HDMI Physical Layer Compliance Testing - 2.0 and beyond

September 23, 2014
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   • HDMI 2.0 new features
   • HDMI 2.0 timeline

2. Keysight HDMI 2.0 physical layer compliance test solutions
   • Source Compliance test solution
   • Cable Assembly compliance test solution
   • Sink Compliance test solution

3. What lies beyond 2.0?
HDMI Organizational Structure

- **HDMI LLC** is responsible **up to HDMI 1.4b**
  - Ruled by “7C” (7 founding companies)
  - No open industry participation in the definition of the Spec
  - CTS (Compliance Test Spec) includes vendor-specific test procedures

- **HDMI Forum** is responsible for **HDMI 2.0 and later**
  - Open industry consortium with 80+ members, 1000+ Adopters
  - Keysight is a member of the Technical Working Group and Test Subgroup
  - Keysight was recently elected into Board of Directors
  - Generic CTS describes vendor independent test procedures
  - MOI’s (method of implementation) is created by each T&M vendor
  - MOI’s of all T&M vendors are linked in the CTS document available to Adopters
HDMI 2.0 Features at a Glance

- Up to 18 Gbps bandwidth
- Up to 4K @ 50/60Hz Video format supported
- Up to 32 audio channels
- Up to 1536 kHz audio sample frequency
- Dual viewing
- Multi-stream audio
- CEC extensions
- 21:9 Aspect Ratio
- Dynamic Auto Lip-Sync
# HDMI Feature Comparison

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</table>
Another Test Event

- All Keysight MOIs were successfully executed
- All Keysight physical layer source & sink test MOIs are approved
- First version of CTS 2.0 was released April 11th
- CTS contains links to the individual MOIs for each Test ID
The HDMI Founders have established Authorized Testing Centers (ATC) where licensed manufacturers can submit their products for compliance testing.
HDMI 2.0 test solution overview from Keysight

**Source Test**
- N5399C HDMI Electrical Compliance Test Software

**Cable Assembly Test**
- E5071C Option TDR ENA Network Analyzer

**Sink Test (ParBERT)**
- N5990A Automatic SW for HDMI compliance
- E4887A ParBERT TMDS Signal Generator

**Sink Test (AWG)**
- N5990A Automatic SW for HDMI compliance
- M8190A/M8195A AWG

**Protocol Test**
- U4998A SW for HDMI compliance
- U4998A (N5998A) HDMI 1.4 protocol analyzer/generator

**Fixture**
- HDMI 2.0 TPA

**DUT**
- HDMI 2.0 TPA

**Signal Conditioning**
- HDMI 2.0 TPA
- HDMI 2.0 TPA

**HW**
- DSO90000A Infinium real time scope 13 GHz

**SW**
- HDMI 2.0 TPA
- HDMI 2.0 TPA

Protocol Test on U4998A is supported up to HDMI 1.4b
For HDMI 2.0 third party protocol testers are supported in Valiframe SW

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**Protocol Test**
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HDMI 2.0 test solution overview from Keysight

HDMI 2.0 webcast

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The HDMI Interface
HDMI 1.4

Transmitter

Data TX

xN PLL

Ck

+5
SDA
SCL
DDC GND

Reserved
HPD

CEC

Sink (Display)

Data RX

xN PLL

Ck Frequency = Data Rate/N
HDMI 1.4:
Data Rates: 250M to 3.4 Gbs
N=10

TMDS (AV Link)

Channel (cable)

E-DDC (i2c)

Ethernet/Audio Return Channel

EDID

HDCP

HEC/ARC

CEC Controller

KEYSIGHT TECHNOLOGIES
The HDMI Interface
HDMI 2.0: Interface Changes

Ck Frequency = Data Rate/N
HDMI2.0:
Data Rates: 3.4 Gbs to 6Gbs
N=40

EDID  HDPC  SCDC

HEC/ARC  +V

CEC Controller

KEYSIGHT TECHNOLOGIES
### CTS Requirements: Tests Identified in HDMI

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<th>Measurement Type Required</th>
<th>HDMI 2.0 Test</th>
<th>Test Point Coverage</th>
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<td>TP1</td>
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<tr>
<td>7-3 Voff</td>
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<td>7-8 TMDS Clock Duty Cycle</td>
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<td>Differential</td>
<td>HF1-8 Data Eye</td>
<td>TP2EQ</td>
<td>Single Ended</td>
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</tbody>
</table>
CTS Requirements: Test points (TP1, TP2EQ)

- **HDMI TX**
- **HDMI Cable**
- **HDMI RX**
- **TP1**
- **TP1’**
- **TP2**
- **TP2EQ**

**HDMI 2.0 Webcast**

- **HDMI RX**
- **TP2**
- **TP2EQ**

**Oscilloscope Signal Processing**

- **HDMI Rec Connector**
- **Fixture De-Embed**
- **T-Line-Embed**
- **Modeled Skew**
- **Reference Equalization**
- **Differential**

