USB 3.1 Gen 2 (10 Gbps) Cable Assembly Test Challenges

Last Update: February 26, 2015
Disclaimer

The USB 3.1 compliance test requirements are not final. Therefore, all opinions, judgments, recommendations, etc. that are presented herein are the opinions of the presenter of the material and do not necessarily reflect the opinions of the USB-IF, or other member companies.

Reference Documents

- Universal Serial Bus 3.1 Specification (Revision 1.0, July 26, 2013)
- Universal Serial Bus 3.1 Connectors and Cable Assemblies Compliance Document (Draft)
- Universal Serial Bus Type-C Cable and Connector Specification (Revision 1.0, August 11, 2014)
- Universal Serial Bus Type C Connectors and Cable Assemblies Compliance Document (Draft)
Agenda

• Introduction
• USB Type-C Cable and Connector
• USB 3.1 – What’s different?
• USB 3.1 Cable and Connector Compliance Test Challenges
• Summary
• Questions
Keysight Digital Standards Program

- Our solutions are driven and supported by Keysight experts involved in international standards committees:
  - Joint Electronic Devices Engineering Council (JEDEC)
  - PCI Special Interest Group (PCI-SIG®)
  - Video Electronics Standards Association (VESA)
  - Serial ATA International Organization (SATA-IO)
  - USB-Implementers Forum (USB-IF)
  - Mobile Industry Processor Interface (MIPI) Alliance
  - And many others…

- We’re active in standards meetings, workshops, plugfests, and seminars.
- We get involved so you benefit with the right solutions when you need them.
Keysight Digital Standards Program

We understand your future requirements, because we help shape them

The Keysight Digital Standards Team maintains engagement in the top high tech standards organizations
USB Implementers Forum (USB-IF)

USB-IF Board Members
Intel, NEC, HP, Microsoft, ST-Ericsson, LSI

Marketing WG
Device WG
Compliance Review Board
Newark “USB C” WG
Compliance Committee
USB 3.1 Test Spec WG

Keysight
Active Membership

USB 3.1 Tools and Test Procedures
Test House Approval
Interop. Workshop Testing

Training and equipment

owner
work in progress
influences
responsible
approval

USB 3.1 Gen2
Cable Assembly
Test Challenges

Page 6
Worldwide Shipment of USB-enabled Devices

- USB is the most successful interface in the history of PC
- Device charging over USB has become a major consumer feature
- USB installed base is 10+ billion units and growing at 3+ billion units a year
- Adoption is virtually 100% in PC and peripheral categories

USB 3.1 Gen2
Cable Assembly
Test Challenges

Source: In-Stat, May 2011
Keysight is the leading USB solution provider to test labs worldwide

Approved labs are listed at [www.usb.org/developers/compliance/labs](http://www.usb.org/developers/compliance/labs)

Note: SuperSpeed certified test labs in RED.
Terminology

Here are some terms and their meanings used during this presentation

- **Gen1**: physical layer associated with a 5.0 Gbps signaling rate
- **Gen2**: physical layer associated with a 10 Gbps signaling rate
- **GenX**: generic term used to refer to any of the combinations of Gen1 and Gen2
- **SuperSpeed**: architectural layer portions when operating with a Gen1 PHY
- **SuperSpeedPlus**: architectural layer portions when operating with a Gen2 PHY
USB Type-C Cable and Connector

Key Features:
- USB 2.0 (HS, FS, LS)
- USB 3.1 (Gen1, Gen2)
- Reversible plug orientation and direction
- Smaller size
- Extra pins for VBUS to achieve higher power (up to 100W)
- Display standards are looking at this as the next Gen display connector

Source: IDF14 (NETS002), Intel
USB Type-C Functional Signal Plan

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

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>A9</th>
<th>A10</th>
<th>A11</th>
<th>A12</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>TX1+</td>
<td>TX1−</td>
<td>VBUS</td>
<td>CC1</td>
<td>D+</td>
<td>D−</td>
<td>SBU1</td>
<td>VBUS</td>
<td>RX2−</td>
<td>RX2+</td>
<td>GND</td>
</tr>
<tr>
<td>GND</td>
<td>RX1+</td>
<td>RX1−</td>
<td>VBUS</td>
<td>SBU2</td>
<td>D−</td>
<td>D+</td>
<td>CC2</td>
<td>VBUS</td>
<td>TX2−</td>
<td>TX2+</td>
<td>GND</td>
</tr>
</tbody>
</table>

