参考資料

デザイン・ガイド: TIDA-01515
デュアル・ポート USB Type-C™ 電力配信 (PD) パワー・バンクのリファレンス・デザイン

概要

USB Type-C™はフォーム・ファクタの小さいコンセント、プラグ、ケーブルの標準です。コネクタは反転可能で、ケーブルは逆にも接続できるため、ユーザーにとって使いやすい設計です。USB Type-C コネクタは既存の USB プロトコルと互換性があり、すべての Type-A および Type-B コネクタに置き換わることが期待されています。このパワー・バンクのリファレンス・デザインは、ノート PC を充電するための、高度に統合された USB Type-C 電力配信 (PD) を実現します。このデザインには 1 つの USB Type-C PD ポートが実装されており、接続されているデバイスの充電用のソース電力、およびパワー・バンクの充電用のシンク電力として使用できます。セカンダリ USB Type-A ポートはソース専用のポートで、BC1.2 アドバタイズメントが実装されています。

リソース

TIDA-01515	デザイン・フォルダ
TPS65988	プロダクト・フォルダ
BQ25703A	プロダクト・フォルダ
BQ4050	プロダクト・フォルダ
TPS563200	プロダクト・フォルダ
TLV70433	プロダクト・フォルダ
TPD6S300A	プロダクト・フォルダ

TI E2E™ Community

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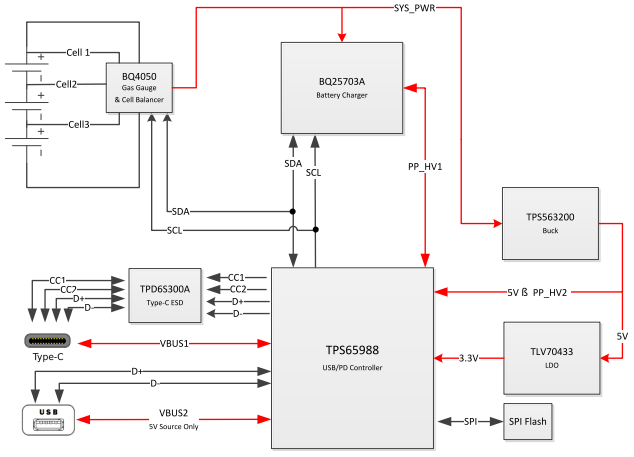
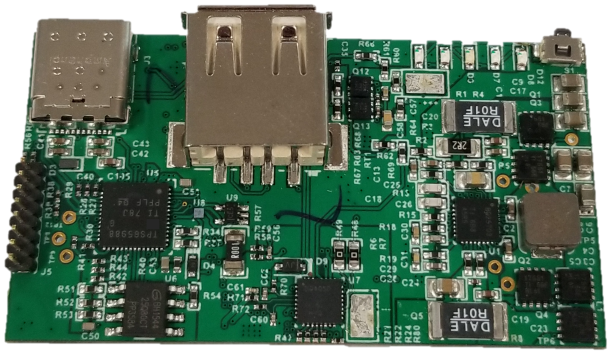
特長

- プライマリ USB Type-C ポート
  - 最大 20V / 2.25A の PD ソース (外部デバイスの充電)
  - 最大 20V / 2.25A の PD シンク (パワー・バンク内のバッテリの充電)
  - BC1.2 アドバタイズメントおよび検出
- セカンダリ USB Type-A ポート
  - 電力ソース 5V Type-A ポート
  - BC1.2 アドバタイズメント

アプリケーション

- ネットワーク接続の周辺機器とプリンタ
- コンシューマ向けバッテリ・チャージャ
- パワー・バンク





1 System Description

For some people, carrying multiple devices is a normal, if not necessary part of daily life. The average user's dependency on these devices 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 their devices while on the go. This reference design offers a power bank solution that can provide 45 W of power to charge a notebook or other portable electronics while away from traditional power sources. This reference design uses USB Type-C Power Delivery (PD) to enable high powered charging from a small form factor device. This design also features a legacy USB Type-A port to charge legacy devices using the BC1.2 protocol.

1.1 Key System Specifications

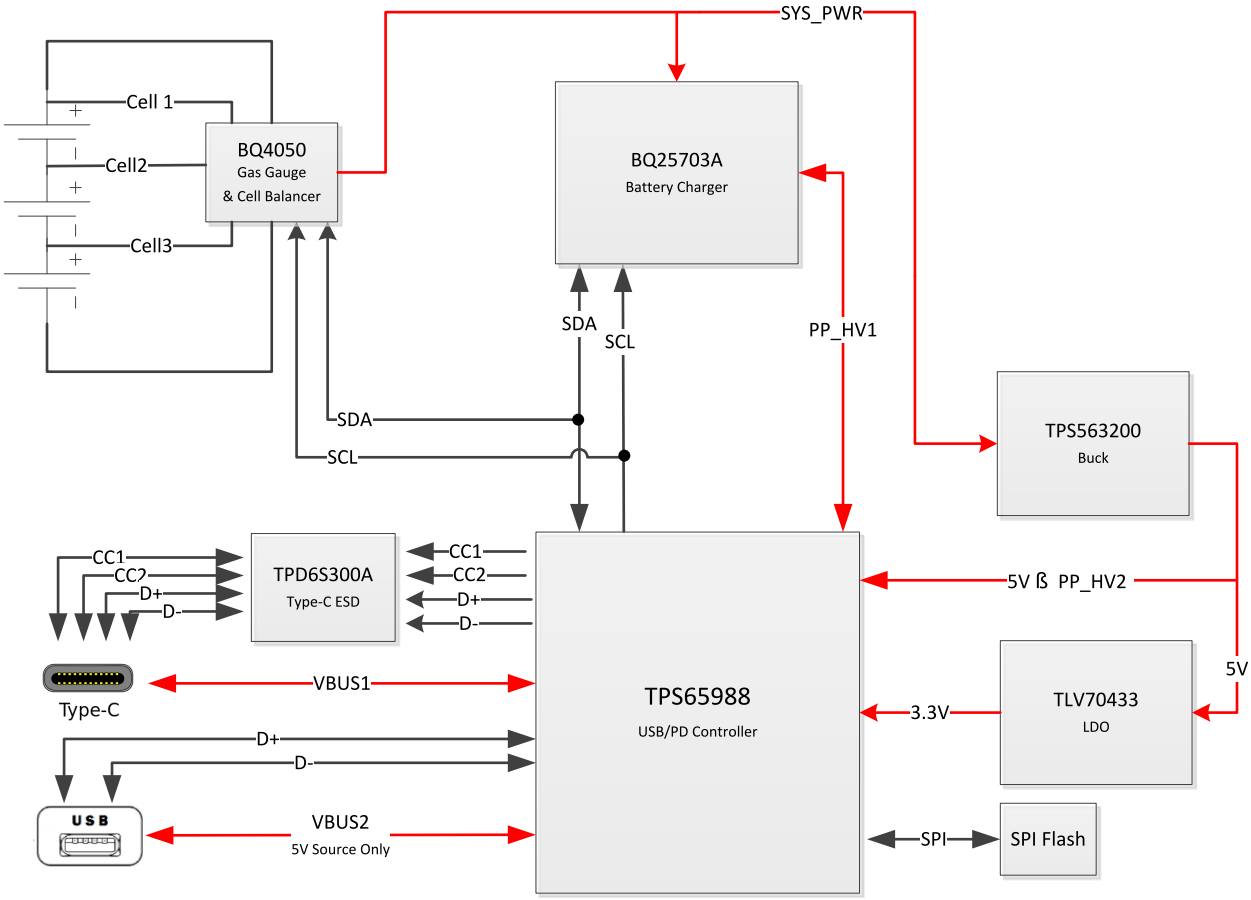
表 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Number of Batteries	Three Cells
Type of Batteries	Lithium-ion Cells
Minimum Output Voltage	5 V
Maximum Output Voltage (Type-C Port)	20 V
Maximum Output Power (Type-C Port)	45 W

