected by how much data is being moved from the equipment to the computer; some devices only require retrieval of a few data waveform samples while others required retrieving thousands or tens of thousands of waveform samples for complete waveforms.

The Operation Complete query (*OPC?) reports to the remote computer when the requested operation has completed, and is very handy for troubleshooting where the test sequence may have stopped with errors; the execution adds time to the overall sequence. Once the sequence is running well, the *OPC? commands should be removed from most locations in the software sequence. Using *OPC? after running a fixed number of samples is appropriate. Please refer to the programming manual for the few other commands that are used with *OPC?.

# Typical Cost-of-Test Improvements

The examples discussed thus far in the application note have been for specific attributes such as completing autoscale, acquiring a fixed number of samples or executing a test script. Many transceivers require pauses in the testing to tune the laser or to complete temperature cycling. The more complex or expensive transmitter normally has more testing applied than the simpler, lower-rate transmitters. Let's explore case studies for three different transmitters, comparing the characteristics, tests performed and improvements achieved for each transmitter.

Many production lines use one reference receiver per mainframe. Adding another reference receiver in each mainframe, or adding reference receivers with multiple channels improves floor space utilization, cost per transceiver and production line throughput. Let's consider three case studies, which use these assumptions:

- Each has tuning of the laser bias included in the test sequence and times
- All examples use one mainframe
- The baseline for each example has none of the cost-of-test improvements
- Each test station has one mainframe and the designated number of modules
- Number of DUT's per year is estimated by:
  1. Using 20 hours per day and 300 days per year to determine seconds per year
  2. Calculating total test sequence time in seconds
  3. Dividing result from 1 by result from 2
- Cost per DUT is estimated by:
  A. Determining list price of mainframe, options and designated modules
  B. Using 5 year useful service life
  C. Dividing the result from A by the product of 3 and B

## Case Study A: High-volume, low-cost transceiver (SFP)

The simplest example is for high volume, inexpensive devices. The baseline case has one 86105C-100 and the parallel station adds a second 86105C-100. Note the 2X improvement in test cost.

| DUT characteristics | Tests performed |
|---|---|
| Lower cost | Extinction ratio |
| One optical channel | Total jitter |
| Moderate performance | Mask margin, low specification |
| < 7 Gb/s | Average power |

| | One 86105C-100 | | Two 86105C-100 | |
|---|---|---|---|---|
| Baseline | Number of DUT's/year: | 366 K | Number of DUT's/year: | 595 K |
| | Cost per DUT: | $0.031 | Cost per DUT: | $0.031 |
| | Cost improvement: | 1X | Cost improvement: | 1X |
| Faster autoscale | Number of DUT's/year: | 782 K | Number of DUT's/year: | 1168 K |
| Eye Tuning | Cost per DUT: | $0.015 | Cost per DUT: | $0.016 |
| Rapid Eye | Cost improvement: | 2X | Cost improvement: | 2X |
| Fewer samples | | | | |

Improvements achieved:

- 3.2X throughput – 366 K to 1168 K units
- 2X cost improvement – $0.031 to $0.016
- ½ the footprint – one mainframe instead of two

25

# Typical Cost-of-Test Improvements

## Case Study B: More complex transceiver (SFP+)

More complex devices require more tests and operate at higher data rates. Note the 2X improvement in test cost.

| DUT characteristics | Tests performed |
|---|---|
| Higher cost | Extinction ratio |
| One optical channel | Total jitter |
| Higher performance | Mask margin, moderate specification |
| 10 to 14 Gb/s | Average power |
| | Rise time |
| | Crossing % |
| | Eye height |

| | One 86105D | | Two 86115D-004 | |
|---|---|---|---|---|
| Baseline | Number of DUT's/year: | 343 K | Number of DUT's/year: | 859 K |
| | Cost per DUT: | $0.035 | Cost per DUT: | $0.029 |
| | Cost improvement: | 1X | Cost improvement: | 1.2X |
| Faster autoscale | Number of DUT's/year: | 663 K | Number of DUT's/year: | 1396 K |
| Eye Tuning | Cost per DUT: | $0.018 | Cost per DUT: | $0.018 |
| Rapid Eye | Cost improvement: | 2X | Cost improvement: | 2X |
| Fewer samples | | | | |

