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Part 1-2: Common components - USB Power Delivery specification

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Universal Serial Bus interfaces for data and power - Part 1-2: Common components - USB Power Delivery specification

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The text of this International Standard is based on the following documents:

Draft	Report on voting
100/4327/CDV	100/4380/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

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Universal Serial Bus

Power Delivery Specification

Revision:	***3.2***
Version:	***1.1***
Release Date:	***2024-10***

Revision History

Revision	Version	Comments	Issue Date
1.0	1.0	Initial release Revision 1.0	5 July, 2012
1.0	1.1	Including errata through 31-October-2012	31 October 2012
1.0	1.2	Including errata through 26-June-2013	26 June, 2013
1.0	1.3	Including errata through 11-March-2014	11 March 2014
2.0	1.0	Initial release Revision 2.0	11 August 2014
2.0	1.1	Including errata through 7-May 2015	7 May 2015
2.0	1.2	Including errata through 25-March-2016	25 March 2016
2.0	1.3	Including errata through 11-January-2017	11 January 2017
3.0	1.0	Initial release Revision 3.0	11 December 2015
3.0	1.0a	Including errata through 25-March-2016	25 March 2016
3.0	1.1	Including errata through 12-January-2017	12 January 2017
3.0	1.2	Including errata through 21-June-2018	21 June 2018
3.0	2.0	Including errata through 29-August-2019	29 August 2019
3.1	1.0	Including errata through May 2021	May 2021
3.1	1.1	Including errata through July 2021 This version incorporates the following ECNs: • EPR Clarifications • Define AMS starting point	July 2021
3.1	1.2	Including errata through October 2021 This version incorporates the following ECNs: • Clarify use of Retries • Battery Capabilities • FRS timing problem • PPS power rule clarifications • Peak current support for EPR AVS APDO	October 2021
3.1	1.3	This version incorporates the following ECNs: • Robust EPR Source Operation • EPR Source Caps Editorial • SRC PPS behavior in low current request • Enter USB	January 2022
3.1	1.4	Editorial changes This version incorporates the following ECNs: • Capabilities Mismatch Update • Chunking Timing Issue • OT Mitigation	April 2022

Revision	Version	Comments	Issue Date
3.1	1.5	Editorial changes This version incorporates the following ECNs: • Timer Description Corrections • Change Source_Info Requirements • AMS Update	July 2022
3.1	1.6	Editorial changes This version incorporates the following ECNs: • USB4® V2 Updates • Data Reset Issues • Increase tSenderResponse • PPS Power Limit Bit Update • Support for Asymmetric Mode • Timer Description Corrections Revisited	October 2022
3.1	1.7	Editorial Changes This version incorporates the following ECNs: • Data Reset Invalid Reject Handling • Source request • Source Transition • EPR Entry	January 2023
3.1	1.8	Editorial Changes This version incorporates the following ECNs: • Slew rate exemption for Power Role Swap. • EUDO cable speed clarification. • Update to PPS Requirements. • Deprecate Interruptibility. • Section 7.3 restructure and update.	April 2023
3.1	1.9	Editorial Changes	July 2023

Revision	Version	Comments	Issue Date
3.2	1.0	This version incorporates the following ECNs: • VDM-use Conditions. • tTypeCSinkWaitCap. • tFirstSourceCap Clarification • Hard Reset Clarification. • Unrecognized Country Code • EPR Entry Process-1 • SPR AVS Definition • EPR Power Rules Clarifications	October 2023
3.2	1.1	This version incorporates the following ECNs: • Power Transition time from EPR to PR_Swap • Capabilities Mismatch Update • Deprecate GotoMin and GiveBack Features and Update Power Reserve • EPR Entry requirements Clarification • EPRMDO and Entry Clarification. • Remove 10.2.4 power sharing between ports • Source PDP rating field clarifications • Source Power Rules update. • Source_Info Message Clarifications. • Correction to BMC description. • EPR Source cap clarification. • Delaying of VCONN Swap. • EPR_Request in SPR Mode. • Generic transition diagram. • Removing the usage of Ping message • Sink Standby • Source Info Support	October 2024

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1 Introduction

USB has evolved from a data interface capable of supplying limited power to a primary provider of power with a data interface. Today many devices charge or get their power from USB Ports contained in laptops, cars, aircraft or even wall sockets. USB has become a ubiquitous power socket for many small devices such as cell phones and other hand-held devices. Users need USB to fulfill their requirements not only in terms of data but also to provide power to, or charge, their devices simply, often without the need to load a driver, in order to carry out “traditional” USB functions.

