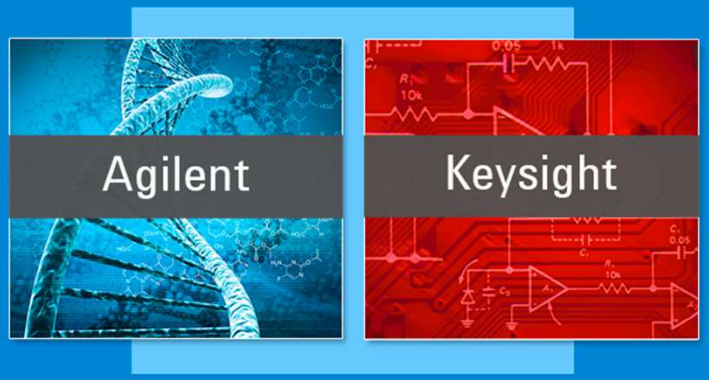
INTEGRIDAD DE SEÑAL

TDR/TDT basados en Analizador Vectorial de Redes



Héctor Carreño
Application Engineer
hector_carreno@agilent.com

Need help?
contactcenter_spain@agilent.com
91 631 3300

AGENDA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- TDR based on VNAs
- Advanced TDR for Signal Integrity
- Stressed Eye Diagram Analysis
- Hot TDR Measurements
- Compliance Support: MOIs
- Correlation Data among VNA and Sampling Scopes

AGENDA

KEYSIGHT TECHNOLOGIES

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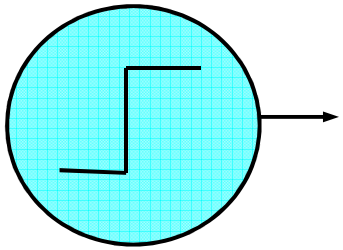
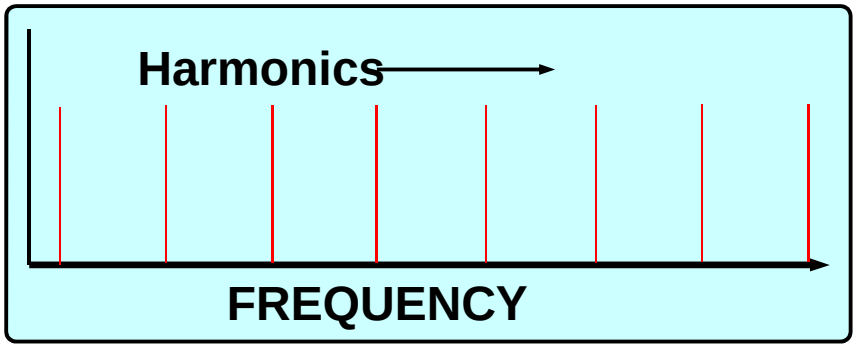
TDR vs Network Analyzer Sources

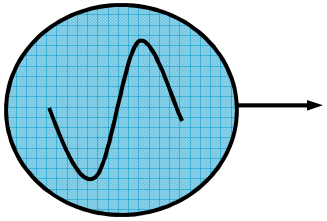
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

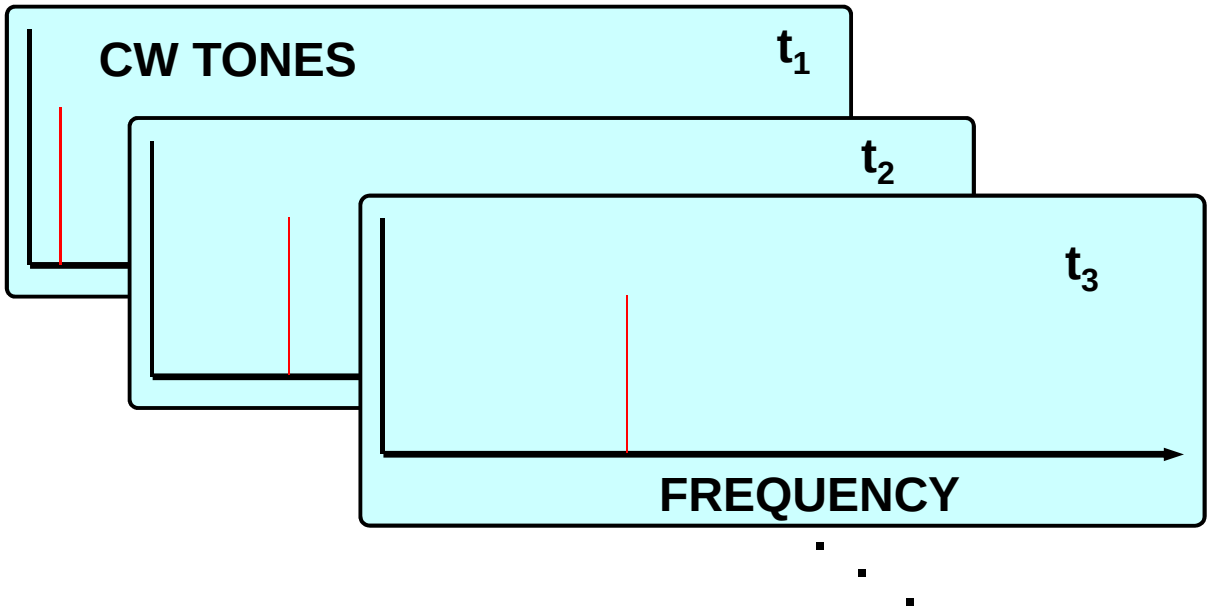


STEP / SNAP GENERATOR





SYNTHESIZED VNASOURCE



How the VNA measure the time domain ?

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

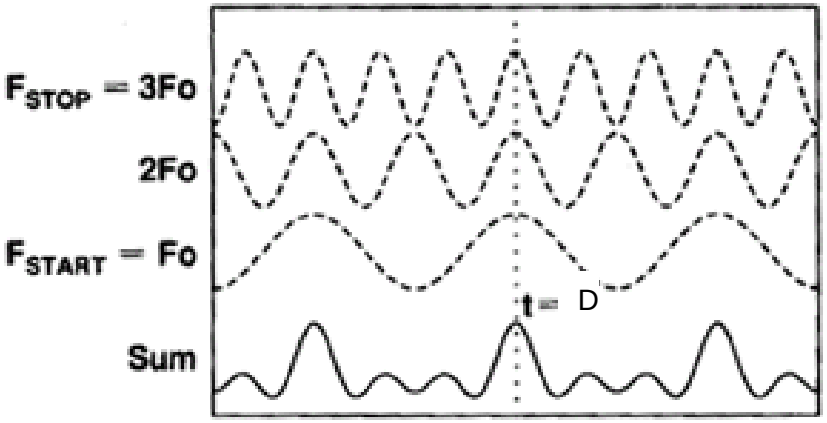


Fig.1

Infinite frequency component create an impulse!

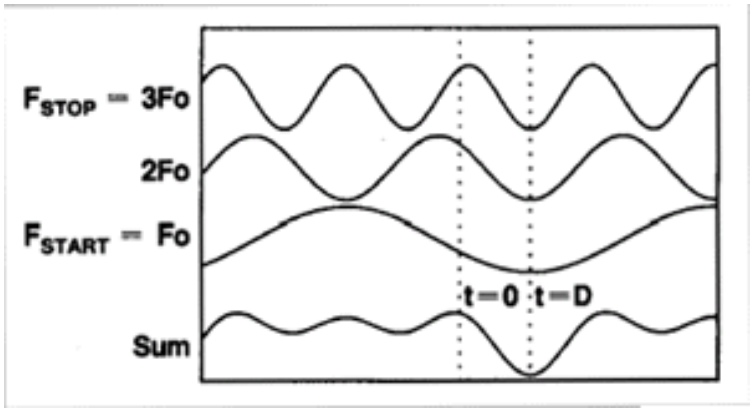


Fig.3

Open

Short

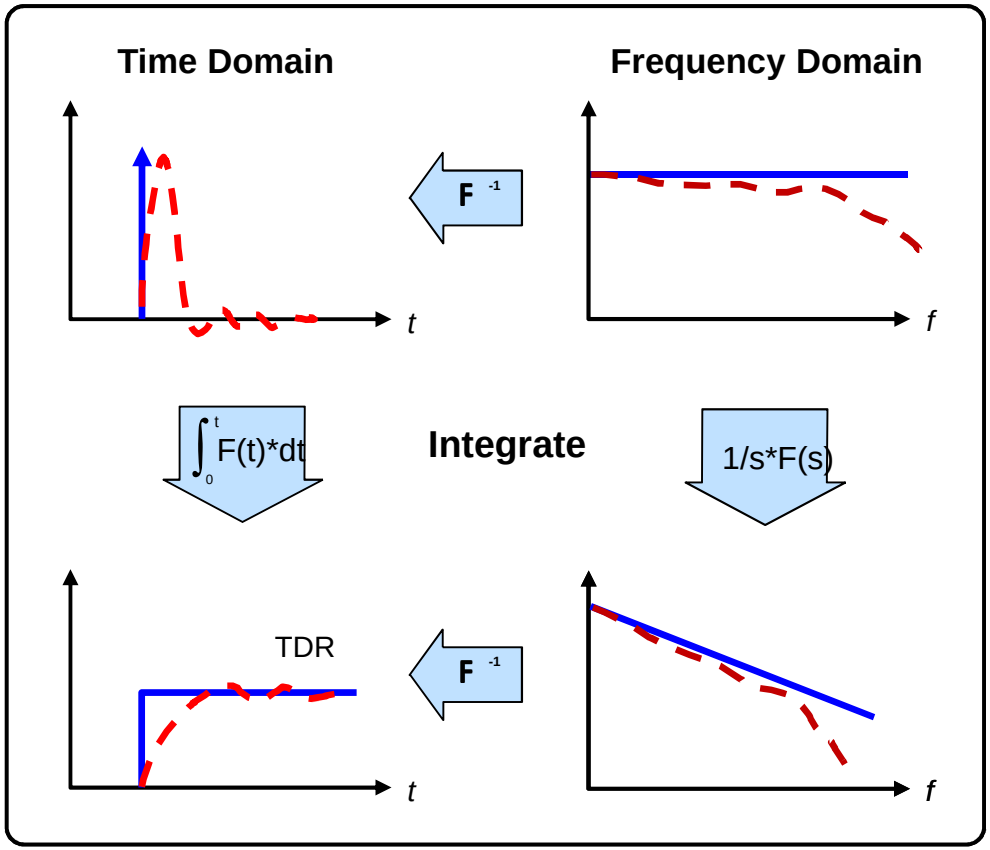
t=0 t=D

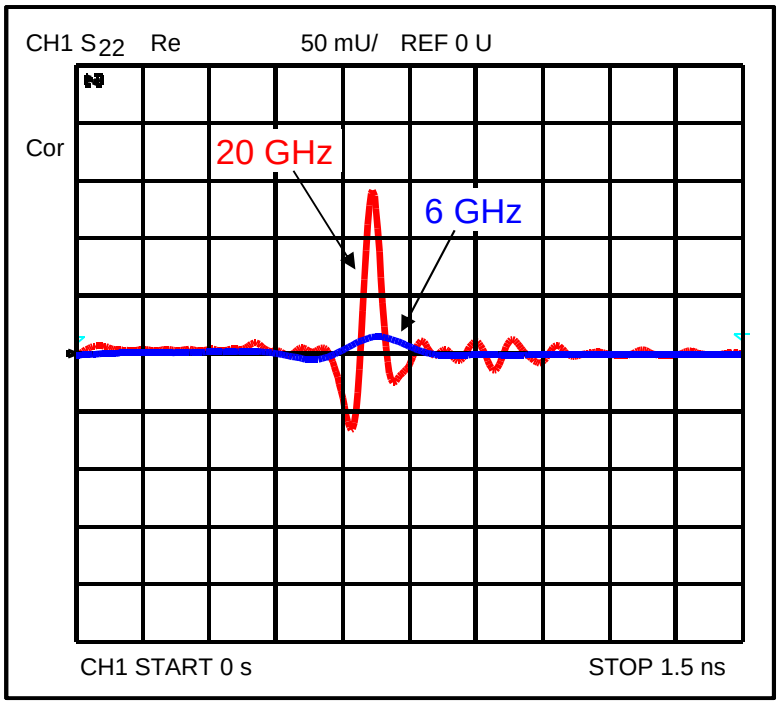
TDR Basics Using a Network Analyzer

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- DUT is stimulated by one “harmonic” at a time
- use inverse-Fourier transform to compute time-domain
- resolution inversely proportionate to frequency span

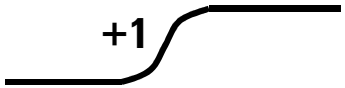




Analyzing Low Pass Reflections

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Impedance	Low Pass Step Response	Low Pass Impulse Response
Short		
Open		
$R > Z_0$		
$R < Z_0$		
Shunt C		
Series L		
Series C		
Shunt L		

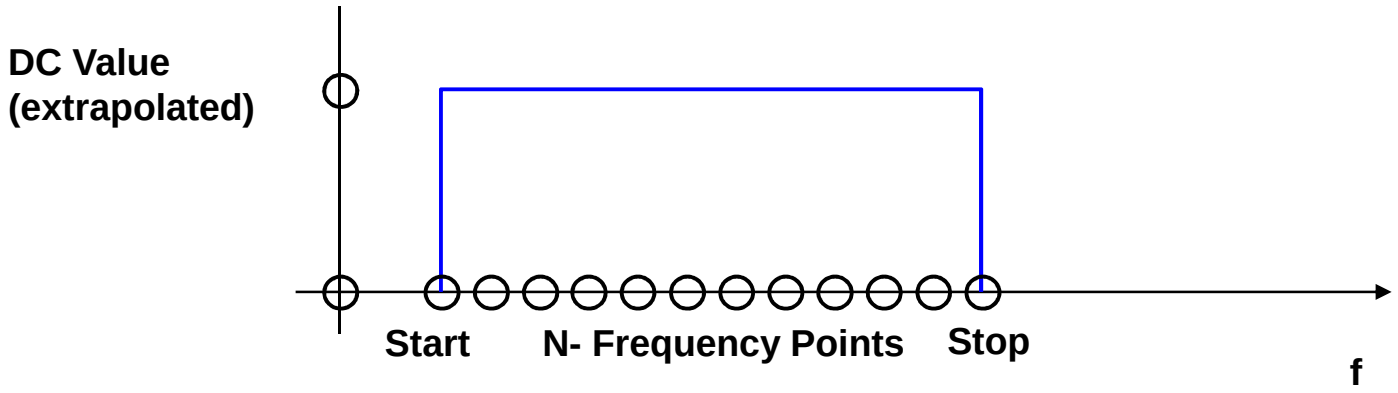
Low Pass Stimulus

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Require equally spaced points

Fstop = N * Fstart



To insure that these criteria are met, press the “**set frequency low pass**”

Time Domain Resolution

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Response resolution (see presentation_1)

- Ability to Resolve Closely Spaced Responses
- Dependent Upon Step Rise Time (10-90%) and Impulse Width (50%)

