USB Type-C和PD充电口在汽车上的应用

MPS Standard DC/DC PL

Dec. 2018

Index

介绍

- USB Type-C接口和Power Delivery快充被越来越多的设备所采用。

IPAD Pro首次使用Type-C接口， 支持15V/2.5A PD快充

Iphone Xs, Iphone 8, Iphone X 都支持9V/2A PD快充

Huawei Mate 20 Pro支持9V/2A PD快充. P10/P20/Mate10也支持PD快充

小米6， 小米8, MIX都支持18W PD快充

Samsung/LG至S8/G5之后都支持9V PD快充

Sony, MEIZU, HTC… Many others Phone support USB PD charging and some of them support PPS.

Type-C and PD Benefits

USB Type-C和PD因为其快速充电特性而被智能手机所采用；接下来笔记本电脑，AC适配器也采用了Type-C接口和PD。其主要优点有：

- Type-C接口可以支持很宽的电源范围，又能支持信号传输，有可能一统所有接口
- 接口可以正反插，Source/Sink可以自己识别方向
- PD可以支持最大20V/5A功率传输, Type-C可以支持最大15W
- 默认的线材可以支持3A电流，加了E-Marker芯片的线材可以支持5A电流。接口支持5A
- Type-C接口更薄，更小
- 支持20Gbps的高速USB3.2传输速率
- 支持模拟或者数字音频，支持数字视频，如Display Port, HDMI, Thunderbolt
- 向下兼容USB Type-A, USB2.0

Applications

AC Adapters

Notebooks

Smartphones

Headphones

Automotive

BT Speakers

Power Banks

Accessories

USB-C Receptacle Diagram

- Type C Cable Plug 公头

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			VConn	VBUS	TX2−	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

- Type C Receptacle 母口

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

Pin Description:

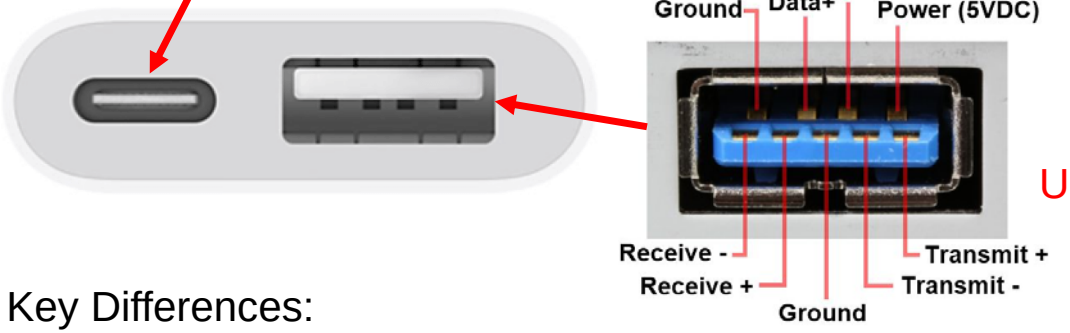
- **Vbus & GND:** Power pins (4x each) can support up to 5A of current
- **CC1/2:** Connection detection and current advertisement of the power source
- **Vconn:** Provides up to 1.5W for active cables, e-marked cables, VPDs, and alternate mode adapters
- **D+/D-:** USB data lines for BC1.2 detection and USB2.0 communication
- **TX/RX 1&2:** SuperSpeed USB 3.1 Gen1/2 data communication lines
- **SBU1/2:** Sideband pins used for USB PD Alternate Modes and Analog Audio
  - DisplayPort: AUX communication
  - Analog audio: Mic and AGND

Comparison to micro USB

USB-C

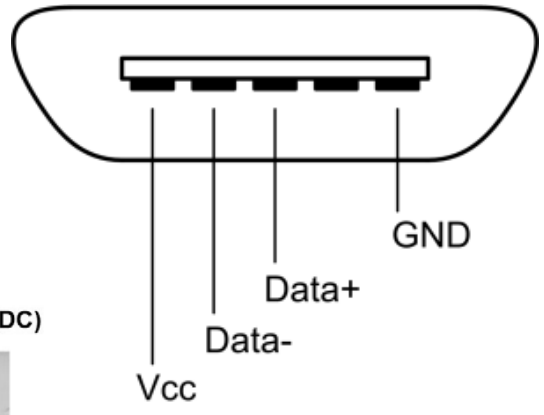
Figure 2-1 USB Type-C Receptacle Interface (Front View)

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



USB-A (3.1)

Micro USB-B 公头



Key Differences:

- USB-C can handle 5A vs. 1.5A of uUSB due to extra power and ground pins
- USB-C supports Power Delivery for up to 100W and Alternate Modes enabling video and audio over the connector
- USB-C connector is reversible
- USB-C can handle 20Gbps data-rate vs. 480Mbps for uUSB and 10Gbps on USB-A
- Thin form factor vs. USB-A for thinner notebook PCs

Most Common Cable Types

Type-C to Type-C cable

Power Direction

This is the only cable which can use USB PD

56k Rp in connector

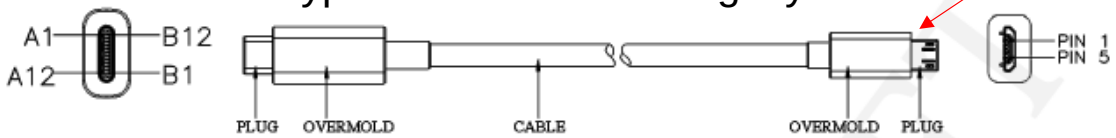
Type-A to Type-C cable

Power Direction

Type-A port is common for AC adapters and notebooks

5.1k Rd in connector

Type-C to micro USB legacy cable



Power Direction

Micro-B port is common for older mobile devices

Type-C电源管理

Source to Sink Connection/up-plug Detection

Figure 4-5 Pull-Up/Pull-Down CC Model

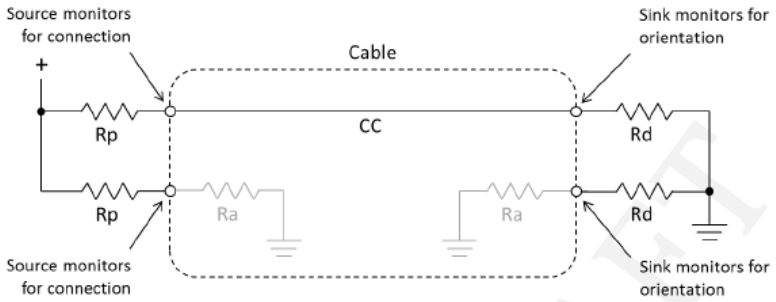
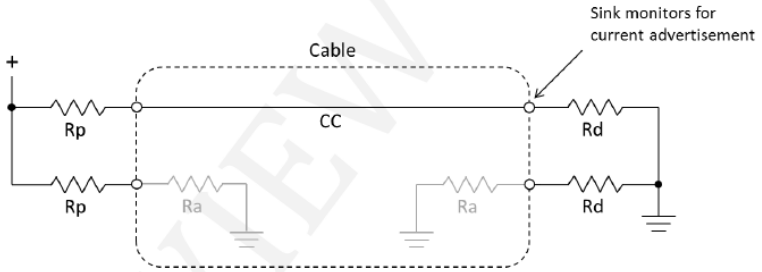


