

E5080B Method of Implementation (MOI) for USB Type-C to Legacy Adapter Assembly Compliance Test

Using Keysight Network Analyzer with Enhanced TDR App
For Type-C to Legacy USB Adapter Assemblies



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1. Revision History

Revision	Comments	Date
1.0	First draft for E5080B series	30-Nov-2020
1.1	Updated new release of USB-IF compliance tool	12-Jan-2021

Reference documents

1. Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document; Revision 2.0 (Apr 29, 2020).
2. Universal Serial Bus Type-C Cable and Connector Specification; Release 2.0 (August 2019).

2. Configuration Requirements

Description	Test Equipment	Qty
Network Analyzer	<p>Keysight Network Analyzer: (20 GHz is recommended as USB4/Type-C cable/connector requires measurements up to 20 GHz)</p> <ul style="list-style-type: none"> • E5080B-4K0: 4-port test set, 9 kHz to 20 GHz or • P5024/25A Streamline USB Series VNA or • M9804/05A PXI Multiport VNA <p>Note: Ensure that E5080B firmware revision is at least version A.14.10 or above (Windows 10)</p>	1 ea.
Software	<p>S9x011A/B Enhanced time-domain analysis with TDR</p> <p>* Selection is based on the VNA platforms. x=6 for ENA, x=7 for Streamline USB, x=5 for PXI</p>	1 ea.
Compliance Tool	<p>Compliance Tool provided by USB-IF: https://compliance.usb.org/files/IntePar_1p6.zip (Released 3-Jan-2021)</p>	1 ea.
ECal or Mechanical Cal Kit	N4433D-010/0DC 4-Ports Electronic Calibration (ECal) Module or 85052D Economy Mechanical Calibration Kit	1 ea.
Test Fixture	<p>USB Type-C official test fixture and calibration standards, or an equivalent set of fixtures and standards.</p> <p>Note: Fixtures for testing USB Type-C and USB Legacy connectors and cable assemblies are available for purchase through LUXSHARE-ICT.</p>	1 ea.
Adapter (for E5080B only)	Coaxial straight Female-SMA Female-SMA 50-Ohm adapters (Keysight 1250-1666).	4 ea.
RF cable	<p>3.5 mm or SMA cables of 4 GHz bandwidth or more (EG: 5062-6691)</p> <p>* Y1740A-100 (3.5-mm m-m, 36 inch) cable is recommended for USB and PXI VNA.</p>	4 ea.
Terminator	50-ohm terminations to terminate unused channels.	14 ea.

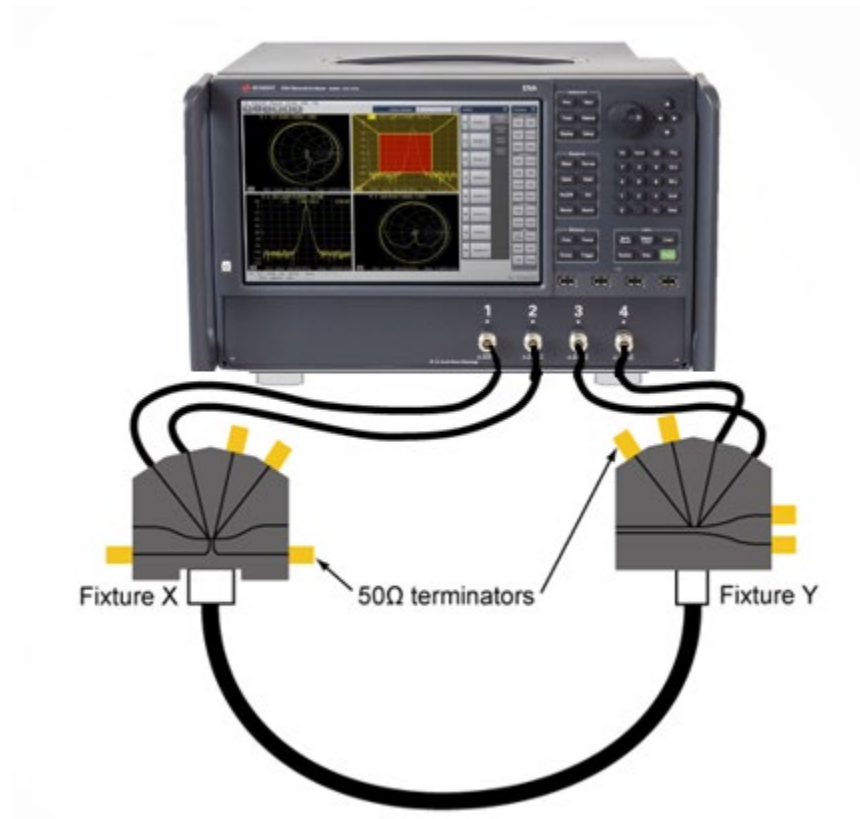
3. Test Procedure

3.1 Test flow chart

Steps	Procedure
Step 1	<p>The VNA should be powered on and allowed to warm up - recommendation is for 24 hours prior to measurement.</p> <ul style="list-style-type: none"> - Recommended to set the frequency sweep range 20 GHz for the USB Type-C SuperSpeed pairs as required by the spec. - The IF Bandwidth should be low enough to help reduce noise effects (e.g. < 300 Hz).
Step 2	<p>Set measurement conditions by recalling a state file or manual setup.</p> <p>There are <u>3 type of USB Type-C Cable-Connector tests state files and MOIs</u>. Choose the right one base on your DUT type.</p> <ul style="list-style-type: none"> - Type-C to Type-C Passive Cable Assemblies (for High Speed Signal and Low Speed Signals) - Type-C to Legacy USB Cable Assemblies - Type-C to Legacy USB Adapter Assemblies
Step 3	Connect USB Type-C Test fixture to test ports of the VNA.
Step 4	For Time Domain Measurements, perform Electronic Calibration (ECal) and de-embedding.
Step 5	For Frequency Domain Measurements, perform Electronic Calibration (ECal) and de-embedding.
Step 6	<p>Perform Time Domain Measurements</p> <ul style="list-style-type: none"> - D+/D- Differential Impedance (Normative) - D+/D- Intra-Pair Skew (Normative) - [Raw Cable] Characteristic Impedance (Informative) - [Raw Cable] Intra-Pair Skew (Informative) - [Mated Connector] Differential Impedance (Informative)
Step 7	<p>Perform Frequency Domain Measurements</p> <ul style="list-style-type: none"> - D+/D- Pair Attenuation (Normative) - Channel Metrics (ILfitatNq, IMR, IXT, IRL) (Normative) - Differential-to-Common Mode conversion) (Normative) - Cable Shielding Effectiveness (Normative) - [Raw Cable] Differential Insertion Loss (Informative) - [Mated Connector] Differential Insertion Loss (Informative) - [Mated Connector] Differential Return Loss (Informative) - [Mated Connector] Differential NEXT & FEXT between SS Signal Pairs (Informative) - [Mated Connector] Differential NEXT & FEXT between D+/D- Pair and SS Signal Pairs (Informative) - [Mated Connector] Differential to Common Mode Conversion (Informative) - Differential Insertion Loss (Informative) - Differential Return Loss (Informative) - Differential NEXT between SS Signal Pairs (Informative) - Differential NEXT & FEXT between D+/D- Pair and SS Signal Pairs (Informative)

3.2 Test port cable and fixture connection

Cable under test will be tested in the following manner

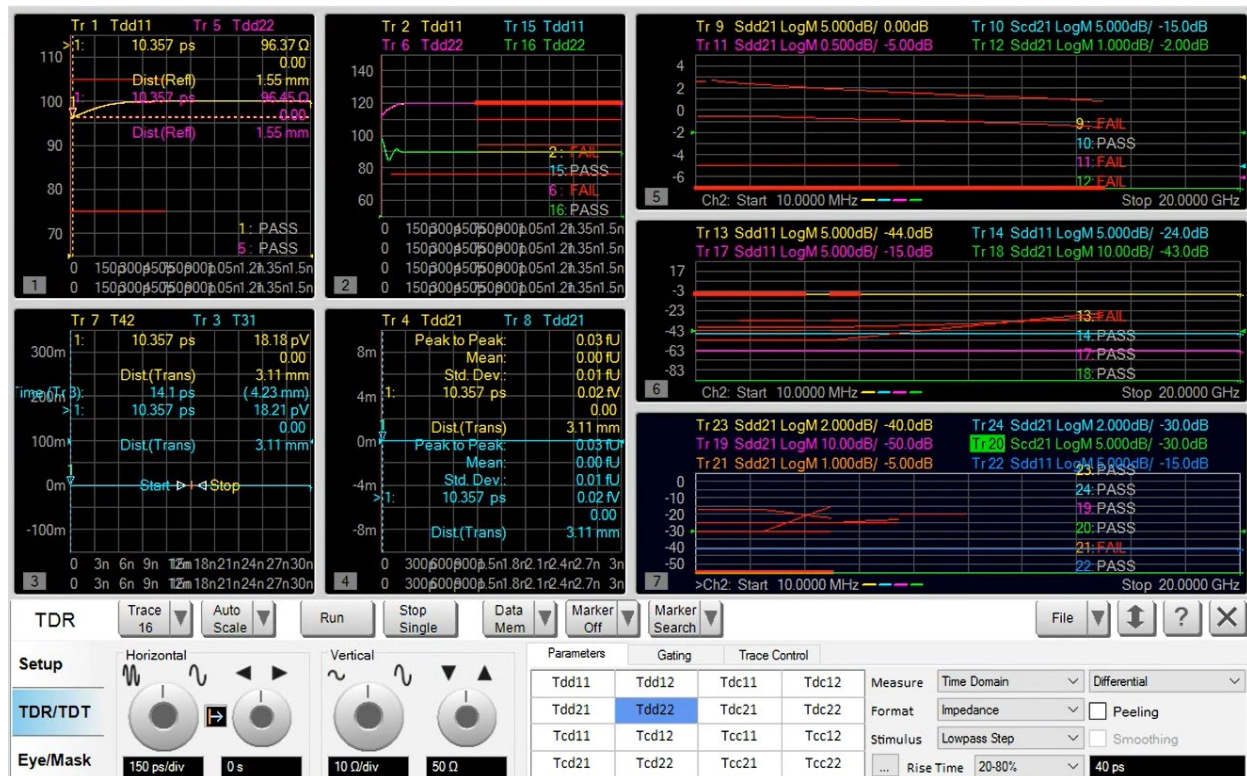


3.3 Description of measurement window

The following figure is the description of the measurement window.

