TI Designs: TIDA-01627
USB Type-C™ PD Power Bank Reference Design

Description

This power bank reference design offers highly-integrated USB Type-C™ power delivery (PD) for charging notebooks. The key aspect of this design is to reduce the bill of materials (BOM) cost while maintaining the overall functionality. The design implements unique considerations for reducing quiescent current and covers all the required aspects to guide users through the part selection and trade-off considerations.

Resources

TIDA-01627	Design Folder
TPS65987D	Product Folder
BQ25703A	Product Folder
TPD8S300	Product Folder
TPS563200	Product Folder

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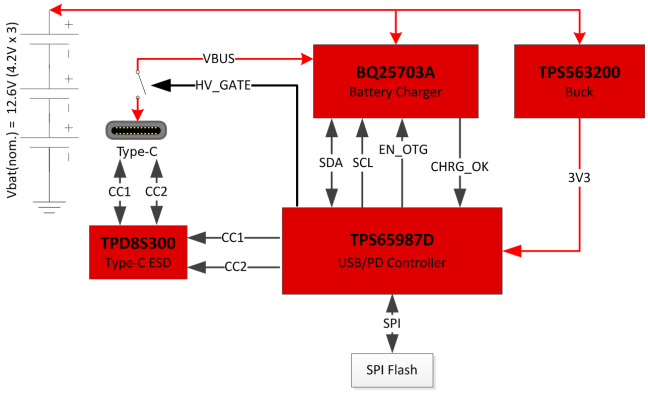
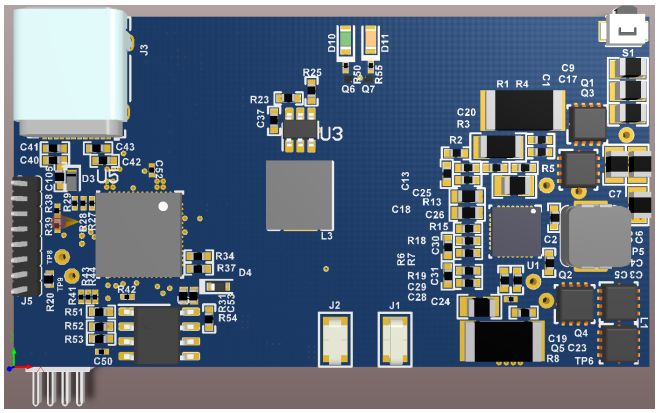
Features

- Supports 5 V at 3 A, 9 V at 3 A, 14.8 V at 2 A, 15 V at 3 A, and 20 V at 2.25 A for Power Data Objects (PDOs)
- Supports up to 45 W of Power to Charge Portable Devices
- Automatically Charges After Connecting to USB PD Source

Applications

- Charging Notebooks
- Charging Cell Phones
- Charging or Powering Other USB Type-C or PD Devices





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1 System Description

For many, carrying multiple devices is a normal if not necessary part of daily life. The average user's dependency on these gadgets continues to increase while the overall battery life is decreasing. Many users have no choice but to carry an alternate portable source of power to help recharge gadgets while on the move. This reference design offers a power bank solution that can provide 45 W of power to charge a notebook while away from traditional power sources.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Number of batteries	Three cells
Type of batteries	Lithium-ion cells
Minimum output voltage	5 V
Maximum output voltage	20 V
Maximum power	45 W

2 System Overview

This reference design has been built around two key components: TPS65987D and BQ25703A. TPS65987D is the PD controller which controls all of the USB Type-C™ and PD negotiations, in addition to controlling the BQ25703A battery charger over I^2C. This battery charger chip manages all the power and battery charging. The chip also works as a reverse buck-boost to provide power in on-the-go (OTG) mode. TPD8S300 provides protection from electrostatic discharge (ESD) and VBUS to CC short and the TPS563200 generates 3.3 V from the battery to power the PD controller.

