Application Report
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Using a TPS6598x EVM to Emulate USB Type-C and Power Delivery Products

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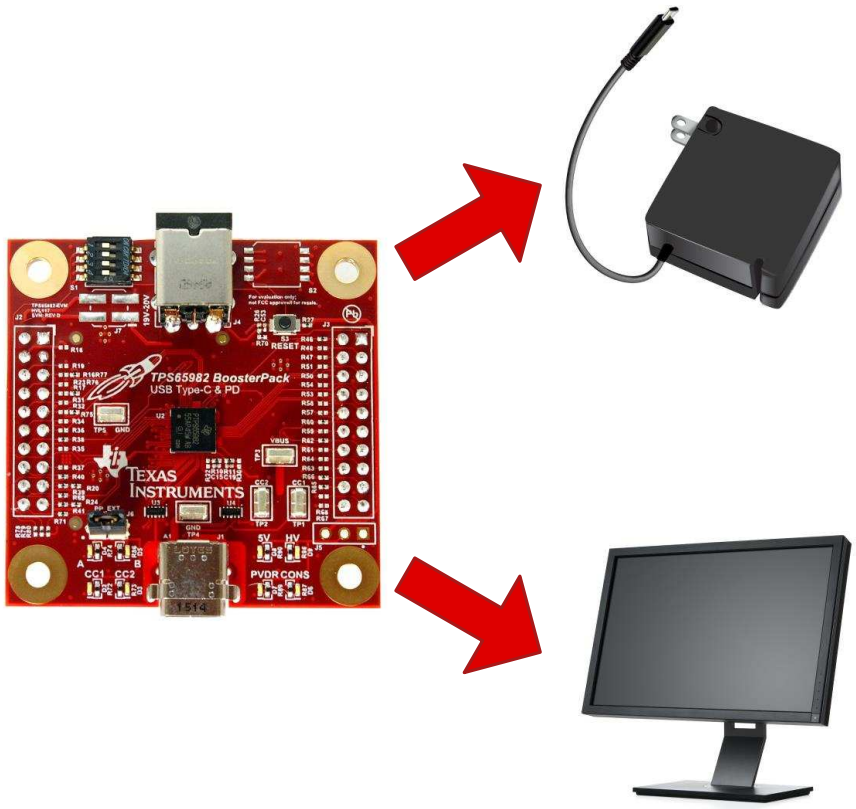
ABSTRACT

USB Type-C (USB-C) is emerging as a universal interface that can be used for power, data, video, and audio applications. The TPS6598x product family offers stand-alone USB Type-C and Power Delivery controllers for systems that include a Type-C interface. The product folder on TI.com for each TPS6598x device includes an evaluation module (EVM) that can be used for Type-C testing, PD testing, and application emulation. The EVMs also serve as an effective starting point to learn about the TPS6598x devices before incorporating them into a system design.

Each EVM comes with base firmware that can emulate various Type-C and PD products. This feature can be used to interface with all Type-C and PD products on the market. The TPS6598x product folders also include user-friendly configuration and utilities tools for customizing firmware and interacting with the TPS6598x device. The TPS6598x Host Interface Utility Tool can be used to interact with a TPS6598x firmware configuration, obtain capabilities of a connected Type-C product, and load firmware onto TPS6598x flash memory. The TPS6598x Application Customization Tool can be used to create custom firmware images, load firmware, and import configuration settings from a TPS6598x device. Firmware images created using this tool can be directly loaded onto the TPS6598x EVM to create the desired application.



