# USB Type-C Cable-Connector Assemblies Compliance Test Solutions

Keysight Technologies

2021.01.20

Test Solution Overview using Keysight's Network Analyzer with Enhanced TDR Application

### անուներներ



# **Revision History**

Revision	Date	Changes
Initial 1.0 30-Dec-2020		<ul> <li>Initial release</li> <li>Ref 1: Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document Revision 2.0 (Apr 29, 2020)</li> <li>Ref 2: Universal Serial Bus Type-C Cable and Connector Specification Release 2.0 (August 2019)</li> </ul>
		Compliance Document       Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document         Revision 2.0 April 29, 2020       Revision 2.0
		April 29, 2020 This is an unapproved USB-IF Newark Mechanical Group Draft, subject to change. Copyright © 2019 USB 3.0 Promoter Group. All rights reserved.

### Purpose

This slide shows how to conduct USB4.0/Type-C Cable & Connector Assemblies Compliance Test using Keysight S9x011A/B Enhanced TDR application on

- E5080B-4K0: 4-port test set, 9 kHz to 20 GHz or
- P5024A/25A-400 Keysight Streamline USB series VNA or
- M9804A-400 PXI Multiport VNA





# **Keysight Digital Standard Program**

KEYSIGHT TECHNOLOGIES Our solutions are driven and supported by Keysight experts who involved actively in international standards committees to deliver faster and highest quality compliance tests.





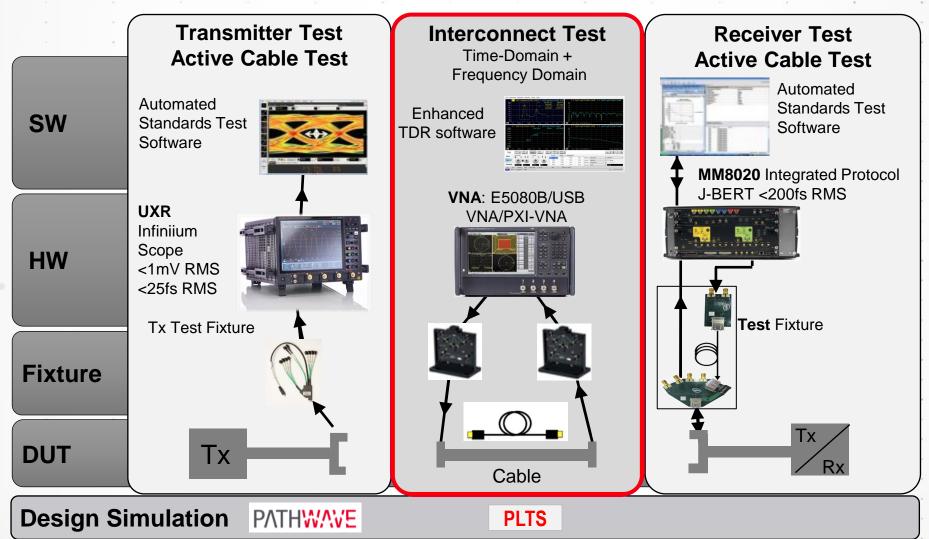


DEC



# **Keysight HSD Total Solutions**

Example: USB Type-C





# **Keysight Solutions to Enable the Type-C Revolution**

### GET THE RESOLUTION YOU NEED



### **Fast to Market**

MOIs and setup files are ready to enable a quick and easy test setup

### **Standard Compliance**

Complete solution to test the interoperability and compliance of standards requirements.

### **One Solution for All**

Accelerate your design, debug, characterization to compliance in one complete solution



### 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	T <b>X1+</b>	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	<b>A</b> 4	A3	A2	A1
GND	RX2+	RX2-	VBUS	SBU1	D-	D+	сс	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

Ref: USB Type-C Spec R2.0 - August 2019; Fig2.1 and Fig2.2



# **USB Type-C Cable/Connector Compliance Test Cable Assembly**

### **Type-C to Type-C Cable Assemblies**

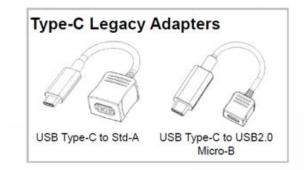
- USB2.0 Pairs
- USB3.2 Gen 1 and USB4 Gen2 Pairs
- USB3.2 Gen 2 and USB4 Gen 2 Pairs
- USB4 Gen3 Pairs

### **Type-C to Legacy USB Cable Assembles**

- USB2.0: Std-A to Type-C, Type-C to Std-B, Type-C to Mini-B, Type-C to Micro-B
- USB3.1 Gen 2: Std-A to FF Type-C, FF Type-C to Std-B, FF Type-C to Micro-B

### **Type-C to Legacy USB Adapters**

- USB2.0 Type-C to USB2.0 Micro-B
- USB FF Type-C to USB3.1 Std-A



Type-C to Type-C Cable Assemblies

CABLE

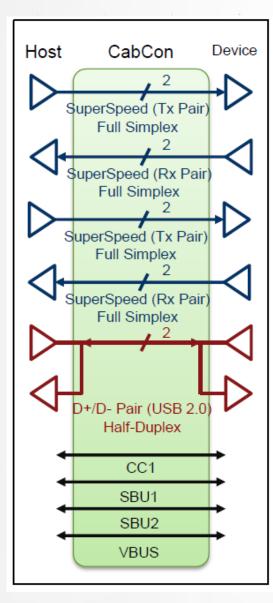
PLUG



P2



# **USB Type-C Cable/Connector Compliance Test Cable Assembly**

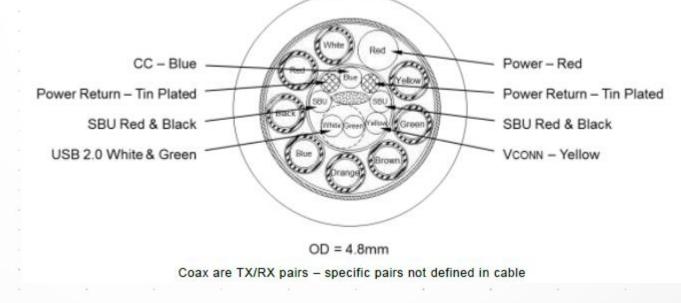


### SuperSpeed (TX/RX) Signals Pairs

- Coaxial wires, twin-axial or shielded twisted pairs.
- Used for either USB3.2 or USB4 signaling.
- Shielding is needed for signal integrity and EMC performance.

### **D+/D- Signal Pairs**

- Typical unshielded twisted pair (UTP).
- Intended to transmit the USB2.0 Low-Speed, Full-Speed and High-Speed signaling



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

#### **Time Domain Measurements Frequency Domain Measurements** D+/D- Impedance D+/D- Pair Attenuation D+/D- Propagation Delay Channel Metrics (ILfitatNq, IMR, IXT, IRL) D+/D- Intra-pair Skew Channel Operating Margin, COM (Normative – USB4 Gen3) **Differential to Common Mode Conversion** [Raw Cable] Characteristic Impedance [Raw Cable] Intra-Pair Skew Cable Shielding Effectiveness [Mated Connector] Differential Impedance • [Raw Cable] Differential Insertion Loss [Low Speed Signal] Characteristic Impedance [Mated Connector] Channel Metrics (ILfitatNq, IMR, IXT, IRL) [Mated Connector] Diff. Insertion Loss (ILfitatNq) [Mated Connector] Diff. Return Loss [Mated Connector] Diff. NEXT & FEXT between SS Signal Pairs • [Mated Connector] Diff. NEXT & FEXT between D+/D- Pair and SS Signal Pairs [Mated Connector] Differential to Common Mode Conversion Diff Insertion Loss Diff Return Loss Diff. NEXT & FEXT between SS Signal Pairs Diff. NEXT & FEXT between D+/D- Pair and SS Signal Pairs [Low Speed Signal] Crosstalk, VBUS Loop L/C, Coupling Factor • [Low Speed Signal] Coupling between CC and Differential D+/D-• [Low Speed Signal] Single-ended Coupling between CC and D+/D-• [Low Speed Signal] Coupling between VBUS and Differential D+/D-• [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-

Test Measurement Parameters (Type-C to Legacy USB Cable Assemblies)

Time	Domain	Measu	rements	S		Frequenc	y Domai	n Mea	sureme	nts					
<ul> <li>D+/I</li> <li>D+/I</li> <li>Diffe</li> <li>[Ray</li> <li>[Ray</li> </ul>	w Cable] ( w Cable] I	ation Del air Skew pedance Character ntra-Pair	of SS Pai istic Impe Skew			<ul> <li>D+/D- Pa</li> <li>Channel I</li> <li>Differentia</li> <li>Cable Sh</li> <li>[Raw Cable Sh</li> <li>[Mated Cable</li></ul>	Metrics (IL al to Commi ielding Effe onnector] I onnector] I onnector] I onnector] I onnector] I onnector] I onnector] I connector] I connector] I	fitatNq, non Mod ectivene ntial Ins Diff. Inse Diff. Ret Diff. NE Diff. NE Diff. NE Differen	de Conver ess ertion Los ertion Los urn Loss XT & FEX XT & FEX tial to Cor n SS Sign	rsion ss s (ILfitatN T betwee n betwee nmon Mo al Pairs	en SS Sig en D+/D- l de Conve	Pair and S ersion	S Signal	Pairs	
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Note: Normative parameters for the USB Type-C cable assembly are highlighted in blue

Test Measurement Parameters (Type-C to Legacy USB Adapter Assemblies)

<ul> <li>D+/D- Impedance (USB 2.0)</li> <li>D+/D- Intra-pair Skew (USB 2.0)</li> <li>[Raw Cable] Characteristic Impedance</li> <li>[Raw Cable] Intra-Pair Skew</li> <li>[Mated Connector] Differential Impedance</li> <li>[Mated Connector] Differential Impedance</li> <li>[Mated Connector] Diff. Insertion Loss ( [Mated Connector] Diff. NEXT &amp; FEXT I [Mated Connector] Diff. NEXT &amp; FEXT I Diff. Insertion Loss</li> <li>Diff. NEXT/FEXT between SS Signal Pa Diff. NEXT/FEXT between D+/D- and S</li> </ul>	Frequency Domain Measurements								
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Note: Normative parameters for the USB Type-C cable assembly are highlighted in blue

### Frequency Domain Measurements

- Channel Operating Margin (COM)
- D+/D- Pair Attenuation
- ILfitatNq, IMR, IXT, IRL, Differential to Common Mode Conversion
- Cable Shielding Effectiveness
- Insertion Loss (Informative)
- Return Loss (Informative)
- NEXT/FEXT between SS Signal Pairs (Informative)
- NEXT/FEXT between D+/D- and SS Signal Pairs (Informative)
- [Raw Cable] Insertion Loss (Informative)
- [Mated Connector] Channel Metrics (ILfitatNq, IMR, IXT, IRL)
- [Mated Connector] Insertion Loss (Informative)
- [Mated Connector] Return Loss (Informative)
- [Mated Connector] NEXT/FEXT between SS Signal Pairs (Informative)
- [Mated Connector] NEXT/FEXT between D+/D-and SS Signal Pairs (Informative)
- [Mated Connector] Differential to Common Mode Conversion
   (Informative)
- [Low Speed Signal] Crosstalk, VBUS Loop L/C, Coupling Factor

### **Time Domain Measurements**

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



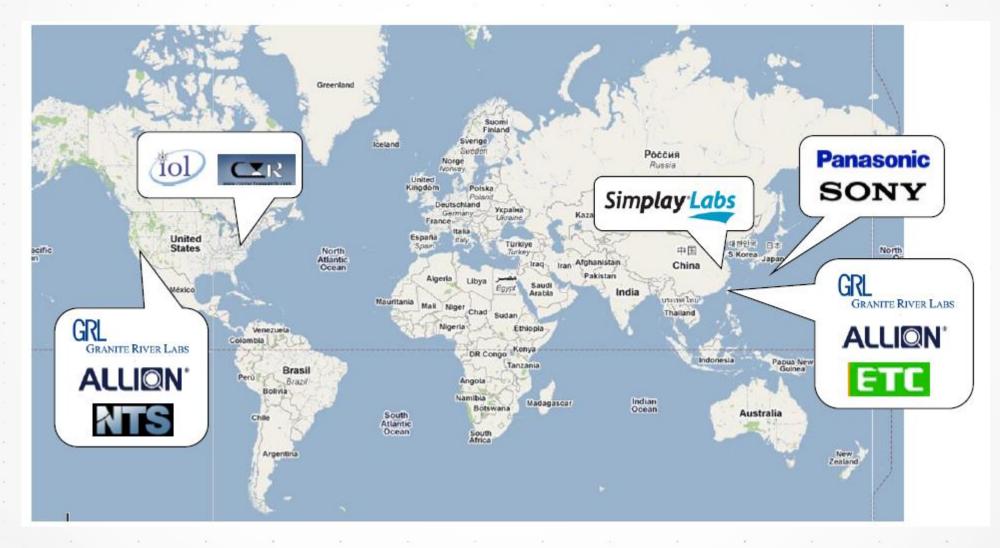
# **One-box Solution**





# **ENA Option TDR Compliance Test Solution**

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





# **USB Type-C Cable/Connector Compliance Test Configuration**

### 1. ENA Mainframe (\*1)

- E5080B-4K0: 4-port test set, 9 kHz to 20 GHz
- S96011B Enhanced Time Domain Analysis
- ECal Module (N4433A; 4-ports)



