Optical Sampling Scope Measurements

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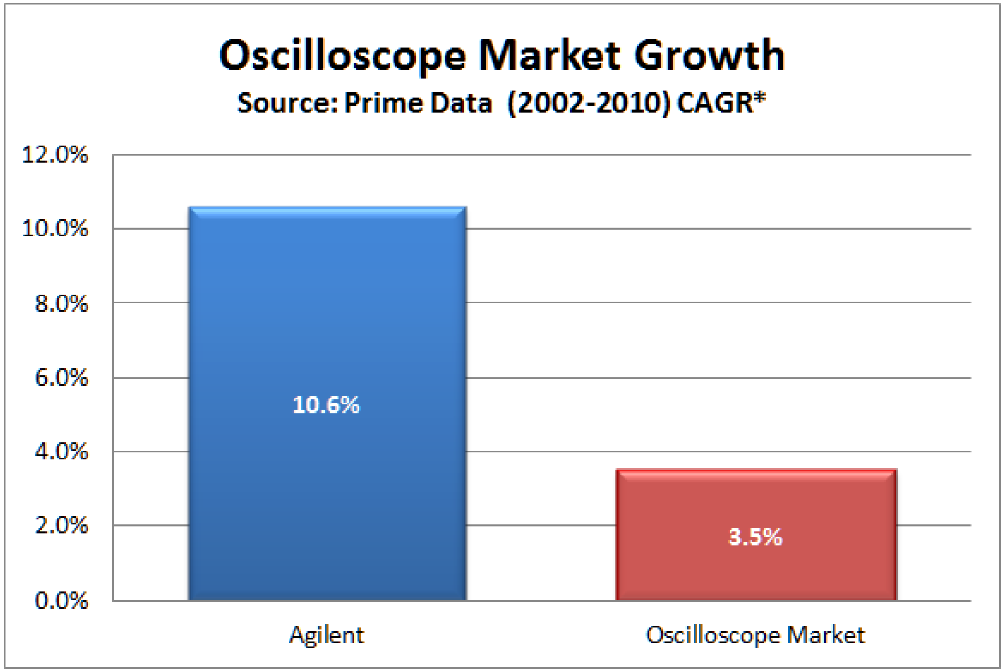
October 14, 2013

Agilent Oscilloscopes – Portfolio Overview



* CAGR = Compound Annual Growth Rate

15+ Years

New

86100D DCA-X

New

90000 Q-Series

90000 X-Series

New

U1600 Series

U2700 Series

New

1000B Series

2000 X-Series

New

3000 X-Series to 1GHz

6000 Series

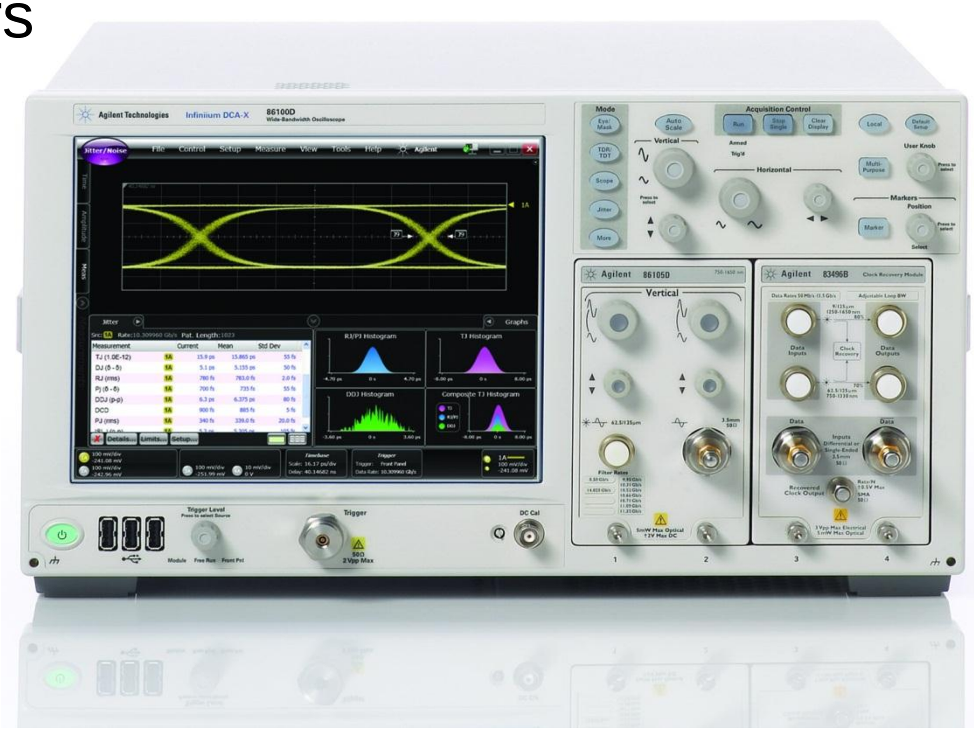
7000B Series

9000 Series

90000 Series

Table Of Content

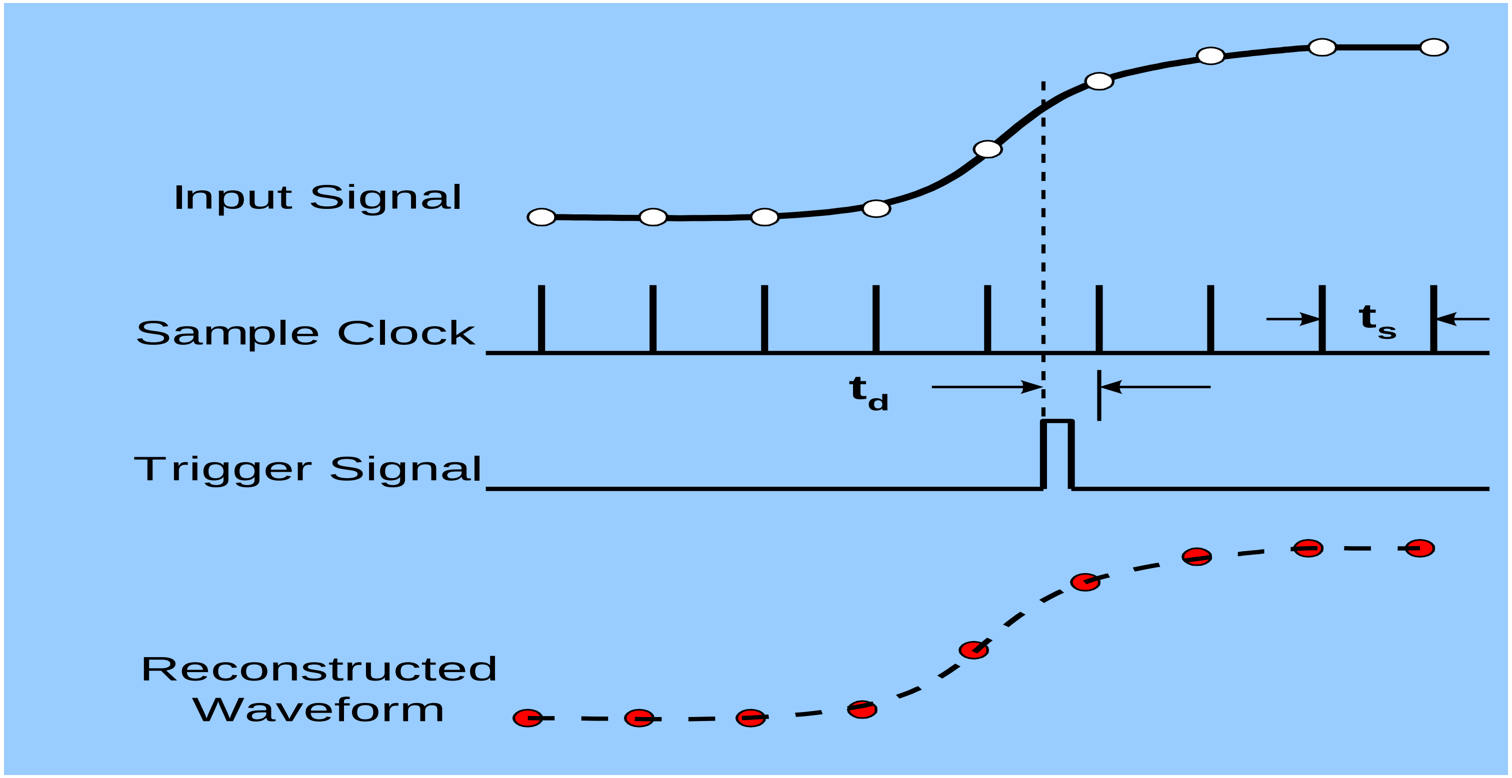
- ❑ Viewing Digital Waveforms
- ❑ Optical Reference Receivers
- ❑ Eye Measurements
- ❑ Jitter Measurements
- ❑ DCA Family