| B12 | B11 | B10 | B9  | B8  | B7  | B6  | B5  | B4  | B3  | B2  | B1  |

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

<table>
<thead>
<tr>
<th>A12</th>
<th>A11</th>
<th>A10</th>
<th>A9</th>
<th>A8</th>
<th>A7</th>
<th>A6</th>
<th>A5</th>
<th>A4</th>
<th>A3</th>
<th>A2</th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>RX2+</td>
<td>RX2−</td>
<td>VBUS</td>
<td>SBU1</td>
<td>D−</td>
<td>D+</td>
<td>CC</td>
<td>VBUS</td>
<td>TX1−</td>
<td>TX1+</td>
<td>GND</td>
</tr>
<tr>
<td>GND</td>
<td>TX2+</td>
<td>TX2−</td>
<td>VBUS</td>
<td>VCONN</td>
<td></td>
<td></td>
<td>SBU2</td>
<td>VBUS</td>
<td>RX1−</td>
<td>RX1+</td>
<td>GND</td>
</tr>
</tbody>
</table>

| B1  | B2  | B3  | B4  | B5  | B6  | B7  | B8  | B9  | B10 | B11 | B12 |
USB Type-C Cable Assemblies

Type-C to Type-C Cable Assemblies

Two cables are defined:
• USB3.1 Type-C to Type-C
• USB2.0 Type-C to Type-C

Type-C Legacy Cable Assemblies

USB Type-C to USB3.1
• Standard-A
• Standard-B
• Micro-B

USB Type-C to USB2.0
• Standard-A
• Standard-B
• Micro-B
• Mini-B

Type-C Legacy Adapters

USB Type-C to Std-A
USB Type-C to USB2.0 Micro-B
USB Type-C Cable Assembly Compliance Test

- All SuperSpeed TDR impedance and S-parameter specifications are informative, with the exception of differential to common mode conversion.

- The normative specifications are based on the following integrated S-parameters:
  - Insertion Loss Fit at Nyquist Frequencies (ILfitatNq)
  - Integrated Multi-reflection (IMR)
  - Integrated Crosstalk between SuperSpeed Pairs (INEXT/IFEXT)
  - Integrated Return Loss (IRL)

### Table: IMR Specifications

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Gen1</th>
<th>Gen2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-7 dB</td>
<td>-4 dB</td>
</tr>
<tr>
<td>5</td>
<td>-12 dB</td>
<td>-6 dB</td>
</tr>
<tr>
<td>10</td>
<td>N/A</td>
<td>-11 dB</td>
</tr>
</tbody>
</table>

### Equations

\[ IMR = dB \left( \frac{\int_{0}^{f_{\text{max}}} |ILD(f)|^2 |V_{\text{in}}(f)|^2 df}{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 df} \right) \]

\[ INEXT = dB \left( \frac{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 (|NEXT(f)|^2 + 0.125^2 |C2D(f)|^2) df + |V_{dd}(f)|^2 |NEXTd(f)|^2 df}{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 df} \right) \]

\[ IFEXT = dB \left( \frac{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 (|FEXT(f)|^2 + 0.125^2 |C2D(f)|^2) df + |V_{dd}(f)|^2 |FEXTd(f)|^2 df}{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 df} \right) \]

\[ IRL = dB \left( \frac{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 |SDD21(f)|^2 (|SDD11(f)|^2 + |SDD22(f)|^2) df}{\int_{0}^{f_{\text{max}}} |V_{\text{in}}(f)|^2 df} \right) \]
# USB 3.1 Gen1 vs Gen2 Overview

<table>
<thead>
<tr>
<th></th>
<th>Gen1</th>
<th>Gen2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data rate</strong></td>
<td>5 Gb/s</td>
<td>10 Gb/s</td>
</tr>
<tr>
<td><strong>Encoding</strong></td>
<td>8b/10b</td>
<td>128b/132b (20% additional bandwidth over 8b/10b)</td>
</tr>
<tr>
<td><strong>Tx REF EQ</strong></td>
<td>Post: -3 dB</td>
<td>Pre: 2.2 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post: -3.1 dB</td>
</tr>
<tr>
<td><strong>Rx REF EQ</strong></td>
<td>CTLE</td>
<td>CTLE (6 level) + 1 tap DFE</td>
</tr>
<tr>
<td><strong>CDR (JTF BW)</strong></td>
<td>4.9 MHz</td>
<td>7.5 MHz</td>
</tr>
<tr>
<td><strong>Eye Height / Mask</strong></td>
<td>132 psec (0.66 UI)</td>
<td>71.4 psec (0.714 UI)</td>
</tr>
<tr>
<td></td>
<td>100mV</td>
<td>70mV</td>
</tr>
</tbody>
</table>

