

USB 2.0 Cable-Connector Assembly Compliance Tests

Test Solution Overview Using the Keysight E5071C ENA Option TDR

Rev 01.10 2016/10/18 Updates for “Errata for “USB Revision 2.0 April 27, 2000” as of May 28, 2002”

Purpose

- This slide will show how to make measurements of USB 2.0 cable & connector assemblies compliance tests by using the Keysight E5071C ENA Option TDR.

Keysight Digital Standards Program

Our solutions are driven and supported by Keysight experts involved in international standards committees:

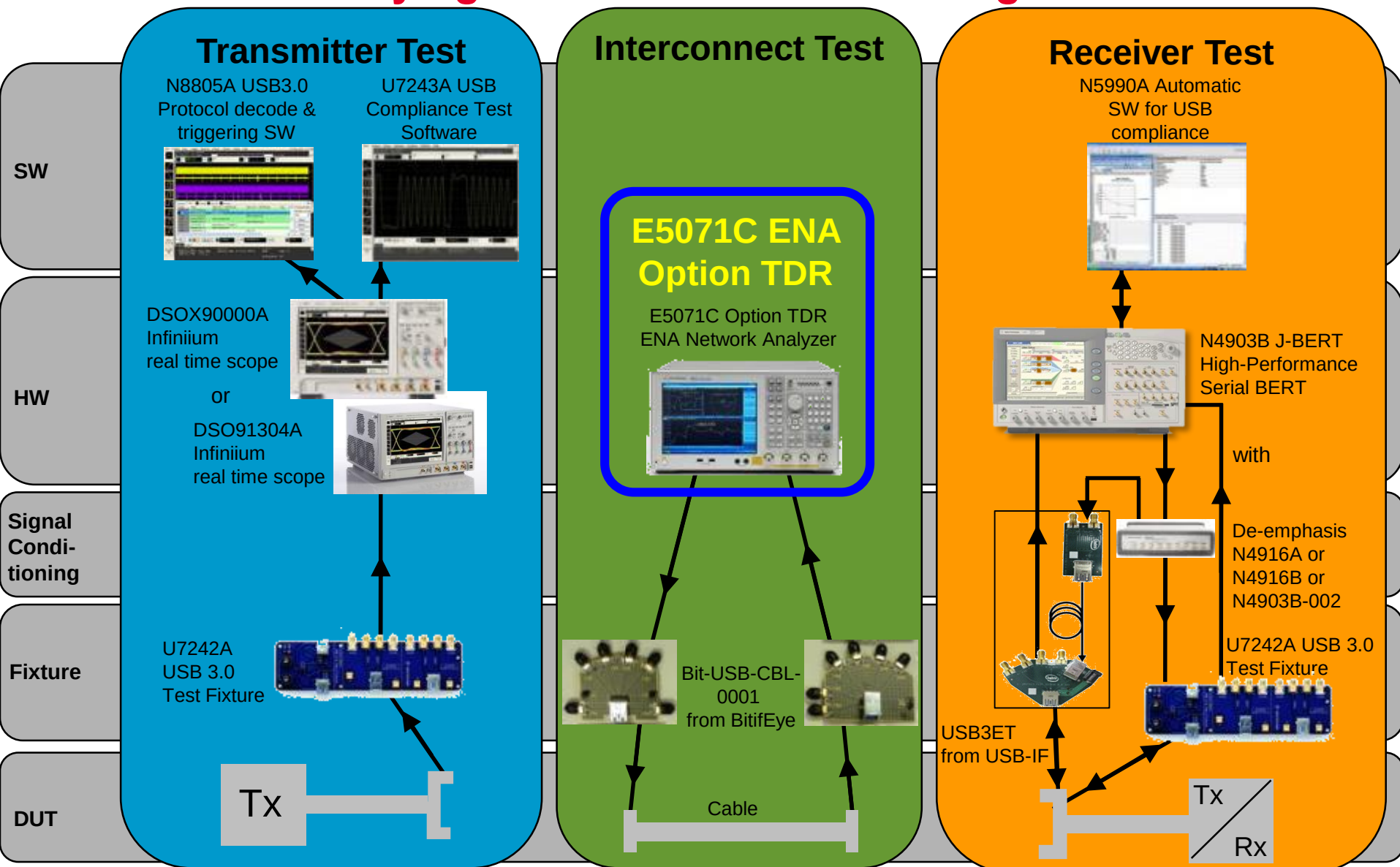
- Joint Electronic Devices Engineering Council (JEDEC)
- PCI Special Interest Group (PCI-SIG®)
- Video Electronics Standards Association (VESA)
- Serial ATA International Organization (SATA-IO)
- [USB-Implementers Forum \(USB-IF\)](#)
- Mobile Industry Processor Interface (MIPI) Alliance
- Optical Internetworking Forum (OIF)

