Agilent Technologies *PCI Express® (PCIe®)*

Test Solution Overview Using the Agilent E5071C ENA Option TDR

Last update: 2013/04/24 (HK)

Purpose

• This slide will show how to make measurements of PCI Express® Compliance Testing by using the Agilent E5071C ENA Option TDR.

Agilent Digital Standards Program

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

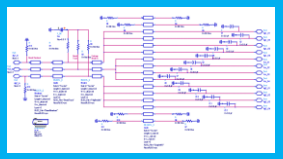
- Joint Electronic Devices Engineering Council (JEDEC)
- PCI Special Interest Group (PCI-SIG®)
- Video Electronics Standards Association (VESA)
- Serial ATA International Organization (SATA-IO)
- USB-Implementers Forum (USB-IF)
- Mobile Industry Processor Interface (MIPI) Alliance
- Optical Internetworking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

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

Our customers test with highest confidence and achieve compliance faster

PCIe – Agilent Total Solution

Physical layer – interconnect design



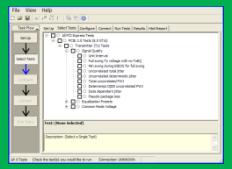
ADS design software

86100D DCA-J/TDR

E5071C ENA option TDR

Physical layer-transmitter test

90000 X-Series oscilloscope



N5393C PCI Express electrical compliance software

86100CU-400 PLL and Jitter Spectrum Measurement SW

Physical layer-receiver test

J-BERT N4903B –complete receiver tolerance

N4916B 4-tap de-emphasis signal converter

N4880A Clock Multiplier

N5990A automated compliance and device characterization test software

Data link/transaction layer

- U4301A Protocol Analyzer
- U4305A Exerciser
- Protocol Test Card
- Multiple probes with ESP technology

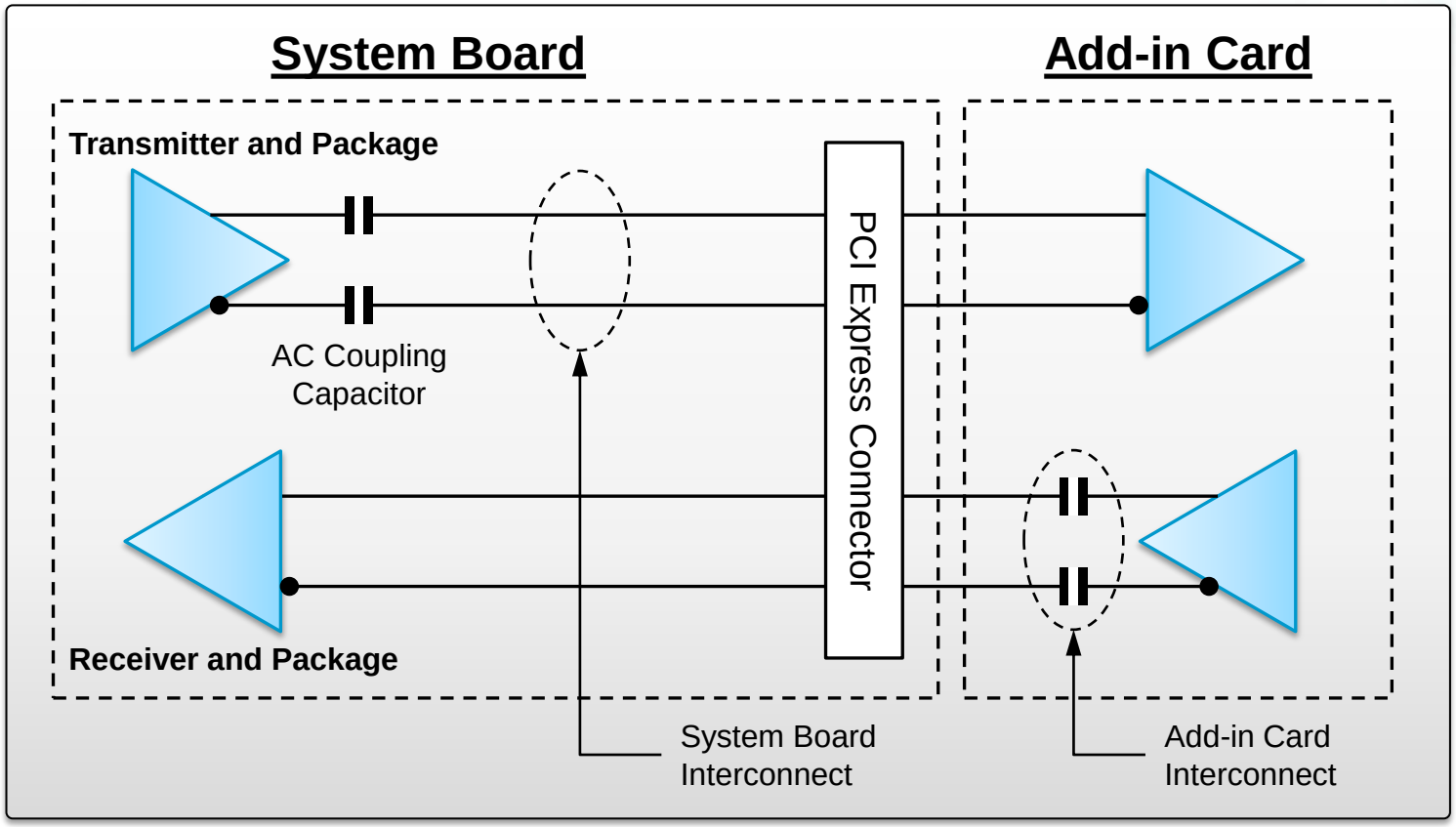
Industry's lowest scope noise floor/sensitivity and trigger jitter

DSA-X Series & Q Series

Automated compliance software – accurate, efficient and consistent

X1 through x16 Analysis and Exerciser support, with industry's only ESP probing technology

