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A Standalone Controller Eases Compliance With USB PD Standards

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The USB Power Delivery (PD) market continues to grow in portable, battery-operated, electronic devices like cell phones, laptops, wireless speakers, power tools, and much more. USB PD provides a great benefit to consumers because it can provide up to 240 W (in the USB PD Revision 3.1 specification) from the same USB Type-C connector. Fig. 1 depicts a cell phone being charged by a USB Type-C connector.

USB PD poses new power requirement challenges because of the variety of voltage and current combinations available—5 V, 9 V, 15 V, 20 V, 28 V, 36 V, 48 V and 1.5 A, 3 A, and 5 A, etc.—to supply the wide range of power levels the USB PD standard can provide. The power source, such as a wall adapter, and the inline devices, such as a cell phone, communicate their power capabilities and power needs, respectively, in proper voltage and current levels before the source provides power over the USB cable.

Some solutions require multiple integrated circuits (ICs), including port detectors, microcontrollers and chargers for power delivery. While these solutions work, they take up space on a board, increase the solution cost, and require custom firmware, which can be time-consuming to create. A standalone PD controller can help address these challenges by managing the power negotiations without firmware development.

In this article, we begin by reviewing the evolution of USB power delivery, going from 500 mA at 5 V in the early USB editions to a maximum power capability of 48 V at 5 A (240 W max.) in the current standard. We will briefly show how the assimilation of 5-V, 9-V, 15-V, 20-V, 28-V, 36-V, and 48-V voltage rails within the USB PD standard provides versatility in power delivery, requiring fewer cables around the house. The benefit of the programmable output voltage capability within USB PD is also discussed.

We then describe the system requirements for implementing USB PD, and what functional blocks are needed. As we'll see, the USB PD design blocks must not only provide compatibility with adapters and powered devices designed to USB 3.1 (the latest standard) but also must be backwards compatible with legacy adapters and powered devices designed according to the earlier USB standards. Finally, we will introduce Maxim Integrated's MAX77958 standalone PD controller, which eliminates the need for custom firmware by including port detection and nonvolatile memory.

Fig. 1. A cell phone with a USB Type-C connector for charging.

USB PD Power Requirements

One of USB PD's significant benefits is allowing consumers to charge their 2.5-W cell phone and their 25-W cordless power drill using the same cable and power adapter. The days of having drawers filled with different cables or never finding the correct charger will soon be a thing of the past.

Before we begin looking at USB PD, it is essential to revisit previous USB standards to understand some of the USB PD benefits and challenges. The first USB standards—USB 1.1 and USB 2.0—were for data delivery rather

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than power delivery. They only allowed for maximum delivery of 5 V and 500 mA across a USB cable. The traditional USB cable only supported power flow in one direction—that is from Type-A to Type-B. For USB On-the-go capability, a special adapter had to be used.

Over time, consumers began demanding more from USB. They wanted to quickly charge a battery over a USB cable, where a 500-mA maximum current was no longer adequate. The BC1.2 standard answered these consumer demands by allowing the transfer of up to 7.5 W—5 V and 1.5 A—over a USB cable.

The BC1.2 standard expanded the ability to charge a battery over USB, and each new USB standard after BC1.2 has added to power capacity. Type-C introduced a reversible cable with the same connector on both ends and made it easier for power to flow in both directions. Type-C 1.3 also extended the power capability to 15 W (max) while USB PD 3.0 upgraded the system wattage to 100 W (max). The most recent specification update, USB PD 3.1, extends the power capability even further up to 240 W (max).

BC 1.2 and Type-C 1.3 continue to supply the 5-V voltage rail used in all previous versions of the USB standard and have increased the power capabilities to 7.5 W and 15 W, respectively, by increasing the maximum current to 1.5 A and 3 A. USB PD 3.0 has also increased both the current and voltage capabilities to reach 100 W (max). It allows two devices to transfer up to 20 V and 5 A across a USB cable. The new PD 3.1 specification supports up to 48 V and 5 A.

Fig. 2 summarizes the power capabilities and maximum current and voltage that each USB standard allows.

