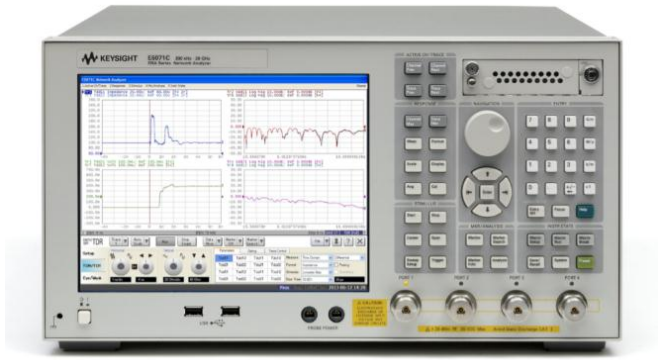
High-Definition Multimedia Interface (HDMI) Source/Sink Impedance Compliance Test

Test Solution Overview

Using the E5071C ENA Option TDR



Keysight Technologies
Component Test Division

Revision 01.10
2015/03/12 (YS)

KEYSIGHT TECHNOLOGIES

Reference Documents

- High-Definition Multimedia Interface (HDMI) Specification Version 2.0
- High-Definition Multimedia Interface (HDMI) Version 2.0 Compliance Test Specification

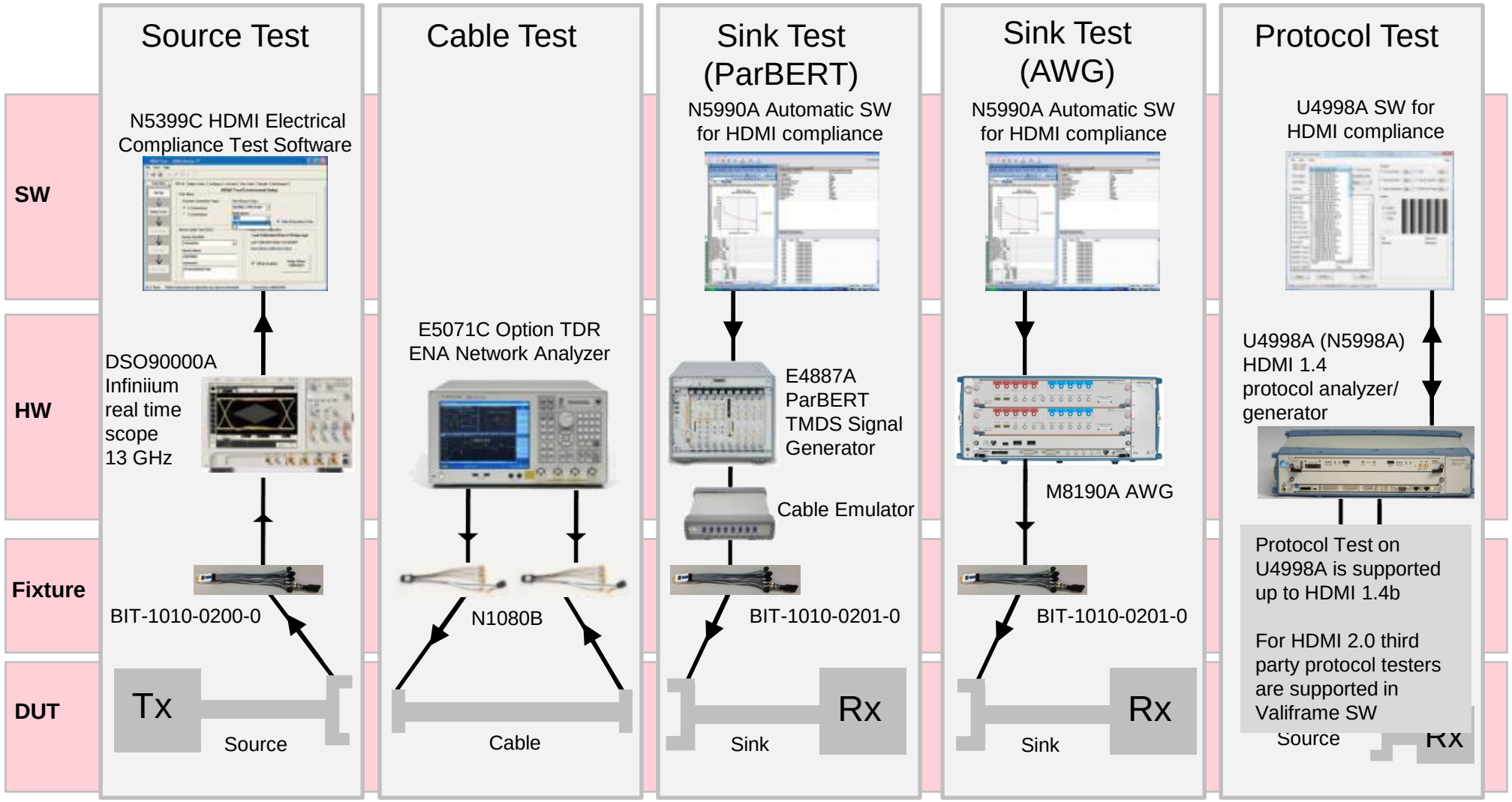
Keysight Digital Standards Program

- 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



HDMI Versions

Ver	Date	
1.0	2002/12/09	• Initial release
1.1	2004/05/20	• Minor corrections
1.2	2005/08/22	• Minor corrections
1.2a	2005/12/14	• Minor corrections
1.3	2006/06/22	• Type C “Mini-Connector” (4.1.9.5, 4.1.9.6) • Cable Categories 1 and 2 (4.2.6) • Deep Color [4:4:4] (6.5, 8.3.2) • Reference Cable Equalizer (4.2.3.2, 4.2.5, 4.2.6) • Higher-speed single-link (4.1.2, 4.2.3,through 4.2.6, 8.3.2) • High-bitrate compressed audio formats (5.3.11, 7.2.4, 7.3.3, 7.6.2)
1.3a	2006/11/10	• Minor corrections
1.4	2009/06/05	• Type D Connector (4.1.9.7, 4.1.9.8, 4.1.10.6) • 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) • Audio Return Channel Overview (7.12) • 3D and 4K x 2K video format (8.2.3, 8.3.2, Appendix H) • HDMI Ethernet and Audio Return Channel (HEAC) features(Supplement 2)
1.4a	2010/03/04	• Minor corrections
1.4b	2011/10/11	• Minor corrections
2.0	2013/09/04	• **TMDS Character Rates dfrom 340 to 600Mcsc (6.1.1)** • Scrambling for EMI/RFI reducation at all TMDS Character rates (6.1.2) • TMDS Character Error Detection (6.2)

