Universal Serial Bus 3.1 Specification Revision 1.0
Keysight Method of Implementation (MOI) for USB 3.1 Connectors and Cables Assemblies Compliance Tests
Using Keysight E5071C ENA Option TDR

Note: The final USB 3.1 Connectors and Cable Assemblies Compliance Document (Revision 1.0) is not yet released. Test coverage and requirements are based on an early draft test specification and will be updated when the final test specification is complete.
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Keysight MOI for USB 3.1 Connectors & Cable Assemblies Compliance Tests
1. Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Comments</th>
<th>Issue Date</th>
</tr>
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<tbody>
<tr>
<td>0.50</td>
<td>Draft Revision.</td>
<td>Feb. 06, 2015</td>
</tr>
</tbody>
</table>

2. Purpose

This test procedure was written to explain how to use the Keysight ENA Option TDR to make the connectors and cable assemblies measurements required per USB 3.1 Specification Revision 1.0 and Connectors and Cable Assemblies Compliance Document Draft.

3. References

- Universal Serial Bus 3.1 Specification Revision 1.0 (July 26, 2013)
- Universal Serial Bus 3.1 Connectors and Cable Assemblies Compliance Document Draft

4. Required Equipment

<table>
<thead>
<tr>
<th>Description</th>
<th>Test Equipment</th>
<th>QTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Analyzer</td>
<td>Keysight E5071C ENA Series Network Analyzer</td>
<td>1 ea.</td>
</tr>
<tr>
<td></td>
<td>Option 4D5 (14 GHz) or 4K5 (20 GHz)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Option TDR (Enhanced time domain analysis)</td>
<td></td>
</tr>
<tr>
<td>4-port ECAL</td>
<td>Keysight N4433A (4-port, 20 GHz)</td>
<td>1 ea.</td>
</tr>
<tr>
<td>Test Fixture</td>
<td>USB 3.1 official test fixtures and calibration standards</td>
<td>1 ea.</td>
</tr>
<tr>
<td>Adapter</td>
<td>83059B coaxial adapter for E5071C ports</td>
<td>4 ea.</td>
</tr>
<tr>
<td>RF cable</td>
<td>3.5 mm or SMA cables of 14 GHz bandwidth or more</td>
<td>4 ea.</td>
</tr>
</tbody>
</table>

Note: Opt.4K5 (20GHz) is recommended as Type-C cable/slider requires measurements up to 15 GHz.

Note: Fixtures for testing USB 3.1/Type-C connectors and cable assemblies are available for purchase through Luxshare-ICT.

5. Test Procedure

5.1. Outline of Test Procedure

1. Setup
   - Automatic setup by recalling a state file or manual setup

2. Calibration
   - ECal Calibration and De-embedding
   - TRL Calibration
   - Adjustment of Effective Rise Time

3. Measurements
   4-1. Time-domain Measurements
      - D+/D- Pair Propagation Delay
      - D+/D- Pair Propagation Delay Skew
      - Differential Crosstalk between D+/D- and SuperSpeed Gen 2 Signal Pairs
      - [Raw Cable] Characteristic Impedance (Informative)
      - [Raw Cable] Intra-Pair Skew (Informative)
      - [Mated Connector] Impedance (Informative)

   4-2. Frequency-domain Measurements
      - D+/D- Pair Attenuation
      - Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)
      - Differential to Common-mode Conversion
      - Cable Shielding Effectiveness
      - [Raw Cable] Differential Insertion Loss (Informative)
      - [Mated Cable Assembly] Differential Insertion Loss (Informative)
      - [Mated Cable Assembly] Differential Near-end Crosstalk (NEXT) between SuperSpeed Gen 2 Signal Pairs (Informative)
      - [Mated Cable Assembly] Differential Near-end and Far-end Crosstalk (NEXT and FEXT) between D+/D- Pair and SuperSpeed Gen 2 Signal Pairs (Informative)
Normative & Informative Measurement Parameters

Note: Hard keys (Keys on the E5071C’s front panel) are displayed in Blue color and Bold. (Example: Avg, Analysis)

Note: Soft keys (Keys on the E5071C’s screen) are displayed in Bold. (Example: S11, Real, Transform)

Note: Buttons of the TDR software are displayed in Green color and Bold. (Example: Trace, Rise Time)

Note: Tabs of the TDR software are displayed in Brown color and Bold. (Example: Setup, Trace Control)
5.2. Setup

5.2.1. Recalling a State File
This section describes how to recall a state file of the E5071C that includes all the measurement settings for USB3.1 connectors and cable assemblies compliance tests. The state file can be downloaded at: http://www.keysight.com/find/ena-tdr_compliance
Copy the state file into the E5071C’s directory via USB mass storage device and recall the state file using the TDR software. Necessary parameters for testing are automatically set up in the E5071C. Refer to Appendix for the details about manual setup. If TDR setup wizard is shown, click Close button in the TDR setup wizard main window.

1. Open Setup tab.
2. Click Advanced Mode to show the dialog box.
3. A dialog box appears requesting for confirmation. Then click Yes. (Uncheck “Use Advanced Calibration Methods”)
4. Click File and select Recall State.
5. Specify a folder and a file name, and click Open.

The E5071C’s channel 1 is used for time-domain measurements by using the TDR software displayed at the bottom of the E5071C’s screen. The channel 2 is used for frequency-domain measurements by using the hard keys on the front panel and the soft keys on the right side of the screen.
5.2.2. Saving a State File

All the measurement settings including calibration information can be saved in a state file (*.tdr). After performing calibration, all necessary calibration coefficients are saved in a state file and can be recalled for the next measurements.

1. Press **Save/Recall > Save Type** and select **State & Cal** as a state file type.
2. Click **File** of the TDR software and select **Save State**.
3. Enter file name and save the state file with calibration information.
5.3. Calibration
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 E5071C firmware for the USB3.1 connectors and cable assemblies compliance tests.

5.3.1. 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 E5071C’s test ports. The effect of the fixture is removed by de-embedding the fixture traces with S-parameter Touchstone files.

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

1. ECal Calibration
   a) Press Channel Next to select Channel 1.
   b) Click Setup tab.
   c) Click ECal to launch the TDR Setup Wizard.
   d) Connect the E5071C ports (port 1 to 4) to the ECal module with RF cables.
   e) Click Calibrate to perform ECal Calibration.
   f) Click Next >.
g) Click **Finish** to complete ECal calibration.