Channel 1- Time Domain	Channel 2- Frequency Domain
<p>5.1. D+/D- Diff. Impedance (Tr 1 & Tr 5)</p> <p>5.2. D+/D- Intra-pair Skew (Tr 3)</p> <p>5.7 [Raw Cable] Diff. Impedance (Tr 2 & Tr 6)</p> <p>5.8 [Raw Cable] Intra-Pair Skew (Tr 3)</p> <p>5.10 [Mated Connector] Diff. Impedance (Tr 15 & Tr 16)</p>	<p>5.3. D+/D Pair Attenuation/Diff. Insertion Loss (Tr 11)</p> <p>5.4 Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)</p> <p>5.5 Differential to Common Mode Conversion (Tr 10)</p> <p>5.6 Cable Shielding Effectiveness (Tr 13 & Tr 14)</p> <p>5.9 [Raw Cable] Differential Insertion Loss (Tr 9)</p> <p>5.11 [Mated Connector] Diff. Insertion Loss (Tr 12)</p> <p>5.12 [Mated Connector] Diff. Return Loss. (Tr 17)</p> <p>5.13 [Mated Connector] Diff. NEXT & FEXT between SS Signal Pairs (Tr 18)</p> <p>5.14 [Mated Connector] Diff. NEXT & FEXT between D+/D- Pair and SS Signal Pairs (Tr 19)</p> <p>5.15 [Mated Connector] Differential to Common Mode Conversion (Tr 20)</p> <p>5.16 Diff. Insertion Loss (Tr 21)</p> <p>5.17 Diff. Return Loss (Tr 22)</p> <p>5.18 Diff. NEXT between SS Signal Pairs (Tr 23)</p> <p>5.19 Diff. NEXT & FEXT between D+/D- Pair and SS Signal Pairs (Tr 24)</p>

Normative and informative parameters



Note:

1. Hard Keys are displayed in **Blue color** and **Bold**. (Example: **Avg, Analysis**)
2. Soft keys (Keys on the screen) are displayed in **Bold**. (Example: **S11, Real, Transform**)
3. Buttons (in the TDR) are displayed in **Green color** and **Bold**. (Example: **Trace, Rise Time**)
4. Tabs (in the TDR) are displayed in **Brown color** and **Bold**. (Example: **Setup, Trace Control**)

4 Measurement Setups

4.1 Recalling a state file

This section describes how to recall a state file for Time Domain and Frequency Domain settings.

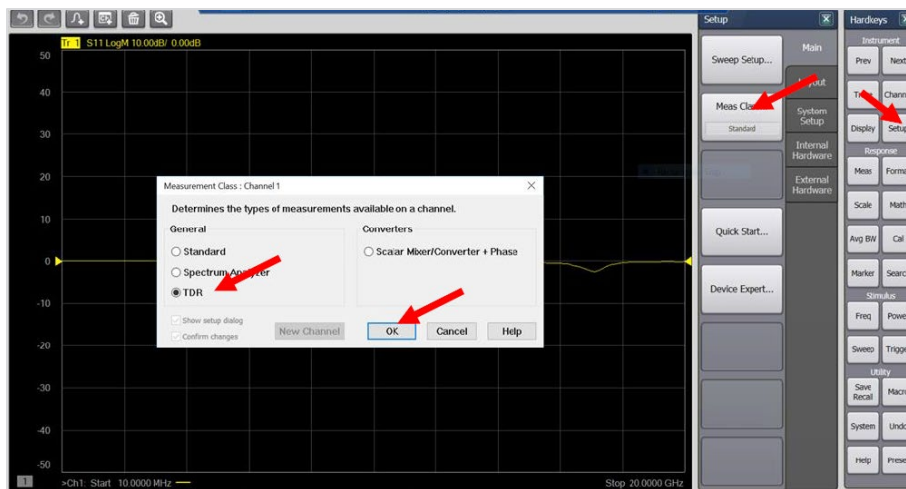
A state file can be downloaded from Keysight.com at the following URL.

www.keysight.com/find/ena-tdr_compliance

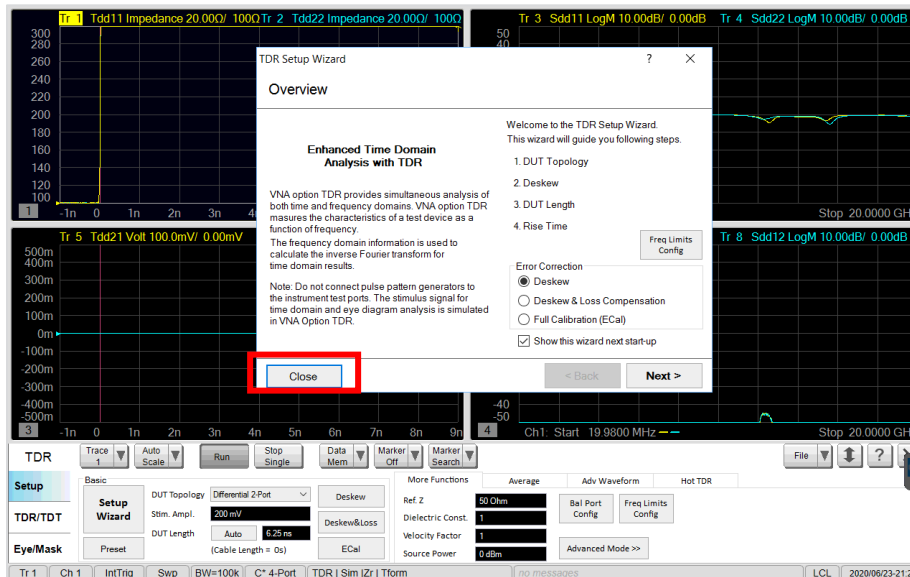
If you use your local PC to download, save the state file to a USB mass storage device in order to move it to the VNA unit. Connect the USB mass storage device into the front USB port of the VNA unit.

For manual measurement settings, refer to Chapter 6.0 Appendix for manual setup procedure.

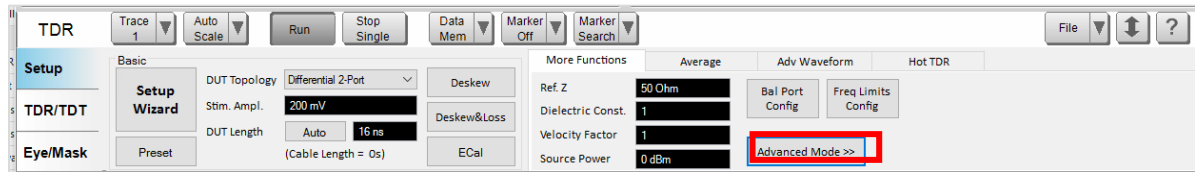
1. Click **Setup > Main > Meas Class...** to launch measurement class setup dialog box
2. Select **TDR** and click OK.



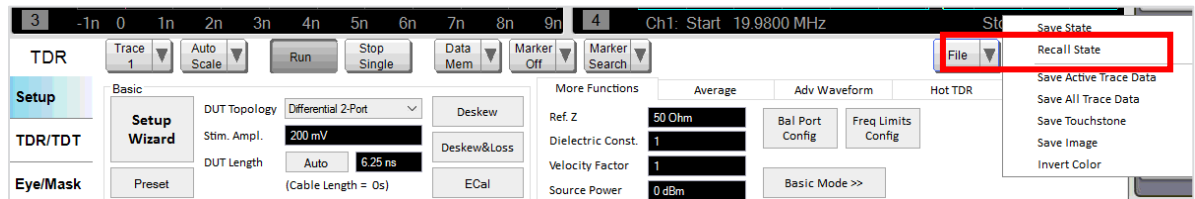
3. Select Close and confirm with Yes to close the setup wizard.



4. Select Click **Advanced Mode** of TDR software and Click Yes to enter the advanced mode.



5. Click **File > Recall State**. Select the state file (*.tdr) and click Open to recall.



6. The windows will launch pre-define state file configuration for USB Type-C to Legacy USB Adapter compliance testing.



7. All the measurement settings including calibration information can be saved. Select **File > Save State As... > State and Cal Set Date (*.csa)** to save the settings.

4.2 Common parameters setup for frequency domain measurements

1. Press **Channel Next** to select Channel 2.
2. Select **Sweep** > Sweep Setup and key-in sweep properties as below:
 - Set **Start** value to “10 MHz”.
 - Set **Stop** value to “20 GHz”.
 - Set **Points** and set to “1500”.
 - Set **IF Bandwidth** to “1 kHz”.

Sweep Type **Timing**

Sweep Type

- ☒ Linear Frequency
- ☐ Log Frequency
- ☐ Power Sweep
- ☐ CW Time
- ☐ Segment Sweep
- ☐ Phase Sweep

Sweep Properties

Start: 10.000000 MHz

Stop: 19.999998000 GHz

Power: 0.00 dBm

Points: 1500

IF Bandwidth: 1.0 kHz

3. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** Select and check “**Enable Port Z Conversion (all ports)**” to turn ON Port Z conversion.
4. Select **Meas** > **Balanced** > **Topology...** > **BAL-BAL**
5. Select **Balanced Port** > **1 BAL** > **Port 1- Port 2**
6. Select **Balanced Port** > **2 BAL** > **Port 3- Port 4**

Balanced Setup

Topology **Port Z**

Topology: BAL-BAL

Balanced Port	VNA (+)Port	VNA (-)Port	True Mode
1 BAL	Port 1	Port 2	<input type="checkbox"/>
2 BAL	Port 3	Port 4	<input type="checkbox"/>
3 Unused	-	-	<input type="checkbox"/>
4 Unused	-	-	<input type="checkbox"/>

4.3 Calibration setup

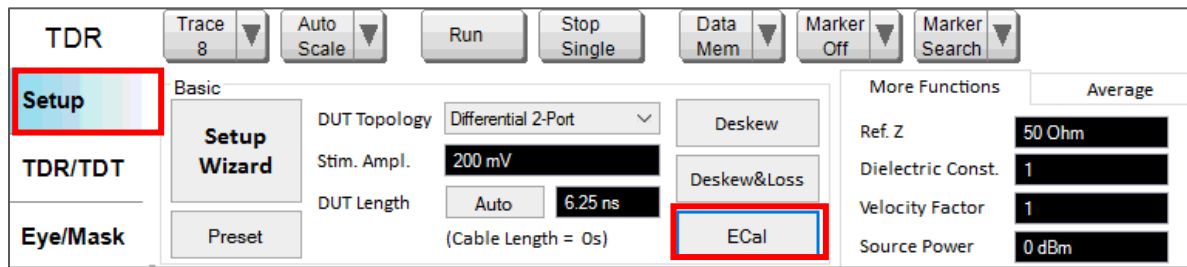
The purpose of this step is to calibrate the RF effects such as delay, loss or mismatch of RF cables and test fixture traces before measurements. In order to remove the fixture trace effect, two calibration methods (ECal calibration & de-embedding or TRL calibration) are available with the VNA firmware.