2 System Overview

This reference design has been built around three key components: TPS65988, BQ25703A, and BQ4050. TPS65988 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. The BQ4050 is used for cell-balancing in the design to ensure that all three batteries remain at an equal voltage. TPD8S300 provides protection from electrostatic discharge (ESD) and VBUS to CC short.

2.1 Block Diagram



2.2 Design Considerations

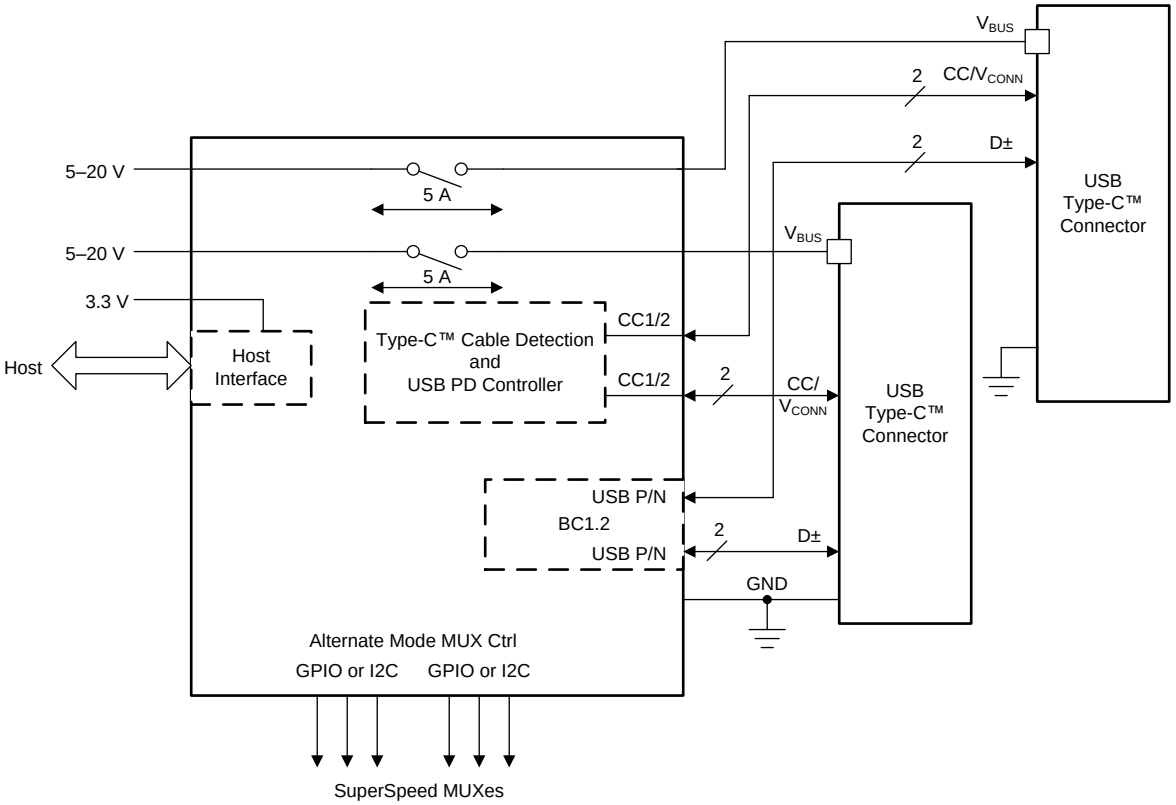
TIDA-01515 illustrates how to design a USB Type-C PD Power Bank featuring a Type-C PD port and a USB Type-A BC1.2 charging port. The design theory highlighted below can be referenced when designing other USB Type-C PD systems using the TPS65988.

2.3 Highlighted Products

2.3.1 TPS65988

The TPS65988 is a stand-alone USB Type-C and Power Delivery (PD) controller providing cable plug and orientation detection for two USB Type-C connectors. Upon cable detection, the TPS65988 communicates on the CC wire using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS65988 enables the appropriate power path and configures alternate mode settings for external multiplexers. The TPS65988 is fully configurable to fit in many different applications.