There are, however, still many devices which either require an additional power connection to the wall, or exceed the USB default current in order to operate. Increasingly, international regulations require better energy management due to ecological and practical concerns relating to the availability of power. Regulations limit the amount of power available from the wall which has led to a pressing need to optimize power usage. The USB Power Delivery Specification has the potential to minimize waste as it becomes a standard for charging devices that are not satisfied by ***[USBBC 1.2]*** or ***[USB Type-C 2.4]***.

Wider usage of wireless solutions is an attempt to remove data cabling but the need for “tethered” charging remains. In addition, industrial design requirements drive wired connectivity to do much more over the same connector.

USB Power Delivery is designed to enable the maximum functionality of USB by providing more flexible power delivery along with data over a single cable. Its aim is to operate with and build on the existing USB ecosystem; increasing power levels from existing USB standards, for example ***[USBBC 1.2]***, enabling new higher power use cases such as USB powered Hard Disk Drives (HDDs), laptops and monitors.

With USB Power Delivery the power direction is no longer fixed. This enables the product with the power (USB Host or Peripheral) to provide the power. For example, a display with a supply from the wall can power, or charge, a laptop. Alternatively, USB Chargers are able to supply power to laptops and other Battery powered devices through their, traditional power providing, USB Ports.

USB Power Delivery enables Hubs (including Hubs embedded in other devices such as docks or monitors) to become the means to optimize power management across multiple peripherals by allowing each device to take only the power it requires, and to get more power when required for a given application. ***Optionally*** the Hubs can communicate with the PC to enable even more intelligent and flexible management of power either automatically or with some level of user intervention.

USB Power Delivery allows low power cases such as headsets to Negotiate for only the power they require. This provides a simple solution that enables USB devices to operate at their optimal power levels.

The Power Delivery Specification, in addition to providing mechanisms to Negotiate power also can be used as a side-band channel for standard and vendor defined messaging. The specification enables discovery of cable Capabilities such as supported speeds and current levels. Power Delivery enables alternative modes of operation by providing the mechanisms to discover, enter and exit Modes such as EPR Mode, USB4® Mode or Alternate Modes.

1.1 Overview

This specification defines how USB Devices can Negotiate for more current and/or higher or lower voltages over the USB cable (using the USB Type-C® CC wire as the communications channel) than are defined in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USB4]***, ***[USB Type-C 2.4]*** or ***[USBBC 1.2]*** specifications. It allows Devices with greater power requirements than can be met with today's specification to get the power they require to operate from V_{BUS} and Negotiate with external power sources (e.g., Chargers).

In addition, it allows a Source and Sink to swap Power Roles such that a USB Device could supply power to the USB Host. For example, a display could supply power to a laptop to operate or charge its Battery. This specification also adds a mechanism to swap the Data Roles such that the upstream facing Port becomes the downstream facing Port and vice versa. It also enables a swap of the end supplying V_{CONN} to a powered cable.

The USB Power Delivery Specification is guided by the following principles:

- Works seamlessly with legacy USB Devices.

- Compatible with existing spec-compliant USB cables.
- Minimizes potential damage from non-compliant cables (e.g., 'Y' cables etc.).
- Optimized for low-cost implementations.

This specification defines mechanisms to discover, enter and exit Alternate Modes defined either by a standard or by a particular vendor. These Alternate Modes can be supported either by the Port Partner or by a cable connecting the two Port Partners.

The specification defines mechanisms to discover the Capabilities of cables which can communicate using Power Delivery.

