Keysight Technologies
How to Test USB Power Delivery (PD) Over Type-C™
Keysight and Type-C: Create a faster path to done

Application Note

HARDWARE + SOFTWARE + PEOPLE = USB INSIGHTS
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.

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

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)
Type-C Power Delivery

The USB Type-C connection has broadened the range of USB usability by incorporating a dynamic power system called Power Delivery (PD). Increased USB capability is achieved by providing up to 20 volts, 5 amps and 100 watts for powering and charging many more device types, in addition to expanded data transfer capabilities. USB PD’s intelligent and flexible system level power management supports bi-directional power that can switch direction for connected provider (sourcing power) and consumer (sinking power) devices. This dynamic power makes it possible for USB Type-C to support other standards for video and audio signals, such as DisplayPort or Thunderbolt through use of the ALT mode.

How Power Delivery Works

First, an end-to-end USB Type-C connection is made between devices, and cable orientation is determined through the configuration channel (CC) line. USB connection initialization begins with PD. As a first task, PD learns the functionality of the connected cable through an electronic connection between the PD circuit and any full-featured Type-C cable which includes an e-mark chip. The e-mark chip provides cable configuration information and allows it to be electronically recognized and configured according to its current carrying capability (3A or 5A), performance (USB 2.0 or USB 3.1 Gen 1 or Gen 2), and vendor identification (USB Type-C Cable ID function).

Following the cable recognition, the PD circuit and the connected device use the dedicated CC1/CC2 line to send and receive bi-phase marked coding (BMC) messages and begin power negotiation. USB Type-C devices are configured with one of six specified fixed power profiles available for power sources (Figure 2). Devices communicate the power profile they require to the PD circuit, at a given time, and request a specific level of electrical power, variable up to 5 A and 20 V. USB PD dynamically manages the power allocations, adjusting voltage and current, and establishes provider/consumer roles for all the devices connected.

| Hand-held devices, today’s peripherals | Profile 1 | 5V @ 2A | 10W Default start-up profile |
| Tablets, netbooks, most peripherals | Profile 2 | 5V @ 2A, 12V @ 1.5A | 18W |
| Thinner notebooks, larger peripherals | Profile 3 | 5V @ 2A, 12V @ 3A | 36W |
| Larger notebooks, hubs, docks | Profile 4 | 5V @ 2A, 12V, 20V @ 3A | 60W Limit for Micro-B/AB connector |
| Workstations, hubs, docks | Profile 5 | 5V @ 2A, 12V, 20V @ 5A | 100W Limit for Standard A/B connector |

Figure 2. USB Type-C power profiles.
How Power Delivery Works (Continued)

Flexible bi-directional charging is new to USB and now possible using PD’s dynamic control of higher voltage and currents. PD can quickly charge device batteries using its charge adapter which is capable of outputting different and higher voltage levels from 5 V up to 20 V, and current of either 3 A or 5 A, depending on the Type-C cable and connector. Devices are able to request a higher voltage when they are charging using CC1/CC2 lines. When a device charges, all other connected devices must negotiate the amount of power they require, and power can be re-negotiated if another devices requires additional power. PD can also optimize to a lower battery voltage and higher charging current making the time needed for re-charge much faster. PD’s bi-directional power makes it possible for a device that is being powered to also provide power to other devices. In addition to power management of connected devices, PD also manages power to support Type-C Alternate modes.

The higher and dynamically variable power provided by USB Type-C PD requires a great deal more verification and testing by design engineers to achieve compliance. In addition to managing bi-directional power for a device, the CC1/CC2 line signal must be verified for proper protocol transmission for changing power and managing ALT modes while other D± and ALT mode signals are active. Type-C PD’s dynamic ability and range of possible power configurations, combined with the added challenge of evolving specifications for USB 2.0, USB 3.1 Gen 1 and Gen 2, and PD compliance, make Type-C device test validation much more challenging than traditional USB test.

<table>
<thead>
<tr>
<th><strong>Power delivery terminology</strong></th>
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<td><strong>DFP</strong></td>
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<td><strong>BIST</strong></td>
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<td><strong>CC</strong></td>
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Test Challenges

Power delivery specifications continue to evolve. However, power, PHY layer, and protocol layer remain the key test categories for compliance test. Important test parameters design engineers must consider include many different voltage levels, device charging, cable functionality, and determination of provider versus consumer device status. A clear understanding of Type-C device compliance test needs, and the instrumentation and software required to achieve reliable, accurate measurements is vital and will ensure the best and most cost effective results.

Power and charge of devices

When a Type-C device requests a power profile (see Figure 2) such as "profile 2, 12 V", engineers must verify that the correct voltage and current (or wattage profile) are applied. This requires monitoring the CC line for proper protocol and measuring the generated voltage and currents. This is accomplished by monitoring the CC1/CC2 line, a 300 kHz signal, which is tested using an oscilloscope to analyze an eye diagram. Analysis and adjustment of the CC line code can be challenging because cable voltages are continually changing and crosstalk may be present as well.