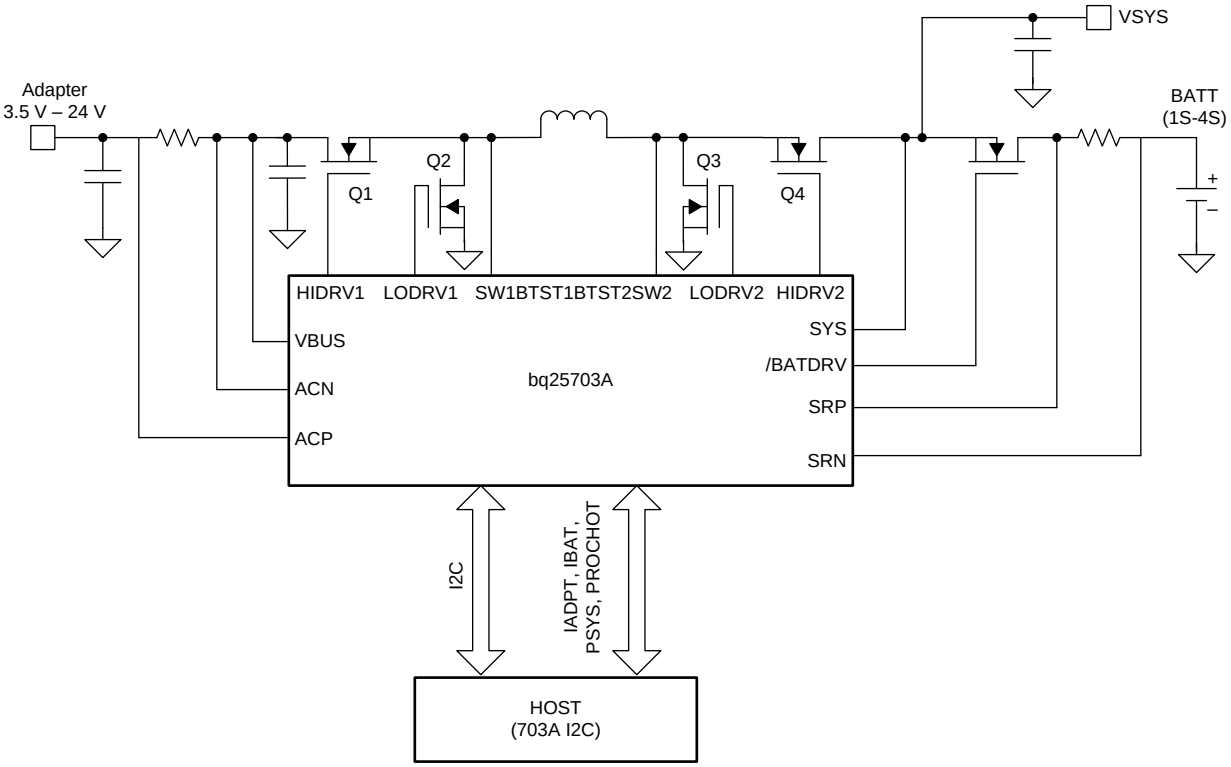
図 1. TPS65988 Simplified Schematic



2.3.2 BQ25703A

The bq25703A is a synchronous NVDC battery buckboost charge controller, offering low component count, high efficiency solution for space-constraint, multi-chemistry battery charging applications. The NVDC-1 configuration allows the system to be regulated at battery voltage, but not drop below system minimum voltage. The system keeps operating even when the battery is completely discharged or removed. When load power exceeds input source rating, the battery goes into supplement mode and prevents the system from crashing. The bq25703A charges battery from a wide range of input sources including USB adapter, high voltage USB PD sources and traditional adapters.

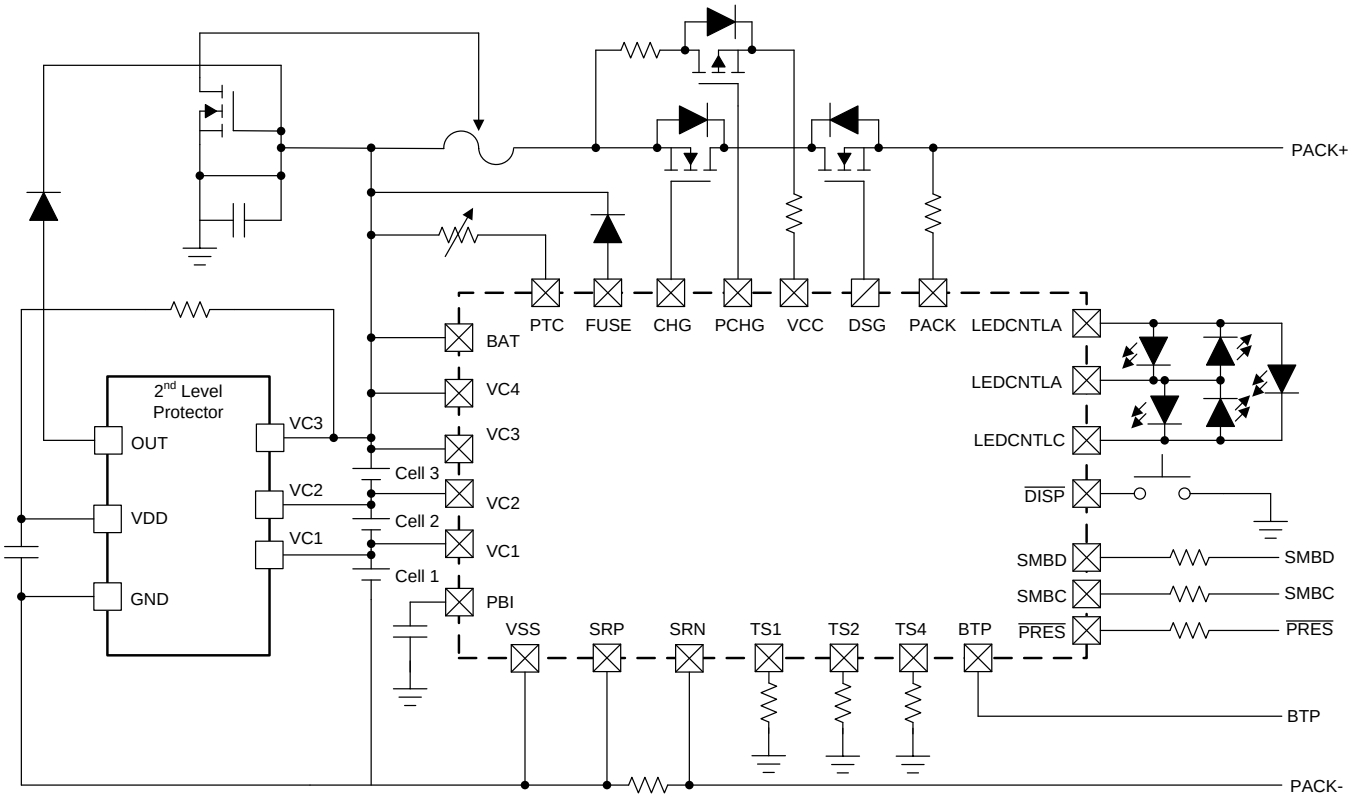
図 2. BQ25703A Application Diagram



2.3.3 BQ4050

The bq4050 device, incorporating Compensated End-of-Discharge Voltage (CEDV) technology, is a highly integrated, accurate, 1-series to 4-series cell-gas gauge and protection solution, that enables autonomous charger control and cell balancing. The bq4050 device provides a fully integrated pack-based solution with a flash programmable custom reduced instruction-set CPU (RISC), safety protection, and authentication for Li-Ion and LiPolymer battery packs. The bq4050 gas gauge communicates through an SMBus compatible interface and combines an ultra-low power, high-speed TI bqBMP processor, high-accuracy analog measurement capabilities, integrated flash memory, an array of peripheral and communication ports, a N-CH FET drive, and a SHA-1 Authentication transform responder into a complete, high-performance battery management solution.

