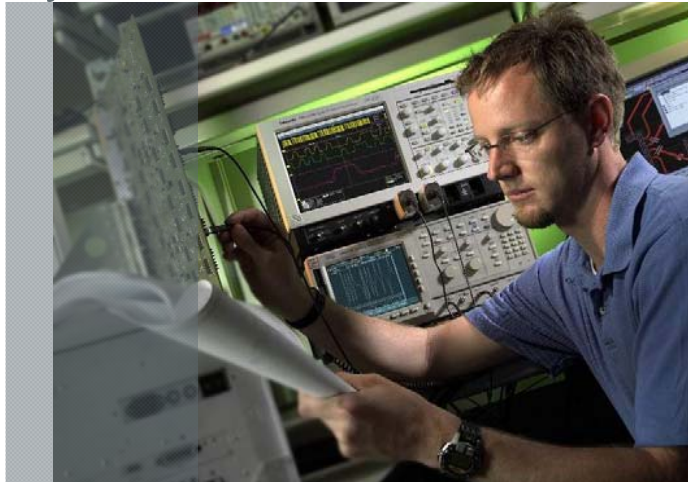# MIPI technology and Tek test solution

Oct. 25th 2011

Ryan Yu

Tektronix ®

Agenda

- MIPI Standards Overview

- MIPI PHY Testing (D-PHY and M-PHY)

- MIPI CSI/DSI/DigRF
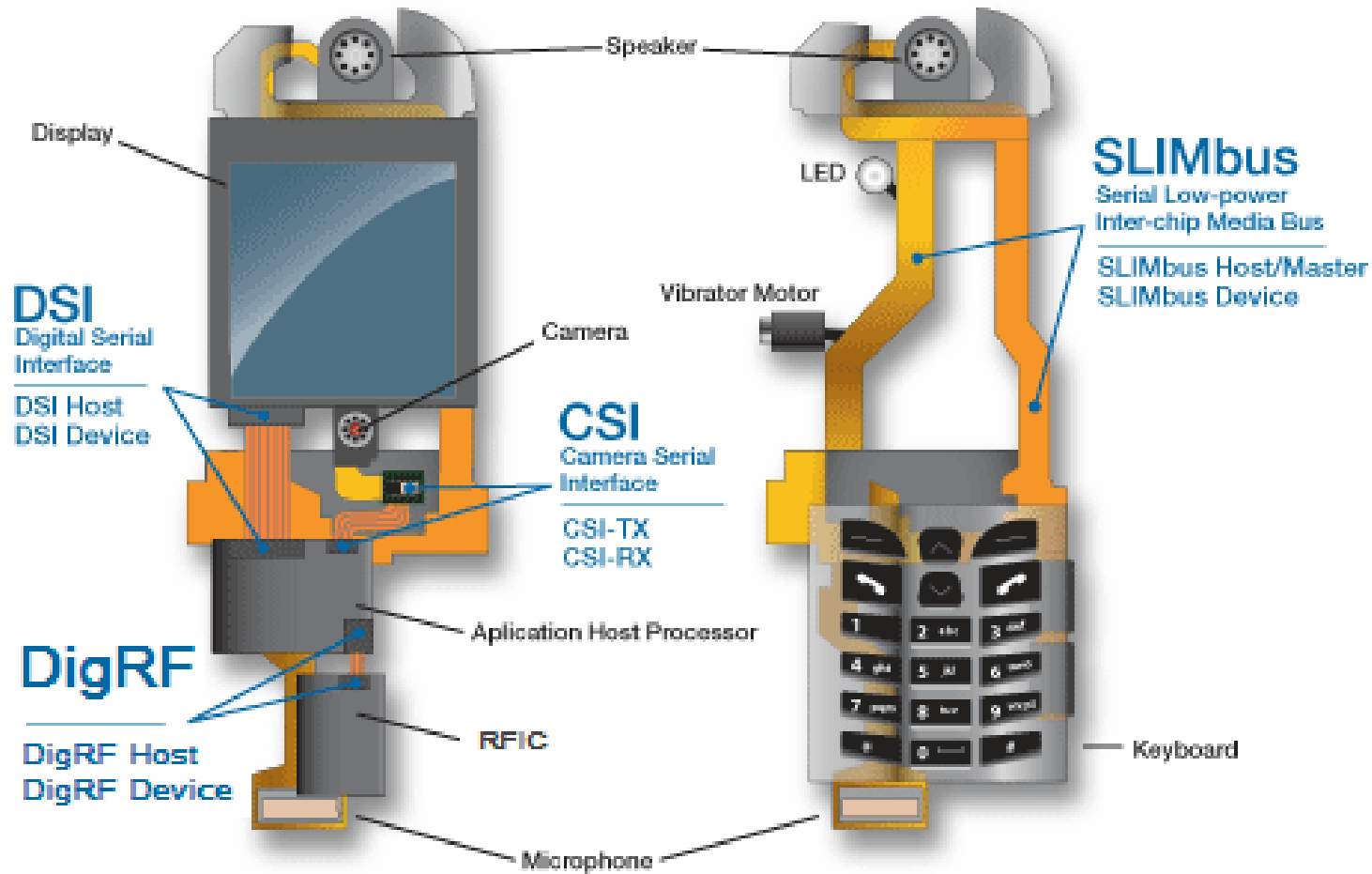
- Summary, Q&A

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Tektronix & MIPI Alliance

- Tektronix is a **Contributor Member** of the MIPI Alliance
  - Tektronix participates in several MIPI Working Groups.

- Tektronix Testing Support for MIPI includes;
  - Analog Validation
  - Protocol Debug and Verification

- Tektronix is engaged on MIPI Test Methodologies working alongside the UNH-IOL.
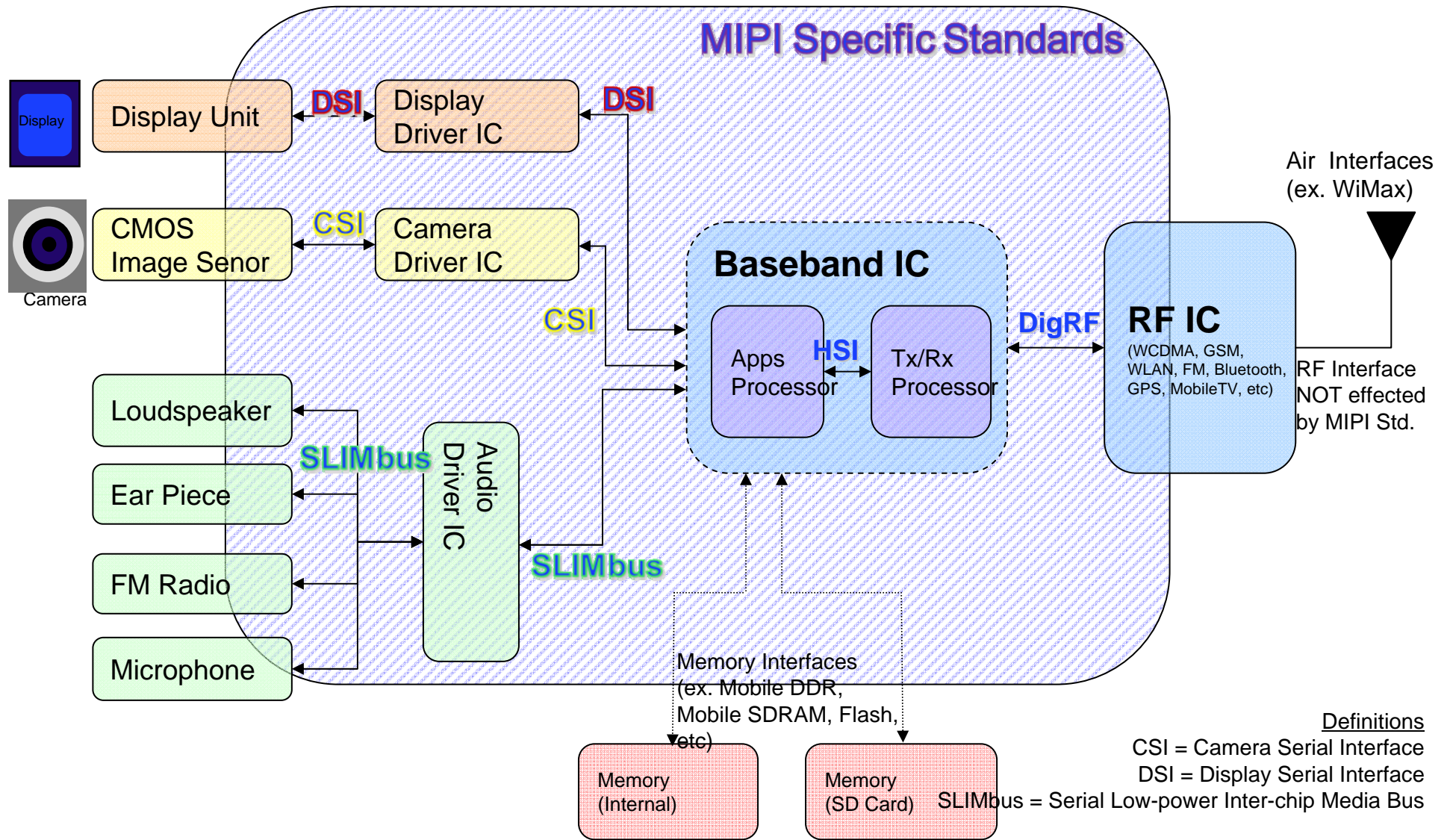
Example of Mobile Terminal

MIPI Standards Overview
## Example Mobile Terminal Block Diagram

MIPI Specific Standards

Display

Display Unit — **DSI** — Display Driver IC — **DSI**

Camera

CMOS Image Senor — **CSI** — Camera Driver IC

CSI

Loudspeaker

Ear Piece

SLIMbus

Audio Driver IC

FM Radio

SLIMbus

Microphone

Baseband IC

Apps Processor — **HSI** — Tx/Rx Processor

DigRF

RF IC
(WCDMA, GSM, WLAN, FM, Bluetooth, GPS, MobileTV, etc)

Air Interfaces
(ex. WiMax)

RF Interface NOT effected by MIPI Std.

Memory Interfaces
(ex. Mobile DDR, Mobile SDRAM, Flash, etc)

Memory (Internal)

Memory (SD Card)

Definitions
CSI = Camera Serial Interface
DSI = Display Serial Interface
SLIMbus = Serial Low-power Inter-chip Media Bus

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What is MIPI DSI ?