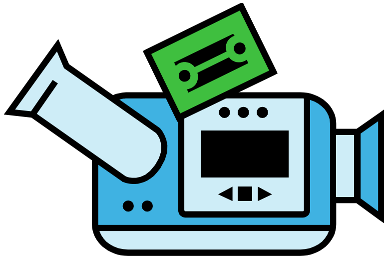


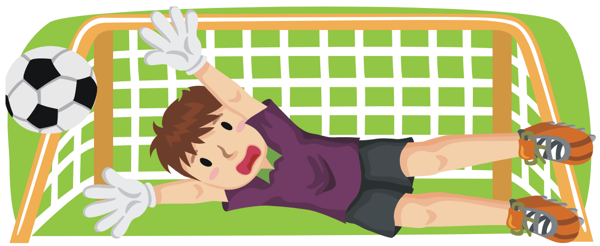
Viewing Digital Waveforms

Scope Types	• Sampling Techniques
Scope Trigger	• Equivalent Vs. Real Time
Scope Mode	• Capturing A Waveform
Basics – Eye	• Creating an Eye Diagram

Real-Time Scope Technique

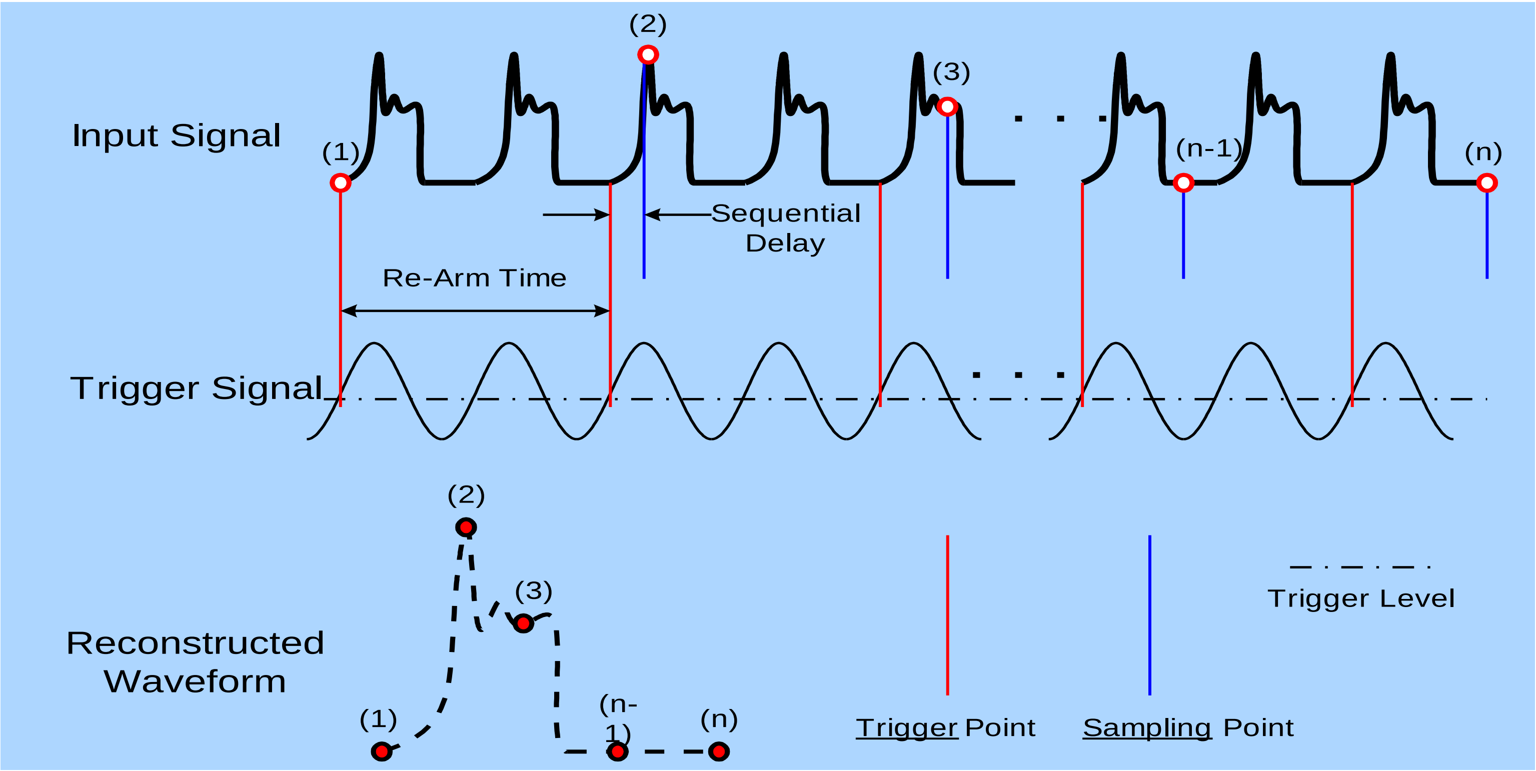


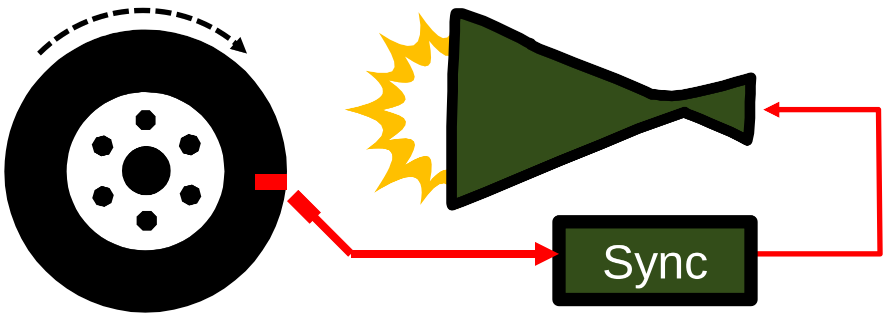




Real-time scopes are like television cameras: they continuously record and play back the time around an event.

Equivalent-Time Scope Technique

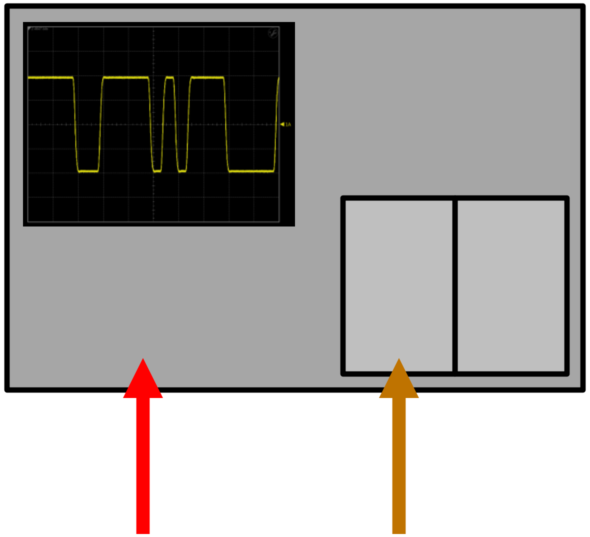




Equivalent-time scopes are like stroboscope lights: they precisely capture a series of samples (images) from a signal (object) that repeats continuously.

Triggering The Oscilloscope

Equivalent-Time Scope
(also called Sampling Scope)

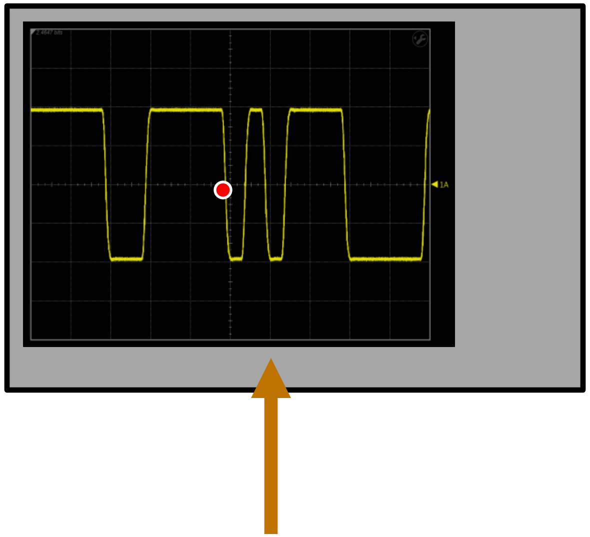


Clock/Trigger **Signal**

Each point is sampled after a certain delay relative to the trigger signal

Most accurate method to capture and analyze repeating waveforms.

Real Time Scope



Signal

Sampler runs continuously but only points near an “event” are displayed.

Great for non-repeating signals and for finding single events such as glitches.