4.3.1. ECal calibration on time domain

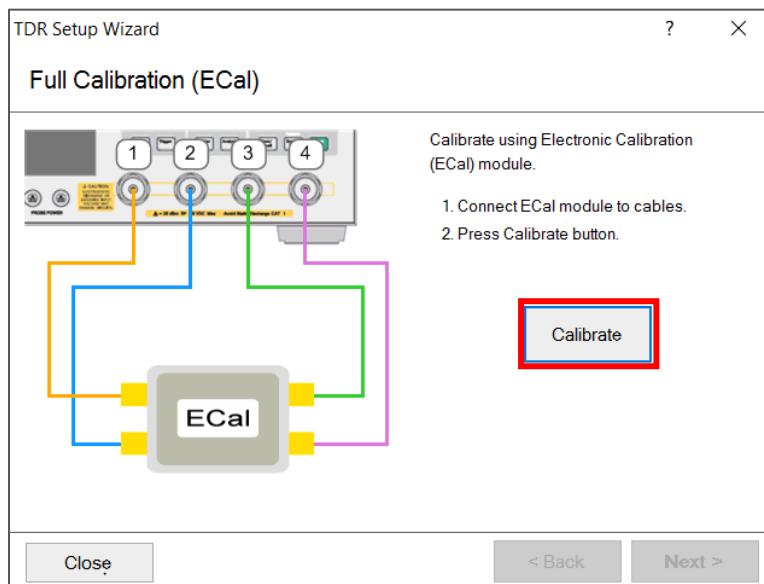
Full calibration is performed by using the 4-port ECal Module (i.e. N4433A) at the end of RF cables connected to the VNA's test ports. The effect of the fixture is removed by de-embedding the fixture traces with S-parameter Touchstone files.

ECal calibration and de-embedding for time-domain measurements are performed by the TDR software.

1. Press **Channel Next** to select Channel 1.
2. Click **Setup** tab.
3. Click **ECal** to launch the TDR Setup Wizard.



4. Connect the VNA ports (port 1 to 4) to the ECal module with RF cables.
5. Click **Calibrate** to perform ECal Calibration.



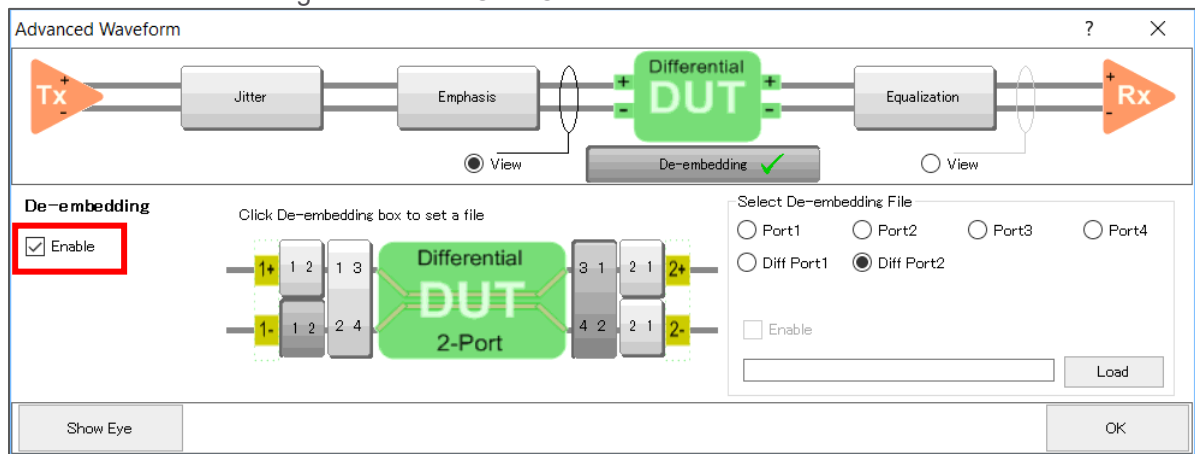
6. Click **Next >** to proceed
7. Click **Finish** to complete the ECal.

4.3.2 De-embedding on time domain

1. Click **Adv Waveform** tab > **De-embedding** to launch Advanced Waveform wizard.



2. Click De-embedding box to set the Touchstone file. 2 port files (*.s2p) for single ended lines or 4 port files (*.s4p) for differential lines can be selected for the de embedding function.
3. Load the USB Type-C and Legacy USB's 2X THRU de-embedding Touchstone file based on your port topology:
Select **Port1/2** > Load "**USB Type-C 2X THRU**" file.
Select **Port3/4** > Load "**Legacy USB 2X THRU**" file.
Note: De-embedding file will be provided by test fixture vendor based on your purchase.
4. Enable the de-embedding function and Click OK.



Note: For more details about the de-embedding function, refer to the VNA help below.

http://ena.support.keysight.com/e5080/manuals/webhelp/eng/index.htm#S3_Cals/Fixturing.htm#deembed

4.3.3. ECal calibration on frequency domain

ECal calibration and de-embedding for frequency-domain measurements are performed by the VNA firmware.

1. Press **Channel Next** to select Channel 2.
2. Connect the VNA ports (Port 1 to 4) to the ECal module with RF cables.
3. Press **Cal** > **Main** > **Other ECal** > **Ecal...** > select **4-Port ECal** and click **Next** to proceed Ecal.

Select Calibration Ports and ECal Module

Cal Type Selection

- 4 Port ECal
- 3 Port ECal
- 2 Port ECal
- 1 Port ECal

4 Port ECal Configuration

Select 1st Port: 1

Select 2nd Port: 2

Select 3rd Port: 3

Select 4th Port: 4

Selected Cal Kit: NOT FOUND

Serial No.:

Characterization: Factory

View/Select ECal Module

☐ Show Advanced Settings (Orientation & Thru Cal) ☐ Calibrate source and receiver power

< Back Next > Cancel Help

4.3.4. De-embedding on frequency domain

1. Press **Cal** > **Fixtures** > **Fixture Setup** > **2-port DeEmbed...** and check on **Enable De-embedding (all ports)** to de-embed fixture trace.
2. Select **User S2P File** and specify a 2-port de-embedding file (*.s2p).
 Note: De-embedding file will be provided by test fixture vendor based on your purchase.
 Select **Port-1/2** > User Defined (S2P File) > Load "**USB Type-C 2X THRU**" file.
 Select **Port-3/4** > User Defined (S2P File) > Load "**Legacy USB 2X THRU**" file.
3. Close and proceed.

2 Port De-embedding

☒ Enable De-embedding (all ports) ☐ Enable Extrapolation

Select De-embedding

Port 1 User Defined (S2P File) ☐ Reverse adapter ports

User S2P File... <None Selected>

VNA

1

Network 1

1 2

DUT

	Min Frequency	Max Frequency
Port Range:	0.009 MHz	20. GHz
S2P Range:	not available	not available

Close Help

Note: Other method like Automatic Fixture Removal (AFR) is also applicable. Refer more to VNA help:

http://ena.support.keysight.com/e5080/manuals/webhelp/eng/s3_cals/auto_fixture_removal.htm#Overview

Note: For more details about the de-embedding function, refer to the VNA help below.

2-port de-embedding -

http://ena.support.keysight.com/e5080/manuals/webhelp/eng/index.htm#S3_Cals/Fixturing.htm#deembed

4.3.5. Adjustment of effective rise time

After performing the calibration, the effective rise time entering the USB connector pins should adjusted for the specification in time domain measurements.

1. Press **Channel Next** to select Channel 1.
2. Double click to maximize the selected trace in the screen.
3. Open **TDR/DT** tab. Select the trace of interest.
4. Confirm effective rise time for each trace.

Trace	Test Parameters	Rise Time %	Target Rise Time
Tr 1 & 5	D+/D- Differential Impedance	20 - 80 %	400 ps
Tr 4	D+/D- Propagation Delay	20 - 80 %	400 ps
Tr 3 & 7	D+/D- Intra-Pair Skew	20 - 80 %	400 ps
Tr 2 & 6	[Raw Cable] Characteristic Impedance	10 - 90 %	200 ps
Tr 15 & 16	[Mated Connector] Differential Impedance	20 - 80 %	40 ps

5 Measurement and Data Analysis

The connections for Type-C to Legacy adapter assembly, raw cable and mated connector are assumed as follows (Note: TF stands for Test Fixture). For adapter assembly frequency domain measurements, the standard compliance tool is used for the pass/fail judgment. The manual measurement procedures for raw cable, mated connector, and several test items of adapter assembly using the Enhanced Option TDR are also supported with the limit lines.

1. Connect USB test fixtures to the test port cables according to tables below. Unused terminals should be terminated with 50-ohm terminators.
2. Press **Channel Next** key on the instrument front panel to select Channel 1.
3. Click **Stop Single** for Time Domain measurements.
4. Press **Trigger** > **Single** for Frequency Domain measurements.

Type-C to legacy adapter assembly connection

TF 1	Cable Assembly		TF 2
Type-C (Receptacle)	Type-C (Plug)	Type-A/B/Micro-B/Mini-B (Plug)	Type-A/B/Micro-B/Mini-B (Receptacle)
D+/D-	↔		D+/D-
Tx1+/Tx1-	↔		Rx+/Rx-
Rx1+/Rx1-	↔		Tx+/Tx-
Tx2+/Tx2-	n/a		n/a
Rx2+/Rx2-	n/a		n/a

Raw cable connection

TF1	Raw Cable	TF2
D+/D-	↔	D+/D-
Tx1+/Tx1-	↔	Tx1+/Tx1-
Rx1+/Rx1-	↔	Rx1+/Rx1-
Tx2+/Tx2-	n/a	Tx2+/Tx2-
Rx2+/Rx2-	n/a	Rx2+/Rx2-

Mated connector connection

TF 1	Mated Connector	TF 2
Type-C (Receptacle)		Type-C (Plug)
D+/D-	↔	D+/D-
Tx1+/Tx1-	↔	Tx1+/Tx1-
Rx1+/Rx1-	↔	Rx1+/Rx1-
Tx2+/Tx2-	↔	Tx2+/Tx2-
Rx2+/Rx2-	↔	Rx2+/Rx2-

5.1 D+/D- differential 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 signal conductors of the USB Type-C connectors have the proper impedance.

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 D+	TF1 D-	TF2 D+	TF2 D-

Note: Unused fixture pots should be terminated with 50-ohm terminators.

2. Press **Channel Max** to maximize Channel 1 on the screen.
3. Select **Trace 1 (Tdd11)**.
4. Double-click the Trace to maximize the selected trace on the screen.
5. Click Stop Single.
6. Confirm the measured impedance is within the limit shown below. Otherwise, it will show Fail.
7. Select **Trace 5 (Tdd22)** and repeat Step 5-6 for the far end of the DUT.

DUT Type	Max Limit	Min Limit
Type-C to Type-C passive cable assembly	105 Ω	75 Ω
Type-C to legacy cable assembly	105 Ω	75 Ω
Type-C to legacy adapter assembly	105 Ω	75 Ω

Note: The measurement should be evaluated using a 400ps (20%-80%) rise time.

5.2 D+/D- intra-pair skew

The propagation delay skew measurement ensures that the signal on both the D+ and D- lines of cable assembly arrive at the receiver at the same time.

