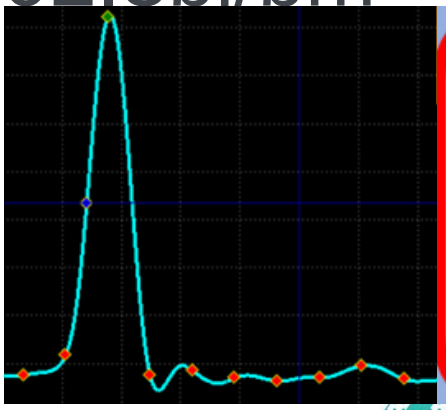
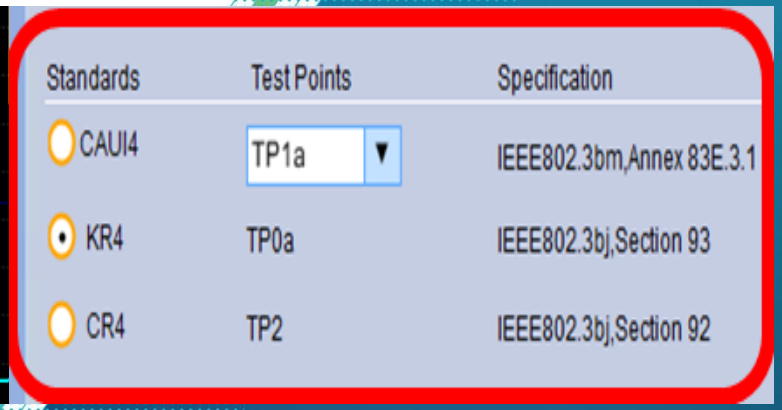
Tektronix

DataCom 100G
OIF-CEI/IEEE 802.3bj/bm





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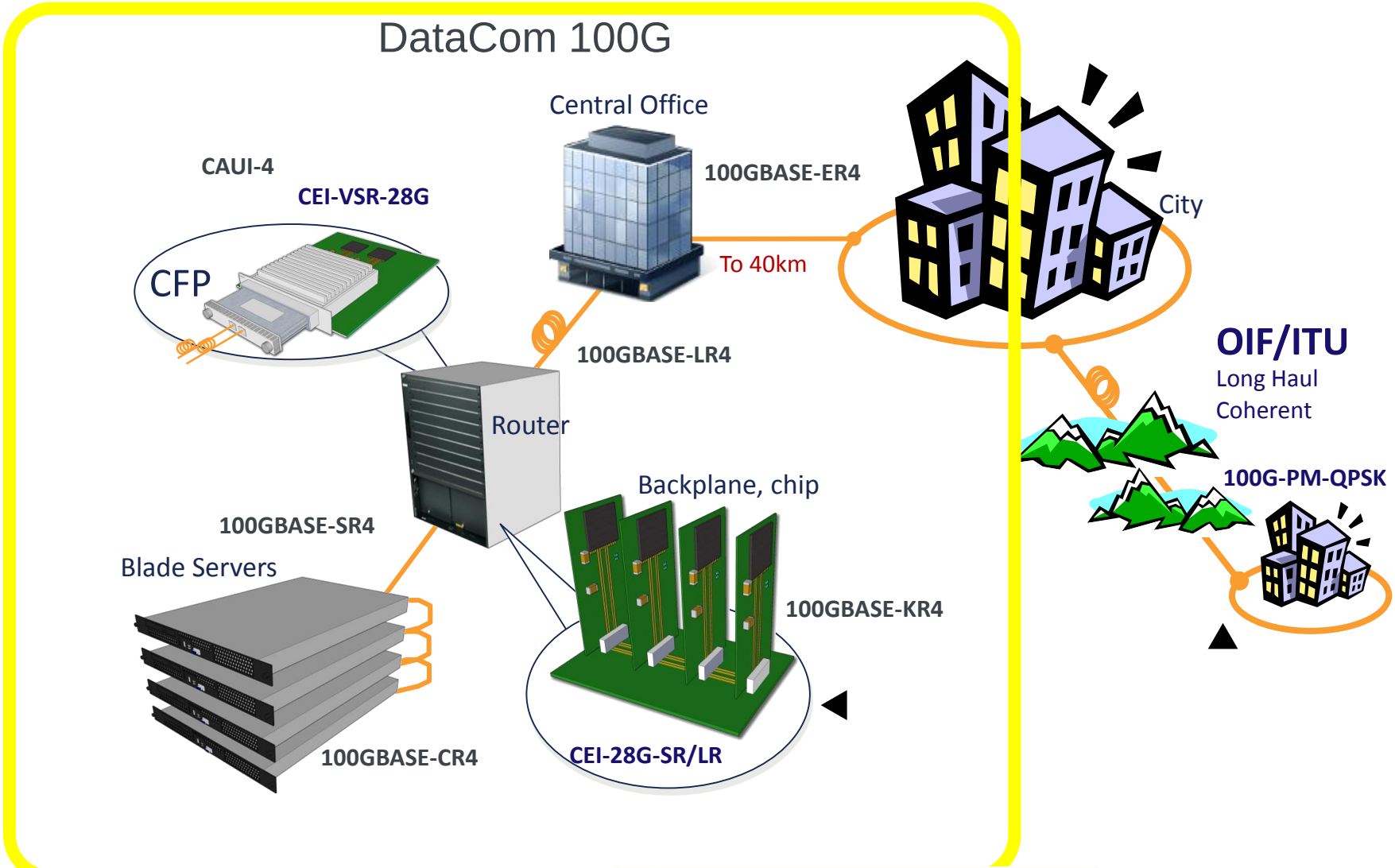
100G Ecosystem (DCOM401)



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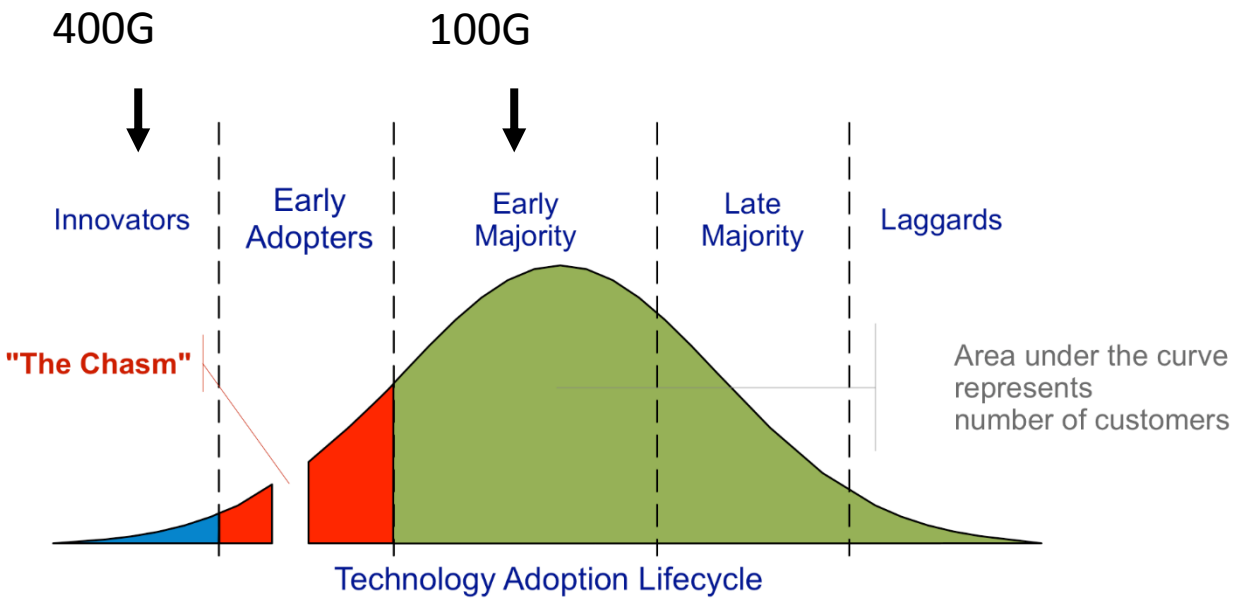
100G is in mainstream products today
400G is in the early spec draft stage.

STD/Year	Module Interconnect	IEEE Std LAN Side	Per/Lane data rate	Instrumentation (3dB point)
2008	XLAUI	802.3bg : (40G FR)	40Gbps	BW: 44 GHz ORR
2009	CEI 3.0	802.3ba : (100G LR4/ER4)	25.78Gbps	BW: 44 GHz
2014	KR4	802.3bj : (100G KR4/CR4/KP4)	25.78Gbps	BW: 33 GHz **(Bessel-Thompson, BT)**
2015	CAUI4	802.3bm: (100G SR4)	25.78Gbps	BW: E-33GHz/O-33GHz **(BT)**
2017	CEI 3.1 / CDAUI-8	802.3bs : (400G LR8)	56Gbps	BW: E-44GHz/O-66 GHz **(BT)**
2018	CEI 3.1 / CDAUI-8	802.3bs: (400G DR4)	112Gbps	BW: E-44GHz/O-66GHz **(BT)**



The Top-to-Bottom *100G* Standards

(Main actors only, not a comprehensive table)

Distance	Standard	Modulation/signaling	e.g.
X,000 km…40 km	OIF, OTN, ITU	Complex optical	DP-QPSK
10, 40 km	Ethernet	NRZ SM	100GBASE-ER4/LR4
2 km	*MSA "CLR4"*	NRZ SM	100G-CLR4
500 m	*MSA "PSM4"*	NRZ SM	100G PSM4
100 m	Ethernet	NRZ MM	100GBASE-SR4
~100 m	Infiniband (IB)	NRZ over active cable; or interconnect	"CAUI-4" going
10 m	Ethernet, IB	NRZ on passive Cu cable	100GBASE-CR4
Backplane < 1m	Ethernet, OIF CEI	NRZ	100GBASE-KR4, CEI LR
		PAM4	100GBASE-KP4
Interconnect module to chip, chip to chip	OIF CEI, Ethernet	NRZ	VSR CAUI-4

100G across the stack

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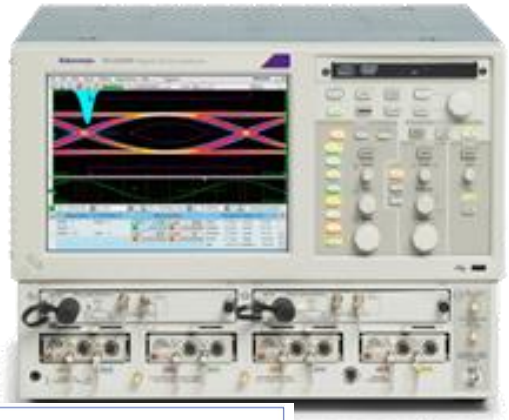
Tektronix 100G/400G Signal Acquisition Systems

Equivalent Time Signal Acquisition • Real Time Signal Acquisition Software Control and Analysis

- **Two world class acquisition systems cover the breadth of any 400G Verification and design needs, with the lowest noise, highest bandwidth in the industry**
  - Real Time (70GHz ATI) single shot acquisition and triggering capabilities are key tools for advanced analysis and debug.
  - Equivalent Time low noise, high sensitivity tools enable the best margin in product and device characterization.