Capturing A Waveform

Today's oscilloscopes can acquire:

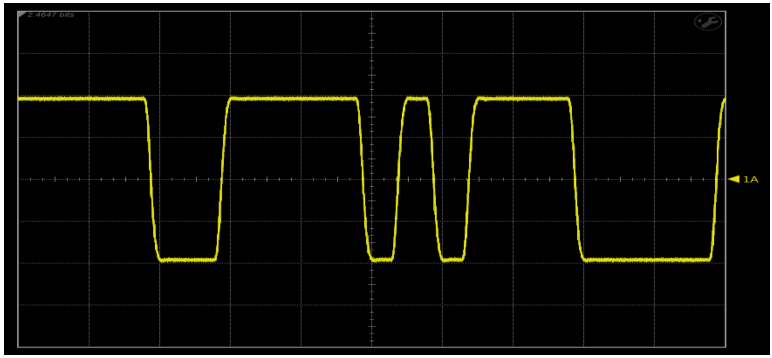
- Up to 2G samples/waveform (RT)
- Up to 32M samples/waveform (ET)

Displaying a small fraction of the waveform allows you to check individual bits for issues

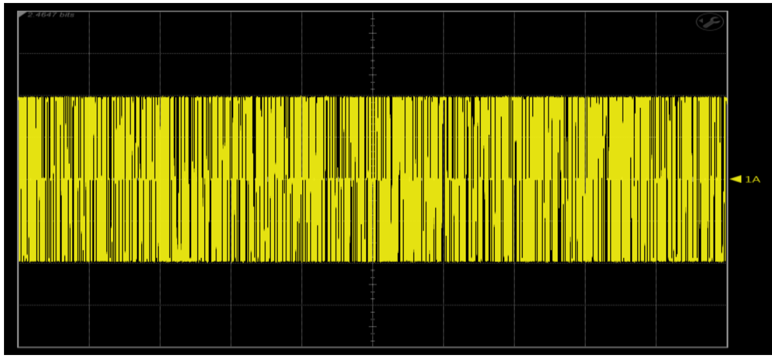
- Need to know where to look
  (e.g., find isolated bits such as "000000100")
- Difficult, time consuming or even impossible to judge the "health" of the whole waveform

Advanced display and analysis techniques:

- Eye diagram
- Jitter decomposition



20 bits out of a PRBS15 pattern

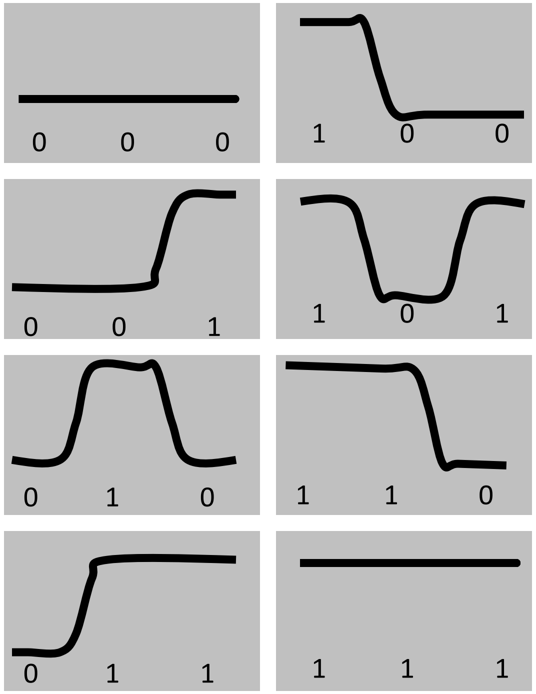


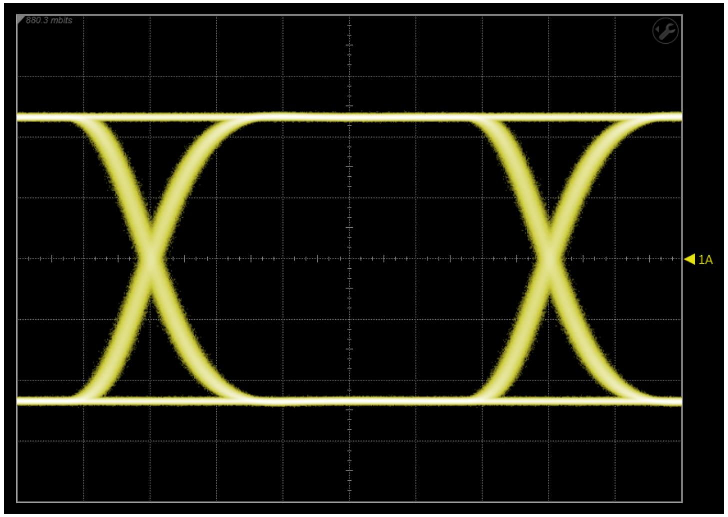
Whole PRBS15 pattern

Creating An Eye Diagram

Overlay of a multitude of bits from throughout the data pattern

- Consider all the possible waveforms in a 3 bit sequence on a common timebase
- Rather than a snapshot of a small section of the pattern, this provides a good view of the overall quality of the signal
- Potentially see the response to the entire pattern in a single display
- Important implications when viewing ‘real or live traffic’ data streams





Optical Reference Receivers

Motivation	• Consistency
Filters	• Filter Design
Tolerances	• Ideal Vs. Actual Hardware
Corrections	• SIRC Technology

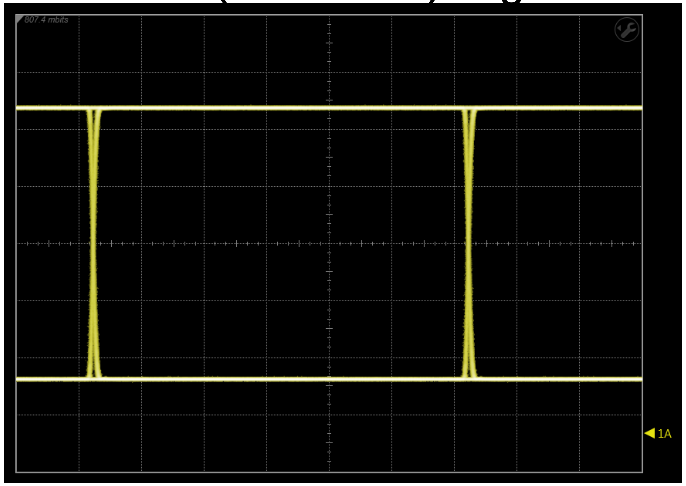
Motivation: Measurement Consistency

- Many lasers exhibit so-called relaxation oscillations at frequencies in the vicinity or above the bit rate
- These oscillations tend to make measurements inconsistent
- Faster oscilloscope channels tend to display more noise
- Slower oscilloscope channels tend to display more inter-symbol interference

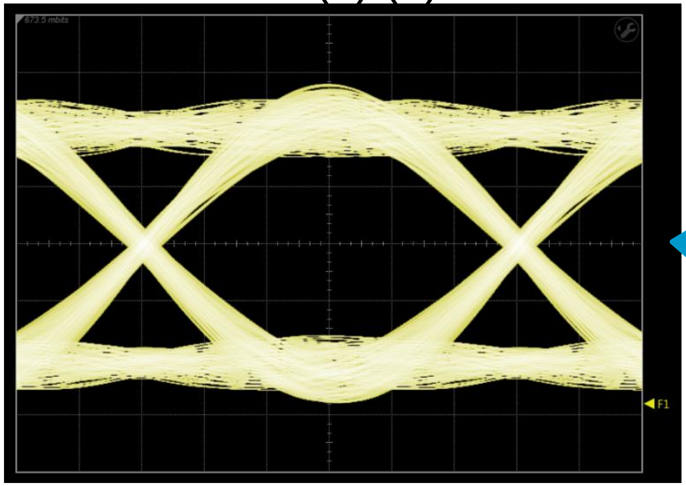
Needed: a defined measurement system that maximizes the consistency of eye diagrams and waveforms

Filter Design (3 dB_e BW = 0.75 * bit rate)

Ideal (unfiltered) Signal

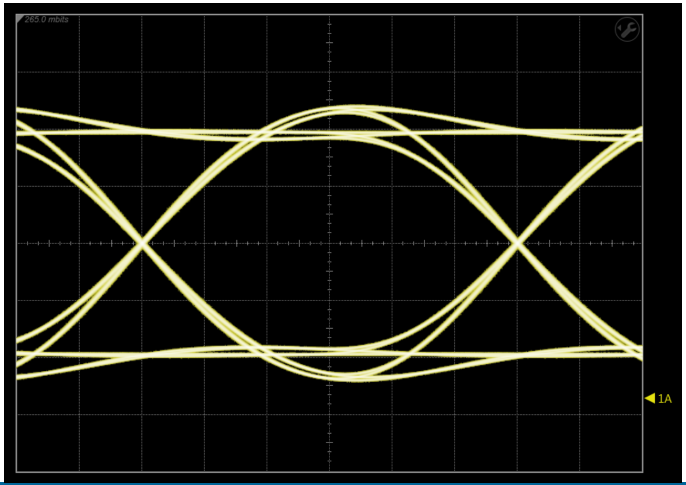


Sin(x)/(x)