Figure 4-33 Sink Monitoring for Current in Pull-Up/Pull-Down CC Model



- Source
  - Disables Vbus by default and pulls up both of its CC pins through Rp
  - Monitors CC below 2.04V to detect attach, then enables Vbus
  - Monitors CC rising above 2.75V to detect removal, then disables Vbus and Vconn

- Sink
  - Pulls down both of its CC pins to ground through Rd
  - Monitors CC above 0.25V and Vbus to detect attach
  - Monitors Vbus dropping below 0.8-3.67V to detect removal

Type-C Source Configuration

Figure 4-7 Source Functional Model for CC1 and CC2

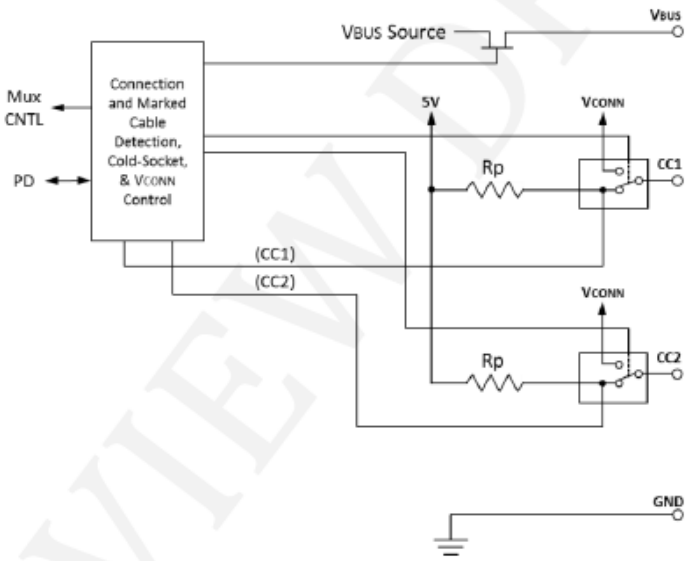


Table 4-20 Source CC Termination (Rp) Requirements

Source Advertisement	Current Source to 1.7 – 5.5 V	Resistor pull-up to 4.75 – 5.5 V	Resistor pull-up to 3.3 V ± 5%
Default USB Power	80 µA ± 20%	56 kΩ ± 20% (Note 1)	36 kΩ ± 20%
1.5 A @ 5 V	180 µA ± 8%	22 kΩ ± 5%	12 kΩ ± 5%
3.0 A @ 5 V	330 µA ± 8%	10 kΩ ± 5%	4.7 kΩ ± 5%

- Required Circuitry:
  - Trimmed current sources or pull-up resistor(s) (Rp) on the CC pins
  - Comparators and de-bounce on the CC pins to monitor for attach, detach, Orientation (opt.), and Vconn (opt.)
  - 5V Vbus power supply, disconnect FET, and pull-down circuit
  - Vconn power supply (3-5.5V), current limit (up to 1.5W), and CC mux if supported (opt.)

Type-C Source Port States

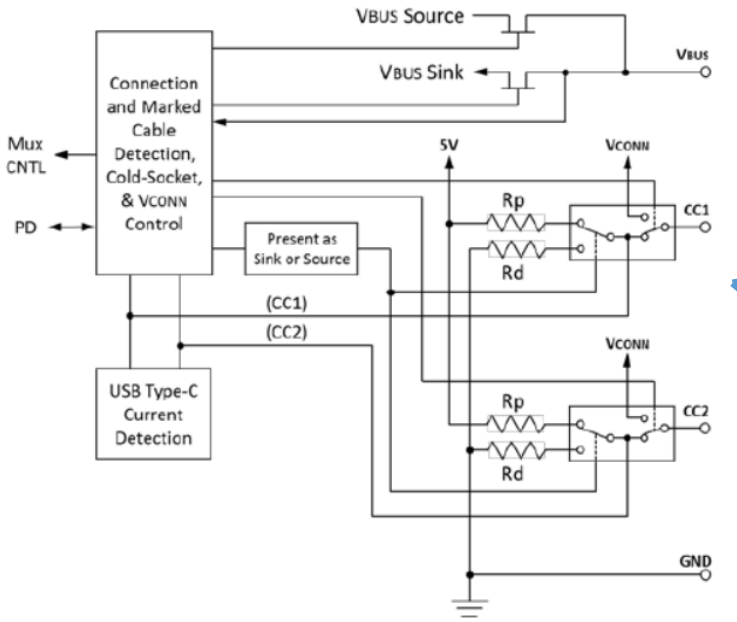
Table 4-10 Source Perspective

CC1	CC2	State	Position
Open	Open	Nothing attached	N/A
Rd	Open	Sink attached	①
Open	Rd		②
Open	Ra	Powered cable without Sink attached	①
Ra	Open		②
Rd	Ra	Powered cable with Sink, VCONN-Powered Accessory (VPA), or VCONN-Powered USB Device~~VCONN-powered Accessory~~ (VPD) attached	①
Ra	Rd		②
Rd	Rd	Debug Accessory Mode attached (Appendix B)	N/A
Ra	Ra	Audio Adapter Accessory Mode attached (Appendix A)	N/A

- List of all possible resistor combinations or “states” from the source’s perspective
- Normal sink just has Rd on one CC pin
- When Vconn is required, Rd will be on one CC pin (the one passing through the cable) and Ra will be on the other CC pin

Dual Role Power Operation

Figure 4-11 DRP Functional Model for CC1 and CC2



- Required Circuitry: Everything in Source & Sink plus:
  - Timing control for toggling between source and sink modes (DRP toggle)
  - State machine (timing + modes) associated with Try.SNK (optional)
  - State machine (timing + modes) associated with Try.SRC (optional)

What is Vconn?