2.1 Block Diagram

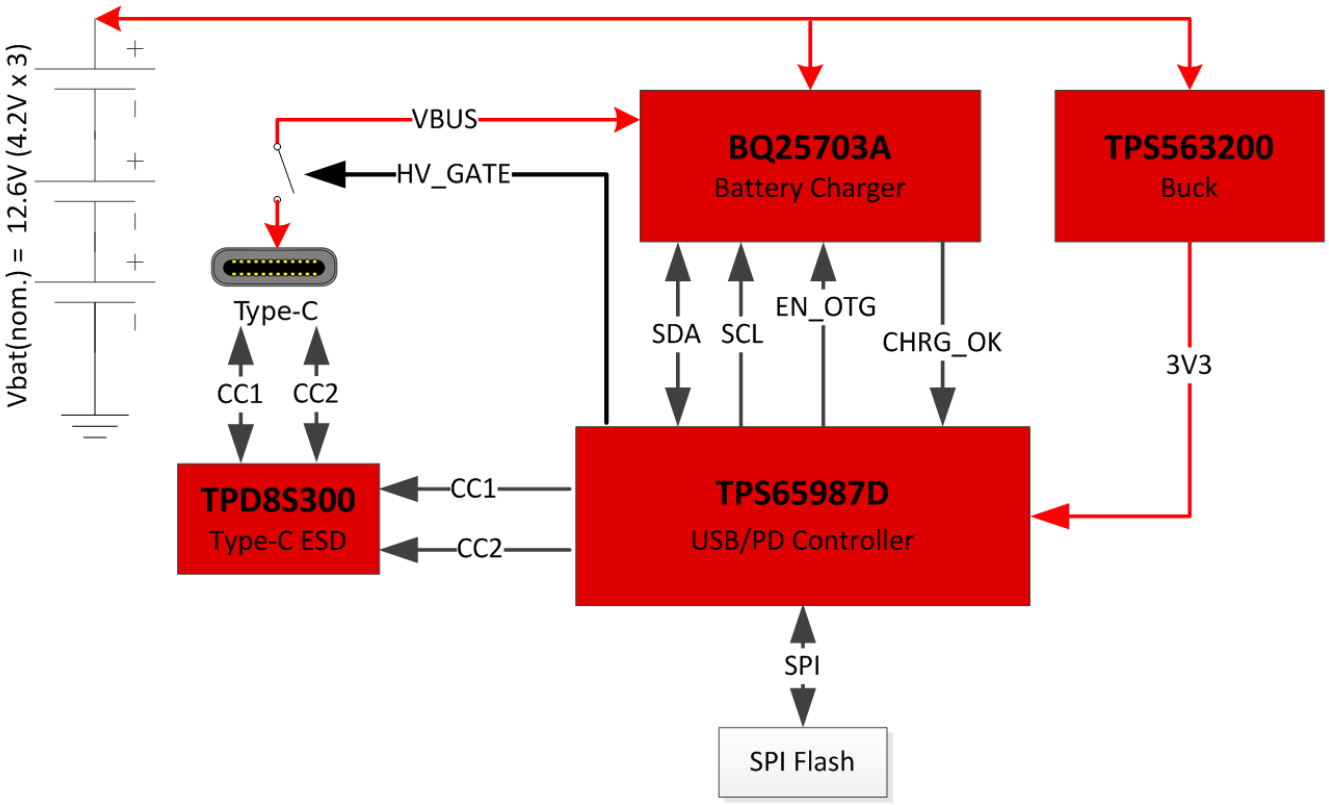


Figure 1. TIDA-01627 Block Diagram

2.2 Design Considerations

This TIDA-01627 system demonstrates how to manufacture reliable power banks using USB-Type-C and PD ports. To achieve this objective, the reference design uses the most-integrated USB-PD controller and battery controller in the market. The unique combination of these two devices ensures the most reliable and cost-effective solution to charge a notebook on the go.

This reference design has been tested with three lithium-ion cells; however, it can support one to four cells by simply changing the values of R12 and R14. For more details on this custom setting, see *bq25703A I2C Multi-Chemistry Battery Buck-Boost Charge Controller With System Power Monitor and Processor Hot Monitor*. Note that the batteries must be sized properly to support the PD load, which the power bank must also support.

The following subsections show the various parts of this design and the devices which they use.

2.2.1 TPS65987D USB Type-C™ and PD Controller With Firmware Upgrade Capability

The TPS65987D is a highly-integrated USB Type-C and PD controller. This device is the brain of this system and is responsible for negotiating contract with the connected device, controlling various settings of the BQ25703A device. This device was chosen as it provides I^2C master functionality, which can be configured to control any I^2C slave by just using it's configuration utility.

Figure 2 shows the TPS65987D signals schematic. Figure 3 shows the TPS65987D power lines schematic.

