High-Definition Multimedia Interface (HDMI) Source/Sink Impedance Compliance Test

*Test Solution Overview*

*Using the E5071C ENA Option TDR*
Reference Documents

- High-Definition Multimedia Interface (HDMI) Specification Version 2.0
- High-Definition Multimedia Interface (HDMI) Version 2.0 Compliance Test Specification
Keysight Digital Standards Program

• Our solutions are driven and supported by Keysight experts involved in international standards committees:
  • Joint Electronic Devices Engineering Council (JEDEC)
  • PCI Special Interest Group (PCI-SIG®)
  • High-Definition Multimedia Interface (HDMI) Forum
  • Video Electronics Standards Association (VESA)
  • Serial ATA International Organization (SATA-IO)
  • USB-Implementers Forum (USB-IF)
  • Mobile Industry Processor Interface (MIPI) Alliance
  • And many others…

• We’re active in standards meetings, workshops, plugfests, and seminars.
• We get involved so you benefit with the right solutions when you need them.

Keysight experts help define next generation standards and solutions
Keysight HDMI 2.0 Total Test Solution

**Source Test**
- N5399C HDMI Electrical Compliance Test Software
- DSO90000A Infinium real time scope 13 GHz
- BIT-1010-0200-0

**Cable Test**
- E5071C Option TDR ENA Network Analyzer
- N1080B

**Sink Test (ParBERT)**
- N5990A Automatic SW for HDMI compliance
- E4887A ParBERT TMDS Signal Generator
- BIT-1010-0201-0

**Sink Test (AWG)**
- N5990A Automatic SW for HDMI compliance
- M8190A AWG
- BIT-1010-0201-0

**Protocol Test**
- U4998A SW for HDMI compliance
- U4998A (N5998A) HDMI 1.4 protocol analyzer/generator
- Protocol Test on U4998A is supported up to HDMI 1.4b

For HDMI 2.0 third party protocol testers are supported in Valiframe SW Source Sink
## HDMI Versions

<table>
<thead>
<tr>
<th>Ver</th>
<th>Date</th>
<th>Details</th>
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<tr>
<td>1.0</td>
<td>2002/12/09</td>
<td>• Initial release</td>
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<td>2005/08/22</td>
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<td>1.2a</td>
<td>2005/12/14</td>
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<td>1.3</td>
<td>2006/06/22</td>
<td>• Type C “Mini-Connector” (4.1.9.5, 4.1.9.6)</td>
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<td>• Cable Categories 1 and 2 (4.2.6)</td>
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<td>• Deep Color [4:4:4] (6.5, 8.3.2)</td>
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<td>• Reference Cable Equalizer (4.2.3.2, 4.2.5, 4.2.6)</td>
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<td>• Higher-speed single-link (4.1.2, 4.2.3, 4.2.6, 4.2.8, 8.3.2)</td>
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<td>• High-bitrate compressed audio formats (5.3.11, 7.2.4, 7.3.3, 7.6.2)</td>
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<td>1.3a</td>
<td>2006/11/10</td>
<td>• Minor corrections</td>
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<td>1.4</td>
<td>2009/06/05</td>
<td>• Type D Connector (4.1.9.7, 4.1.9.8, 4.1.10.6)</td>
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<td>• Type E Connector and Cable (4.1.9.9, 4.1.9.10, 4.1.10.7, 4.1.10.8, 4.2.1, 4.2.3.2, 4.2.6)</td>
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<td>• Audio Return Channel Overview (7.12)</td>
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<td>• 3D and 4K x 2K video format (8.2.3, 8.3.2, Appendix H)</td>
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<td>• HDMI Ethernet and Audio Return Channel (HEAC) features(Supplement 2)</td>
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<td>1.4a</td>
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<td>2.0</td>
<td>2013/09/04</td>
<td>• <strong>TMDS Character Rates from 340 to 600Mcsc (6.1.1)</strong></td>
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<td>• Scrambling for EMI/RFI reduction at all TMDS Character rates (6.1.2)</td>
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<td>• TMDS Character Error Detection (6.2)</td>
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HDMI Overview

The HDMI cable carry four differential pairs that make up the TMDS data and clock channels. These channels are used to carry video, audio and auxiliary data. In addition, HDMI carries a VESA DDC channel.

At the source, TMDS encoding converts the 8 bits per TMDS data channel into the 10 bit DC-balanced, transition minimized sequence which is then transmitted serially across the pair at a rate of 10 bits per TMDS clock period.