- Real Time
  - 70GHz Analog Bandwidth, 4.3ps rise time (20%-80%)
  - 200GS/s Sample Rate
  - <125fs jitter noise floor
  - ≥25GHz Edge trigger bandwidth
  - Compact 5 ¼” Oscilloscope package
  - No physical clock recovery required (key to 400G)
  - Comprehensive CTLE, DFE, FFE signal processing
  - Lowest noise real time acquisition system
  - Best Electrical solution on the planet

- Equivalent Time
  - 85GHz Optical Bandwidth
  - 70GHz Electrical Bandwidth
  - <100fs jitter noise floor
  - 20nW to .6uW Optical Resolution.
  - Automated test of 80 Industrial Stds.
  - Best Optical solution on the planet



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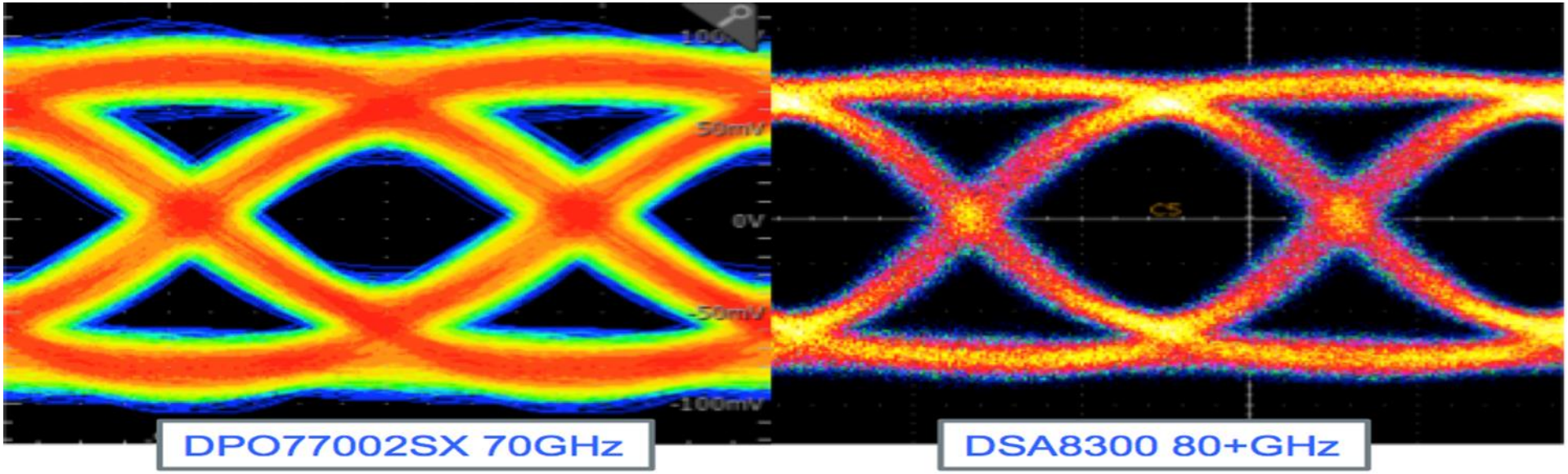
Real Time –vs- Equivalent Time



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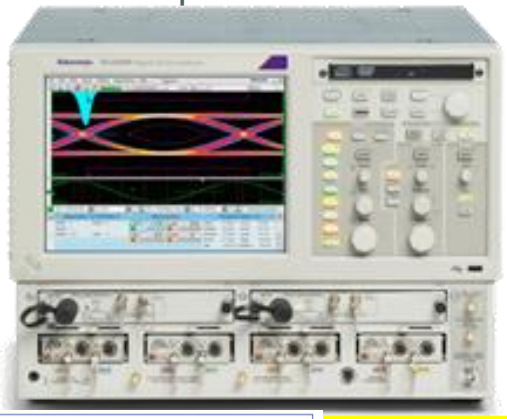

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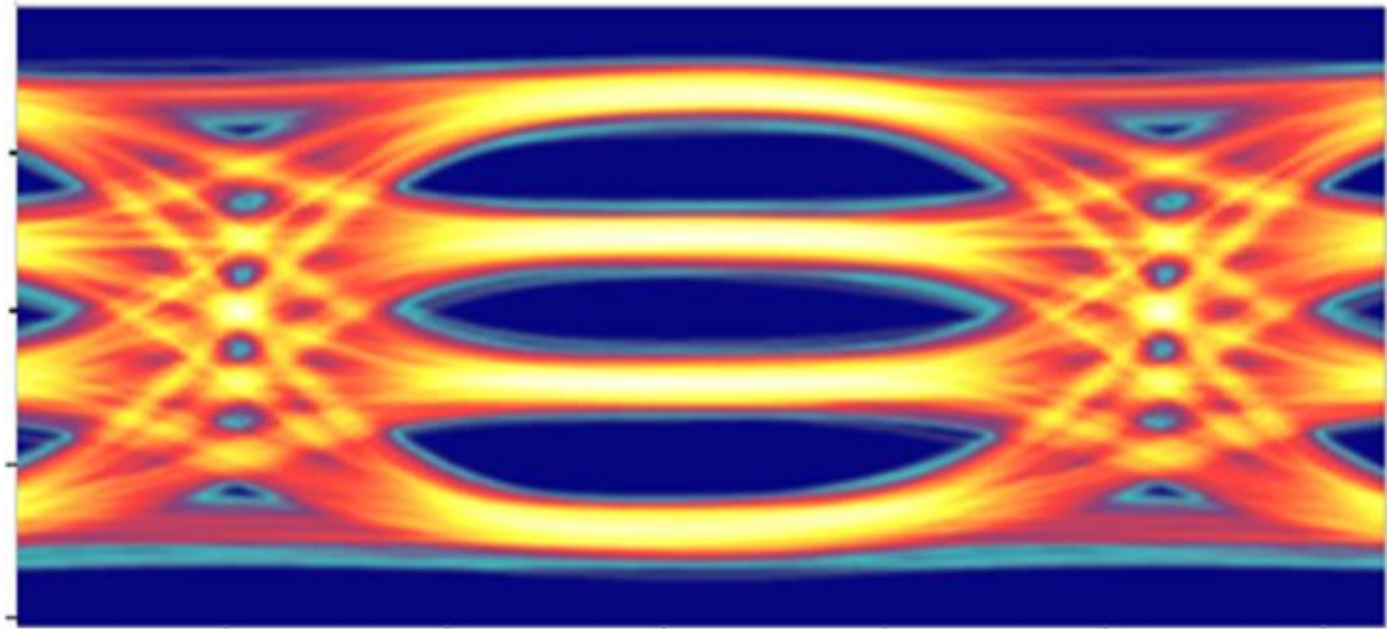
80C15 – Multi-Mode/Single-Mode up to 32GBd
80C10C – Single-Mode, 25-32 and 53-56GBd in one



Multi-Mode, Single-Mode: 80C10C vs 80C15

Several key considerations are important in optical analysis.

- Multi-Mode and Single-Mode support are needed to span SR16,LR8, FR8 optical links.
- Noise is THE key spec in optics. The high sensitivity low noise 80C15 is uniquely designed for 28G Baud PAM4 specs (LR8,FR8)
- DR4 specifications require optical BW out to 84 GHz, which is what the 80C10C is designed for.

Feature / Specification	80C15	80C10C
Input Fiber Type	SMF + MMF 9, 50, 62.5 µm	SMF 9 µm
Wavelength Range	780nm-1650nm	1290-1620nm
Unfiltered Optical Bandwidth	32+ GHz	80+ GHz
Unfiltered Risetime, typ	14 ps	7 ps opt. F1 6 ps opt. F3
Filter Rates [Gb/s] (not full filter)	TDEC, 26…32	26…**44.5** Gb/s (26G: F1 or F2)
Typ Noise [uW] at 1310 @26Gb/s	10 / 14	16 / NA
26 Gb/s Mask Sensitivity **AOP @ 1310nm**	***-9 dBm***	-6 dBm
Usable Electrical Out ***accessory**	***32 Gb/s***	> 44 Gb/s

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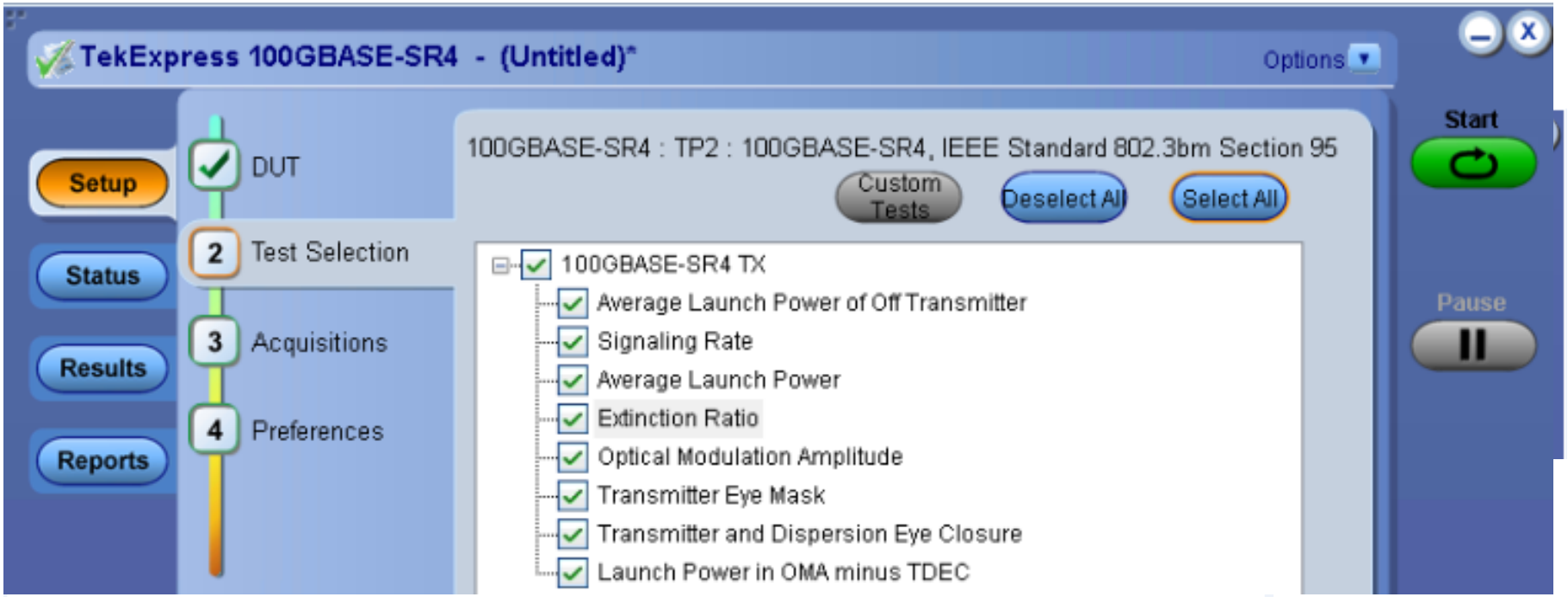
Automation of 100GBASE-SR4 measurements

- Operates on Tektronix DSA8300 Series Oscilloscopes
- Automate setup & quickly generate reports
- Meets Compliance needs of 100GBase-SR4 (Transmitter and Dispersion Eye Closure ---- TDEC)



Transmitter and Dispersion Eye Closure

Measurement Details	Measured Value	Test Result	Margin	Low Limit	High Limit	Comments
TDEC	1.4086 dB	Pass	H: 2.8914 dB	N.A	4.3 dB	OMA: 2959.320uW, Pave: 2010.459uW
COMMENTS	BER: 5e-05, OMA-Method: OMA-Eye, SCOPE Noise: 0.0 uW, Data Pattern: PRBS31/Non-Repetitive					

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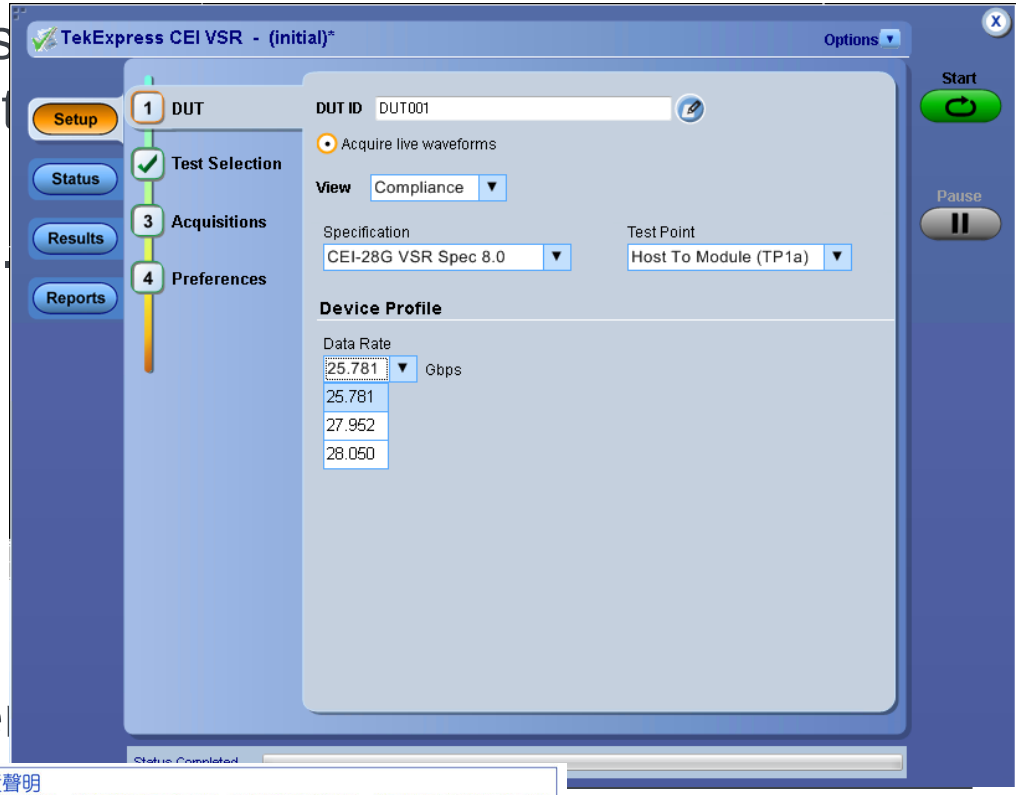
Automation of OIF-CEI-VSR : Option CEI-VSR