We're active in standards meetings, workshops, plugfests, and seminars

Our customers test with highest confidence and achieve compliance faster

The JEDEC logo consists of the word "JEDEC" in a bold, blue, sans-serif font.The PCI EXPRESS logo features the text "PCI" in a large, bold, black font, followed by a blue stylized arrow pointing right, and the word "EXPRESS" in a smaller, bold, black font below it.The SERIAL ATA logo features the word "SERIAL" in a small, black, sans-serif font above the word "ATA" in a large, bold, blue font, with a yellow stylized arrow pointing right.The DisplayPort logo is a large, bold, black letter "D" with a stylized arrow pointing right.The HDMI logo features the word "HDMI" in a large, bold, black font, with the text "HIGH-DEFINITION MULTIMEDIA INTERFACE" in a smaller, black, sans-serif font below it.The USB logo features the word "USB" in a large, bold, blue font, with a stylized arrow pointing right.The MIPI logo features the word "mipi" in a large, bold, black font, with the text "mobile industry processor interface" in a smaller, black, sans-serif font below it.The OIF logo features a blue diamond shape to the left of the text "OIF" in a large, bold, blue font, with the text "OPTICAL INTERNETWORKING FORUM" in a smaller, black, sans-serif font to the right.

USB 3.0 – Keysight Total Solution Coverage

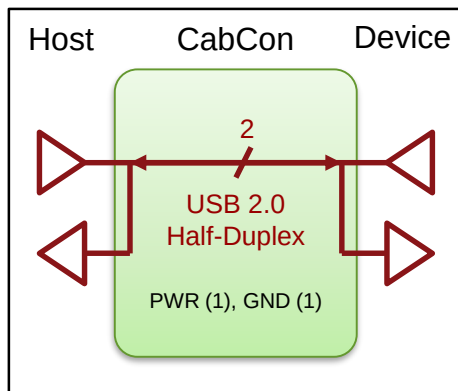


Reference Document

- Universal Serial Bus Specification, Revision 2.0, April 27, 2000
- Errata for “USB Revision 2.0 April 27, 2000” as of May 28, 2002
- Universal Serial Bus Cables and Connectors Class Document (Revision 2.0)

USB 2.0 Cable/Connector Compliance Test

Cable Assembly

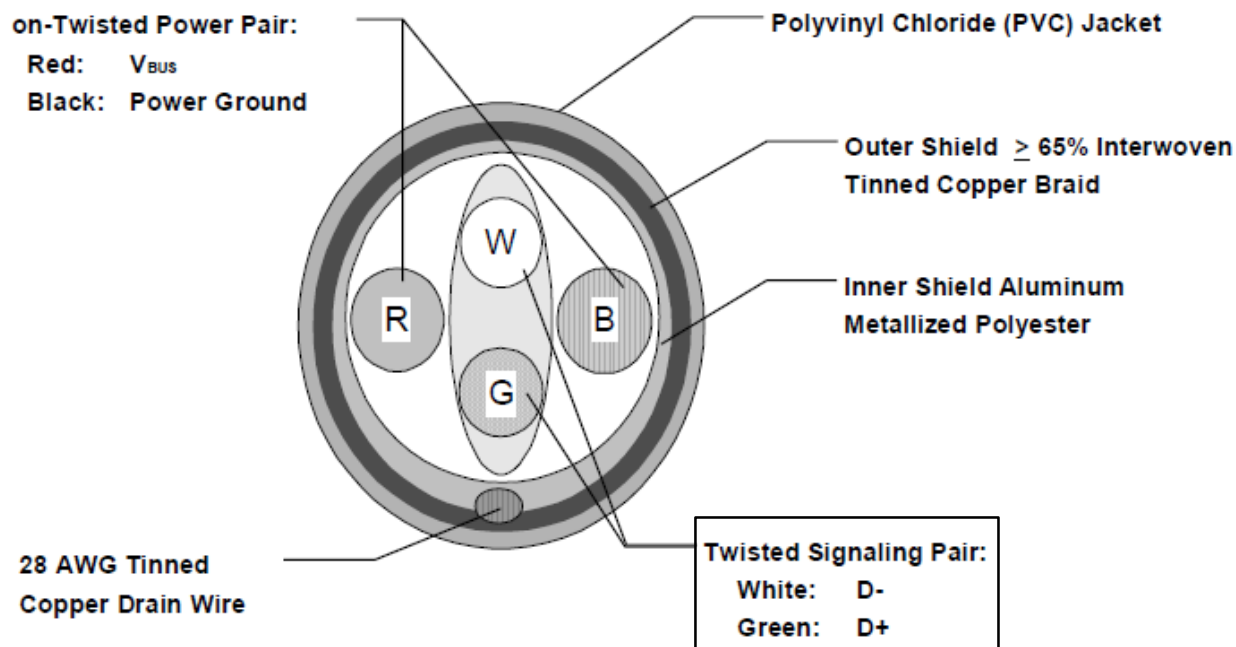


Three Data Rates:

Low Speed at 1.5 Mbps

Full Speed at 12 Mbps

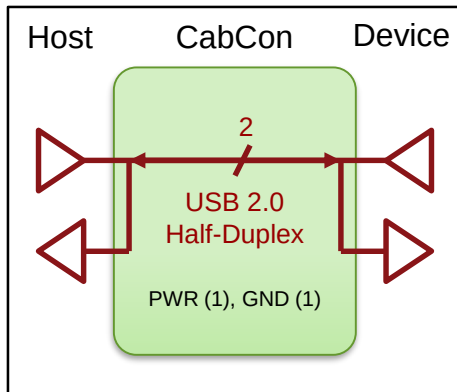
High Speed at 480 Mbps



Typical High-/Full-Speed Cable Construction

USB 2.0 Cable/Connector Compliance Test

Measurement Parameters



Time Domain Measurements

Cable Impedance (High/Full-Speed)