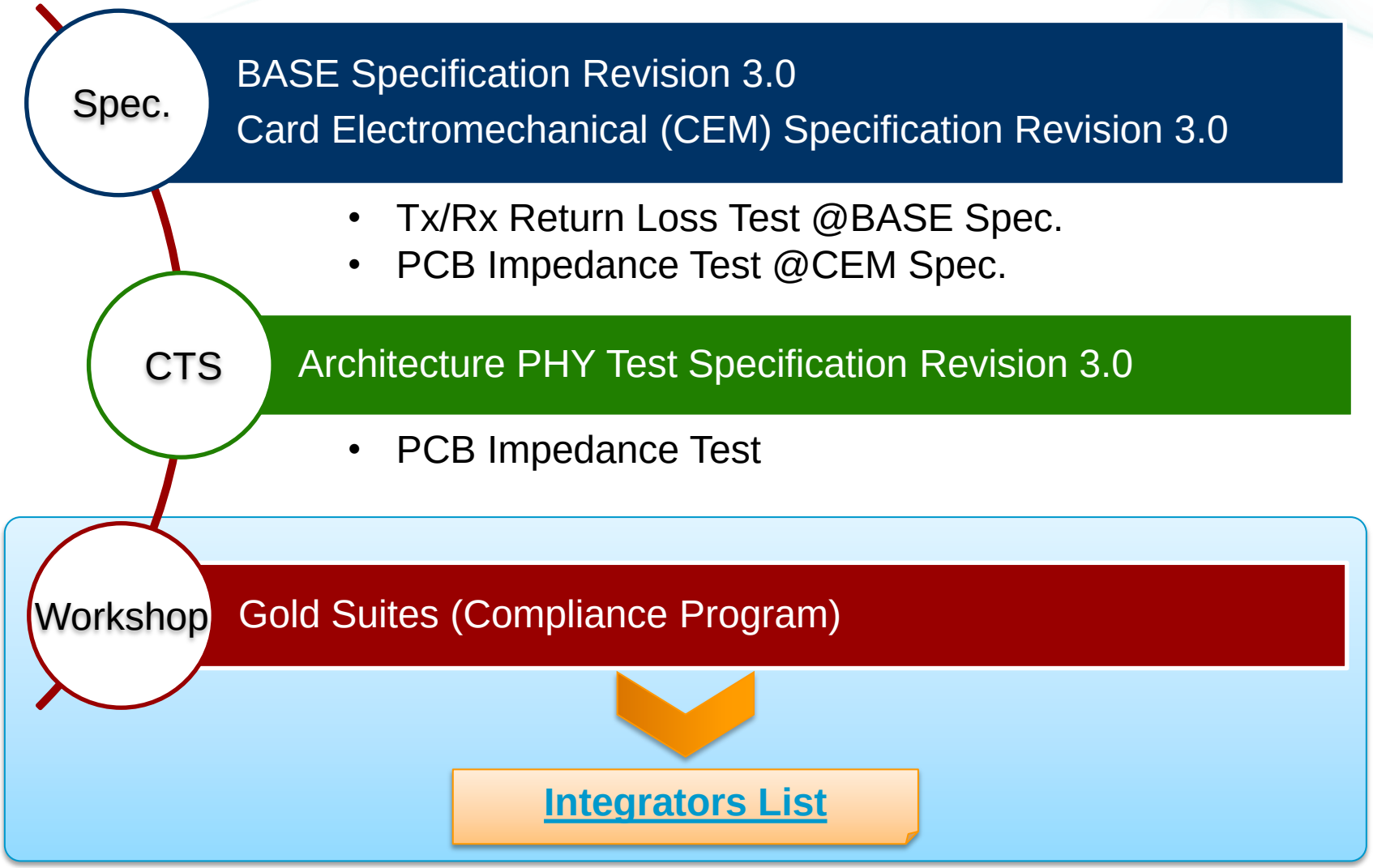
PCIe PHY Electrical Architecture



Full-duplex for each lane (Tx and Rx)

PCIe 3.0 Specs and Compliance Program Overview

with PHY Electrical Test Items



PCIe 3.0 Test Solution

Solution Overview using E5071C ENA Option TDR

•PCIe 3.0 compliance testing requires parametric measurements in both time and frequency domains

Traditional Solution

Frequency Domain
•Tx/Rx Return Loss Test (Sdd11/22)

Vector Network Analyzer (VNA)

Time Domain
•PCB Impedance Test (TDR) for Add-in card and System board

TDR Scope

New Solution

•**ALL** parameters can be measured with **ENA Option TDR**

One-box Solution !!

PCIe 3.0 PCB Impedance Test Solution

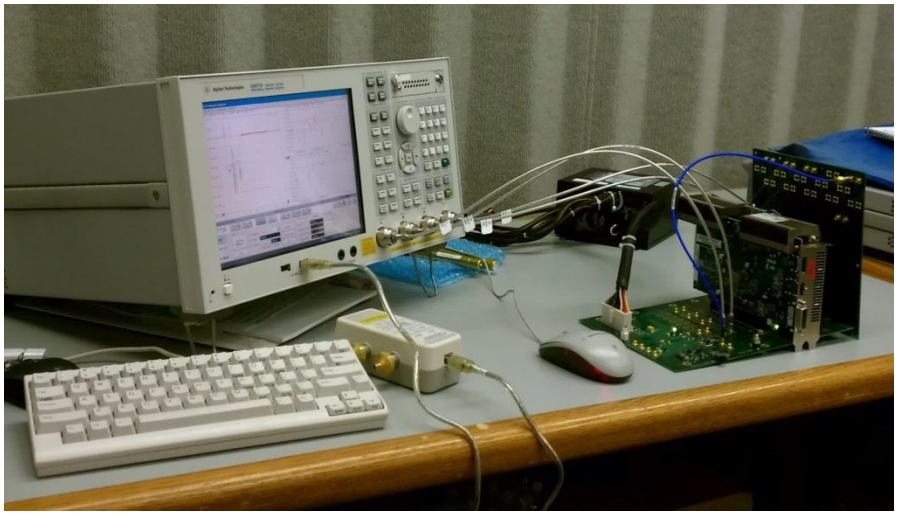
Measurement Parameters

◆PCB Impedance Test

	2.5 GT/s	5 GT/s	8 GT/s
Differential Impedance	N/A	68 - 105 Ω	70 - 100 Ω

This applies to both the add-in card and the system board.

Measurement example of Add-in card PCB trace impedance test:

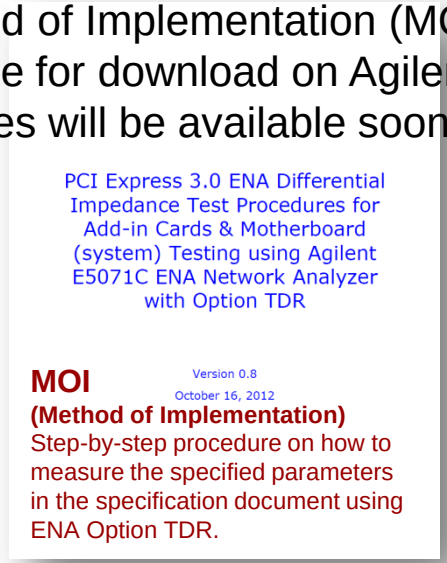


PCIe 3.0 PCB Impedance Test Solution

ENA Option TDR Solution

- ENA Mainframe
  - E5071C-4K5: 4-port, 300kHz to 20GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module
  - N4433A for E5071C-4K5

- Method of Implementation (MOI) document available for download on Agilent.com, and state files will be available soon.



www.agilent.com/find/ena-tdr_compliance

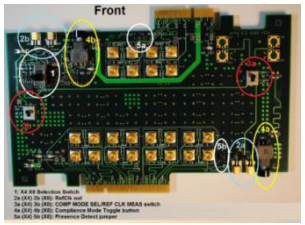
www.agilent.com/find/ena-tdr_pcie-pcb

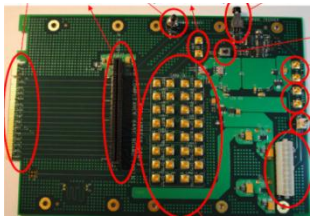
PCI Express Test Fixtures

Specialized test fixtures available from the PCI-SIG:

- The **Compliance Load Board (CLB)** is used for testing platforms.
- The **Compliance Base Board (CBB)** is used for testing add-in cards.

The following links provide copies of the draft CLB 3.0 Test Fixture User's Document and the CBB 3.0 Test Fixture User's Document. Go to the CLB and CBB ordering instructions for more information.