2. De-embedding
   a) Click **Adv Waveform** tab
   b) Click **De-embedding** to launch Advanced Waveform wizard.
   c) 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.
   d) Load the Touchstone file.
e) Enable the de-embedding function.
f) Click OK.

Note: For more details about the de-embedding function, refer to the E5071C ENA help below.
http://ena.support.keysight.com/e5071c/manuals/webhelp/eng/measurement/fixture_simulator/obtaining_characteristics_after_embedding_de_embedding_4_port.htm

5.3.1.2. Frequency-Domain Measurements
Ecal calibration and de-embedding for frequency-domain measurements are performed by the E5071C firmware.

1. Ecal Calibration
   a) Press Channel Next to select Channel 2.
   b) Connect the E5071C ports (port 1 to 4) to the ECal module with RF cables.
   c) Press Cal > ECal > 4-Port Cal.

2. De-embedding (In case of 2-port file)
   a) Press Analysis > Fixture Simulator > De-Embedding > Select Port > and select E5071C’s Port (1 to 4) to de-embed fixture trace.
   b) Press Analysis > Fixture Simulator > De-Embedding > User File and specify a 2-port de-embedding file (*.s2p).
   c) Press Analysis > Fixture Simulator > De-Embedding > Select Type to set to User.
   d) Continue the same for the other ports of the E5071C.
   e) Press Analysis > Fixture Simulator > De-Embedding to turn on De-Embedding.

3. De-embedding (In case of 4-port file)
a) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > Select Topology > C**.
b) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > Ports > 1-3-2-4**.
c) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > User File (nwk1)... and specify a 4-port de-embedding file (*.s4p)**.
d) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > Type (nwk1) > De-Embed**.
e) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > User File (nwk2)... and specify a 4-port de-embedding file (*.s4p)**.
f) Press **Analysis > Fixture Simulator > De-Embedding SnP > Topology > Type (nwk2) > De-Embed**.
g) Press **Analysis > Fixture Simulator > De-Embedding SnP > De-Embedding SnP** to turn on.

Note: For more details about the de-embedding function, refer to the E5071C ENA help below.

http://ena.support.keysight.com/e5071c/manuals/webhelp/eng/measurement/fixture_simulator/obtaining_characteristics_after_embedding_de_embedding_4_port.htm

5.3.2. **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 E5071C, and TRL calibration is performed with the E5071C firmware by measuring the TRL calibration standards such as Thru, Short, Lines or Load.

The calibration can be applied for both channels, channel 1 for time domain measurements and channel 2 for frequency-domain measurements.

5.3.2.1. **Selecting TRL Cal Kit**

1. Press **Channel Next** to select Channel 1 or Channel 2
2. Press **Cal > Cal Kit** and select **User**.
3. Press **Cal > Modify Cal Kit > Import Cal Kit** and select the cal kit definition file (*.ckx) and click **Open**.
4. Confirm that the imported cal kit is set for the selected channel by pressing **Cal > Cal Kit**.

5.3.2.2. **Performing TRL Calibration**

1. **Thru measurement**
   a) Connect Thru standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.
   b) Press **Cal > Calibrate > 4-port TRL Cal > Thru/Line > 1-2 Thru/Line**.
c) Connect Thru standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 3 with the RF cable.

d) Press Cal > Calibrate > 4-port TRL Cal > Thru/Line > 1-3 Thru/Line.

e) Connect Thru standard of USB 3.1 TRL calibration kit to the E5071C port 3 and port 4 with the RF cable.

f) Press Cal > Calibrate > 4-port TRL Cal > Thru/Line > 3-4 Thru/Line.

2. Reflect measurement

a) Connect Short standard of USB 3.1 TRL calibration kit to the E5071C port 1 with the RF cable.

b) Press Cal > Calibrate > 4-port TRL Cal > Reflect > Port1 Reflect.

c) Connect Short standard of USB 3.1 TRL calibration kit to the E5071C port 2 with the RF cable.

d) Press Cal > Calibrate > 4-port TRL Cal > Reflect > Port2 Reflect.

e) Connect Short standard of USB 3.1 TRL calibration kit to the E5071C port 3 with the RF cable.

f) Press Cal > Calibrate > 4-port TRL Cal > Reflect > Port3 Reflect.

g) Connect Short standard of USB 3.1 TRL calibration kit to the E5071C port 4 with the RF cable.

h) Press Cal > Calibrate > 4-port TRL Cal > Reflect > Port4 Reflect.

3. Line/Match measurement

a) Connect Line 1 standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.

b) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-2 Line/Match > Line/Match 1 (Line1).

c) Connect Line 2 standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.

d) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-2 Line/Match > Line/Match 2 (Line2).

e) Connect Line 3 standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.

f) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-2 Line/Match > Line/Match 3 (Line3).

g) Connect Line 4 standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.

h) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-2 Line/Match > Line/Match 4 (Line4).

i) Connect Load standard of USB 3.1 TRL calibration kit to the E5071C port 1 and port 2 with the RF cable.
j) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-2 Line/Match > Line/Match 5 (Load).
k) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 1-3 Line/Match and repeat step a) to step j) by connecting line and load standards to the E5071C port 1 and port 3 with the RF cable.
l) Press Cal > Calibrate > 4-port TRL Cal > Line/Match > 3-4 Line/Match and repeat step a) to step j) by connecting line and load standards to the E5071C port 3 and port 4 with the RF cable.

4. Press Cal > Calibrate > 4-port TRL Cal > Done to complete calibration. The calibration coefficients are calculated and the error correction is automatically turned on.

5. Repeat the above TRL calibration for another channel after confirming that the imported cal kit is set for the channel by pressing Cal > Cal Kit.

5.3.3. Adjustment of Effective Rise Time
After performing the calibration, the effective rise time entering the USB 3.1 connector pins is adjusted for the specification in time-domain measurements (Table 5-1). 1X Thru standard is connected to the E5071C port with RF cables. DUT is disconnected during the adjustment procedure.