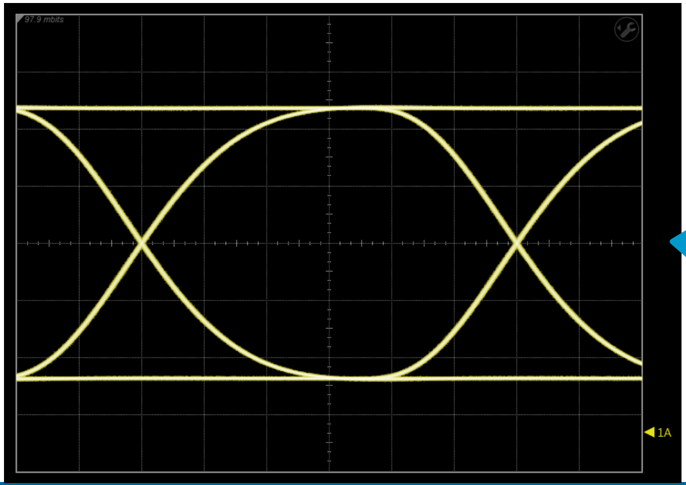


RT Scope

4th Order Butterworth

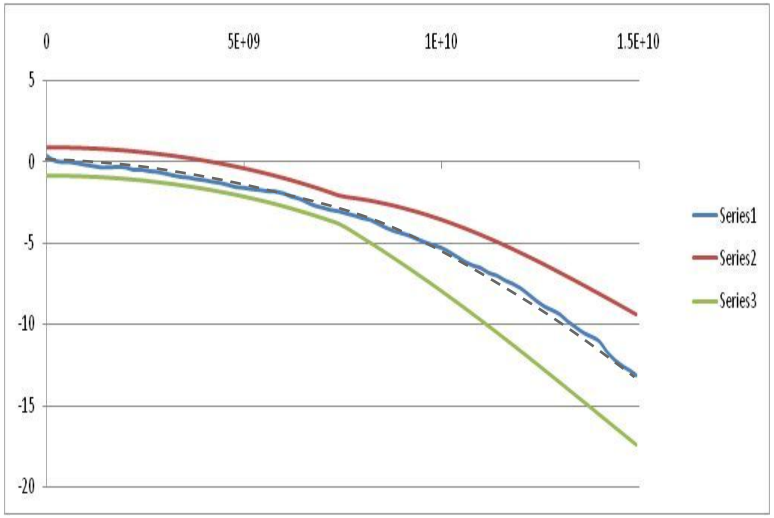


4th Order Bessel-Thomson

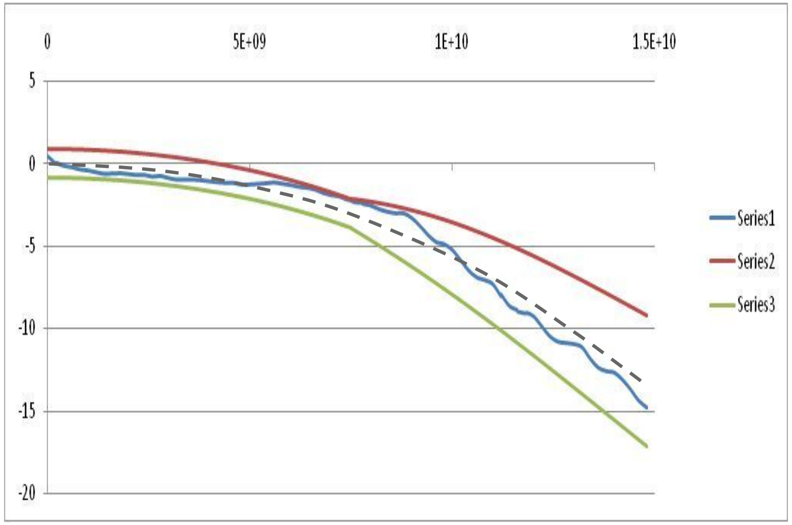


DCA

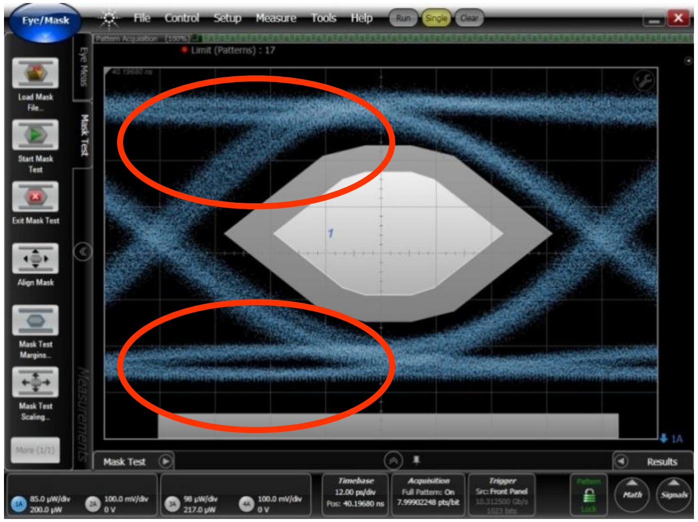
Ideal Vs. Actual Hardware



Receiver B



Receiver A



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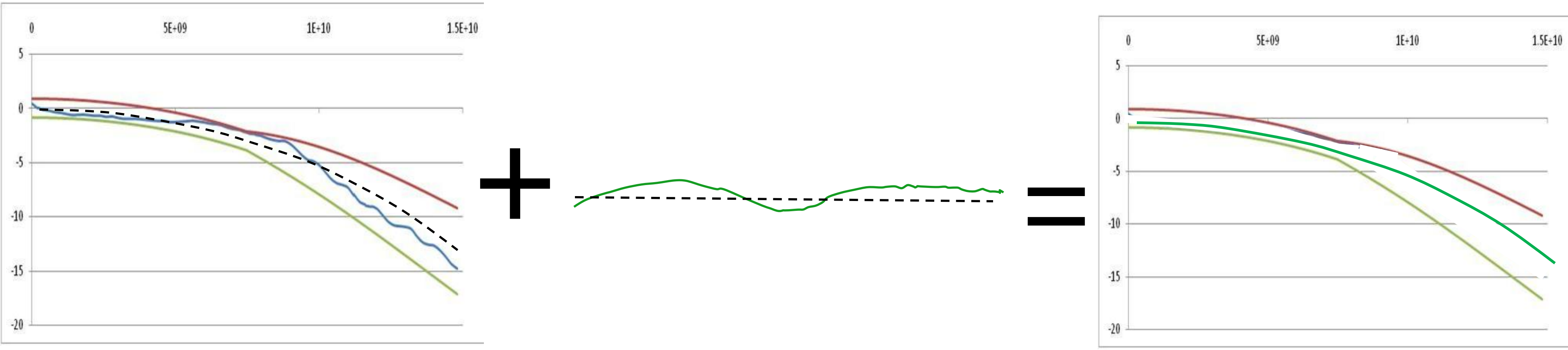
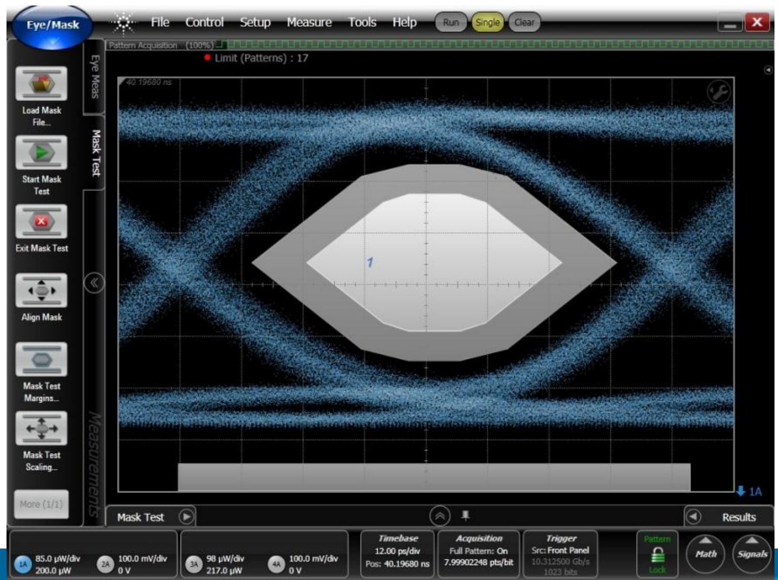
OPD Oscilloscope Innovation

SIRC Technology

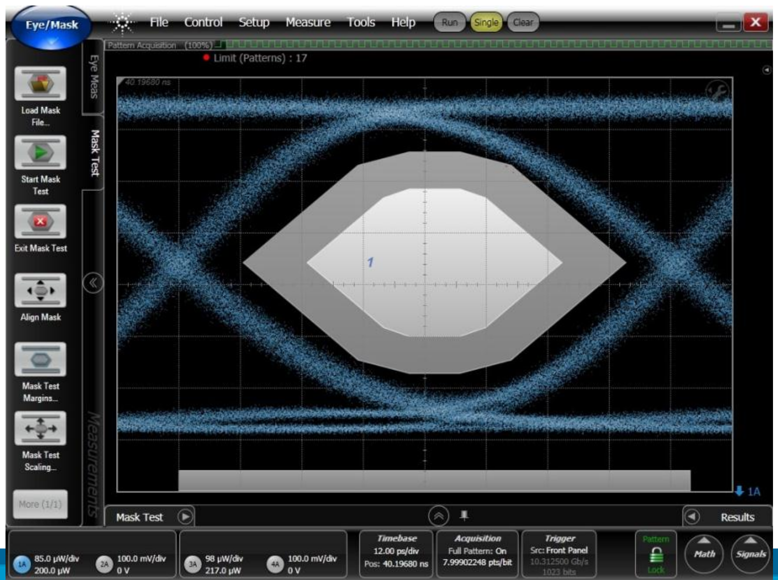
(SIRC = System Impulse Response Correction)