- Operates on Tektronix DSA8300 Series Oscilloscopes
- Automate setup & quickly generate reports
- Meets Compliance needs of CEI-28G-VSR
- PRBS9 for all measurements
  Transition time measurement
  VEC – Vertical Eye Closure
  -Informative Test under H2M.
- Updated to CEI3.1 Revision
- CAUI4/CR4/KR4/SR4

  Solutions under developme



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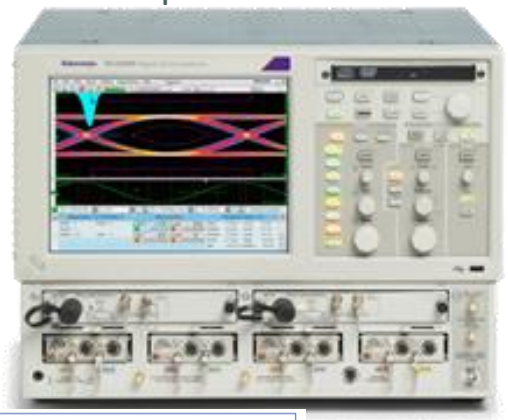

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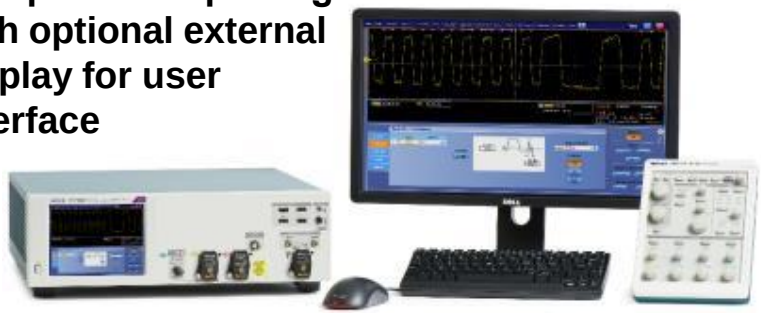
Scalable Performance

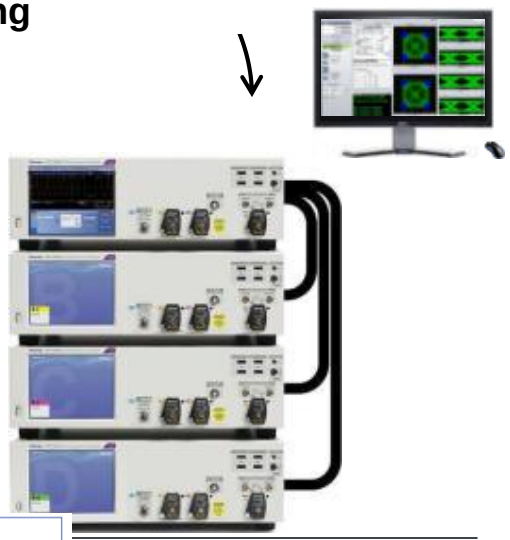
- Compact instrument for increased configuration flexibility
- UltraSync high performance synchronization for multi-unit configurations

Compact 5 ¼” package with optional external display for user interface



Additional performance using multiple units

Configuration flexibility with precisely-synchronized timing



UltraSync High Performance Synchronization & Control bus

- 12.5 GHz Sample Clock Reference
- Coordinated Trigger
- High speed data path
- 2X 70GHz channels
- 4X 33GHz channels

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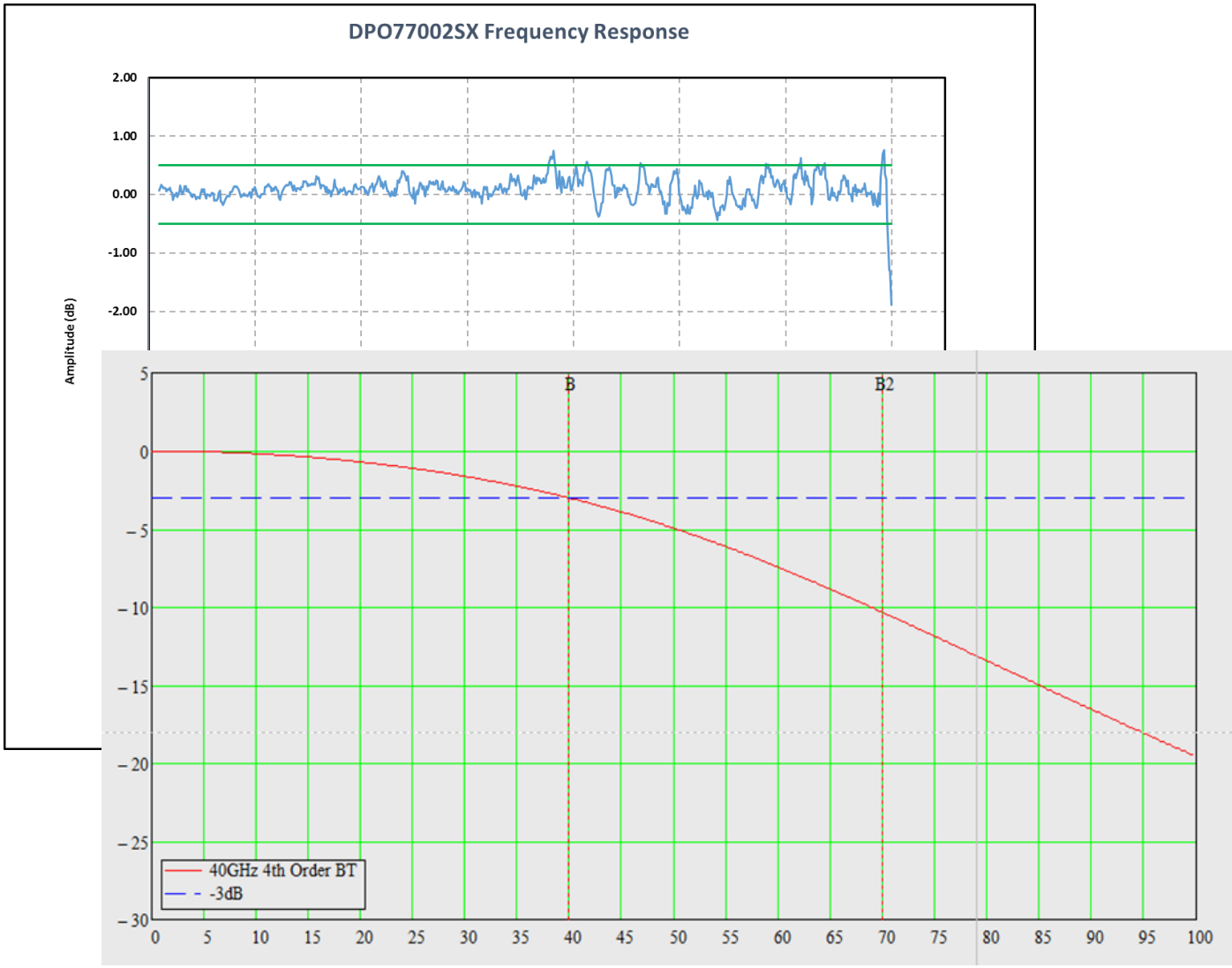
Tektronix DPO77002SX Frequency Response

Flat intermodulation overlap zone offers the cleanest, low noise acquisition system available today.

Bandwidth to 70GHz can be channel modeled in DSP to map precisely to the 40G Bessel Thompson response required by OIF-CEI physical layer measurements today.



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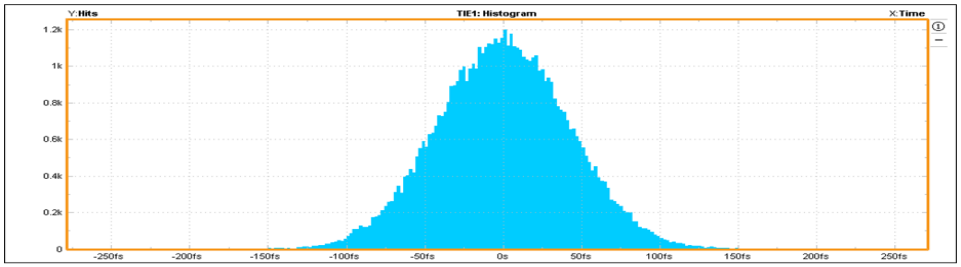

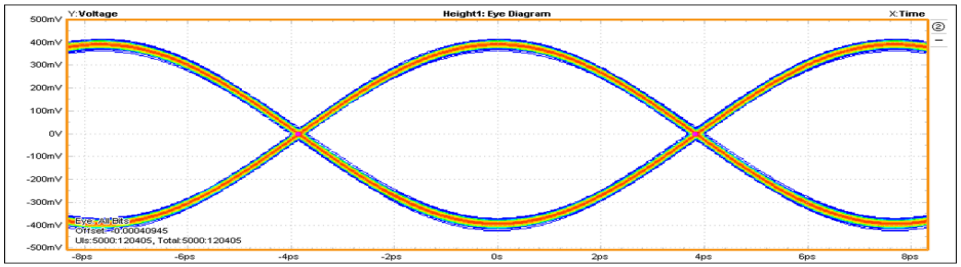

Real Time

- Multi channel time synchronized operation.
- Advanced analysis CTLE/DFE and Complex Math.
- Complex modulation analysis tools.
- Unprecedented jitter noise floor.
  - ~ 40fs RMS clock jitter (64 GHz clock)
  - <125fs jitter noise floor (64Gbps PRBS)

Measurement Results

Hide Current Aquisitions | Summary View

Description	Mean	Std Dev	Max	Min
TIE1, Math4	4.4985as	41.903fs	159.37fs	-167.66fs
Current Acquisition	4.4985as	41.903fs	159.37fs	-167.66fs
Height1, Math4	729.78mV	0.0000V	729.78mV	729.78mV
Current Acquisition	729.78mV	0.0000V	729.78mV	729.78mV
TJ@BER1, Math4	573.74fs	0.0000s	573.74fs	573.74fs
Current Acquisition	573.74fs	0.0000s	573.74fs	573.74fs
RJ–δδ1, Math4	38.441fs	0.0000s	38.441fs	38.441fs
Current Acquisition	38.441fs	0.0000s	38.441fs	38.441fs
DJ–δδ1, Math4	35.570fs	0.0000s	35.570fs	35.570fs
Current Acquisition	35.570fs	0.0000s	35.570fs	35.570fs
Width@BER1, Math4	14.811ps	0.0000s	14.811ps	14.811ps
Current Acquisition	14.811ps	0.0000s	14.811ps	14.811ps
PJ1, Math4	80.938fs	0.0000s	80.938fs	80.938fs
Current Acquisition	80.938fs	0.0000s	80.938fs	80.938fs
DJ1, Math4	83.367fs	0.0000s	83.367fs	83.367fs
Current Acquisition	83.367fs	0.0000s	83.367fs	83.367fs
RJ1, Math4	38.441fs	0.0000s	38.441fs	38.441fs
Current Acquisition	38.441fs	0.0000s	38.441fs	38.441fs
DDJ1, Math4	0.0000s	0.0000s	0.0000s	0.0000s

Source Reference Levels

Source	Autoset Method	Rise High	Rise Mid	Rise Low
Ch1	Auto	70.16mV	400uV	-69.36mV
Ch2	Auto	-44.04mV	-114.6mV	-185.16mV
Ch3	Auto	1V	0V	-1V
Ch4	Auto	1V	0V	-1V
Math1	Auto	1V	0V	-1V
Math2	Auto	-80.697mV	-302mV	-523.31mV
Math3	Auto	209.4mV	982.61uV	-207.43mV
Math4	Auto(Low-High(full wfm))	308.9mV	-409.45uV	-309.72mV
Ref1	Auto	1V	0V	-1V
Ref2	Auto	1V	0V	-1V
Ref3	Auto	1V	0V	-1V
Ref4	Auto	1V	0V	-1V