HDMI Overview

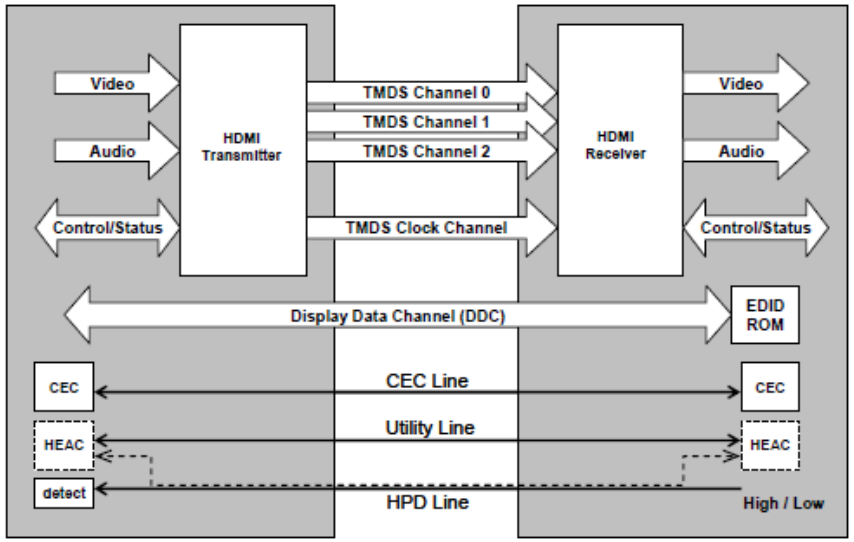


Figure 3-1 HDMI Block Diagram

Note:
- CEC: Consumer Electronics Control
- HEAC: HDMI Ethernet and Audio Return Channel

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

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.

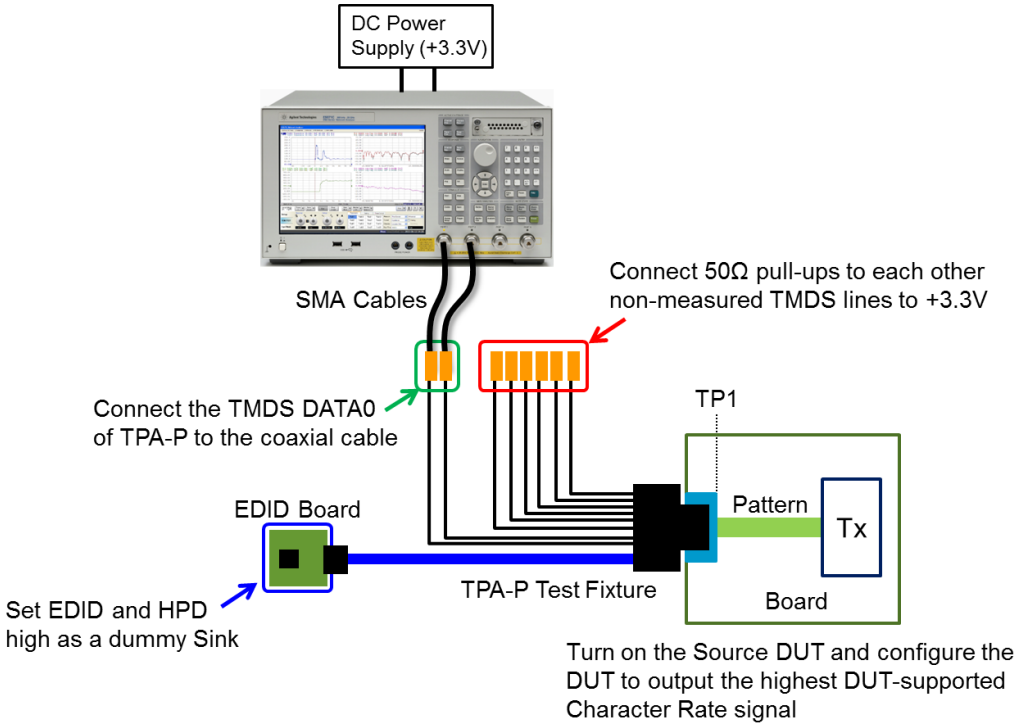
Source TMDS Electrical 6G Tests
HF1-1: Vl and Vswing
HF1-2: Trise, Tfall
HF1-3: Inter-pair Skew
HF1-4: Intra-pair Skew
HF1-5: Differential Voltage
HF1-6: Clock Duty Cycle and Clock Rate
HF1-7: Clock Jitter
HF1-8: Data Eye Diagram
HF1-9: Differential Impedance

