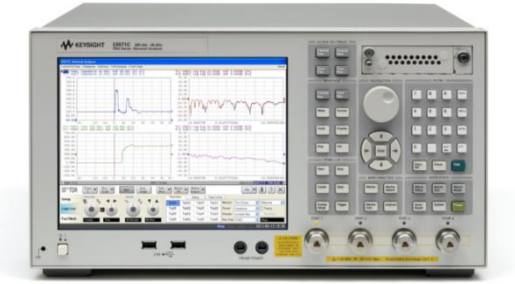
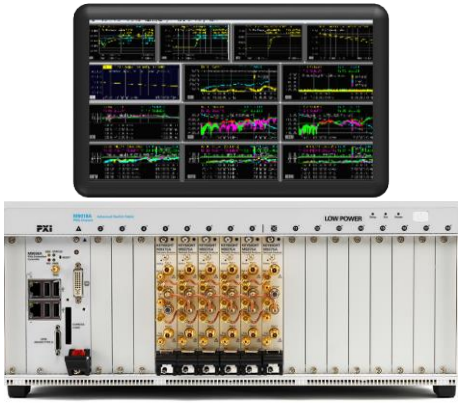
USB Type-C™ Cable-Connector Assembly Compliance Tests



Test Solution Overview Using the Keysight E5071C ENA Option TDR & M937X PXIe Multiport VNA



Revision 01.01
Last Update 2016/04/19

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Revision History

Revision	Date	
Draft	2015/02/06	• Initial release • Spec 1.0 and compliance document draft
01.00	2015/11/24	• Spec 1.1. and compliance document 1.0 • Minor corrections
01.01	2016/4/19	• Added M937X PXIe Multiport vector network analyzer (VNA) • Minor corrections

Purpose

- This slide will show how to make measurements of USB Type-C™ Cable & Connector Assemblies Compliance Tests by using the Keysight E5071C ENA Option TDR & M937XA PXIe VNA.

Keysight Digital Standards Program

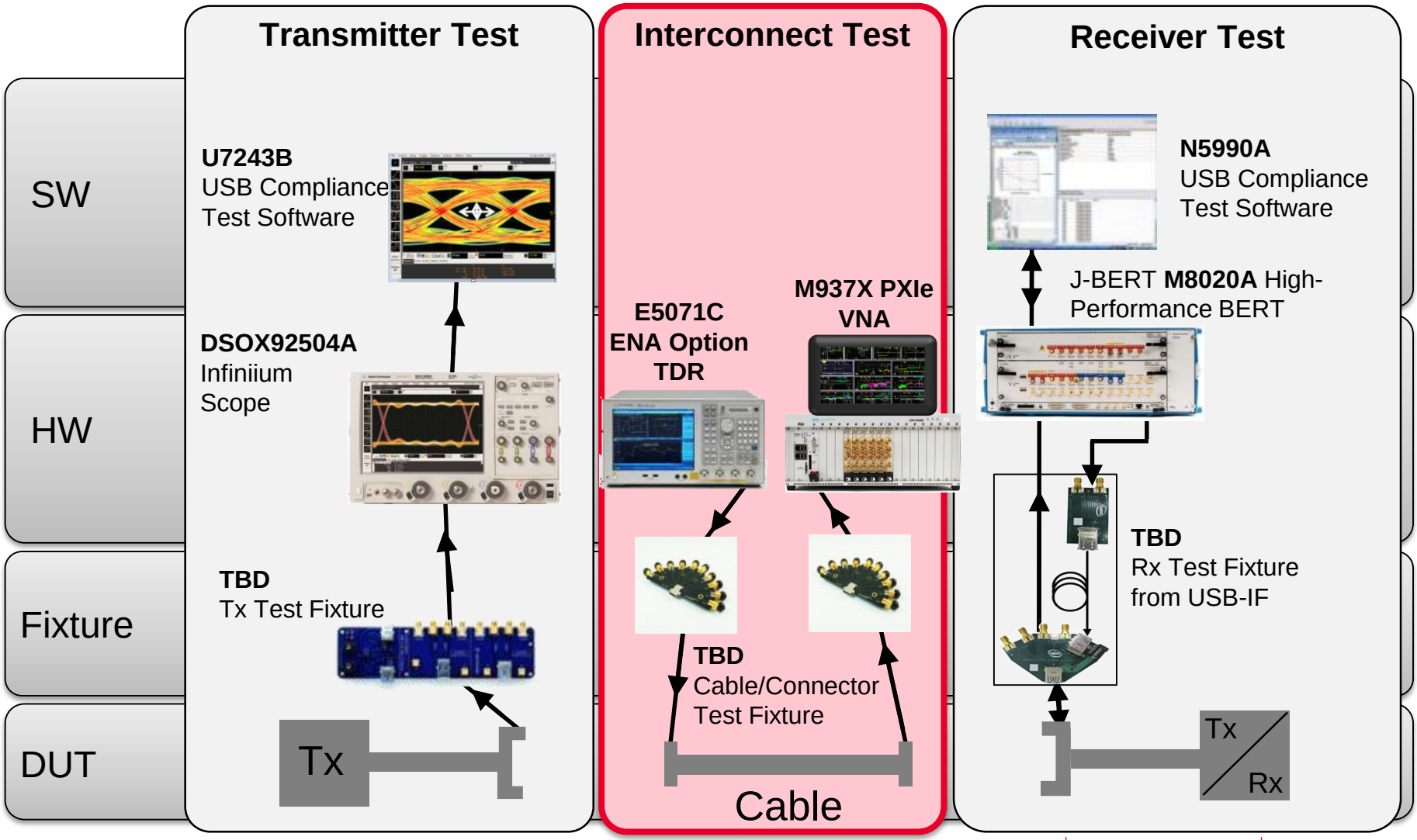
Our solutions are driven and supported by Keysight experts involved in international standards committees:

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

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

Our customers test with highest confidence and achieve compliance faster

USB 3.1 – Keysight Total Solution Coverage



Keysight Solutions to Enable the Type-C Revolution

Create a faster path to *done*

Keysight's Type-C solution set is ready for complete testing of the standards converging on this universal interface.

Whether you're focused on design or validation, our solution will accelerate you from debug to characterization to compliance to done.

Reference Document

- Universal Serial Bus Type-C Cable and Connector Specification Revision 1.1 (April 3, 2015)
- Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document Revision 1.0 (October 6, 2015)

USB Type-C Cable/Connector Compliance Test

Functional Signal Plan

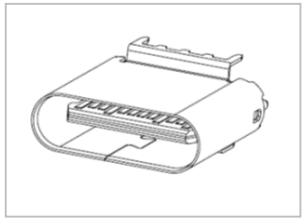


Figure 2-1 USB Type-C Receptacle Interface (Front View)

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1−	VBUS	CC1	D+	D−	SBU1	VBUS	RX2−	RX2+	GND
GND	RX1+	RX1−	VBUS	SBU2	D−	D+	CC2	VBUS	TX2−	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

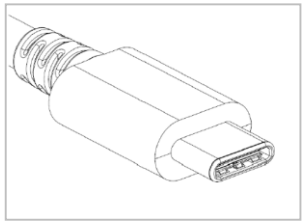


Figure 2-2 USB Full-Featured Type-C Plug Interface (Front View)

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2−	VBUS	SBU1	D−	D+	CC	VBUS	TX1−	TX1+	GND
GND	TX2+	TX2−	VBUS	VCONN			SBU2	VBUS	RX1−	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

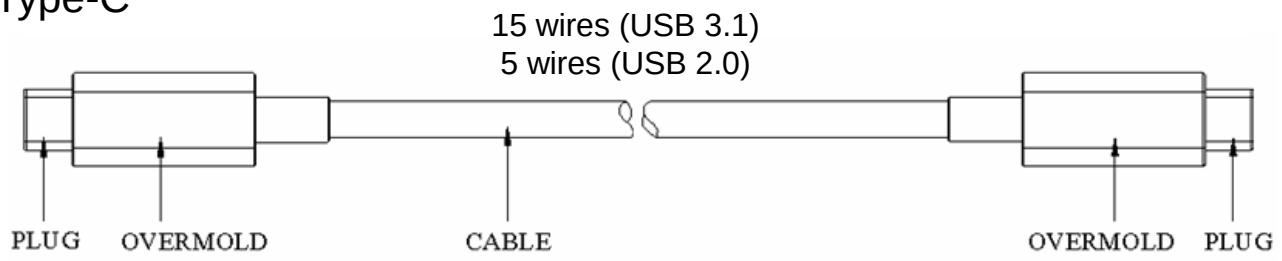
USB Type-C Cable/Connector Compliance Test

Cable Assembly

Type-C to Type-C Cable Assemblies

Two cables are defined:

- USB3.1 Type-C to Type-C (5 Gbps or 10 Gbps)
- USB2.0 Type-C to Type-C



Type-C Legacy Cable Assemblies

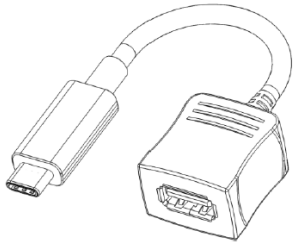
USB Type-C to USB3.1 (10 Gbps only)

- Standard-A
- Standard-B
- Micro-B

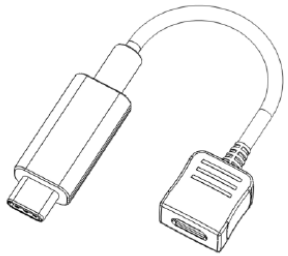
USB Type-C to USB2.0

- Standard-A
- Standard-B
- Micro-B
- Mini-B

Type-C Legacy Adapters



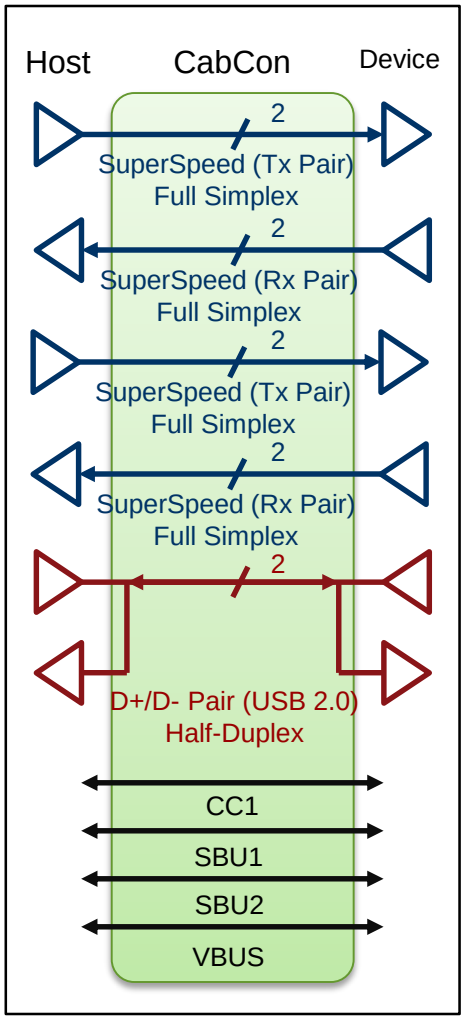
USB Type-C to Std-A



USB Type-C to USB2.0 Micro-B

USB Type-C Cable/Connector Compliance Test

Cable Assembly

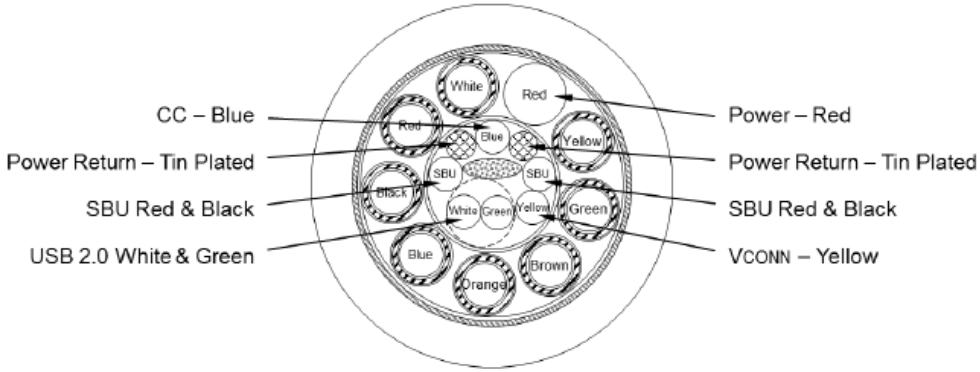


SuperSpeed signal pairs

- Coaxial wires, twin-axial or shielded twisted pairs.
- Shielding is needed for signal integrity and EMC performance.

D+/D- signal pair

- Typically unshielded twisted pair (UTP).
- Intended to transmit the USB 2.0 low-Speed, full-Speed and high-speed signaling.



Full-featured Type-C cable (coax are SS pairs)

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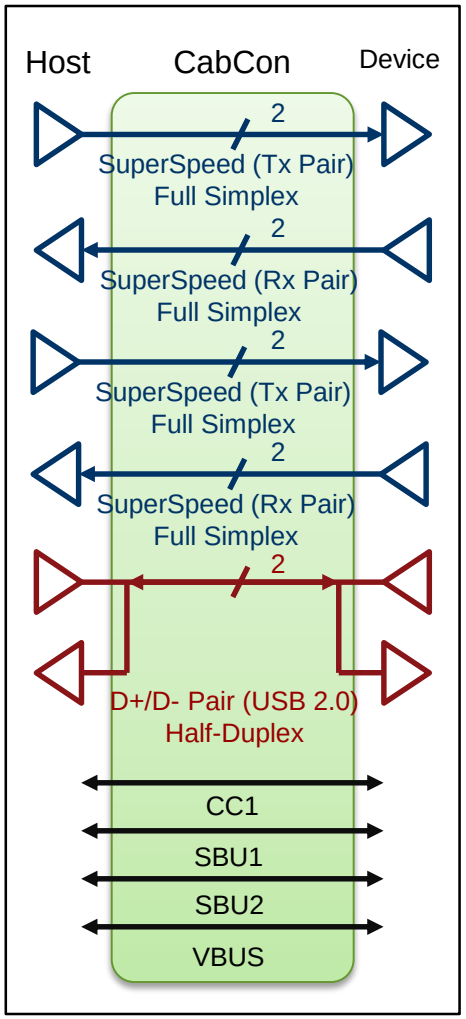
USB Type-C Cable/Connector Compliance Test

Measurement Parameters (Type-C to Type-C Passive Cable Assemblies)



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

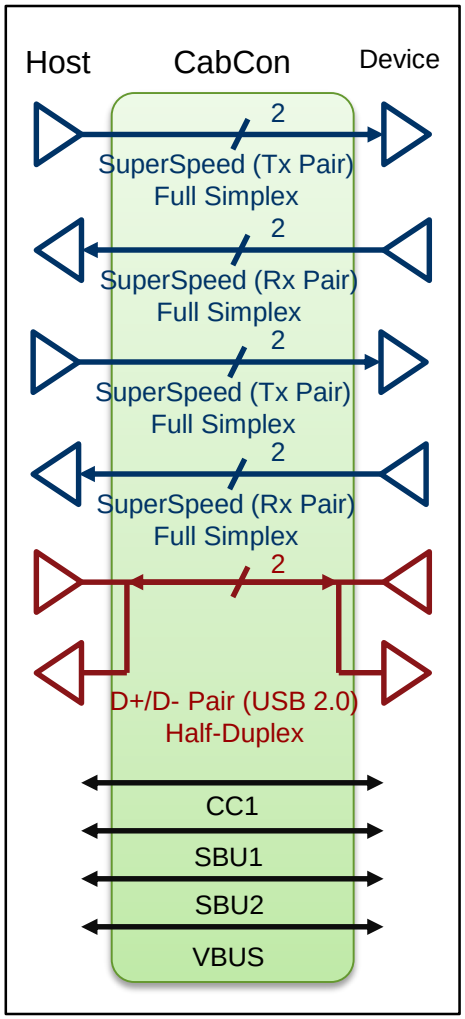
Frequency Domain Measurements

- 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-

Note: Normative parameters for the USB Type-C cable assembly are highlighted in blue

USB Type-C Cable/Connector Compliance Test

Measurement Parameters (Type-C to Legacy Cable Assemblies)



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)
- Differential Impedance
- [Raw Cable] Characteristic Impedance (Informative)
- [Raw Cable] Intra-Pair Skew (Informative)
- [Mated Connector] Differential Impedance (Informative)

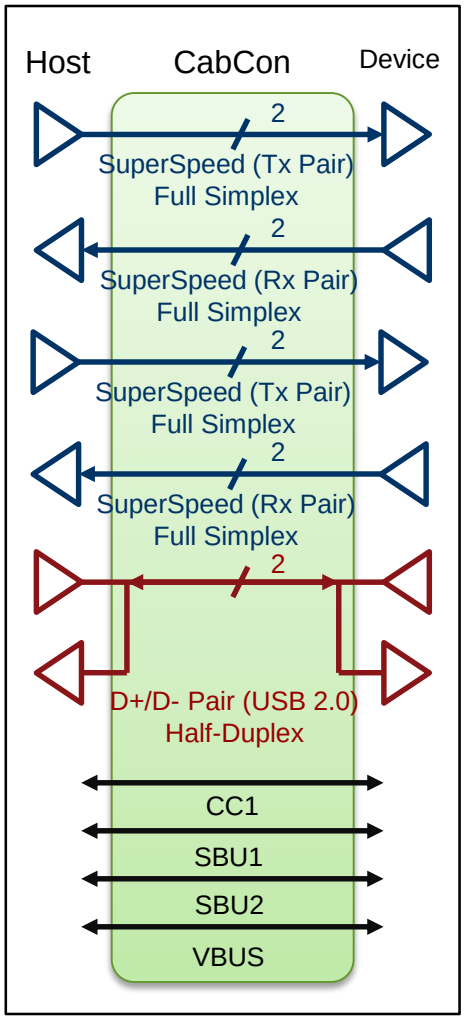
Frequency Domain Measurements

- D+/D- Pair Attenuation (USB 2.0)
- ILfitatNq, IMR, IXT, IRL, Differential to Common Mode Conversion
- Shielding Effectiveness
- Insertion Loss (Informative)
- NEXT 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)

Note: Normative parameters for the USB Type-C cable assembly are highlighted in blue

USB Type-C Cable/Connector Compliance Test

Measurement Parameters (Type-C to Legacy Adapter Assemblies)



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- Intra-pair Skew (USB 2.0)
- [Raw Cable] Characteristic Impedance (Informative)
- [Raw Cable] Intra-Pair Skew (Informative)
- [Mated Connector] Differential Impedance (Informative)

Frequency Domain Measurements

- D+/D- Pair Attenuation (USB 2.0)
- ILfitatNq, IMR, IXT, IRL, Differential to Common Mode Conversion
- Insertion Loss (Informative)
- Return Loss (Informative)
- NEXT 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)

Note: Normative parameters for the USB Type-C cable assembly are highlighted in blue

USB Type-C Cable/Connector Compliance Test

Solution Overview

- ALL normative and informative parameters specified for USB Type-C cable/connector compliance testing can be measured with the ENA Option TDR.

Frequency Domain

•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] Crosstalk, VBUS Loop L/C, Coupling Factor

Time Domain

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

Traditional Solution

Vector Network Analyzer (VNA)

TDR Scope

New Solution

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

One-box Solution !!

* Note: Compliance standard tool from USB-IF is required for pass/fail judgment of high-speed and low-speed signal tests

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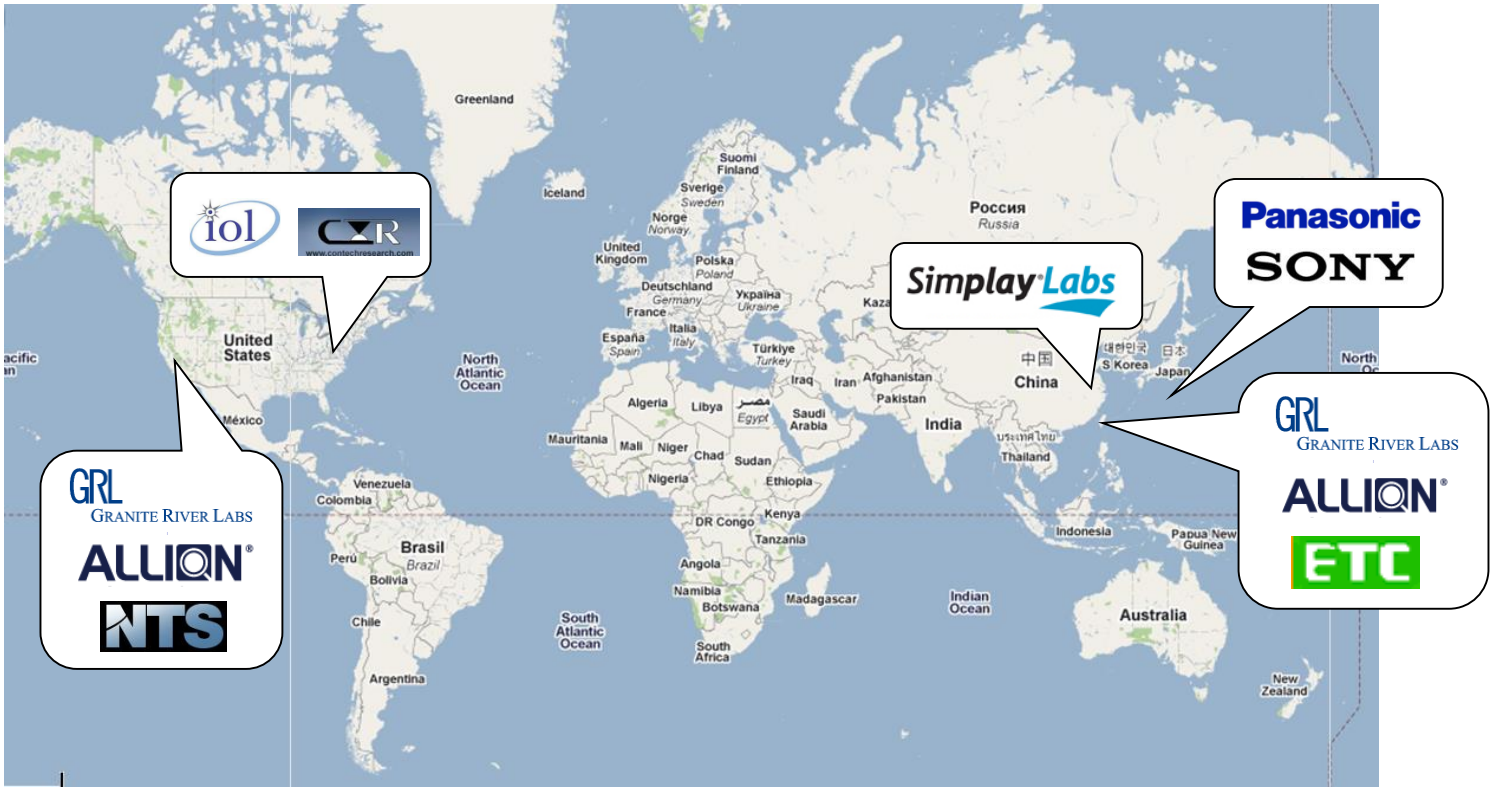
ENA Option TDR Compliance Test Solution

Certified Test Centers using ENA Option TDR

Test Centers Support ENA Option TDR

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



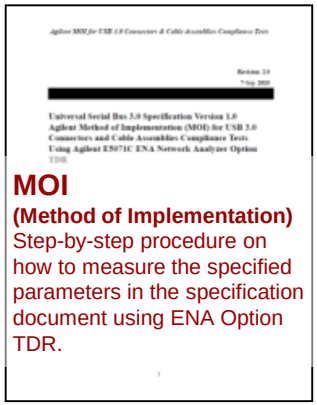
USB Type-C Cable/Connector Compliance Test

Configuration

- ENA Mainframe (*1)
  - E5071C-4K5: 4-port, 300 kHz to 20 GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module (N4433A)

*1: Type-C cable/connector requires measurements up to 15 GHz.
*2: The list above includes the major equipment required. Please contact our sales representative for configuration details.