- DSI is the specification for processor-to-display interconnect in handheld platforms
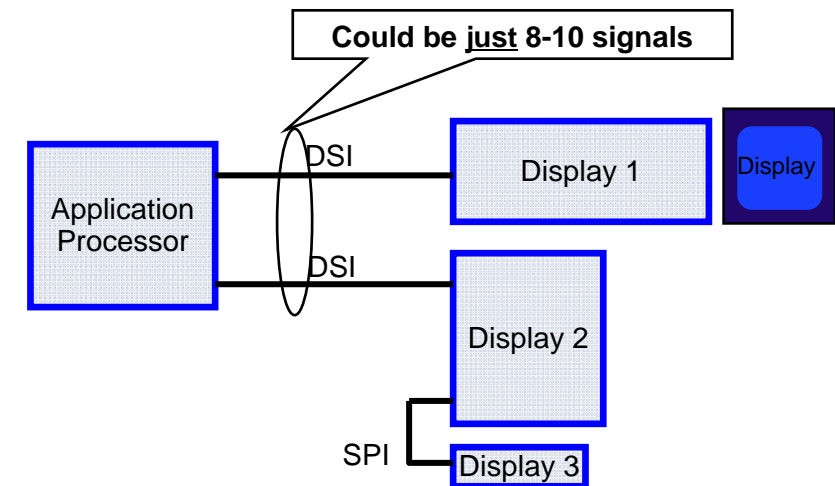
- **Legacy Standards in a Mobile Device**
  - Exposed wide standards
    - RGB, VS, HS or DE
  - All are parallel busses
    - Each 45-50 signals
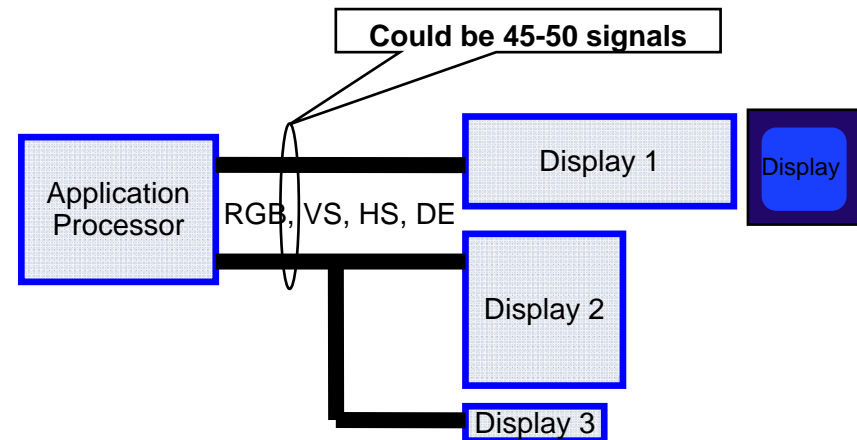
- **MIPI DSI-1**
  - **Physical layer is D-Phy**
  - Protocol layer is DSI-1
  - Only Single standard: DSI-1
    - Multiple Displays – One Interface
      - Supports all Common Display technologies
  - A Serial bus
    - Just 8-10 signals
      - 5:1 ratio savings in signals
    - Lower EMI

- **MIPI DSI-2**
  - **Physical layer is M-Phy**
  - Protocol layer is DSI-2
  - Higher Datarate
    - Backward Compatible to DSI

Legacy

Could be 45-50 signals

Application Processor

RGB, VS, HS, DE

Display 1

Display

Display 2

Display 3

DSI

Could be just 8-10 signals

Application Processor

DSI

Display 1

Display

DSI

Display 2

SPI

Display 3

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What is MIPI CSI ?

- CSI is the serial interface specification for Camera/ imaging peripherals and host processors
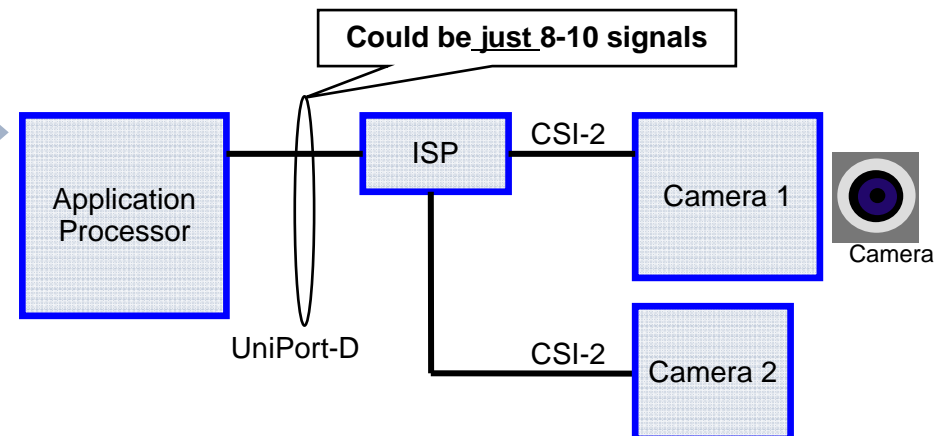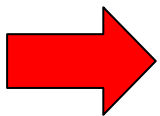
- The Legacy Standards in a Mobile Device
  - Exposed wide standards
    - YUV-10, YUV-8, etc
  - All are parallel busses
    - Each 20-36 signals
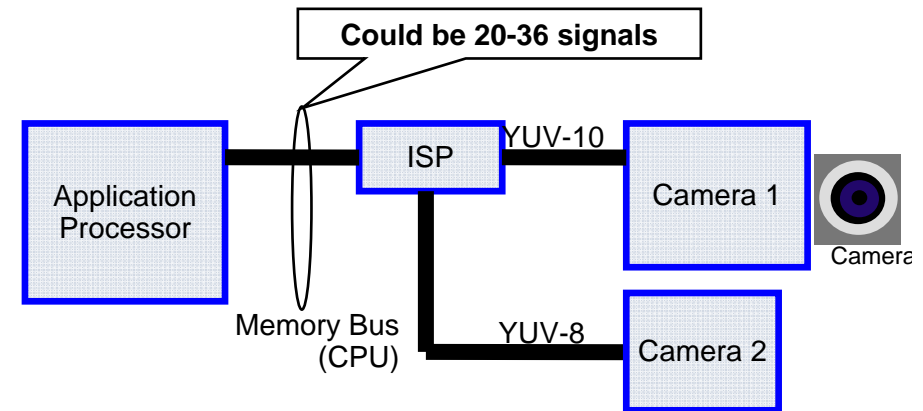
- **MIPI CSI-2**
  - **Physical layer is D-Phy**
  - Protocol layer is CSI-2
  - Only Single standard
    - Multiple Cameras – One Interface
  - A Serial bus
    - Just 8-10 signals
      - 3:1 ratio savings in signals
    - Lower EMI

- **MIPI CSI-3**
  - **Physical layer is M-Phy**
  - Protocol layer is CSI-3
  - Higher Datarate
    - Backward Compatible to CSI-2

Legacy

Could be 20-36 signals

Application Processor — ISP — YUV-10 — Camera 1 — Camera

Memory Bus (CPU) — YUV-8 — Camera 2

CSI

Could be just 8-10 signals

Application Processor — ISP — CSI-2 — Camera 1 — Camera

UniPort-D — CSI-2 — Camera 2

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What is MIPI D-PHY ?

- It's a PHY standard for interfacing Camera (CSI) & Display (DSI)
- Two modes of transmission
  - High Speed (HS) and Low Power (LP)
- Modes are mixed during the operation
  - Transitions from LP to HS and back to LP on the fly
- Maximum Data Rate
  - High Speed mode: 80 Mbps – 1 Gbps, Typically at ~500 Mbps.
  - Low Power mode: Up to 10 Mbps
- Bus termination
  - 50 ohms in HS
  - Hi-Z in LP
- Dual simplex communication. Bi-directional & Half-duplex are optional.

Low-Power signaling level (e.g. 1.2V)

Max LP-RX High

Minimum LP-RX Low threshold

HS diff. swing (e.g. 200mV)

HS common level (e.g. 200mV)

0 Volt - Reference ground

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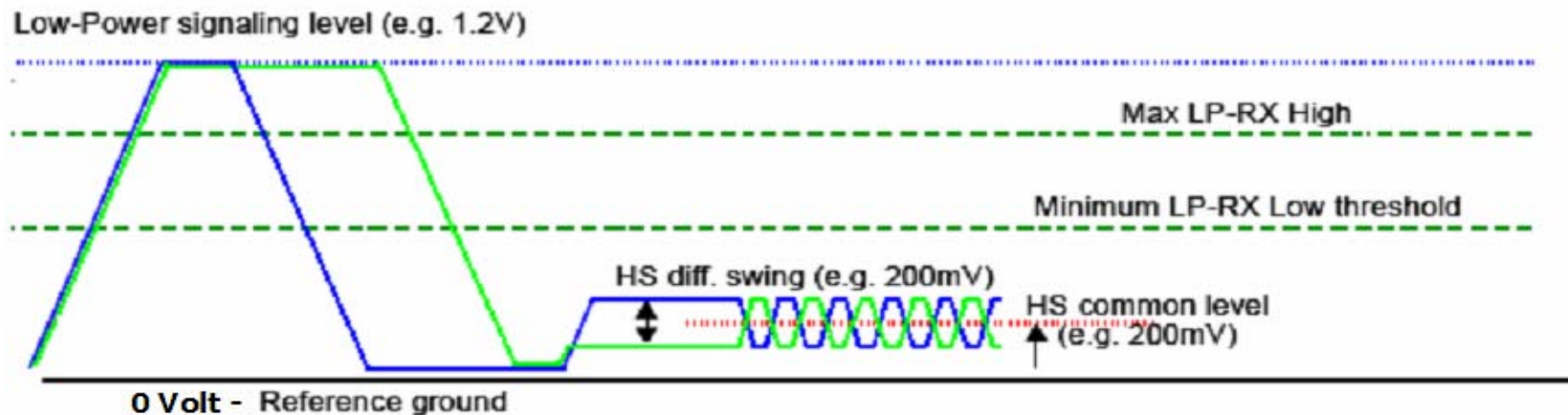
D-PHY Testing Challenges

- Logo/Compliance testing is NOT required, but Optional.
    - MIPI is Chip-to-Chip/ Chip-to-Peripheral interface, **similar to DDR**.
    - Mobile Phones do NOT need compliance logos, **unlike USB/ SATA**

- Bursty, High/Low amplitude nature of D-PHY Tx signaling behavior makes measurement setups critical for proper evaluation
    - Vertical scaling
    - High-Impedance probing
    - Sample rate

- Characterization is significantly important
    - Mobile OEMs select the suppliers based on characterization reports.

- No two MIPI devices are the same
    - Specification enables **custom limits.**
    - Up to 4 lanes of Data traffic, Variable Data Rates
    - Multiple different data formats

Test Equipment &Setups need to be Very Flexible

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MIPI Alliance D-PHY CTS and Tektronix

D-PHY Tx Testing Solution – Continued

- ■ Scope
  - **Recommend: DPO7354 or DPO/DSA/MSO70404/B**
    - For risetime (150ps) measurements within +/-5% of spec
  - DPO7254 can be used when risetime is **NOT** a concern.