Contents

1 Introduction 3
1.1 Purpose and Scope 3
1.2 Items Required 3
1.3 TPS6598x EVM 3
1.4 TPS6598x Tools 4
2 Emulating a Type-C Charger 6
2.1 Create a Tablet 6
2.2 Connect Type-C Charger to Tablet 6
2.3 Use TPS6598x Utilities GUI to Obtain Capabilities 7
2.4 Create a Firmware Image Using TPS6598x Application Customization Tool 9
2.5 Load Firmware on to EVM to Create a Charger 17
3 System Demo 18
4 Conclusion 22

List of Figures

1 TPS65982-EVM 4
2 TPS6598x Application Customization Tool 5
3 TPS6598x Host Interface Utility Tool 5
4 Configuration ID 1 for TPS65982-EVM Base Firmware 6
5 Charger System Set-Up 6
6 *Configure* Tab in TPS6598x Utilities GUI 7
7 *Register List* Tab in TPS6598x Utilities GUI 7
8 Data Status Register 8
9 PD Status Register 8
10 Rx Source Cap Register 8
11 Rx Sink Cap Register 9
12 Load Defaults Page of TPS6598x Application Customization Tool 10
13 Rx Sink Cap (0x31) – Sink Capabilities of a Notebook 10
14 Transmit Source Capabilities (0x32) 11
15 Transmit Sink Capabilities (0x33) 11
16 Autonegotiate Sink (0x37) 11
17 GPIO 3 12
18 GPIO 7 12
19 GPIOs 14-15 13
20 System Configurations 14
21 Control Configuration (0x29) 15
22 Intel VID Config Register (0x52) 16
23 Display Port Capabilities (0x51) 16
24 Texas Instruments VID Config (0x54) 16
25 Alternate Mode Entry Queue (0x38) 17
26 System Set-Up for Firmware Loading 17
27 SPI FW Update on TPS65982 Utilities GUI 18
28 Type-C and PD System Demo 19
29 LED Indicators on the Charger EVM 20
30 Tx Source Capabilities Register 21
31 Tx Sink Capabilities Register 21
32 Active PDO Register 22

1 Introduction

1.1 Purpose and Scope

This application report outlines the process of using TPS6598x EVMs to interface with and emulate Type-C and PD products on the market. This emulation is useful when developing a product with a Type-C receptacle. As an example, a Type-C charger is implemented on a TPS65982-EVM. The TPS6598x Host Interface Utility Tool is used to gain information about the Type-C charger and to load firmware onto the external flash on the EVM. The TPS6598x Application Customization Tool is used to customize a firmware image to behave like a Type-C and PD Charger.

1.2 Items Required

The following hardware and software items are required:

- Hardware
  - TPS6598x EVM (x2)
  - TotalPhase Aardvark I^2C/SPI Host Adapter (described in the TPS65982-EVM User's Guide and TPS65982-HIUTILITY) and USB standard-B to -A cable
  - Barrel-jack laptop charger
  - USB Type-C to Type-C cable
  - Windows 7 computer
  - Type-C charger
- Software
  - TPS6598x Application Customization Tool
  - TPS6598x Host Interface Utility Tool

1.3 TPS6598x EVM

All TPS6598x EVMs come with a base firmware image that can be used to emulate various Type-C and PD applications, such as tablets, dongles, notebooks, and more. The DIP switch allows the user to switch between the different configurations. Also, this base firmware image has various configured GPIOs that illuminate LEDs for debugging purposes. For example, the TPS65982-EVM has LEDs to indicate the voltage that has been negotiated, the orientation of the Type-C cable, and Alternate Mode entry. See Figure 1 and *TPS65982 Evaluation Module* for more information regarding EVM functionality.

Custom firmware can be easily loaded into the external flash for the TPS6598x EVMs through the SPI and I^2C interface. In this document, the Aardvark is used to load a full-flash firmware image onto the external flash on the TPS65982-EVM. Upon power up, the TPS65982 device loads the application firmware over SPI. For more information on how to create firmware and load onto the TPS6598x devices, see the *TPS6598x Application-Customization Tool User Guide* and *TPS6598x Utilities Tool User Guide*.

