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USB TYPE C + PD POWER SUPPLIES:

ADVANTAGES AND IMPLEMENTATION

Universal ease of use of a standard USB-C connector with power delivery

WHITEPAPER

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ABSTRACT

Many powered devices will benefit from the universal ease of use of a standard USB-C connector teamed with power delivery (PD). By implementing the latest and highest-powered version of the USB PD standard, feature packed built-in versatility is available for medical and industrial markets. Learn about how USB-C + PD complies with USB and USB PD standards to provide system features and benefits including the reversible and robust USB-C output connector and USB-C + PD for higher power applications and reduced charge time of higher-capacity battery. In this white paper, the advantages and challenges of implementation associated with USB-C + PD are discussed. Although not limited to portable products, the solution for a hand-held imaging medical device is used for illustration.

BACKGROUND

Electronic product roadmaps tend to share some universal goals, regardless of industry, market or purpose. Design for user experience includes ease-of-use and improved portability, which requires smaller and lighter products with longer battery life. A good solution generally goes unnoticed, but the user is painfully aware of the inconvenience cause by a poor design. Such is the case with the seemingly mundane choices available for electronic connectors.

A product that requires data, sound, video and power will often have multiple connector ports, such VGA, HDMI, DB-9 and a DC power plug. Until relatively recently, each of these connectors served one purpose each, could be unreliable, have limited insertion lifeand could be difficult to locate. In addition to causing confusion, inefficiency and increased set-up time, which frustrates the user, multiple ports introduce multiple potential failure points for reliability and leads to an inherently bulky design. They also increase costs due to engineering time, higher tooling costs and increased part numbers on a final Bill of Materials(BOM).

DESIGN FOR USER EXPERIENCE INCLUDES EASE-OF-USE AND IMPROVED PORTABILITY, WHICH REQUIRES SMALLER AND LIGHTER PRODUCTS WITH LONGER BATTERY LIFE. THE UBIQUITOUS ADOPTION OF THE UNIVERSAL SERIAL BUS (USB) STANDARD ILLUSTRATES THE INDUSTRY'S FRUSTRATION WITH THE LACK OF OTHER OPTIONS FOR HIGH SPEED DATA AND POWER.

These cost and inconvenience factors are exacerbated in the case of industrial or medical applications, the patient monitor shown in Figure 1, for example. This is for technical reasons, such as ingress requirements for cleaning as well as unknown environmental conditions, and because of the critical naturre of the device's use model.

The ubiquitous adoption of the Universal Serial Bus (USB) standard illustrates the industry's frustration with the lack of other options for high speed data and power. Most applications, including consumer electronics products have adopted USB. Apple is the remarkable exception, which highlights the need for high speed data and power in a reversible port, and sets the expectation in the industry that USB type C enabled with power delivery for variable DC voltage on-demand will be the de facto solution in the coming years.

Figure 1: Patient monitor with multiple connectors

PRIOR USB STANDARDS

Below, the features of various types of prior USB connectors are outlined. The most commonly seen today are shown in Figure 2, alongside the newer USB-C.

- Type-A:
  - Standard flat, rectangular interface
  - Most computers have multiple USB-A ports for connecting peripherals
  - Game consoles, TVs, and other devices
  - Only inserts in one way
- Type-B:
  - Almost square connector
  - Mostly used for printers and other powered devices that connect to a computer

    - No longer common, replaced by smaller options
- Mini-USB:
    - Smaller connector type that was standard for mobile devices before micro-USB.
    - On some cameras, the PlayStation 3 controller, MP3 players, and similar
- Micro-USB:
    - Current standard (though slowly declining in popularity) for mobile and portable devices
    - Smart phones, tablets, USB battery packs, and game controllers

Figure 2: Common USB connectors

USB DATA SPEEDS AND COMPATIBILITES

USB data speeds have increased over time increasing its functionality for streaming video and sound. There are two speeds still in use today: USB 2.0 and USB3.x.