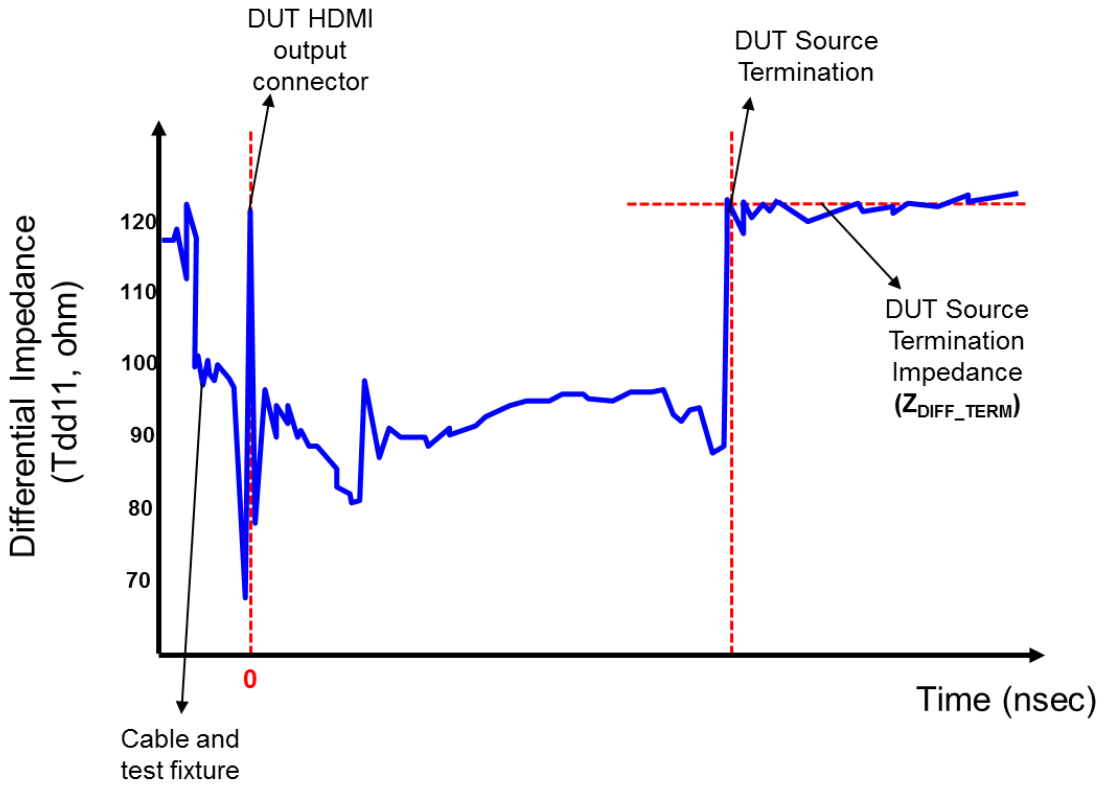
Sink TMDS Electrical 6G Tests
HF2-1: Min/Max Differential Swing Tolerance
HF2-2: Intra-pair Skew
HF2-3: Jitter Tolerance
HF2-4: Differential Impedance
HF2-52: Character Error Rate

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.