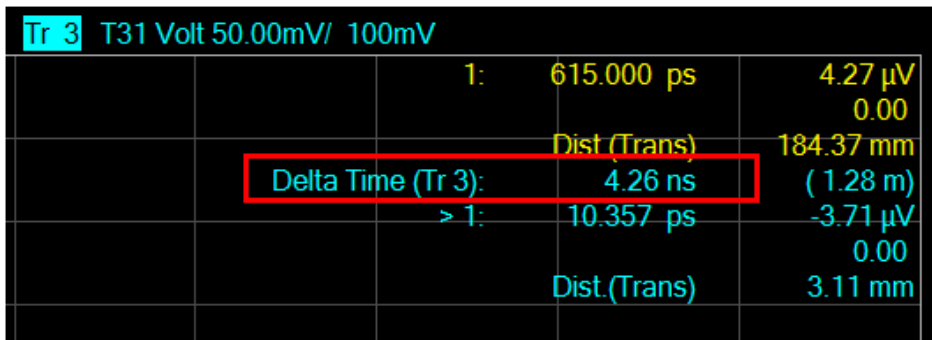
1. Connect the VNA ports (port 1 to port 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 D+	TF1 D-	TF2 D+	TF2 D-

2. Press Double-click on the instrument front panel to enlarge the trace.
3. Press **Channel Next** to select Channel 1.
4. Select **Trace 3 (T31)**.
5. Click **Stop Single**
6. Read the Delta Time and confirm the measured value is within the limit shown below. Otherwise, Fail.

DUT Type	Test Limit
Type-C to Type-C passive cable assembly Type-C to legacy cable assembly	If Delta Time < 100 psec: Pass, else: Fail
Type-C to legacy adapter assembly	If Delta Time < 20 psec: Pass, else: Fail

Note: The measurement should be evaluated using a 400ps (20%-80%) rise time.



5.3 D+/D- pair attenuation/differential insertion loss

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

1. Connect VNA ports (port 1 to port 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 D+	TF1 D-	TF2 D+	TF2 D-

2. Press **Channel Next** to select Channel 2.
3. Select **Trace 11 (Sdd21)**.
4. Press Double-click on the instrument front panel to enlarge the trace.
5. Press **Trigger** > Single.
6. Run and confirm the measured values is within the limit shown below. Otherwise, it will show Fail.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
Type-C to Type-C passive cable assembly	50 MHz	100 MHz	-1.02 dB	-1.43 dB
	100 MHz	200 MHz	-1.43 dB	-2.40 dB
Type-C to legacy cable assembly	200 MHz	400 MHz	-2.40 dB	-4.35 dB
Type-C to legacy adapter assembly	50 MHz	400 MHz	-0.70 dB	-0.70 dB

5.4 Channel metrics (ILfitatNq, IMR, IXT, IRL, differential-to-common-mode conversion)

The test results of channel metrics will check with a standard tool (InterPar.exe) provided by USB-IF.

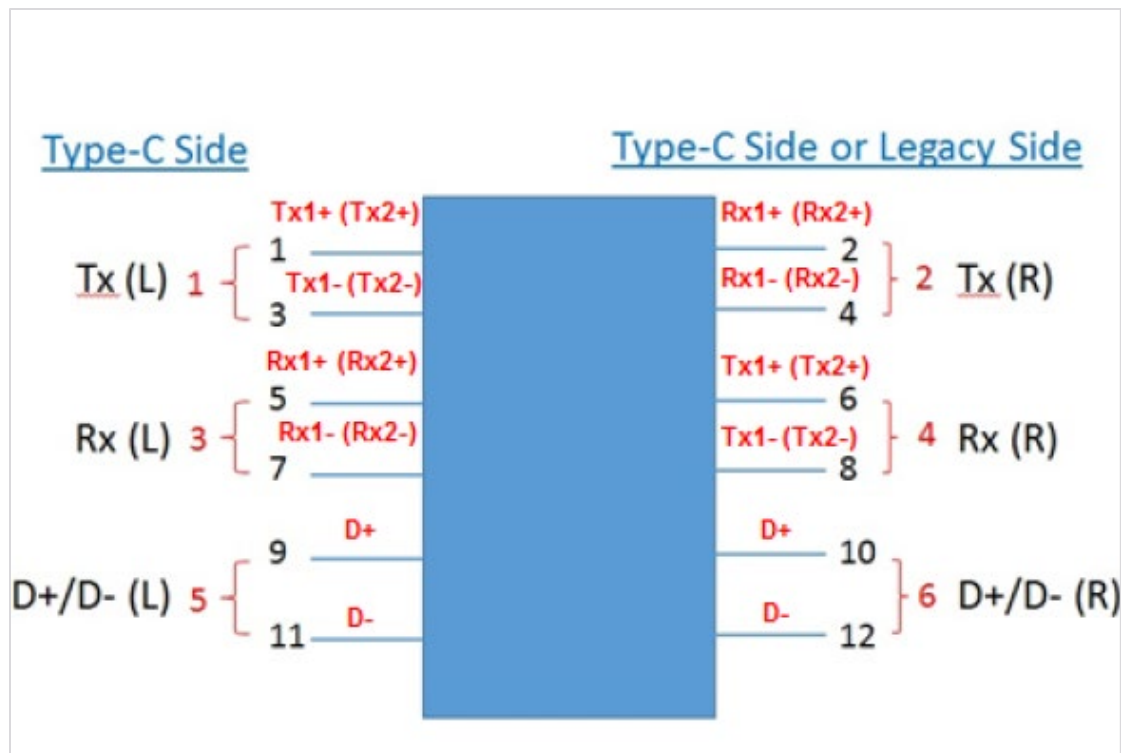
The USB Type-C compliance tool may be down-loaded from the following link:

https://compliance.usb.org/files/IntePar_1p6.zip (Released 3-Jan-2021)

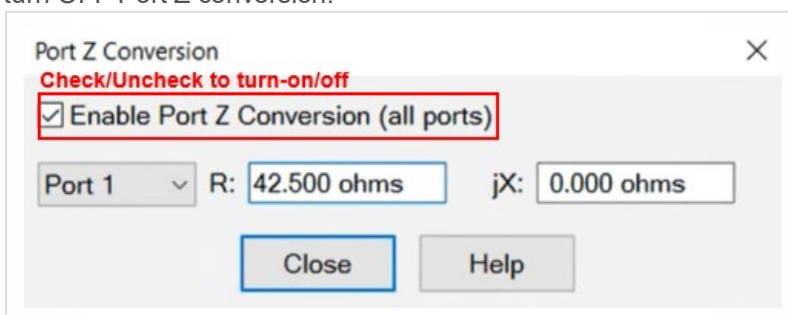
Fifteen 4-port Touchstone files (*.s4p) will measure and save by the VNA firmware, and then imported by the compliance tool to conduct cable assembly compliance test.

Note: Trace 11 is allocated for the measurements though, other traces can be used to check the measurement results with the limit line and the pass/fail judgment as described in Note below

Note: Turn off the Port Z conversion in order to perform the measurements based on 50-ohm port impedance setting which required by the standard compliance tool.



1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.
2. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** uncheck “**Enable Port Z Conversion (all ports)**” to turn OFF Port Z conversion.

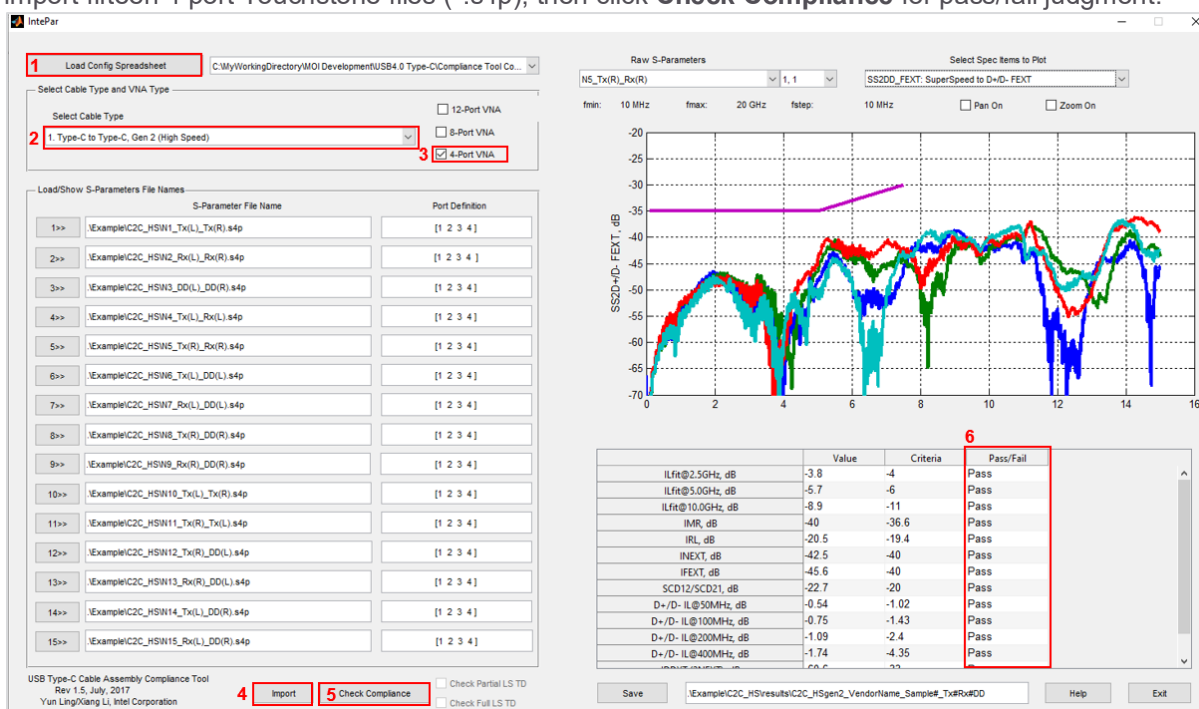


3. Press **Channel Next** to select Channel 2.
4. The same connection can use for below measurement for Pass/Fail testing. Select the desired trace as described to check the limit line and the pass/fail judgment. Press Double-click on the instrument front panel to enlarge the trace.
 - 5.3 D+/D- Pair Attenuation (**Trace 11**)
 - 5.5: Differential-to-Common-Mode Conversion (**Trace 10**)
 - 5.15: Differential Insertion Loss (**Trace 21**)
 - 5.16: Differential Return Loss (**Trace 22**)
 - 5.17: Differential NEXT between SS Signal Pair (**Trace 23**)
 - 5.18: Differential NEXT and FEXT between D+/D- Pair and SS Signal Pairs (**Trace 24**)
5. Press **Trigger** > Single.
6. Press **Save Recall** > **Save Other** > **Save Data...** > **Filename.s4p** to save the measured Touchstone file (*.s4p). Select format “Real/Imaginary”.

7. Connect the VNA ports with test fixture ports shown below and repeat step 3 to step 6 to save all necessary Touchstone files (*.s4p) for VNA.