- **USB 2.0** introduced many modern USB norms, including support for Mini and Micro cables. This is the slowest speed of USB still used today, but it is still common in flash drives and devices like mice and keyboards.
- **USB 3.x** is the current standard for USB speeds. It is faster than USB 2.0, and thus recommended for devices like external hard drives. One can typically identify a USB 3.x port or connector by its blue coloring. Many USB 3.0 ports also

have an SSsymbol (which stands for Super Speed). Most new computers have at least one USB 3 port, and good-quality flash drives use this standard.

USB-C + PD: Advantages and Implementation

USB-C is the emerging standard for high speed data transfer of video and sound for several very simple and straight forward reasons. USB-C is, at once, robust and inexpensive, especially for the number of connections available. USB Type-C connector extends to the inclusion of a 24-pin connector. As seen in Figures 3 and 4, this provides four ground connections, four Vbus connection, two pairs of TX high-speed data path, two pairs of RX high-speed data path and two pairs of USB2.0 interface. It is compact and reversible which contributes to improved mechanical design and a positive user experience. The two CC channels enable USB-C connector to determine the orientation; the Vconn cable power and the other will be used for USB-Power Delivery(PD) communication. Finally, when paired with a PD chip, the format allows for higher power utilization or faster charging capabilities of battery powered devices and the built-in versatility for power and voltage negotiation means that a single power supply could serve multiple products and result in a reduction of accessory part numbers and lowered costs due to standardization

POWER DELIVERY VIA USB

A Device Policy Manager(DPM) communicates with a power supply to provide the required power (Voltage, Current) over Vbus. PD communication gives commands through DPM or Policy Engine(PE) to the power supply to requests the desired power level and modes while monitoring the performance and the PD chip that is integrated into the USB-C connector enables the communication between the source and the sink to elevate Vbus to supply voltage from 5V up to 20V and current up to 5A. USB Type-C PD supports dynamic power negotiation, allowing minimum charge time, maximum battery life and performance. Not only does it regulate the power output level, but also

the PD chip features a single wire communication protocol that enables any source to become the power sink and vice versa.

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1-	VBUS	CC1	D+	D-	SBU1	VBUS	RX2-	RX2+	GND
GND	RX1+	RX1-	VBUS	SBU2	D-	D+	CC2	VBUS	TX2-	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Cable Ground
SuperSpeed Data Path (TX for USB 3.1, or reconfigured in Alternate Mode)
SuperSpeed Data Path (RX for USB 3.1, or reconfigured in Alternate Mode)
Cable Bus Power (from 5V up to 20V)
Configuration Channel
Sideband Use
USB 2.0 Interface

Two pins on the USB Type-C receptacle, CC1 and CC2, are used in the discovery, configuration and management of connections across USB type-C cable.

Figure 3: Receptacle pins for USB type C

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2-	VBUS	SBU1	D-	D+	CC	VBUS	TX1-	TX1+	GND
GND	TX2+	TX2-	VBUS	VCONN			SBU2	VBUS	RX1-	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

- Cable Ground
- SuperSpeed Data Path (RX for USB 3.1, or reconfigured in Alternate Mode)
- SuperSpeed Data Path (TX for USB 3.1, or reconfigured in Alternate Mode)
- Cable Bus Power (from 5V up to 20V)
- Configuration Channel
- Sideband Use
- USB 2.0 Interface

Within a standard USB Type-C cable, only a single CC wire within each plug is connected through the cable to establish signal orientation and the other CC pin is repurposed as **VCONN** for powering electronics in the USB Type-C plug. Also, only one set of USB 2.0 D+/D- wires are implemented in a USB Type-C cable.

Figure 4: Plug pins for USB type C

CHALLENGES OF IMPLEMENTING POWER DELIVERY

To provide such high-power output, the desired voltage and current must be negotiated through USB power pins with DPM. For the power supply to achieve such efficiency and meet functional safety standards for medical product, PD verification process must be conducted during the design phase.

The initial power (source to sink) and data (host to device) relationship using the two CC1 and CC2 pins on the USB Type-C receptacle must established using the following methodology:

- The orientation of the connection is detected, with the connection the two pairs of CC pins, as a twisted-through connection or straight-through connection. If both ports try to act as the source or sink, a collision resolution is commenced.