Improvements achieved:

- 4X throughput – 343 K to 1396 K units
- 2X cost improvement – $0.035 to $0.018
- ¼ the footprint – one mainframe instead of four

## Case Study C: Optical transceiver with multiple channels (QSFP)

The most complex devices require more tests, have multiple channels and require temperature cycling. Note the 3X improvement in test cost.

| DUT characteristics | Tests performed |
|---|---|
| Higher cost | Extinction ratio |
| One optical channel | Total jitter |
| Higher performance | Mask margin, demanding specification |
| 10 to 14 Gb/s | Average power |
| | Rise time |
| | Crossing % |
| | Eye height |

| | One 86105D | | Two 86115D-002 | |
|---|---|---|---|---|
| Baseline | Number of DUT's/year: | 73 K | Number of DUT's/year: | 348 K |
| | Cost per DUT: | $0.164 | Cost per DUT: | $0.086 |
| | Cost improvement: | 1X | Cost improvement: | 1.9X |
| Faster autoscale | Number of DUT's/year: | 100 K | Number of DUT's/year: | 585 K |
| Eye Tuning | Cost per DUT: | $0.121 | Cost per DUT: | $0.051 |
| Rapid Eye | Cost improvement: | 1.4X | Cost improvement: | 3.2X |
| Fewer samples | | | | |

Improvements achieved:

- 8X throughput – 73 K to 585 K units
- 3X cost improvement – $0.016 to $0.005
- ⅛ the footprint – one mainframe instead of eight

26

# Reporting/Displaying Results for One Channel When Multiple Channels Are Being Tested

Once the transceiver is tested for all key parameters, often data must be provided for each device, either tabular or graphical or both. When measuring several devices in parallel, the instrument screen may have data and eyes for several channels being simultaneously displayed. If the DCA display is saved to document a transceiver waveform and measurement results, all channel data is displayed rather than a single channel. The DCA has the feature to save only the desired channel's image using remote commands; an example is shown in Figure 20. The left display shows all four channels being displayed as often seen on the mainframe screen when testing parallel channels. The right display shows the screen capture of only one channel.



*Figure 20a and b. Typical measurement results showing all channels and only one of the parallel channels.*

## Remote command to save image from one channel (firmware A.1.60 or later)

If user desires measured values from only one channel,
insert this command prior to measuring desired channel   :MEASure:EYE:LIST:CLEar

Choose the channel to save                               :DISK:SIMage:SINClude CHAN3A

Save the image                                           :DISK:SIMage:FNAMe "filename.jpg"

# Using an Optical Channel When an Electrical Channel is Damaged and Will Not Calibrate

Maintaining a high up-time for the production line is crucial to reduce costs. When only optical measurements are needed and the electrical channel of the reference receiver will not calibrate because of the electrical input being damaged, the user will be prompted to proceed with the optical calibration as shown in Figure 21.



*Figure 21. Dialogue box for reference receiver calibration and failure of electrical calibration.*

## Remote commands to calibrate module with optical and electrical channel (example of 86105C in left slot) (firmware A.01.50 or later)

| | |
|---|---|
| Initiate calibration | :CALibrate:VERTical:SLOT1:STARt |
| | :CALibrate:CONTinue |
| After disconnecting everything | :CALibrate:CONTinue |
| Query if calibration is done | :CAL:SDONE? |
| Response | "Disconnect or disable everything ......." |
| Continue | :CAL:CONTinue |
| Query if calibration is done | :CALibrate:SDONe? |
| Response if channel failed | "The calibration of the electrical ......" |
| Continue | :CALibrate:CONTinue |
| Query if calibration is done | :CAL:SDONE? |
| Response | "86105C Vertical Calibration has ......" |

# Key Considerations to Improve Manufacturing Cost of Test

- *Measure multiple transceivers simultaneously.* Using 86115D reference receivers at least doubles the optical measurement capacity for a typical test system.  Using 86115D Option 004 further increases capacity by allowing the user to measure one set of transmitters while setting up the next set.