- **TJ**: 132 psec (0.66 UI) vs 71.4 psec (0.714 UI)
- **Target Channel**: 3 meter (-17 dB @ 2.5 GHz) vs 1 meter (-23 dB @ 5 GHz)
Gen2 Reference Transmitter Equalization

3-tap FIR Equalizer

Gen2 TXEQ Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preshoot (dB)</td>
<td>2.2±1.0</td>
<td>Normative</td>
</tr>
<tr>
<td>De-emphasis (dB)</td>
<td>-3.1±1.0</td>
<td>Normative</td>
</tr>
<tr>
<td>C-1</td>
<td>-0.083</td>
<td>Informative</td>
</tr>
<tr>
<td>C1</td>
<td>-0.125</td>
<td>Informative</td>
</tr>
<tr>
<td>Nominal Boost (dB)</td>
<td>4.7</td>
<td>Informative</td>
</tr>
<tr>
<td>Va/Vd</td>
<td>0.834</td>
<td>Informative</td>
</tr>
<tr>
<td>Vb/Vd</td>
<td>0.584</td>
<td>Informative</td>
</tr>
<tr>
<td>Vc/Vd</td>
<td>0.750</td>
<td>Informative</td>
</tr>
</tbody>
</table>

Note: Refer to “USB 3.1 CTLE” ECN (20131608-ECN) for details.
Gen2 Reference Receiver Equalization

Multi-level CTLE + 1 tap DFE

- Eye closed at end of channel
- Need equalizer to open eye
- Iterate through multiple CTLE settings for best eye opening

Note: Refer to “USB 3.1 CTLE” ECN (20131608-ECN) for details.
Compliance Channels
Used to test for worst case channel conditions

**USB 3.0 Compliance Channels**
- **Standard connector:**
  - Channel loss will dominate
  - 11" PCB trace for device testing
  - 5" PCB trace for host testing
  - 3 meter USB 3.0 cable
- **Micro connector:**
  - Channel loss will dominate
  - 11” PCB trace for device testing
  - 5" PCB trace for host testing
  - 1 meter USB 3.0 cable
- **Tethered:**
  - Channel loss will dominate
  - 11” PCB trace for device testing
  - 5” PCB trace for host testing
  - short USB 3.0 cable
- **Short Channel:**
  - no cable and shortest possible PCB traces

**USB 3.1 Compliance Channels**
10 dB 6 dB 7 dB
- Die to die target is 23 dB @ 5 GHz
- Host/device exceeding 10/7 dB may need repeater
Keysight USB 3.1 Total Test Solution

Transmitter Test

- U7243B
  - USB Compliance Test Software

- DSOX92504A
  - Infiniium Scope

- TBD
  - Tx Test Fixture

Interconnect Test

- E5071C ENA Option TDR

- TBD
  - Cable/Connector Test Fixture

Receiver Test

- N5990A
  - USB Compliance Test Software

- M8020A
  - J-BERT High-Performance Serial BERT

- TBD
  - Rx Test Fixture from USB-IF

Cable

- USB 3.1 Gen2
  - Cable Assembly Test Challenges
USB 3.1 Cable Assembly

- Backwards compatible with existing USB 3.0 connectors
- Cable assembly insertion loss budget $\geq -6 \text{ dB} @ 5 \text{ GHz}$
  - Targeted for 1 meter, not 3 meters
  - Longer than 1 meter may require an active cable

Enhanced SuperSpeed signal pairs
- Typically Shielded Differential Pair (SDP), twisted, or coaxial signal pairs
- Shield needed for signal integrity and EMI performance

D+/D- signal pair
- Typically unshielded twisted pair (UTP)
- Intended to transmit the USB 2.0 signals

