

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



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 USB Type-C communication, power delivery negotiations, power role swaps, and data role swaps. This board features charging current up to 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 I²C communication to the battery charger integrated circuit (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

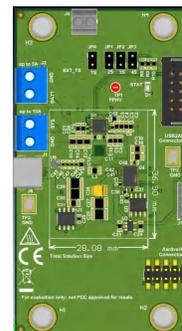
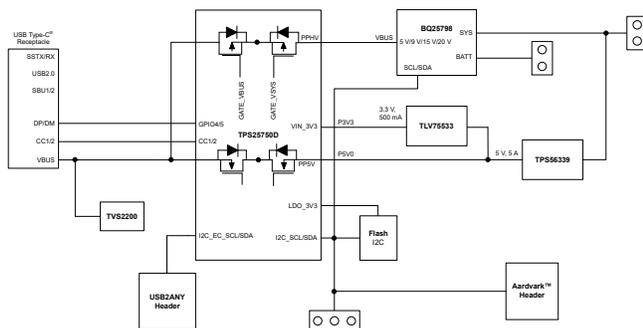
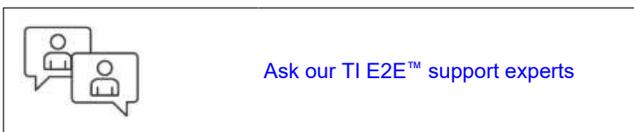
TIDA-050047	Design Folder
TPS25750, BQ25798	Product Folder
TPS54531, TLV755P	Product Folder
TVS2200	Product Folder

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](#)
- [Wireless speaker](#)
- [Headsets, headphones, and earbuds](#)
- [Portable electronics](#)
- [Industrial](#)



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 66-W sinking and up to 45-W sourcing. This reference design can support charging 2S to 4S batteries via a USB Type-C port, in addition to USB Type-C communication and power delivery negotiations.

This board features charging up to 18.8 V or 5 A, without the need for any external FETs. Furthermore, an external microprocessor is also not necessary as the USB-PD Controller handles the I²C 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 USB Type-C Input
Source Capabilities	5 V - 20 V	Output from BQ25798
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

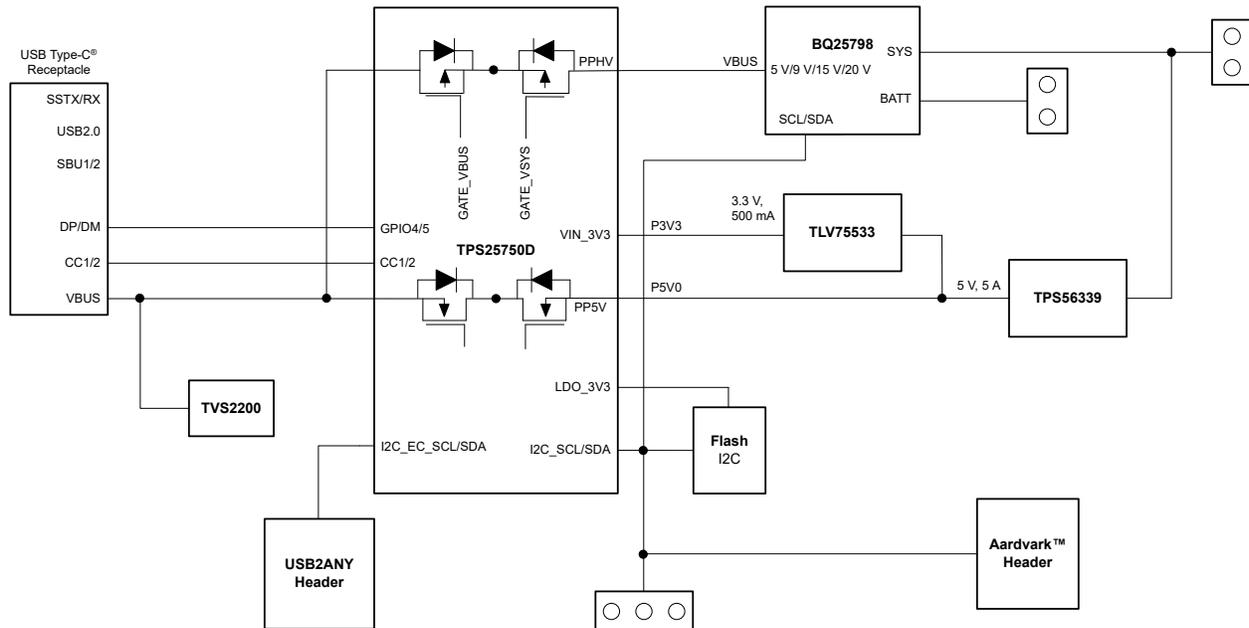


Figure 2-1. TIDA-050047 Block Diagram

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 USB Type-C connector.

2.3 Highlighted Products

2.3.1 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.