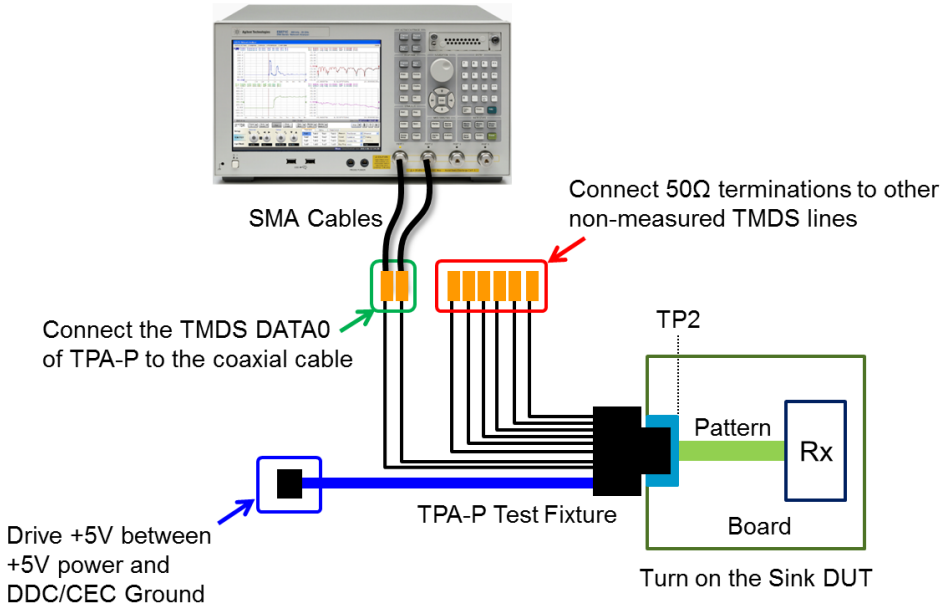


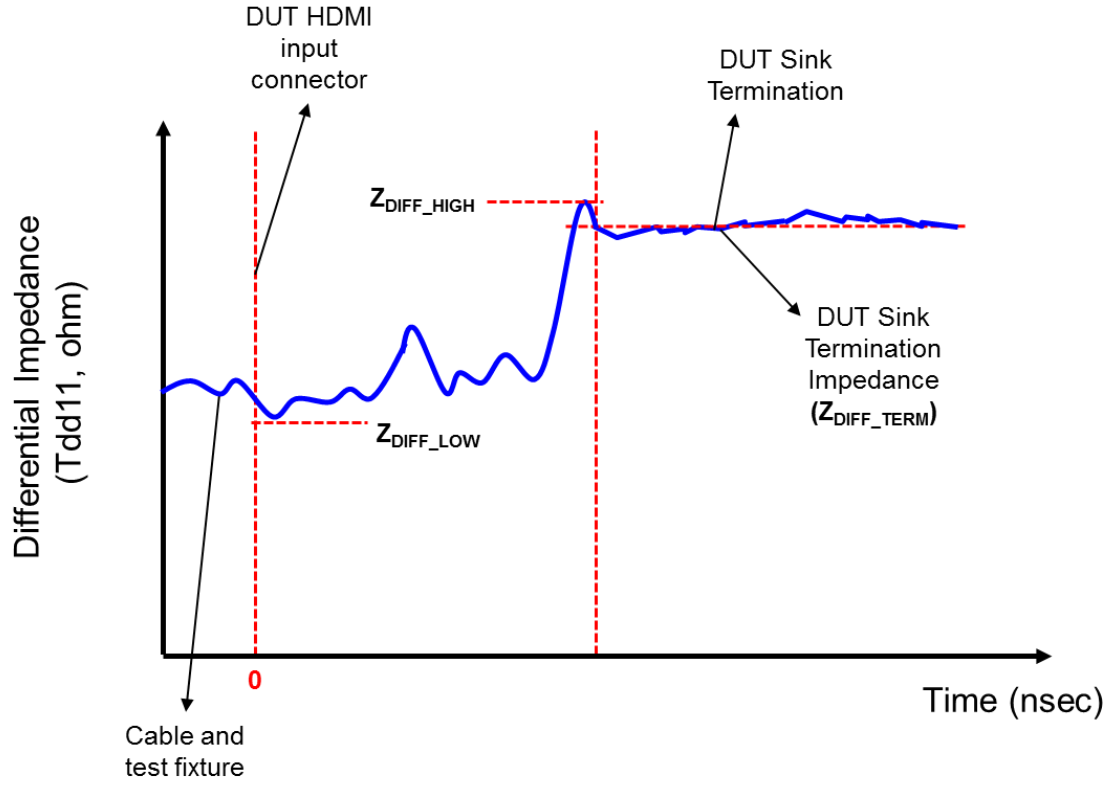


HDMI Source/Sink Impedance Compliance Test

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

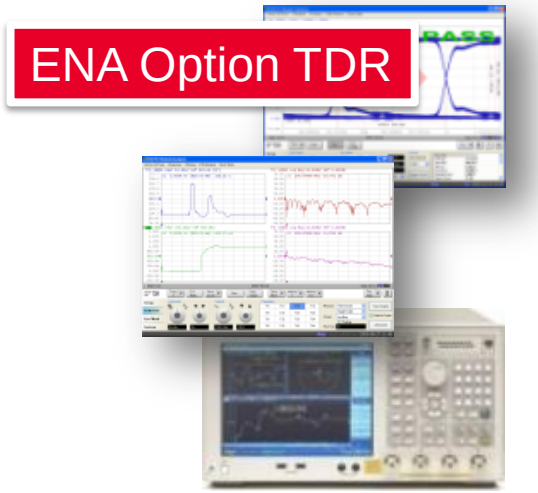
Time Domain (Hot TDR)
- HF1-9: Differential Impedance
- HF2-4: Differential Impedance

Traditional Solution

TDR Scope

New Solution

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

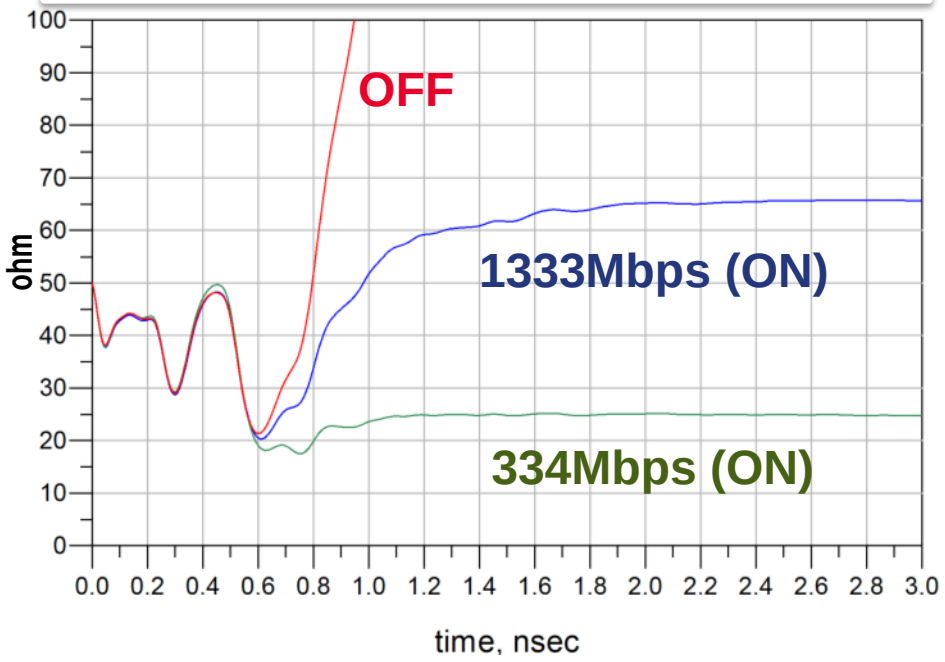


Hot TDR Measurements

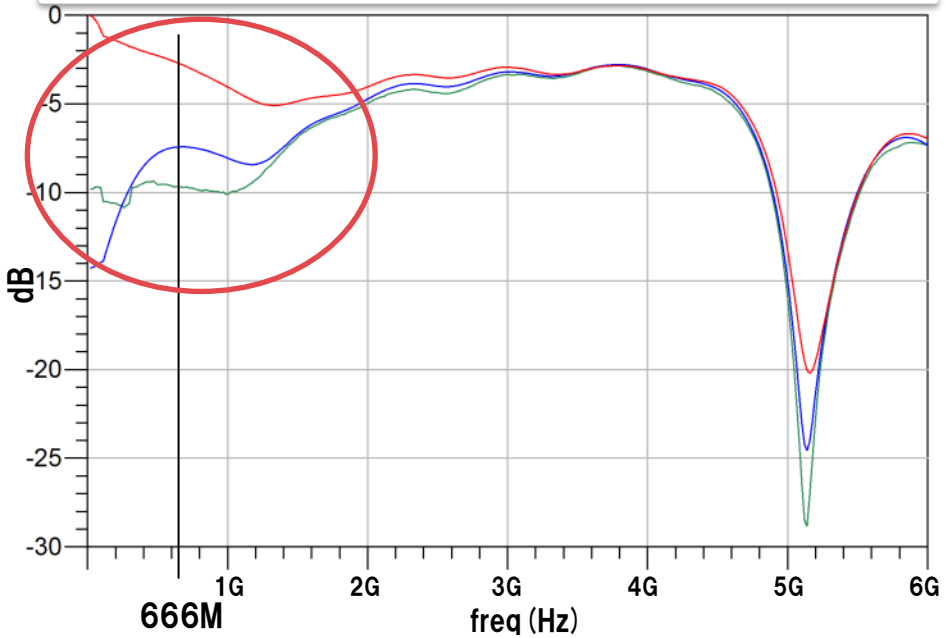
Why Measure?

