Introduction to USB Power Delivery

Electronic Design
Anirban Sengupta
Thu, 2016-01-14 11:11

Since its early days, USB has been positioned as an external bus standard for fast data communications. When observing how the standard has evolved over the years, one can notice a distinct bias toward increasing the speed of data communications *(Fig. 1)*. Moreover, each generation has been branded using terms such as "full-speed," "Hi-speed," "Super-speed," and "super-speed+" *(Fig. 2)*, which again reemphasized the positioning of USB as a communications protocol.

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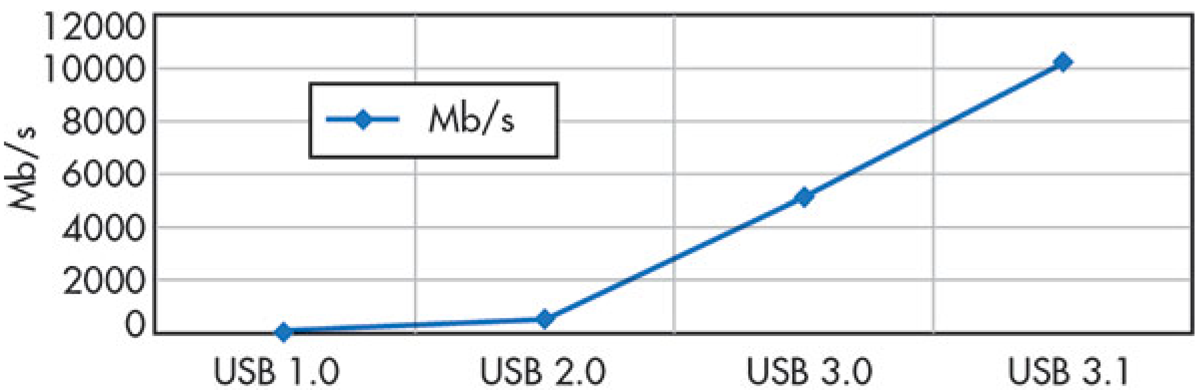
However, another area of evolution for USB was sidelined earlier in its development—power delivery. With the focus on speed, power delivery was never the priority for USB. In fact, the first time a specification was made specifically for power delivery occurred only a few years ago in 2010: The Battery Charging Specification – BC 1.2 increased USB power delivery from 4.5 W to 7.5 W. This specification introduced a mode called CDP (charging downstream port) that allowed for higher charging current (up to 1.5 A) compared to traditional USB.



However, this specification was only a precursor for what was to come. Almost at the same time as the USB 3.1 release, the USB Implementers Forum (USB-IF) released the USB Power Delivery Specification. This new USB power delivery specification allows power transfers of up to 100 W, along with other features and benefits.

History of USB Power Delivery: A Secondary Function Gains Prominence

Power management has been part of USB specifications since early generations. Power management in these initial generations was not intended for battery charging. Its purpose was solely to enable peripherals to power

In line with this functionality, USB 1.0 described a power source of 5 V @ 100 mA (0.5 W) while USB 2.0 cribed a power source of 5 V @ 500 mA (2.5 W).

Despite there being no such guidelines in the specifications, designers figured out ways to use USB for battery charging. As a result, USB-based charging products were created and launched in the market. However, due to the lack of a specification, interoperability was a major issue for first-generation USB battery chargers. This interoperability issue, coupled with the rising popularity of battery-charging applications, gave the USB-IF enough reason to consider creating specifications for battery charging. This resulted in the Battery Charging Spec – BC 1.1 (later revised to BC 1.2). With this spec, the USB-IF blessed battery charging as a legitimate application for USB.

It's important to note that BC-1.1 was released as an Engineering Change Notice (ECN) to USB 2.0 and it significantly deviated from the sanctions of USB 2.0. As per USB 2.0, any USB device could be classified as either low power (5 V @ 100 mA) or high power (5 V @ 500 mA). On connection, a USB device was allowed to draw 100-mA current initially while enumerating and negotiating its power budget with the host. Based on the enumeration, the host would either raise the power delivery to 2.5 W or continue at 0.5 W.

The battery-charging spec went on to define more power sources than what was recommended above:

1. Standard downstream port (SDP): power source compliant with USB 2.0 Spec.

2. Charging downstream port (CDP): power source not compliant to USB 2.0. CDP can supply up to 7.5 W (5 V, 1.5 A) and the 1.5-A current can be supplied before enumeration.

While both SDP and CDP were located on typical hosts like desktops and notebooks, the third type of port defined by the BC spec included power sources like wall and auto adapters:

3. Dedicated charging port (DCP): There's no enumeration here, and charging occurs without any digital connection. DCP supplies up to 1.5 A and 5 V.