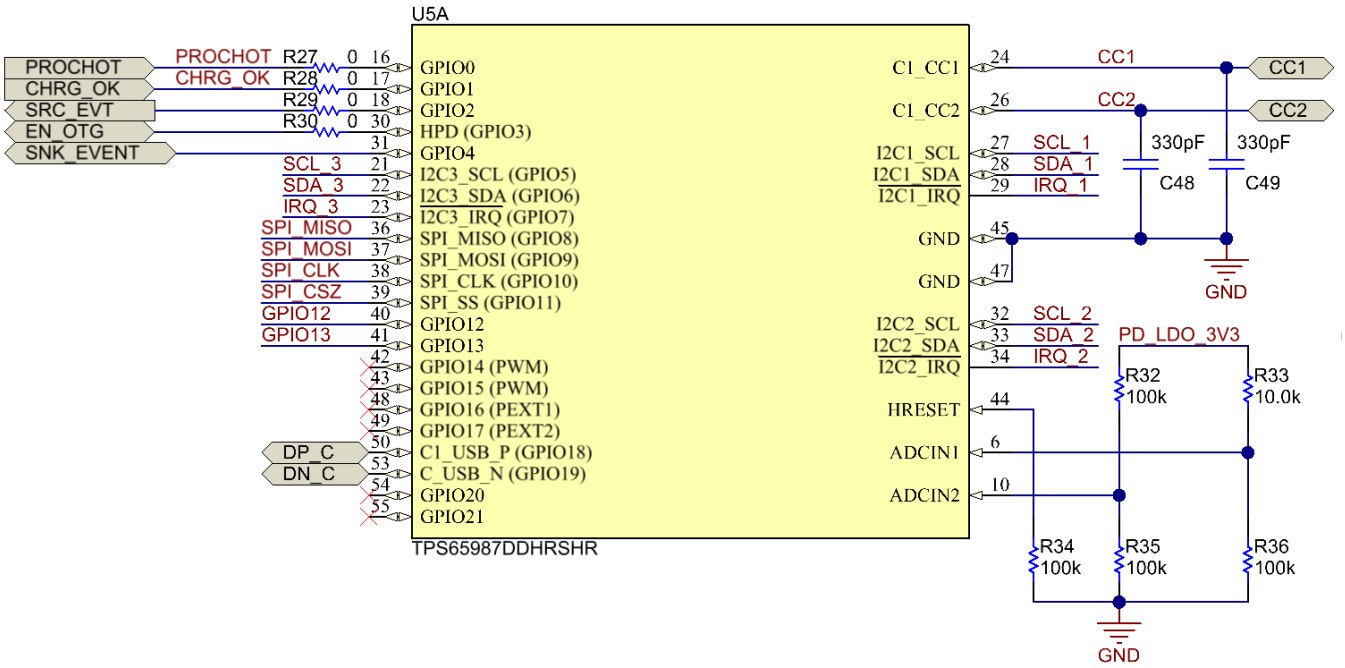


Figure 2. TPS65987D Signals Schematic

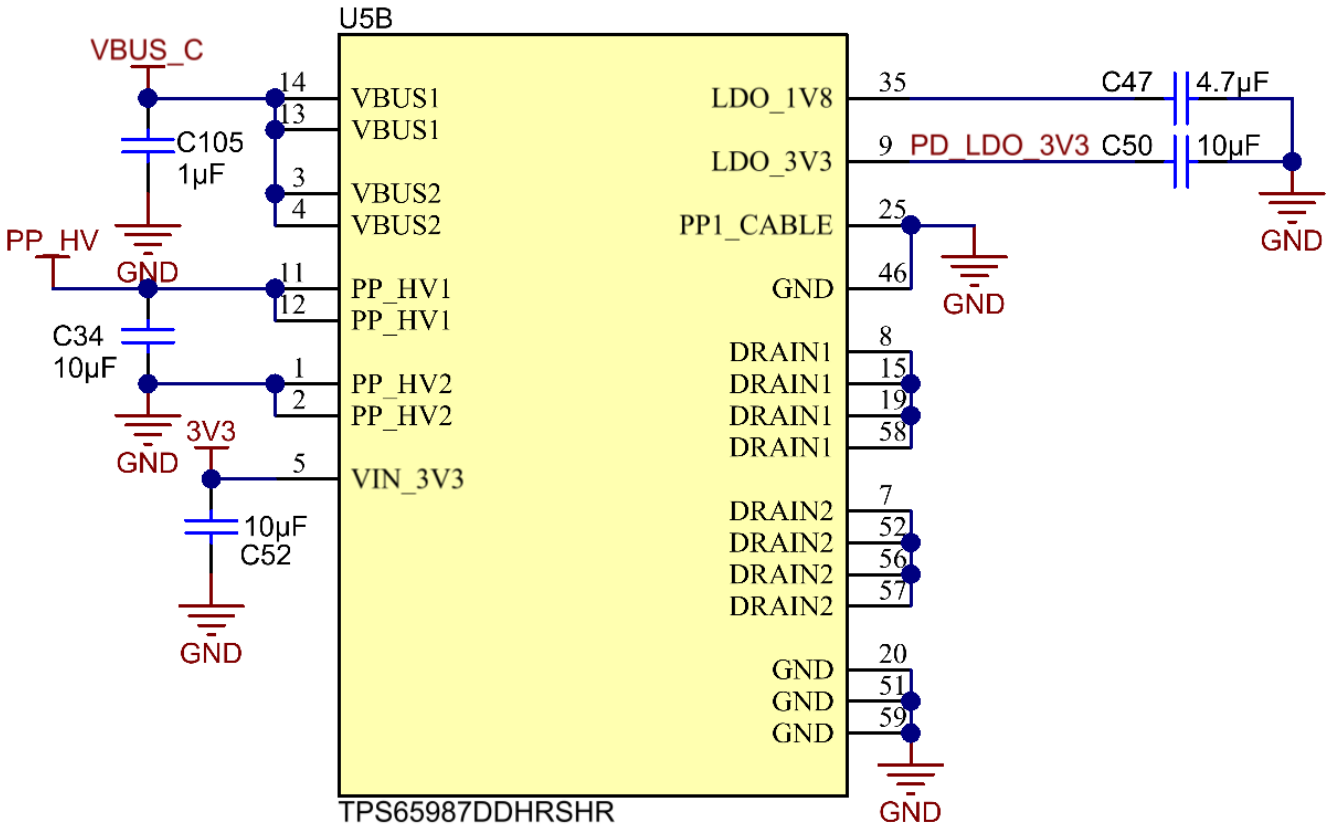


Figure 3. TPS65987D Power Lines Schematic

2.2.2 BQ25703A Multi-Chemistry, Battery Buck-Boost Charge Controller With System Power Monitor

The BQ25703A is a buck-boost, narrow-voltage DC (NVDC) charge controller for multi-chemistry portable applications such as notebooks and other mobile devices with rechargeable batteries. This device provides seamless transition between converter operation modes (buck, boost, or buck-boost), fast transient response, and high light-load efficiency. The BQ25703A takes input voltage from 3.5 V to 24 V and charges one to four batteries in series. The BQ25703A also supports USB On-The-Go (OTG) to provide a 4.48-V to 20.8-V output at the USB port.

