Method of Implementation (MOI)
USB 3.0 Connectors and Cable Assemblies
Compliance Tests
Using Keysight Network Analyzer with Enhanced TDR App
# Table of Contents

1. Revision History ........................................................................................................... 3  
2. Configuration Requirements ........................................................................................ 4  
3. Test Flow Chart .............................................................................................................. 5  
   3.1 Test Flow Chart ........................................................................................................... 5  
   3.2 Test Port Cable and Fixture Connection ...................................................................... 6  
   3.3 Description of Measurement Window ........................................................................... 8  
4. Measurement Setups ........................................................................................................ 9  
   4.1 Recalling a State File ................................................................................................... 9  
   4.2 Perform Calibration Setup .......................................................................................... 11  
   4.2.1. ECal Calibration and De-embedding ................................................................... 11  
   4.2.2 TRL Calibration ..................................................................................................... 15  
   4.2.3. Adjustment of Effective Rise Time ....................................................................... 16  
5. Measurement and Data Analysis ...................................................................................... 19  
   5.1 [Mated Connector] Differential Impedance ................................................................ 19  
   5.2 [Raw Cable] Impedance ............................................................................................. 19  
   5.3 SS Lines Propagation Delay Skew .............................................................................. 20  
   5.4 Differential Insertion Loss (Frequency Domain Analysis) ........................................ 20  
   5.5 Differential-to-Common-Mode Conversion (Frequency Domain Analysis) ............. 20  
   5.6 Near End Crosstalk .................................................................................................... 20  
   5.7. Crosstalk Between D+/D- and Super Speed ............................................................... 21  
   5.8. D+/D- Pair Propagation Delay .................................................................................. 22  
   5.9 D+/D- Pair Propagation Delay Skew .......................................................................... 22  
   5.10 D+/D- Pair Attenuation (Frequency Domain Analysis) ........................................... 23  
   6.1. Channel & Trace Setup .............................................................................................. 24  
   6.2. D+/D-Pair Propagation Delay and Propagation Delay Skew .................................... 24  
   6.3 Crosstalk Compensation ............................................................................................. 26  
   6.4 D+/D-Pair Propagation Delay .................................................................................... 26  
   6.5. Differential Crosstalk between D+/D- and SS Signal Pairs ........................................ 26  
   6.6 [Raw Cable] Characteristic Impedance (Informative) ................................................ 27  
   6.7 [Mated Connector] Impedance .................................................................................. 27  
   6.8 D+/D Pair Attenuation ............................................................................................... 28  
   6.9. Differential to Common-mode Conversion .................................................................. 28  
   6.10 [Raw Cable] Differential Insertion Loss (Informative) ............................................. 28  
   6.11 Defining Limit Line Tables ....................................................................................... 28  
Web Resources .................................................................................................................. 29
1. Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Comments</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>First draft for E5080B series</td>
<td>30-June-2020</td>
</tr>
</tbody>
</table>

Reference Documents

2. Universal Serial Bus 3.0 Connectors and Cable Assemblies Compliance Document.
## 2. Configuration Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Test Equipment</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Analyzer</td>
<td>Keysight Network Analyzer: (20 GHz is recommended as USB4/Type-C cable/connector requires measurements up to 20 GHz) • E5080B-4K0: 4-port test set, 9 kHz to 20 GHz or • P5024A-400 USB VNA or • M9804A-400 PXI Multiport VNA Note: Ensure that VNA firmware revision is at least version A.14.10 or above (Windows 10)</td>
<td>1 ea.</td>
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<tr>
<td>Software</td>
<td>S9x011A/B Enhanced time-domain analysis with TDR • Selection is based on the VNA platforms. x=6 for ENA, x=7 for Streamline USB, x=5 for PXI</td>
<td>1 ea.</td>
</tr>
<tr>
<td>ECal or Mechanical Cal Kit</td>
<td>N4433D-010/0DC 4-Ports Electronic Calibration (ECal) Module or 85052D Economy Mechanical Calibration Kit</td>
<td>1 ea.</td>
</tr>
<tr>
<td>Test Fixture</td>
<td>USB 3.0 official test fixture and calibration standards, or an equivalent set of fixtures and standards. List of calibration standards • Short • Thru • 1/2 Thru • Line 1, Line 2, Line 3</td>
<td>1 ea.</td>
</tr>
<tr>
<td>Adapter</td>
<td>3.5mm(f)-Type N(m) adapters (Keysight 1250-1744).</td>
<td>4 ea.</td>
</tr>
<tr>
<td>RF cable</td>
<td>3.5 mm or SMA cables of 4 GHz bandwidth or more • Y1740A-100 (3.5-mm m-m, 36 inch) cable is recommended for USB and PXI VNA</td>
<td>4 ea.</td>
</tr>
<tr>
<td>Terminator</td>
<td>50-ohm terminations to terminate unused channels (EG: Keysight 909D-301)</td>
<td>12 ea.</td>
</tr>
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</table>
3. Test Flow Chart