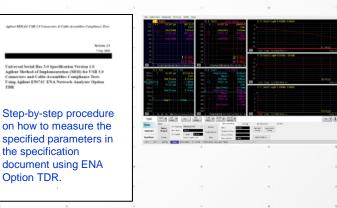
Other option: P5024A/P5025A USB VNA and M9804A/M9805A PXI Multiport VNA

### 2. USB Type-C Test Fixtures

Fixtures for testing USB4/Type-C connectors and cable assemblies are available for purchase through Luxshare-ICT. <u>http://en.luxshare-ict.com/product/index.html</u>

3. Keysight MOIs and State Files Configurations www.keysight.com/find/ena-tdr\_compliance www.keysight.com/find/ena-tdr\_usbtype-c-cabcon







### STATE FILE AVAILABLE FOR EASY SETUP

### 3 State files:

2

3

**KEYSIGH** 

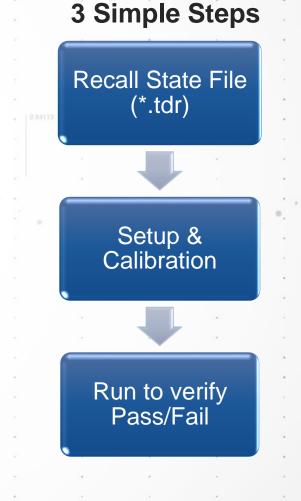


- [High Speed] Measurement Parameters
- [Low Speed Signal] Measurement Parameters

Type-C to Legacy USB Cable Assemblies

### **Type-C to Legacy USB Adapter Assemblies**

Note: State file includes both Normative and Informative measurements parameters



### STATE FILE AVAILABLE FOR EASY SETUP

### [Type-C to Type-C Passive Cable Assemblies, High-Speed]

Channel 1- Time Domain	Channel 2- Frequency Domain
5.1. D+/O- Diff. Impedance (Tr 1 & Tr 5) 5.2. D+/D- Intra-pair Skew (Tr 3) 5.3. D+/D Propagation Delay (Tr 4) 5.9.[Raw Cable] Impedance (Tr 2 & Tr 6) 5.10.[Raw Cable] Intra Pair Skew (Tr 3) 5.12.[Mated Connector] Diff. Impedance (Tr 15 & Tr 16)	<ul> <li>5.4. D+/D Pair Attenuation (Tr 11)</li> <li>5.5 Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)</li> <li>5.6 Channel Operating Margin, COM (Normative – USB4 Gen3)</li> <li>5.7. Differential to Common Mode Conversion (Tr 10)</li> <li>5.8. Cable Shielding Effectiveness (Tr 13 &amp; Tr 14)</li> <li>5.11. [Raw Cable] Differential to Sci (Tr 9)</li> <li>5.13. [Mated Connector] Diff. Insertion Loss (ILfitatNq) (Tr 12)</li> <li>5.14. [Mated Connector] Diff. Return Loss (ILfitatNq) (Tr 12)</li> <li>5.16. [Mated Connector] Diff. NEXT &amp; FEXT between SS Signal Pairs (Tr 18)</li> <li>5.16. [Mated Connector] Diff. NEXT &amp; FEXT between D+/D Pair and SS Signal Pairs (Tr 19)</li> <li>5.17. [Mated Connector] Differential to Common Mode Conversion (Tr 20)</li> <li>5.18. Diff Insertion Loss (Tr 21)</li> <li>5.20. Diff. NEXT &amp; FEXT between SS Signal Pairs (Tr 23)</li> <li>5.21. Diff. NEXT &amp; FEXT between D+/D Pair and SS Signal Pairs (Tr 24)</li> </ul>

#### File Instrument Response Stimulus Utility Help

115 11	10.357 pa	5 Too22 301.53 G	Tr.2 Tdd11	Tr15 Tdd11 Tr16 Tdd22		Tr 9 Sdd21 LogM 5000dB/ 0.00dB	Tr 10 Sed21 LogM 2.000dB/ -20.0dB
110		0.00	150		4		
105	Dist (Ref) 10.352 ps	1.55 mm	130		2		
100	Thursday.	100	120		0		
95			110		-2-		91 FAL
90			100		4	Canada Sanata Sanata Sanata Sanata	10 PASS
85			90		- 5		12 PASS
50			20	- 2: FAIL	5	>Ch2: Start 9.00000 kHt	Stop 20,0000 GHz
75			60 50	10 PASS		Tr 13 Sdd11 LogM 1.000dB/ -55.0dB Tr 17 5.dd11 LogM 5.000dB/ -15.0dB	Tr 14 Sdd11 LogM 1.000dB/ -40.0dB Tr 18 Sdd21 LogM 10.00dB/ -43.0dB
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Tr 7		3 131	Tr B Tod21	Tr 4 Teld21			13 PASS
300m	10.357 ps	2.47 µV		Peak 6.40 g Mean 4.99 g			14 PASS 17 PASS
25977 31	Dist(Trans)	3.11 mm		Dev: 1.46 µ	-63		IL PASS
200m t-	10.367 ps	(+1.45 m) 636.60 mV	4m 10.3	157 ps -4.63 p		Ch2: Start 9.00000 kHz	Step 20.0000 GHs
150m	Dist(Trans)	000		Trans) 3.11 m	1	Tr 23 Sdd21 LogM 2:000dB/ -40 0dB	
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-100m			30		-46		20 PASS
150m			-10m		-48		12 PASS
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		<b>DUT Length</b>	Auto 16 as		Velocity Facto	e 1	
ye/Mask	Preset		(Cable Length = Os)	ECal	Source Power	0.4Rm Basic Mod	ie >>

### [Type-C to Type-C Passive Cable Assemblies, Low-Speed]

**Channel 2- Frequency Domain** 

**Channel 1- Time Domain** 

5.22. [Low Speed Signal] Characteristic Impedance (Tr 25 & Tr 26 / Tr 27 & Tr 28) 5.23. [Low Speed Signal] Coupling between CC and Different Dr/D. (Tr 30) 5.26. [Low Speed Signal] Coupling between CC and Different Dr/D. (Tr 30) 5.26. [Low Speed Signal] Coupling between VBUS and Differential Dr/D. (Tr 31) 5.26. [Low Speed Signal] Single-ended Coupling between SUL A and SBU_B (Tr 34) 5.28. [Low Speed Signal] Single-ended Coupling between SBU_A and SBU_B and CC (Tr 35) 5.29. [Low Speed Signal] Single-ended Coupling between SBU_A and SBU_B and CC (Tr 35) 5.29. [Low Speed Signal] Coupling between SBU_A/SBU_B and Differential Dr/D. (Tr 36)		Stidiard I III	ne bernann			onia		qu			
Tr 27 T11 50000/ 20 00       Tr 28 T22 5 0000/ 20 00         Tr 33 Sdd11 5 000dB/ 47 0dB       Tr 34 S21 10 00dB/ 480 0dF         Tr 33 Sdd11 5 000dB/ 45 0dB       Tr 36 Sdd11 10 00dB/ 480 0dF         10       10         10       10         10       10         10       10         10       10         10       10         10       10         10       10         11       112         12       123         110       10         120       10         130       10         140       10         150       10         150       20         150       30         150       30         150       30         150       30         150       30         150       30         150       30         150       30         150       30         150       750       90         110       12       13         110       12       13         110       12       12         12       12					Factor (Tr 2 5.24. [Low 9 5.25. [Low 9 5.25. [Low 9 5.26. [Low 9 5.26. [Low 9 5.27. [Low 9 5.27. [Low 9 5.28. [Low 9 5.28. [Low 9 5.29. [Low 9	9) Speed 9 Speed 9 Tr 31 8 Speed 9 D+/D- ( Speed 9 I SBU_1 Speed 9 J_B an Speed 9	Signal] ( Signal] S a Tr 32) Signal] ( Tr 33) Signal] S B (Tr 34 Signal] S d CC (T Signal] (	Coupling Single-er Coupling Single-er Single-er r 35) Coupling	between ided Cou between ided Cou	CC and Different pling between VBUS and pling between pling between	ential CC
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etup Horizontal Verical Verical T11 T12 T13 T14 Messure Time Dorsen Single-Ended T21 T22 T23 T24 Pormat Ingedance Control Presing	70 65 60 55 45 40 35 30 25		Tr 28 T22 51	25:PASS 26:PASS 27:PASS 28:PASS	-20 -30 -50 -50 -70 -80 -90 -100	Tr 31 S2 Tr 33 Sd Tr 35 S2	1 10.00dB d11 5.000 1 10.00dB	/ -87.048 dsy -40.0d / -85.0d8	1732 S B 1734 S	30:PA\$S 31:FAL 32:FAL 33:PA\$S 34:FAL 33:PA\$S 34:FAL 33:PA\$S 34:FAL 33:PA\$S	
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### STATE FILE AVAILABLE FOR EASY SETUP

### [Type-C to Legacy USB Cable Assemblies]

Channel 1- Time Domain	Channel 2- Frequency Domain
5.1. D+/D- Diff. Impedance (Tr 1 & Tr 5) 5.2. D+/D-Intra-pair Skew (Tr 3) 5.3. D+/D Propagation Delay (Tr 4) 5.8 [Raw Cable] Diff. Impedance (Tr 2 & Tr 6) 5.9 [Raw Cable] Intra-Pair Skew (Tr 3) 5.11 [Mated Connector] Diff. Impedance (Tr 15 & Tr 16) 5.17. Diff. Impedance (Tr 25 & Tr 26)	<ul> <li>5.4. D+D Pair Attenuation (Tr 11)</li> <li>5.5 Channel Metrics (eH, eW, ILlitatNq, IMR and IXT)</li> <li>5.6 Differential to Common Mode Conversion (Tr 10)</li> <li>5.7 Cable Shiekling Effectiveness (Tr 13 &amp; Tr 14)</li> <li>5.10 [Raw Cable] Differential Insertion Loss (Tr 9)</li> <li>5.12 [Mated Connector] Diff. Insertion Loss (ILfitatNq) (Tr 12)</li> <li>5.13. [Mated Connector] Diff. NEXT &amp; FEXT between SS Signal Pairs (Tr 18)</li> <li>5.15. [Mated Connector] Diff. NEXT &amp; FEXT between D+/D-Pair and SS Signal Pairs (Tr 19)</li> <li>5.16. [Mated Connector] Differential to Common Mode Conversion (Tr 20)</li> <li>5.18. Diff Insertion Loss (Tr 21)</li> <li>5.20. Diff. NEXT &amp; FEXT between D+/D-Pair and SS Signal Pairs (Tr 24)</li> </ul>

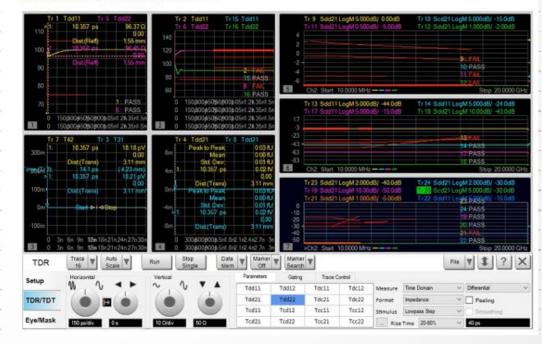
#### File Instrument Response Stimutus Utility Heli

