High throughput validation for 400G/800G optical transceivers

Dr. Ali EMSIA
Tektronix GmbH, Germany

online / October 5th – 8th / 2020
Photonics Days
Berlin Brandenburg
innovationconference

MASSTART

virtual conference session:
Data Center Interconnects – Towards Mass Manufacturing
online / October 6th 2020 / 4 – 7pm

Tektronix®

High throughput validation for 400G/800G optical transceivers

Presenter: Dr. Emsia

Tektronix High-End Solutions Overview

Tektronix®

- Tektronix is a leading T&M company serving engineering and technical professionals
- Founded in 1946, acquired by Danaher in 2007, 2016 a Fortive company
- Headquartered in Beaverton, Oregon
- Leadership positions in key products and markets
- Highly-respected brand based on high quality innovative products, engineering excellence and global service and support
- Award winning:
  - Oscilloscopes
  - Signal Sources
  - Spectrum Analyzers
  - Video Test

KEITHLEY
A Tektronix Company

- Keithley is a leader in precision electrical test
- Founded in 1946, acquired by Tektronix in 2010
- Headquartered in Solon, OH
- Offering instruments and systems to meet any measurement requirement from nanovolts to gigahertz
- 21 R&D 100 awards as well as honors from Semiconductor International, Solid State Technology, Electronic Products, Test & Measurement World magazines

Tektronix® – A Fortive Company

FORTIVE

Professional Instrumentation

Revenue $3.0B
GM% >50%
OP Margin >20%

Field Solutions*

FLUKE
QUALITROL

Product Realization*

Tektronix
Invetech
Pacific Scientific Energetic Materials Company

Sensing Technologies

Gems Sensors & Controls
setra
Anderson-Negele

Industrial Technologies

Revenue $3.2B
GM% ~40%
OP Margin High teens

Transportation Technologies

Gilbarco Veeder-Root
TELETRAC NAVMAN

Automation & Specialty

Kollmorgen – Because Motion Matters™
Thomson
Portescap
Jacobs Vehicle Systems

Franchise Distribution

Matco Tools
Ammco coats

Tektronix High-End Solutions Overview

TEKTRONIX SIMPLIFIES SERIAL STANDARDS TESTING COMPLEXITY WITH MEASUREMENT EXPERTISE AND TOOLS THAT PROVIDE ACCURATE TEST RESULTS FOR HIGH-SPEED COMPUTER AND COMMUNICATIONS SYSTEM DESIGNS

DSA8300 Series Oscilloscopes

Characterizes the electrical and optical signal performance of components, boards & systems.

DPO70000SX ATI Performance Oscilloscopes

Performs pass/fail compliance test and debugging of high speed electrical components, boards & systems.

OM4000 Lightwave Signal Analyzers

Analyzes optical modulation formats used in next generation long-haul networks.

RF Recorder & Playback /Signal Analyzers

Analyzes RF up to 26.5GHz at Real Time with 800MHz acquisition bandwidth

BERTScope Bit Error Rate Testers

Stress tests communication system receivers to ensure error-free operation in real-world environments.

Keithley Waver-Testing

Characterization of semiconductor at device, wafer or cassette level. Configurable at customer needs.

AWG Arbitrary Waveform Generators

Aids research efforts by generating complex signal patterns that help evaluate communications system designs.

Parameter Analyzer / Curve Tracer

Synchronized I-V and C-V characteristic

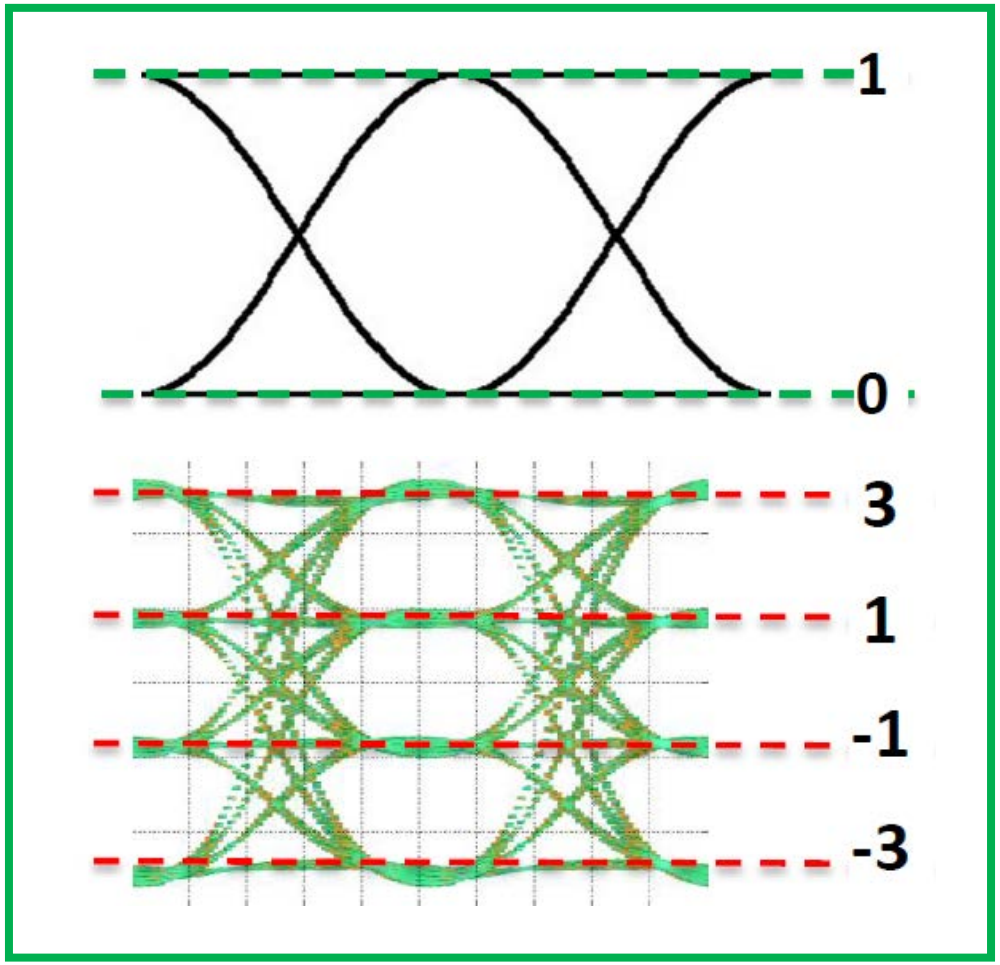
Why does the Industry need PAM-4?

