The basics of USB Type-C® Power Delivery

Description

This document is a brief overview of USB Type-C Power Delivery. The USB standard has evolved from offering limited power alongside data transfer to become a primary flexible power source, widely used for charging devices like phones, tablets, and laptops.

The European parliament has adopted a law requiring USB Type-C to be the mandatory cable for a large number of products starting December 2024.

The goal of this law is to limit tons of waste and to simplify the lives of end users by providing compatibility between chargers, cables on the following list of devices: mobile phones, tablets, digital camera modules, headsets, portable video game consoles, digital e-readers, portable speakers, keyboards, mouses, portable navigation systems and in-ear headphones.

In 2026, laptops should be added in this list, and we can forecast that the monitors are in this updated list.

Making end users' lives easy does not mean that the technical requirements are easy to manage. As the saying goes, it is not easy to make easy things!

1 When taking about USB Type-C Power Delivery (also called USB Type-C PD), what does it mean?

This has different meanings:

- **Universal serial bus or USB**: defines the protocol for data transfer

The USB4® and USB 3.2 specifications together specify transfer rates up to 80 Gbp/s still compatible with USB2.0 (up to 480 Mb/s).

Standard is USB4® Specification v2.0.

- **Type-C**: defines the connector and cable shape

The significant advantage of this connector is the fact there is no up and down side: it is a reversible connector.

Standard is USB Type-C® Cable and Connector Specification Release 2.3.

- **Power Delivery or PD**: defines power capabilities to supply equipment

Standard is USB PD R3.2 V1.0.

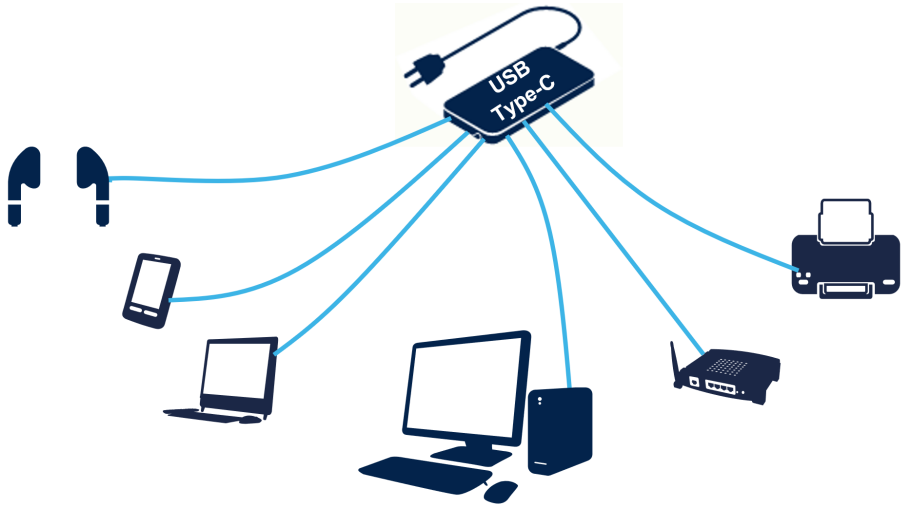
It comes with a protocol that brings real-time possibilities:

- To change dynamically who provides power (V_{BUS}), independently of the USB data role
- To change the USB data role dynamically. This replaces the OTG from the previous USB specifications
- To carry authentication messages to know what the connected devices are.

With these new standards, USB is becoming the most popular cable around. Not only to transfer data but also to charge equipment.

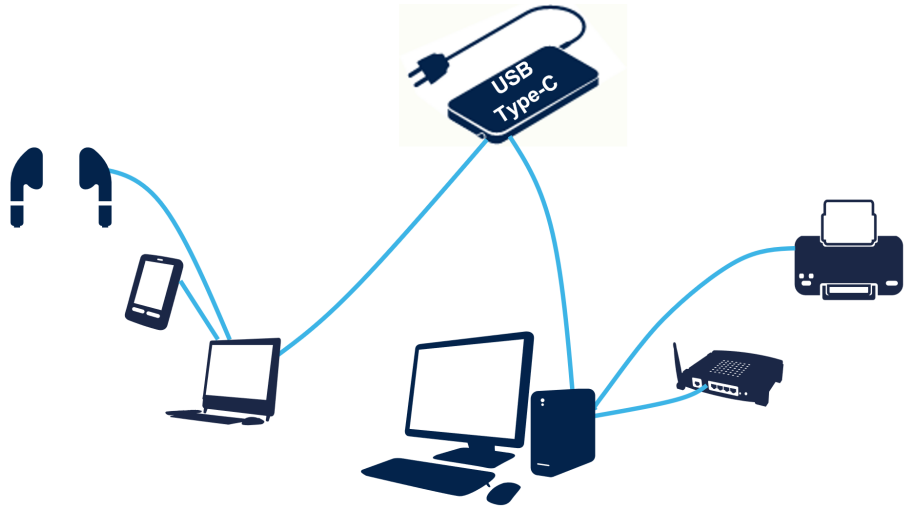
It is possible to imagine various configurations, starting from the basic one being a power adaptor associated with a single device. However, as most devices are USB Type-C compatible, a power adaptor can be associated with various devices via a USB hub or via a multioutput power adaptor to charge multiple devices.