Propagation Delay

Propagation Delay Skew

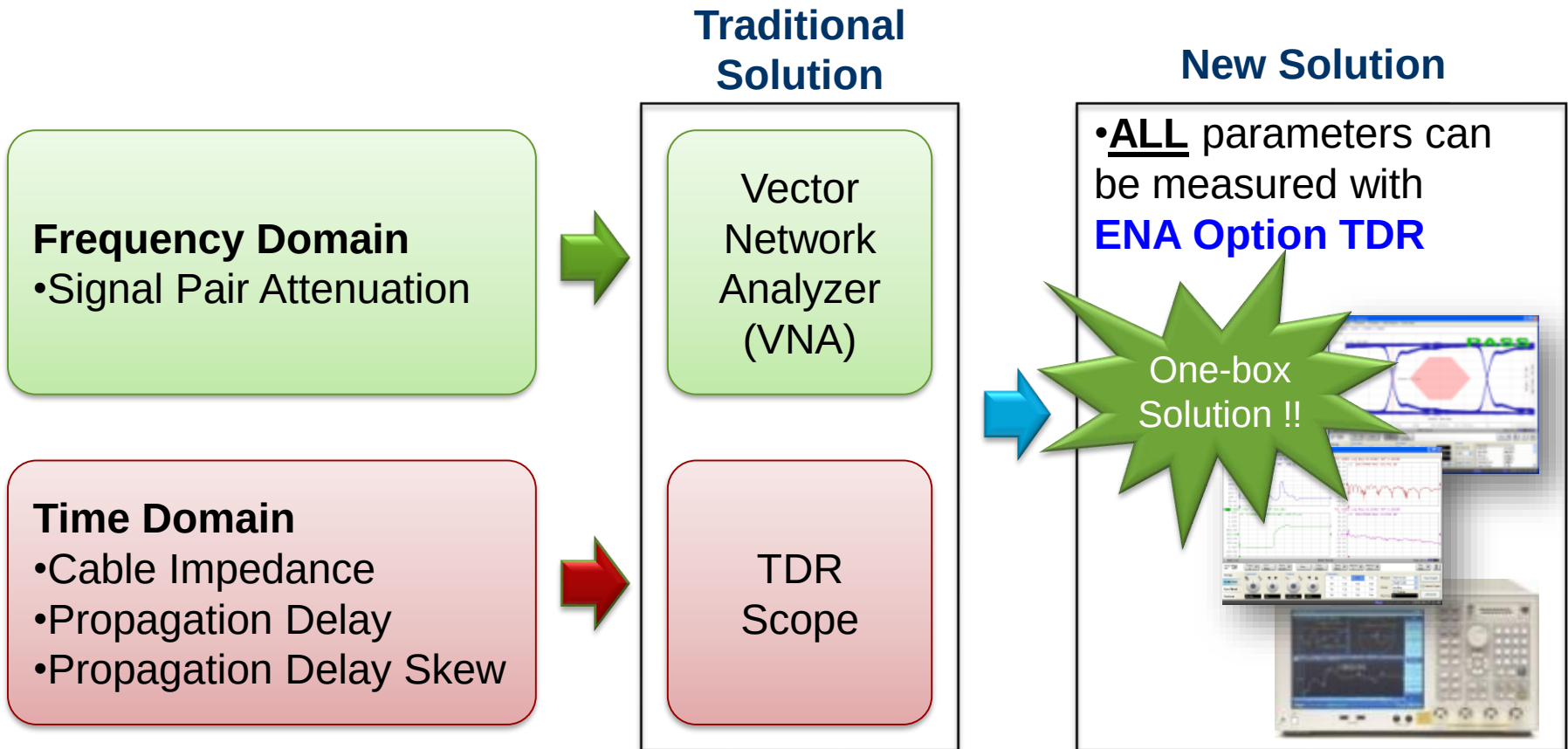
Frequency Domain Measurements

Signal Pair Attenuation (High/Full-Speed)

USB 2.0 Cable/Connector Compliance Test

Solution Overview

- USB 2.0 cable/connector compliance testing requires parametric measurements in both time and frequency domains



ENA Option TDR Compliance Test Solution

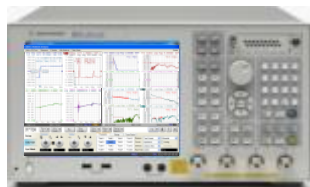
Certified Test Centers using ENA Option TDR

Test Centers Support ENA Option TDR

ENA Option TDR is used world wide by certified test centers of USB, HDMI, DisplayPort, MHL, Thunderbolt and SATA.



