Technical Article

Migrating from a barrel jack to USB Type-C PD

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Over the last few years, the USB Type-C® with Power Delivery (PD) standard has been adopted in a wide variety of electronics. This adoption has been driven by benefits such as a unified port (reducing e-waste), the convenience of a reversible connector, and high-power capability.

As Figure 1 shows, the latest release of USB PD 3.1 extends the power capability of USB up to 240 W, more than doubling the 100 W of available power from the previous USB PD 3.0 specification. This allows a wide range of new applications to now be powered from USB. In order to reduce e-waste, the European Union and India have started passing legislation mandating USB Type-C for personal electronics in 2025, and it is expected that this trend will likely extend to other applications such as power tools, smart speakers, vacuum cleaners, e-bike chargers and networking. These trends and regulations are forcing manufacturers to seek out simple and inexpensive ways to convert the power connectors on their products from a barrel jack to a USB-C connector.

USB Protocol	Nominal Voltage	Maximum Current	Power
USB 2.0	5V	500mA	2.5W
USB 3.1	5V	900mA	4.5W
USB BC1.2	5V	Up to 1.5A	Up to 7.5W
USB Type-C	5V	3A	15W
USB PD 3.0	Configurable up to 20V	5A	Up to 100W
USB PD 3.1	Configurable up to 48V	5A	Up to 240W

Figure 1. USB power standards where the latest USB PD 3.1 release extends the power capability of USB up to 240 W. Source: Texas Instruments

In this Power Tip, we will discuss system power considerations and demonstrate how you can quickly and easily implement a USB-C connector and power management circuitry that negotiates the appropriate USB PD contract for the power requirements your design.

USB PD power flows

It is also worth noting that there are three types of power flow in the USB PD ecosystem: devices that can only sink power, devices that can only source power, or devices that allow bi-directional power flow (dual-role power.) In this article, we'll focus on sink-only applications.

Before a sink device utilizing USB PD can accept power from a USB PD power source, some hand-shaking and negotiation must take place between the device being powered and the power source. This is because the voltage on the USB PD power bus can be variable from 5V to 48V, depending on the power capability of the power source. Obviously, you would not want to apply 48V to a sink device that is only designed to operate from a 15V input source. In a USB PD sink application, a dedicated device called a port controller is needed to perform this power contract negotiation and provide protections like over-current and over-voltage. Previously, adding a USB PD port controller configured with the proper functionality required in-depth knowledge of the USB certification and a large amount of firmware development effort. To simplify the power architecture and reduce design complexity, a preprogrammed USB PD controller allows the designer to configure the maximum and minimum voltage and current sink capability through a simple resistor-divider setting, as shown in Figure 2. This removes the need for external electrically erasable programmable read-only memory (EEPROM), an MCU, or any type of firmware development.

ADCIN1 Decoded Value	Minimum Voltage Configuration
0	5V
1	9V
2	12V
3	15V
4	20V
ADCIN2 Decoded Value	**Maximum Voltage Configuration**
1	9V
3	12V
5	15V
7	20V

Figure 2. The ADCIN pin of a preprogrammed USB PD controller that allows designers to configure the max and min voltage as well as the current sink capability through a simple resistor divider setting. Source: Texas Instruments

Negotiating power contracts and matching system power requirements

Before converting your product to USB PD, it is important to understand the limitations and requirements of the USB PD ecosystem. On the source side of the cable, a USB PD power source will be providing power to your system, but the person using your product could connect absolutely any USB PD adapter or other power source. You need to consider what power contract is needed to provide full power to your system. In addition, consider how your system will behave if insufficient power is available from that adapter.

The available current through the USB Type-C cable is limited to 3 A for voltages below 20V, and 5A for voltages 20V and above. Additionally, USB PD power sources are only required to generate the minimum voltage necessary to provide rated power at the maximum allowed cable current. For example, a 45W adapter will typically provide a maximum output voltage of 15V, since 45W divided by 3A is 15V.

What if your system is designed to run from a 15V source, but needs 50W of power? In this case, you need to configure your port controller to accept a higher voltage contract (e.g., 20V) to ensure you have enough power to run your system, and you need to ensure your system is designed to handle this slightly higher input voltage. This may require you to make slight modifications to your product beyond just adding the USB Type-C connector and port controller. Additionally, typically you still want your product to be functional when connected to a USB PD source with insufficient power capacity, but perhaps operate at reduced performance level.

Design example

Consider, a product that needs to charge a 4S-7S battery at 27W that was previously powered through a 15V barrel jack. In this example, a buck-or-boost converter was used, since the battery voltage could be higher or lower than the 15V input, depending on the state of charge. Converting this design to a USB PD input only requires a simple stand-alone USB PD controller like the TPS25730 and buck-boost battery charger. Figure 3 shows the system architecture. You can see that only a few components were required to convert the barrel jack to a USB PD port. The simple resistors connected to the ADCIN1 through ADCIN4 pins set the power profile without the need for any firmware development. In this case, the product must still charge from a 5V power source even though available power is reduced, so the TPS25730 is configured for a 20V maximum voltage and 5V minimum voltage, with the operating current set to 3A.