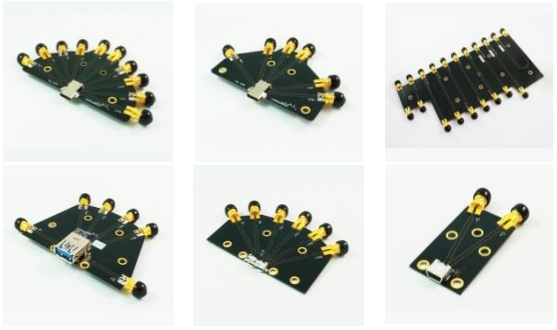
- Method of Implementation (MOI) documents and state files (4K5) available for download on Keysight.com



MOI
(Method of Implementation)
Step-by-step procedure on how to measure the specified parameters in the specification document using ENA Option TDR.

USB Type-C Test Fixtures

Fixtures for testing USB 3.1/Type-C connectors and cable assemblies are available for purchase through Luxshare-ICT.
http://web.luxshare-ict.com/en/ProductList.php?id1=22&id2=92



www.keysight.com/find/ena-tdr_compliance
www.keysight.com/find/ena-tdr_usbtype-c-cabcon

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USB Type-C Cable/Connector Compliance Test

[High Speed] Measurement Parameters (**Normative** & **Informative**)

Time Domain

D+/D- Impedance (Tdd11, Tdd22)

D+/D- Propagation Delay (Tdd21)

D+/D- Intra-Pair Skew (T31, T42)

[Raw Cable] Intra-Pair Skew (T31, T42)

[Raw Cable] Characteristic Impedance (Tdd11, Tdd22)

[Mated Connector] Diff. Impedance (Tdd11, Tdd22)

Frequency Domain

D+/D- Pair Attenuation (Sdd21)

ILfitatNq, IMR, IXT, IRL, Mode Conversion (s4p files)

Shielding Effectiveness (Sds21, Scs21)

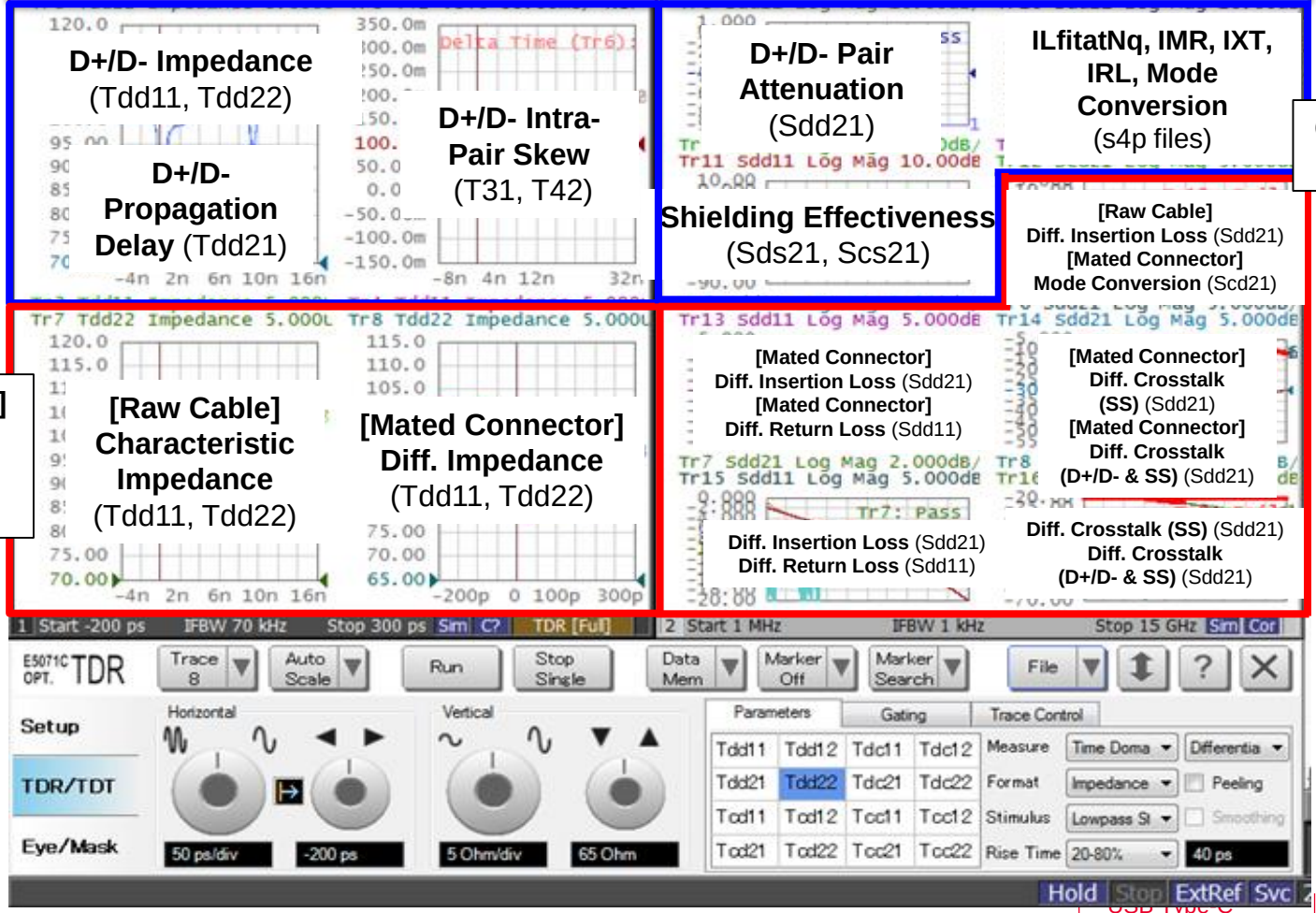
[Raw Cable]
Diff. Insertion Loss (Sdd21)
[Mated Connector]
Mode Conversion (Scd21)

[Mated Connector]
Diff. Insertion Loss (Sdd21)
[Mated Connector]
Diff. Return Loss (Sdd11)

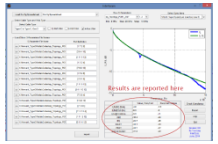
[Mated Connector]
Diff. Crosstalk (SS) (Sdd21)
[Mated Connector]
Diff. Crosstalk (D+/D- & SS) (Sdd21)

Diff. Insertion Loss (Sdd21)
Diff. Return Loss (Sdd11)

Diff. Crosstalk (SS) (Sdd21)
Diff. Crosstalk (D+/D- & SS) (Sdd21)



Compliance Tool

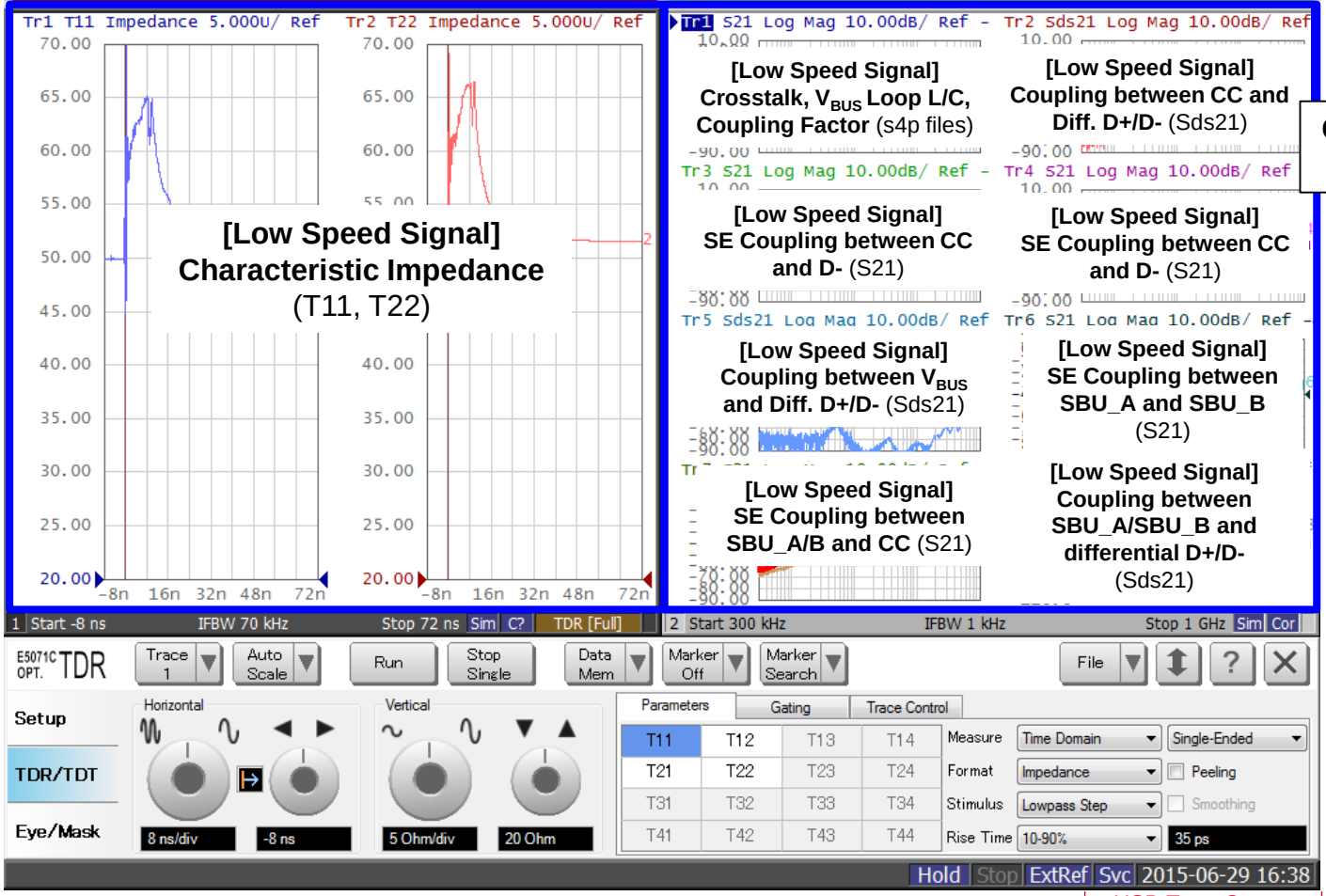


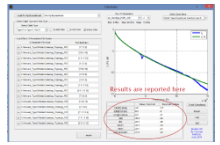
USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Measurement Parameters (**Normative** & **Informative**)

Time Domain

Frequency Domain





Compliance Tool

USB Type-C Cable/Connector Compliance Test

Measurement Parameters (Normative & Informative)

Time Domain

D+/D- Impedance (Tdd11, Tdd22)

D+/D- Propagation Delay (Tdd21)

D+/D- Intra-Pair Skew (T31, T42)

[Raw Cable] Intra-Pair Skew (T31, T42)

[Raw Cable] Characteristic Impedance (Tdd11, Tdd22)

[Mated Connector] Diff. Impedance (Tdd11, Tdd22)

Diff. Impedance (Tdd11, Tdd22)

Frequency Domain

D+/D- Pair Attenuation (Sdd21)

ILfitatNq, IMR, IXT, IRL, Mode Conversion (s4p files)

Shielding Effectiveness (Sds21, Scs21)

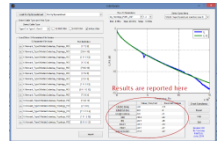
[Raw Cable]
Diff. Insertion Loss (Sdd21)
[Mated Connector]
Mode Conversion (Scd21)

[Mated Connector]
Diff. Insertion Loss (Sdd21)
[Mated Connector]
Diff. Return Loss (Sdd11)

[Mated Connector]
Diff. Crosstalk (SS) (Sdd21)
[Mated Connector]
Diff. Crosstalk (D+/D- & SS) (Sdd21)

Diff. Insertion Loss (Sdd21)
Diff. Insertion Loss (Sdd21)

Diff. Crosstalk (SS) (Sdd21)
Diff. Crosstalk (D+/D- & SS) (Sdd21)



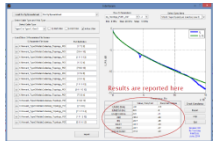
Compliance Tool

USB Type-C Cable/Connector Compliance Test

Measurement Parameters (**Normative** & **Informative**)

Time Domain

Frequency Domain



Compliance Tool

D+/D- Impedance (Tdd11, Tdd22)

D+/D- Intra-Pair Skew (T31, T42)

D+/D- Pair Attenuation (Sdd21)

ILfitatNq, IMR, IXT, IRL, Mode Conversion (s4p files)

[Raw Cable] Diff. Insertion Loss (Sdd21)
[Mated Connector] Mode Conversion (Scd21)

[Raw Cable] Intra-Pair Skew (T31, T42)

[Raw Cable] Characteristic Impedance (Tdd11, Tdd22)

[Mated Connector] Diff. Impedance (Tdd11, Tdd22)

[Mated Connector] Diff. Insertion Loss (Sdd21)
[Mated Connector] Diff. Return Loss (Sdd11)

[Mated Connector] Diff. Crosstalk (SS) (Sdd21)
[Mated Connector] Diff. Crosstalk (D+/D- & SS) (Sdd21)

Diff. Insertion Loss (Sdd21)
Diff. Return Loss (Sdd11)

Diff. Crosstalk (SS) (Sdd21)
Diff. Crosstalk (D+/D- & SS) (Sdd21)

USB Type-C Cable/Connector Compliance Test

Measurement Procedure

Step 1: Setup

•Manual or automatic setup by recalling a state file.
•State files for the ENA Option TDR will be provided for fast setup. Operators' error can be minimized.

Step 2: Calibration

Time-domain Cal	Frequency-domain Cal
ECal + De-embedding or In-fixture TRL Cal	
Adjustment of Effective Rise Time	

•Calibration for frequency-domain measurements shall be performed to remove the unwanted test fixture trace effect.
•ECal + De-embedding or TRL calibration are available with ENA Option TDR.
•Adjustment of effective rise time step is required for time-domain measurements.

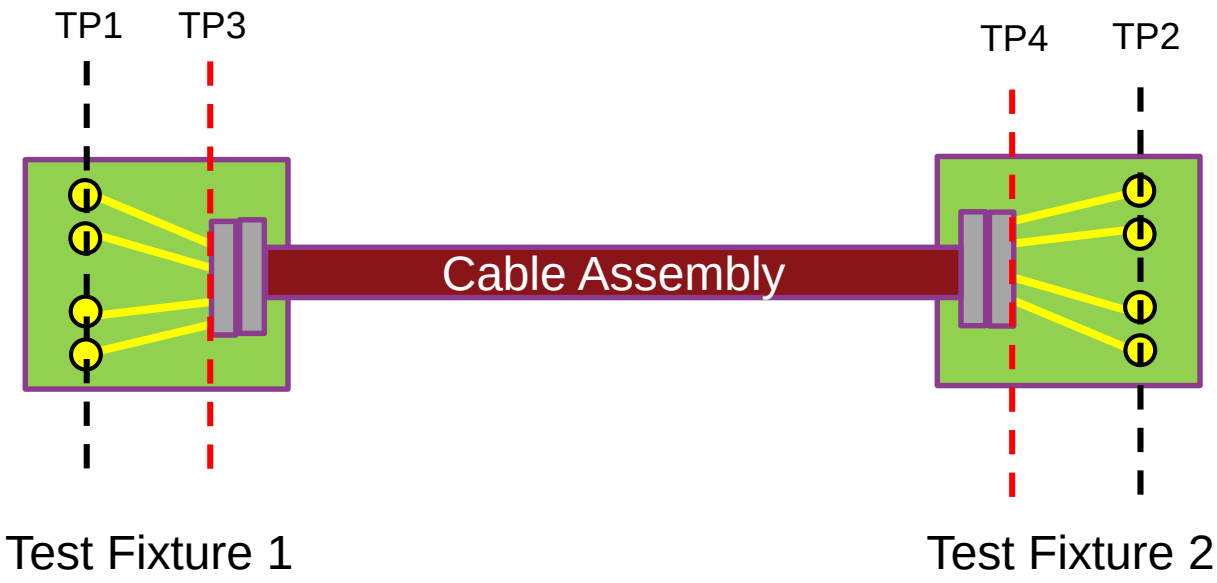
Step 3: Measurement

•The ENA Option TDR can be used to perform all measurements.
•Compliance standard tool is required for pass/fail judgment of ILfitatNq, IMR, IXT, IRL, differential to common mode conversion.

USB Type-C Cable/Connector Compliance Test

Calibration

•Calibration shall be performed to remove the unwanted test fixture trace effect.
•The procedures of 2x Thru de-embedding and In-fixture TRL calibration are the official procedure introduced in the USB Type-C Compliance Specification.

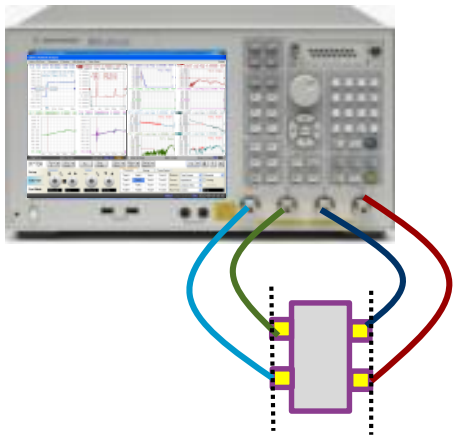


USB Type-C Cable/Connector Compliance Test

Calibration

1. ECal + De-embedding

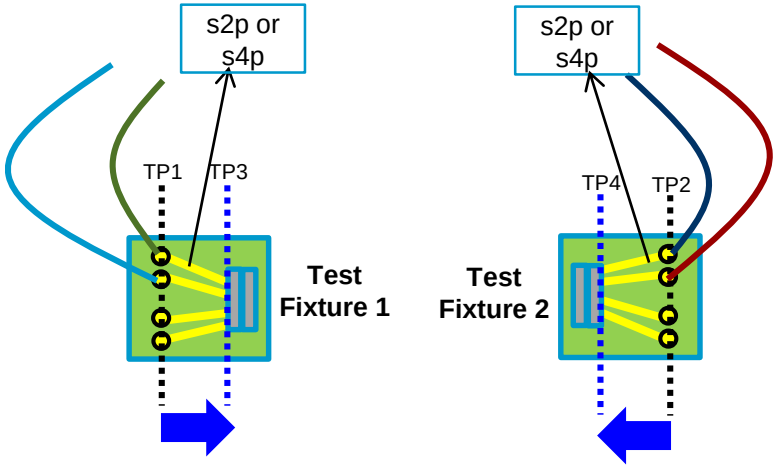
1. Full calibration with ECal



ECal (i.e. N4433A)

•Full 4-port calibration is performed using the 4-port ECal module (i.e. N4433A).
•The reference plane is established at the end of RF cables connected to the ENA's test ports.

2. De-embedding S-parameters of fixture traces



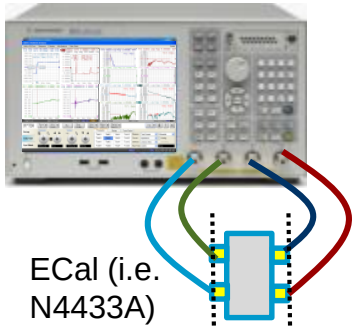
•S-parameter Touchstone files (*.s2p or .s4p) of fixture traces are excluded from total performance in frequency-domain by using the de-embedding function of the ENA.
•The reference plane is moved to the edge of USB connectors on the test fixtures (TP1->TP3 & TP2->TP4).

