고속 시리얼 통신규격의 Signal Integrity 측정을 위한 키사이트 네트워크분석기 기반 TDR 솔루션 소개

KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

내용

- 키사이트 네트워크 분석기 기반 TDR 장비 Overview
- Cable/Connector Compliance 시험 항목 예
- 최신 고속 Digital 규격 측정에 필요한 기능
  - Stressed Eye Diagram 분석
  - Hot TDR 측정: Active Device에 대한 실제 사용조건에서의 임피던스 분석기능
- Summary

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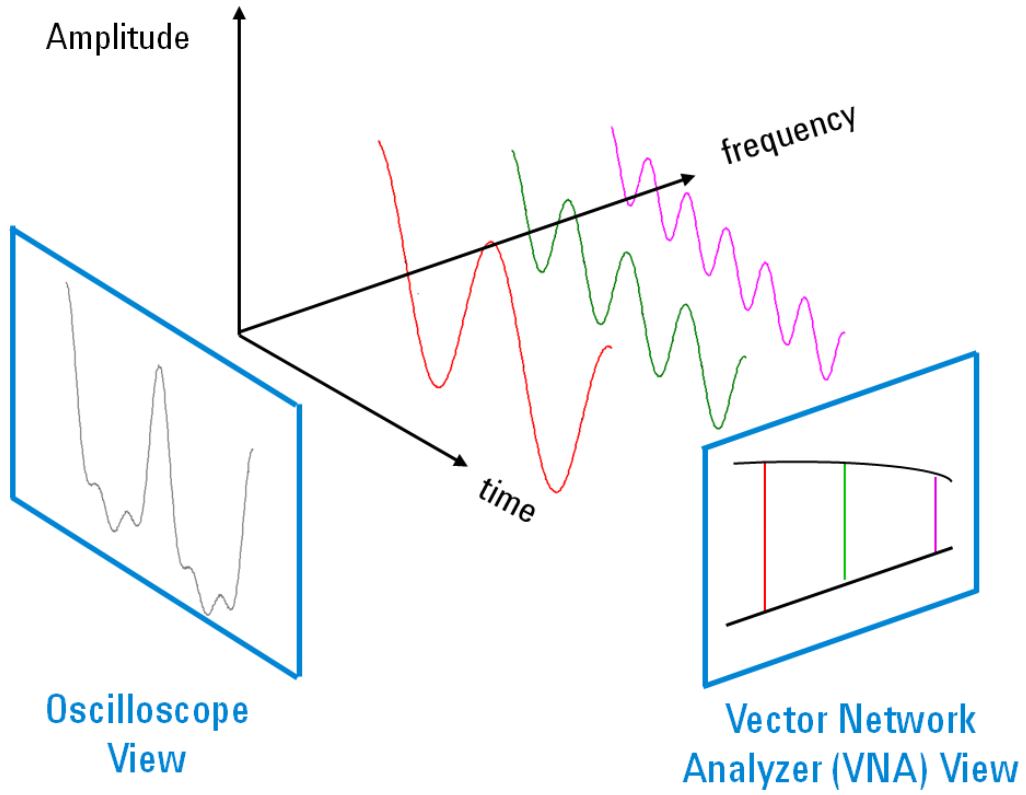
시간영역과 주파수영역 측정

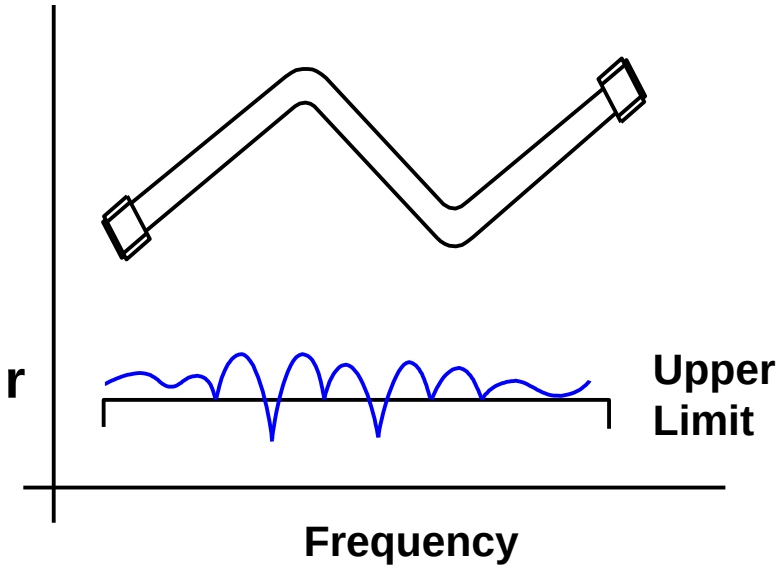


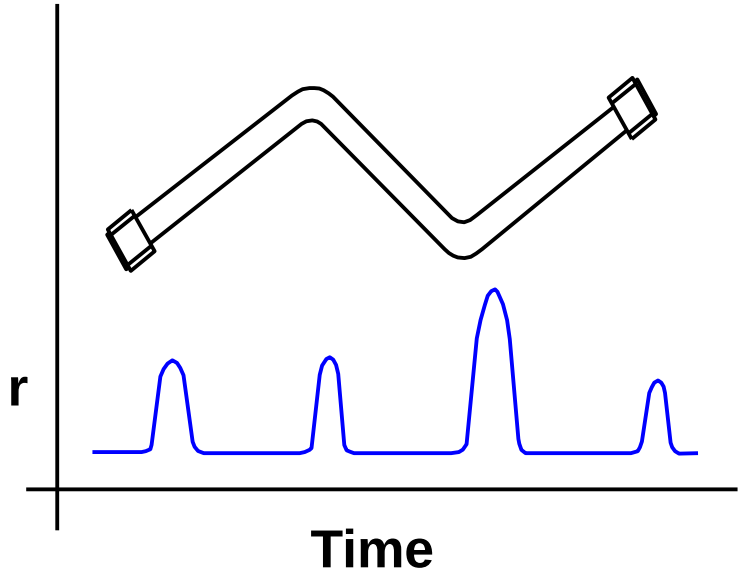
신호를 시간영역과 주파수 영역에서 바라보았을 때 보여지는 모습은 다르게 나타나지만 안에 있는 정보 혹은 내용은 **차이가 없습니다.**

즉 두 개의 영역은 같은 신호를 보여주는데 서로 다른 특성의 정보를 보여주고 있다고 볼 수 있습니다.

TDR 측정 이란?

Time Domain Reflectometry



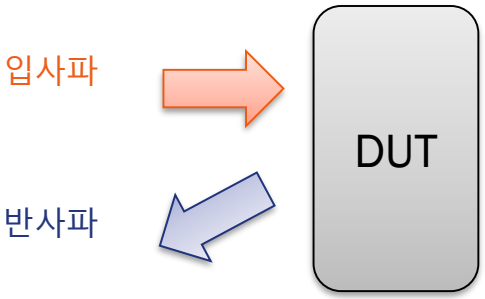


Time Domain 측정

TDR 측정

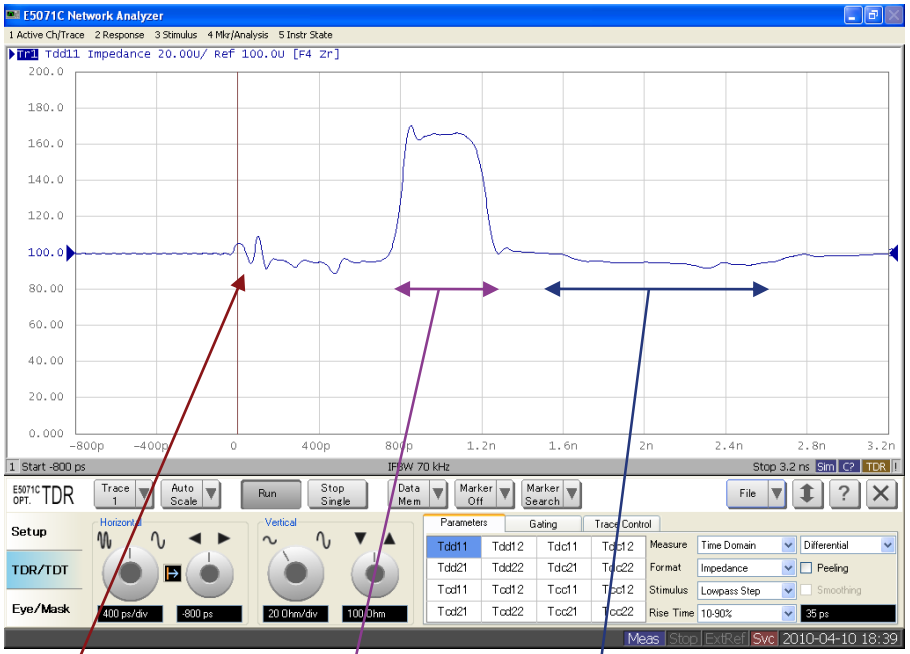
- x-축은 시간이거나 거리입니다.

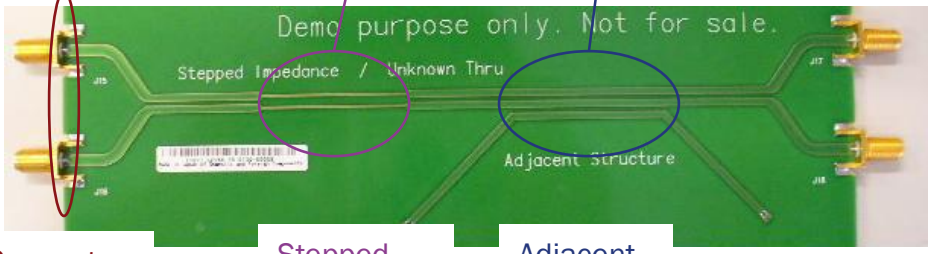
- Discontinuities 위치를 확인하기 위하여 임피던스 프로파일을 측정합니다.



- 반사파의 모습이나 극성을 분석하여 전송선의 임피던스 특성을 분석할 수 있습니다.

$$Z_o = \sqrt{L/C}$$





Connector

Stepped impedance

Adjacent trace

키사이트 VNA 솔루션

Performance

PNA-X, NVNA
Industry-leading performance
10 M to 13.5/26.5/43.5/50/67 GHz
Up to 1.5 THz with extenders

PNA
Performance VNA
10 M to 20, 40, 50, 67 GHz
Up to 1.5 THz with extenders

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

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

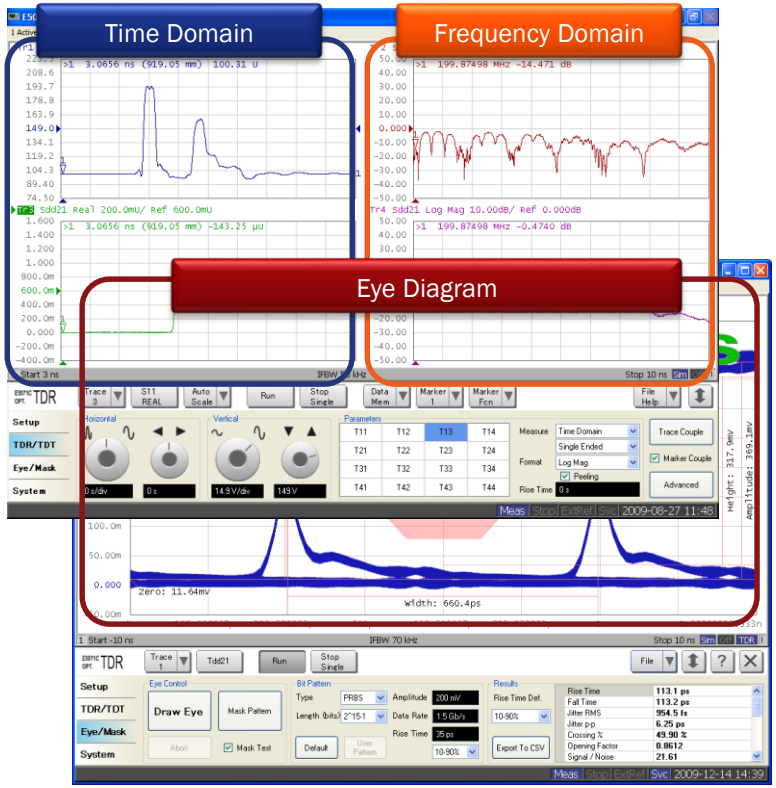
E5061B
NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz

ENA Series

FieldFox
Handheld RF Analyzer
5 Hz to 50 GHz

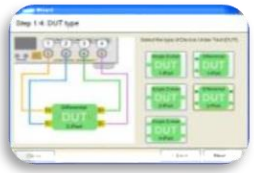
ENA TDR 옵션

ENA TDR 옵션은 ENA 장비 안에 설치되는 소프트웨어로 고속 시리얼통신의 interconnect 분석을 위한 **one-box solution** 입니다.