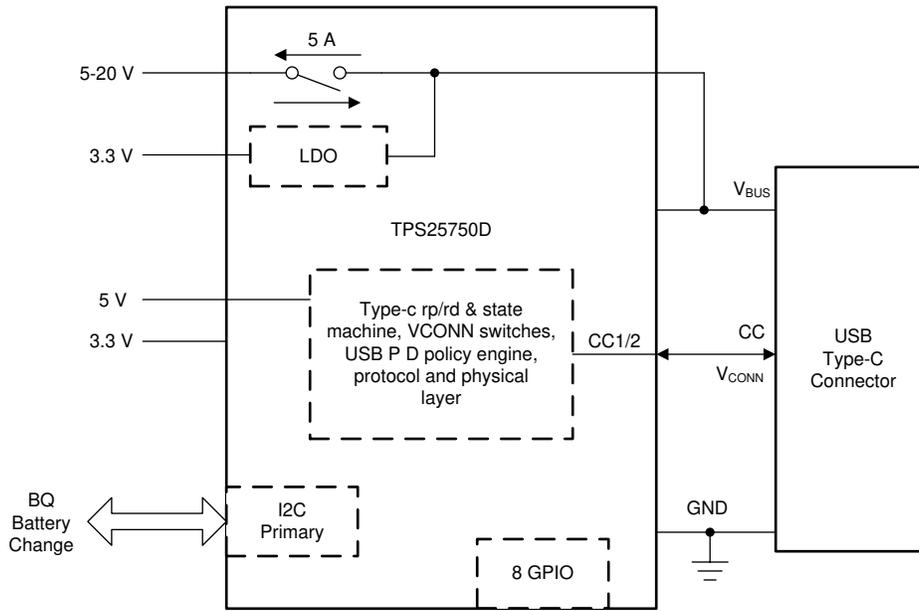


Figure 2-2. TPS25750D Typical Application Circuit

2.3.2 BQ25798

The BQ25798 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 BQ25798 supports input source detection through D+ and D- which is compatible with USB 2.0, USB 3.0 power delivery, non-standard adapters, and high voltage adapters. With dual-input source selection, USB OTG support, and an integrated 16-bit multichannel analog-to-digital converter (ADC), the BQ25798 is a complete charging design.

