Keysight Technologies
How to Correlate USB Type-C Simulation and Measurement
Keysight and Type-C: Create a faster path to done

Application Note
Overview

USB Type-C™ is a breakthrough standard designed to meet the demand for technology that supports new, ever smaller and thinner computers and devices, higher-speed data, and more power and flexibility. Key USB Type-C areas of focus include the connection between devices, managing power, and ensuring valid data transmissions. The USB Type-C connection provides:
- Dynamic power and transmission of USB 2.0 with other protocols
- The ability to be a key interface for many new and future devices
- Backward compatibility
- Ease-of-use as a result of reversibility

Design and test engineers face a number of challenges as they work to integrate USB Type-C into their products, while ensuring interoperability and achieving test compliance. Because USB Type-C compliance test standards have increased and become more complex due to higher data transmission speeds, more power, and additional functionality, successful testing requires highly accurate and standard-compliant test instruments, software, and fixtures.

This measurement brief is one in a series of five covering various aspects of the challenges and solutions for USB Type-C design and test. Topics covered in the series include:
- Cable and connector
- Power delivery
- Transmit/receive
- Simulation-measurement correlation
- Alternate (ALT) mode
  (DisplayPort, Thunderbolt, MHL)

Figure 1. USB Type-C pin out. Notice the symmetrical and reversible structure.

USB Type-C Design Simulation and Validation

Upgrading or integrating USB Type-C into a device is complex. Previous versions with 4- or 8-pin power, ground, and data connection will move to 24-pins with multiple power, ground, Tx/Rx lines, control lines and more. There are several benefits to knowing how your Type-C device will function as early as possible in the design process. Physical layer design simulation helps to ensure a valid layout with optimal performance, eventual test compliance for new device designs, and prevention of possible re-designs later. To avoid costly hardware prototyping cycles and to identify problems early, it is best to perform simulation of the design for compliance testing.

Simulation and design validation for Type-C device performance involves characterization of clock and data signals for the transmitter, receiver, and channel for various stress signals to help ensure interoperability.
Transmitter

During transmitter (Tx) test, a high-speed real-time oscilloscope is used to measure signal quality of each of the specified compliance waveform patterns as they are transmitted. An oscilloscope with a bandwidth of 20 GHz (30 GHz for Thunderbolt) is used to measure eye height, eye width, signal amplitudes, jitter analysis, average data rate, and rise/fall times for each signal.

Transmitter compliance tests include:
- Transmitter eye test
- Transmitter spread spectrum clocking (SSC) profile test
- Low frequency periodic signaling (LFPS) and LFPS-based pulse width modulation messaging (LBPM) protocol test

Receiver

The receiver (Rx) validation test must characterize the performance of the USB device under varying conditions of amplitude and jitter. The receiver is tested with worst case input signal conditions (the stressed eye) varied by a series of sinusoidal jitter frequencies and amplitudes while an error detector monitors the receiver for mistakes or bit errors and calculates the bit error ratio (BER).

A bit error ratio testers’ (BERT) pattern generator applies different jitter conditions to test the receiver’s ability to properly detect transmitted digital signal content, including worst-case impaired input signals, and the bit error ratio. While emulating the receiver in test mode, and receiving the calibrated test signal, the BERT is able to detect the digital content and monitor the performance according to the target BER. The BERT contains both a pattern generator and signal analysis capabilities, as well as calibrated stress conditions such as SSC, sinusoidal jitter (SJ), random jitter (RJ), de-emphasis, and inter-symbol interference (ISI).

Receiver compliance tests include:
- Jitter tolerance test
- Low frequency periodic signaling (LFPS) and LFPS-based pulse width modulation messaging (LBPM) protocol test

Channel (connector & cable)

Channel test includes analysis of S-parameters, which are best measured using a signal analyzer.

Channel compliance tests include:
- Insertion loss fit at Nyquist frequency (ILfitatNy)
- Integrated multi-reflection (IMR)
- Integrated crosstalk (IXT)

It is important for design engineers to also consider that since the Type-C connection is reversible, both sets of Tx/Rx lines must be tested. Additionally, if alternate protocols will be transmitted to and from the device, they must be tested as well.
Design and Simulation/Measurement Correlation Challenges

New device design begins with electronic design automation (EDA) schematic capture, followed by simulation, layout, EM-simulation and then finally tests for compliance to standards. Having confidence in a simulated compliance report is made much easier if the same compliance-standard measurement software is applied to both simulated waveforms from the EDA solution, and measured waveforms captured with test equipment on the bench. Keysight is unique in its ability provide both EDA software and test and measurement equipment that share the same compliance test suites approved by the standards committees. Using a common set of measurement algorithms improve the correlation of simulation and hardware test results, thereby increasing confidence in the methodology of simulated compliance testing for design sign-off.