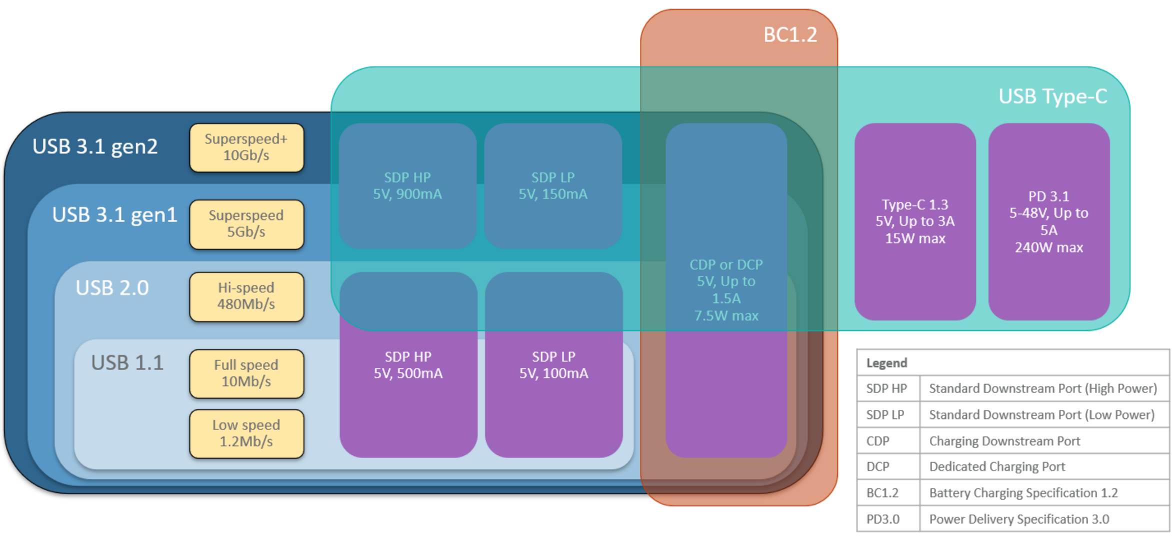

Fig. 2. Power capabilities of each USB specification.

The voltage rails that a USB PD power source provides are variable. The USB PD 3.1 standard states that not only does a power source have to offer the minimum voltage of 5 V and the maximum voltage of 48 V, but it must also provide a few voltage rails in between.

The USB PD 3.0 standard requires that a power source provides specific voltage rails depending on the power capabilities of the source. Sources that can provide more than 15 W must offer 5-V and 9-V rails. Those that can provide more than 27 W must offer 5-V, 9-V and 15-V rails. Finally, power sources that can provide more than 45 W must offer 5-V, 9-V, 15-V and 20-V rails.

The power source also provides different current outputs at each of these voltage rails. A power source with a 5-V rail provides between 500 mA and 3 A at this rail. Those with a 9-V rail, transfer currents between 1.67 A and 3 A at 9 V. A power source supplies between 1.8 A and 3 A at the 15-V rail. Finally, the power sources provide between 2.25 A and 5 A at 20 V (Fig. 3).

The USB PD 3.1 standard adds three additional voltage rails for power sources. These sources may also provide fixed voltage rails at 28 V, 36 V, and 48 V to support power levels up to 140 W, 180 W and 240 W, respectively. A power source may supply up to 5 A for each of these voltage rails.

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In addition to the standard voltage and current supplies, the USB PD specification also provides a Programmable Power Supply (PPS) capability. The PPS capability allows inline devices to request small changes in voltage and current from the power source.

The PPS capability is most useful to speed up charging of lithium-ion batteries by optimizing the operating point for the switching charger. During the constant-current phase of a charging cycle, the charger provides the battery with a fixed current and the battery's voltage will slowly increase to the final charge termination voltage.