3.1 Test Flow Chart

1. Set measurement conditions.
2. Connect matched 3.5 mm cables to the test ports of the instrument.
3. For Time Domain Measurements, perform Electronic Calibration (ECal) or Deskew & Loss Compensation and adjust the rise time on each trace.
4. For Frequency Domain Measurements, perform TRL calibration at the 3.5 mm cables for all ports.

5. **Perform Time Domain Measurements**
   - D+/D- Pair Intra-Pair Skew (USB 2.0 Normative)
   - D+/D- Pair Propagation Delay (USB 2.0 Normative)
   - [Mated Connector] Impedance (Normative)
   - Differential Near End Crosstalk between SS Pairs (Normative)
   - Differential Crosstalk Between D+/D- and Super Speed (Normative)
   - [Raw Cable] Characteristic Impedance (Informative)
   - SS Lines Intra-Pair Skew (Informative)

6. **Perform Frequency Domain Measurements**
   - D+/D- Pair Attenuation (USB 2.0 Normative)
   - Differential Insertion Loss (Normative)
   - Differential-to-Common-Mode Conversion (Normative)

**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)*
3.2 Test Port Cable and Fixture Connection

Cable under test will be tested in the following manner:

Example: Testing Insertion Loss.
Table 4.1 USB3.0 Connection by connector type

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>ENA Port #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>ENA Port #</td>
<td>1 2 3 4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connector Imp.</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y9 Y10</td>
<td>X8 X9 Y5 Y6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cable Imp.</td>
<td>Y5 Y6 X5 X6</td>
<td>Y6 Y7 X5 X6</td>
<td>Y8 Y9 X5 X6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-Pair Skew</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y5 Y6</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y5 Y6</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Mode Conversion</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y5 Y6</td>
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</tr>
<tr>
<td>Near End Crosstalk</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y5 Y6</td>
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<td></td>
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</tr>
<tr>
<td>Feature PIN Number</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y8 Y9</td>
<td>X8 X9 Y5 Y6</td>
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<td></td>
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</tr>
<tr>
<td>D+/D- and SS Crosstalk</td>
<td>X2 X3 X5 X6</td>
<td>X2 X3 X5 X6</td>
<td>X2 X3 X5 X6</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>D+/D- Propagation Delay</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D+/D- Intra-Pair Skew</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D+/D- Attenuation</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>Micro-AB(X) to Micro-AB(Y)</th>
<th>Micro-AB(X) to Standard-B(Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENA Port #</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Connector Imp.</td>
<td>X6 X7 Y9 Y10</td>
<td>X6 X7 Y8 Y9</td>
</tr>
<tr>
<td>Cable Imp.</td>
<td>Y6 Y7 X9 X10</td>
<td>Y5 Y6 X9 X10</td>
</tr>
<tr>
<td>Intra-Pair Skew</td>
<td>X6 X7 Y2 Y3</td>
<td>X6 X7 Y2 Y3</td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>X6 X7 Y2 Y3</td>
<td>X6 X7 Y2 Y3</td>
</tr>
<tr>
<td>Mode Conversion</td>
<td>X6 X7 Y2 Y3</td>
<td>X6 X7 Y2 Y3</td>
</tr>
<tr>
<td>Near End Crosstalk</td>
<td>X6 X7 Y9 Y10</td>
<td>X6 X7 Y9 Y10</td>
</tr>
<tr>
<td>Feature PIN Number</td>
<td>X6 X7 Y9 Y10</td>
<td>X6 X7 Y9 Y10</td>
</tr>
<tr>
<td>D+/D- &amp; and Crosstalk</td>
<td>X2 X3 X6 X7</td>
<td>X2 X3 X6 X7</td>
</tr>
<tr>
<td>D+/D- Propagation Delay</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
</tr>
<tr>
<td>D+/D- Intra-Pair Skew</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
</tr>
<tr>
<td>D+/D- Attenuation</td>
<td>X2 X3 X2 X3</td>
<td>X2 X3 X2 X3</td>
</tr>
</tbody>
</table>
3.3 Description of Measurement Window