- 由于Vbus是一个高压电源，而且在有些情况下Vbus电源会关闭；所以叫增加了另外一个低压电源Vconn。主要给一些逻辑芯片供电；
- Vconn is an additional power rail supplied on the unused CC pin for the following uses:
  - **Electronically marked cable:** A USB Type-C cable that uses USB PD to provide the cable's characteristics.
    - E.g. Any cable which can handle > 3A
  - **Active cable:** An electronically marked cable with additional electronics to condition (re-drive) the data path signals
    - E.g. Thunderbolt cable which is longer than 0.5m
  - **Alternate Mode Adapter (AMA):** A USB PD Device which supports Alternate Modes and acts as a UFP
    - E.g. DisplayPort adapter or MacBook dongle
  - **Vconn-Powered USB Device (VPD):** A USB direct-connect or captive-cable device that can be powered solely from either VCONN or VBUS. VPDs may optionally support the VPD charge-through capability.
    - E.g. USB-C headphones can be powered from Vconn
  - **Vconn-Powered Accessory:** An accessory that is powered from Vconn to operate in an Alternate Mode

When is Vconn Needed?

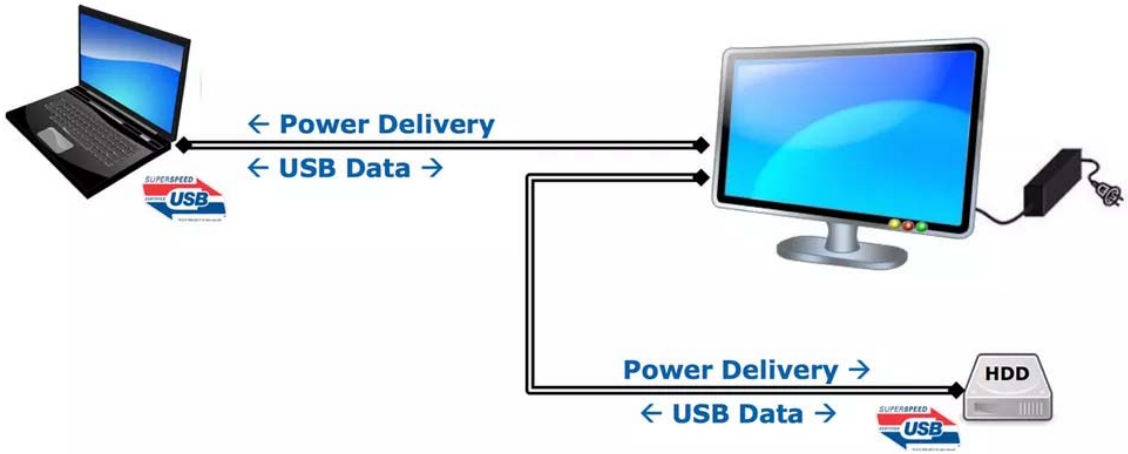
Table 4-4 USB Type-C Source Port's VCONN Requirements Summary

D+/D−	SSTX/SSRX, VPD	> 3 A	VCONN Requirements
No	No	No	Not required to source VCONN
Yes	No	No	Not required to source VCONN
Yes	Yes	No	Required to source 1 W. VCONN power may be removed after the source has read the cable's eMarker and has determined that it is not an active cable nor a VPD.
No	No	Yes	Required to source ~~1 W~~100 mW. VCONN power may be removed after the source has read the cable's eMarker and has determined the cable's current carrying capacity.
Yes	No	Yes	Required to source ~~1 W~~100 mW. VCONN power may be removed after the source has read the cable's eMarker and has determined the cable's current carrying capacity.
Yes	Yes	Yes	Required to source 1 W. VCONN power may be removed after the source has read the cable's eMarker and has determined the cable's current carrying capacity and that it is not an active cable nor a VPD.

- Vconn is required in the following conditions:
  - Data rates exceed USB2.0
  - More than 3A or current is required on the input
  - USB PD Alternate Modes need to be supported (e.g Thunderbolt, DP, etc)

USB PD Details & Features

Main Power Features of USB PD

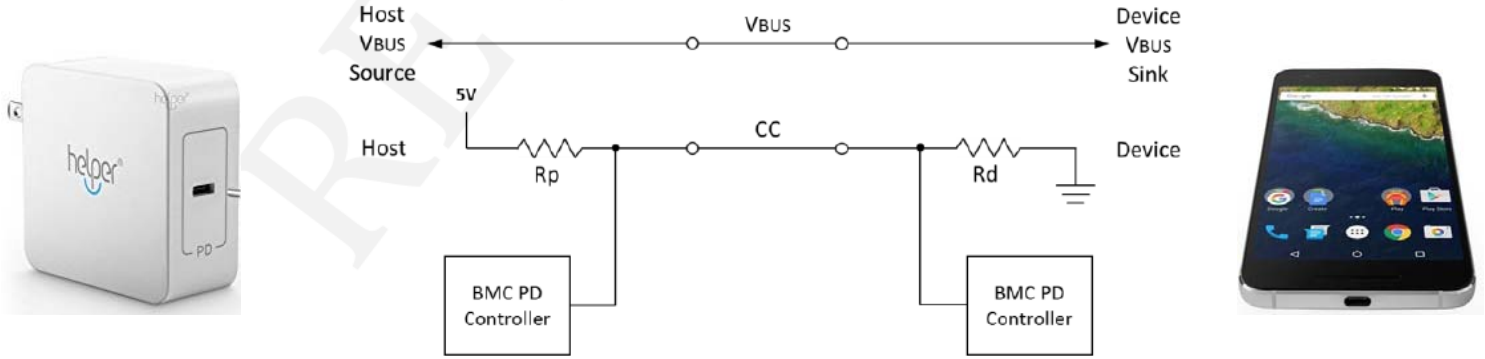


- For > 15W of power (5V @ 3A), USB PD is required
- USB PD can increase the Vbus voltage up to 21V (7 voltages are allowed)
- USB PD can increase the Vbus current up to 5A
- Enables authentication between source and sink
- Allows swapping of power, data, and Vconn roles
- Supports Alternate Modes such as DisplayPort, Thunderbolt, and HDMI
- Allows for intelligent power management of multi-port systems such as notebooks and USB hubs

PD over CC Pin Block Diagram

Figure 4-35 illustrates how the *USB PD* BMC signaling is carried over the USB Type-C cable's CC wire.