**Table 5-1: Specification of Effective Rise Time**

<table>
<thead>
<tr>
<th>Trace</th>
<th>Test Items</th>
<th>Rise Time %</th>
<th>Target Rise Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tr 1 &amp; 5</td>
<td>D+/D- Pair Propagation Delay Skew</td>
<td>10 – 90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 2</td>
<td>D+/D- Pair Propagation Delay</td>
<td>10 – 90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 6</td>
<td>Differential Crosstalk between D+/D- and SuperSpeed Gen 2 Signal Pairs</td>
<td>10 – 90 %</td>
<td>500 ps</td>
</tr>
<tr>
<td>Tr 3 &amp; 7</td>
<td>[Raw Cable] Characteristic Impedance</td>
<td>10 – 90 %</td>
<td>200 ps</td>
</tr>
<tr>
<td>Tr 4 &amp; 8</td>
<td>[Mated Connector] Impedance</td>
<td>20 – 80 %</td>
<td>40 ps</td>
</tr>
</tbody>
</table>

1. Press Channel Next to select Channel 1.
2. Press Trace Max 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 1 (Trace 5) (Adjust effective rise time for Trace 1 then Trace 5)
  a) Connect 1X Thru standard to the E5071C port 1 (port 2) 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 “Volt”.
  f) Click Marker Search and select “Rise Time (10–90%)”.
g) Click T11 (T22).
h) Press Display > Equation to 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 Display > Equation to turn on the equation editor.

- Trace 2
a) Connect 1X Thru standard to the E5071C port 1 with the RF cable.
b) Click Trace 2.
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.
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).
Click Marker Search and select “Rise Time (10–90%)” to turn off the marker.

Select Measure to “Time Domain” and “Differential”.

Click Tdd21.

- Trace 6
  a) Connect 1X Thru standard to the E5071C port 1 with the RF cable.
  b) Click Trace 6.
  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.
  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”.
  m) Click Tdd21.

- Trace 3 (Trace 7) (Adjust effective rise time for Trace 3 then Trace 7)
  a) Connect 1X Thru standard to the E5071C port 1 (port 3) 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 (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”.
  m) Select Format to “Impedance”.
  n) Click Tdd11 (Tdd22).

- Trace 4 (Trace 8) (Adjust effective rise time for Trace 4 then Trace 8)
  a) Connect 1X Thru standard to the E5071C port 1 (port 3) with the RF cable.
b) Click Trace 4 (Trace 8).

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” (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 (40 ps).

k) Click Marker Search and select “Rise Time” (20–80 %) to turn off the marker.

l) Select Measure to “Time Domain” and “Differential”.

m) Select Format to “Impedance”.

n) Click Tdd11 (Tdd22).
5.4. Measurement
The connections for cable assembly, raw cable and mated connector are assumed as follows (Note: TF stands for Test Fixture).

[Cable Assembly]

<table>
<thead>
<tr>
<th>TF1</th>
<th>Cable Assembly</th>
<th>TF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std-A (Receptacle)</td>
<td>Std-A (Plug)</td>
<td>Micro-B (Plug)</td>
</tr>
<tr>
<td>D+/D-</td>
<td>⇔</td>
<td>D+/D-</td>
</tr>
<tr>
<td>Tx+/Tx-</td>
<td>⇔</td>
<td>Rx+/Rx-</td>
</tr>
<tr>
<td>Rx+/Rx-</td>
<td>⇔</td>
<td>Tx+/Tx-</td>
</tr>
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</table>

[Raw Cable]

<table>
<thead>
<tr>
<th>A Side</th>
<th>Raw Cable</th>
<th>B Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+/D-</td>
<td>⇔</td>
<td>D+/D-</td>
</tr>
<tr>
<td>Tx+/Tx-</td>
<td>⇔</td>
<td>Tx+/Tx-</td>
</tr>
<tr>
<td>Rx+/Rx-</td>
<td>⇔</td>
<td>Rx+/Rx-</td>
</tr>
</tbody>
</table>

[Mated Connector]

<table>
<thead>
<tr>
<th>TF1</th>
<th>Mated Connector</th>
<th>TF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std-A (Receptacle)</td>
<td>Mated Connector</td>
<td>Micro-B (Receptacle)</td>
</tr>
<tr>
<td>D+/D-</td>
<td>⇔</td>
<td>D+/D-</td>
</tr>
<tr>
<td>Tx+/Tx-</td>
<td>⇔</td>
<td>Tx+/Tx-</td>
</tr>
<tr>
<td>Rx+/Rx-</td>
<td>⇔</td>
<td>Rx+/Rx-</td>
</tr>
</tbody>
</table>

5.4.1. 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. Connect the E5071C ports (port 1 to port 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF2 D+</td>
<td>TF2 D-</td>
</tr>
</tbody>
</table>

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

2. Press Channel Next to select Channel 1.
3. Press Channel Max to maximize Channel 1 on the screen.
4. Press Trace Max to maximize the selected trace on the screen.
5. Select Trace 1 (T31).
6. Click Stop Single.
7. Read Delta Time (Tr5) on the E5071C screen.
8. Confirm the measured intra-pair skew of D+/D- pair is lower than 100 psec.

5.4.2. 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 the E5071C ports (port 1 to port 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF2 D+</td>
<td>TF2 D-</td>
</tr>
</tbody>
</table>

2. Select **Trace 2 (Tdd21)**.
3. Click **Stop Single**.
4. Read marker value of Trace 2 on the screen.

5. Confirm the measured propagation delay is within the limit shown below.

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard-A to Standard-B</td>
<td>&lt;26 nsec</td>
</tr>
<tr>
<td>Standard-A to Standard-A</td>
<td>&lt;26 nsec</td>
</tr>
<tr>
<td>Standard-A to Micro-AB</td>
<td>&lt;10 nsec</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>

5.4.3. Differential Crosstalk between D+/D- and SuperSpeed Gen 2 Signal Pairs

The differential near-end crosstalk (DDNEXT) and far-end crosstalk (DDFEXT) between the D+/D- pair and the SuperSpeed Gen 2 signal pairs shall be measured in time domain for the mated cable assembly.