The following figure is the description of the measurement window.

<table>
<thead>
<tr>
<th>CH1 Time Domain</th>
<th>CH2 Frequency Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Mated Connector] Impedance</td>
<td>[Raw Cable] Impedance</td>
</tr>
<tr>
<td>Tr1: Tdd11</td>
<td>Tr2: Tdd11</td>
</tr>
<tr>
<td>Tr6: Tdd22</td>
<td>Tr6: Tdd22</td>
</tr>
<tr>
<td>SS Lines Intra-Pair Skew</td>
<td>Near End Crosstalk</td>
</tr>
<tr>
<td>Tr3: T31</td>
<td>Tr4: Tdd21</td>
</tr>
<tr>
<td>Tr7: T42</td>
<td>Diff-to-Common Mode Conversion</td>
</tr>
<tr>
<td>D+/D- Intra-Pair Skew</td>
<td>D+/D- &amp; SS Crosstalk</td>
</tr>
<tr>
<td>D+/D- Propagation Delay</td>
<td>Tr8: Tdd21</td>
</tr>
<tr>
<td>Tr3: T31</td>
<td>D+/D- Attenuation</td>
</tr>
<tr>
<td>Tr7: T42</td>
<td>Tr10: Scd21</td>
</tr>
</tbody>
</table>

Normative and Informative parameters for the USB3.0 cable assembly

Actual measurement windows in the state file
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 USB3.0 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 Perform 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 for the USB3.0 connectors and cable assemblies compliance tests.

4.2.1. ECal Calibration and De-embedding

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.

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

**ECal Calibration on Time Domain:**

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.

**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 Touchstone file.
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#dee mbed
**Frequency-Domain Calibration**: ECal calibration and de-embedding for frequency-domain measurements are performed by the VNA firmware.

**ECal Calibration on Frequency Domain:**

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

![Select Calibration Ports and ECal Module](image)

**De-embedding on Frequency Domain (For 2-Ports File):**

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).
3. Continue the same for the other ports of the VNA.

![2 Port Deembedding](image)
De-embedding on Frequency Domain (For 4-Ports File):

1. Press Cal > Fixtures > Fixture Setup > N-port DeEmbed… and check on Enable De-embedding (all ports) to de-embed fixture trace.
2. Select Topology > A.
3. Select User S2P File and specify a 4-port de-embedding file (*.s2p).

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#dee mbed

4/6/8-Port De-embedding -
http://ena.support.keysight.com/e5080/manuals/webhelp/eng/index.htm#S3_Cals/Fixturing.htm#4- PortEmbed
4.2.2 TRL Calibration

TRL calibration is performed to remove the RF effects (i.e. mismatch, loss or delay) of RF cables and test fixtures. The definition file of TRL calibration standards is imported to the VNA, and TRL calibration is performed with the VNA firmware by measure the TRL calibration standards such as Thru, Short, Lines or Load. The calibration can be applied for the both channels, Channel 1 for time domain measurements and Channel 2 for frequency-domain measurements.

Selecting TRL Cal Kit

1. Press **Channel Next** to select Channel 1 or Channel 2
2. Press **Cal > Cal Sets & Cal Kits > Cal Kit...**
3. Select the Standard Cal Kits from the list and click **Insert...** and **OK**.

4. Confirm that the imported cal kit is set for the selected channel by pressing **Cal > Main > Basic Cal**
Performing TRL Calibration

The Thru, Reflect & Line/Match Calibration (TRL) Cal process can be done by SmartCal selection. It requires that you already have TRL calibration standards defined and included in a VNA cal kit.