- ■ Probes
  - **Probing Considerations**
    - Measure both SE and Diff performance
    - Must have >1.2V dynamic range
    - Needs minimum probe attenuation
      - 1X best, but 2.5X or 5X ok
  - **Recommend:**
    - **Four TAP3500 for DPO7000 or Four P7240 for MSO/DPO/DSA70000/B**
    - (Ch1: D+), (Ch2: D-), (Ch3: Clk+), (Ch4: Clk-)
    - TAP2500 fine for low datarate DUTs
  - **Alternatives:**
    - **For Solder-Down**
      - **TDP3500 for DPO7000 or P73xx for 70000 Series**
      - (Ch1: D+, Gnd), (Ch2: D-, Gnd), (Ch3: Clk+ &Clk-)
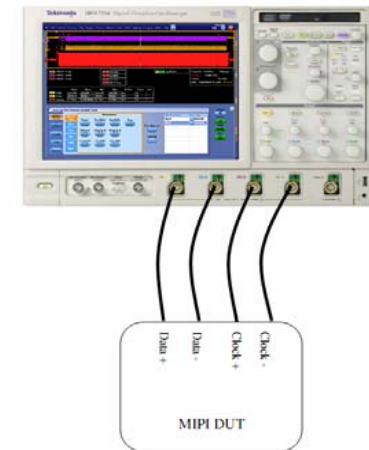
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D-PHY Tx Testing Solution from Tektronix

- **New Tektronix Oscilloscope Option; MIPI D-PHY Essentials**
  - An option to DPOJET Analysis providing specific D-PHY setup library & MOI
  - Automated measurement set
  - Based on D-PHY Base Spec v0.9 and UNH's Conformance Test Suite v0.08.
  - Compatible with Tektronix DPO7000, DPO/DSA70000/B and MSO70000 oscilloscopes

- **Requires DPOJET Advanced Timing & Analysis Software**

- **Benefits**
  - Characterization
  - Proper vertical settings
  - Breadth of Tests Coverage
  - Comprehensive Test Reports

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Opt.D-PHY *(Existing)*

- ## Opt.D-PHY : D-PHY Essentials
  - DPOJET option for setup library &MOI
  - Automation similar to Opt. USB3 or Opt. PCE
  - Provides Debug Analysis and Characterization Testing
  - Based on D-PHY Base Spec v0.9 and UNH's Conformance Test Suite v0.08.
  - Runs on DPO7000, DPO/DSA/MSO70000/B Series oscilloscopes

- ## Opt.DJA is Pre-Requisite

- ## Differentiation
  - Flexible for Debug Analysis &Characterization
  - Breadth of Tests Coverage

- ## Value proposition
  - DPOJET Detailed Test Reports
  - DPOJET Scalable for early start on M-PHY (Next Generation Standard)
  - Tek 3.5GHz scope is the minimal configuration for accurate testing
    - i.e. unlike Agilent 4G scope at entry-level

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New Opt.D-PHYTX

- **Opt.D-PHYTX : D-PHY Automated Solution**
  - TekExpress option for Fully-Automated testing
  - Automation similar to Opt.USB-TX
  - Provides Conformance and Characterization Testing
  - Based on D-PHY Base Spec v1.0 and UNH's Conformance Test Suite v0.98.
  - Runs on DPO7000, DPO/DSA/MSO70000/B Series oscilloscopes

- **Opt.TEKEXP is Pre-Requisite**

- **Differentiation**
  - Un-parallel Automation (Auto-Cursors/ Regions)
  - For Conformance testing to Latest CTS (v0.98)
  - Based on Latest Base spec (v1.0)

- **Value proposition**
  - Custom-limits/ Limits-Editing on the fly
  - Test Reports
    - Zoom-in waveform captures at the Cursors/ Regions
    - Pass/Fail Summary with Margin details
  - Tek 3.5GHz scope is the minimal configuration for accurate testing
    - i.e. unlike Agilent 4G scope at entry-level

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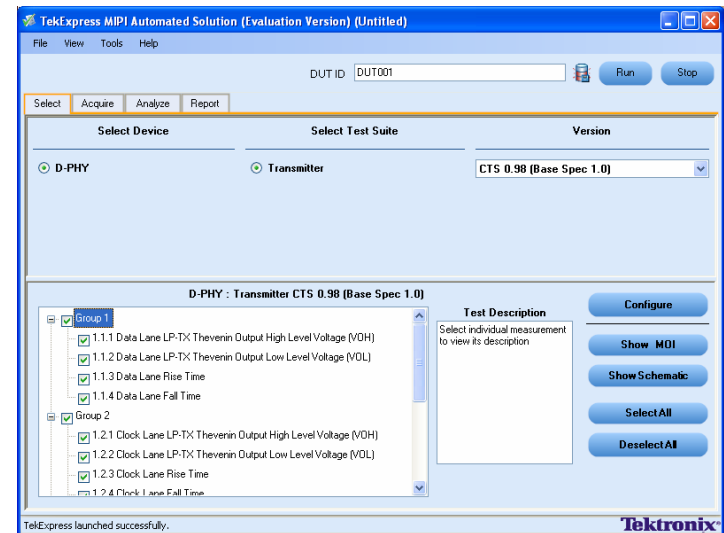
Opt.D-PHYTX and Opt.D-PHY
Testing Recommendations

Feature	Opt.D-PHY (D-PHY Essentials)	Opt.D-PHYTX (D-PHY Automated Solution)
Pre-Requisite tools	DPOJET	TEKEXP
Automatic measurement selections based on device ID, test group, and selected probes.		✓
Single button execution for all measurements		✓
Configurable setup and Editing of test limits	✓	✓
Detailed or Summary Reports	Detailed Only	Detailed &Summary
Automatically Save Test Reports and Waveforms		✓
Re-analyze pre-recorded waveforms	✓	✓
D-PHY Specific User Interface		✓
Base Specification Revision	V0.9	V1.0
Conformance Test Specification Revision	V0.08	V0.98
Testing Recommendation	Debug , Analysis &Characterization	Conformance, Verification, &Characterization

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D-PHYTX Select Panel
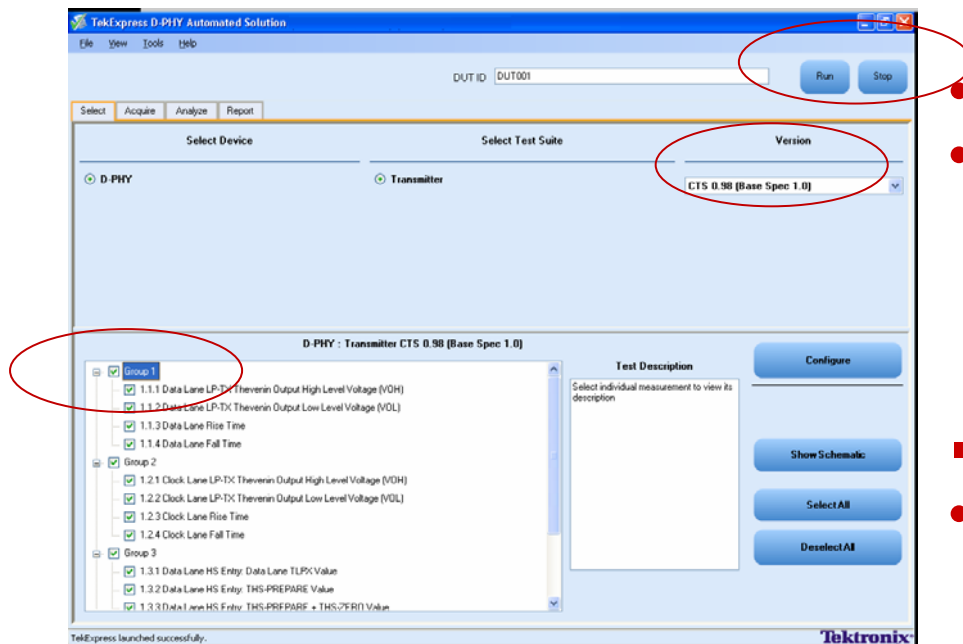
- Feature: Single-Button Testing
  - Perform Single-button Fully-Automated testing

- Feature: Latest CTS
- Benefits:
  - Allows conformance testing to the latest CTS as of date.

- Feature: Selective Testing
- Benefits:
  - Allows selecting individual tests or group-wise tests through tree-structure.

D-PHYTX Configure Panel
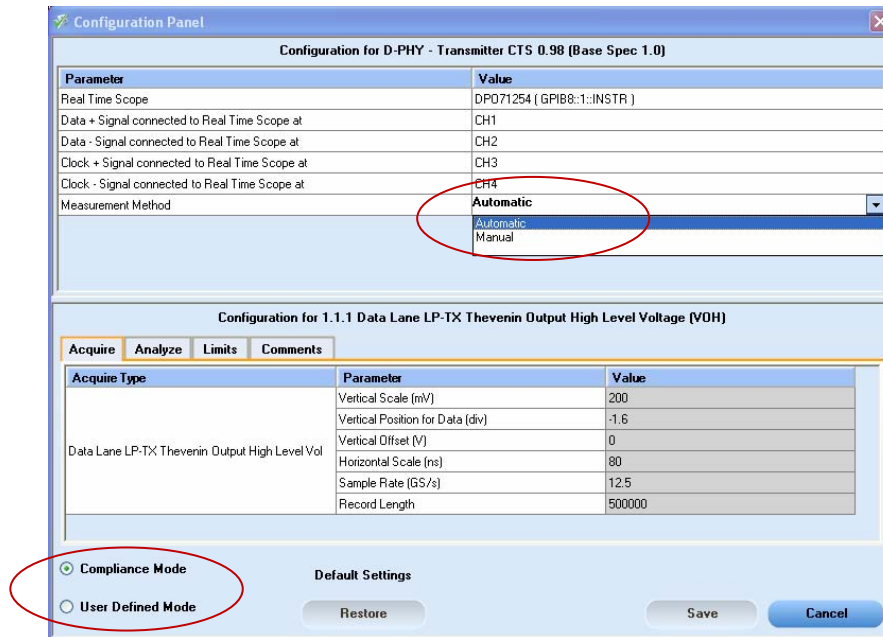
- Feature: Automated Testing
- Benefits:
  - Does not require operator intervention to conduct time consuming testing
  - Reduces the amount of time required to conduct testing
  - Enables customers to test devices faster

- Feature: Setup Customization/ User-Defined Mode
- Benefits:
  - Modify the test setup as per the DUT configuration.
  - Unit Intervals are automatically calculated based on the DUT datarates.