This device is perfect for this reference design because it can work as a battery controller as well as a DC-DC converter. When the power bank is a sink and charging its own battery, then this chip assists with charging the batteries, whereas during the power source mode, this chip works as a DC-DC converter to generate the VBUS.

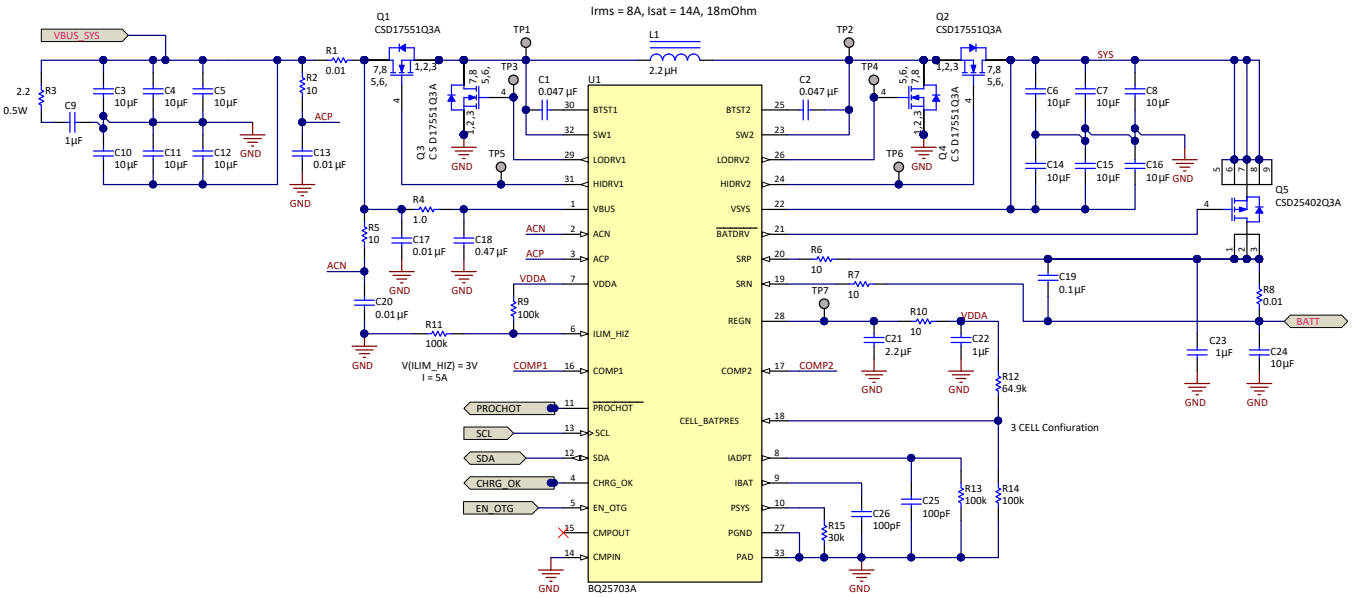


Figure 4. Battery Controller Schematic

2.2.3 TPD8S300 USB Type-C™ Port Protector

The TPD8S300 is a single-chip, USB Type-C, port protection solution that provides 20-V short-to-VBUS overvoltage and IEC ESD protection. The TPD8S300 integrates four channels of 20-V short-to-VBUS overvoltage protection for the CC1, CC2, SBU1, and SBU2 pins of the USB Type-C connector. Additionally, IEC 61000-4-2 system level ESD protection is required to protect a USB Type-C port from ESD strikes generated by end-product users. The TPD8S300 integrates eight channels of IEC61000-4-2 ESD protection for the CC1, CC2, SBU1, SBU2, DP_T (top side D+), DM_T (top side D–), DP_B (bottom side D+), and DM_B (bottom side D–) pins of the USB Type-C connector. This integration means IEC ESD protection is provided for all of the low-speed pins on the USB Type-C connector in a single chip in the TPD8S300 device. Additionally, the CC and SBU lines require high-voltage IEC ESD protection that is 22-V DC tolerant to simultaneously support IEC ESD and short-to-VBUS protection; unfortunately, not many discrete market solutions are available that can provide this kind of protection. The TPD8S300 integrates this high-voltage IEC ESD diode and has been specifically designed to guarantee that it works in conjunction with the overvoltage protection field-effect transistors (FETs) inside the device. This sort of solution is very hard to generate with discrete components.

Figure 5 shows the TPD8S300 schematic.