115 1; 110	Tdd11 Ti 10.357 pe	5 Ted22 301.53 C	150	2 Tdd11 6 Tdd22	Tr 15 1 Tr 16			Tr 9 Sdd21LogM5 Tr 11 Sdd21LogM0	0004B/ 0.004B 5004B/ -5:004B		d21 LogM 2 000dB/ d21 LogM 1 000dB/	
105	Dist.(Ref) 10.367 pt	1.55 mm 301.28 0 400	140				2			_		
95 90	DetiRet	155 mm	120				-2				DT FAL	
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10 75 70 65 11 0 15	50;300;450;50;50;50;50;50;50;50;50;50;50;50;50;5	1 : FAIL 5 : FAIL 5 : FAIL	70 60 50	150,000,0500 nEn -6n -4n				>Ch2: Start 9.000001 Tr 13 Sdd11 LogM 1. Tr 17 Sdd11 LogM 5			Bitop Id11 LogM 1,000dB/ Id21 LogM 10.00dB/	
Tr 7 350m 1: 300m		3 T31 -2.47 µV 0.00	10m dm	B Told21 PéaktoP	Tr.4 eak: earl	6.40 gU 4.89 gU	-23 -43 -63				13 PASS 14 PASS 17 PASS	
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Orthop -		14Slart	-4m -6m	1036 Dist(Te	7 pe	4.65µV - 060 3.11 mm	23 23 35 49 49				23 PAL 24 PAS 20 PASS	
-100m	n 6n 5n 125n18	21-24-22-25	-10m	300600900	1 E-0 R-0 1	04.02 2	-44 -45	Ch2-Start 9.00000			21 PASS	20.0000 GH
TDR	Trace W	Auto V		Stop		Marker	Marker				File V 1	? X
etup	Basic	DUT Topology	Offerential 2-Po		1.02010		ore Functio		Adv Wave	larm	Hot TDR	
DR/TDT	Setup Wizard	Stim, Ampl.	200 mV	16 ns	Deskev&	Ref.	Z lectric Con	50 Ohm	Bal Port Config	Freq Limits Config		
			Julo .			Vela						

### [Type-C to Legacy USB Adapter Assemblies]

Channel 1- Time Domain	Channel 2- Frequency Domain
5.1. D+/D- Diff. Impedance (Tr 1 & Tr 5) 5.2. D+/D- Intra-pair Skew (Tr 3) 5.7 [Raw Cable] Diff. Impedance (Tr 2 & Tr 6) 5.8 [Raw Cable] Intra-Pair Skew (Tr 3) 5.10 [Mated Connector] Diff. Impedance (Tr 15 & Tr 16)	<ul> <li>5.3. D+/D Pair Attenuation/Diff. Insertion Loss (Tr 11)</li> <li>5.4 Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)</li> <li>5.5 Differential to Common Mode Conversion (Tr 10)</li> <li>5.6 Cable Shielding Effectiveness (Tr 13 &amp; Tr 14)</li> <li>5.9 [Raw Cable] Differential Insertion Loss (Tr 12)</li> <li>5.11 [Mated Connector] Diff. Insertion Loss (Tr 12)</li> <li>5.13 [Mated Connector] Diff. Return Loss. (Tr 17)</li> <li>5.13 [Mated Connector] Diff. NEXT &amp; FEXT between DS: Signal Pairs (Tr 18)</li> <li>5.14 [Mated Connector] Diff. NEXT &amp; FEXT between D+/D. Pair and SS Signal Pairs (Tr 19)</li> <li>5.15 [Mated Connector] Diff. NEXT &amp; FEXT between D+/D. Pair and SS Signal Pairs (Tr 19)</li> <li>5.16 [Diff. Insertion Loss (Tr 22)</li> <li>5.18 Diff. NEXT &amp; FEXT between D+/D. Pair and SS Signal Pairs (Tr 24)</li> </ul>

#### Normative and Informative Parameters



## USB Type-C Cable/Connector Compliance Test Setup & Calibration Procedure

Setup Calibration Measurement

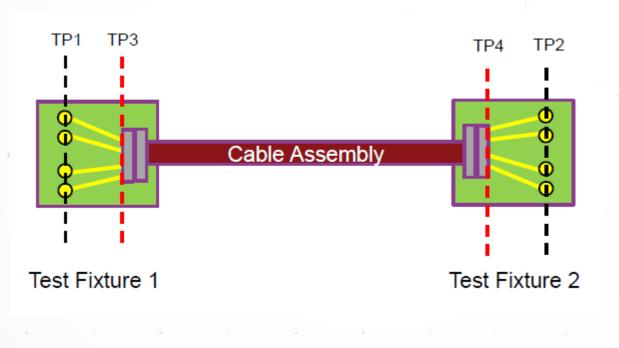
- Manual or automatic setup by recalling a state file.
- State files for Enhanced TDR will be provided for fast setup and minimized human error.

- Calibration for frequency-domain measurements shall be performed to remove the unwanted test fixture trace effect.
- ECal+ De-embedding are available with Enhanced TDR.
- The Enhanced TDR can be used to perform all measurements.
  Compliance standard tools by USB-IF are required for pass/fail judgment of Channel Operating Margin (COM), ILfitatNq, IMR, IXT, IRL, differential to common mode conversion.



# USB Type-C Cable/Connector Compliance Test Calibration

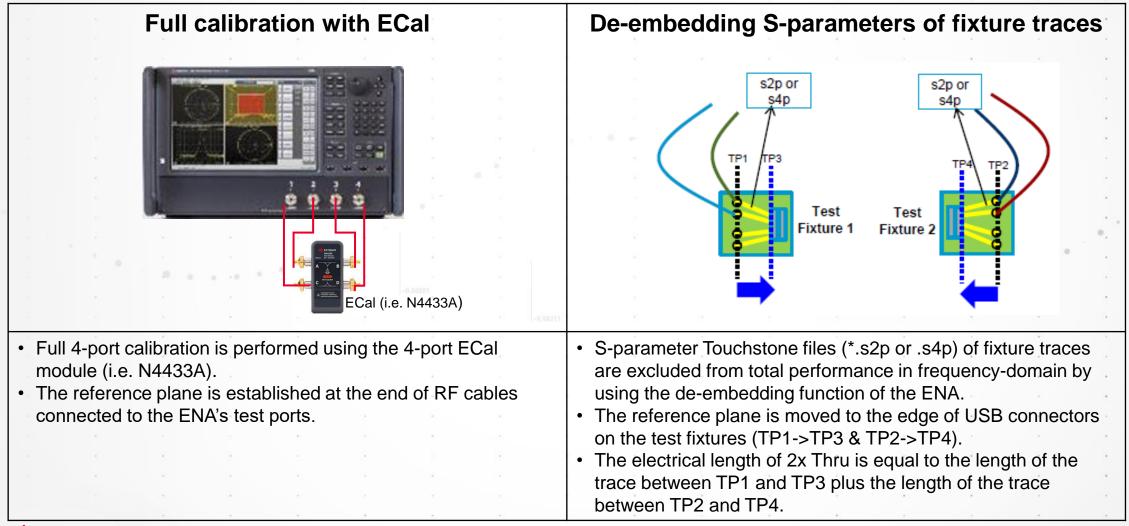
- Calibration shall be performed to remove the unwanted test fixture trace effect.
- The procedures of 2xThru de-embedding are the official procedure introduced in the USB Type-C Compliance Specification.





### Calibration

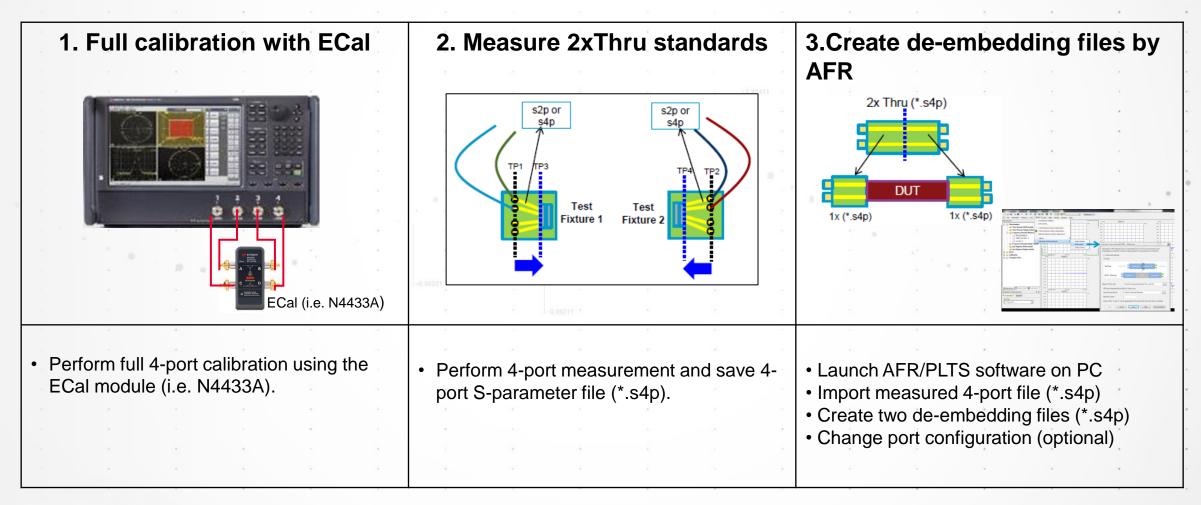
### Step 1: ECal+ De-embedding



Note from USB.org: Other calibration methods are allowed. For example, the automatic fixture removal or AFR; the 2X THRU structure may be used for AFR.

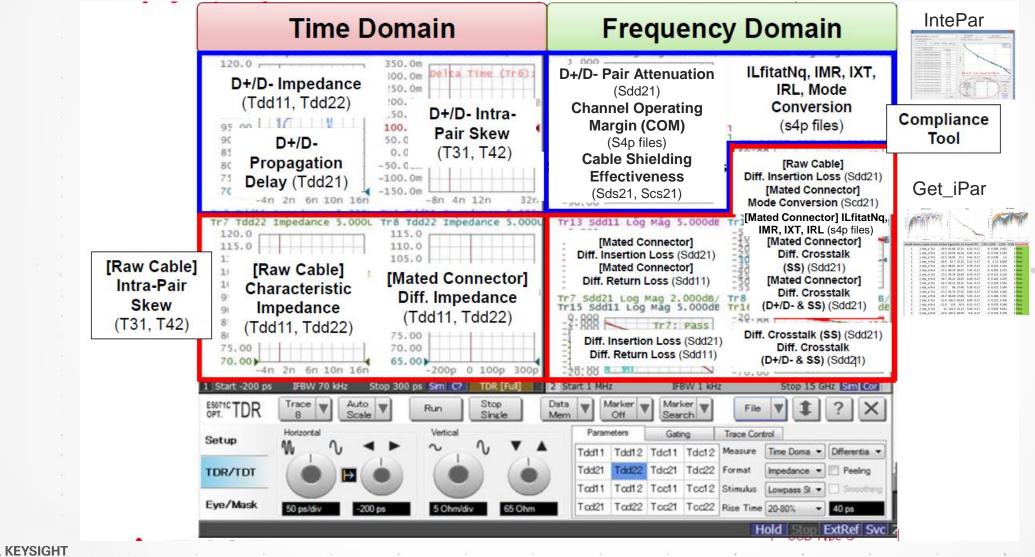
### USB Type-C Cable/Connector Compliance Test Calibration

Alternative: Creating De-embedding files using AFR (S96007) or PLTS software (N1930B)





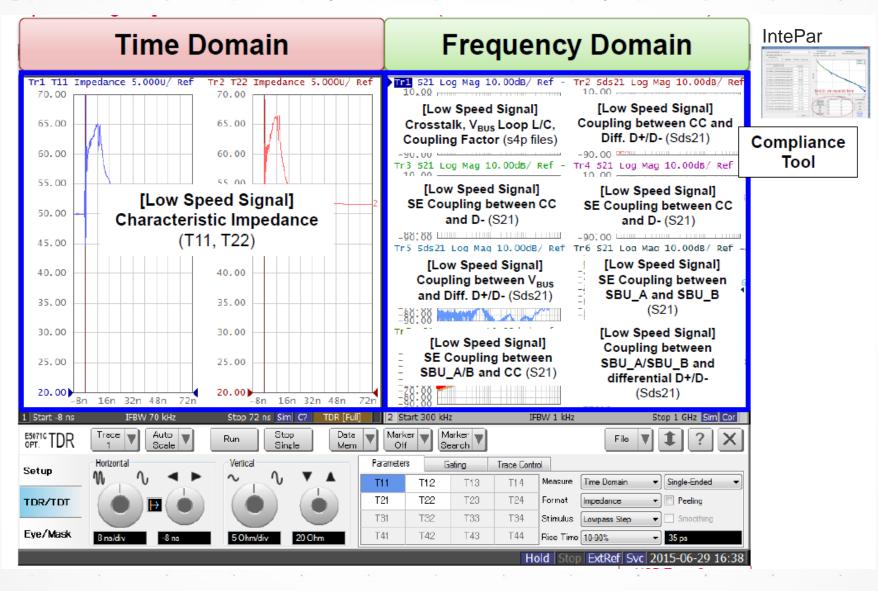
[High Speed] Measurement Parameters (Normative & Informative)