3 Breakthroughs

for Signal Integrity Design and Verification



Simple and Intuitive Operation

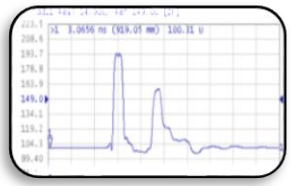
Fast and Accurate Measurements

ESD Robustness

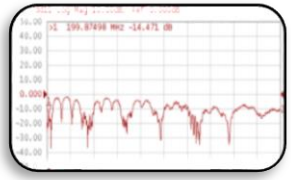
One-box 솔루션

고속 시리얼 통신의 Interconnect 분석

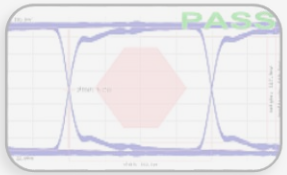
Time domain

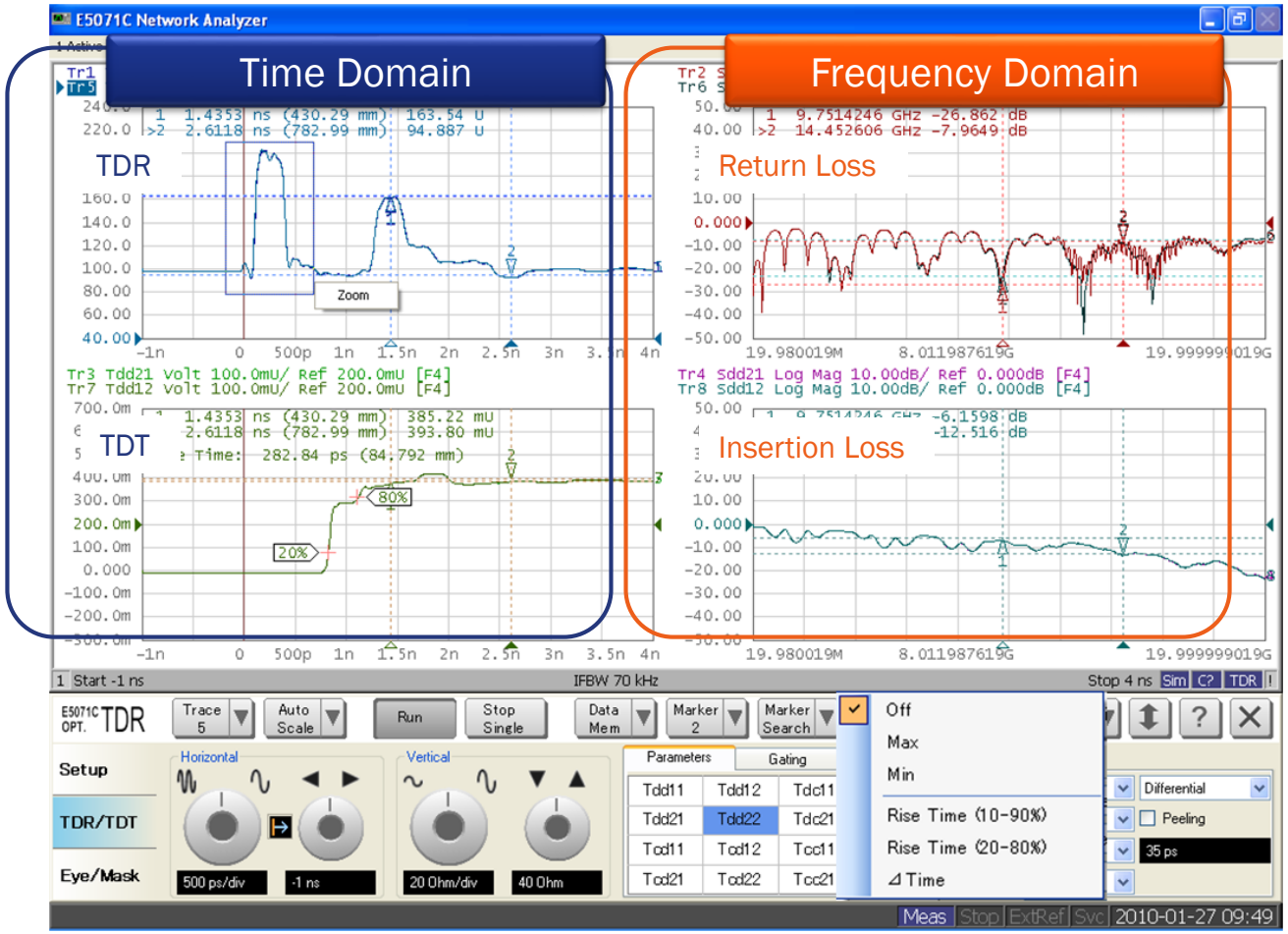


Frequency domain



Eye diagram

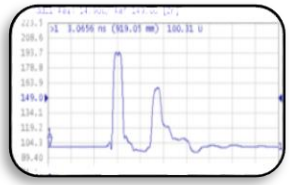




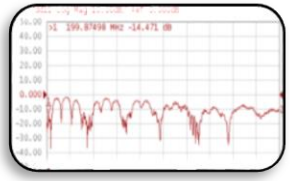
One-box 솔루션

고속 시리얼 통신의 Interconnect 분석

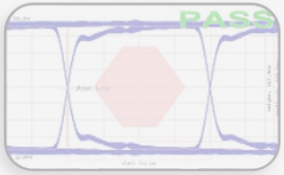
Time domain

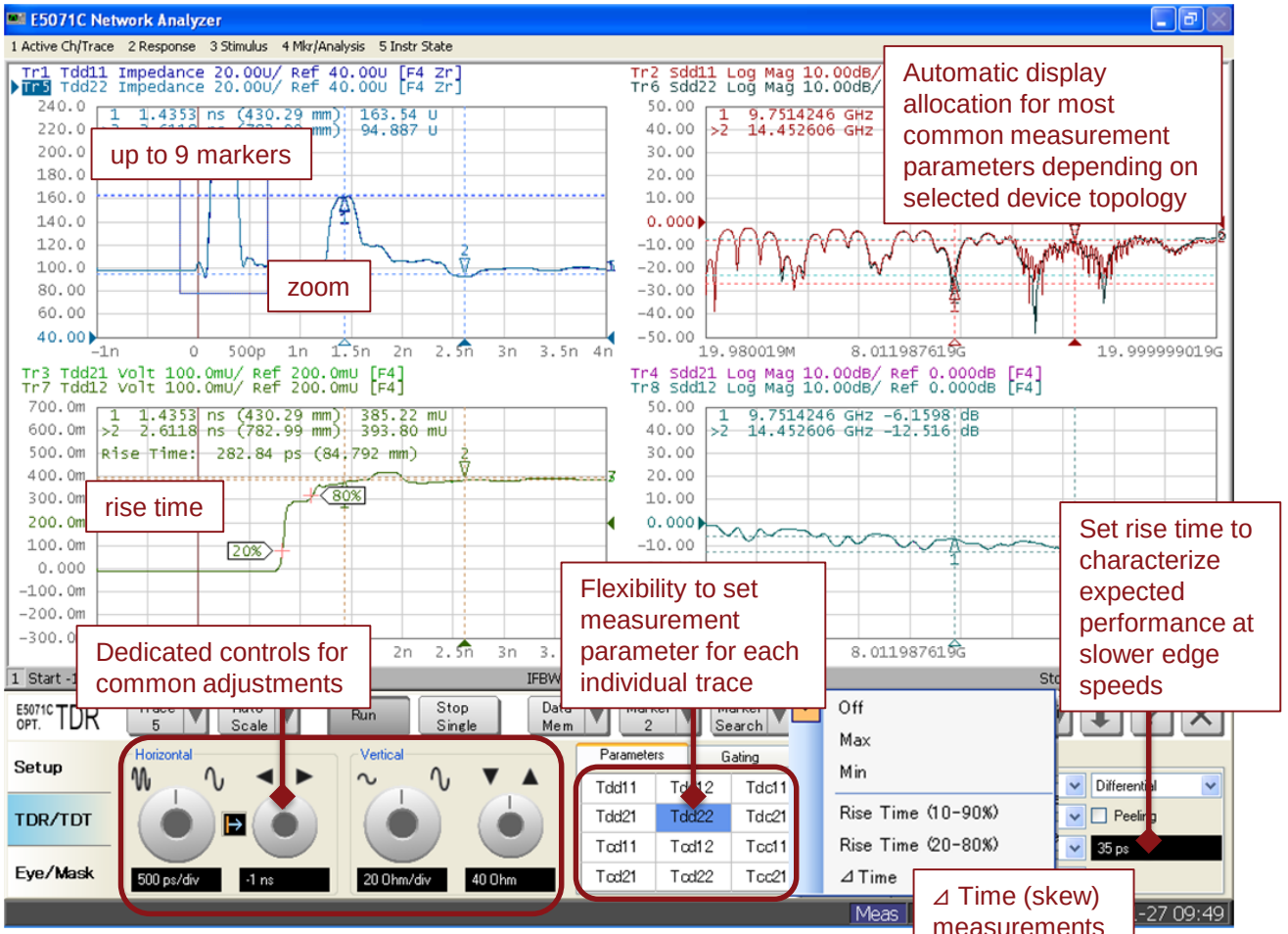


Frequency domain



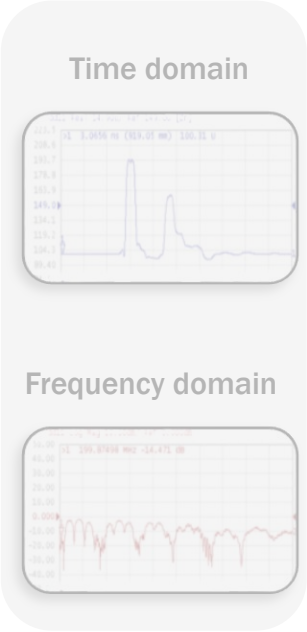
Eye diagram



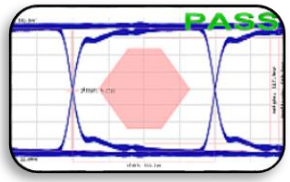


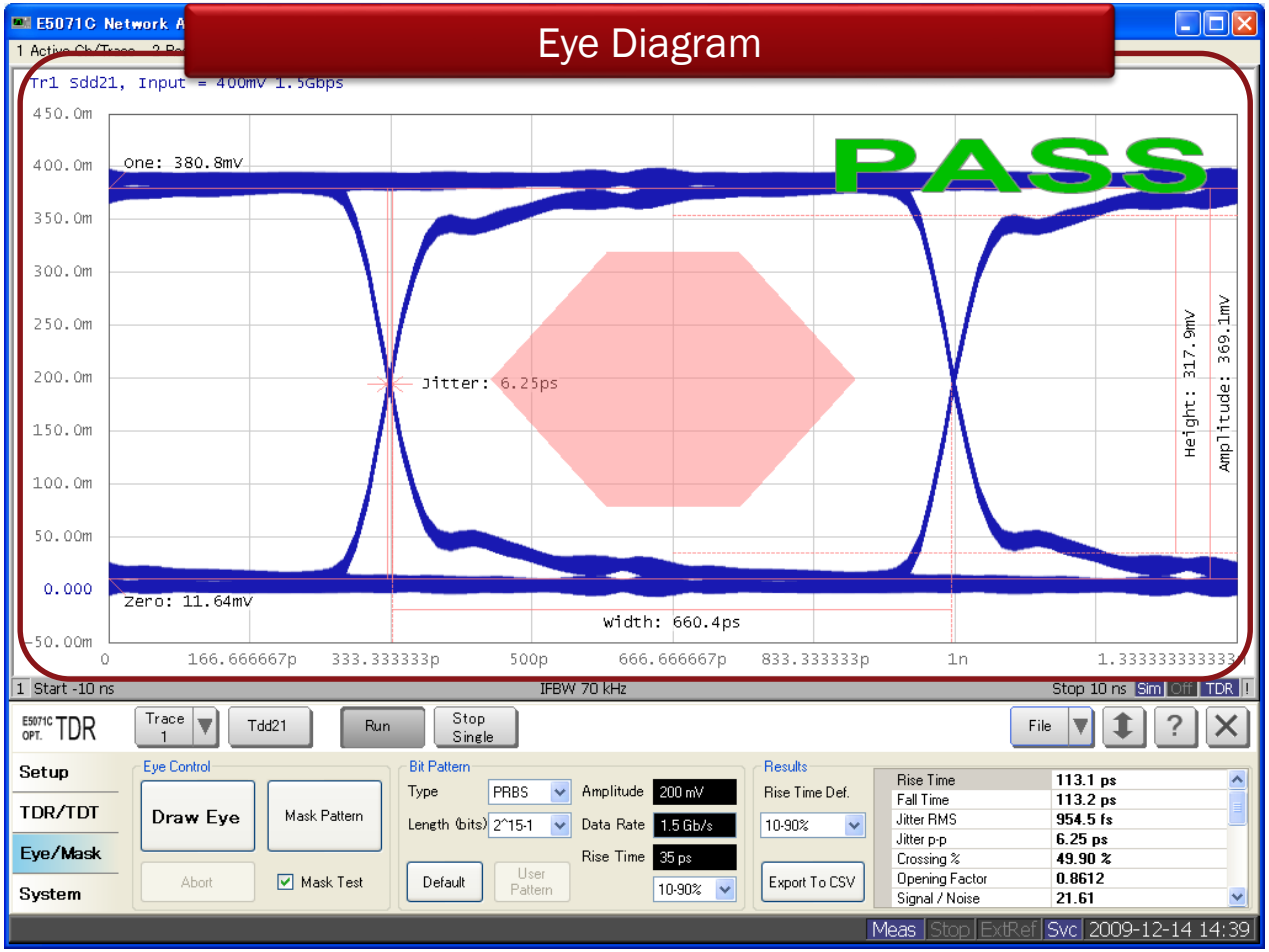
One-box 솔루션

고속 시리얼 통신의 Interconnect 분석



Eye diagram

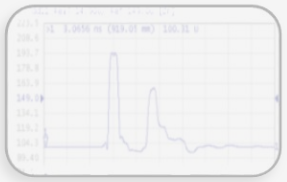




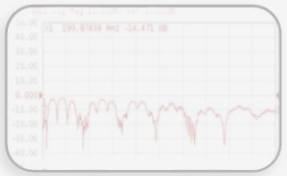
One-box 솔루션

고속 시리얼 통신의 Interconnect 분석

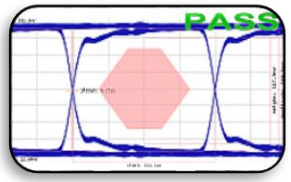
Time domain

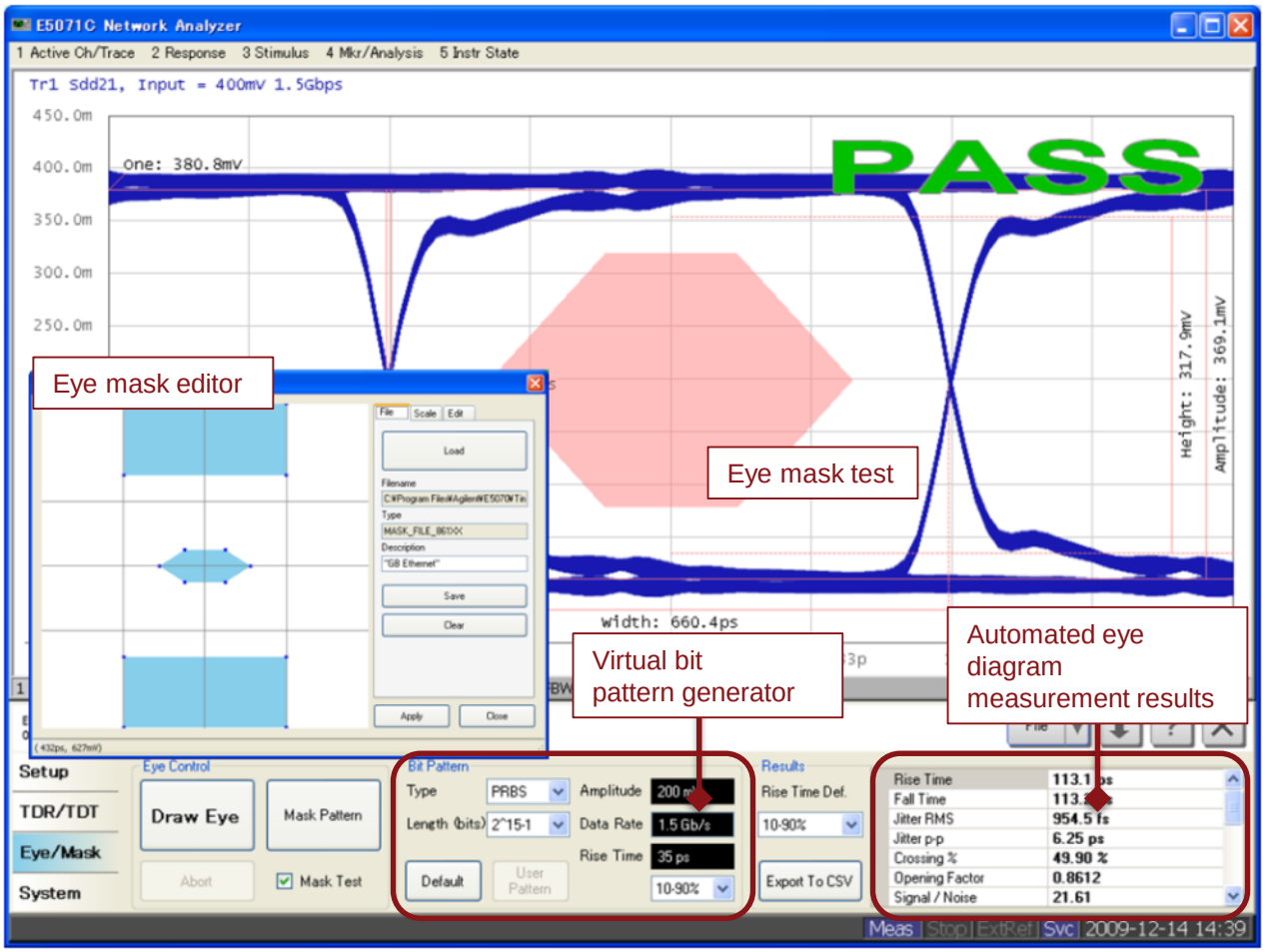


Frequency domain



Eye diagram

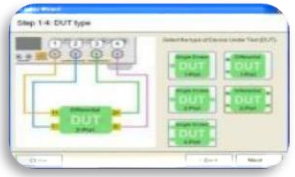




Three Breakthroughs

for Signal Integrity Design and Verification

Simple and Intuitive

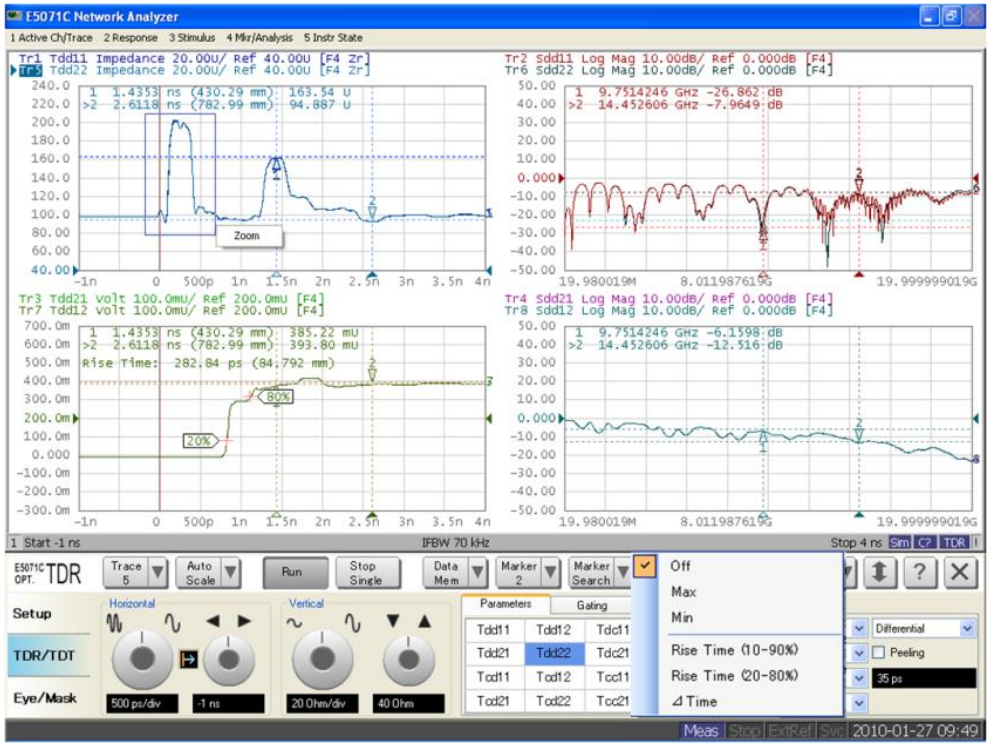


기존의 TDR 스코프 장비와 비슷한 느낌과 모습

Vector network analyzers 와 S-파라메타 측정에 익숙하지 않은 사용자도 직관적으로 사용할 수 있는 구성.