USB Type-C Cable/Connector Compliance Test

Calibration

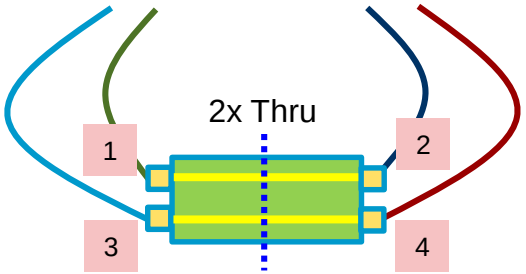
Creating de-embedding files with PLTS

1. Full calibration with ECal



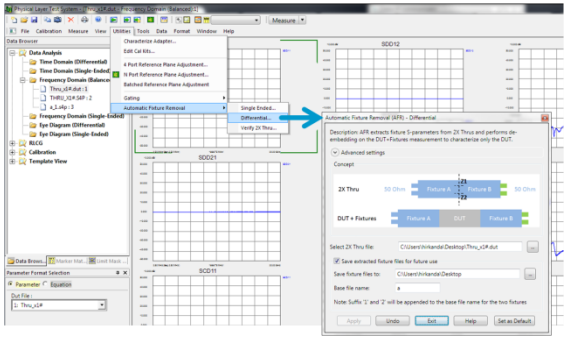
•Perform full 4-port calibration using the ECal module (i.e. N4433A).

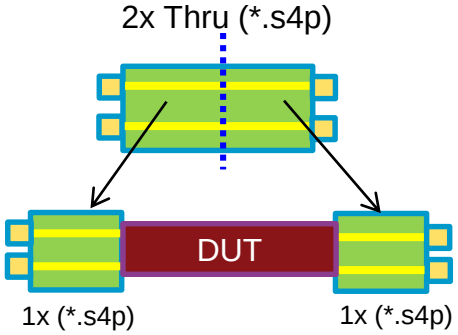
2. Measure 2x Thru standards



•Perform 4-port measurement and save 4-port S-parameter file (*.s4p).

3. Create de-embedding files by AFR with PLTS



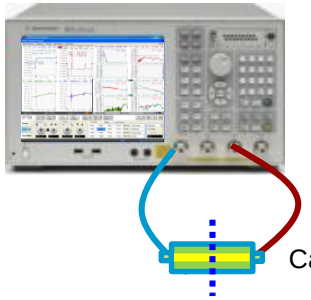


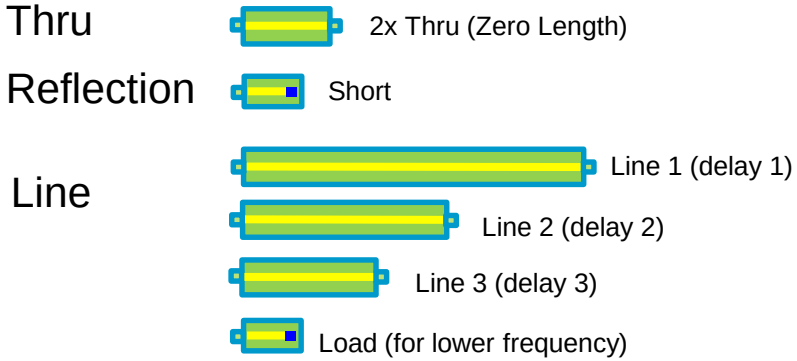
•Launch PLTS software on PC
•Import measured 4-port file (*.s4p)
•Create two de-embedding files (*.s4p)
•Change port configuration (optional)

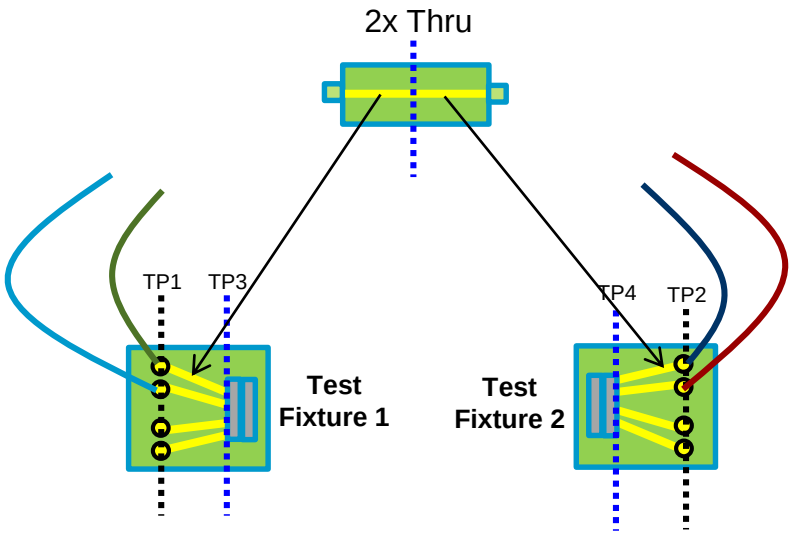
USB Type-C Cable/Connector Compliance Test

Calibration

2. TRL Calibration







•TRL (Thru, Reflection, Line) calibration is performed by using the USB Type-C official TRL calibration standards for three combinations between the ENA's test ports (Port 1&2, Port 1&3, Port 3&4).

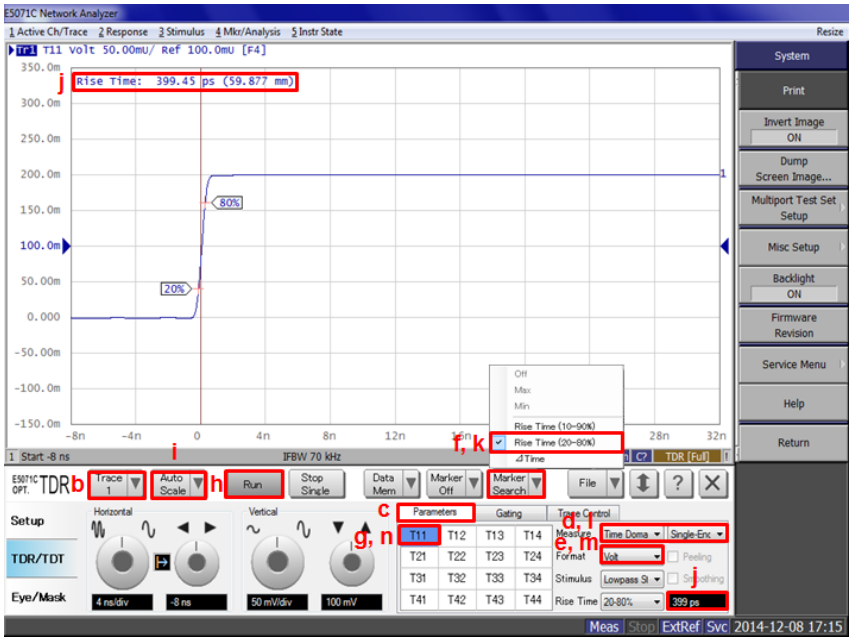
•The electrical length of 2x Thru is equal to the length of the trace between TP1 and TP3 plus the length of the trace between TP2 and TP4.
•Reference plane is set at the edge of USB connectors on the test fixtures (TP3 & TP4).

USB Type-C Cable/Connector Compliance Test

Calibration (Adjustment of Effective Rise Time in Time Domain)

Test Items	Rise Time (%)	Target Rise Time
[D+/D-] Impedance, Propagation Delay, Intra-Pair Skew	20 – 80 %	400 ps
[Raw Cable] Characteristic Impedance	10 – 90 %	200 ps
[Mated Connector] Differential Impedance [Type-C to Legacy Cable] Differential Impedance	20 – 80 %	40 ps

•The effective rise time for test items is specified as shown in the table.

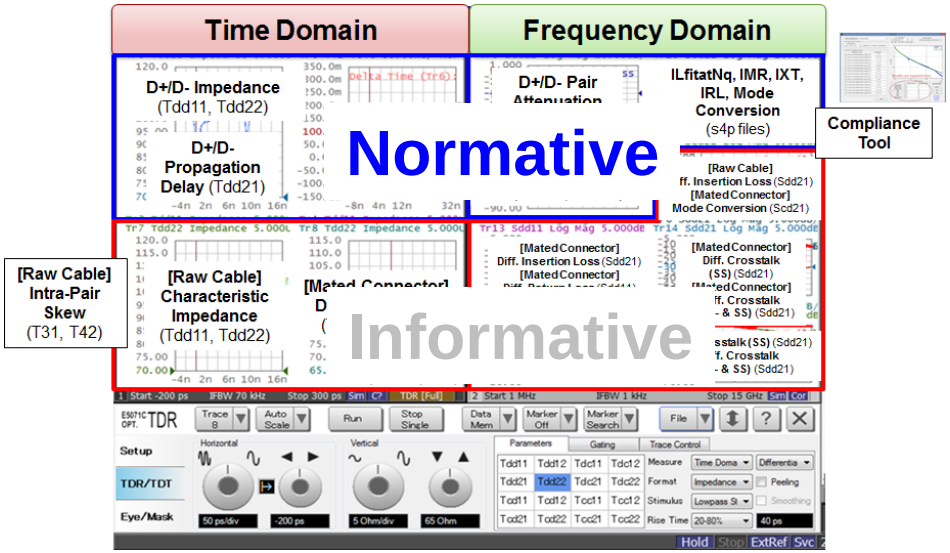


•The effective rise time entering the USB Type-C connector pins is adjusted for the specification in time-domain measurements.
•1x Thru standard is connected to the E5071C port with RF cables. DUT is disconnected during the adjustment procedure.

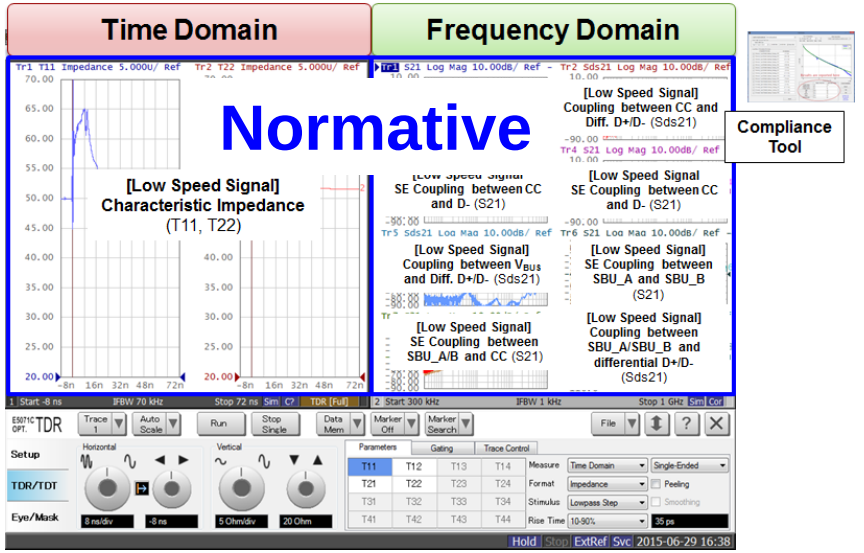
USB Type-C Cable/Connector Compliance Test

Normative Parameters

[Type-C to Type-C Passive Cable Assemblies] High Speed Measurement Parameters



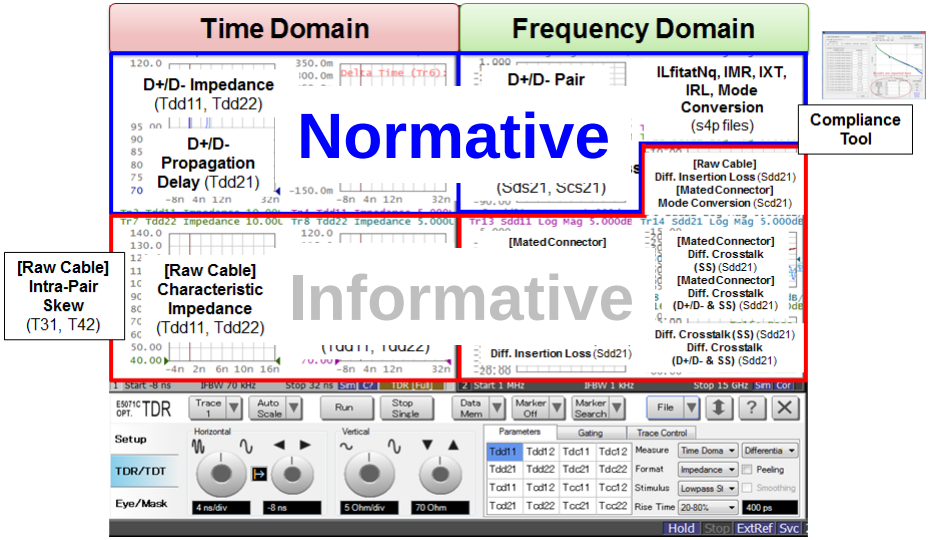
[Type-C to Type-C Passive Cable Assemblies] Low Speed Signal Measurement Parameters



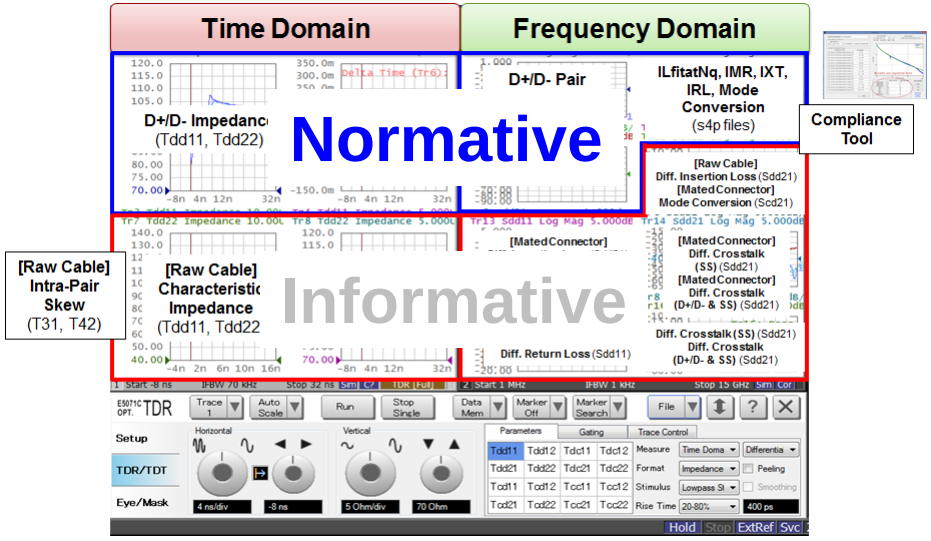
USB Type-C Cable/Connector Compliance Test

Normative Parameters

[Type-C to Legacy Cable Assemblies]

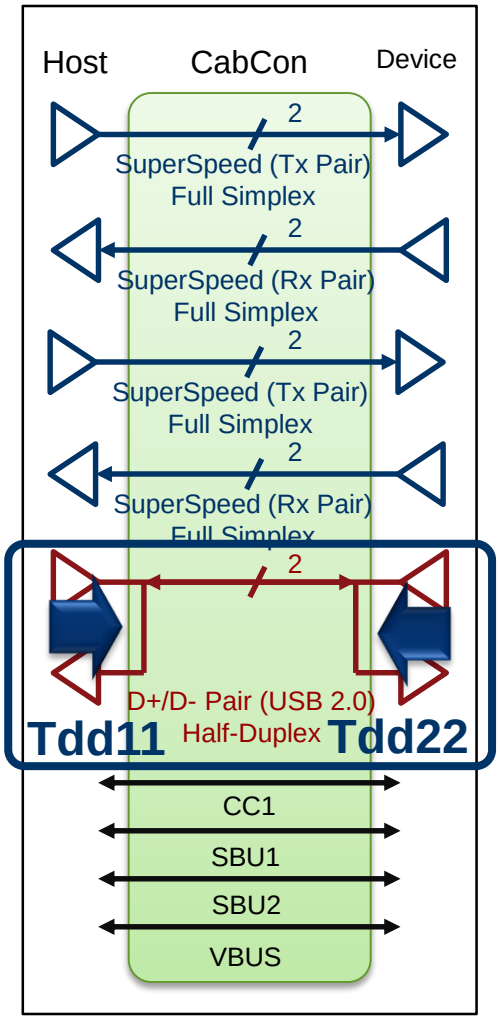


[Type-C to Legacy Adapter Assemblies]



USB Type-C Cable/Connector Compliance Test

D+/D- Impedance (**Normative**)



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.

D+/D- Impedance - Specification

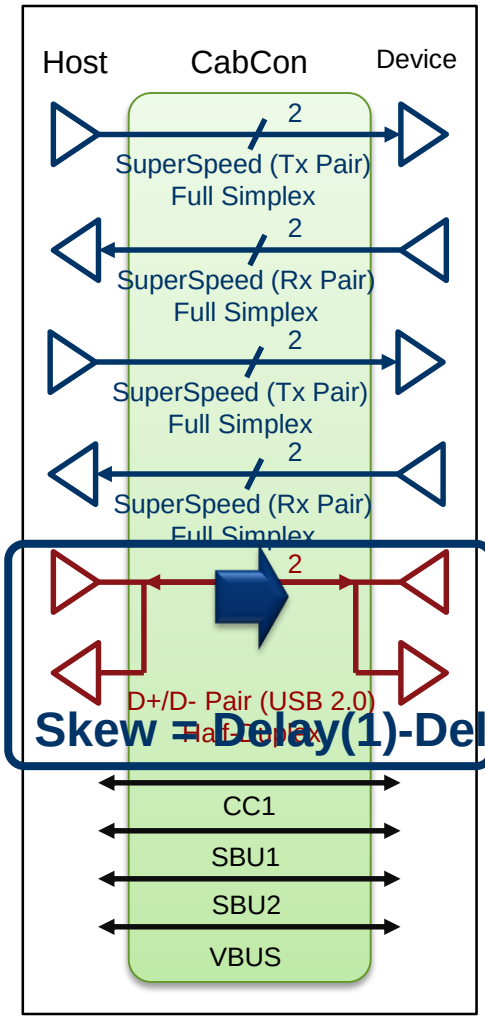
DUT Type	Limit
Type-C to Type-C passive cable assembly Type-C to legacy cable assembly Type-C to legacy adapter assembly	75 ohms min and 105 ohms max.

Note: Should be measured with a TDR in a differential mode using a 400 ps (20%-80%) rise time.

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

D+/D- Intra-Pair Skew (**Normative**)

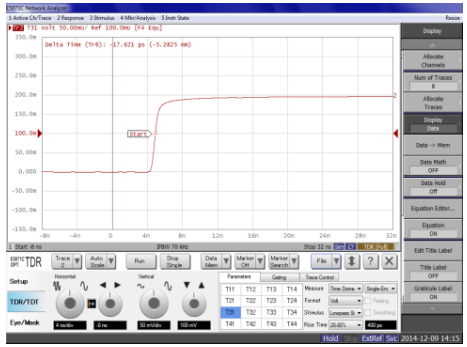


Skew = Delay(1)-Delay(2)

- Intra-pair skew measurement ensures the signal on both the D+ and D- lines of a cable assembly arrive at the receiver at the same time.

D+/D- Intra-Pair Skew - Specification

DUT Type	Limit
Type-C to Type-C passive cable assembly Type-C to legacy cable assembly	<100 ps
Type-C to legacy adapter assembly	<20 ps

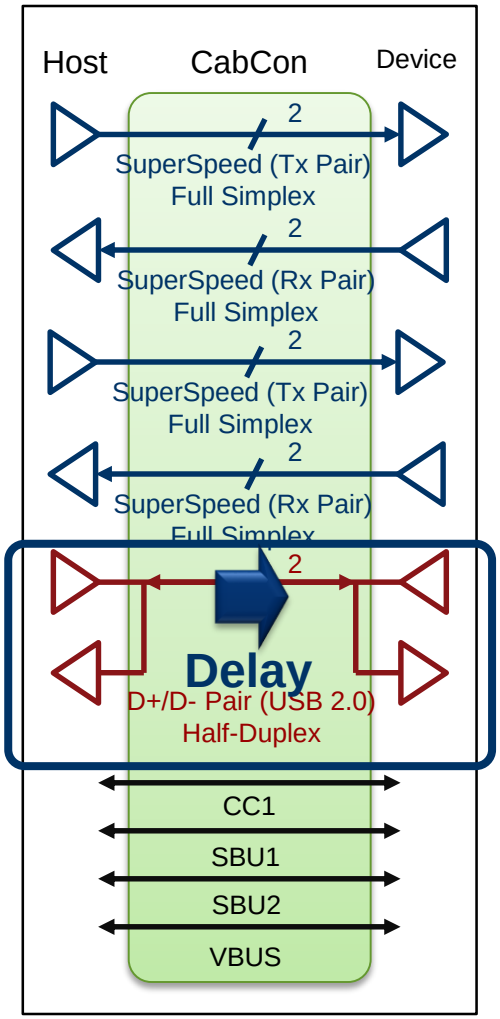


Note: Should be measured with a TDR in a differential mode using a 400 ps (20%-80%) rise.

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

D+/D- Propagation Delay (**Normative**)



- Propagation delay measurement verifies the end-to-end propagation of the D+/D- lines of the cable assembly.

D+/D- Propagation Delay - Specification

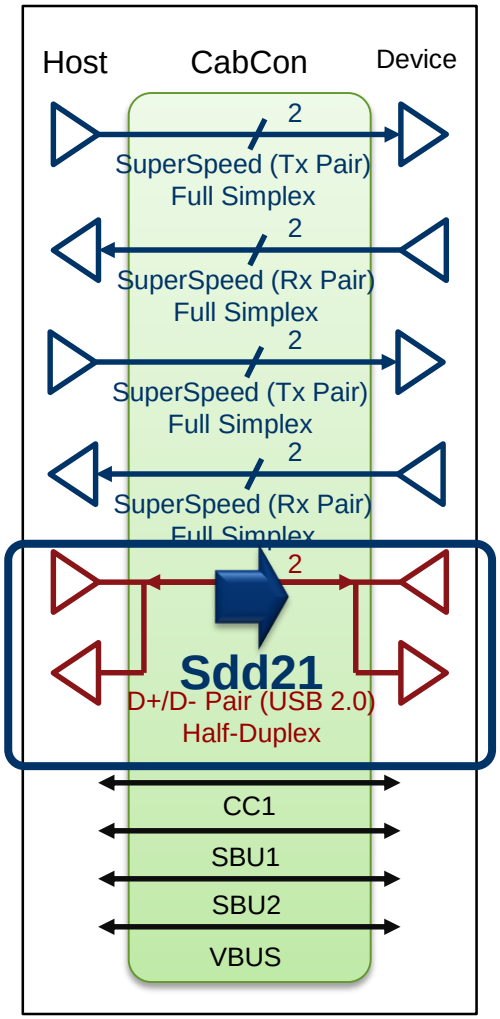
DUT Type	Limit
Type-C to Type-C passive cable assembly Type-C to legacy cable assembly	<20 ns
Type-C to legacy cable assembly (Type-C to Micro-B cable assembly)	<10 ns

Note: Should be measured with a TDR in a differential mode using a 400 ps (20%-80%) rise time.