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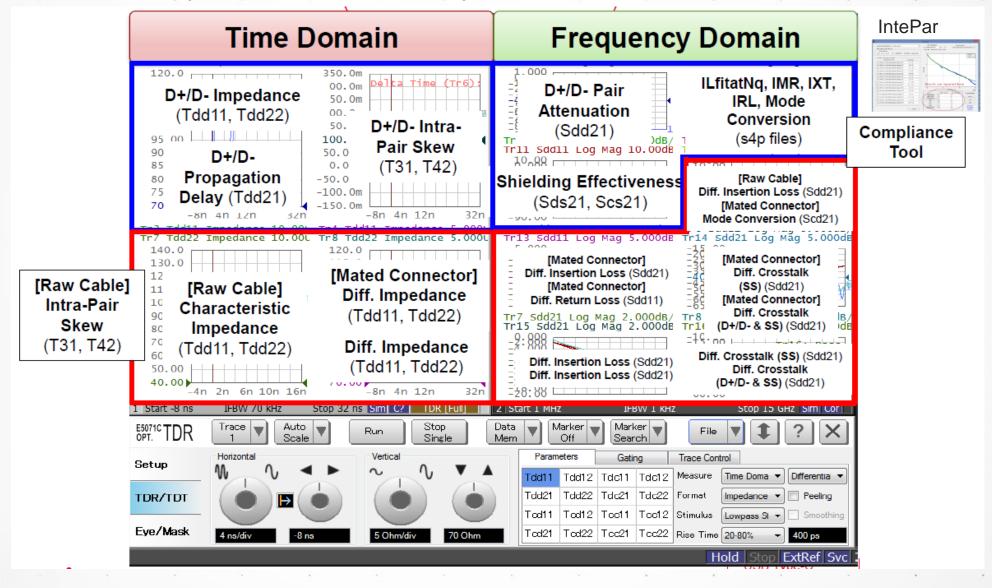
ECHNOLOGIES

[Low Speed] Measurement Parameters (Normative& Informative)



KEYSIGHT

**Measurement Parameters (Normative& Informative)** 





**Measurement Parameters (Normative& Informative)** 

	Time Dor	nain	Frequency	/ Domain	IntePar
	115.0 300	<ul> <li>D+/D- Intra-</li> <li>Pair Skew</li> <li>(T31, T42)</li> <li>.om</li> </ul>	D+/D- Pair Attenuation (Sdd21) Tr11 sdd11 Log Mag 10.00d8 Cable Shielding Effectiveness (Sds21, Scs21)	ILfitatNq, IMR, IXT, IRL, Mode Conversion (s4p files) [Raw Cable] Diff. Insertion Loss (Sdd21) [Mated Connector] Mode Conversion (Scd21)	Compliance Tool
[Raw Cable] Intra-Pair Skew (T31, T42)	140.0       12         130.0       11         12       11         11       [Raw Cable]         10       Characteristic         90       Impedance         70       (Tdd11, Tdd22)         50.00       75	Tdd22 Impedance 5.0000         0.0         5.0         0.0         Mated Connector]         Diff. Impedance         (Tdd11, Tdd22)         0.00         -8n 4n 12n       32n		Image Structure       Image Structure         Image Structure       Image Structure	
	1     Start -8 ns     I-BW /0 KHz     Stop 3       E5071C TDR     Trace I     Auto Scale       OPT.     Horizontal       Setup     Image: Comparison of the start of the st	Run Stop Single Vertical 5 Ohm/div 70 Ohm		timulus Lowpass SI - Smoothing	



# **Normative Vs Informative Measurement**



Normative

- Normative information is provided to allow interoperability of components designed to USB specification.
- Mandatory requirement to meet USB compliance specification.
- Pass/Failure criteria to meet compliance.



- Informative information, when provided, may illustrate possible design implementations or design targets.
- Aim to help cables/connectors manufacturers to manage the procurement.

27

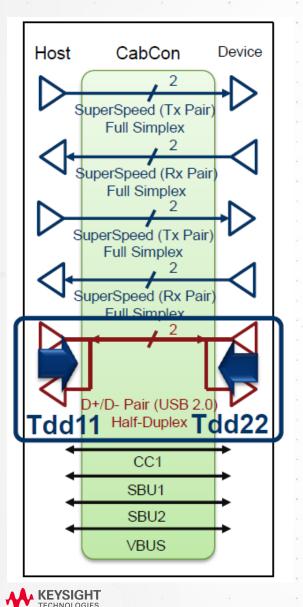
• Not part of the USB Type-C compliance requirements.

### Informative



### Normative

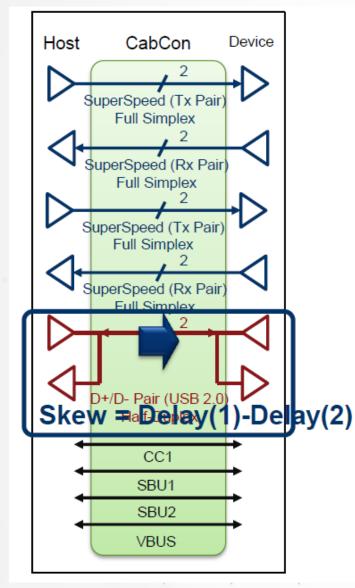
# **D+/D- Differential Impedance**



- EIA 364-108
- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an
- indication of multiple reflection induced noise.
- This test ensures that the D+/D- lines of the entire cable assembly have the proper impedance.

DUT Type	Limit					
Type-C to Type-C passive cable assembly	75 Ω Min 105 Ω Max					
Type-C to legacy cable assembly						
Type-C to legacy adapter assembly						
Note: The impedance should be evaluated using a 400ps (20%-80%) rise time						

### **D+/D- Intra-Pair Skew**

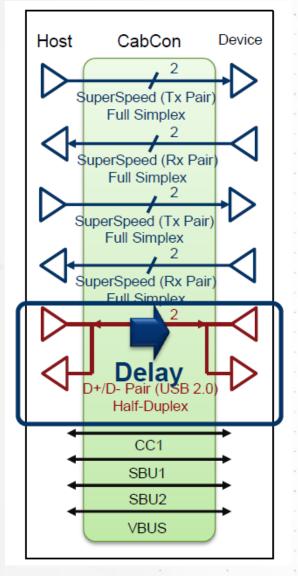


- EIA 364 103
- This test ensures that the signal on both the D+ and D- lines of cable assembly arrive at the receiver at the same time.

а С	DUT Typ	e				Lir	nit						
50 A A 10	Type-C to assembly	•••	-C pas	ssive c	able	10	100 ps max.						
-	Type-C to	o lega	cy cab	le asse	embly								
	Type-C to	20	ps ma	ax.									
а Э Э	Note: The rise time		surem	ent sho	ould be	evalu	lated	using	a 400p	os (20%	%-80%	5)	
3			+				1		*		•		
	in Tr	1.52		*									



# **D+/D- Propagation Delay**



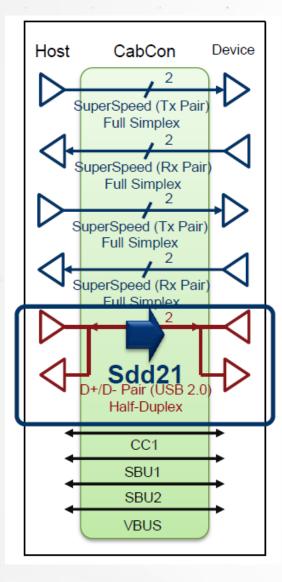
- EIA 364-103
- The purpose of the test is to verify the end-to-end propagation of the D+/D- lines of the cable assembly.

DUT Type	Limit
Type-C to Type-C passive cable assembly	26ns max.
Type-C to legacy cable assembly	10ns max for USB Type-C to Micro-B cable assembly;
	20ns max for all other USB Type-C to legacy USB cable assemblies.
Note: The impedance should be evitime	valuated using a 400ps (20%-80%) rise



31

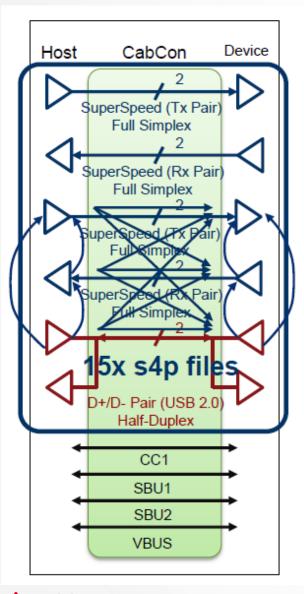
# **D+/D- Pair Attenuation**



- EIA 364 101
- This test ensures the D+/D- pair of a cable assembly are able to provide adequate signal strength to the receiver in order to maintain a low error rate.

* *	DUT Typ	е					Limit						
	Type-C to assembly	••	-C pa	issive	cable		≥ −1.02 dB @ 50 MHz ≥ −1.43 dB @ 100 MHz						
е - - 	Type-C to	o legad	cy cat	ole ass	sembly		≥ -2.40 dB @ 200 MHz ≥ -4.35 dB @ 400 MHz						
	Type-C to	o legad	cy ada	apter a	assembl	у-	-0.7 dB	max (	2 400	MHz			
	Note: The time	e impe	danc	e shou	ıld be ev	valu	ated us	ing a 4	00ps	(20%-8	80%) ri	ise	
3							÷.		•			•	
2							15	5					
	10 C						*		*	*-		*	

## **Channel Metrics**

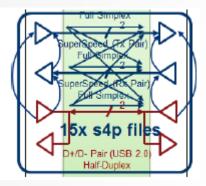


- Five parameters (ILfitatNq, IMR, IXT, IRL and Differential to Common-Mode Conversion) are calculated for SS+ pairs and D+/D- pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail
- judgment for five parameters based on measured Touchstone files.

DUT Type	Signal Integrity Compliance Requirements
Type-C to Type-C Cable Assembly (USB 3.2 Gen1/Gen2 and USB4 Gen2) Type-C to Legacy Cable Type-C to Legacy Adapter	ILfitatNq, IMR, IRL, INEXT and IFEXT, IDDXT_1NEXT+FEXT and, IDDXT_2NEXT, Differential-to -Common-Mode Conversion. (15x s4p or 3x s8p or 1x s12p file) USB-IF compliance tool: IntePar.exe https://compliance.usb.org/files/IntePar_1p6.zip
Type-C to Type-C Cable Assembly (USB4 Gen3 only)	COM + ILfitatNq, IMR, IRL, INEXT and IFEXT, IDDXT_1NEXT+FEXT and, IDDXT_2NEXT, Differential-to -Common-Mode Conversion. (44x s4p or 10x s8p or 5x s12p or 2x s20p) USB-IF compliance tool: Get_iPar.exe https://compliance.usb.org/files/Ger_iPar_v0p91a_release.zip

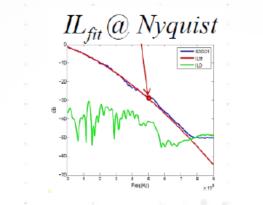
### Normative

# **Channel Metrics using Compliance Tool**

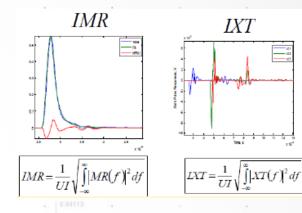


Touchstone S-parameter files (\*s4p) are saved and imported to the tool

KEYSIGH1



Differential insertion loss is fitted with a smooth function to obtain the insertion loss at Nyquist frequency of 2.5/5/10 GHz (ILfitatNq).