Test Path Name	Trace	Port 1	Port 2	Port 3	Port4
Tx(L), Tx(R) [1,2,3,4]	Tr-10/ 21/22	TF1 Tx1+	TF1 Tx1-	TF2 Rx+	TF2 Rx-
Rx(L), Rx(R) [5,6,7,8]	Tr-10/ 21/22	TF1 Rx1+	TF1 Rx1-	TF2 Tx+	TF2 Tx-
D+/D-(L), D+/D-(R) [9,10,11,12]	Tr-11	TF1 D+	TF1 D-	TF2 D+	TF2 D-
Tx(L), Rx(L) [1,3,5,7]	Tr-23	TF1 Tx1+	TF1 Tx1-	TF1 Rx1+	TF1 Rx1-
Tx(R), Rx(R) [2,4,6,8]	Tr-23	TF2 Rx1+	TF2 Rx1-	TF2 Tx1+	TF2 Tx1-
Tx(L), D+/D-(L) [1,3,9,11]	Tr-24	TF1 Tx1+	TF1 Tx1-	TF1 D+	TF1 D-
Rx(L), D+/D-(L) [5,7,9,11]	Tr-24	TF1 Rx1+	TF1 Rx1-	TF1 D+	TF1 D-
Tx(R), D+/D-(R) [2,4,10,12]	Tr-24	TF2 Rx+	TF2 Rx-	TF2 D+	TF2 D-
Rx(R), D+/D-(R) [6,8,10,12]	Tr-24	TF2 Tx+	TF2 Tx-	TF2 D+	TF2 D-
Tx(L), Rx(R) [1,3,6,8]	N/A	TF1 Tx1+	TF1 Tx1-	TF2 Tx+	TF2 Tx-
Tx(R), Rx(L) [2,4,5,7]	N/A	TF2 Rx+	TF2 Rx-	TF1 Rx1+	TF1 Rx1-
Tx(R), D+/D-(L) [2,4,9,11]	Tr-24	TF2 Rx+	TF2 Rx-	TF1 D+	TF1 D-
Rx(R), D+/D-(L) [6,8,9,11]	Tr-24	TF2 Tx+	TF2 Tx-	TF1 D+	TF1 D-
Tx(L), D+/D-(R) [1,3,10,12]	Tr-24	TF1 Tx1+	TF1 Tx1-	TF2 D+	TF2 D-
Rx(L), D+/D-(R) [5,7,10,12]	Tr-24	TF1 Rx1+	TF1 Rx1-	TF2 D+	TF2 D-

8. Open the Excel spreadsheet [High_Config_4ports_[1324].xlsx and modify “Cable Type” to **7 (Type C to Legacy Adapter)** and S-parameter Path and Name to match them with fifteen 4 port Touchstone files (*.s4p) you measured . Do not change “Number of VNA Ports” and “Port Arrangement”.
9. Launch the USB.org compliance test tool and load the excel spreadsheet “[High_Speed]_Config_4ports_[1324].xlsx” by clicking “**Load Config Spreadsheet**”. Click **Import** to import fifteen 4 port Touchstone files (*.s4p), then click **Check Compliance** for pass/fail judgment.



- After completed the measurement, Press **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** check “**Enable Port Z Conversion (all ports)**” to turn ON Port Z conversion as default setting.

5.5 Differential-to-common-mode conversion

The main purpose of this requirement is to limit the cable assembly EMI emission.

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Rx+	TF2 Rx-

- Select **Trace 10 (Scd21)**.
- Press **Trigger** > Single. Press Double-click on the instrument front panel to enlarge the trace.
- Confirm the measured differential to common mode conversion is less than or equal to -20 dB across the frequency range from 100 MHz to 10 GHz.

Note: The conversion does not require embedding the reference host and the reference device with the mated cable assembly; it is for the mated cable assembly only.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
Type-C to Type-C passive cable assembly	100 MHz	10 GHz	-17.00 dB	-17.00 dB
Type-C to legacy cable assembly	100 MHz	10 GHz	-20.00 dB	-20.00 dB
Type-C to legacy adapter assembly	100 MHz	7.5 GHz	-15.00 dB	-15.00 dB

- Repeat the same operation of step 3 to step 4 for all the combinations below to confirm the measured differential-to-common-mode conversion is within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Tx+	TF2 Tx-

5.6 Cable shielding effectiveness

Shielding Effectiveness is checked with a standard compliance tool (IntePar.exe) provided by USB IF after the measurements have made using a shielding effectiveness test fixture. Download the tool from USB-IF link: https://compliance.usb.org/files/IntePar_1p6.zip (Released 3-Jan-2021)

4 port Touchstone files (*.s4p) is measured and saved by the VNA firmware, and then imported by the compliance tool to conduct cable assembly compliance tests. The manual measurement procedure using the ENA Option TDR is also supported with the limit lines.

Note: The Port Z conversion is turned off, so the measurements are performed based on 50-ohm port impedance setting required by the standard tool.

- Connect the VNA ports (port 1 to 3) to the test fixture ports with RF cables.

VNA Port#	Port 1 (SE)	Port 2 (Bal+)	Port 3 (Bal-)
Test Fixtures	SE	Tx1+	Tx1-

- Press **Meas** > Balanced > Topology > SE-BAL
- In the setup table, select Balanced Port > 1 SE = Port 1 (VNA+).

4. In the setup table, select Balanced port > 2 BAL = Port 2 (VNA+) & Port 3 (VNA-) as shown below.

Balanced Setup

Topology Port Z

Topology SE-BAL

Balanced Port	VNA (+)Port	VNA (-)Port	True Mode
1 SE	Port 1	-	<input type="checkbox"/>
2 BAL	Port 2	Port 3	<input type="checkbox"/>
3 Unused	-	-	<input type="checkbox"/>
4 Unused	-	-	<input type="checkbox"/>

5. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** uncheck “Enable Port Z Conversion (all ports)” to turn OFF Port Z conversion.

Port Z Conversion

Check/Uncheck to turn-on/off

☒ Enable Port Z Conversion (all ports)

Port 1 R: 42.500 ohms jX: 0.000 ohms

Close Help

6. Click Adv Waveform tab > De-embedding and turn off De Embedding.

Advanced Waveform

Tx Jitter Emphasis Differential DUT Equalization Rx

De-embedding

Enable

Click De-embedding box to set a file

Select De-embedding File

Port1 Port2 Port3 Port4

Diff Port1 Diff Port2

Enable

Load

7. Press **Trace Next** to select **Trace 13 (Sds21)**
8. Press **Trigger** > Single.
9. Press **Trace Next** to select **Trace 14 (Scs21)**
10. Press **Meas** > Balanced > Other > Scs21
11. Press **Trigger** > Single

12. Confirm the measured Sds21/Scs21 is within the limits shown below.

Differential model (Sds21)

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
Type-C to Type-C passive cable assembly	10.0 MHz	1.6 GHz	-55.0 dB	-55.0 dB
	1.6 GHz	4.0 GHz	-50.0 dB	-50.0 dB
	5.0 GHz	6.0 GHz	-50.0 dB	-50.0 dB
Type-C to legacy cable assembly	10.0 MHz	1.6 GHz	-49.0 dB	-49.0 dB
	1.6 GHz	4.0 GHz	-44.0 dB	-44.0 dB
	5.0 GHz	6.0 GHz	-44.0 dB	-44.0 dB
Type-C to legacy adapter assembly	10.0 MHz	1.6 GHz	-44.0 dB	-44.0 dB
	1.6 GHz	4.0 GHz	-39.0 dB	-39.0 dB
	5.0 GHz	6.0 GHz	-39.0 dB	-39.0 dB

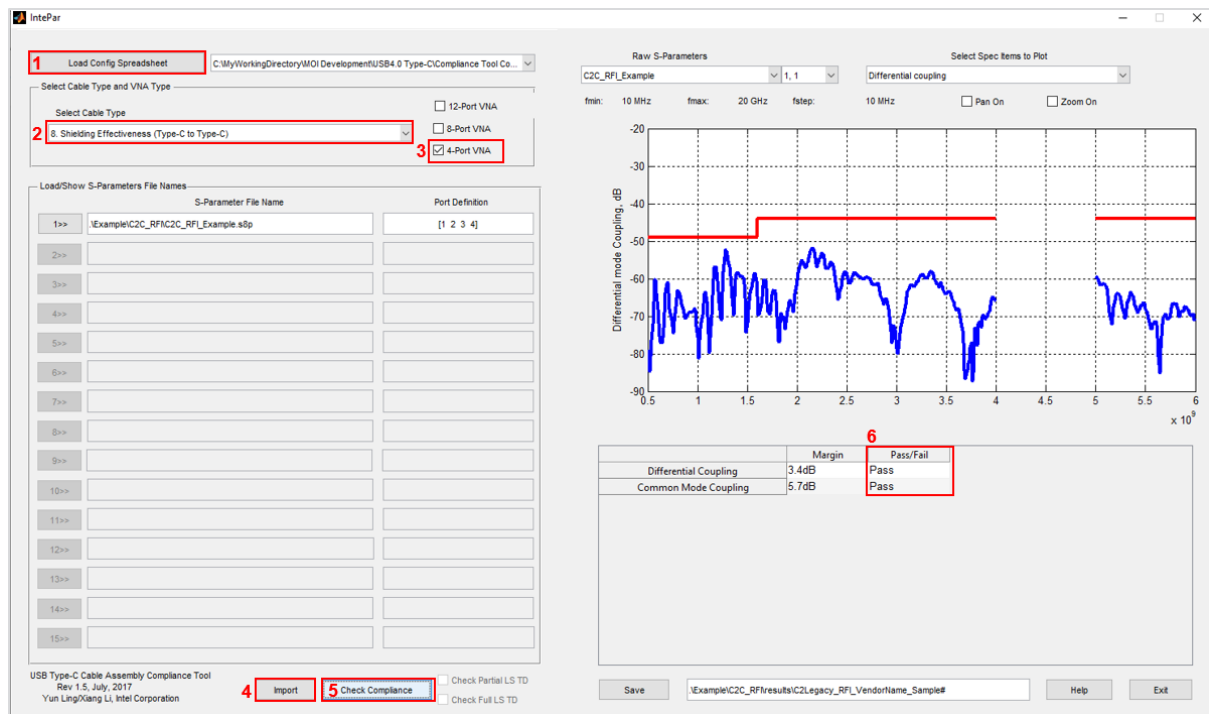
Common model (Scs21)

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
Type-C to Type-C passive cable assembly	10.0 MHz	1.6 GHz	-40.0 dB	-40.0 dB
	1.6 GHz	4.0 GHz	-35.0 dB	-35.0 dB
	5.0 GHz	6.0 GHz	-35.0 dB	-35.0 dB
Type-C to legacy cable assembly	10.0 MHz	1.6 GHz	-34.0 dB	-34.0 dB
	1.6 GHz	4.0 GHz	-29.0 dB	-29.0 dB
	5.0 GHz	6.0 GHz	-29.0 dB	-29.0 dB
Type-C to legacy adapter assembly	10.0 MHz	1.6 GHz	-24.0 dB	-24.0 dB
	1.6 GHz	4.0 GHz	-24.0 dB	-24.0 dB
	5.0 GHz	6.0 GHz	-24.0 dB	-24.0 dB

13. Press **Save Recall** > **Save Other** > **Save Data...** > **Filename [1-2-3-4].s4p** to save the measured Touchstone file (*.s4p). Select format "Real/Imaginary".
14. Repeat the same operation of step 10 to step 11 for all the following combinations to confirm the measured Sds21/Scs21 is within the specification.