Figure 1. Standard charging configuration



Knowing that a PC has several Type-C connectors, a daisy-chain configuration can be used. This limits the number of outputs on the power adaptor or avoids the need to use an additional hub.

Figure 2. **Daisy chain charging configuration**



USB Type-C brings flexibility and limits waste by avoiding the need to change power adaptors when the user changes its equipment, thanks to a universal connector. It is also cost-effective, as a single power adaptor can supply various devices.

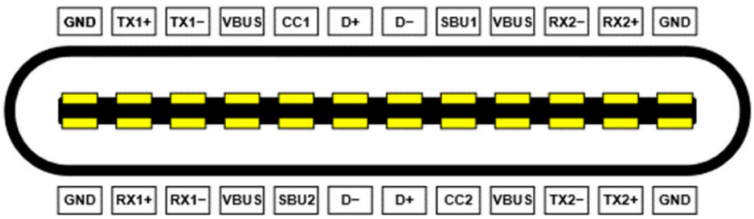
The original USB from the mid 90's had a 5 V V_{BUS} line able to deliver 0.5 A mainly to supply an external hard disk drive. Only very low equipment was addressed by the USB standard. Various and numerous proprietary adapters were needed for power higher than 2.5 W. An evolution was the USB BC (battery charging) 1.2, which manages 1.5 A at 5 V on a power adapter. 1.5 A is provided only when data lines are shorted on the adapter to inform the device.

After various evolutions, data rate and power capabilities have been upgraded. An important one is the Type-C connector in 2014. The major benefits are data rate and power increases, mechanical and electrical reversibility (data role and power role).

1.1 Type-C connector

On the Type-C legacy, the voltage is maintained to 5 V with three possible static power source capabilities: 0.5 A, 1.5 A or 3.0 A.

Figure 3. **Type-C connector**



Pin description:

- GND: ground
- V_{BUS}: power supply lines
- TX1+, TX1-, RX1+, RX1-, TX2+, TX2-, RX2+, and RX2-: Super Speed lines for data transfer
- CC1 and CC2 are the control lines
- SBU1 and SBU2 are control lines used for alternate modes such as DisplayPort™
- D+, and D-: USB 2.0 data lines.

The latest major evolution of the Power Delivery standard is related to the power capability:

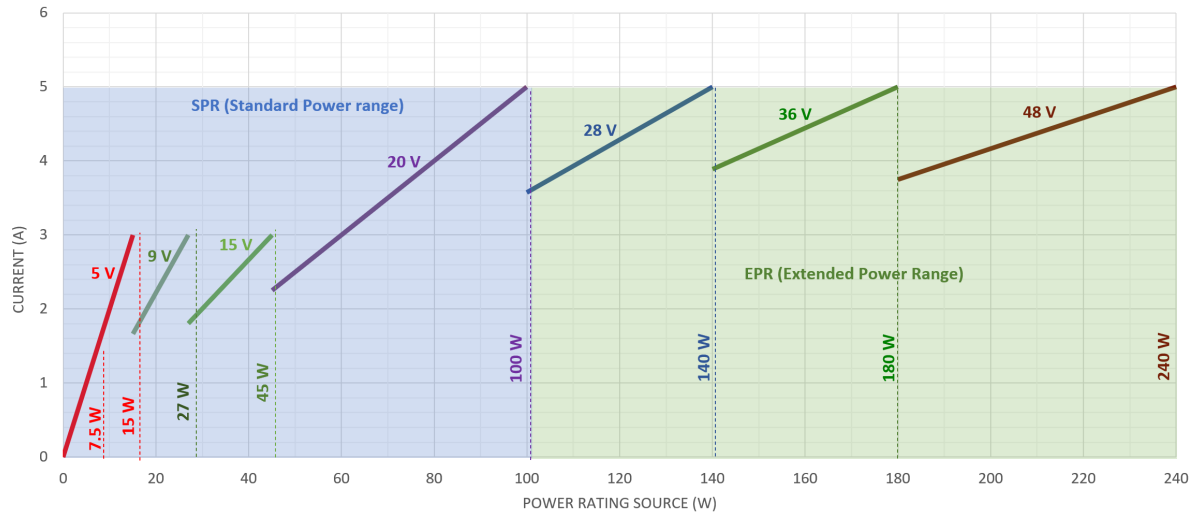
- SPR (standard power range) is proposed in the original PD version able to deliver up to 20 V - 5 A (100 W)
- EPR (extended power range) has been released in 2022 in the 3.1 PD version to deliver up to 48 V - 5 A (240 W).