1. Connect Thru standard of USB 3.0 TRL calibration kit to the VNA Port 1-4 with the RF cable.
2. Press Cal > Main > Other Cals > Smart Cal....
3. Select the DUT connectors and Cal Kit for each port. The LOWEST port number of each port pair MUST include TRL standards. TRL appears as the Cal Method.
4. Check Modify Cal, Next, then View/Modify to change default TRL options if necessary.
5. Follow the prompts to complete the calibration.
6. Check the accuracy of the calibration

4.2.3. Adjustment of Effective Rise Time

After performing the calibration, the effective rise time entering the USB 3.0 connector pins should adjusted for the specification in time domain measurements in Table 4.1 below.

1X Thru standard is connected to the VNA port with RF cables. DUT is disconnected during the adjustment procedure.

Table 4.1: Specification of Effective Rise Time

<table>
<thead>
<tr>
<th>Trace</th>
<th>Test Parameters</th>
<th>Rise Time %</th>
<th>Target Rise Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tr 3 &amp; 7</td>
<td>D+/D-Pair Propagation Delay Skew</td>
<td>10 –90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 4</td>
<td>D+/D-Pair Propagation Delay</td>
<td>10 –90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 4</td>
<td>Differential Near-End Crosstalk between SS Pairs</td>
<td>20 –80 %</td>
<td>50 ps</td>
</tr>
<tr>
<td>Tr 8</td>
<td>Differential Near-end &amp; Far-End Crosstalk between D+/D-and SS Signal Pairs</td>
<td>10 –90 %</td>
<td>500 ps</td>
</tr>
<tr>
<td>Tr 2 &amp; 6</td>
<td>[Raw Cable] Characteristic Impedance</td>
<td>10 –90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 1 &amp; 5</td>
<td>[Mated Connector] Differential Impedance</td>
<td>20 –80 %</td>
<td>50 ps</td>
</tr>
</tbody>
</table>

1. Press Channel Next to select Channel 1.
2. Double click to maximize the selected trace in the screen.
3. Open TDR/TDT tab.
4. Adjust effective rise time for each trace with the following procedure.

Trace 3 and Trace 7 for D+/D-Pair Propagation Delay Skew

a) Connect 1X Thru standard to the VNA port 1 (port 2) with the RF cable.
b) Click Trace 3 (Trace 7).
c) Click Parameter tab.
d) Select Measure to “Time Domain” and “Single-Ended”.
e) Select Format to “Volt”.
f) Click Marker Search and select “Rise Time (10–90%)”.
g) Click T11(T22).
h) Press Math > Analysis > Equation Editor... to disable/turn off the equation editor.
i) Click Run to measure the rise time on the screen.
j) Click Auto Scale and select “X&Y”.
k) Enter rise time until the measured rise time is close to the specified value (200 ps).
l) Click Marker Search and select “Rise Time (10–90%)” to turn off the marker.
m) Click T31(T42).
n) Press Math > Analysis > Equation Editor... to enable/turn on the equation editor.

Trace 4 for D+/D-Pair Propagation Delay
a) Connect 1X Thru standard to the VNA port 1 with the RF cable.
b) Click Trace 4.
c) Click Parameter tab.
d) Select Measure to “Time Domain” and “Single-Ended”.
e) Select Format to “Volf”.
f) Click Marker Search and select “Rise Time (10–90%)”.
g) Click T11.
h) Click Run to measure the rise time on the screen.
i) Click Auto Scale and select “X&Y”.
j) Enter rise time until the measured rise time is close to the specified value (200 ps).
k) Click Marker Search and select “Rise Time (10–90%)” to turn off the marker.
l) Select Measure to “Time Domain” and “Differential”. Select Format to “Impedance”.
m) Click Tdd21.