Receiver A without SIRC



Receiver A with SIRC



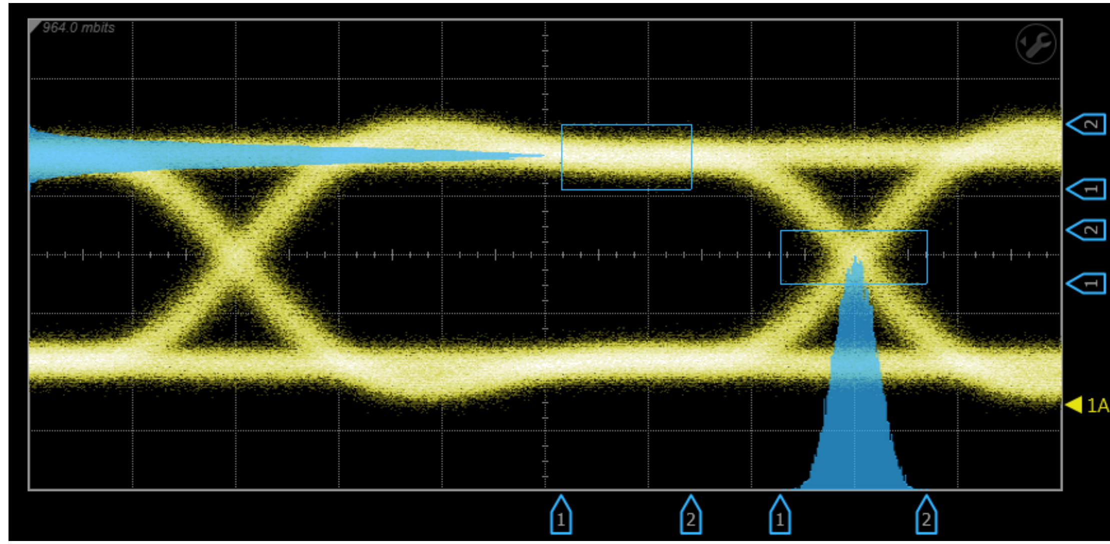
Eye Measurements

Histograms	• To measure *anything*
ER, OMA	• Basic characteristics
Jitter	• RMS & Peak-Peak
Masks	•Standard, Margins

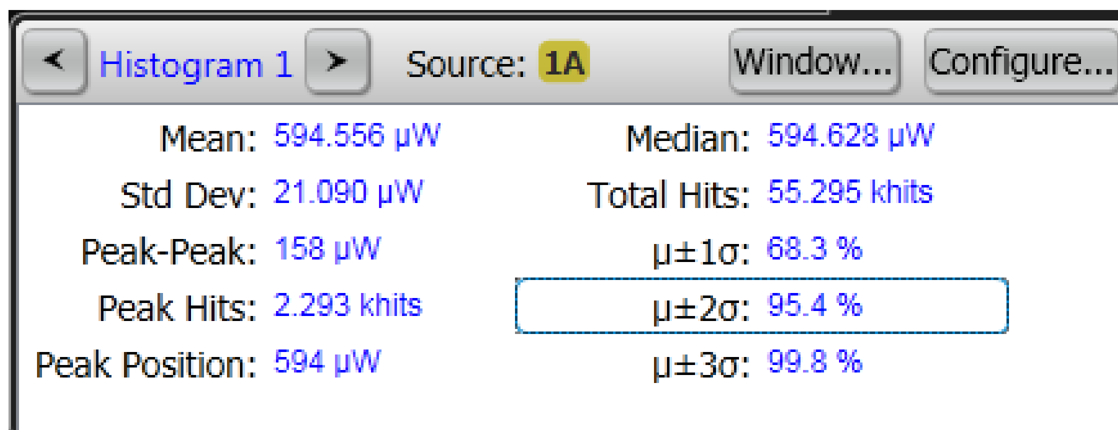
Histograms

Histograms provide statistical analyses into amplitude or edges.

Windows define which samples are taken into account.



Mean, standard deviation, number of samples (hits) can then be used for further analysis.

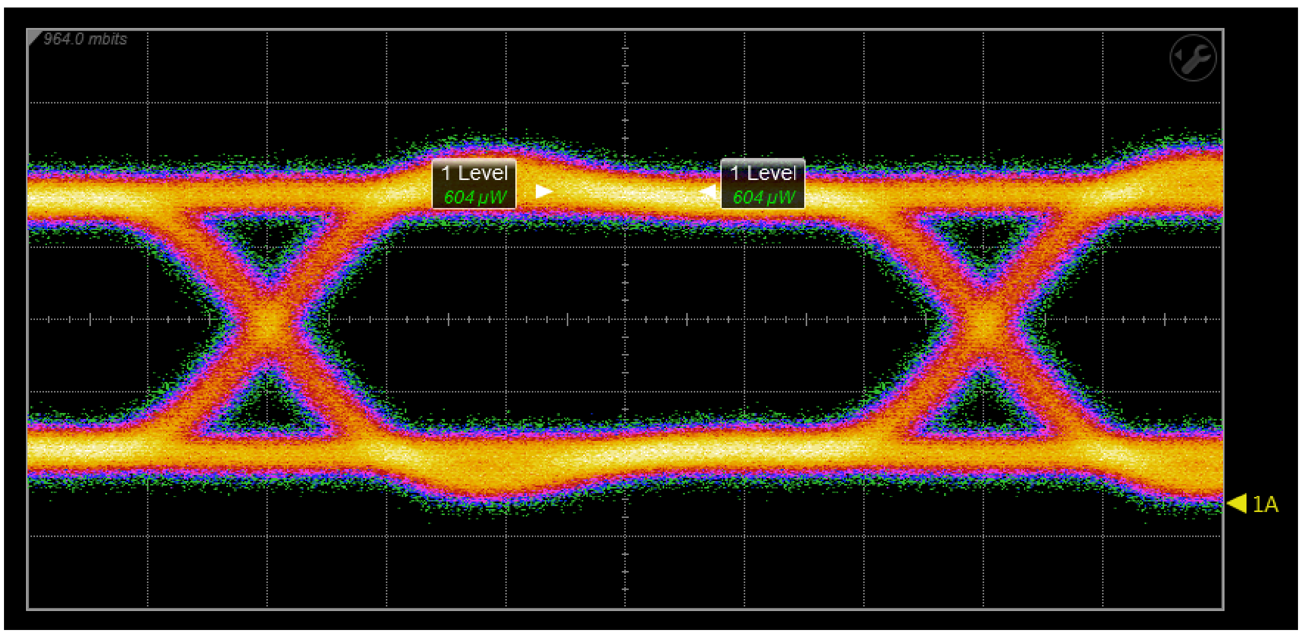


Extinction Ratio, Optical Modulation Amplitude

$$OMA = P_{one} - P_{zero}$$

$$ER = P_{one} / P_{zero} = (P_{one} - P_{dark}) / (P_{zero} - P_{dark})$$

Small measurement errors can cause big fluctuations of ER if the zero level is close to the dark level!



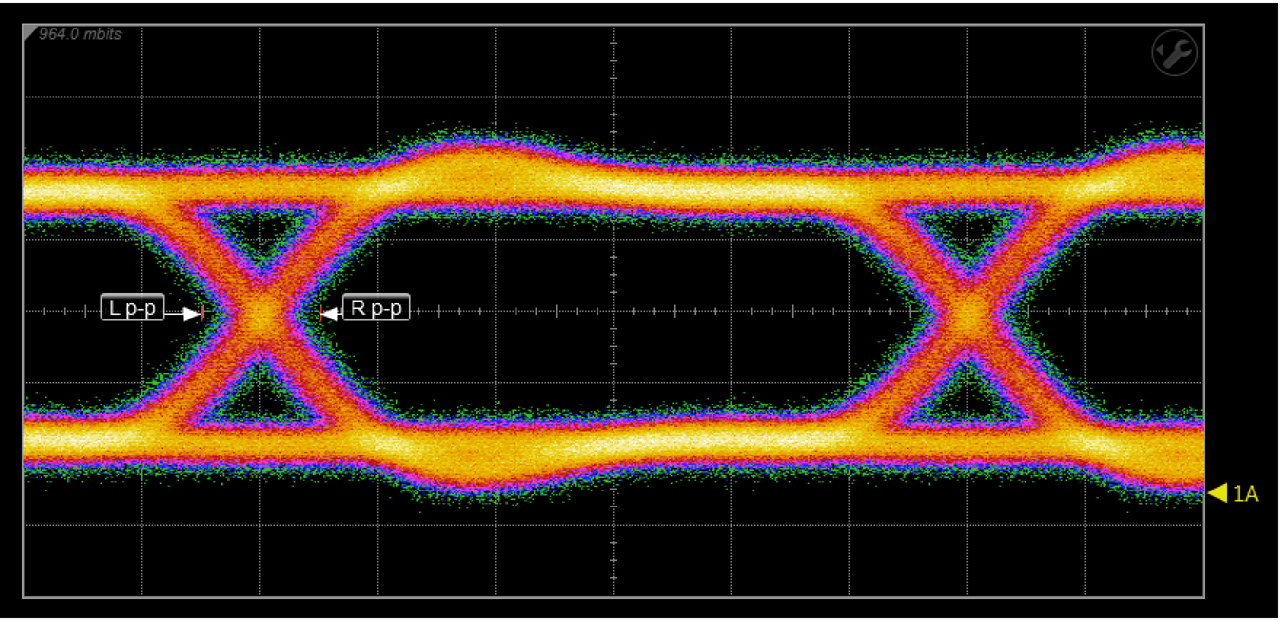
Measurement		Current
Zero Level	1A	96 µW
One Level	1A	604 µW
Ext. Ratio	1A	7.987 dB