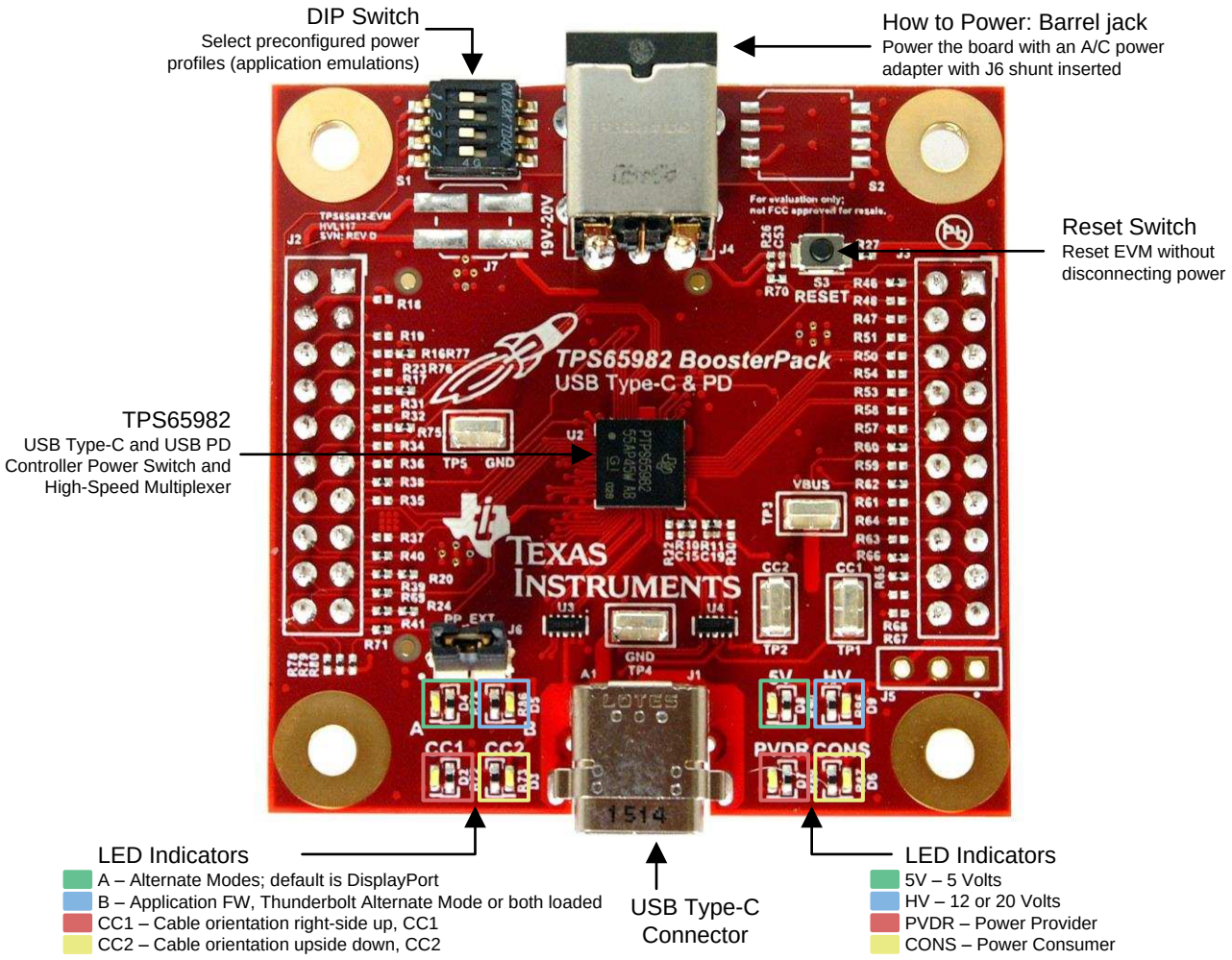


Figure 1. TPS65982-EVM

1.4 TPS6598x Tools

Texas Instruments provides the following user-friendly tools for seamless development of a Type-C application: TPS6598x Application Customization Tool and TPS6598x Host Interface Utility Tool.

The TPS6598x Application Customization Tool allows the user to customize configuration settings to meet the needs of the application. The tool provides various default configurations to be used as a starting point in firmware image development. Once the settings are configured, the user can use the tool to create a low-region or full-flash binary image, which can be directly loaded onto the TPS6598x over the SPI and I^2C interface.