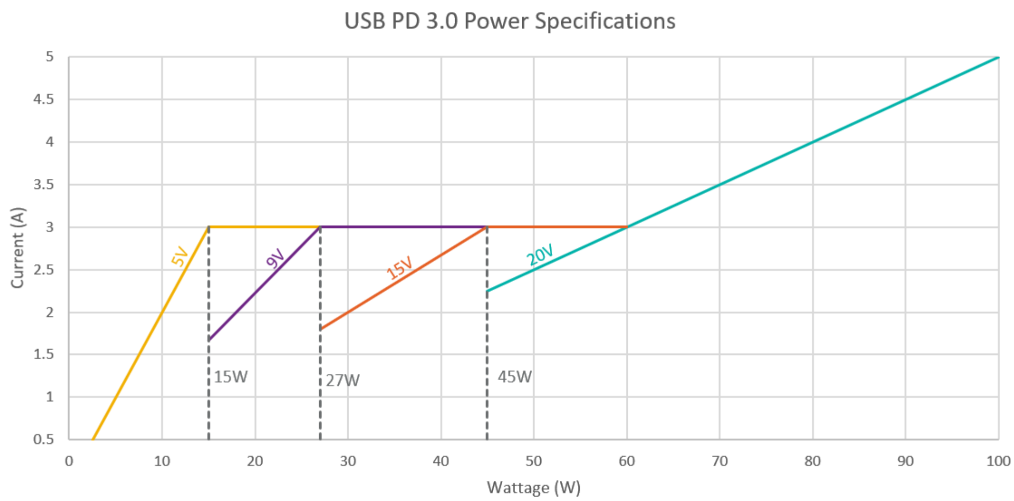

Fig. 3. USB PD 3.0 voltage and current capabilities.

Normally the input to the charger will be fixed, which creates power losses when the input to the charger is much larger than the battery voltage. The PPS feature adjusts the input voltage of the charger such that it operates near its peak efficiency. With the resulting lower power dissipation, the battery can be charged faster with increased charging current.

PPS allows for countless voltage and current combinations along a USB cable. Designers who want to use the PPS capability must find a way for a power source and an inline device to agree how much power the source should provide.

USB PD Design Blocks

It is no small task for charging to begin under a discrete USB PD system. A power source, such as a wall adapter, connects to the inline device, such as a phone or power drill, through a USB cable. Both devices typically need multiple ICs to implement the back-and-forth communication to get the power source ready to provide the inline device power as illustrated in Fig. 4.

The CC pin detection IC identifies the cable orientation and source current capability by measuring the voltage of the CC pins. This IC also requests the power source's voltage and current capabilities and communicates back to the power source when the inline device selects a voltage and current.

The BC1.2 detection IC supports legacy USB adapters. Although newer devices are more widely adopting USB Type-C, many applications still use older USB specifications. BC1.2-compatible ports have D+/D- pins instead of CC pins to communicate a power source's power capabilities. The BC1.2 detection IC reads the D+/D- pins to configure charging for applications still using legacy USB standards.

The charger IC safely and effectively charges the battery on the inline device. The power source will provide a constant voltage to the inline device, the charger's input source. The charger will then ensure the battery is charged to the battery's voltage, current, and temperature specifications.

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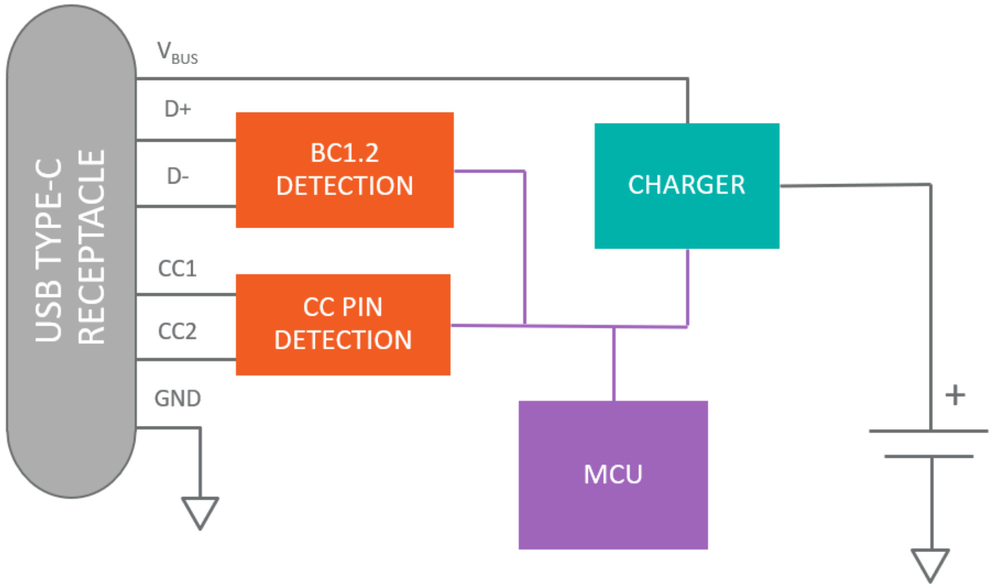

Fig. 4. USB PD design block diagram.