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D-PHYTX Configure Limits Panel
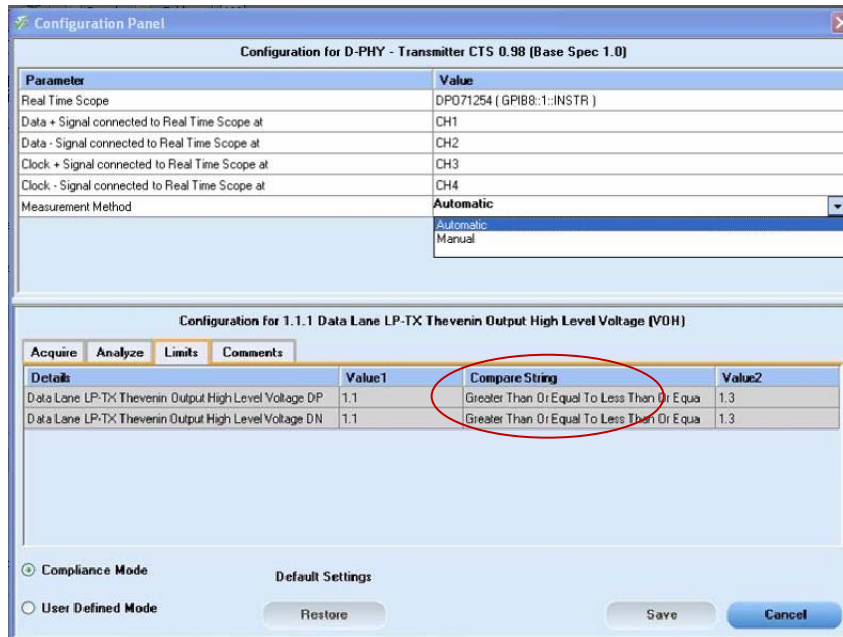
- Feature: Margin Testing/ Characterization

- Benefits:
  - Allows custom-limits or limits-editing to perform Margin testing.
  - Performs characterization of your design.

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D-PHYTX Acquire Panel
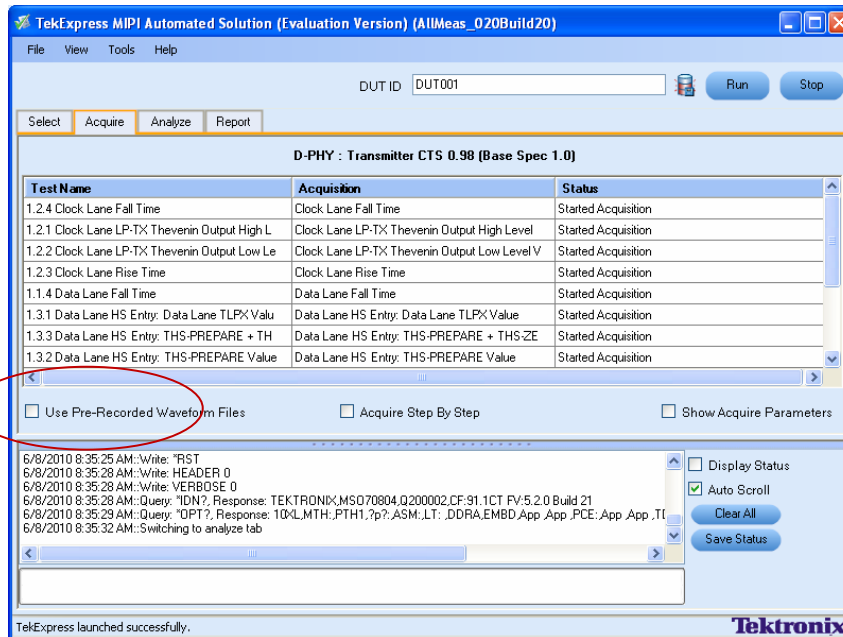
- **Feature: Pre-recorded waveforms**

- **Benefits:**
  - Performs Live or Off-line Analysis through any Windows PC/ system

- **Feature: LAN/ GPIB Connectivity**

- **Benefits:**
  - Allows remote execution of tests

D-PHYTX Analyze Panel

- **Feature:**
  - Reliable Results

- **Benefits:**
  - Avoids double testing, through accurate and reliable results from single-run

D-PHYTX Reports Panel

- **Feature:** Detailed test reports

- **Benefits:**
  - Provides Pass/Fail summary table
  - Provides margin details on each test
  - Provides waveform screenshot of testing region, through hyperlinks for each test.
  - Provides "single-printable" consolidated report for all lanes and all tests.

Opt.D-PHYTX
UI-design and Reports

- Clock Continuous mode

- Escape mode

Opt.D-PHYTX
Fully-Automated Temperature Chamber testing

- **Supports HS tests only**

- **Setup**
  - 4x P75xx probes
  - High Temp Tips (020-2958-xx - Kit of 10)
 - Socket Cable XL (020-2960-xx)
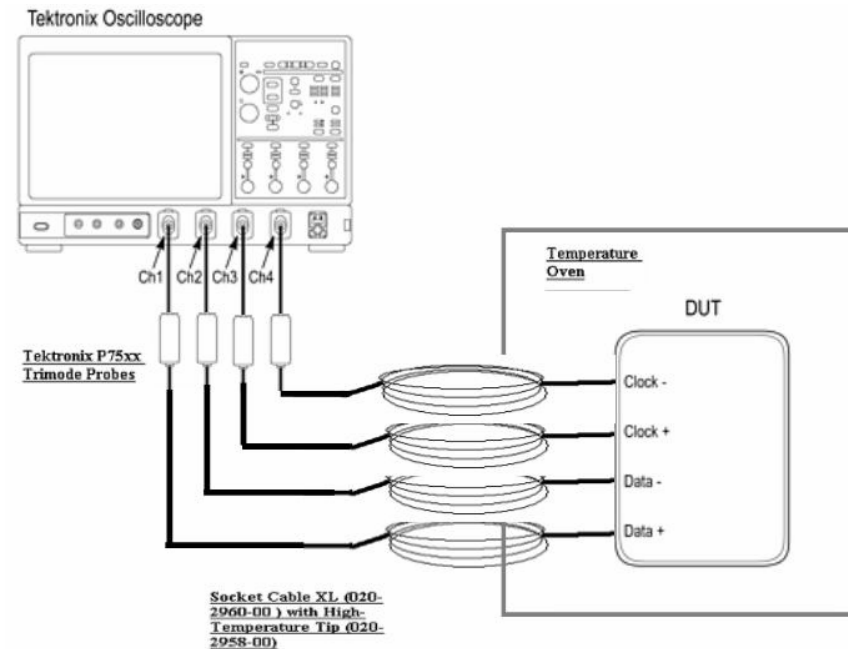
Opt.D-PHYTX Release2
Error Handling

- Test reports with Errors/ Exceptions information help identify Setup/ Acquisition issues quickly

| Error code	Error Description
50111	Waveform file not found
50001	Could not find HS region
50002	Could not find LP region
50003	HS UI could not be computed
50004	Pattern 011111/100000 not found
50006	Pattern 111000 not found
50007	Pattern 000111 not found
50008	Possible improper Clock
50009	Could not find HS Trail
50010	Could not find TREOT

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Opt.D-PHYTX Release3
Updated Features &Benefits 1

- **100%** Tests coverage
  - 9 new measurements added (Test IDs: 1.1.5, 1.1.6, 1.1.7, 1.2.5, 1.3.15, 1.3.16, 1.4.15, 1.4.16, 1.5.4)
  - Only automated SW that supports all 49 Tx CTS tests.

- Latest Specifications (v1.0) support
 - Only SW that supports both Base Spec v1.0 and CTS v1.0
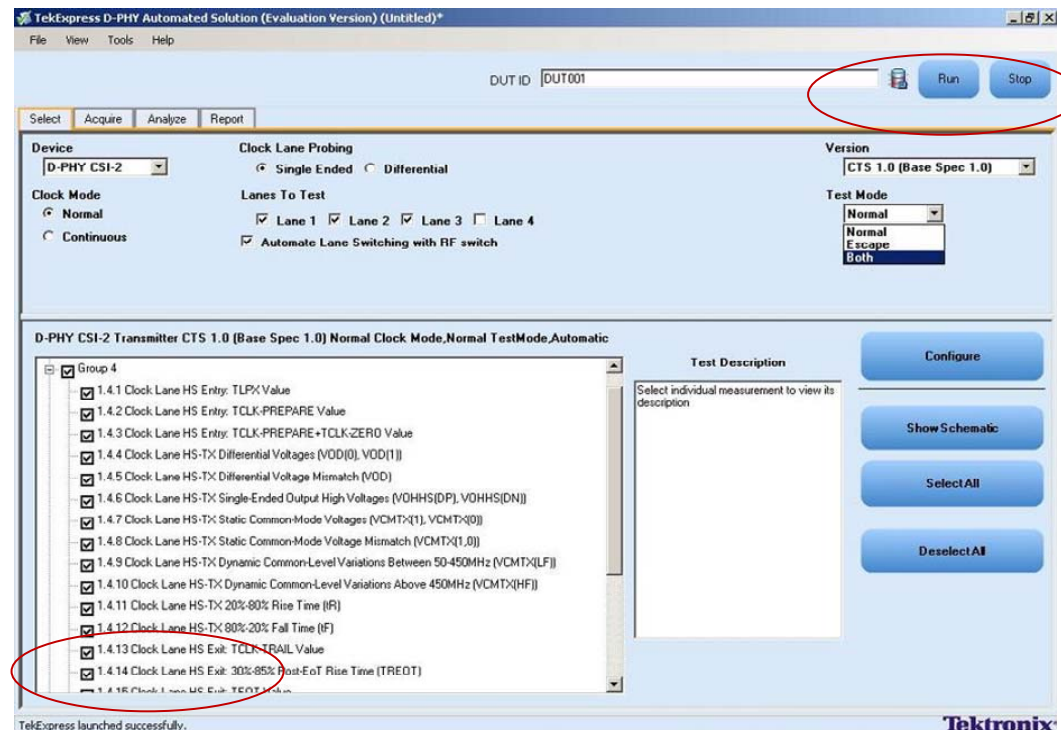
Opt.D-PHYTX Release3
Updated Features &Benefits 2