While the BC spec did solve quite a few issues, other areas of improvement remained open. Some of the most notable ones were:

• Which port to use? Not all OEMs correctly labeled the CDP and SDP. As a result, the user experience was that some ports charged connected devices quickly while other ports didn't charge at all.

• 7.5 W is not enough: For quite a few devices that could potentially draw power from a USB source, the 7.5-W limit didn't improve things much. Examples include hard drives and external drives.

• Power flow only unidirectional: Power is limited from host to connected device.

• In some cases, data transfer and power delivery failed to work simultaneously.

The USB Power Delivery spec addresses these issues by increasing the maximum power delivery to 100 W (from 7.5 W), along with other benefits:

• Power direction no longer fixed.

• Optimized power management across peripherals.

• Intelligent and flexible system-level management of power.

• Low-power cases can negotiate only for the power required by them.

The Future of USB Power Delivery

From 7.5 to 100 W:

Not all peripherals could be powered by a USB cable as long as the maximum power was capped at 7.5 W. Examples include hard-disk drives (HDDs), solid-state drives, printers, and monitors. Consequently, these peripherals required independent power sources at an additional cost. With a power-delivery spec that allows for a theoretical 100-W max power budget, many of these peripherals can now be powered by USB cables.

Quoting the USB PD introduction document released by USB-IF: "**Extend ease of use, reduce clutter, reduce even more waste.**"

The power-delivery spec allows for a maximum voltage of 20 V (4× the previous 5-V spec) and a maximum current of 5 A (more than 3× the previous max of 1.5 A). The power-delivery spec also classifies power sources in terms of profiles:

• Profile 1 (Default Startup): 10 W (5 V @ 2 A)

• Profile 2: 18 W (5 V @ 2 A -> 12 V @ 1.5A)

• Profile 3: 36 W (5V @ 2 A -> 12 V @ 3A)

• Profile 4 (Micro B/AB limit): 60 W (5 V @ 2 A -> 20 V @ 3 A)

• Profile 5 (Standard B/AB limit): 100 W (5 V @ 2 A -> 20 V @ 5 A)

When a device is connected to a host, an initial power supply of 10 W occurs to initiate the power negotiation. Based on the final profile selected, the power transfer is 18, 36, 60, or 100 W.

There's also a major change in the process of negotiating power. Earlier generations made use of the data wires for enumeration purpose: USB power delivery specifies negotiation using the V_{BUS} only, without affecting the data bus. This leads to the second benefit:

Data transfer during power delivery:

The power-delivery spec removes the data bus from the process of negotiating power delivery. This makes possible simultaneous data transfer and power flow. This means devices can continue with their primary function while also charging.

Bidirectional power transfer:

Historically, a USB connection allowed for bidirectional data transfer, but power only flows from host to peripheral. The USB Power Delivery spec sanctions bidirectional power delivery. For example, if a laptop is connected to an external monitor that's plugged into the wall, the laptop can now be charged by the monitor.

ver management across peripherals:

The power-delivery spec helps to optimize power flow across multiple peripherals by:

• Allowing devices to draw as much power as they require and draw more power when an application demands it. Say, for example, a phone is charging through a USB connection to a PC. Then we connect a USB RAID array, which needs additional power at the start to get all of the disks spinning, but can subsequently be lowered to a steady state. The system can lower the power delivery to the phone, provide it to the RAID array, and then move it back to the phone when the power is available again.

• Incorporating intelligent /flexible power management across multiple peripherals. For example, battery-backed devices draw more power than devices connected to external power source.

• Allowing low-power devices to negotiate only the power that they require. For example, headsets can draw less power than external HDDs.

Together, these enable any externally powered peripheral to serve as a power source and hub for any host or devices connected to it.

Overall System-Level Power Management

USB power delivery can have a substantial impact on overall system-level power-management efficiency. Let's say we need to connect a HDD and display to a laptop. The pre-power delivery implantation would be:

1. Connect a power source to all three system components—HDD, display, and laptop.

2. HDD and display are both connected to the laptop.

3. Data exchange between HDD-laptop and display-laptop

4. Power flows only from laptop to HDD or display.

With the power-delivery spec, the above implementation simplifies to the following extent:

1. Connect the display to a power source.

2. No additional power sources required for laptop or HDD. The user just needs to connect both to the display via a USB connection. Power will flow from display to laptop and HDD.

Other Considerations

Taking full advantage of the power-delivery spec involves a few more requirements. The USB-IF covered most of these requirements in the USB Type-C specification to simplify deployment.