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

D+/D- Pair Attenuation (**Normative**)



•Ensures the D+/D- pair of a cable assembly can provides adequate signal strength to the receiver to maintain a low error rate.

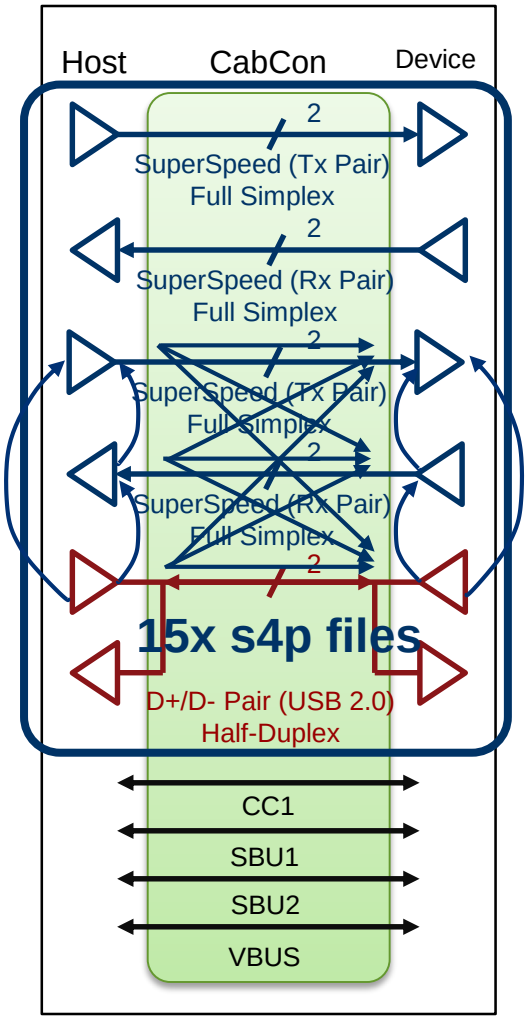
D+/D- Pair Attenuation - Specification

DUT Type	Limit
Type-C to Type-C passive cable assembly Type-C to legacy cable assembly	≥-1.02 dB @50 MHz ≥-1.43 dB @100 MHz ≥-2.40 dB @200 MHz ≥-4.35 dB @400 MHz
Type-C to legacy adapter assembly	≥-0.7 dB @400 MHz

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

ILfitatNq, IMR, IXT, IRL, Differential to Common-Mode Conversion (**Normative**)



- Five parameters (ILfitatNq, IMR, IXT, IRL and Differential to Common-Mode Conversion) are calculated for SS+ pairs and D+/D- pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment for five parameters based on measured Touchstone files. (15x s4p or 3x s8p or 1x s12p file)

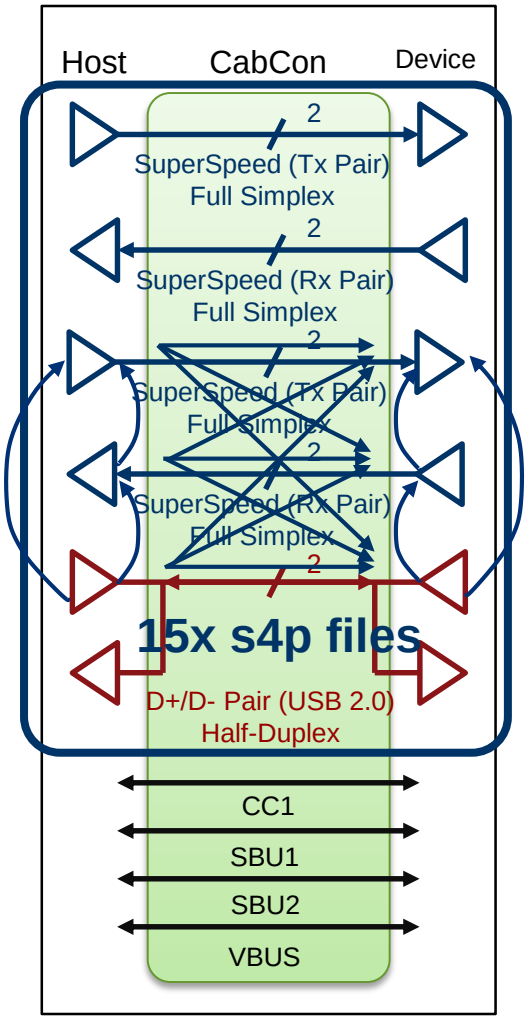
ILfitatNq, IMR, IXT, IRL, Mode Conversion - Specification

Parameter	Limit
ILfitatNq	[Gen2] ≥-4 dB @2.5 GHz, ≥-6 dB @5 GHz, ≥-11 dB @10 GHz [Gen1 only] ≥-7 dB @2.5 GHz, ≥-12 dB @5 GHz
IMR	≤0.126 * ILfitatNq^2 + 3.024 * ILfitatNq - 23.392 dB (f_{max} = 12.5 GHz)
ISSXT	INEXT ≤-40 dB, IFEXT ≤-40 dB
IDDXT	2NEXT ≤-33 dB, 1NEXT + 1FEXT ≤-34.5 dB (Informative)
IRL	≤0.046 * ILfitatNq^2 + 1.812 * ILfitatNq - 10.784 dB
Mode Conversion	≤-20 dB from 100 MHz to 10 GHz

Note: USB 2.0-only Type-C to Type-C cable assembly includes only the D+/D- pair, VBUS and CC lines. Only the signal integrity requirement applicable to those signals shall be tested for such cable assemblies.

USB Type-C Cable/Connector Compliance Test

ILfitatNq, IMR, IXT, IRL, Differential to Common-Mode Conversion (**Normative**)



- Five parameters (ILfitatNq, IMR, IXT, IRL and Differential to Common-Mode Conversion) are calculated for SS+ pairs and D+/D- pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment for five parameters based on measured Touchstone files. (15x s4p or 3x s8p or 1x s12p file)

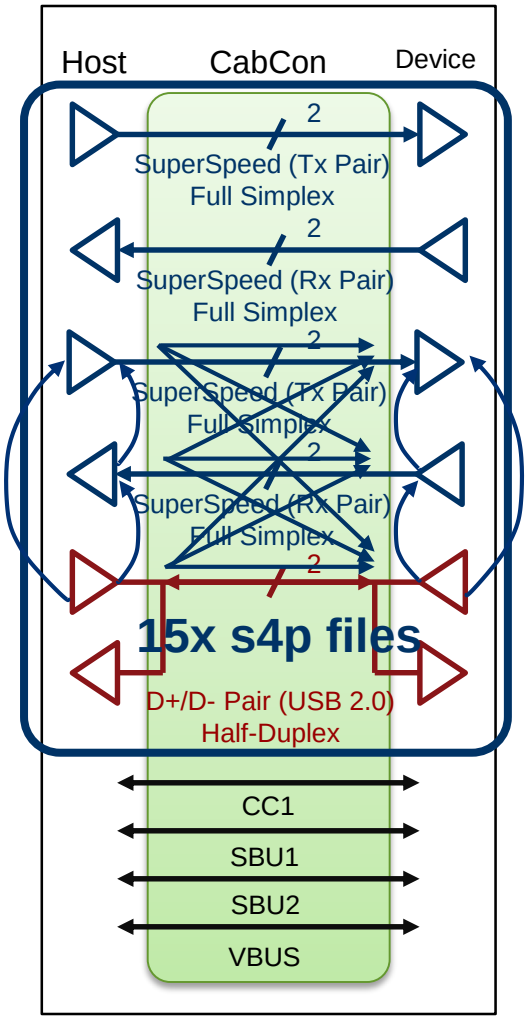
ILfitatNq, IMR, IXT, IRL, Mode Conversion - Specification

Parameter	Limit
ILfitatNq	≥-4 dB @2.5 GHz, ≥-3.5 dB @2.5 GHz (USB Type-C plug to USB 3.1 Standard-A plug cable assembly) ≥-6 dB @5 GHz
IMR	≤0.126 * ILfitatNq^2 + 3.024 * ILfitatNq - 21.392 dB
ISSXT	≤-37 dB
IDDXT	≤-28.5 dB
IRL	≤0.046 * ILfitatNq^2 + 1.812 * ILfitatNq - 9.748 dB
Mode Conversion	≤-20 dB from 100 MHz to 10 GHz

Note: SS pairs is only applicable to Type-C to legacy USB 3.1 (Gen 2) cable assembly.

USB Type-C Cable/Connector Compliance Test

ILfitatNq, IMR, IXT, IRL, Differential to Common-Mode Conversion (**Normative**)



- Five parameters (ILfitatNq, IMR, IXT, IRL and Differential to Common-Mode Conversion) are calculated for SS+ pairs and D+/D- pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment for five parameters based on measured Touchstone files. (15x s4p or 3x s8p or 1x s12p file)

ILfitatNq, IMR, IXT, IRL, Mode Conversion - Specification

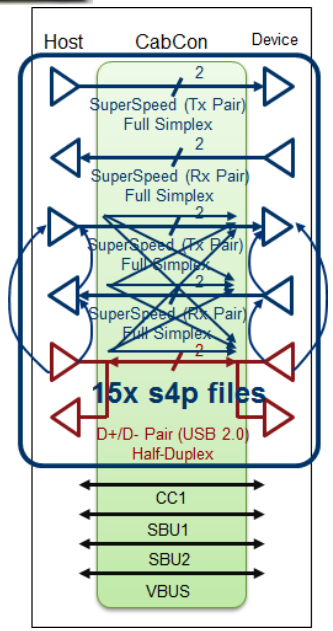
Parameter	Limit
ILfitatNq	≥-2.4 dB @2.5 GHz, ≥-3.5 dB @5 GHz
IMR	≤-34 dB for Tb = 200 ps, ≤-27 dB for Tb = 100 ps
ISSXT	≤-37 dB
IDDXT	≤-30 dB
IRL	≤-14.5 dB for Tb = 200 ps, ≤-12 dB for Tb = 100 ps
Mode Conversion	≤-15 dB from 100 MHz to 7.5 GHz

Note: SS pair requirements are only applicable to the USB Type-C to USB Standard-A receptacle adaptor assembly. Tb is the unit interval - Tb=200 ps is for USB 3.1 Gen 1 and Tb=100 ps is for USB 3.1 Gen 2.

USB Type-C Cable/Connector Compliance Test

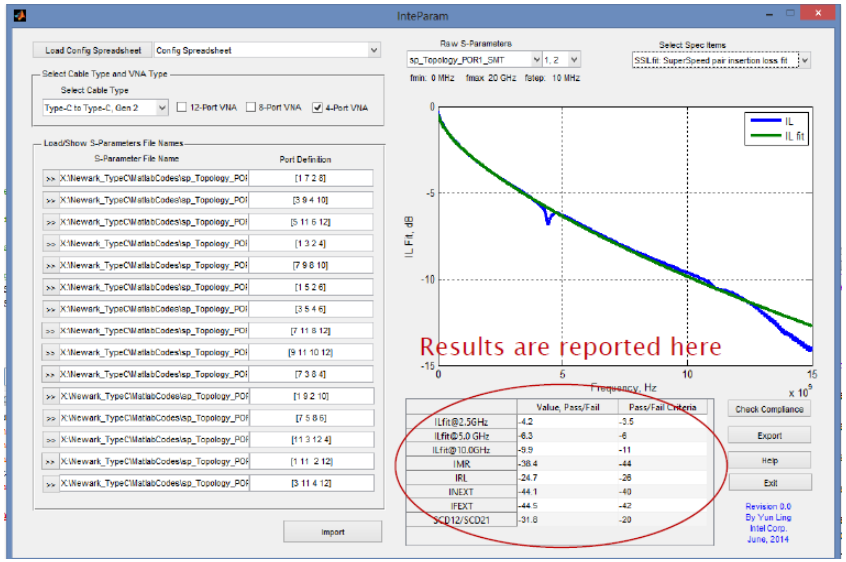
ILfitatNq, IMR, IXT, IRL, Differential to Common-Mode Conversion (**Normative**)

ENA Option TDR



Perform frequency-domain (S-parameter) measurements to save 15x 4-port Touchstone files (*.s4p) for SS signal pairs and D+/D- signal pair.

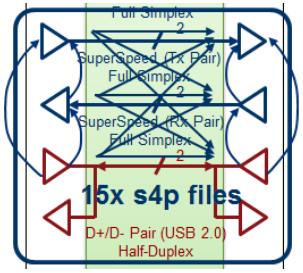
USB Type-C Standard Tool



Import 15x Touchstone files (*.s4p) to do pass/fail judgment.

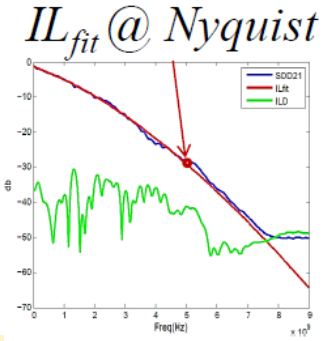
USB Type-C Cable/Connector Compliance Test

ILfitatNq, IMR, IXT, IRL, Differential to Common-Mode Conversion (**Normative**)

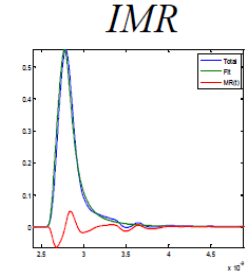


15x s4p files

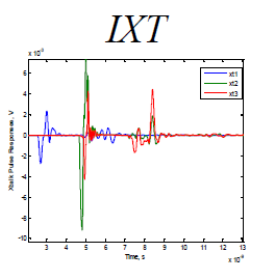
15x 4-port Touchstone S-parameter files (*.s4p) are saved and imported to the tool.



Differential insertion loss is fitted with a smooth function to obtain the insertion loss at Nyquist frequency of 5 GHz (ILfitatNq).

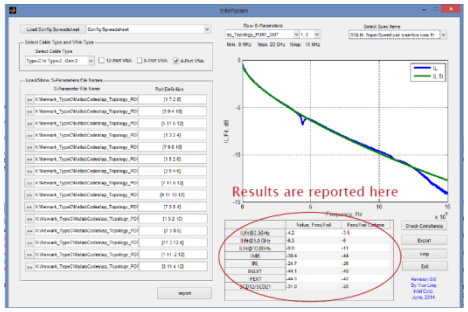


$$IMR = \frac{1}{UI}\sqrt{\int_{-\infty}^{\infty}|MR(f)|^2\,df}$$

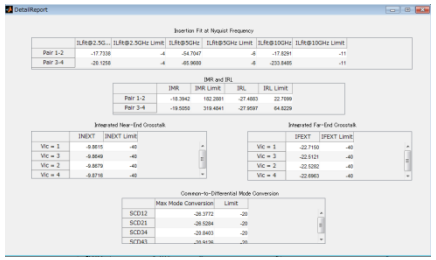


$$IXT = \frac{1}{UI}\sqrt{\int_{-\infty}^{\infty}|XT(f)|^2\,df}$$

Integrated crosstalk (IXT), integrated multi-reflection (IMR) etc response are calculated from S-parameter files.



The tool performs pass/fail judgment based on the previous calculation.

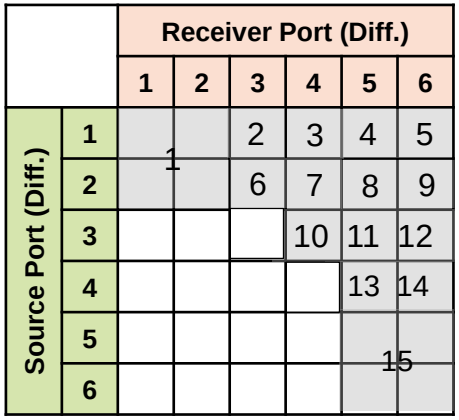


USB Type-C Cable Compliance Test

Obtaining Multiport Touchstone Files (*s12p) with Multiport VNA

- USB Type-C standard tool requires multiport Touchstone file(s) for the pass/fail judgment of cable assemblies with 6x differential (=12x single-ended) ports.
- To improve throughput of total characterization, the 12-port VNA can create an *.s12p file with a single measurement.

4-port VNA

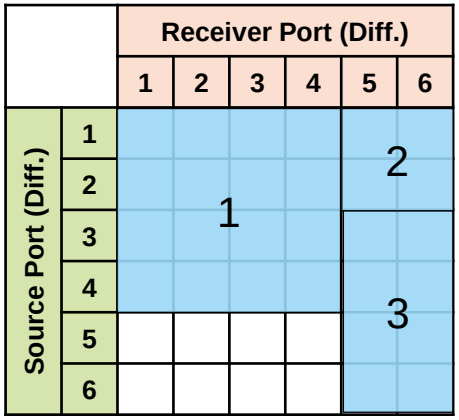


Port combinations (# of tests):

1&2, 1&3, 1&4, … 1&6 (5)
2&3, 2&4, 2&5, 2&6 (4)
3&4, 3&5, 3&6 (3)
4&5, 4&6, (2)
5&6 (1)

=>15x s4p files

8-port VNA

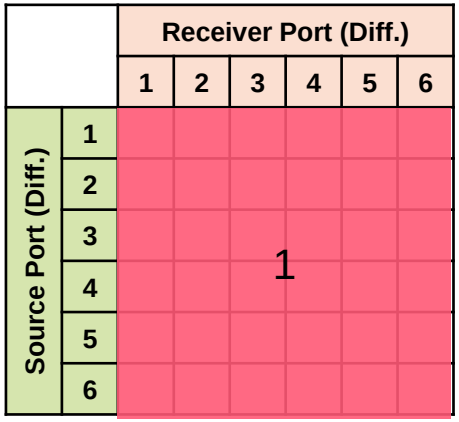


Port combinations (# of tests):

1, 2, 3, 4 (1)
1, 2, 5, 6 (1)
3, 4, 5, 6 (1)

=> 3x s8p files

12-port VNA



Port combinations (# of tests):

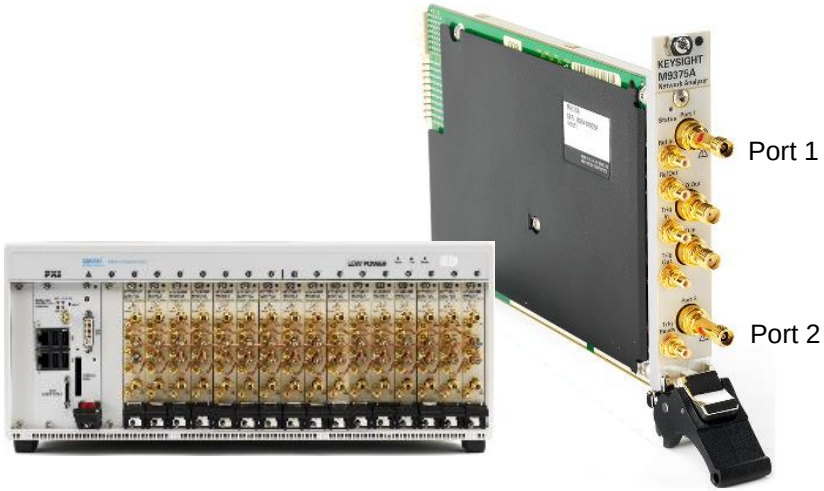
1, 2, 3, 4, 5, 6 (1)

=> 1x s12p file

KEYSIGHT TECHNOLOGIES

USB Type-C Cable Compliance Test

M937XA PXIe VNA Multiport Configuration



Keysight PXI VNA (M937XA)

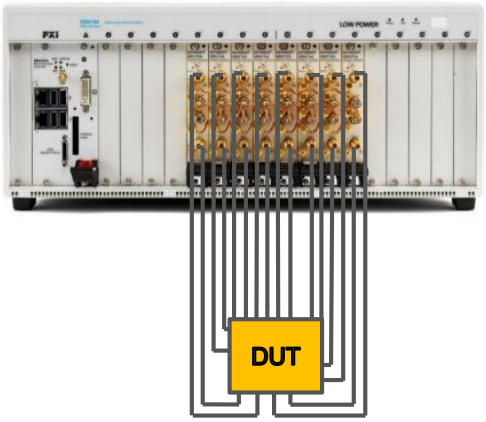
- Full two-port VNA that fits in just *one* slot.
- Performs fast, accurate measurements and reduces cost-of-test by simultaneously characterizing many devices using a single PXI chassis.

Feature	Benefit
Choice of six frequency ranges, and the ability to upgrade the frequency range (Six frequency models: 4, 6.5, 9, 14, 20, 26.5 GHz)	Pay only for the frequency range you need with the widest choice of frequency ranges from 300 kHz **up to 26.5 GHz**.
Cascade multiple PXI modules to address multiport applications	**Up to 16 modules (32-port)** can be added to a single chassis to configure multiport test solutions with a smaller form factor
True multiport VNA with N-port correction capability	A receiver for each test port provides **no degradation in performance** up to 32-ports (i.e. dynamic range, trace noise, stability)
Electronic calibration (ECal) control	Perform fast, easy and accurate **multiport calibrations**

USB Type-C Cable Compliance Test

M937XA PXIe VNA Multiport Configuration

Recommended Configuration of Multiport VNA



Model / Option	Description	ea
M9374A	300 k to 20 GHz, 2-port, PXIe Vector Network Analyzer	2 (for 4-port VNA) 4 (for 8-port VNA) 6 (for 12-port VNA)
M9374A-010	Time domain analysis	1 (*1)
M9374A-551	Full N-port calibrated measurement	1 (*1)
N4433A	ECal module, 300 k to 20 GHz, 4-port.	1
M9018A	18-slot PXIe chassis	1
M9037A	High-performance embedded controller	1

*1: At least one PXI VNA module must have option 010 or 551 to enable the capabilities in a multiport configuration.
*2: The list above includes the major equipment required. Please contact our sales representative for configuration details.