1. Connect the E5071C ports (port 1 to port 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF1 Tx+</td>
<td>TF1 Tx-</td>
</tr>
</tbody>
</table>

2. Select Trace 6 (Tdd21).
3. Click Stop Single.
4. Click Auto Scale and select “X&Y”.
5. Read the peak-to-peak (p-p) value on the screen.
6. Confirm the measured crosstalk in percentage does not exceed the limits below.
   • USB 3.1 Standard-A connector: 2 % (p-p <= 8 mV)
   • USB 3.1 Standard-B connector: 2 % (p-p <= 8 mV)
   • USB 3.1 Micro connector family: 2 % (p-p <= 8 mV)

7. Connect the E5071C ports to the test fixture ports, and repeat step 3 to step 6 to confirm the measured crosstalk for all the following combinations is within the specification.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF1 Rx+</td>
<td>TF1 Rx-</td>
</tr>
<tr>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF2 Tx+</td>
<td>TF2 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF2 Rx+</td>
<td>TF2 Rx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF2 D-</td>
<td>TF2 Tx+</td>
<td>TF2 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF2 D-</td>
<td>TF2 Rx+</td>
<td>TF2 Rx-</td>
<td></td>
</tr>
<tr>
<td>TF1 D+</td>
<td>TF1 D-</td>
<td>TF1 Rx+</td>
<td>TF1 Rx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF2 D-</td>
<td>TF1 Tx+</td>
<td>TF1 Tx-</td>
<td></td>
</tr>
</tbody>
</table>

5.4.4. D+/D- Pair Attenuation

1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF2 D+</td>
<td>TF1 D-</td>
<td>TF2 D-</td>
</tr>
</tbody>
</table>

2. Press **Channel Next** to select Channel 2.
3. Press **Trace Next** to select Trace 1 (Sdd21).
4. Press **Trace Max** to maximize the selected trace on the screen.

5. Press **Trigger** > **Single**.

6. Confirm the measured attenuation of D+/D- pair is within the limit shown below.

<table>
<thead>
<tr>
<th>Start Frequency</th>
<th>Stop Frequency</th>
<th>Start Limit</th>
<th>Stop Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 MHz</td>
<td>24 MHz</td>
<td>-670 dB</td>
<td>-950 dB</td>
</tr>
<tr>
<td>24 MHz</td>
<td>48 MHz</td>
<td>-950 dB</td>
<td>-1.35 dB</td>
</tr>
<tr>
<td>48 MHz</td>
<td>96 MHz</td>
<td>-1.35 dB</td>
<td>-1.9 dB</td>
</tr>
<tr>
<td>96 MHz</td>
<td>200 MHz</td>
<td>-1.9 dB</td>
<td>-3.2 dB</td>
</tr>
<tr>
<td>200 MHz</td>
<td>400 MHz</td>
<td>-3.2 dB</td>
<td>-5.8 dB</td>
</tr>
</tbody>
</table>

5.4.5. **Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)**

The test results of channel metrics are checked with a standard tool (*CableComp Tool*) provided by USB-IF. Six 4-port Touchstone files (*.s4p) are measured and saved by the E5071C firmware, and then imported by the compliance tool to conduct cable assembly compliance test of the channel metrics.

1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>Test path name</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>host_tx_pair_thru</td>
<td>TF1 Tx+</td>
<td>TF2 Rx+</td>
<td>TF1 Tx-</td>
<td>TF2 Rx-</td>
</tr>
</tbody>
</table>

2. Press **Trace Next** to select Trace 1 (Sdd21).

3. Press **Trigger** > **Single**.

4. Press **Save/Recall** > **Save SnP** > **S4P** > **[1-2-3-4]**... to save the measured Touchstone file.

5. Connect the E5071C ports with test fixture ports shown below and repeat step 3 to step 4 to save all necessary Touchstone files (*.s4p) in the E5071C.

<table>
<thead>
<tr>
<th>Test path name</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>host_rx_pair_thru</td>
<td>TF1 Rx+</td>
<td>TF2 Tx+</td>
<td>TF1 Rx-</td>
<td>TF2 Tx-</td>
</tr>
<tr>
<td>a-side_next</td>
<td>TF1 Rx+</td>
<td>TF1 Tx+</td>
<td>TF1 Rx-</td>
<td>TF1 Tx-</td>
</tr>
<tr>
<td>a-b_fext</td>
<td>TF1 Rx+</td>
<td>TF2 Rx+</td>
<td>TF1 Rx-</td>
<td>TF2 Tx-</td>
</tr>
<tr>
<td>b-side_next</td>
<td>TF2 Tx+</td>
<td>TF2 Rx+</td>
<td>TF2 Tx-</td>
<td>TF2 Rx-</td>
</tr>
<tr>
<td>b-a_fext</td>
<td>TF2 Tx+</td>
<td>TF1 Tx+</td>
<td>TF2 Tx-</td>
<td>TF1 Tx-</td>
</tr>
</tbody>
</table>

6. Launch compliance test tool and import six 4-port Touchstone files (*.s4P) for pass/fail judgement.

5.4.6. **Differential to Common-Mode Conversion**

1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Tx+</td>
<td>TF2 Rx+</td>
<td>TF1 Tx-</td>
<td>TF2 Rx-</td>
</tr>
</tbody>
</table>

2. Press **Trace Next** to select Trace 2 (Sdd21).

3. Press **Trigger** > **Single**.
4. 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.
5. Connect the E5071C ports to the test fixture ports.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>TF1 Rx+</td>
<td>TF2 Tx+</td>
<td>TF1 Rx-</td>
<td>TF2 Tx-</td>
</tr>
<tr>
<td>Fixtures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

5.4.7. Cable Shielding Effectiveness
1. Connect the E5071C ports (port 1 to 3) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Port 1 (SE)</td>
<td>Port 2 (Bal+)</td>
<td>Port 3 (Bal-)</td>
</tr>
<tr>
<td>Fixtures</td>
<td>SE</td>
<td>Tx+</td>
<td>Tx-</td>
</tr>
</tbody>
</table>

2. Press Analysis > Fixture Simulator > Topology > Device > SE-Bal.
3. Press Analysis > Fixture Simulator > Topology > Port1(se) > 1.
5. Press Analysis > Fixture Simulator > De-Embedding to turn off De-Embedding.
6. Press Trace Next to select Trace 3.
8. Press Trace Next to select Trace 4.
11. Confirm the measured Sds21/Scs21 is less than or equal to -40 dB in the frequency range from 100 MHz to 10 GHz.
12. 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.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Port 1 (SE)</td>
<td>Port 2 (Bal+)</td>
<td>Port 3 (Bal-)</td>
</tr>
<tr>
<td>Fixtures</td>
<td>SE</td>
<td>Rx+</td>
<td>Rx-</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>D+</td>
<td>D-</td>
</tr>
</tbody>
</table>

15. Press Analysis > Fixture Simulator > Topology > Port2(bal) > 2-4.
16. Press Analysis > Fixture Simulator > De-Embedding to turn on De-Embedding.