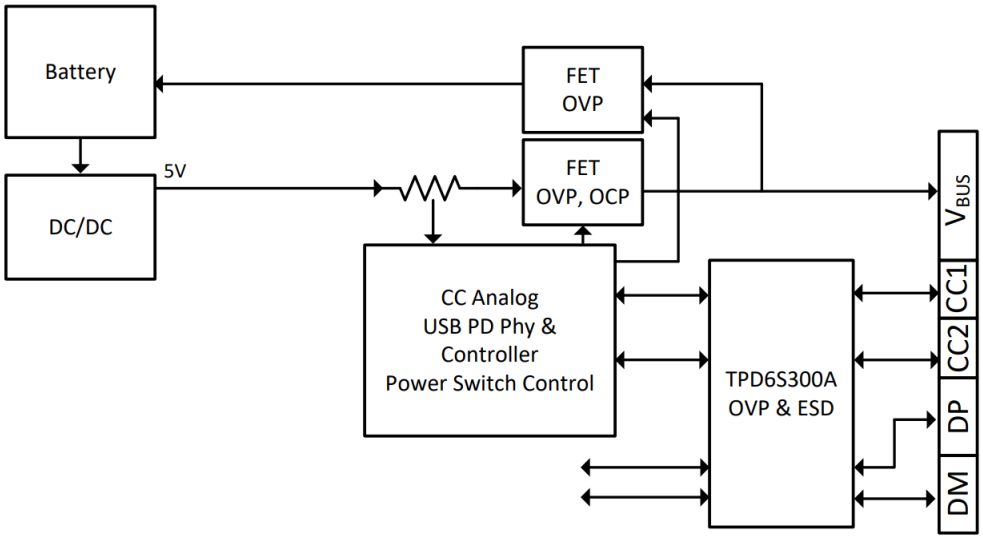
図 3. BQ4050 Simplified Schematic



2.3.4 TPD6S300A

The TPD6S300A is a single-chip USB Type-C port protection device that provides 20-V Short-to-VBUS overvoltage and IEC ESD protection. Since the release of the USB Type-C connector, many products and accessories for USB Type-C have been released that do not meet the USB Type-C specification. One example of this is USB Type-C Power Delivery adaptors that only place 20 V on the VBUS line. Another concern for USB Type-C is that mechanical twisting and sliding of the connector could short pins due to the close proximity they have in this small connector. This can cause 20-V VBUS to be shorted to the CC and SBU pins. Also due to the proximity of the pins in the Type-C connector, there is a heightened concern that debris and moisture will cause the 20-V VBUS pin to be shorted to the CC and SBU pins. These non-ideal equipments and mechanical events make it necessary for the CC and SBU pins to be 20-V tolerant, even though the pins only operate at 5 V or lower. The TPD6S300A enables the CC and SBU pins to be 20-V tolerant without interfering with normal operation by providing overvoltage protection on the CC and SBU pins. The device places high voltage FETs in series on the SBU and CC lines. When a voltage above the OVP threshold is detected on these lines, the high voltage switches are opened up, isolating the rest of the system from the high voltage condition present on the connector. Finally, most systems require IEC 61000-4-2 system level ESD protection for external pins. The TPD6S300A integrates IEC 61000-4-2 ESD protection for the CC1, CC2, SBU1, SBU2, DP, and DM pins, eliminating the need to place high voltage TVS diodes externally on the connector.

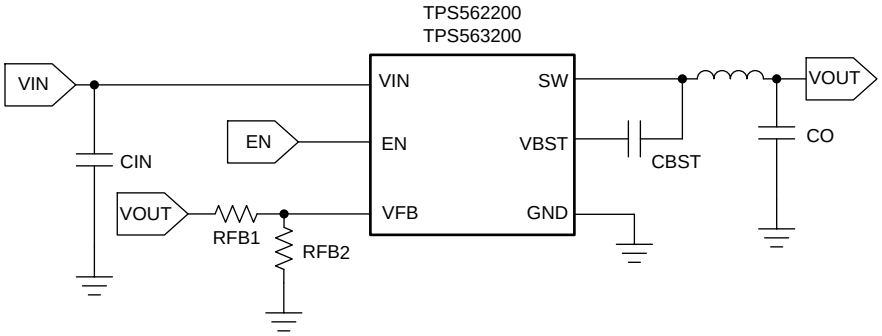
図 4. TPD8S300 Application Diagram



2.3.5 TPS563200

The TPS562200 and TPS563200 are simple, easy-to-use, 2 A and 3 A synchronous step-down (buck) converters in 6-pin SOT-23 package. The devices are optimized to operate with minimum external component counts and also optimized to achieve low-standby current. These switch mode power supply (SMPS) devices employ D-CAP2 mode control providing a fast transient response and supporting both low equivalent series resistance (ESR) output capacitors such as specialty polymer and ultra-low ESR ceramic capacitors with no external compensation components. TPS562200 and TPS563200 operate in Advanced Eco-mode, which maintains high efficiency during light load operation. The devices are available in a 6-pin 1.6mm x 2.9mm SOT (DDC) package, and specified from –40°C to 85°C of ambient temperature.

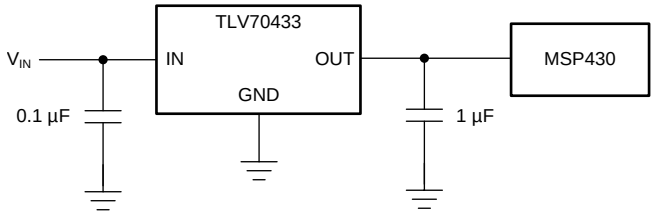
図 5. TPS563200 Simplified Schematic



2.3.6 TLV70433

The TLV704 series of low-dropout (LDO) regulators are ultra low quiescent current devices designed for extremely power-sensitive applications. Quiescent current is virtually constant over the complete load current and ambient temperature range. These devices are an ideal power-management attachment to low-power micro controllers, such as the MSP430. The TLV704 operates over a wide operating input voltage of 2.5 V to 24 V. Thus, the device is an excellent choice for both battery-powered systems as well as industrial applications that undergo large line transients. The TLV704 is available in a 3-mm × 3-mm SOT23-5 package, which is ideal for cost-effective board manufacturing.

図 6. TLV70433 Typical Application



3 System Design Theory

3.1 TPS65988 PD Controller Sub System

The TPS65988 is the main chip that controls most of the circuitry in the TIDA-01515 design. The TPS65988 primarily controls all of the PD negotiation for the USB Type-C port. It allows the Power Bank to source up to 20 V at 2.25 A and also sink up to 20 V. The TPS65988 uses one of the its internal power paths for the USB Type-C power. The power path for the Type-C port is used bidirectionally so that the TIDA-01515 can both source and sink power using the same power path. This is enabled from a system perspective through the BQ25703A buck-boost charger IC. The TPS65988 is the I^2C master to the BQ25703A and is able to write to the BQ25703A to adjust the charge voltage/current and also to adjust the output voltage/current when the TPS65988 needs to be a source on the USB Type-C port. The TPS65988 is also used for BC1.2 detection and advertisement on the USB Type-C port when legacy devices are connected. The TPS65988 uses its second power path for a source only implementation to source 5V on the USB Type-A port. Additionally, BC1.2 advertisement is enabled on the USB Type-A port through the TPS65988.

The TPS563200 and TLV70433 are not enabled until the button on the Power Bank is pushed. Once the button is pushed, the TPS65988 keeps the supply enabled when a source contract is enabled by enabling the Source Event GPIO in configuration. When the Type-C cable is removed and the TPS65988 no longer needs to source power, the TPS563200 and TLV70433 are both disabled and the Power Bank consumes less power. When a PD adapter is connected to the Type-C port, the button does not need to be pushed to charge the power bank. Instead, the TPS65988 will boot in dead battery mode and enable the sink switch. it also enables the BQ25703A to enable charging of the batteries.