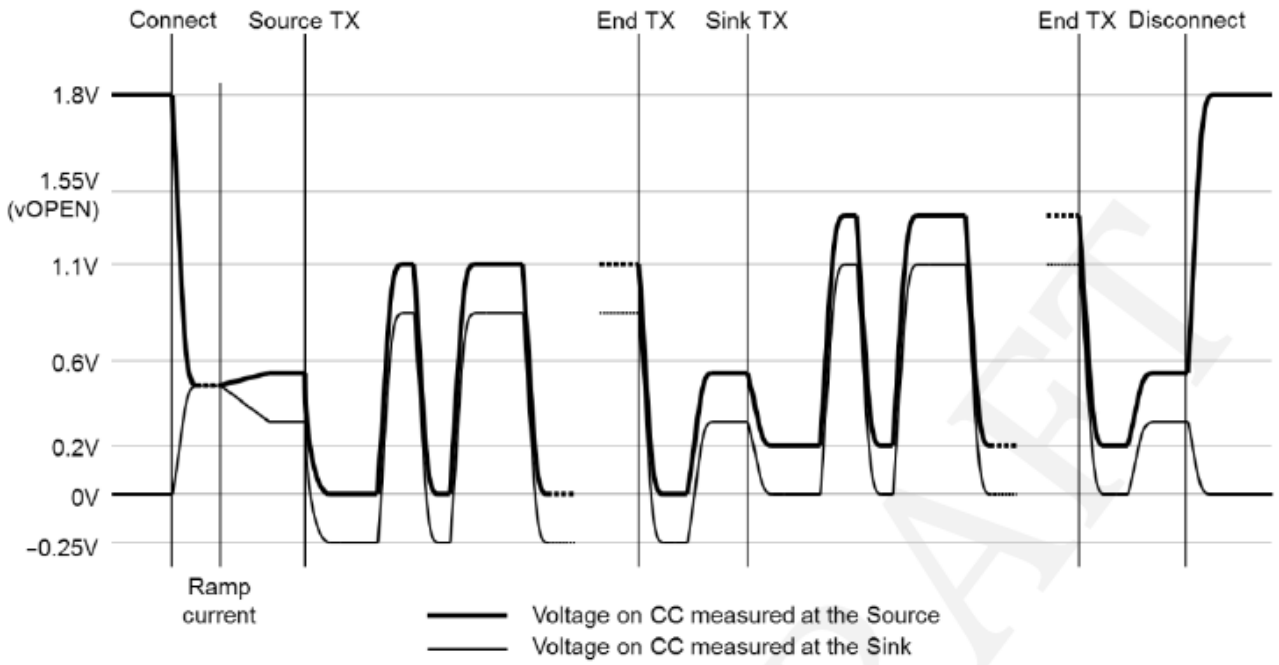
Figure 4-35 USB PD over CC Pins



- Implicit contract is in place when source and sink are attached at 5V with a valid Rp advertisement
- Explicit contract is in place once the source sends the PS_RDY message (after going to the requested voltage level)
- During an explicit contract, the source must advertise an Rp in accordance with the USB PD 3.0 collision avoidance scheme

PD over CC Pin Block Diagram

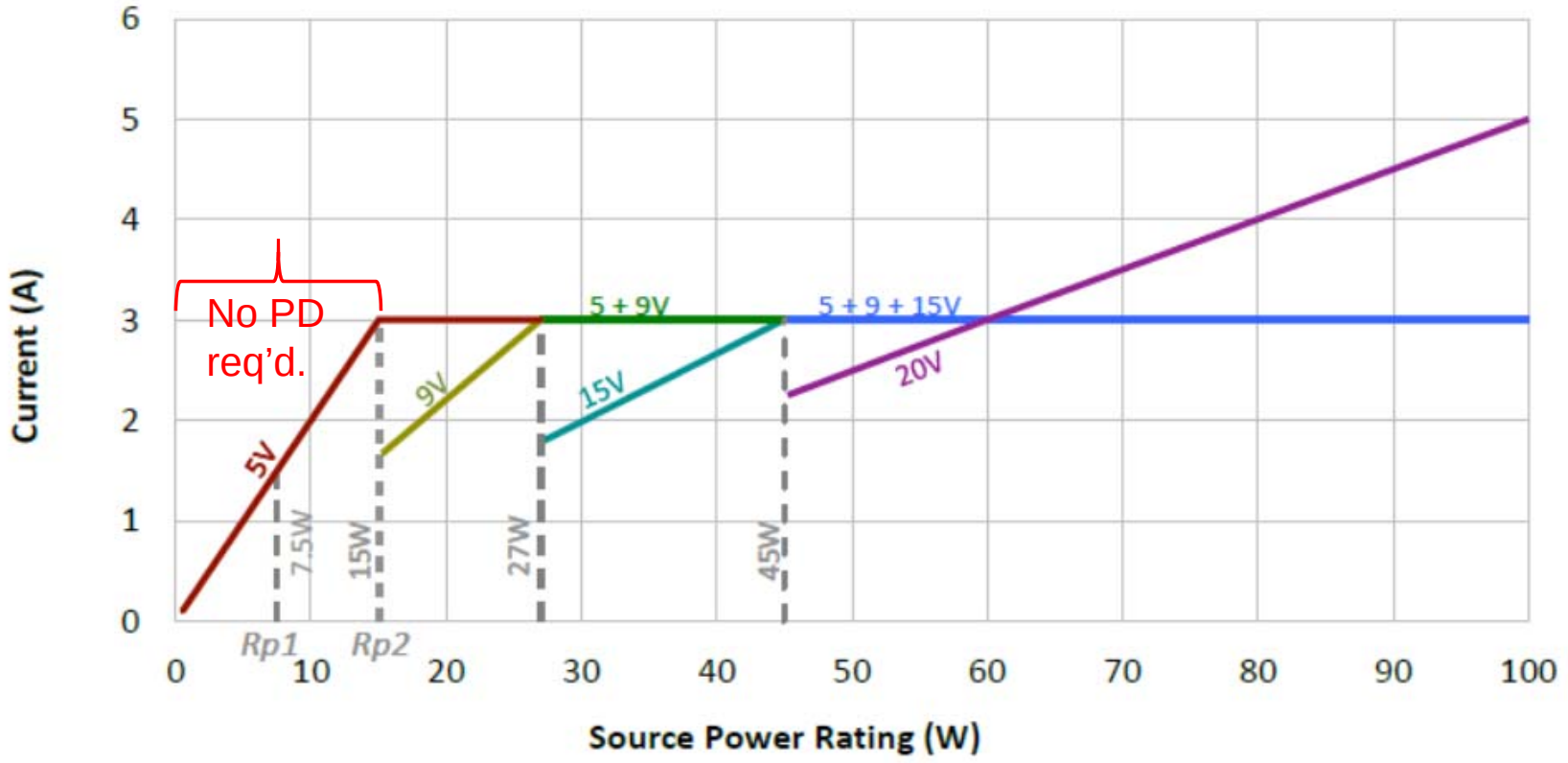
Figure 4-36 USB PD BMC Signaling over CC