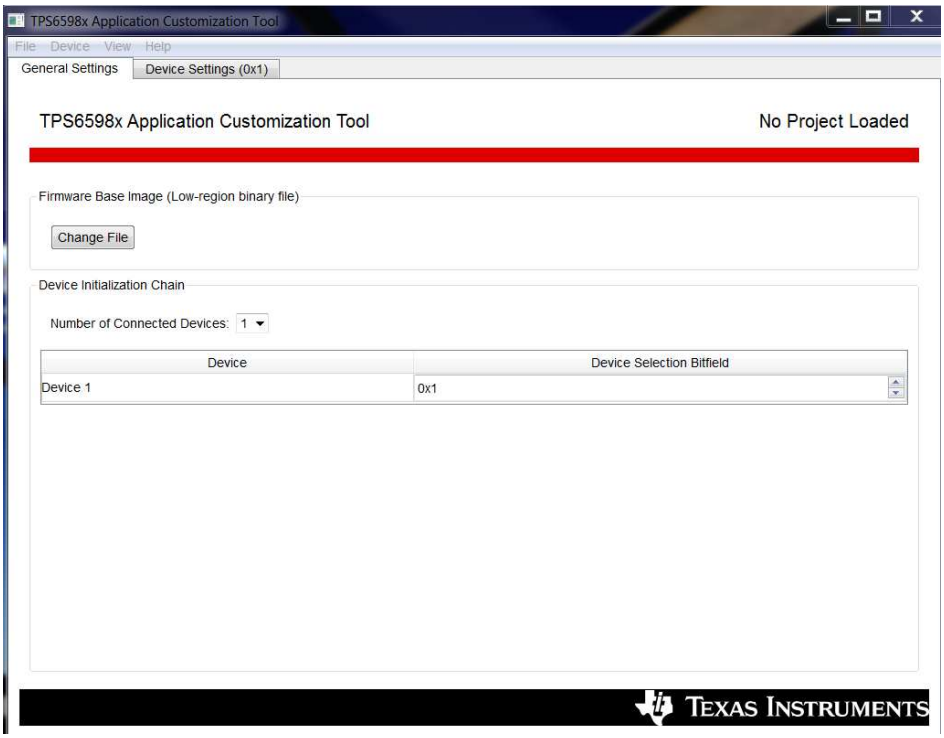


Figure 2. TPS6598x Application Customization Tool

The TPS6598x Host Interface Utility Tool is a GUI application that can be used to interact with TPS6598x devices over the host interface. The capabilities of the tool include firmware loading (SPI or I^2C), reading and writing to virtual registers, and executing 4CC functions.

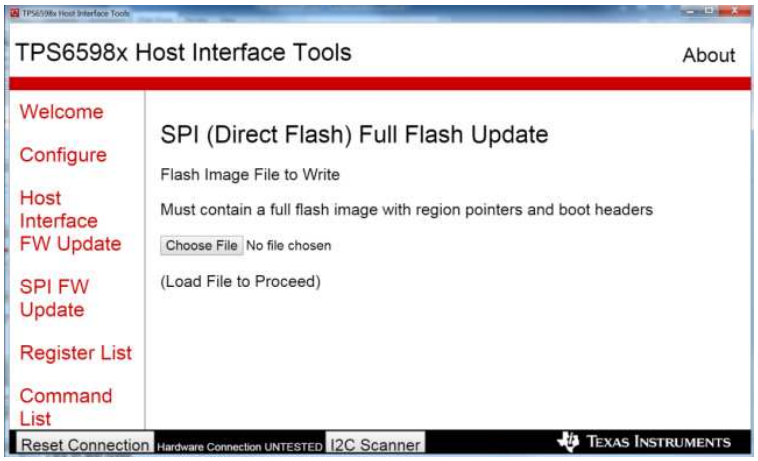


Figure 3. TPS6598x Host Interface Utility Tool

This document describes the functions of each tool that are within the scope of this application. For more information regarding the functionality of each tool, see the *TPS6598x Application-Customization Tool User Guide* and *TPS6598x Utilities Tool User Guide*.