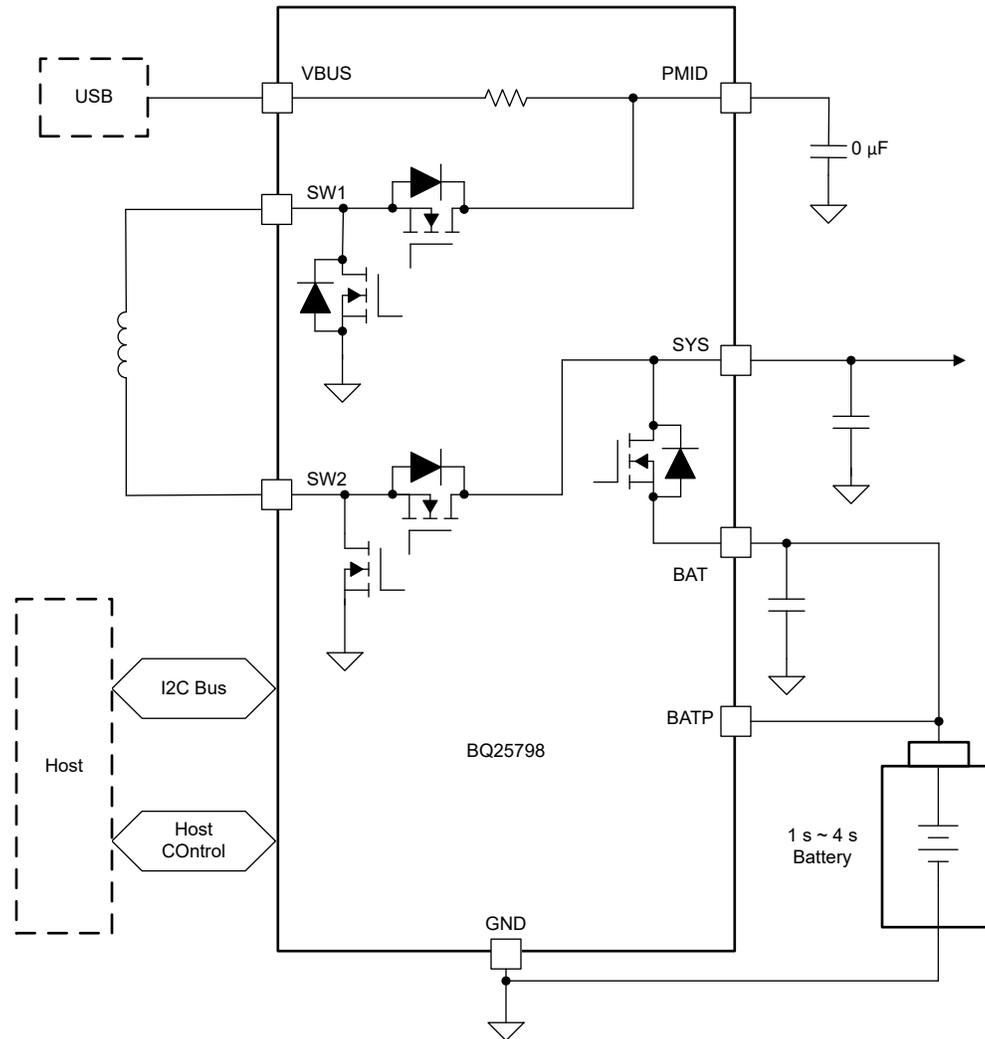


Figure 2-3. BQ25798 Typical Application Circuit

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 BQ25798 via I²C enabling a simpler design that doesn't require any external FETs or any FW development.

2.4.1 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. The device features two I²C ports, one of which is a Master port which connects to the battery charger to communicate the proper configurations to set it up for charging mode, charging current, OTG mode and so on. The Master port can be used with header J7 to communicate to the BQ25798. The second I²C port, or the Slave port, can be used to directly program the TPS25750, and program the BQ25798 via host microcontroller (MCU), or program both, and is available on J3.

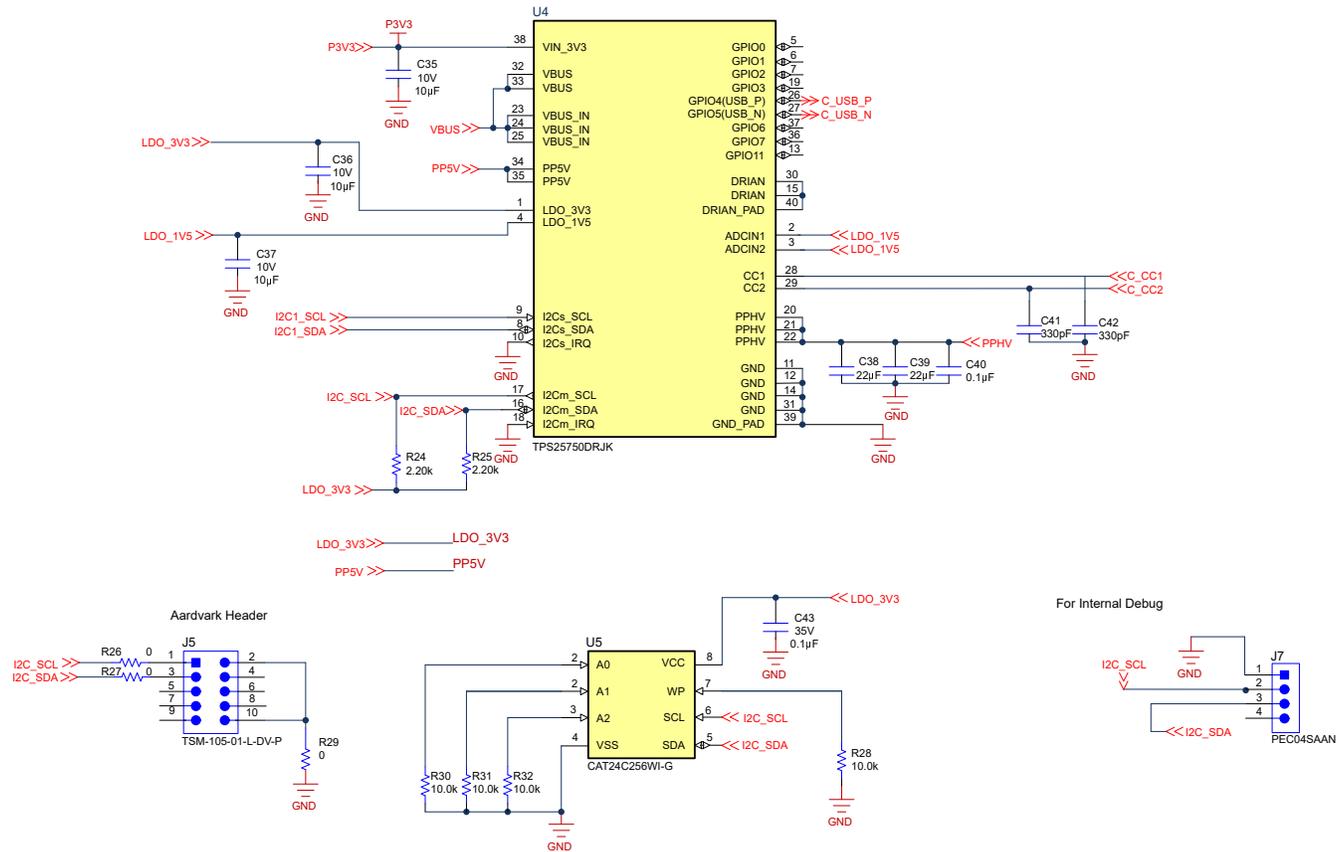


Figure 2-4. TPS25750D Schematic

2.4.2 BQ25798 Battery Charger

The BQ25798 is a highly integrated switch-mode buck-boost charger for 1 to 4 cell Li-ion battery and Li-polymer 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 receives I²C 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.