Informative electrical performance targets are provided for raw cables, mated connectors, and mated cable assemblies. These targets are not part of the USB 3.1 compliance requirements, but provided for the purpose of design guidelines and manufacturing control.
5.4.8. [Raw Cable] Characteristic Impedance (Informative)
1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Tx+</td>
<td>A Side Tx-</td>
<td>B Side Tx+</td>
<td>B Side Tx-</td>
</tr>
</tbody>
</table>

2. Press **Channel Next** to select Channel 1.
3. Select **Trace 3 (Tdd11)**.
4. Click **Stop Single**.
5. Confirm the measured characteristic impedance is within the limit shown below.

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential characteristic impedance</td>
<td>85</td>
<td>95</td>
<td>Ohm</td>
<td>*1</td>
</tr>
<tr>
<td>Single-ended characteristic impedance</td>
<td>42</td>
<td>48</td>
<td>Ohm</td>
<td></td>
</tr>
</tbody>
</table>

*1. For the Shielded Differential Pair (SDP)
6. Select **Trace 7 (Tdd22)** and repeat step 5 for the impedance measurement at the device-end of DUT.
7. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Rx+</td>
<td>A Side Rx-</td>
<td>B Side Rx+</td>
<td>B Side Rx-</td>
</tr>
</tbody>
</table>

8. Repeat the same operation of step 3 to step 6 to confirm the measured impedance is within the specification.

5.4.9. [Raw Cable] Intra-Pair Skew (Informative)
1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Tx+</td>
<td>A Side Tx-</td>
<td>B Side Tx+</td>
<td>B Side Tx-</td>
</tr>
</tbody>
</table>

2. Select **Trace 1 (T31)**.
3. Click **Stop Single**.
4. Confirm the measured intra-pair skew is less than 15 ps/m.
5. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Rx+</td>
<td>A Side Rx-</td>
<td>B Side Rx+</td>
<td>B Side Rx-</td>
</tr>
</tbody>
</table>

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

5.4.10. [Raw Cable] Differential Insertion Loss (Informative)
1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Tx+</td>
<td>B Side Tx+</td>
<td>A Side Tx-</td>
<td>B Side Tx-</td>
</tr>
</tbody>
</table>
2. Press **Channel Next** to select Channel 2.
3. Press **Trace Next** to select Trace 5 (Sdd21).
4. Press **Trigger > Single**.
5. Confirm the measured differential insertion loss is xx.
6. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Connection</td>
<td>A Side Rx+</td>
<td>B Side Rx+</td>
<td>A Side Rx-</td>
<td>B Side Rx-</td>
</tr>
</tbody>
</table>

7. Repeat the same operation of step 4 to step 5 to confirm the measured insertion loss is within the specification.

5.4.11. [Mated Connector] Impedance (Informative)
1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Tx+</td>
<td>TF1 Tx-</td>
<td>TF2 Tx+</td>
<td>TF2 Tx-</td>
</tr>
</tbody>
</table>

2. Press **Channel Next** to select Channel 1.
3. Select **Trace 4 (Tdd11)**.
4. Click **Stop Single**.
5. Confirm the measured characteristic impedance is within the limit, 90 +- 10 ohm.
6. Select **Trace 8 (Tdd22)** and repeat step 5 for the far end of DUT.
7. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Rx+</td>
<td>TF1 Rx-</td>
<td>TF2 Rx+</td>
<td>TF2 Rx-</td>
</tr>
</tbody>
</table>

8. Repeat the same operation of step 3 to step 6 to confirm the measured impedance for Rx pair is within the specification.

5.4.12. [Mated Cable Assembly] Differential Insertion Loss (Informative)
1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Tx+</td>
<td>TF2 Tx+</td>
<td>TF1 Tx-</td>
<td>TF2 Tx-</td>
</tr>
</tbody>
</table>

2. Press **Channel Next** to select Channel 2.
3. Press **Trace Next** to select Trace 6 (Sdd21).
4. Press **Trigger > Single**.
5. Confirm the measured differential insertion loss is less than or equal to -6 dB from DC to 5 GHz and no strong resonance within DC to 5 GHz.
6. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Rx+</td>
<td>TF2 Rx+</td>
<td>TF1 Rx-</td>
<td>TF2 Rx-</td>
</tr>
</tbody>
</table>

7. Repeat the same operation of step 4 to step 5 to confirm the measured insertion loss for Rx pair is within the specification.
5.4.13. [Mated Cable Assembly] Differential Near-end Crosstalk (NEXT) between SuperSpeed Gen 2 Signal Pairs (Informative)

1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 Tx+</td>
<td>TF1 Rxa+</td>
<td>TF1 Tx-</td>
<td>TF1 Rx-</td>
</tr>
</tbody>
</table>

2. Press **Trace Next** to select Trace 7 (Sdd21).
3. Press **Trigger > Single**.
4. Confirm the measured differential crosstalk is less than or equal to -34 dB up to 5 GHz.
5. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF2 Tx+</td>
<td>TF2 Rxa+</td>
<td>TF2 Tx-</td>
<td>TF2 Rx-</td>
</tr>
</tbody>
</table>

6. Repeat the same operation of step 3 to step 4 to confirm the measured NEXT for the far end is within the specification.


1. Connect the E5071C ports (port 1 to 4) to the test fixture ports with RF cables.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 Rxa+</td>
<td>TF1 D-</td>
<td>TF1 Tx-</td>
</tr>
</tbody>
</table>

2. Press **Trace Next** to select Trace 8 (Sdd21).
3. Press **Trigger > Single**.
4. Confirm the measured differential crosstalk is less than or equal to -30 dB up to 5 GHz.
5. Repeat the same operation of step 3 to step 4 for all the following combinations to confirm the measured crosstalk is within the specification.