2 Emulating a Type-C Charger

This section describes the procedure of using TPS6598x EVMs to emulate a Type-C charger on the market. Before beginning the procedure, understanding the capabilities required of a charger is important. Because the charger must only provide power, the port can be configured as a downstream-facing port (DFP) or source only. This port is not required for data; therefore, USB2 and USB3 capabilities can be disabled. By using the TPS65982-EVM to interface with a Type-C charger the configuration settings, including source capabilities, Type-C current, and Alternate Modes, can be obtained.

2.1 Create a Tablet

Using the EVM firmware that is preloaded onto the TPS65982-EVM, emulating the various applications is possible by configuring the S1 dip-switch bank. By switching to Configuration ID 1, the EVM can emulate a typical tablet (see Figure 4), which provides a common use case for a Type-C charger. Other configurations can be used to interface with the charger, but the configuration must have the correct port presentation to interface with a DFP charger (must be a dual-role port or upstream-facing port). After configuring the switch bank, power cycle the EVM by removing power or pressing the reset button (S3) to load the desired configuration.

CFG ID	Switch S1	Port Type	Type-C Power	PD Source			PD Sink Capabilities			Alternate Mode Support		PD Control	Application
		Data Power	A	V at A	V at A	V at A	V at A	V at A	V at A	TBT Support	DP Support	Initiated DR/PR Swaps	
1	1→ ■ ■ ← 0 ■ ← 0 ■ ← 0	DRP Rp/Rd	3	5 at 3	—	—	5 at 3	12 to 20 at 2	—	—	DFP_D Config C, D and E	Initiate DR swap to DFP Initiate PR swap to Snk	Tablet and Ultrabook

Figure 4. Configuration ID 1 for TPS65982-EVM Base Firmware

2.2 Connect Type-C Charger to Tablet

Now that the user has a TPS65982-EVM to emulate a tablet, it can be directly connected to a Type-C charger. The TPS65982-EVM will also be connected to Aardvark to interface with the TPS6598x Host Interface Utility Tool. Follow this procedure to set-up the system:

Step 1. Place the S1 switch on the TPS65982-EVM into configuration ID 1 (see Figure 4).

Step 2. Connect the TPS65982-EVM to the Aardvark.

Step 3. Connect the Type-C charger to the TPS65982-EVM.

Step 4. Connect the USB standard-B to -A cable from the Aardvark to the computer. In Figure 5, an FTDI-based adapter is used instead of an Aardvark

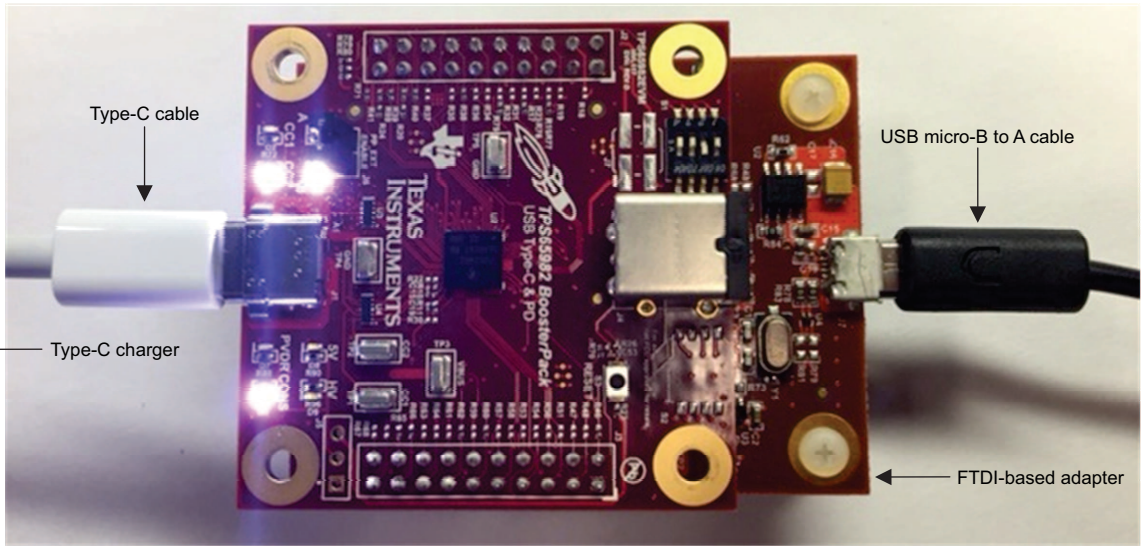


Figure 5. Charger System Set-Up

2.3 Use TPS6598x Utilities GUI to Obtain Capabilities

With the charger system step-up as described in Section 2.2, the utilities GUI can now interface with the TPS65982-EVM. Follow these steps to obtain the charger configuration settings:

Step 1. Open the TPS6598x Utilities GUI.