Miscellaneous Settings

	Gating	Qualify	Population
State	Cursors	Off	Off
Source	--	--	--
Size	--	--	--

Pattern Length

Source	Data Rate	Pattern Type	Pattern Length
MATH4	130.00Gb/s	Repeating	2UI

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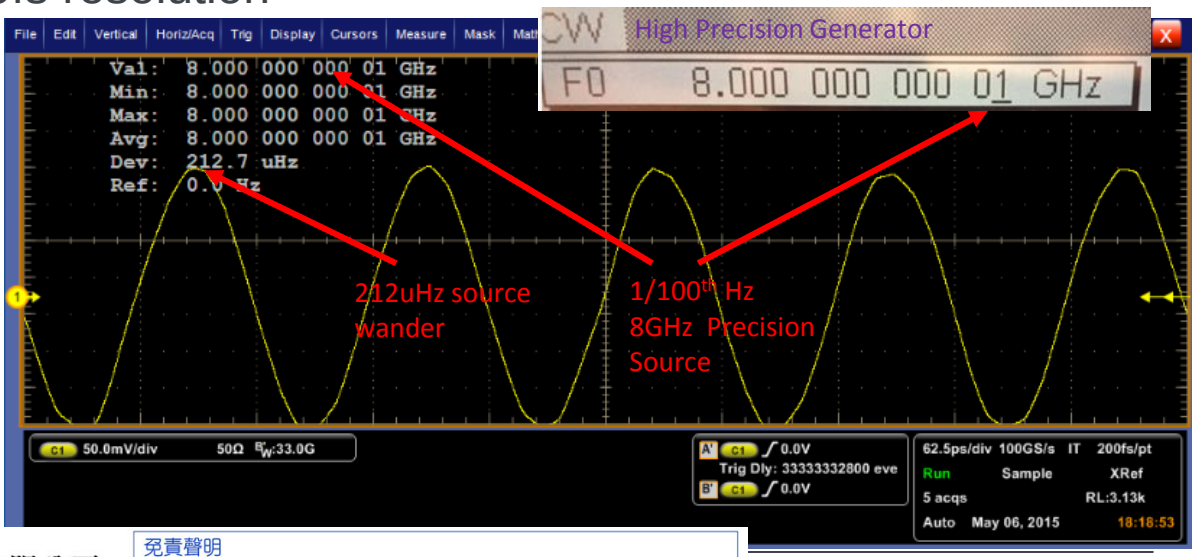
Real Time

- New HW trigger performance level easily triggers on 100G tributary Runt
- New Internal 13-digit precision frequency counter (54bit) provides frequency analysis to 25GHz, with 200fs resolution
- Highly accurate clock stability measurements
- Accurate to < 1 part per billion



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CAUI-4 TX on Tabasco Signaling rate clock stability (How good is your time base?)

Signaling rate per lane (range)	83E.3.1.1	25.78125 ± 100 ppm	GBd

- Typical DataCom clock stability measurements are classified in the 100ppm regions. Consumer level products operate in the 300-500ppm area.
- We've traditionally measured this with DPOJET with a 20Mpt acquisition, but many discount this method as being in-effective as.. "what can you tell looking at a 100us window of time about clock stability?"
- Tabasco has introduced a trigger level frequency counter which has unique application in this area.

- 25.781Gbps 1010 signal being shown here. Center (Avg) frequency is 12.890489GHz
- Do the math:
- Max = 12.890948GHz, Min = 12.89028GHz
- Max – Min = .67MHz (.000668GHz)
- PPM Deviation = (Delta Freq /Center Freq)* 1E6PPM
- (.00067GHz/12.89049GHz)*1E6PPM = **51.8 PPM**
- True Long term clock stability measurements are a key differentiator on the current 70KSX instruments.

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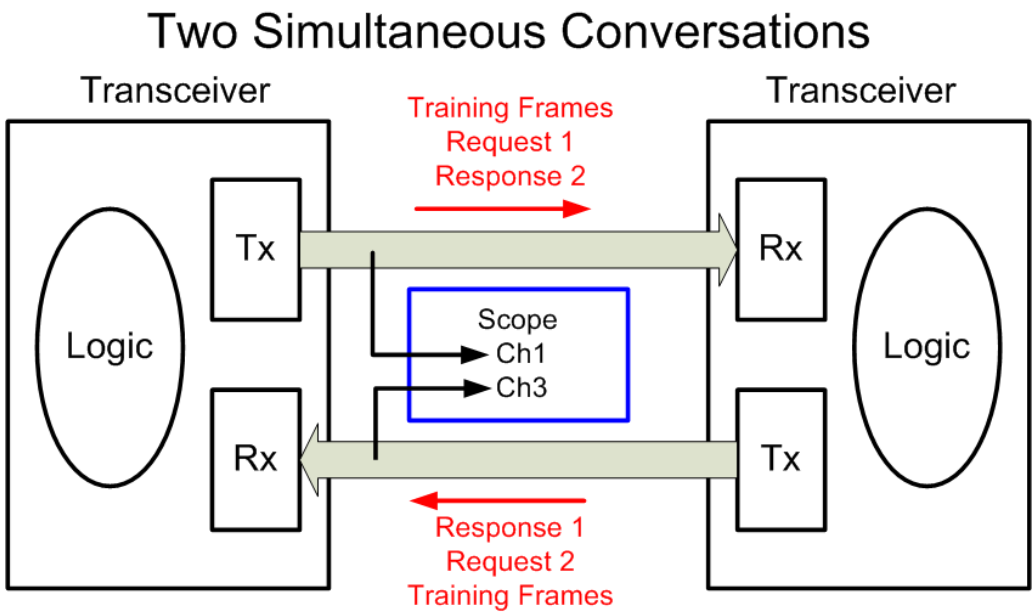
Link Training

NEGOTIATED LINK SETTINGS

- Negotiations determine Data Rate and Transceiver Settings
- Oscilloscope ideally suited to eavesdrop on both sides of the negotiation process
- Essential Data Captured in Real-Time, Logic-Analyzer Style
- Fast-Frame Waveforms Decoded and Marked



Each "Left/Right Side" of a Lane Transmits **Coefficient Update Requests** for (far) transmitter changes, and **Status Report Responses** to confirm (near) transmitter changes.

The oscilloscope eavesdrops on both full-duplex conversations.

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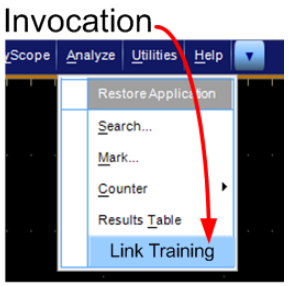
Link Training

EASE OF USE

- Ready:
  - Analyze->Link Training
- Set:
  - Arm Scope
- Go!
  - Initiate Link Training on DUT
- Results Posted in 3 seconds



Link Training

INTERACTIVE RESULTS TABLE AND FAST-FRAME RECORDS

- Fast-Frame Records:
  - Time-Aligned Hex and Bit-Level Decode
  - Marks (Frame, Control Channel, and Training Data)
- Results Table
  - All Negotiation Data is captured in Results Table
  - Click Row to View Waveform
  - Scroll Through Table Rows
  - Verify Negotiation Requests/Responses
  - Export Negotiation Data

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Link Training

NEGOTIATION DETAILS

- Negotiation Requests and Responses Time-Aligned in Results Table

Results Table

Lane1 | B1 | B3 | Marks

Index	c1 Preset	c1 Init	c1 Parity	c1 Co[+1]	c1 Co[0]	c1 Co[-1]	c1 Ready	c1_Co[+1]	c1_Co[0]	c1_Co[-1]	c3 Preset	c3 Init	c3 Parity	c3 Co
0	Normal	Normal	Odd	Hold	Hold	Hold	Continue	Not Upd	Not Upd	Not Upd				
1											Normal	Normal	Odd	Hold
2											Preset			
3	Preset													
4								Max	Max	Max				
5														
6											Normal			
7	Normal													
8														
9								Not Upd	Not Upd	Not Upd				
10														
11									Updated					
12														
13									Not Upd					
14														
15										Updated				

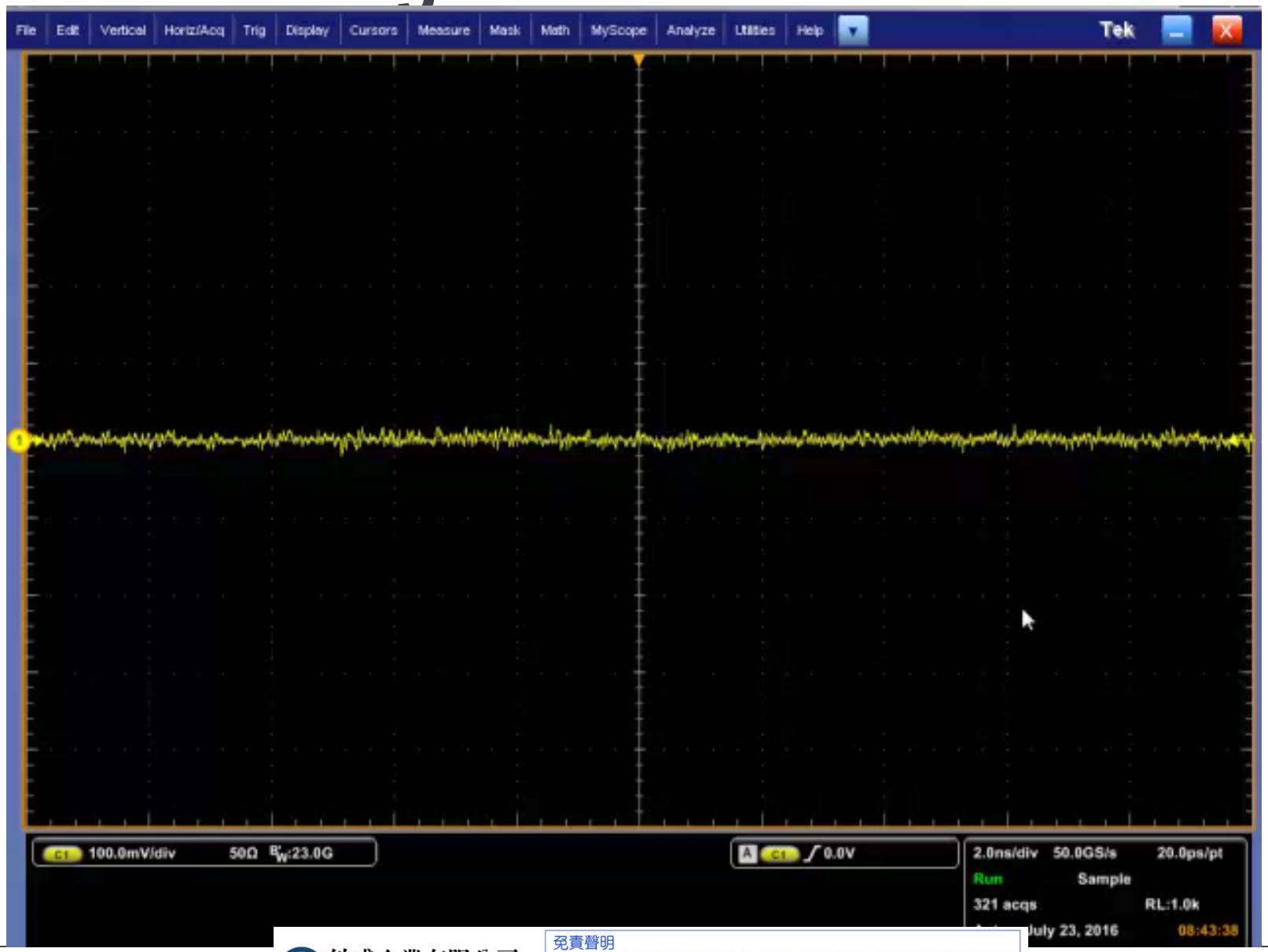
Dock | X | Options ▼ | Export | Copy | Settings | Close

Link Training

NEGOTIATION DETAILS

- Decoded and Marked Fast-Frame Records

Link Training.. The Movie.



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Link Training Narrative:

- Here is what the presenter should say:
- “Having connected the scope between the DUTs using P7633 Diff Probes and 80/20 power splitters, and Default Setup on the scope, all you need to do is
- Select Analyze->Link Training
- Arm the scope using the Arm Button on the pop-up Control Window.
- Initiate Link Training on the DUTs (“power-up the lane”).
- About 3 seconds later you get a Results Table and a set of Fast-Frame Waveforms containing the Link Training Negotiation History (Control Channel Data). This is a standard Results Table that lets you select rows to view the Fast-Frame Waveforms that match the data in that row. Each Row contains the Link Training Requests and Responses for both DUTs. The table is sparse because we show only the changes in the negotiation data, from top to bottom. The Waveforms fully decode the Control Channel data and match the values in the table row. You may dismiss/re-open the Control Window pop-up at any time.
- If you want to re-run the experiment, all you need to do is
- Re-Arm the scope (using the Arm Button on the pop-up Control Window)
- Initiate Link Training on the DUTs (“power-up the lane”).
- Easy.”