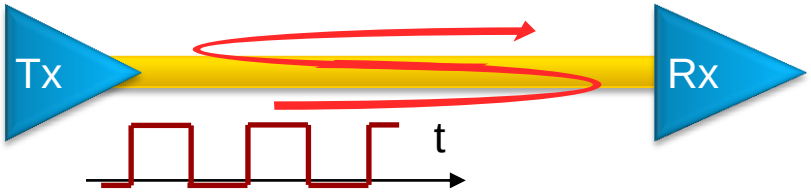




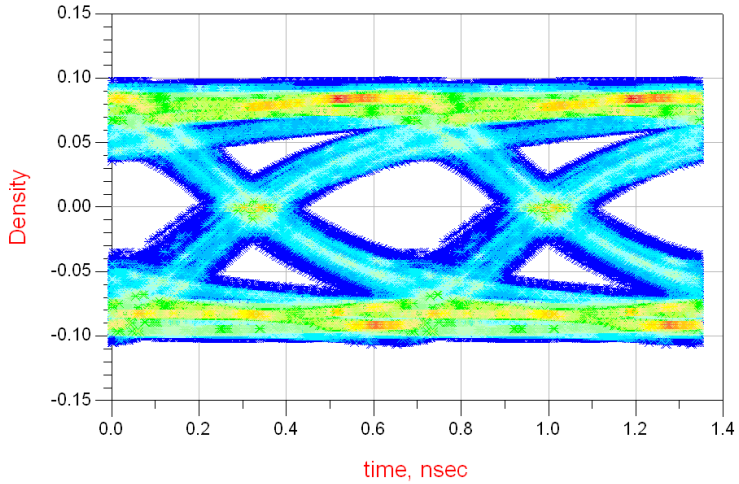
Importance of Tx/Rx Interface Characterization

◆**Why measure S-parameter and impedance on Tx/Rx device?**

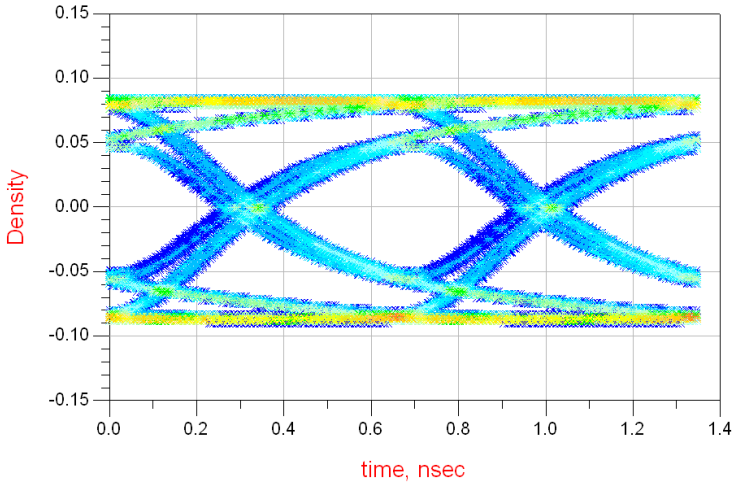
A portion of the transmitted signal is reflected from the receiver due to impedance mismatches. If the transmitter is not impedance matched, additional reflections occur, causing eye closure. For high speed digital system, Tx/Rx interface should be tested by S-parameter and Impedance.



◆**Transmitter Termination Effects (ADS simulation)**



Transmitter Impedance **NOT** Matched



Transmitter Impedance Matched

PCIe 3.0 Tx/Rx Return Loss Test Solution

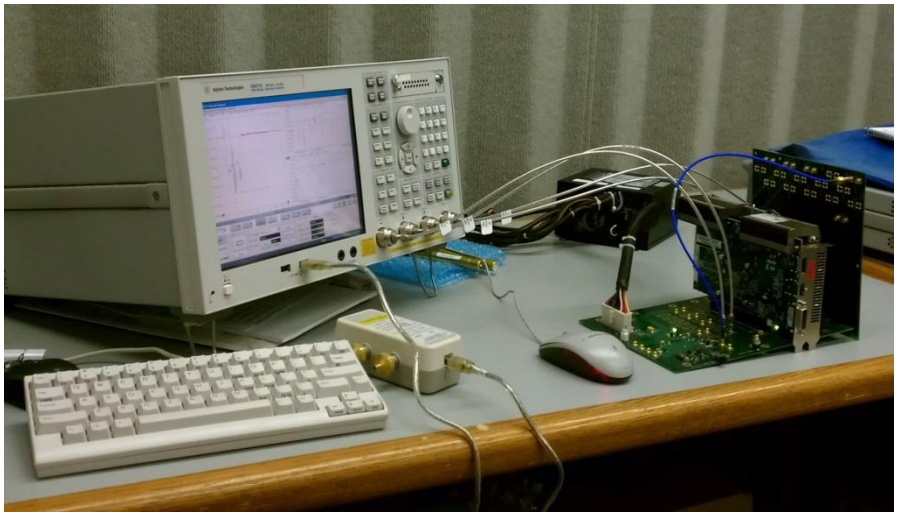
Measurement Parameters

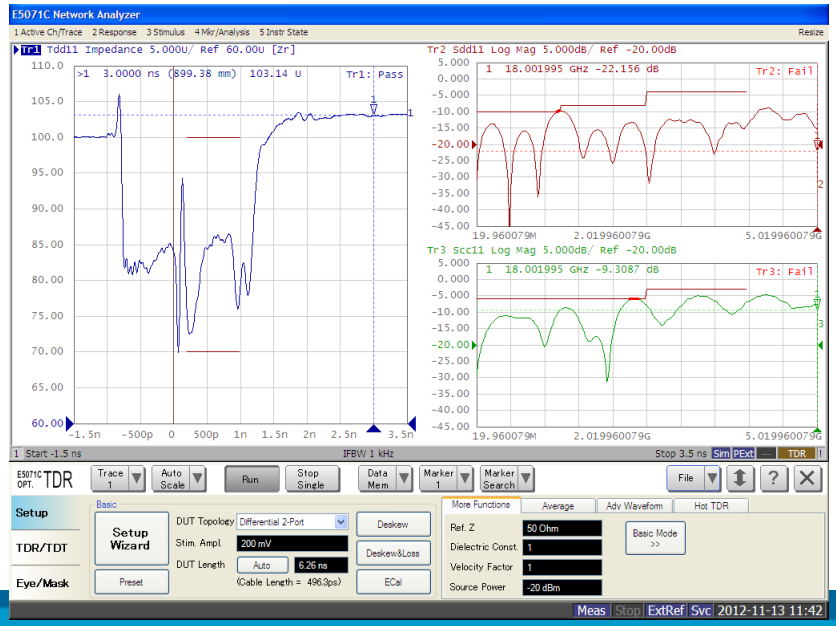
◆Tx/Rx Return Loss Test (BASE Spec.)

	2.5 GT/s	5 GT/s	8 GT/s
Differential Return Loss	-10 dB	-8 dB	-4 dB @Tx / -5 dB @Rx
Common-mode Return Loss	-6 dB		-3 dB

The DUT must be powered up and DC isolated, and its data+/data- outputs must be in the low-Z state at a static value.