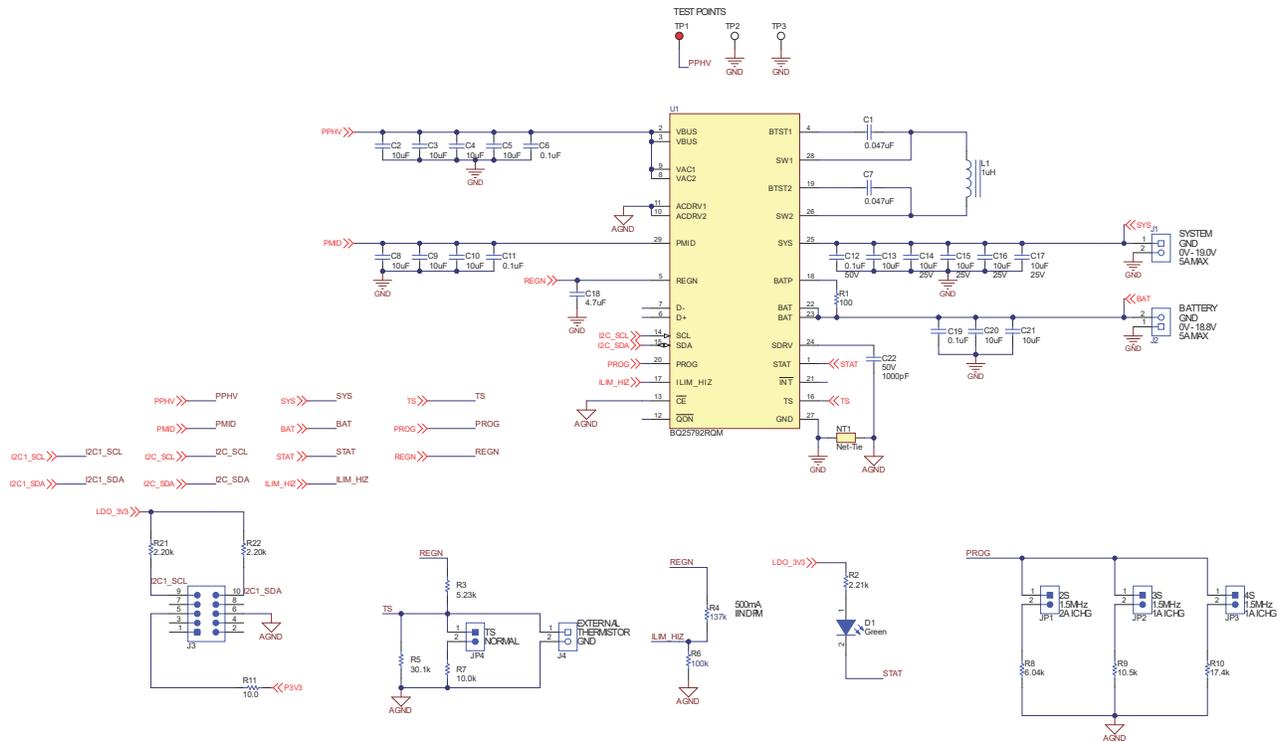


Figure 2-5. BQ25798 Schematic

2.4.3 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. Due to the buck topology selection, a 2S-4S battery is needed to work with the TPS54531 to achieve a 5-V output operation using the battery as the input. For this design, the TPS54531 is a good choice, the device features integrated FETs and a wide input voltage range. Since this converter is 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.

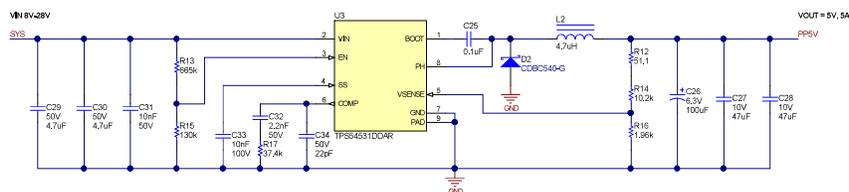


Figure 2-6. TPS54531 Buck Converter Schematic

2.4.4 TLV75533 LDO

To power on the TPS25750D device the system needs to source power, the VIN_3V3 input pin must also be supplied. Therefore, the TLV75533 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 drops 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.

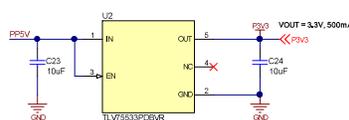


Figure 2-7. TLV75533 Schematic

2.4.5 USB Type-C® Receptacle

Figure 2-8 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 USB Type-C port for added protection.