<table>
<thead>
<tr>
<th>E5071C</th>
<th>Port 1</th>
<th>Port 2</th>
<th>Port 3</th>
<th>Port 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Fixtures</td>
<td>TF1 D+</td>
<td>TF1 Rxa+</td>
<td>TF1 D-</td>
<td>TF1 Tx-</td>
</tr>
<tr>
<td>TF1 D+</td>
<td>TF2 Rxa+</td>
<td>TF1 D-</td>
<td>TF2 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF1 D+</td>
<td>TF2 Rxa+</td>
<td>TF1 D-</td>
<td>TF2 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF2 Rxa+</td>
<td>TF2 D-</td>
<td>TF2 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF1 Rxa+</td>
<td>TF2 D-</td>
<td>TF1 Tx-</td>
<td></td>
</tr>
<tr>
<td>TF2 D+</td>
<td>TF1 Rxa+</td>
<td>TF2 D-</td>
<td>TF1 Tx-</td>
<td></td>
</tr>
</tbody>
</table>

The procedures of manual setup for time-domain and frequency-domain measurements are introduced in the section. All the following parameters are saved in the E5071C’s state file, which is available at: [http://www.keysight.com/find/ena-tdr_usb3_1-cabcon](http://www.keysight.com/find/ena-tdr_usb3_1-cabcon)

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>>.
5. A dialog box appears requesting for confirmation. Then click Yes. (Clear the check box for “Use Advanced Calibration Methods”)
6. Click Stop Single.
7. Set DUT Length to “16 ns”.
8. Open TDR/TDT tab.
9. Click Trace Control tab.
10. Clear Time and Marker check box under Coupling.
12. Press **Channel Max** to maximize the screen of channel 1.

6.2. **D+/D- Pair Propagation Delay Skew**

6.2.1. **Parameter Setup**
1. Select **Trace 1**.
2. Open **Parameters** tab.
4. Select Formant to “Volt”.
5. Select **Rise Time** to 10-90% and input value (200 ps).
6. Click **T31**.

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

9. Select Trace 1 in the From list.
10. Select Trace 5 in the To list.
11. Click **Copy**.
12. Click **Close**.

13. Select **Trace 5**.
14. Open **Parameters** tab.
15. Click T42.
16. Select Trace 1 (T31).
17. Click Marker Search and select Δ Time.
18. Check Δ Time.
19. Select Target (Stop) to Trace 5 and click OK.

6.2.2. Crosstalk Compensation
1. Select Trace 1.
2. Press Display > 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 5**.
7. Press **Display > Equation Editor… > Enter an equation “S42-S41”**.
8. Check **Enabled** to enable the equation on trace.
9. Click **Apply**.
10. Click **Close**.

6.3. **D+/D- Pair Propagation Delay**
1. Select **Trace 2**.
2. Open **Parameters** tab.
4. Select Formant to “Volt”.
5. Select **Rise Time** to 10-90% and input value (200 ps).
6. Click **Tdd21**.
7. Input vertical scale (100 mV/div) and vertical position (200 mV).
8. Press **Marker Search > Target > Target Value** and enter 200 mU.
9. Press **Marker Search** and turn on **Tracking**.

6.4. **Differential Crosstalk between D+/D- and SuperSpeed Gen 2 Signal Pairs**
1. Select **Trace 6**.
2. Open **Parameters** tab.
4. Select Formant to “Volt”.
5. Select **Rise Time** to 10-90% and input value (500 ps).
6. Click **Tdd21**.
7. Press **Marker Fctn > Statistics >** and turn it **ON**.

6.5. **[Raw Cable] Characteristic Impedance (Informative)**
1. Select **Trace 3**.
2. Open **Parameters** tab.
4. Select Format to “Impedance”
5. Select **Rise Time** to 10-90% and input value (200 ps).
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 the Trace 3 in the From list.
11. Select the Trace 7 in the To list.
12. Click **Copy**.
13. Click Close.
15. Open Parameter tab.
16. Click Tdd22.

6.6. [Mated Connector] Impedance (Informative)
1. Select Trace 4.
2. Open Parameters tab.
4. Select Format to “Impedance”
5. Select Rise Time to 20-80% and input value (40 ps).
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 the Trace 4 in the From list.
11. Select the Trace 8 in the To list.
12. Click Copy.
13. Click Close.
15. Open Parameters tab.
16. Click Tdd22.

6.7. Common Parameters Setup for Frequency-domain Measurements
1. Press Channel Next to select Channel 2.
2. Press Sweep Setup > Points and set to “1,601”.
3. Press Start > Set start value to “10 MHz”.
4. Press Stop > Set stop value to “12 GHz”.
5. Press Avg > Set IF Bandwidth to “1 kHz”.
6. Press Analysis > Fixture Simulator and turn it ON.
7. Press Analysis > Fixture Simulator > Topology > Device > Bal-Bal
8. Press Analysis > Fixture Simulator > Topology > Port1 (bal) > 1-3
9. Press Analysis > Fixture Simulator > Topology > Port2 (bal) > 2-4
11. Press Display > Allocate Traces > x8 (2 columns by 4 rows).
12. Press Analysis > Fixture Simulator > BalUn ON All Traces to enable mixed-mode S-parameters (i.e. Sdd21) measurements on all traces.
13. Press Analysis > Fixture Simulator > Port ZConversion > Port1 Z0 Real and set the port impedance to “45 ohm”.
14. Press Analysis > Fixture Simulator > Port ZConversion > Port2 Z0 Real and set
the port impedance to “45 ohm”.

15. Press Analysis > Fixture Simulator > Port ZConversion > Port3 Z0 Real and set the port impedance to “45 ohm”.

16. Press Analysis > Fixture Simulator > Port ZConversion > Port4 Z0 Real and set the port impedance to “45 ohm”.

17. Press Analysis > Fixture Simulator > Port ZConversion > Port ZConversion and turn ON.

6.8. D+/D- Pair Attenuation
1. Press Trace Next to select Trace 1.
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 2.
3. Press Scale > Scale/Div to 5 dB/div.
4. Press Scale > Reference Value to -20 dB.