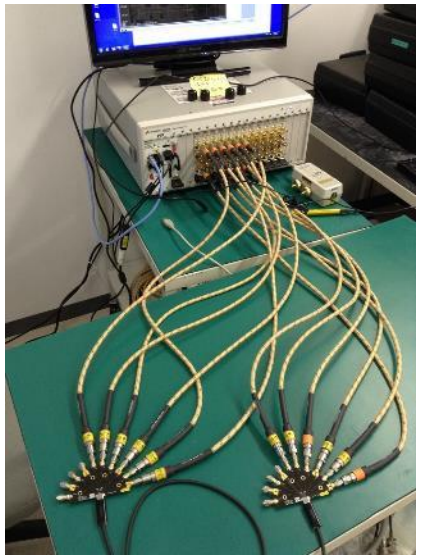
For more information of M937X PXI VNA:

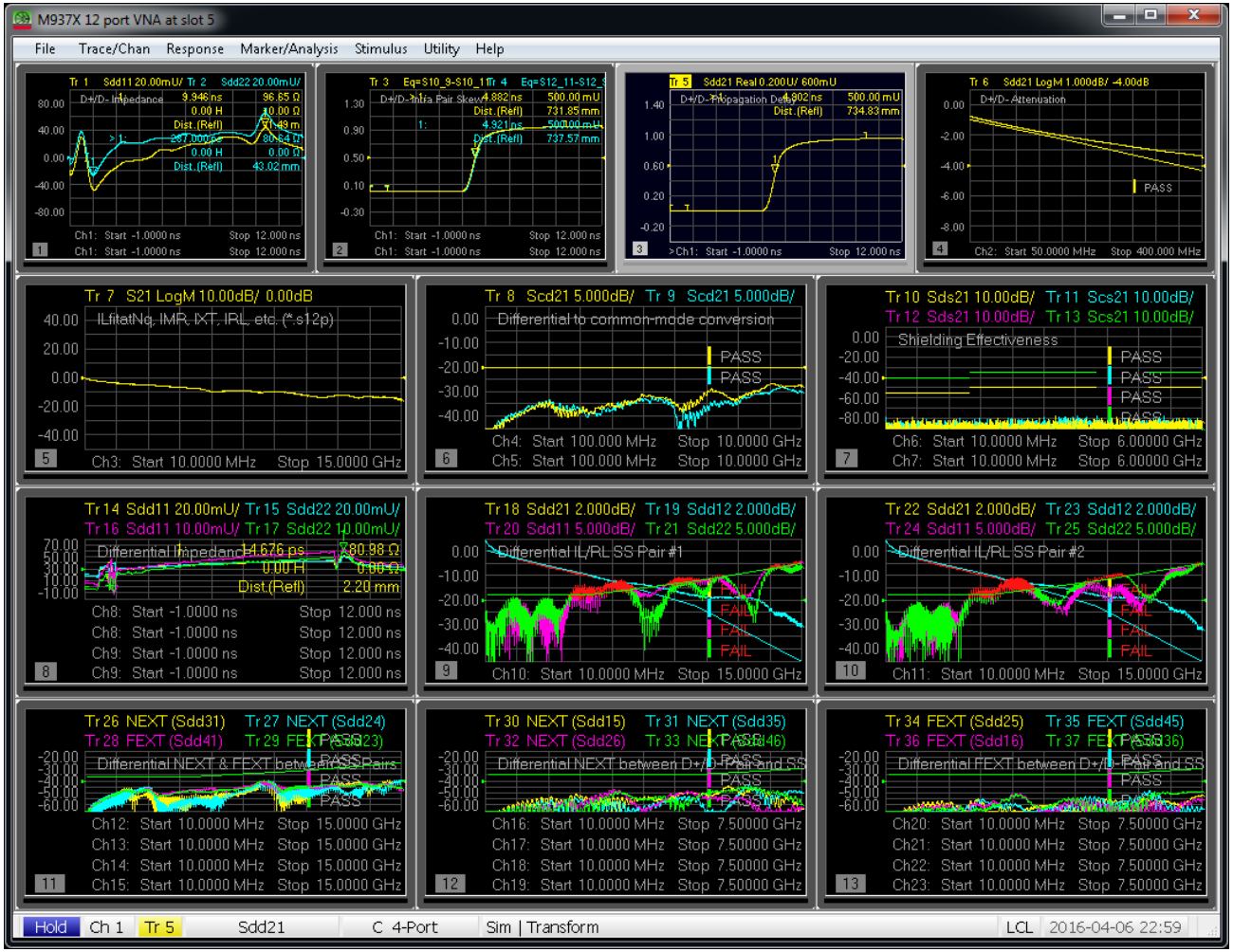
[MOI page] www.keysight.com/find/pxivna_usbtype-c-cabcon
[Product page] www.keysight.com/find/pxivna
[Configuration Guide] http://literature.cdn.keysight.com/litweb/pdf/5991-4885EN.pdf
[Data Sheet] http://literature.cdn.keysight.com/litweb/pdf/M9370-90002.pdf

USB Type-C Cable Compliance Test

M937XA PXIe VNA Multiport Configuration

- All measurement parameters of compliance tests can be obtained with a single cable connection using a 12-port PXI VNA.

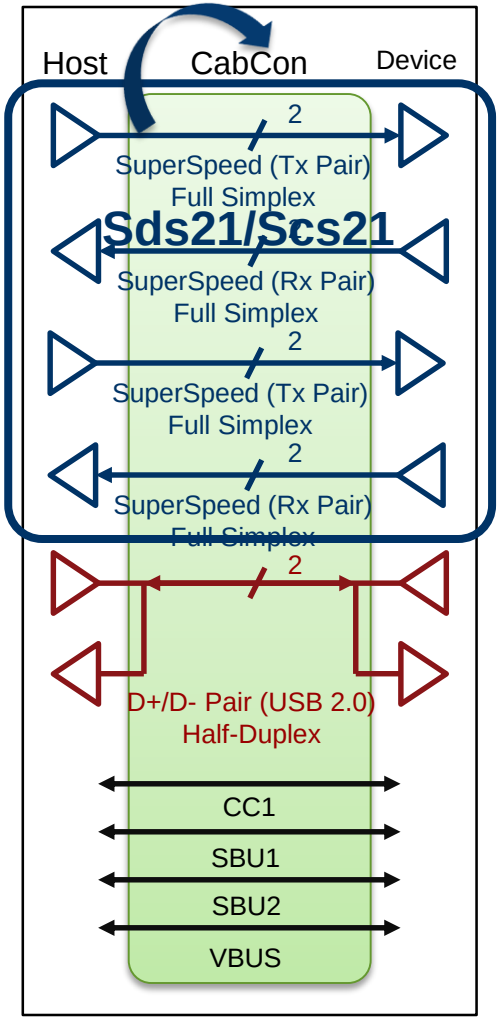




KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

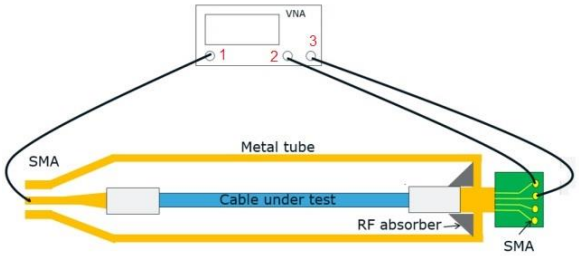
Shielding Effectiveness (**Normative**)



- Measures the radio frequency interference (RFI) level from the cable assembly
- The coupling factor from differential Tx / Rx pairs to single-ended cable shield (i.e. Sds21/Scs21) is calculated.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment based on Touchstone files.

Shielding Effectiveness - Specification

DUT Type	Limit
Type-C to Type-C passive cable assembly	Differential model ≤-55 dB (≤1.6 GHz), ≤-50 dB (1.6 GHz to 4 GHz / 5 GHz to 6 GHz) Common mode ≤-40 dB (≤1.6 GHz), ≤-35 dB (1.6 GHz to 4 GHz / 5 GHz to 6 GHz)
Type-C to legacy cable assembly	Differential model ≤-49 dB (≤1.6 GHz), ≤-44 dB (1.6 GHz to 4 GHz / 5 GHz to 6 GHz) Common mode ≤-34 dB (≤1.6 GHz), ≤-29 dB (1.6 GHz to 4 GHz / 5 GHz to 6 GHz)

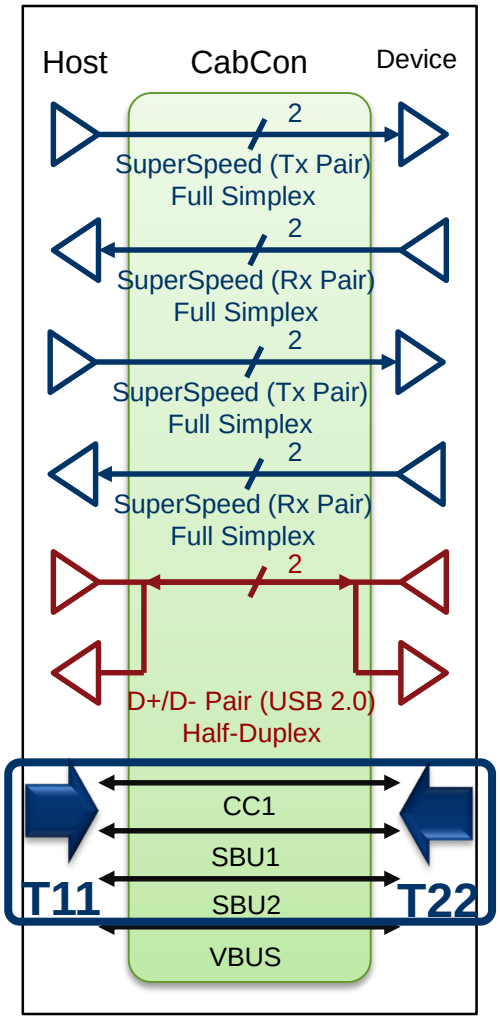


Shielding effectiveness test fixture

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Characteristic Impedance (**Normative**)



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.

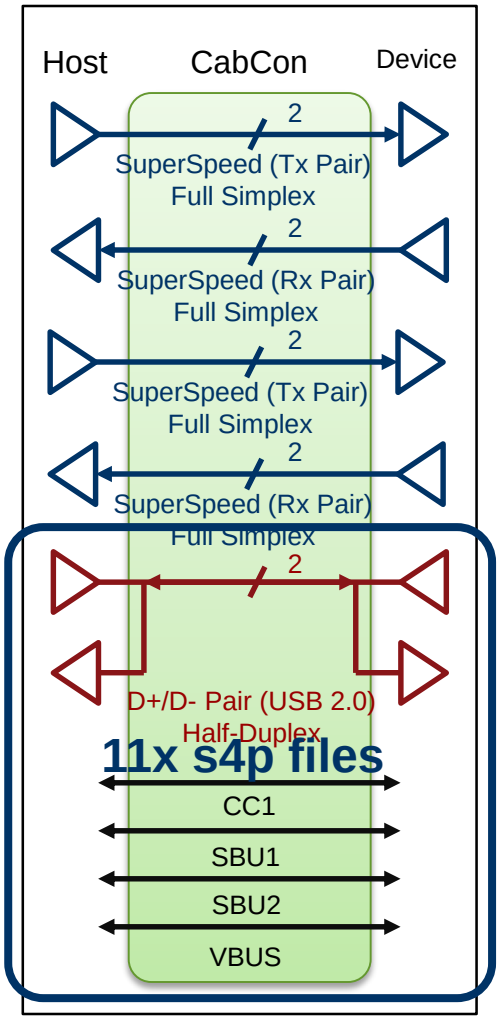
[Low-Speed Signal] Characteristic Impedance - Specification

DUT Type	Limit
CC unshielded or shielded wires	32 ohm to 93 ohm
SBU unshielded or shielded wires	32 to 53 ohm

KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Crosstalk, V_{BUS} Loop L/C, Coupling Factor (**Normative**)



- Crosstalk, V_{BUS} loop inductance, V_{BUS} capacitance and coupling factor are calculated for low speed signal and D+/D- pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment based on measured Touchstone files. (11x s4p or 3x s8p or 1x s12p file)

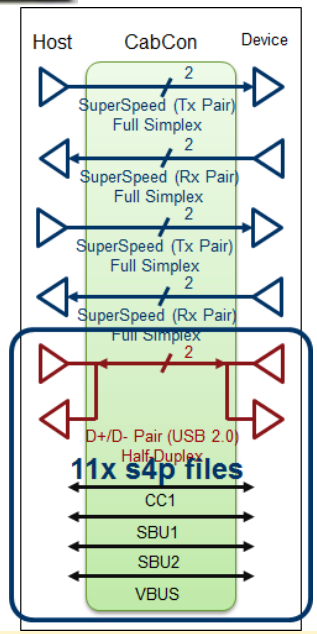
Crosstalk, V_{BUS} Loop L/C, Coupling Factor - Specification

Parameter	Limit
Coupling between CC and Differential D+/D1	Refer to the slide for each test parameter
Single-ended Coupling between CC and D-	
Coupling between V_{BUS} and Differential D+/D-	
V_{BUS} Loop Inductance, Coupling Factor, V_{BUS} Capacitance	
Single-ended Coupling between SBU_A and SBU_B	
Single-ended Coupling between SBU_A/SBU_B and CC	
Coupling between SBU_A/SBU_B and Differential D+/D-	

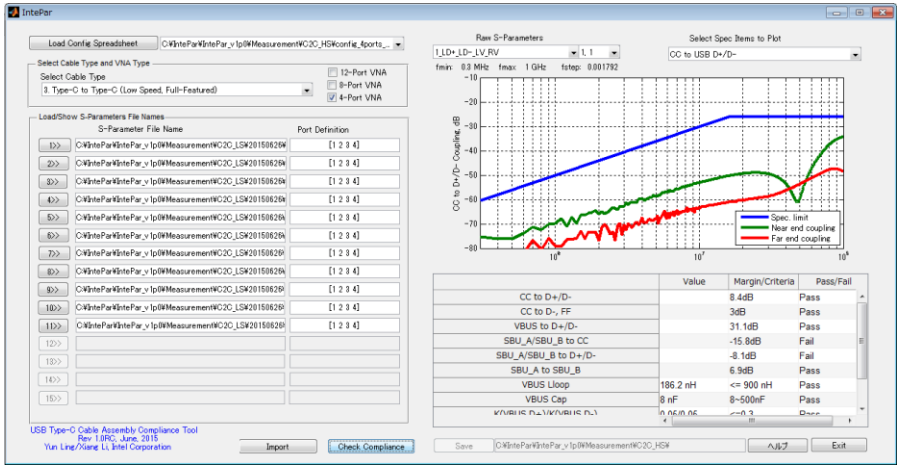
KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Crosstalk, V_{BUS} Loop L/C, Coupling Factor (**Normative**)



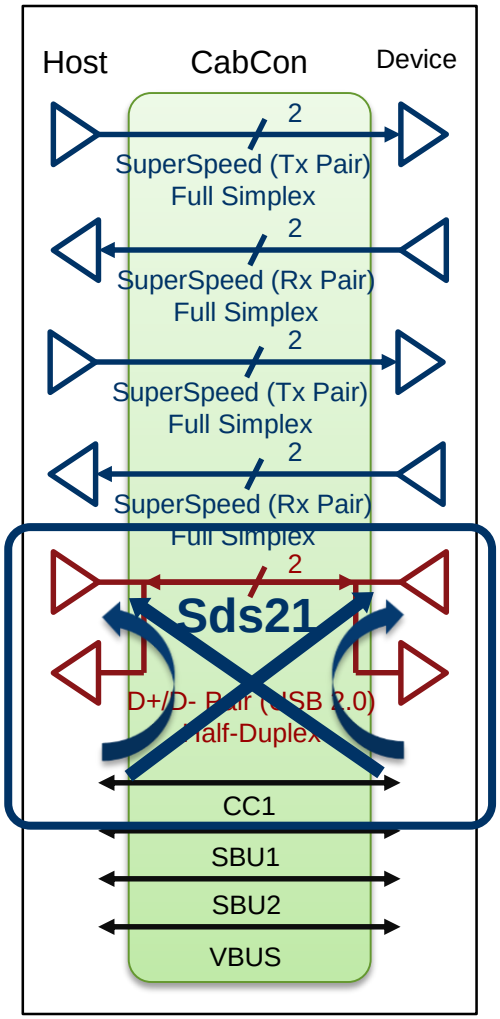
Perform frequency-domain (S-parameter) measurements to save 11x 4-port Touchstone files (*.s4p) for low speed signal and D+/D- signal pair.



Import 11x Touchstone files (*.s4p) to do pass/fail judgment.

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Coupling between CC and Differential D+/D- (**Normative**)



- Measure of coupling between CC and differential D+/D-.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

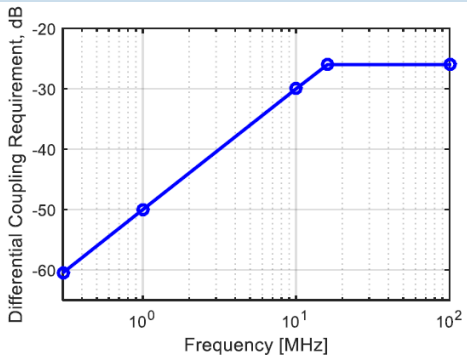
Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] CC and D+/D- - Specification

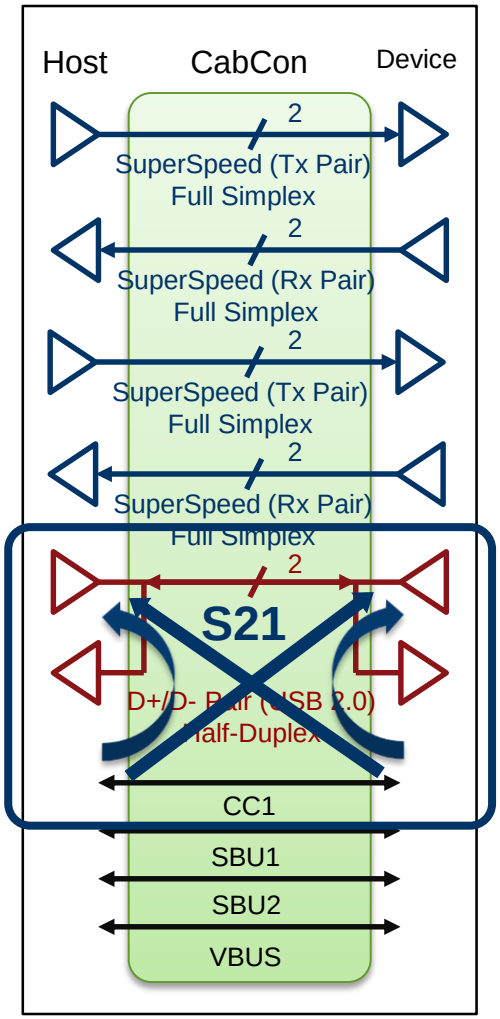
DUT Type	Limit
Full-featured cable, charged-through cable	-60.5 dB @0.3 MHz -50 dB @1 MHz -30 dB @10 MHz -26 dB @16 MHz -26 dB @100 MHz



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Single-ended Coupling between CC and D- (**Normative**)



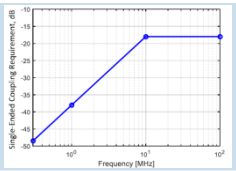
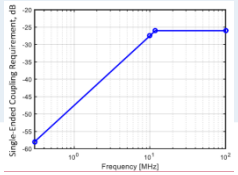
- Measure of single-ended coupling between CC and D-.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

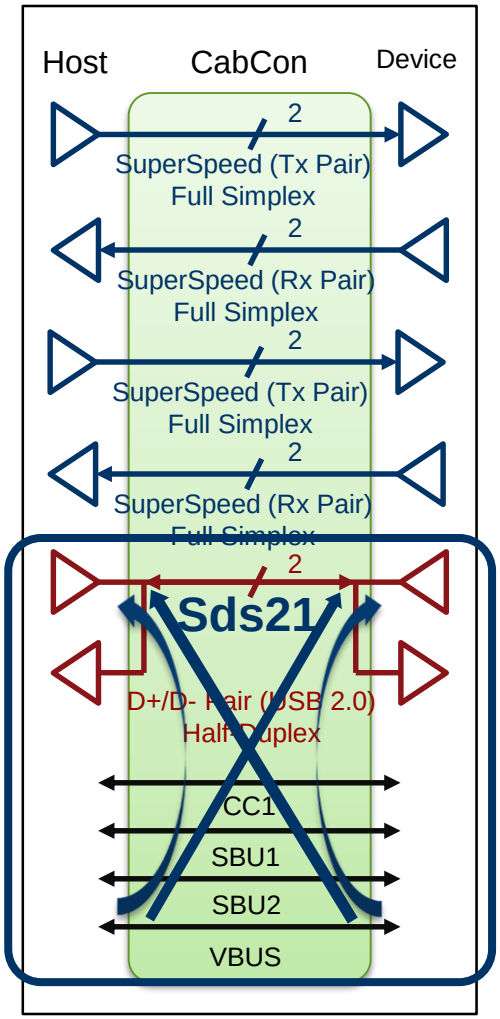
DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] CC and USB D- - Specification

DUT Type	Limit
USB 2.0 Type-C cable 	-48.5 dB @0.3 MHz -38 dB @1 MHz -18 dB @10 MHz -18 dB @100 MHz
Full-featured cable 	-58 dB @0.3 MHz -27.5 dB @10 MHz -26 dB @11.8 MHz -26 dB @100 MHz

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Coupling between V_{BUS} and Differential D+/D- (**Normative**)