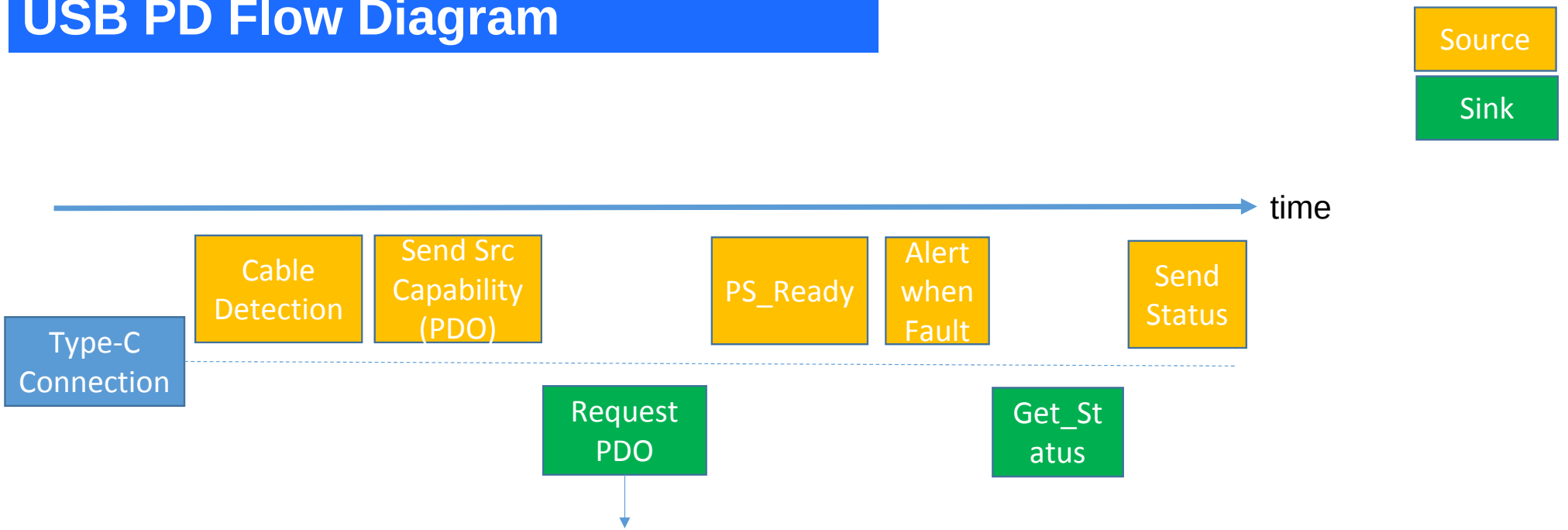
- Since the CC voltage never drops below vOPEN, the source will not register a disconnect event during PD communication
- The sink does not monitor CC for disconnect detection
- The sink employs a 10-20ms debounce to detect changes in the Rp advertisement, which will not trigger during PD communication

USB PD 2.0 Source Power Rules

Figure 10-1 Source Power Rule Illustration



USB PD Flow Diagram



Power Data Object (PDO)

Table 6-9 Fixed Supply PDO - Source

Bit(s)	Description
B31...30	Fixed supply
B29	Dual-Role Power
B28	USB Suspend Supported
B27	Unconstrained Power
B26	USB Communications Capable
B25	Dual-Role Data
B24	Unchunked Extended Messages Supported
B23...22	***Reserved*** – ***Shall*** be set to zero.
B21...20	Peak Current
B19...10	Voltage in 50mV units
B9...0	Maximum Current in 10mA units

USB PD 2.0 vs. 3.0 Power Supply Features

Table 10-7 Programmable Power Supply PDOs and APDOs based on the PDP

PDP (W)	5V fixed	9V fixed	15V fixed	20V fixed	5V Prog	9V Prog	15V Prog	20V Prog
x <= 15W	PDP/5	-	-	-	PDP/5	-	-	-
15 < x <= 27W	3A	PDP/9	-	-	3A or PDP/5[2]	PDP/9	-	-
27 < x <= 45W	3A	3A	PDP/15	-	PDP/5[1]	3A or PDP/9[2]	PDP/15	-
45 < x <= 100W	3A	3A	3A	PDP/20	-	PDP/9[1]	3A or PDP/15[2]	PDP/20[2]

Notes:
1. This PPS APDO is Optional.
2. The PPS *May* offer more than 3A when a 5A cable is present.

PD 2.0

PD 3.0

Table 10-8 Programmable Power Supply Voltage Ranges

	Fixed Nominal Voltage			
	5V Prog	9V Prog	15V Prog	20V Prog
Maximum Voltage	5.9V	11V	16V	21V
Minimum Voltage	3V	3V	3V	3V

The voltage output at the Source's connector ***Shall*** be +/-5% for both the Maximum Voltage and the Minimum Voltage.

USB PD 3.0 vs. 2.0 Differences

- PPS is only allowed in USB PD 3.0
  - USB PD 2.0 is limited to a maximum 7 fixed-power PDOs
  - USB PD 3.0 can use Augmented Power Data Objects which contain programmable power supply information
- Collision Avoidance is required in USB PD 3.0
  - Source must be able to change Rp between 1.5A and 3.0A