Range Resolution

- The Ability to Locate a Single Response in Time

$$\text{Range Resolution} = \frac{\text{Time Span}}{\text{Points} - 1}$$

To Increase Alias Free Range

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

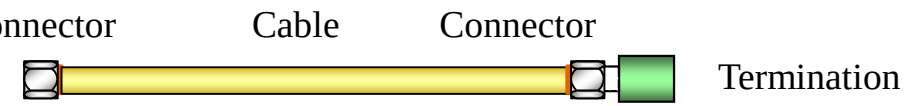
AFR = (Number Points -1)/Span

- Increase the number of points
- Decrease frequency span

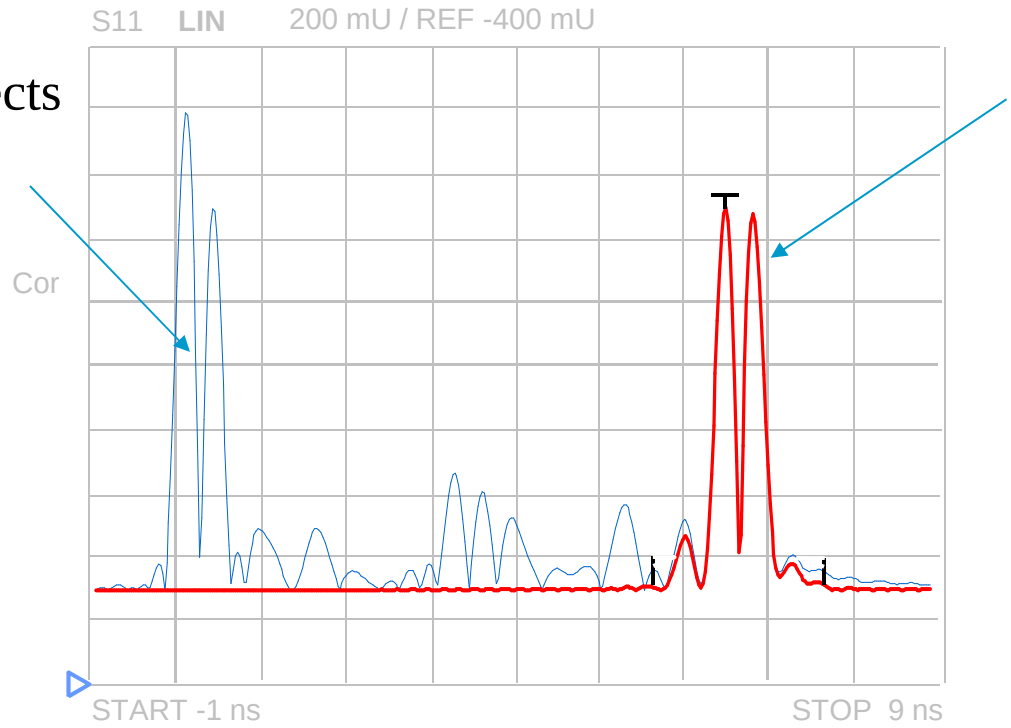
Gating : Time Domain

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years



Remove the effects of the Input Connector

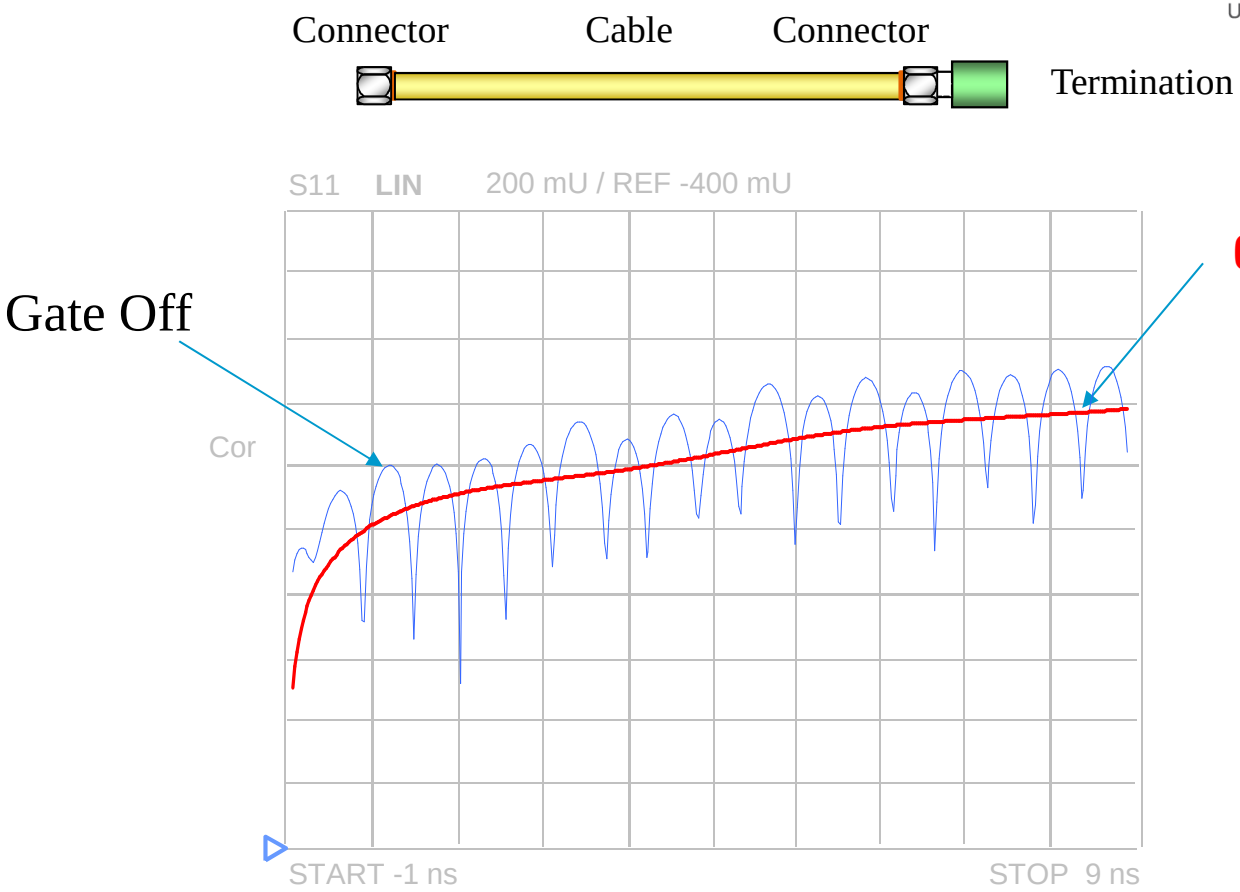


Gate On

Gating : Frequency Domain

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

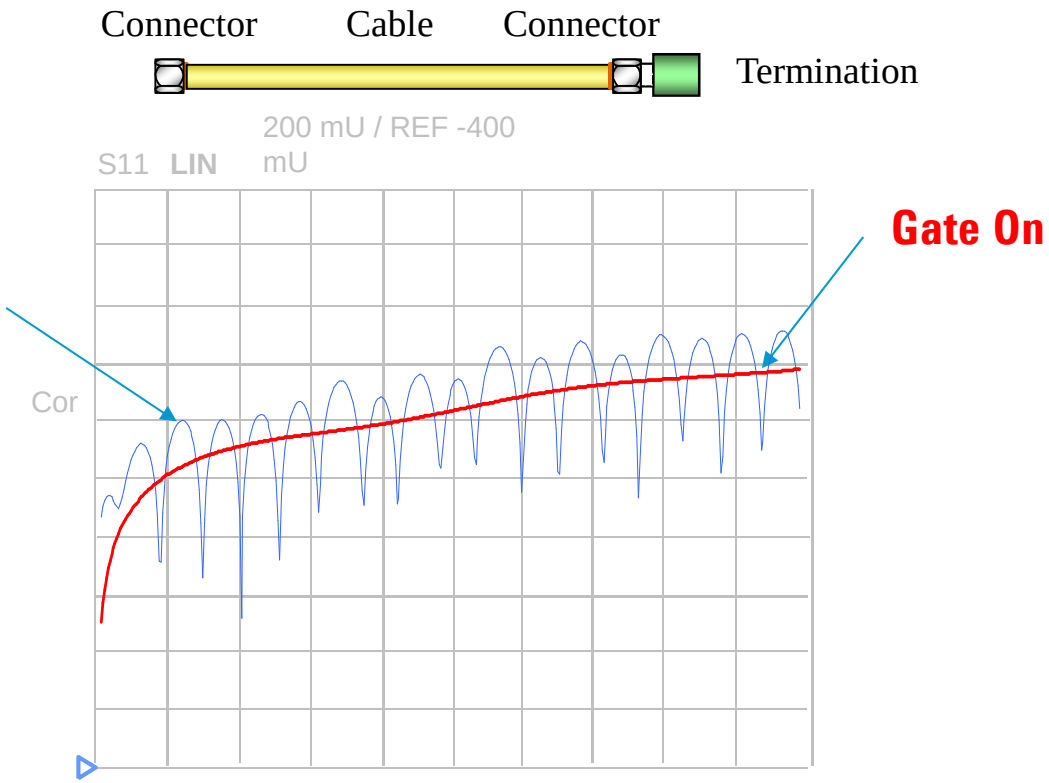


Use Gating to show the frequency response of the output connector & termination only

Demo: TDR based on VNA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years



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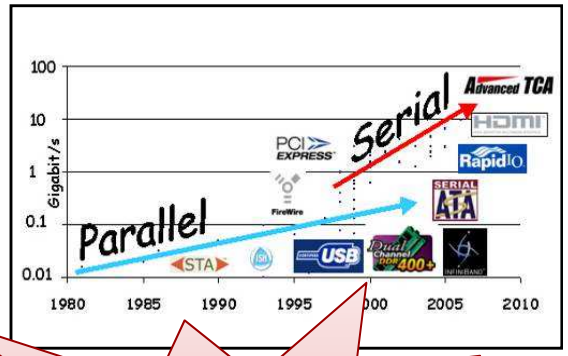
Technology Trends

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

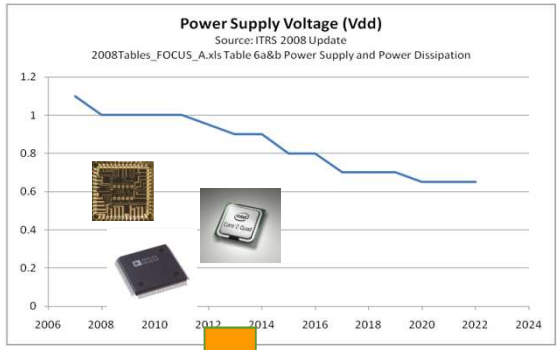
Data Rates Increase（>1Gbps）



Need to consider RF effects
(loss, crosstalk, EMI, etc…)