- **Multi-lane Full-Automation using external RF Switch**
  - Only solution that supports automation for multilane DUTs.
  - Enables Single-button execution for "multi-lane" DUTs.
  - Provide single-printable report for all lanes together.
  - The results in the report are tabulated lane-by-lane.
  - Switch: www.keithley.com/products/switch/rfmicrowave/?mn=S46
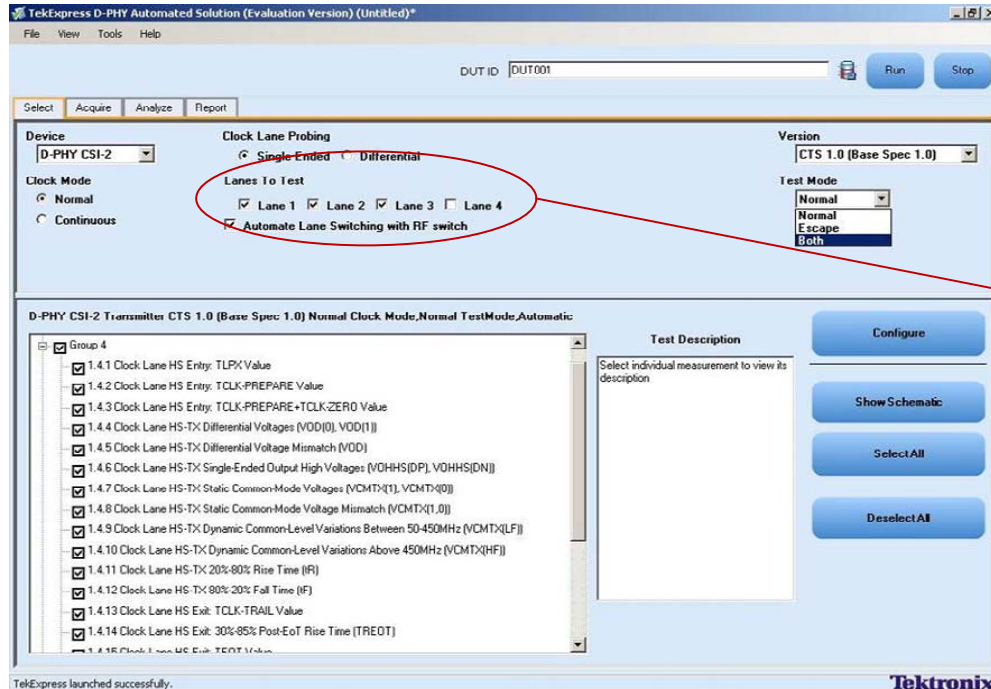
Keithley S46 Microwave Switch System
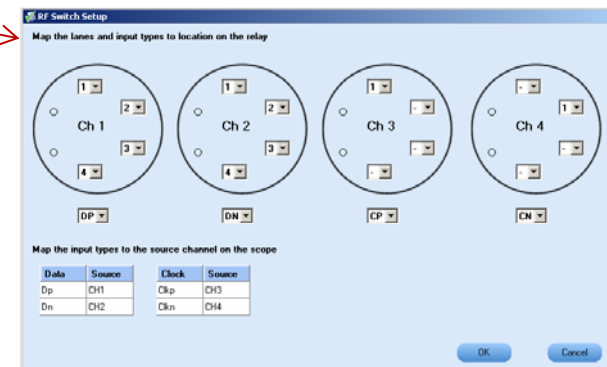
Opt.D-PHYTX Release3
Updated Features &Benefits 2

- **Multi-lane Full-Automation Setup Details:**
  - Use external RF Switch: www.keithley.com/products/switch/rfmicrowave/?mn=S46
  - Probe using 4xSingle-Ended or 3x Differential supported probes

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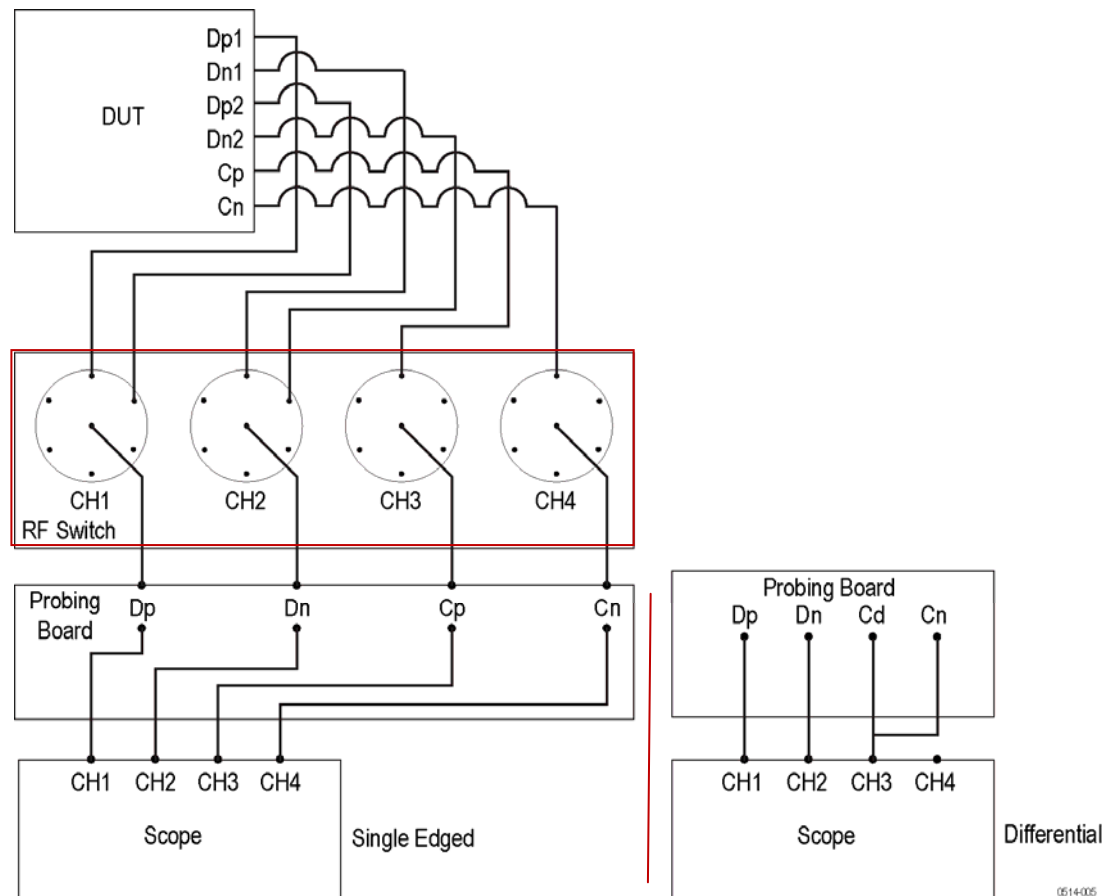
Opt.D-PHYTX Release3
Updated Features &Benefits 3

- Improved reports with "Zoom-In" screenshots of the cursors placement for each test.

D-PHY Tx Testing Solution – Continued

- Fixtures
  - Issue with HS vs. LP termination, Z id load variation, C load
  - Ideally, fixture would provide active reference termination
  - Solder-in high impedance SE probes or DIFF probes connected for SE are best for in-situ test
  - **No standard fixture defined by MIPI**
  - **Tektronix Recommendation:**
    - **Follow guidance and purchase as necessary from UNH-IOL**
    - MIPI D-PHY Reference Termination Board $2,395.00
    - MIPI TLIS Board $795.00
    - MIPI D-PHY Probing Board $450.00
    - SMA Alignment Fixture $95.00
    - SMA Couplers $9.00
    - http://www.iol.unh.edu/services/testing/mipi/MIPI_Test_Fixture_Order_Form.doc

- Test Data Generation
  - Vendor specific
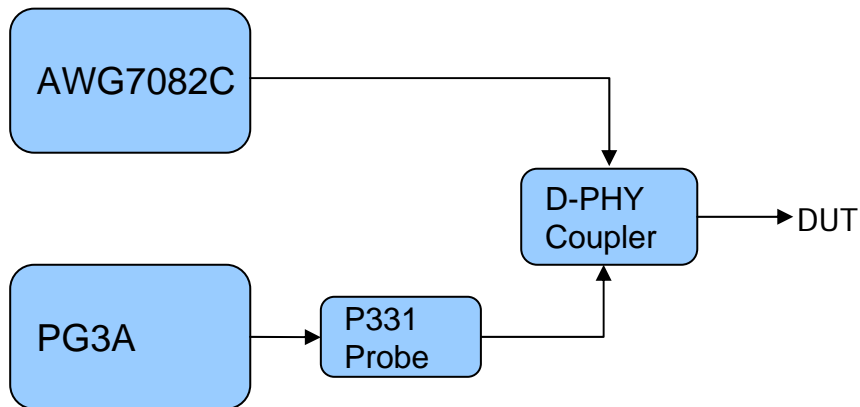 - **No standard test pattern generation defined**

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D-PHY Tx Testing Solution – Continued

MIPI D-PHY
REFERENCE TERMINATION BOARD (RTB)
OVERVIEW AND DATASHEET
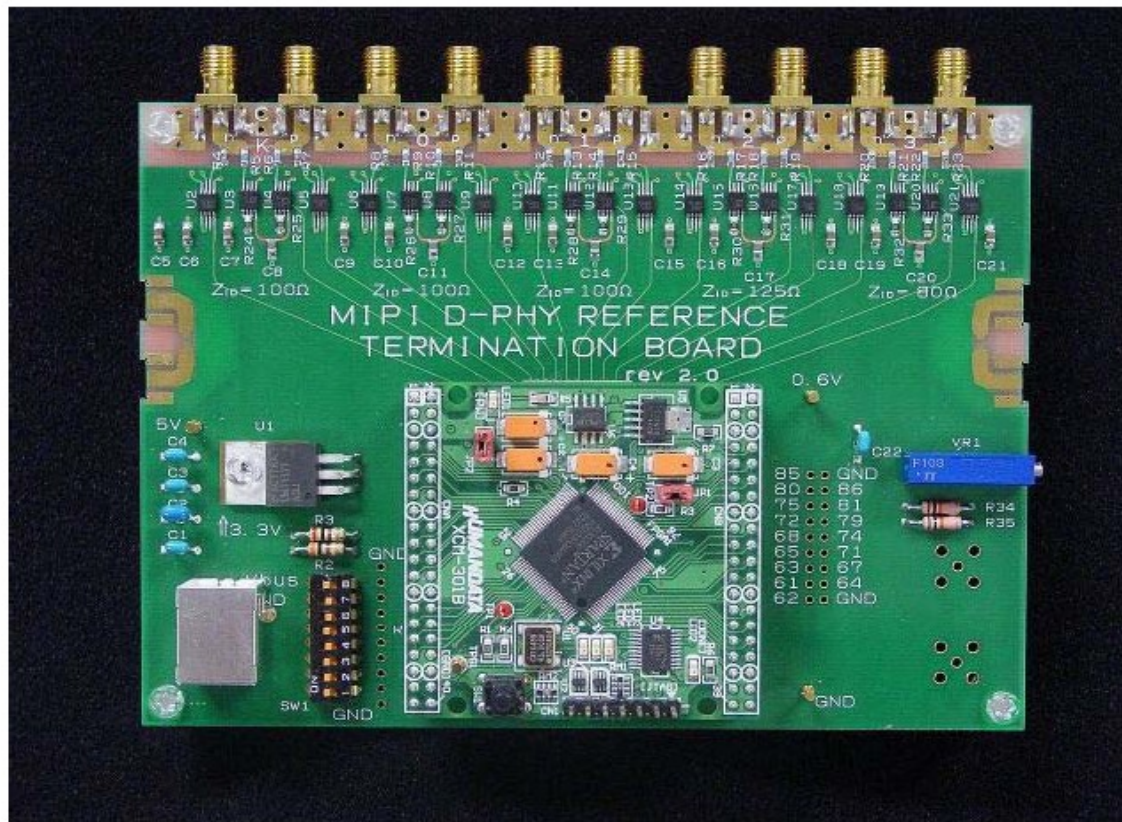
D-PHY Rx Testing Solution

