USB 3.1 testing part 3: Power Delivery

Randy White - October 22, 2015

Read part 1 of this series on the basics of transmitter and receiver testing for the latest version of USB and part 2 on type-C cable assemblies.

The USB PD (Power Delivery) revision 2.0 is the perfect complement to the new USB 3.1 Type-C connector. Just as the Type-C connector is fully reversible and could eventually be used on virtually every device you can and can't imagine. PD will make sure power flows bi-directionally across devices—from laptops to displays—based on which device has power to spare and which needs power. Add in DisplayPort capabilities via Alternate Mode and you have the interconnect people have wanted for years.

As with all previous USB iterations, you expect to simply plug in your device and everything will just work. Getting to the "just works" phase for something as ambitious as USB Type-C, however, implies that products will need extensive and thorough interoperability testing under a comprehensive range of scenarios and conditions. In the case of PD, this presents a significant challenge caused by the large number of conditions that must be tested and, currently, the lack of formal compliance test requirements and certification programs.

The original USB Power Delivery spec dates back to July 2012 for use on standard type A and B connections to deliver increased power. This specification defined five fixed-power profiles for the power sources and mapped out a flexible power management scheme that let devices request power at an appropriate level through a bidirectional data channel. The power configuration protocol used a 24 MHz BFSK (binary frequency-shift-keying)-coded transmission channel on the V_BUS line.

A new version of the power delivery spec was released in August 2014 as part of the USB 3.1 suite and has been updated slightly since then. The current specification is Power Delivery Rev. 2.0, Version 1.1 and was released in May 2015. It covers the Type-C cable with four power/ground pairs and a separate configuration channel (CC), which now hosts a DC coupled low-frequency BMC (Biphase Mark Code)-coded data channel that is intended to help reduce RF interference. PD protocols were also updated to facilitate such Type-C features as cable ID function, Alternate Mode negotiation, increased V_BUS currents, and V_CONN-powered accessories.

The updates work to improve power handling and make the user experience better with multi device setups such as what's shown in Figure 1. In addition to the providing up to 100 W (which requires a higher V_BUS voltage) the direction of the power sourcing can be dynamically configured, which is referred to as a role swap. The additional control signals provided with the Type-C connector will make this operation slightly easier than trying to fit this into the legacy connectors. As you can imagine, the example configurations similar to what's shown with the two setups in Fig. 1. require additional protocol support. One of the more challenging parts of testing PD is checking the protocol and operational states that can vary significantly in this environment.
Figure 1. The Power Delivery Rev 2.0 specification is intended to improve power handling and improve the user experience for multi-device setups.

Adding to the challenges of PD testing—beyond the 500-page specification itself—is the overlap across the various USB 3.1 testing programs including USB 3.1 Tx/Rx, Type-C testing, alt-mode testing and more (Figure 2). There are also issues around the reversible Type-C cable, which adds another wrinkle that validation engineers will need to handle. When a connector is turned or reversed, the Tx/Rx pairs are actually re-routed to a different pair. This means that tests will need to happen with the connector in one direction, and then again with the connector reversed—a time consuming process. In some cases such as USB 3.1 Gen2 (10 Gb/s), Dual-Role Device supporting Gen1 (5 Gb/s) backwards compatibility as well as Sink/Source capabilities means the test coverage multiplies exponentially.

Figure 2. USB Power Delivery testing involves more than just testing to ensure compliance with the 500-page specification due to overlap with other USB 3.1 testing as well as alt-mode.

The test setup
The setup for PD testing is relatively straightforward as shown in Figure 3. Recommended equipment includes an oscilloscope with 60 MHz or higher bandwidth equipped with PD electrical and protocol analysis software, passive and current probes, a PD coupon or breakout fixture, and a protocol analyzer or equivalent PD controller. The PD coupon resides between the DUT and a Type-C cable and provides access to VBUS and CC lines to facilitate cable testing, CC electrical and protocol decode testing, power provider stress testing and source/sink testing.

Figure 3. This is an example of a test setup for provider/consumer PD testing.

USB PD software running on an oscilloscope automates many of the USB PD electrical parametric and protocol measurements. Currently available software automates USB PD BMC physical layer compliance eye mask and parametric testing, USB PD protocol decode and compliance, and electronic mark ("e-mark") compliance tests for active USB Type-C cables and adaptors. It also provides pass/fail reporting along with detailed analysis for debug and troubleshooting.

In lieu of a formal certification program, USB-IF is hosting plugfests and interoperability workshops where you can bring your designs for intensive interoperability testing and debug. Recent plugfests have provided a number of insights and areas that will require closer attention.

When setting up a PC coupon, pay close attention to the ground reference because improper setup can cause tests to fail. The ground should be shared at a common location and as close to the near-end as possible. Don’t mistakenly create a current loop and keep the distance between the signal and ground as short as possible. With high power comes the potential for higher IR drops, which can affect measurement results.

Another tough test challenge stems from the tight specification for changing power states, in particular how fast can the DUT can source and sink current. Per the specification, a device can ask for current as fast as 150 mA/µs, but not faster. What if the request is too fast? One consequence could be unwanted EMI, or even damage to the receiver under certain circumstances. Being too...
slow is not as bad as slewing too fast, but problems could still result. The PD provider test is used to ensure this specification is being met.

At a recent plugfest in Portland, Ore. there were some DUTs that struggled to consistently meet the 150 mA/µs requirement. Despite that fact that DUTs are failing this test, the USB-IF feels strongly that it should help make sure there are no interoperability issues. So this is one specification to pay close attention to during design and then to test thoroughly before heading to an upcoming compliance workshop.

Another area that seems to be causing problems is role swap when a device changes from being a consumer to a provider or vice versa. The challenge is whether the device can complete the role swap in the time frame defined in the spec and then stabilize the device and get power states in the correct mode. The screen image in Figure 4, taken using an Ellisys analyzer/generator, shows how this works. In this case, you can see activity on both the host and device side. The top transaction (circled) shows the role swap request being accepted. Then the new source advertises its voltage and current supply capabilities. The bottom half of the screen shows the old and new source capabilities. In this case the old source operated at a much higher power profile while the new source has transitioned to the 5 V profile.

Figure 4. Consumer/provider role swap is a common source of problems.

There’s no question that USB PD design and test is a challenging undertaking, particularly in the early stages as the industry comes together to figure out how to addresses and resolve interoperability issues. But the core test solutions are already coming together, and testing is sure to get easier and more refined over the coming months. Assuming all goes as planned, USB Type-C will really be the only interconnect you’ll ever need.

Also see

- USB 3.1 testing: Start to finish, part 1
- USB 3.1 testing part 2: Type-C cable assemblies
- USB Type-C Could Change the Laptop/Smartphone Supply Chain
- **USB Ain't So Simple Anymore**