6.10. Cable Shielding Effectiveness
1. Press Trace Next to select Trace 3.
2. Press Scale > Scale/Div to 10 dB/div.
3. Press Scale > Reference Value to -40 dB.
4. Press Trace Next to select Trace 4.
5. Press Scale > Scale/Div to 10 dB/div.
6. Press Scale > Reference Value to -40 dB.

6.11. [Raw Cable] Differential Insertion Loss (Informative)
1. Press Trace Next to select Trace 5.
3. Press Scale > Scale/Div to 5 dB/div.
4. Press Scale > Reference Value to -6 dB.

6.12. [Mated Cable Assembly] Differential Insertion Loss (Informative)
1. Press Trace Next to select Trace 6.
3. Press Scale > Scale/Div to 2 dB/div.
4. Press Scale > Reference Value to -6 dB.
1. Press **Trace Next** to select Trace 7.
2. Press **Meas > Sdd21**.
3. Press **Scale > Scale/Div** to 5 dB/div.
4. Press **Scale > Reference Value** to -25 dB.

1. Press **Trace Next** to select Trace 8.
2. Press **Meas > Sdd21**.
3. Press **Scale > Scale/Div** to 5 dB/div.
4. Press **Scale > Reference Value** to -20 dB.

6.15. Defining Limit Line Tables
1. Press **Trace Next** to select trace to set the limit line table.
2. Press **Analysis > Limit Test > Limit Line** and turn it ON to display limit lines.
3. Press **Analysis > Limit Test > Edit Limit Line** 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>0</td>
<td>0 s</td>
<td>600 μs</td>
<td>10 μs</td>
<td>10 μs</td>
</tr>
<tr>
<td>1</td>
<td>0 s</td>
<td>600 μs</td>
<td>75 μs</td>
<td>75 μs</td>
</tr>
<tr>
<td>2</td>
<td>0 s</td>
<td>600 μs</td>
<td>100 μs</td>
<td>100 μs</td>
</tr>
<tr>
<td>3</td>
<td>0 s</td>
<td>600 μs</td>
<td>150 μs</td>
<td>150 μs</td>
</tr>
<tr>
<td>4</td>
<td>0 s</td>
<td>600 μs</td>
<td>200 μs</td>
<td>200 μs</td>
</tr>
</tbody>
</table>

4. Press **Analysis > Limit Test > Limit Test** and turn it ON.
5. Press **Analysis > Limit Test > Fail Sign** to switch the fail sign ON/OFF. When turned on, the Fail sign is displayed on the E5071C’s screen, if one or more failed traces are within the channel.
6. Press **System > Misc Setup > Beeper > Beep Warning** to turn ON/OFF the warning beeper.
7. [Appendix] Defining TRL Calibration Kit

The TRL calibration kit file is defined with the E5071C before TRL calibration. Refer to the values defined by the fixture.

1. Create a new cal kit file.
   A) Press Cal > Cal Kit and select User to setup a cal kit definition file.
   B) Press Cal > Modify Cal Kit > Label Kit (User) and enter name of new cal kit file. (i.e. USB3.1 TRL).

2. Define thru standard.
   A) Press Cal > Modify Cal Kit > Define STDs > 1. No Name > Label and enter “Thru”.
   B) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > STD Type and select Delay/Thru.
   C) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Offset Delay and enter the value of thru standard. (i.e. 0.0000 s)
   D) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Offset Z0 and enter the value of the thru standard. (i.e. 50.000 ohm)
   E) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Offset Loss and enter the value of the thru standard. (i.e. 0.0000 ohm/s)
   F) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Min. Frequency and enter the value of the thru standard. (i.e. 0.0000 Hz)
   G) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Max. Frequency and enter the value of the thru standard. (i.e. 20.000 GHz)
   H) Press Cal > Modify Cal Kit > Define STDs > 1.Thru > Media and select Coaxial.

   A) Press Cal > Modify Cal Kit > Define STDs > 2. No Name > Label and enter “Short”.
   B) Press Cal > Modify Cal Kit > Define STDs > 2.Short > STD Type and select Short.
   C) Press Cal > Modify Cal Kit > Define STDs > 2.Short > Offset Delay and enter the value of short standard. (i.e. 0.0000 s)
   D) Press Cal > Modify Cal Kit > Define STDs > 2.Short > Offset Z0 and enter the value of the short standard. (i.e. 50.000 ohm)
   E) Press Cal > Modify Cal Kit > Define STDs > 2.Short > Offset Loss and enter the value of the short standard. (i.e. 0.0000 ohm/s)
   F) Press Cal > Modify Cal Kit > Define STDs > 2.Short > Min. Frequency and enter the value of the short standard. (i.e. 0.0000 Hz)
   G) Press Cal > Modify Cal Kit > Define STDs > 2.Short > Max. Frequency and
enter the value of the short standard. (i.e. 20.000 GHz)

H) Press **Cal > Modify Cal Kit > Define STDs > 2.Short > Media** and select **Coaxial**.

4. Define open standard.

   A) Press **Cal > Modify Cal Kit > Define STDs > 3.No Name > Label** and enter “Open”.

   B) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > STD Type** and select **Open**.

   C) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Offset Delay** and enter the value of open standard. (i.e. 0.0000 s)

   D) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Offset Z0** and enter the value of the open standard. (i.e. 50.000 ohm)

   E) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Offset Loss** and enter the value of the open standard. (i.e. 0.0000 ohm/s)

   F) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Min. Frequency** and enter the value of the open standard. (i.e. 0.0000 Hz)

   G) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Max. Frequency** and enter the value of the open standard. (i.e. 20.000 GHz)

   H) Press **Cal > Modify Cal Kit > Define STDs > 3.Open > Media** and select **Coaxial**.

5. Define load standard.

   A) Press **Cal > Modify Cal Kit > Define STDs > 4.No Name > Label** and enter “Load”.

   B) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > STD Type** and select **Load**.