**Figure 3-2. USB 3.1 Cable**
USB 3.1 Cable/Connector Compliance Test

Measurement Parameters

Time Domain Measurements
• D+/D- Pair Propagation Delay (USB2.0)
• D+/D- Pair Propagation Delay Skew (USB2.0)
• NEXT/FEXT between D+/D- and Gen2 Signal Pairs
• [Raw Cable] Characteristic Impedance (Informative)
• [Raw Cable] Intra-Pair Skew (Informative)
• [Mated Connector] Impedance (Informative)

Frequency Domain Measurements
• D+/D- Pair Attenuation (USB2.0)
• Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)
• Differential to Common-Mode Conversion
• Cable Shielding Effectiveness
• [Raw Cable] Insertion Loss (Informative)
• [Mated Cable Assembly] Insertion Loss (Informative)
• [Mated Cable Assembly] NEXT between Gen2 Signal Pairs (Informative)
• [Mated Cable Assembly] NEXT/ FEXT between D+/D- and Gen2 (Informative)
USB 3.1 Cable/Connector Compliance Test
Measurement Parameters

Time Domain
- [Raw Cable] Impedance
- [Mated Connector] Impedance
- Intra-Pair Skew

Frequency Domain
- Raw Cable] Impedance
- [Mated Connector] Impedance
- [Mated Cable Assy] Gen2 NEXT
- D+/D- & Gen2 NEXT & FEXT
- Mode Conversion
- Cable Shielding Effectiveness
- Insertion Loss
- Mode Conversion
- Gen2 NEXT & FEXT

Note: Normative parameters in BLUE.
USB 3.1 Cable/Connector Compliance Test

USB 3.0 vs USB 3.1

1. Time Domain Measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Changes from USB 3.0 to USB 3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+/D- Pair Propagation Delay (USB2.0)</td>
<td>No change</td>
</tr>
<tr>
<td>D+/D- Pair Propagation Delay Skew (USB2.0)</td>
<td>No change</td>
</tr>
<tr>
<td>Crosstalk between D+/D- and Gen2 Pairs</td>
<td>No change</td>
</tr>
<tr>
<td>[Raw Cable] Characteristic Impedance (Informative)</td>
<td>83 to 97 ohm =&gt; 85 to 95 ohm</td>
</tr>
<tr>
<td>[Raw Cable] Intra-Pair Skew (Informative)</td>
<td>No change</td>
</tr>
<tr>
<td>[Mated Connector] Impedance (Informative)</td>
<td>Normative =&gt; Informative 75 to 105 ohm @ 50 ps (20-80%) =&gt; 80 to 100 ohm @ 40 ps (20-80%)</td>
</tr>
</tbody>
</table>
## USB 3.1 Cable/Connector Compliance Test

### USB 3.0 vs USB 3.1

2. Frequency Domain Measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Changes from USB 3.0 to USB 3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+/D- Pair Attenuation (USB2.0)</td>
<td>No change</td>
</tr>
<tr>
<td>Differential to Common Mode Conversion</td>
<td>Max freq 7.5 GHz =&gt; 10 GHz</td>
</tr>
<tr>
<td>Channel Metrics (ILfitatNq, IMR, IXT, eW, eH)</td>
<td>New for USB 3.1 Compliance tool provided by USB-IF</td>
</tr>
<tr>
<td>Cable Shielding Effectiveness</td>
<td>New for USB 3.1</td>
</tr>
<tr>
<td>[Raw Cable] Insertion Loss (Informative)</td>
<td>lower loss required</td>
</tr>
<tr>
<td>[Mated Cable Assembly] Insertion Loss (Informative)</td>
<td>Normative =&gt; Informative</td>
</tr>
<tr>
<td></td>
<td>&gt;= -6 dB (DC to 5 GHz)</td>
</tr>
<tr>
<td>[Mated Cable Assembly] NEXT between Gen2 Pairs (Informative)</td>
<td>Normative =&gt; Informative time domain =&gt; frequency domain</td>
</tr>
<tr>
<td>[Mated Cable Assembly] NEXT and FEXT between D+/D- and Gen2 pairs (Informative)</td>
<td>New for USB 3.1</td>
</tr>
</tbody>
</table>
USB 3.1 Cable/Connector Challenges

Tighter device margins (1UI is 100 ps @10 Gbps)

- Significant loss at higher frequencies require more rigorous approach to removing fixture effects, to measure the true performance of the device

- Channel response affected by many features in channel (loss, reflection, crosstalk, mode conversion)