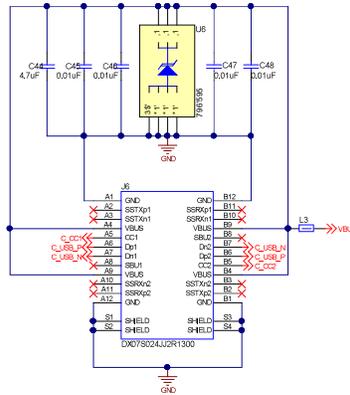


Figure 2-8. USB Type-C® Receptacle Circuit with TVS2200

2.4.6 Supporting Components for Programming

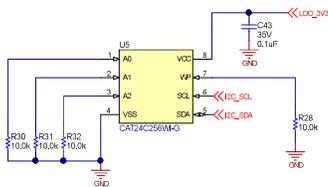


Figure 2-9. Flash IC

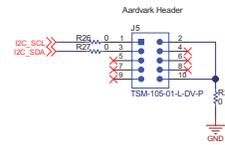


Figure 2-10. Aardvark™ Connector

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. Microsoft® Windows® PC running the web-based TPS25750 application customization tool GUI
2. The TIDA-050047 board
3. Bidirectional power supply for battery connection testing
4. High-current USB Type-C cable
5. E-load or resistive Load for system connection testing

3.2 Application Customization Tool

Configuration Process

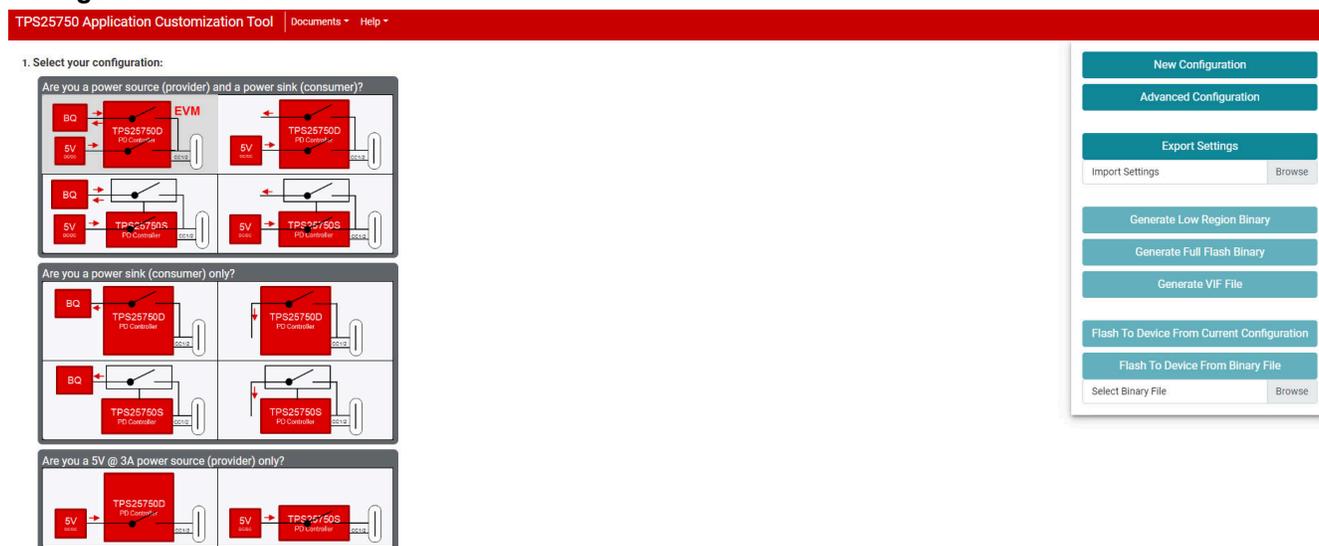


Figure 3-1. TPS25750 Application Selection

First, the select the configuration depending on the application. For this reference design, choose the first option, which is selected by default as shown in [Figure 3-1](#).

2. What is the maximum power that can be sourced?
- 15W (5V)
 - 27W (9V)
 - 45W (15V)
 - 60W (20V)
 - 100W (20V)
3. What is the required sink power or power consumed?
- 15W (5V)
 - 27W (9V)
 - 45W (15V)
 - 60W (20V)
 - 100W (20V)
4. What is the preferred power role?
- Power source (provider)
 - Power sink (consumer)
5. Do you have a preferred data role?
- No
 - Host (PC, hub, etc.) to which devices are connected - Downstream Facing Port (DFP)
 - Device (USB flash drive, USB monitor, USB mouse, etc.) that connects to another USB Host - Upstream Facing Port (UFP)
 - Host & Device - Dual Role Port (DRP)
6. What is the supported USB Highest Speed?
- No USB data is being used
 - USB 2
 - USB 3.2 Gen 1
 - USB 3.2 Gen 2

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 45 W (15 V, 3 A or 20 V, 2.25 A) and sinking up to 66 W. 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.