So what are these limitations and how does Type-C overcome them?

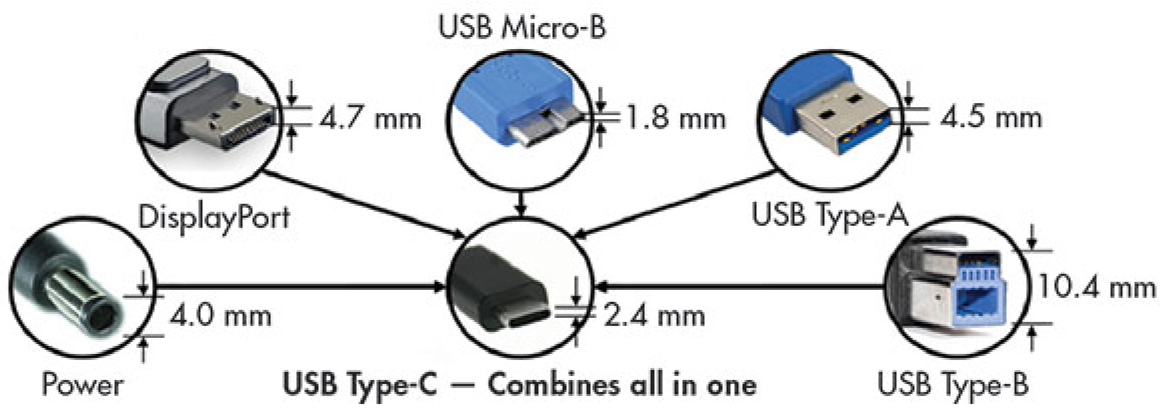
What if a peripheral requires a non-USB signal? For example, display signals are of a non-USB type, and thus external displays are currently connected via DisplayPort and not USB. The power-delivery spec would allow the display to power up a host, but then the spec is not valid for a non-USB port.

Limitations of USB Type-A and Type-B (current USB-IF standard): The USB receptacle on a USB host or USB hub is a Type-A connector. Corresponding type-A plugs are found in cables and small peripherals (e.g., mouse). However, some larger peripherals (e.g., printer) use detachable cables. Thus, there's a receptacle required on such peripherals. This receptacle is Type-B. Type-A and Type-B connectors are similar electrically, but different chanically. As per the USB-IF spec, a cable can deliver power only when one end is connected to Type-A and other end to Type-B. This was done deliberately to prevent users from connecting host to host (leading to the risk of a short circuit). *Power flow occurs only from Type-A to Type-B, and thus with this current setup, bidirectional power flow is not possible.* In such an ecosystem, implementing the power-delivery spec fully is complicated.

The new USB-IF Type-C standard solves the above problems by:

• Transporting both the USB signal along with a DisplayPort signal over the same connector.

• Replacing Type-A and Type-B connectors with a single connector (Type-C) that supports bidirectional power flow. The plug height is just 2.4 mm—much less than Type-A (4.5 mm) or Type-B (10.4 mm). Hence, it's a useful feature for hosts that are striving for a slim design.



Together, this leads to a simplified implementation of USB with low-cost power delivery up to 100 W. From a product-design perspective, the Type-C connector allows OEMs to achieve sleeker designs by eliminating multiple ports *(Fig. 3)*. For example, the ultra-thin MacBook (the world's first product with a Type-C connector) has replaced three connectors—USB Type-A, mini DisplayPort, and power—with a single Type-C port.

The role of the USB-IF is limited to facilitating USB-related innovation by defining the governing specifications. The responsibility of getting actual products out in the market lies with semiconductor companies and product manufacturers.

The simplicity enabled by USB power delivery and the Type-C connector is being carried over into the design of USB controllers, too. For example, Cypress offers the CCG1 programmable USB Type-C and Power Delivery controller. The controller integrates voltage-monitoring and current-monitoring circuitry that's critical for power-adapter applications. It also provides design flexibility with firmware that can be upgraded during product development, on the production line, or in the field. This means that when there's a future ECN for USB power delivery published by the USB-IF, it can be implemented in existing design through a firmware revision to achieve compliance.

Controllers are also taking advantage of the reduced footprint enabled by the Type-C connector. Cypress' CCG2 USB Type-C controller, for instance, is designed for EMCA (Electronically marked Cable assembly) cables. With its small size and integrated capabilities (Type-C transceiver, termination resistors, and system-level ESD protection), only five external components are required.

For more information, read the technical application note "Designing USB Type-C Products," or view the video "Introduction to USB Type-C":

References:

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