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Solutions Overview

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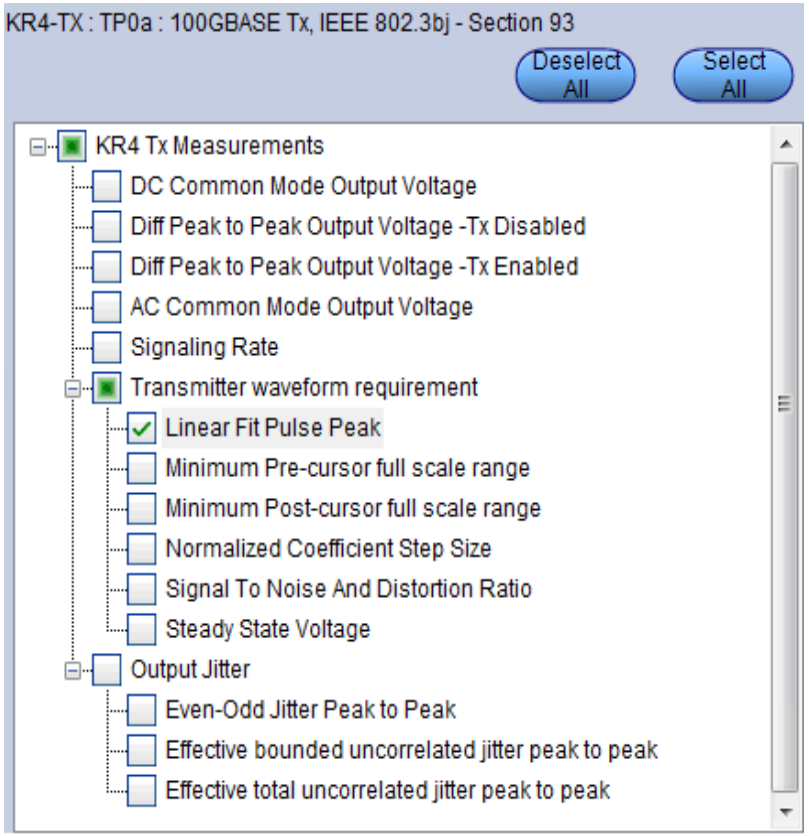
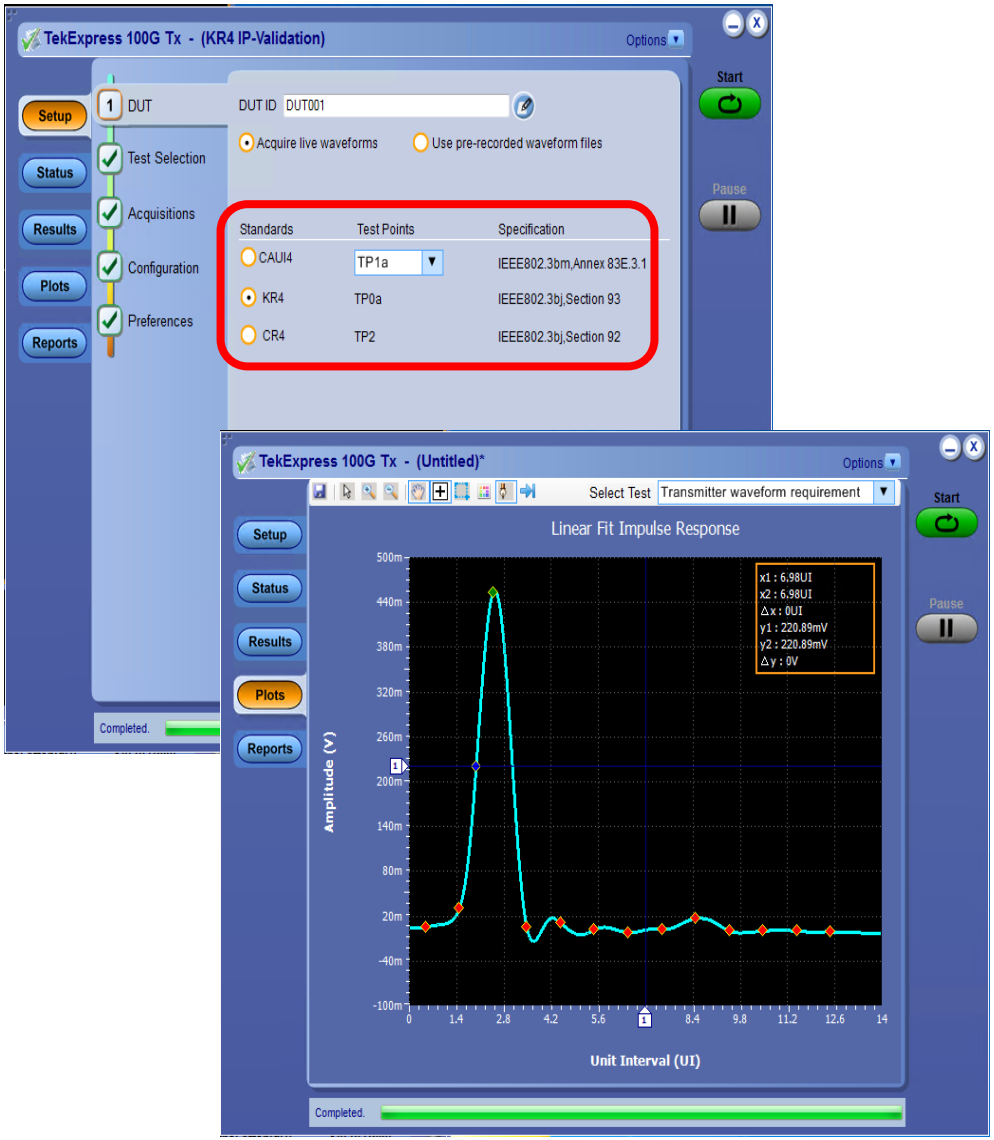
Tektronix®

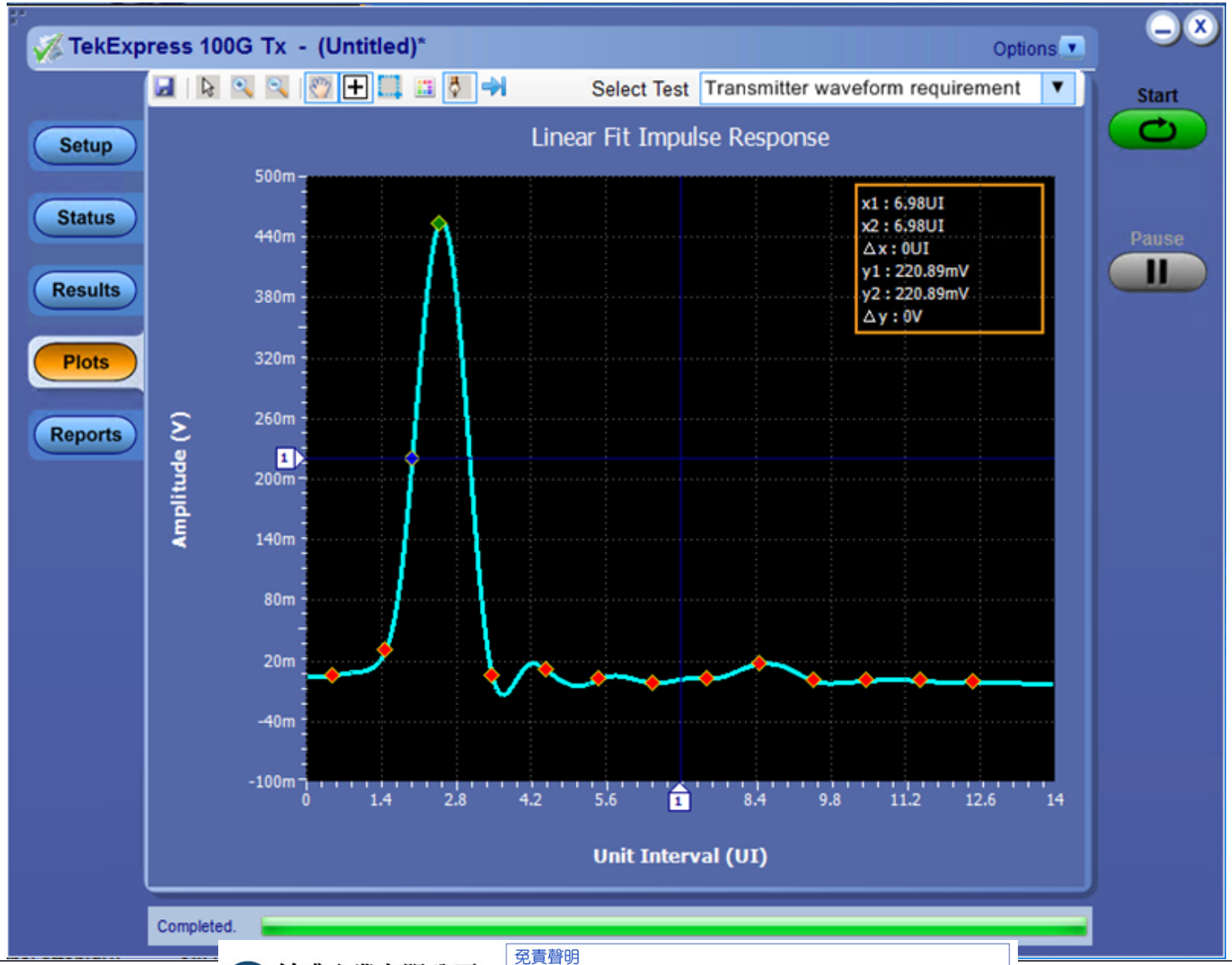
CAUI4/KR4/CR4 (100G) Compliance

- Launched at OFC 2016, Tektronix introduces the most comprehensive 100G compliance tool set to date.





CR4/KR4: Linear Fit Pulse Peak



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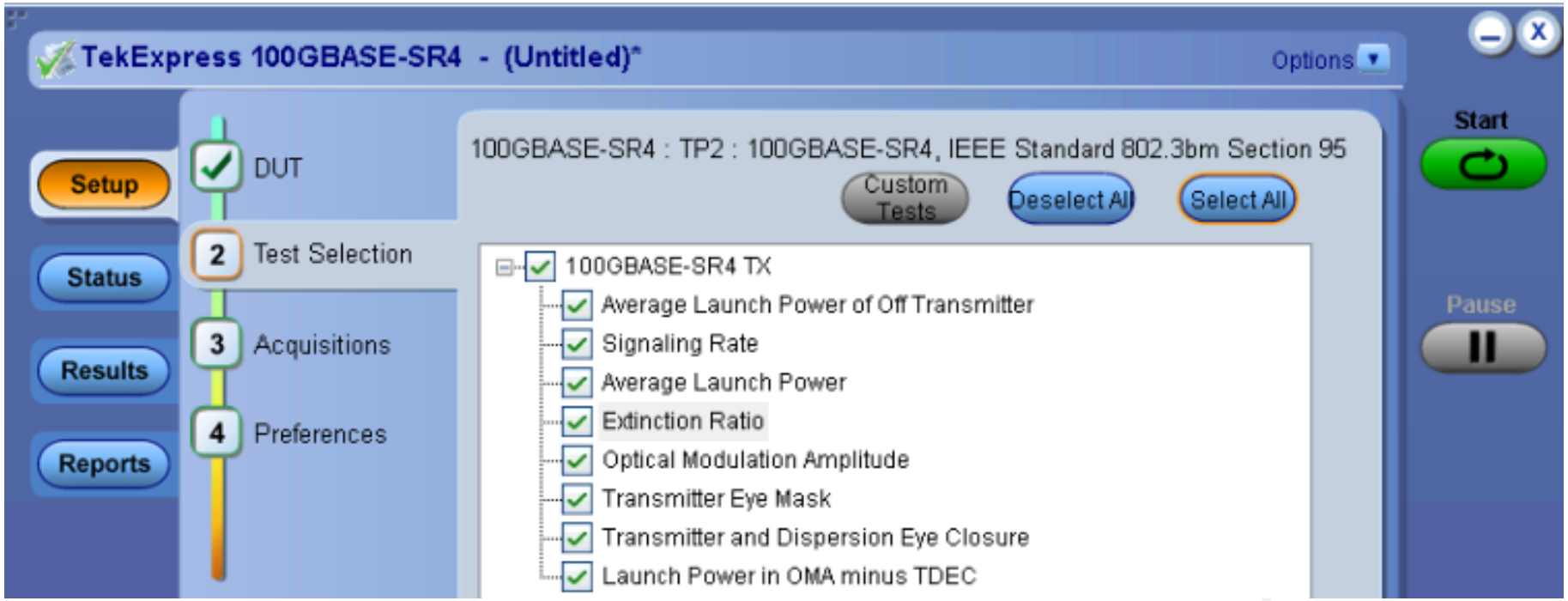
Automation of 100GBASE-SR4 measurements