Measurement example of Add-in card return loss test:





PCIe 3.0 Tx/Rx Return Loss Test Solution

ENA Option TDR Solution

- ENA Mainframe
  - E5071C-480/480: 4-port, 9kHz/100kHz to 8.5GHz
  - E5071C-4D5: 4-port, 300kHz to 14GHz
  - E5071C-4K5: 4-port, 300kHz to 20GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module
  - N4431B for E5071C-480/485
  - N4433A for E5071C-4D5/4K5

•Method of Implementation (MOI) document and state files will be available for download on Agilent.com

www.agilent.com/find/ena-tdr_compliance

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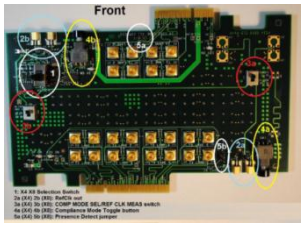
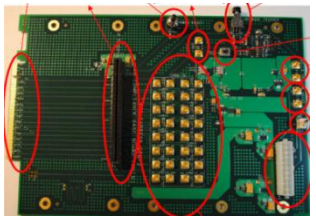




ENA Option TDR Compliance

One-box Solution for TDR/S-parameter Compliance Test

Certified MOIs

- Cable/Connector

SUPERSPEED USB CERTIFIED USB — Time & Frequency	DisplayPort — Time & Frequency	MHL Mobile High-Definition Link — Time & Frequency
SERIAL ATA — Time & Frequency	HDMI HIGH-DEFINITION MULTIMEDIA INTERFACE — Frequency	PCI EXPRESS — PCI Express 3.0 ENA Differential Impedance Test Procedures for Add-in Cards & Motherboard (system) Testing using Agilent E5071C ENA Network Analyzer — Time & Frequency

- Transmitter/Receiver (Hot TDR)

SERIAL ATA — Time & Frequency	mipi alliance — Time & Frequency

More Standards Currently Under Investigation

Test Centers Support ENA Option TDR

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

For more detail about compliance test solution by the ENA Option TDR, visit **www.agilent.com/find/ena-tdr_compliance**

PCIe 3.0 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?

PCI Express® Compliance Testing

http://www.pcisig.com/specifications/pciexpress/compliance/

The PCI-SIG provides PCI Express compliance tests that are utilized for testing PCI Express systems and add-in cards at each PCI-SIG Compliance Workshop. The PCI-SIG also publishes an Integrators List. For a PCI Express system, add-in card, or other device to be placed on the Integrators List, the system or device must pass interoperability and compliance testing, and the vendor must also submit a Product Listing Request Form for the system or device tested.

PCI Express Compliance Testing

There are five different test areas that make up PCI Express compliance testing.

- Electrical testing: Examines platform and add-in card signal quality.
- Configuration testing: Examines configuration space in PCI Express devices.
- Link protocol testing: Tests device behavior for link-level protocol.
- Transaction protocol testing: Tests device behavior for transaction level protocol.
- Platform BIOS testing: Tests platform BIOS ability to recognize and configure PCI Express devices.

For a summary of the tests that are utilized at PCI-SIG Compliance Workshops for testing PCIe 2.0 and PCIe 3.0 products please see the PCIe Workshop Testing Summary (77kb pdf)

PCI Express® 3.0 Integrators List

http://www.pcisig.com/developers/compliance_program/integrators_list/pcie_3.0

Another valuable benefit of the Compliance Program is inclusion on the PCI-SIG Integrators List. This list includes all products that have successfully completed the rigorous testing procedures of the Compliance Workshop. Inclusion on the list is only available to PCI-SIG member companies and cannot be used for individual marketing programs. However, many companies do refer to the list when making company-to-company purchases.

For a product to be listed on the Integrators List below, it must satisfy the following criteria:

- Demonstrated interoperability (80% pass) at the Compliance Workshop.
- Demonstrated compliance to the applicable compliance test suite at the same Compliance Workshop.
- Completed Product Listing Request Form for the product tested, submitted to PCI-SIG following the Compliance Workshop. Submit forms to PCI-SIG Tech Support.

This list will be updated after every Compliance Workshop.

Agilent VNA Solutions

Performance

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

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

Mm-wave solutions
Up to 2 THz

PNA-X receiver
8530A replacement

PNA Series

E5072A
Best performance ENA
30 kHz to 4.5, 8.5 GHz

E5071C
World's most popular economy VNA
9 kHz to 4.5, 8.5 GHz
300 kHz to 20.0 GHz

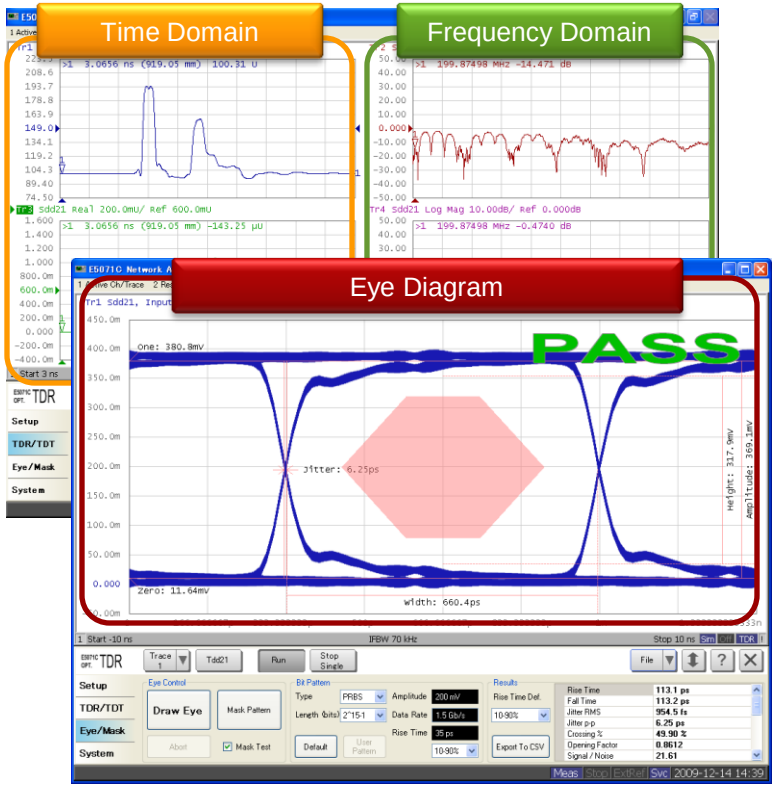
E5061B
NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz

ENA Series

FieldFox
Handheld RF Analyzer
5 Hz to 4/6 GHz

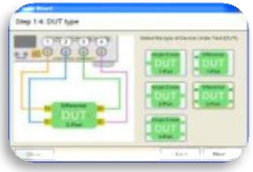
What is ENA Option TDR?

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

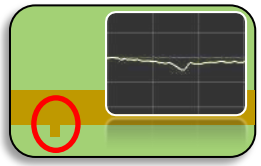


3 Breakthroughs

for Signal Integrity Design and Verification



Simple and Intuitive Operation



Fast and Accurate Measurements

ESD Robustness

What is ENA Option TDR?

[Video]

Agilent ENA Option TDR

Changing the world of Time Domain Reflectometry (TDR) Measurements

- www.youtube.com/watch?v=hwQNlyyJ5hI&list=UUAJAjd97CfnCehC4jZAfkxQ&index=20&feature=plcp
- www.agilent.com/find/ena-tdr