- **DDC**: used for configuration and status exchange between a single Source and a single Sink
- **CEC (optional)**: provides high-level control functions between all of the various audiovisual products in a user’s environment.
- **HEAC (optional)**: provides Ethernet compatible data networking between connected devices and an Audio Return Channel in the opposite direction from TMDS

Note:
- CEC: Consumer Electronics Control
- HEAC: HDMI Ethernet and Audio Return Channel
HDMI 2.0 Compliance Test – TMDS Electrical Tests

Measurement Parameters

• HF1-9 (Source) / HF2-4 (Sink) Differential Impedance measured with TDR/TDT Network Analyzer
  • Differential impedance measured while the source/sink is powered on and the source transmitting data (Hot TDR Measurements). Hot TDR measurement is the impedance analysis of active devices under actual operation conditions.

<table>
<thead>
<tr>
<th>Source TMDS Electrical 6G Tests</th>
<th>Sink TMDS Electrical 6G Tests</th>
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<tr>
<td>HF1-1: Vl and Vswing</td>
<td>HF2-1: Min/Max Differential Swing Tolerance</td>
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<td>HF1-2: Trise, Tfall</td>
<td>HF2-2: Intra-pair Skew</td>
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<td>HF1-3: Inter-pair Skew</td>
<td>HF2-3: Jitter Tolerance</td>
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<tr>
<td>HF1-4: Intra-pair Skew</td>
<td><strong>HF2-4: Differential Impedance</strong></td>
</tr>
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<td>HF1-5: Differential Voltage</td>
<td>HF2-52: Character Error Rate</td>
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<tr>
<td>HF1-6: Clock Duty Cycle and Clock Rate</td>
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<tr>
<td>HF1-7: Clock Jitter</td>
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<tr>
<td>HF1-8: Data Eye Diagram</td>
<td></td>
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<tr>
<td><strong>HF1-9: Differential Impedance</strong></td>
<td></td>
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</table>
HDMI Source/Sink Impedance Compliance Test

Source TMDS Differential Impedance Measurement

- Confirm that the TMDS impedance of the Source DUT is within the specified limits, on each TMDS data differential pairs (D0, D1, and D2), while the source is transmitting data.
HDMI Source/Sink Impedance Compliance Test

Sink TMDS Differential Impedance Measurement

- Confirm that the TMDS impedance of the Sink DUT is within the specified limits, on each TMDS data differential pairs (D0, D1, and D2), while the sink in powered on.
HDMI Source/Sink Impedance Compliance Test Solution

**Time Domain (Hot TDR)**
- HF1-9: Differential Impedance
- HF2-4: Differential Impedance

VNA-based solutions offer significant advantages for **Hot TDR** measurements.
Hot TDR Measurements

Why Measure?

• **Hot TDR** measurement is the impedance analysis of active devices **under actual operation conditions**

• Typically, impedance of the device in the OFF state and ON state (Hot TDR) is significantly different. Impedance may vary with the data rate as well.

**TDR (Time Domain)**

- OFF
- 1333Mbps (ON)
- 334Mbps (ON)

**Return Loss (Freq Domain)**

- 666M
- 1G
- 2G
- 3G
- 4G
- 5G
- 6G

**Test Solution Overview**
Hot TDR Measurements

Why Measure?

1. Signal transmitted from Source …

2. Partial reflection from Sink due to impedance mismatches …

3. Re-reflection from Source due to impedance mismatches …

Eye Degradation
Hot TDR Measurements

Why Measure?

Source Impedance **NOT** Matched

Source Impedance Matched
Advantage of VNA-based Solution for Hot TDR Measurements

**TDR Oscilloscope**
- **Wideband receiver** captures all of the signal energy from the source.
- Extensive averaging is necessary to obtain a stable waveform.

**VNA (ENA Option TDR)**
- **Narrowband receiver** minimizes the effects of the data signal from the source.
- In many cases, averaging is not necessary to obtain a stable waveform.
[Video] HDMI 2.0 Source Impedance Measurement Example

Wide IF Bandwidth (IFBW)

Transmitter spurs contribute significant measurement errors, resulting in highly unstable results.