USB 2.0 Cable/Connector Compliance Test Configuration

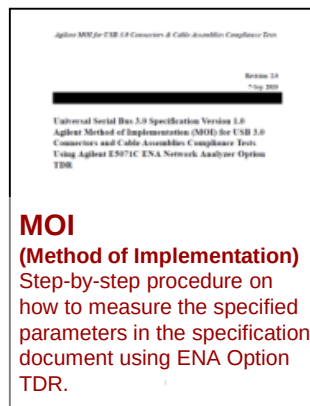


- ENA Mainframe (*1)
 - E5071C-440: 4-port, 9 kHz to 4.5 GHz
 - E5071C-445: 4-port, 100 kHz to 4.5 GHz
 - E5071C-460: 4-port, 9 kHz to 6.5 GHz
 - E5071C-465: 4-port, 100 kHz to 6.5 GHz
 - E5071C-480: 4-port, 9kHz to 8.5GHz
 - E5071C-485: 4-port, 100kHz to 8.5GHz
 - E5071C-4D5: 4-port, 300kHz to 14GHz
 - E5071C-4K5: 4-port, 300kHz 20GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module (or Mechanical Cal Kit)
 - N4431B for E5071C-44x/46x/48x
 - N4433A for E5071C-4D5/4K5

*1: Signal pair attenuation test requires the test frequency from 64 kHz. When using E5071C-4x5, the lower frequency is limited to either 100 kHz or 300 kHz depending on the frequency option.

- Method of Implementation (MOI) document available for download on Keysight.com
- State files (44x, 46x, 48x, 4D5, 4K5) and cal kit definition file for official cal fixtures are also available

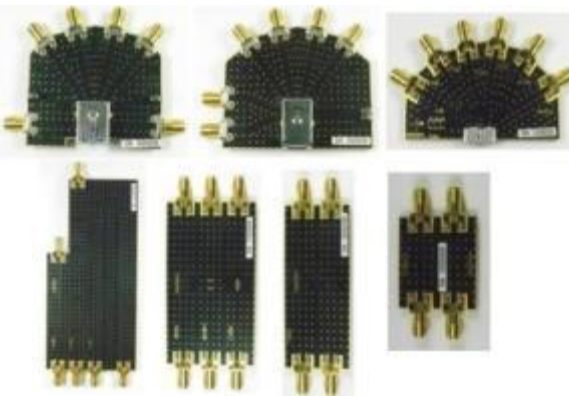
www.keysight.com/find/ena-tdr_compliance
www.keysight.com/find/ena-tdr_usb2-cabcon



Cable Test Fixtures

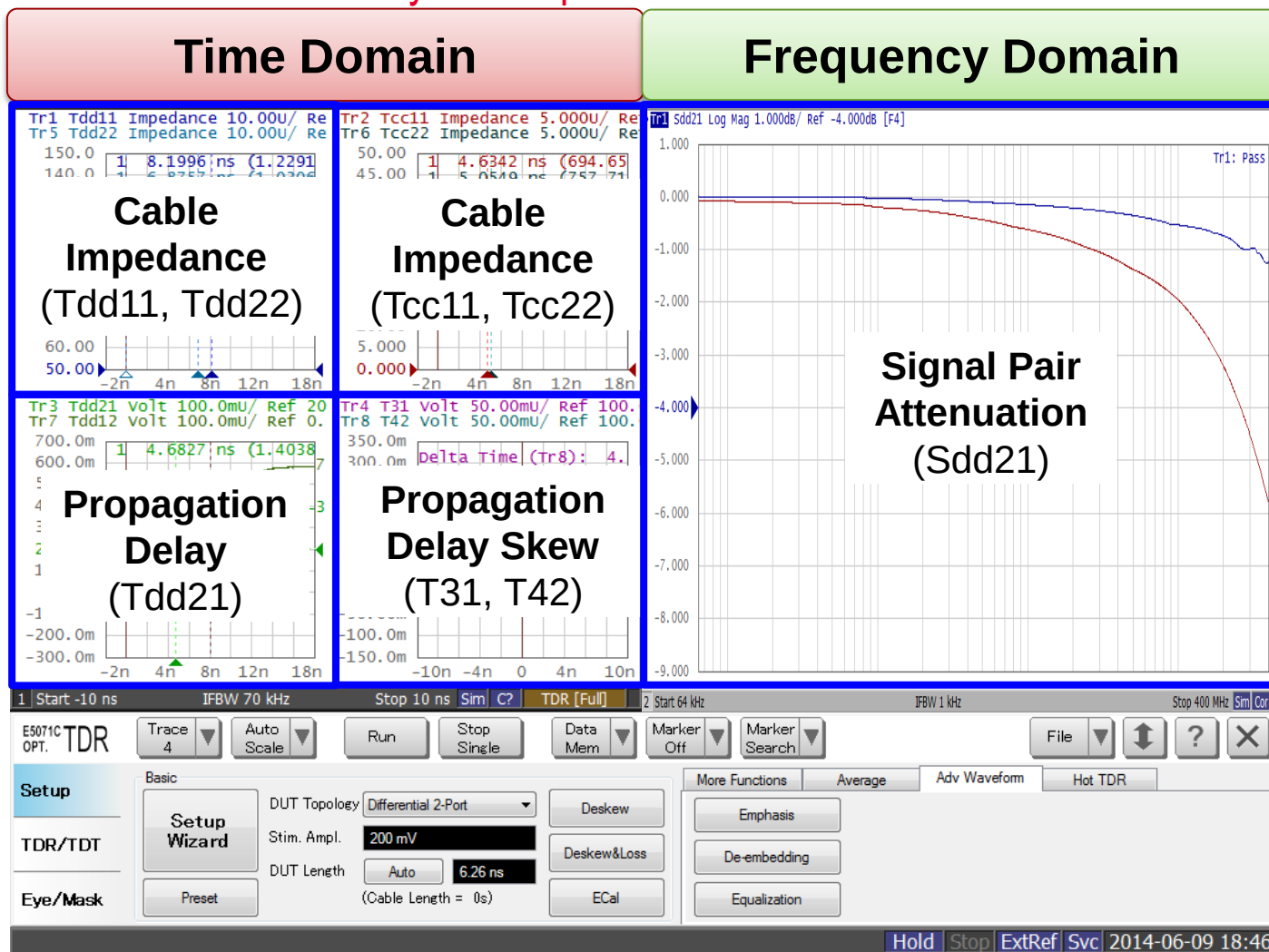
Fixtures for testing USB 2.0/3.0 cable assemblies are available for purchase through Allion and BitifEye.