- Measure of coupling between V_{BUS} and differential D+/D-.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

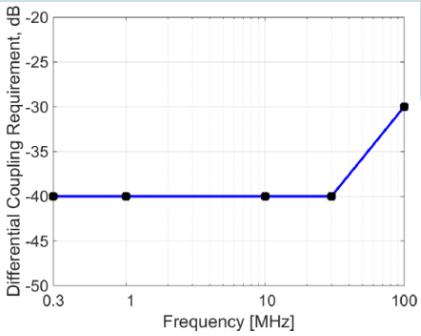
Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] V_{BUS} and D+/D- - Specification

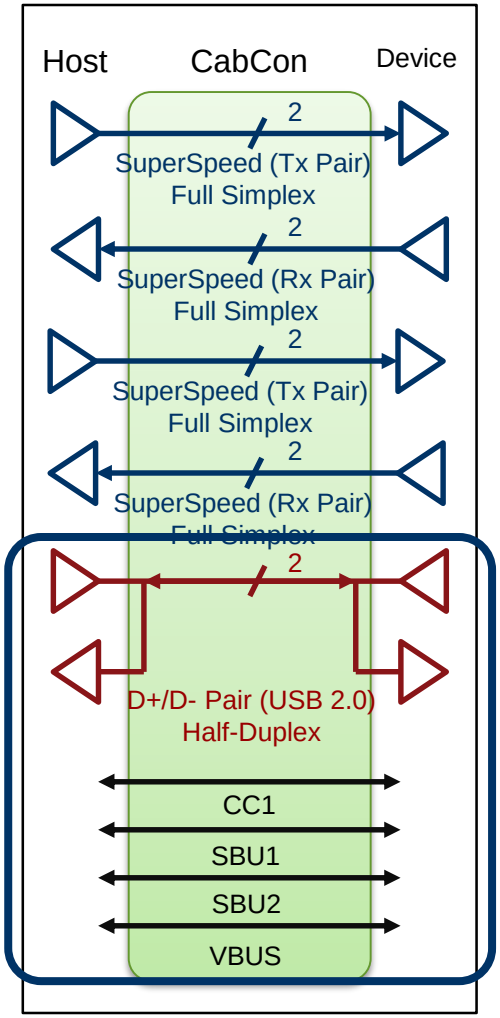
DUT Type	Limit
Full-featured cable, charged-through cable	-40 dB @0.3 MHz -40 dB @1 MHz -40 dB @30 MHz -30 dB @100 MHz



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

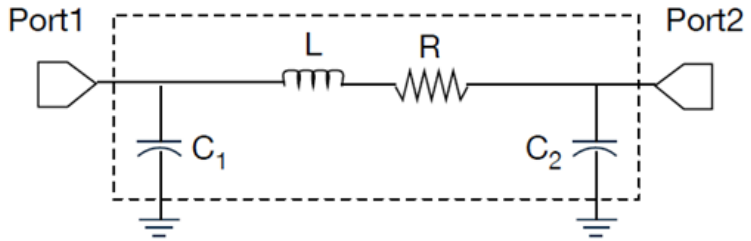
[Low Speed Signal] V_{BUS} Loop Inductance, Coupling Factor, V_{BUS} Capacitance (**Normative**)



- The loop inductance of V_{BUS} and its coupling factor to low speed lines (CC, SBU_A/B, D+/D-) is controlled to limit noise induced on low speed signaling lines.
- For fully featured cables, the range of V_{BUS} bypass capacitance shall be 8 nF up to 500 nF for high-speed return-path bypassing.

[Low-Speed Signal] V_{BUS} Loop L, Coupling Factor, V_{BUS} C - Specification

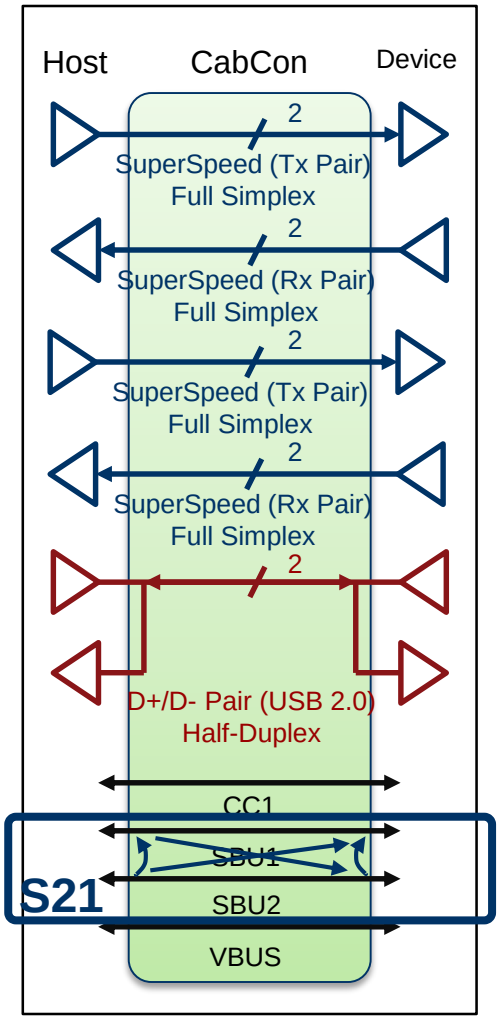
Parameter	Limit
V_{BUS} loop inductance	≤900 nH
Mutual inductance coupling factor	≤0.3
V_{BUS} capacitance	8 nF to 500 nF



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Single-ended Coupling between SBU_A and SBU_B (**Normative**)



- Measure of single-ended coupling between SBU_A and SBU_B.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

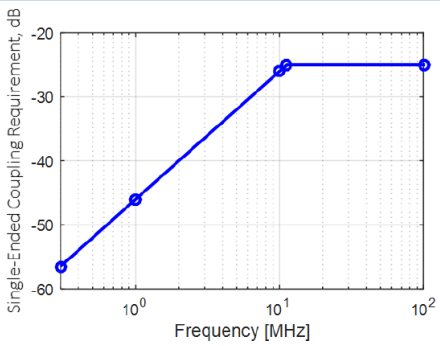
Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] SBU_A and SBU_B - Specification

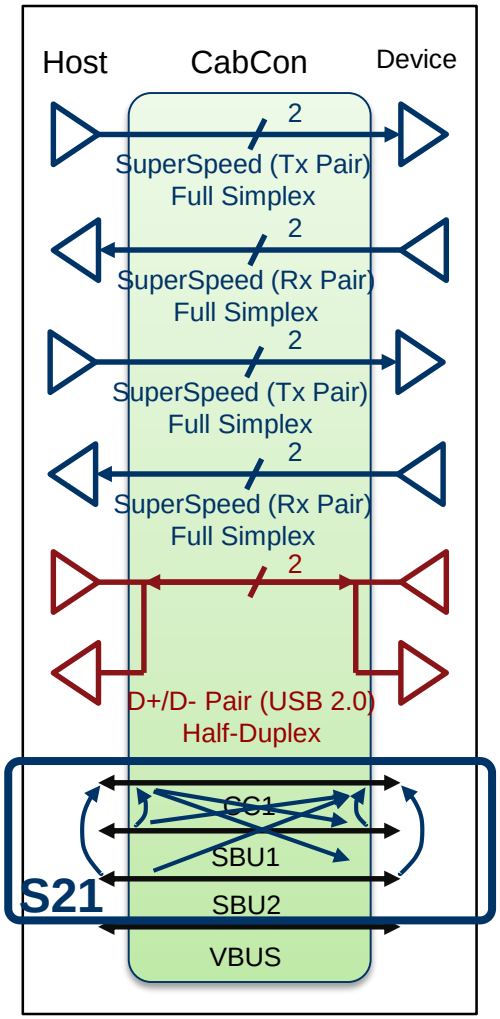
DUT Type	Limit
Full-featured cable	-56.5 dB @0.3 MHz -46 dB @1 MHz -26 dB @10 MHz -25 dB @11.2 MHz -25 dB @100 MHz



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Single-ended Coupling between SBU_A/SBU_B and CC (**Normative**)



- Measure of single-ended coupling between SBU_A and CC, and between SBU_B and CC.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

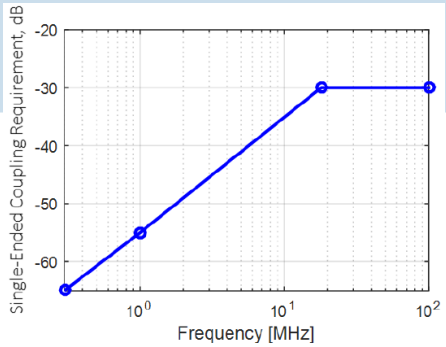
Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] SBU_A/SBU_B and CC - Specification

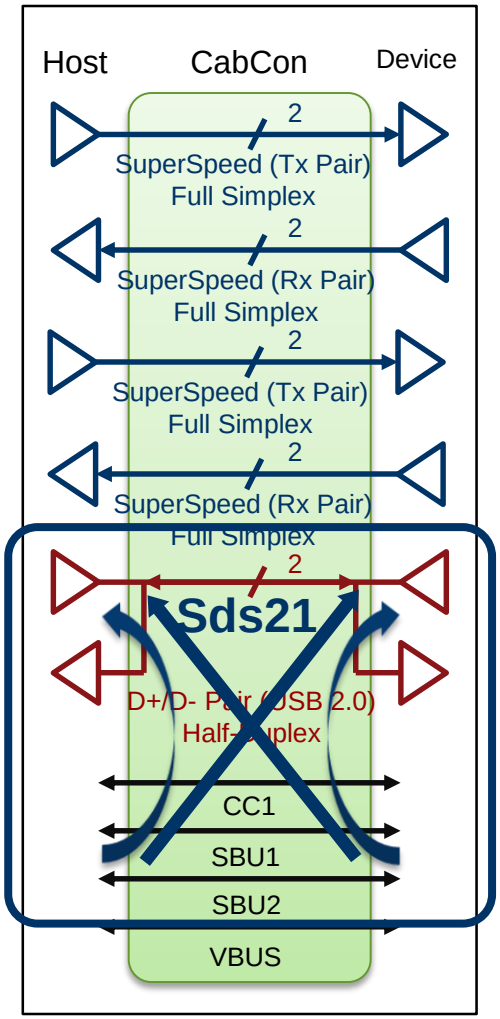
DUT Type	Limit
Full-featured cable	-65 dB @0.3 MHz -55 dB @1 MHz -30 dB @18 MHz -30 dB @100 MHz



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Low Speed Signal] Coupling between SBU_A/SBU_B and Differential D+/D- (**Normative**)



- Measure of coupling between SBU_A and differential D+/D-, and between SBU_B and differential D+/D-.
- Coupling or crosstalk, both near-end and far-end, among the low speed signals shall be controlled.

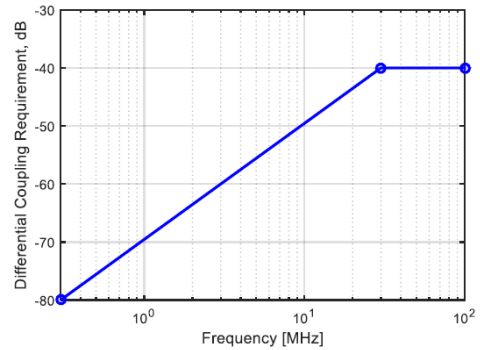
Coupling Matrix for Low Speed Signals

Coupling Matrix	D+/D− (DF)	VBUS	SBU_B/SBU_A
CC	FF, CT	FF, CT	FF
D+/D− (DF)	N/A	FF, CT	FF
SBU_A/SBU_B	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charged-through cable (including USB 2.0 function)

[Low-Speed Signal] SBU_A/SBU_B and D+/D- - Specification

DUT Type	Limit
Full-featured cable	-80 dB @0.3 MHz -40 dB @30 MHz -40 dB @100 MHz

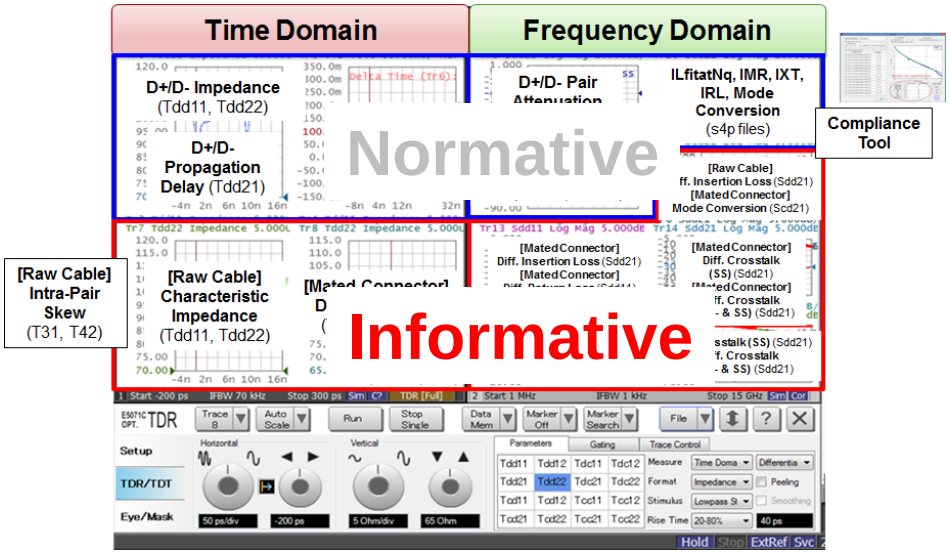


KEYSIGHT TECHNOLOGIES

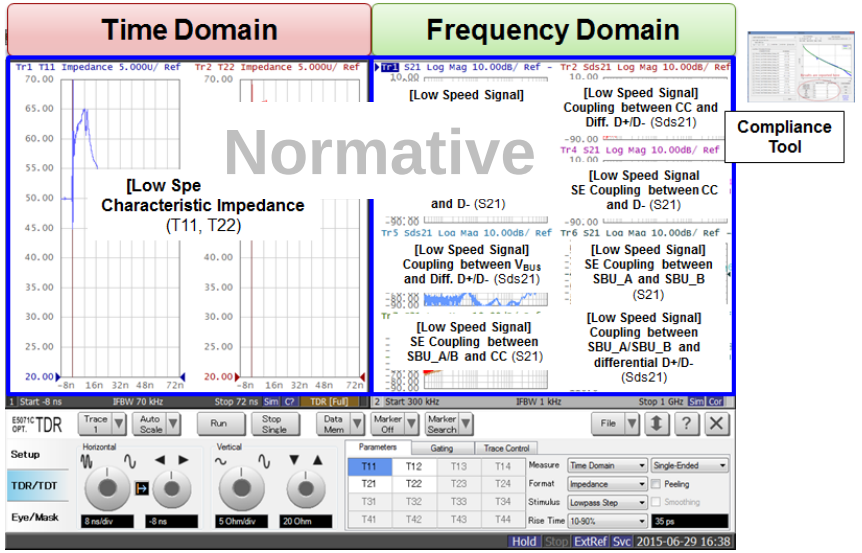
USB Type-C Cable/Connector Compliance Test

Informative Parameters

[Type-C to Type-C Passive Cable Assemblies] High Speed Measurement Parameters



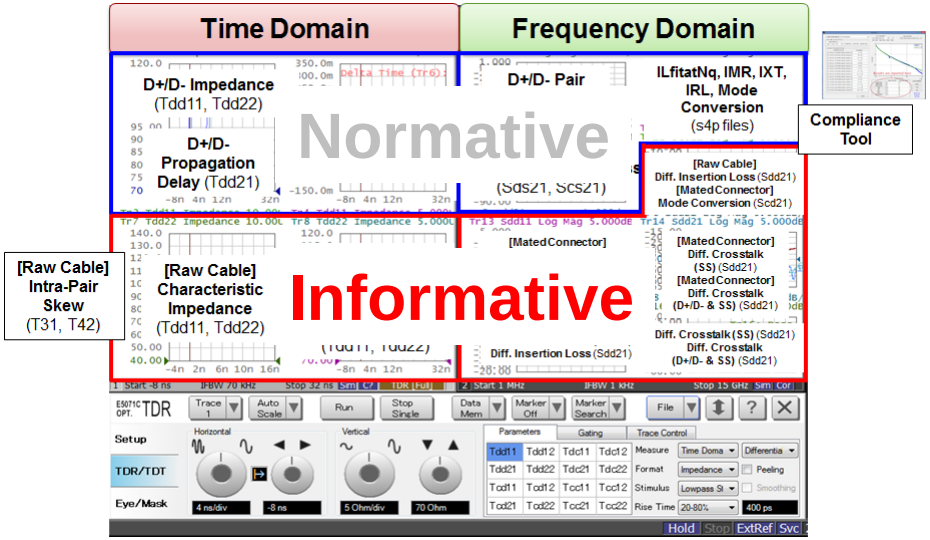
[Type-C to Type-C Passive Cable Assemblies] Low Speed Signal Measurement Parameters



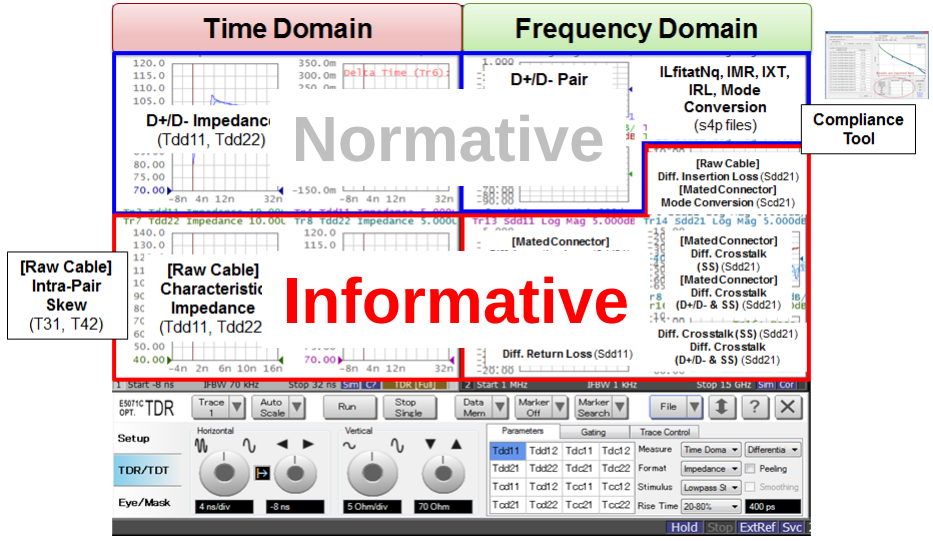
USB Type-C Cable/Connector Compliance Test

Informative Parameters

[Type-C to Legacy Cable Assemblies]

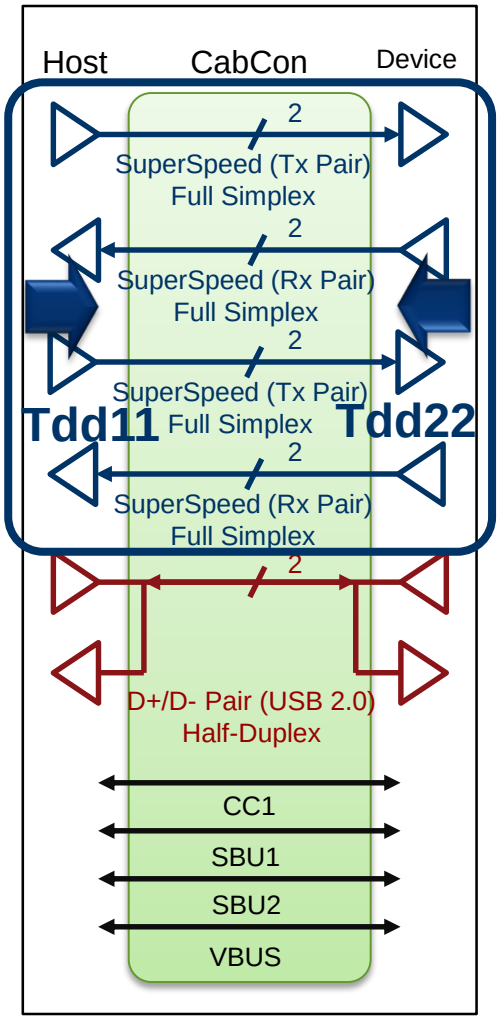


[Type-C to Legacy Adapter Assemblies]



USB Type-C Cable/Connector Compliance Test

[Raw Cable] Characteristic Impedance (**Informative**)



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.

[Raw Cable] Characteristic Impedance - Design Target

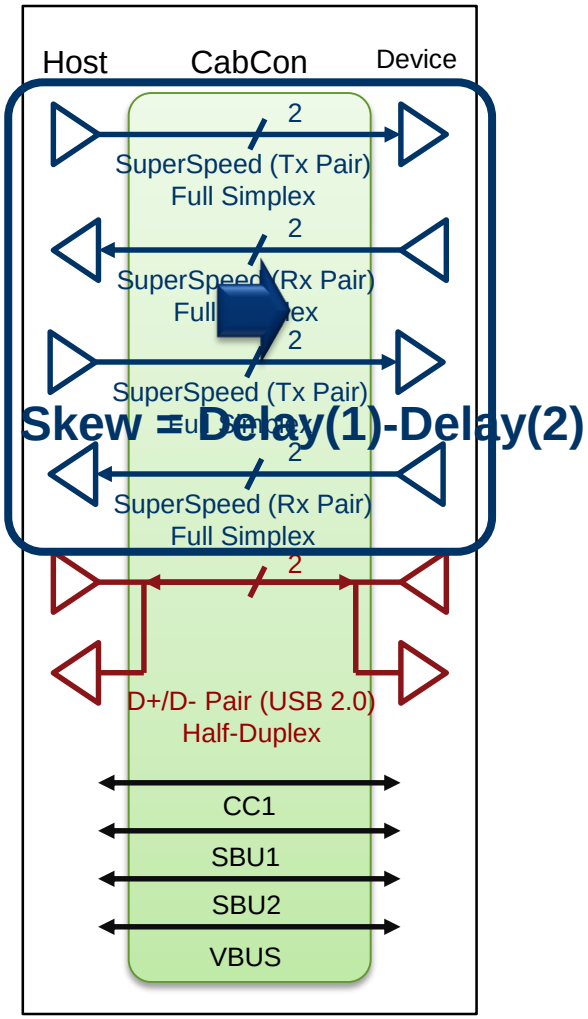
DUT Type	Limit
Shielded Differential Pair (SDP)	90 +- 5 ohm.
Single-ended coaxial SS+ signal wires	45 +- 3 ohm.