- **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)



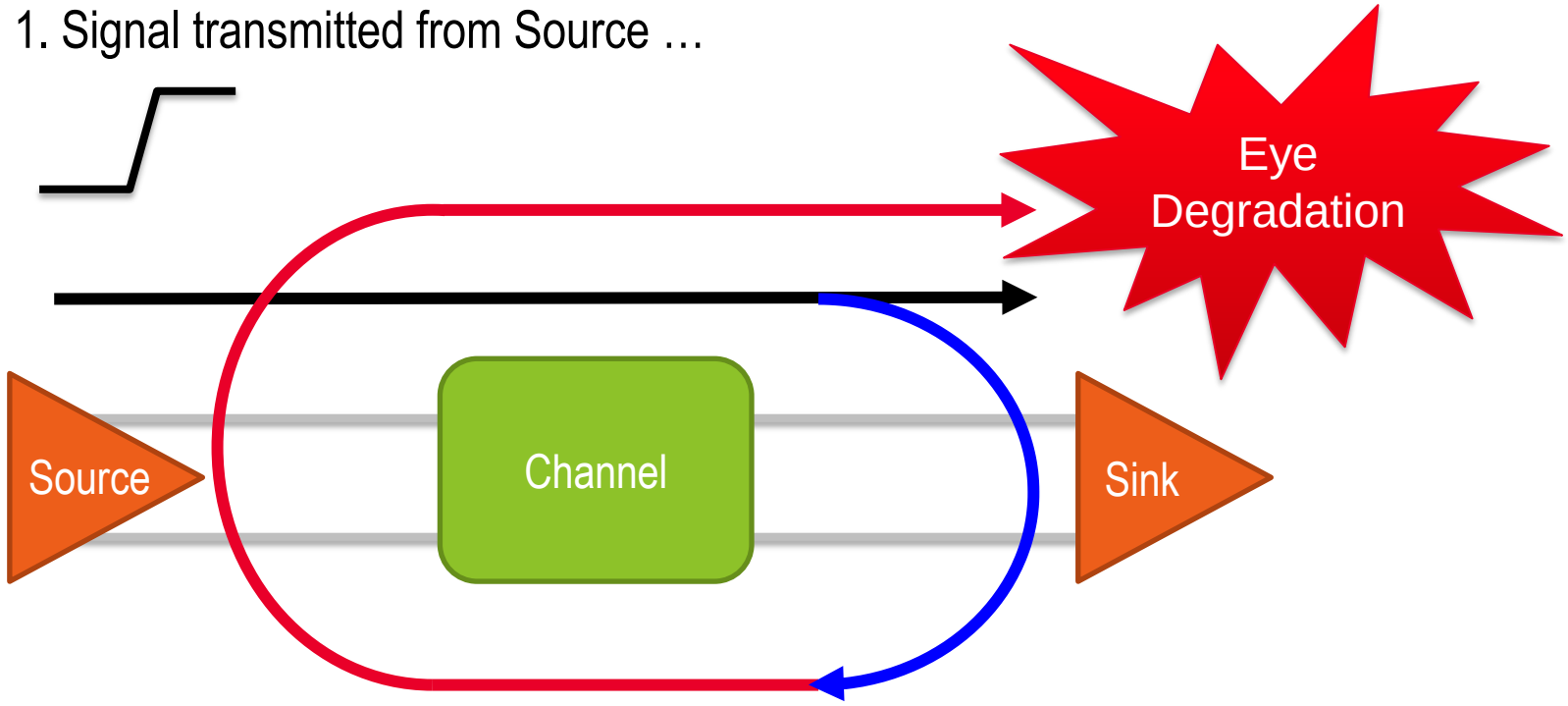
Return Loss (Freq Domain)



Hot TDR Measurements

Why Measure?

1. Signal transmitted from Source …



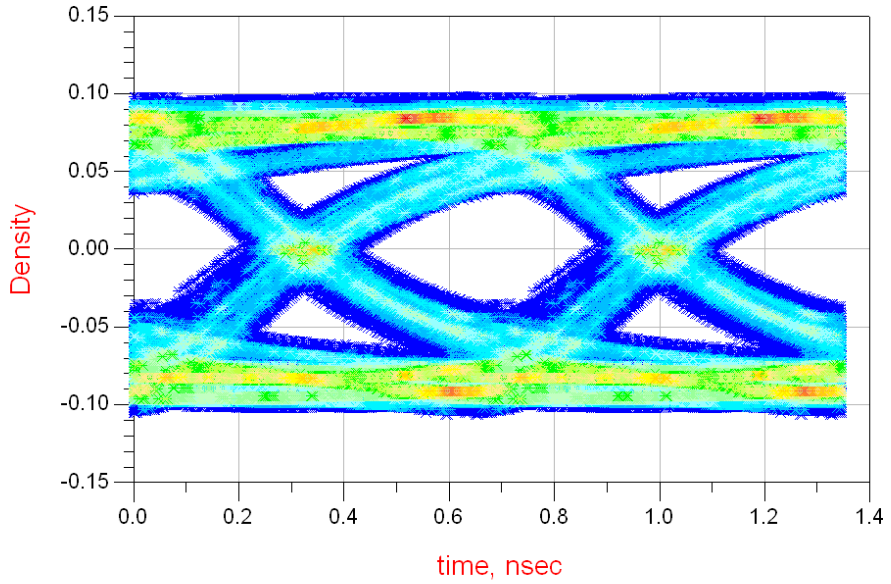
3. Re-reflection from Source due to impedance mismatches ...

2. Partial reflection from Sink due to impedance mismatches …

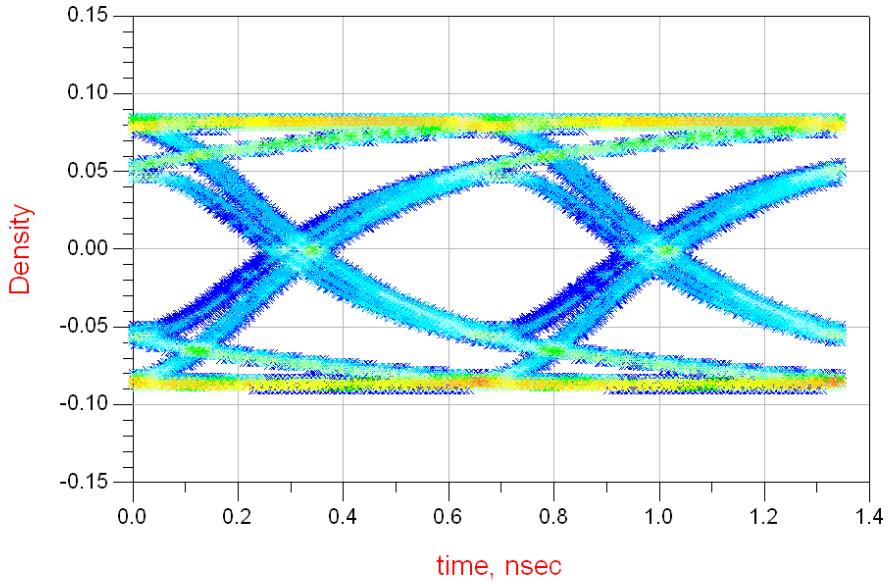
Hot TDR Measurements

Why Measure?