<http://www.usb.org/developers/tools/#cablefixtures>



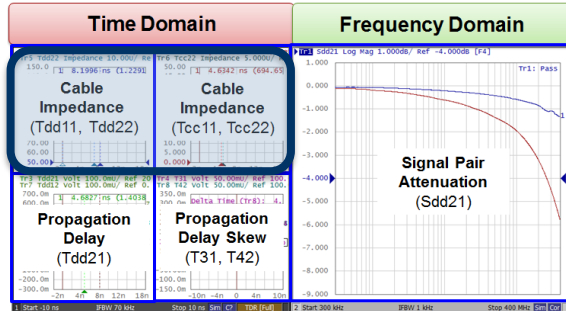
USB 2.0 Cable/Connector Compliance Test

Measurement Parameters by ENA Option TDR



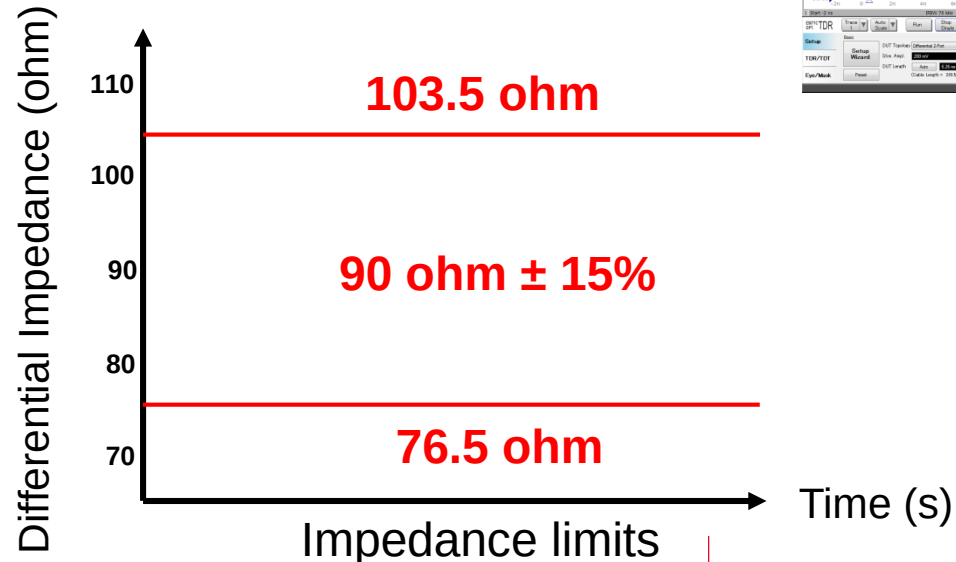
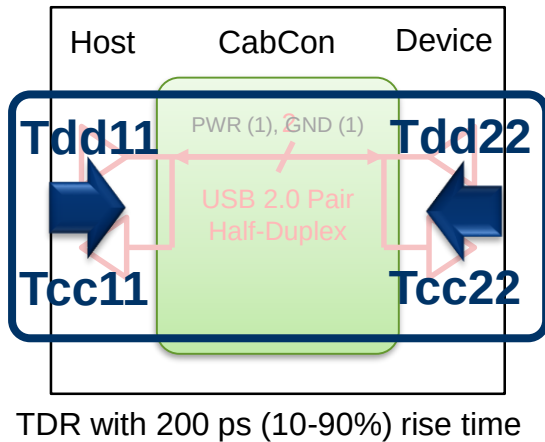
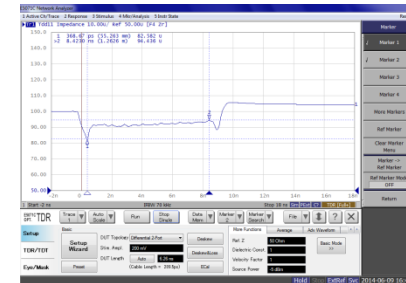
USB 2.0 Cable/Connector Compliance Test