Note: Should be measured with a TDR in a differential mode using a 200 ps (10%-90%) rise time.

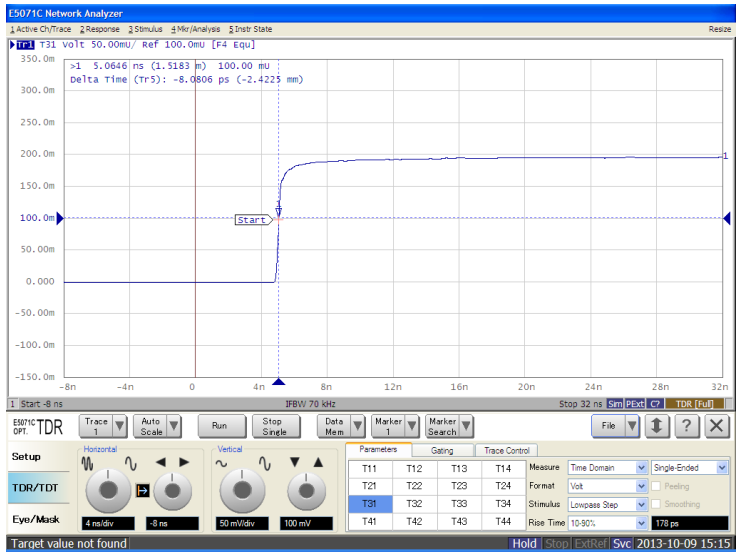
KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

[Raw Cable] Intra-Pair Skew (**Informative**)



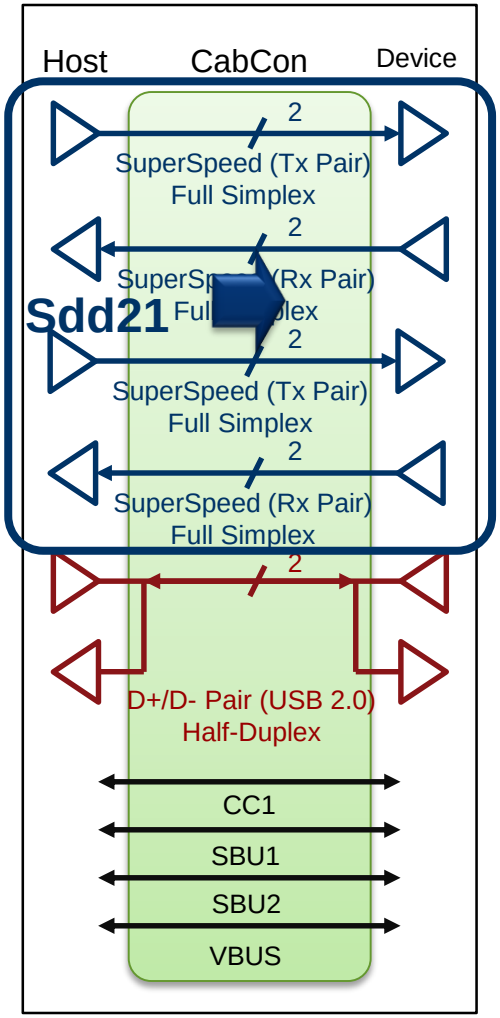
- Intra-pair skew measurement ensures the signal on both SS+ Tx+ and Tx- lines (or Rx+ and Rx- lines) of a cable assembly arrive at the receiver at the same time.
- If Delta Time < 10 ps/m: Pass, else: Fail



Note: Should be measured with a TDR in a differential mode using a 200 ps (10%-90%) rise time with a crossing at 50% of the input voltage.

USB Type-C Cable/Connector Compliance Test

[Raw Cable] Differential Insertion Loss (**Informative**)



- Measure of frequency response that the differential signal sees as it propagates through the interconnect.
- Cable loss depends on wire gauges, plating and dielectric materials.

[Raw Cable] Differential Insertion Loss - Design Target

Differential Insertion Loss Examples with Twisted Pair Construction

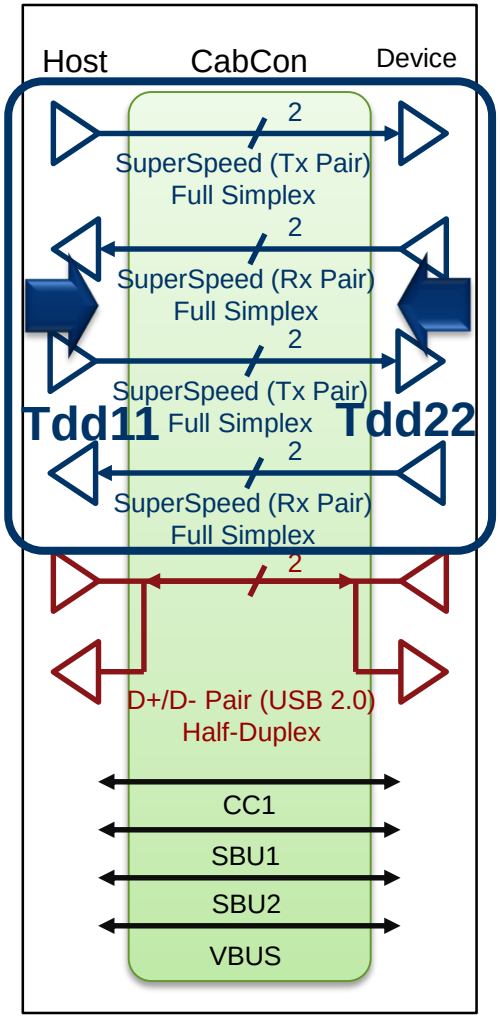
Frequency	34AWG	32AWG	30AWG	28AWG
0.625 GHz	−1.8 dB/m	−1.4 dB/m	−1.2 dB/m	−1.0 dB/m
1.25 GHz	−2.5 dB/m	−2.0 dB/m	−1.7 dB/m	−1.4 dB/m
2.50 GHz	−3.7 dB/m	−2.9 dB/m	−2.5 dB/m	−2.1 dB/m
5.00 GHz	−5.5 dB/m	−4.5 dB/m	−3.9 dB/m	−3.1 dB/m
7.50 GHz	−7.0 dB/m	−5.9 dB/m	−5.0 dB/m	−4.1 dB/m
10.00 GHz	−8.4 dB/m	−7.2 dB/m	−6.1 dB/m	−4.8 dB/m
12.50 GHz	−9.5 dB/m	−8.2 dB/m	−7.3 dB/m	−5.5 dB/m
15.00 GHz	−11.0 dB/m	−9.5 dB/m	−8.7 dB/m	−6.5 dB/m

Differential Insertion Loss Example with Coaxial Construction

Frequency	34AWG	32AWG	30AWG	28AWG
0.625 GHz	−1.8 dB/m	−1.5 dB/m	−1.2 dB/m	−1.0 dB/m
1.25 GHz	−2.8 dB/m	−2.2 dB/m	−1.8 dB/m	−1.3 dB/m
2.50 GHz	−4.2 dB/m	−3.4 dB/m	−2.7 dB/m	−1.9 dB/m
5.00 GHz	−6.1 dB/m	−4.9 dB/m	−4.0 dB/m	−3.1 dB/m
7.50 GHz	−7.6 dB/m	−6.5 dB/m	−5.2 dB/m	−4.2 dB/m
10.0 GHz	−8.8 dB/m	−7.6 dB/m	−6.1 dB/m	−4.9 dB/m
12.5 GHz	−9.9 dB/m	−8.6 dB/m	−7.1 dB/m	−5.7 dB/m
15.0 GHz	−12.1 dB/m	−10.9 dB/m	−9.0 dB/m	−6.5 dB/m

USB Type-C Cable/Connector Compliance Test

[Mated Connector] Differential Impedance (**Informative**)



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.

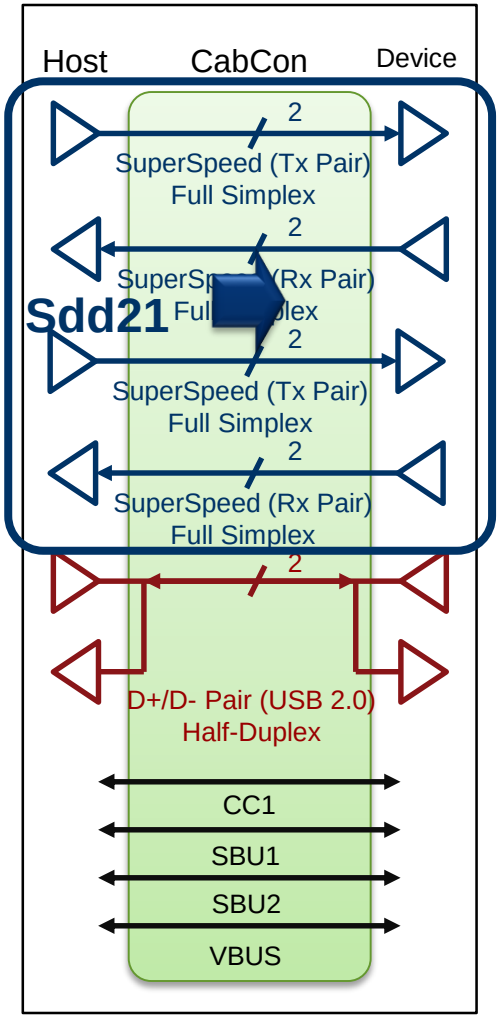
[Mated Connector] Differential Impedance - Design Target

DUT Type	Limit
Mated connector	85 +- 9 ohm.

Note: Should be measured with a TDR in a differential mode using a 40 ps (20%-80%) rise time.

USB Type-C Cable/Connector Compliance Test

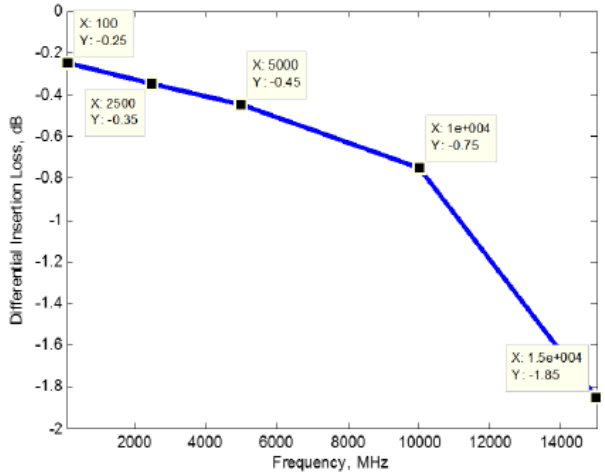
[Mated Connector] Differential Insertion Loss (**Informative**)



- Measure of frequency response that the differential signal sees as it propagates through the interconnect.

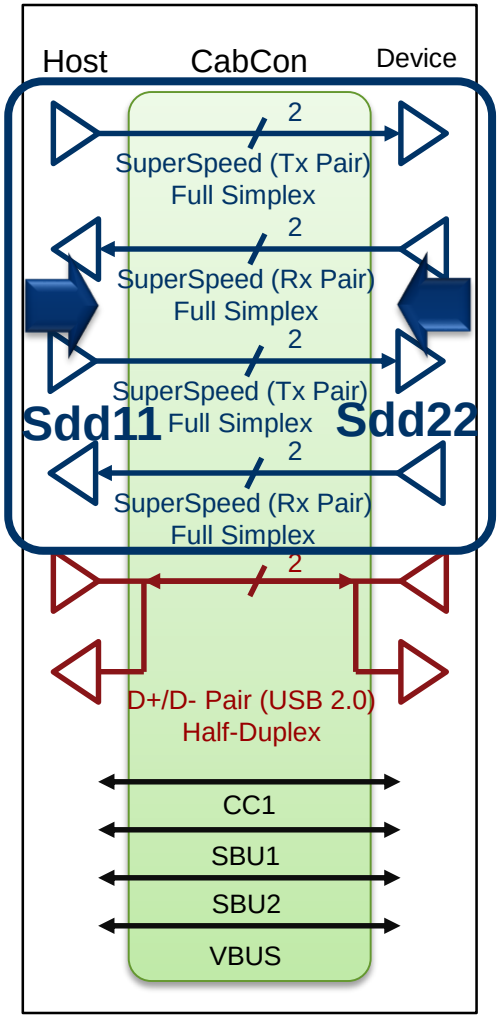
[Mated Connector] Differential Insertion Loss - Design Target

DUT Type	Limit
Mated connector	≥-0.25 dB @100 MHz ≥-0.35 dB @2.5 GHz ≥-0.45 dB @5 GHz ≥-0.75 dB @10 GHz ≥-1.85 dB @15 GHz



USB Type-C Cable/Connector Compliance Test

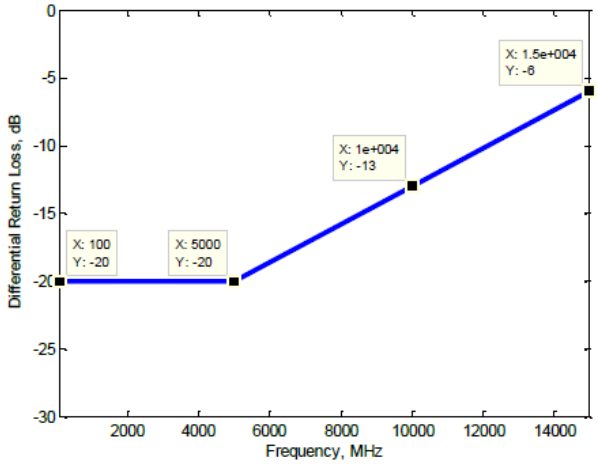
[Mated Connector] Differential Return Loss (**Informative**)



- Measure of frequency response that the differential signal sees as it is reflected through the interconnect.

[Mated Connector] Differential Return Loss - Design Target

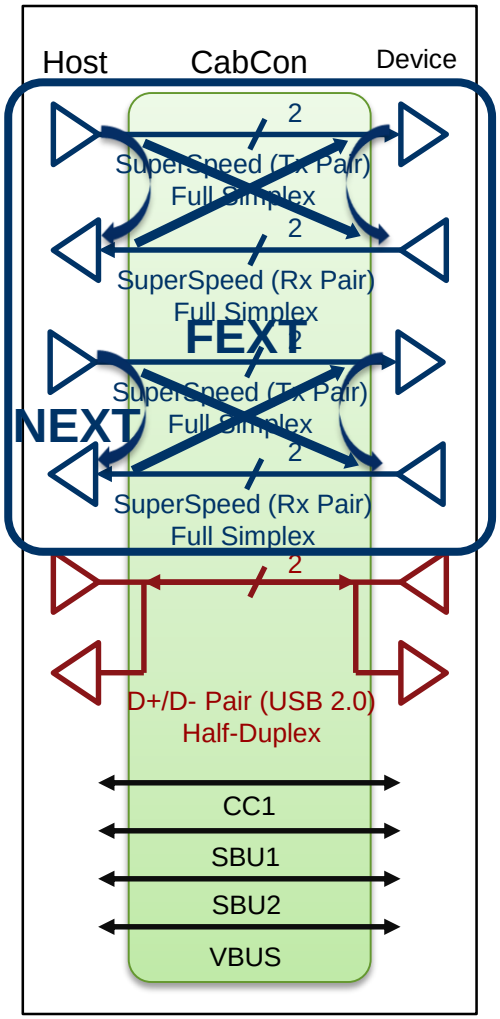
DUT Type	Limit
Mated connector	≤-20 dB @100 MHz ≤-20 dB @5 GHz ≤-13 dB @10 GHz ≤-6 dB @15 GHz



KEYSIGHT TECHNOLOGIES

USB Type-C Cable/Connector Compliance Test

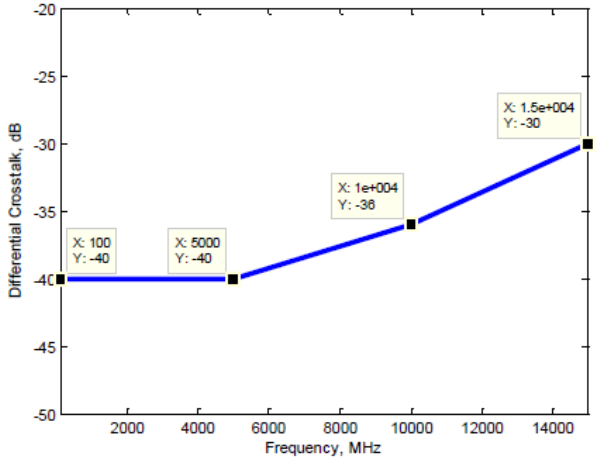
[Mated Connector] Differential NEXT & FEXT between SS Signal Pairs (**Informative**)



- Measure of coupling between the SS differential pairs (Tx/Rx pair).

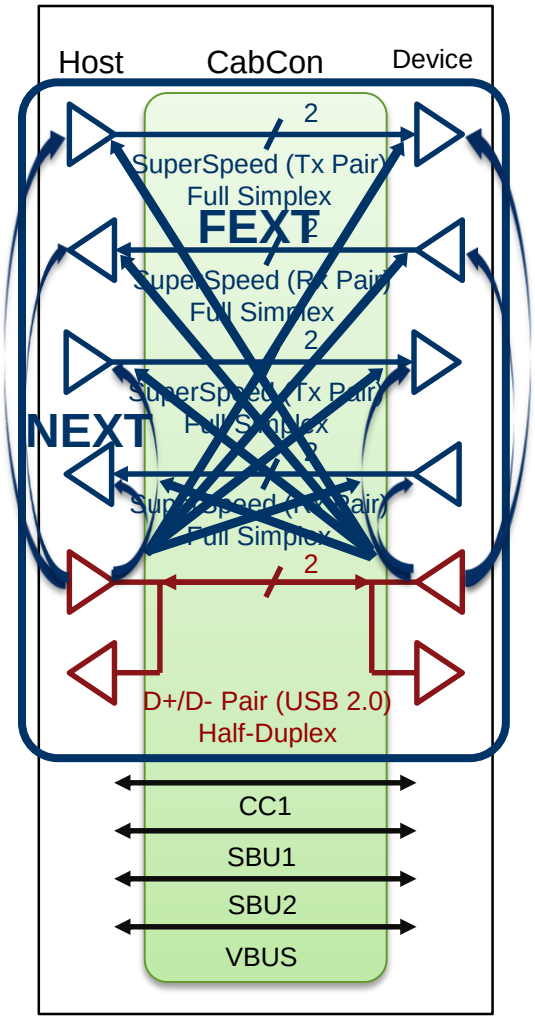
[Mated Connector] Differential Crosstalk - Design Target

DUT Type	Limit
Mated connector	≤-40 dB @100 MHz ≤-40 dB @5 GHz ≤-36 dB @10 GHz ≤-30 dB @15 GHz



USB Type-C Cable/Connector Compliance Test

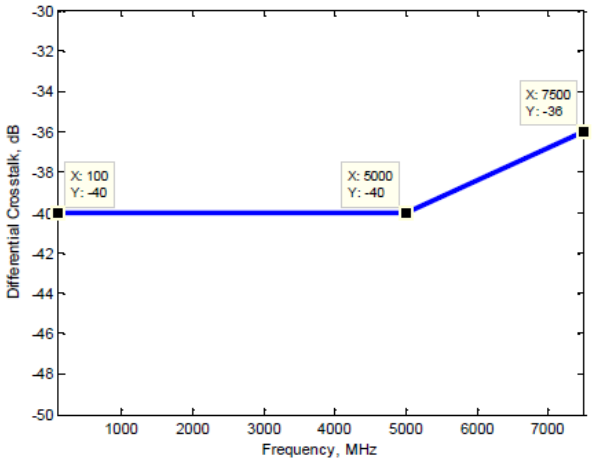
[Mated Connector] Differential NEXT & FEXT between D+/D- Pair and SS Signal Pairs (**Informative**)



- Measure of coupling between D+/D- pair and the SS differential pairs (Tx/Rx pair).

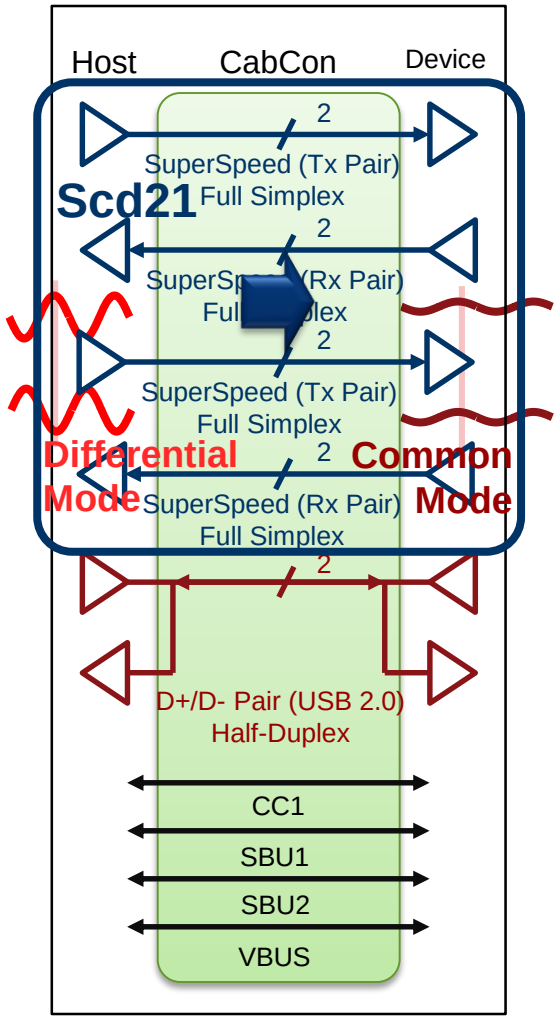
[Mated Connector] Differential Crosstalk - Design Target

DUT Type	Limit
Mated connector	≤-40 dB @100 MHz ≤-40 dB @5 GHz ≤-36 dB @7.5 GHz



USB Type-C Cable/Connector Compliance Test

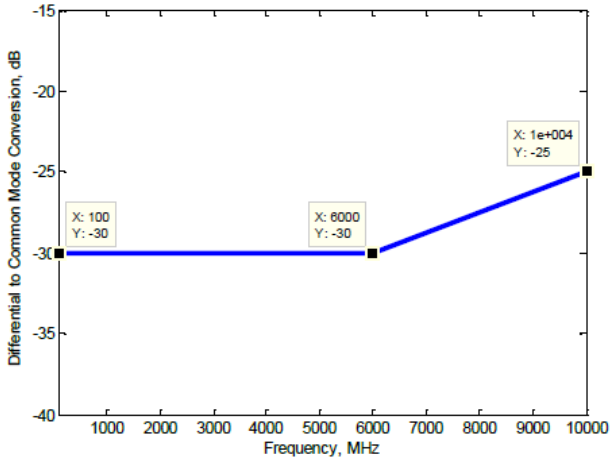
[Mated Connector] Differential to Common-Mode Conversion (**Informative**)



- Common-mode current is directly responsible for EMI and Scd21 is a measure of EMI generation.
- Main purpose of this requirement is to limit EMI emission.