- Operates on Tektronix DSA8300 Series Oscilloscopes
- Automate setup & quickly generate reports [(SR4/TDEC DataSheet)]
- Meets Compliance needs of 100GBASE-SR4



Transmitter and Dispersion Eye Closure						
Measurement Details	Measured Value	Test Result	Margin	Low Limit	High Limit	Comments
TDEC	1.4086 dB	Pass	H: 2.8914 dB	N.A	4.3 dB	OMA: 2959.320uW, Pave: 2010.459uW
COMMENTS	BER: 5e-05, OMA-Method: OMA-Eye, SCOPE Noise: 0.0 uW, Data Pattern: PRBS31/Non-Repetitive					

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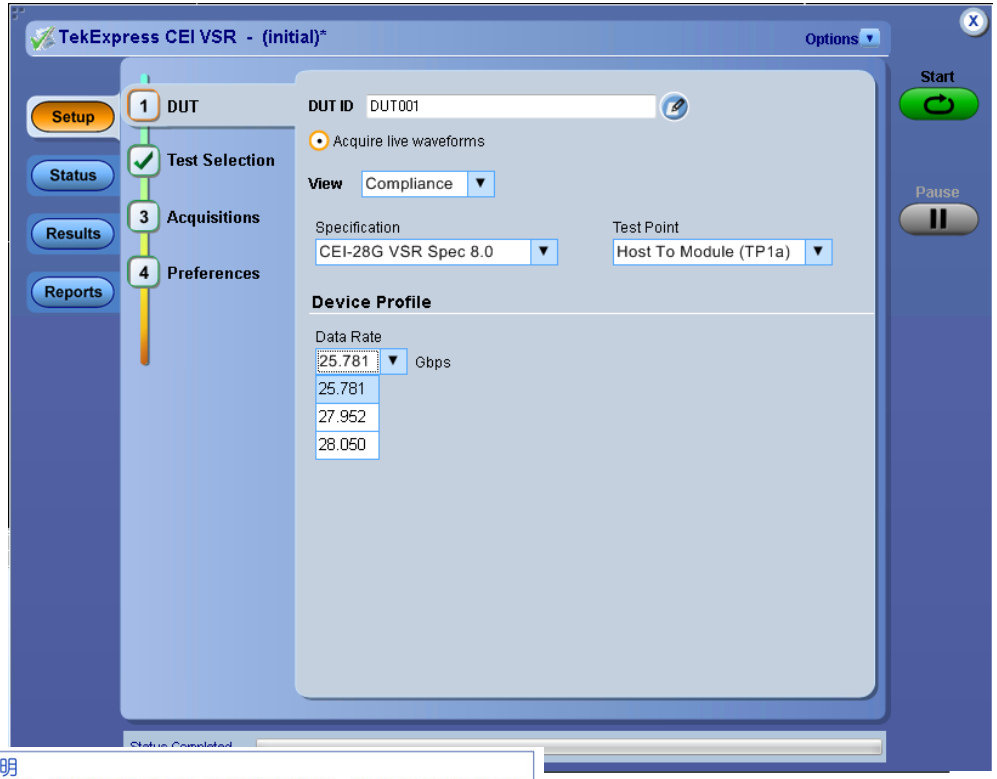
Automation of OIF-CEI-VSR : Option CEI-VSR

- Operates on Tektronix DSA8300 Series Oscilloscopes
- Automate setup & quickly generate reports
- Meets Compliance needs of CEI-28G-VSR
- PRBS9 for all measurements and 8180 support in addition for Transition time measurement.
  VEC – Vertical Eye Closure
  -Informative Test under H2M.
- Updated to CEI3.1 Revision
- CDAUI8 under development



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Tektronix
Component Solutions

CR4 -ETUJ measurement correlation with Keysight DSA

29 SEPTEMBER 2016

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ETUJ measurement in CR4

Effective bounded uncorrelated jitter and effective random jitter are measured on each of two specific transitions in a PRBS9 pattern . The two transitions occur in the sequence of five zeros and four ones and nine ones and five zeros, respectively.

- Determine the parameters *m*left and *b*left of Equation that best fit *QLi* as a function of *ti* for bins with *CDFLi* in the range of 10–3 to 2.5 × 10–2. Similarly determine the parameters of *m*right and *b*right that best fit *QRi* as a function of *ti* for bins with *CDFRi* in the range of 10–3 to 2.5 × 10–2.

$$Q_{left} = m_{\text{left}} \cdot t + b_{\text{left}}$$

$$Q_{right} = m_{\text{right}} \cdot t + b_{\text{right}}$$

$$\text{effective bounded uncorrelated jitter} = EBUJ = b_{\text{left}}/m_{\text{left}} - b_{\text{right}}/m_{\text{right}}$$

$$\text{effective random jitter} = ERJ = \frac{m_{\text{left}} - m_{\text{right}}}{2 \cdot m_{\text{right}} \cdot m_{\text{left}}}$$

$$\text{effective total uncorrelated jitter} = 7.9 \cdot ERJ + EBUJ$$

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ETUJ Tek Results

TEK FOLLOWED PROCEDURE AS RECOMMENDED IN STANDARD

Effective total uncorrelated jitter peak to peak									
Measurement Details	Lane	Iteration	Measured Value	Test Result	Margin	Low Limit	High Limit	Units	Comments
Effective total uncorrelated jitter peak to peak	Lane0	0	0.10376	Pass	H:0.0762	N.A	0.18	UI	ERJ Value: 0.01291 UI
Effective total uncorrelated jitter peak to peak	Lane0	1	0.09986	Pass	H:0.0801	N.A	0.18	UI	ERJ Value: 0.01173 UI

Effective bounded uncorrelated jitter peak to peak									
Measurement Details	Lane	Iteration	Measured Value	Test Result	Margin	Low Limit	High Limit	Units	Comments
Effective bounded uncorrelated jitter peak to peak	Lane0	0	0.00178	Pass	H:0.0982	N.A	0.1	UI	ERJ Value: 0.01291 UI
Effective bounded uncorrelated jitter peak to peak	Lane0	1	0.00716	Pass	H:0.0928	N.A	0.1	UI	ERJ Value: 0.01173 UI

Result with Average of 10 Runs

TUJ = 105mUI

BUJ = 5.75mUI

ERJ = 12.611mUI

Every 1mUI of ERJ will increase TUJ about 8mUI.

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KEYSIGHT Measurement Results

KEYSIGHT MEASURED RESULTS

Pass	# Failed	# Trials	Test Name	Worst Actual	Worst Margin	Pass Limits
✓	0	5	Total Uncorrelated Jitter	58.7 mUI	67.4 %	VALUE <= 180.0 mUI

ETUJ = 7.9*RJ+BUJ

7.9 * ERJ (5.6mUI) + BUJ (8mUI)
= 53mUI (58.4 shown here, based on a separate run)

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Measuring RJ using DPOJET for TUJ measurement

WHEN WE MEASURE RJ CONSIDERING ALL THE EDGES ON THE WAVEFORM SIMILAR TO THE KEYSIGHT METHOD

7.9 * RJdd (7.32mUI) + BUJ (8.7mUI)= 65.8mUI.

. The difference of 45 mUI is reduced to 7mUI.

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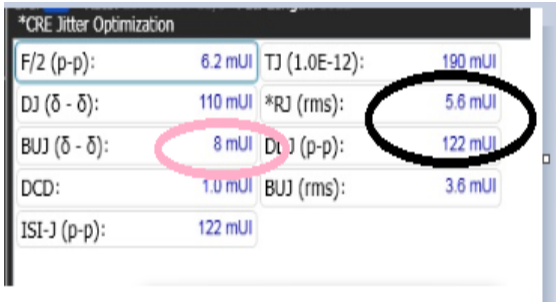
EBUJ and ETUJ correlation with Key sight for the Same Signal Generator (BERT scope)

Setup : Tek setup : 2 channel tabasco stacked equipment with 10 Db attenuator at front end . Key sight Setup is direct connection to 86108B precession waveform Analyzer.

Measurement	Units	TEK RESULT ATI CHANNEL	KS Results WIN 7
Effective BUJ			
Avg		0.009766	1.26E-02
Stddev		0.002317958	7.70E-03
Range		0.00604	1.90E-02
Min		0.00713	6.00E-03
Max		0.01317	2.50E-02
sum		0.04883	6.30E-02
Worst	UI	0.01317	2.50E-02
Effective TUJ			
Avg		0.065998	5.36E-02
Stddev		0.002369445	2.91E-03
Range		0.00619	6.84E-03
Min		0.06326	5.18E-02
Max		0.06945	5.87E-02
sum		0.32999	2.68E-01
Worst	UI	0.06945	5.87E-02

- The main difference in ETUJ is due to ERJ between KS and TEK
- ERJ in KS is about 5.6mUI
- ERJ in Tek is about 7.879mUI



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ERJ Measurement

- ERJ Measurement in Tek at different scope bandwidth setting as follows

Bandwidth	RJ	RJ(H)	RJ(V)
70Ghz	7.812e-3	3.63e-3	6.35e-3
50Ghz	7.09e-3	3.26e-3	6.27e-3
33Ghz	6.11e-3	3.56e-3	5.41e-3

- RJ(V) decreases with decrease in bandwidth showing the vertical noise influences on RJ
- Non ATI mode ERJ (7mUI) but BUJ max is 1mUI making the ETUJ comparable to Key sight results

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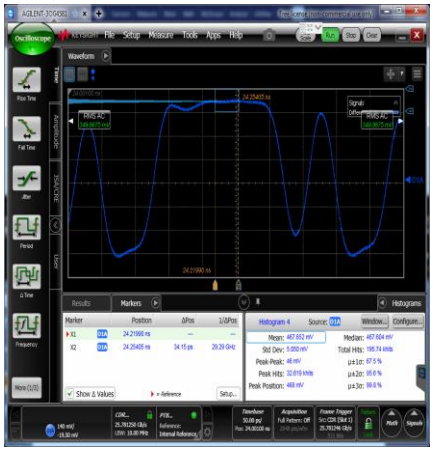
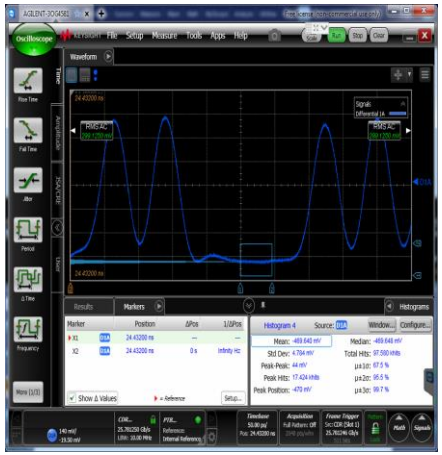
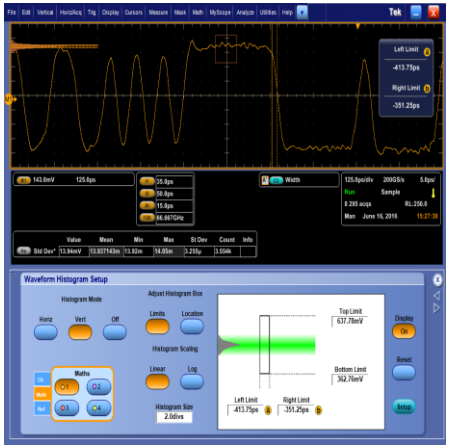
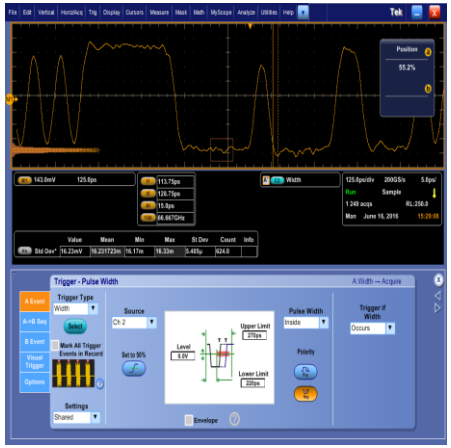
Noise Estimation

MEASURED SCOPE NOISE









Measured 1 Level 5mV, 0 level is 4.7mV

Base Noise = 4.85mv

Measured at 1 Level 13.34mV, and at 0 level is 16.23mV

Scope inherent is 14.75mV.