Cable Impedance for High/Full-Speed



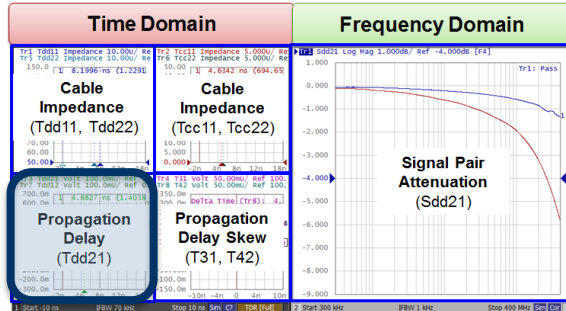
- Insure the signal conductors have the proper impedance
- Measure the minimum and maximum impedances found between the connector and the open circuited far end of the cable

- $Z_0 = 90 \text{ ohm} \pm 15\%$ (differential)
- $Z_{CM} = 30 \text{ ohm} \pm 30\%$ (common-mode)



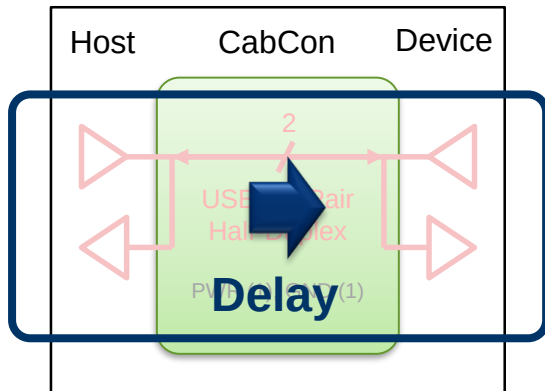
USB 2.0 Cable/Connector Compliance Test

Propagation Delay

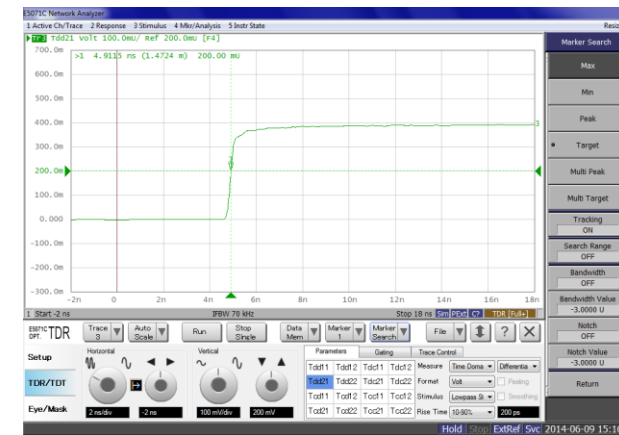


- Verify the end-to-end propagation of the cable
- For a standard USB detachable cable, the cable delay is measured from the Series A connector pins to the Series B connector pins
- For other cables, the delay is measured from the Series A connector to the point where the cable is connected to the device

- $T_{FSCBL} < 26 \text{ ns}$ (Full/High-Speed)
- $T_{LSCBL} < 18 \text{ ns}$ (Low-Speed)
- Cable delay $< 5.2 \text{ ns/m}$