Smaller component spacing

Lower Power Supplies



SNR Degradation

Need for Fast, high dynamic range and Accurate measurements

Shorter design cycles

Simple and Intuitive operation

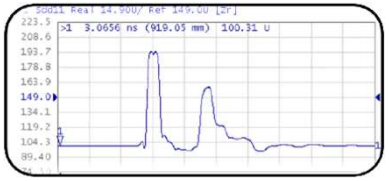
Lower cost of ownership

ESD Robustness

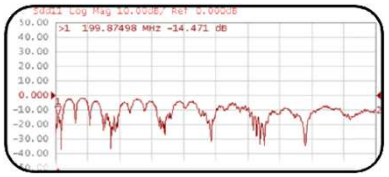
One-Box Solution for Signal Integrity

KEYSIGHT TECHNOLOGIES

Time domain



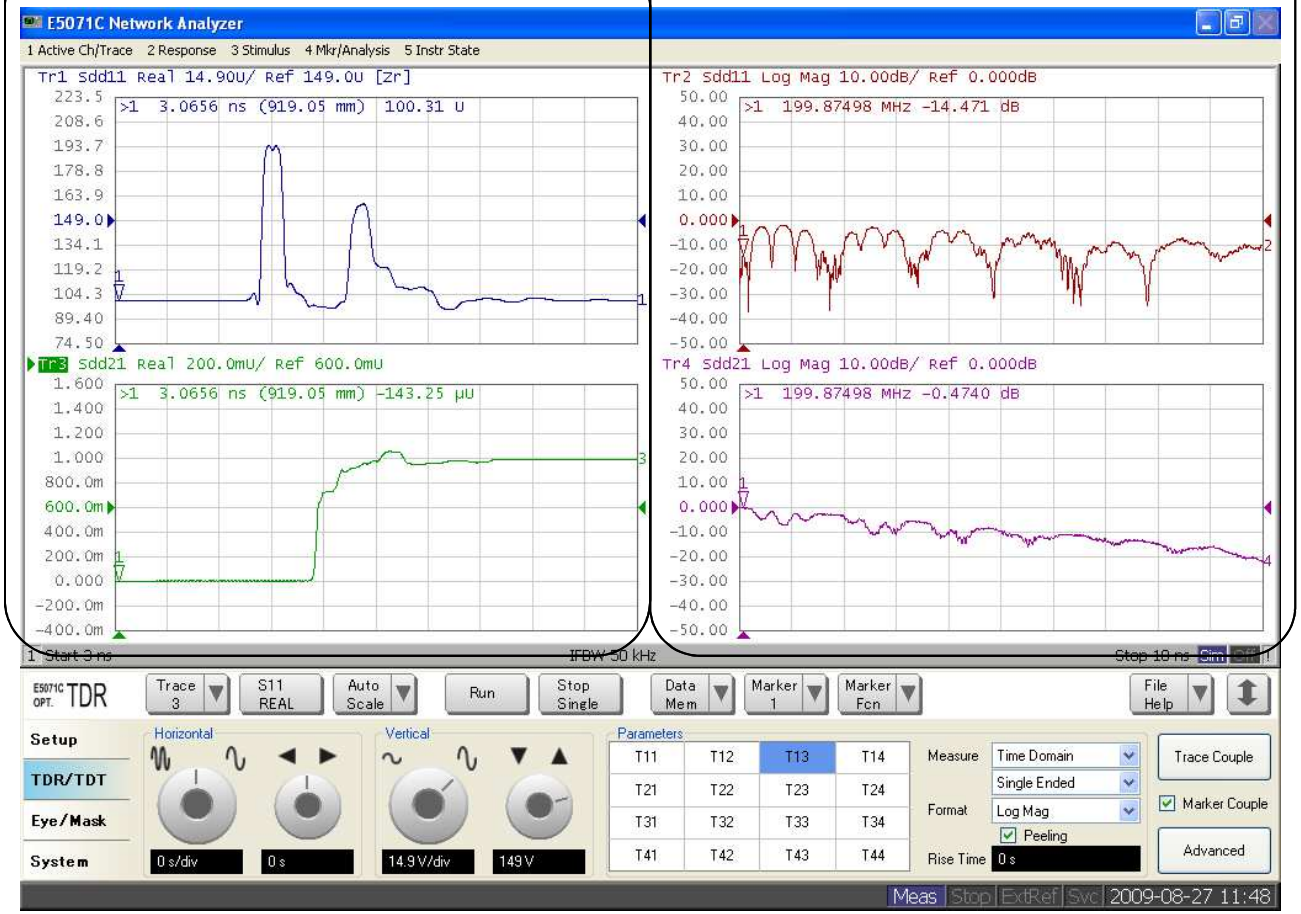
Frequency domain



Eye diagram

Time domain

Frequency domain

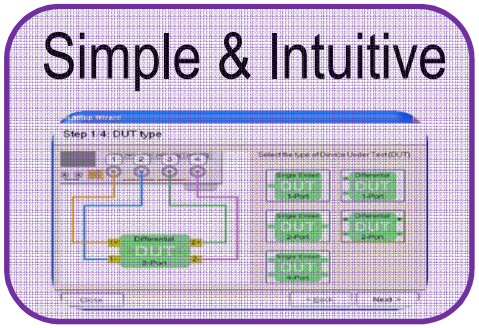


Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

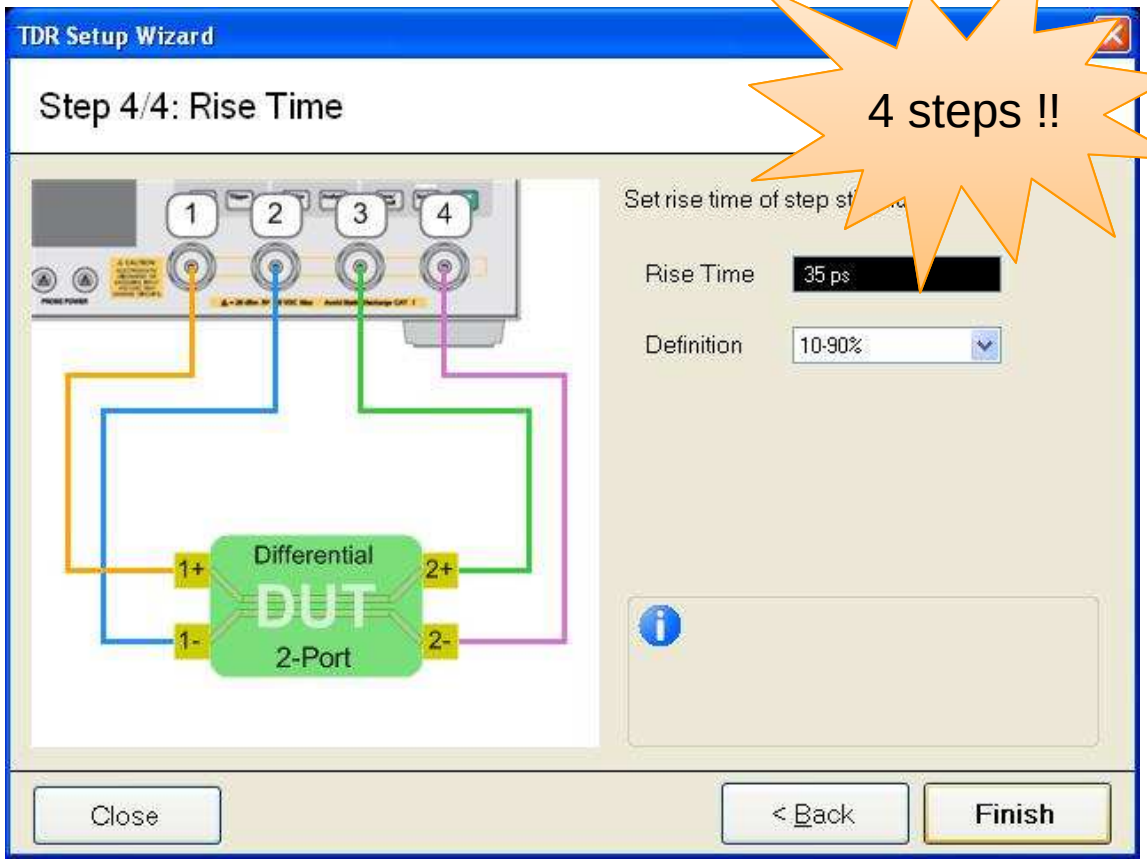
Simple & Intuitive



Fast & Accurate

ESD Robustness

TDR Setup Wizard



Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

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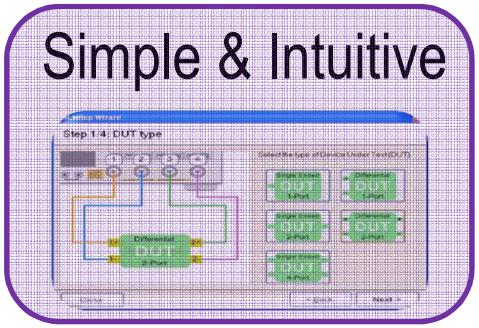
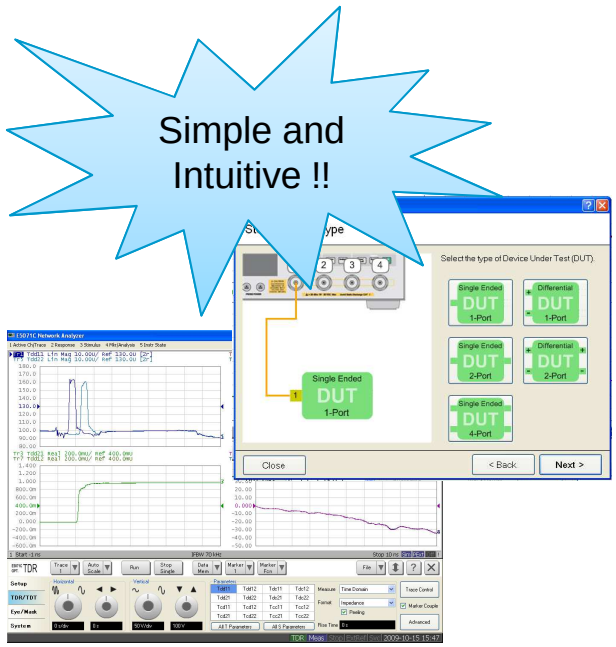
Simple & Intuitive



Fast & Accurate

ESD Robustness

ENA Option TDR



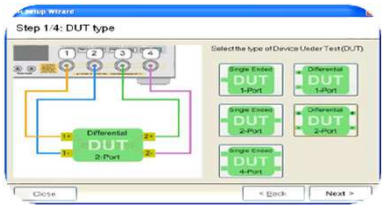
Simple UI & Setup Wizard

Signal Integrity Design & Verification

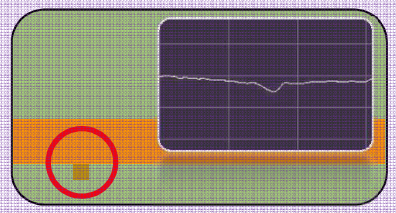
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

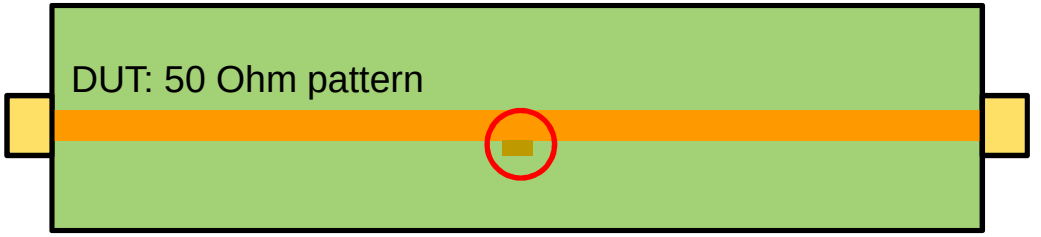
Simple & Intuitive



Fast & Accurate



ESD Robustness

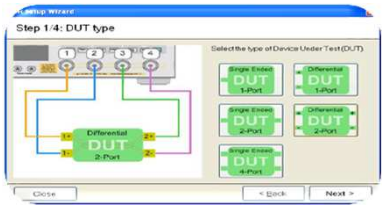


Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Simple & Intuitive



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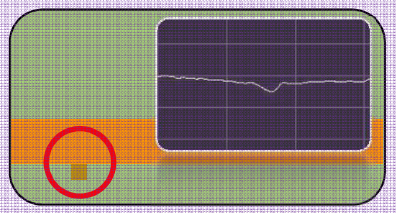

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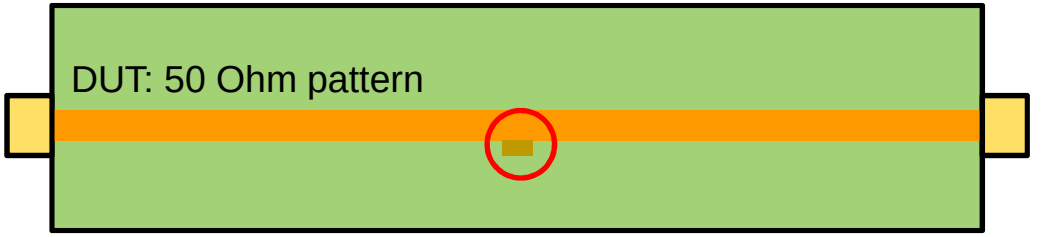
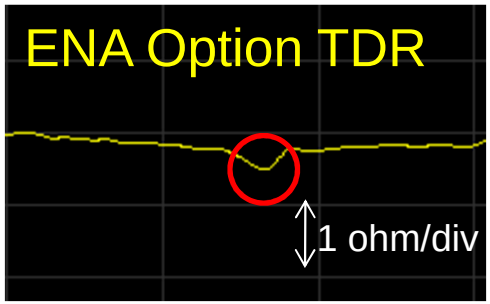
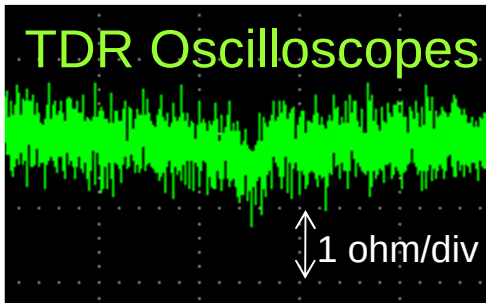






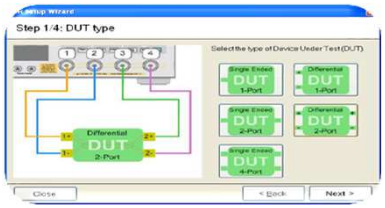
VNA Based TDR measurements
= Low Noise

Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Simple & Intuitive



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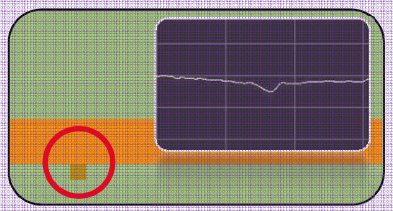

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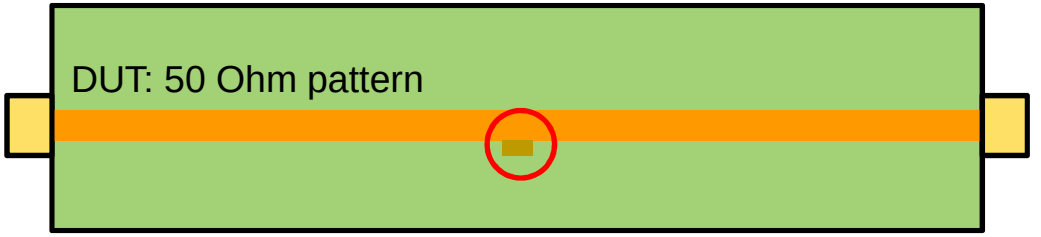
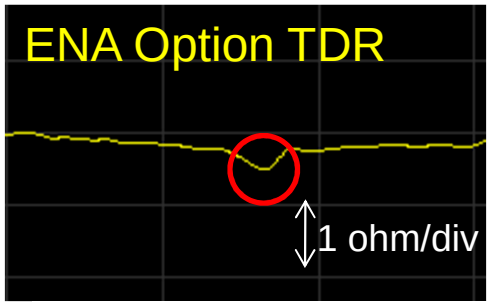
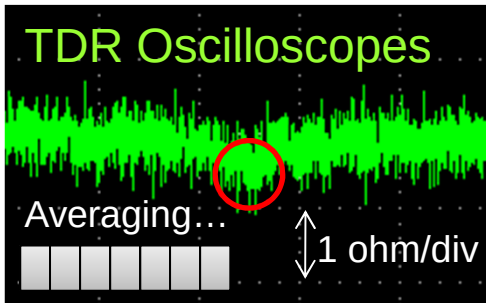






Averaging
gives precise measurement

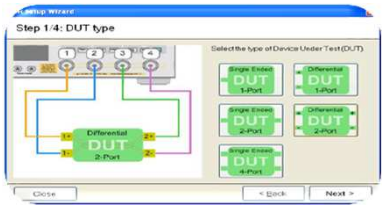
BUT…

Signal Integrity Design & Verification

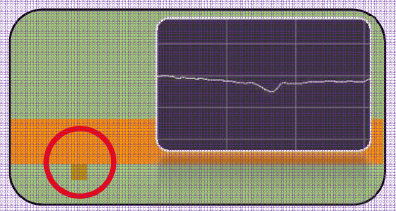
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

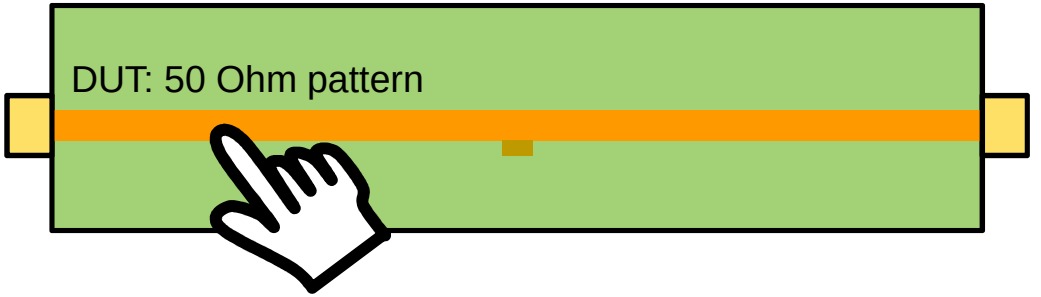
Simple & Intuitive

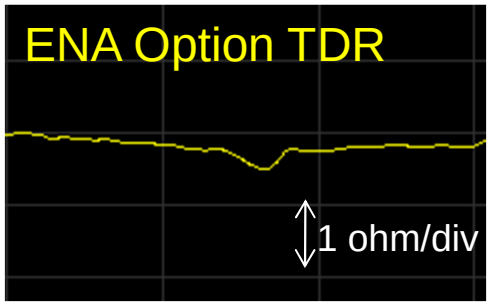


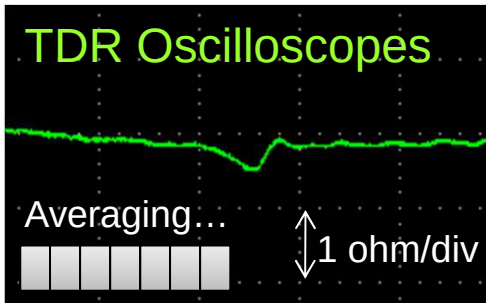
Fast & Accurate



ESD Robustness







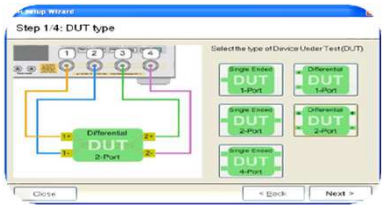
Real-Time Analysis

Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Simple & Intuitive



Fast & Accurate

ESD Robustness

ESD Robustness

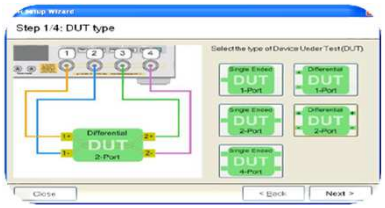
TDR oscilloscope is sensitive to ESD

Signal Integrity Design & Verification

KEYSIGHT TECHNOLOGIES

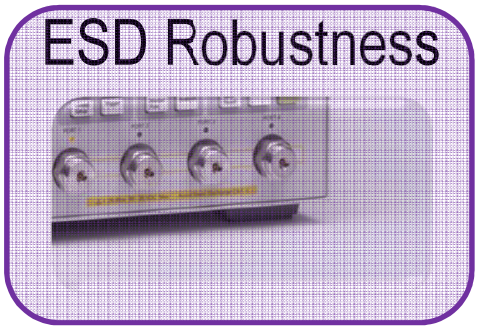
Unlocking Measurement Insights for 75 Years