PAM-4 SIGNALING ENABLES HIGHER DATA THROUGHPUT

- NRZ > 28 Gb/s limits trace length or increases cost

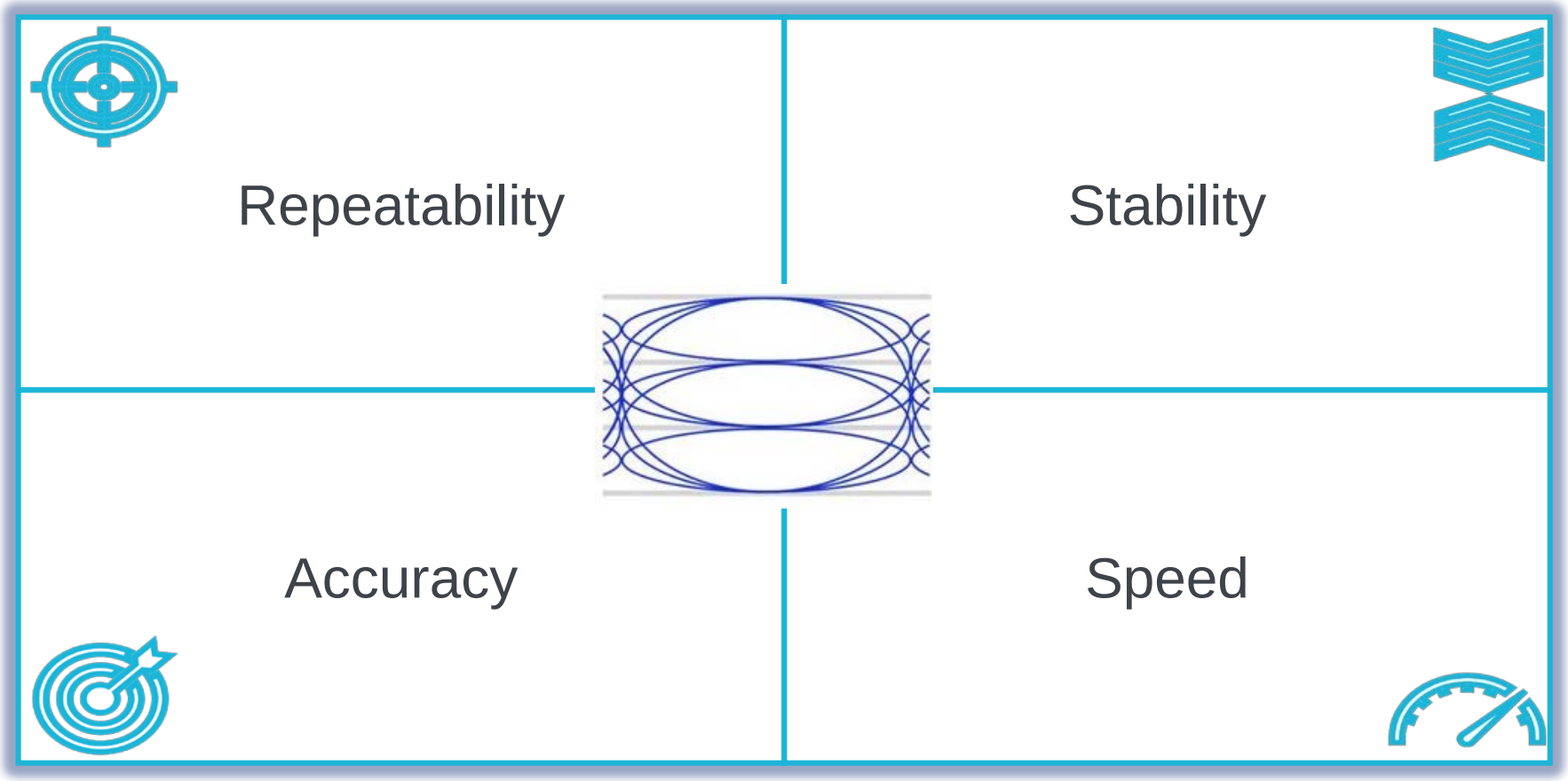
✓ PAM-4 offers 2 times the throughput at the same Baud rate

  - at 28 GBaud PAM-4 = 56 Gb/s
  - PAM-4 packs 2 bits / symbol -> needs half the channel BW
  - Allows designers to develop products to fit cost structure of available channel technologies.