Additional Resources

•ENA Option TDR Reference Material

www.agilent.com/find/ena-tdr

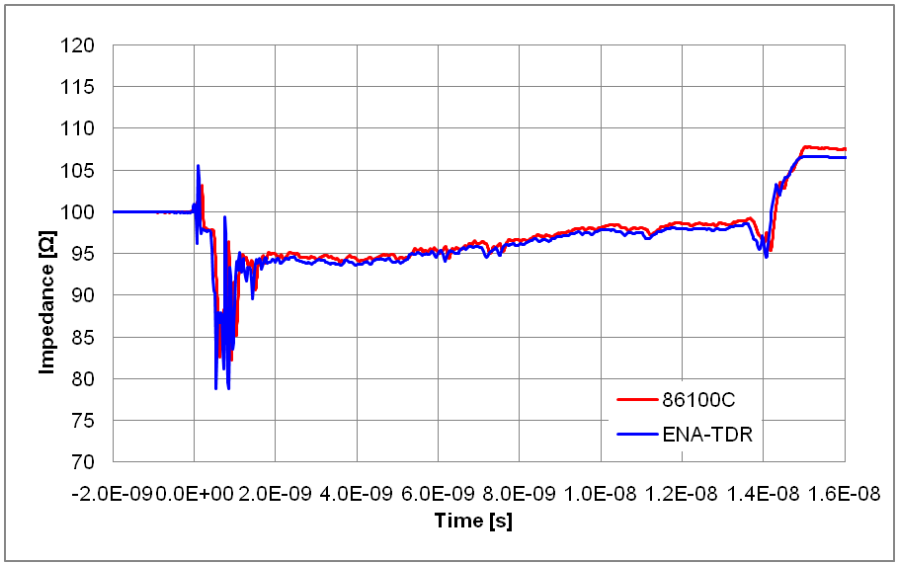
- Technical Overview (5990-5237EN)
- Application Notes
  - Correlation between TDR oscilloscope and VNA generated time domain waveform (5990-5238EN)
  - Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope (5990-5446EN)
  - Effective Hot TDR Measurements of Active 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)

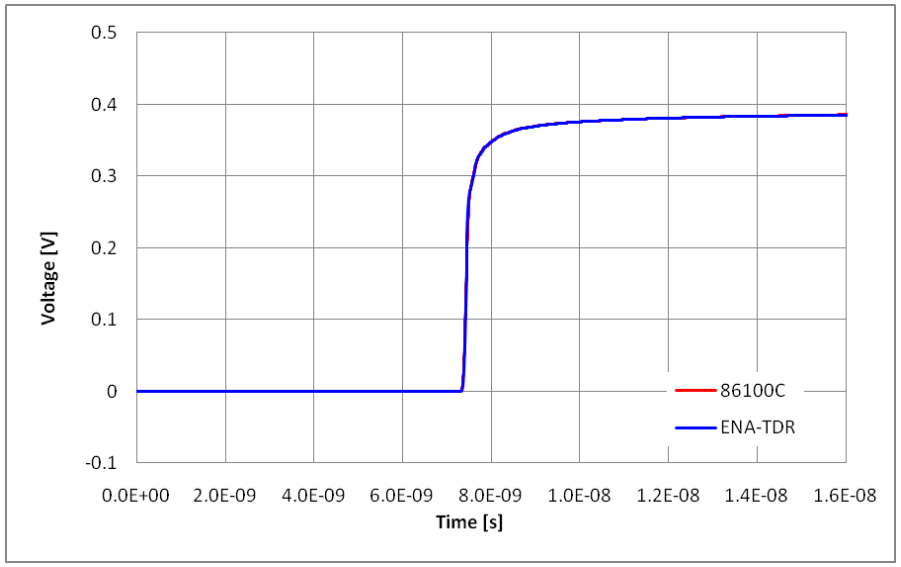
•Method of Implementation (MOI) for High Speed Digital Standards

www.agilent.com/find/ena-tdr_compliance

Measurement Correlation
TDR/TDT

- DUT: USB3.0 Cable
- 50 ps rise time (20-80%)

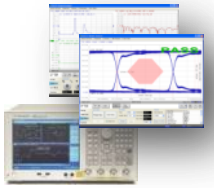




Measurement Correlation

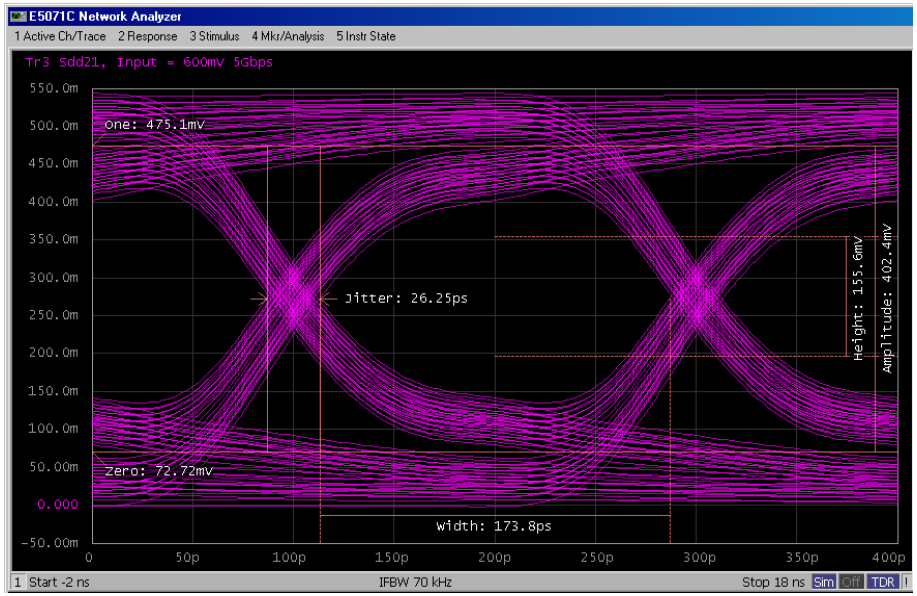
Eye Diagram

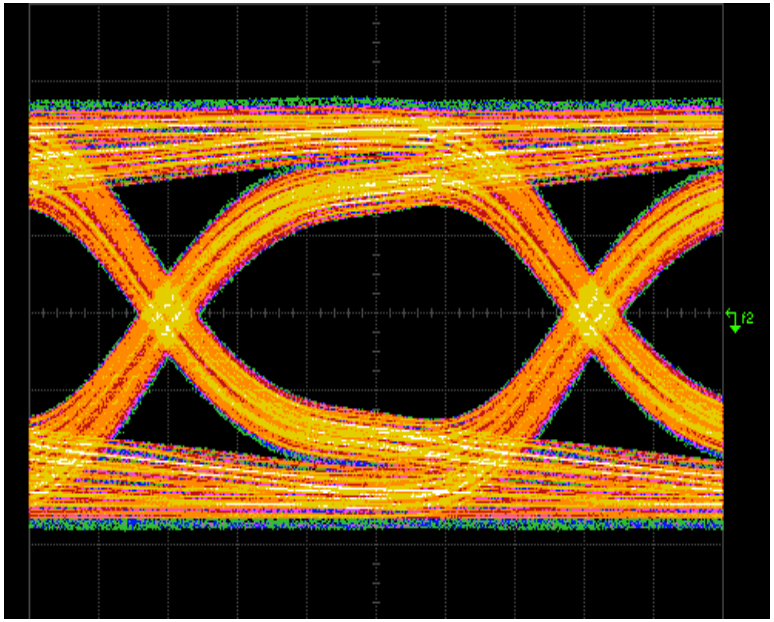
- DUT: USB3.0 Cable
- PRBS (2^7-1) @ 5 Gbps



ENA Option TDR
(simulated)

N4903B + 86100C
(live)