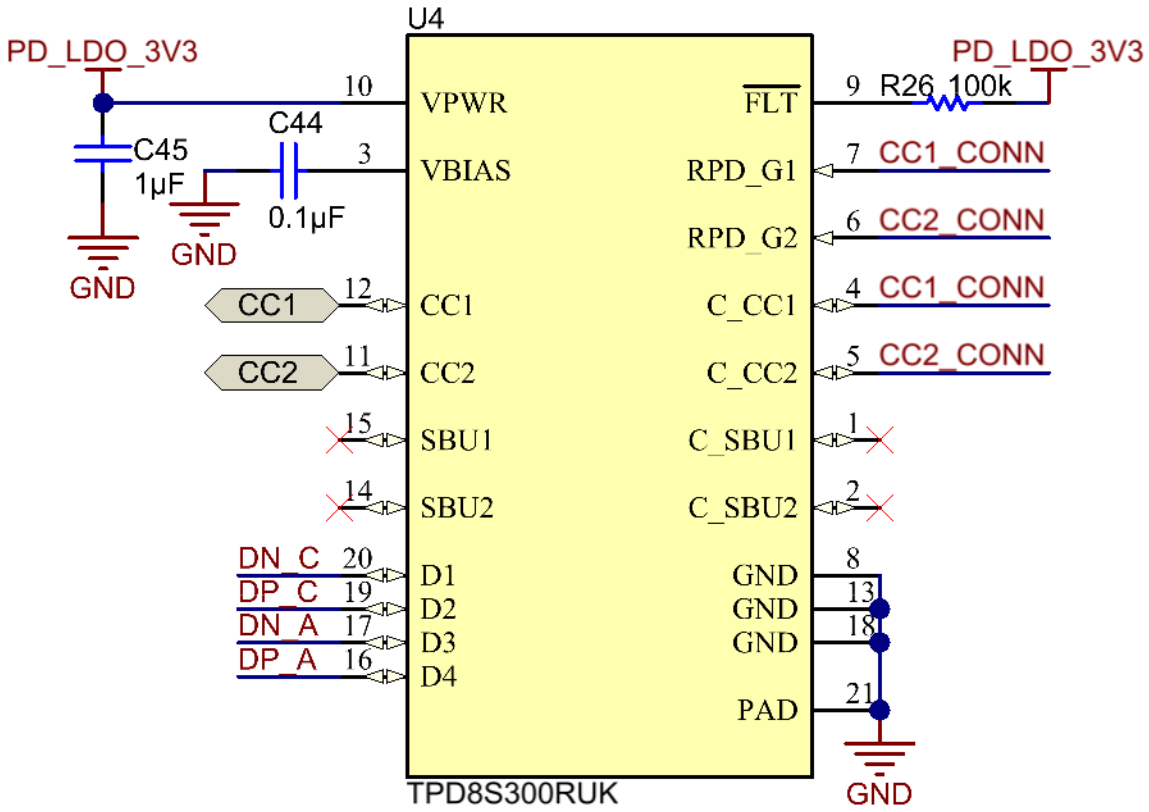


Figure 5. TPD8S300 Schematic

2.2.4 TPS563200 DC-DC Converter

The TPS563200 is an easy-to-use, synchronous step-down, DC-DC converter optimized for low standby current with minimum external components. A high switching frequency of typically 650 KHz allows the use of small inductors and provides fast transient response as well as high output voltage accuracy by using the D-CAP2™ mode control. In this reference design, this DC-DC converter functions to generate the 3.3-V rail to power up the TPS65987D device. If nothing is connected to the power bank, then the enable input goes low and everything shuts down. If any PD power sink is connected to the power bank, then this input remains high for as long as the device is connected.

3 System Powering Scheme

This power bank reference design features two different power modes: power source mode and power sink mode.

3.1 Power Source Mode

In this mode, the power bank works as a source and the device connected to it draws power. To start in this mode, the user must press the S1 switch and then ensure that the device is connected after the LED turn on. The user can release this switch after connecting the device, after which it will no longer respond to further presses. If the device comes up as a sink, then the TPS65987D device drives the “SRC_EVT” node high, which ensures that U3 remains turned on even after S1 is released by maintaining 3.3 V at the SYS_EN node. The TPS65987D device drives the SRC_EVT node low when it detects disconnection, which forces the SYS_EN node down after some time, after which U3 eventually turns off and leads to a system shutdown.

Figure 6 shows a schematic of the 3.3-V power scheme of the power bank.