- **Require generation of SE signals**

- **Recommend: PG3A Pattern Generator from Moving Pixel**
  - PG3ACAB (External module), Or, PG3AMOD (Plug-in for TLA)
  - DPhy-P6980
  - P331 or P375

- **Alternatives:**
  - DTG5078 with Pattern Gen files
  - AWG7052 or AWG7102 for D-PHY &M-PHY
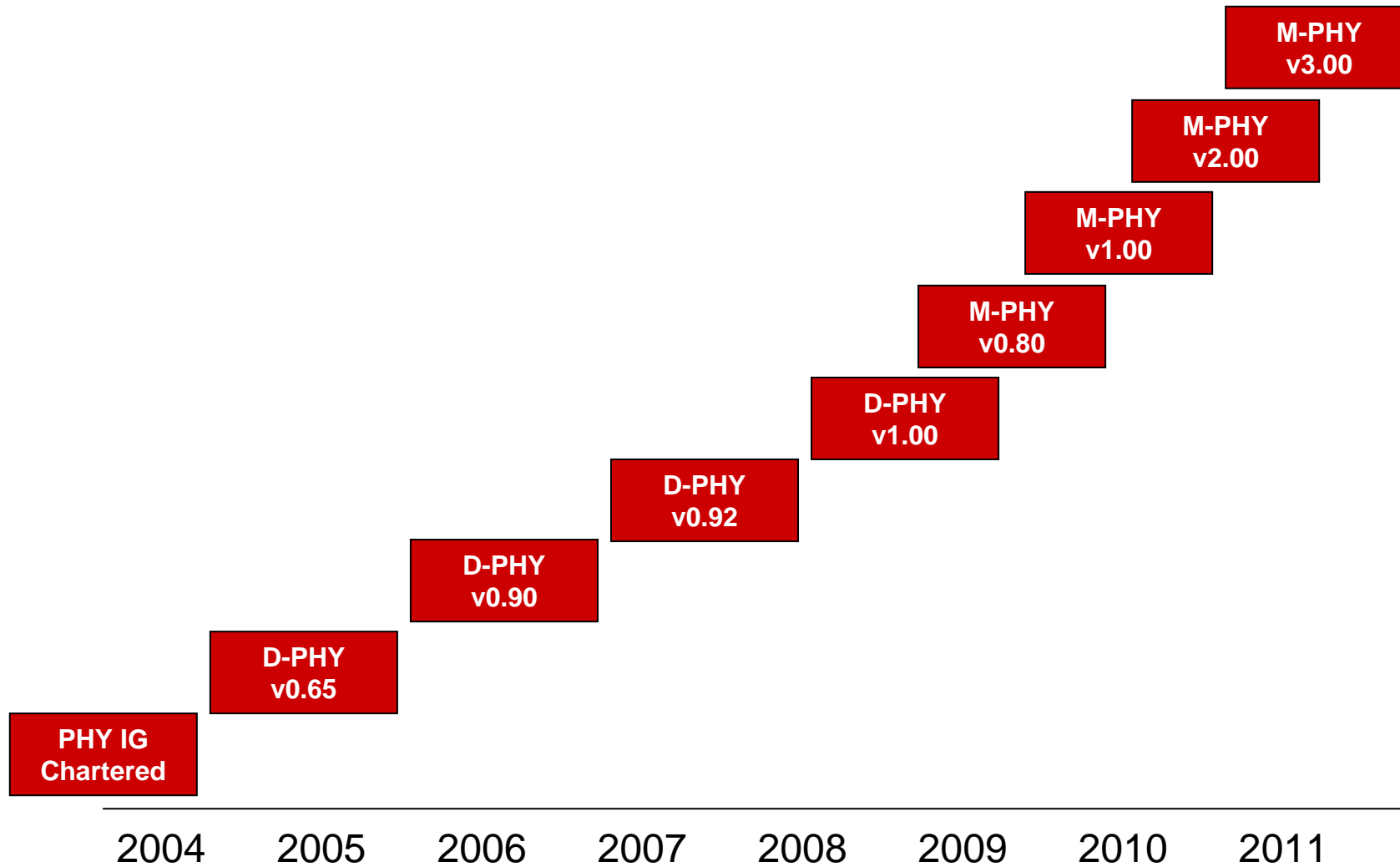
PHY Specification History

M-PHY v3.00

M-PHY v2.00

M-PHY v1.00

M-PHY v0.80

D-PHY v1.00

D-PHY v0.92

D-PHY v0.90

D-PHY v0.65

PHY IG Chartered

2004   2005   2006   2007   2008   2009   2010   2011

Chart courtesy of MIPI Alliance

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What is M-PHY ?

- M-PHY is a flexible architecture that allows the implementer to support high data rates at minimal power, cost & I/O redesign

- Brings to the mobile device industry an optimized chip-to-chip spec for High Definition Video, large Internet data traffic loads

		D-PHY	M-PHY
Min. # of pins per direction		4	2
Min. # of pins for Min. configuration		4	4
		only unidir or half-duplex	dual-simplex
Data rate per lane	HS	>80 Mb/s (Practical limit 1Gb/s)	~ 1¼ , 2½ , 5 Gb/s ~ 1½ , 3 , 6 Gb/s
	LS	< 10 Mb/s	10k-600Mb/s
Electrical signaling	HS	Diff (200mVpk)	Diff (200/120mVpk)
	LS	LVCMOS1.2V	Diff (400/240mVpk)
HS Clocking method		DDR Source-Sync Clk	Custom Clk
Line coding		None or 8b9b	8b10b
Power – Energy/bit		Low	Lower

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M-PHY Architecture

- A Fast, Scalable, Serial Communications Architecture
  - Link – Connects M-PHY Transmitter to an M-PHY Receiver
  - Sub-link – Manage one or more lanes
  - Lane – Operation defined in the protocol (DSI, CSI, UniPro, DigRF)

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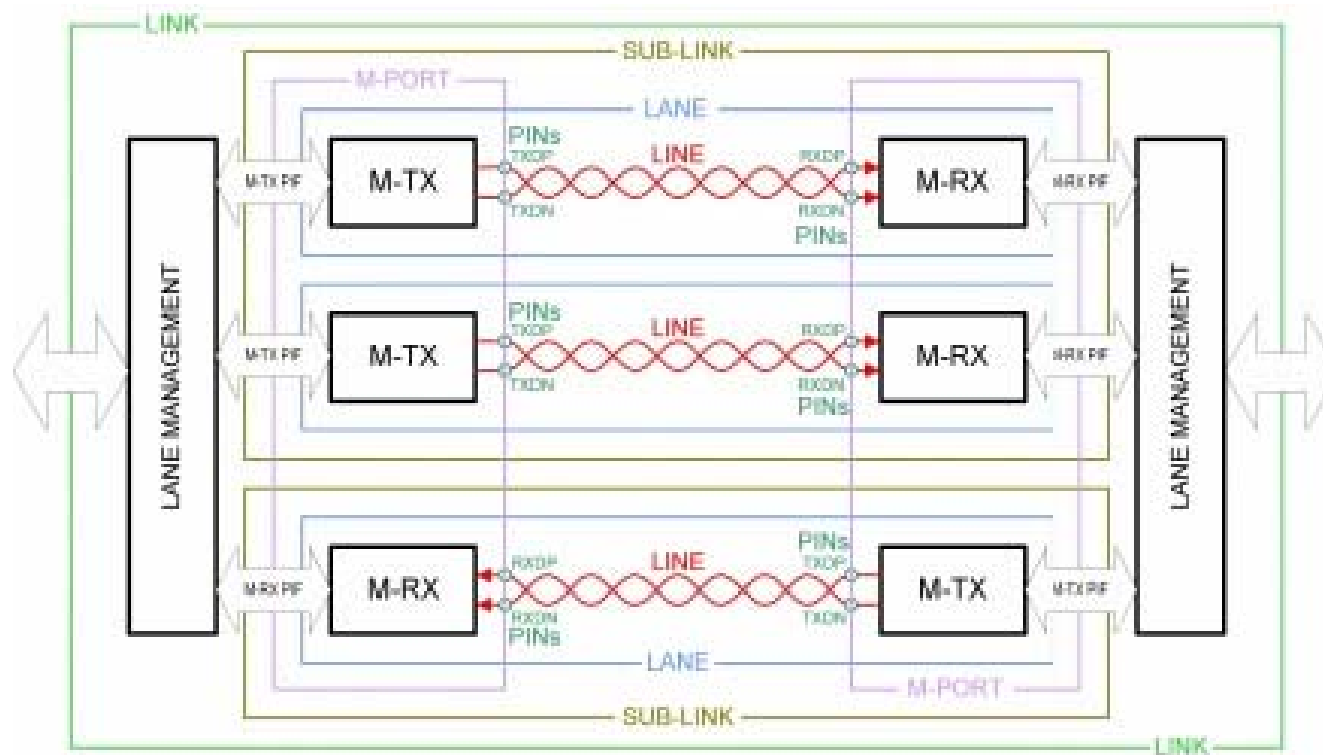
M-PHY Testing Challenges

Signaling Mode	Speed	Level (V)	Impedance
MPHY-PWM	576Mbps	500e-3/250e-3 260e-3/130e-3	10k/50 ohms
MPHY-SYS	576Mbps	500e-3/250e-3 260e-3/130e-3	10k/50 ohms
MPHY-HS	5.83Gbps	250e-3/130e-3	50 ohms

- Higher data rate will increase importance of Signal Integrity of links
  - Acquisition capability of oscilloscope will need to increase
  - More emphasis on timing/jitter and noise (signal integrity)
  - Receiver testing will be needed to stress-test resulting BER

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M-PHY signaling scheme

- **Non-Return-to-Zero (NRZ)**

- **Pulse Width Modulation**
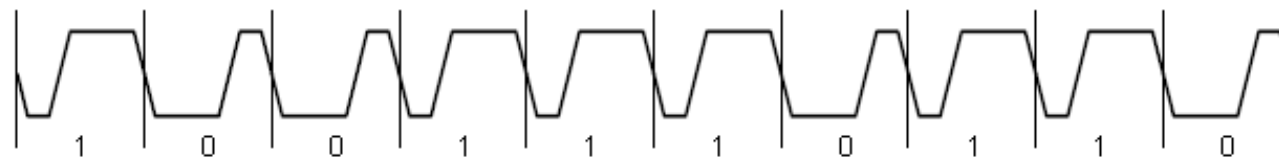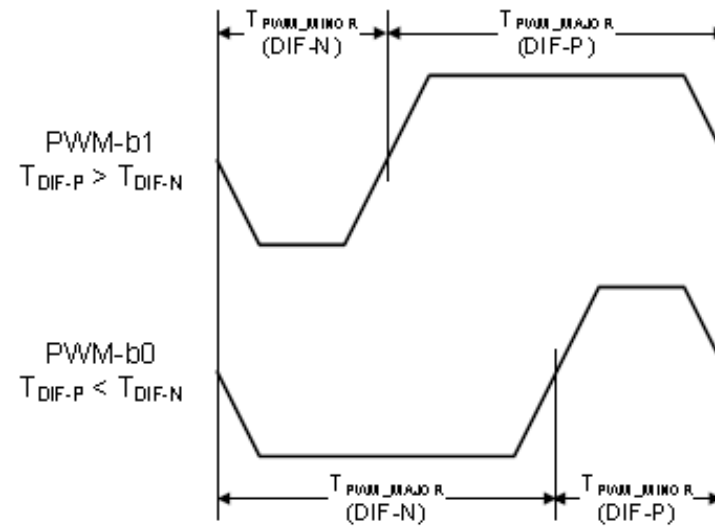
Figure 4   PWM Bit Waveforms and Bit Stream Example

M-PHY Physical Layer Testing Solution

- Oscilloscopes
  - DPO70604B for HS-GEAR1
  - DPO/DSA/MSO70804 for other HS-GEARs
    - For risetime (70ps) measurements within +/-5% of spec

- Probes
  - Recommend:
    - **2x P73xxSMA or P73xx or P75xx per each Lane**
      - **TDPxx can support limited HS Gears**
  - Probing Considerations
    - Two types of terminations - Restive terminated, and not Terminated.
      - LS mode can operate either terminated or not terminated
      - HS mode it is always terminated, so the swing are halved.