- **Optional (TPA s4p)**
- **Required Std s4p file, skew values**
- **Required. Std model**
- **Eye Diagram Jitter Measurement, etc.**

**Keysight Technologies**
Test Device: Control and Capability

For your device:
- HDMI1.4b & HDMI2.0?
- What are the Formats it can do?
- HDCP On/Off?
- How are you going to control it?
Keysight HDMI Source Test Solution

Infiniium DSO91304A

N5399C HDMI Source Compliance Software

Infiniium DSO90000 X-series

N5380B SMA Probe Head (6)
1169A Probe Amplifiers (4)

N5444A SMA Probe Head (6)
N280XA Probe Amplifiers (4)

N2809A Precision Probe Cal software

VTF-501 FlexEDID

BIT-0101-0200-0

E364xA

Keysight U3020AS26 Switch

Switches

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HDMI 2.0 test solution overview from Keysight

Source Test
- N5399C HDMI Electrical Compliance Test Software
- DSO90000A Infinium real time scope 13 GHz
- N1080B

Cable Assembly Test
- E5071C Option TDR
- ENA Network Analyzer
- HDMI 2.0 TPA

Sink Test (ParBERT)
- N5990A Automatic SW for HDMI compliance
- E4887A ParBERT TMDS Signal Generator
- M8190A AWG
- new Cable Emulator

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Protocol Test
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For HDMI 2.0 third party protocol testers are supported in Valiframe SW

HDMI 2.0 is supported up to HDMI 1.4b

HDMI 2.0 webcast
Physical Layer Cable Assembly Testing

Points to Know:

- HDMI2.0 doesn’t require new cable testing; still follows HDMI1.4b spec
- Standard Cable measurements for characterization and compliance testing: skew, impedance, attenuation, and crosstalk.
- “Stressed” Eye Diagram Analysis of Interconnects: allowing direct measurement of eye characteristics at the end of the link.

**Time Domain**
- Intra-Pair Skew (T31, T42)
- Inter-Pair Skew (Tdd21)
- Impedance (Tdd11)
- Impedance (Tdd22)

**Frequency Domain**
- Attenuation (Sdd21)
- Phase (Sdd21)
- FEXT (Sdd21)

**Eye Diagram Analysis**
- Jitter insertion
- Emphasis
- Equalization

Complete characterization of interconnects (Time domain, frequency domain, and Eye diagram)
Physical Layer Source/Sink Impedance Testing

Points to Know:

- Impedance measurements of Source and Sink required in HDMI2.0
- Source impedance measurements during transmission of actual data pattern (Hot TDR measurements) is required
- DC voltage bias can be applied through internal bias-tees
- Hot TDR with ENA-TDR, fast, accurate and no worry about ESD
Hot TDR Issue: Bad effect of Tx output signal

TDR impedance test result varies due to output signal from Tx

Tx output signal is also input to the VNA’s receiver and affects test result.

IF BW = 70kHz

Tx output spurious
Hot TDR Issue: Bad effect of Tx output signal

Tx output effect can be minimized by narrowing IF BW (receiver filter bandwidth)

IF BW = 1kHz
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Protocol Test
U4998A SW for HDMI compliance

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Signal Conditioning

Fixture
N1080B

DUT
Tx Source

Rx Sink

Cable

5071C Option TDR ENA Network Analyzer

E4887A ParBERT TMDS Signal Generator

M8190A/M8195A AWG

HDMI 2.0 TPA

HDMI 2.0 TPA

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N5990A Automatic SW for HDMI compliance

N1080B

New Cable Emulator

U4998A (N5998A) HDMI 1.4 protocol analyzer/generator

DSO9000A Infiniium real time scope 13 GHz

13 GHz
HDMI 2.0 Sink Test Setup
ParBERT *and* AWG are supported

Same N5990A Test automation controls both setups

ParBERT E4887A

+ TTCs + Bias-Ts

+ HW CE

+ Delay lines

AWS M8190A/M8195A

Much lower cost
Fewer accessories
Less re-configuration

Plus real-time oscilloscope for calibration (in both cases)
Different Approaches for Digital Data Generation

**BERT**
- Uses a limiting amplifier which generate ones and zeros
- Uses one clock cycle per bit

(+) very fast and accurate digital signals
(+) amount of jitter can be adjusted on the fly
(−) difficult to realize adjustable transition times, emulate ISI, requires external HW
CE
(−) higher cost
(−) higher system complexity
(−) less flexibility

**AWG**
- Uses a DAC and a linear amplifier to generate arbitrary signal levels
- Uses oversampling

(−) slower bit rate at given sample rate
(−) jitter changes require re-calculation of the waveform
(+) much more flexible in generating adjustable transition times and emulate ISI
(+) less expensive
(+) simpler setup