The scope noise SQRT(14.75^2-4.85^2) = 13.91mV

Percentage of RJ due to Scope noise is (1-(4.85/13.91)) is 65%

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RJ real measurement

TUJ	BUJ	Rj	RJ(H)	RJ(v)
0.071	0.007	0.0082	0.0035	0.0073

Now we know that in vertical, there is a possibility of 65% contribution of this noise from the scope itself. So new RJ(V) = 0.35*0.0073 = 0.0025mUI.

The total Rj is SQRT (0.0035+0.0025) = 0.0043mUI.

The Total Jitter TUJ is around 7.9(*0.0043) +0.007 = 41mUI , Close to ~53mUI.

We can be conservative here considering the scope internal noise on the RJ(V) can be up to 50%, then the TUJ ~50mUI.

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TUJ measurement with variable % of Scope noise contribution

TUJ	BUJ	Rj	RJ(H)	RJ(v)
0.071	0.007	0.0082	0.0035	0.0073

% of RHV for Measurement	RH(v)	RJ(H)	RJ	Buj	TUJ
0.33	0.0073	0.0035	0.002409	0.007	0.040566
0.5	0.0073	0.0035	0.00365	0.007	0.04695
0.6	0.0073	0.0035	0.00438	0.007	0.051292
0.7	0.0073	0.0035	0.00511	0.007	0.05593
0.8	0.0073	0.0035	0.00584	0.007	0.060787

We can be conservative and apply the 80% of the measured RJ(v) will be ideal

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CONCLUSION

- Measure EBUJ using current algorithm.
- Measure RJ, RJ(v), RJ(H) using the DPOJET
- Deduce RJ after compensating RJ(V) by scope noise contribution as 80% of RJ(V) as default value.
- Calculate the TUJ = 7.9*RJ(deduced one) +EBUJ.

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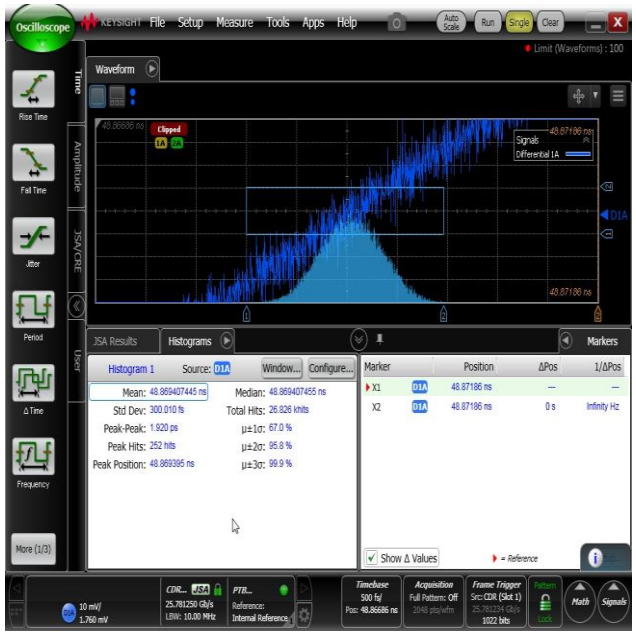
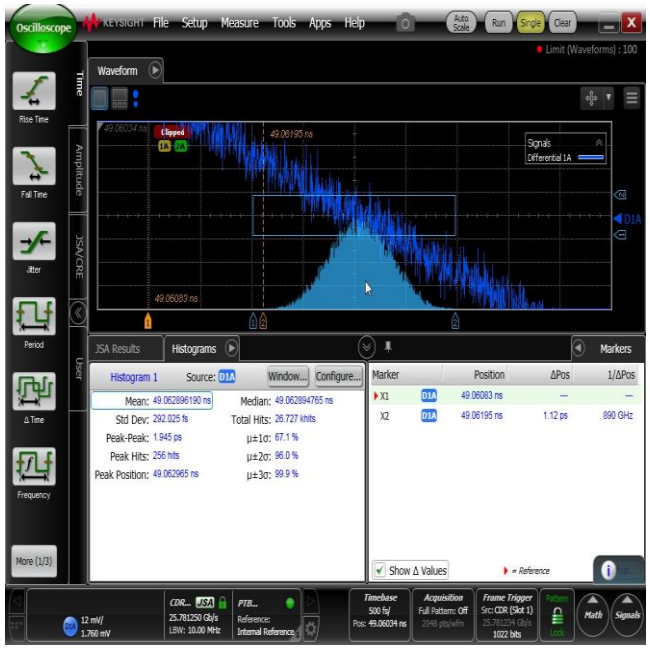
RJ Measurement on Key sight manual method





RJ manual is SQRT(293fs^2+300fs^2) = 417fs. Jitter Analysis method measures RJ at the bottom of the Q scale and Rj is as low as 220fs.

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100G-CR4 Measurements	Tektronix Real Time Scope					Tektronix Sampling Scope					KeySight Sampling Scope		
	Run #	Result	Mean	Max	Min	Run #	Result	Mean	Max	Min	Mean	Max	Min
	1	1105.02				1							
	2	1100.62				2							
	3	1099.21				3							
Differential peak to peak output voltage - TX Enabled	4	1098.06	1101.20			4							
(mV)	5	1103.12	6	1105.02	1098.06	5					956.8	957.9	956
	1	485.1				1	480.02						
	2	487.28				2	480.03						
	3	487.6				3	480.07						
	4	487.46				4	480.05						
Linear Fit Pulse Peak (mV)	5	487.32	486.952	487.6	485.1	5	480.04	480.042	480.07	480.02	439	439	438.9
	1	498.67				1	469.66						
	2	498.64				2	470.19						
	3	498.84				3	469.44						
	4	498.78				4	470.94						
Steady State Voltage (mV)	5	498.76	498.738	498.84	498.64	5	470.28	470.102	470.94	469.44	458.2	458.4	458
	1	31.67				1	32.5538						
	2	31.829				2	32.2651						
	3	31.827				3	32.531						
	4	31.809				4	32.319						
Signal to Noise and Distortion Ratio (dB)	**5**	**31.799**	**31.7868**	**31.829**	**31.67**	**5**	**32.507**	**32.4358**	**32.5538**	**32.2651**	**32.22**	**32.25**	**32.16**
	1	0.00079				1							
	2	0.00091				2							
	3	0.00085				3							
	4	0.00078				4							
Even Odd Jitter (UI)	5	0.00092	0.00085	0.00092	0.00078	5					0.00208	0.0032	0.0004
	1	0.00035				1							
	2	0.00237				2							
	3	0.00156				3							
	4	0.0031	0.00192			4							
Effective Bounded Uncorrelated Jitter (UI)	5	0.00226	8	0.0031	0.00035	5					0.0062	0.009	0.004
	1	0.0505				1							
	2	0.04561				2							
Effective Total Uncorrelated Jitter (UI)	5	0.05293	4	0.05318	0.04561	5					0.05044	0.0564	0.04745

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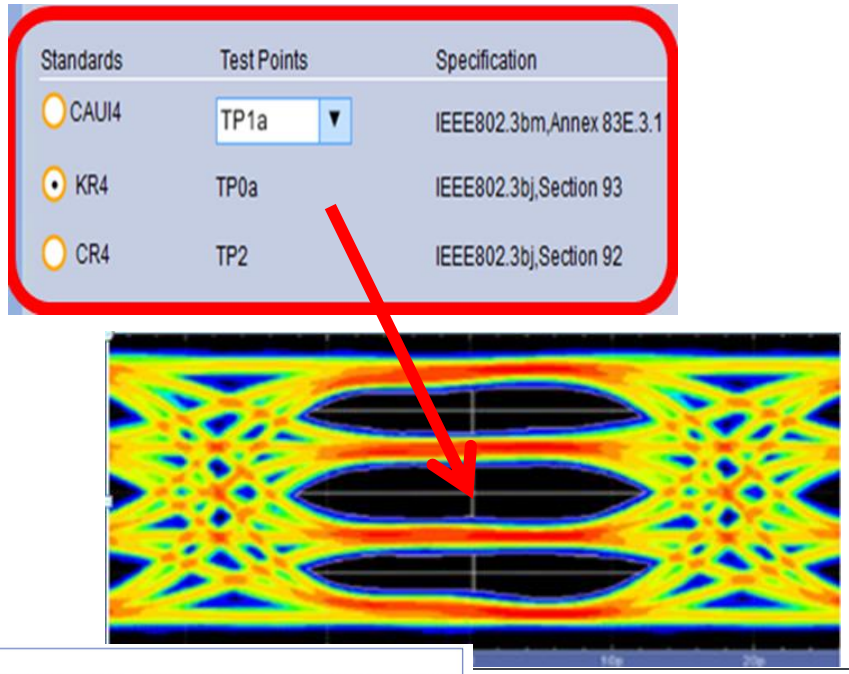
100G Summary

- 100G is presently mainstream in the industry today. It's transitioned fully into the "Systems" domain where demands for Turnkey Physical Layer automation systems are key to enabling customers.
- IEEE is unique in that there is no industry sanctioned interoperability program. Cross silicon interop and debug is very real. Leverage the RT debug value proposition heavily in customer dialogs considering ET or RT based validation solutions..
- 100G to 400G transition is much closer than we anticipated (pulled in 2 years sooner than normal IEEE 10 year cadence). Ensure customers are solidly aware of our 400G strength's as you show our 100G solutions.



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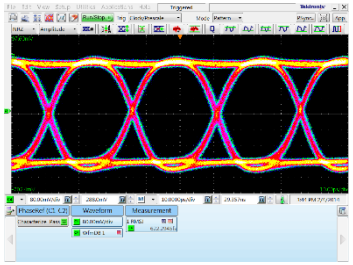
PatternPro Product Portfolio
Value Proposition

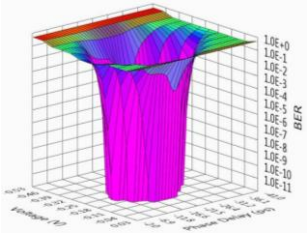
1 or 2 channel form factor

- **PatternPro** PPG/PED is a line of serial data instruments targeted at high-speed BERT testing. Designed to specifically address:
  - **Multi-channel** testing (e.g. 4 lane BERT for 100GE and coherent)
  - **High-speed** NRZ testing (at >40Gb/s with roadmap to 56 Gb/s)
  - **Multi-level** testing (PAM4 and QAM16)
- Product line emphasis is on **high-performance**, **value**, and **ease of use**
- Separate instruments for PPG and PED, buy what you need
- PC GUI software to control instruments and perform analysis

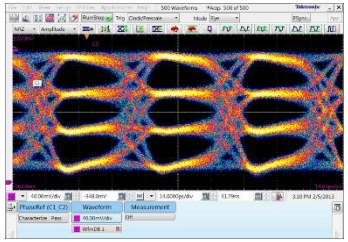
4 channel form fa



>40Gb/s NRZ BERT Systems



JTOL J2/J9 Bathtub Contour Analysis



PAM4 generation and analysis

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PPG and PED instruments

Options and configurations

PPG Base Instruments

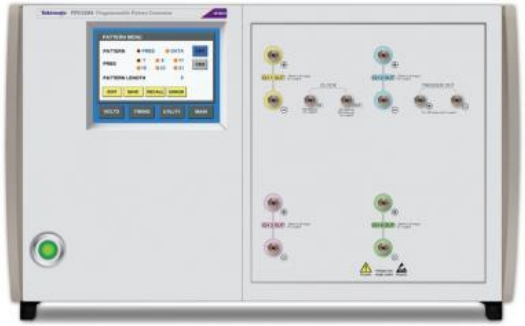
PPG1251 12.5Gb/s PPG
- Jitter insertion (LF+HF)

PPG1600x/300X 16&30Gb/s PPG
- 1/2/4 Channel
- HF jitter insertion
- High output amplitude (up to 4V diff)

PPG320X 32Gb/s PPG
- 1/2/4 Channel
- Adjustable output
- LF jitter insertion
- HF jitter insertion

PPG4001 40Gb/s PPG
- LF jitter insertion
- HF jitter insertion

Industry's only 40G PPG with Jitter Insertion



PPG3204 32Gb/s
4 channel PPG

PED3202 32Gb/s
2 channel PED

PED Base Instruments

PED320X 32Gb/s PED
- 1/2 Channel
- Full or half rate clock input
- AC coupled input