- Signal Generators
  - AWG7112B

- Software
  - DPOJET Timing and Analysis with M-PHY setup files and MOIs*
  - ERRDT Scope Error Detector
  - SerialXpress Software for AWG.
  - DigRFv4 Decode Software from Moving Pixel

*Early-Market needs. Contact Tektronix MIPI Solutions team for complete details.

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M-PHY Physical Layer Testing Solution

- Oscilloscopes
  - DPO70604B for HS-GEAR1
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Tektronix Supported by UNH-IOL
## For D-PHY & M-PHY Conformance Testing

CSI/DSI HS Data Listing for Logic Analyzer

- Low Level Protocol
  - Disassemble & Display of data (4 lanes) and clock
  - For Link widths of less than 4 user has option to select Lower Link Width
  - Decode & Display LP & HS transition states
  - Display HS Data in Byte Format
 - Suppression of idle cycles for easy analysis

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CSI/DSI HS Data Protocol for Logic Analyzer

- Packet by packet view of data

- Decode & Display Long & Short packets

- Payload data decoded

- Payload extracted & stored for further analysis

- Packet data can be exported and saved as Bitmap Image

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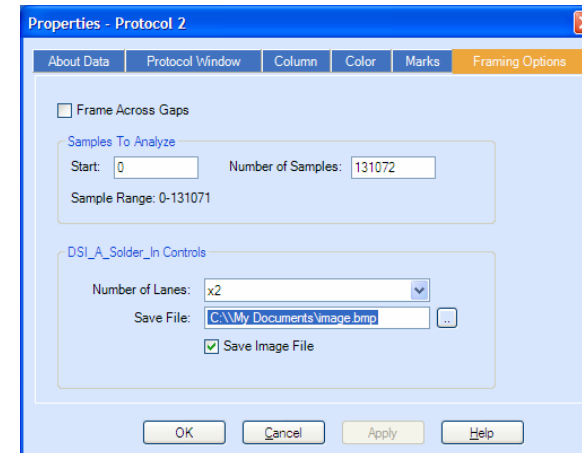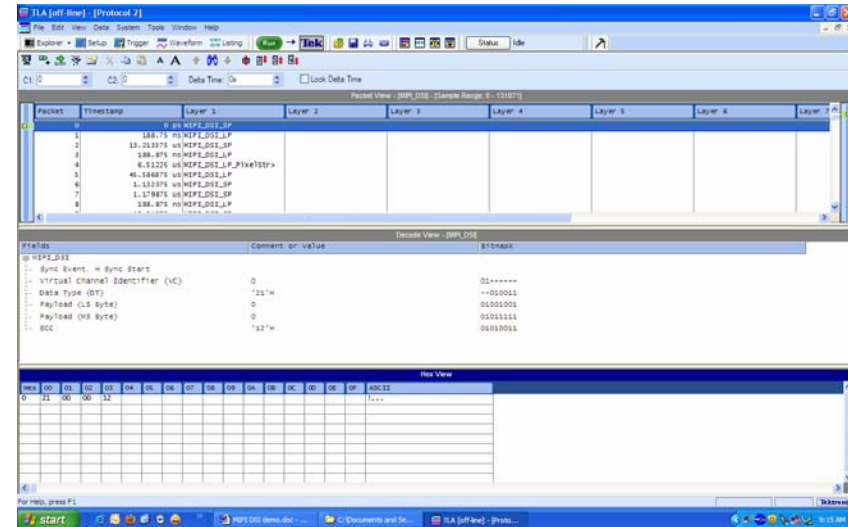
DigRF – Standard & Testing Support

- Inter-Chip specification for connecting Baseband IC to RF IC
  - Protocol Layer Debug/Validation
  - Physical Layer Debug/Validation

- RF-IC Validation
  - Protocol Layer Validation
 - Physical Layer Validation
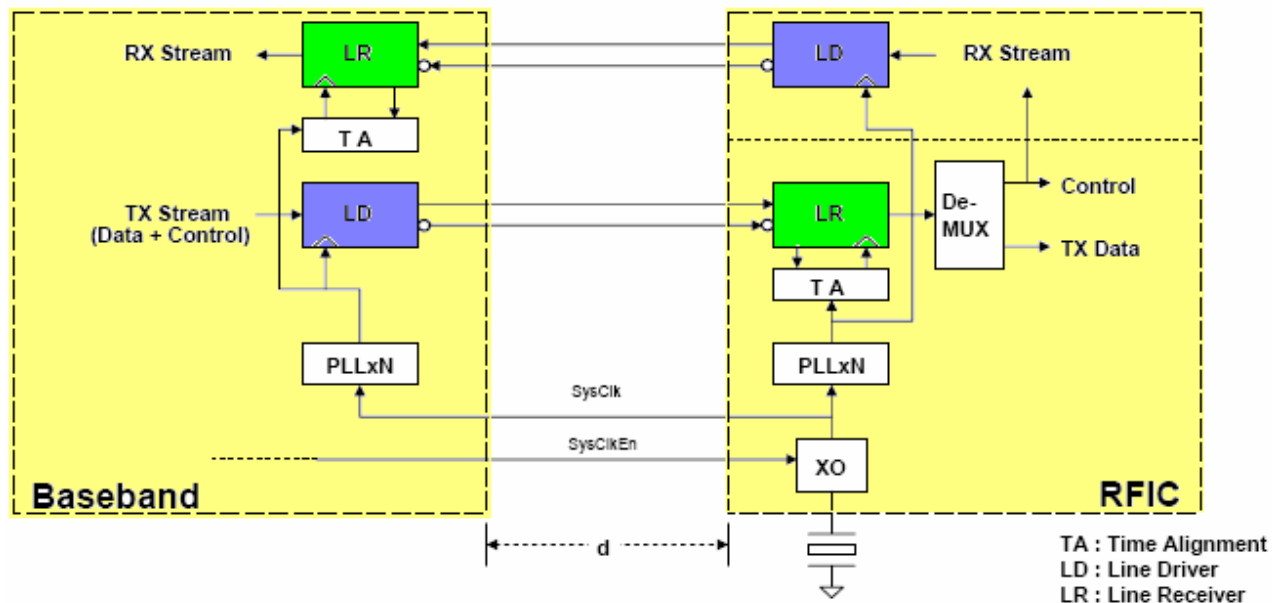
Analysis – Signal Integrity

- DPOJET Jitter and Timing Analysis Software provide the highest accuracy and lowest noise jitter measurements available

- Identifies rare anomalies or glitches in seconds with Real-Time DPO acquisition

- Most complete trigger system in the industry

- User customizable User Interface

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Analysis – Digital Verification & Debug

- **Glitch Capture & Display**
  - Only LA to trigger on glitches and display their location

- **Set Up & Hold Trigger & Display**
  - Only LA to trigger on these type of violations and display their location

- **125ps Timestamp resolution**
  - Highest resolution LA will find more glitches