- *Follow recommended steps to set up and measure.* Set up the instrument, adjust delay between the channels, autoscale the channels and acquire samples. Once the samples are acquired for all channels, then turn on the measurements and record the data which improves overall measurement speed.

- *Enable Rapid Eye.* Rapid Eye makes more efficient use of acquired samples, streamlines the alignment of channels and greatly improves measurement speed.

- *Enable Eye Tuning.* Reduces the time and tedium in tuning the laser.

- *Include the bit rate for autoscale.* Bit rates for DUT's are almost always known and are easily entered.

- *Choose the appropriate computer interface for your situation.* Enhance the total test time by choosing between type of LAN, GPIB or USB based on the network load and amount of test data that must be retrieved for each transmitter.

# Choosing Mainframe and Software Version

Many users need to know the key equipment characteristics to help them determine whether to move from the installed base of 86100C DCA-J's to 86100D DCA-X's, and whether to transfer to the Flex DCA interface. The first table summarizes key differences between the two mainframes, with the DCA-X providing more user display, faster speeds and more remote control options.

| Characteristic | 86100C DCA-J | 86100D DCA-X |
|---|---|---|
| Screen size, diagonal | 8.4″ | 10.4″ |
| Screen resolution | 640 x 480 | 1024 x 768 |
| Relative measurement speed | Baseline | ~20 to 30% faster |
| Remote control | • From PC to mainframe that is running Classic software<br>• From PC running Flex to mainframe | • From PC to mainframe that is running Classic or Flex DCA<br>• From PC running Flex to mainframe |
| Autoscale | Baseline | ~20 to 25% faster |

The second table shows differences between the two operating systems. Flex DCA provides mask margin uncertainty, ability to log SCPI commands as they are manually selected from the front panel, and the local option to save one channel's waveforms. Classic DCA provides GPIB control.

| Characteristic | Classic DCA | Flex DCA |
|---|---|---|
| Channel offset | Hardware skew | Software delay |
| Eye Tuning | Yes | Yes |
| Hit Ratio | Yes | Yes |
| Rapid Eye | Yes | Yes |
| Mask margin uncertainty | No | Yes |
| Save one channel's waveform out of many parallel channels | Remote | Local and remote |
| Typical test script | ~10% faster than Flex on DCA-X | Baseline |
| GPIB capability | Yes | No |
| SCPI recorder | No | Yes |

## Summary

In our increasingly competitive global environment, manufacturers constantly seek means to improve their product costs, including the cost of test. Agilent has provided designers and manufacturing engineers regular and significant enhancements in testing for many years, and the latest enhancements described in this application note provide the largest gains ever offered for testing optical transceivers. Test developers now have multiple tools to apply to their specific test situations that will enable 2X to 17X improvement in acquiring test results. Depending on the amount of tuning, temperature cycling and overhead in the overall test sequence, manufacturing engineers and their managers will greatly appreciate the 2X to 5X reduction in the transmitter cost of test, which can be as low as a few cents per device.

# Appendix A: DCA Cost-of-Test Enhancements Summary

The Agilent Digital Communications Analyzer has a long heritage of helping users improve their cost-of-test. The table below summarizes the key contributions made by the DCA over time.

| Date | Manufacturing Cost-of-Test Enhancements |
| --- | --- |
| 2011 | Enhanced autoscale speed<br>Add Hit Ratio to mask margin choices<br>Added Rapid Eye<br>Feature to save one channel waveform and data<br>For Flex DCA: Added mask margin uncertainty |
| 2010 | Added 86115D reference receiver with multiple optical channels<br>Added Eye Tuning |
| 2008 | Added auto mask margin |
| 2007 | Added OMA measurements |
| 2005 | Added S-parameters |
| 2004 | Introduced 86105C with multiple filter rates per module<br>Added bit rate to autoscale remote command<br>Added extinction ratio correction factor<br>Introduced significant jitter capabilities at high accuracy<br>Provided jitter separation analysis with a single button<br>Added advanced acquisition system with Pattern Lock |
| 2002 | Added vertical mask alignment method<br>Acquire multiple channels at once in Eye Mode<br>Make measurements and analyze masks on multiple channels |
| 2000 | Create custom masks on external computer |