To facilitate optimum charging, the specification defines two mechanisms a USB Charger can Advertise for the device to use:

1) A list of Fixed Supply voltages each with a maximum current. The device selects a voltage and current from the list. This is the traditional model used by devices that use internal electronics to manage the charging of their Battery including modifying the voltage and current actually supplied to the Battery. The side-effect of this model is that the charging circuitry generates heat that can be problematic for small form factor devices.

2) A list of programmable voltage ranges, in SPR PPS Mode, each with a maximum current. The device requests a voltage (in 20mV increments) that is within the Advertised range and a maximum current. The USB PPS Charger delivers the requested voltage until the maximum current is reached at which time the USB PPS Charger reduces its output voltage so as not to supply more than the requested maximum current. During the high current portion of the charge cycle, the USB PPS Charger can be directly connected (through an appropriate safety device) to the Battery. This model is used by devices that want to minimize the thermal impact of their internal charging circuitry.

3) A list of adjustable voltage ranges, in SPR AVS Mode or EPR AVS Mode, each with a maximum current. The device requests a voltage (in 100mV increments) that is within the Advertised range and a maximum current. The USB AVS Charger delivers the requested voltage.

1.2 Purpose

The USB Power Delivery specification defines a power delivery system covering all elements of a USB system including USB Hosts, USB Devices, Hubs, Chargers and cable assemblies. This specification describes the architecture, protocols, power supply behavior, connectors and cabling necessary for managing power delivery over USB at up to 100W in SPR Mode and 240W in EPR Mode. This specification is intended to be fully compatible with and extend the existing USB infrastructure. It is intended that this specification will allow system OEMs, power supply and Peripheral developers adequate flexibility for product versatility and market differentiation without losing backwards compatibility.

USB Power Delivery is designed to operate independently of the existing USB bus defined mechanisms used to Negotiate power which are:

- ***[USB 2.0]***, ***[USB 3.2]*** in band requests for high power interfaces.
- ***[USBBC 1.2]*** mechanisms for supplying higher power (not mandated by this specification).
- ***[USB Type-C 2.4]*** mechanisms for supplying higher power.

Initial operating conditions remain the USB Default Operation as defined in ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.4]*** or ***[USBBC 1.2]***.

- The DFP sources ***vSafe5V*** over V_{BUS}.
- The UFP consumes power from V_{BUS}.

1.2.1 Scope

This specification is intended as an extension to the existing ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.4]*** and ***[USBBC 1.2]*** specifications. It addresses only the elements required to implement USB Power Delivery. It is targeted at power supply vendors, manufacturers of ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.4]*** and ***[USBBC 1.2]*** platforms, devices and cable assemblies.

Normative information is provided to allow interoperability of components designed to this specification. ***Informative*** information, when provided, illustrates possible design implementation.

1.3 Section Overview

This specification contains the following sections:

Table 1.1 Section Overview

Section	Description
Section 1, "Introduction"	Introduction, conventions used in the document, list of terms and abbreviations, references, and details of parameter usage.
Section 2, "Overview"	Overview of the document including a description of the operation of *PD* and the architecture.
Section 3, "USB Type-A and USB Type-B Cable Assemblies and Connectors"	Mechanical and electrical characteristics of the cables and connectors used by *PD*. Section ***Deprecated***. See ***[USBPD 2.0]*** for legacy *PD* connector specification.
Section 4, "Electrical Requirements"	Electrical requirements for *Dead Battery* operation and cable detection.
Section 5, "Physical Layer"	Details of the *PD PHY Layer* requirements
Section 6, "Protocol Layer"	*Protocol Layer* requirements including the *Message*s, timers, counters, and state operation.
Section 7, "Power Supply"	Power supply requirements for both *Provider*s and *Consumer*s.
Section 8, "Device Policy"	*Device Policy Manager* requirements. *Policy Engine Atomic Message Sequence* (*AMS*) diagrams and state diagrams
Section 9, "States and Status Reporting"	*PDUSB Device* requirements including mapping of V_{BUS} to USB states. *System Policy Manager* requirements including descriptors, events, and requests.
Section 10, "Power Rules"	*PDP Rating* definitions for *PD*.
Section A, "CRC calculation"	Example *CRC* calculations.
Section B, "Message Sequence Examples (Deprecated)"	Scenarios illustrating *Device Policy Manager* operation. ***Deprecated***
Section C, "VDM Command Examples"	Examples of *Structured VDM* usage.Section ***Deprecated***.
Section D, "BMC Receiver Design Examples"	*BMC* Receiver Design Examples.
Section E, "FRS System Level Example"	*FRS* System Level Example.