Finally, the microcontroller block (MCU) organizes the communication between the other ICs. The MCU communicates with the CC pin detection IC to determine the power capability of the power source. Then, the MCU compares the power source's capability with the charger and battery's power needs to determine how much current and voltage the power source should provide.

The MCU communicates the final power settings back to the CC pin detection IC to configure the power source correctly. Once the correct current and voltage are confirmed, the MCU will configure and enable the charger.

USB PD requires more elements than legacy USB or standard Type-C designs provide. More ICs lead to higher costs and larger solution sizes. A complex firmware design is also needed to manage the communication between the different elements and meet all the USB PD 3.0 standard requirements. The firmware design alone can create longer development cycles unless a designer has an intimate knowledge of USB specifications.

A Standalone Controller

Standalone PD controllers can help simplify USB PD designs by having the CC pin detection, BC1.2 detection, and MCU integrated in one IC. The four-IC design now becomes just two, which saves board space and costs.

The most powerful element integrated in the standalone PD controller is the embedded MCU, which integrates all the USB PD 3.0 standard communication protocol and timing requirements. The designer no longer needs to spend development time coming up-to-speed on these specifications.

One example of a standalone PD controller is the MAX77958 (Fig. 5). Two unique features of the MAX77958 are the nonvolatile memory and the I^{2}C master port that directly controls a companion charger. Both features help eliminate the need for an external MCU and custom firmware development.

Designers can generate customized scripts for typical applications using a graphical user interface (GUI) and then load them into the nonvolatile memory of the IC. The PD controller automatically executes commands, such as toggling GPIO or sending an I^{2}C command to the charger through the I^{2}C master port.

The customization script is written in the GUI using simple, user-friendly commands. The software translates the customization script to hexadecimal format and writes it to the IC configuration area. Developers can define simple functions and sequences based on the functionality they need for their application.

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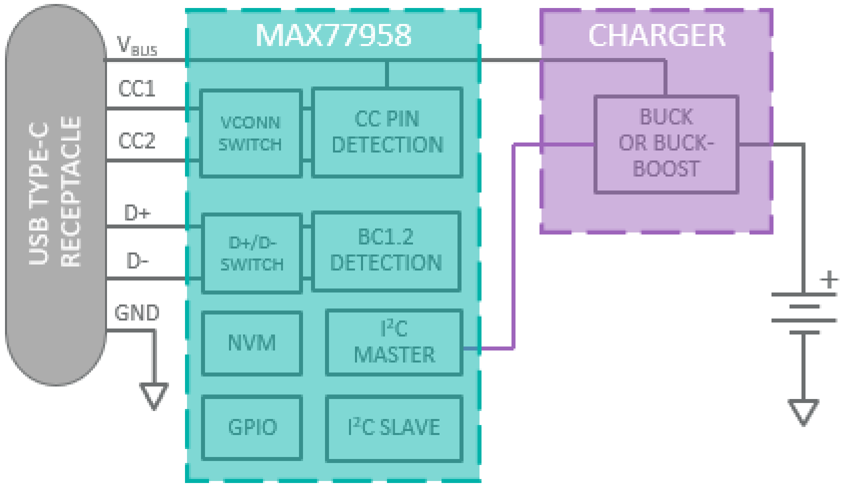

Fig. 5. USB Type-C v1.3 and PD 3.0-compliant standalone PD controller.

Fig. 6 shows some of the functions a designer can use for programming the customization script. The GUI outputs a binary (bin) and hexadecimal (hex) file based on the customization script. The customization scripts are a unique feature that drastically reduces development time.