# Appendix B: Typical Test Script for Four Optical Channels

Using efficient remote commands and more measurement channels are the most efficient means to improve cost-of-test. The table below summarizes the overall test flow. The test script listed below the table measures four optical channels on two 86115D's.

| Lines | Description |
|-------|-------------|
| 1-11 | Set up the instrument for mode and data rate<br>• Lines 4 and 5 access the benefits of Rapid Eye and de-skew<br>• Line 6 enables faster autoscale by stating the bit rate |
| 12-27 | Choose optical wavelengths, filter and displayed channels<br>• Lines 22-25 turn on simultaneous measurement channels |
| 28-31 | Autoscale and acquire samples for all four channels<br>• Line 28-30 facilitates faster overall acquisition by choosing just enough samples |
| 32-47 | Measure desired parameters for one channel, report results on screen and to remote interface, and capture screen shot of one channel<br>• Line 52 enables more consistent mask margin results by choosing the Hit Ratio<br>• Line 54-55 saves data and waveform for one channel from parallel channels |
| 48-85 | Measure and report for remaining three channels<br>• Lines 81-82, 108-109 and 135-136 save data and waveform for one channel from parallel channels |

# Appendix B: Typical Test Script for Four Optical Channels

## Test Script Listing

1. :SYSTem:DEFault
2. :ACQuire:STOP
3. :SYSTem:MODE EYE
4. :ACQuire:RLENgth:AUTo MANual
5. :ACQuire:RLENgth 8192
6. :TIMebase:BRATe 9.9532800E+9
7. :ACQuire:REYE ON
8. :ACQuire:REYE:ASKew ON
9. :TRIGger:BWLimit EDGE
10. :CHAN1A:WAVelength WAVelength3
11. :CHAN2A:WAVelength WAVelength3
12. :CHAN3A:WAVelength WAVelength3
13. :CHAN4A:WAVelength WAVelength3
14. :CHAN1A:FSELect FILTer2
15. :CHAN2A:FSELect FILTer2
16. :CHAN3A:FSELect FILTer2
17. :CHAN4A:FSELect FILTer2
18. :CHAN1A:FILTer ON
19. :CHAN2A:FILTer ON
20. :CHAN3A:FILTer ON
21. :CHAN4A:FILTer ON
22. :CHAN1A:DISPlay ON
23. :CHAN2A:DISPlay ON
24. :CHAN3A:DISPlay ON
25. :CHAN4A:DISPlay ON
26. :SYSTem:AUToscale
27. *OPC?
28. :LTESt:ACQuire:CTYPe SAMPles
29. :LTESt:ACQuire:CTYPe:SAMPles 3E5
30. :LTESt:ACQuire:STATe ON
31. :ACQuire:RUN
32. *OPC?
33. :MEASure:EYE:ERATio:UNITs DECibel
34. :MEASure:EYE:ERATio:SOURce1 CHAN1A
35. :MEASure:EYE:ERATio
36. :MEASure:EYE:ERATio?
37. :MEASure:EYE:APOWer:UNITs DBM
38. :MEASure:CGR:APOWer:SOURce1 CHAN1A
39. :MEASure:EYE:APOWer
40. :MEASure:CGR:APOWer?
41. :MEASure:EYE:JITTer:SOURce1 CHAN1A
42. :MEASure:EYE:JITTer
43. :MEASure:EYE:JITTer?
44. :MTESt:SOURce CHAN1A
45. :MTESt:LOAD:FNAMe "C:\Program Files\Agilent\FlexDCA\Demo\Masks\Ethernet\009.95328 - 10GbE_9_953_May02.mskx"
46. :MTESt:LOAD
47. :MTESt:MARGin:METHod AUTO