- **Support packages for uP and Memory devices**
  - Complete analysis of the Baseband design
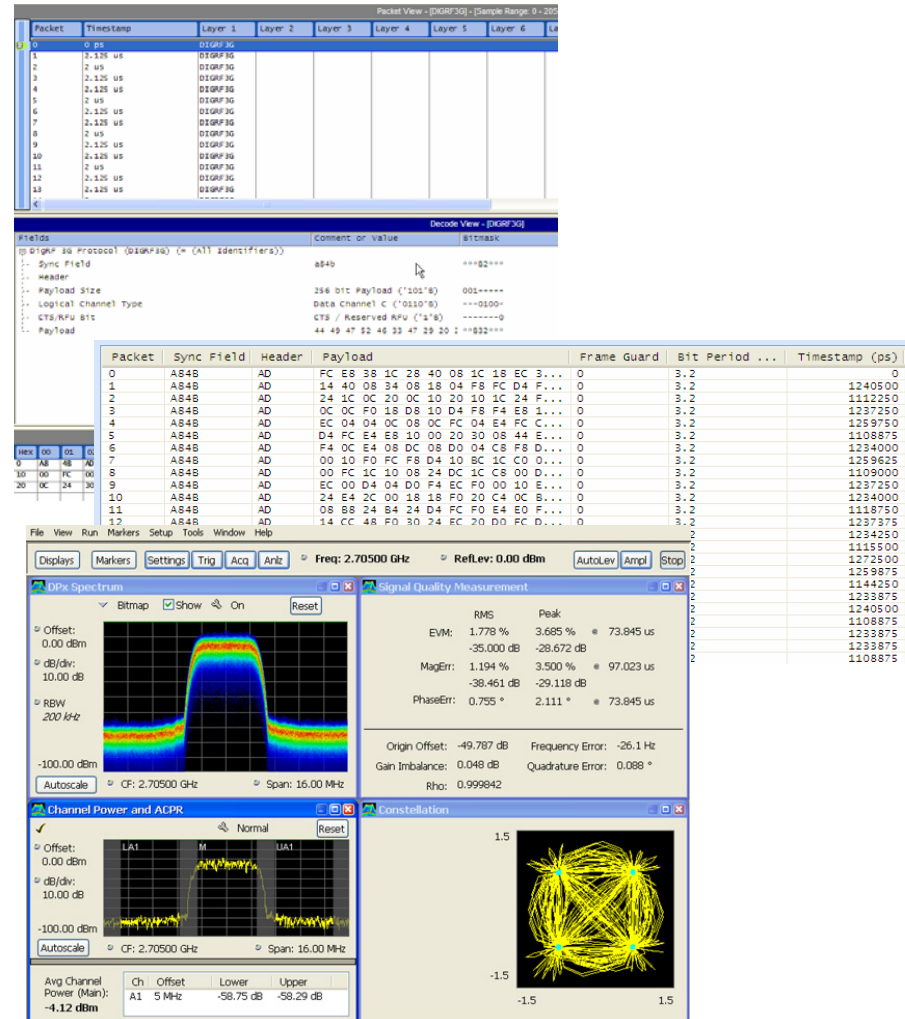
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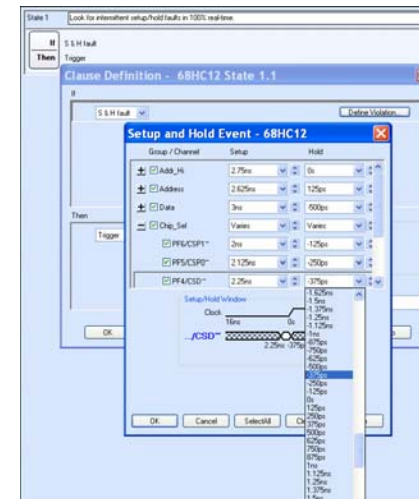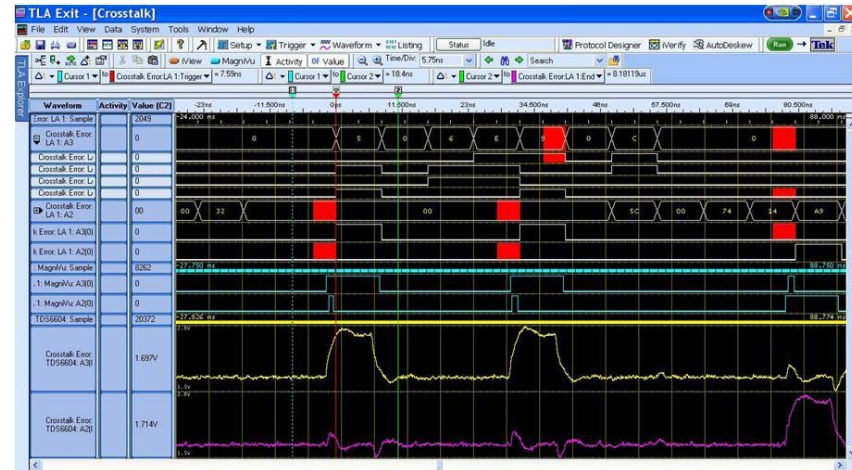
Analysis – DigRF Verification & Debug

- DigRF packets decoded and displayed

- Ability to Search & Filter on fields within DigRF packets

- Flexible data extraction for complete analysis
  - Extract IQ data for Modulation Analysis
  - Extract sync, header & payload data

- Transitional mode acquisition
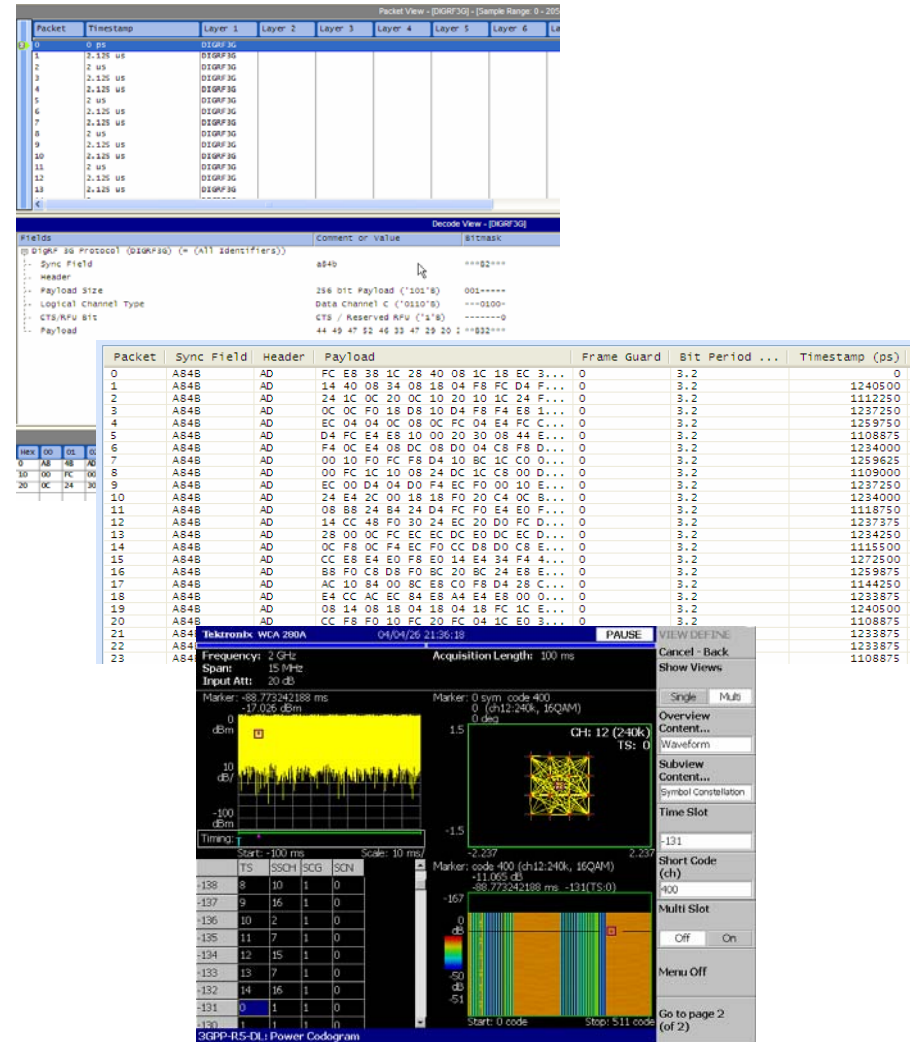
Analysis – DigRF Verification & Debug

- **Seamless integration between Digital and Modulation Domains**
  - IQ is automatically extracted and loaded into RSAVu

- **No specialized hardware or probing is required**

- **Customizable, allowing propriety and non compliant DigRF signals to acquired and analyzed**

- **DigRF solution is available** free of charge
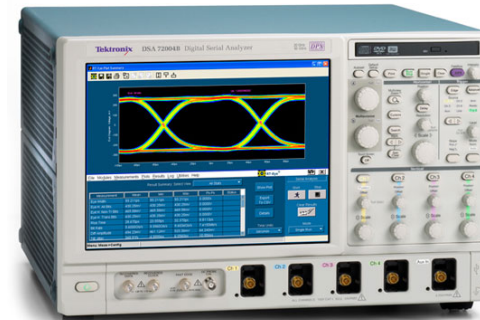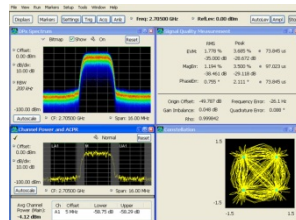
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Summary - Tektronix MIPI Testing Support

CSI/DSI Protocol & Logic Analysis

D-PHY & M-PHY/ Physical Layer Analysis

DigRF Verification & Debug
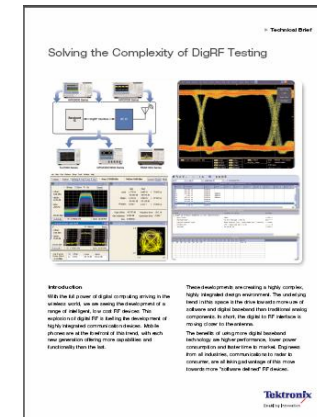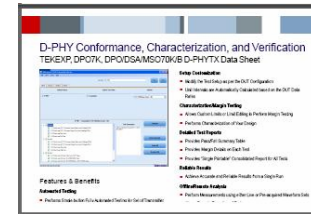
CSI/DSI Pattern Generation

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Additional References
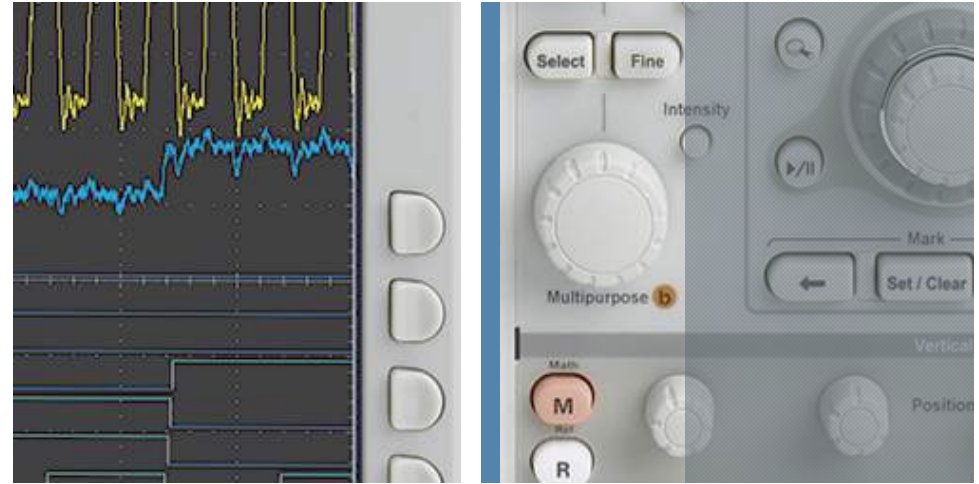
www.Tek.com/MIPI:

- D-PHY Datasheet

- D-PHY/ CSI/ DSI Application Note

- DigRF Application Note
  - http://www2.tek.com/cmswpt/tidetails.lotr?ct=TI&cs=tbr&ci=11854&lc=EN

- Fact Sheet:
  - http://www2.tek.com/cmswpt/pidetails.lotr?ct=PI&cs=psa&ci=15031&lc=EN

- Opt. D-PHY MOI
  - http://www.tek.com/applications/computing/serial/recommended_equipment.html#mipi

- DPOJET Analysis Tool
  - http://www2.tek.com/cmsreplive/psrep/13555/61W_21170_3_2010.04.16.08.11.57_13555_EN.pdf

Other:

- D-PHY Conformance Test Spec (CTS):
  - Rev 0.98: https://members.mipi.org/mipi-testing/file/UNH-IOL/UNH-IOL%20Test%20Suite%20Documents/DPHY/MIPI_D-PHY_Conformance_Test_Suite_(v0.98).pdf
  - Rev 0.08: https://members.mipi.org/mipi-testing/file/UNH-IOL/UNH-IOL%20Test%20Suite%20Documents/DPHY/MIPI%20D-PHY%20Conformance%20Test%20Suite%20(v0.08).doc

- MIPI Alliance Video on Tek Solutions
  - http://www.youtube.com/watch?v=Mf9rv-X2YG4&feature=channel

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Thank You