Thorough testing is also required to ensure that fast charge of device batteries, up to 20V/5A/100W, and adaptive fast charging is safe and reliable. One of the biggest challenges for PD layout verification is the effects of noise, ripple and switching, especially with 10 to 20 G signals, on dc power integrity. Power delivery integrity measurements are made with an oscilloscope and include:

- Supply drift
- PARD (periodic and random disturbances)—noise, ripple and switching transients on power rails
- Static and dynamic load response
- Programmable power rail response
- High frequency transients and noise
- Product electrical validation at extended temperatures
Test Challenges (Continued)

Figure 3. USB power delivery typical power integrity measurements: load response, PARD

Cable functionality including provider/consumer

USB Type-C cables require more testing because PD provides so much more functionality. Each cable configuration scenario, including varying, bi-directional power, USB data transfer, provider/consumer role assignment, and ALT modes used, must be tested.

Testing begins with verification of the active Type-C cable by testing voltage levels to and from the e-mark chip. Next, verification of whether the dual role port (DRP) device is a provider or consumer and currently sourcing or sinking power occurs. The oscilloscope, along with current probes, power supplies and fixtures are used to make measurements such as rise time, fall time, voltage and high-low levels.

PD compliance verification includes testing of other low speed lines: secondary bus (SB), VBUS and GND. The CC line is a shielded pair, and when combined with unshielded D± lines and a potential for up to 100 W power lines, presents a risk of crosstalk. PD is constantly negotiating power to devices, and the VBUS and D± are changing while devices try to decode the CC line, which makes a very challenging configuration to operate within.
Keysight Solutions for Type-C Power Delivery Test

For a real-time protocol triggering and decode tool to debug the PD line using SOP, SOP’, and SOP”, Keysight provides the N8837A USB PD software for Infiniium Series oscilloscopes, and the DSOXT3UPD, DSOX4UPD, and DSOX6UPD protocol options for InfiniiVision 3000T X-, 4000 X-, and 6000 X-Series oscilloscopes. These USB PD protocol software options provide an easy way to debug the Type-C CC BMC encoded 300 kbps signal including, advanced USB triggering, time-correlated decode trace, protocol lister/tabular window view, and USB PD protocol search capability.

An example configuration for physical layer device test includes an oscilloscope, probes, current probe, USB PD protocol software, coupons/fixtures and a PD controller.

With 300 kHz data transfer rates, a Keysight Infiniium oscilloscope of 500 MHz or more that includes a long record length to capture the entire packet is recommended. Although predominantly DC signals, most have AC characteristics so it is important to ensure high enough scope bandwidth to address this. When analyzing the 5 V DC supply signal, it is better to use a probe offset to see transients on the signal. The use of a DC block may miss DC and low frequency content.
Keysight Solutions for Type-C Power Delivery Test (Continued)

Other recommended test components include:
- Two N2873A passive probes for CC1/2 and VBUS test
- An 1147B current probe for load current
- Power delivery controller and associated software and coupons
- Keysight power supply and load. USB PD validation testing needs source and load solutions that meet a stringent combination of requirements for slew rate, transient response and power demands. Keysight recommends the N6752A (100 W) or N6786A (80 W) high performance DC source module and N3303A DC electronic load module
- Keysights’ N7020A power rail probe is designed specifically for analysis of PD 5 V, 10 V or 20 V and has a bandwidth of 2 GHz to capture non-DC signal artifacts. The N7020A power rail probe characteristics address the top concerns for power rail measurements:
  - 1:1 attenuation for low noise
  - ± 24 V offset support power rails up to 24 V to cover PD 20 V
  - 50 kΩ input impedance at DC ensures low DC loading of the power rail being measured
  - 2G Hz bandwidth for capturing high frequency noise and transients that can adversely affect clock and data jitter
For test and debug of low speed signals such as CC1, CC2, VBUS, SBU1, SBU2 and ground, the N7016A Type-C low speed signal access and control fixture is recommended. The fixture connects to the high speed fixture through a captive Type-C cable. This allows engineers to break out the USB 3.1 signals from downstream USB devices for system diagnosis and control. It also allows for signal probing with a high impedance passive probe for in-depth signal analysis.
Conclusion

USB Type-C power delivery opens a whole new set of possibilities for USB connected devices with higher, bi-directional power, and power for non-USB devices through ALT mode. Design and test engineers are faced with numerous test variables and scenarios that must be considered for device verification and compliance. The increased number of tests can be efficiently managed with a selection of the best instruments, fixtures, and software to make test setup easier and provide accurate sources, loads and measurements for fast, accurate compliance test 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.

Related literature

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