7. Do you have a Vendor ID provided by the USB-IF?

- Yes, enter here as a 4-digit hexadecimal number:
- No, use the TI Vendor ID in the Vendor Information File (VIF)

8. Do you have a desired Product ID?

- Yes, enter here as a 4-digit hexadecimal number:
- No, use "0x0000" as the Product ID

Figure 3-3. Vendor or 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.

Battery Charger Configuration

9. Select the battery charger component to integrate:

- BQ25790, BQ25792, or BQ25798
- BQ25713
- BQ25731

10. What is the battery charging voltage?

 V

11. What is the battery charging current?

 A

12. What is the charge termination current?

 A

13. What is the pre-charge current?

 A

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 BQ25798, 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 is set to a low 400 mA, this is the current that the battery charges at once the battery has reached almost full capacity
- Pre-charge current depends on the selected battery charger, select 400 mA for the BQ25798 device

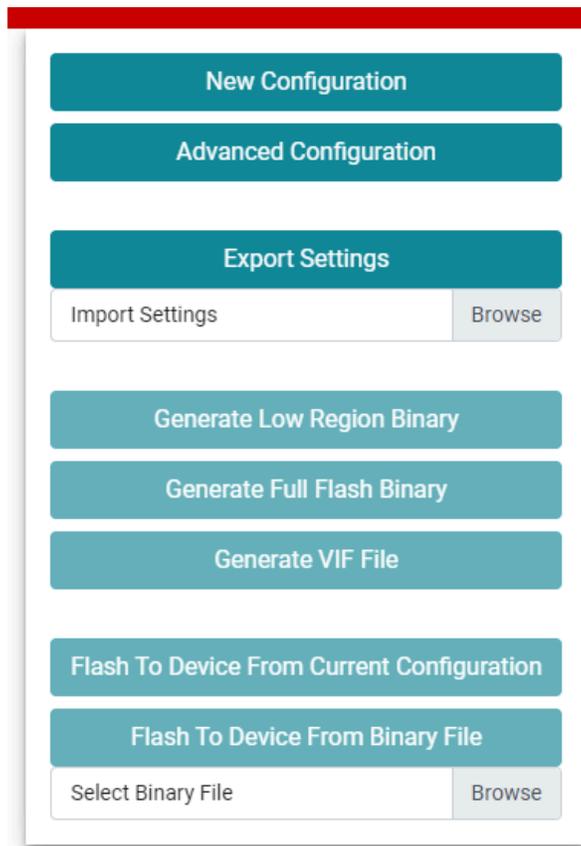


Figure 3-5. Exporting the Selected Settings

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 option is to use the Aardvark™ header. Export the binary using the *Generate Full Flash Binary* option and then use Flash Center by Total Phase to program the selected configurations to the TPS25750D. If the customer board makes use of a TIVA chip, the binary can be flashed using *Flash To Device From Current Configuration*.

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 BQ25798, 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 is 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, powers on the BQ25798 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, the controller loads 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 sinks 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 powers on using VBUS and loads the proper configurations from the Flash to program the BQ25798 for charging the battery.

3.4 Test Results

At start-up, the TPS25750D PD controller sends the initial I²C commands to set up the BQ25798 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 sets up the buck-boost battery charger BQ25798 for a V_{IN} of 5 V and charging the battery at 1 A based on this particular configuration.