The possible voltages delivered according to the Power Delivery specification are:

- For SPR: 5, 9, 15 and 20 V
- For EPR: 5, 9, 15, 20, 28, 36 and 48 V.

With a maximum current capability of 5 A as shown in Figure 4:

Figure 4. Available voltages according to Power Delivery specification



Power delivery standard specifies that low voltage devices, such as those operating at 5 V, must not be damaged when connected to a new USB power adaptor, even if it can deliver up to 48 V. As an example, a power source that can deliver 180 W (36 W - 5A) can also deliver lower voltages (5 V, 9 V, 15 V with 3 A max and 20 V, 28 V with 5 A max) for backward compatibility. It is important to note that no specific cable is needed for Power Delivery between 2.5 W and 60 W (20 V-3 A). However, for Power Delivery above 3.0 A and above 20 V, a specific cable with an electronic marker is required.

1.2 How does it work?

Voltage management is carried out using the common criteria lines in three steps:

- Step 1: On the source side, the CC lines are connected to a pull-upped resistors, while on the sink side, the CC lines are connected to a pull-down resistor. A single CC line is path-thought the Type-C cable. Attachment and orientation processes are performed using a resistance divider on the CC line.
- Step 2: When attachment is complete, the source provides 5 V on V_{BUS}
- Step 3: Software negotiation with a specific controller on active CC line:
  - The source sends its capabilities (PDOs) on one CC line
  - If the sink is PD capable, it sends a request according to its power profile need
  - The source switches to the requested power profile.

Result: The complete system is running with the right power profile.