Measurement Challenges

MAJOR INDUSTRY CHALLENGES WITH PAM-4 SIGNALS



Contrast Between PAM-4 and NRZ

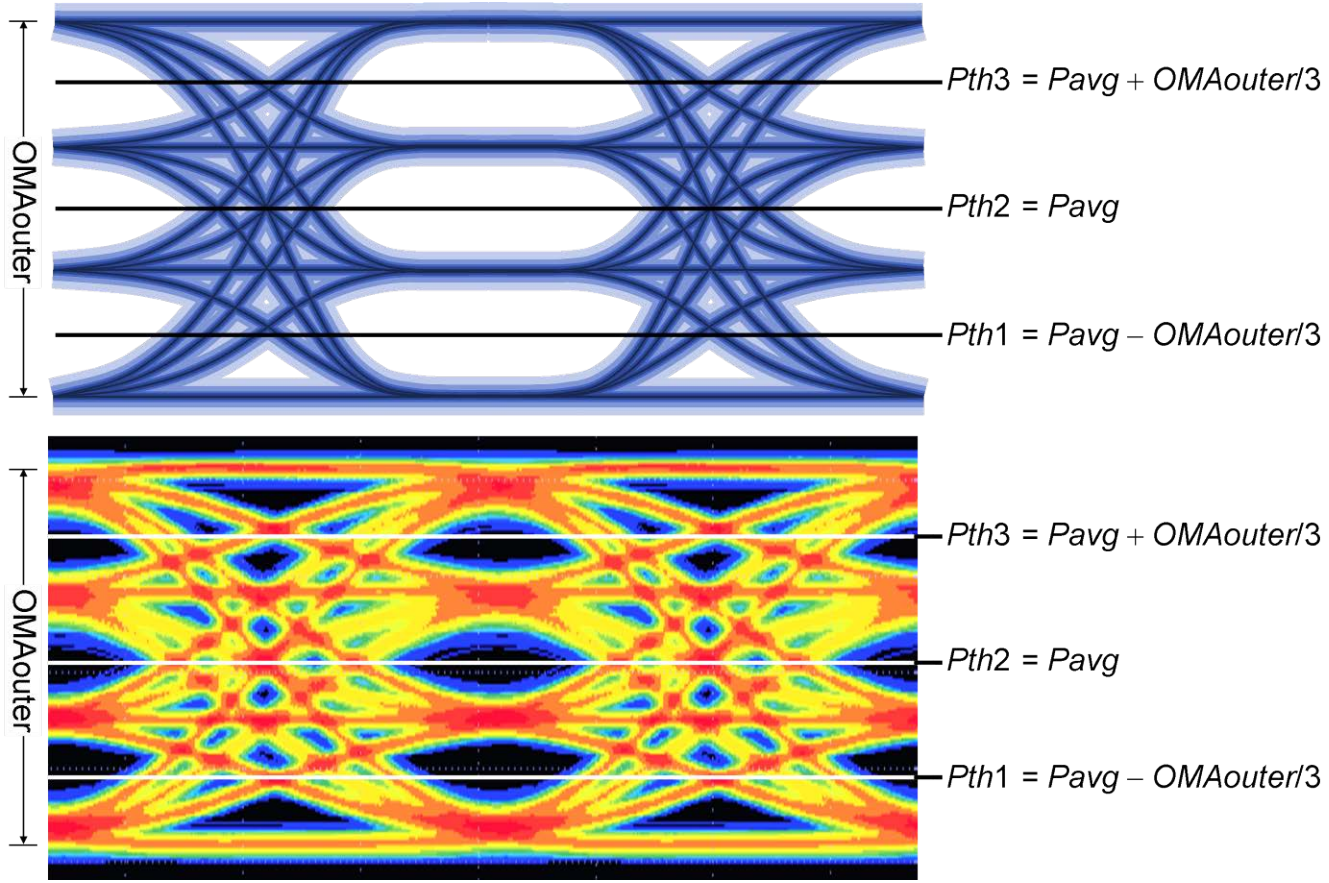
COMPARISON OF PAM-4 VERSUS NRZ OPTICAL MEASUREMENTS

- PAM4 Measurements
  - Transmitter and dispersion eye closure quaternary (**TDECQ**)
  - Outer Optical Modulation Amplitude (OMA_{outer})
  - Outer Extinction Ratio (OER)
  - Level separation mismatch ratio (R_{LM})

- NRZ Measurements
  - Tx Eye Mask
  - Optical Modulation Amplitude (OMA)
  - Extinction ratio (ER)

Transmitter and Dispersion Eye Closure Quaternary (TDECQ)

- Compare the real signal to a **simulated ideal signal**
  - Test and ideal signals have the same OMAouter