- The USB-C + PD communication is established, and Bi-phase Mark Coded communications are carried on the CC wire of the USB Type-C cable.
- The communication will determine how to setup and manage the power and accessory modes and dynamically monitor the detach and re-attach.

Next the source defines the capability of USB-C cable through EMCA identifier and communicates to sink and the sink will ask for the specified power level at certain current/voltage.

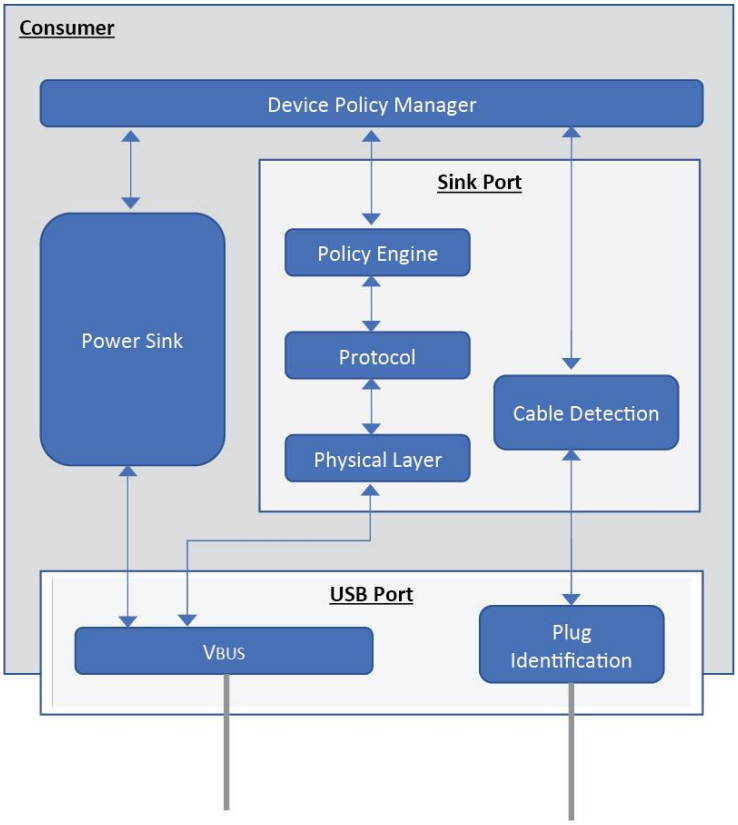
- The source will then evaluate the requested setting and EMCA caps to determine if the request is acceptable or not.
- The downstream facing port (DFP) capable of USB-PD communication will send Vconn message to initiate Vconn SWAP and enable the desired voltage to provide the power requested.
- Vconn will be established on one of the CC pins that was not used by USB PD communication, to supply power to the local plug.

SECURITY IMPLEMENTATION

The use of communication to authenticate power electronic peripherals is surprisingly important. The use of aftermarket products is very common and can result in reduced user satisfaction and liability for the OEM. Fortunately, the USB-C + PD products offer a few approaches with a varying degree of burden and security. The approaches for the Phasium products (outlined in the next section) are as follows; they are representative of the ways in which solutions are implemented:

- Identifying the product ID by PD message of Get_Manufacturer_Info and Manufacturer_Info
    - Easiest way to achieve the goal
    - PD’s standard command which is used to get the manufacturer information of devices
    - TA can verify the information and enable more functions, e.g.extra power profile
    - Difficult to prevent copy-cats

- Implement Alternate-Mode and UVDM (unstructured VDM)
    - Use UVDM to exchange information with its port partner



    - Use it to implement an simple authentication flow. E.g. SHA256 or something else for identifying the product ID
- Implement USB Authentication flow by Security_Request and Security_Response
    - Customer can refer to the spec of USB_AUTHENTICATION R1_0, requires an extra chip
    - Highest security, highest cost

The schematic for the communication protocol is shown in Figure 5.