Table 5-13 Rp values used for Collision Avoidance

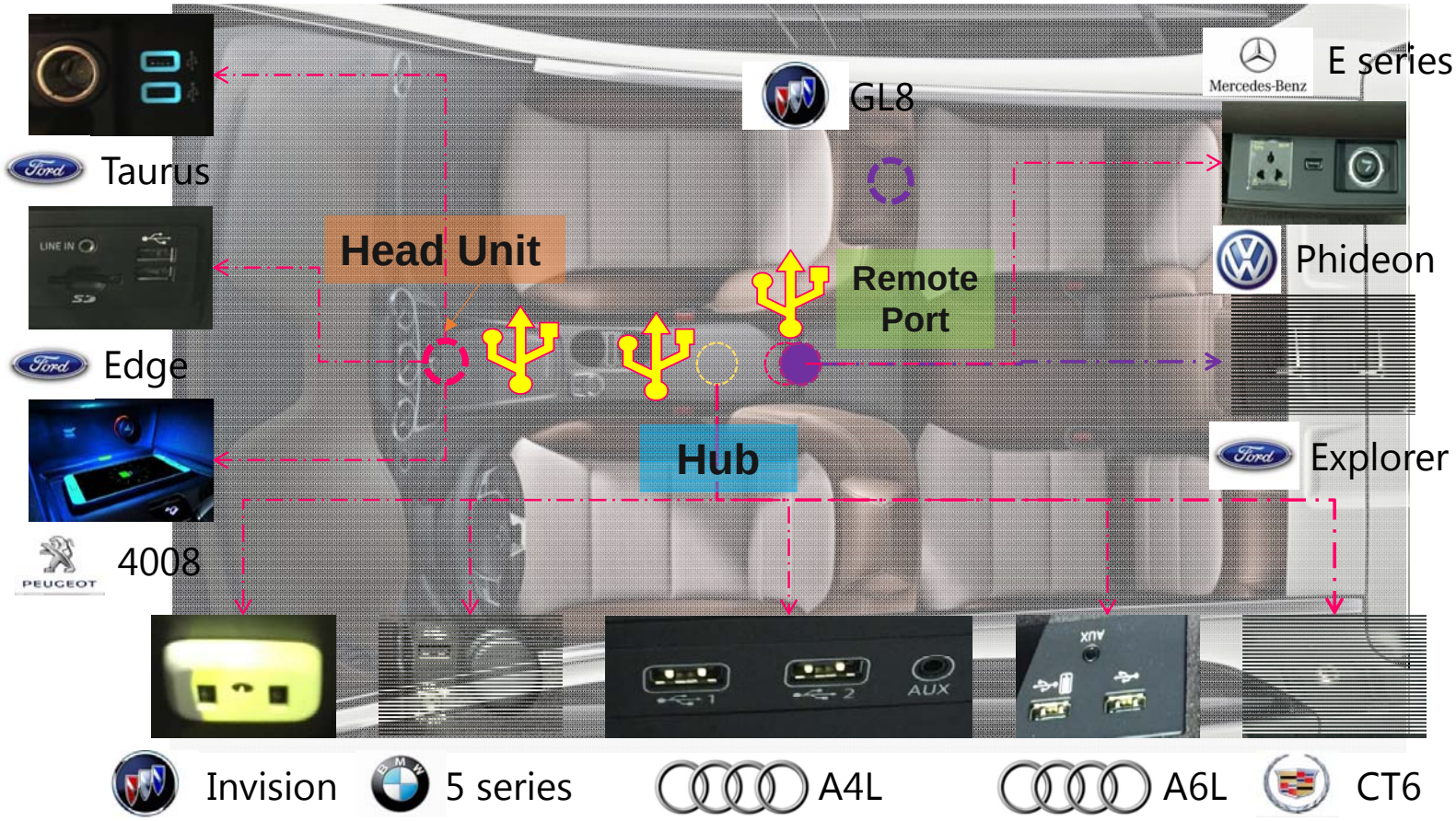
Source Rp	Parameter	Description	Sink operation	Source operation
1.5A@5V	*SinkTxNG*	Sink Transmit "No Go",	Sink cannot initiate an AMS. Sink can only respond to Messages as part of an AMS	Source can initiate an AMS *tSinkTx* after setting Rp to this value.
3A@5V	*SinkTxOk*	Sink Transmit "Ok"	Sink can initiate an AMS.	Source cannot initiate an AMS while it has this value set.

- Battery_Status Message: reports state of charge, meaning a fuel gauge is required
- Battery capabilities extended message: reports designed capacity and last full charge capacity
- All other changes are purely protocol related: https://e2e.ti.com/blogs_/b/powerhouse/archive/2016/07/14/usb-power-delivery-2-vs-3

USB Type-C and PD在汽车上的应用

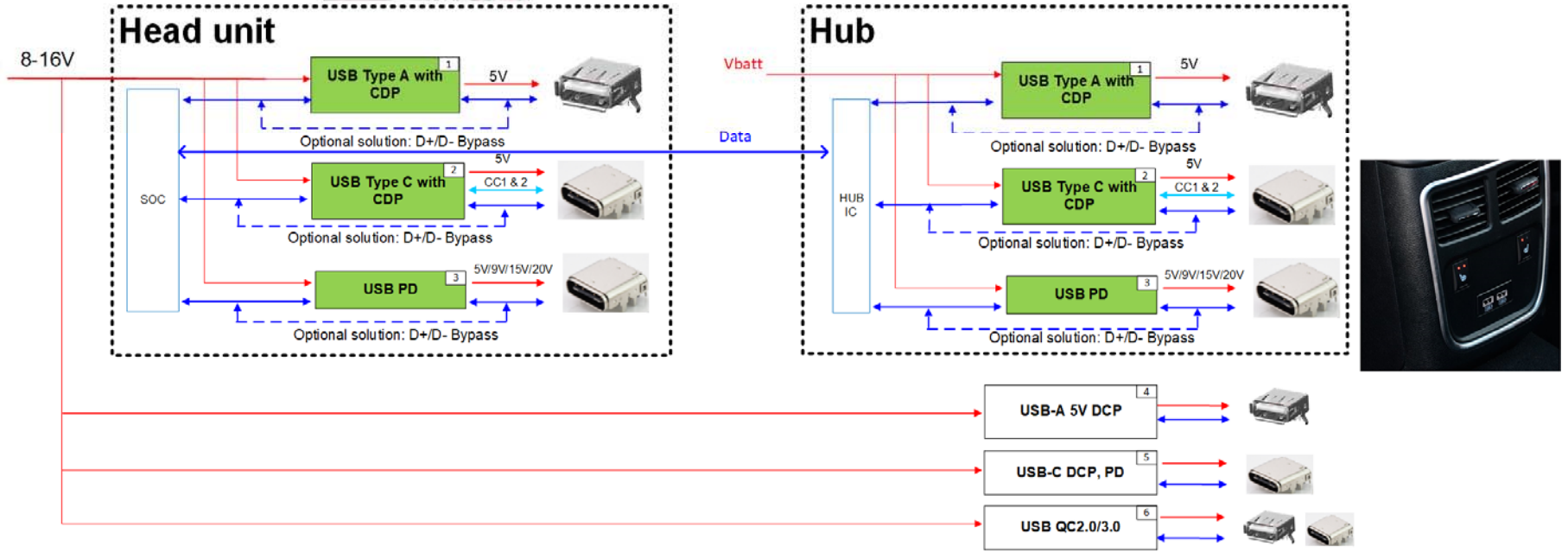
车载USB的需求

车载USB口主要分为三类：娱乐导航上的USB口；扶手箱内的USB HUB; 以及后排座只充电USB口。
目前已经有些车型开始使用USB Type-C接口，带USB PD功能的USB口也正在设计之中。