Fast and Accurate

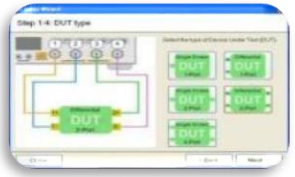
ESD Robustness



Three Breakthroughs

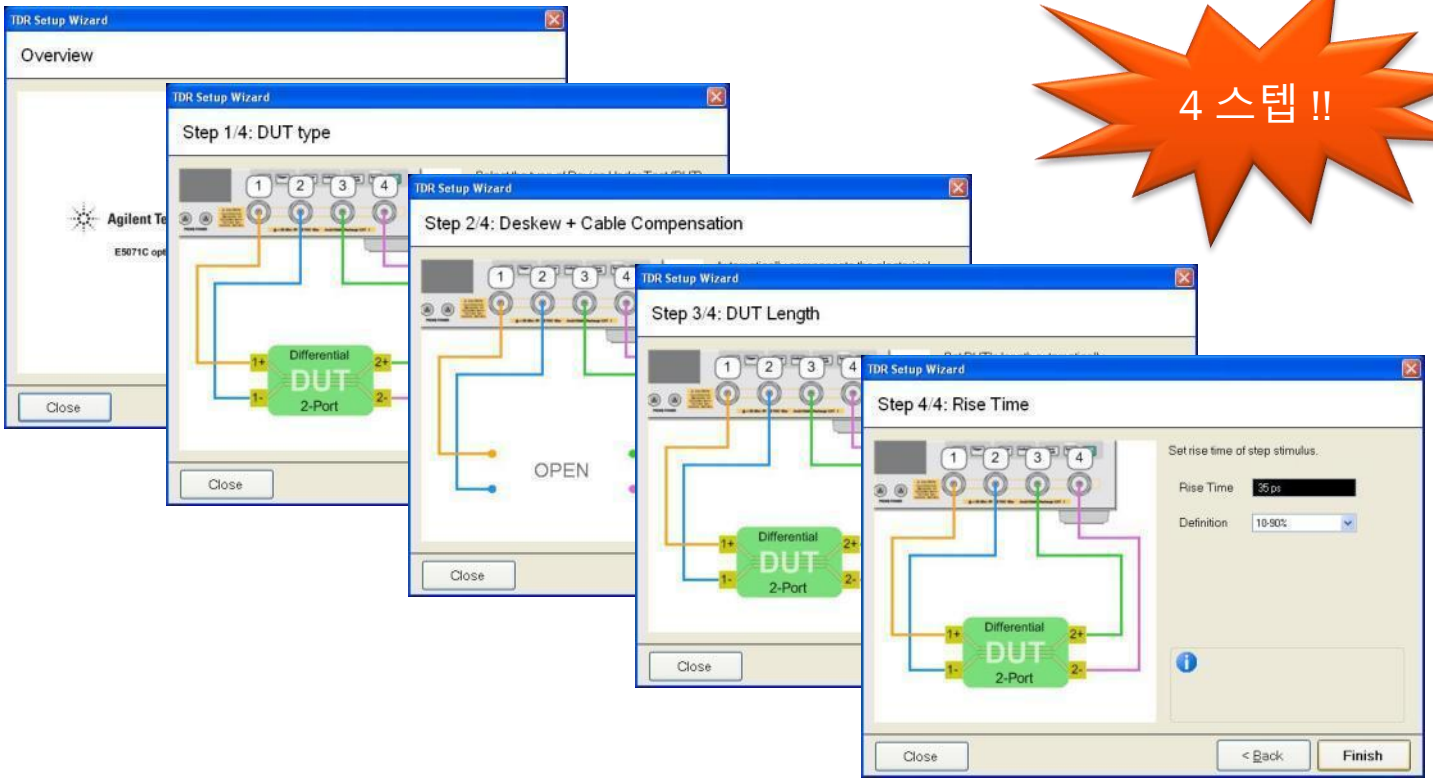
for Signal Integrity Design and Verification

Simple and Intuitive



Setup Wizard

사용자가 필요한 설정과정, error 교정 작업 등을 손쉽게 진행할 수 있도록 도와줍니다.



4 스텝 !!

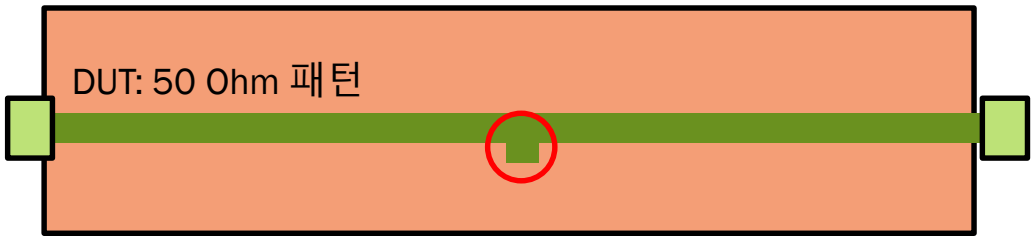
Fast and Accurate

ESD Robustness

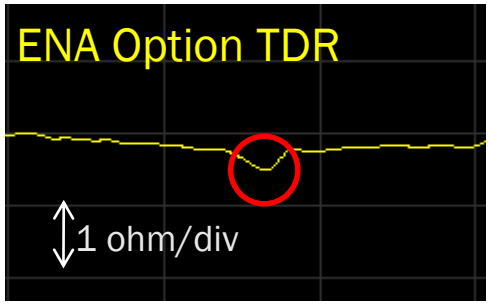
Three Breakthroughs

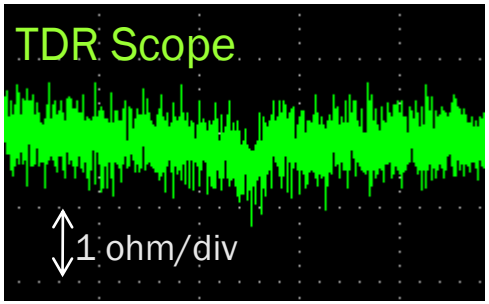
for Signal Integrity Design and Verification

Simple and Intuitive

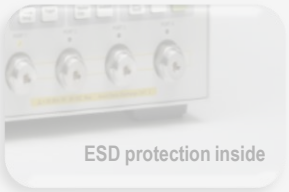


Fast and Accurate





ESD Robustness



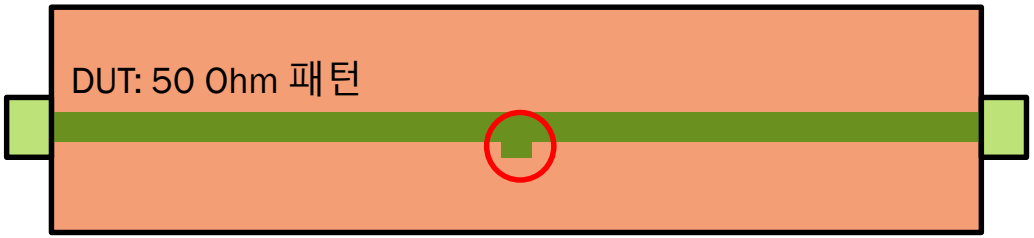
VNA 기반의 TDR 측정

= Low Noise

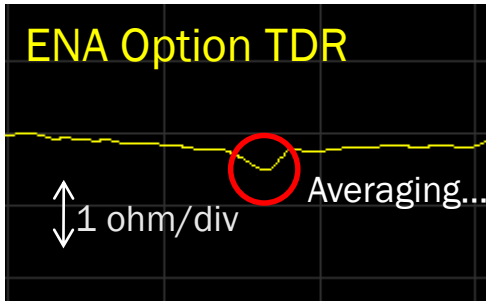
Three Breakthroughs

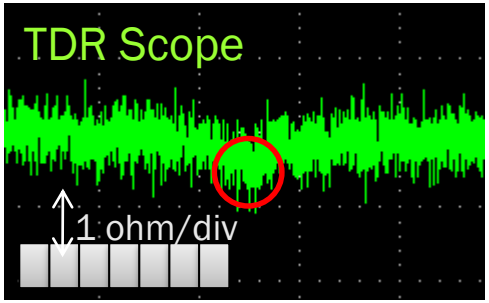
for Signal Integrity Design and Verification

Simple and Intuitive



Fast and Accurate





ESD Robustness

Averaging

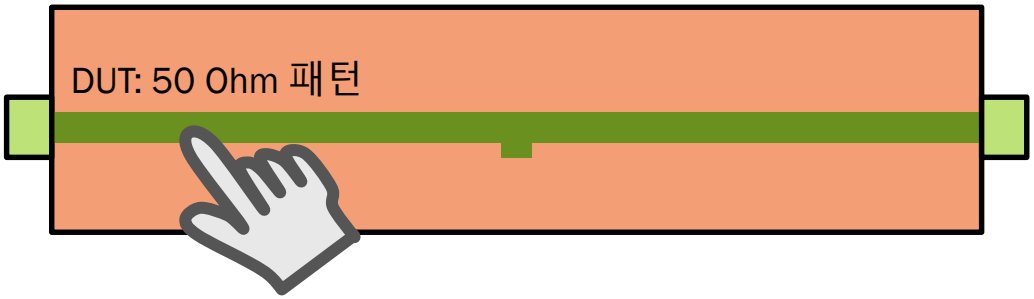
can lower noise

BUT...

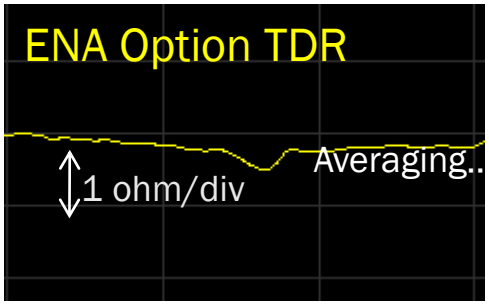
Three Breakthroughs

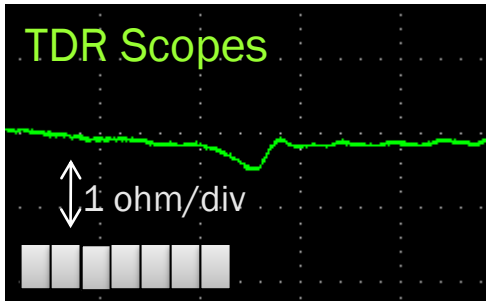
for Signal Integrity Design and Verification

Simple and Intuitive

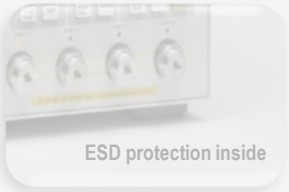


Fast and Accurate





ESD Robustness



Real-Time Analysis

Three Breakthroughs

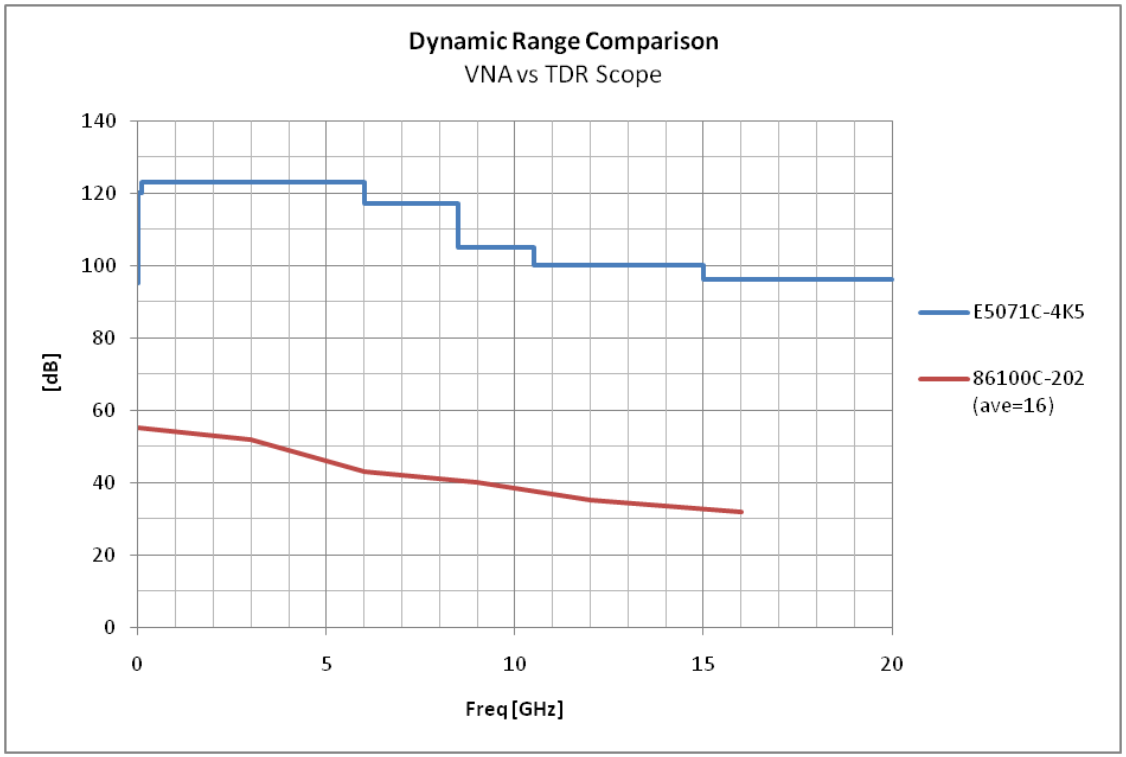
for Signal Integrity Design and Verification

Simple and Intuitive

Fast and Accurate

ESD Robustness

네트워크 분석기에서 Dynamic range는 receiver가 정확하게 측정할 수 있는 최대 파워와 receiver의 noise floor의 차를 말합니다.



•E5071C Datasheet (5989-5479EN) July 10, 2009 ... System Dynamic Range 10Hz IFBW
•86100C Technical Specifications (5989-0278EN) October 1, 2009 ... Attenuation Dynamic Range Internal

Three Breakthroughs

for Signal Integrity Design and Verification

Simple and Intuitive

Fast and Accurate

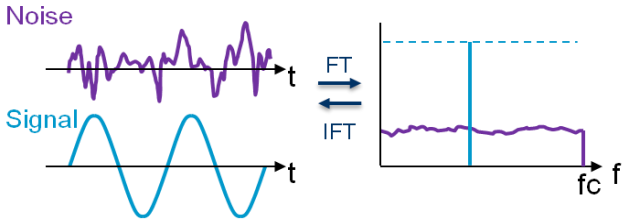
ESD Robustness

ENA TDR 옵션

[Source]

•Source는 측정하고자 하는 주파수 대역에서 파워 크기가 일정합니다.

-> 높은 주파수 대역에서 정확도가 유지됩니다.

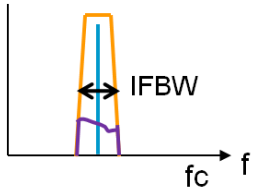


[Receiver]

•Narrowband

•노이즈는 필터의 stopband 에 의해서 감쇄가 됩니다.

-> Noise reduction

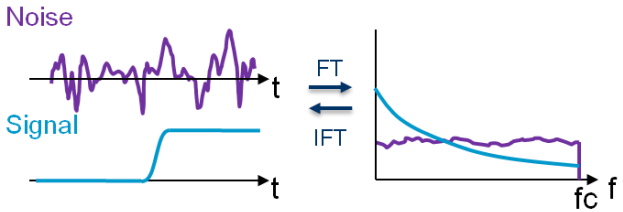


TDR 스코프

[Source]

•Source의 파워는 주파수가 증가함에 따라 급격하게 감소합니다.

-> 높은 주파수 대역에서 정확도가 많이 감소합니다.

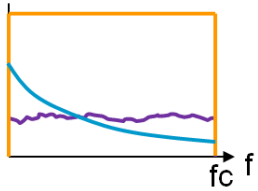


[Receiver]

•Broadband

•시스템의 측정 bandwidth 안에 존재하는 모든 노이즈가 측정됩니다.

->NO noise reduction



For further details (including mathematical analysis), refer to the White Paper “Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope” (5990-5446EN).

Three Breakthroughs

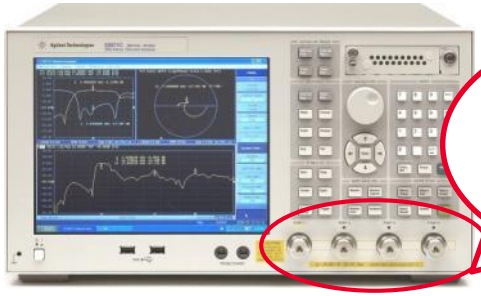
for Signal Integrity Design and Verification

Simple and Intuitive

Fast and Accurate

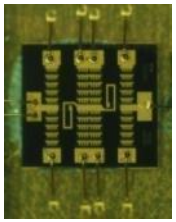
ESD Robustness

ENA TDR 옵션



ESD 보호회로가 장비 내부에 설치되어 있습니다.

ESD (Electro Static Discharge)에 대한 높은 내성은 장비의 모든 port에 RF 측정성능은 유지하면서 ESD 방지할 수 있는 보호회로를 설치할 수 있기 때문입니다.,.



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

ESD에 대한 성능을 시험하기 위하여 ENA 옵션 TDR은 IEC801-2 Human Body Model에 준한 ESD Survival 시험을 받았습니다.