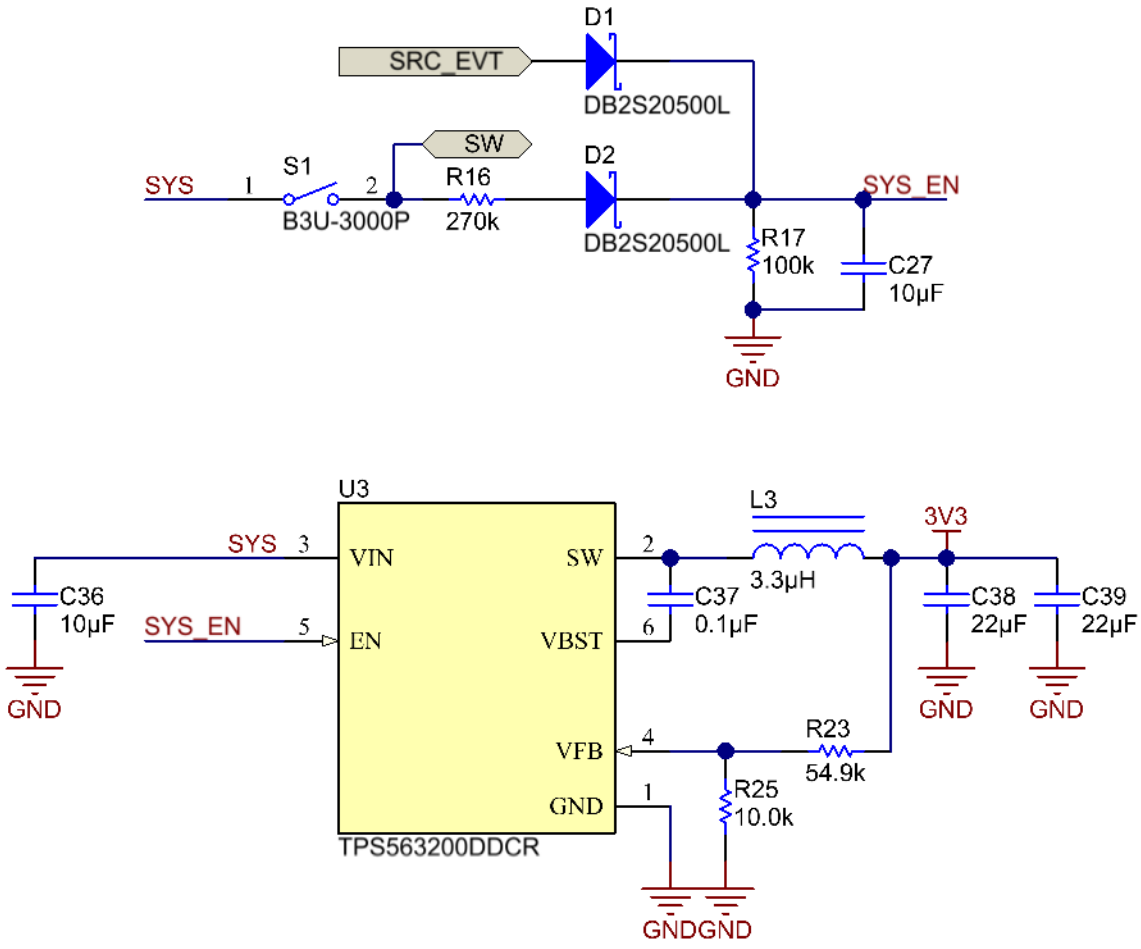


Figure 6. Schematic of 3.3-V Power Scheme of Power Bank

3.2 Power Sink Mode

Whenever the designer connects a PD source, this power bank begins charging in dead battery mode. The LED turn on automatically to indicate the charging status. Pressing the user switch S1 causes a power role swap and, if accepted by the connected device, causes the power bank to enter power source mode.

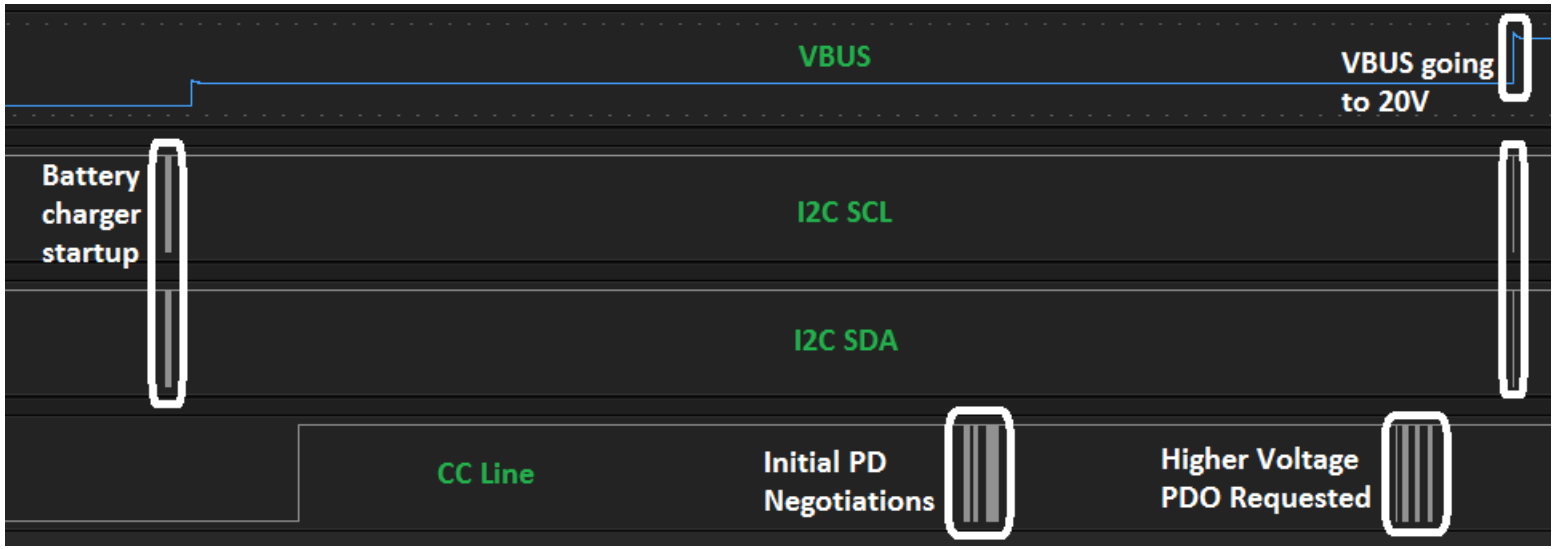
4 Test Data

The following subsections show the PD logs, which were taken during various use cases.

4.1 Power Bank When Charging Notebook

The power bank registers as a power source when the user presses the switch with the power bank connected to a notebook. The power bank sends its source power data object (PDO) and the notebook requests for the suitable PDO from the available options. From the given case in Figure 8, the power bank presents various PDOs, for which the notebook chooses a 20-V PDO.