Trace 8 for Diff. Crosstalk between D+/D-and SS Signal Pairs
a) Connect 1X Thru standard to the VNA port 1 with the RF cable.
b) Click Trace 8.
c) Click Parameter tab.
d) Select Measure to “Time Domain” and “Single-Ended”.
e) Select Format to “Volf”.
f) Click Marker Search and select “Rise Time (10–90%)”.
g) Click T11.
h) Click Run to measure the rise time on the screen.
i) Click Auto Scale and select “X&Y”.
j) Enter rise time until the measured rise time is close to the specified value (500 ps).
k) Click Marker Search and select “Rise Time (10–90%)” to turn off the marker.
l) Select Measure to “Time Domain” and “Differential”. Select Format to “Impedance”.
m) Click Tdd21.
**Trace 2 and Trace 6 [Raw Cable] Characteristic Impedance**

a) Connect 1X Thru standard to the VNA Port 1 (Port 3) with the RF cable.
b) Click **Trace 2 (Trace 6)**.
c) Click **Parameter** tab.
d) Select Measure to **"Time Domain"** and **"Single-Ended"**.
e) Select Format to **"Volf"**.
f) Click **Marker Search** and select “Rise Time (10–90%)”.
g) Click **T11 (T33)**.
h) Click **Run** to measure the rise time on the screen.
i) Click **Auto Scale** and select “**X&Y**”.
j) Enter rise time until the measured rise time is close to the specified value (200 ps).
k) Click **Marker Search** and select **"Rise Time (10–90%)"** to turn off the marker.
l) Select Measure to **"Time Domain"** and **"Differential"**. Select Format to **"Impedance"**
m) Click **Tdd11 (Tdd22)**.

**Trace 1 and Trace 5 [Mated Connector] Differential Impedance**

a) Connect 1X Thru standard to the VNA Port 1 (Port 3) with the RF cable.
b) Click **Trace 1 (Trace 5)**.
c) Click **Parameter** tab.
d) Select Measure to **"Time Domain"** and **"Single-Ended"**.
e) Select Format to **"Volf"**.
f) Click **Marker Search** and select “Rise Time (20–80%)”.
g) Click **T11 (T33)**.
h) Click **Run** to measure the rise time on the screen.
i) Click **Auto Scale** and select “**X&Y**”.
j) Enter rise time until the measured rise time is close to the specified value (50 ps).
k) Click **Marker Search** and select **"Rise Time (20–80%)"** to turn off the marker.
l) Select Measure to **"Time Domain"** and **"Differential"**. Select Format to **"Impedance"**
m) Click **Tdd11 (Tdd22)**.
5. Measurement and Data Analysis

1. Connect USB 3.0 official test fixtures to the test port cables according to the Table 5.1 Connector Impedance, Cable Impedance, Intra-Pair Skew, Insertion Loss, and Mode Conversion Connection.
2. Unused terminals should be terminated with 50-ohm terminators.
3. Press Channel Next key on the instrument front panel to select channel 1.
4. Click Stop Single for Time Domain measurements.

<table>
<thead>
<tr>
<th>Table 5.1 Connector Impedance, Cable Impedance, Intra-Pair Skew, Insertion Loss, and Mode Conversion Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
</tr>
<tr>
<td>PIN #</td>
</tr>
</tbody>
</table>

| PIN #      | X6    | X7    | Y6    | Y7    | X9    | Y10   | X10   | Y9    | X9    | Y5    | Y6    | Y6    |

5.1 [Mated Connector] Differential Impedance

1. Connect the VNA ports (port 1 to 4) to the test fixture ports with RF cables. Note: Unused fixture pots should be terminated with 50-ohm terminators.
2. Press Channel Max to maximize Channel 1 on the screen.
3. Press Trace Max to maximize the selected trace on the screen.
4. Select Trace 1 (Tdd11).
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 Tdd22.

<table>
<thead>
<tr>
<th>Limit</th>
<th>Start Time</th>
<th>End Time</th>
<th>Start Limit</th>
<th>End Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>0 s</td>
<td>600 ps</td>
<td>105 Ω</td>
<td>105 Ω</td>
</tr>
<tr>
<td>Min</td>
<td>0 s</td>
<td>600 ps</td>
<td>75 Ω</td>
<td>75 Ω</td>
</tr>
</tbody>
</table>

5.2 [Raw Cable] Impedance

1. Select Trace 2 (Tdd11).
2. Click Stop Single.
3. Confirm the measured impedance is within the limit shown below. Otherwise, it will show Fail.
4. Select Trace 6 (Tdd22) and repeat Step 2-3 for Tdd22.