ESD Survival	IEC 801-2 Human Body Model. (150 pF, 330 Ω) RF Output Center pins tested to 3 kV, 10 cycles

Three Breakthroughs

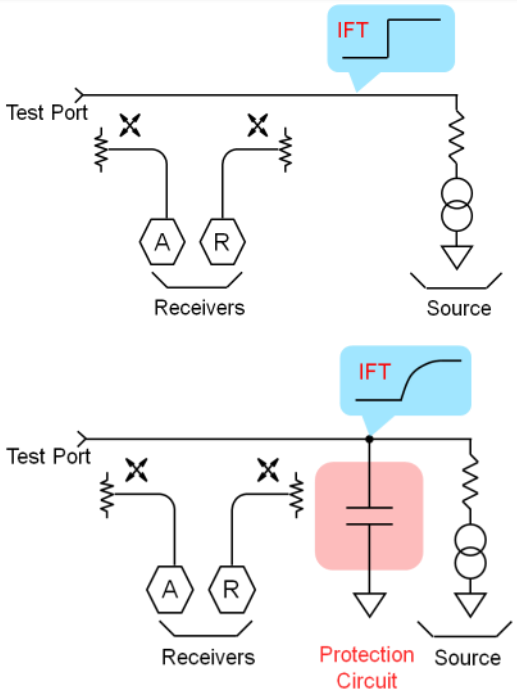
for Signal Integrity Design and Verification

Simple and Intuitive

Fast and Accurate

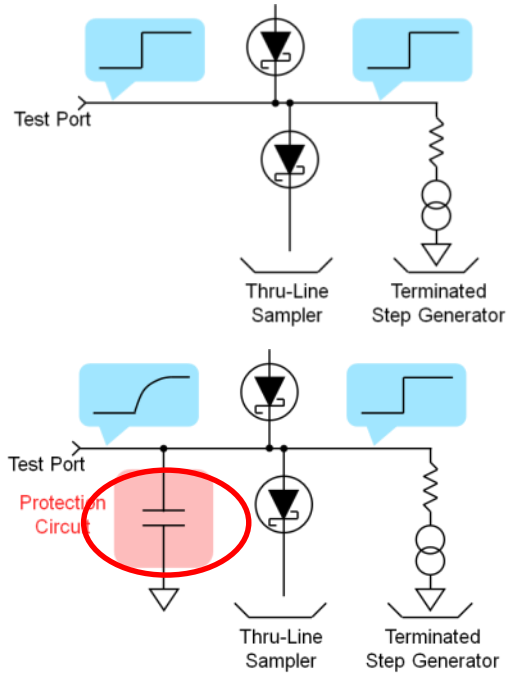
ESD Robustness

ENA TDR 옵션



ENA TDR 옵션은 전송되고 반사되는 두 신호를 측정하여 벡터비를 측정하는 방식으로 동작하기 때문에 ESD 방지회로의 효과가 서로 상쇄되게 됩니다.

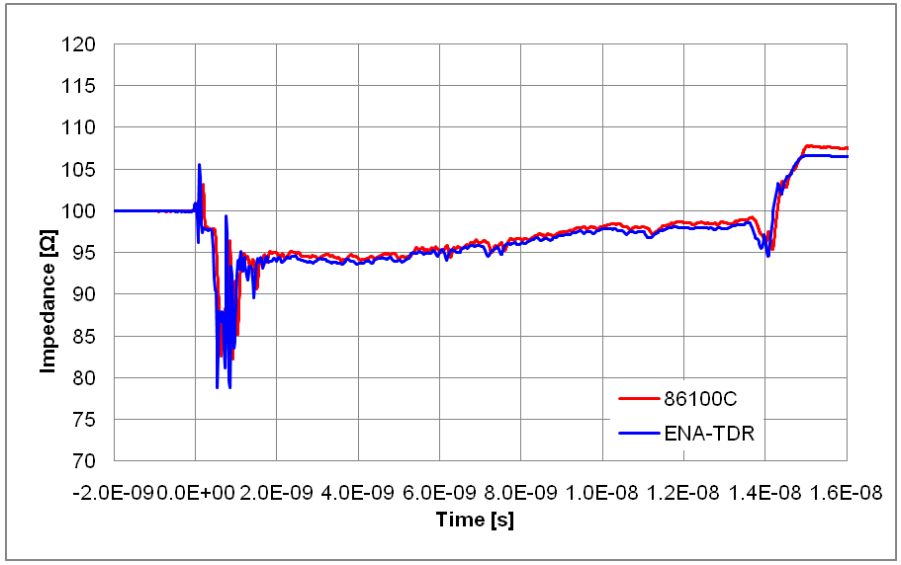
TDR 스코프

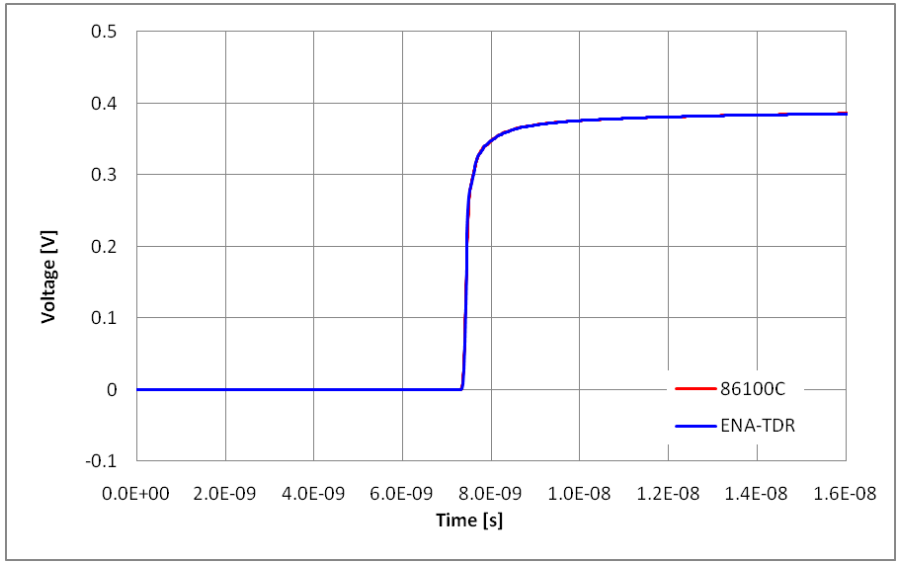


ESD 보호회로가 step stimulus 신호의 rise time을 낮추는 효과가 있기 때문에 보호회로를 잘 설계하는 것이 어렵습니다.

측정 Correlation
TDR/TDT

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

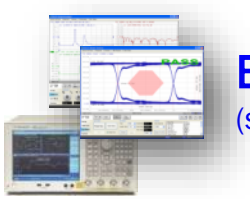




측정 Correlation

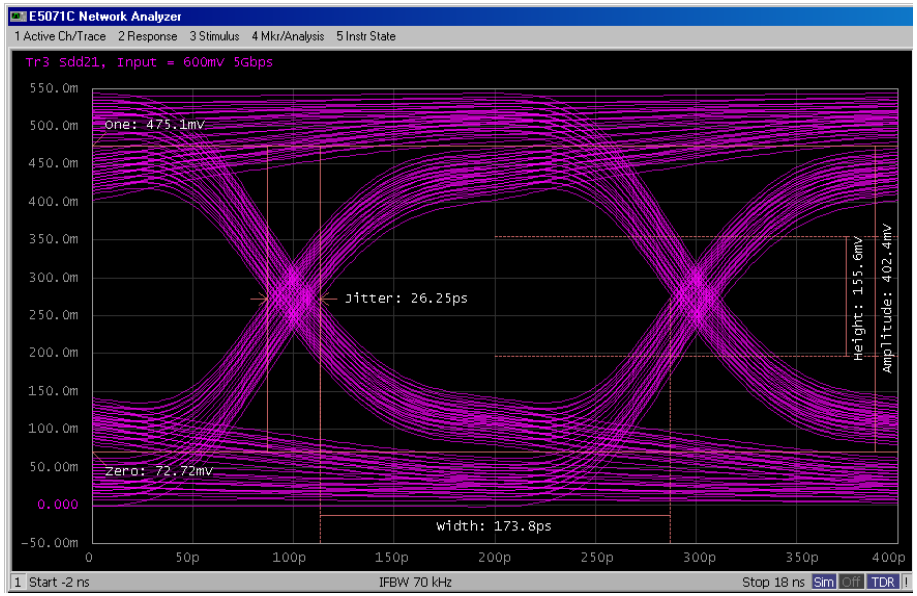
Eye Diagram

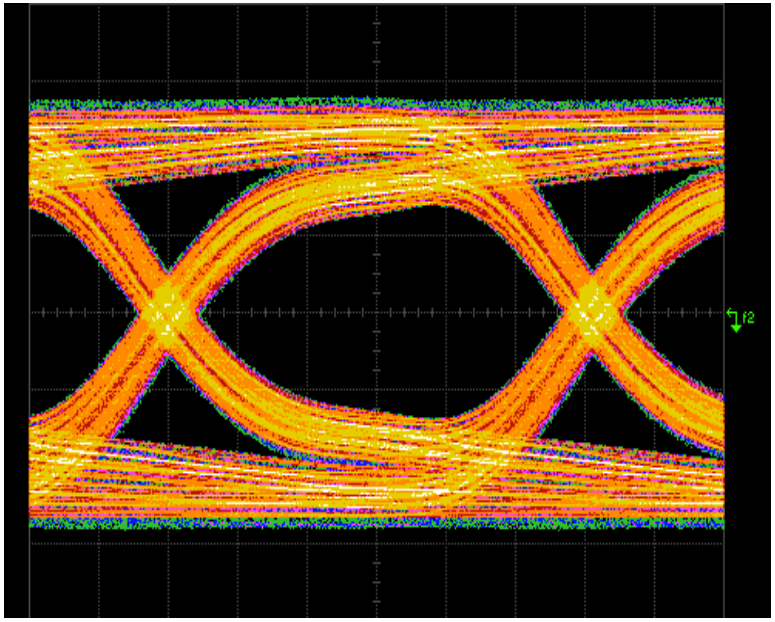
- DUT: USB3.0 Cable
- PRBS (2^7-1) @ 5 Gbps



ENA TDR 옵션
(simulated)

N4903B + 86100C
(live)



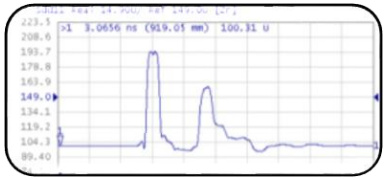


ENA 옵션 TDR 요약

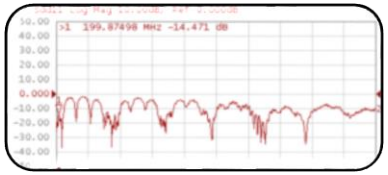
Keysight ENA TDR 옵션 어플리케이션...

- 고속 시리얼 통신 **interconnect** 분석을 위한 **one-box solution** 을 제공합니다.

Time domain



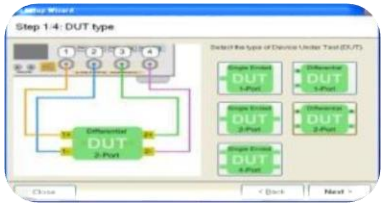
Frequency domain



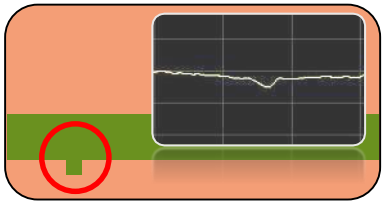
Eye diagram

- 신호 **integrity** 설계와 검증을 위한 **세가지 breakthroughs** 가 있습니다.

Simple & Intuitive Operation



Fast & Accurate Measurements



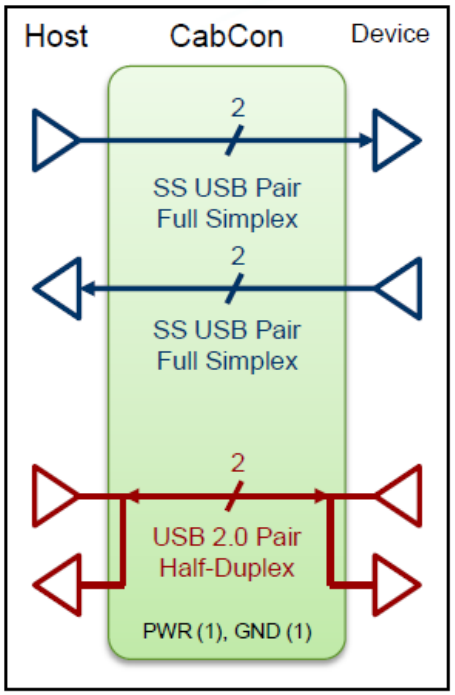
ESD Robustness

내용

- 키사이트 네트워크 분석기 기반 TDR 장비 Overview
- Cable/Connector Compliance 시험 항목 예
- 최신 고속 Digital 규격 측정에 필요한 기능
  - Stressed Eye Diagram 분석
  - Hot TDR 측정: Active Device에 대한 실제 사용조건에서의 임피던스 분석기능
- Summary

Cable / Connector Compliance 시험

측정 Parameter - USB 3.0



Time Domain Measurements

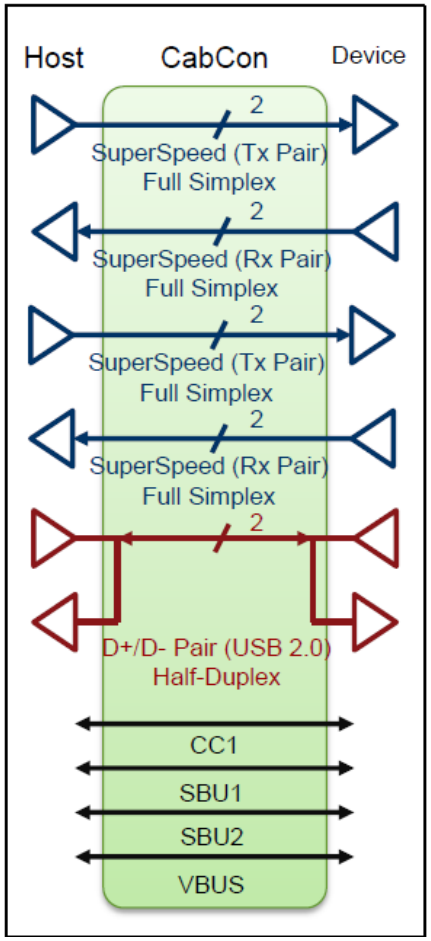
Mated Connector Impedance
Raw Cable Impedance
Intra-Pair Skew
D+/D- Pair Skew (USB 2.0)
D+/D- Propagation Delay (USB 2.0)
Diferential Near End Crosstalk (NEXT)
Differential Crosstalk Between D+/D- and Super Speed

Frequency Domain Measurements

Differential Insertion Loss (Sdd21)
Differential-to-common Mode Conversion (Scd21)
D+/D- Pair Attenuation (USB 2.0)

Cable / Connector Compliance 시험

측정 Parameter - USB Type-C



USB Type-C connectors and cable assemblies must meet or exceed the requirements specified by the most current version of Chapter 3 of the USB Type-C Specification and applicable Supplements.

Time Domain Measurements

- •D+/D- Impedance (USB 2.0)
- •D+/D- Propagation Delay (USB 2.0)
- •D+/D- Intra-pair Skew (USB 2.0)
- •[Raw Cable] Characteristic Impedance (Informative)
- •[Raw Cable] Intra-Pair Skew (Informative)
- •[Mated Connector] Differential Impedance (Informative)
- •[Low Speed Signal] Characteristic Impedance

Frequency Domain Measurements

- •D+/D- Pair Attenuation (USB 2.0)
- •ILfitatNq, IMR, IXT, IRL, Differential to Common Mode Conversion
- •Shielding Effectiveness
- •Insertion Loss (Informative)
- •Return Loss (Informative)
- •NEXT/FEXT between Gen2 Pairs (Informative)
- •NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)
- •[Raw Cable] Insertion Loss (Informative)
- •[Mated Connector] Insertion Loss (Informative)
- •[Mated Connector] Return Loss (Informative)
- •[Mated Connector] NEXT/FEXT between Gen2 Pairs (Informative)
- •[Mated Connector] NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)
- •[Mated Connector] Differential to Common Mode Conversion (Informative)
- •[Low Speed Signal] Coupling between CC and Differential D+/D-
- •[Low Speed Signal] Single-ended Coupling between CC and USB D-
- •[Low Speed Signal] Coupling between VBUS and Differential D+/D-
- •[Low Speed Signal] VBUS Loop Inductance, Coupling Factor, VBUS Capacitance
- •[Low Speed Signal] Single-ended Coupling between SBU_A and SBU_B
- •[Low Speed Signal] Single-ended Coupling between SBU_A/SBU_B and CC
- •[Low Speed Signal] Coupling between SBU_A/SBU_B and Differential D+/D-

Cable / Connector Compliance 시험

측정 Parameter - HDMI

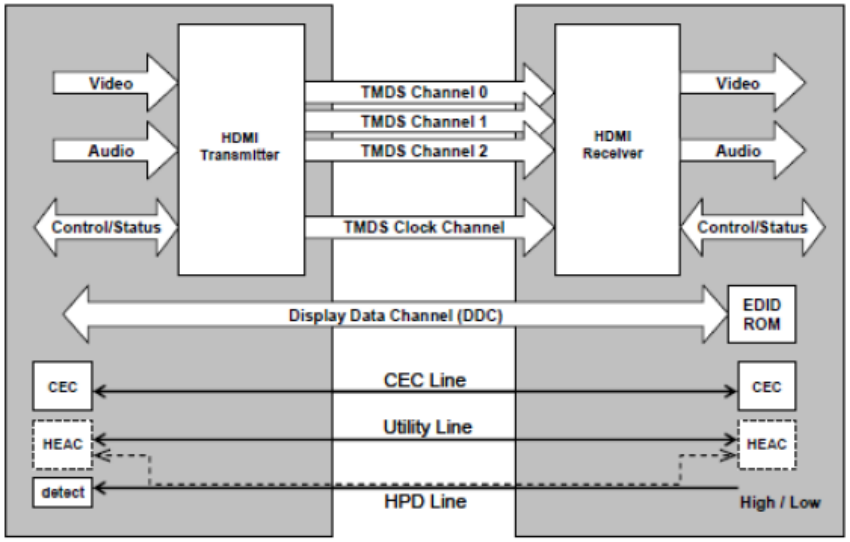


Figure 3-1 HDMI Block Diagram

Eye Diagram Measurement

Test ID 5-3: TMDS Data Eye Diagram

Time Domain Measurements

Test ID 5-4: Intra-Pair Skew

Test ID 5-5: Inter-Pair Skew

Test ID 5-8: Differential Impedance

Frequency Domain Measurements (*)

Test ID 5-6: Far End Crosstalk

Test ID 5-7: Attenuation and Phase

Cable / Connector Compliance 시험

솔루션 overview

• Cable/connector compliance 시험은 시간영역과 주파수 영역에서의 파라메타 측정으로 구성됩니다.

