Design Guide: TIDA-050047

Integrated USB Type-C PD and Charging Reference Design for 2-4 Cell Batteries

TEXAS INSTRUMENTS

Description

The Integrated USB Type-C® PD and Charging Reference Design for 2-4 Cell Batteries is a 2 in 1, USB Type-C and PD controller along with a battery charging system. This reference design can support charging 2S to 4S batteries through a USB Type-C port, in addition to the standard Type-C communication, Power Delivery negotiations, power role swaps, and data role swaps. This board features charging up to 20 V at 5 A, without the need for any external FETs enabling a much smaller design size, reducing total BOM cost, and so on. In addition, an external microprocessor is not necessary as the USB-PD Controller can handle the I^2C communication to the battery charger IC. As a result, there is no need for any Firmware development work and the design greatly reduces the total time needed to market.

Resources

TIDA-050047	Design Folder
TPS25750, BQ25792	Product Folder
TPS54531, TLV755P	Product Folder
TVS2200	Product Folder

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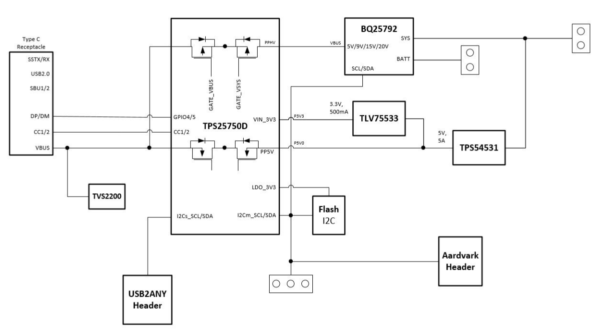
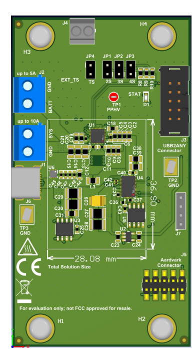
Features

- Configurable as Source-Sink or Sink-Only power roles
- Configuration Options Selected through Binary Vending Machine GUI
- Comprehensive Power Path Management and Protection
- Supports Charging of a 2S-4S Battery
- Seamless Transition Among Buck, Buck-boost and Boost Functionality
- OTG Mode Support in Source Mode

Applications

- Battery Pack: Cordless Power Tool
- Retail Automation and Payment
- Wirless Speakers
- Headsets, Headphones, and Earbuds
- Portable Electronics
- Industrial Applications





1 System Description

The Integrated USB Type-C PD and Charging reference design is a USB Type-C and PD controller system along with a battery charging system capable of 100W sinking and up to 45W sourcing. This reference design can support charging 2s to 4s batteries via a USB Type-C port, in addition to Type-C communication and Power Delivery negotiations.

This board features charging up to 20 V at 5 A, without the need for any external FETs. Furthermore, an external microprocessor is also not necessary as the USB-PD Controller will handle the I^2C communications to the battery charger IC to configure the appropriate functionality. Some examples include setting the charging voltage, charging current and configuring it for OTG Mode.

1.1 Key System Specifications

Table 1-1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Sink Capabilities	5 V - 20 V	VBUS from Type-C Input
Source Capabilities	5 V - 20 V	Output from BQ25792
Cell Configurations	2 cell - 4 cell	Battery Cell Number
Charge Current	Up to 5A	Battery Charging Current
OTG Capability	Up to 45W	Sourcing Power From Battery

2 System Overview

2.1 Block Diagram

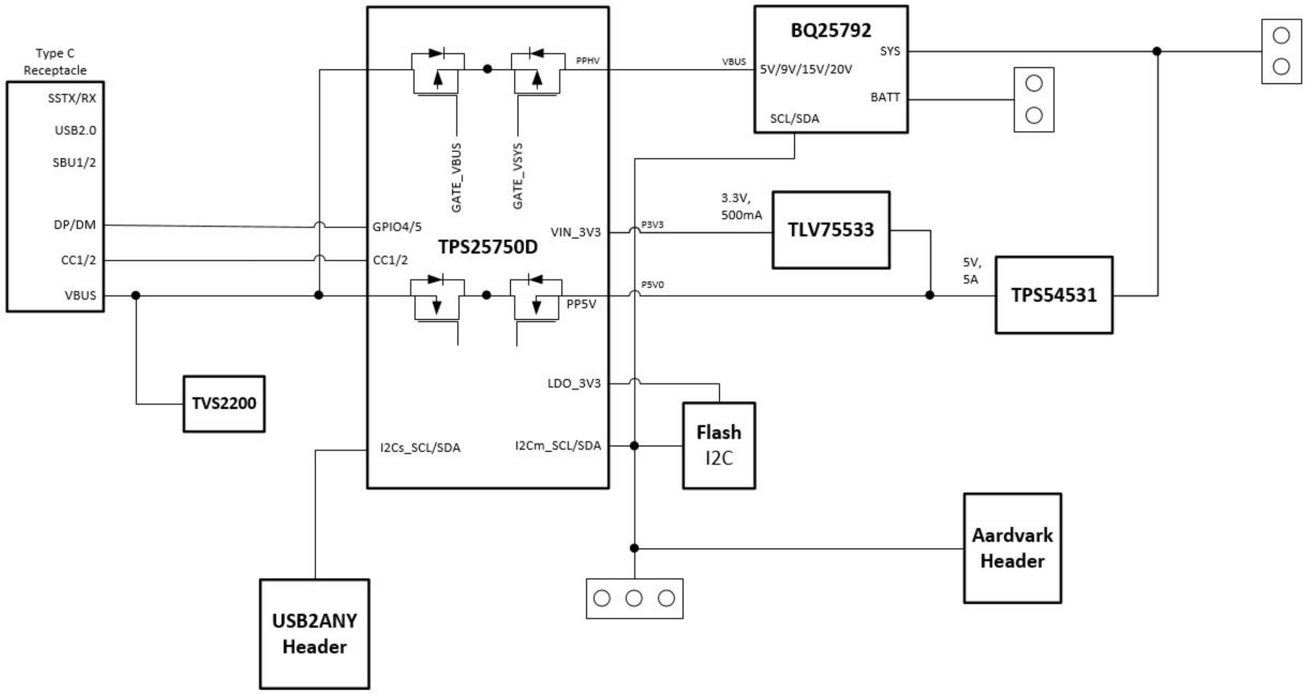


Figure 2-1. TIDA-050047 Block Diagram

2.2 Design Considerations

TIDA-050047 shows an example of how to implement a USB Type-C PD system alongside a switching battery charger that is capable of handling high power and current. This design can be used in power tools, power banks, and any various other personal electronic systems. This design could assist different functions from the ability to charge a battery, as well as, providing power to the system or switching to OTG mode to source power to the connected device all through the Type-C connector.