Source Impedance **NOT** Matched

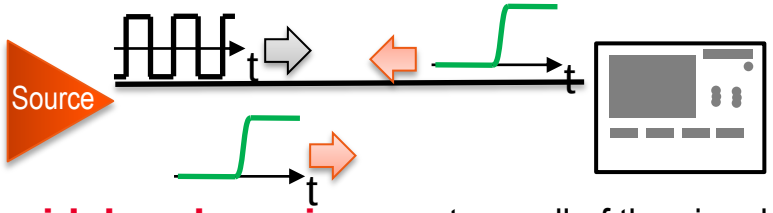


Source Impedance Matched

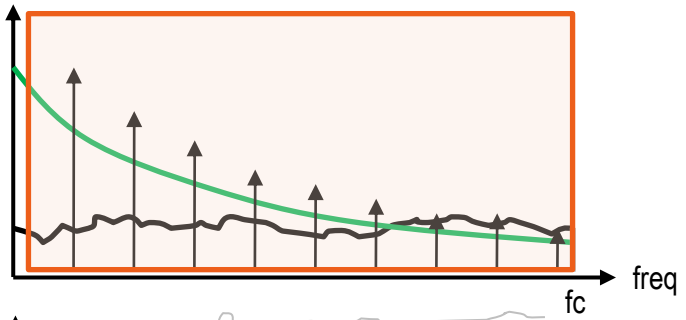


Advantage of VNA-based Solution for Hot TDR Measurements

TDR Oscilloscope

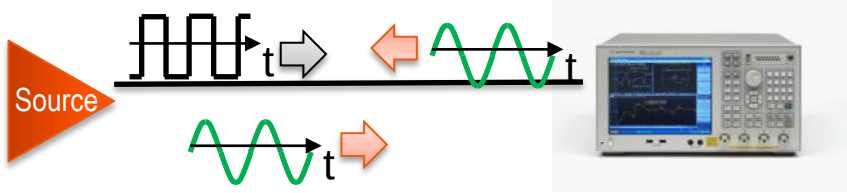


•**wideband receiver** captures all of the signal energy from the source

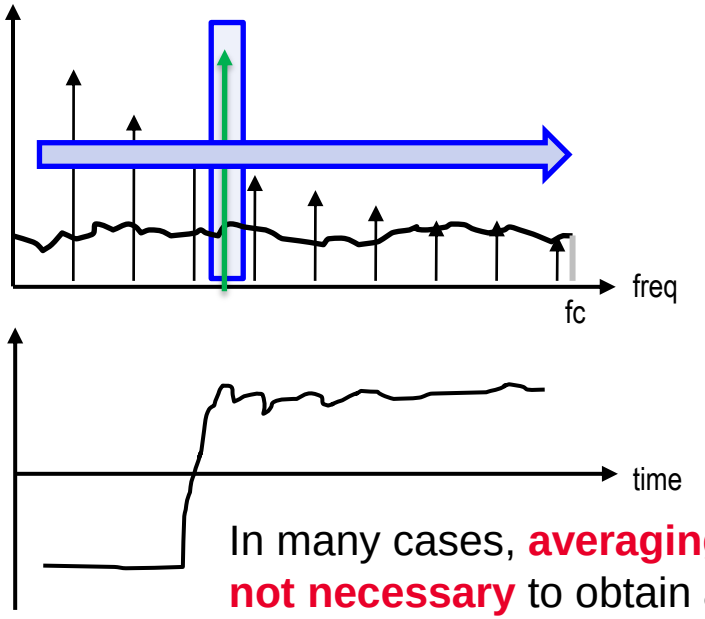


Extensive averaging is necessary to obtain a stable waveform.

VNA (ENA Option TDR)



•**narrowband receiver** minimizes the effects of the data signal from the source