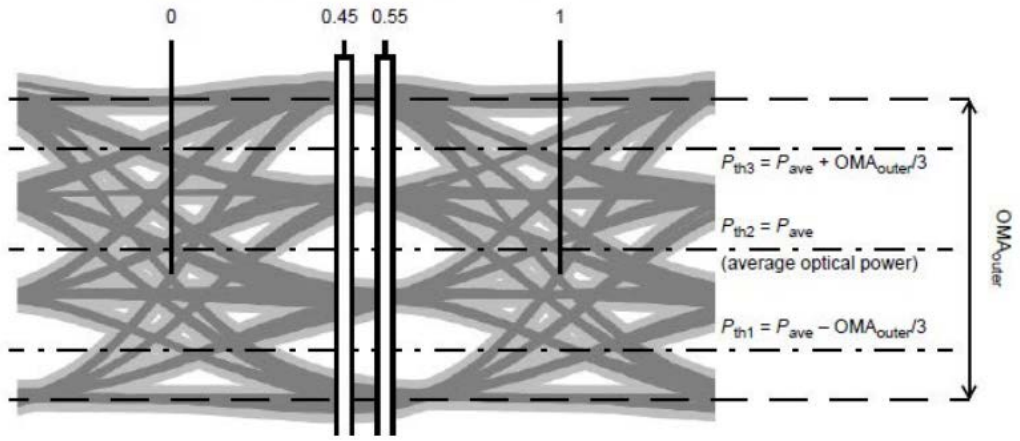


Measurement Differences

PAM4 TDECQ

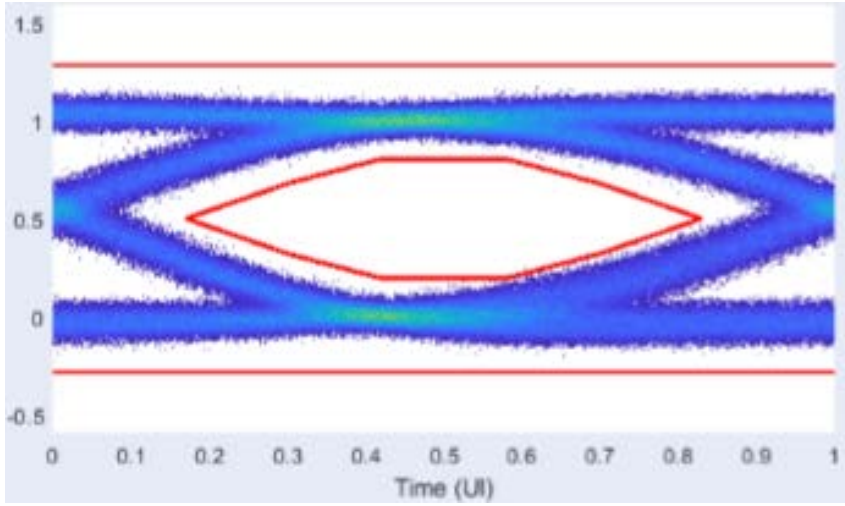
- Measures each of the optical transmitter's vertical eye closure as measured through and optical to electrical converter.

$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$



NRZ Eye Mask

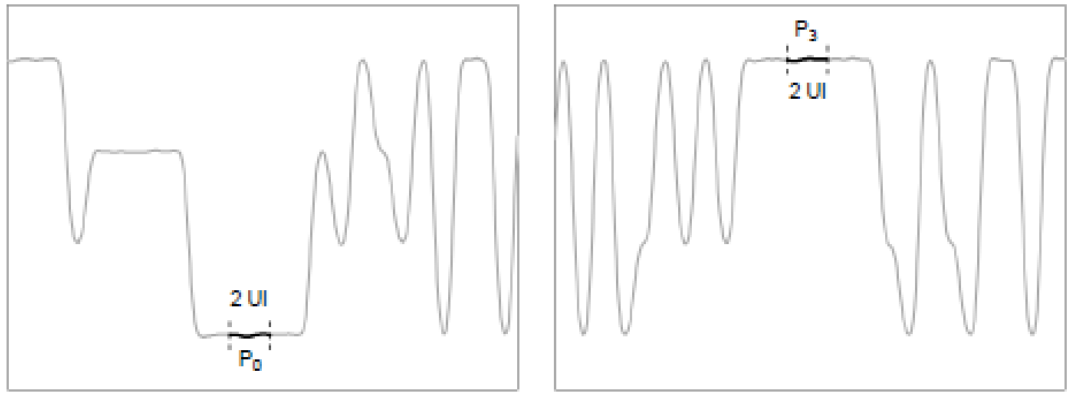
- Measures the number of hits on a mask to characterize the BER of a transmitter.



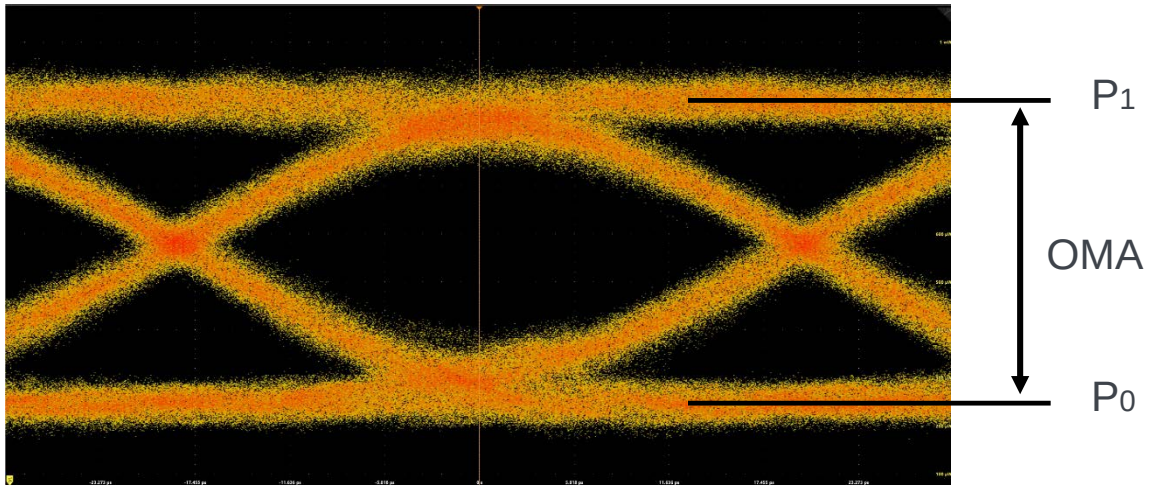
OMAouter

PAM4

- **From 121.8.4 Outer Optical Modulation Amplitude (OMAouter)**
  - … the difference between the average optical launch power level P3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P0, measured over the central 2 UI of a run of 6 zeros…