図 7. TPS65988 Signals Schematic

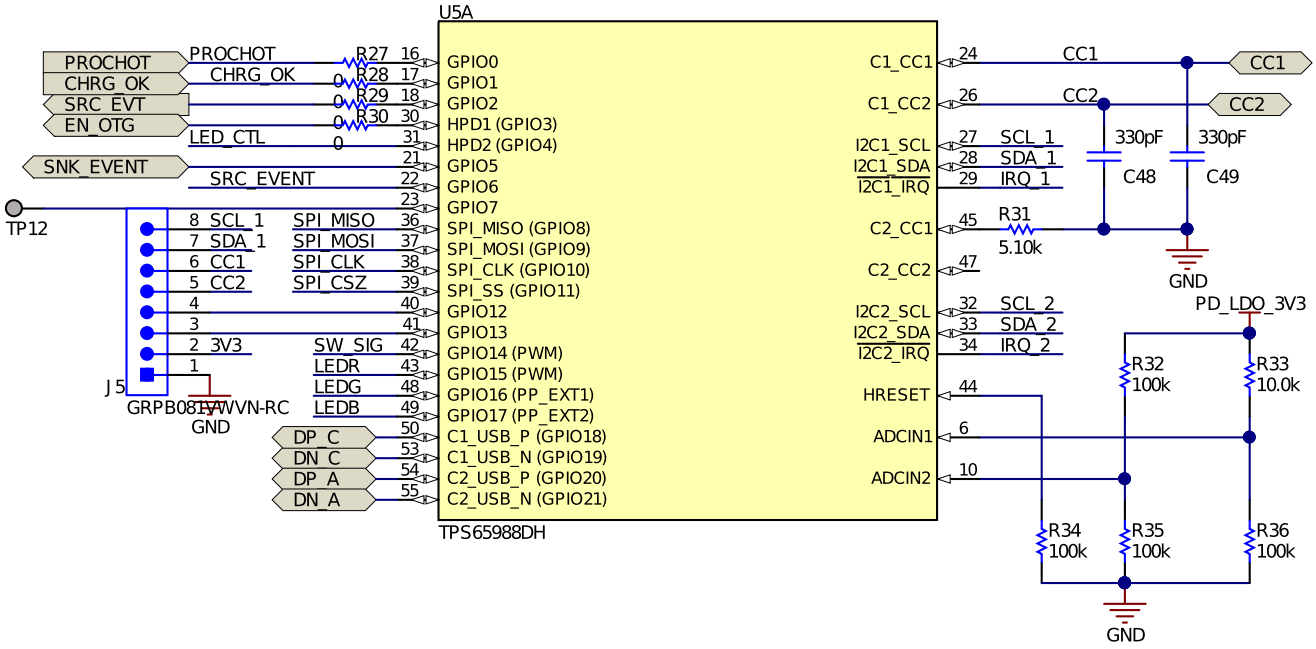
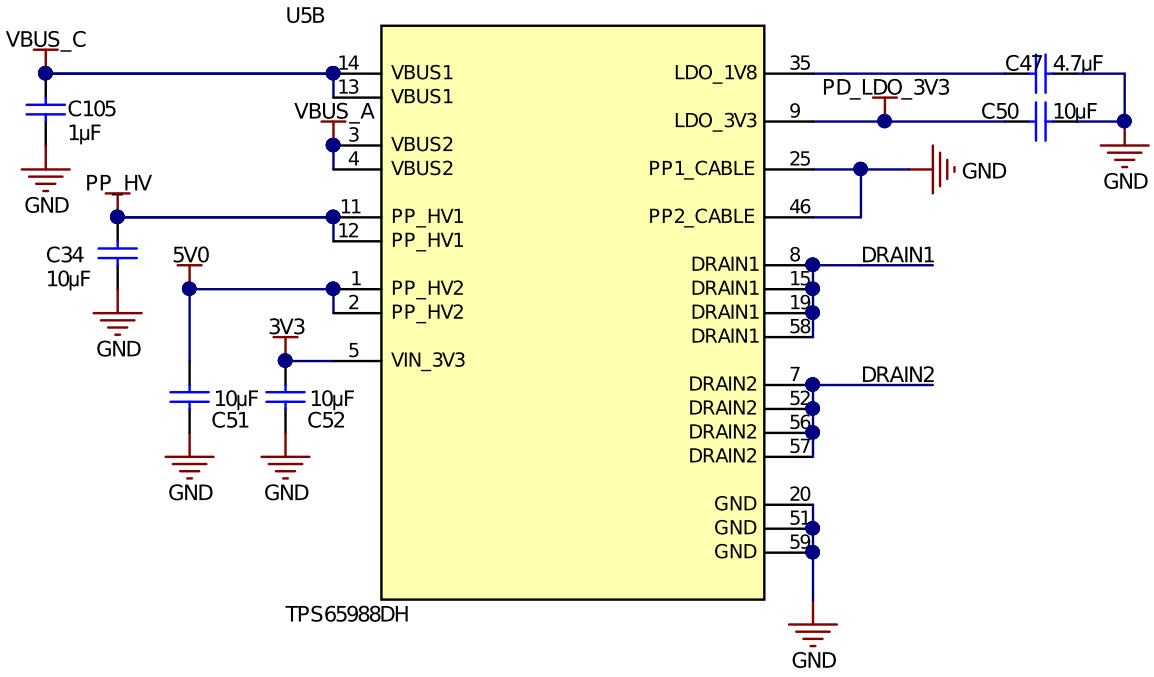


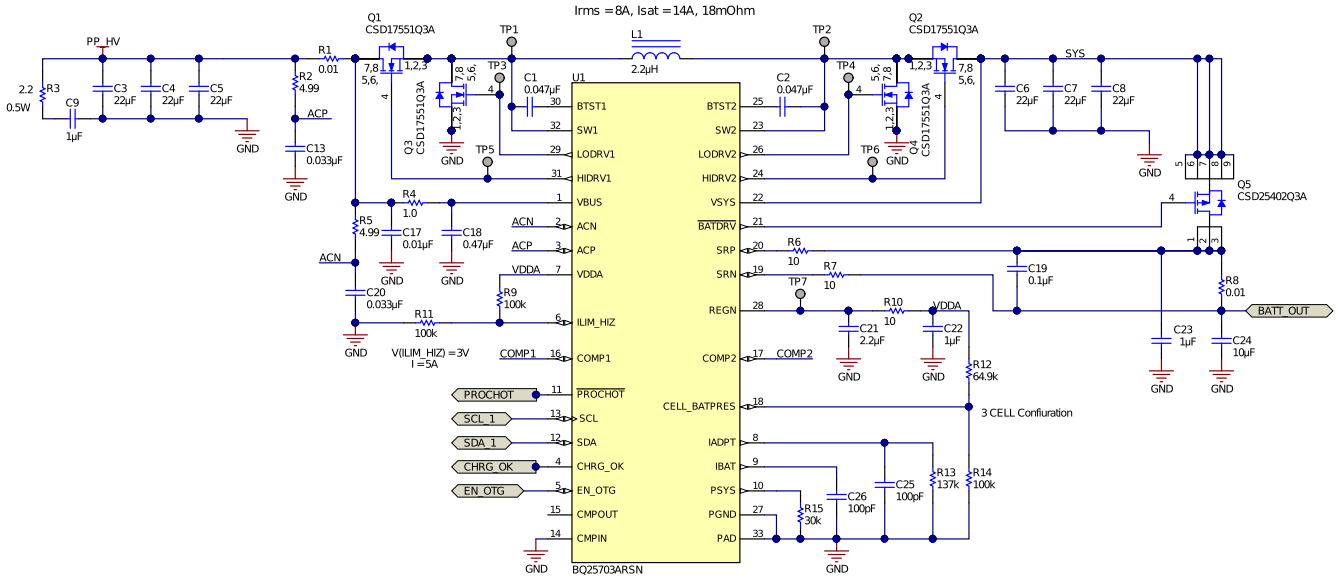
図 8. TPS65988 Power Lines Schematic



3.2 BQ25703A Bi-directional Buck-Boost Charger Sub System

The BQ25703A handles the battery charging and also generates the USB Type-C voltage from the battery voltage. When a Type-C PD connection is made, the TPS65988 sends I²C writes to the BQ25703A to tell it to either generate a source voltage or enable the charging function to charge the batteries in the power bank.