2.3 Highlighted Products

TPS25750D

The TPS25750D is a stand-alone USB Type-C and Power Delivery (PD) controller providing cable plug and orientation detection for a single USB Type-C connector. Upon cable detection, the TPS25750D communicates on the CC wire using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS25750D enables the appropriate power path for sourcing or sinking power depending on the contract negotiation and configuration.

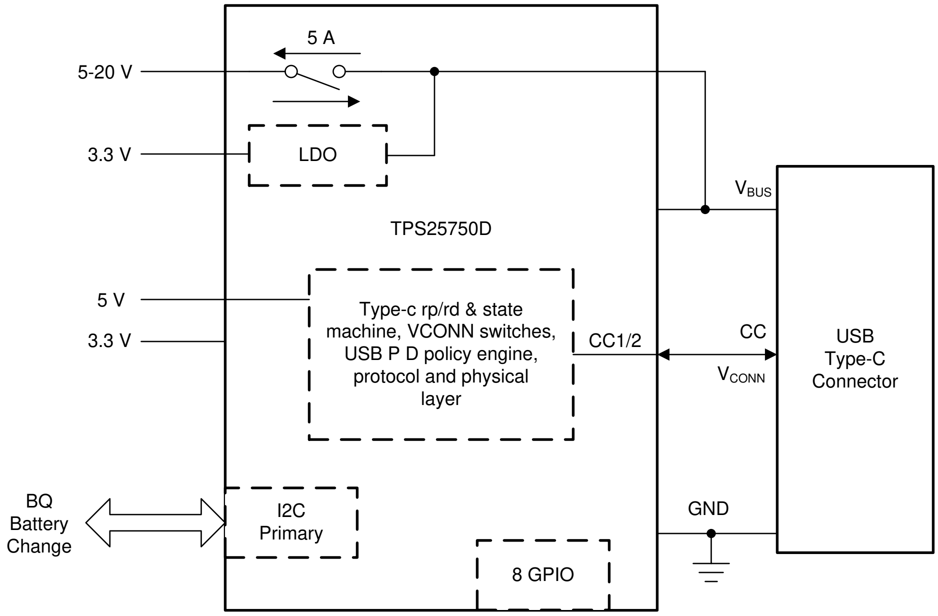


Figure 2-2. TPS25750D Typical Application Circuit

BQ25792

The BQ25792 is an integrated switched-mode buck-boost battery charge management device intended for 1- to 4-series cell Li-ion and Li-polymer batteries. The charger features a narrow VDC architecture (NVDC) which allows the system to be regulated to a minimum value even if the battery is completely discharged. Additionally, the BQ25792 supports input source detection through D+ and D- which is compatible with USB2.0, USB3.0 power delivery, non-standard adapters, and high voltage adapters. With dual input source selection, USB OTG support, and an integrated 16-bit multi-channel analog-to-digital converter (ADC), the BQ25790 is a complete charging solution.