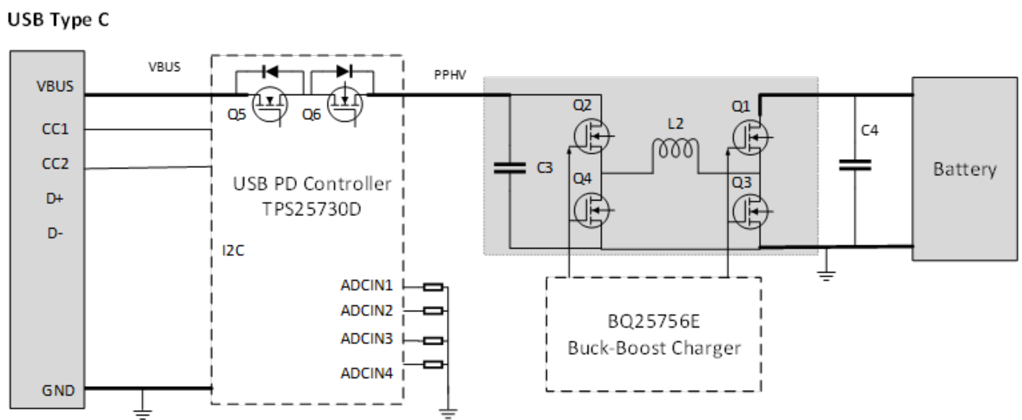

Figure 3. The 27W USB PD sink-only charger reference design block diagram. Source: Texas Instruments

Input voltage dynamic power management

Besides supporting a USB PD source input, the design should also support legacy USB input sources, such as 5V and 2A. To avoid collapse of the input voltage when the input power is limited, the BQ25756E provides an input voltage dynamic power-management feature in the BQ25756E which will reduce the charge current if the input voltage drops to a value set by the parameter Vin_dpm. The Vin_dpm should be set slightly lower than the input voltage minus the voltage drop through the cable and power path so that it can maximize the battery charge current while not overloading the input source, or creating an instability on the input bus.

Figure 4 shows experimental results charging from a 5V, 2A source with a 1 meter USB cable (0.25Ω resistance). When you set Vin_dpm to 4.75V, you can see that the input charge current is limited and unstable (left side of Figure 4). When properly configured, with the Vin_dpm set to 4.35V to account for the resistive drop, the input voltage is stable and the charge current is increased by 50%, which will significantly shorten charging times.

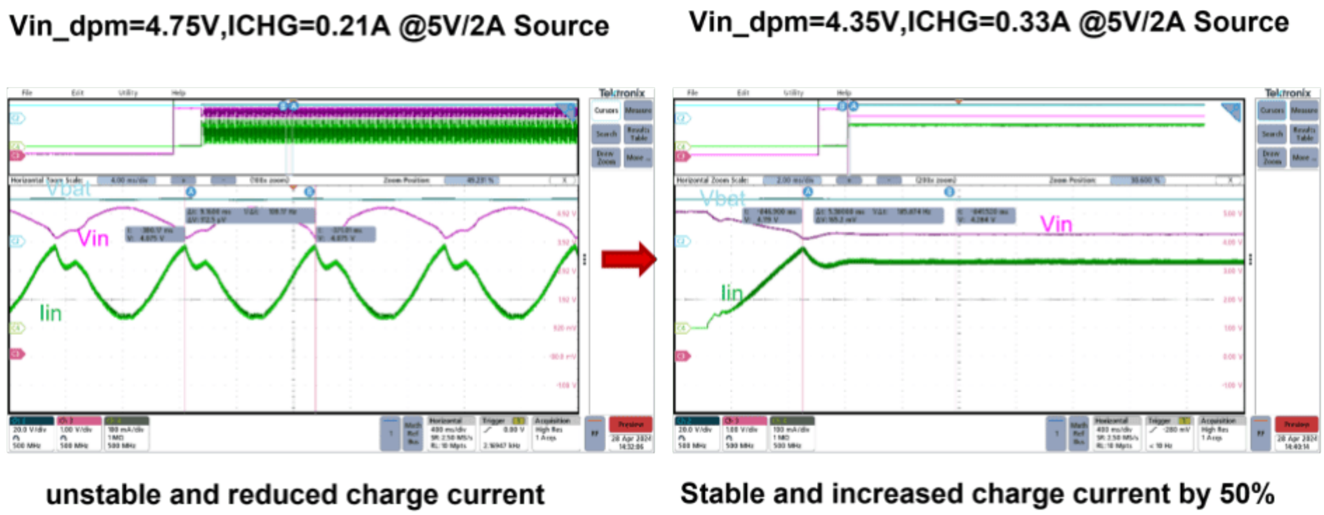

Figure 4. Input dynamic power management when charging from a 5V, 2A source with a 1m USB cable. Source: Texas Instruments

Implementing USB PD

With a simplified USB PD controller and battery charger architecture, you don't need to have in-depth knowledge of USB PD. Not only can you eliminate the need for an extra MCU and EEPROM (and exert no firmware effort), but you can use just a simple resistor divider to configure your voltage and current sink capability and quickly convert your barrel jack to a USB Type-C input. For complete details of the example design highlighted here, check out the 27W USB Power Delivery Sink-Only Charger Reference Design for 4- to 7-Cell Batteries.

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