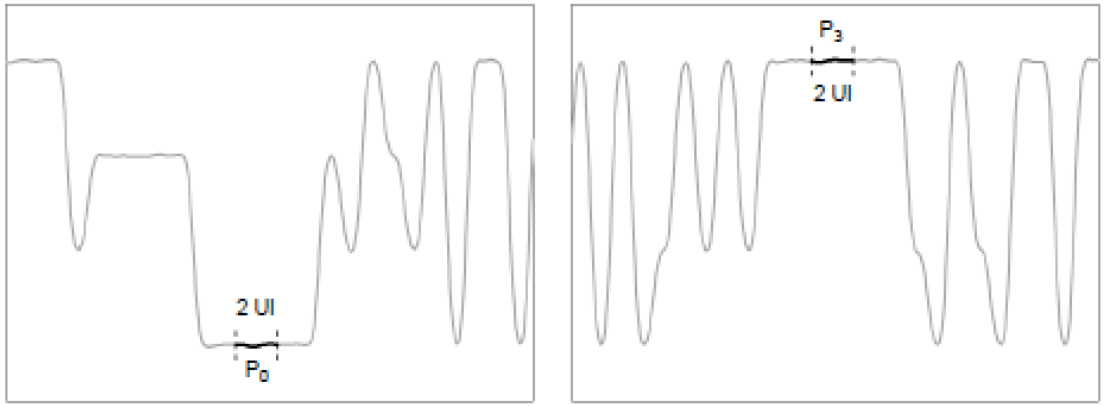
NRZ



Extinction Ratio

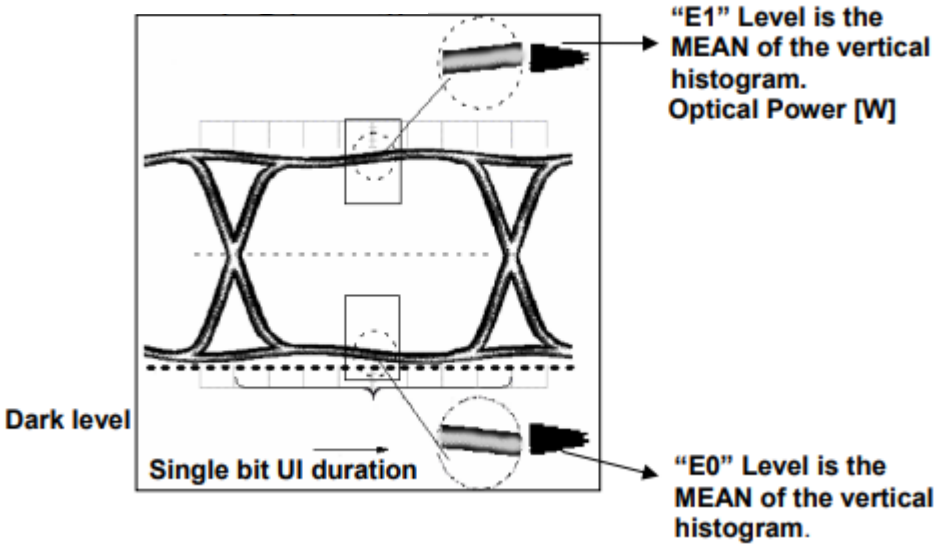
PAM4

- ER = 10Log(P_3 / P_0)
- Sensitive to proper dark-level calibration and DSP



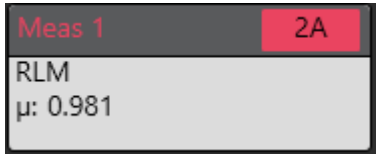
NRZ

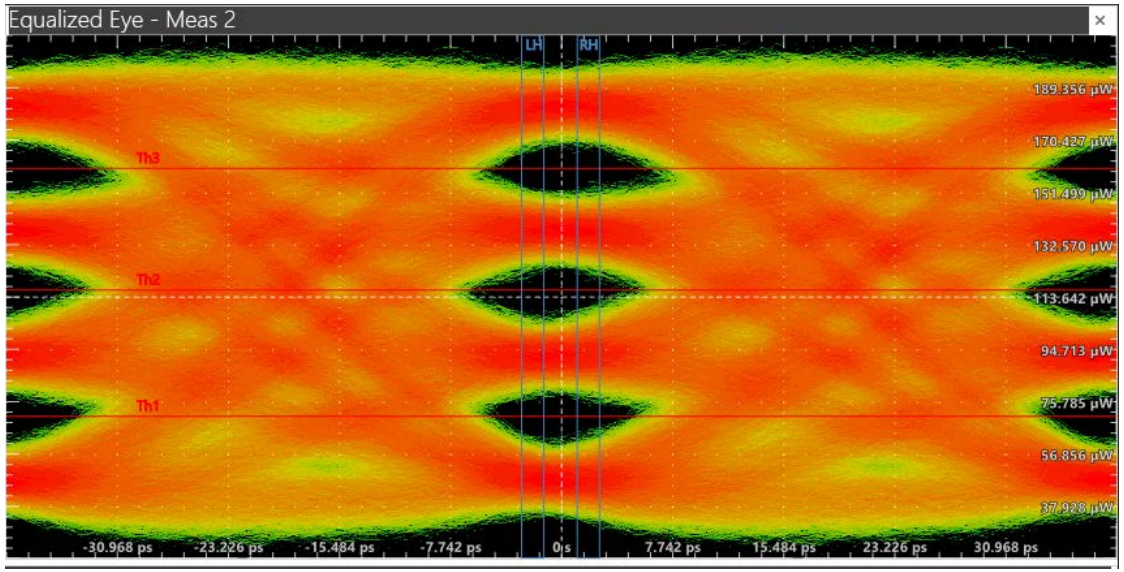
ER = 10Log(E_1 / E_0)