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

Lo	ad Config Spreadsheet C://www.config Spreadsheet	pment/US
Select Ca	ble Type and VNA Type	
Selec	t Cable Type	
1. Type	s-C to Type-C, Gen 2 (High Speed)	
Load/Sho	w S-Parameters File Names	
	S-Parameter File Name	
1>>	.\Example\C2C_HS\N1_Tx(L)_Tx(R).s4p	
2>>	.\Example\C2C_HS\N2_Rx(L)_Rx(R).s4p	
3>>	.\Example\C2C_HS\N3_DD(L)_DD(R).s4p	
4>>	.\Example\C2C_HS\N4_Tx(L)_Rx(L).s4p	
5>>	.VExampleIC2C_HSIN5_Tx(R)_Rx(R).s4p	
6>>	.\Example\C2C_HS\N6_Tx(L)_DD(L).s4p	
7>>	.\Example\C2C_HSW7_Rx(L)_DD(L).s4p	
8>>	.\Example\C2C_HS\N8_Tx(R)_DD(R).s4p	
9>>	.lExample1C2C_HSIN9_Rx(R)_DD(R).s4p	
10>>	.\Example\C2C_HS\N10_Tx(L)_Tx(R).s4p	
11>>	.VExampleIC2C_HSW11_Tx(R)_Tx(L).s4p	
12>>	.\Example\C2C_HS\N12_Tx(R)_DD(L).s4p	
13>>	.VExample1C2C_HSW13_Rx(R)_DD(L).s4p	
14>>	.\Example\C2C_HS\N14_Tx(L)_DD(R).s4p	
15>>	VExampleIC2C_HSIN15_Rx(L)_DD(R).s4p	

2 3 4]

234]

234] 234]

2 3 4]

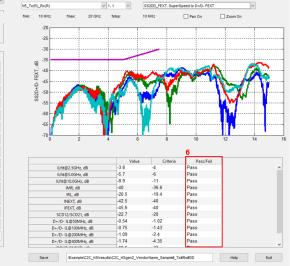
2 3 41

2 3 4]

2 3 41

2 3 4]

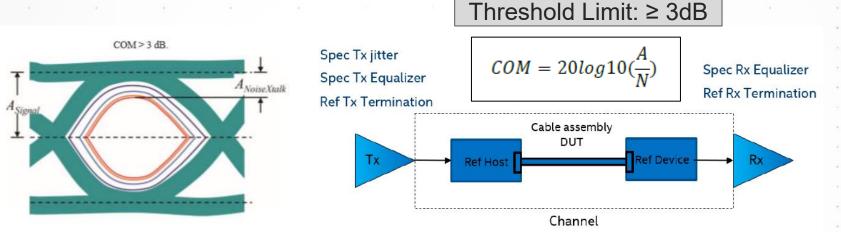
2 3 41



The USB-IF compliance tool performs pass/fail judgment based on the previous calculation.

# **Channel Operating Margin (COM) for USB4 Gen3 (New)**

- COM is the channel signal-to-noise ratio to measure the channel electrical quality.
- The technical detail of COM may be found in IEEE Std 802.3bj<sup>™</sup>-2014 Clause 93a.



where A is the signal amplitude and N is the combined noise at BER (bit -error-ratio), which includes the noise sources from ISI, crosstalk, transmitter jitter, etc.

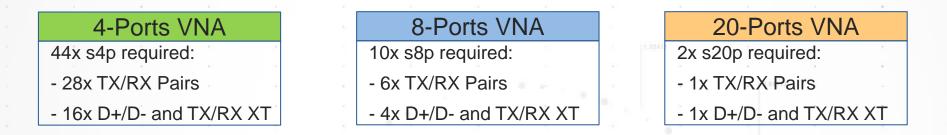
- Collaterals needed to calculate COM:
  - Measured cable S-parameters
  - Reference hosts/devices
  - Reference Tx/Rx termination
  - COM configuration file



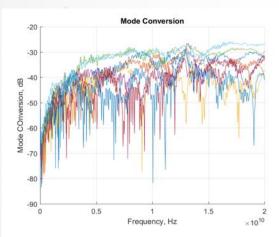
### Normative

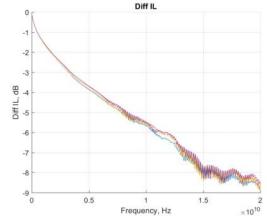
# **Channel Operating Margin (COM) for USB4 Gen3 (New)**

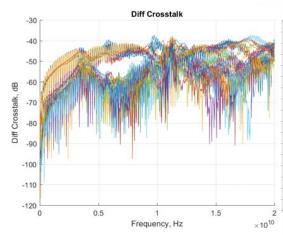
- Channel Operating Margin (COM) is verified using a standard compliance tool (Get\_iPar.exe) provided by USB IF after the measurements have made.
- Full S-parameters touchstone files for High-speed TX/RX pairs + D+/D- Pairs to run the COM tool.



Improve throughput of total measurement with M9804/05A PXIe VNA Multiport Configuration!





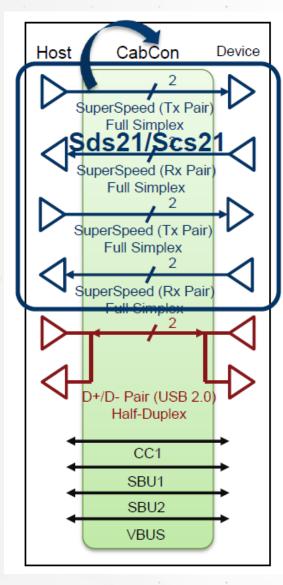


ost#	Device	Cable	Victim	ILfitat	Signal	ISI_m	Crosst	FFE	CTEL G	DFE	СОМ	COML	Pass/Fai
1	1	s4p_e	Tx1	-20.9	61.88	25.31	6.33	-0.17	-8	0.308	3.925	3	Pass
1	1	s4p_e	Rx1	-21.5	60.08	26.54	4.82	-0.17	-8	0.336	3.582	3	Pass
1	1	s4p_e	Tx2	-21.5	59.95	27.2	6.42	-0.17	-8	0.338	3.3	3	Pass
1	1	s4p_e	Rx2	-20.9	61.7	25.53	5.31	-0.17	-8	0.31	4.009	3	Pass
1	2	s4p_e	Tx1	-16.7	88.81	30.77	8.79	-0.17	-5	0.223	5.154	3	Pass
1	2	s4p_e	Rx1	-17.1	84.14	28.47	7.41	-0.17	-6	0.203	5.272	3	Pass
1	2	s4p_e	Tx2	-17.2	83.76	28.08	8.39	-0.17	-6	0.213	5.218	3	Pass
1	2	s4p_e	Rx2	-16.7	86.21	28.65	8.48	-0.17	-6	0.181	5.439	3	Pass
2	1	s4p_e	Tx1	-16.7	89.13	29.21	6.41	-0.17	-5	0.229	5.542	3	Pass
2	1	s4p_e	Rx1	-17.2	84	27.46	5.28	-0.17	-6	0.212	5.549	3	Pass
2	1	s4p_e	Tx2	-17.2	83.75	27.92	6.83	-0.17	-6	0.218	5.362	3	Pass
2	1	s4p_e	Rx2	-16.7	86.46	27.66	5.83	-0.17	-6	0.186	5.741	3	Pass
2	2	s4p_e	Tx1	-12.4	126.5	43.83	8.89	-0.17	-3	0.121	5.306	3	Pass
2	2	s4p_e	Rx1	-12.9	119	33.9	8.33	-0.17	-4	0.078	6.346	3	Pass
2	2	s4p_e	Tx2	-13	118.4	35.13	9.08	-0.17	-4	0.092	6.041	3	Pass
2	2	s4p_e	Rx2	-12.4	126.3	40.69	9.8	-0.17	-3	0.119	5.738	3	Pass



### Normative

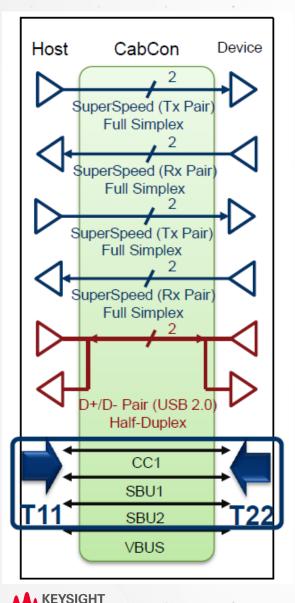
# **Cable Shielding Effectiveness**



- 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.

DUT Type	Limit
Type-C to Type-C (USB 3.2) Cable Assembly	Differential model: $\leq$ -55 dB for f $\leq$ 1.6 GHz, $\leq$ -50 dB for 1.6 GHz $\leq$ f $\leq$ 4.0 GHz and 5 GHz $\leq$ f $\leq$ 6 GHz Common model: $\leq$ -40 dB for f $\leq$ 1.6 GHz, $\leq$ -35 dB for 1.6 GHz $\leq$ f $\leq$ 4 GHz and 5 GHz $\leq$ f $\leq$ 6 GHz
Type-C to USB Legacy (USB 3.2) Cable Assembly	Differential model: $\leq$ -49 dB for f $\leq$ 1.6 GHz, $\leq$ -44 dB for 1.6 GHz $\leq$ f $\leq$ 4GHz and 5 GHz $\leq$ f $\leq$ 6 GHz Common model: $\leq$ -34 dB for f $\leq$ 1.6 GHz, $\leq$ -29 dB for 1.6 GHz $\leq$ f $\leq$ 4 GHz and 5 GHz $\leq$ f $\leq$ 6 GHz
Type-C to Standard-A Receptacle Adapter	Differential model: $\leq$ -44 dB for f $\leq$ 1.6 GHz, $\leq$ -39 dB for 1.6 GHz $\leq$ f $\leq$ 4 GHz and for 5 GHz $\leq$ f $\leq$ 6 GHz Common model: $\leq$ -24dB for f $\leq$ 1.6 GHz, $\leq$ -24 dB for 1.6 GHz $\leq$ f $\leq$ 4 GHz and for 5 GHz $\leq$ f $\leq$ 6 GHz

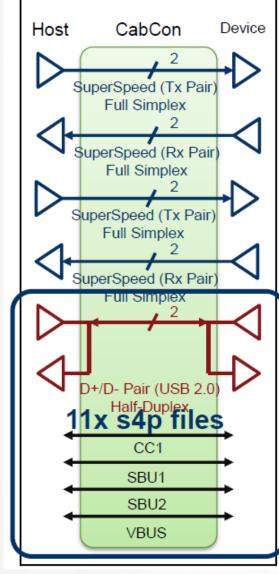
## [Low Speed Signal] Characteristic Impedance



- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- This test ensures that the CC and SBU\_A & SBU\_B wires lines have the proper impedance.

а С	DUT Ty	ре				Li	mit				÷
2 1 2	CC unsl zCable_		l or shi	elded	wires	_	2 Ω Mir 3 Ω Ma				2 • •
	SBU un zCable_		ed or s	hieldeo	d wires	-	2 Ω Mir 3 Ω Ma				•
									с. С		<b>*</b> .
											•
1.4	*			¥.			*				
	5										
3							÷.				•
22	*						10	5			2
	*						*				
	₫r.	0.50		2		.t.		10		0	 
14	-			6				4			. 3

## [Low Speed Signal] Crosstalk, VBUS Loop L/C, Coupling Factor

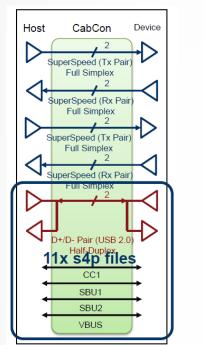


- Crosstalk, VBUS loop inductance, VBUS capacitance and coupling factor are calculated for low-speed signal and D+/D-pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment based on measured Touchstone files. (11x s4p or 3x s8p or 1x s12p file)

Test Parameters	Limit
Coupling between CC and Differential D+/D-	Refer to next slide for
Single-ended Coupling between CC and D+/D-	each test parameters
Coupling between VBUS and Differential D+/D-	
VBUS Loop Inductance, Coupling Factor, VBUS 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-	



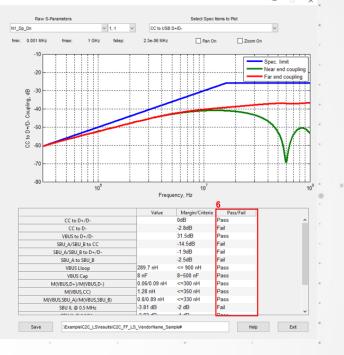
## [Low Speed Signal] Crosstalk, VBUS Loop L/C, Coupling Factor