주파수 영역
•Insertion Loss (Sdd21)
•Mode Conversion (Scd21)
•Crosstalk (NEXT, FEXT) (TDT)

시간 영역
•Mated Connector Impedance Profile (TDR)

기존 솔루션

벡터 네트워크 분석기

TDR 스코프

새로운 솔루션

•모든 parameter를 **ENA TDR 옵션**으로 측정이 가능합니다.

One-box 솔루션 !!

KEYSIGHT TECHNOLOGIES

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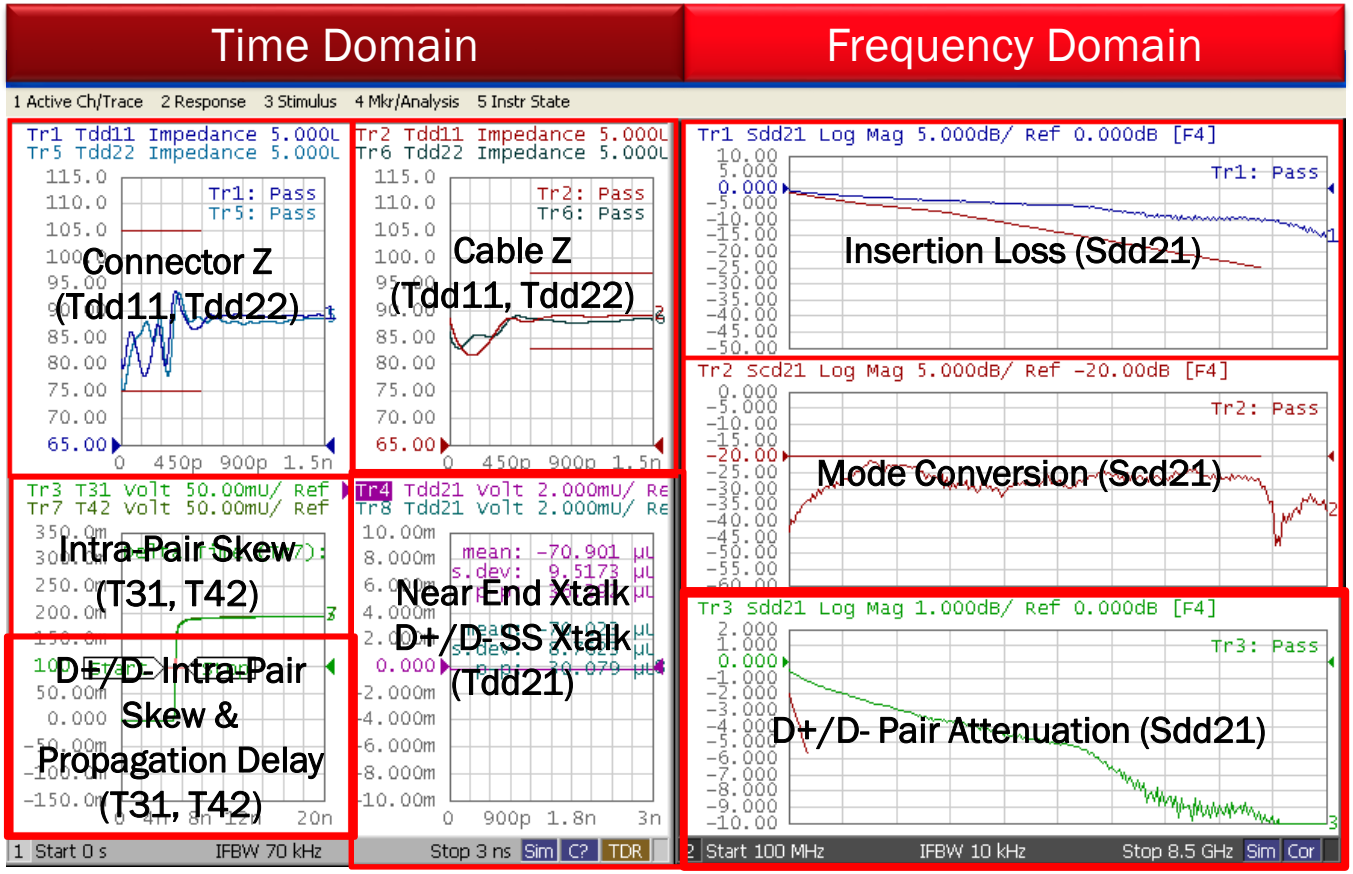
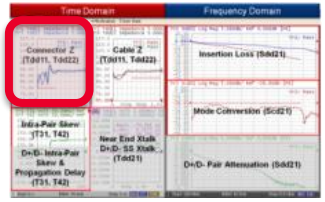
Cable / Connector Compliance 시험

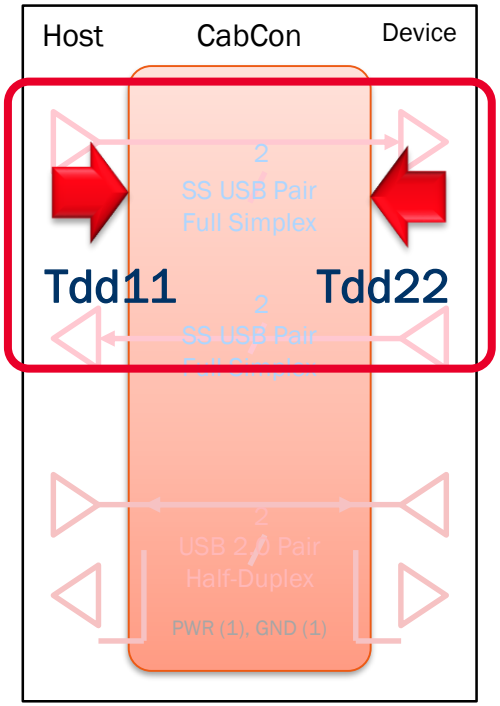
Parameter 측정



Cable / Connector Compliance 시험

Mated Connector Impedance – USB 3.0





• 임피던스 mismatch 에 의해서 발생되는 반사는 Receiver 단에서 노이즈로 나타나게 됩니다. 따라서 임피던스 프로파일을 측정함으로써 임피던스 mismatch에 의한 영향을 판단할 수 있는 것입니다.

• 임피던스는 가장 많이 사용되는 파라메타입니다. 하지만 Receiver 단에서 보여지는 신호특성을 간접적으로 측정하는 파라메타라고 할 수 있습니다.

TDR with 50 ps (20-80%) rise time

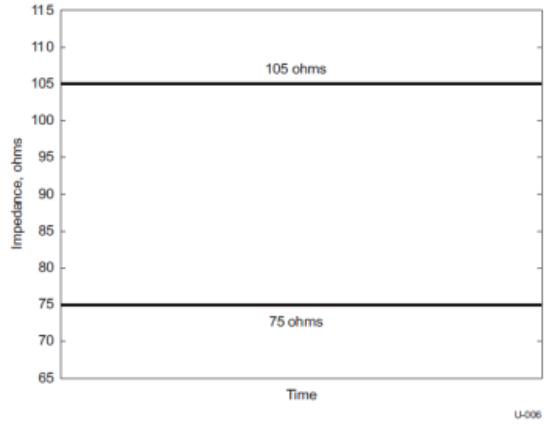
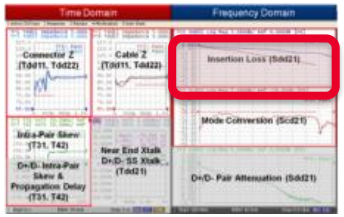
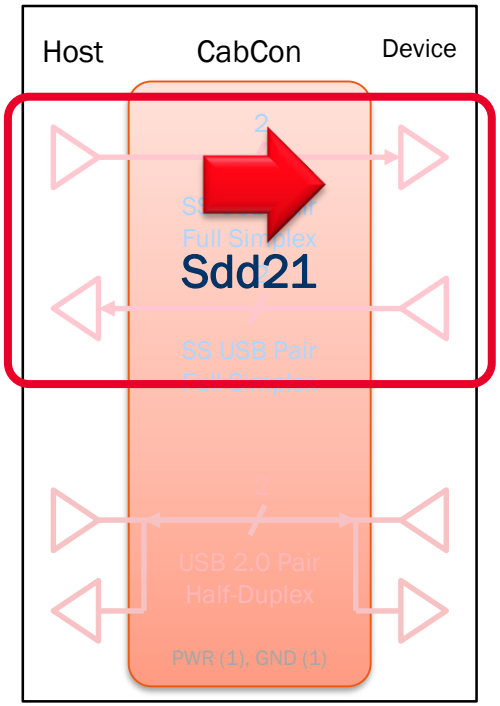


Figure 5-21. Impedance Limits of a Mated Connector

Cable / Connector Compliance 시험

SS Differential Insertion Loss (Sdd21) – USB 3.0





- Differential 신호가 interconnect를 통과하면서 진행할 때 바라보게 되는 주파수 응답 특성을 말합니다.
- Receiver 단에서 보여지는 신호특성을 직접적으로 측정하는 파라메타라고 할 수 있습니다.

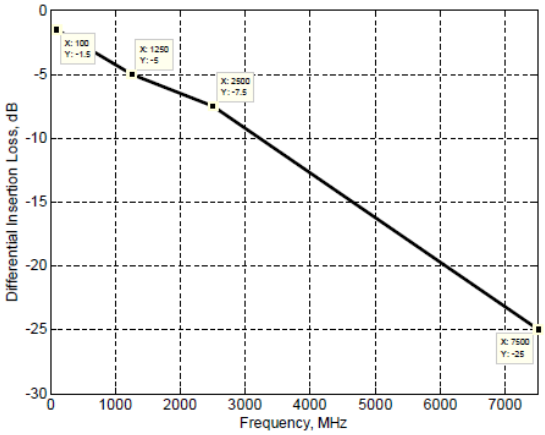


Figure C- 1. USB 3.0 Cable assembly differential insertion loss requirement

KEYSIGHT TECHNOLOGIES

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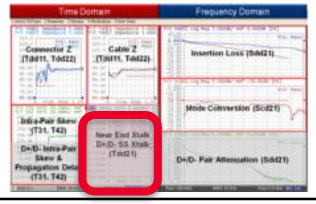
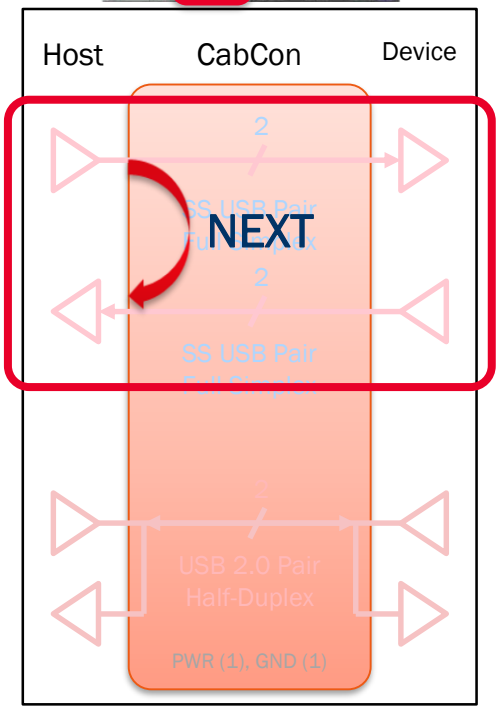
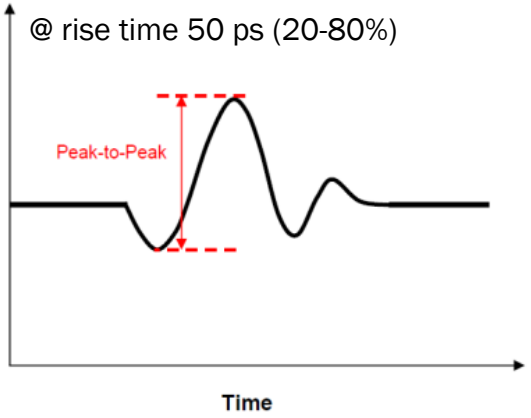
Cable / Connector Compliance 시험

Differential Near End Crosstalk Between SS Pairs (NEXT) – USB 3.0





- Differential pair 간의 coupling을 측정합니다.
- Crosstalk은 시간영역이나 주파수영역에서 측정됩니다.



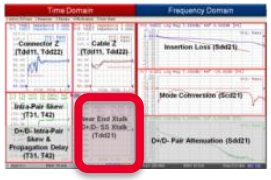
Standard-A	If p-p <= 3.6 mV: Pass, else: Fail
Standard-B	If p-p <= 7.2 mV: Pass, else: Fail
Micro-AB	If p-p <= 4.8 mV: Pass, else: Fail

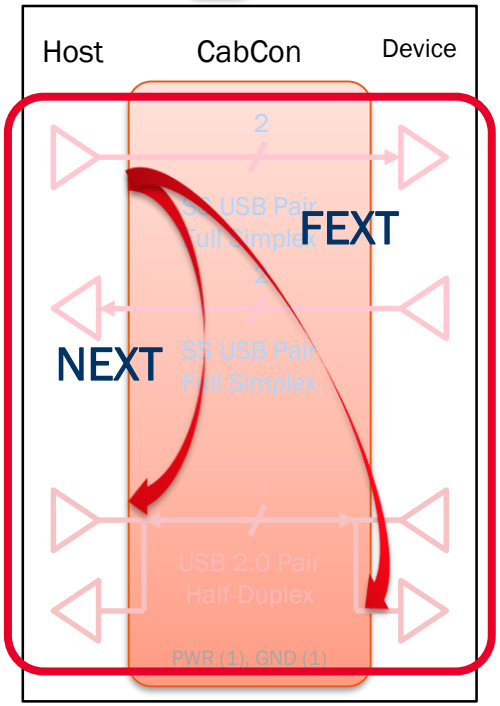
KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

Cable / Connector Compliance 시험

Differential Crosstalk Between D+/D- and SS Pairs (NEXT/FEXT) – USB 3.0





- Differential pair 간의 coupling을 측정합니다.
- Crosstalk은 시간영역이나 주파수영역에서 측정됩니다.

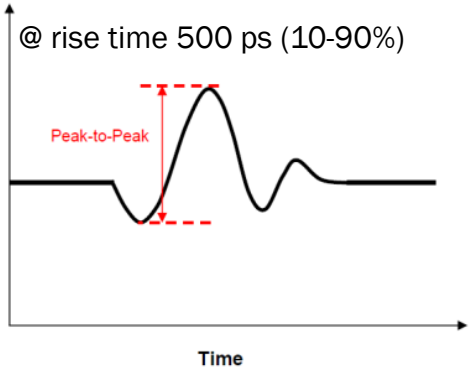


Figure C- 2. I

Standard-A	If p-p <= 8.0 mV: Pass, else: Fail
Standard-B	If p-p <= 8.0 mV: Pass, else: Fail
Micro-AB	If p-p <= 8.0 mV: Pass, else: Fail

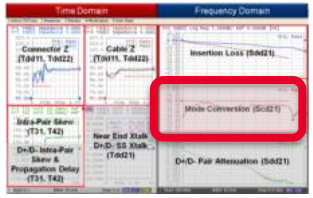
KEYSIGHT TECHNOLOGIES

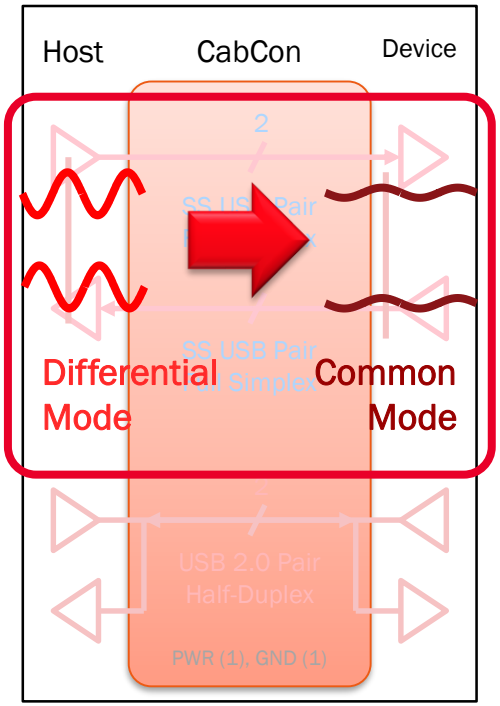
TMG 티엠게이트

Cable / Connector Compliance 시험

Differential to Common Mode Conversion (Scd21)

– USB 3.0





- Common-mode 신호는 직접적으로 EMI에 영향을 미치는 신호입니다. 즉 Scd21은 EMI 발생과 관련된 측정입니다.
- 이 측정의 목적은 EMI 방사에 대한 제한을 두기 위한 것입니다.