1.4 Conventions

1.4.1 Precedence

If there is a conflict between text, figures, and tables, the precedence ***Shall*** be tables, figures, and then text.

In there is a conflict between a generic statement and a more specific statement, the more specific statement ***Shall*** apply.

1.4.2 Keywords

The following keywords differentiate between the levels of requirements and options.

Table 1.2 Keywords

Keyword	Definition
Conditional Normative	***Conditional Normative*** is a keyword used to indicate a feature that is mandatory when another related feature has been implemented. Designers are mandated to implement all such requirements, when the dependent features have been implemented, to ensure interoperability with other compliant devices.
Deprecated	***Deprecated*** is a keyword used to indicate a feature, supported in previous releases of the specification, which is no longer supported.
Discard	See ***Discarded***.
Discarded	***Discard***, ***Discards*** and ***Discarded*** are equivalent keywords indicating that a *Packet* when received ***Shall*** be thrown away by the *PHY Layer* and not passed to the *Protocol Layer* for processing. No ***GoodCRC*** *Message* ***Shall*** be sent in response to the *Packet*.
Discards	See ***Discarded***.
Ignore	See ***Ignored***.
Ignored	***Ignore***, ***Ignores*** and ***Ignored*** are equivalent keywords indicating *Message*s or *Message* fields which, when received, ***Shall*** result in no special action by the receiver. An ***Ignored*** *Message* ***Shall*** only result in returning a ***GoodCRC*** *Message* to acknowledge *Message* receipt. A *Message* with an ***Ignored*** field ***Shall*** be processed normally except for any actions relating to the ***Ignored*** field.
Ignores	See ***Ignored***.
Informative	***Informative*** is a keyword indicating text with no specific requirements, provided only to improve understanding.
Invalid	***Invalid*** is a keyword when used in relation to a *Packet* indicates that the *Packet*'s usage or fields fall outside of the defined specification usage. When ***Invalid*** is used in relation to an *Explicit Contract* it indicates that a previously established *Explicit Contract* which can no longer be maintained by the *Source*. When ***Invalid*** is used in relation to individual *K-code*s or *K-code* sequences indicates that the received *Signaling* falls outside of the defined specification.
May	***May*** is a keyword that indicates a choice with no implied preference.
May Not	***May Not*** is a keyword that is the inverse of ***May***. Indicates a choice to not implement a given feature with no implied preference.
N/A	***N/A*** is a keyword that indicates that a field or value is not applicable and has no defined value and ***Shall Not*** be checked or used by the recipient.
Normative	See ***Shall***.
Optional	***Optional***, ***Optionally*** and ***Optional Normative*** are equivalent keywords that describe features not mandated by this specification. However, if an ***Optional*** feature is implemented, the feature ***Shall*** be implemented as defined by this specification.
Optional Normative	See ***Optional***.
Optionally	See ***Optional***.