RMS & Peak-Peak Jitter

$Jitter_{rms}$: independent of acquisition time

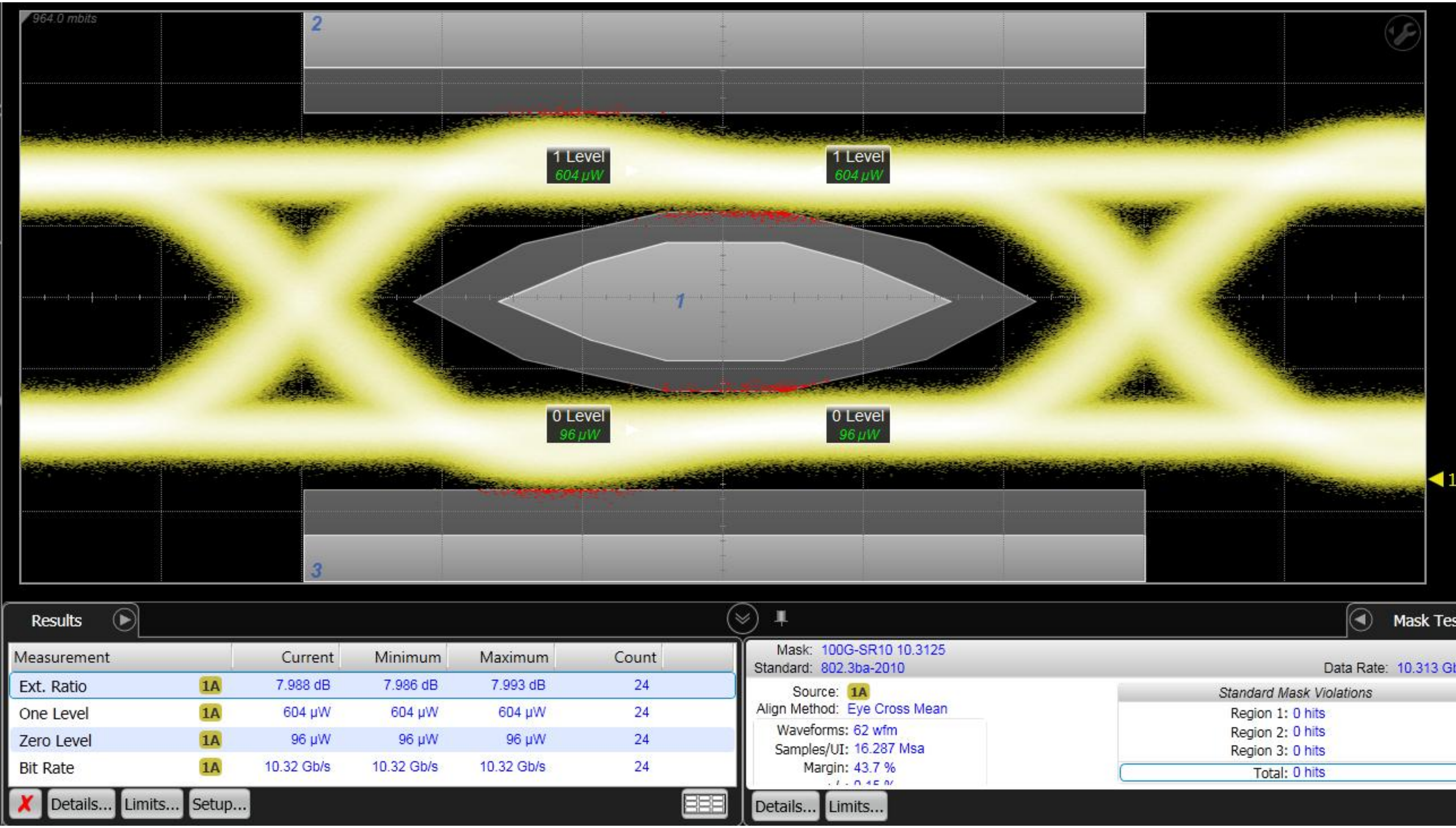
$Jitter_{p-p}$: increases with acquisition time

The more samples, the more likely outliers will occur!



Measurement		Current
Crossing %	1A	49.8 %
Jitter[p-p]	1A	16.376 ps
Jitter[rms]	1A	2.264 ps
Bit Rate	1A	10.32 Gb/s

Mask and Mask Margins



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Jitter Measurements

Motivation	• System Level BER
Science	• Jitter Decomposition Tree
Analysis	• Jitter Details
Amplitude	• Interference / Noise

Motivation: System Level BER

Design goal for digital communication: error free transmission

- "Error free" often defined as tolerable bit error ratio
  - Software protocols (such as IP or OSI stack) can handle residual errors

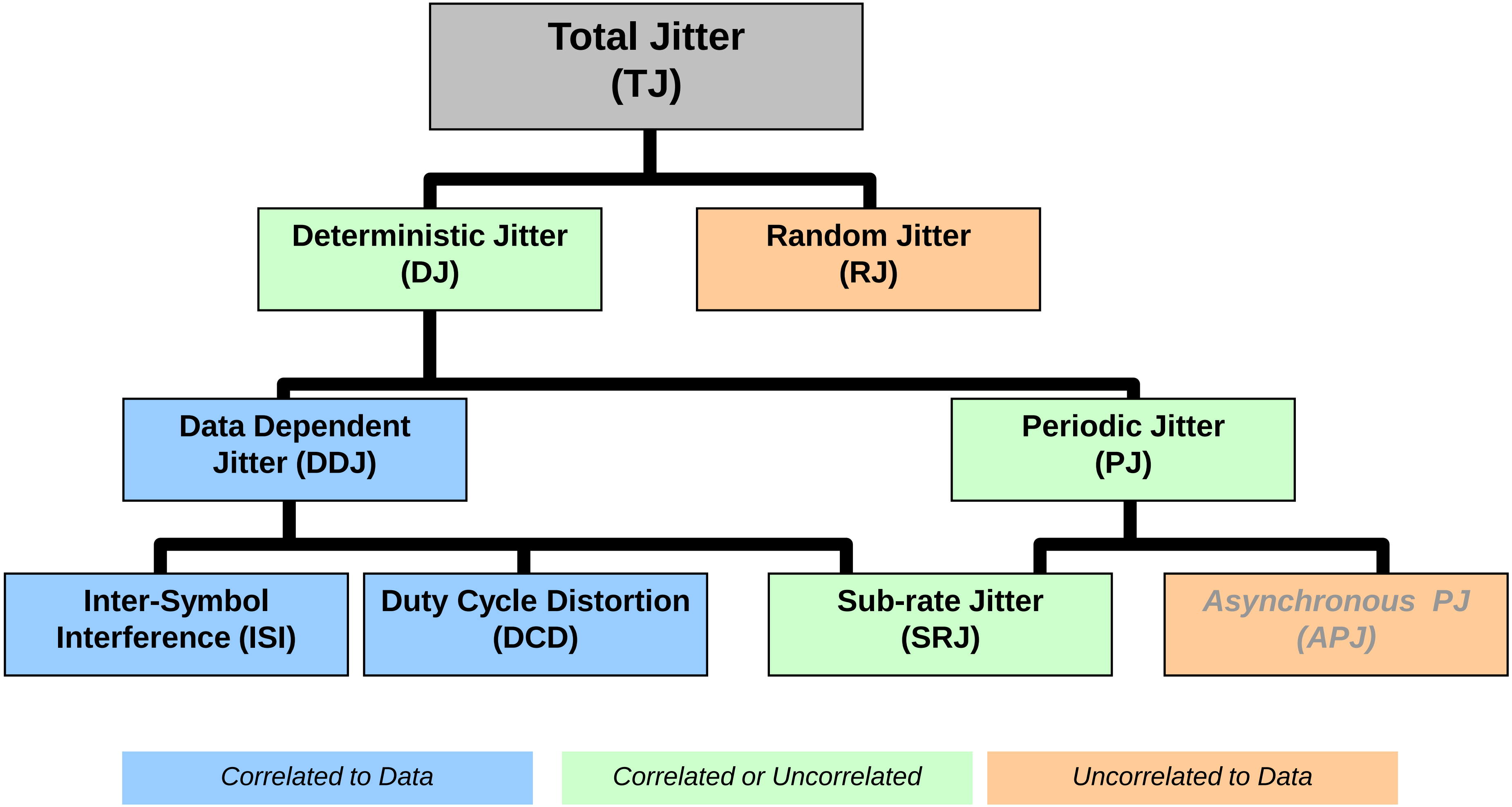
- Bit Error Ratio (BER) = # of incorrect bits / # of total bits
  - Practical BER goals range from 1E-9 to 1E-15

When the BER is worse than needed:

- **What causes the bit errors?**
- **What needs to be improved?**

Jitter Decomposition Tree

See also: Precision Jitter Analysis Using the Agilent 86100C DCA-J (PN 86100C-1)