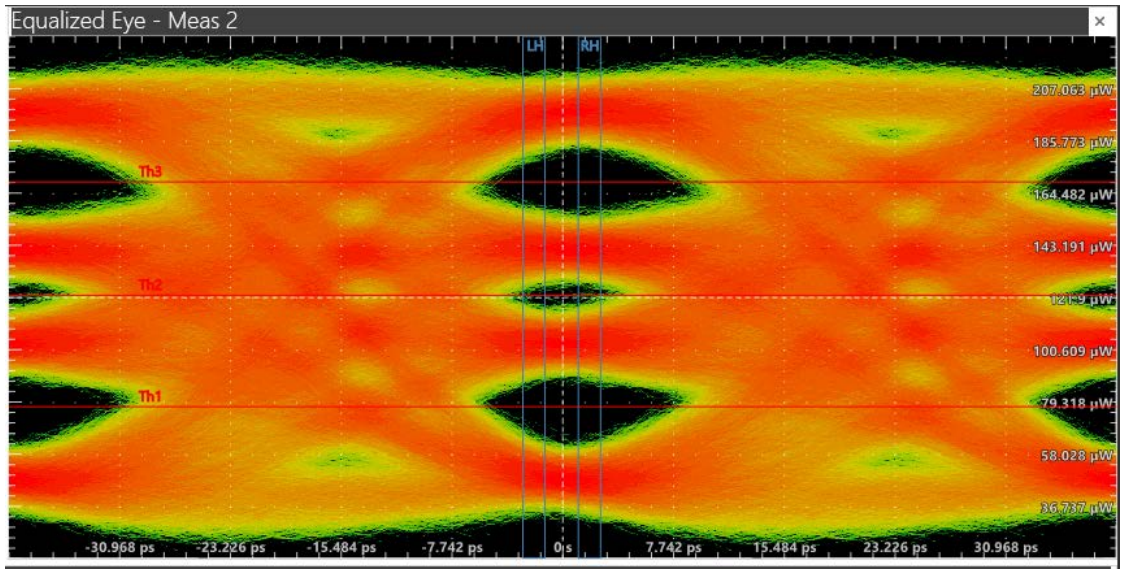


RLM

Level Separation Mismatch Ratio: Defined as a function of the mean signal level transmitted for each PAM4 signal.



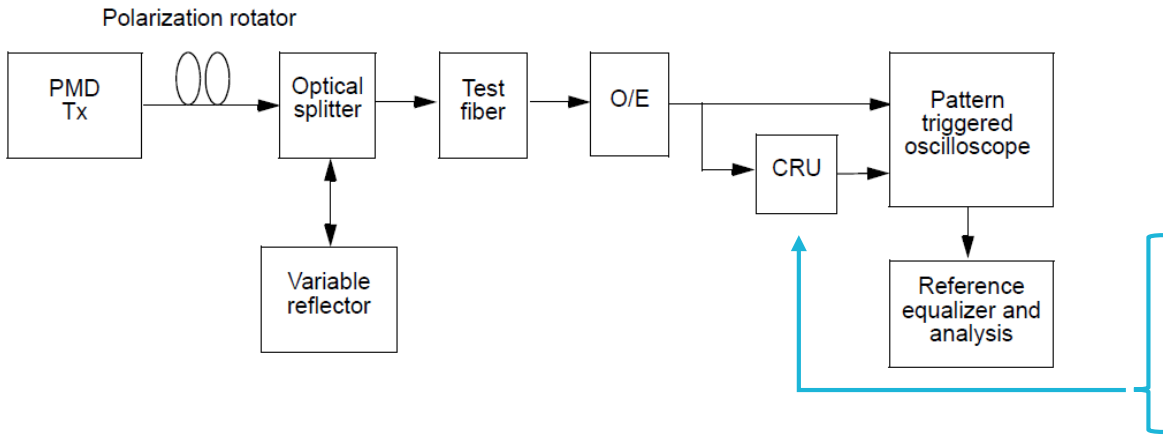




Market update

WHAT CHANGED ON THE TRANSCEIVER MARKET?

- Technical Challenges:
  - IEEE 802.3bs/cd **mandates** to use an optical clock recovery in order to guarantee accurate results unless you prove alternate solution with same results.



e.g. 400GBASE-DR4: The clock recovery unit (CRU) has a corner frequency of 4 MHz and a slope of 20 dB/decade. The CRU can be implemented in hardware or software depending on oscilloscope technology.

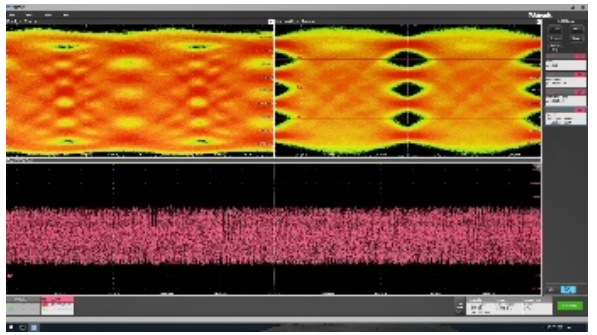
TCR801

Optical clock recovery will guarantee no field failures!
Optical clock recovery will guarantee highest yield.