図 9. BQ25703A Schematic

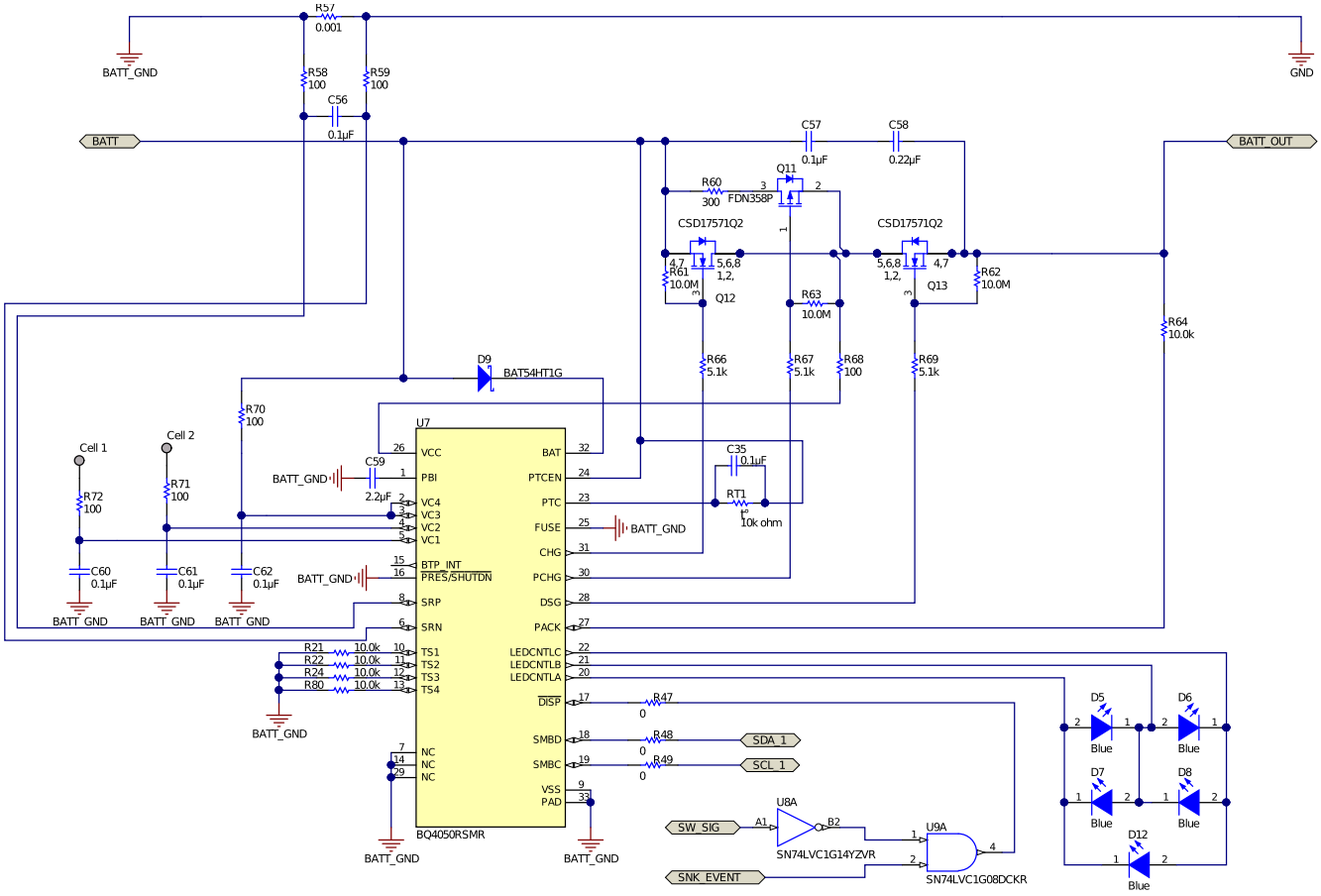


3.3 BQ4050

The BQ4050 is used as the gas gauge in this reference design. When the button is pressed on the power bank, the user can tell the charge of the battery through the amount of LEDs that are on. The Charge on the LEDs are shown when either the button is pressed, or the USB Type-C port is sinking power. The BQ4050 is also used for cell balancing. Since this power bank design features three batteries in a series, it is important to ensure that each cell is at the same voltage. The BQ4050 handles this aspect of the design.

The TPS65988 is also the I^2C master for the BQ4050 in this design and ensures that it is correctly initialized and configured by sending I^2C commands on boot-up.

図 10. BQ4050 Schematic



3.4 System Powering Scheme

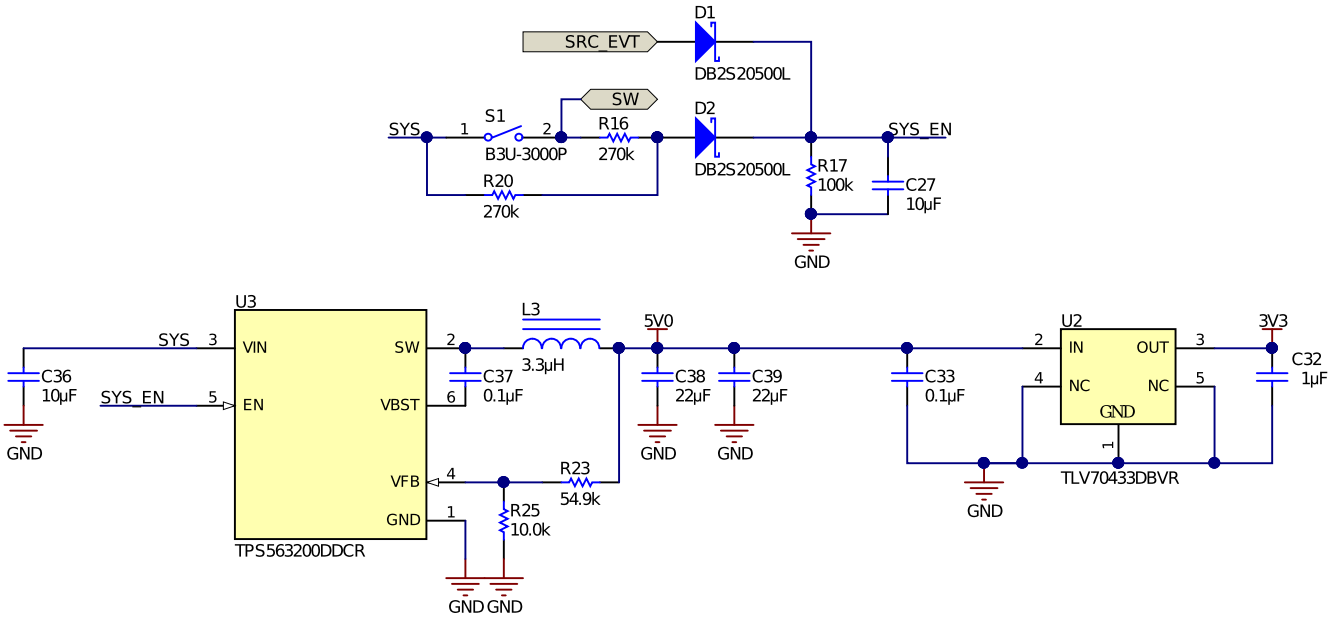
This power bank reference design features two different power modes: power source mode and power sink mode.