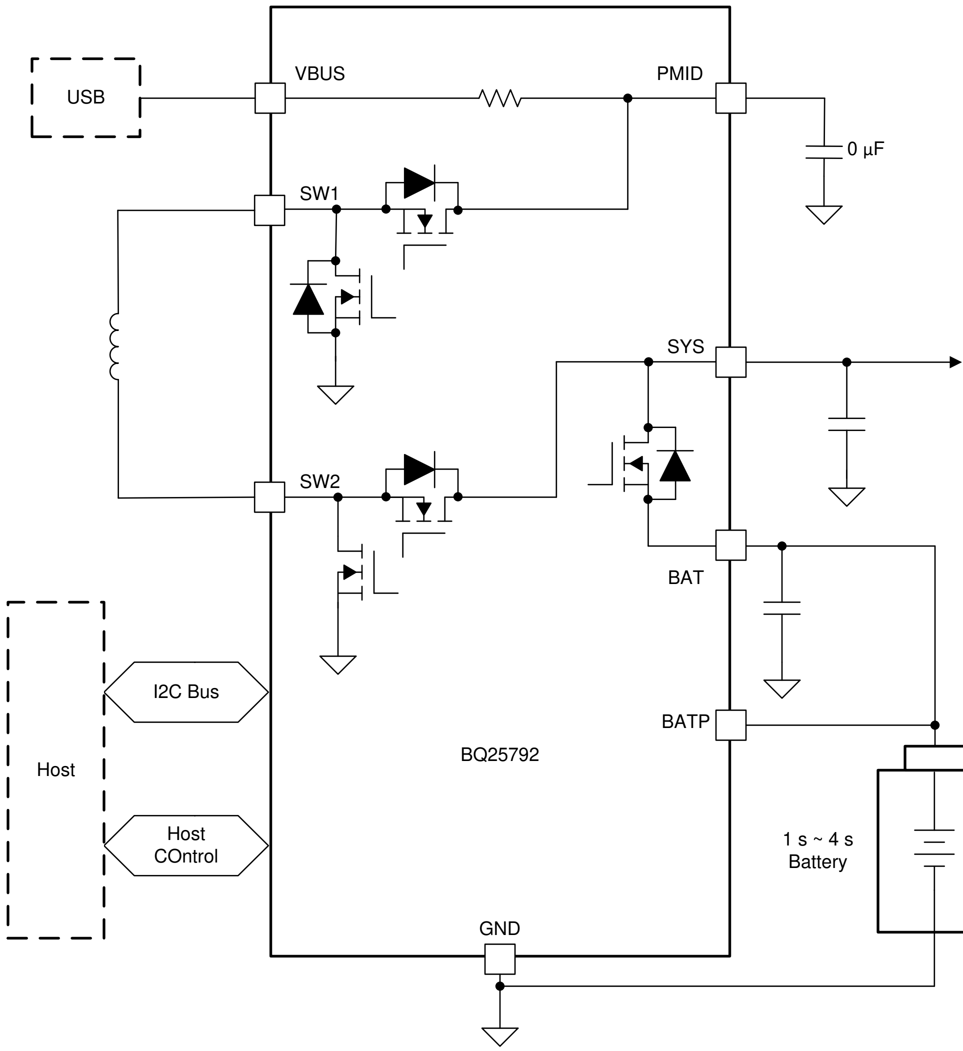


Figure 2-3. BQ25792 Typical Application Circuit

2.4 System Design Theory

The following sections highlight subsystems of the TIDA-050047 design, discuss their features, and how they are implemented. This section illustrates how the TPS25750D PD Controller is interfaced with the BQ25792 via I^2C enabling a simpler design that doesn't require any external FETs or any FW development.

TPS25750D PD Controller

The TPS25750D is a highly integrated stand-alone USB Type-C and Power Delivery (PD) controller optimized for applications supporting USB-C PD Power and provides robust protection and fully managed internal power paths. It features two I^2C ports, one of which is a Master port which will connect to the battery charger to communicate the proper configurations to set it up for charging mode, charging current, OTG mode and so on.

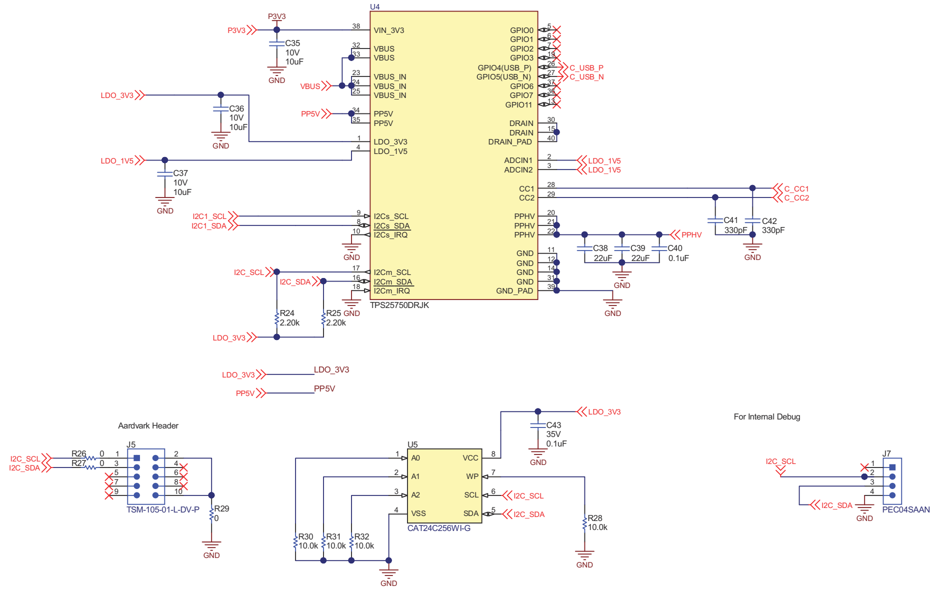


Figure 2-4. TPS25750D Schematic

BQ25792 Battery Charger

The BQ25790 is a highly integrated switch-mode buckboost charger for 1-4 cell Li-ion battery and Lipolymer battery. The integration includes four switching MOSFETs (Q1, Q2, Q3, Q4), input and charging current sensing circuits, battery FET (QBAT) and all the loop compensation of the buck-boost converter. This battery charger will receive I^{2}C commands from the PD controller to set up the registers appropriately for the desired application. There are sockets to connect the charger to a system as well as a battery.