Jitter Analysis

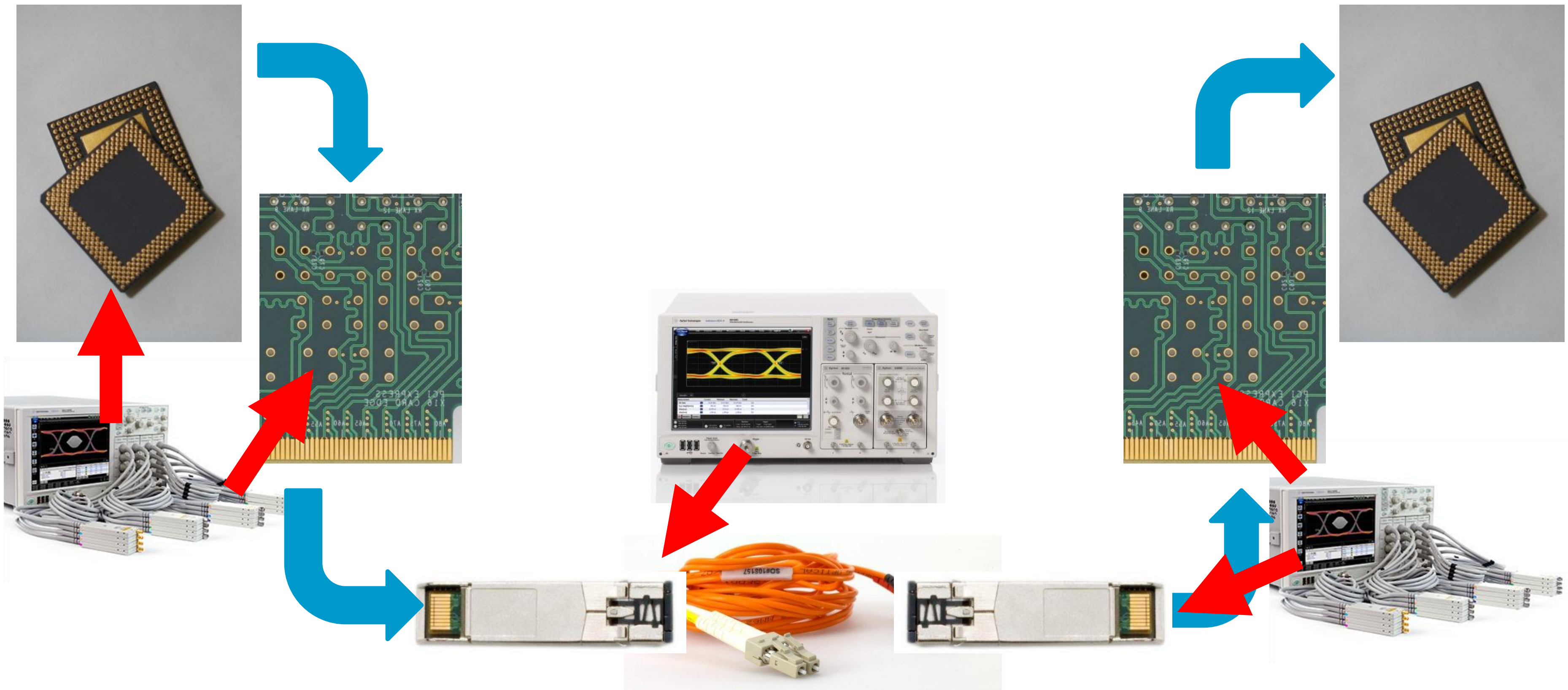
Interference / Noise Analysis

DCA Family

Mainframe	• 86100D DCA-X
Modules	• Optical, Electrical, CDR, TDR
FlexDCA	• Primary DCA-X Software
Applications	•For Standard Compliance

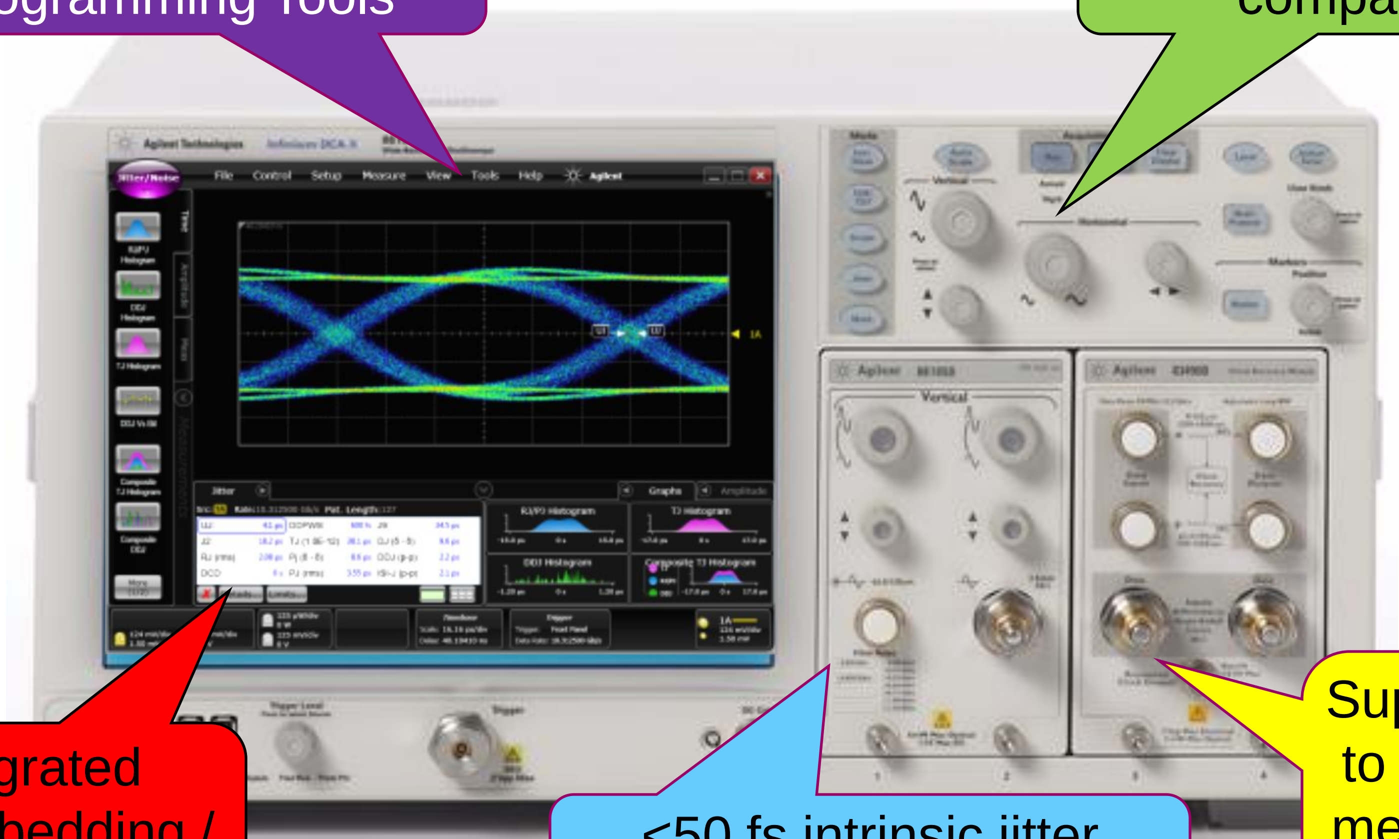
System Level Perspective

ASIC – electrical – TRX – optical – TRX – electrical – ASIC



86100D DCA-X Wide-Bandwidth Oscilloscope

Engineered for unmatched measurement <u>accuracy</u>, <u>insight</u>, and <u>ease-of-use</u>