Industry Challenges

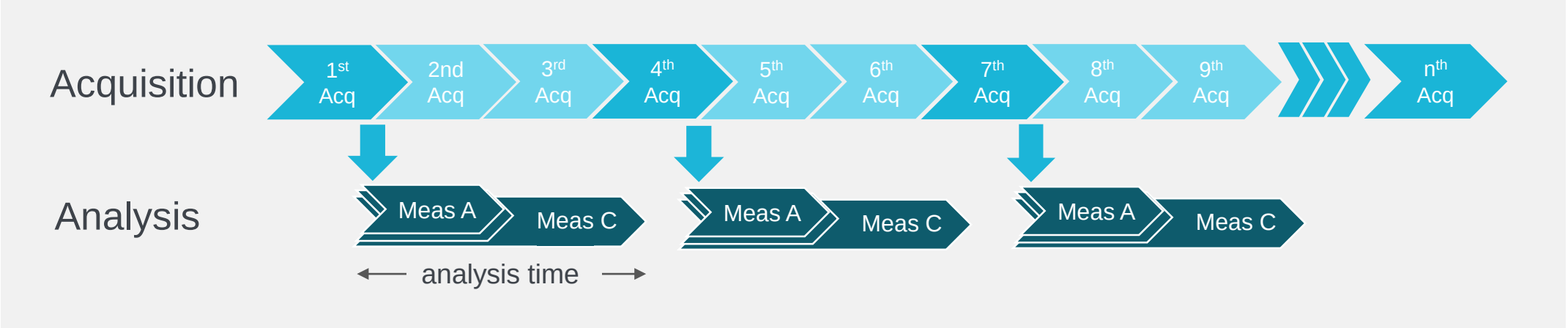
AND HOW TO OVERCOME THEM

- Able to adapt to market changes or ramps (Covid-19)
- Instrument remote access
- Test accuracy (false passes or repeatability issues)
- Cost of test
- Multi-channel testing



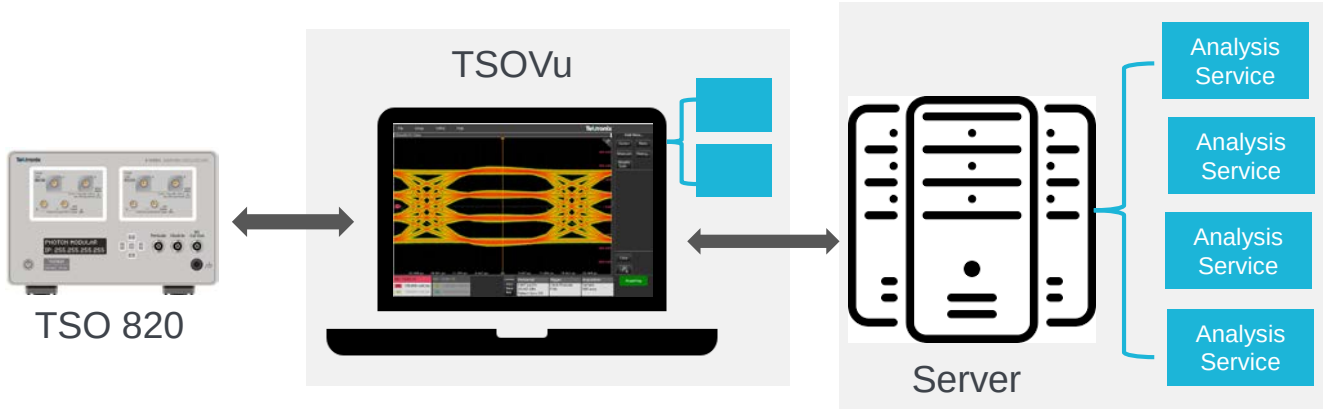
New Work Flow with Edge Computing

IMPROVE ANALYSIS TIME



Improve analysis time by:

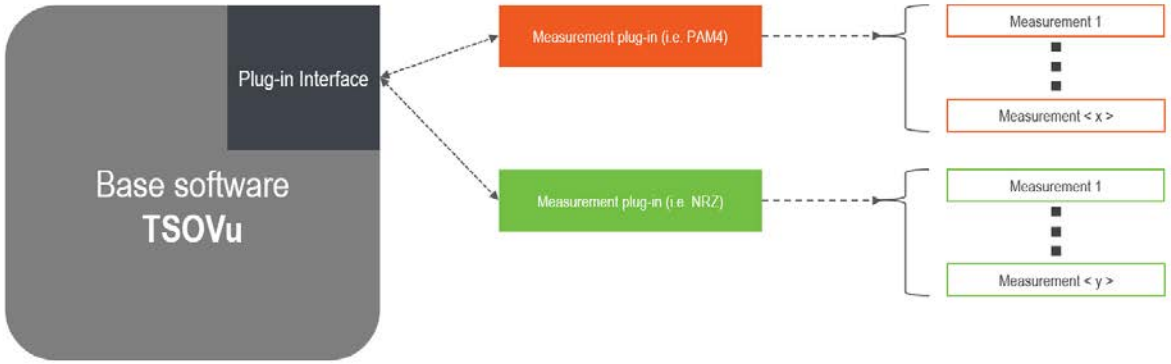
- Acquisition and measurements run in parallel
- Measurements across multiple channels run in parallel

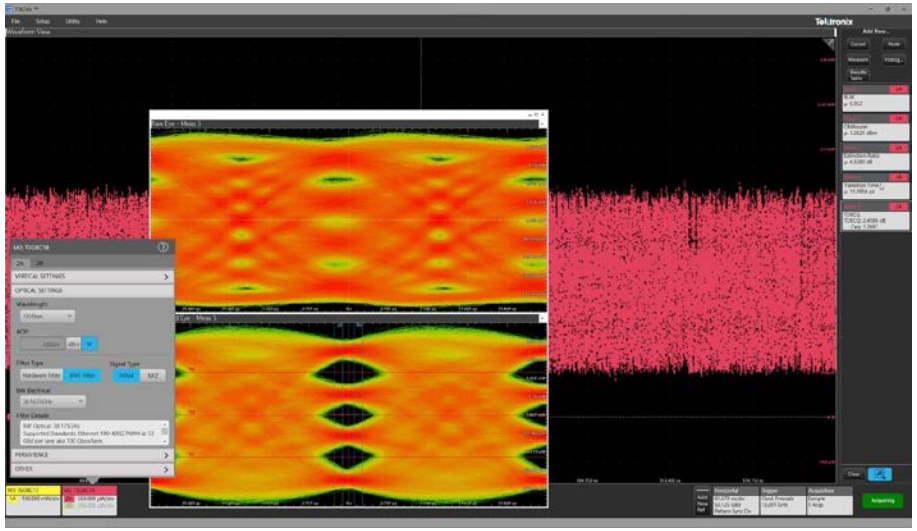


Product Overview: TSOVu

NEW OPTICAL TRANSCEIVER TEST PLATFORM – SOFTWARE

- New measurement plug-in interface with dynamic UI
  - Enables expansion of the measurement library for supporting new standards, emerging and final, as well as custom developed measurements
- Flat, intuitive, and modular user interface with multiple display modes
- Offline and Remote modes of operation
  - Extend analysis and visualization capability beyond the base oscilloscope features
- Fast acquisition and analysis of NRZ / PAM4 signals on multiple inputs
  - Simultaneously measurement for increased throughput
- Comprehensive SCPI based Programmatic Interface
  - Synchronous PI: automation without sleep/wait statements
- Support for multiple file formats enables exporting / importing data for analysis