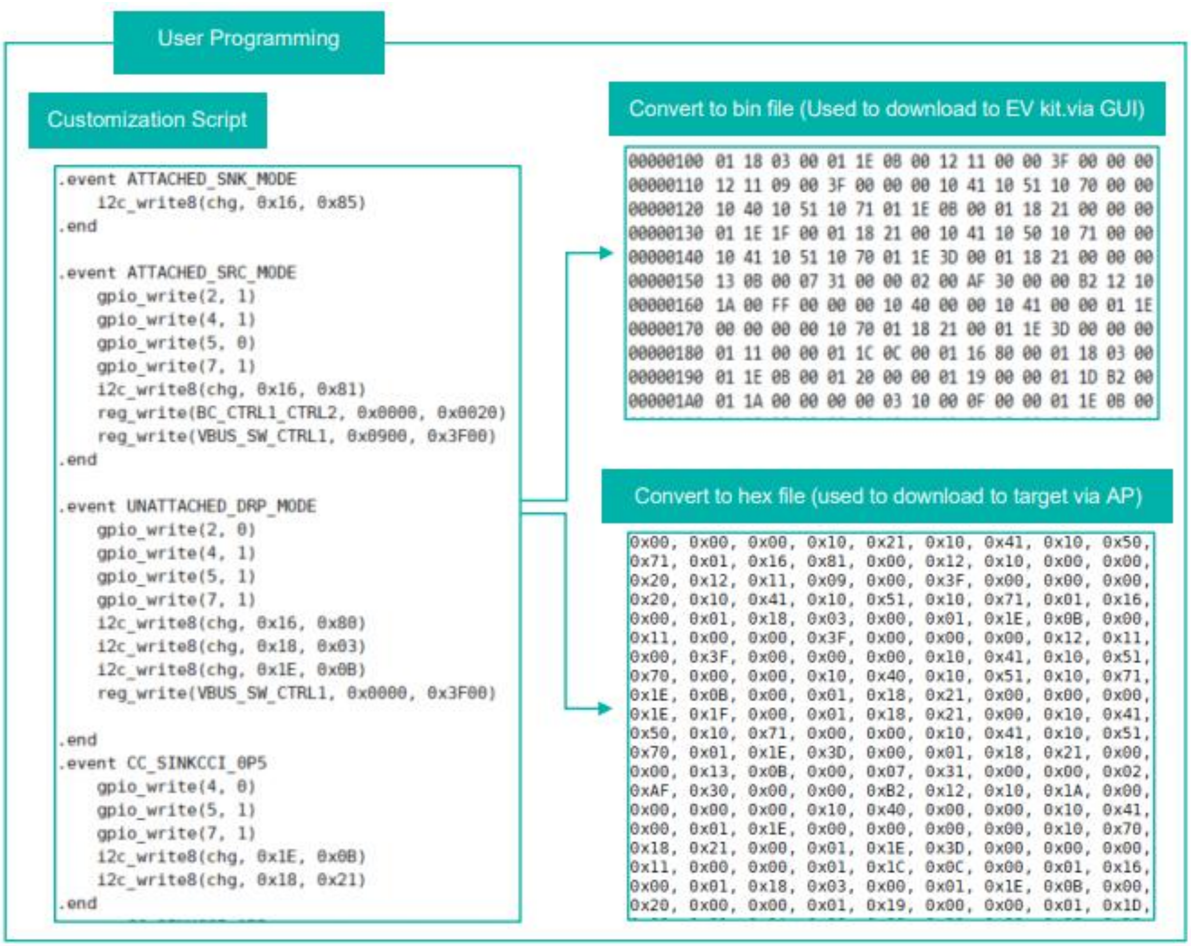

Fig. 6. User programming of customization script.

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Conclusion

The USB PD specification dramatically expands the number of battery-operated devices that can be charged through a USB cable. The specification outlines seven new voltage rail requirements—5 V, 9 V, 15 V, 20 V, 28 V, 36 V, and 48 V—to help accommodate the wide range of power capabilities. Power sources and inline devices now need to negotiate a current and voltage level before charging can begin.

Standalone PD controllers integrate most blocks into one IC, which helps simplify the design process. Some even eliminate the need for an external MCU and customized firmware. Standalone PD controllers help accelerate your design development to ensure you are staying ahead of the latest trends in USB PD.

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Samantha Morehead served as an application engineer, providing design assistance in addition to technical training and support for all of Maxim Integrated's broad market products. Samantha joined the company after earning her BSEE from Santa Clara University.

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For further reading on power supply-related safety and compliance issues, see How2Power's special section on Power Supply Safety and Compliance.

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