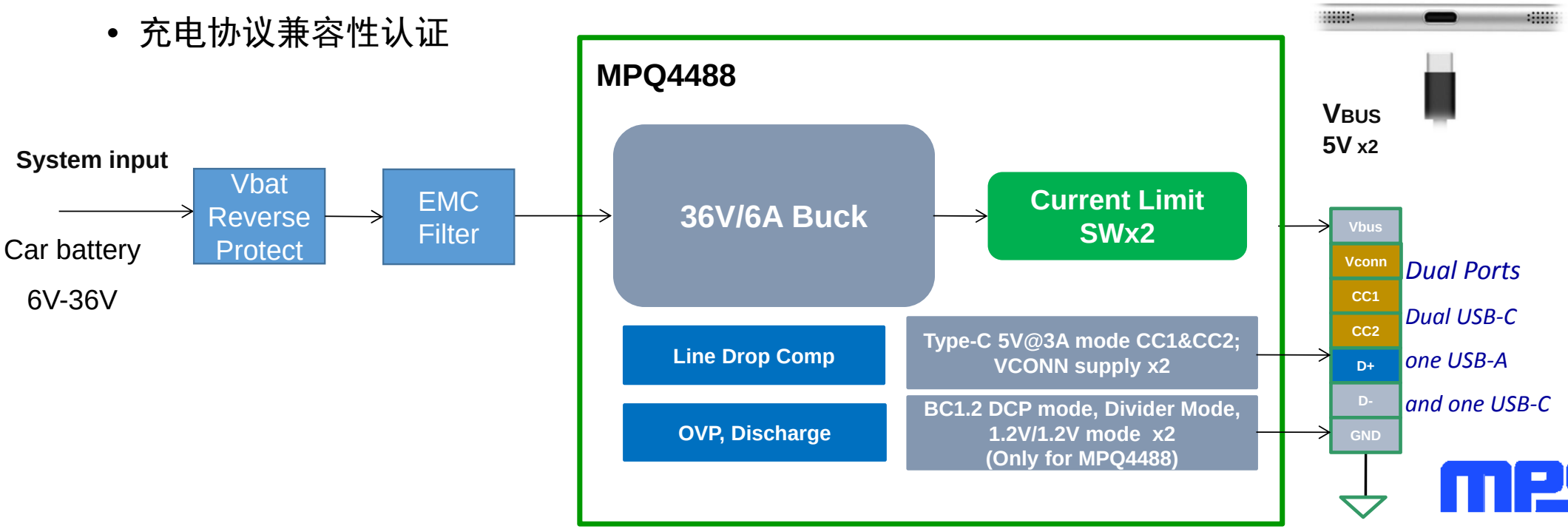
Auto USB Charging Block diagram

Head Unit和Hub口都支持边充电边传数据

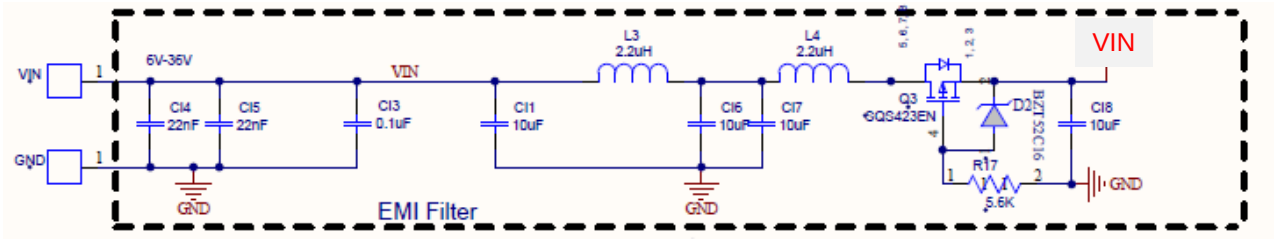


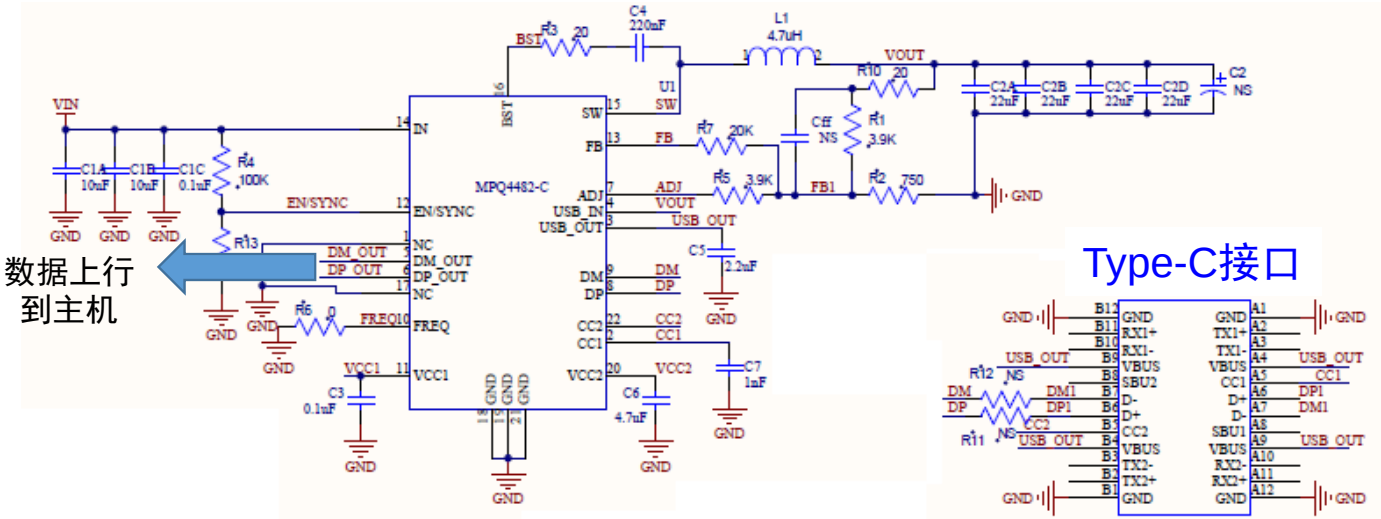
车载USB口的需求

- 模块输入防反插电路
- 模块输入Pulse电压测试：模拟自动启停，瞬态高压，负压，load dump等测试
- EMC兼容性
- 模块温升管理，过热保护
- USB输出电压线损补偿，输出过流保护，短电池保护等
- 充电协议兼容性认证