- Managing EMI and RFI levels from the cable assembly
Removing the Fixture Effects from Measurement

Overview

• Error correction shall be performed to remove the unwanted test fixture trace effects
• The **2x Thru de-embedding** and **in-fixture TRL calibration** are the methods introduced in the USB 3.1 Cable and Connector Compliance Specification (draft)
Removing the Fixture Effects from Measurement
2x Thru De-embedding Procedure

1. Full calibration with ECal

   - The calibration reference plane is established at the end of RF cables

   ![Calibration Setup](image1.png)

2. De-embed S-parameters of fixture traces

   - The calibration reference plane is extended to the edge of USB connectors (TP1=>TP3, TP2=>TP4).

   ![Measurement Setup](image2.png)
Removing the Fixture Effects from Measurement
Creating De-embedding Files Using AFR

1. Full calibration with ECal

2. Measure 2x Thru standards

3. Create de-embedding files using Automatic Fixture Removal (AFR) on Physical Layer Test System (PLTS) software

The AFR feature extracts two de-embedding files for fixtures 1 and 2 from the 2x thru S-parameters.
Removing the Fixture Effects from Measurement

In-fixture TRL Calibration

• Use the set of TRL standards on the calibration board to conduct TRL calibration
• The calibration reference plane is extended to the edge of USB connectors (TP3, TP4).

TRL Standards

- Thru
- Reflect
- Line 1
- Line 2
- Line 3
- Load

TP1 TP3
TP4 TP2
Removing the Fixture Effects from Measurement
AFR vs TRL

[USB Cable Assembly] Differential Insertion Loss

- Freq [GHz]
- dB

PASS
FAIL

AFR
TRL
No Cal
Type-C Limit
New Compliance Methodology

Traditional Method

Interconnects have been characterized by measuring parametric characteristics such as insertion loss and impedance.
New Compliance Methodology

Traditional Method

The limitation of the traditional parametric measurement is that it does not allow tradeoffs among the various test parameters.

Will this spec violation really cause a interoperability issues?
New Compliance Methodology
Stressed Eye Diagram Analysis of Interconnects

Input the expected worst case performance of the transmitter as the “stressed” signal to the cable assembly…

… apply equalization and evaluate the eye diagram at the output of the cable assembly.
New Compliance Methodology

Channel Metrics

There are three signal integrity impairments that impact the end-to-end link performance: attenuation, reflection and crosstalk.

Three parameters are used as the channel metrics to represent these three impairments:

- Insertion loss fit at Nyquist frequency (ILfitatNq)
- Integrated multi-reflection (IMR)
- Integrated crosstalk (IXT)

\[
IL_{fit \@ \ Nyquist}
\]

\[
IMR = \frac{1}{UT} \sqrt{\int_{-\infty}^{\infty} |MR(f)|^2 df}
\]

\[
IXT = \frac{1}{UT} \sqrt{\int_{-\infty}^{\infty} |XT(f)|^2 df}
\]
New Compliance Methodology

Channel Margin

Based on channel eye height (eH) and/or eye width (eW) instead of component S-parameters profiles.

**Pass/Fail Criteria**

- \( eH = f_H(ILfitatNq, IMR, IXT) > 0 \)
- \( eW = f_W(ILfitatNq, IMR, IXT) > 0 \)

**AND**

- \( ILfitatNq \geq -22 \text{ dB} \)
- \( IMR \leq 60 \text{ mV} \)
- \( IXT \leq 25 \text{ mV} \)


“Methodology Used to Determine SuperSpeed USB 10 Gbps (USB 3.1) - Gen2 Channel and Cable Assembly High Speed Compliance”
New Compliance Methodology
Reference Hosts and Devices

- The cable assembly S-parameters are combined with the reference host/device S-parameters to obtain the S-parameters of the entire channel.
- A cable assembly needs to pass with both “long” host/device and “short” host/device.