48. :MTESt:MARGin:STATe ON
49. :MTESt:MARGin:AUTo:METHod HRATio
50. :MTESt:MARGin:AUTo:HRATio 5.0E-5
51. :MEASure:MTESt:MARGin?
52. :DISK:SIMage:SINClude CHAN1A
53. :DISK:SIMage:FNAMe "D:\User Files\Screen Images\Flex Channel 1.jpg"
54. :DISK:SIMage:SAVE
55. *OPC?
56. :MEAS:EYE:LIST:CLEAR
57. :MEASure:EYE:ERATio:UNITs DECibel
58. :MEASure:EYE:ERATio:SOURce1 CHAN2A
59. :MEASure:EYE:ERATio
60. :MEASure:EYE:ERATio?
61. :MEASure:EYE:APOWer:UNITs DBM
62. :MEASure:CGR:APOWer:SOURce1 CHAN2A
63. :MEASure:EYE:APOWer
64. :MEASure:CGR:APOWer?
65. :MEASure:EYE:JITTer:SOURce1 CHAN2A
66. :MEASure:EYE:JITTer
67. :MEASure:EYE:JITTer?
68. :MTESt:SOURce CHAN2A
69. :MTESt:LOAD:FNAMe "C:\Program Files\Agilent\FlexDCA\Demo\Masks\Ethernet\009.95328 - 10GbE_9_953_May02.mskx"
70. :MTESt:LOAD
71. :MTESt:MARGin:METHod AUTO
72. :MTESt:MARGin:STATe ON
73. :MTESt:MARGin:AUTo:METHod HRATio
74. :MTESt:MARGin:AUTo:HRATio 5.0E-5
75. :MEASure:MTESt:MARGin?
76. :DISK:SIMage:SINClude CHAN2A
77. :DISK:SIMage:FNAMe "D:\User Files\Screen Images\Flex Channel 2.jpg"
78. :DISK:SIMage:SAVE
79. *OPC?
80. :MEAS:EYE:LIST:CLEAR
81. :MEASure:EYE:ERATio:UNITs DECibel
82. :MEASure:EYE:ERATio:SOURce1 CHAN3A
83. :MEASure:EYE:ERATio
84. :MEASure:EYE:ERATio?
85. :MEASure:EYE:APOWer:UNITs DBM
86. :MEASure:CGR:APOWer:SOURce1 CHAN3A
87. :MEASure:EYE:APOWer
88. :MEASure:CGR:APOWer?
89. :MEASure:EYE:JITTer:SOURce1 CHAN3A
90. :MEASure:EYE:JITTer
91. :MEASure:EYE:JITTer?
92. :MTESt:SOURce CHAN3A
93. :MTESt:LOAD:FNAMe "C:\Program Files\Agilent\FlexDCA\Demo\Masks\Ethernet\009.95328 - 10GbE_9_953_May02.mskx"
94. :MTESt:LOAD
95. :MTESt:MARGin:METHod AUTO
96. :MTESt:MARGin:STATe ON
97. :MTESt:MARGin:AUTo:METHod HRATio
98. :MTESt:MARGin:AUTo:HRATio 5.0E-5
99. :MEASure:MTESt:MARGin?
100. :DISK:SIMage:SINClude CHAN3A
101. :DISK:SIMage:FNAMe "D:\User Files\Screen Images\Flex Channel 3.jpg"
102. :DISK:SIMage:SAVE
103. *OPC?
104. :MEAS:EYE:LIST:CLEAR
105. :MEASure:EYE:ERATio:UNITs DECibel
106. :MEASure:EYE:ERATio:SOURce1 CHAN4A
107. :MEASure:EYE:ERATio
108. :MEASure:EYE:ERATio?
109. :MEASure:EYE:APOWer:UNITs DBM
110. :MEASure:CGR:APOWer:SOURce1 CHAN4A
111. :MEASure:EYE:APOWer
112. :MEASure:CGR:APOWer?
113. :MEASure:EYE:JITTer:SOURce1 CHAN4A
114. :MEASure:EYE:JITTer
115. :MEASure:EYE:JITTer?
116. :MTESt:SOURce CHAN4A
117. :MTESt:LOAD:FNAMe "C:\Program Files\Agilent\FlexDCA\Demo\Masks\Ethernet\009.95328 - 10GbE_9_953_May02.mskx"
118. :MTESt:LOAD
119. :MTESt:MARGin:METHod AUTO
120. :MTESt:MARGin:STATe ON
121. :MTESt:MARGin:AUTo:METHod HRATio
122. :MTESt:MARGin:AUTo:HRATio 5.0E-5
123. :MEASure:MTESt:MARGin?
124. :DISK:SIMage:SINClude CHAN4A
125. :DISK:SIMage:FNAMe "D:\User Files\Screen Images\Flex Channel 4.jpg"
126. :DISK:SIMage:SAVE
127. *OPC?