3.4.1 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, then it no longer responds to additional 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.

図 11 shows a schematic of the 3.3-V power scheme of the power bank.

図 11. Schematic of 3.3-V Power of Power Bank



3.4.2 Power Sink Mode

Whenever the user connects a PD source, this power bank begins charging in dead battery mode. The LED turns 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 Connecting a PD Adapter

The Power Bank would become the power sink when a PD adapter is connected. This is done so that the batteries inside the power bank can be charged. When a PD adapter is connected, there will be a 20-V contract active on VBUS. After the 20-V contract is active, the TPS65988 will send I^2C messages to the BQ25703A to enable the charging algorithm in the battery charger IC.

図 12. Various Signals During PD Adapter Connect and Disconnect

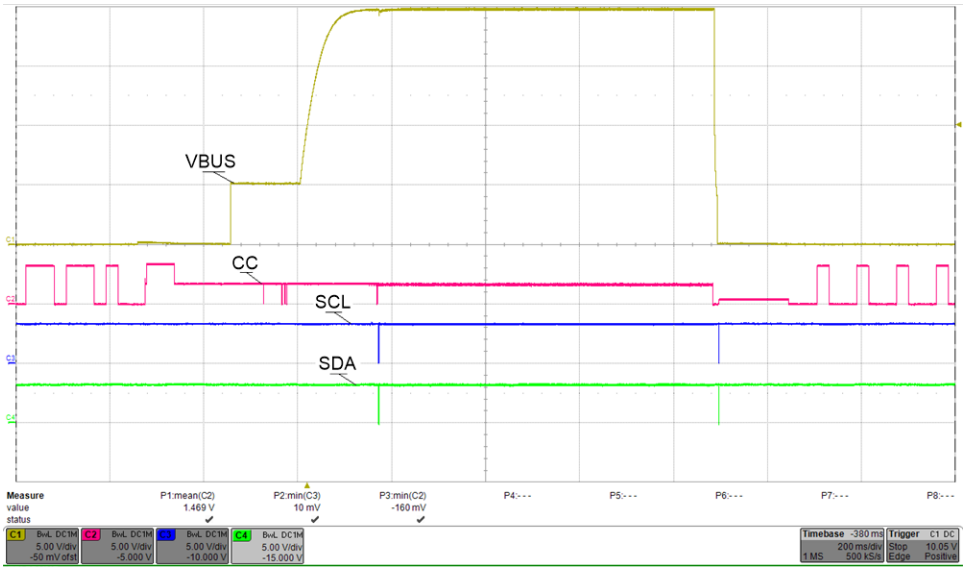


図 12 highlights the CC communication and VBUS voltage when a 20-V PD adapter is connected. It can be seen that PD negotiation takes place and VBUS rises to 20-V. The last PD message seen on the CC line when VBUS is at 20-V is a "PS Ready" message. This is a message sent by the PD adapter to indicate to the sink that the power supply is at the correct negotiated voltage and ready to supply current. Directly after this message is sent, I^2C messages are sent from the TPS65988 to the BQ25703A to enable the charger.

The PD adapter is disconnected at the end of the capture in 図 12. It can be seen that VBUS drops to 0 V and some I^2C messages are sent from the TPS65988 to the BQ25703A to disable the charger.

4.2 Power Bank When Charging a 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 図 13, the power bank presents various PDOs, for which the notebook chooses a 20-V PDO.

図 13. Power Bank as a Source

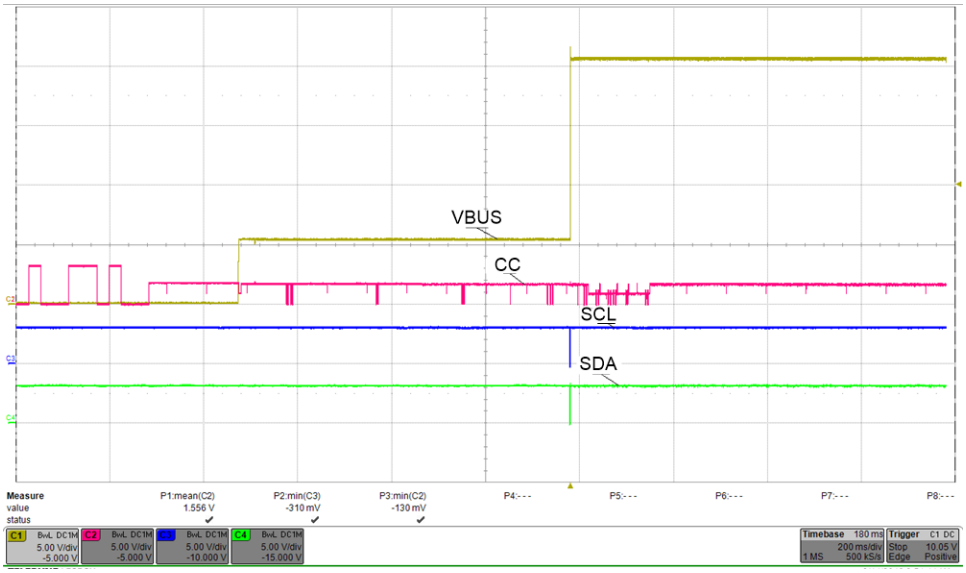
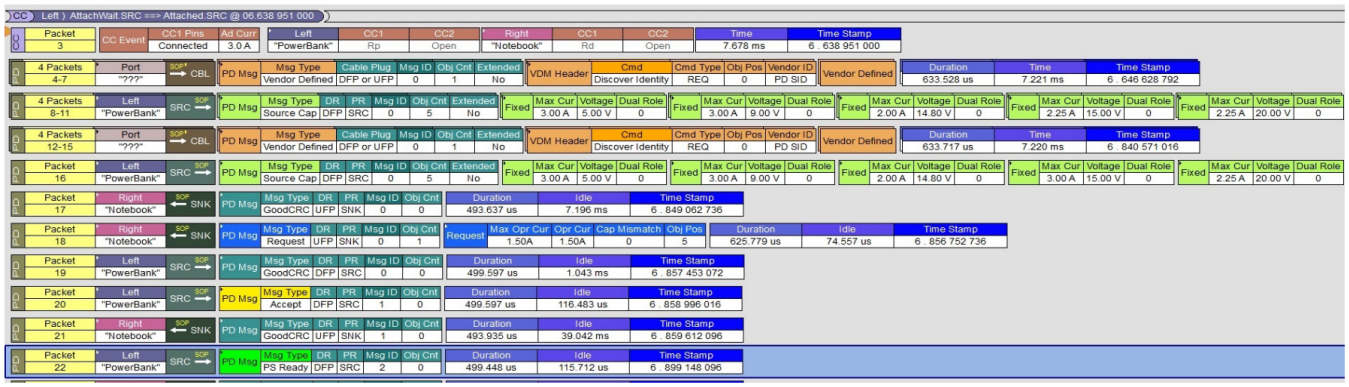


図 14. PD Log When Using Power Bank as a Source



4.3 Power Bank Charging a Cell Phone on Type-A port

The second port of the TPS65988 is used to control a Type-A port. In hardware, the second set of CC lines are terminated with an Rd on both to emulate a connection to the TPS65988. When a cell phone is connected to the Type-A port of the power bank, the power bank will advertise BC1.2 DCP capabilities on the USB Type-A port. When the BC1.2 detection is complete, the phone begins charging.