<table>
<thead>
<tr>
<th>Limit</th>
<th>Start Time</th>
<th>End Time</th>
<th>Start Limit</th>
<th>End Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>600 ps</td>
<td>1.5 ns</td>
<td>97 Ω</td>
<td>97 Ω</td>
</tr>
<tr>
<td>Min</td>
<td>600 ps</td>
<td>1.5 ns</td>
<td>83 Ω</td>
<td>83 Ω</td>
</tr>
</tbody>
</table>
5.3 SS Lines Propagation Delay Skew

1. Select Trace 3 (T31).
2. Press Double-click on the instrument front panel to enlarge the trace.
3. Read the Delta Time and confirm the measured value is within the limit shown below. Otherwise, Fail.
4. Press Double-click on the instrument front panel to shrink the trace.
5. Select Trace 7 (T42) and repeat Step 3-4 for T42.

<table>
<thead>
<tr>
<th>Test Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>If Delta Time &lt; 15 psec: Pass, else: Fail</td>
</tr>
</tbody>
</table>

5.4 Differential Insertion Loss (Frequency Domain Analysis)

1. Select Trace 9 (Sdd21).
2. Press Double-click on the instrument front panel to enlarge the trace.
3. Run and confirm the measured return loss is within the limit shown below. Otherwise, it will show Fail.

<table>
<thead>
<tr>
<th>Start Frequency</th>
<th>End Frequency</th>
<th>Start Limit</th>
<th>End Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 MHz</td>
<td>1.25 GHz</td>
<td>-1.50 dB</td>
<td>-5.00 dB</td>
</tr>
<tr>
<td>1.25 GHz</td>
<td>2.50 GHz</td>
<td>-5.00 dB</td>
<td>-7.50 dB</td>
</tr>
<tr>
<td>2.50 GHz</td>
<td>7.50 GHz</td>
<td>-7.50 dB</td>
<td>-25.00 dB</td>
</tr>
</tbody>
</table>

5.5 Differential-to-Common-Mode Conversion (Frequency Domain Analysis)

1. Select Trace 10 (Scd21).
2. Press Double-click on the instrument front panel to enlarge the trace.
3. Run and confirm the measured values is within the limit shown below. Otherwise, it will show Fail.

<table>
<thead>
<tr>
<th>Start Frequency</th>
<th>End Frequency</th>
<th>Start Limit</th>
<th>End Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 MHz</td>
<td>7.50 GHz</td>
<td>-20.00 dB</td>
<td>-20.00 dB</td>
</tr>
</tbody>
</table>

6.6 Near End Crosstalk

1. Connect USB 3.0 official test fixtures to the test port cables according to the Table 8.2 Near End Crosstalk Connection. Unused terminals should be terminated with 50-ohm terminators.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
<td>Port1</td>
<td>Port2</td>
<td>Port3</td>
</tr>
<tr>
<td>X8 Y5</td>
<td>X8</td>
<td>X9</td>
<td>X5</td>
</tr>
</tbody>
</table>
2. Connect an USB 3.0 Cable to the test fixtures.
3. Select Trace 4 (Tdd21).
4. Press Double-click on the instrument front panel to enlarge the trace
5. Click Stop Single.
6. Read the peak-to-peak (p-p) value and confirm the measured value is within the limit shown below

<table>
<thead>
<tr>
<th>Type</th>
<th>Test Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard-A</td>
<td>If p-p &lt;= 3.6 mV: Pass, else: Fail</td>
</tr>
<tr>
<td>Standard-B</td>
<td>If p-p &lt;= 7.2 mV: Pass, else: Fail</td>
</tr>
<tr>
<td>Micro-AB</td>
<td>If p-p &lt;= 4.8 mV: Pass, else: Fail</td>
</tr>
</tbody>
</table>