VNA Port#	Port 1 (SE)	Port 2 (Bal+)	Port 3 (Bal-)
Test Fixtures	SE	Rx1+	Rx1-

15. Launch compliance tool and select "**9. Shielding Effectiveness (Type-C to Legacy)**" for "Select Cable Type", check "**4-Port VNA**". Load 4 port Touchstone file (*.s4p) by clicking "1>>", click "Import" to import 4-port Touchstone file (*.s4p), then click "Check Compliance" for pass/fail judgment.



16. Press **Meas** > Balanced> Topology > BAL-BAL to reset the setting.
17. In the setup table, select Balanced Port > 1 BAL = Port 1 (VNA+) & Port 2 (VNA-)
18. In the setup table, select Balanced port > 2 BAL = Port 3 (VNA+) & Port 4 (VNA-) as shown below
19. Press Analysis > Fixture Simulator > De Embedding to turn on De Embedding.

Balanced Setup

Topology Port Z

Topology BAL-BAL

Balanced Port	VNA (+)Port	VNA (-)Port	True Mode
1 BAL	Port 1	Port 2	<input type="checkbox"/>
2 BAL	Port 3	Port 4	<input type="checkbox"/>
3 Unused	-	-	<input type="checkbox"/>
4 Unused	-	-	<input type="checkbox"/>

20. After completed the measurement, Press **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** check “**Enable Port Z Conversion (all ports)**” to turn ON Port Z conversion as default setting.

Informative measurements

Informative electrical performance targets are provided for raw cables mated connectors and mated cable assemblies. These targets are not part of the USB Type-C compliance requirements but provided for the purpose of design guidelines and manufacturing control. For [Raw Cable] and [Mated Connector] measurements, apply the appropriate calibration depending on the test fixture and also set the appropriate port-Z conversion by pressing Channel Next to select Channel 2 frequency domain measurements, then **Cal > Fixtures > Fixture Setup > Port Z...** Set Port Z Conversion (45-ohm for all Port1 /2/3/4 Z0 Real for [Raw Cable] and 42.5-ohm for all Port1/2/3/4 Z0 Real for [Mated Connector].

5.6 [Raw cable] differential impedance (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	A Side Tx1+	A Side Tx1-	B Side Tx1+	B Side Tx1-

2. Press **Channel Next** to select Channel 1
3. Select **Trace 2 (Tdd11)**.
4. Double-click the Trace to maximize the selected trace on the screen.
5. Click Stop Single.
6. Confirm the measured impedance is within the limit shown below. Otherwise, it will show Fail.
7. Select **Trace 6 (Tdd22)** and repeat Step 4-5 for far-end of the DUT.

DUT Type	Max Limit	Min Limit
Shielded Differential Pair (SDP)	95 Ω	85 Ω
Single-ended coaxial SS+ signal wires	48 Ω	42 Ω

Note: The impedance should be evaluated using a 200ps (10%-90%) rise time.

8. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	A Side Rx1+	A Side Rx1-	B Side Rx1+	B Side Rx1-

9. Repeat the same operation of step 3 to step 7 to confirm the measured impedance for Rx pair is within the specification.

5.7. [Raw cable] intra-pair skew (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	A Side Tx1+	A Side Tx1-	B Side Tx1+	B Side Tx1-

2. Press Double-click on the instrument front panel to enlarge the trace.
3. Select **Trace 3 (T31)**.
4. Click **Stop Single**.
5. Read the Delta Time and confirm the measured value is within the limit shown below. Otherwise, Fail.

Test Limit
If Delta Time < 10 psec: Pass, else: Fail

Note: The measurement should be evaluated using a 200ps (10%-90%) rise time.

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	A Side Rx1+	A Side Rx1-	B Side Rx1+	B Side Rx1-

- Repeat the same operation of step 3 to step 5 to confirm the measured skew for Rx pair is within the specification.

5.8 [Raw cable] differential insertion loss (informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
RF Connection	A Side Tx1+	A Side Tx1-	B Side Tx1+	B Side Tx1-

- Press **Channel Next** to select Channel 2.
- Select **Trace 9 (Sdd21)**.
- Press **Trigger** > Single
- Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail. Change and set the limit according to DUT type. (Refer Manual setup section on Defining limit line).

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
Twisted Pair Construction (34AWG)	625 MHz	1.25 GHz	-1.8 dB	-2.5 dB
	1.25 GHz	2.50 GHz	-2.5 dB	-3.7 dB
	2.50 GHz	5.00 GHz	-3.7 dB	-5.5 dB
	5.00 GHz	7.50 GHz	-5.5 dB	-7.0 dB
	7.50 GHz	10.00 GHz	-7.0 dB	-8.4 dB
	10.00 GHz	12.50 GHz	-8.4 dB	-9.5 dB
	12.50 GHz	15.00 GHz	-9.5 dB	-11.0 dB
Coaxial Construction (34 AWG)	625 MHz	1.25 GHz	-1.8 dB	-2.8 dB
	1.25 GHz	2.50 GHz	-2.8 dB	-4.2 dB
	2.50 GHz	5.00 GHz	-4.2 dB	-6.1 dB
	5.00 GHz	7.50 GHz	-6.1 dB	-7.6 dB
	7.50 GHz	10.00 GHz	-7.6 dB	-8.8 dB
	10.00 GHz	12.50 GHz	-8.8 dB	-9.9 dB
	12.50 GHz	15.00 GHz	-9.9 dB	-12.1 dB

Note: The limit is based on 34 AWG conductor size. Change and set the test limit based on DUT type limit below (34AWG/32AWG/30AWG/28AWG) as stated in USB Type-C CTS.

Table 3-21 Differential Insertion Loss Examples for TX/RX 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

Table 3-22 Differential Insertion Loss Examples for USB TX/RX 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

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
RF Connection	A Side Rx1+	A Side Rx1-	B Side Rx1+	B Side Rx1-

- Repeat the same operation of step 3 to step 5 to confirm the measured insertion loss is within the specification.

5.9 [Mated connector] differential impedance (informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Tx1+	TF2 Tx1-

- Press **Channel Next** to select Channel 1
- Select **Trace 15 (Tdd11)**. Change and set the limit according to table below (Refer Manual setup section on Defining limit line).
- Double-click the Trace to maximize the selected trace on the screen.
- Click Stop Single.
- Confirm the measured impedance is within the limit shown below. Otherwise, it will show Fail.

7. Select **Trace 16 (Tdd22)**. Repeat Step 4-5 for far-end of the DUT.

DUT Type	Max Limit	Min Limit
Mated connector – USB 3.2 Gen2 and USB4 Gen2	94 Ω	76 Ω

Note: The impedance should be evaluated using a 40ps (20%-80%) rise time.

8. Repeat the same operation of step 3 to step 7 to confirm the measured impedance for following combinations are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Rx1+	TF2 Rx1-
	TF1 Tx2+	TF1 Tx2-	TF2 Tx2+	TF2 Tx2-
	TF1 Rx2+	TF1 Rx2-	TF2 Rx2+	TF2 Rx2-

5.10 [Mated connector] differential insertion loss (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Tx1+	TF2 Tx1-

- 6 Press Channel Next to select Channel 2.
- 7 Select **Trace 12 (Sdd21)**.
- 8 Press **Trigger** > Single
- 9 Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail.

Start Frequency	End Frequency	Start Limit	End Limit
100 MHz	2.50 GHz	-0.6 dB	-0.6 dB
2.50 GHz	5.00 GHz	-0.6 dB	-0.8 dB
5.00 GHz	10.00 GHz	-0.8 dB	-1.0 dB
10.00 GHz	12.50 GHz	-1.0 dB	-1.25 dB
12.50 GHz	15.00 GHz	-1.25 dB	-1.50 dB

- 10 Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Repeat the same operation of step 3 to step 5 to confirm the measured values are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Rx1+	TF2 Rx1-
	TF1 Tx2+	TF1 Tx2-	TF2 Tx2+	TF2 Tx2-
	TF1 Rx2+	TF1 Rx2-	TF2 Rx2+	TF2 Rx2-

5.11 [Mated connector] differential return loss (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Tx1+	TF2 Tx1-

2. Press Channel Next to select Channel 2.
3. Select **Trace 17 (Sdd11)**.
4. Press **Trigger** > Single

- Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail.

Start Frequency	End Frequency	Start Limit	End Limit
100 MHz	5 GHz	-20 dB	-20 dB
5 GHz	10 GHz	-20 dB	-13 dB
10 GHz	15 GHz	-13 dB	-6 dB

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Repeat the same operation of step 3 to step 5 to confirm the measured values are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Rx1+	TF2 Rx1-
	TF1 Tx2+	TF1 Tx2-	TF2 Tx2+	TF2 Tx2-
	TF1 Rx2+	TF1 Rx2-	TF2 Rx2+	TF2 Rx2-

5.12 [Mated connector] differential NEXT & FEXT between SS signal pairs (informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF1 Rx1+	TF1 Rx1-

- Press **Channel Next** to select Channel 2.
- Select **Trace 18 (Sdd21)**.
- Press **Trigger** > Single
- Run and confirm the measured differential crosstalk is within limit below. Otherwise, it will show Fail.

Start Frequency	End Frequency	Start Limit	End Limit
100 MHz	5 GHz	-40 dB	-40 dB
5 GHz	10 GHz	-40 dB	-36 dB
10 GHz	15 GHz	-36 dB	-30 dB

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Repeat the same operation of step 3 to step 5 to confirm the measured value is within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Rx1+	TF2 Rx1-
	TF2 Tx1+	TF2 Tx1-	TF2 Rx1+	TF2 Rx1-
	TF2 Tx1+	TF2 Tx1-	TF1 Rx1+	TF1 Rx1-
	TF1 Tx2+	TF1 Tx2-	TF1 Rx2+	TF1 Rx2-
	TF1 Tx2+	TF1 Tx2-	TF2 Rx2+	TF2 Rx2-
	TF2 Tx2+	TF2 Tx2-	TF2 Rx2+	TF2 Rx2-
	TF2 Tx2+	TF2 Tx2-	TF1 Rx2+	TF1 Rx2-
	TF2 Tx2+	TF2 Tx2-	TF1 Rx2+	TF1 Rx2-

5.13 [Mated connector] differential NEXT and FEXT between D+/D pair and SS signal pairs (informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 D+	TF1 D-	TF1 Tx1+-	TF1 Tx1-

- Press **Channel Next** to select Channel 2.

3. Select **Trace 19 (Sdd21)**.
4. Press **Trigger** > Single
5. Run and confirm the measured differential crosstalk is less than or equal to -30dB up to 5GHz. Otherwise, it will show Fail.