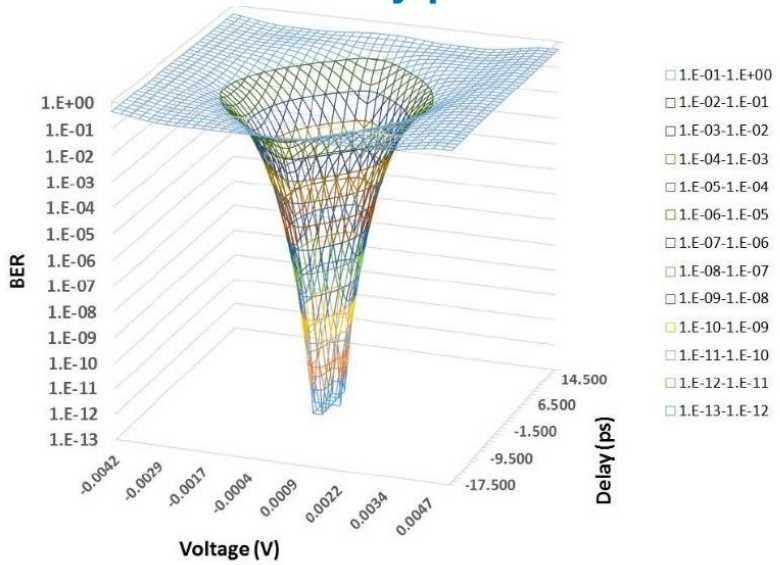
PPG400X 40Gb/s PED
- 1/2 Channel
- Full or half rate clock input
- AC coupled input

Industry's best PED sensitivity

6mV auto-align and auto-sync

Best in class PED Sensitivity

- PED can measure input data signals of 6-750mVpp
- With 6mVpp, PED properly center voltage & phase sampling point and synchronizes to input pattern
- Contour plot below measured at 28Gb/s with 6mVpp input signal
- **Highly sensitive PED allows for very precise BER measurements at low input power levels**



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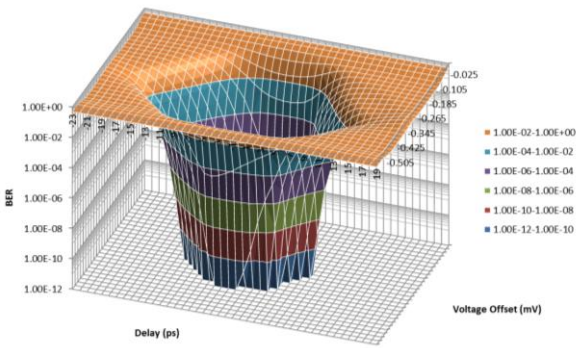
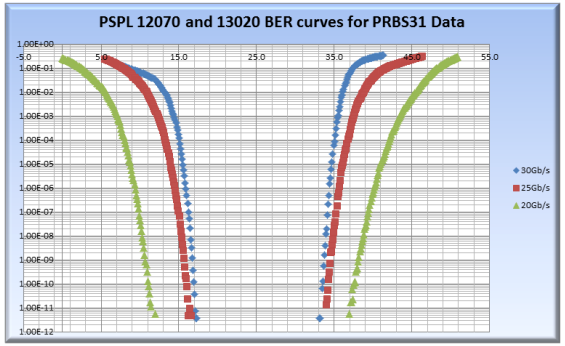
Automation and Programming

- Complete SCPI command set
  - Easy to use command structure
  - Existing Labview drivers available from NI.com
  - Rapid BER measurements execution enables comprehensive standards-based automatic testing and high throughput



- Example code available in C, VB, Labview for quick implementation

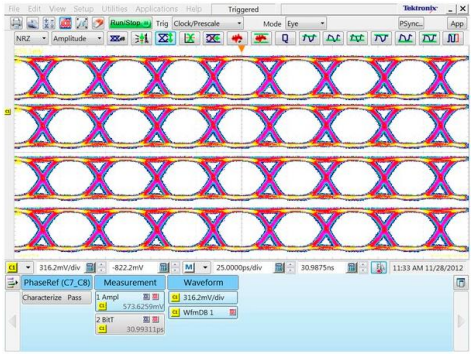


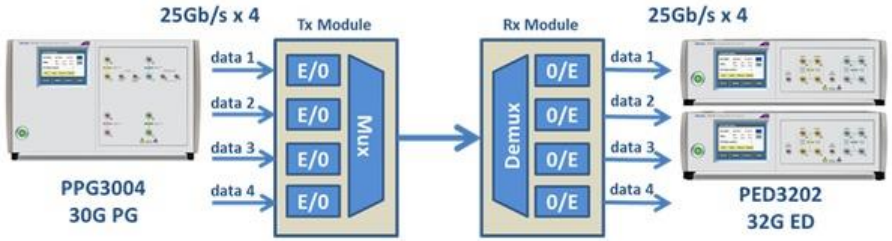
- Labview-based SW GUI available free-of-charge (including source code)
  - Bathtubs
  - Contour plots
  - Jitter Tolerance (JTOL)
  - PAM4 analysis

Tektronix BERT System for CAUI-4 Testing

Enables CAUI-4 Stressed Receiver Sensiti

- Multi channel 32Gb/s pattern generator
  - Low inherent jitter <250fsec RMS
  - ~10psec rise/fall time (20-80%)
  - RJ, SJ, and BUJ jitter stress
  - Full rate or half rate clock output
  - DC coupled outputs
  - PRBS or custom patterns
  - Adjustable channel phase delay

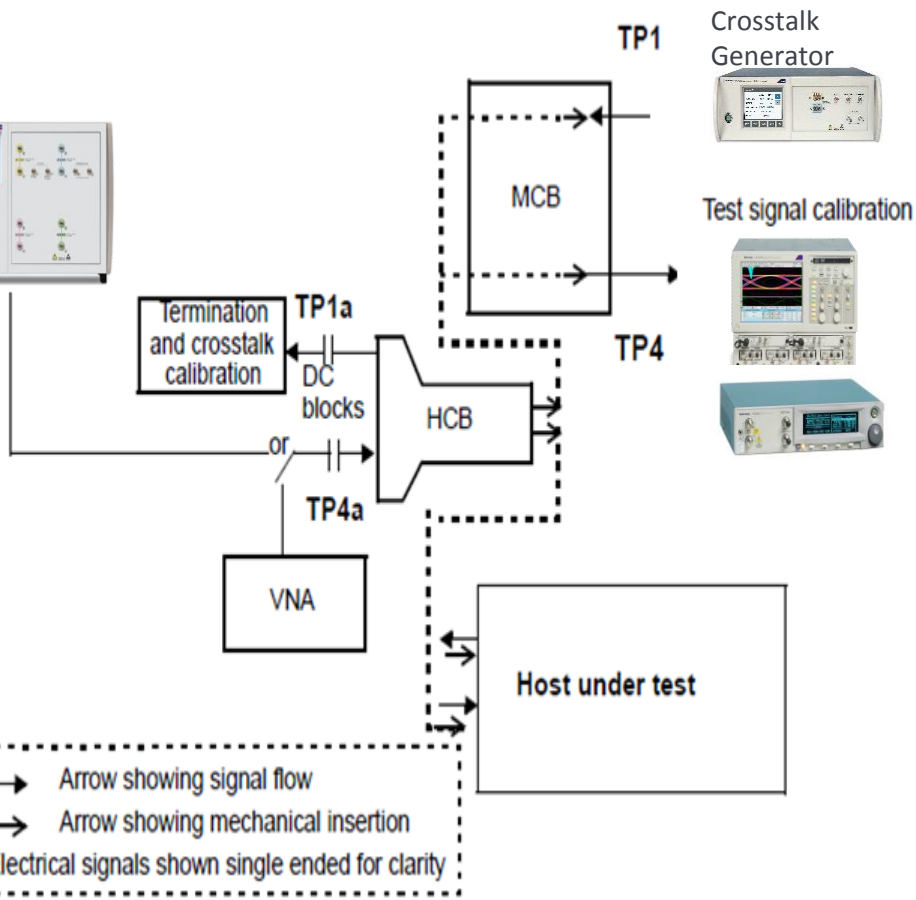




CAUI-4 MOI Module Test

CAUI4 ELECTRICAL STRESSED RECEIVER TEST SETUP

PPG3204
- ✓ Sinusoidal jitter
- ✓ Random jitter
- ✓ Bounded Uncorrelated Jitter



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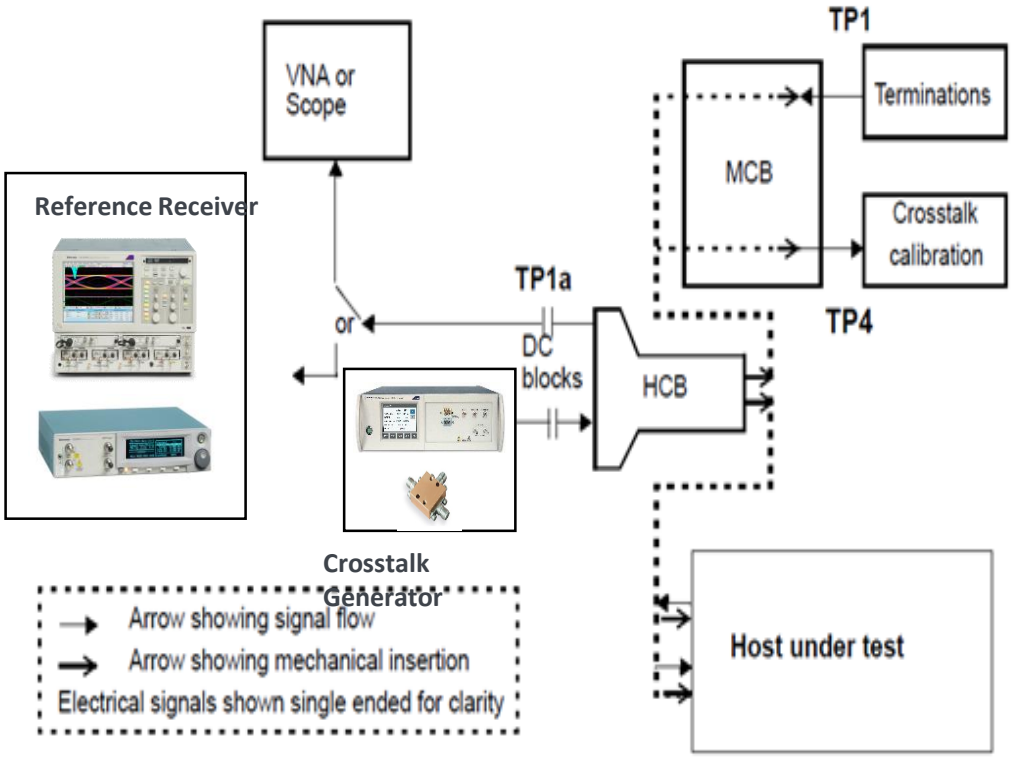
CAUI4 MOI Module Test

CAUI4 ELECTRICAL STRESSED RECEIVER CONFIGURATION

Item	Description	Qty
PPG3204/HFJ/ADJ	4-ch 32Gb/s PPG w/ jitter insertion OR 2-ch 32Gb/s PPG w/ jittter insertion	1
PPG3002, crosstalk generator	2CH 30G PPG	1
PSPL5333, crosstalk generation	1:2 power splitter	2

CAUI-4 MOI Module Test

CAUI-4 ELECTRICAL TRANSMITTER CONFIGURATION



CAUI4 MOI Module Test

CAUI-4 ELECTRICAL TRANSMITTER CONFIGURATION

Item	Description	Qty
DSA8300/ADVTRIG/JNB 02	Sampling scope mainframe	1
80E09B	2-ch 60GHz sampling head	1
82A04B	Phase reference module	1
PPG3002, crosstalk generator	2CH 30G PPG	1
PSPL5333, crosstalk generation	1:2 power splitter	2
CR286A/HS/XLBW	Clock Recovery module	1
80A08	Accessory kit	1

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CAUI-4 Spec Compliance

- **Tektronix BERT system enables CAUI-4 testing**

Key CAUI4 Parameter	Specification	PPG/PED Performance
Data rate	25.78125 Gb/s	1.5-32 Gb/s
Common-mode voltage	-0.3V to 2.8V	-2 to +3V
Max differential output voltage	900mVpp	2000mVpp
PPG intrinsic TJ	<0.28UI	<0.18UI
PPG intrinsic RJ (pk-pk)	<0.15UI	<0.12UI
PPG max EOJ	<0.035UI	<0.005
BER Test capability	1E-15	<1E-15
Transition time	10ps	10ps
BUJ, RJ insertion for stress baseline	TJ=0.28UI, RJ=0.15UI	BUJ insertion up to $50ps_{pp}$ at 2.5G up to PRBS31 RJ insertion up $5ps_{RMS}$
SJ insertion for stress	Table 88-13	Full SJ insertion

Frequency range	Sinusoidal jitter, peak-to-peak (UI)
$f < 100$ kHz	Not specified
100 kHz $< f \leq$ 10 MHz	$5 \times 10^5 / f$
10 MHz $< f <$ 10 LB[a]	0.05

[a] LB = loo
the recei

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