図 15. Power Bank BC1.2 Advertisement on USB Type-A Port

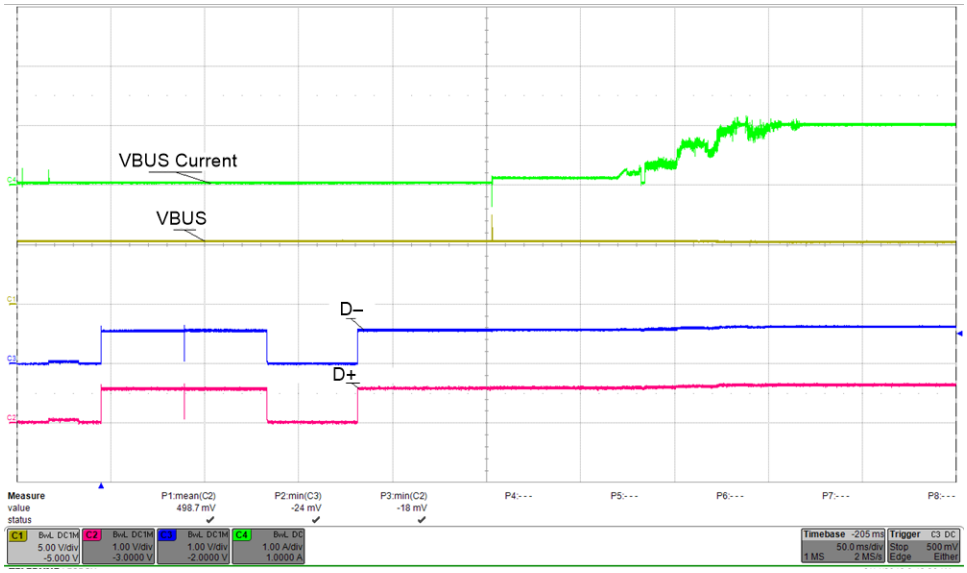
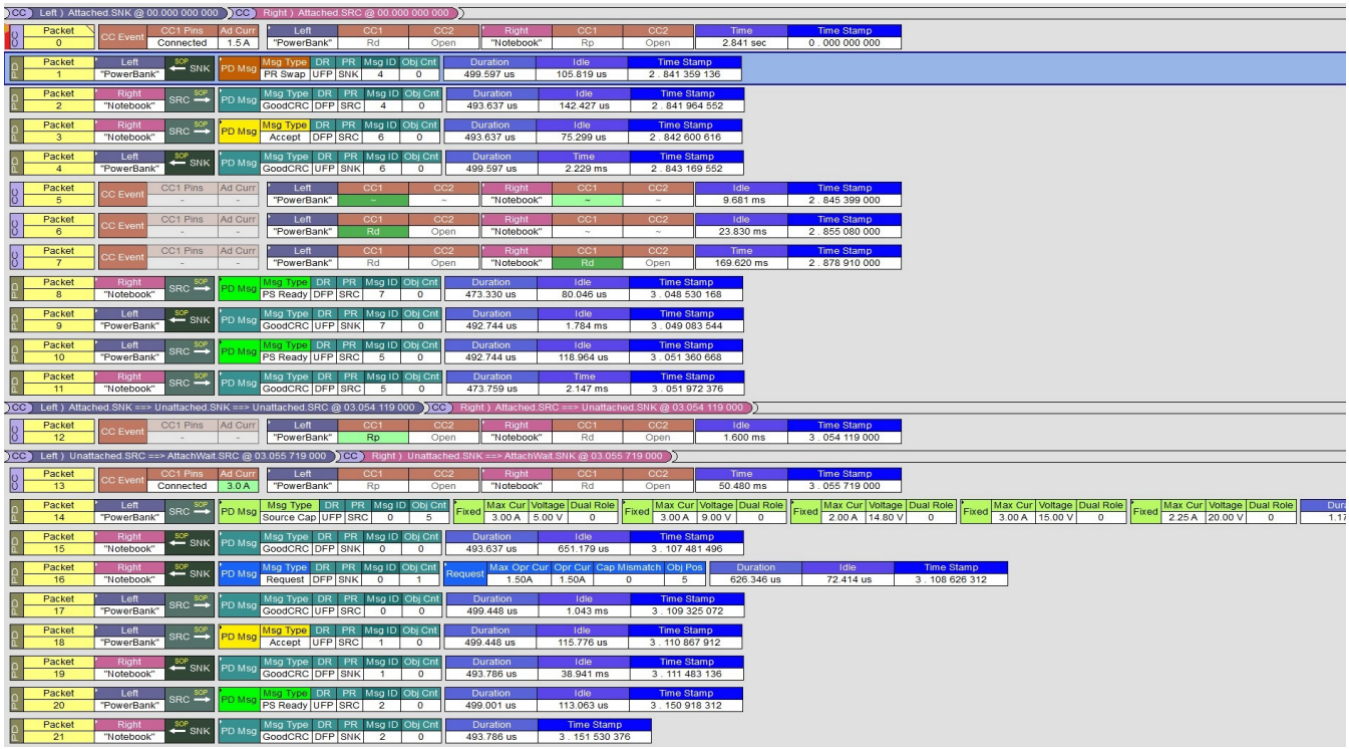


図 15 highlights the D+/D- USB2.0 lines during BC1.2 negotiation. The BC1.2 DCP negotiation is completed on the D+/D- lines. When this is complete, the cell phone enables its charger and current is then pulled from VBUS.

4.4 Power Role Swap to Source Upon Switch Press

If the user connects the power bank to a notebook without pressing the switch, 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 swap to start charging the notebook. The following logs in 図 16 show the power role sequence after pressing the switch.

図 16. PD Log During Power Role Swap



5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01515.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01515.

5.3 PCB Layout Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01515.

5.4 Altium Project

To download the Altium project files, see the design files at TIDA-01515.

5.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01515.

5.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01515.

6 Software Files

To download the software files, see the design files at TIDA-01515.

7 Related Documentation

1. Texas Instruments, *TPS65987DDH Power Path Performance and Protection*.
2. Texas Instruments, *USB Type-C™ PD Power Bank Reference Design*.

7.1 商標

7.2 Third-Party Products Disclaimer

8 About the Author

Eric Beljaars is an Applications Engineer for Texas Instruments where he is responsible for supporting USB Type-C and PD controllers. Eric earned his bachelor of science in electrical engineering (BSEE) from The University of Oklahoma in Norman, OK.

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