Simple & Intuitive

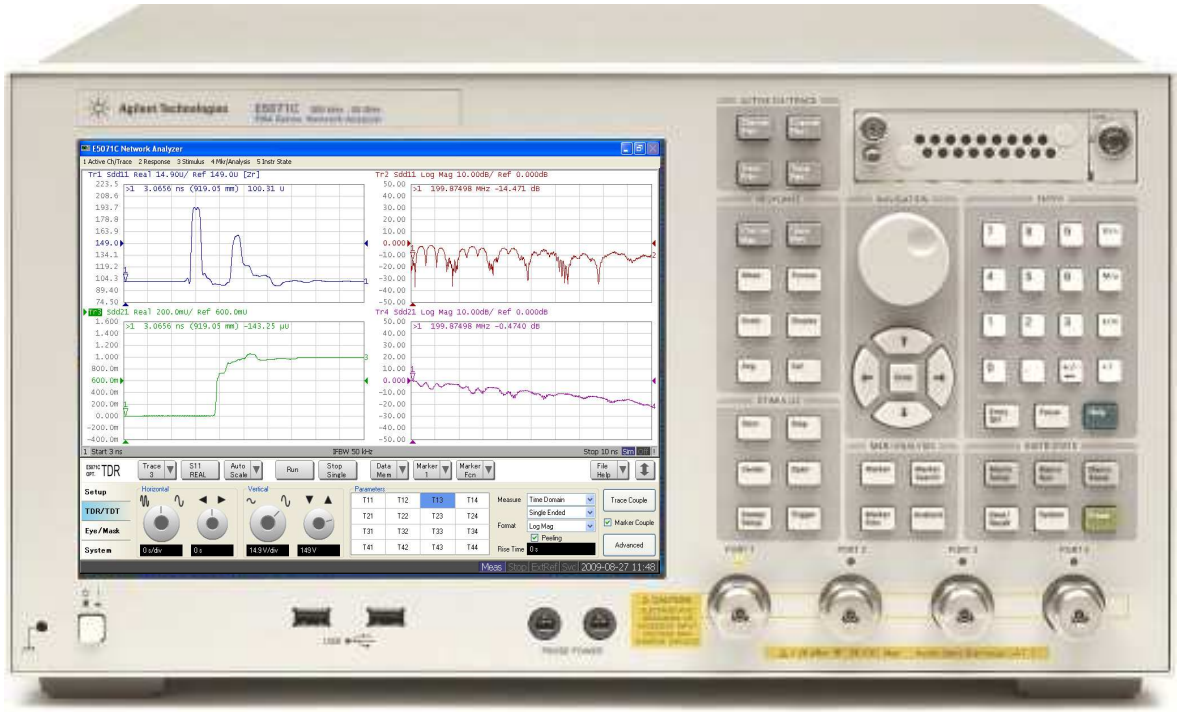


Fast & Accurate

ESD Robustness



ESD Robustness

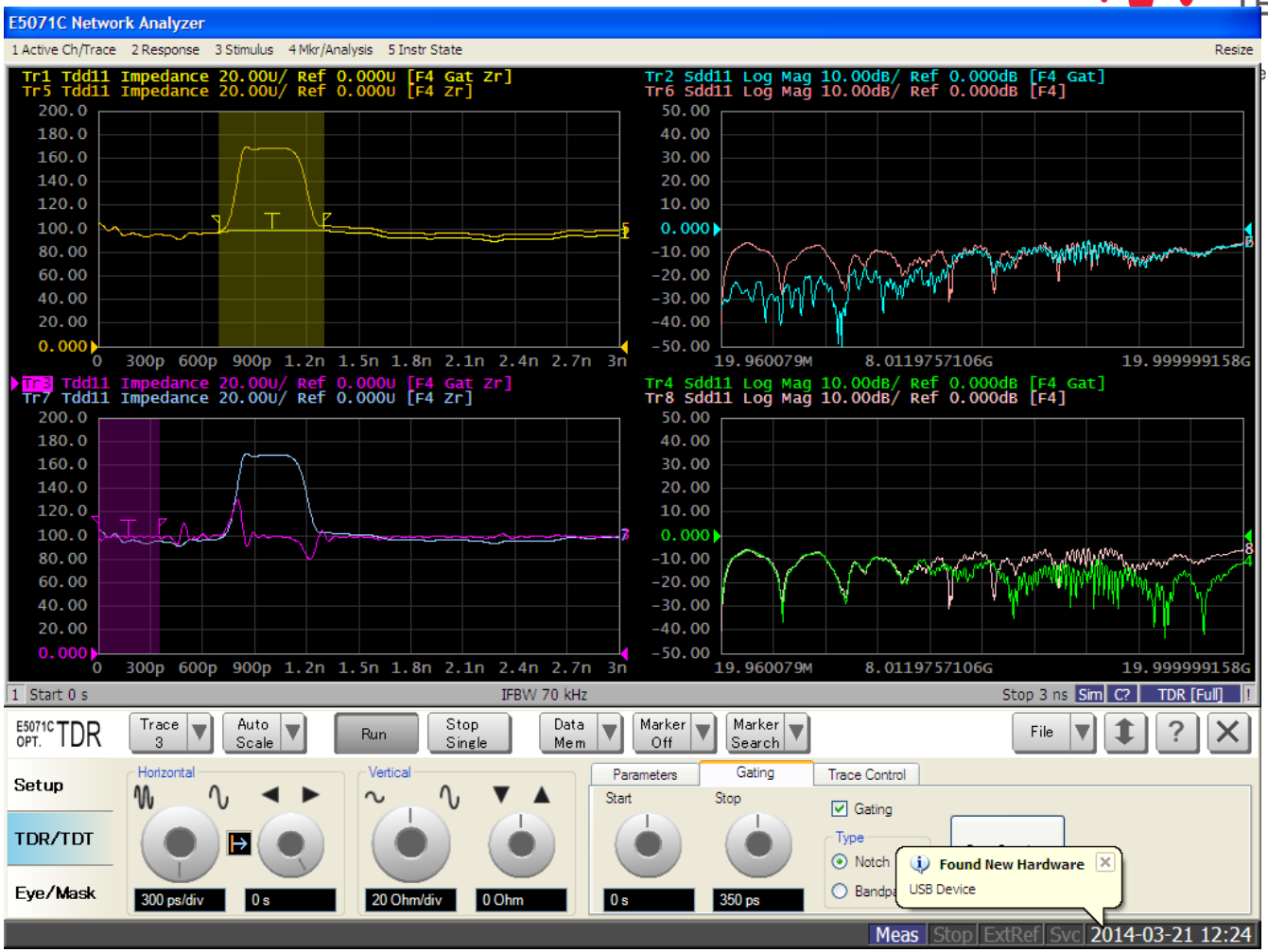


ESD protection circuit inside

Demo: Advanced TDR

KEYSIGHT TECHNOLOGIES

ement Insights for 75 Years



AGENDA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

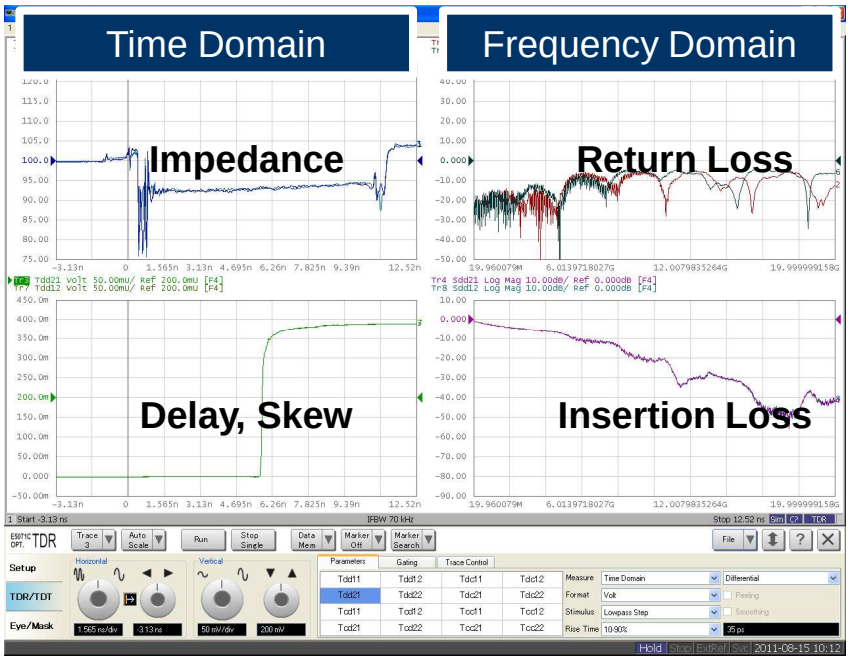
- TDR based on VNAs
- Advanced TDR for Signal Integrity
- **Stressed Eye Diagram Analysis**
- Hot TDR Measurements
- Compliance Support: MOIs
- Correlation Data among VNA and Sampling Scopes

Parametric Characteristic are enough?

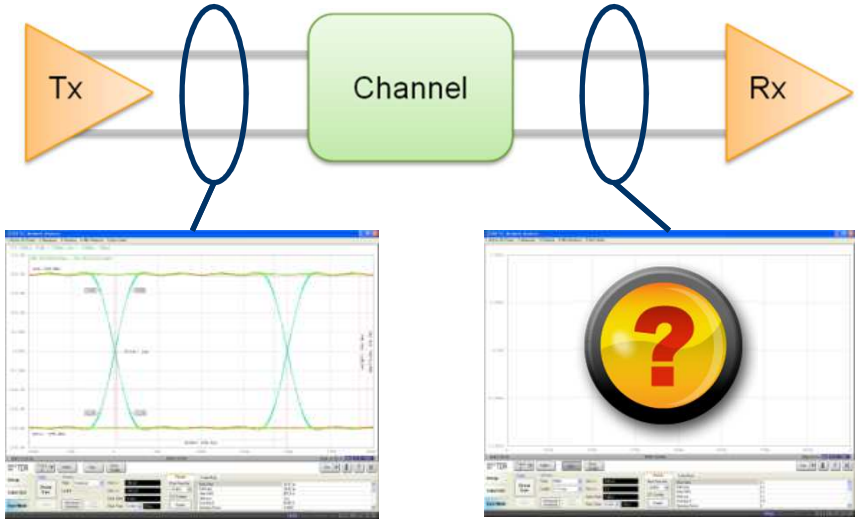
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Interconnects have traditionally been characterized by measuring parametric characteristics such as insertion loss and impedance.



One challenge with such characterization is how to translate the measurements into what the eye diagram will look like at the end of a link….

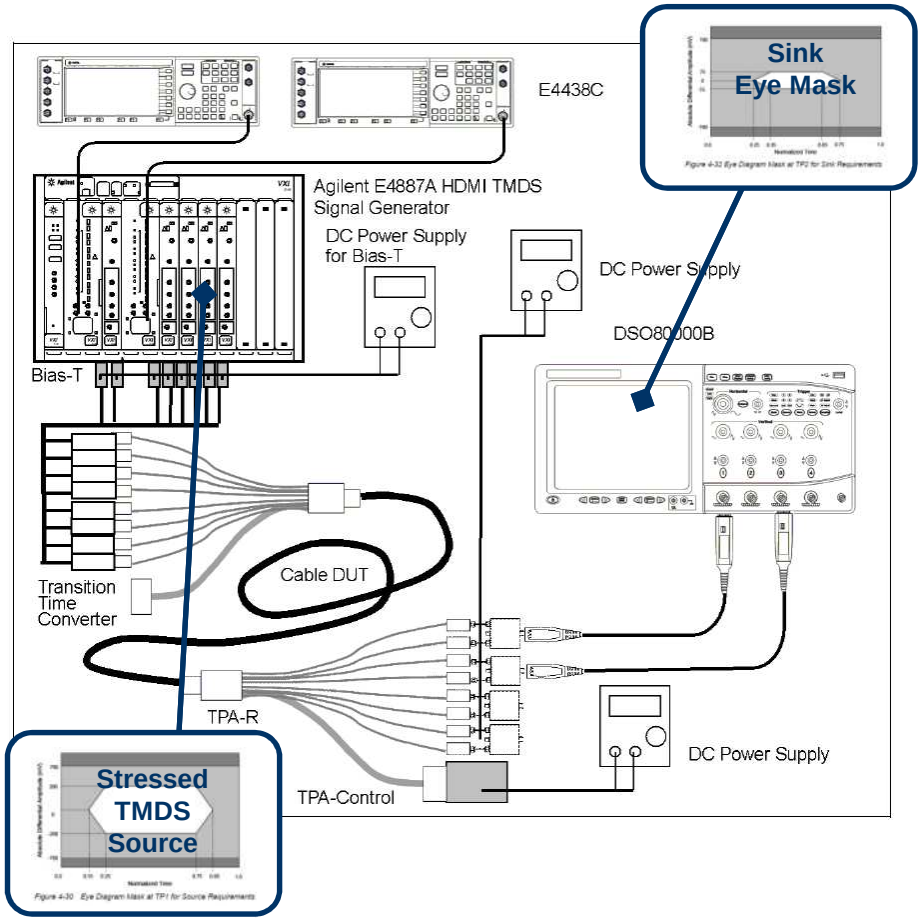


Agilent Technologies

Traditional eye diagram

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years



Many instruments…

How to setup for proper measurements?

Total solution cost?

Only eye diagram measurements available…

How to troubleshoot and isolate root cause upon device failure?

“Stressed” eye diagram testing on VNA

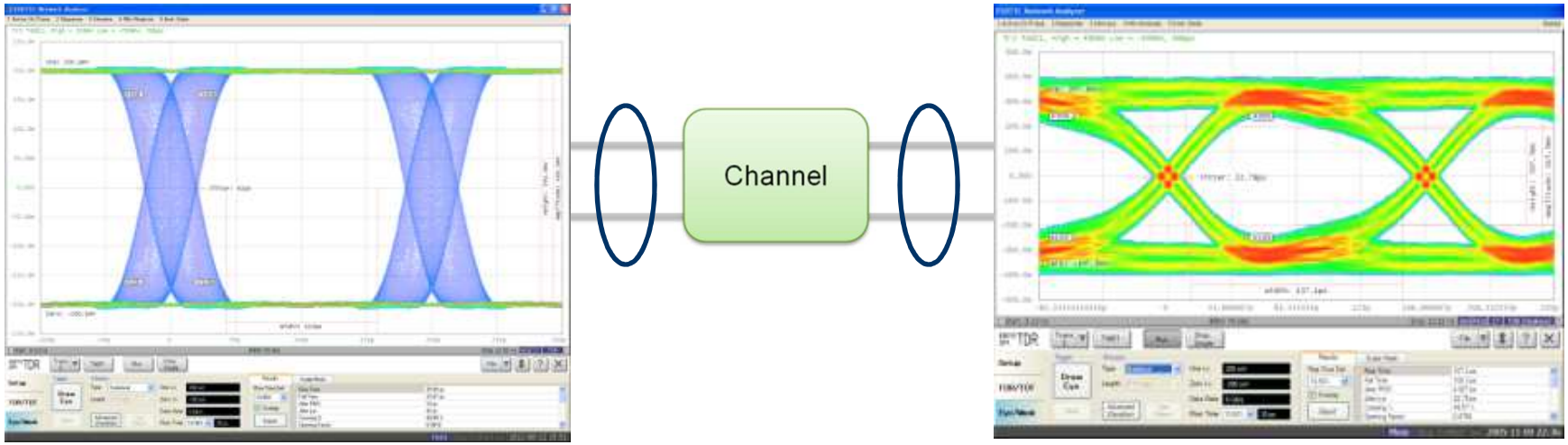
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Another approach is to characterize the interconnect using the eye diagram. This has the advantage of allowing direct measurement of eye characteristics at the end of the link. This process is called **“stressed” eye diagram testing**.

Input the expected worst case performance of the transmitter as the “stressed” signal to the interconnect…

… and evaluate the eye diagram at the output of the interconnect.

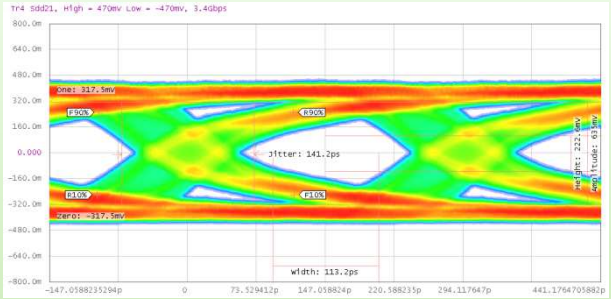


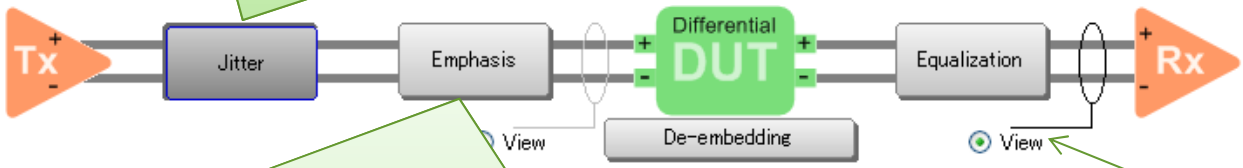
Advanced Waveform Analysis

KEYSIGHT TECHNOLOGIES

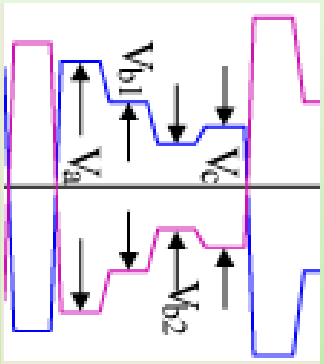
Unlocking Measurement Insights for 75 Years

Jitter Injection feature provides eye diagram test with a condition similar to the real implementation.





Emphasis is the intentional amplitude alteration of data signal to improve eye opening. The amplitude alterations are determined by the previous bits.



Equalizer is used for the same purpose as emphasis.
It amplifies a particular frequency band to compensate the attenuation of DUT.