Simulation of USB 3.1 SuperSpeed+ Type-C designs is especially important due to the increased test challenges of higher data rates, tighter Type-C compliance margins, and signals that are severely degraded in the channel and show a closed eye at the Rx input pin. Proper simulation during design can help alleviate problems that may appear later in the design cycle. An end-to-end simulation from the Tx pin to the Rx pin that encompasses packages, PCBs, and cable connectors will reveal if the signal is experiencing any bottlenecks. Testing the compliance of a design before committing to prototype production can save time and money, and design changes are much easier to make in a simulated environment than on actual PCBs or devices. Also, using the same compliance tools to post-process simulated waveforms and measured waveforms can reduce the overall design to ship cycle.

Keysight Solutions

Keysight’s design simulation software, Advanced Design System (ADS), enables end-to-end simulation of the USB 3.1 Type-C transmitter, receiver, and channel. Design engineers can start with an example schematic design from the W2353EP USB Compliance Test Bench (CTB) within ADS and customize it to reflect the desired IP-block choice. The USB CTB writes the simulated electrical and timing waveforms to a file, in a format that Keysight’s U7243B USB 3.1 compliance test software for Infiniium oscilloscopes uses for offline or stored data. ADS and the USB CTB can help solve the problem of simulation-measurement correlation. If the simulation that is run with the compliance software passes, designers can fabricate with confidence. When the prototype comes back from fabrication it can be plugged into the physical test bench for measurements using the exact same compliance application on an Infiniium oscilloscope.

Figure 2. USB design simulation in ADS software.
If any discrepancies arise, they can be attributed to activities that occur in the interim between the simulation phase and the physical design phase because the compliance application software is identical in both cases.

The W2353EP USB CTB software is available from within ADS and consists of two parts: the simulated test bench, and the Waveform Bridge script. The simulated test bench is composed of sub-circuits, namely a USB transmitter, a channel, and a USB receiver. Once the simulated test bench has been adapted to reflect a pre-manufacture design, the channel simulation runs, writing the appropriate waveforms to the dataset. The Waveform Bridge script creation is an automated process that takes waveforms in the data set and writes them to file that the U7243B USB 3.1 compliance test software for Infiniium oscilloscopes can parse. This application can run live data on the oscilloscope, as well as use stored signals. In addition, users can run the application in "remote" mode, meaning that it can run on any Windows PC (including one with Advanced Design System software on it).

Physical layer simulations may include these waveforms:
- Host: Tx_AMI, Host PCB traces, Via field
- Cable: S-Parameters
- Device: Rx_AMI, Device PCB traces, Via field

Together with U7243B USB transmitter compliance test software application, Keysight’s Infinium oscilloscopes can be used to perform transmitter compliance and validation testing as defined by the USB 3.1 specification. The combined software and instrument capability provides the high performance measurements required to address the high serial speeds of USB 3.1 and the decreased margin that these speeds impose.

**Conclusion**

The USB 3.1 and Type-C specifications introduce many new challenges in USB device design. Verifying compliance of USB transmitter, receiver and channel designs as early as possible in the development phase can expedite device designs and prevent costly re-design cycles. Ensuring that simulation software contains the same measurement science as the instruments’ measurement software used for device verification test will save time and prevent questionable results.

Keysight’s Type-C solution set --software, instruments and fixtures --is ready for complete testing of the standards converging on this universal interface. Whether you’re focused on design or validation, our solution will accelerate you from debug to characterization to compliance to done.
Evolving Since 1939

Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology. From Hewlett-Packard to Agilent to Keysight.

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A personalized view into the information most relevant to you.

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Keysight Services
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Keysight Services can help from acquisition to renewal across your instrument’s lifecycle. Our comprehensive service offerings—one-stop calibration, repair, asset management, technology refresh, consulting, training and more—helps you improve product quality and lower costs.

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Up to ten years of protection and no budgetary surprises to ensure your instruments are operating to specification, so you can rely on accurate measurements.

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