7. Repeat Step1-6 for other Standards connections.

5.7. Crosstalk Between D+/D- and Super Speed

1. Connect USB 3.0 official test fixtures to the test port cables according to the Table 8.3 Near-End Crosstalk Connection. Unused terminals should be terminated.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
<td>Port1</td>
<td>Port2</td>
</tr>
<tr>
<td>PIN #</td>
<td>X2</td>
<td>X3</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>X3</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>X3</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>X3</td>
</tr>
<tr>
<td></td>
<td>X5</td>
<td>X6</td>
</tr>
<tr>
<td></td>
<td>X8</td>
<td>X9</td>
</tr>
<tr>
<td></td>
<td>Y5</td>
<td>Y6</td>
</tr>
<tr>
<td></td>
<td>Y8</td>
<td>Y9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Micro-AB to Micro-AB</th>
<th>Micro-AB to Standard-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
<td>Port1</td>
</tr>
<tr>
<td>PIN #</td>
<td>X2</td>
</tr>
<tr>
<td></td>
<td>X2</td>
</tr>
<tr>
<td></td>
<td>X2</td>
</tr>
<tr>
<td></td>
<td>X6</td>
</tr>
<tr>
<td></td>
<td>X9</td>
</tr>
<tr>
<td></td>
<td>Y6</td>
</tr>
<tr>
<td></td>
<td>Y9</td>
</tr>
</tbody>
</table>

2. Connect an USB 3.0 Cable to the test fixtures.
3. Select Trace 8 (Tdd21).
4. Press Double-click on the instrument front panel to enlarge the trace
5. Click Stop Single.
6. Read the peak-to-peak (p-p) value and confirm the measured value is within the limit shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Test Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard-A</td>
<td>If p-p &lt;= 8.0 mV: Pass, else: Fail</td>
</tr>
<tr>
<td>Standard-B</td>
<td>If p-p &lt;= 8.0 mV: Pass, else: Fail</td>
</tr>
<tr>
<td>Micro-AB</td>
<td>If p-p &lt;= 8.0 mV: Pass, else: Fail</td>
</tr>
</tbody>
</table>

7. Repeat Step 1-6 for other Standards connections.

5.8. D+/D- Pair Propagation Delay

The propagation delay measurement is to verify the end to end propagation of the D+/D- lines of the cable assembly.

1. Connect USB 3.0 official test fixtures to the test port cables according to the Table 8.4 D+/D- Pair Propagation Delay, D+/D- Pair Intra-Pair Skew and D+/D- Pair Attenuation Connection.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
<td>Port1</td>
<td>Port2</td>
<td>Port3</td>
</tr>
<tr>
<td>X2</td>
<td>Y3</td>
<td>Y2</td>
<td>X3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIN #</th>
<th>Micro-AB to Micro-AB</th>
<th>Micro-AB to Standard-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNA Port#</td>
<td>Port1</td>
<td>Port2</td>
</tr>
<tr>
<td>X2</td>
<td>X3</td>
<td>Y2</td>
</tr>
</tbody>
</table>

2. Press Double-click on the instrument front panel to enlarge the trace.
3. Select Trace 3 (T31).
4. Click Stop Single.
5. Read Marker Value 1 on Trace 3 and confirm the measured value is within the limit shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Test Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard-A to Standard-B</td>
<td>If the time at the rising edge &lt; 26 ns: Pass, else: Fail</td>
</tr>
<tr>
<td>Standard-A to Standard-A</td>
<td></td>
</tr>
<tr>
<td>Standard-A to Micro-AB</td>
<td>If the time at the rising edge &lt; 10 ns: Pass, else: Fail</td>
</tr>
<tr>
<td>Micro-AB to Micro-AB</td>
<td></td>
</tr>
<tr>
<td>Micro-AB to Standard-B</td>
<td></td>
</tr>
</tbody>
</table>

Note: 10ns for Micro-USB due to a maximum cable length of 2 meters stated in CTS

5.9 D+/D- Pair Propagation Delay 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. Press Double-click on the instrument front panel to enlarge the trace.
2. Press Channel Next to select Channel 1.
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.
5.10 D+/D- Pair Attenuation (Frequency Domain Analysis)

1. Select Trace 11 (Sdd21).
2. Press Double-click on the instrument front panel to enlarge the trace.
3. Run and confirm the measured values is within the limit shown below. Otherwise, it will show Fail.