The following 8 ref host/device combinations are defined:
- Long Host to Long Device
- Long Device to Long Host
- Long Host to Short Device
- Long Device to Short Host
- Short Host to Long Device
- Short Device to Short Host
- Short Host to Short Device
- Short Device to Short Host

Long ref host/device channel to expose loss

Short ref host/device channel to expose multi-reflection (and crosstalk)
New Compliance Methodology

Procedure

1. Measure S-parameters of all six combinations of the Gen2 differential pairs.

2. Import the touchstone files into the USB 3.1 Standard Tool to perform pass/fail judgment for all combinations of reference host and device.
Managing RF Interference

Digital data has a broadband spectrum, with significant content at harmonics of the Nyquist frequency. (e.g. 2.5 GHz for 5 Gbps USB 3.0 overlaps the WiFi 2.4 GHz - 2.5GHz band)
5.6.1.3.2.7 Cable Shielding Effectiveness

The cable assembly shielding effectiveness (SE) test measures the radio frequency interference (RFI) level from the cable assembly. To perform the measurement, the cable assembly shall be installed in the cable SE test fixture as shown in Figure 5-29. The coupling factors from the cable to the fixture are characterized. The Cable SE test fixtures and specification values are under development and are to be included in future updates to this specification.

Figure 5-29. Set Up For Cable SE Measurement (subject to change)
USB 3.1 Cable/Connector Compliance Test Solution

USB 3.1 Cable/Connector Compliance testing requires measurements in both time and frequency domains.

**Frequency Domain**
- D+/D- Attenuation
- Channel Metrics (eH, eW, ILfitatNq, IMR and IXT)*
- Differential to Common-Mode Conversion
- Cable Shielding Effectiveness
- [Raw Cable]
  - Insertion Loss (Informative)
- [Mated Cable Assy]
  - Insertion Loss (Informative)
  - NEXT between Gen2 Pairs (Informative)
  - NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)

**Time Domain**
- D+/D- Propagation Delay
- D+/D- Propagation Delay Skew
- Crosstalk between D+/D- and Gen2 Pairs
- [Raw Cable]
  - Characteristic Impedance (Informative)
  - Intra-Pair Skew (Informative)
- [Mated Connector]
  - Impedance (Informative)

* Compliance standard tool from USB-IF is required for pass/fail judgment of channel metrics tests.

**Traditional Solution**
- Vector Network Analyzer (VNA)
- TDR Scope

**New Solution**
- ALL parameters can be measured with ENA Option TDR
  - One-box solution
USB 3.1 Cable/Connector Compliance Test

Typical Configuration

- ENA Mainframe [1]
  - E5071C-4D5: 4-port, 300 kHz to 14 GHz
  - E5071C-4K5: 4-port, 300 kHz to 20 GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module (N4433A)

[1] 20 GHz option is recommended, since the Type-C cable/connector requires measurements up to 15 GHz.

[2] The list above includes the major equipment required. Please contact our sales representative for configuration details.

Method of Implementation (MOI)

- MOI document and instrument setup file will be made available for download on Keysight.com

Test Fixtures (TBD)

Fixtures for testing USB 3.1 connectors and cable assemblies will be made available for purchase through USB-IF.
Certified Method of Implementation (MOI)

Compliance test solutions (i.e. certified MOIs) for ENA Option TDR are available for free download at [www.keysight.com/find/ena-tdr_compliance](http://www.keysight.com/find/ena-tdr_compliance)

<table>
<thead>
<tr>
<th>Cable / Connector</th>
<th>Tx/Rx Impedance (Hot TDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB</td>
<td>HDMI</td>
</tr>
<tr>
<td>HDMI</td>
<td>SATA</td>
</tr>
<tr>
<td>SATA</td>
<td>MIPI</td>
</tr>
<tr>
<td>DisplayPort</td>
<td>10GBASE-KR/40GBASE-KR</td>
</tr>
<tr>
<td>100BASE-TX</td>
<td>MHL</td>
</tr>
<tr>
<td>10GBASE-T</td>
<td>Thunderbolt</td>
</tr>
<tr>
<td>10GBASE-KR/40GBASE-KR</td>
<td>SD Card (UHS-II)</td>
</tr>
<tr>
<td>MHL</td>
<td>Cfast</td>
</tr>
<tr>
<td>PCIe</td>
<td></td>
</tr>
<tr>
<td>BroadR-Reach</td>
<td></td>
</tr>
</tbody>
</table>
Certified Test Centers using ENA Option TDR

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

Keysight USB Design & Test Information Resource Center
www.keysight.com/find/usb

USB Design and Test - A Better Way (Brochure)

Interconnect testing solutions: ENA Option TDR
www.keysight.com/find/ena-tdr_compliance