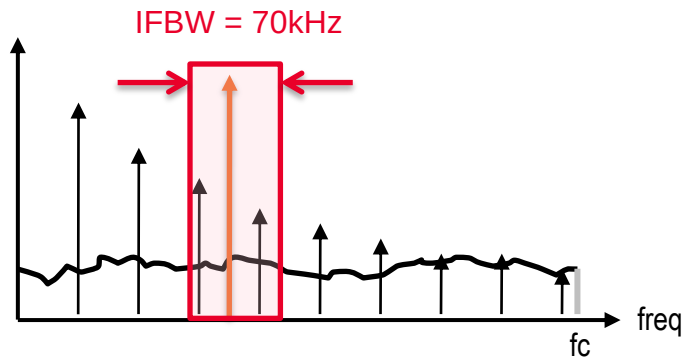


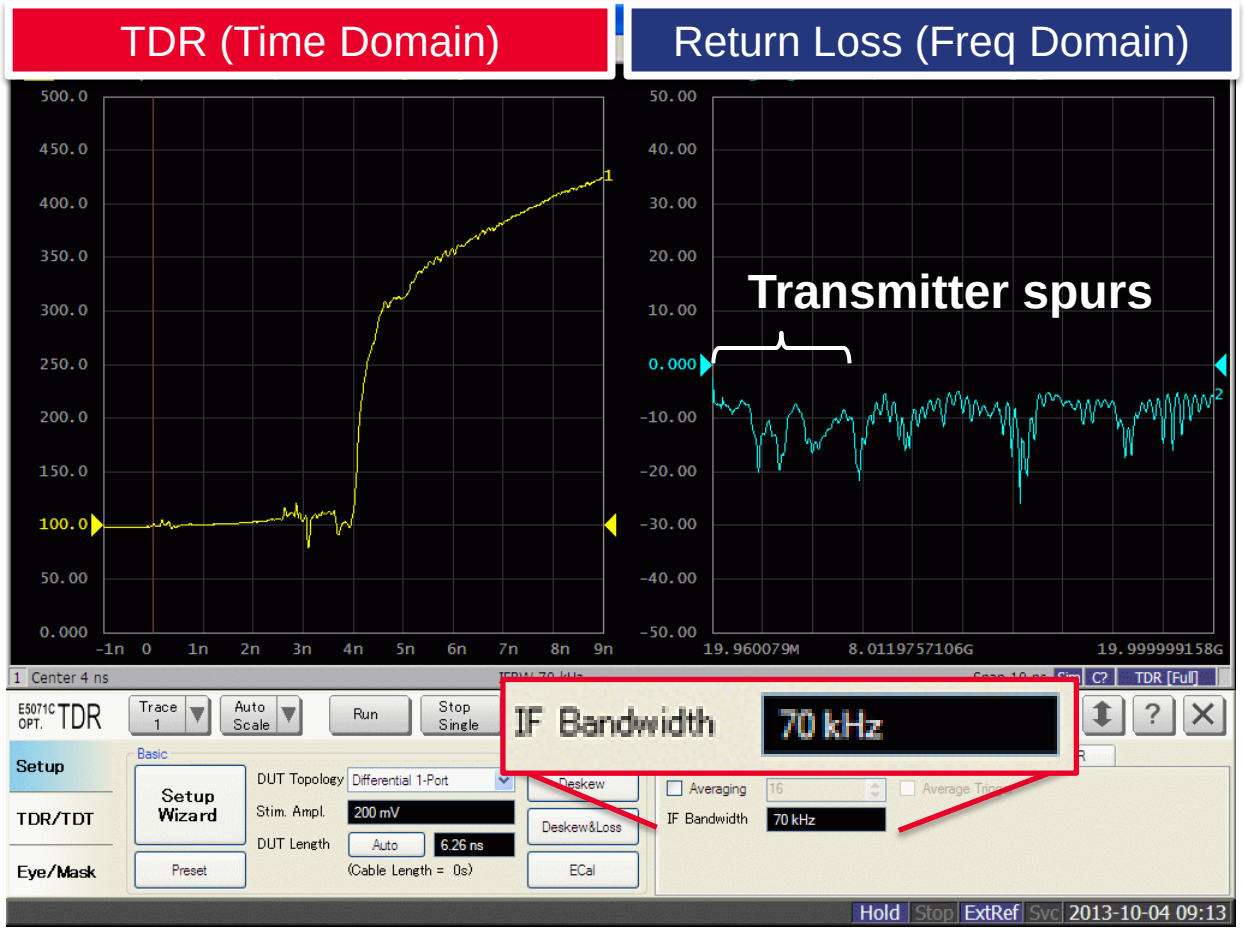
In many cases, **averaging is not necessary** to obtain a stable waveform.

[Video] HDMI 2.0 Source Impedance Measurement Example

Wide IF Bandwidth (IFBW)