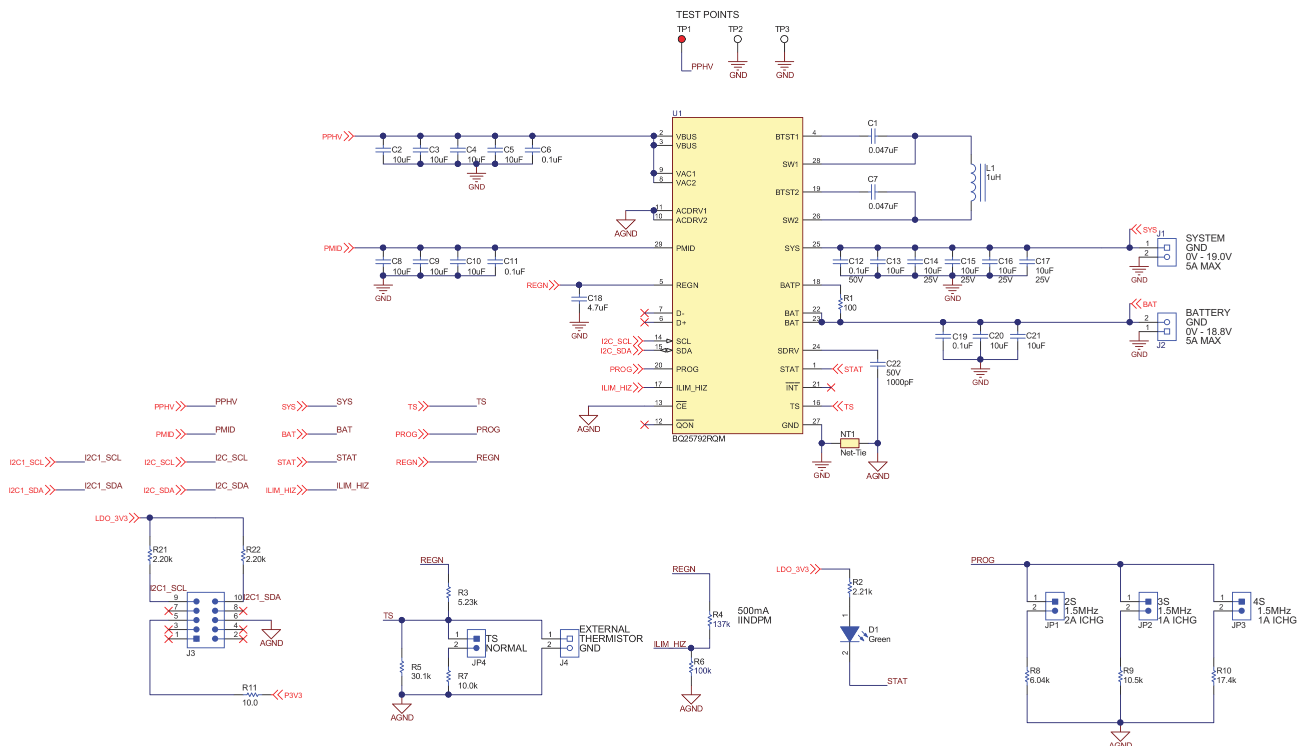


Figure 2-5. BQ25792 Schematic

TPS54531 Buck Converter

For Sourcing capabilities, this design uses the PP5V power path to supply a 5 V source and the PPHV power path to source higher voltages. Therefore to keep a constant 5 V system source readily available on VBUS for the PD controller and for VCONN support, a buck converter is needed. For this design, the TPS54531 provided a good solution, it features integrated FETs and a wide input voltage range. Since this converter will be connected to the System rail of the battery charger, it can handle any input voltage in the range of 3.5 V to 28 V and provide a 5 V output capable of delivering up to 5 A. For a Sink-Only application, this device is not needed and a 5 V rail can be omitted.

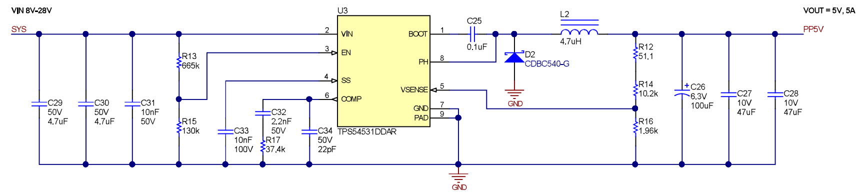


Figure 2-6. TPS54531 Buck Converter Schematic

TLV75533 LDO

To power on the TPS25750D device when the system needs to source power, the VIN_3V3 input pin must also be supplied. Therefore, the TLV7533 was chosen to provide the 3.3 V needed to power the PD controller. The input is connected to the TPS54531 output of 5 V, which will be dropped down to 3.3 V. However, this input supply is not needed for Sink-only applications and so the 3.3 V rail can be omitted as well if that is the case.

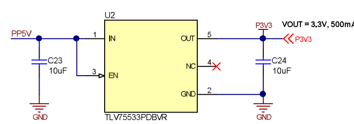


Figure 2-7. TLV75533 Schematic

USB Type-C Receptacle

Figure 2-9 shows the schematic of the USB Type-C receptacle that this design uses. From this receptacle, the communication (CC1 and CC2) and VBUS pins are mapped appropriately to the TPS25750D PD controller. In addition, the TVS2200 diode, which is a 22-V Precision Surge Protection Clamp, was also added to the design at the Type-C port for added protection.

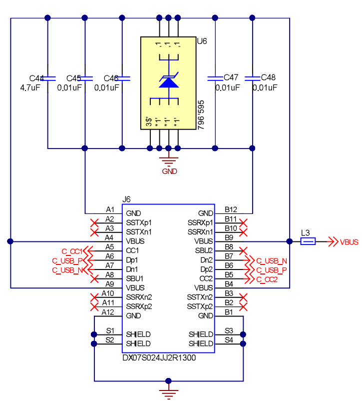


Figure 2-8. USB Type-C Receptacle Circuit with TVS2200

Supporting Components for Programming

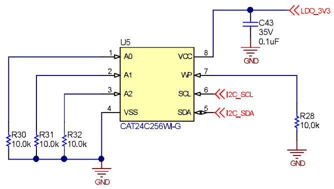


Figure 2-9. Flash IC Circuit

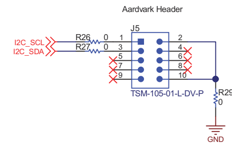


Figure 2-10. Aardvark Connector

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware and Software Requirements

To fully test the TIDA-050047, the following components are required:

1. Windows PC running the web-based TPS25750 Application Customization Tool GUI
2. The TIDA-050047 board
3. Bi-Directional Power Supply for Battery Connection Testing
4. High Current Type-C Cable
5. E-load or Resistive Load for System Connection Testing