Step 2. Click *Configure* and set the configuration settings for Aardvark or FTDI, depending on the interface used to test (see Figure 6)

Step 3. Click *Test Configuration Settings* to verify successful connection. The register mode return value can be either APP or BOOT:

APP— EVM has FW

BOOT— EVM has no FW

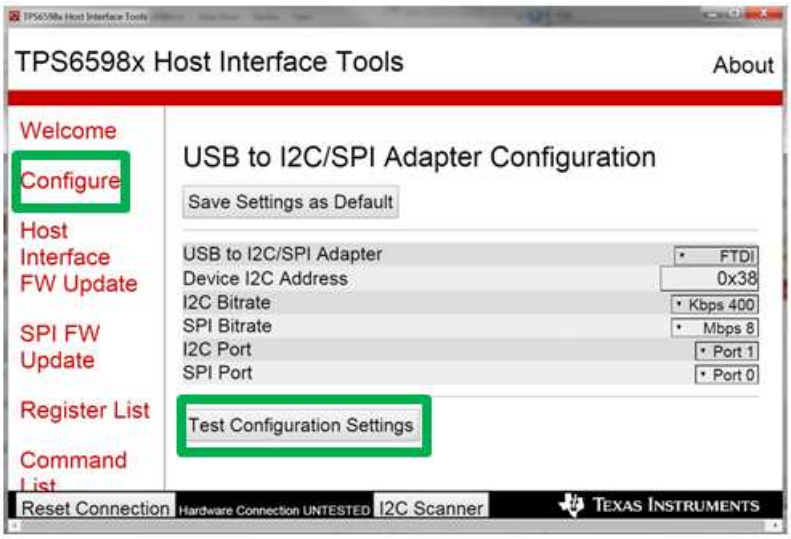


Figure 6. *Configure* **Tab in TPS6598x Utilities GUI**

Step 4. Click *Register List* to view various registers to obtain product information (see Figure 7).

Step 5. Click each register and record relevant information.

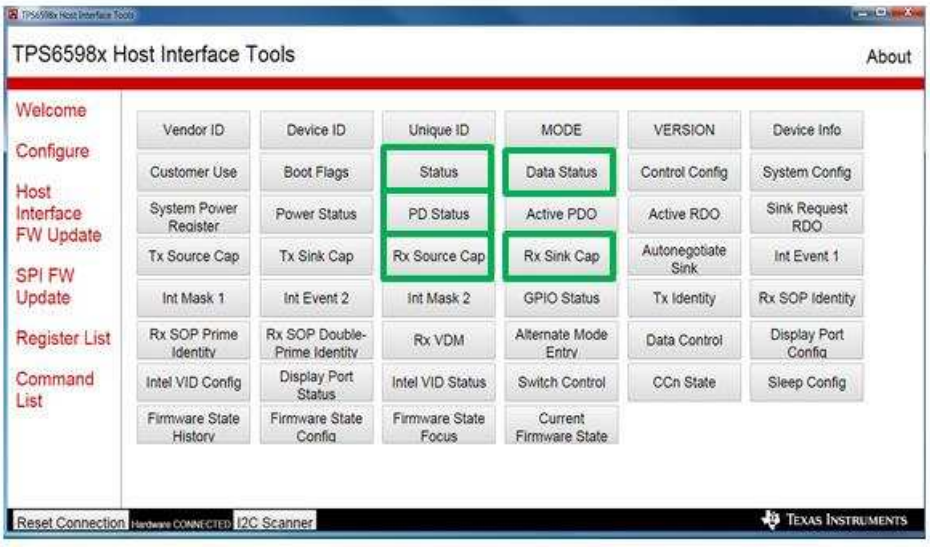


Figure 7. *Register List* **Tab in TPS6598x Utilities GUI**

2.3.1 Data Status Register

By clicking the *Data Status* register button, the user can view information regarding the types of data and the present Alternate Mode connections. As shown in Figure 4, the tablet EVM configuration supports USB2, USB3, DisplayPort, and Thunderbolt. Therefore, the status of the registers in this tab indicates the charger data capabilities. As expected, the register indicates that neither USB data nor Alternate Modes are supported.