Table 1.2 Keywords (Continued)

Keyword	Definition
Reserved	***Reserved*** is a keyword indicating bits, bytes, words, fields, and code values that are set-aside for future standardization. Their use and interpretation ***May*** be specified by future extensions to this specification and ***Shall Not*** be utilized or adapted by vendor implementation. A ***Reserved*** bit, byte, word, or field ***Shall*** be set to zero by the sender and ***Shall*** be ***Ignored*** by the receiver. ***Reserved*** field values ***Shall Not*** be sent by the sender and ***Shall*** be ***Ignored*** by the receiver.
Shall	***Shall*** and ***Normative*** are equivalent keywords indicating a mandatory requirement. Designers are mandated to implement all such requirements to ensure interoperability with other compliant devices.
Shall Not	***Shall Not*** is a keyword that is the inverse of ***Shall*** indicating non-compliant operation.
Should	***Should*** is a keyword indicating flexibility of choice with a preferred alternative; equivalent to the phrase “it is recommended that…”.
Should Not	***Should Not*** is a keyword is the inverse of ***Should***; equivalent to the phrase “it is recommended that implementations do not…”.
Static	***Static*** is a keyword indicating that a field that never changes.
Valid	***Valid*** is a keyword that is the inverse of ***Invalid*** indicating either a Packet or *Signaling* that fall within the defined specification or an *Explicit Contract* that can be maintained by the *Source*.

1.4.3 Numbering

Numbers that are immediately followed by a lowercase “b” (e.g., 01b) are binary values. Numbers that are immediately followed by an uppercase “B” are byte values. Numbers that are immediately followed by a lowercase “h” (e.g., 3Ah) or are preceded by “0x” (e.g., 0xFF00) are hexadecimal values. Numbers not immediately followed by either a “b”, “B”, or “h” are decimal values.

1.5 Related Documents

Document references listed in *Table 1.3, "Document References"* are inclusive of all approved and published ECNs and Errata.

Table 1.3 Document References

Bookmark Reference	Title
[DPTC2.1]	DisplayPort™ Alt Mode on *USB Type-C* Standard *www.vesa.org*.
[IEC 60950-1]	IEC 60950-1:2005 Information technology equipment – Safety – Part 1: General requirements: Amendment 1:2009, Amendment 2:2013. *www.iec.ch*.
[IEC 60958-1]	IEC 60958-1:2021 Digital Audio Interface Part:1 General. *www.iec.ch*.
[IEC 62368-1]	IEC 62368-1:2018 Audio/Video, information, and communication technology equipment – Part 1: Safety requirements. *www.iec.ch*.
[IEC 62368-3]	IEC 62368-3:2017 Audio/video, information, and communication technology equipment - Part 3: Safety aspects for DC power transfer through communication cables and ports *www.iec.ch*.
[IEC 63002]	IEC 63002:2021 Interoperability specifications and communication method for external power supplies used with computing and consumer electronics devices *www.iec.ch*.
[ISO 3166]	ISO 3166 international Standard for country codes and codes for their subdivisions. *http://www.iso.org/iso/home/standards/country_codes.htm*.
[TBT3]	see [USB4] Chapter 13 for Thunderbolt™ 3 device operation.
[UCSI]	*USB Type-C* Connector System Software Interface (UCSI) Specification *https://www.usb.org/documents*.
[USB 2.0]	Universal Serial Bus 2.0 Specification, *https://www.usb.org/documents*.
[USB 3.2]	Universal Serial Bus 3.2 Specification *https://www.usb.org/documents*.
[USB Type-C 2.4]	Universal Serial Bus Type-C Cable and Connector Specification, *https://www.usb.org/documents*.
[USB4]	Universal Serial Bus 4 Specification (USB4®), *https://www.usb.org/documents*.
[USBBC 1.2]	Universal Serial Bus Battery Charging Specification plus Errata (referred to in this document as the Battery Charging specification). *https://www.usb.org/documents*.
[USBPD 2.0]	Universal Serial Bus Power Delivery Specification, *https://www.usb.org/documents*.
[USBPDCompliance]	USB Power Delivery Compliance Test Specification, *https://www.usb.org/documents*.
[USBPDFirmwareUpdate 1.0]	Universal Serial Bus Power Delivery Firmware Update Specification, *https://www.usb.org/documents*.
[USBTypeCAuthentication 1.0]	Universal Serial Bus Type-C Authentication Specification, *https://www.usb.org/documents*.
[USBTypeCBridge 1.1]	Universal Serial Bus Type-C Bridge Specification, *https://www.usb.org/documents*.