SCPI Recorder & Programming Tools

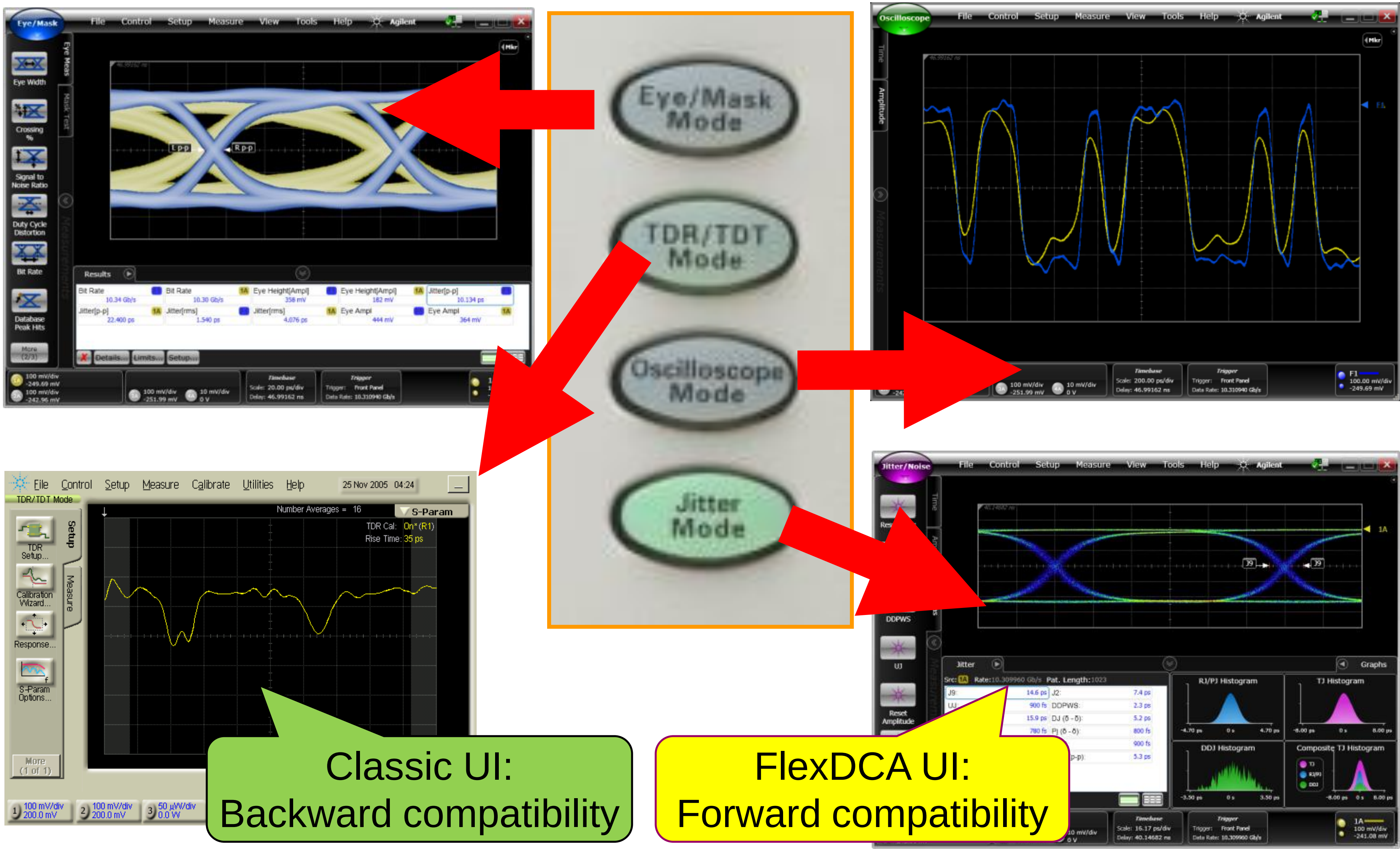
Fully backwards compatible

Integrated De-Embedding / Embedding

<50 fs intrinsic jitter (when using 86108B)

Support for up to 16 parallel measurement channels

Four Instruments In One



Optical Modules

86105C Optical/Electrical Module

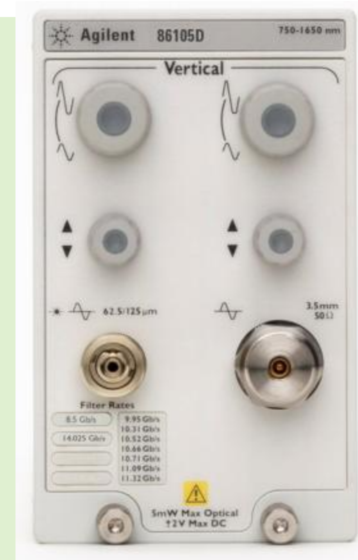
- 9 GHz amplified optical channel
  - 750-1600 nm
  - 9/125 to 62.5/125 um fibers
  - 155 Mbps to 11.3 Gbps options
- 20 GHz electrical channel

*Optimized for greatest **flexibility***

86105D Optical/Electrical Module

- 20 GHz optical channel
  - 750-1650 nm
  - 9/125 to 62.5/125 um fibers
  - 8.5 Gbps to 14.025 Gbps
- 35 GHz electrical channel

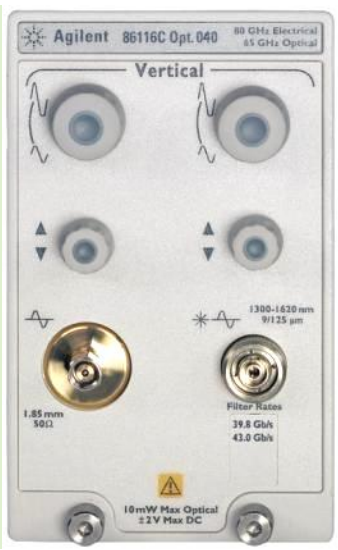
*Optimized for best **accuracy***



86116C Optical/Electrical Module

- Option 25: 45 GHz (typical) optical
- Option 40: 70 GHz (typical) optical
  - 1200-1600 nm
  - 9/125 fiber (single-mode)
- 93 GHz (typical) electrical channel

*Optimized for **highest bandwidth***



86115D Dual/Quad Optical Module

- 20 GHz optical channels
  - 750-1650 nm
  - 9/125 to 62.5/125 um fibers
  - 8.5 Gbps to 14.025 Gbps

*Optimized for **lowest cost of test***

Electrical Modules

86112A Dual Electrical Module

- 20 GHz electrical channel
- Characteristic rms noise:
    - 0.25 mV (12 GHz BW)
    - 0.5 mV   (20 GHz BW)

86117A Dual Electrical Module

- 50 GHz electrical channel
- Characteristic rms noise:
    - 0.4 mV (30 GHz BW)
    - 0.6 mV (50 GHz BW)

86108B Precision Waveform Analyzer

- Combines 3 modules into one
  (Two 50 GHz electrical channels, 32G clock recovery and precision timebase)
- <50 fs intrinsic jitter
- 50 or 35 GHz bandwidth
- 32 or 16 Gb/s CDR
- Jitter Spectrum Analysis to find root causes

Remote Heads & External Modules

86118A Dual Remote Heads

- 2 remote heads/module
- Max. 2 modules/frame
- 70 GHz channels
- Characteristic rms noise:
  - 0.4 mV (30 GHz BW)
  - 1.3 mV (70 GHz BW)

N1045A Electrical Mini-Module

- 2 or 4 remote heads/module
- Max 4 modules/frame
- 60 GHz channels
- Characteristic rms noise:
  - 0.3 mV (20 GHz BW)
  - 0.8 mV (60 GHz BW)

N4877A Clock Recovery

- N4877A: Electrical Only
- N1070A: Electrical with optical front end
- Continuous 0.05 to 32 Gb/s
- Adjustable loop bandwidth
- PLL and Jitter Spectrum Analysis

Specialty Modules

83496B Clock Recovery Module

- Option 100: Electrical Only
- Option 101: Optical & Electrical
- Continuous 0.05 to 14.2 Gb/s
- Adjustable loop bandwidth
- PLL and Jitter Spectrum Analysis

86107A Precision Timebase

- <100 fs jitter (86100D mainframe)

54754A Differential TDR Module

- 18 GHz electrical channel
- 35 ps step generators *(effective rise time software adjustable from 15 to 500 ps)*
- Single-ended or differential
- TDR or TDT operation
- Can be used as a 2-channel receiver module

Application Software

- 200: Jitter Analysis
- 201: Advanced Waveform Analysis
- 202: Enhanced Impedance and S-Parameters
- 300: Amplitude Analysis
- 400: PLL and Jitter Spectrum (83496B or 86108A)
- 401: Advanced Eye Analysis (supports PRBS31)
- 500: Productivity Package
- SIM: InfiniiSim-DCA Waveform Transformation
- JSA: Jitter Spectrum Analysis (86108A/B)
- N1019A: User Defined Applications framework
- N1012A: OIF-CEI:3.0 Compliance Test Application
- N1014A: SFF-8431 Compliance Test Application

Probing

The Industry's First 30 GHz Probing System
InfiniiMax III probe amp/probe head architecture

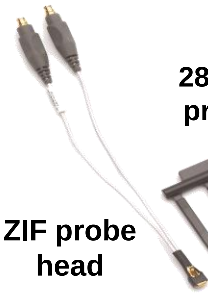
Probe Amplifier

Probe amps –
16 GHz, 20 GHz,
25 GHz, 30 GHz

Performance verification and de-skew fixture

Probe Heads

30 GHz Browser with LED Headlight



ZIF probe head

28 GHz ZIF probe tips

16 GHz solder-in probe head

28 GHz 2.92mm/3.5mm/SMA probe head

Probe Adapters

Sampling scope adapter

High impedance probe adapter

Precision BNC 50 ohm adapter adapter

Accessories

See www.agilent.com/find/N1027A *(or lit # 5991-2340EN)* ***for full list***

DCA-X References

- Compatibility: Backwards compatible with all sampling scope modules ever sold (e.g., for 54750A, 83480A, 86100A/B/C/D mainframes) Forward compatible with mini-modules, FlexDCA and application software
- Web Site: www.agilent.com/find/dcax *(main page)*
  www.agilent.com/find/86100D_download *(firmware upgrades)*
- Video: http://www.youtube.com/watch?v=4vnkC5DuDvk
  (search YouTube "86100D" and/or "FlexDCA" for related videos)
- Sampling Scope Theory: Dennis Derickson, Markus Müller: *Digital Communications Test and Measurement*, Chapter 7; Prentice Hall, 2008 (ISBN 0-13-220910-1)
- Pricing (US):

86100D Mainframe (hardware)	\$21K - \$29K
Licenses for advanced measurements (ea.)	\$3K-\$14K
Application Software	\$4K - \$10K
Electrical Modules (ea.)	\$15K - \$125K
Optical Modules (ea.)	\$36K - \$88K

Agilent Technologies
OPD Oscilloscope Innovation

October 14, 2013

Thank you for listening!

Any questions?