3.2 Application Customization Tool

Configuration Process

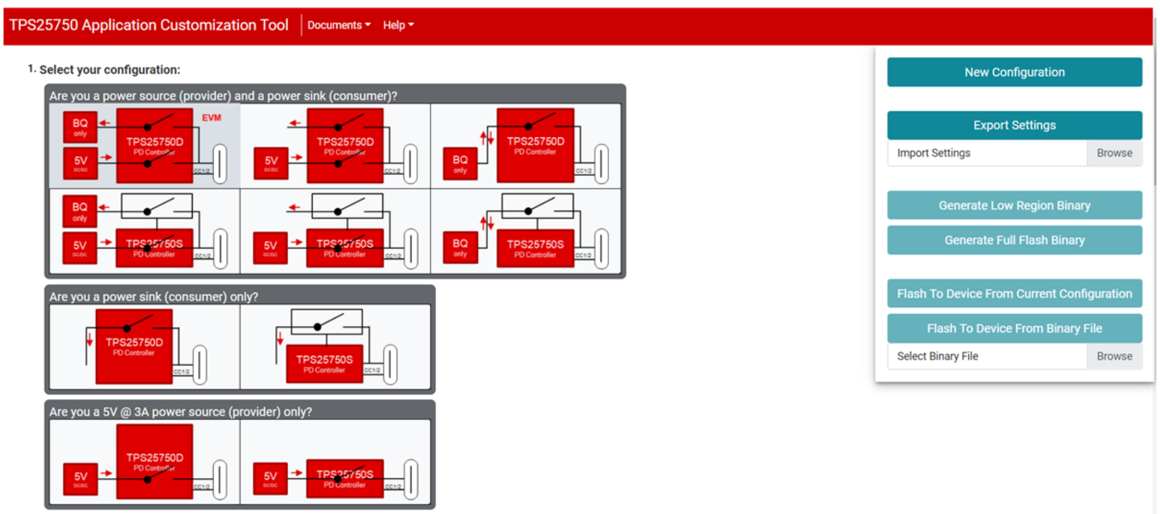


Figure 3-1. TPS25750 Application Selection

First, the configuration needs to be selected depending on the application. For this reference design, we need to choose the first option, it is selected by default as shown in Figure 3-1.

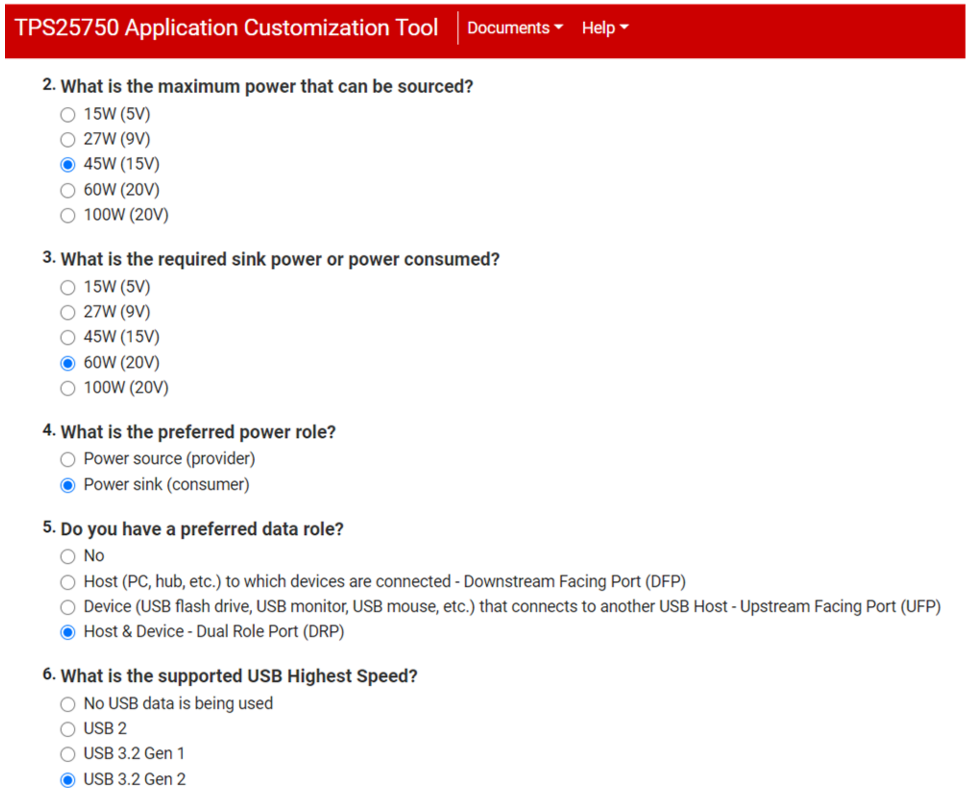


Figure 3-2. Supported Power Questions

Questions 2 through 6 are used to set up the power and data configurations as needed for this reference design. TIDA-050047 is capable of sourcing up to 45W (15 V/3A or 20 V/2.25A) and sinking up to 100W. Depending on your preference, you can select the settings as you wish to test them. For this reference design, the settings shown in Figure 3-2 can be followed.

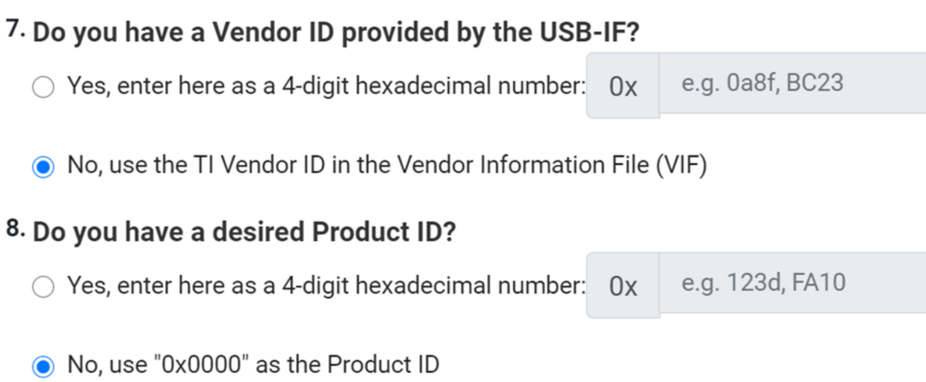


Figure 3-3. Vendor/Product ID Information

Questions 7 and 8 pertain to the Vendor ID and Product ID, these are not necessary but if you want to input your own, you can do this here. For this project, the second option can be used for both questions.