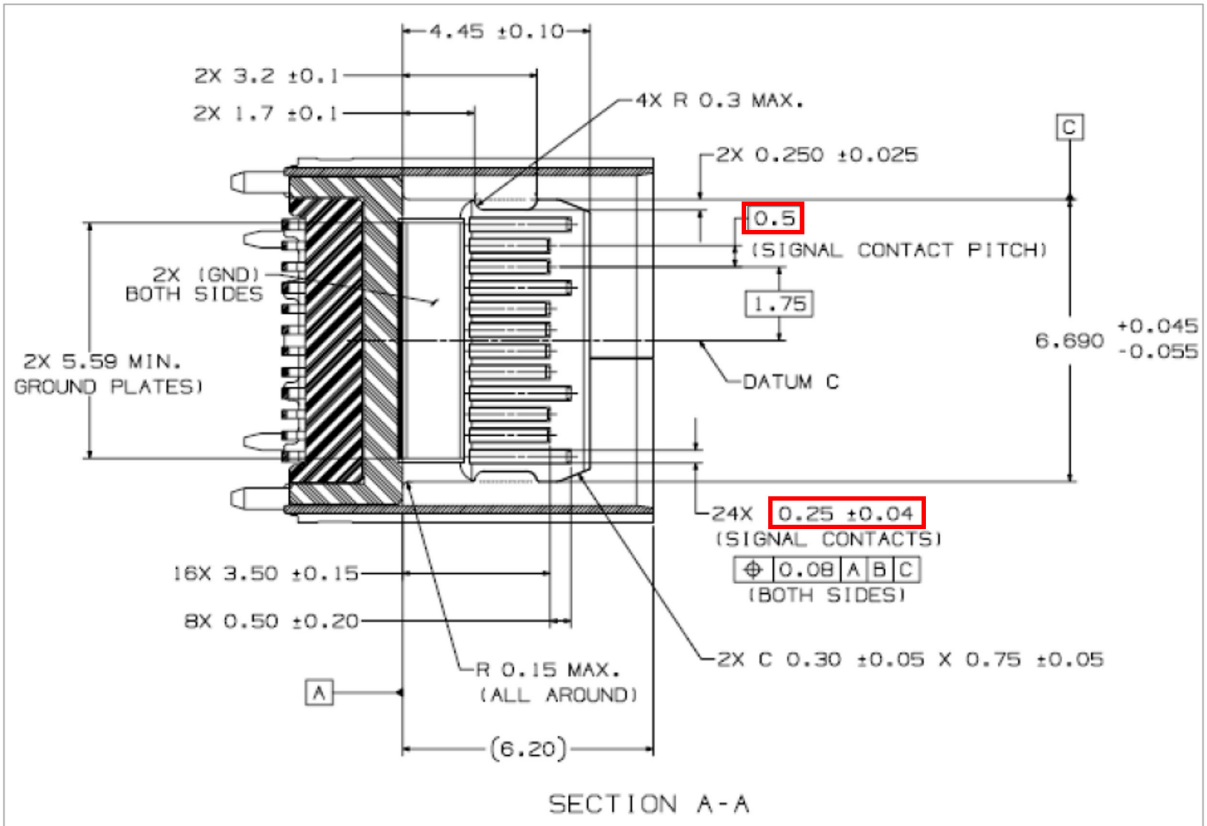
1.3 Requirements

Like most of the connectors, various kinds of surges can appear on their pins and may damage the electronic circuit. On top of ESD (electro-static discharge) or EOS (electrical over stress), the Type-C connector embeds V_{BUS} pins up to 20 V (SPR) or 48 V (EPR) and this leads to other issues.

1.3.1 Connector size

Device downsizing is possible due to connector size reduction. Figure 5 shows the dimensions of the Type-C connector as specified in the standard.

Figure 5. Connector dimensions according to the Type-C standard



Source: USB Type-C cable and connector specification

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The red rectangles on the drawing give the dimension between the two pins:

1. Distance between two pins: 0.5 mm - 0.25 mm = 0.25 mm
2. Considering the worst case: 0.5 mm - 0.29 = 0.21 mm.

This narrow dimension may be dangerous if security is not managed.

1.3.2 Risk on CC lines (CC1 and CC2)

This narrow dimension induces a high risk of short-circuit between 2 pins with plugging or unplugging the connector. Knowing V_{BUS} max is 22 V (20 V + tolerance) in SPR mode and 55 V (48 V + tolerance) in EPR, this may be critical as the V_{BUS} pin has a much higher voltage than the absolute maximum rating (AMR) of the other pins (in this case CC line pins). To avoid the risk, a protection has been integrated in TCPP series. This protection is also compliant with IEC 61000-4-2

1.3.3 Risk on SBU lines (SBU1, SBU2)

This is the same requirement as CC lines, so the same kind of protection as those on CC lines have been intergated on SBU lines.

1.3.4 Risk on D+/- lines (D+, D-)

D+/- lines are only subjected to IEC 61000-4-2

1.3.5 Risk on SS Rx/Tx lines

These lines are only subjected to IEC 61000-4-2 as coupling capacitors on SS lines remove DC and the associated risk of a short-circuit to V_{BUS}.

1.3.6 Risk on V_{BUS} pin

As this pin may be indirectly connected to the main lines, this pin is subjected to the EOS defined in IEC 61000-4-5.

Surges on this pin are generally low and most of the manufacturers consider around 100 V surges under 2 Ohms. A protection such as ESDA25P35-1U1M for SPR or SMAJ48A for EPR is generally powerful enough to keep the devices safe.

2 Conclusion

USB Type-C PD is becoming the most popular connector because it is easy to use, it is cost-effective, and it limits cable and power adapter waste. To meet these three criteria, it is mandatory to comply with the USB Type-C PD standards.

To get waste reduction and to get accepted by the market, this imposes a high reliability product for a long lifetime.

STMicroelectronics has developed the TCPP series for these reasons and they are the perfect match with STM32 embedding UCPD.

For further information on the Power Delivery interface, go to AN5225.

Revision history

Table 1. **Document revision history**

Date	Revision	Changes
22-Jul-2024	1	Initial release.

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