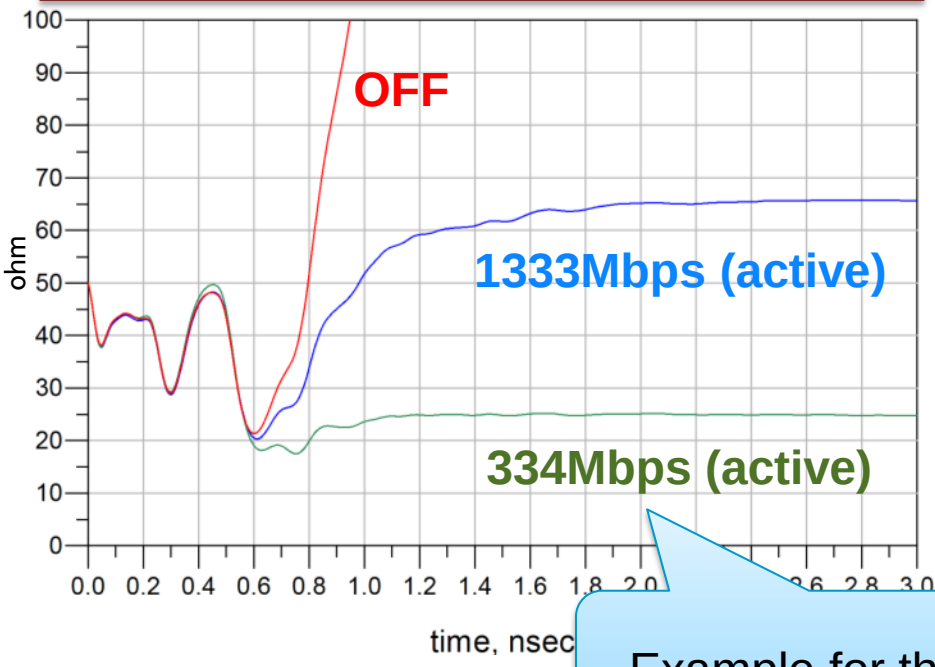
Hot TDR Measurements

Why Measure?

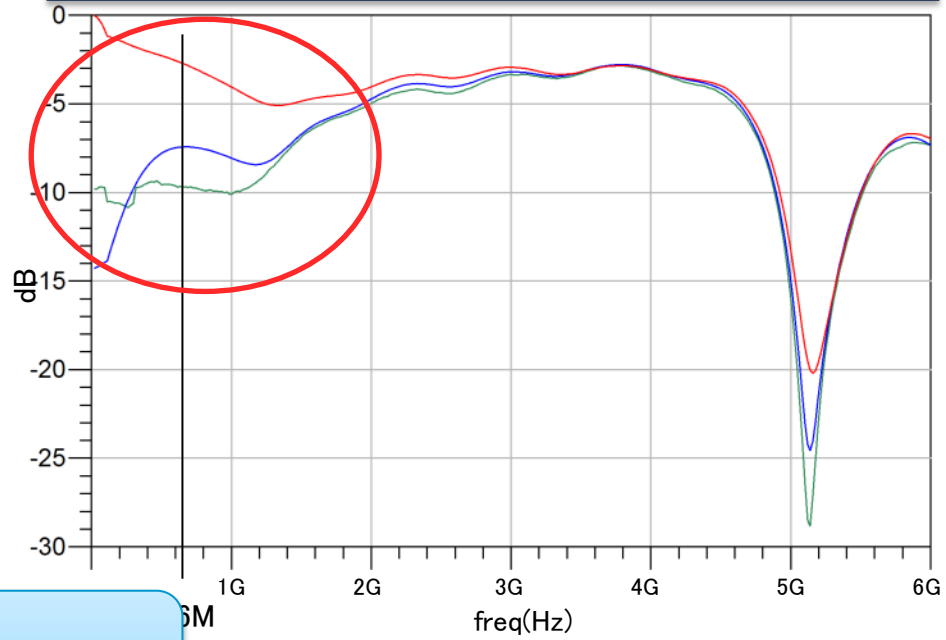
- **Hot TDR** measurement is the impedance analysis of active devices under actual operation conditions.

- 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)



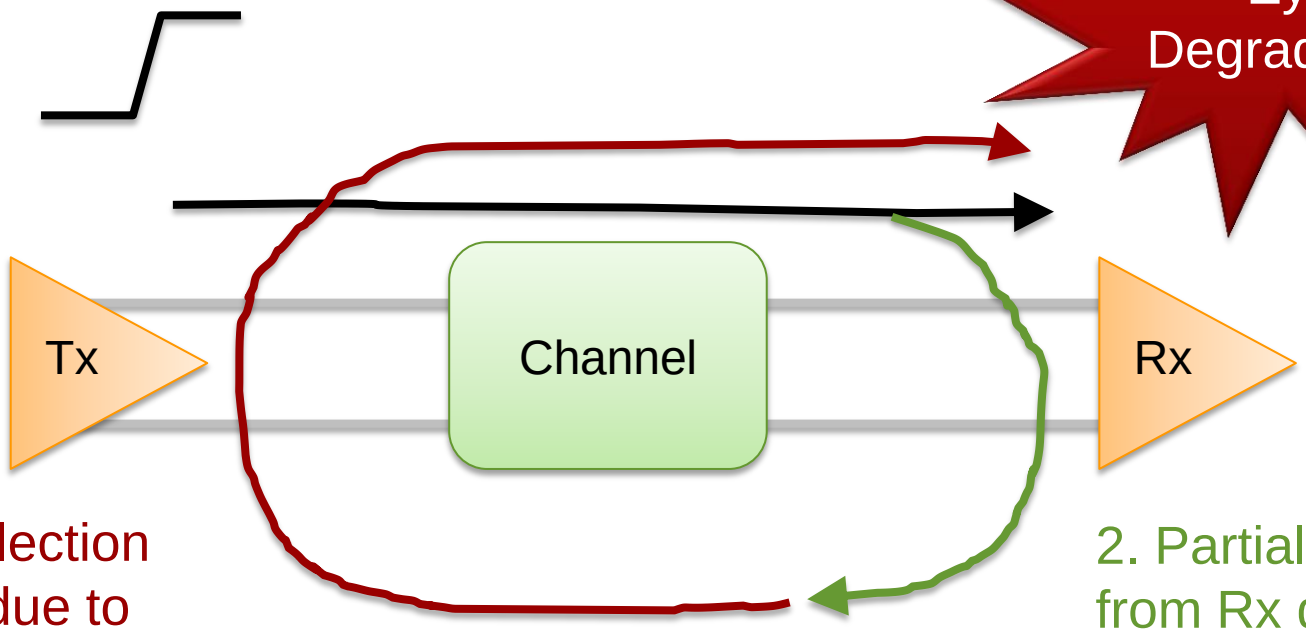
Example for the DDR

Hot TDR Measurements

Why Measure?

Multi-reflection effect to be more critical if bitrate increased.

1. Signal transmitted from Tx …



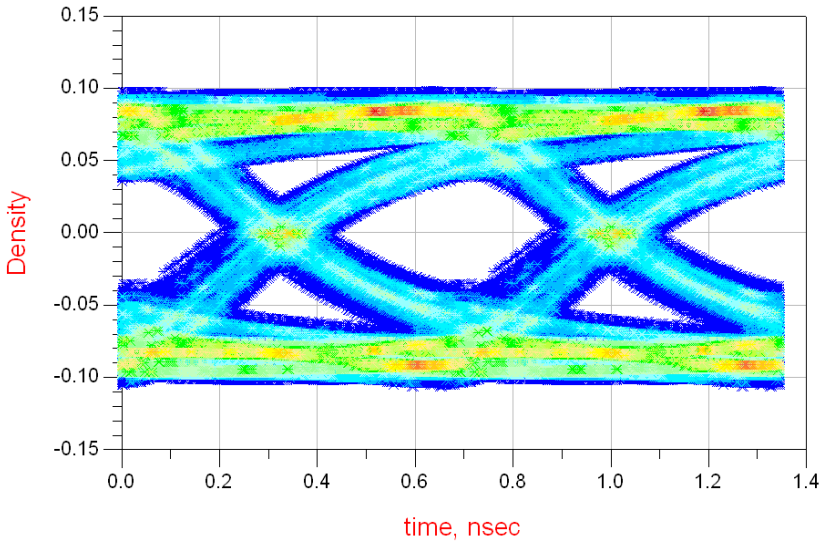
3. Re-reflection from Tx due to impedance mismatches ...