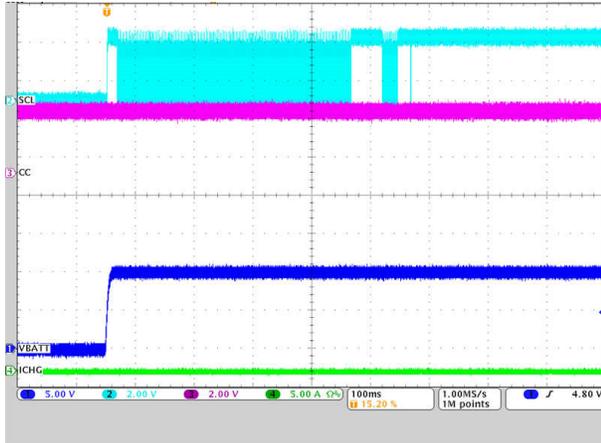


Figure 3-6. Power On Reset (POR) Commands

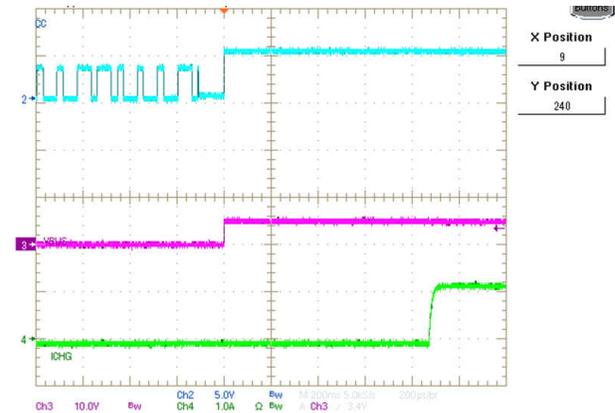


Figure 3-7. Example of a 5-V Sink Contract Charging a Battery

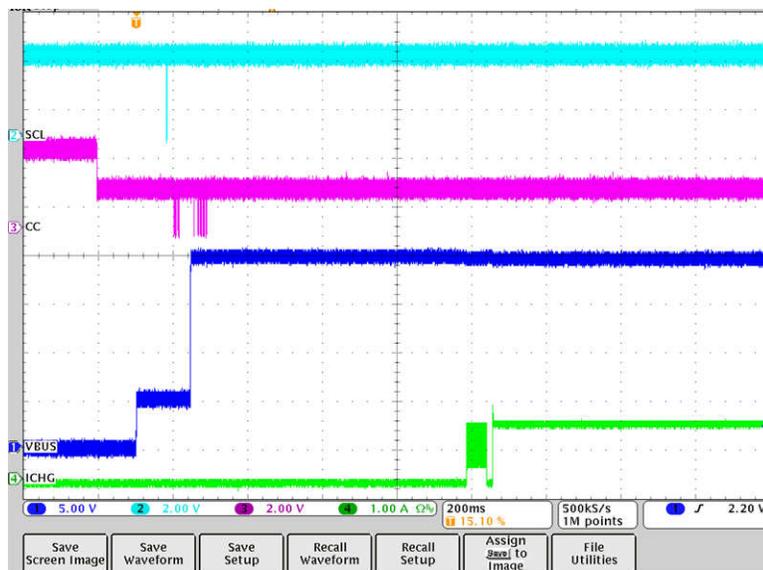


Figure 3-8. 20-V Sink Charging at 1 A

Similarly, when a 20 V Sink PDO contract is negotiated, the same behavior can be seen where the PD controller sets up V_{IN} at 20 V this time, while maintaining charging at 1 A.

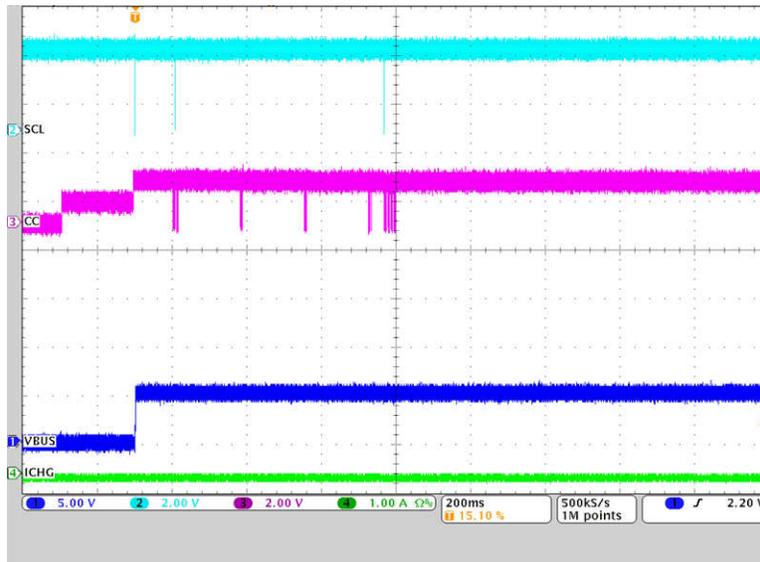


Figure 3-9. Sourcing 5 V with BQ25798 in OTG Mode

When the TPS25750D negotiates a source PDO contract, the device configures the BQ25798 to operate in OTG mode so that the battery can source the power needed for the port partner. In this case, the BQ25798 needs to boost up the battery voltage up to 5 V to source power to the other device.