<table>
<thead>
<tr>
<th>Start Frequency</th>
<th>End Frequency</th>
<th>Start Limit</th>
<th>End Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 MHz</td>
<td>24 MHz</td>
<td>-670 mV</td>
<td>-950 mV</td>
</tr>
<tr>
<td>24 MHz</td>
<td>48 MHz</td>
<td>-950 mV</td>
<td>-1.35 dB</td>
</tr>
<tr>
<td>48 MHz</td>
<td>96 MHz</td>
<td>-1.35 dB</td>
<td>-1.90 dB</td>
</tr>
<tr>
<td>96 MHz</td>
<td>200 MHz</td>
<td>-1.90 dB</td>
<td>-3.20 dB</td>
</tr>
<tr>
<td>200 MHz</td>
<td>400 MHz</td>
<td>-3.20 dB</td>
<td>-5.80 dB</td>
</tr>
</tbody>
</table>
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/TDT 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-Pair Propagation Delay and Propagation Delay Skew

1. Select Trace 3.
2. Open Parameters tab.
4. Select Formant to “Volf”.
5. Select Rise Time to “10-90%” and input value to 200 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” (Delta Time)
18. Check “Δ Time”
19. Select Target (Stop) to **Trace 7** and click OK

20. Input vertical scale (100 mV/div) and vertical position (100 mV).
21. Press **Search**> **Target**> **Target Value** and enter 100 mV.
22. Press **Search**> **Target**> **Tracking**> and turn on **Tracking**.
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.
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.

![Equation Editor](image)

6.4 D+/D-Pair Propagation Delay

1. Select Trace 4.
2. Open Parameters tab.
4. Select Formant to “Volt”.
5. Select Rise Time to “10-90%” and input value “200 ps” (follow raise time requirement by USB.org).
6. Click Tdd21.

6.5 Differential Crosstalk between D+/D-and SS Signal Pairs

1. Select Trace 8.
2. Open Parameters tab.
4. Select Formant to “Volt”.
5. Select Rise Time to “10-90%” and input value “200 ps” (follow raise time requirement by USB.org).
6. Click Tdd21.
7. Press Math > Analysis > Statistics > and turn it ON.

6.6 [Raw Cable] Characteristic Impedance (Informative)

1. Select Trace 2.
2. Open Parameters tab.
4. Select Formant to “Impedance”.
5. Select Rise Time to “10-90%” and input value “200 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 2 in the From list.
11. Select Trace 6 in the To list.
12. Click Copy.
13. Click Close.
15. Open Parameter tab.
16. Click Tdd22.

6.7 [Mated Connector] Impedance

1. Select Trace 1.
2. Open Parameters tab.
4. Select Formant to “Impedance”.
5. Select Rise Time to “20-80%” and input value “50 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 in the From list.
11. Select Trace 5 in the To list.
12. Click Copy.
13. Click Close.
14. Select Trace 5.
15. Open Parameter tab.
16. Click Tdd22.
6.8 D+/D Pair Attenuation

1. Press Trace Next to select Trace 11.
2. Press Meas> Other> Sdd21
3. Press Scale> Scale/Div to 1 dB/div.
4. Press Scale> Reference Value to -4 dB.

6.9. Differential to Common-mode Conversion

1. Press Trace Next to select Trace 10.
2. Press Meas> Other> Scd21
3. Press Scale> Scale/Div to 5 dB/div.
4. Press Scale> Reference Value to -20 dB.

6.10 [Raw Cable] Differential Insertion Loss (Informative)

1. Press Trace Next to select Trace 9.
2. Press Meas> Other> Sdd21
3. Press Scale> Scale/Div to 5 dB/div.
4. Press Scale> Reference Value to -6 dB.

6.11 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 line table.

<table>
<thead>
<tr>
<th>Type</th>
<th>Begin Stimulus</th>
<th>End Stimulus</th>
<th>Begin Response</th>
<th>End Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Max 0.000000 Hz 5.000000 GHz</td>
<td>-30.0000 dB</td>
<td>-30.0000 dB</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Off 0.000000 Hz 0.000000 Hz</td>
<td>0.000000 dB</td>
<td>0.000000 dB</td>
<td></td>
</tr>
</tbody>
</table>

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”.

![Limit Test Setup Window]
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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www.keysight.com/find/contactus