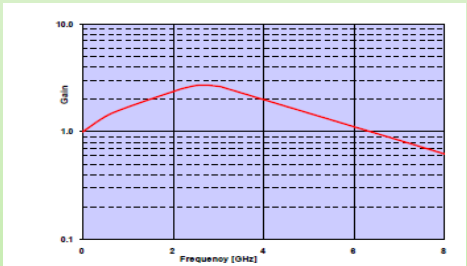


Figure 4-27 Gain of Reference Cable Equalizer

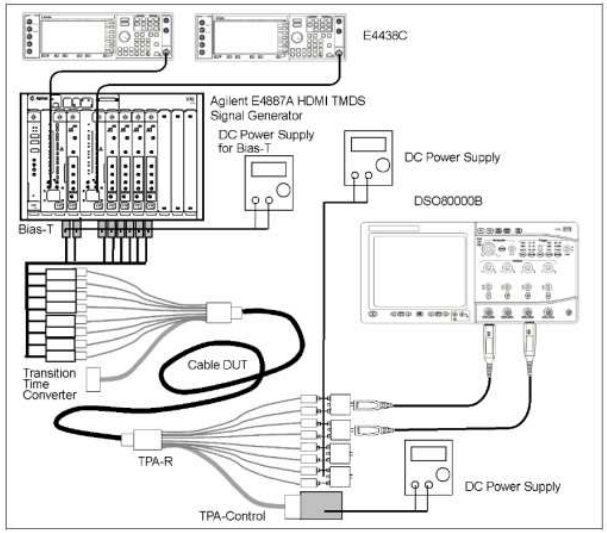
Complete Characterization

KEYSIGHT TECHNOLOGIES

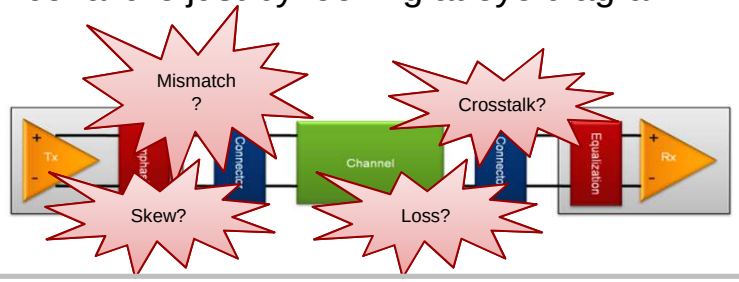
Unlocking Measurement Insights for 75 Years

Traditional Solution

Only **stressed eye diagram** analysis available.

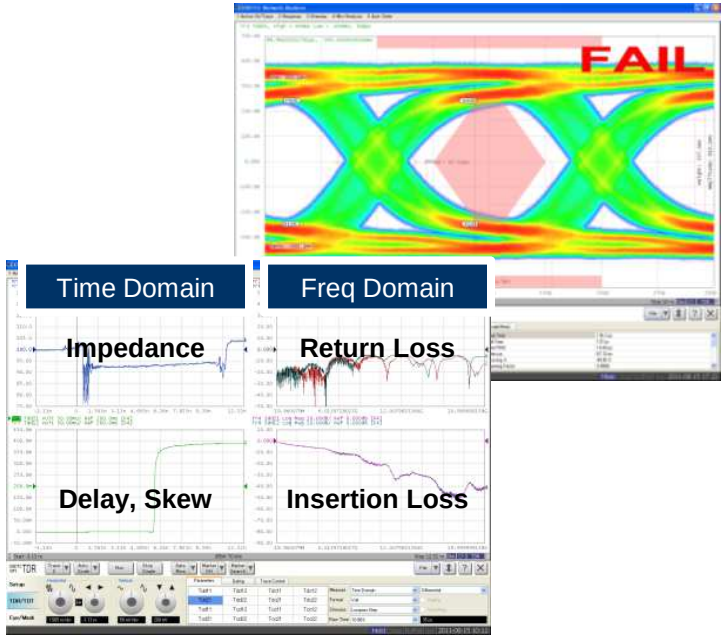


Difficult to troubleshoot and isolate root cause upon device failure just by looking at eye diagram.



ENA Option TDR

Both **stressed eye diagram** and **parametric** analysis available.



Parametric tests provide insight into root cause of device failure.

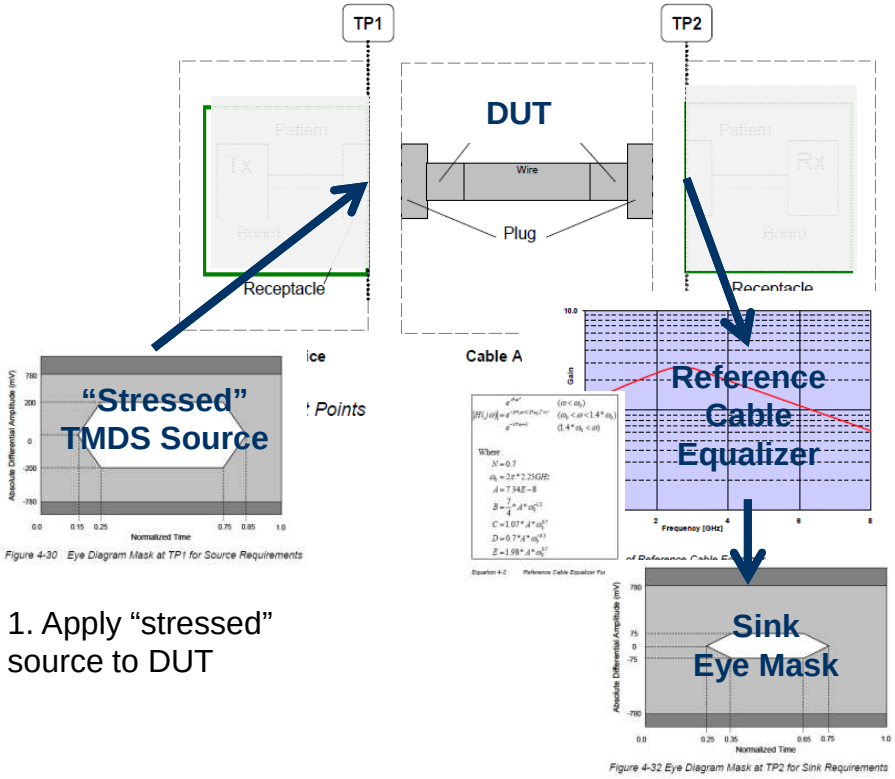
Demo: HDMI1.4b

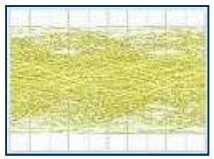
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

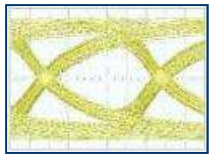
For HDMI Cable Assembly compliance test, there is the option of testing with either **parametric parameters**, or **stressed eye diagram (recommended)**.

Stressed Eye Diagram Measurement Overview





2. Apply equalizer to DUT output.



1. Apply "stressed" source to DUT

3. Set eye mask and perform mask test

AGENDA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- TDR based on VNAs
- Advanced TDR for Signal Integrity
- Stressed Eye Diagram Analysis
- **Hot TDR Measurements**
- Compliance Support: MOIs
- Correlation Data among VNA and Sampling Scopes

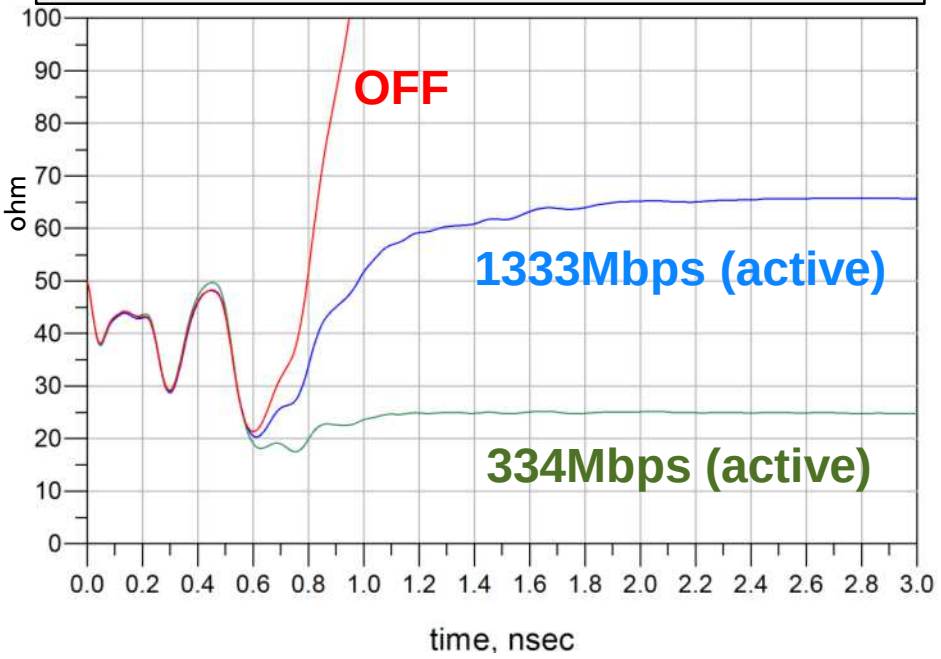
Why Measure Hot TDR?

KEYSIGHT TECHNOLOGIES

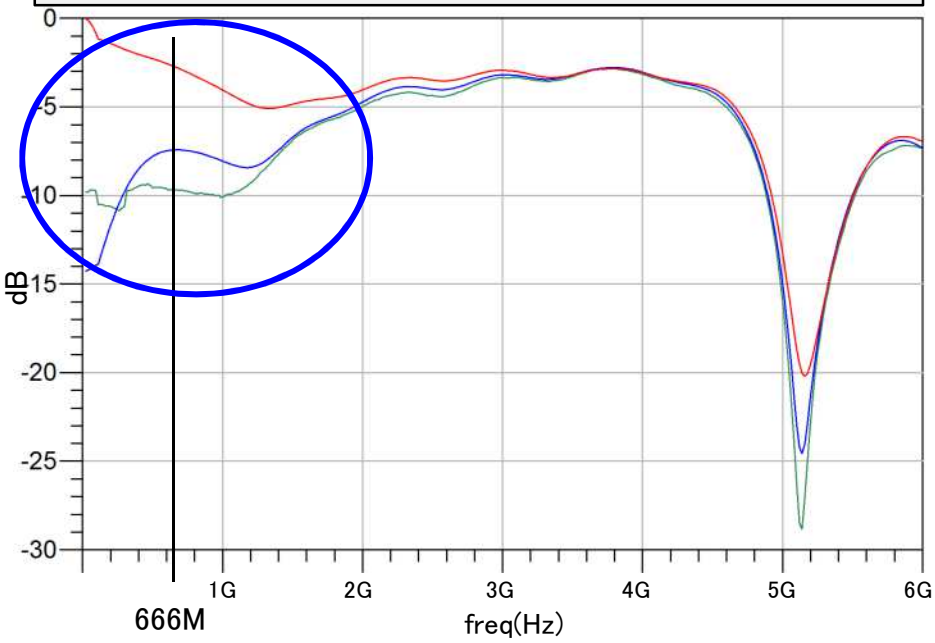
Unlocking Measurement Insights for 75 Years

- 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)

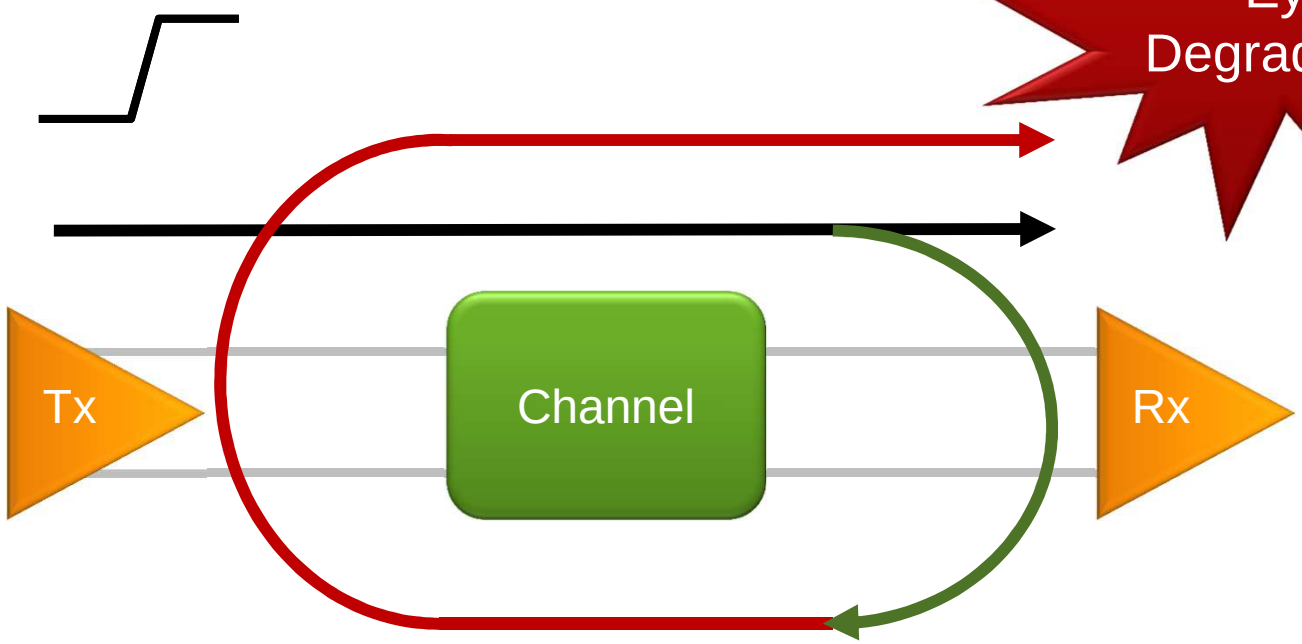


Multiple Reflections

KEYSIGHT TECHNOLOGIES

Unloc Measure nsights for 75 Years

1. Signal transmitted from Tx …



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

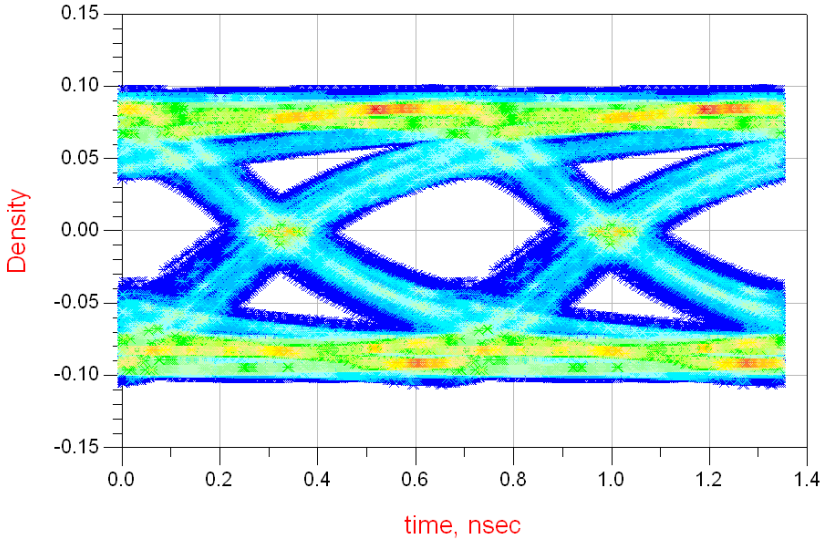
2. Partial reflection from Rx due to impedance mismatches …

Source Termination Effects

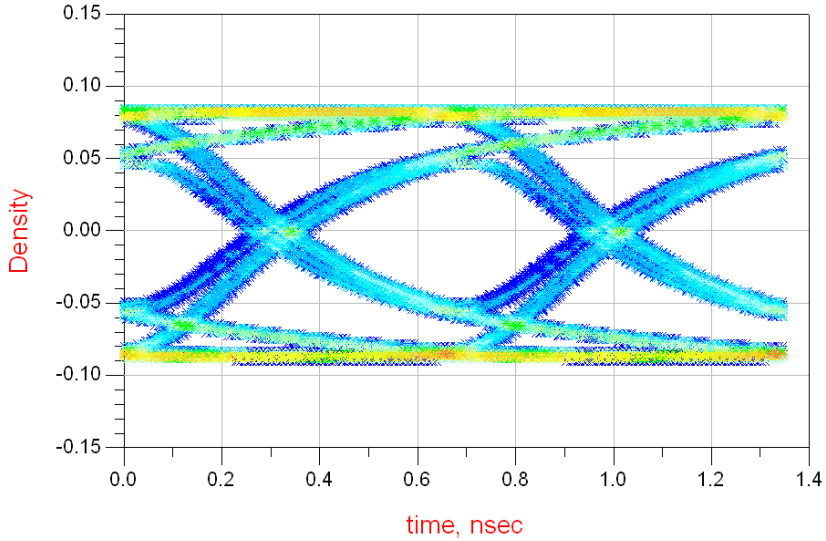
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Source Impedance **NOT** Matched



Source Impedance Matched



Many Standards Require Hot TDR

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Serial ATA

Unlocking Measurement Insights for 75 Years

7.4.13 Return Loss and Impedance Balance

Transmitters (Tx):
When measuring output impedance of transmitters the operating condition shall be during transmission of **MFTP**. This is to assure the measurement is performed during a mode of operation that represents normal operation.