Figure 5: Communication schematic for security implementation

CASE STUDY: Power supply for a medical imaging system

The information above outlines the advantages and reasoning for the presumed popularity of the USB-C + PD solutions. These include: the reduction in number of connectors; ease of use due to reversibility: for industrial and medical products, there are fewer ingress points; cost reduction and size reduction. A theoretical side-by-side of the Phasium USB-C + PD power supplies versus a conventional multi-port approach illustrates the simplicity of this approach.

The Phasium USB-C + PD Product Line

Phasium offers a line of power supply solutions for all USB-C+PD enabled products regardless of power and voltage incompatibilities. The products are offered at 24W, 40W, 60W and 100W with current limits at 3A (24W and 40W) or 5A (60W and 100W) and voltages and preset standards of 5V, 9V, 10.4V, 15V and 20V. An image of the 60W power supply is shown below in Figure 6.

Figure 6: Phasium USB-C + PD 60W power supply

These power supplies offer the following features:

- 60601-1
- Class B
- 4th ed EMC
- Reversable USB-C output
- Class I or II
- IP22
- High power density
- Custom options upon request

- Additional features
    - Embedded MCU with an OTP-ROM of 32kB and an SRAM of 1.5kB to perform role of Policy Engine
    - Supports USB PD 2.0 and 3.0 & Other Proprietary Protocols
    - Embedded BMC Transceiver
    - In negotiation phase Vendor Defined Messages (VDMs) can be used for positive ID
    - Built-in Synchronous Rectifier Driver and Controller
    - Built-in Shunt Regulator for Constant-Voltage and Constant-Current Control (Battery Charging)
    - Programmable Cable Compensation
    - BLD Pin for Quick Discharge of Output Capacitor
    - USBP Pin for Direct Drive of External Blocking P-MOSFET
    - Power-Saving Mode in Standby Mode Protection
    - Adaptive Output Over-Voltage Protection
    - Adaptive Under-Voltage Protection
    - Firmware-Programmable Over-Current Protection
    - Firmware-Programmable Over-Temperature Protection

The Phasium USB-C + PD Compared to a Conventional Solution

The cost comparison in Figure 7 may present as over-simplified but Occam's razor is most commonly described as 'the simplest answer is most often correct.' One can quibble about the philosopher’s intent but in this case, the numbers speak for themselves.

If one uses the example of a typical medical imaging system, such an ultrasound unit or anything else with both video and sound, and compares the utilization of a USB-C +PD solution versus a conventional solution with a DB9 connector for video, a USB-A for data and a barrel plug for power, the reason the industry is gravitating toward USB-C + PD is obvious. Over a seven year product life, typical for medical products, a cost savings of more than $1.5M dollars could be expected. That is before one takes into account additional efficiencies such as part number reductions.

- USB- C +PD
  - NRE: $50k
  - Material costs:
    - USB-C = $2.50
    - Total = $2.50
  - Product life: $400,000

- DB9 + USB-A + Power
  - NRE: $150k
  - Material costs:
    - DB9 = $5.50
    - USB-A = $2.50
    - Barrel plug for power = $5.50
    - Total = $13.50
  - Product life: $2,040,000

Total savings=$1,640,000
+ part number reduction

Figure 7: Cost comparison of USB–C + PD

CONCLUSIONS

The USB-C + PD power supply solutions provide universal ease of use due their robust design and versatility and reversibility.

Cost savings are available to the OEM do to reduced engineering and tooling resource requirements in development and the reduction of part related costs in production.

Built in versatility for power and voltage means that a single power supply could serve multiple products and result in a reduction of part numbers.

Security is easily implemented protecting against liability due to the failure of aftermarket or counterfeit products.

Reduction in charge time for battery powered products is available with the high power enabled by PD.

Medical grade 13485 manufacturing and quality is available at a similar cost to off the shelf consumer products with the line of Phasium USB-C + PD products.

Phasium designs and manufactures high-efficiency, smart, power products and assemblies for medical and industrial markets. Using advanced conversion techniques, resourceful mechanical design, and conservative design rules, the company's competitively priced products include standard and custom adapters, power supplies, battery packs, chargers, and docking stations. With an ISO 13485 facility, Phasium is the premier power brand of Megmeet.

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