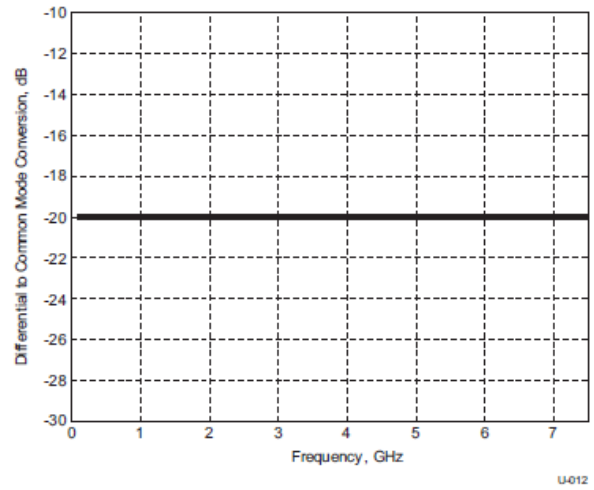


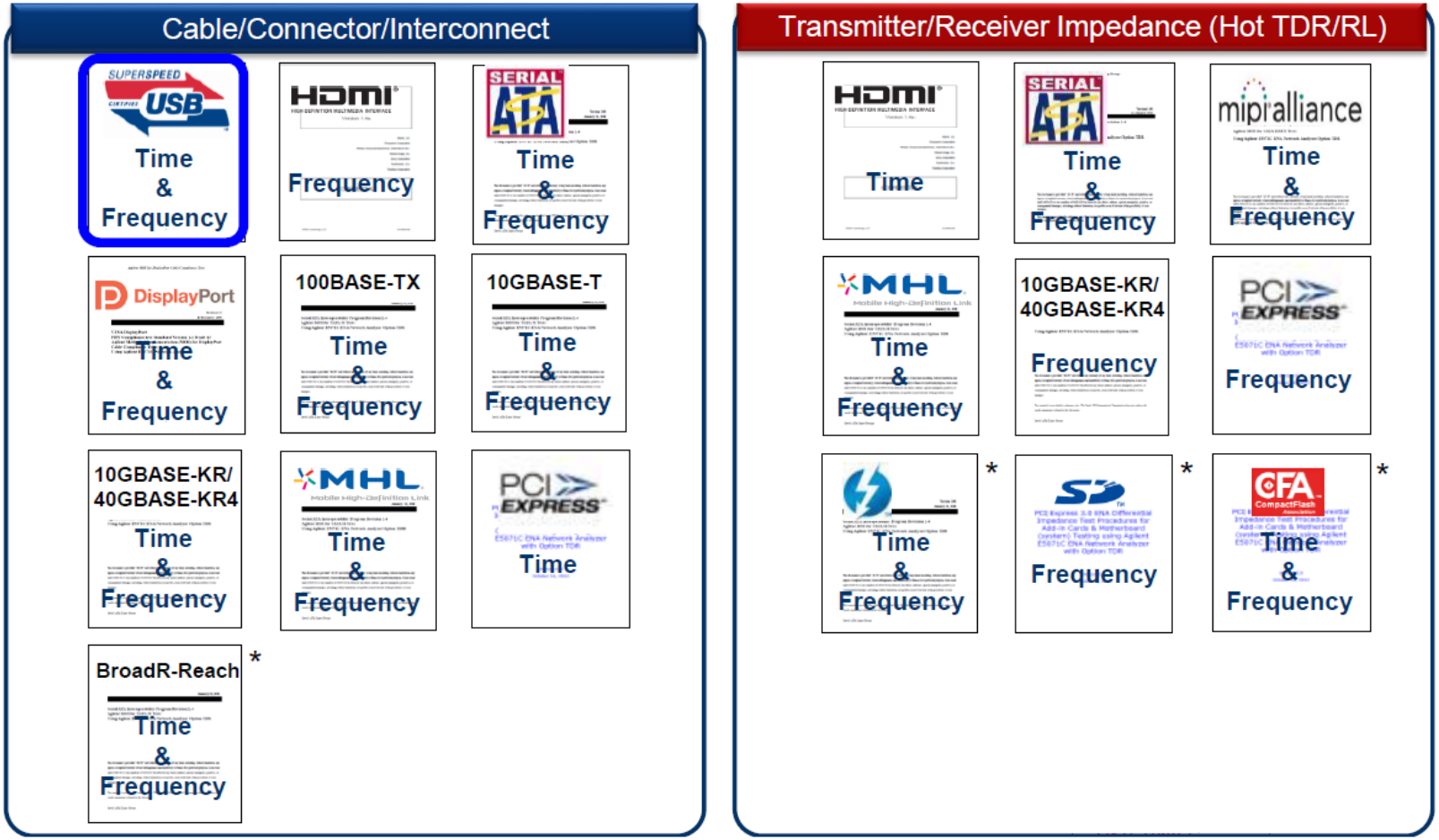
Figure 5-26. Differential-to-Common-Mode Conversion Requirement

KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

ENA TDR 옵션 Compliance

TDR / S-parameter Compliance 시험을 위한 One-box 솔루션



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

KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

키사이트 MOI 웹사이트 주소

www.keysight.com/find/ena-tdr_compliance

KEYSIGHT TECHNOLOGIES

Hardware | Software | Services & Support | Industries & Technologies | About Keysight

Home > Software > ... > Network Analyzer Software > E5071C-TDR Enhanced Time Domain Analysis > Details

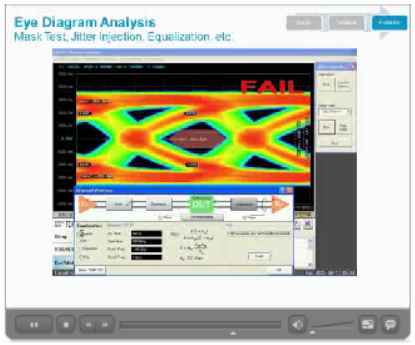
Method of Implementation (MOI) for High Speed Digital App

Overview

Each high speed communication standard establishes a specification to ensure the quality of products. To verify compliance, componer
compliance test for each standard. Using MOIs and state files, you can efficiently perform compliance tests with the E5071C-TDR and M

Learn more: E5071C-TDR Product Details

Learn more: M937xA PXIe Multiport VNA Product Details

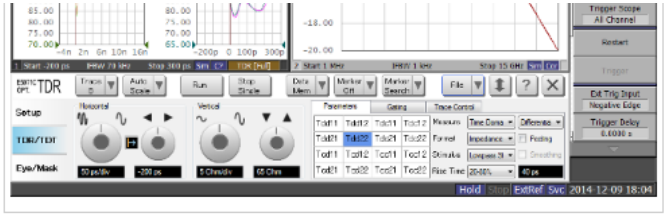


Standards supported by E5071C-TDR / M937xA PXIe Multiport VNA

Standards		MOIs & State Files: Cable-Connector Assembly	MOIs & State Files: Tx/Rx Impedance	Test Solution Overview
USB	USB 2.0	E5071C	*Coming soon...*	Available
	USB 3.0	E5071C	N/A	Available
	USB 3.1	E5071C	N/A	Available
	USB Type-C™	E5071C / M937xA / BitifEye	N/A	Available

Standards		MOIs & State Files: Cable-Connector Assembly	MOIs & State Files: Tx/Rx Impedance	Test Solution Overview
USB	USB 2.0	E5071C	*Coming soon...*	Available
	USB 3.0	E5071C	N/A	Available
	USB 3.1	E5071C	N/A	Available
	USB Type-C™	E5071C / M937xA / BitifEye	N/A	Available
HDMI	HDMI 1.4b (*4)	E5071C	N/A	Available
	HDMI 2.0	(*2)	E5071C	Available
SATA	v3.0	E5071C	E5071C	Available
DisplayPort	v1.2b	E5071C	N/A	Available
	v1.3	E5071C	N/A	Available
	Alt Mode	*Coming soon...*	N/A	*Coming soon...*
MIPI™	D-PHY v1.1	N/A	E5071C	Available
	M-PHY v3.0	N/A	E5071C	Available
Ethernet	100BASE-TX	E5071C	N/A	Available
	10GBASE-T	E5071C	N/A	Available
	10GBASE-KR / 40GBASE-KR4	E5071C (*3)	E5071C	Available
MHL	v2.0	E5071C	*Coming soon...*	Available
PCIe®	v3.0	E5071C	E5071C	Available
Thunderbolt	v0.9	N/A	Available (*1)	Available
BroadR-Reach	v3.2	E5071C	N/A	Available
SD Card	UHS-II	N/A	Available (*1)	*Coming soon...*
Cfast		N/A	Available (*1)	*Coming soon...*

키사이트 MOI 웹사이트 주소



Documents & Downloads

Method of Implementation (MOI) for USB Type-C to Type-C Cable-Connector Assembly Compliance Test
Keysight Method of Implementation (MOI) for USB Type-C to Type-C Cable-Connector Assembly Compliance Test Using Keysight E5071C ENA Network Analyzer Option TDR
Application Note 2015-1

E5071C-TDR State File for USB Type-C to Type-C Cable High Speed Signal Compliance Tests (Option 4K5)
Programming Example 2015-1

E5071C-TDR State File for USB Type-C to Type-C Cable Low Speed Signal Compliance Tests (Option 4K5)
Programming Example 2015-1

Method of Implementation (MOI) for USB Type-C to Legacy Cable-Connector Assembly Compliance Test
Keysight Method of Implementation (MOI) for USB Type-C to Legacy Cable-Connector Assembly Compliance Test Using Keysight E5071C ENA Network Analyzer Option TDR
Application Note 2016-0

Keysight MOI for USB Type-C Connectors & Cable Assemblies Compliance Tests
(Type-C to Type-C Passive Cable Assemblies)

Revision 01.00
Nov-24, 2015

Universal Serial Bus Type-C™ Specification Revision 1.1

Keysight Method of Implementation (MOI) for USB Type-C™ Connectors and Cables Assemblies Compliance Tests Using Keysight E5071C ENA Option TDR

For Type-C to Type-C Passive Cable Assemblies

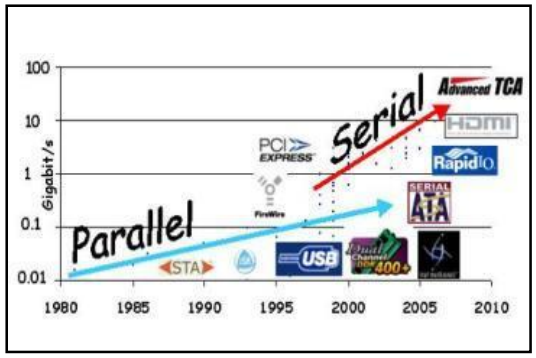
USB Type-C™ and USB-C™ are trademarks of USB Implementers Forum.

내용

- 키사이트 네트워크 분석기 기반 TDR 장비 Overview
- Cable/Connector Compliance 시험 항목 예
- 최신 고속 Digital 규격 측정에 필요한 기능
  - Stressed Eye Diagram 분석
  - Hot TDR 측정: Active Device에 대한 실제 사용조건에서의 임피던스 분석기능
- Summary

고속 디지털 Compliance 시험

통신규격들이 진화하면서 데이터 전송속도는 증가하고 새로운 측정이 필요해지게 되었습니다. 따라서 보다 완벽한 부품들에 대한 측정 및 평가 작업과 실제 사용 조건에서의 측정작업도 점점 더 중요해지게 되었습니다.

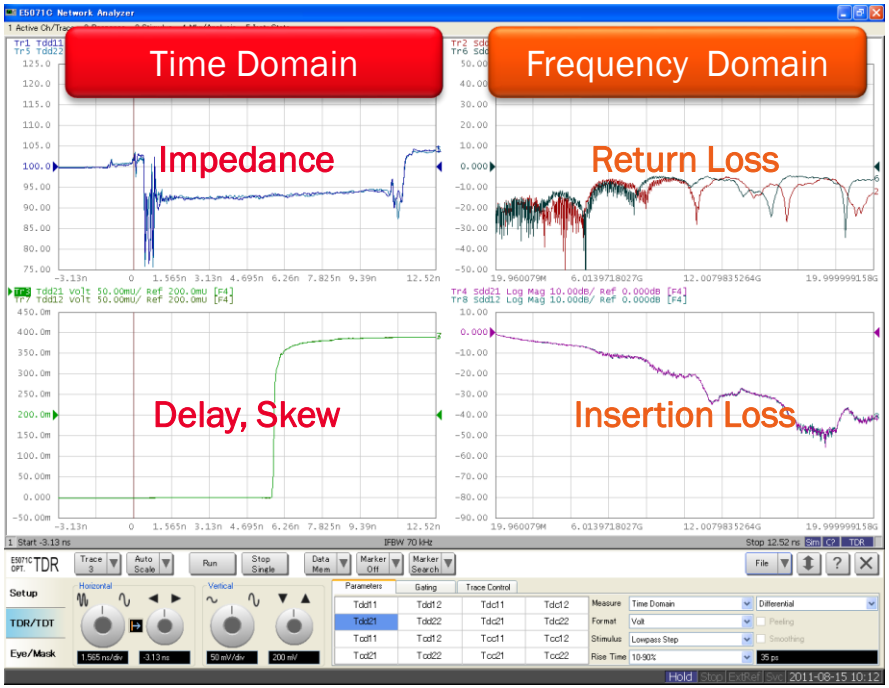


	Data Rate	Compliance Test Parameters
1990s	~100s Mbps	•time domain (impedance, delay, skew, ...)
2000~	1~3 Gbps	•time domain (impedance, delay, skew) •frequency domain (insertion loss, return loss, ...)
2007~	~3 Gbps	•time domain (impedance, delay, skew) •frequency domain (insertion loss, return loss, crosstalk, mode conversion, ...)
2010~	~6 Gbps	•time domain (impedance, impedance in active state, delay, skew, strerssed eye diagram) •frequency domain (insertion loss, return loss, crosstalk, mode conversion, ...)

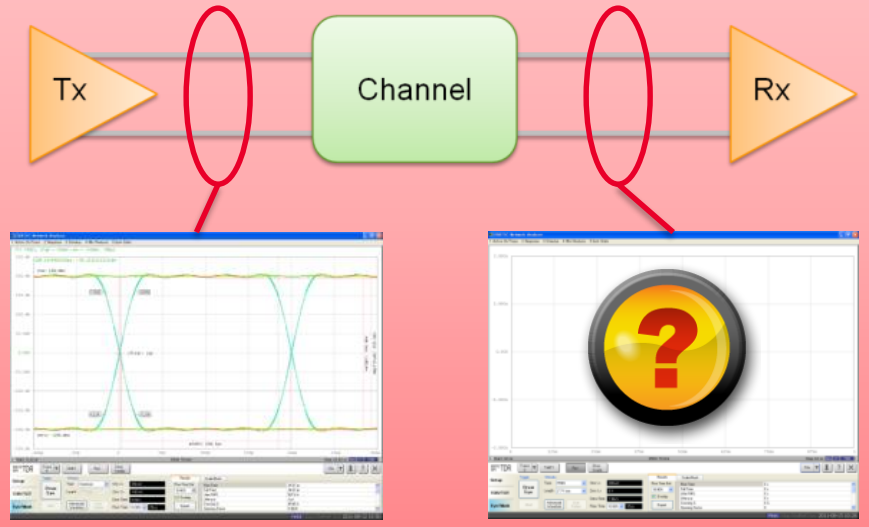
Stressed Eye Diagram 분석

Why Measure?

Interconnect 부분은 반사손실이나 삽입손실, 임피던스 등 파라메타 측정을 통하여 그 특성을 분석할 수 있습니다.



특성 분석 작업 중에 어려운 부분 중 하나는 파라메타 측정을 통한 분석을 통하여 연결 양단에서 나타나는 Eye-Diagram을 보여줄 수 있는가 하는 것입니다.