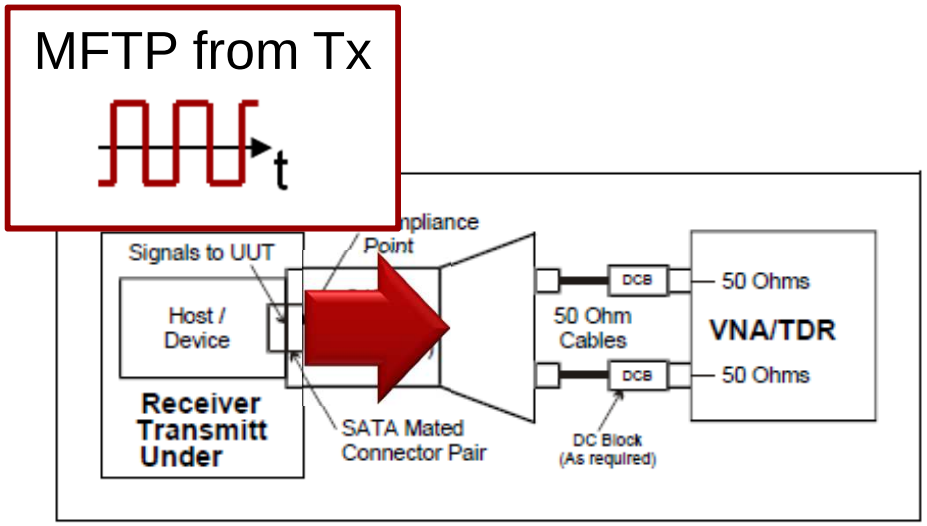


Figure 164 – Return Loss Test

Measurement Challenge

How to avoid effects of the transmitter signal on measurements?

Minimizing Errors from the Tx

KEYSIGHT TECHNOLOGIES

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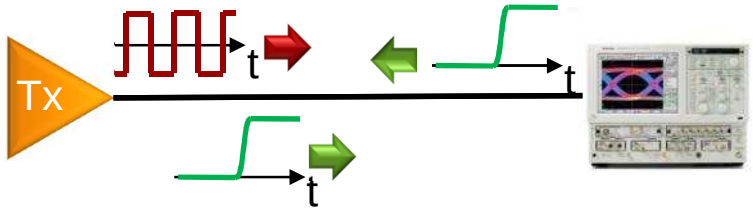
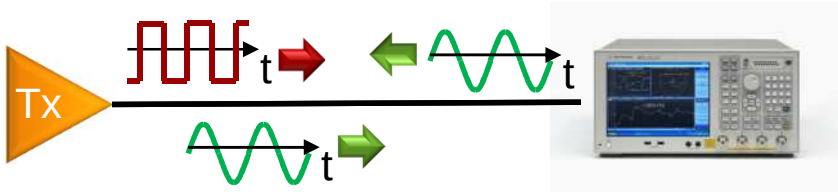
TDR Scopes



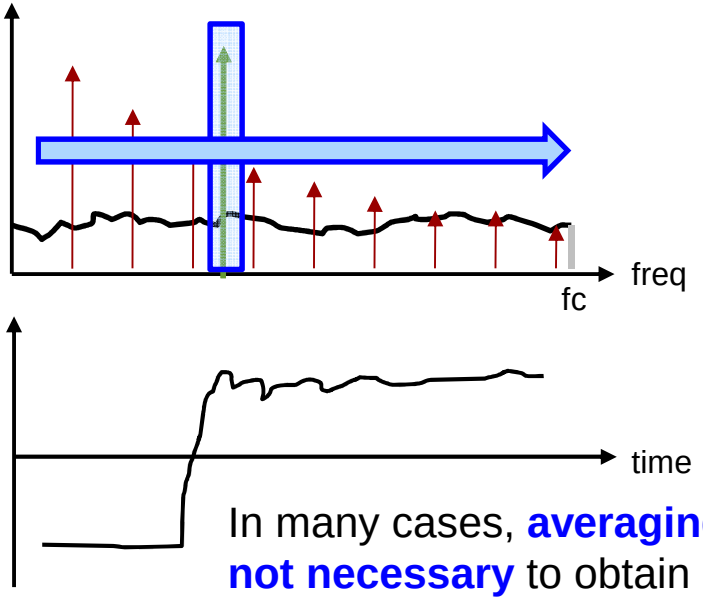
•**wideband receiver** captures all of the signal energy from the transmitter

Extensive averaging is necessary to obtain a stable waveform.

VNA



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

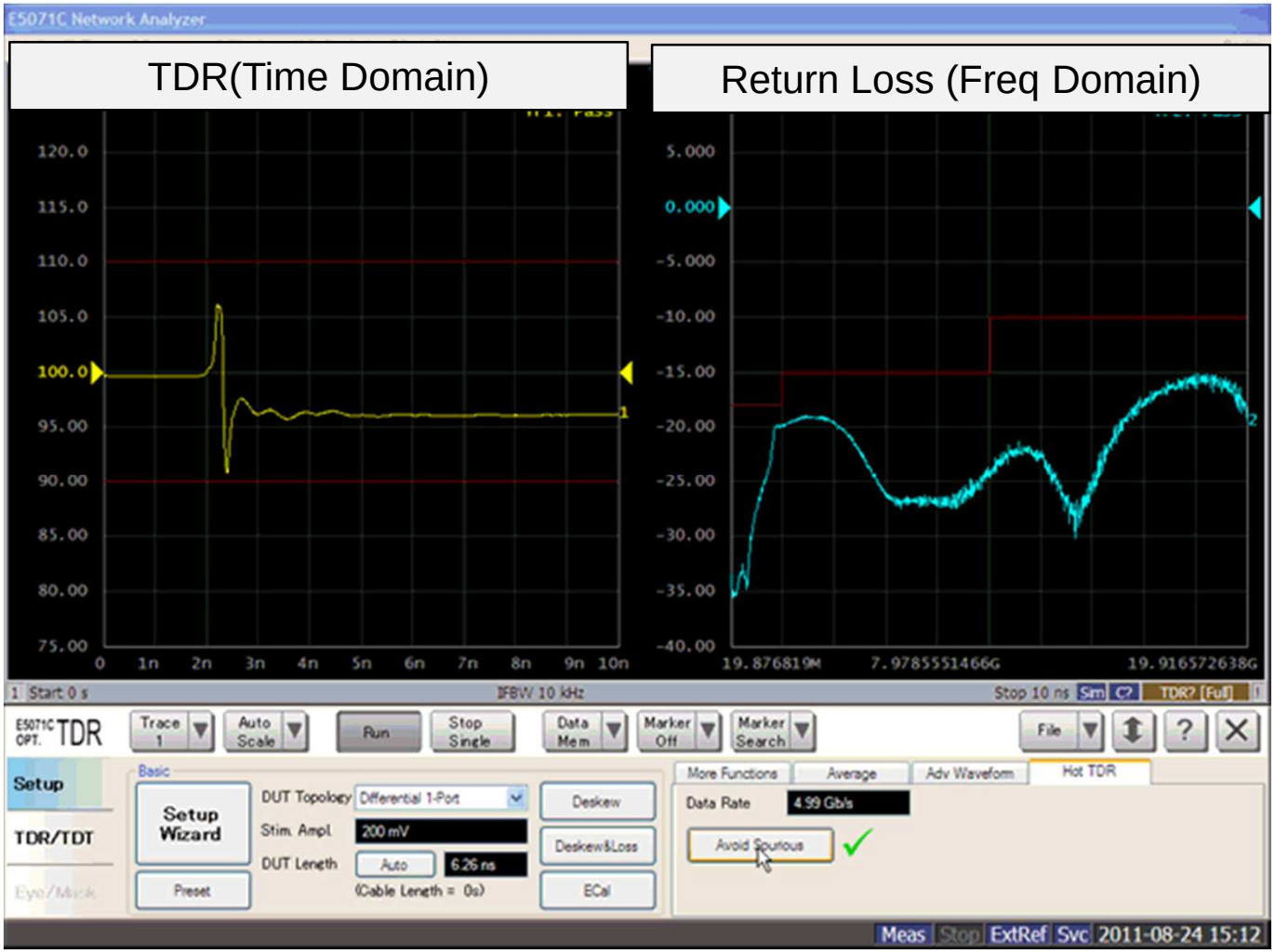


In many cases, **averaging is not necessary** to obtain a stable waveform.

Demo: Hot TDR

KEYSIGHT TECHNOLOGIES

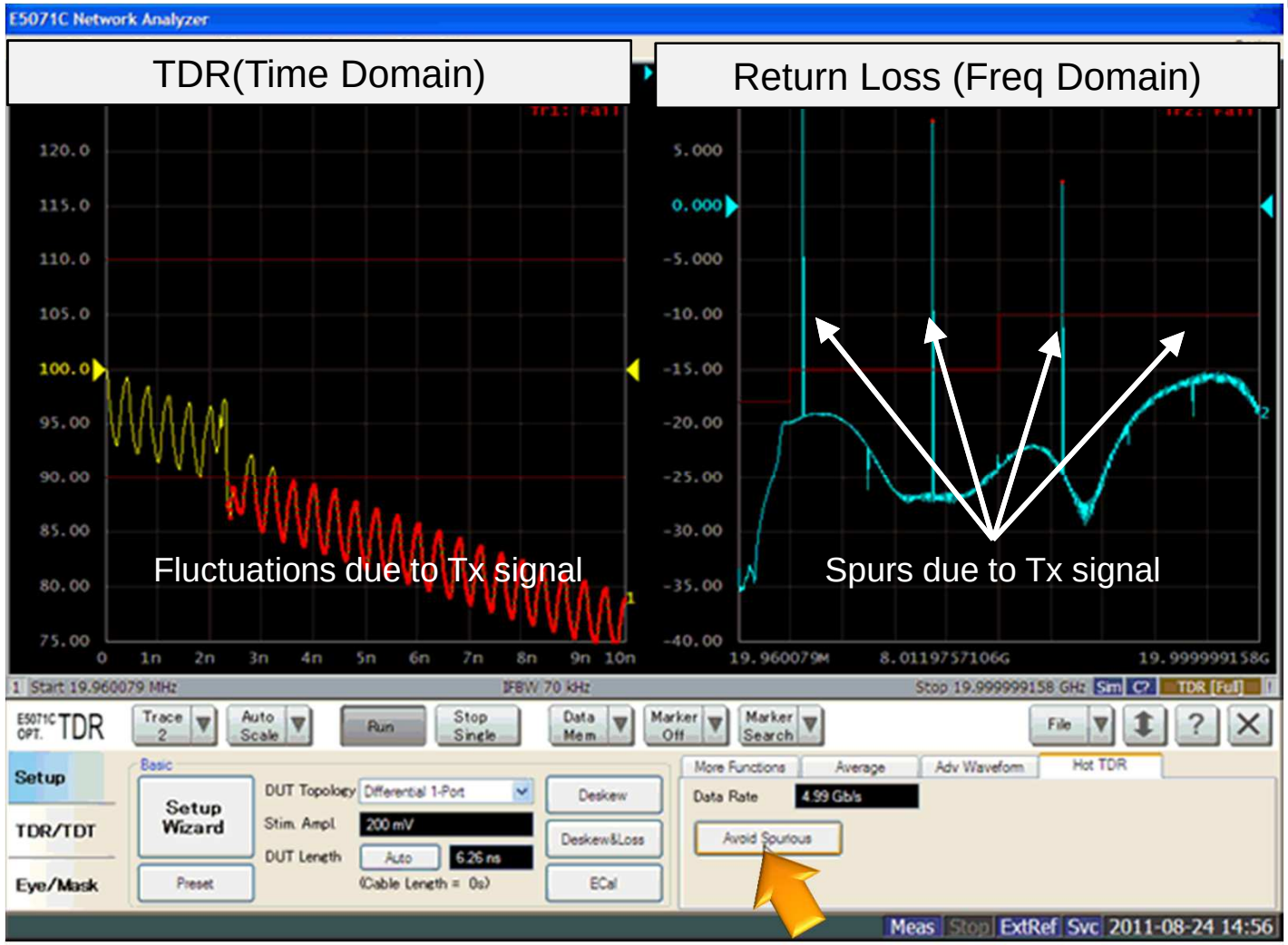
Unlocking Measurement Insights for 75 Years



Avoid Spurious Feature

KEYSIGHT TECHNOLOGIES

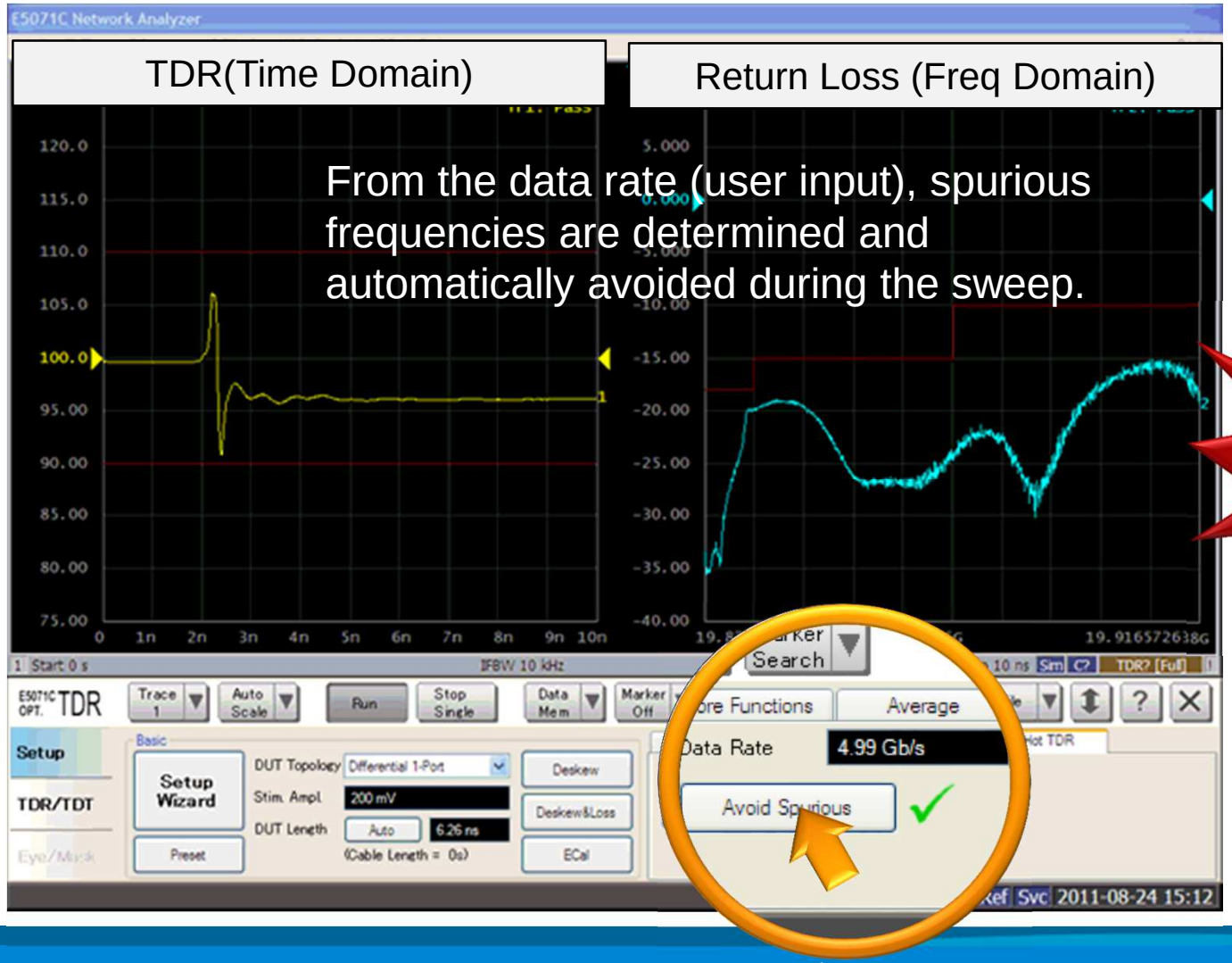
Unlocking Measurement Insights for 75 Years



Avoid Spurious Feature

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years



1-click Operation

AGENDA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- TDR based on VNAs
- Advanced TDR for Signal Integrity
- Stressed Eye Diagram Analysis
- Hot TDR Measurements
- **Compliance Support: MOIs**
- Correlation Data among VNA and Sampling Scopes

Compliance Support

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

→Examples:

DisplayPort

SUPERSPEED USB

•E5071C Method of Implementation (MOI)

[Example] Display Port Cable Compliance Test

Agilent MOI for DisplayPort Cable Compliance Tests

Revision 1.0

15-December 2008

VESA DisplayPort
PHY Compliance test Standard Version 1.1 Draft 12
Agilent Method of Implementation (MOI) for DisplayPort
Cable Compliance Tests
Using Agilent E5071C Network Analyzer

1

• VBA program and operation guide, mask tests, limits, states…

[Example] USB3.0 Cable measurement using the VBA program

Compliance Support

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

Standards supported by E5071C-TDR

Standards		MOIs & State Files		Test Solution Overview
		Cable-Connector Assembly	Source-Sink	
USB	USB3.0	Available	-	Available
	USB3.1	Coming soon...	-	Coming soon...
HDMI	HDMI 1.4b	Available	-	Available
	HDMI 2.0	(*2)	Coming soon...	Coming soon...
SATA		Available	Available	Available
DisplayPort		Available	-	Available
MIPI™	D-PHY	-	Available	Available
	M-PHY	-	Available	Available
Ethernet	100BASE-TX	Available	-	Available
	10GBASE-T	Available	-	Available
MHL		Available	Coming soon...	Available
PCIe®		Available	-	Available
Thunderbolt		-	Available (*1)	Available
BroadR-Reach		Available (*1)	-	Available

*1: Contact Agilent sales representative for more detail.
*2: HDMI 2.0 uses the same cable as HDMI 1.4b.