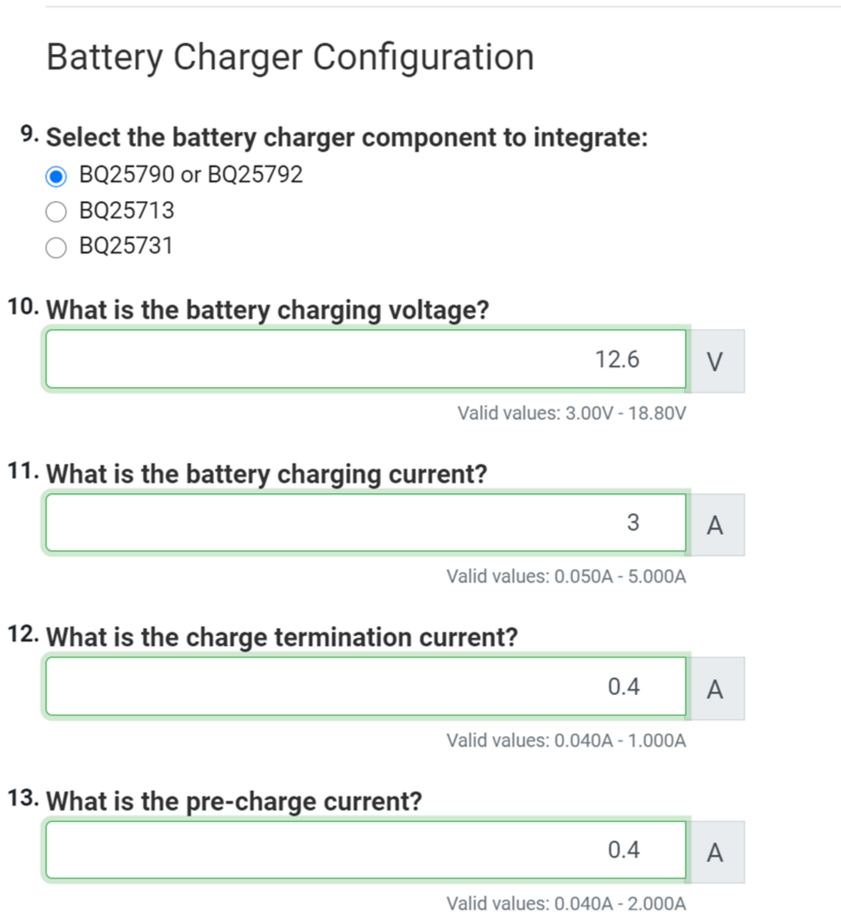


Figure 3-4. Battery Charger Questions

The last section asks questions regarding the battery charger configuration. For this design, the battery charger used is the BQ25792, so the first option can be selected here. The following questions can be filled in to how you would want to test. For example

- Battery charging voltage you can choose to input 12 V for a 3s battery
- Battery charging current can be set to 3 A
- Charge termination current will be set to a low 400mA, this is the current that the battery will charge at once it has reached almost full capacity
- Pre-charge current depends on the battery charger that is chosen, for the BQ25792, 400mA can be chosen

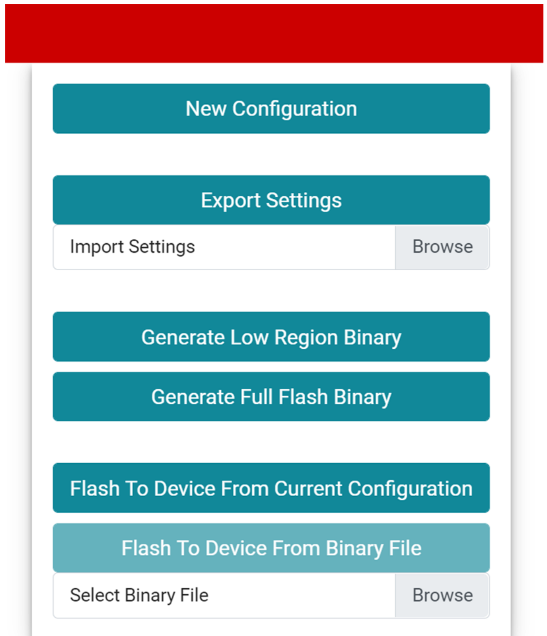


Figure 3-5. Exporting the Selected Settings

When all of the questions are answered, the configuration file is ready to be programmed. There are a few options here to do so, the simplest is to use the *Flash To Device From Current Configuration* Option that connects the Tool to a connected Tiva chip on the board, for example. Another option is to export the binary using the *Generate Full Flash Binary* option and then using an external program, such as the Aardavark by Total Phase to program the selected configurations to the TPS25750D.

3.3 Test Setup

To test the TIDA-050047 reference design after the configurations have been programmed, there are a few connections that need to be made before powering on.

First, the TIDA-050047 needs to be powered on. To provide the necessary power required to power on the TPS25750D for sourcing and the BQ25792, a bidirectional power supply can be connected to the BATT socket at J2. Depending on the cell configuration jumper settings for JP1-JP3, the voltage on the power supply can be set accordingly for the voltage and up to the current limit desired, 1 A should be sufficient for testing. The JP4 jumper also needs to be populated for the default thermistor settings.

Once the connections are properly made, the power supply can be turned on. The power supply on BATT, should power on the BQ25792 and the necessary 5 V and 3.3 V buck converter and LDO that connects to the TPS25750D. Once the PD controller is powered on, it will load the project configurations that were programmed on the Flash IC to operate based on the selected options in the Application Customization Tool.

The TIDA-050047 is now ready to be connected to a port partner via a USB Type-C cable to either source power or the sink power as negotiated.

To test a Sink-Only application, such as in dead battery mode, the same connections can be made, except this time, you do not need to supply power on the BATT pin, instead, it will be sinking power to simulate charging a battery. Therefore, once the correct jumpers are set, when the USB Type-C cable connects to a port partner that offers Source capabilities, the TPS25750D will power on using VBUS and will load the proper configurations from the Flash to program the BQ25792 for charging the battery.