一个Type-C 5V/3A带通信功能的USB口设计案例





主芯片MPQ4482-C提供以下功能：

12V->5V/3A高效Buck;

低阻抗Type-C开关，进行限流和线补检测；

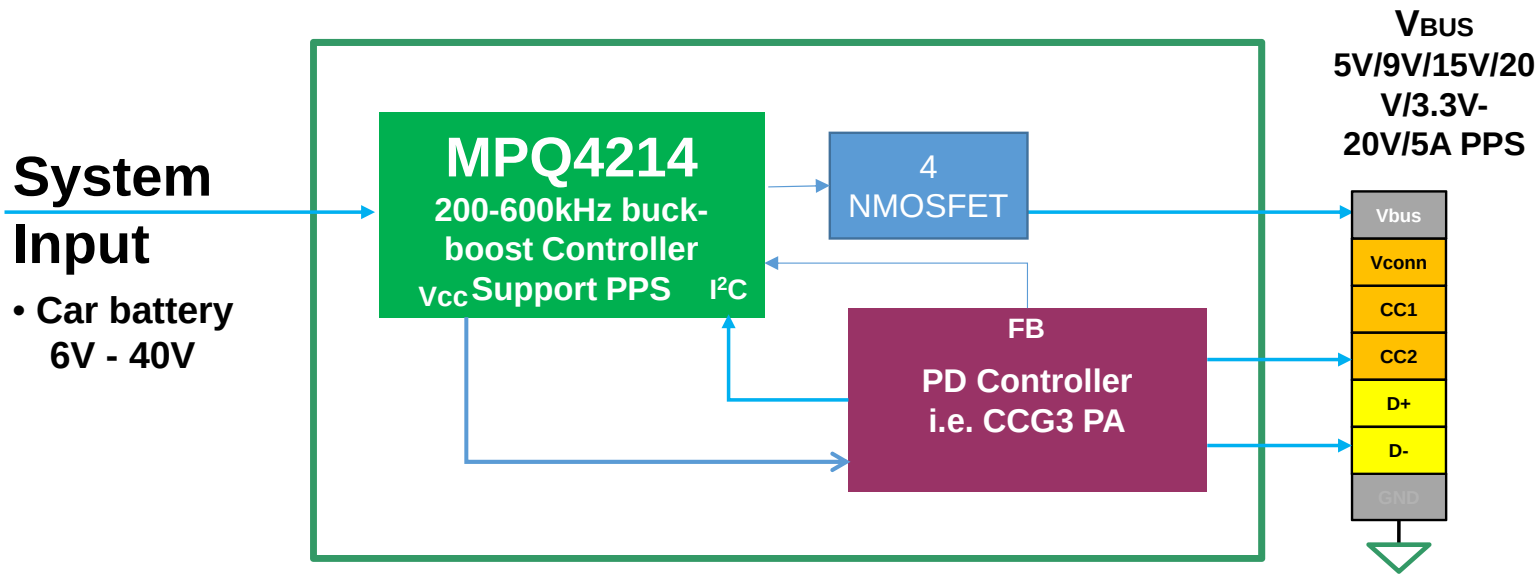
Type-C控制协议

USB2.0 CDP握手协议

- 两级EMC滤波来通过传导EMC
- 采用了PMOSFET结构来进行输入反插保护
- MPQ4482-C内置36V/3A同步Buck变换器，为Type-C端口提供可靠的5V/3A输出电源；
- 内置Type-C开关，进行限流和插入使能
- USB端口上的电压必须满足4.75-5.25V的规范。如果用户在芯片与Type-C口之间加入了很长的内部引线，就必须靠MPQ4482-C的线损补偿功能才能达标。
- USB接口上的信号管脚有可能会错误的短路到汽车电池电压，例如Cable线掉入了点烟器插槽，为了避免损坏内部器件，MPQ4482-C的I/O pin都加入了OVP保护。
- I/O口往往需要更强的ESD防护，所以额外的TVS保护是需要的。

100W USB PD with MPQ4214 and CCG3PA

100w PD Port with I2C Buck-Boost

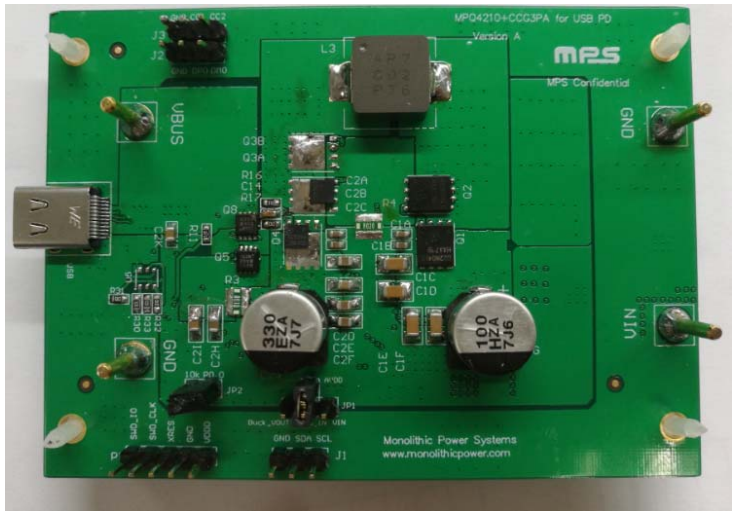


APPLICATIONS

- USB PD Charging port
- USB Hub

- 支持5V/9V/15V/20V/3.3-21V@5A PPS输出PDO
- DP/DM pins support Apple mode/BC1.2 Short mode
- Voltage and CC current limit adjust by I2C or PD controller's DAC
- Fully meet USB PD3.0 specification
- Eliminates external LDO for PD controller
- Auto reduce PDO when temperature is high
- OCP,OTP, Ground/CCx/DP/DM short to battery protect

Demo Board



PDO List when attached with a Sink meter (5A Cable is used)

The End!