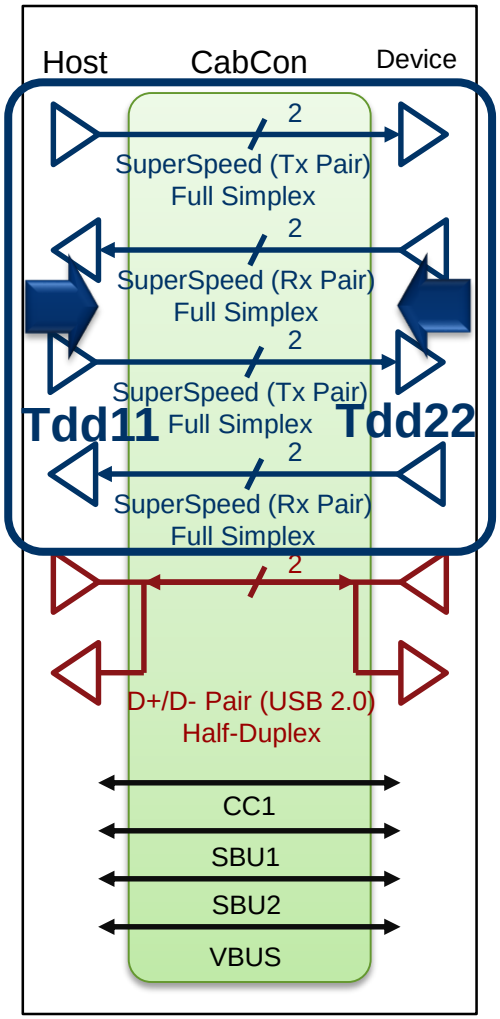
[Mated Connector] Mode Conversion - Design Target

DUT Type	Limit
Mated connector	≤-30 dB @100 MHz ≤-30 dB @6 GHz ≤-25 dB @10 GHz



USB Type-C Cable/Connector Compliance Test

Differential Impedance (**Informative**)



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.

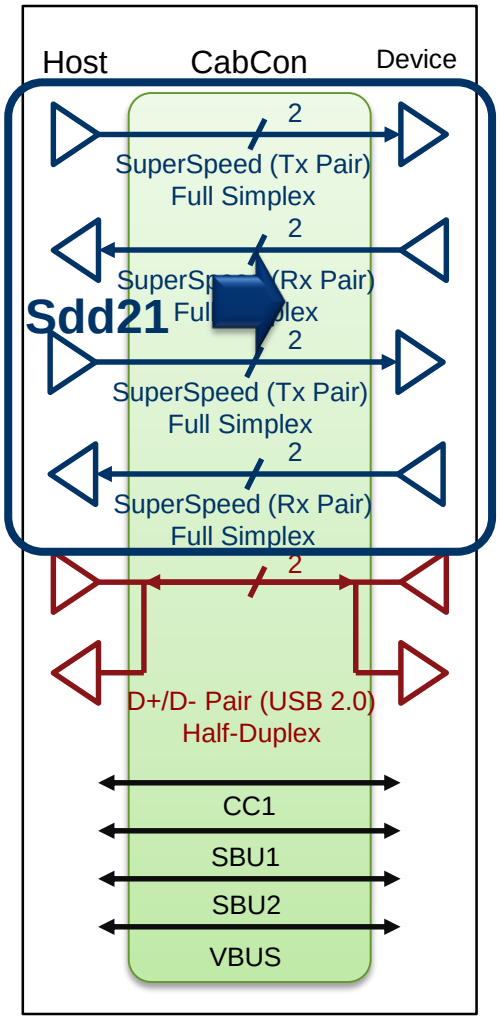
Differential Impedance - Specification

DUT Type	Limit
Type-C to legacy cable assembly	76 ohms min and 96 ohms max.

Note: Should be measured with a TDR in a differential mode using a 40 ps (20%-80%) rise time.

USB Type-C Cable/Connector Compliance Test

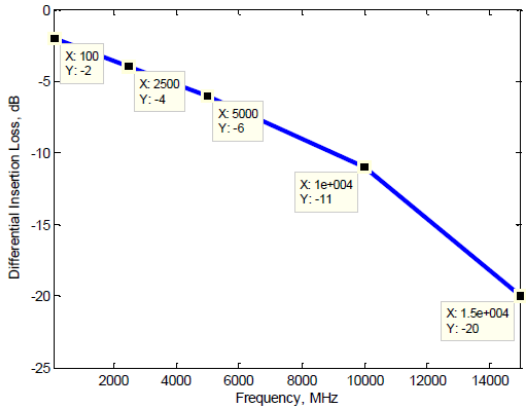
Differential Insertion Loss (**Informative**)



- Measure of frequency response that the differential signal sees as it propagates through the interconnect.

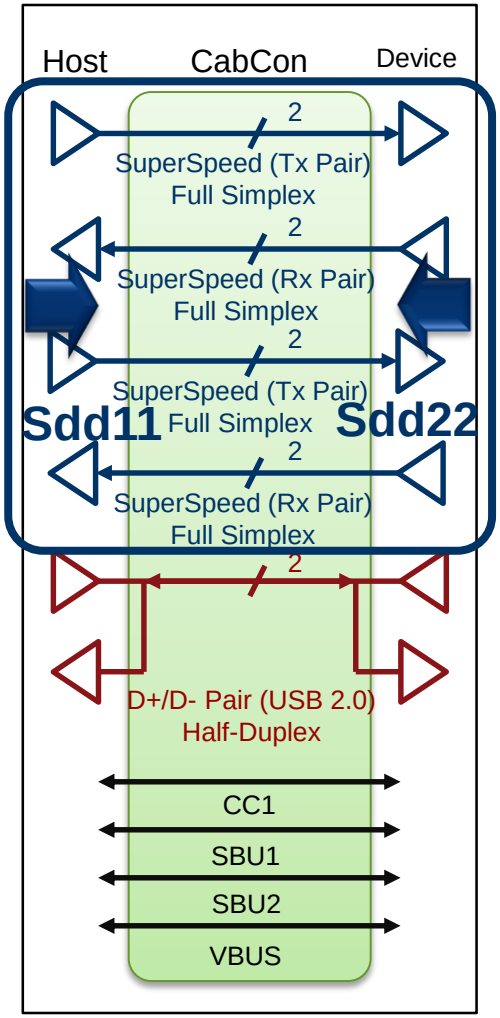
Differential Insertion Loss - Design Target

DUT Type	Limit
Type-C to Type-C passive cable assembly	≥-2 dB @100 MHz ≥-4 dB @2.5 GHz ≥-6 dB @5 GHz ≥-11 dB @10 GHz ≥-20 dB @15 GHz
Type-C to legacy cable assembly	≥-2 dB @100 MHz ≥-4 dB @2.5 GHz ≥-3.5 dB @2.5 GHz (USB Type-C to USB 3.1 Standard-A) ≥-6 dB @5 GHz
Type-C to legacy adapter assembly	≥-2.4 dB to 2.5 GHz ≥-3.5 dB to 5 GHz



USB Type-C Cable/Connector Compliance Test

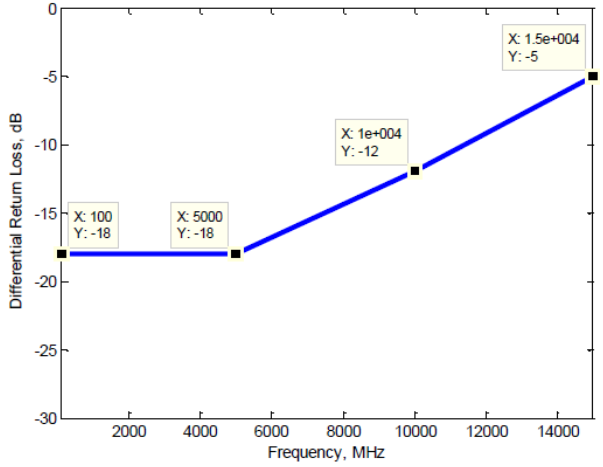
Differential Return Loss (**Informative**)



- Measure of frequency response that the differential signal sees as it is reflected through the interconnect.

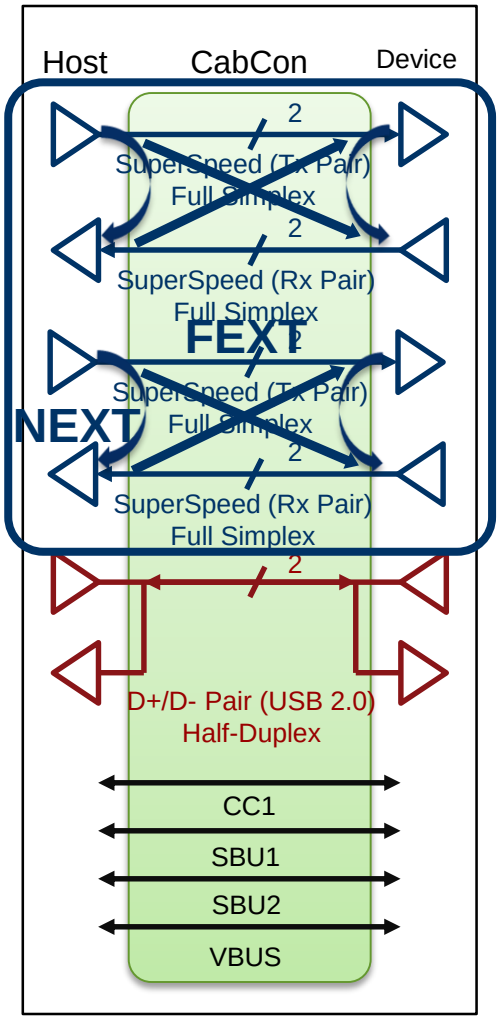
Differential Return Loss - Design Target

DUT Type	Limit
Type-C to Type-C passive cable assembly	≤-18 dB @100 MHz ≤-18 dB @5 GHz ≤-12 dB @10 GHz ≤-5 dB @15 GHz
Type-C to legacy adapter assembly	≤-15 dB to 5 GHz



USB Type-C Cable/Connector Compliance Test

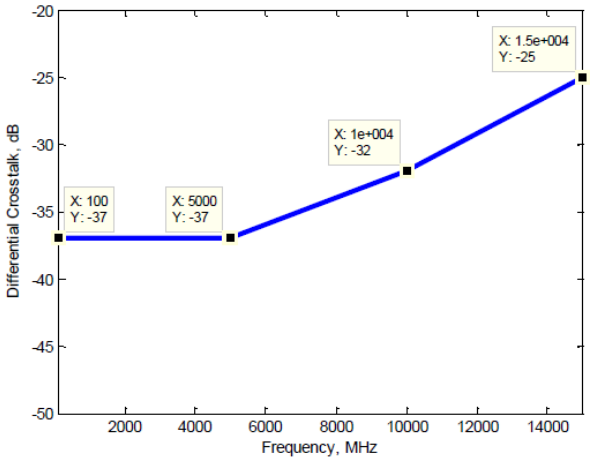
Differential NEXT & FEXT between SS Signal Pairs (**Informative**)



- Measure of coupling between the SS differential pairs (Tx/Rx pair).

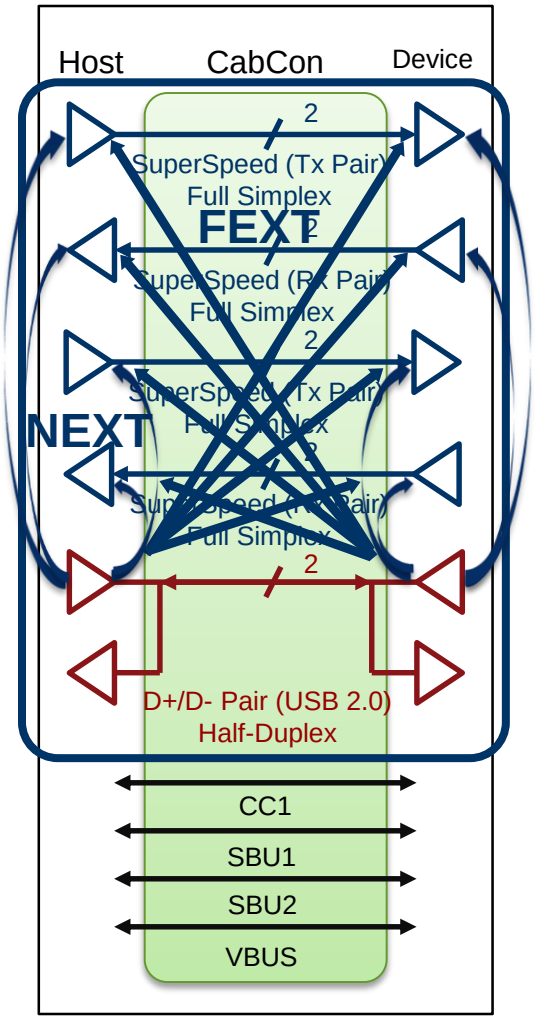
Differential Crosstalk - Design Target

DUT Type	Limit
Type-C to Type-C passive cable assembly	≤-37 dB @100 MHz ≤-37 dB @5 GHz ≤-32 dB @10 GHz ≤-25 dB @15 GHz
Type-C to legacy cable assembly (NEXT only)	≤-34 dB to 5 GHz
Type-C to legacy adapter assembly (NEXT only)	≤-40 dB to 2.5 GHz ≤-34 dB to 5 GHz



USB Type-C Cable/Connector Compliance Test

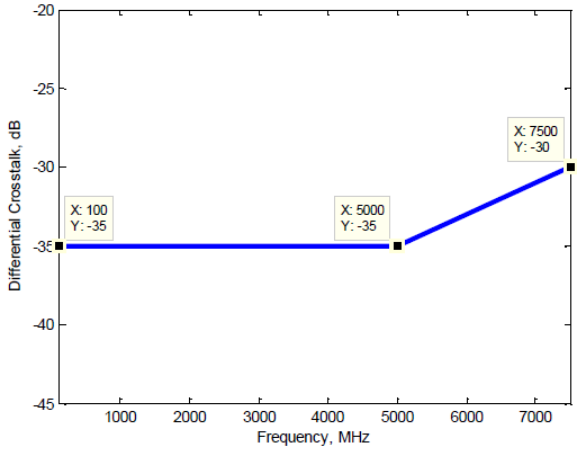
Differential NEXT & FEXT between D+/D- Pair and SS Signal Pairs (**Informative**)



- Measure of coupling between D+/D- pair and the SS differential pairs (Tx/Rx pair).

Differential Crosstalk - Design Target

DUT Type	Limit
Type-C to Type-C passive cable assembly	≤-35 dB @100 MHz ≤-35 dB @5 GHz ≤-30 dB @7.5 GHz
Type-C to legacy cable assembly	≤-30 dB to 5 GHz
Type-C to legacy adapter assembly	≤-30 dB to 2.5 GHz



ENA Option TDR Compliance Test Solution

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

Cable/Connector/Interconnect

- SuperSpeed USB: Time & Frequency
- HDMI: Frequency
- Serial ATA: Time & Frequency
- DisplayPort: Time & Frequency
- 100BASE-TX: Time & Frequency
- 10GBASE-T: Time & Frequency
- 10GBASE-KR/ 40GBASE-KR4: Time & Frequency
- MHL: Time & Frequency
- PCI Express: Time
- BroadR-Reach *: Time & Frequency

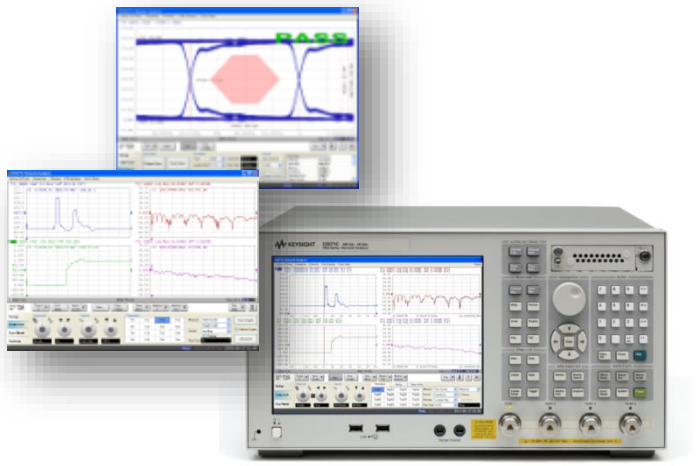
Transmitter/Receiver Impedance (Hot TDR/RL)

- HDMI: Time
- Serial ATA: Time & Frequency
- MIPI Alliance: Time & Frequency
- MHL: Time & Frequency
- 10GBASE-KR/ 40GBASE-KR4: Frequency
- PCI Express: Frequency
- Thunderbolt *: Time & Frequency
- SD *: Frequency
- CFA CompactFlash Association *: Time & Frequency

* For more detail about the compliance test solution with * mark , contact Keysight sales representative.

USB Type-C Cable/Connector Compliance Test Solution

Summary



ENA Option TDR Cable/Connector Compliance Testing Solution is ….

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

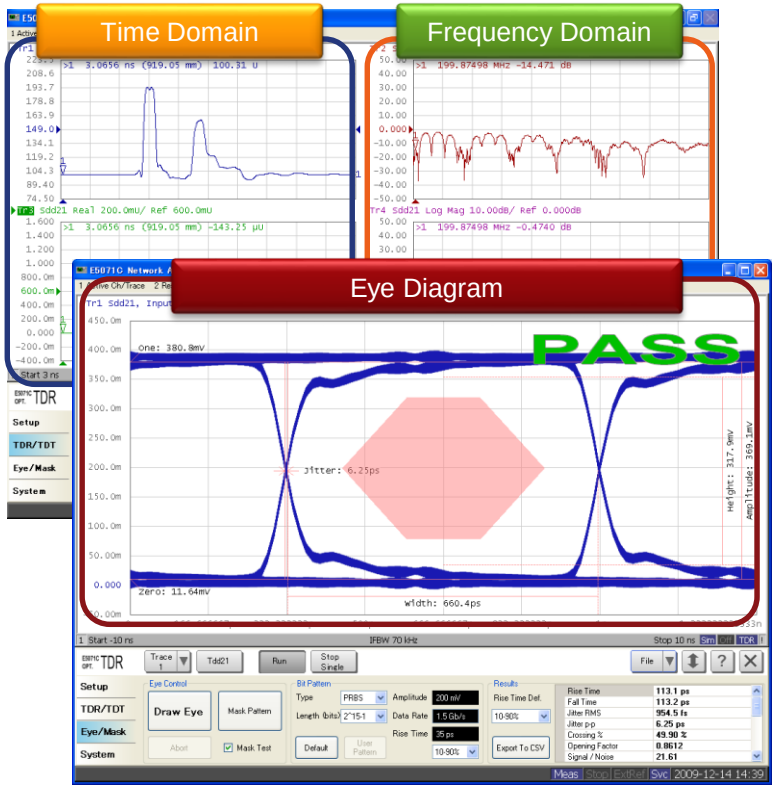
•Similar look-and-feel to traditional TDR scopes, providing ***simple and intuitive operation*** even for users unfamiliar to VNAs and S-parameters

•Adopted by test labs worldwide

Questions?

What is ENA Option TDR?

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



3 Breakthroughs

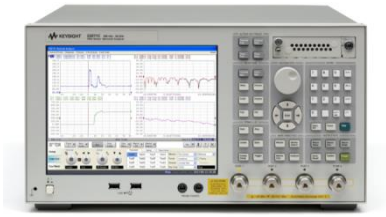
for Signal Integrity Design and Verification

Simple and Intuitive Operation

Fast and Accurate Measurements

ESD Robustness

What is ENA Option TDR?



[Video]

Keysight ENA Option TDR

Changing the world of Time Domain Reflectometry (TDR) Measurements

- https://www.youtube.com/watch?v=uBHXkzk4lzk
- www.keysight.com/find/ena-tdr

Additional Resources

•ENA Option TDR Reference Material

www.keysight.com/find/ena-tdr

•Technical Overview (5990-5237EN)

•Application Notes

- •Correlation between TDR oscilloscope and VNA generated time domain waveform (5990-5238EN)
- •Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope (5990-5446EN)
- •Effective Hot TDR Measurements of Active Devices Using ENA Option TDR (5990-9676EN)
- •Measurement Uncertainty of VNA Based TDR/TDT Measurement (5990-8406EN)
- •Accuracy Verification of Keysight's ENA Option TDR Time Domain Measurement using a NIST Traceable Standard (5990-5728EN)

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

www.keysight.com/find/ena-tdr_compliance