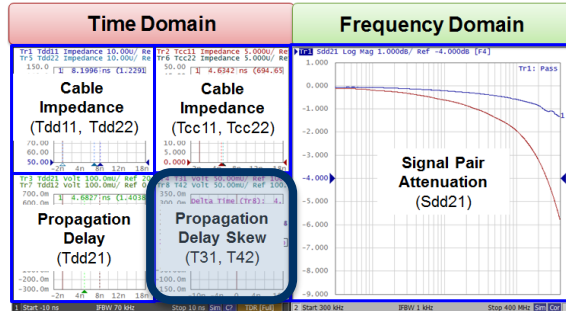


TDR with 200 ps (10-90%) rise time



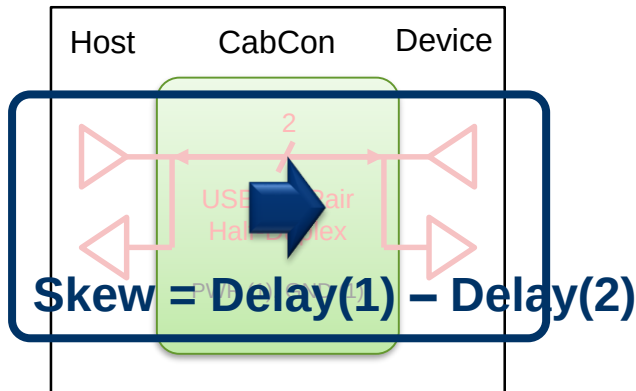
USB 2.0 Cable/Connector Compliance Test

Propagation Delay Skew

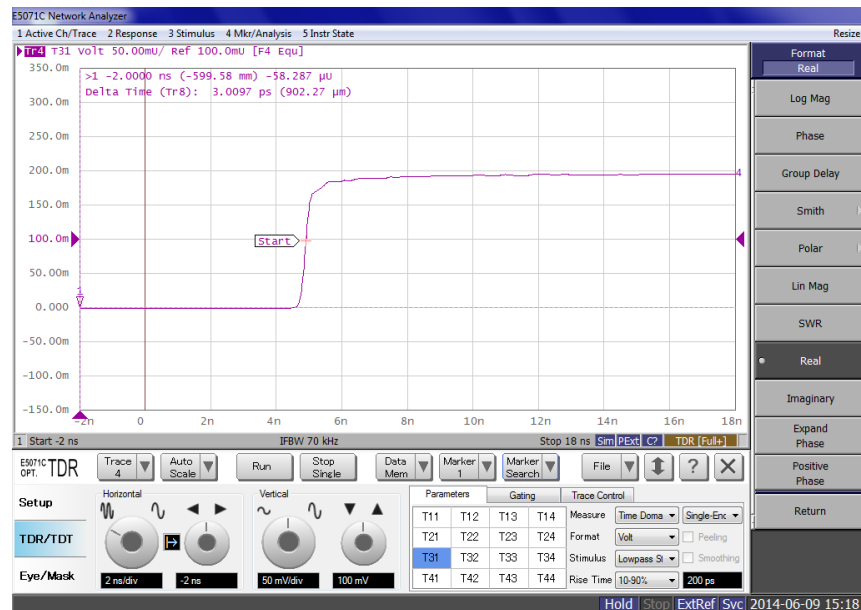


• Insure that the signal on both D+ and D- lines arrive at the receiver at the same time

• The maximum skew introduced by the cable between the differential signal pair (i.e. D+ and D- (T_{SKEW})) must be less than 100 ps

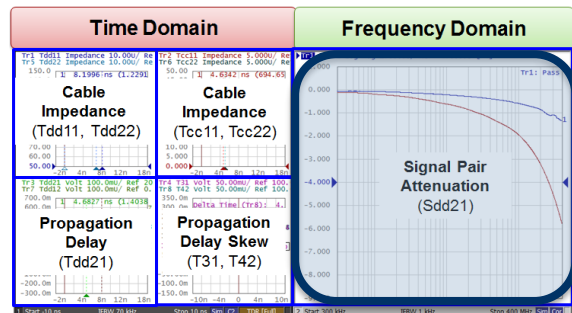


TDR with 200 ps (10-90%) rise time



USB 2.0 Cable/Connector Compliance Test

Signal Pair Attenuation High/Full-Speed

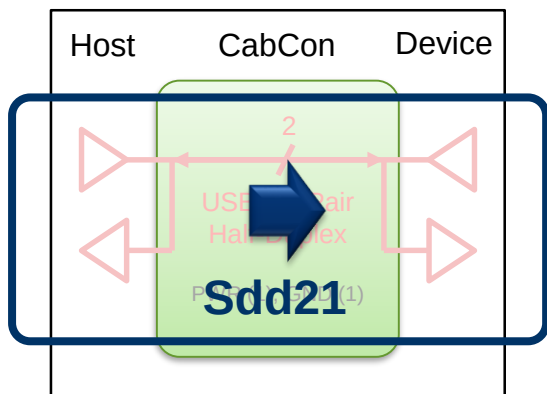
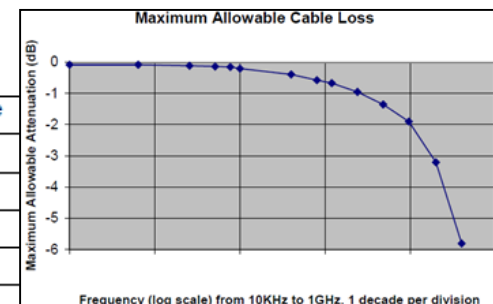


• Insure that adequate signal strength is presented to the receiver to maintain a low error rate

• Must not exceed the loss figure and graph shown below

Table 7-6. Maximum Allowable Cable Loss

Frequency (MHz)	Attenuation (maximum) dB/cable
0.064	0.08
0.256	0.11
0.512	0.13
0.772	0.15
1.000	0.20
4.000	0.39
8.000	0.57
12.000	-0.67 — 0.76 (*1)
24.000	0.95
48.000	1.35
96.000	1.9
200.00	3.2
400.00	5.8



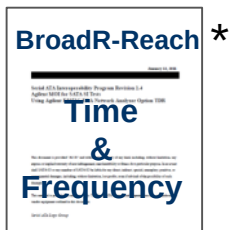
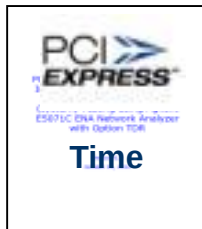
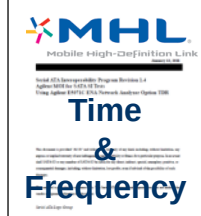
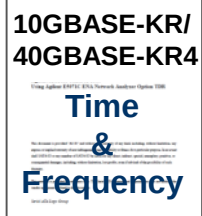
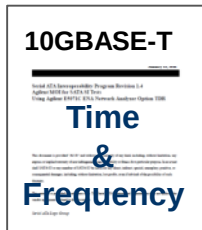
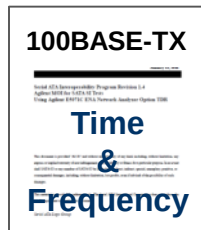
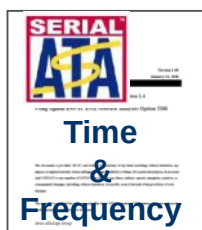
(*1) Errata for "USB Revision 2.0 April 27, 2000" as of May 28, 2002