Start Frequency	End Frequency	Start Limit	End Limit
100 MHz	5 GHz	-40 dB	-40 dB
5 GHz	7.5 GHz	-40 dB	-36 dB

6. Repeat the same operation of step 3 to step 5 for all the following combinations to confirm the measured crosstalk is within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 D+	TF1 D-	TF1 Rx1+	TF1 Rx1-
	TF1 D+	TF1 D-	TF2 Tx1+	TF2 Tx1-
	TF1 D+	TF1 D-	TF2 Rx1+	TF2 Rx1-
	TF1 D+	TF1 D-	TF1 Tx2+	TF1 Tx2-
	TF1 D+	TF1 D-	TF1 Rx2+	TF1 Rx2-
	TF1 D+	TF1 D-	TF2 Tx2+	TF2 Tx2-
	TF1 D+	TF1 D-	TF2 Rx2+	TF2 Rx2-
	TF2 D+	TF2 D-	TF2 Tx1+	TF2 Tx1-
	TF2 D+	TF2 D-	TF2 Rx1+	TF2 Rx1-
	TF2 D+	TF2 D-	TF1 Tx1+	TF1 Tx1-
	TF2 D+	TF2 D-	TF1 Rx1+	TF1 Rx1-
	TF2 D+	TF2 D-	TF2 Tx2+	TF2 Tx2-
	TF2 D+	TF2 D-	TF2 Rx2+	TF2 Rx2-
	TF2 D+	TF2 D-	TF1 Tx2+	TF1 Tx2-
	TF2 D+	TF2 D-	TF1 Rx2+	TF1 Rx2-

5.14 [Mated connector] differential to common-mode conversion (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Tx1+	TF2 Tx1-

7. Press Channel Next to select Channel 2.
8. Select **Trace 20 (Scd21)**.
9. Press **Trigger** > Single.
10. Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail.

Start Frequency	End Frequency	Start Limit	End Limit
100 MHz	2.5 GHz	-30 dB	-30 dB
2.5 GHz	7.5 GHz	-25 dB	-25 dB
7.5 GHz	10 GHz	-20 dB	-20 dB

- Repeat the same operation of step 3 to step 5 to confirm the measured values are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Rx1+	TF2 Rx1-
	TF1 Tx2+	TF1 Tx2-	TF2 Tx2+	TF2 Tx2-
	TF1 Rx2+	TF1 Rx2-	TF2 Rx2+	TF2 Rx2-

5.15 Differential Insertion Loss (Informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Rx+	TF2 Rx-

- Press Channel Next to select Channel 2.
- Select **Trace 21 (Sdd21)**.
- Press **Trigger** > Single
- Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
USB Type-C to Legacy USB3.1 Std-AA Adapter	100 MHz	2.5 GHz	-2.4 dB	-2.4 dB
	2.5 GHz	5.0 GHz	-2.4 dB	-3.5 dB

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Repeat the same operation of step 3 to step 5 to confirm the measured values are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Tx+	TF2 Tx-

5.16 Differential return loss (informative)

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF2 Rx+	TF2 Rx-

- Press Channel Next to select Channel 2.
- Select **Trace 22 (Sdd11)**.
- Press **Trigger** > Single
- Run and confirm the measured value is within the limit shown below. Otherwise, it will show Fail.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
USB Type-C to Legacy USB3.1 Std-AA Adapter	100 MHz	5.0 GHz	-15 dB	-15 dB

- Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Repeat the same operation of step 3 to step 5 to confirm the measured values are within the specification.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Rx1+	TF1 Rx1-	TF2 Tx+	TF2 Tx-

5.17 Differential NEXT between SS signal pairs (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 Tx1+	TF1 Tx1-	TF1 Rx1+	TF1 Rx1-

2. Press **Channel Next** to select Channel 2.
3. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “42.5-ohm” for all Port-3 Z0 Real.
4. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “42.5-ohm” for all Port-4 Z0 Real.
5. Select **Trace 23 (Sdd21)**.
6. Press **Trigger** > Single
7. Run and confirm the measured differential crosstalk is within limit below. Otherwise, it will show Fail.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
USB Type-C to Legacy USB3.1 Std-A Adapter	100 MHz	2.5 GHz	-40 dB	-40 dB
	2.5GHz	5.0 GHz	-40 dB	-34 dB

8. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF2 Tx+	TF2 Tx-	TF2 Rx+	TF2 Rx-

9. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 1 R**: Impedance to “45-ohm” for all Port-1 Z0 Real.
10. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 2 R**: Impedance to “45-ohm” for all Port-2 Z0 Real.
11. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “45-ohm” for all Port-3 Z0 Real.
12. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “45-ohm” for all Port-4 Z0 Real.
13. Press **Trigger** > Single and confirm the value is within the limit.
14. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 1 R**: Impedance to “42.5-ohm” for all Port-1 Z0 Real.
15. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 2 R**: Impedance to “42.5-ohm” for all Port-2 Z0 Real.

5.18 Differential NEXT and FEXT between D+/D- pair and SS signal pairs (informative)

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 D+	TF1 D-	TF1 Tx1+	TF1 Tx1-

2. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “42.5-ohm” for all Port-3 Z0 Real.
3. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “42.5-ohm” for all Port-4 Z0 Real.

4. Press **Channel Next** to select Channel 2. Select **Trace 24 (Sdd21)**.
5. Press **Trigger** > Single
6. Run and confirm the measured differential crosstalk is within limit below. Otherwise, it will show Fail.

DUT Type	Start Frequency	End Frequency	Start Limit	End Limit
USB Type-C to Legacy USB3.1 Std-A Adapter	100 MHz	2.5 GHz	-30 dB	-30 dB

7. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixtures	TF1 D+	TF1 D-	TF1 Rx1+	TF1 Rx1-

8. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
9. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 D+	TF1 D-	TF2 Tx+	TF2 Tx-

10. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “45-ohm” for all Port-3 Z0 Real.
11. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “45-ohm” for all Port-4 Z0 Real.
12. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
13. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 D+	TF1 D-	TF2 Rx+	TF2 Rx-

14. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
15. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF2 D+	TF2 D-	TF2 Tx+	TF2 Tx-

16. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 1 R**: Impedance to “45-ohm” for all Port-1 Z0 Real.
17. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 2 R**: Impedance to “45-ohm” for all Port-2 Z0 Real.
18. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
19. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF2 D+	TF2 D-	TF2 Rx+	TF2 Rx-

20. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
21. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF2 D+	TF2 D-	TF1 Tx1+	TF1 Tx1-

22. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “42.5-ohm” for all Port-3 Z0 Real.
23. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “42.5-ohm” for all Port-4 Z0 Real.
24. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
25. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables.

VNA Port#	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF2 D+	TF2 D-	TF1 Rx1+	TF1 Rx1-

26. Repeat the same operation of step 5 to step 6 to confirm the measured crosstalk is within the specification.
27. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 1 R**: Impedance to “42.5-ohm” for all Port-1 Z0 Real.
28. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 2 R**: Impedance to “42.5-ohm” for all Port-2 Z0 Real.
29. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 3 R**: Impedance to “45-ohm” for all Port-3 Z0 Real.
30. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** > Set **Port Z Conversion** > **Port 4 R**: Impedance to “45-ohm” for all Port-4 Z0 Real.

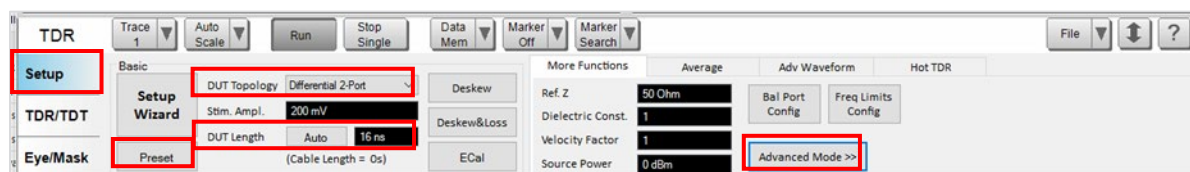
6. Manual Setup

The procedures of manual setup for time domain and frequency domain measurements are introduced in this section for reference. All the required testing parameters have been properly set and saved in the respective standards testing state file (*.tdr).

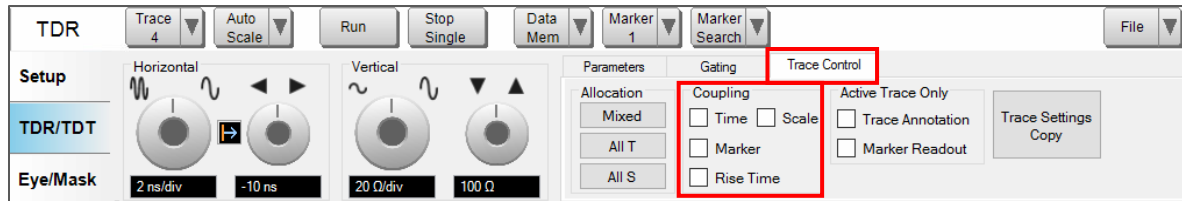
6.1. Channel & trace setup

If TDR setup wizard is shown when launching the TDR software, click **Close** button in the TDR setup wizard main window.

1. Open **Setup** tab in the TDR software
2. Click **Preset** to preset the instrument Click OK in a dialog box to continue.
3. Set **DUT Topology** to “**Differential 2 Port**” Click OK in a dialog box.
4. Click **Advanced Mode>>** and click Yes to enter to Advanced mode.



5. Click **Stop Single**.
6. Set DUT Length to “16 ns”.
7. Open **TDR/DTT** tab.
8. Click **Trace Control** tab.
9. Clear **Time**, **Marker**, **Rise Time** & **Scale** check box under Coupling.

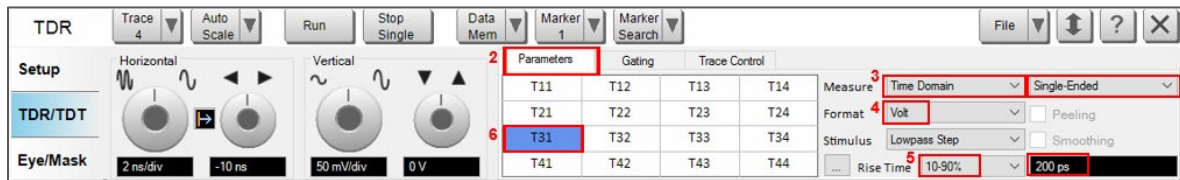


Note:

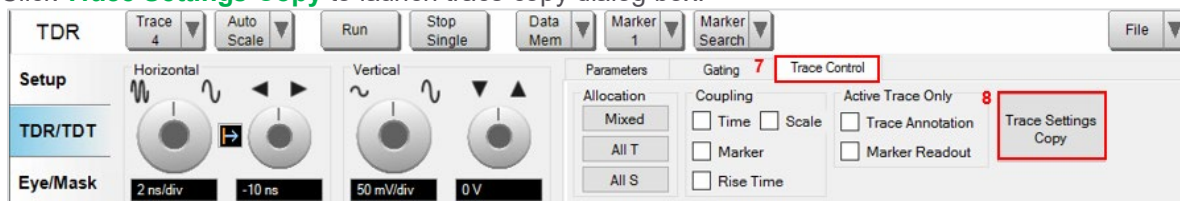
- Selecting **Marker** under **Coupling** will enable all the marker on other traces to be moved in same alignment.
- Selecting **Time** under **Coupling** will enable all other traces using the same X axis (Time).
- Selecting **Rise Time** under **Coupling** will enable all other traces using the same rise time.
- Selecting **Scale** under **Coupling** will enable all other traces using the same scale.