IFBW = 70kHz

Transmitter spurs
Narrow IF Bandwidth (IFBW)

Narrow IFBW setting reduces the effects of the transmitter spurs. In many cases, averaging is not necessary to obtain a stable waveform.
HDMI Source/Sink Impedance Compliance Test Solution

Typical Configuration

- ENA Mainframe
  - E5071C-245/445: 2/4-port, 100k to 4.5GHz
  - E5071C-265/465: 2/4-port, 100k to 6.5GHz
  - E5071C-285/485: 2/4-port, 100k to 8.5GHz
  - E5071C-2D5/4D5: 2/4-port, 300k to 14GHz
  - E5071C-2K5/4K5: 2/4-port, 300k to 20GHz

- Enhanced Time Domain Analysis Option (E5071C-TDR)

- ECal Module
  - N4431B for E5071C-245/445, 265/465, 285/485
  - N4433A for E5071C-2D5/4D5, 2K5/4K5

(*) The list above includes the major equipment required. Please contact our sales representative for configuration details.

- Method of Implementation (MOI) document available for download on HDMI Adopter Extranet
- Instrument setup files are available for free download on Keysight.com

ENAvs Option TDR is listed as an authorized test tool for Source/Sink Impedance Testing in the HDMI 2.0 Compliance Test Specification (CTS)

Test Fixtures

- Keysight
  - N1080B-H06 HDMI EDID Board

AND

- BitifEye (Type A or Type D)
  - BitifEye Bit-1010-0200-0 HDMI 2.0 Type A Source Test Plug Adapter Kit
  - BitifEye Bit-1010-0275-0 HDMI 2.0 Type D Test Plug Adapter Kit
### ENA Option TDR Certified Method of Implementation (MOI)

Available for free download at [www.keysight.com/find/ena-tdr_compliance](http://www.keysight.com/find/ena-tdr_compliance)

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<thead>
<tr>
<th>Cable / Connector</th>
<th>Tx/Rx Impedance (Hot TDR)</th>
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<tbody>
<tr>
<td>• USB</td>
<td>• HDMI</td>
</tr>
<tr>
<td>• HDMI</td>
<td>• SATA</td>
</tr>
<tr>
<td>• SATA</td>
<td>• MIPI</td>
</tr>
<tr>
<td>• DisplayPort</td>
<td>• 10GBASE-KR/40GBASE-KR</td>
</tr>
<tr>
<td>• 100BASE-TX</td>
<td>• MHL</td>
</tr>
<tr>
<td>• 10GBASE-T</td>
<td>• Thunderbolt</td>
</tr>
<tr>
<td>• 10GBASE-KR/40GBASE-KR</td>
<td>• SD Card (UHS-II)</td>
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<tr>
<td>• MHL</td>
<td>• Cfast</td>
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<tr>
<td>• PCIe</td>
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<tr>
<td>• BroadR-Reach</td>
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**HDMI TXRX Test Solution Overview**
Certified Test Centers using ENA Option TDR
ENA Option TDR is used world wide by certified test centers of USB, HDMI, DisplayPort, MHL, Thunderbolt and SATA.

HDMI - Authorized Test Centers (ATC) [http://www.hdmi.org/manufacturer/authorized_test_centers.aspx](http://www.hdmi.org/manufacturer/authorized_test_centers.aspx)
HDMI Source/Sink Impedance Compliance Test Solution

Summary

• Narrow-band receiver architecture provides fast and accurate Hot TDR measurements
• Similar look-and-feel to traditional TDR scopes, providing simple and intuitive operation even for users unfamiliar to VNAs and S-parameters
• Adopted by test labs worldwide
What is ENA Option TDR?

The ENA Option TDR is an application software embedded on the ENA, which provides an one-box solution for high speed serial interconnect analysis.

3 Breakthroughs for Signal Integrity Design and Verification

- Simple and Intuitive Operation
- Fast and Accurate Measurements
- High ESD Robustness
What is ENA Option TDR?
[Video] Changing the world of Time Domain Reflectometry (TDR) Measurements

https://www.youtube.com/watch?v=uBHXkzk4Izk
Additional Resources

ENA Option TDR Reference Material www.keysight.com/find/ena-tdr
• Technical Overview (5990-5237EN)
• Application Notes
  • Correlation between TDR oscilloscope and VNA generated time domain waveform (5990-5238EN)
  • Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope (5990-5446EN)
  • Effective Hot TDR Measurements of Active Devices Using ENA Option TDR (5990-9676EN)
  • Measurement Uncertainty of VNA Based TDR/TDT Measurement (5990-8406EN)
  • Accuracy Verification of Agilent’s ENA Option TDR Time Domain Measurement using a NIST Traceable Standard (5990-5728EN)

Method of Implementation (MOI) for High Speed Digital Standards
www.agilent.com/find/ena-tdr_compliance