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

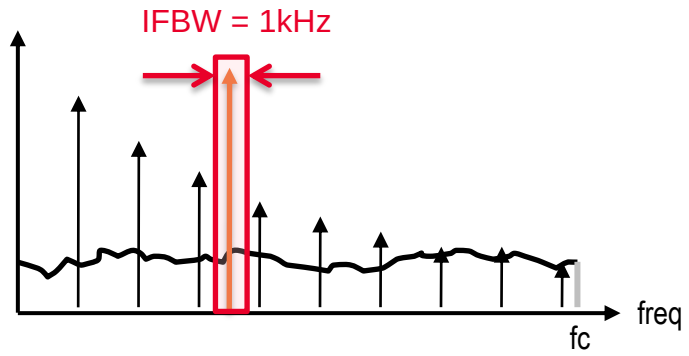


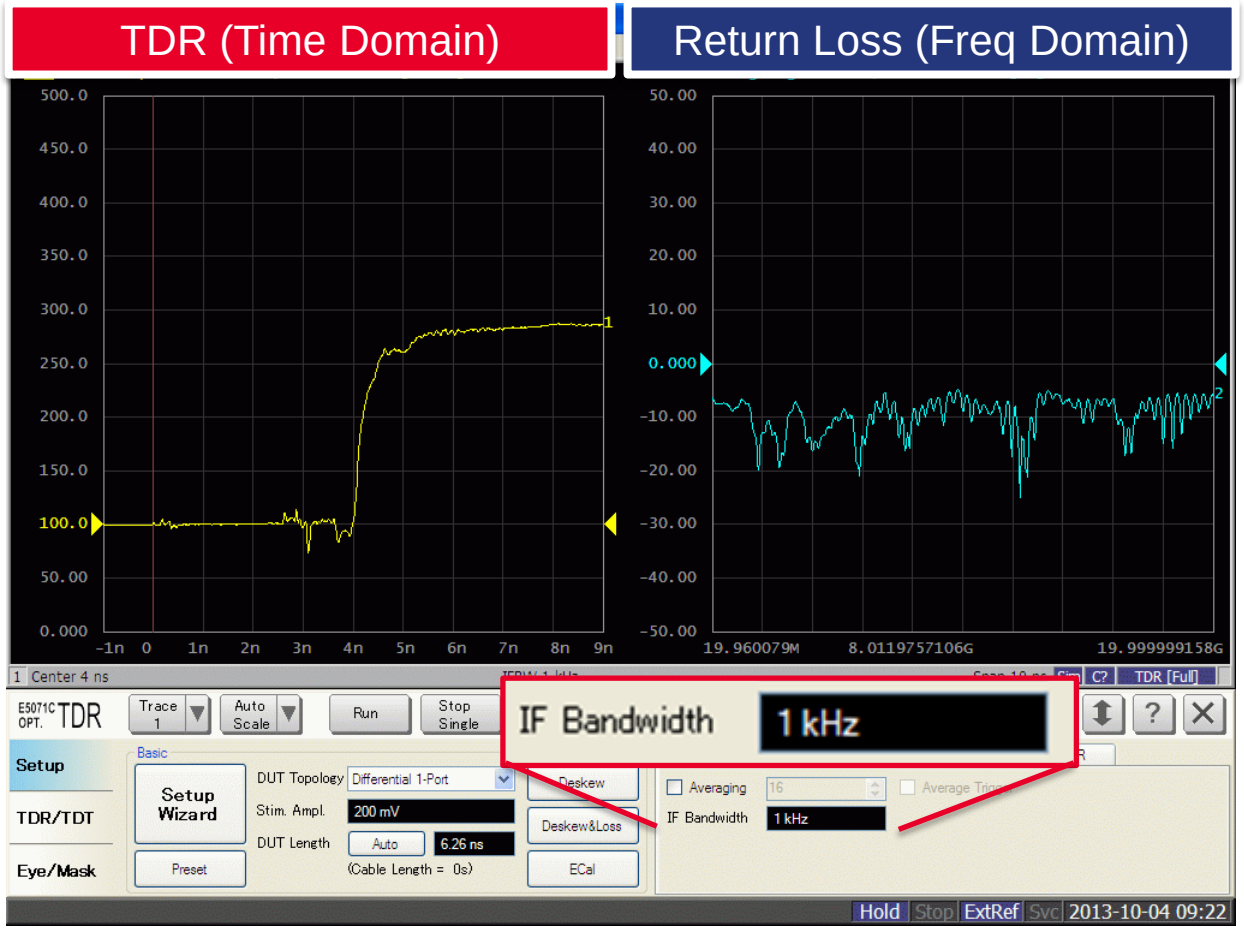


[Video] HDMI 2.0 Source Impedance Measurement Example

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.



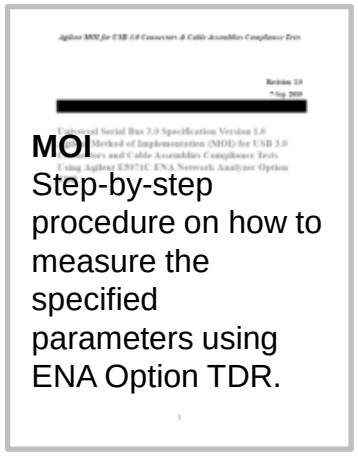


HDMI Source/Sink Impedance Compliance Test Solution

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 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.

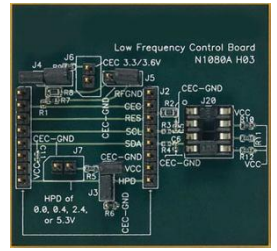


MOI
Step-by-step procedure on how to measure the specified parameters using ENA Option TDR.

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

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 **or**
- BitifEye Bit-1010-0275-0 HDMI 2.0 Type D Test Plug Adapter Kit

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

ENA Option TDR Certified Method of Implementation (MOI)

Available for free download at www.keysight.com/find/ena-tdr_compliance

Cable / Connector

- USB
- HDMI
- SATA
- DisplayPort
- 100BASE-TX
- 10GBASE-T
- 10GBASE-KR/40GBASE-KR
- MHL
- PCIe
- BroadR-Reach

Tx/Rx Impedance (Hot TDR)

- HDMI
- SATA
- MIPI
- 10GBASE-KR/40GBASE-KR
- MHL
- Thunderbolt
- SD Card (UHS-II)
- Cfast

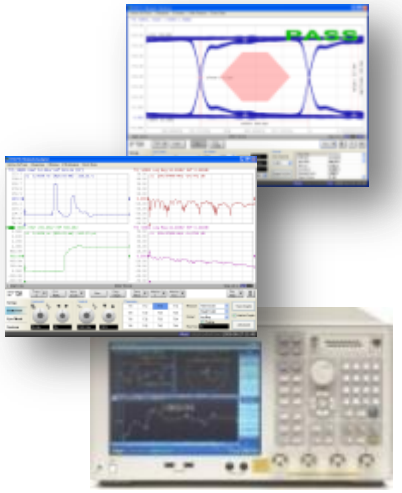
Certified Test Centers using ENA Option TDR

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

HDMI Source/Sink Impedance Compliance Test Solution

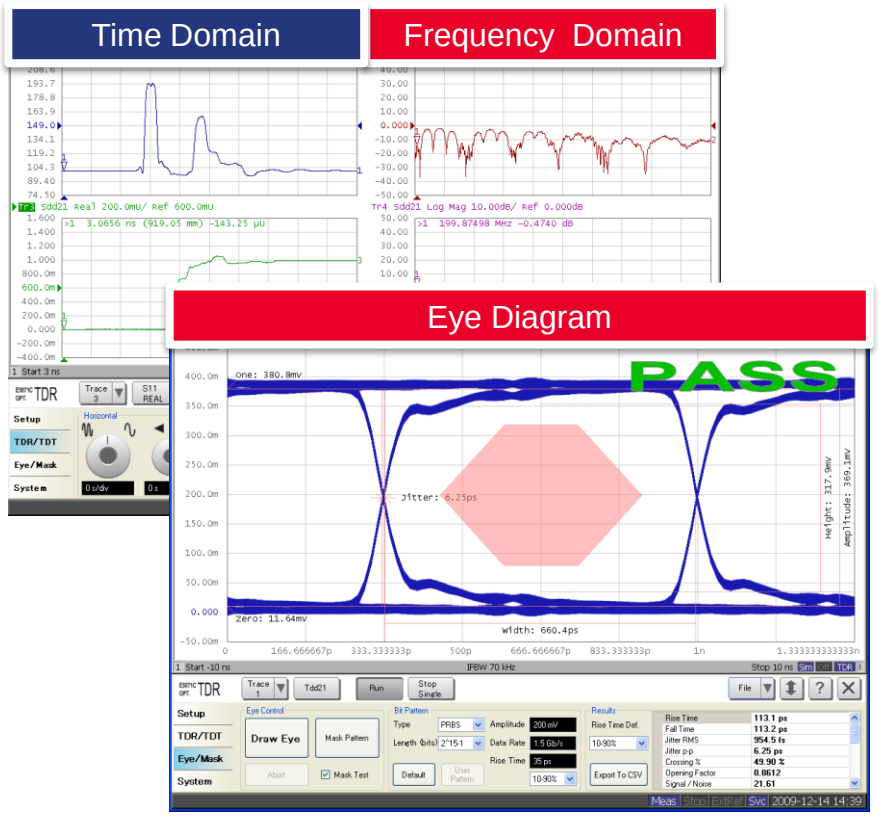
Summary



- 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

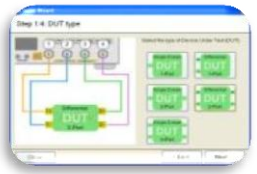
What is ENA Option TDR?

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

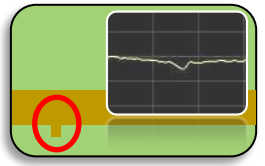


3 Breakthroughs

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=uBHXkzk4lzk

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