2. Partial reflection from Rx due to impedance mismatches …

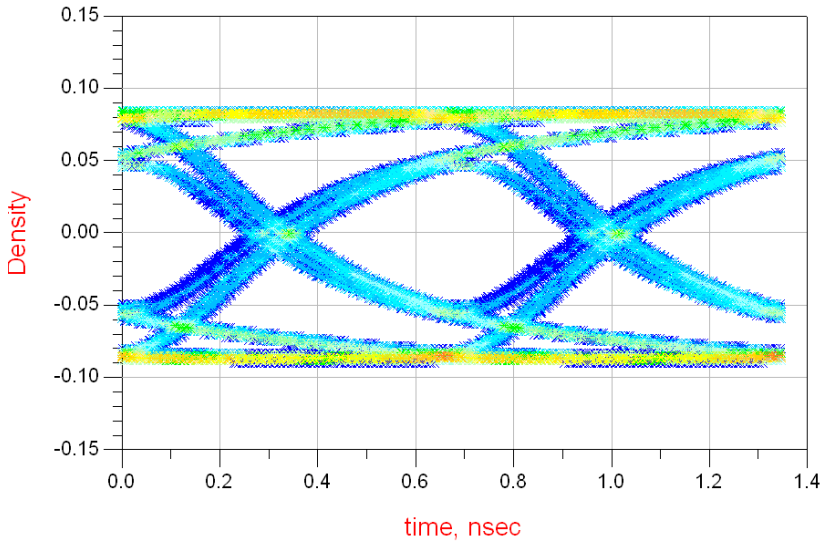
Hot TDR Measurements

Why Measure?

Source Termination Effects



Source Impedance **NOT** Matched

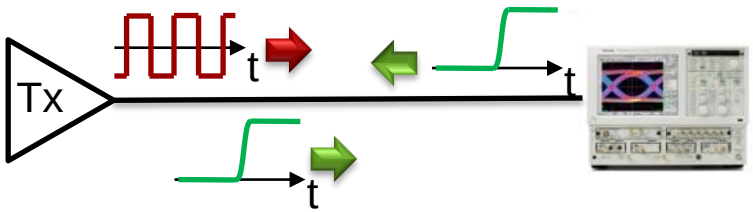


Source Impedance Matched

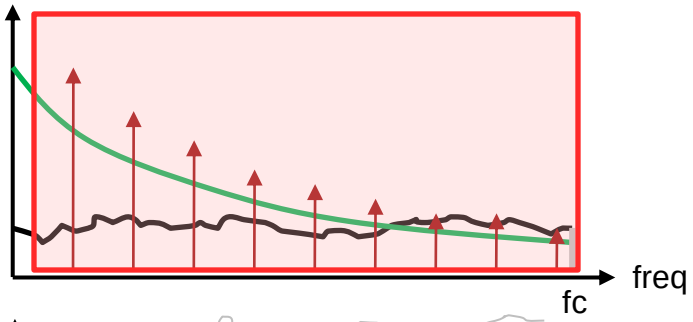
Advantages of ENA Option TDR for Hot TDR

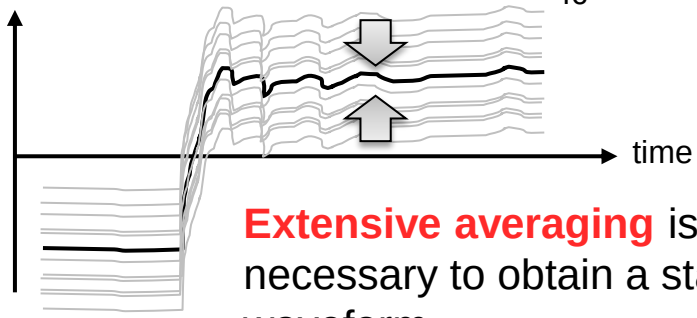
Fast and Accurate Measurements

TDR Scopes



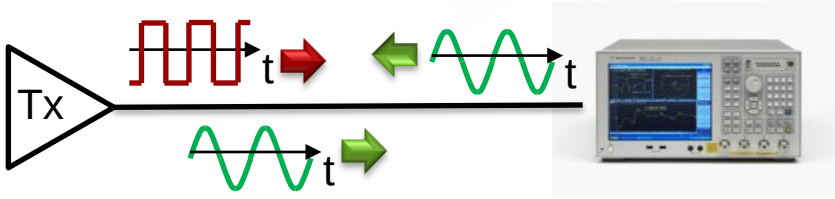
•**wideband receiver** captures all of the signal energy from the transmitter



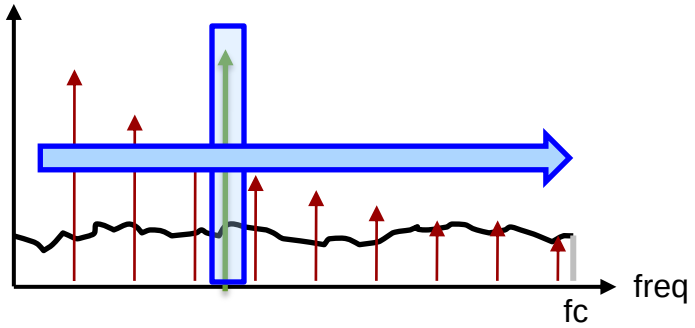


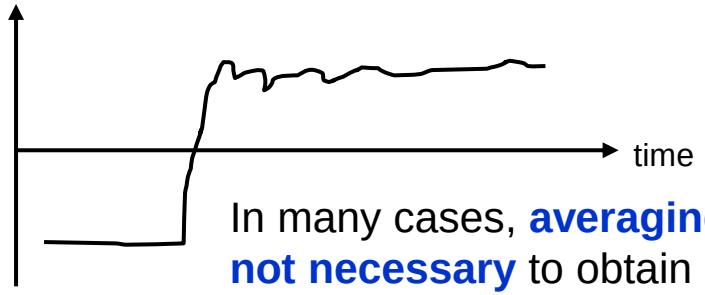
Extensive averaging is necessary to obtain a stable waveform.

ENA Option TDR



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





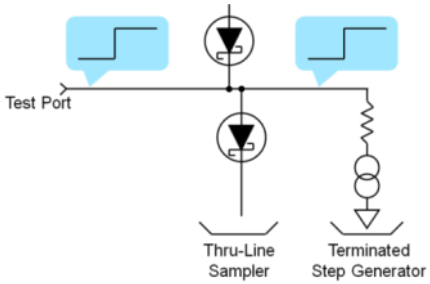
In many cases, **averaging is not necessary** to obtain a stable waveform.

Advantages of ENA Option TDR for Hot TDR

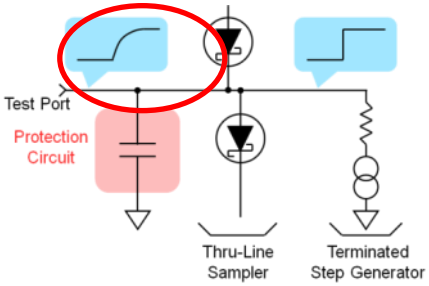
ESD Robustness

TDR Scopes

TDR scopes are sensitive to ESD.