6.2. D+/D- intra-pair skew

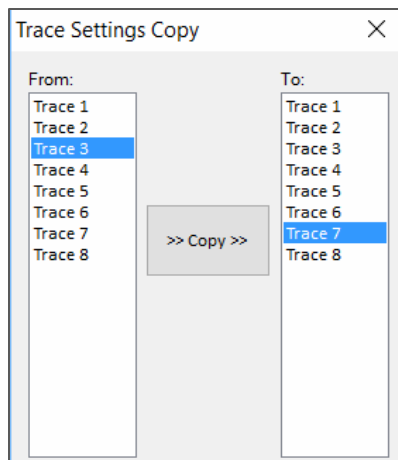
1. Select **Trace 3**.
2. Open **Parameters** tab.
3. Select "**Time Domain**" and "**Single-Ended**" for Measure.
4. Select Formant to "**Volt**".
5. Select **Rise Time** to "**20-80%**" and input value to 400 ps (follow rise time setting in Table 4.1).
6. Click **T31**.



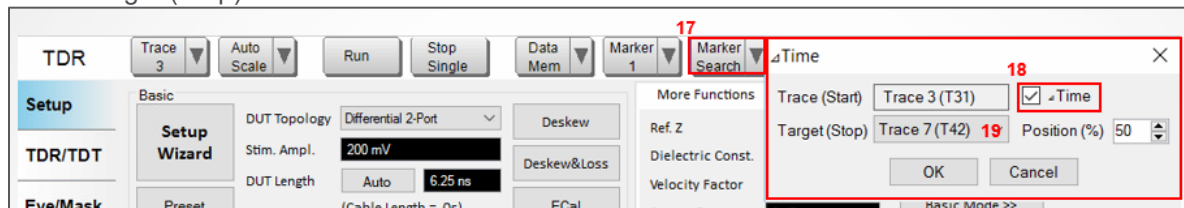
7. Open **Trace Control** tab.
8. Click **Trace Settings Copy** to launch trace copy dialog box.



9. Select **Trace 3** in the From list.
10. Select **Trace 7** in the To list.
11. Click **Copy**.
12. Click **Close**.

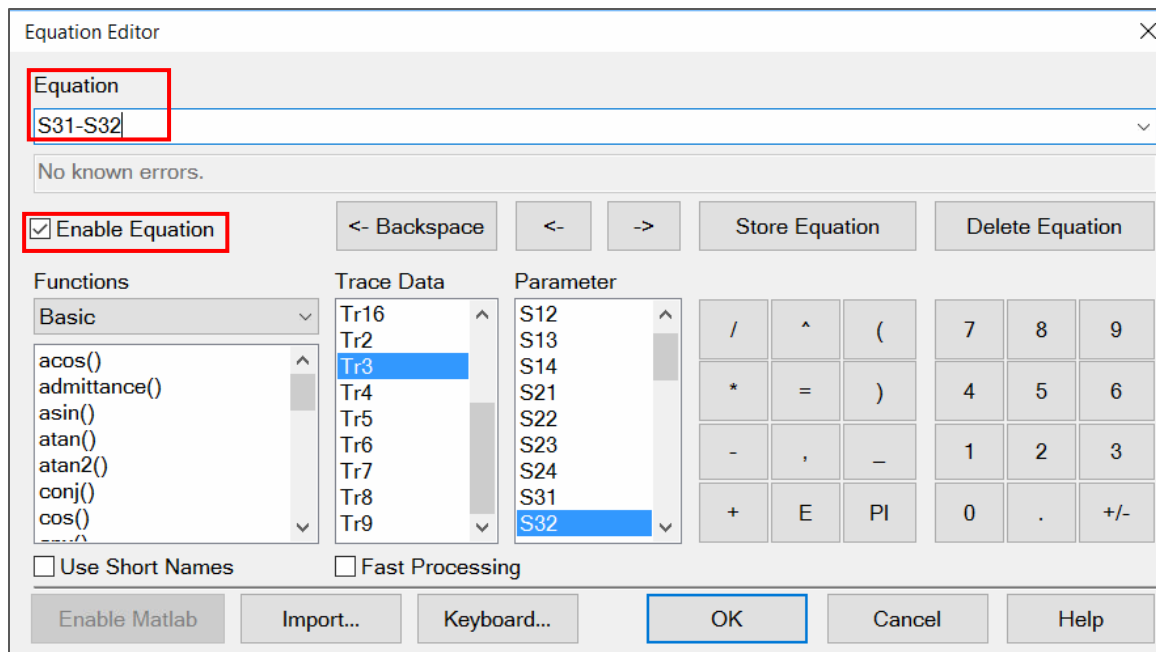


13. Select **Trace 7**.
14. Open **Parameters** tab.
15. Click **T42**
16. Select **Trace 3 (T31)**
17. Click Marker Search and select Δ Time
18. Check Δ Time
19. Select Target (Stop) to **Trace 7** and click OK



6.3 Crosstalk compensation

1. Select **Trace 3**.
2. Press **Math > Analysis > Equation Editor...** Enter an equation "**S31-S32**".
3. Check **Enabled** to enable the equation on trace.
4. Click **Apply**.
5. Click **Close**.
6. Select **Trace 7**.
7. Press **Math > Analysis > Equation Editor...** Enter an equation "**S42-S41**".
8. Check **Enabled** to enable the equation on trace.
9. Click **Apply**.
10. Click **Close**.

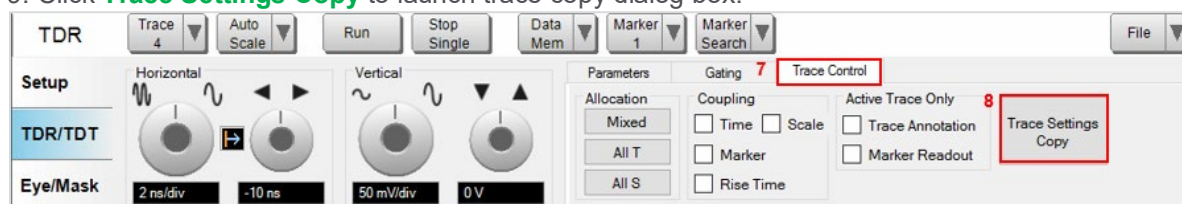


6.4 D+/D- pair propagation delay

1. Select **Trace 4**.
2. Open **Parameters** tab.
3. Select **"Time Domain"** and **"Differential"** for Measure.
4. Select Formant to **"Volt"**.
5. Select **Rise Time** to **"20-80%"** and input value **"400 ps"** (follow raise time requirement by USB.org).
6. Click **Tdd21**.
7. Input vertical scale (100 mV/div) and vertical position (200 mV).
8. Press **Search> Target> Target Value** and enter 200 mV.
9. Press **Search> Target> Tracking> Target** to turn on **Tracking**.

6.5 D+/D- differential impedance

1. Select **Trace 1 (Trace 2/Trace 15)**.
2. Open **Parameters** tab.
3. Select **"Time Domain"** and **"Differential"** for Measure.
4. Select Formant to **"Impedance"**.
5. Select **Rise Time** to **"20-80%"** and input value **"400 ps"** (follow raise time requirement by USB.org).
6. Click **Tdd11**.
7. Input vertical scale (10 Ohm/div) and vertical position (50 Ohm).
8. Open **Trace Control** tab.
9. Click **Trace Settings Copy** to launch trace copy dialog box.



10. Select **Trace 1 (Trace 2/Trace 15)** in the From list.
11. Select **Trace 5 (Trace 6/Trace 16)** in the To list.
12. Click **Copy**.
13. Click **Close**.
14. Select **Trace 5 (Trace 6/Trace 16)**.
15. Open **Parameter** tab.
16. Click **Tdd22**.

6.6 Common parameters setup for frequency-domain measurements

1. Press **Channel Next** to select Channel 2.
2. Select **Sweep** > Sweep Setup and key-in sweep properties as below:
 - Set **Start** value to “10 MHz”.
 - Set **Stop** value to “20 GHz”.
 - Set **Points** and set to “1500”.
 - Set **IF Bandwidth** to “1 kHz”.

The screenshot shows the 'Sweep Setup' dialog box with the 'Sweep Type' tab active. Under 'Sweep Type', 'Linear Frequency' is selected. The 'Sweep Properties' section contains the following settings:

Property	Value
Start	10.000000 MHz
Stop	19.99998000 GHz
Power	0.00 dBm
Points	1500
IF Bandwidth	1.0 kHz

7. Select **Cal** > **Fixtures** > **Fixture Setup** > **Port Z...** Select and check “**Enable Port Z Conversion (all ports)**” to turn ON Port Z conversion.
8. Set **Port impedance** to “42.5-ohm” for all Port1/2/3/4 Z0 Real.
Note: 45-ohm for [Raw Cable] and 42.5-ohm for [Mated Connector].

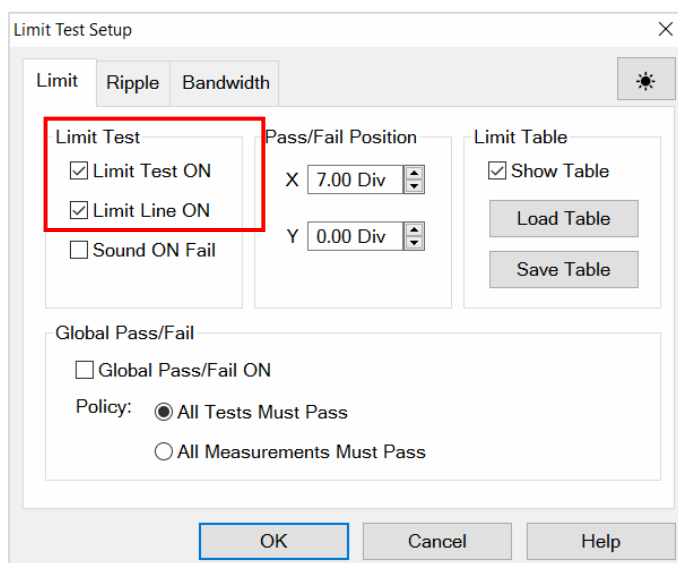
The screenshot shows the 'Port Z Conversion' dialog box. The 'Enable Port Z Conversion (all ports)' checkbox is checked. Below it, the 'Port 1' dropdown is set to 'Port 1', 'R' is 42.500 ohms, and 'jX' is 0.000 ohms. The 'Close' button is highlighted with a blue border.

6.7 Defining limit line tables

1. Press **Trace Next** to select trace to set the limit line table.
2. Press **Math > Analysis > Limit Table >** to edit the limit table.

	Type	Begin Stimulus	End Stimulus	Begin Response	End Response
1	Min	100.0000 MHz	5.00000 GHz	-35.0000 dB	-35.0000 dB
2	Min	5.00000 GHz	7.50000 GHz	-35.0000 dB	-30.0000 dB
3	Off	0.000000 Hz	0.000000 Hz	0.000000 dB	0.000000 dB

3. Press **Math > Analysis > Limit...** > to launch Limit Test Setup window.
4. Select to turn on “Limit Test ON” and “Limit Line ON”, optional to turn on “Sound ON Fail”.



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

Learn more at: www.keysight.com

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