**Digital Data Add jitter Waveform Samples DAC**
M8190A Arbitrary Waveform Generator

Key features
- Sample rate up to 12 GSa/s @ 12 bit resolution
- Deep sample memory, 2G Samples per channel
- Supports data rates up to 6 Gb/s
- Flexible generation of distortions without cable emulators and TTCs
- Approved in Keysight MOI for HDMI 2.0 sink testing
M8190A data signal at 6 Gb/s

6 Gb/s with ISI and jitter
Transition times, ISI and jitter can be arbitrarily added to the waveform – without changing the hardware setup

Jitter tolerance test waveform
(Jitter + ISI + skew +EQ)
HDMI sink test setup using the M8190A

- 5-slot AXIe chassis with embedded controller and two M8190A modules (= 4 differential channels)

No hardware cable emulators, no TTCs
Fewer manual re-connections → better reliability
Smaller and more affordable setup compared to ParBERT
Swing voltage, ISI, etc can be changed “On-the-Fly”
Jitter tolerance test can be done, too!
HDMI Sink Test setup (AWG)

AWG directly connected to TV with N1080B-H04 plug test fixture. 5 V HPD provided by lab power supply.
HDMI 2.0 TMDS electrical sink compliance tests

- 3 Test IDs defined by the Generic CTS
  - HF2-1 Min/Max Differential Swing Tolerance
  - HF2-2 Intra-Pair Skew Tolerance
  - HF2-3 Jitter Tolerance

- Each test ID consists of an initial calibration utilizing an oscilloscope followed by the actual test with the DUT

- N5990A test automation guides the user through the test procedure with detailed instructions about required system connectivity

- Test results are logged to a comprehensive test report
HDMI 2.0 defines additional SCDC control interface required for data rates above 3.4 Gbps per lane

To reduce EMI the HDMI 2.0 specification requires a scrambling scheme for the TMDS data signals above 3.4 Gbps

- Clock ratio is changed to accommodate higher data rates
- These features are controlled via the SCDC control interface
- N5990A test automation SW automatically controls the features to match the currently tested data rate
- If the DUT implements the optional bit error counters these values can be read via the SCDC interface
N5990A Test Automation Software – HDMI 2.0 Rx Test
Compliance Tests and Product Characterization

AWG: Opt. 151
E4887A: Opt. 150
HDMI 2.0 N5990A “ValiFrame” Rx Tests
Test Automation Software – Connection Diagram

Calibration (with oscilloscope)
BitifEye HDMI Frame Generator allows you to control various parameters of the video signal video mode, swing, jitter, skew, pattern to go beyond compliance testing with ‘on-the-fly’ waveform generation.
What lies beyond 2.0 ...
Faster, faster, faster

– Market Requirements for next Revision are currently collected
– New ultra high resolution video formats are already on the horizon
– Requirements for even higher data rates up to 12Gbps per lane are discussed

What does this mean for the test equipment?

We need to get faster as well!
Go Where you Have Never Been Able to Test Before

In Speed, in Bandwidth and in Channel Density

- Sample rate 54 GSa/s to 65 GSa/s per channel
- > 20 GHz bandwidth
- > 32 GBaud symbol rate
- 1, 2 or 4 differential channels per 1-slot AXIe module

- Up to 16 GSa of waveform memory per module (*)
- 8 bits of vertical resolution
- Amplitude up to 2 Vpp(diff.) or 1 Vpp(se), voltage window -1.0 … +3.3V
- Ultra low intrinsic jitter
  (RJrms < 200 fs @ 32 Gb/s PRBS 2^{11}-1)
- 16-tap FIR filter in hardware for frequency response compensation (*)
- Multi-module synchronization up to 16 channels per 5-slot AXIe chassis

**New M8195A 65 GSa/s AWG**

*Explore your possibilities*
M8195A Superior Signal Quality
Intrinsic Jitter measured with a 32 Gb/s PRBS signal
M8195 eye diagrams

12Gbps clean signal

12Gbps signal with ISI and Jitter
Summary

Keysight offers a future proof solution for HDMI sink testing

- Keysight offers an attractive solution for HDMI 2.0 based on the M8190A AWG for immediate test needs

- As the specification evolves in the future, Keysight offers an easy upgrade path to the new M8195A AWG to be able to test future versions of the HDMI standard

- As the new M8195 AWG is based on the same Modular AXIe formfactor the M8190A AWG modules can easily be replaced

- M8195A will also be supported by the N5990A test automation software
Questions?
Backup
HDMI Contribution from BitifEye

- N5990A Test automation software ("ValiFrame")
- Frame Generator software
- Accessories
  - E.g. Bias Tee, variable delay lines, TPA, SCDC controller
- 2100 Series Switching solutions for automated testing
  - Cable test with ENA-TDR
  - Source test with DSO/DSA
  - Sink test with ParBERT or AWG