3.4 Test Results

At startup, the TPS25750D PD controller will send the initial I^2C commands to set up the BQ25792 battery charger for charging, number of cells and so on. These initial commands are based on the answers provided on the Web-based Application Customization Tool for proper functionality. When a 5 V Sink PDO Contract is negotiated, the PD controller will set up the buck-boost battery charger BQ25792 for a VIN of 5 V and charging the battery at 1 A based on this particular configuration.

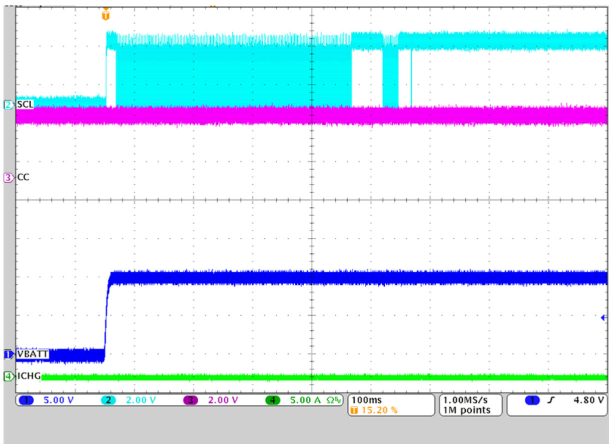


Figure 3-6. Power On Reset (POR) Commands

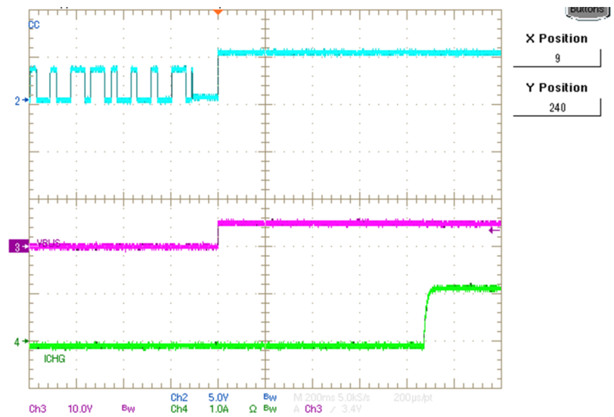


Figure 3-7. Example of a 5V Sink Contract Charging a Battery

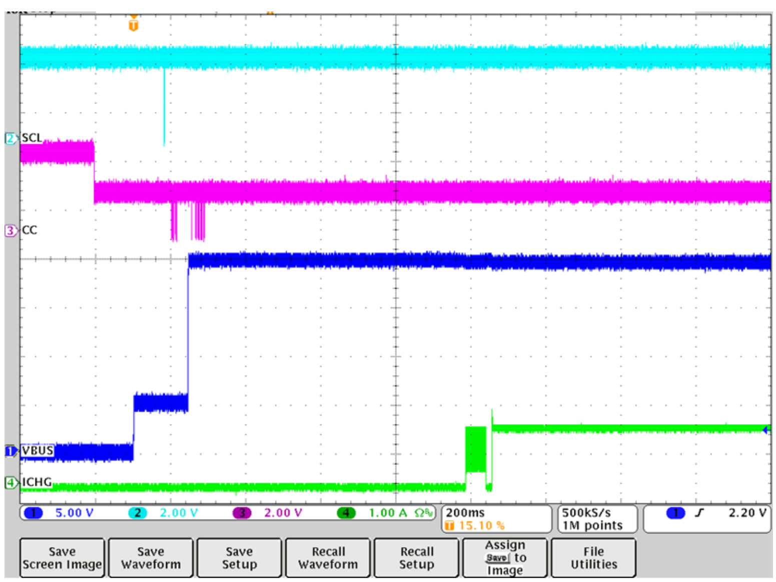


Figure 3-8. 20V Sink Charging at 1 A

Similarly, when a 20 V Sink PDO contract is negotiated, the same behavior can be seen where the PD controller will set up VIN at 20 V this time, while maintaining charging at 1A.

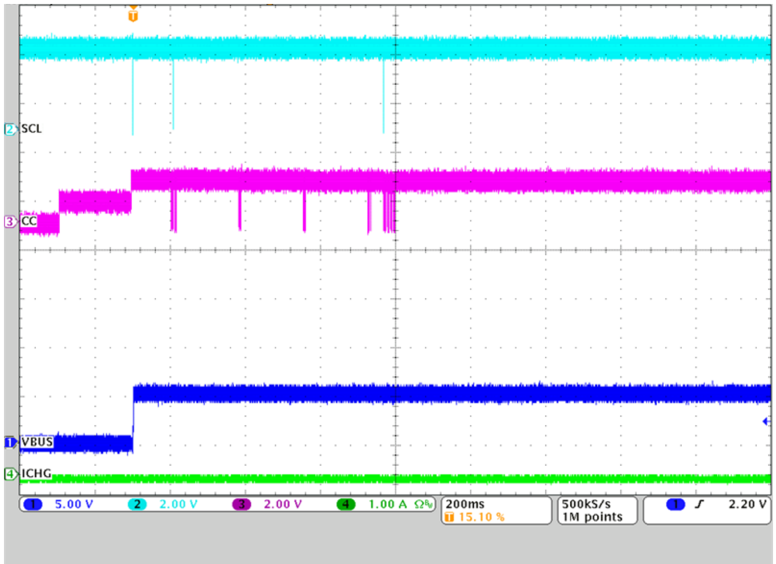


Figure 3-9. Sourcing 5 V with BQ25792 in OTG Mode

When the TPS25750D negotiates a Source PDO contract, it will configure the BQ25792 to operate in OTG mode so that the Battery can source the power needed for the port partner. In this case, the BQ25792 needs to boost up the battery voltage up to 5 V to source power to the other device.