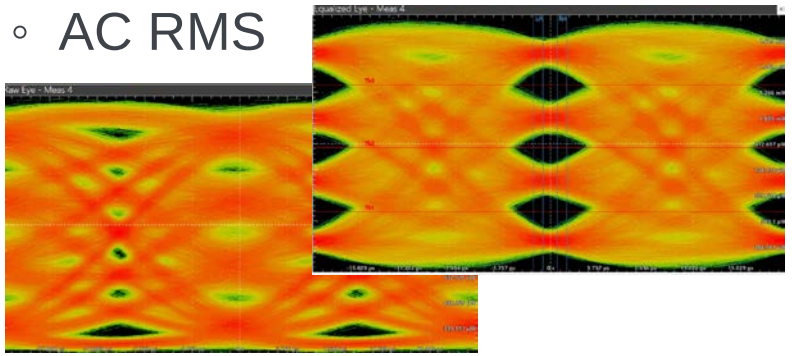




TSOVu Measurements

- PAM4 Measurements
  - RLM
  - Level
  - Level Deviation
  - Level Thickness
  - OMAouter
  - Extinction Ratio
  - Effective Symbol Levels
  - Eye Width
  - Eye Height
  - Transition Time
  - Overshoot
  - Undershoot
  - TDECQ
- Pulse measurements (Timing)
  - Period
  - Frequency
  - Rise
  - Fall
  - Positive Cross
  - Negative Cross
  - Positive Width
  - Negative Width
  - RMS Jitter
  - Pk-Pk Jitter
  - Delay
- Pulse measurements (Amplitude)
  - High
  - Low
  - Amplitude
  - Max
  - Min
  - Mid
  - Mean
  - Pk-Pk
  - AC RMS

Note: Pulse measurements do not require a license to operate



Flexible scaling. Standard.

ADD, RECONFIGURE, AND SCALE TO MATCH EVERYDAY NEEDS

TSO8C17: Single channel optical module

TSO8C18: Dual channel optical module

- A single module to provide 1 or 2 channel testing

Flexible scaling. Standard.

ADD, RECONFIGURE, AND SCALE TO MATCH EVERYDAY NEEDS

- Add a second module to the system to increase channel capacity and measurement throughput

Flexible scaling. Standard.

ADD, RECONFIGURE, AND SCALE TO MATCH EVERYDAY NEEDS

- Need a secondary tester?
- Transfer an optical module to another mainframe to cover other test needs

Flexible scaling. Standard. , 800G

ADD, RECONFIGURE, AND SCALE TO MATCH EVERYDAY NEEDS

- Add a TCR801 Optical Clock Recovery when a clock signal is needed for compliance testing or cannot be provided by DUT/PPG

Quadrants of success

BUSINESS CHALLENGES

Cost of test

- ✓ Lowest cost modular solution
- ✓ Multi-channel testing
- ✓ Highest throughput

Ramp / Scale

- ✓ User upgradable
- ✓ Rack ready, drop-in solution

Lead time

- ✓ Tektronix agile manufacturing can react to changes in demand

WW support

- ✓ Gold-care package
- ✓ World-wide on-site support teams of AEs

3U high

1U high

TECHNICAL CHALLENGES

Repeatability

- ✓ We design and manufacture for repeatability

Stability

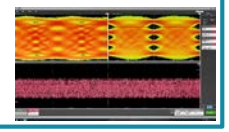
- ✓ Self-compensation

Accuracy

- ✓ NIST-traceable processes

Speed

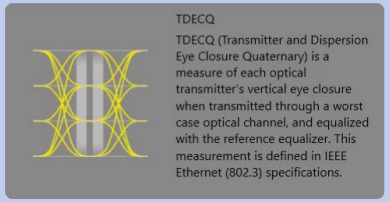
- ✓ Fully synchronous PI
- ✓ Parallel acquisition



Tektronix 8 Series

SYSTEM MEASUREMENT INTEGRITY

- ✓ New platform confidence that measurements are correct, repeatable, and correlate

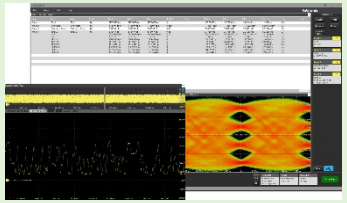


CORE FLEXIBILITY

- ✓ Enables users to adjust to changes in the workflow without sending hardware back to the factory
- ✓ Proactively adapt capital investments to industry changes

REFINED USER EXPERIENCE

- ✓ Networked instrument for all workflows, even "work from home"
- ✓ Streamlined user interface to make complex tasks simple
- ✓ Optimize instrument uptime in automation environments using Synchronous PI



SIMPLIFIED SINGLE PLATFORM

- ✓ The most compact modular sampling oscilloscope to cover all modes of test
- ✓ Modern software architecture with a single code base
- ✓ No more complex optioning schemes as a prerequisite to test

Acknowledgement

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