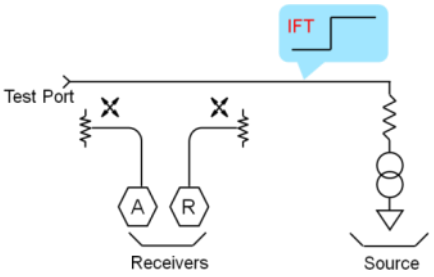
Implementing a protection circuit is difficult, because it will slow down the rise time of the step stimulus.

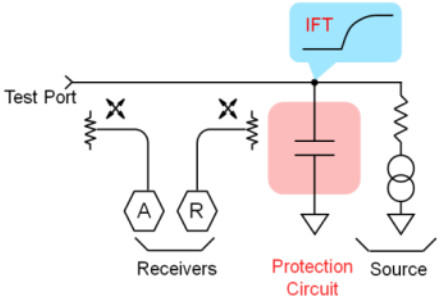


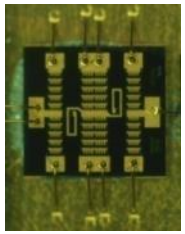
ENA Option TDR

ENA Option TDR has higher robustness against ESD, because protection circuits can be implement more easily.

ENA Option TDR measures the vector ratios of the transmitted and received signals. Therefore, the effects of the protection circuit will be canceled out.





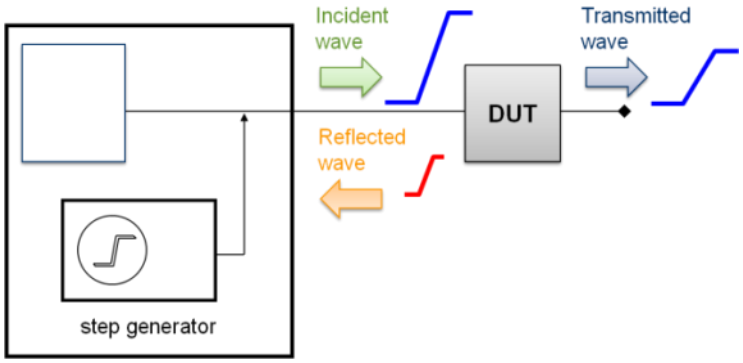


Proprietary ESD protection chip significantly increase ESD robustness, while at the same time maintaining **excellent RF performance** (22ps rise time for 20GHz models).

Advantages of ENA Option TDR for Hot TDR

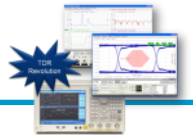
Simple and Intuitive Operation

TDR Scopes



TDR scopes normally has a fixed TDR step voltage.

Attenuators are connected to the instrument to decrease amplitude to a level compliant with requirements.



ENA Option TDR

ENA Option TDR has internal variable attenuators, to allow for flexibility in setting the stimulus level to comply with requirements.

•Option 23x/24x/26x/28x/43x/44x/46x/48x

Range[5, 6]	
9 kHz to 5 GHz	–55 to 10 dBm
5 GHz to 6 GHz	–55 to 9 dBm
6 GHz to 7 GHz	–55 to 8 dBm
7 GHz to 8.5 GHz	–55 to 7 dBm

•Option 2D5/2K5/4D5/4K5

Range[5, 6]	
300 kHz to 1 MHz	–85 to 8 dBm
1 MHz to 6 GHz	–85 to 10 dBm
6 GHz to 8 GHz	–85 to 9 dBm
8 GHz to 10.5 GHz	–85 to 7 dBm
10.5 GHz to 15 GHz	–85 to 3 dBm
15 GHz to 20 GHz	–85 to 0 dBm

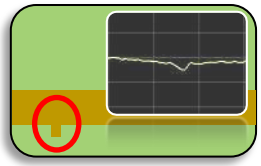
Advantages of ENA Option TDR for Hot TDR

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

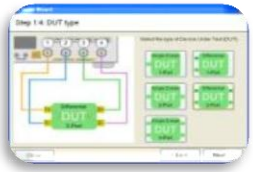
Comprehensive Signal Integrity Measurement Solution for Next Generation High Speed Digital Standards

3 Breakthroughs

for Hot TDR Measurements



Fast and Accurate Measurements



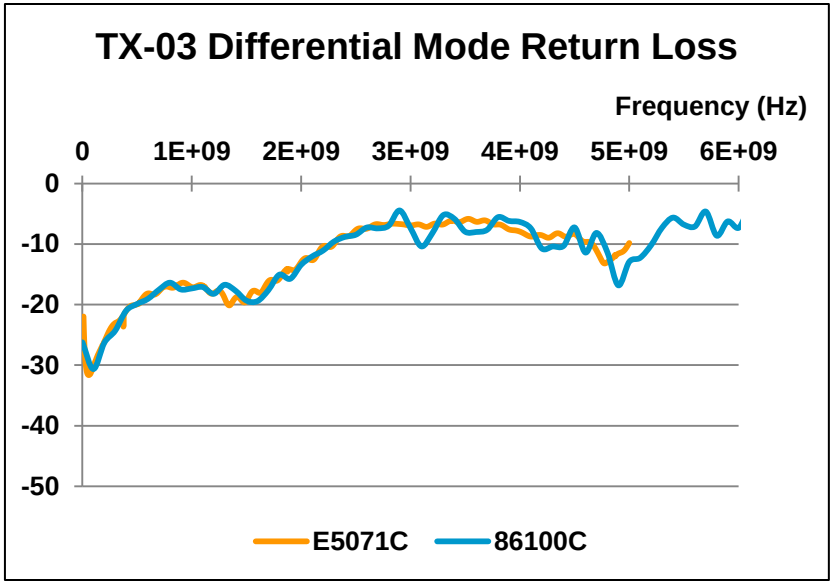
Simple and Intuitive Operation

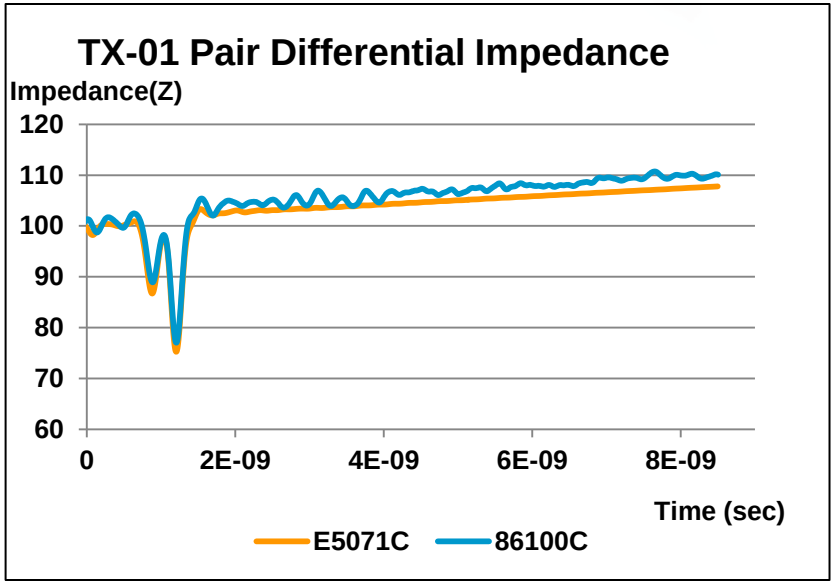
ESD Robustness

Advantages of ENA Option TDR

Fast and Accurate Measurements

Correlation between 86100C TDR oscilloscope and E5071C ENA Option TDR





Time (sec)