Transmitter testing solutions: Oscilloscopes
www.keysight.com/find/scopes

Receiver testing solutions: M8000 JBERT
www.keysight.com/find/usb3_receiver_test

N1930B Physical Layer Test System (PLTS)
www.keysight.com/find/plts

USB-IF
www.usb.org
USB 3.1 Cable/Connector Challenges

Summary

• Significant loss at higher frequencies require more rigorous approach to removing fixture effects, to measure the true performance of the device
  • 2x thru de-embedding using Automatic Fixture Removal (AFR)
  • TRL Calibration

• Channel response affected by many features in channel (loss, reflection, crosstalk, mode conversion)
  • Paradigm shift from traditional parametric testing to stressed eye testing (Channel Metrics/Margin)

• Managing EMI and RFI levels from the cable assembly
  • Cable Shielding Effectiveness

Keysight has the tools and expertise to help you conquer USB 3.1 Physical Layer Test Challenges
USB Type-C Cable/Connector Compliance Test

Measurement Parameters

Time Domain Measurements
- D+/D- Impedance (USB 2.0)
- D+/D- Propagation Delay (USB 2.0)
- D+/D- Intra-pair Skew (USB 2.0)
- [Raw Cable] Characteristic Impedance (Informative)
- [Raw Cable] Intra-Pair Skew (Informative)
- [Mated Connector] Impedance (Informative)
- [CC/SBU] Characteristic Impedance

Frequency Domain Measurements
- D+/D- Pair Attenuation (USB 2.0)
- Differential to Common Mode Conversion
- ILfitatNq, IMR, IXT, IRL
- Shielding Effectiveness
- Insertion Loss (Informative)
- Return Loss (Informative)
- NEXT/FEXT between Gen2 Pairs (Informative)
- NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)
- [Raw Cable] Insertion Loss (Informative)
- [Mated Connector] Insertion Loss (Informative)
- [Mated Connector] Return Loss (Informative)
- [Mated Connector] NEXT/FEXT between Gen2 Pairs (Informative)
- [Mated Connector] NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)
- [Mated Connector] Differential to Common Mode Conversion (Informative)
- Coupling between CC and D+/D-
- VBUS Coupling to SBU_A/SBU_B, CC, and USB D+/D-
- Coupling between SBU_A/SBU_B and CC, SBU_A/SBU_B and USB D+/D-, and SBU_A and SBU_B
# USB Type-C Cable/Connector Compliance Test

## USB 3.1 vs USB Type-C

### 1. Time Domain Measurements

<table>
<thead>
<tr>
<th></th>
<th>USB 3.1 (10 Gbps)</th>
<th>USB Type-C</th>
<th>Changes from USB 3.1 to USB Type-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>D+/D- Differential Impedance</td>
<td>New for Type-C</td>
<td></td>
</tr>
<tr>
<td>D+/D- Pair Propagation Delay</td>
<td>D+/D- Propagation Delay</td>
<td>26 ns/10 ns =&gt; 20 ns, 200 ps (10-90%) rise time =&gt; 400 ps (20-80%) rise time</td>
<td></td>
</tr>
<tr>
<td>D+/D- Propagation Delay Skew</td>
<td>D+/D- Intra-pair Skew</td>
<td>200 ps (10-90%) rise time =&gt; 400 ps (20-80%) rise time</td>
<td></td>
</tr>
<tr>
<td>Crosstalk between D+/D- and Gen2 Signal Pairs</td>
<td>N/A</td>
<td>Not specified for Type-C</td>
<td></td>
</tr>
<tr>
<td>[Raw Cable] Characteristic Impedance (Informative)</td>
<td>[Raw Cable] Characteristic Impedance (Informative)</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>[Raw Cable] Intra-Pair Skew (Informative)</td>
<td>[Raw Cable] Intra-Pair Skew (Informative)</td>
<td>15 ps/m =&gt; 10 ps/m</td>
<td></td>
</tr>
<tr>
<td>[Mated Connector] Impedance (Informative)</td>
<td>[Mated Connector] Differential Impedance (Informative)</td>
<td>90+/−10 ohm =&gt; 85+/− 9 ohm</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>[Mated Cable Assembly] Characteristic Impedance</td>
<td>New for Type-C (low-speed signal requirements)</td>
<td></td>
</tr>
</tbody>
</table>
# USB Type-C Cable/Connector Compliance Test