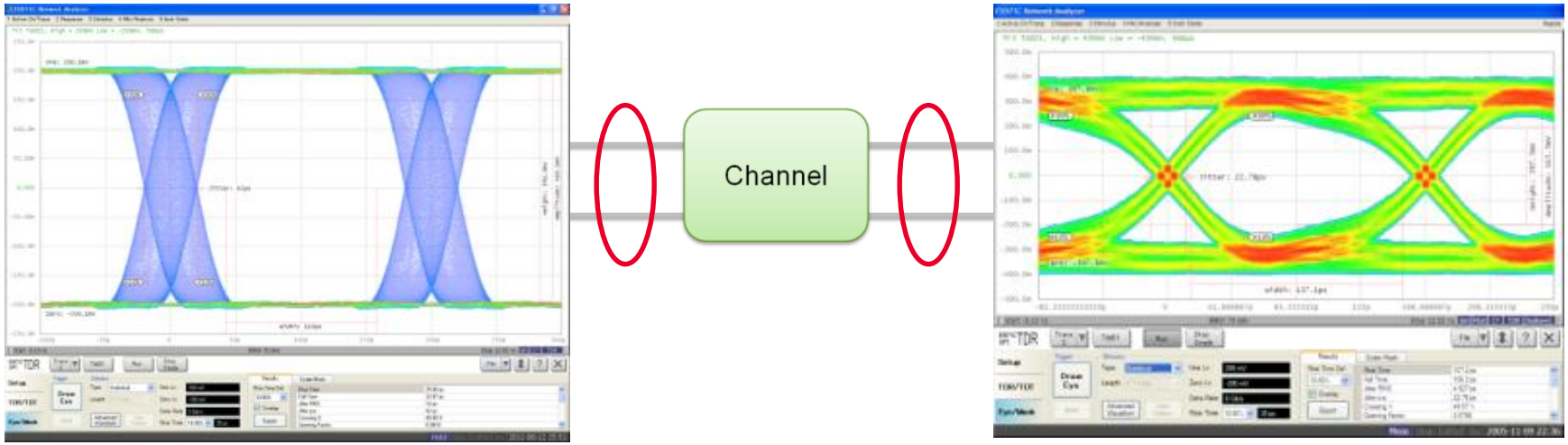
Stressed Eye Diagram 분석

Why Measure?

Interconnect 부분을 분석하는 또 다른 방식은 eye diagram 입니다. 이 측정방법으로 한쪽 link 의 끝 단에서 eye 특성을 직접 확인할 수 있는 것입니다. 이러한 과정을 **"stressed" eye diagram 시험** 이라고 합니다.

Transmitter에서 예상되는 최악의 경우에 대한 "stressed" 신호를 interconnect에 인가한 후에...

... 출력 interconnect 부에서 eye diagram의 특성을 분석합니다.



ENA TDR 옵션의 장점

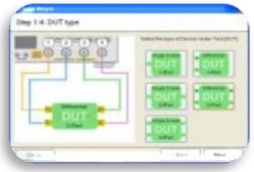
Stressed Eye Diagram 분석

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

3 Breakthroughs

for Stressed Eye Diagram Analysis of Interconnects

Affordable Solution



Simple Setup and Operation

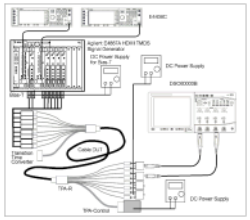
Complete Characterization

KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

ENA TDR 옵션의 장점

Affordable Solution



Traditional Solution

Solution too expensive for majority of cable MFRs !!

$300K ~ $500K

ENA TDR 옵션

8.5GHz, 4P

14GHz, 4P

20GHz, 4P

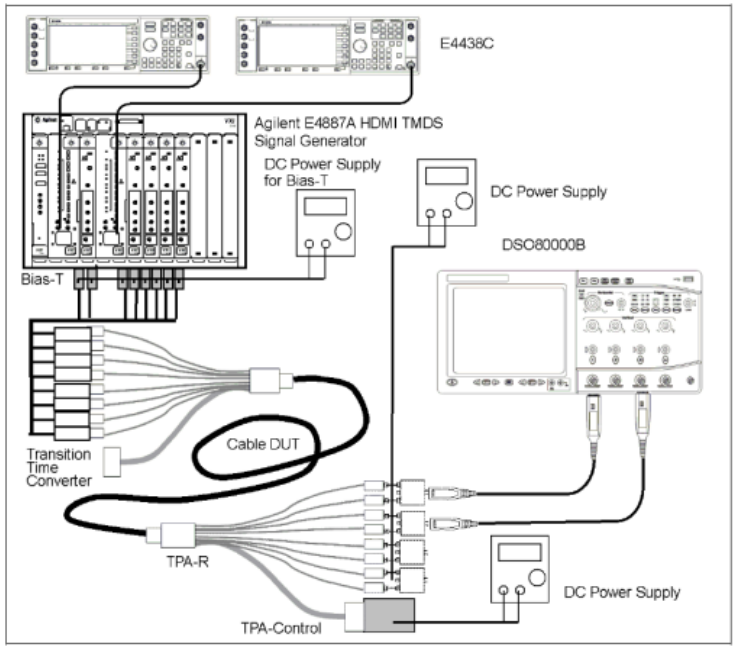
$100K $200K $300K $400K $500K

Price [USD]

ENA TDR 옵션의 장점

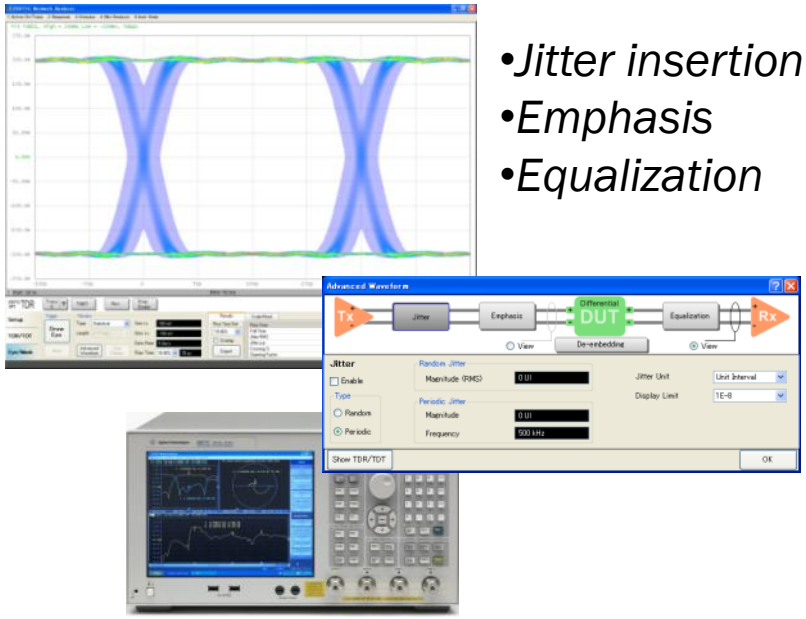
Simple Setup and Operation

Traditional Solution



많은 장비들로 구성되며 장비 setup 과 동작방법이 **복잡합니다.**

ENA TDR 옵션



- *Jitter insertion*
- *Emphasis*
- *Equalization*

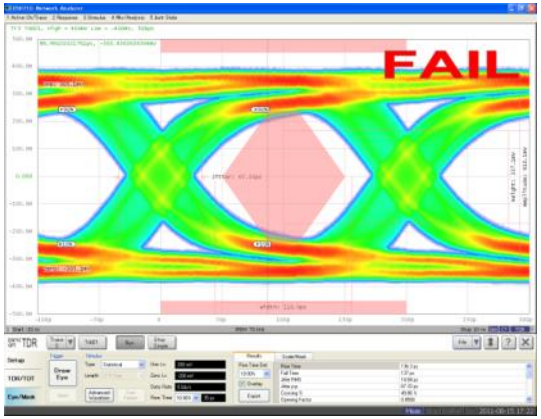
One-box 솔루션으로 장비 setup 과 동작방법이 **간단합니다.**

ENA TDR 옵션의 장점

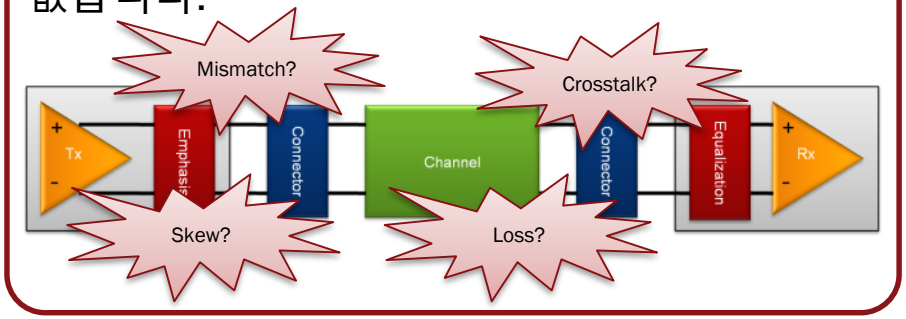
Complete Characterization

Traditional Solution

오직 stressed eye diagram 분석만 가능합니다.

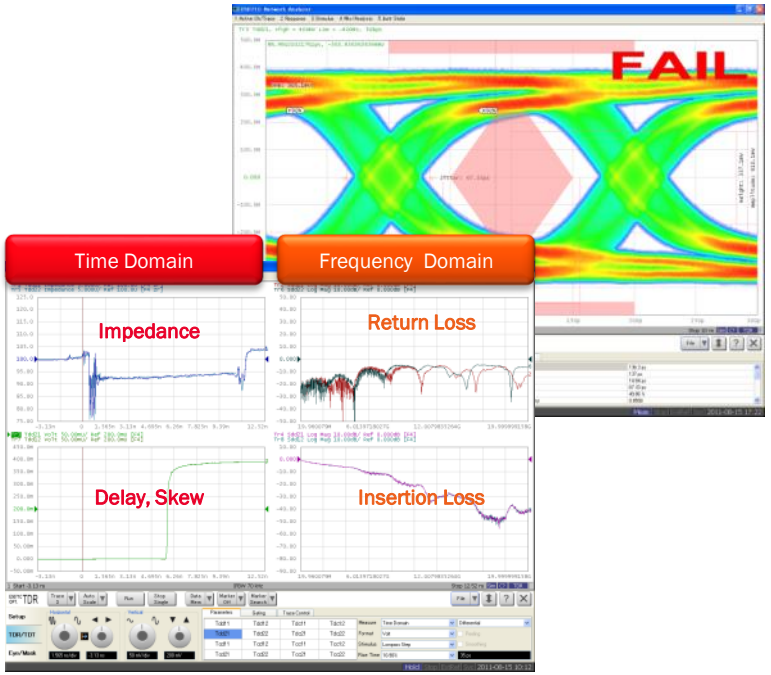


Eye-diagram을 단순하게 보는 것 만으로는 문제해결을 위한 다양한 분석을 할 수 없습니다.



ENA TDR 옵션

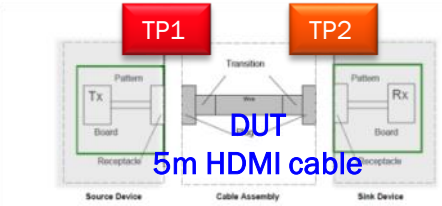
stressed eye diagram 분석과 parametric 분석이 모두 가능합니다.



Parametric tests 를 통해서 디바이스 문제의 근본 원인을 찾을 수 있.

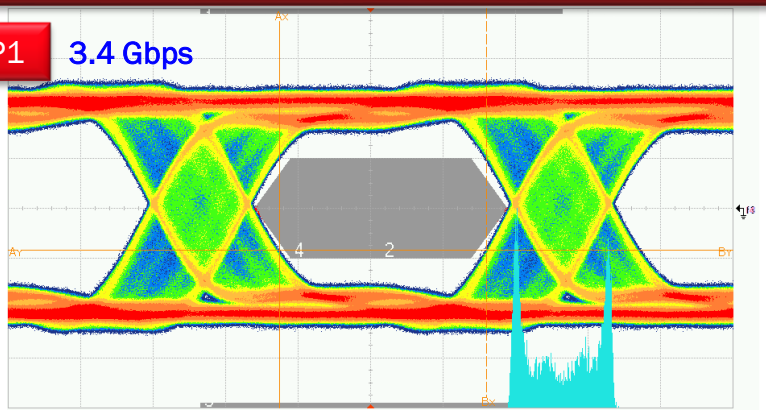
ENA TDR 옵션의 장점

Correlation

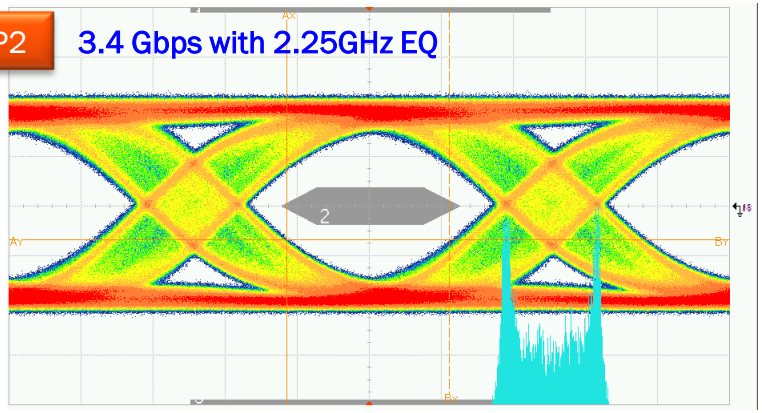


E4887A & 90K Scope

TP1 3.4 Gbps

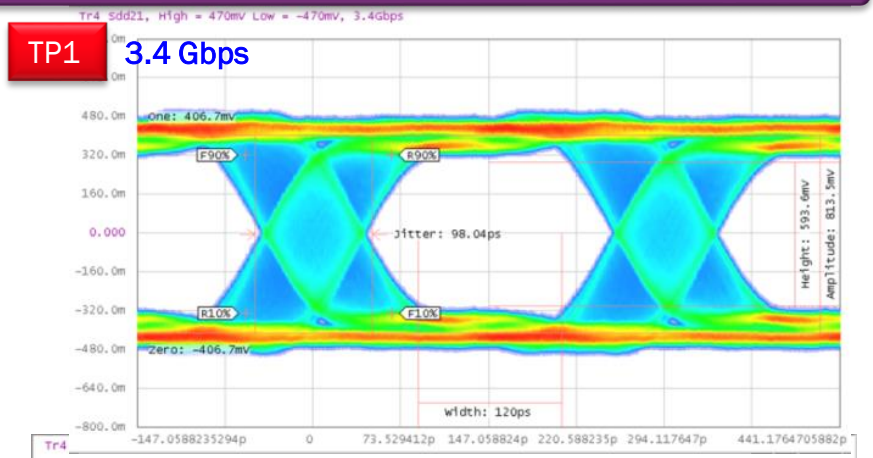


TP2 3.4 Gbps with 2.25GHz EQ

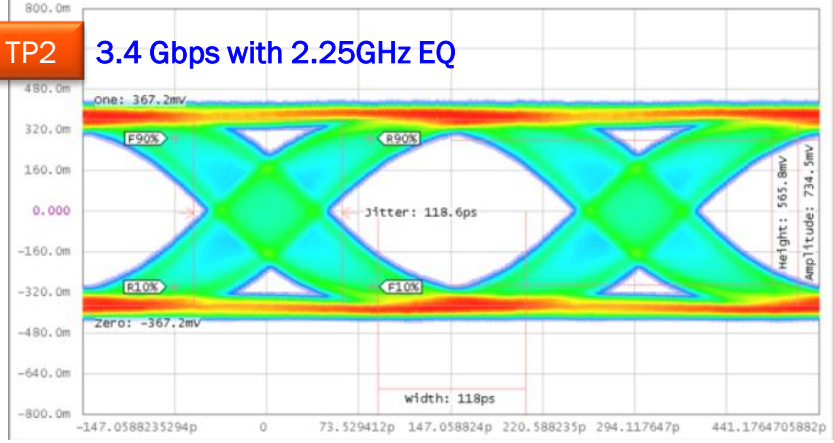


ENA Option TDR

TP1 3.4 Gbps



TP2 3.4 Gbps with 2.25GHz EQ



내용

- 키사이트 네트워크 분석기 기반 TDR 장비 Overview
- Cable/Connector Compliance 시험 항목 예
- 최신 고속 Digital 규격 측정에 필요한 기능
  - Stressed Eye Diagram 분석
  - Hot TDR 측정: Active Device에 대한 실제 사용조건에서의 임피던스 분석기능
- Summary

Hot TDR 측정

Why Measure?

1. Tx 로 부터 신호가 전송됩니다. ...

2. 임피던스 부정합에 의해 Rx에서 부분적인 반사가 나타납니다....

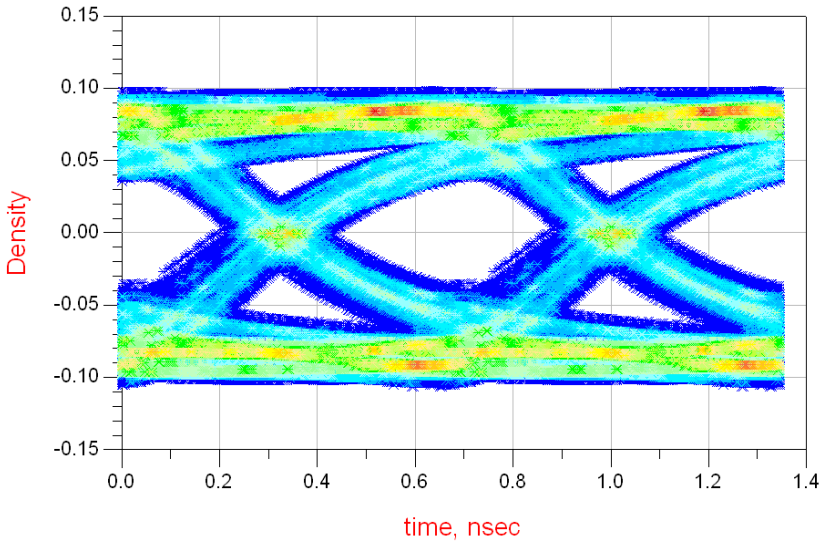
3. Tx 에서의 임피던스 부정합에 의해서 재반사가 나타납니다. ...

•보통 디바이스 상태가 Off 일 경우와 On 일 경우 (Hot TDR) 임피던스 특성이 변하게 됩니다.