- 11x (\*s4p) for low-speed full-feature
- 6x (\*s4p) for low-speed charged-through

lect Cal	ble Type and VNA Type	
Select	Cable Type	12-Port VNA
	-C to Type-C (Low Speed, Full-Featured)	8-Port VNA
e. rype	-c to type-c (cow open), ruinreatured)	3 4-Port VNA
ad/Sho	w S-Parameters File Names	
	S-Parameter File Name	Port Definition
1>>	.\Example\C2C_LS\N1_Dp_Dn.S4P	[1 2 3 4]
2>>	.\Example\C2C_LS\N2_Dp_Vbus.S4P	[1 2 3 4]
3>>	\Example\C2C_LS\W3_Dp_CC.S4P	[1 2 3 4]
4>>	\Example\C2C_LS\N4_Dp_SBUA.S4P	[1 2 3 4]
5>>	1Example1C2C_LSW5_Dp_SBUB.S4P	[1 2 3 4]
6>>	\Example\C2C_LS\N6_Dn_Vbus.S4P	[1 2 3 4]
7>>	\Example\C2C_LS\N7_Dn_CC.S4P	[1 2 3 4]
8>>	\Example\C2C_LS\N8_Dn_SBUA.S4P	[1 2 3 4]
9>>	\Example\C2C_LSW9_Dn_SBUB.S4P	[1 2 3 4]
10>>	\Example\C2C_LSW10_Vbus_CC.S4P	[1 2 3 4]
11>>	\Example\C2C_LSW11_Vbus_SBUA.S4P	[1 2 3 4]
12>>	VExampleIC2C_LSW12_Vbus_SBUB.S4P	[1 2 3 4]
13>>	\Example\C2C_LSW13_CC_SBUA.S4P	[1 2 3 4]
14>>	VExample\C2C_LSW14_CC_SBUB.S4P	[1 2 3 4]
15>>	JExample\C2C_LS\N15_SBUA_SBUB.S4P	[1 2 3 4]

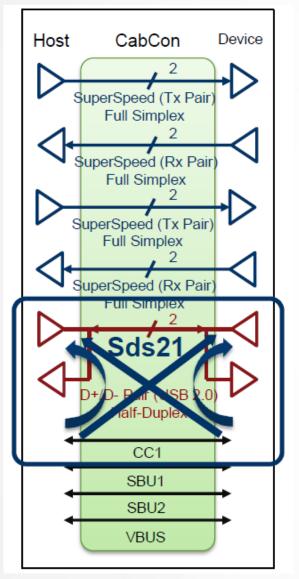


Touchstone S-parameter files (\*s4p) for low-speed signal and D+/D- signal pair are saved and imported to the tool

IntePar tool: Import touchstone files to do the pass/fail judgement

**KEYSIGH1** ECHNOLOGIES

## [Low Speed Signal] Coupling between CC and D+/D-

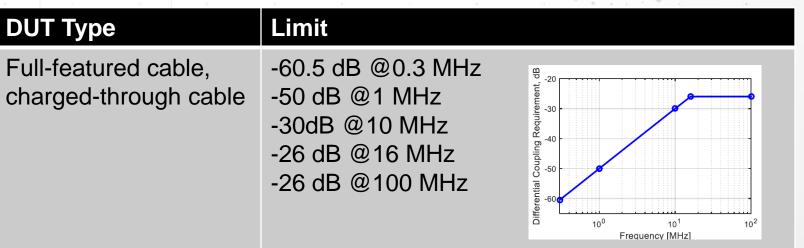


- Measure of coupling between CC and differential D+/D-.
- Coupling or crosstalk, both near-end and far-end, among the lowspeed signals shall be controlled.

 Table 3-25 Coupling Matrix for Low Speed Signals

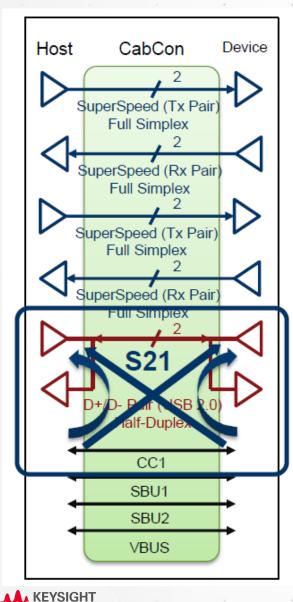
Coupling Matrix	D- (SE)	D+/D- (DF)	VBUS	SBU_B/SBU_A (SE)
CC	FF, CT	FF, CT	FF, CT, CTVPD	FF
D+/D- (DF)	N/A	N/A	FF, CT	FF
SBU_A/SBU_B	N/A	FF	FF	FF

DF: Differential; FF: Full-featured cable; CT: Charge-through cable (including USB 2.0 function); CTVPD: Charge-Through VCONN-Powered USB Device.

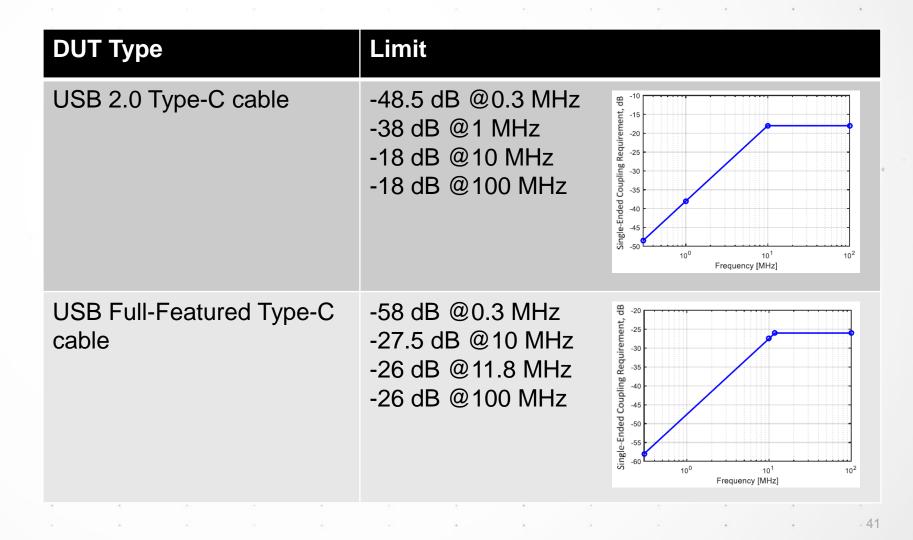


KEYSIGHT TECHNOLOGIES

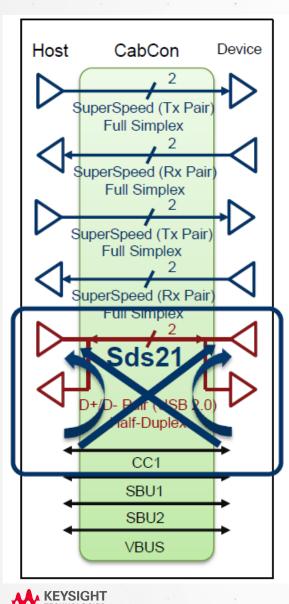
## [Low Speed Signal] SE Coupling between the CC and D+/D-



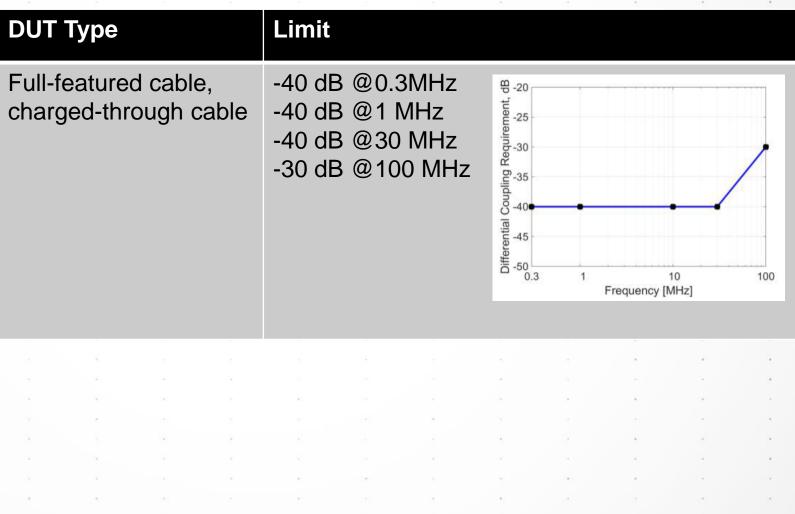
• Measure of single-ended coupling between CC and D+/D-.



# [Low Speed Signal] Coupling between VBUS and Differential D+/D-



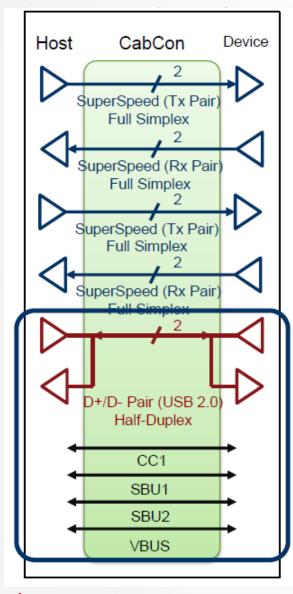
• Measure of coupling between VBUS and differential D+/D-.



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42

#### [Low Speed Signal] VBUS Loop Inductance, Coupling Factor, VBUS Capacitance

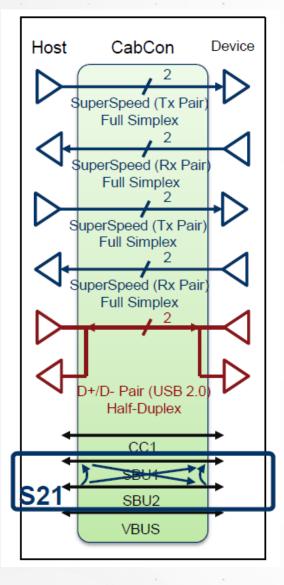


- The loop inductance of VBUS and its coupling factor to low- speed lines (CC, SBU\_A/B, D+/D-) is controlled to limit noise induced on low speed signaling lines.
- For fully featured cables, the range of VBUS bypass capacitance shall be 8 nF up to 500 nF for high-speed return-path bypassing.

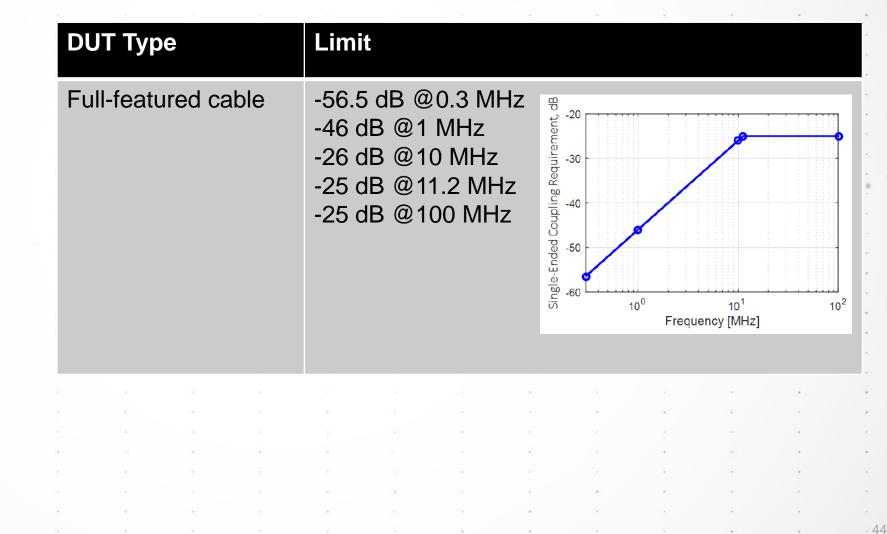
DUT Type	Limit
VBUS loop inductance	≤900nH
Mutual inductance coupling factor	≤0.3
VBUS capacitance	8 nF to 500 nF
Port1 $C_1$	$ \begin{array}{c} L & R \\ M & V \\ C_2 \\ {=} \\ {=} \\ \end{array} $

KEYSIGHT TECHNOLOGIES 43

## [Low Speed Signal] SE Coupling between SBU\_A and SBU\_B

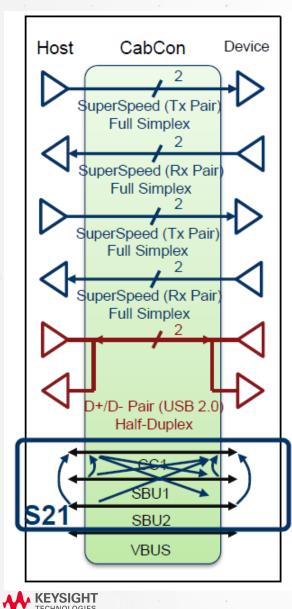


• Measure of single-ended coupling between SBU\_A and SBU\_B.