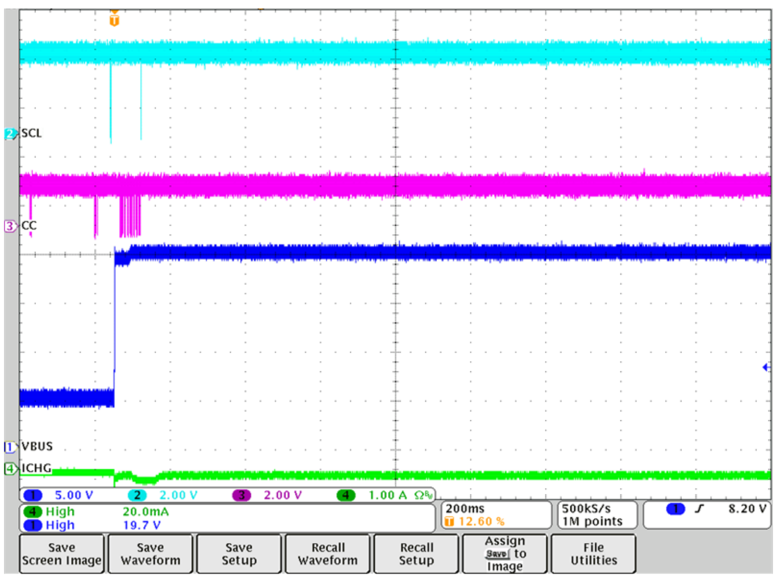


Figure 3-10. Sourcing 20 V with BQ25792 in OTG Mode

The same behavior can be observed when the port partner and the TPS25750D negotiate a 20 V contract using the TPS25750 as a Source.

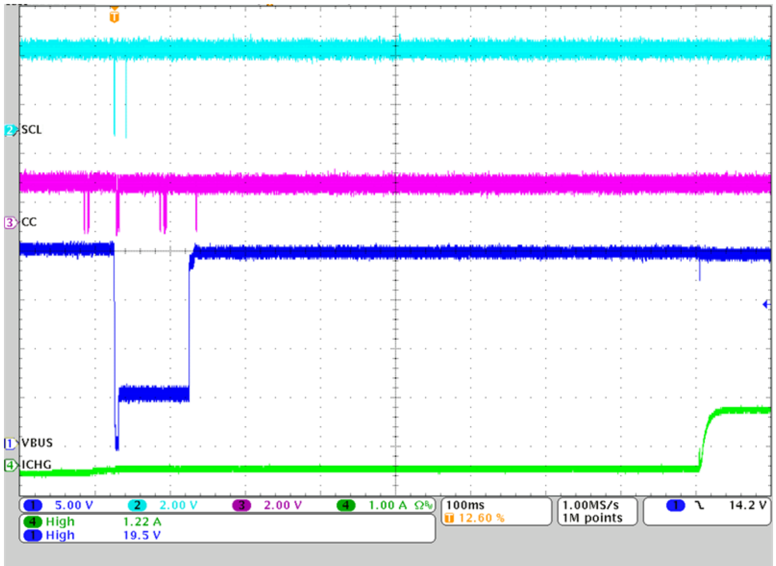


Figure 3-11. Power Role Swap from Source to Sink

One of the features for USB Type-C PD Controllers, such as the TPS25750D is the ability to perform Power Role Swaps depending on when certain conditions change. In the corresponding figure, initially the sourcing can be observed as VBUS is at 20 V but the charging current is at 0 V, then a reset or renegotiation occurs where the PD controller needs to become a Sink and both devices accept this change. Therefore, VBUS goes to 0 V and then negotiates a 20 V Sink PDO contract. Once the Power Role Swap is done, the TPS25750D configures the BQ25792 for charging mode to charge at 1 A, which can be seen at the end of the capture.

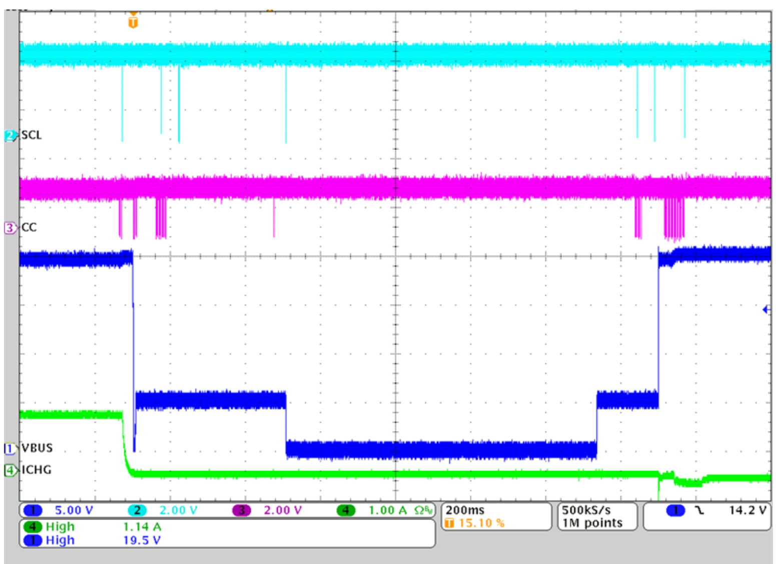


Figure 3-12. Power Role Swap from Sink to Source

Similarly, the same can be done in reverse order, going from the TPS25750D being a Sink and charging the battery, to renegotiating a Sourcing contract with the port partner and supplying the 20 V using the BQ25792.

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050047.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050047.

4.1.3 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050047.

4.2 Software

To download the software binary file needed to configure the TPS25750D for this reference design, see the design files at TIDA-050047.

4.3 Documentation Support

1. Texas Instruments, TPS25750 USB Type-C and USB PD Controller with Integrated Power Switches data sheet
2. Texas Instruments, BQ25792 I2C Controlled, 1-4 Cell, 5-A Buck Boost Charger, Dual-Input Selector data sheet
3. Texas Instruments, Web-Based Application Customization Tool Guide for TPS25750

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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5 About the Author

Hari Patel is an Applications Engineer for Texas Instruments where he is responsible for supporting USB Type-C and PD controllers. Hari earned both his Bachelor of Science and Master of Science in Electrical Engineering from The Univeristy of Florida in Gainesville, FL.

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