## USB 3.1 vs USB Type-C

### 2. Frequency Domain Measurements (1)

<table>
<thead>
<tr>
<th>USB 3.1 (10 Gbps)</th>
<th>USB Type-C</th>
<th>Changes from USB 3.1 to USB Type-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+/D- Pair Attenuation</td>
<td>D+/D- Pair Attenuation</td>
<td>lower loss required</td>
</tr>
<tr>
<td>Differential to Common Mode Conversion</td>
<td>[Mated Cable Assembly] Differential to Common Mode Conversion</td>
<td>No change</td>
</tr>
<tr>
<td>Channel Metrics (ILfitatNq, IMR, IXT, eW, eH)</td>
<td>[Mated Cable Assembly] ILfitatNq, IMR, IXT, IRL</td>
<td>Compliance tool for Type-C</td>
</tr>
<tr>
<td>Cable Shielding Effectiveness</td>
<td>Shielding Effectiveness</td>
<td>Spec change</td>
</tr>
<tr>
<td>[Raw Cable] Differential Insertion Loss (Informative)</td>
<td>[Raw Cable] Differential Insertion Loss (Informative)</td>
<td>Max freq 7.5 GHz =&gt; 15 GHz.</td>
</tr>
<tr>
<td></td>
<td>[Mated Connector] Differential Insertion Loss (Informative)</td>
<td>New for Type-C</td>
</tr>
<tr>
<td></td>
<td>[Mated Connector] Differential Return Loss (Informative)</td>
<td>New for Type-C</td>
</tr>
<tr>
<td></td>
<td>[Mated Connector] NEXT/ FEXT between Gen2 Pairs (Informative)</td>
<td>New for Type-C</td>
</tr>
<tr>
<td></td>
<td>[Mated Connector] NEXT/FEXT between D+/D- and Gen2 Pairs</td>
<td>New for Type-C</td>
</tr>
<tr>
<td></td>
<td>[Mated Connector] Differential to Common Mode Conversion</td>
<td>New for Type-C</td>
</tr>
</tbody>
</table>
# USB Type-C Cable/Connector Compliance Test

## USB 3.1 vs USB Type-C

### 2. Frequency Domain Measurements (2)

<table>
<thead>
<tr>
<th>USB 3.1 (10 Gbps)</th>
<th>USB Type-C</th>
<th>Changes from USB 3.1 to USB Type-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Mated Cable Assembly] Differential Insertion Loss (Informative)</td>
<td>[Mated Cable Assembly] Differential Insertion Loss (Informative)</td>
<td>Max freq 5 GHz =&gt; 15 GHz</td>
</tr>
<tr>
<td>[Mated Cable Assembly] Differential Return Loss (Informative)</td>
<td>[Mated Cable Assembly] Differential Return Loss (Informative)</td>
<td>New for Type-C</td>
</tr>
<tr>
<td>[Mated Cable Assembly] NEXT between Gen2 Pairs (Informative)</td>
<td>[Mated Cable Assembly] NEXT/FEXT between Gen2 Pairs (Informative)</td>
<td>FEXT added for Type-C</td>
</tr>
<tr>
<td>[Mated Cable Assembly] NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)</td>
<td>[Mated Cable Assembly] NEXT/FEXT between D+/D- and Gen2 Pairs (Informative)</td>
<td>Max freq 5 GHz =&gt; 7.5 GHz</td>
</tr>
<tr>
<td>[Mated Cable Assembly] CC to D+/D-</td>
<td>[Mated Cable Assembly] CC to D+/D-</td>
<td>New for Type-C (low-speed signal requirements)</td>
</tr>
<tr>
<td>[Mated Cable Assembly] VBUS Coupling to SBU_A/SBU_B, CC, and USB D+/D-</td>
<td>[Mated Cable Assembly] VBUS Coupling to SBU_A/SBU_B, CC, and USB D+/D-</td>
<td>New for Type-C (low-speed signal requirements)</td>
</tr>
<tr>
<td>[Mated Cable Assembly] Coupling between SBU_A/SBU_B and CC, SBU_A/SBU_B and USB D+/D-, and SBU_A and SBU_B</td>
<td>[Mated Cable Assembly] Coupling between SBU_A/SBU_B and CC, SBU_A/SBU_B and USB D+/D-, and SBU_A and SBU_B</td>
<td>New for Type-C (low-speed signal requirements)</td>
</tr>
</tbody>
</table>