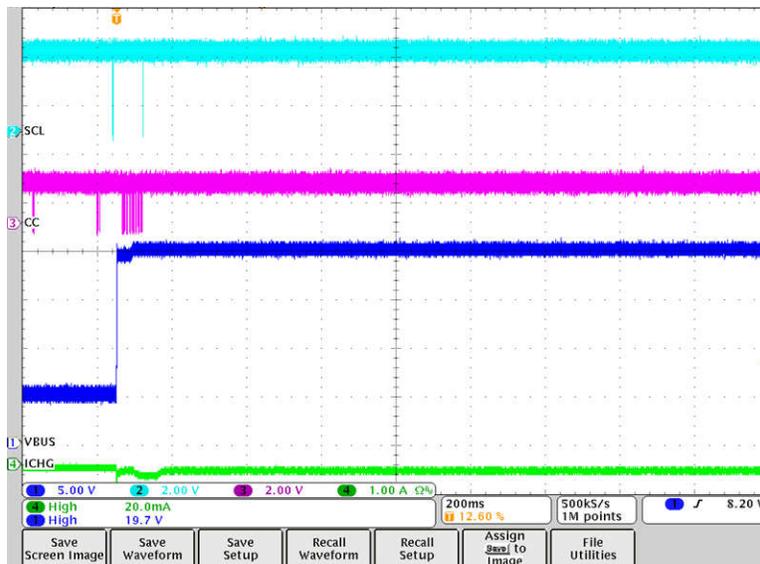


Figure 3-10. Sourcing 20 V with BQ25798 in OTG Mode

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

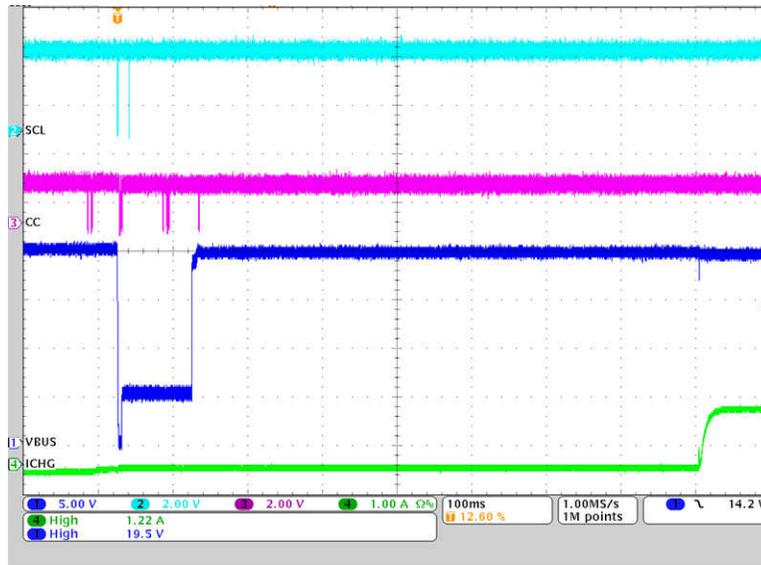


Figure 3-11. Power Role Swap from Source to Sink

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 A, 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 BQ25798 for charging mode to charge at 1 A, which can be seen at the end of the capture.

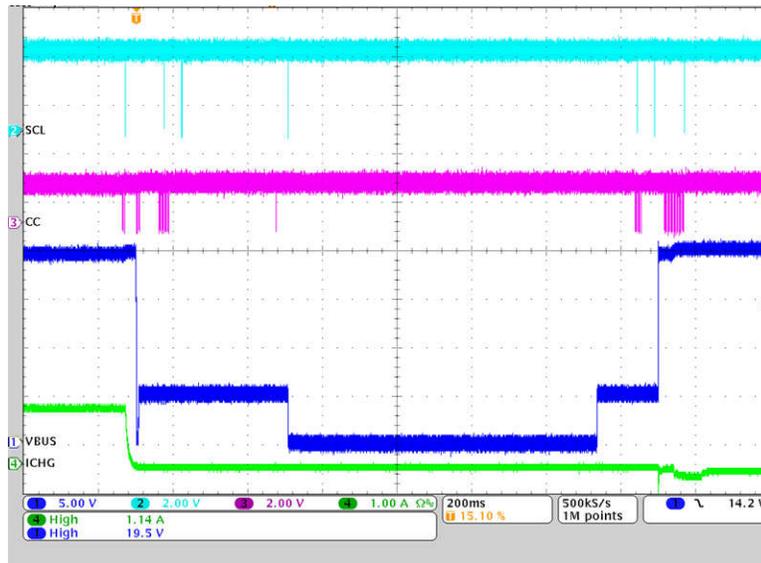


Figure 3-12. Power Role Swap from Sink to Source

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 BQ25798.

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 Optimized for Power Applications](#) data sheet
2. Texas Instruments, [BQ25798 I²C Controlled, 1- to 4-Cell, 5-A Buck-Boost Battery Charger with Dual-Input Selector, MPPT for Solar Panels and Fast Backup Mode](#) 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 University of Florida in Gainesville, FL.

6 Revision History

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

Changes from Revision A (Sep 2023) to Revision B (Apr 2024)	Page
• Updated BQ25798 schematic.....	1

Changes from Revision * (November 2020) to Revision A (September 2023)	Page
• Revision A updates the design guide for changing BQ25792 to BQ25798 in the BOM and all documents. Also included are small updates to GUI images and sinking and charging capabilities are clarified.....	1

Revision History

- Added more description about TPS25750 master and slave I2C ports. Updated TPS25750 schematic.....5
 - Clarified battery voltage range to work with the TPS54531 buck converter.....7
 - Clarified flashing process for EEPROM.....9
-

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