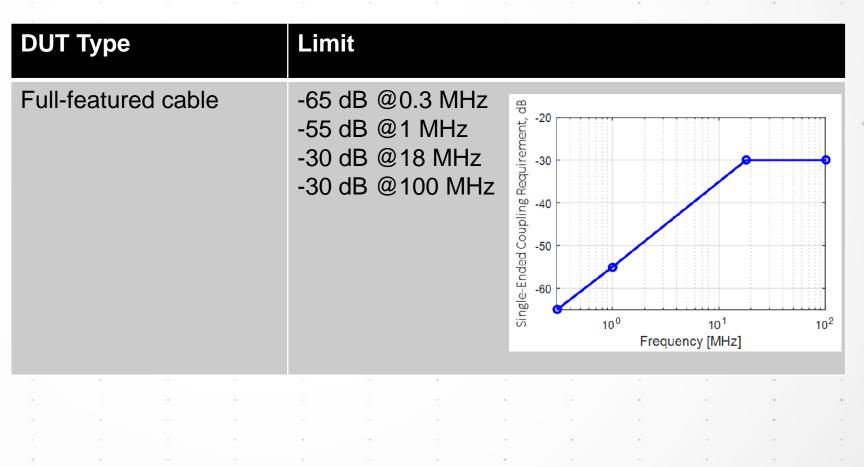




## [Low Speed Signal] SE Coupling between SBU\_A/SBU\_B and CC



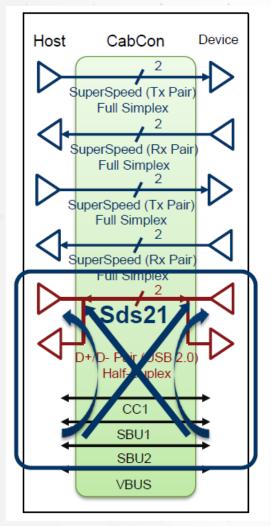
 Measure of single-ended coupling between SBU\_A – CC and SBU\_B -CC.



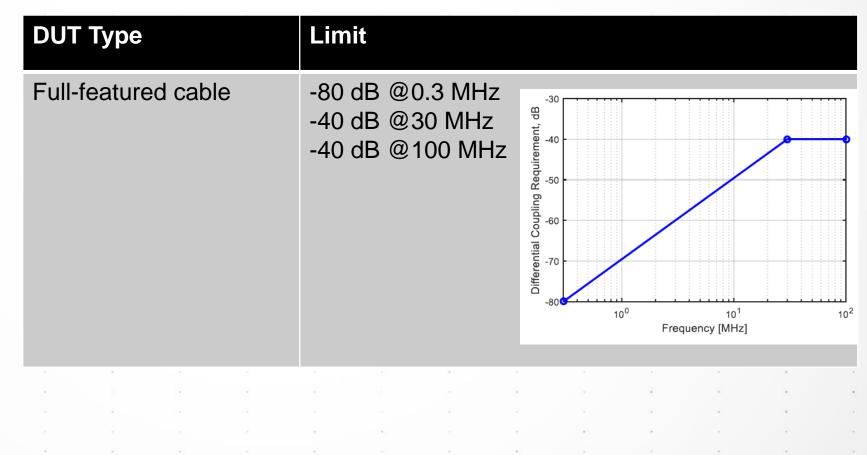
45

46

# [Low Speed Signal] Coupling between SBU\_A/SBU\_B and Differential D+/D-



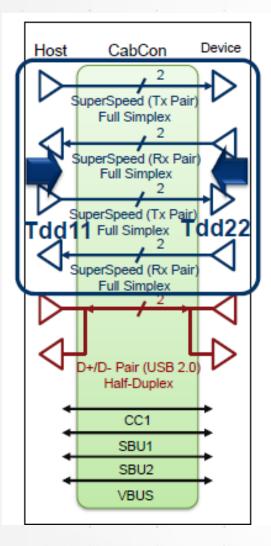
 Measure of coupling between SBU\_A and differential D+/D-, and between SBU\_B and differential D+/D-.





47

## [Raw Cable] Differential Impedance



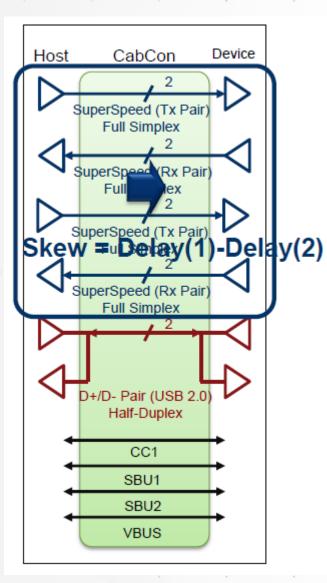
- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter but is an indirect measure of the signal arriving at the receiver.

DUT Type	Limit
Shielded Differential Pair (SDP)	90 Ω ± 5 Ω
Single-ended coaxial SS+ signal wires	$45 \ \Omega \pm 3 \ \Omega$
Note: The impedance should be 90%) rise time	evaluated using a 200ps (10%-



48

## [Raw Cable] Intra-Pair Skew



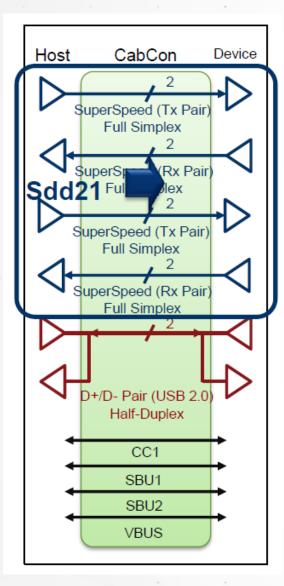
- Intra-pair skew measurement ensures the signal on both SS+
- Tx+ and Tx-lines (or Rx+ and Rx-lines) of a cable assembly
- arrive at the receiver at the same time.

DUT Type	Limit
Shielded Differential Pair (SDP)	< 10 ps/m
Note: It should be measured with (TDT) in a differential mode usin	

with a crossing at 50% of the input voltage



### [Raw Cable] Differential Insertion Loss



- 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.

÷	224		C2		1201.11 824
	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
1	2.50 GHz	-3.7 dB/m	-2.9 dB/m	-2.5 dB/m	-2.1 dB/m
10	5.00 GHz	-5.5 dB/m	-4.5 dB/m	-3.9 dB/m	-3.1 dB/m
2	7.50 GHz	-7.0 dB/m	-5.9 dB/m	-5.0 dB/m	-4.1 dB/m
s.	10.00 GHz	-8.4 dB/m	-7.2 dB/m	-6.1 dB/m	-4.8 dB/m
0	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 Examples for TX/RX with Twisted Pair Construction

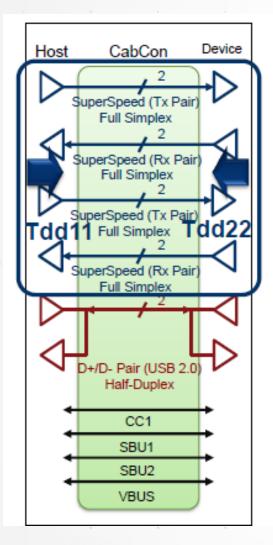
-0.08211	*) (1			
Frequency	34AWG	32AWG	30AWG	28AWG
0.625 GHz	-1.8 dB/m	-1.5 dB/m	-1.2 dB/m	-1.0 dB/m
1.25 GHz	-2.8 dB/m	-2.2 dB/m	-1.8 dB/m	-1.3 dB/m
2.50 GHz	-4.2 dB/m	-3.4 dB/m	-2.7 dB/m	-1.9 dB/m
5.00 GHz	-6.1 dB/m	-4.9 dB/m	-4.0 dB/m	-3.1 dB/m
7.50 GHz	-7.6 dB/m	-6.5 dB/m	-5.2 dB/m	-4.2 dB/m
10.0 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

Differential Insertion Loss Examples for USB TX/RX with Coaxial Construction

. 49

50

## [Mated Connector] Differential Impedance



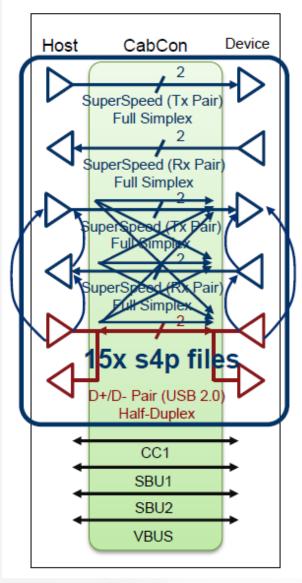
- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter but is an indirect measure of the signal arriving at the receiver.

DUT Type	Limit	×-	U	oper Limit: 9	4 ohm	
Mated Connector for USB 3.2 Gen2 and USB4 Gen2	85 Ω ± 9 Ω	pedance, ohms 38 65 1 r				1
		1				
Note: The impedance evaluated using a 200 rise time.		75-	l	ower Limit:	76 ohm	
evaluated using a 200		20 75 70		Lower Limit:	76 ohm	4
evaluated using a 200	ps (10%-90%)	75		Title	- 2004 - 2014 Anno,	



51

## [Mated Connector] Channel Metrics

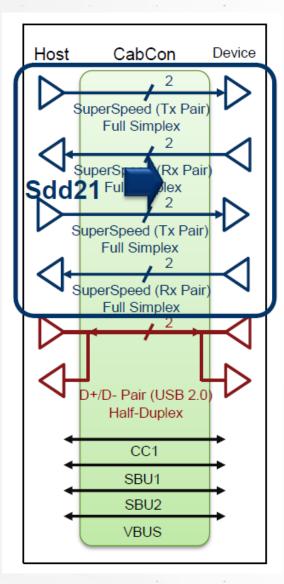


- Five parameters (ILfitatNq, IMR, IXT, IRL and Differential to Common-Mode Conversion) are calculated for SS+ pairs and D+/D-pair.
- USB Type-C standard tool provided by USB-IF will do the pass/fail judgment for five parameters based on measured Touchstone files.

DUT Type	Signal Integrity Compliance Requirements
USB4 Gen3 only (Normative)	ILfitatNq, IMR, IRL, INEXT and IFEXT, IDDXT_1NEXT+FEXT and, IDDXT_2NEXT, Differential-to -Common-Mode Conversion. (44x s4p or 10x s8p or 5x s12p or 2x s20p)
	USB-IF compliance tool: Get_iPar.exe https://compliance.usb.org/files/Ger_iPar_v0p91a_release.zip
	for connector, "Cable_Type" = 0 for passive cable and rts measurements in the config file.

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## [Mated Connector] Differential Insertion Loss

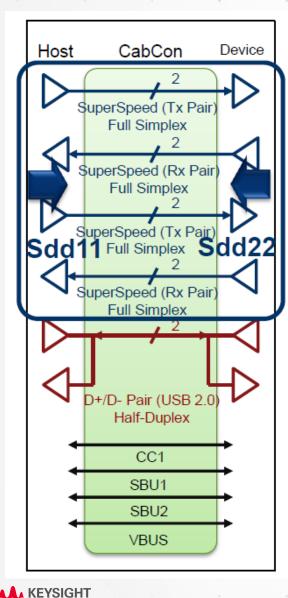


- The IL is evaluated at the TX/RX Gen1, Gen2 and Gen3 generation Nyquist frequencies.
- The IL is **Normative for USB4 Gen 3** and Informative for USB 3.2 Gen2, USB4 Gen2.