Figure 7. !~Varios signals during negotiations



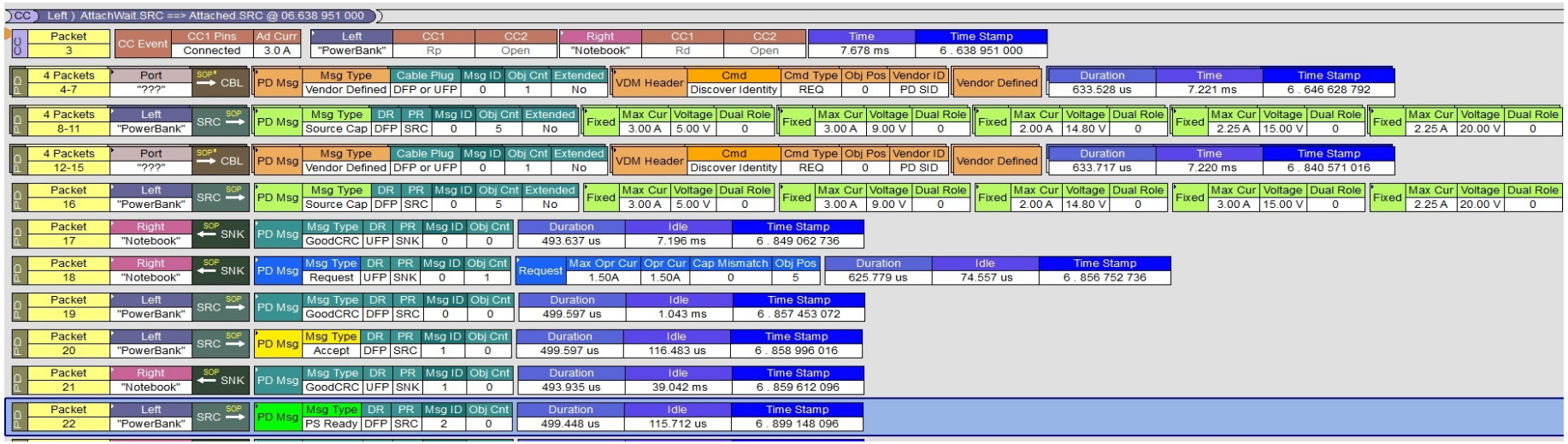


Figure 8. PD Log When Using Power Bank as Source

4.2 Power Swap Upon Switch Press

If the user connects the power bank to a notebook without pressing the switch, then the power bank registers as a sink and starts drawing power from the laptop. In this condition, the user can press the switch and perform a power role reversal to start charging the notebook. The following logs in Figure 9 show the power role sequence after pressing the switch.