Refer to following link for further information:

http://www.home.agilent.com/agilent/editorial.jspx?cc=US&lc=eng&ckey=2022953&nid=-11143.0.00&id=2022953

AGENDA

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

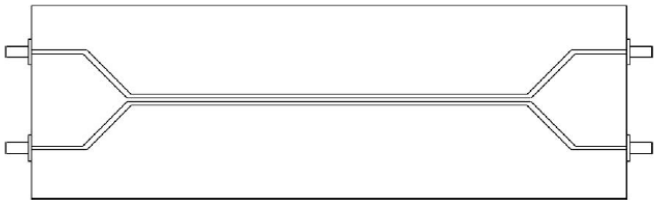
- TDR based on VNAs
- Advanced TDR for Signal Integrity
- Stressed Eye Diagram Analysis
- Hot TDR Measurements
- Compliance Support: MOIs
- **Correlation Data among VNA and Sampling Scopes**

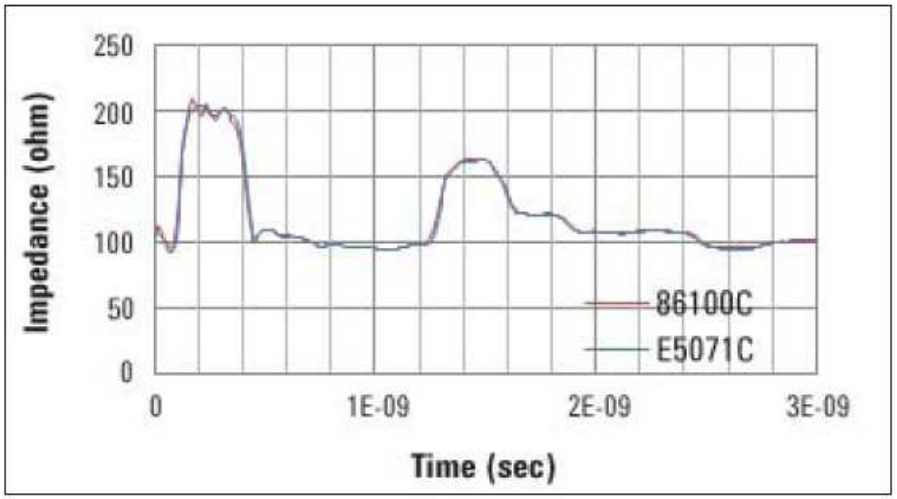
Measurement Correlation
TDR/TDT

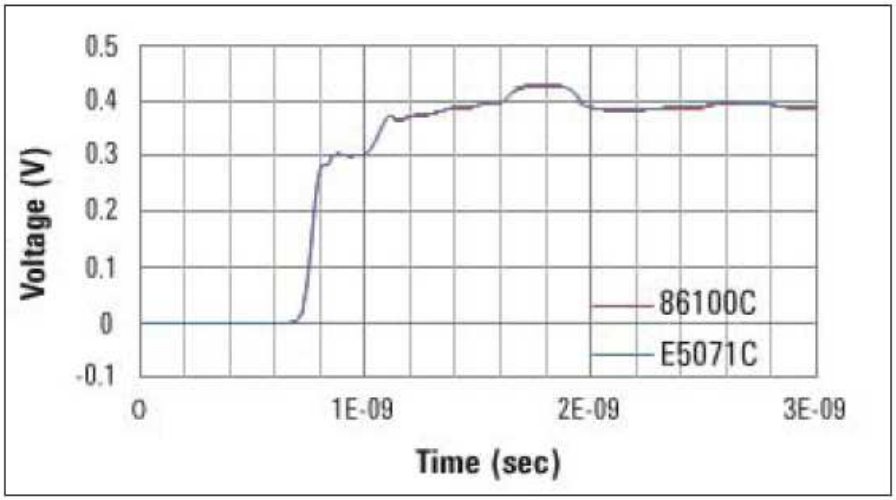
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- DUT: Differential PCB trace
- 35 ps rise time (10-90%)







NOTE: For further details, refer to Application Note, “Correlation between TDR oscilloscope and VNA generated time domain waveform” (5990-5238EN)

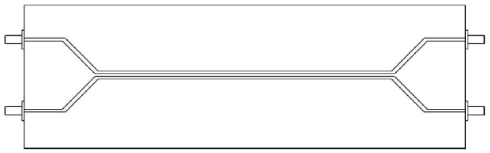
Measurement Correlation

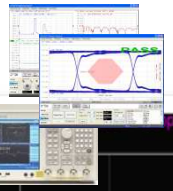
Eye Diagram

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

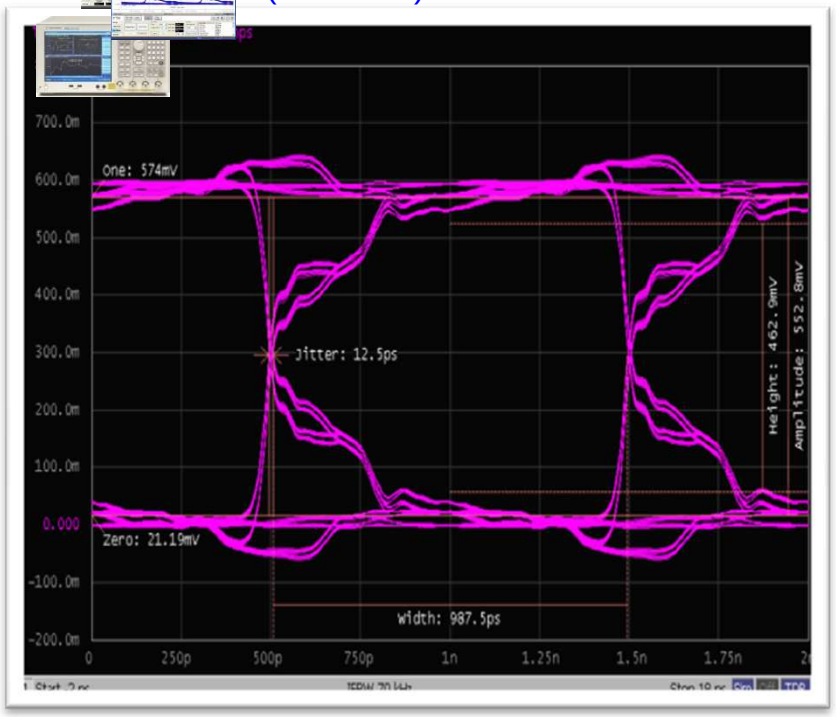
- DUT: differential PCB trace
- PRBS (2^7-1) @ 1 Gbps





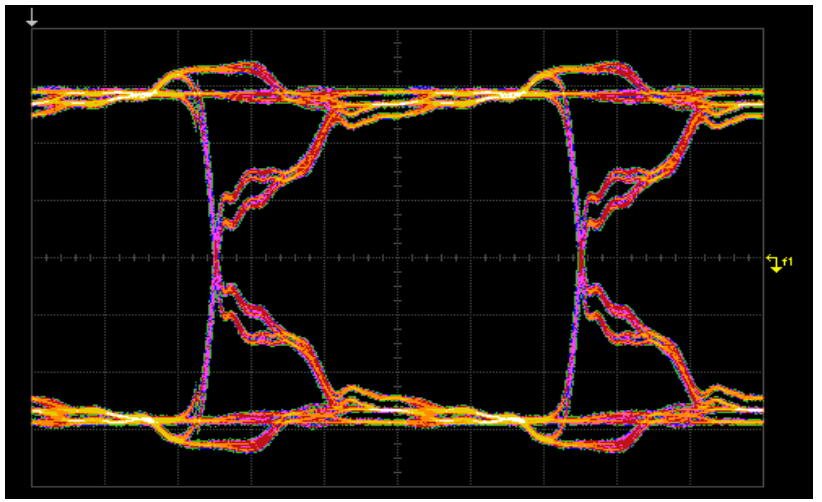
ENA Option TDR

(simulated)



N4903B + 86100C

(live)

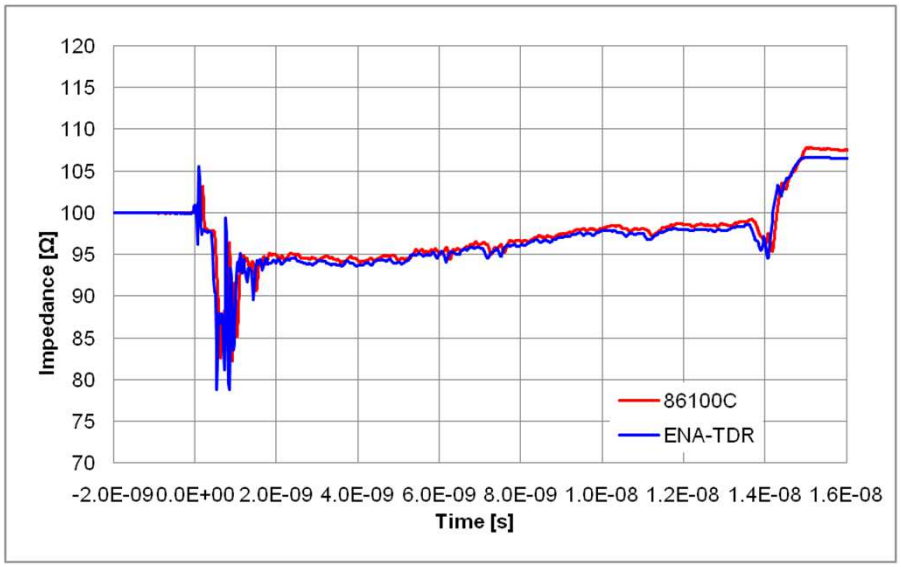


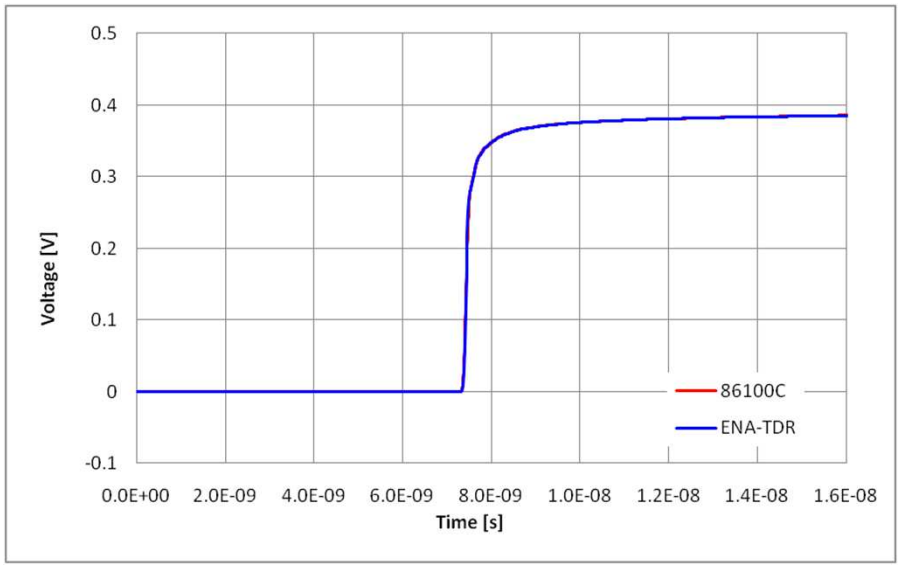
NOTE: For further details, refer to Application Note, “Correlation between TDR oscilloscope and VNA generated time domain waveform” (5990-5238EN)

Measurement Correlation
TDR/TDT

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights for 75 Years

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





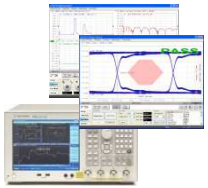
Measurement Correlation

Eye Diagram

KEYSIGHT TECHNOLOGIES

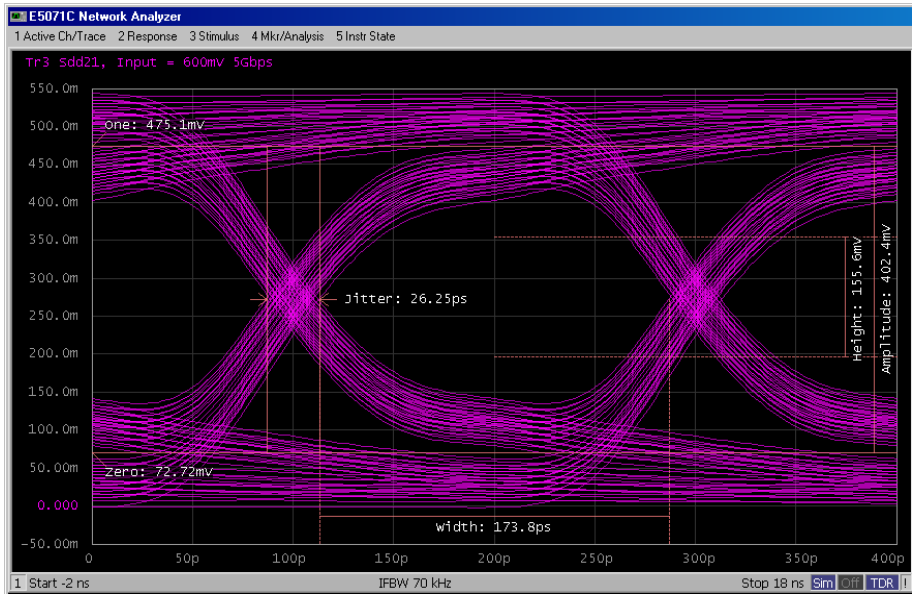
Unlocking Measurement Insights for 75 Years