DUT Type	Limit
USB4 Gen 3 (Normative)	<ul> <li>≥ -0.6 dB @ 2.5 GHz</li> <li>≥ -0.8 dB @ 5.0 GHz</li> <li>≥ -1.0 dB @ 10 GHz</li> <li>≥ -1.25 dB @ 12.5 GHz</li> <li>≥ -1.5 dB @ 15 GHz</li> </ul>
USB 3.2 Gen2, USB4 Gen2 (Informative)	≥ -0.6 dB @ 2.5 GHz ≥ -0.8 dB @ 5.0 GHz ≥ -1.0 dB @ 10 GHz



## [Mated Connector] Differential Return Loss



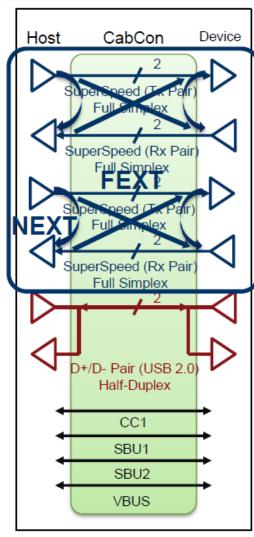
 Measure of frequency response that the differential signal sees as it reflected through the interconnect

DUT TypeLimitUSB4 Gen 3 (Normative) $\geq -20 \text{ dB} @ 100 \text{ MHz}$ $\geq -20 \text{ dB} @ 5 \text{ GHz}$ $\geq -13 \text{ dB} @ 10 \text{ GHz}$ $\geq -6 \text{ dB} @ 15 \text{ GHz}$ USB4 Gen2 (Informative) $= -6 \text{ dB} @ 15 \text{ GHz}$		- 11 1		1						
(Normative) USB 3.2 Gen2 and USB4 Gen2 (Informative) $a_{a_{a_{a_{a_{a_{a_{a_{a_{a_{a_{a_{a_{a$	DUT T	уре				Limit				
<pre>LUSB 3.2 Gen2 and USB4 Gen2 (Informative)</pre> Later 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	USB4	Gen 3	3			≥-20 d	B @10	0 MH	Z	
USB4 Gen2 (Informative)	(Norma	ative)					-			
USB4 Gen2 (Informative)	USB 3	.2 Ge	n2 and				-			
(Informative)							•			
B SECTION B SECTION										
-5     - </td <td></td>										
B B C C C C C C C C C C C C C				0	L		X: 1.5e+004			•
s = -10 -15 -15 -15 -20 -20 -20 -20 -20 -20 -20 -20				-5-			Y: -6	<u>.</u>		
-25 -30 -30 -30 -30 -30 -30 -30 -30 -30 -30			s, B	-10 -		X: 1e+004				
-25 -30 -30 -30 -30 -30 -30 -30 -30 -30 -30		1.42	n Los			Y: -13				
	*		ial Ret		X: 5000		f			
-25 -30 -30 -30 -30 -30 -30 -30 -30 -30 -30	5		ifferent		Y: -20		-			
-30 - 2000 4000 6000 8000 10000 12000 14000										
2000 4000 6000 8000 10000 12000 14000	*			-25 -			-			
	(*)			-30 - 2000	4000 6	000 8000 10000	12000 14000			
				2000	-+000 0		12000 14000			



54

# [Mated Connector] Differential NEXT & FEXT between SS Signal

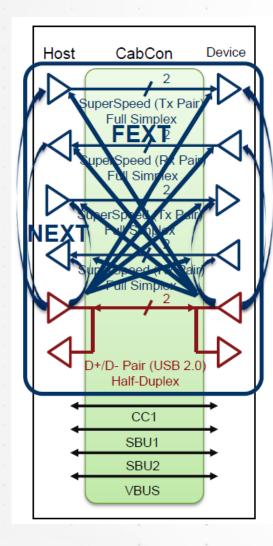


• Measure of coupling between the SS differential pairs (Tx/Rx pair).

DUT T	уре			Limit						
USB4 (Norma				≥-40 dB @100 MHz ≥-40 dB @5 GHz ≥-36 dB @10 GHz						
USB 3 USB4 (Inform	Gen2				3B @1					
-0.50221										
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.*)								•		
с <b>т</b> е	0.000		7.	1		87				



# [Mated Connector] Differential NEXT & FEXT between D+/D- and SS Signal Pairs

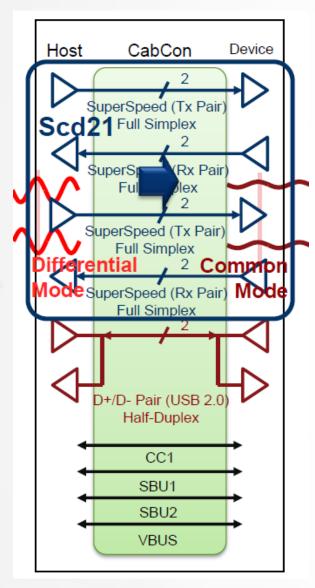


- Measure of coupling between D+/D- and the SS differential pairs
  - (Tx/Rx pair).

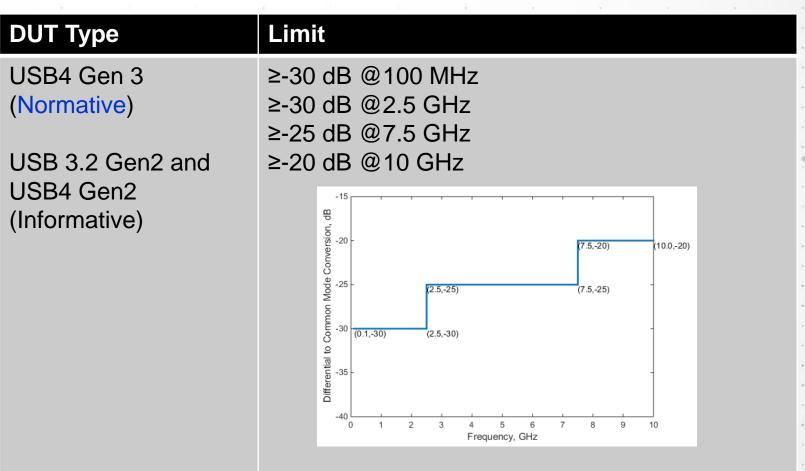
DUT 1	Гуре			Limit						
USB4 (Norm	Gen 3 ative)	≥-40 dB @100 MHz ≥-40 dB @5 GHz ≥-36 dB @10 GHz ≥-30 dB @15 GHz								
USB4	8.2 Ger Gen2 native)	≥-40 d ≥-40 d ≥-36 d	IB @5	GHz						
		а. С								
×			*			÷.:	<u>_</u> *			
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			,		5					



## [Mated Connector] Differential to Common-Mode Conversion

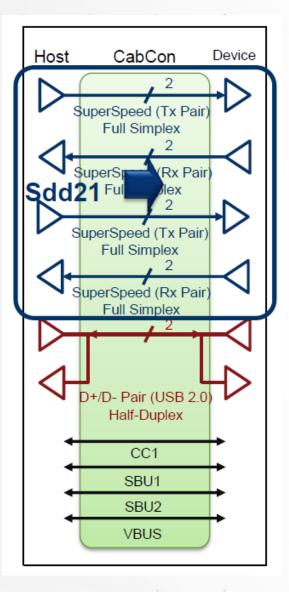


- Common-mode current is directly responsible for EMI and Scd21 is a measure of EMI generation.
- Main purpose of this requirement is to limit EMI emission.



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# **Differential Insertion Loss**



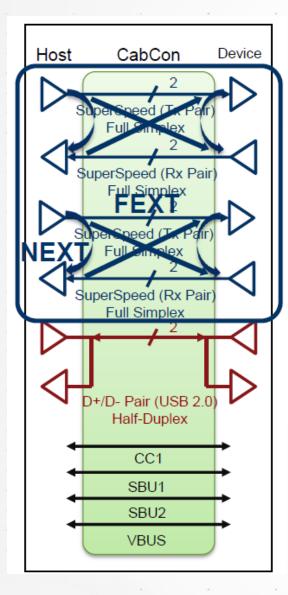
 Measure of frequency response that the differential signal sees as it propagates through the interconnect

DUT Type	Limit
Type-C to Type-C Cable USB4 Gen3	<ul> <li>≥-1.00 dB @ 100 MHz</li> <li>≥-4.20 dB @ 2.5 GHz</li> <li>≥-6.00 dB @ 5 GHz</li> <li>≥-7.5.00 dB @ 10 GHz</li> <li>≥-9.3.00 dB @ 12 GHz</li> <li>≥-11.00 dB @ 15 GHz</li> </ul>
Type-C to Type-C Cable USB3.2 Gen2 and USB4 Gen2	<ul> <li>≥-2.00 dB @ 100 MHz</li> <li>≥-4.00 dB @ 2.5 GHz</li> <li>≥-6.00 dB @ 5 GHz</li> <li>≥-11.00 dB @ 10 GHz</li> <li>≥-20.00 dB @ 15 GHz</li> </ul>
Type-C to Legacy Cable	<ul> <li>≥-2 dB @100 MHz</li> <li>≥-4 dB @2.5 GHz</li> <li>≥-3.5 dB @2.5 GHz (USB Type-C to USB 3.1 Standard-A)</li> <li>≥-6 dB @5 GHz</li> </ul>
Type-C to Legacy Adapter	≥ -2.4 dB to 2.5 GHz, ≥ -3.5 dB to 5 GHz



58

# **Differential NEXT & FEXT between SS Signal**



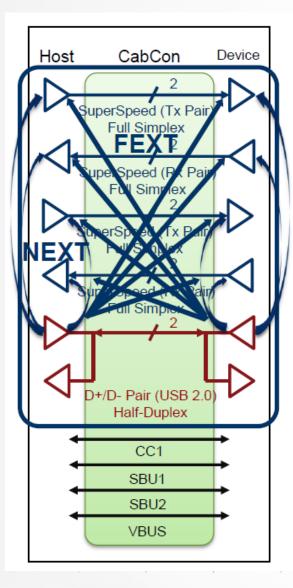
• Measure of coupling between the SS differential pairs (Tx/Rx pair).

DUT	Гуре			Limit								
Туре-	C to Type	-C Cabl	e	≤-40 dB @100 MHz ≤-40 dB @5 GHz ≤-35 dB @10 GHz ≤-32 dB @15 GHz								
	C to Lega T only)	cy Cabl	е	≤-34 c	≤-34 dB to 5 GHz							
	Type-C to Legacy Adapter (NEXT only)				≤-40 dB to 2.5 GHz ≤-34 dB to 5 GHz							
							4					
		3						•	•			
*		5 6 8	е 1 1 1					*	•			
*		0 4 0 8			•			•	•			
* * *	*		- - - - -				54 					
*		5 4 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8			* 		54 					
* * * *							54 					



59

# Differential NEXT & FEXT between D+/D- and SS Signal



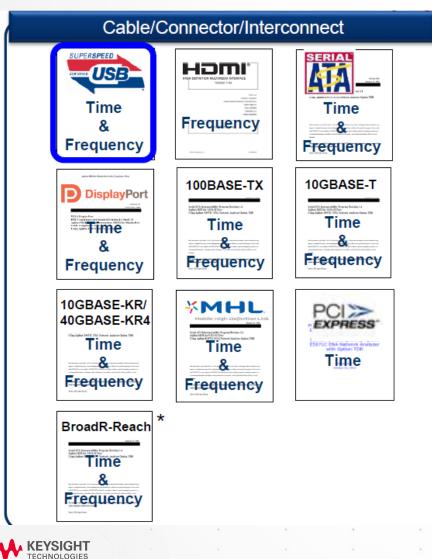
 Measure of coupling between D+/D- and SS differential pairs (Tx/Rx pair).

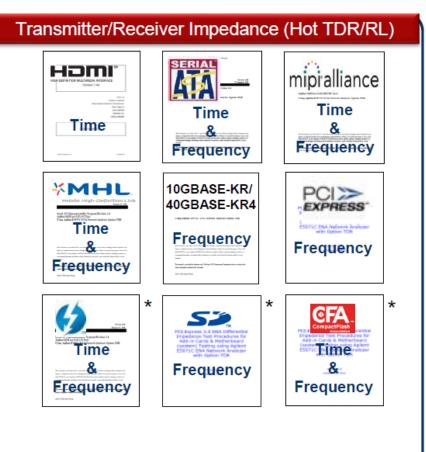
DUT Ty	уре			Limit	Limit								
Туре-С	to Typ	e-C Cab	le	≤-35 c	≤-35 dB @100 MHz ≤-35 dB @5 GHz ≤-30 dB @7.5 GHz								
Туре-С	to Leg	acy Cab	le	≤-30 c	≤-30 dB to 5 GHz								
Туре-С	Type-C to Legacy Adapter				≤-30 dB to 2.5 GHz								
									0				
									*				
				10									
	142	5											
*			¥.										
×					4	10	8						
		3											



# **ENA Option TDR Compliance Test Solution**

Certified MOIs available at: www.keysight.com/find/ena-tdr\_compliance





## **USB Type-C Cable/Connector Compliance Test Solution**

Enhanced TDR Cable/Connector Compliance Testing Solution is ....

- One-box solution which provides complete characterization of highspeed 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 Sparameters
- Adopted by test labs worldwide

#### **Web Resources**

www.keysight.com/find/ena-tdr\_compliance
www.keysight.com/find/usb-vna
www.keysight.com/find/na
www.keysight.com/find/vnasoftware
www.keysight.com/find/ecal





61



# **KEYSIGHT** TECHNOLOGIES