# Appendix C: Hit Ratio Calculations

Common Hit Ratios are 1 hit in 1000 samples or 1 hit in 20,000 samples, which are often restated as 1E-03 and 5E-05. To determine the number of mask violations allowed per unit interval (UI), let's first calculate the number of samples per unit interval.

Without Rapid Eye, equation is:

$$Samples/UI = N_{waveforms} * \frac{t_{UI}}{t_{DIV}} * \frac{L_{record}}{N_{DIV}}$$

With Rapid Eye, the equation is:

$$Samples/UI = N_{waveforms} * L_{record}$$

$N_{waveforms}$    Number of waveforms acquired by the oscilloscope
$t_{UI}$    Time period of one UI (1/Bit Rate)
$t_{DIV}$    Time per division setting of the oscilloscope
$L_{record}$    Record length of a waveform
         (sometimes called samples/waveform or trace length)
$N_{DIV}$    Number of divisions across the oscilloscope's screen

When using Rapid Eye, the record length of the waveform is reduced to retain about the same number of samples per unit interval. The number of expected mask violations with and without Rapid Eye is given by:

$$N_{violations} = Hit\ Ratio * Samples/UI$$

Below is a numerical example starting with 1000 waveforms using a Hit Ratio of 1 hit in 20,000. Note that the number of violations is the same, which will provide the same statistics for the mask margin.

| Factor | Values, no Rapid Eye | Values, with Rapid Eye | Units |
|---|---|---|---|
| $N_{waveforms}$ | 1000 | 1000 | |
| $t_{UI}$ | 117.647 | 117.647 | ps |
| $t_{DIV}$ | 19.8 | 19.8 | ps/DIV |
| $L_{record}$ | 2048 | 1230 | |
| $N_{DIV}$ | 10 | 10 | |
| Samples/UI | 1216874 | 1230000 | |
| Hit Ratio | 5E-05 | 5E-05 | |
| $N_{violations}$ | 61 | 61 | |

# Appendix D: How to Download Help File to Your PC

- Locate the help file on the documentation disc delivered with the DCA or search on **www.agilent.com** for 86100D Online Help

- Copy the file to the hard drive on your PC, in a subdirectory of your choice

- Open Windows® Explorer and open the subdirectory that contains the Help file

- Right click **Help** file

- Click **Properties**

- Click **General** tab

- If there is an Unblock choice, click the button to prevent security messages from arising when opening the Help file

## References

- Infiniium DCA-X Agilent 86100D Wide-Bandwidth Oscilloscope Mainframe and Modules, Technical Specification, literature number 5990-5824

- Infiniium DCA-J Agilent 86100C Wide-Bandwidth Oscilloscope Mainframe and Modules, Technical Specification, literature number 5989-0278

- Infiniium DCA and DCA-J and DCA-X Agilent 86100A/B/C/D Wide-Bandwidth Oscilloscope, Programmers Guide, manual part number 86100-90131

- Agilent Application Note, Techniques for Higher Accuracy Optical Measurements, which covers System Impulse Response Correction (SIRC) , literature number 5990-7884

- Video describing Eye Mask Hit Ratio Technique and Auto Mask Margin **http://wireless.agilent.com/vcentral/viewvideo.aspx?vid=740**

- Video describing testing of optical transceivers in parallel **http://wireless.agilent.com/vcentral/viewvideo.aspx?vid=752**

- ANSI Technology Standard, Fibre Channel Physical Interface-5 (FC-PI-5)

- INCITS Draft Technical Report, Fibre Channel – Methodologies for Signal Quality Specification – MSQS

- IEEE Standard 802.3ba-2010, Part 3 and Amendment 4

- IEEE Standard 802.3aq-2006, Part 3 and Amendment 2

- Common Public Radio Interface (CPRI), Interface Specification, V4.2