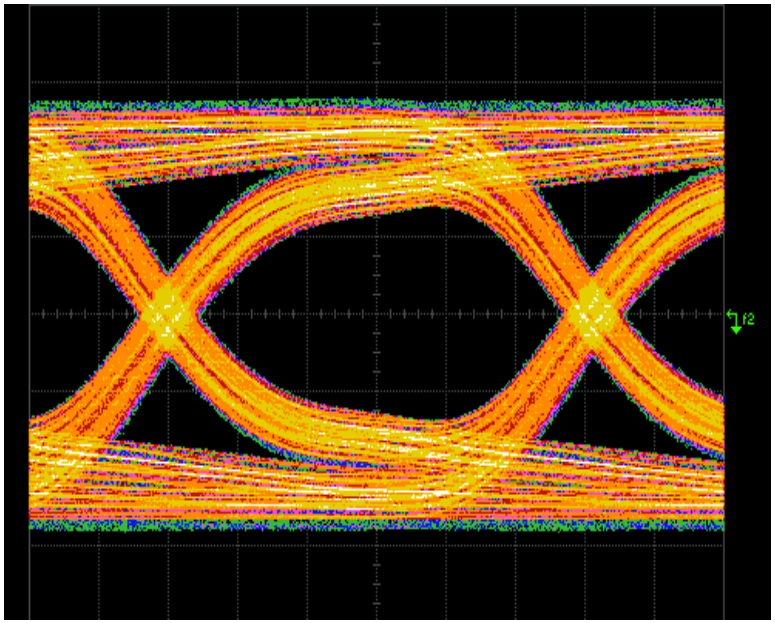
- DUT: USB3.0 Cable
- PRBS (2^7-1) @ 5 Gbps



ENA Option TDR
(simulated)

N4903B + 86100C
(live)



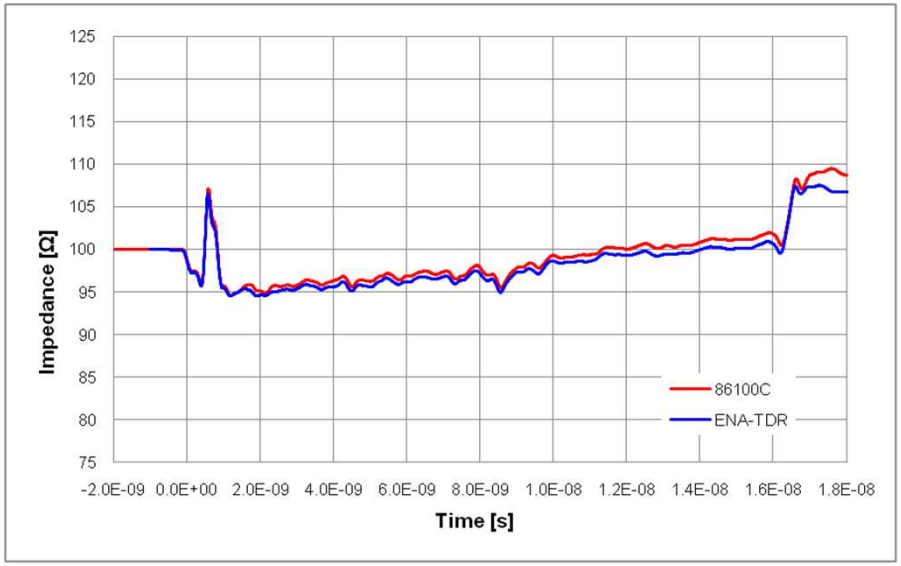


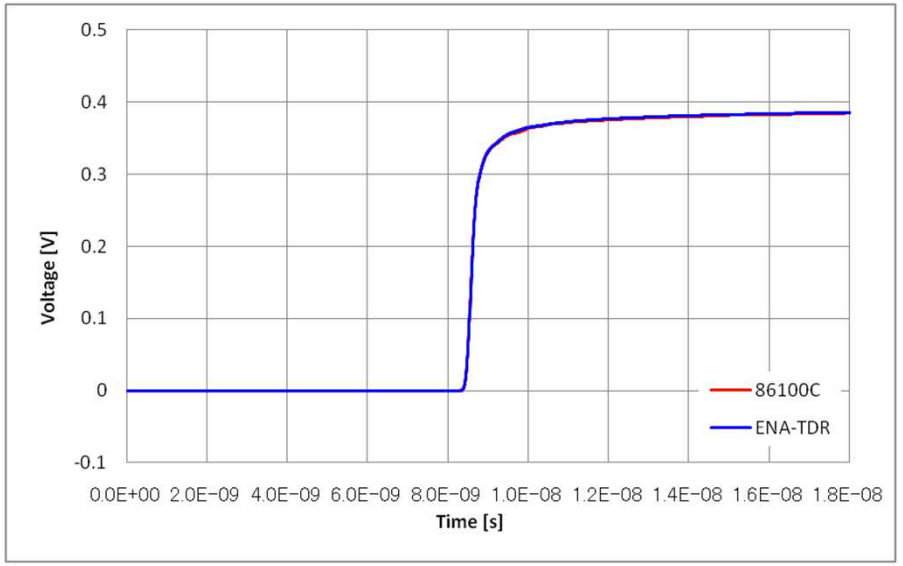
Measurement Correlation
TDR/TDT

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights for 75 Years

- DUT: DisplayPort Cable
- 130 ps rise time (20-80%)

DisplayPort





Measurement Correlation

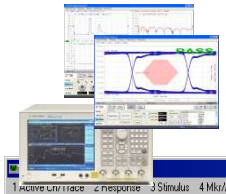
Eye Diagram

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

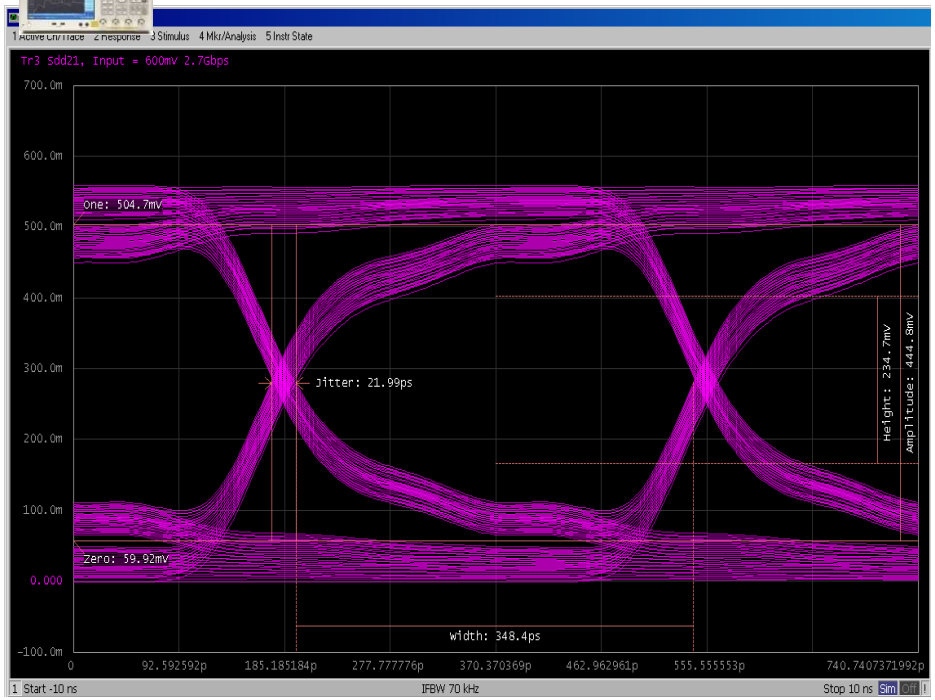
- DUT: DisplayPort Cable
- PRBS (2^7-1) @ 2.7 Gbps

DisplayPort



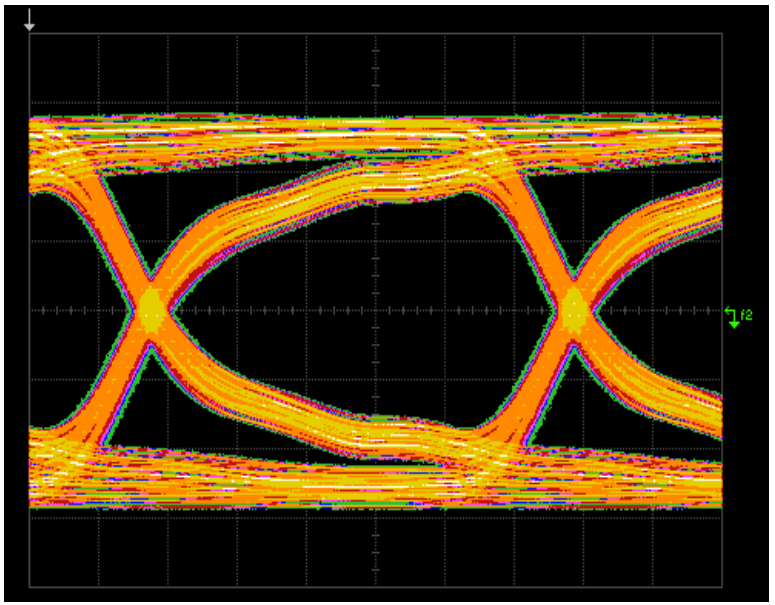
ENA Option TDR

(simulated)



N4903B + 86100C

(live)

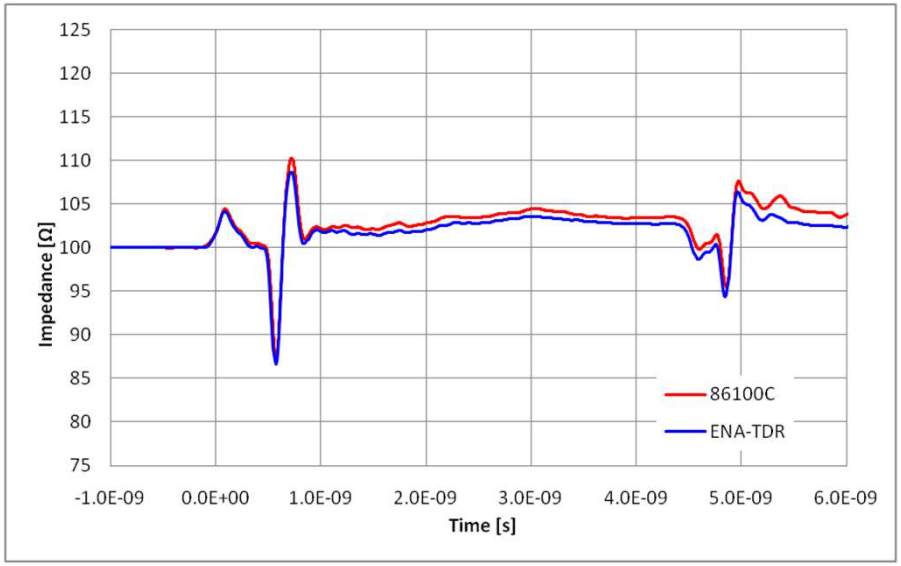


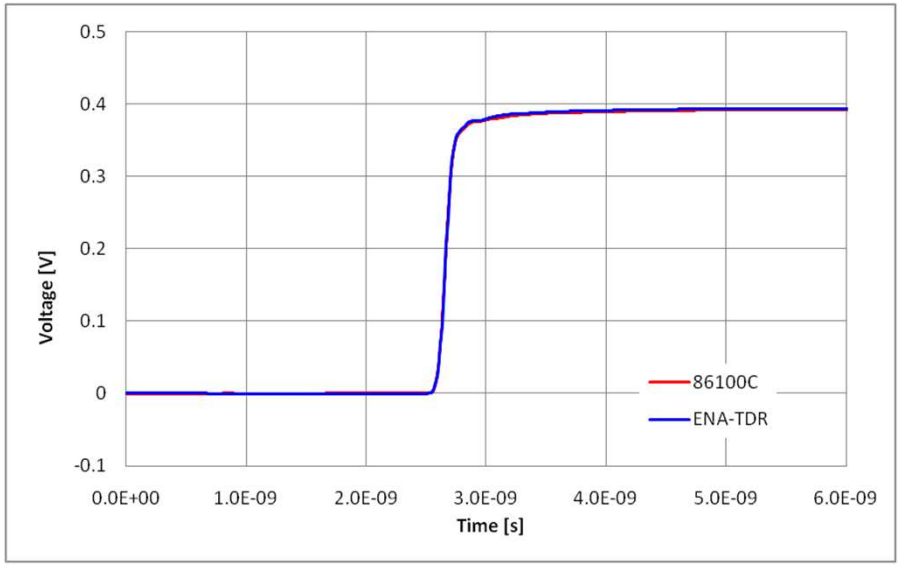
Measurement Correlation
TDR/TDT

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights for 75 Years

- DUT: SATA Cable
- 70 ps rise time (20-80%)

The Serial ATA International Organization





Measurement Correlation

Eye Diagram

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights for 75 Years

- DUT: SATA Cable
- PRBS (2^7-1) @ 6 Gbps

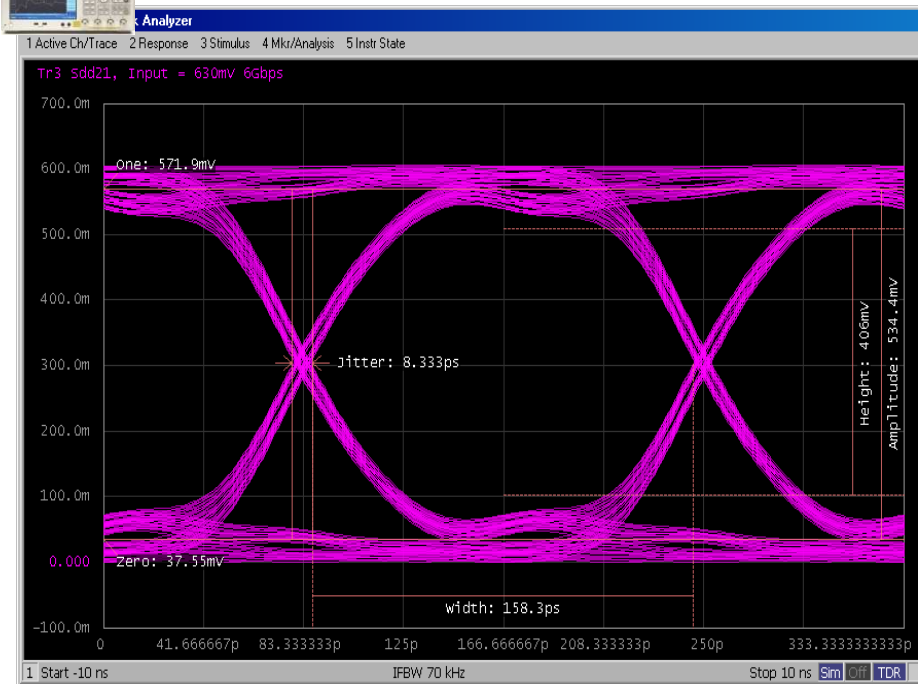
The Serial ATA International Organization

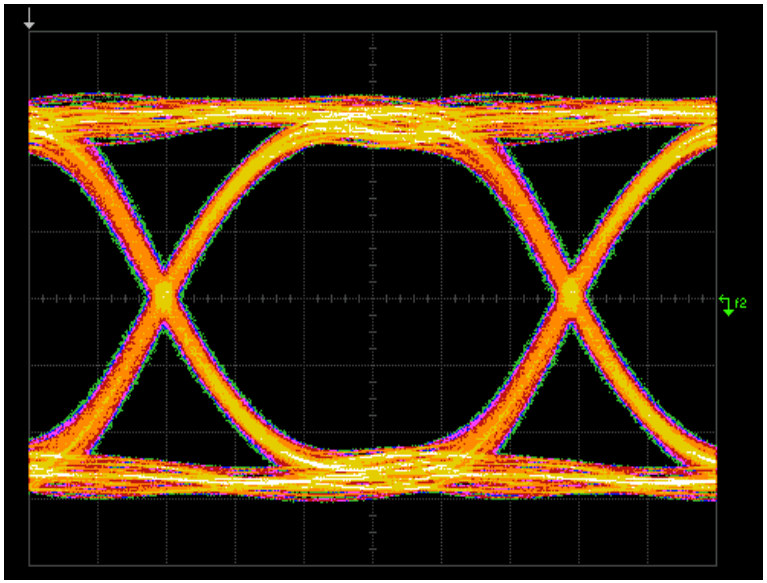
ENA Option TDR

(simulated)

N4903B + 86100C

(live)





Application Note: http://cp.literature.agilent.com/litweb/pdf/5990-5238EN.pdf