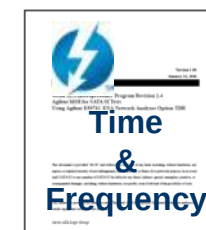
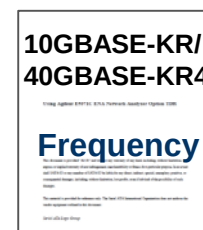
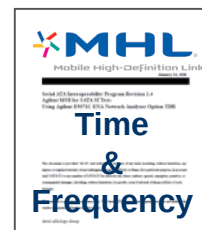
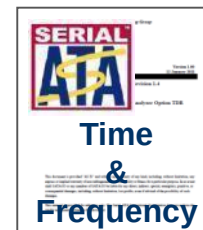
ENA Option TDR Compliance Test Solution

Certified MOIs available at www.keysight.com/find/ena-tdr_compliance

Cable/Connector/Interconnect



Transmitter/Receiver Impedance (Hot TDR/RL)



USB 2.0 Cable/Connector Compliance Test Solution

Summary



ENA Option TDR Cable/Connector Compliance Testing Solution is

- **One-box solution** which provides complete characterization of high speed digital interconnects (time domain, frequency domain, eye diagram)
- 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



Questions?

Keysight VNA Solutions

Performance



FieldFox

Handheld RF Analyzer
5 Hz to 4/6 GHz



E5061B

NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz



E5071C

World's most popular economy VNA
9 kHz to 4.5, 8.5 GHz
300 kHz to 20.0 GHz



E5072A

Best performance ENA
30 kHz to 4.5, 8.5 GHz

ENA Series



PNA

Performance VNA
10 M to 20, 40, 50, 67, 110 GHz
Banded mm-wave to 2 THz



PNA-L

World's most capable value VNA
300 kHz to 6, 13.5, 20 GHz
10 MHz to 40, 50 GHz



PNA-X receiver

8530A replacement



PNA-X, NVNA

Industry-leading performance
10 M to 13.5/26.5/43.5/50/67 GHz
Banded mm-wave to 2 THz



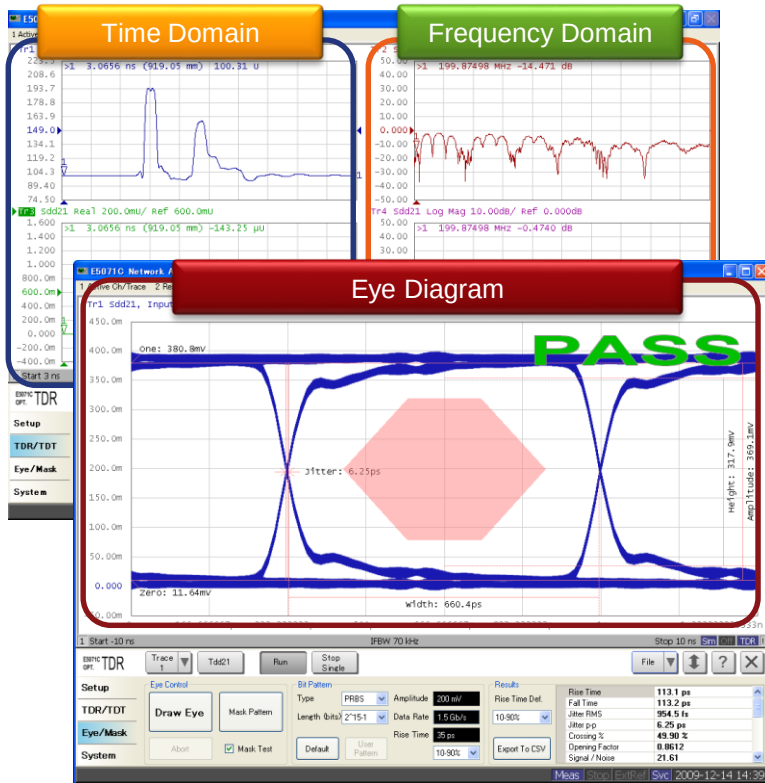
Mm-wave solutions

Up to 2 THz

PNA Series

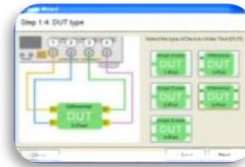
What is ENA Option TDR?

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



ESD Robustness

What is ENA Option TDR?

[Video]

Keysight ENA Option TDR

Changing the world of Time Domain Reflectometry (TDR) Measurements

- www.youtube.com/watch?v=hwQNllyyJ5hI&list=UUAJAJd97CfnCehC4jZAfkxQ&index=20&feature=plcp
- www.keysight.com/find/ena-tdr



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 Keysight's ENA Option TDR Time Domain Measurement using a NIST Traceable Standard (5990-5728EN)

•Method of Implementation (MOI) for High Speed Digital Standards

www.keysight.com/find/ena-tdr_compliance