   C) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Offset Delay** and enter the value of load standard. (i.e. 0.0000 s)

   D) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Offset Z0** and enter the value of the load standard. (i.e. 50.000 ohm)

   E) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Offset Loss** and enter the value of the load standard. (i.e. 0.0000 ohm/s)

   F) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Min. Frequency** and enter the value of the load standard. (i.e. 0.0000 Hz)

   G) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Max. Frequency** and enter the value of the load standard. (i.e. 100.00 MHz)

   H) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Media** and select **Coaxial**.

   I) Press **Cal > Modify Cal Kit > Define STDs > 4.Load > Length Type** and select **Fixed**.

6. Define line 1 standard.
A) Press Cal > Modify Cal Kit > Define STDs > 5.No Name > Label and enter “Line1”.

B) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > STD Type and select Delay/Thru.

C) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Offset Delay and enter the value of line1 standard. (i.e. 938.21 ps)

D) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Offset Z0 and enter the value of the line1 standard. (i.e. 50.000 ohm)

E) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Offset Loss and enter the value of the line1 standard. (i.e. 0.0000 ohm/s)

F) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Min. Frequency and enter the value of the line1 standard. (i.e. 100.00 MHz)

G) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Max. Frequency and enter the value of the line1 standard. (i.e. 376.00 MHz)

H) Press Cal > Modify Cal Kit > Define STDs > 5.Line1 > Media and select Coaxial.

7. Define line 2 standard.

A) Press Cal > Modify Cal Kit > Define STDs > 6.No Name > Label and enter “Line2”.

B) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > STD Type and select Delay/Thru.

C) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > Offset Delay and enter the value of line2 standard. (i.e. 250.43 ps)

D) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > Offset Z0 and enter the value of the line2 standard. (i.e. 50.000 ohm)

E) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > Offset Loss and enter the value of the line2 standard. (i.e. 0.0000 ohm/s)

F) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > Min. Frequency and enter the value of the line2 standard. (i.e. 376.00 MHz)

G) Press Cal > Modify Cal Kit > Define STDs > 6.Line2 > Max. Frequency and enter the value of the line2 standard. (i.e. 1.414 GHz)


8. Define line 3 standard.

A) Press Cal > Modify Cal Kit > Define STDs > 7.No Name > Label and enter “Line3”.

B) Press Cal > Modify Cal Kit > Define STDs > 7.Line3 > STD Type and select Delay/Thru.

C) Press Cal > Modify Cal Kit > Define STDs > 7.Line3 > Offset Delay and enter the value of line3 standard. (i.e. 66.34 ps)
D) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **7.Line3** > **Offset Z0** and enter the value of the line3 standard. (i.e. 50.000 ohm)

E) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **7.Line3** > **Offset Loss** and enter the value of the line3 standard. (i.e. 0.0000 ohm/s)

F) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **7.Line3** > **Min. Frequency** and enter the value of the line3 standard. (i.e. 1.414 GHz)

G) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **7.Line3** > **Max. Frequency** and enter the value of the line3 standard. (i.e. 5.318 GHz)

H) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **7.Line3** > **Media** and select Coaxial.


I) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.No Name** > **Label** and enter “Line4”.

J) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **STD Type** and select Delay/Thru.

K) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Offset Delay** and enter the value of line4 standard. (i.e. 17.06 ps)

L) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Offset Z0** and enter the value of the line4 standard. (i.e. 50.000 ohm)

M) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Offset Loss** and enter the value of the line4 standard. (i.e. 0.0000 ohm/s)

N) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Min. Frequency** and enter the value of the line4 standard. (i.e. 5.318 GHz)

O) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Max. Frequency** and enter the value of the line4 standard. (i.e. 20.000 GHz)

P) Press **Cal** > **Modify Cal Kit** > **Define STDs** > **8.Line4** > **Media** and select Coaxial.

10. Specify sub class of cal kit.

A) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **Sub Class** > **Sub Class 1**.

B) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **TRL Thru** > **Set All** > **1.Thru**.

C) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **TRL Reflect** > **2.Short**.

D) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **TRL Line/Match** > **Set All** > **5.Line1**.

E) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **Sub Class** > **Sub Class 2**.

F) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **TRL Line/Match** > **Set All** > **6.Line2**.

G) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **Sub Class** > **Sub Class 3**.

H) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **TRL Line/Match** > **Set All** > **7.Line3**.

I) Press **Cal** > **Modify Cal Kit** > **Specify CLSs** > **Sub Class** > **Sub Class 4**.

K) Press Cal > Modify Cal Kit > Specify CLSs > Sub Class > Sub Class 5.

L) Press Cal > Modify Cal Kit > Specify CLSs > TRL Line/Match > Set All > 4.Load.

11. Press Cal > Modify Cal Kit and select Export Cal Kit... to Save Cal Kit File (*.ckx).
8. [Appendix] De-embedding File Creation using PLTS AFR

The procedure to create the de-embedding files using the Keysight Physical Layer Test System (PLTS) Automatic Fixture Removal (AFR) function and 2x Thru standard is introduced in the section.

8.1. 2x Thru Standard Measurement
1. Recall the state file as described in 5.2.1. Recalling a State File.
2. Perform the calibration using ECal as described in 5.3.1.2 Frequency-Domain Measurements > 1. ECal Calibration.
3. Connect the E5071C ports (port 1 to 4) to 2x Thru standard with RF cables as shown below (1, 2, 3, 4 are E5071C port numbers).

![2x Thru Diagram](image)

3. Press **Channel Max** to maximize Channel 2 on the screen.
4. Press **Trace Next** to select Trace 6 (Sdd21).
5. Press **Trace Max** to maximize the selected trace on the screen.
6. Press **Analysis > Fixture Simulator > Port ZConversion > Port ZConversion** and turn OFF.
7. Press **Trigger > Single**.
8. Press **Save/Recall > Save SnP > S4P > [1-2-3-4]...**
9. Enter file name and save the 4-port Touchstone file (*.s4P).
10. Press **Analysis > Fixture Simulator > Port ZConversion > Port ZConversion** and turn ON.

8.2. De-embedding File Creation
1. Launch PLTS software.
2. Click **Utilities > Automatic Fixture Removal > Wizard**.
3. Select Differential/4-Ports > Next.

4. Check 2X Thru > Next.
5. Load the Touchstone file for 2x Thru > Next.

6. Click Next.
7. Select **PNA Format** > enter file name > Click **Save Fixture Files** to create two fixture files > Exit.