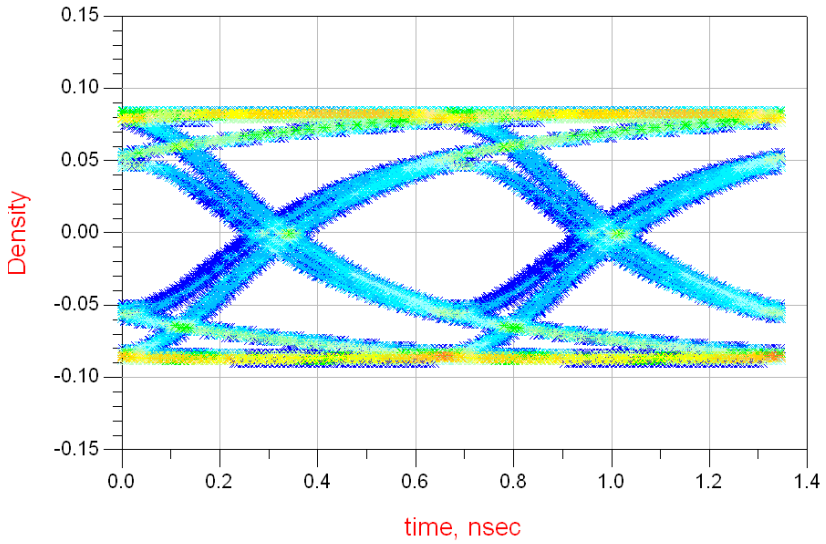
Hot TDR 측정

Why Measure?

Source Termination Effects



Source Impedance **NOT** Matched



Source Impedance Matched

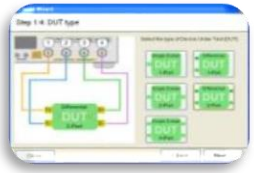
Hot TDR 측정을 위한 ENA TDR 옵션의 장점

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

3 Breakthroughs

for Hot TDR Measurements

Fast and Accurate Measurements



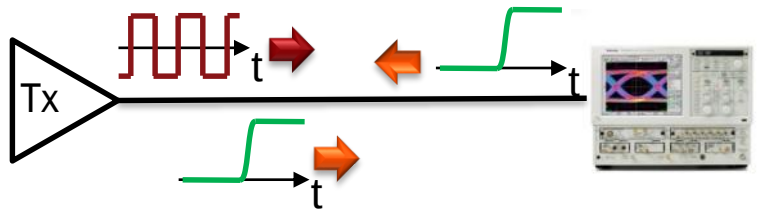
Simple and Intuitive Operation

ESD Robustness

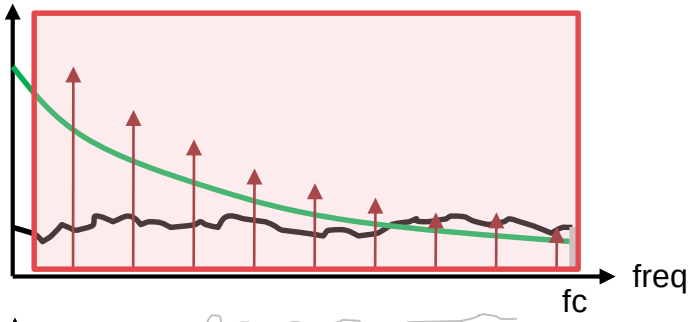
Hot TDR 측정을 위한 ENA TDR 옵션의 장점

Fast and Accurate Measurements

TDR 스코프

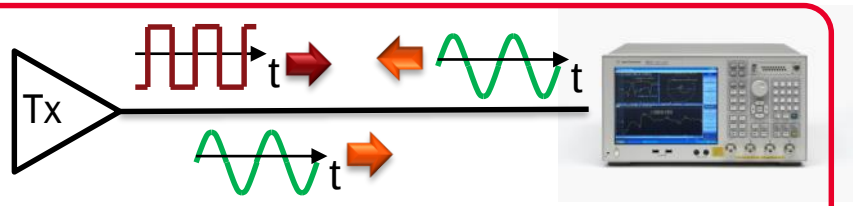


•wideband receiver 로 transmitter로부터 전송되는 모든 신호 에너지를 받습니다.

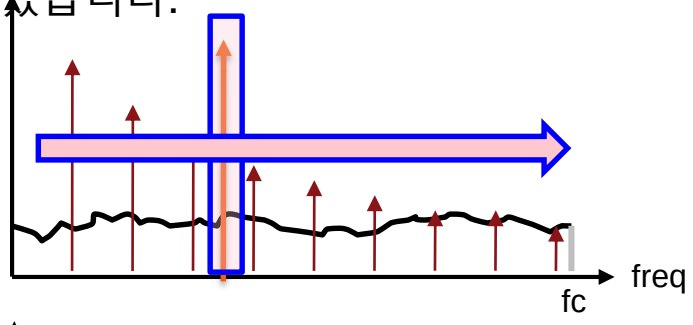


안정적인 결과를 얻기 위해서 Extensive averaging 이 필요합니다.

ENA TDR 옵션



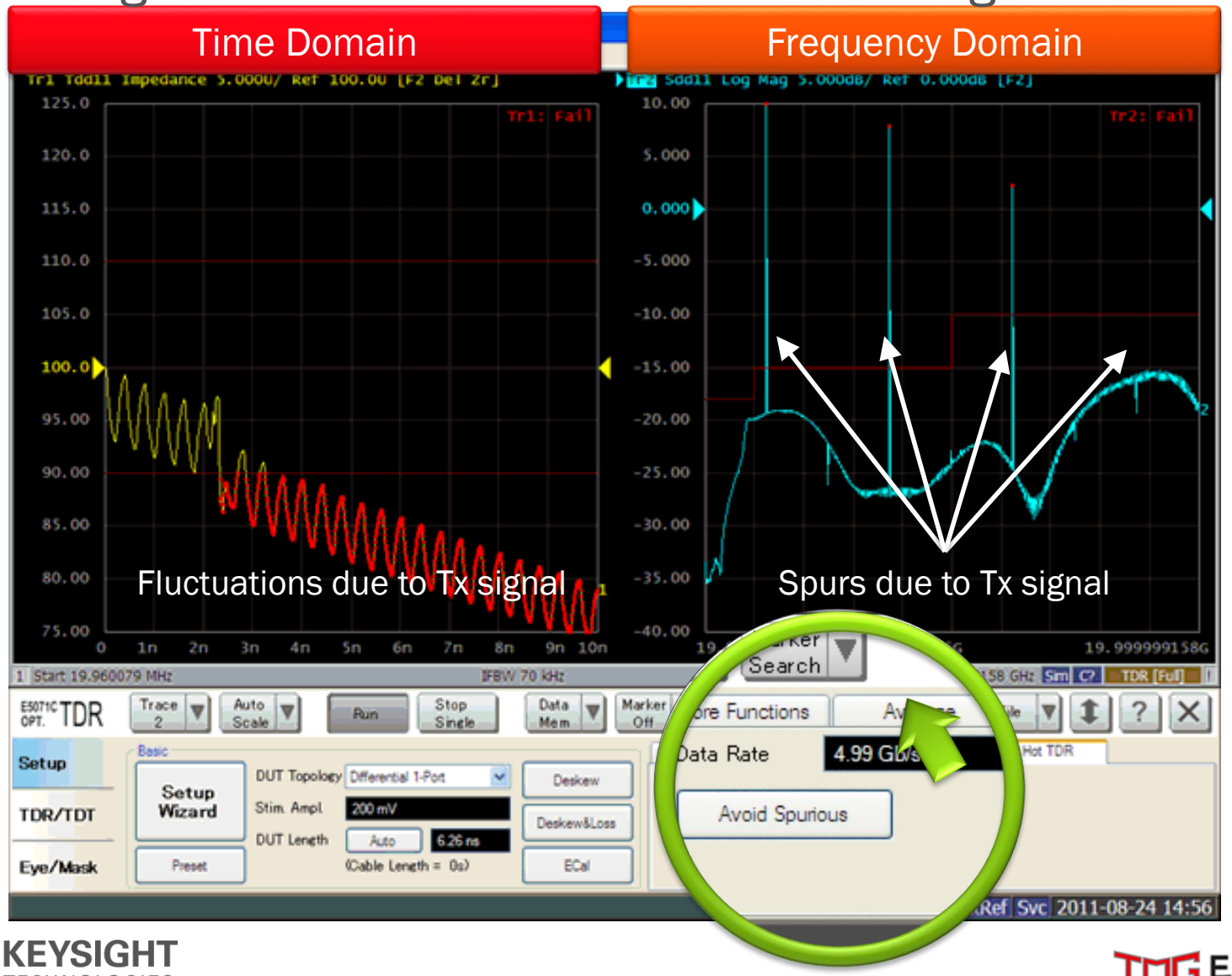
•narrowband receiver 로 transmitter로부터 전송되는 데이터 에너지의 영향을 최소화 할 수 있습니다.



대부분의 경우에 안정적인 결과를 얻기 위한 averaging 은 필요하지 않습니다.

Hot TDR 측정

Avoiding Errors from the Transmitter Signal



Hot TDR 측정

Avoiding Errors from the Transmitter Signal

Hot TDR 측정을 위한 ENA TDR 옵션의 장점

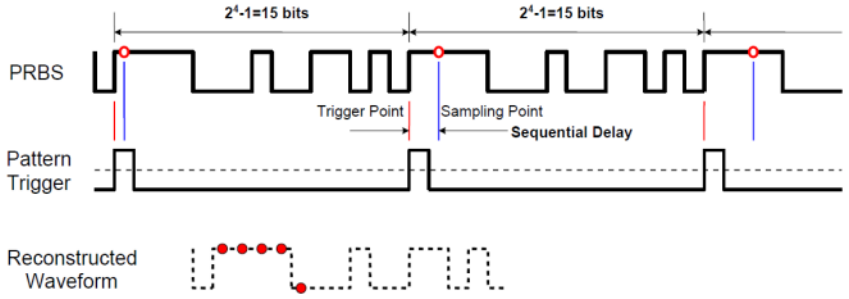
Simple and Intuitive Operation

TDR 스코프

TDR repetition rate 설정은 Tx 신호의 영향을 받지 않도록 설정되어야 합니다.

이상적인 TDR repetition rate 값은 개별적인 DUT에 따라 달라집니다. 그것은 이 설정이 repetition rate와 Tx 신호 rate의 하모닉 성분 등에 의해 정해지기 때문입니다.

이상적인 설정값을 찾는 과정은 대부분 trial and error 방식으로 이루어 집니다.



ENA TDR 옵션

사용자가 입력한 data rate 값으로 부터 spurious 주파수 성분들이 계산되어지며 sweep 과정에서 자동적으로 제거됩니다.

1. Enter data rate
2. Click **[Avoid Spurious]**

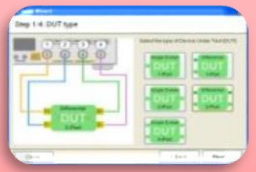
Eye-diagram 과 Hot TDR 측정

차세대 고속 디지털 통신규격을 위한 종합적인 기능을 가진 신호 Integrity 측정 솔루션

3 Breakthroughs

for Stressed Eye Diagram Analysis of Interconnects

Affordable Solution

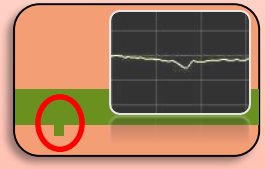


Simple Setup and Operation

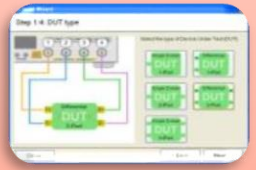
Complete Characterization

3 Breakthroughs

for Hot TDR Measurements



Fast & Accurate Measurements



Simple and Intuitive Operation

ESD Robustness

www.keysight.com/find/ena-tdr

내용

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ENA TDR 옵션 Compliance

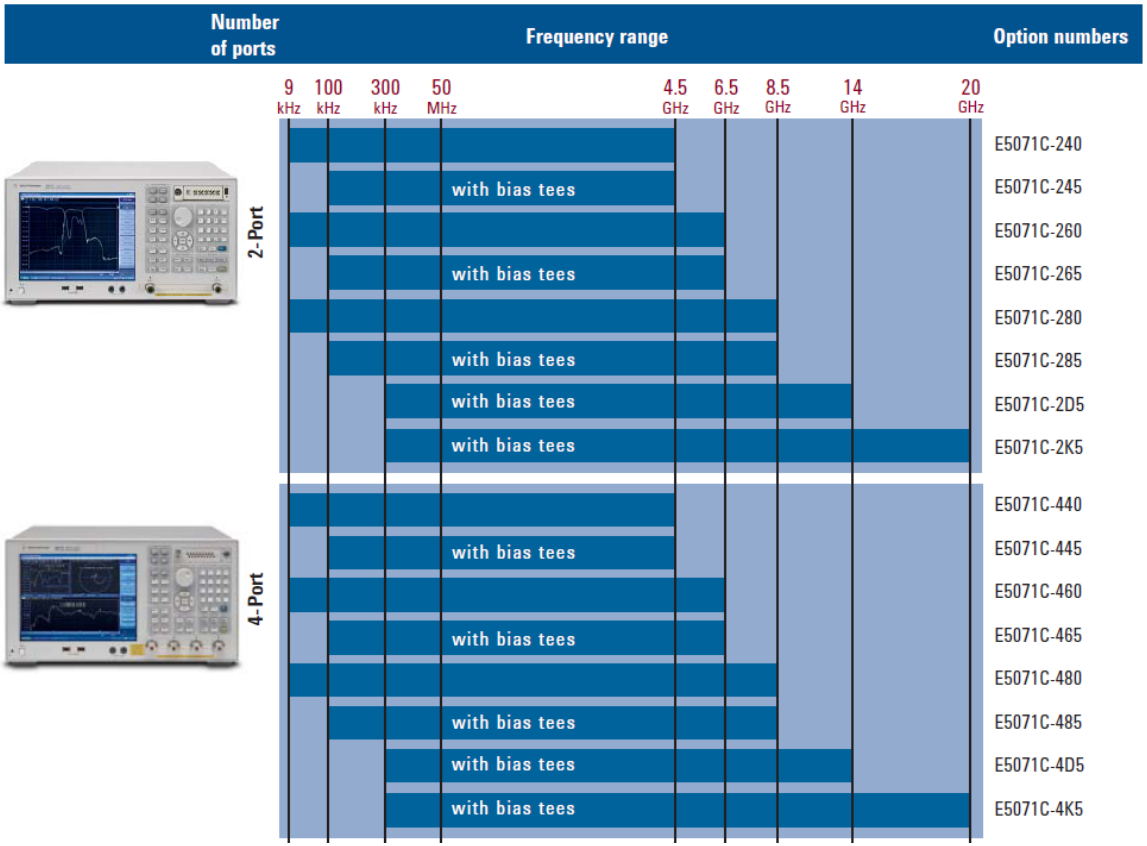
TDR / S-parameter Compliance 시험을 위한 One-box 솔루션

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.

키사이트 E5071C ENA 네트워크 분석기

- 다양한 어플리케이션에 사용할 수 있는 Flexible Lineup



Response Resolution and Bandwidth

시간 영역에서의 response resolution:

- 가까이 근접한 두 개의 응답을 구분할 수 있는 최소 거리입니다.
- Reflection 측정인지 Transmission 측정인지 여부와 유전체의 velocity factor에 의해서 계산됩니다.

response resolution = step rise time * speed of light * velocity of propagation

		E5071C	20GHz	14GHz	8.5GHz	6.5GHz	4.5GHz	3GHz
Rise Time (LPSpec. Step)		min (10-90%)	22.3 ps	31.9 ps	52.5 ps	68.6 ps	99.1 ps	149. ps
Response Resolution	Typ.	min @ LP Step mode, reflection meas, in air (εr = 1)	3.3 mm	4.8 mm	7.9 mm	10.3 mm	14.9 mm	22.4 mm
	Typ.	min @ LP Step mode, reflection meas, in FR4 (εr = 4.9)	1.5 mm	2.2 mm	3.5 mm	4.6 mm	6.7 mm	10.1 mm

[예제]
유전체가 FR4 (εr=4.9, vf=1/√εr=0.45) 인 경우에 20GHz 장비를 사용하여 reflection 측정을 하였을 때 시간영역에서 response resolution 값은?

- response resolution (transmission) = (22.3 ps) x (3.0e8 m/s) x (0.45) = 3.0 mm
- response resolution (reflection) = (22.3 ps) x (3.0e8 m/s) x (0.45) / 2 = 1.5 mm

ENA TDR 옵션 구성

모델/옵션	설명
E5071C-TDR	Enhanced Time Domain Analysis Option

업그레이드 옵션 [*1]

모델/옵션	설명
E5008A-1FP	Enhanced Time Domain Analysis Option Upgrade
E5009A-1FP	Enhanced Time Domain Analysis Option Upgrade from Option 010

[*1] Upgrade options require return to Keysight Service Center for installation.

추가적인 Resources

- **ENA TDR 옵션 관련 자료**

  www.keysight.com/find/ena-tdr

- Technical Overview (5990-5237EN)
- 어플리케이션 노트
  - 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)
- 고속 시리얼 통신규격에 대한 **Method of Implementation (MOI)** 자료

  www.keysight.com/find/ena-tdr_compliance

Questions?