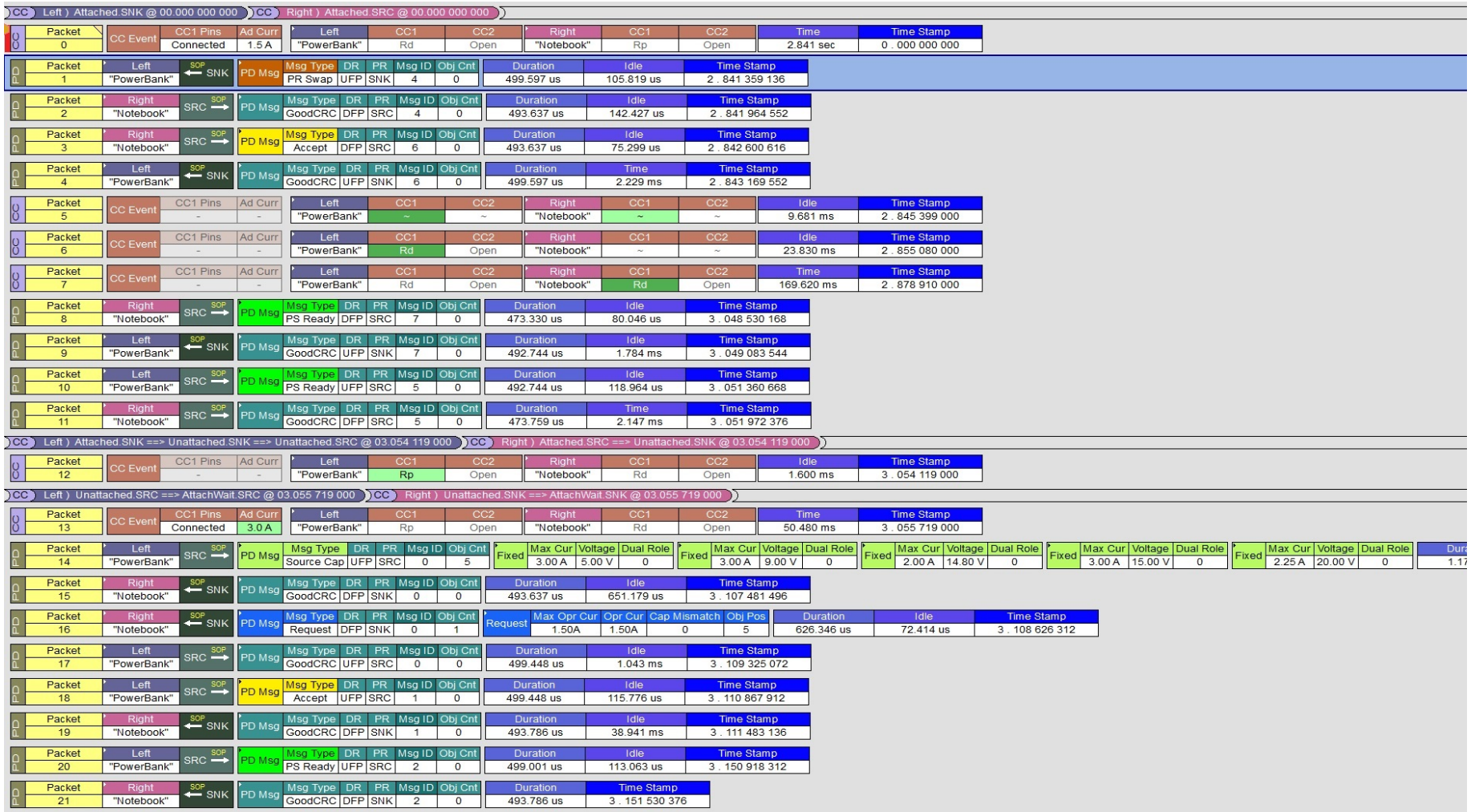


Figure 9. PD Log During Power Role Swap

4.3 Power Bank Charging From PD Power Adapter

The power bank registers as a PD sink and makes a PD contract when it is connected to a PD power adapter. The power bank picks up the right PDO from the available options and starts charging (see Figure 10).

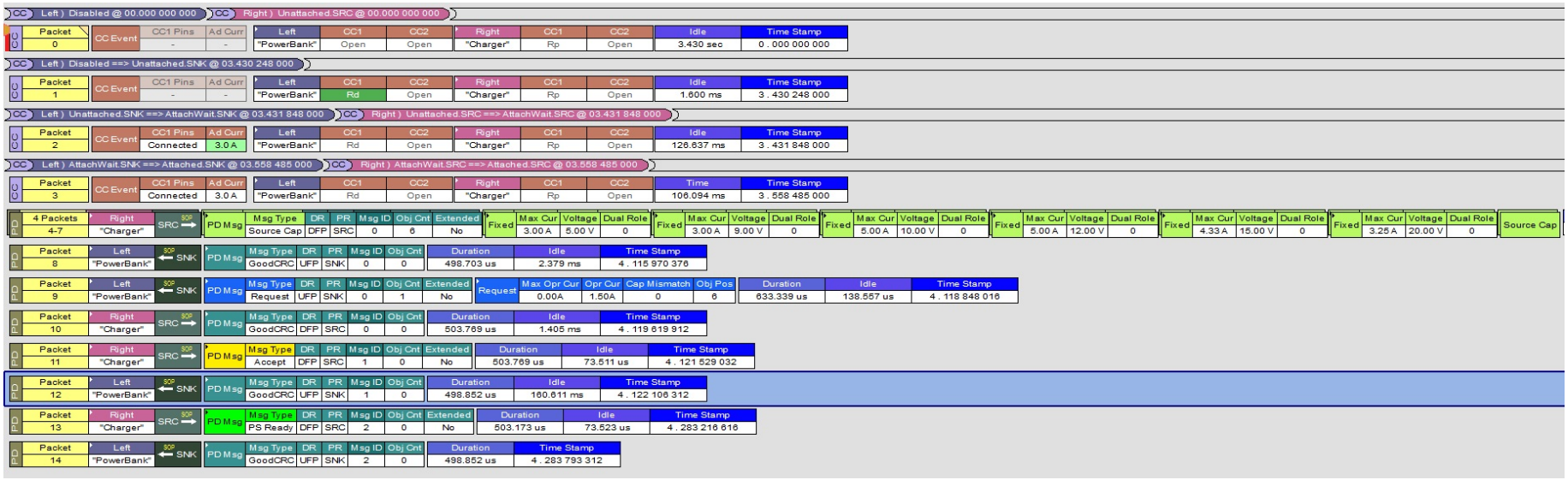


Figure 10. PD Log During Power Bank Charging

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01627.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01627.

5.3 Layout Prints

To download the layer plots, see the design files at TIDA-01627.

5.4 Gerber Files

To download the Ferber files, see the design files at TIDA-01627.

5.5 Assembly Drawing

To download the assembly drawings, see the design files at TIDA-01627.

6 Related Documentation

1. Texas Instruments, *bq25703A I2C Multi-Chemistry Battery Buck-Boost Charge Controller With System Power Monitor and Processor Hot Monitor Data Sheet*

6.1 Trademarks

7 Terminology

BOM— Bill of materials

ESD— Electrostatic discharge

FET— Field-effect transistor

LED— Light-emitting diode

NVDC— Narrow voltage DC

OTG— On-the-go

PD— Power delivery

PDO— Power data object

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (April 2018) to A Revision	Page
• Changed TPS65983B to TPS65987D throughout document	1
• Changed TPD6S300 to TPD8S300 throughout document	1
• Changed TPS62170 to TPS563200 throughout document	1
• Changed block diagram and board images	1
• Changed information in Section 2.2.1	4
• Changed Figure 2	4
• Changed Figure 3	5
• Changed Figure 5	7
• Changed information in Section 2.2.4	7

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