DataConnection	connected
ConnectionOrient	Up side down
ActiveCable	Passive cable
Overcurrent	off
USB2Connection	disconnected
USB3Connection	disconnected
USB3Speed	USB Gen 1 (5 GBps)
DPConnection	False
DPPinAssignment	E/F
TBTConnection	False
TBT Cable Type	No Thunderbolt Connection
ForceLSX	False
TBT Gen1 (10 Gbps) support	0
TBT Gen2 (20 Gbps) support	0

Figure 8. Data Status Register

2.3.2 PD Status Register

The majority of the information in this register is referring to the tablet EVM configuration. However, the information is still useful for choosing the port type and CC pullup for Type-C current capability. The register indicates that the Type-C current is 1.5 A.

PlugDetails	USB type-C fully featured plug
CCPullUp	1.5A current
PortType	Consumer/Provider
PresentRole	Sink
SoftResetType	SoftResetType_None
HardResetType	HardReset_None

Figure 9. PD Status Register

2.3.3 Rx Source Cap Register

This register contains the Source PDOs that are advertised by the far-end PD controller (in the Type-C charger) via the C_CCx lines. Figure 10 shows the contents of the register, which indicate that the charger provides a fixed PDO of 5 V or 14.8 V. Because the charger is a DFP port only, the DRP tablet PD controller (TPS65982-EVM) advertises sink capabilities, and a PD contract is negotiated if possible.

numPDOs	2
PDO1: MaxCurrent or Power	2400 mA
PDO1: Min Voltage or Power	5000 mV
PDO1: Max Voltage	0 PeakCurrentType_100PercentIOC
PDO1: Supply Type	Fixed
PDO2: MaxCurrent or Power	2000 mA
PDO2: Min Voltage or Power	14800 mV
PDO2: Max Voltage	0 PeakCurrentType_100PercentIOC
PDO2: Supply Type	Fixed

Figure 10. Rx Source Cap Register

2.3.4 Rx Sink Cap Register

This register contains the Sink PDOs that are advertised by the far-end PD control (in the Type-C charger). As expected, no sink capabilities are present because chargers are intended to only provide power.

Figure 11. Rx Sink Cap Register

2.4 Create a Firmware Image Using TPS6598x Application Customization Tool

After obtaining the capabilities of the Type-C charger, the TPS6598x Application Customization Tool can be used to create a firmware image that can be loaded onto another TPS65982-EVM. The TPS6598x Application Customization Tool provides default templates that are to be used as a starting point for a user's application. For a Type-C charger, a suitable starting template is the downstream-facing port (DFP) only because it configures the port to only provide power.

Use these steps to create a firmware image using the TPS65982 Application Customization Tool:

Step 1. Open the TPS6598x Application Customization Tool using the desktop icon or start-menu shortcut.

Step 2. Click the *File* menu and then select *New Project*.

Step 3. Select the tps65982_nTBT_C_2_5.tpl file and then click the *Ok* button.

Step 4. Use the discovered Type-C charger capabilities and the *TPS65982 and TPS65986 Firmware User's Guide* to configure each page in the GUI. For more information, see Section 2.4.1 through Section 2.4.6.

Step 5. Click the *File* menu and then select *Save Binary*. Specify a file name and file location for each.

Full-Flash Image (.bin) — used for firmware update over SPI

Low-Region Image (.bin) — used for firmware update over I^2C

Step 6. Click the *File* menu and then select *Save Project*.

Step 7. Specify a file name (.pjt file type) and file location:

This file contains the binary image and file configurations for future modification

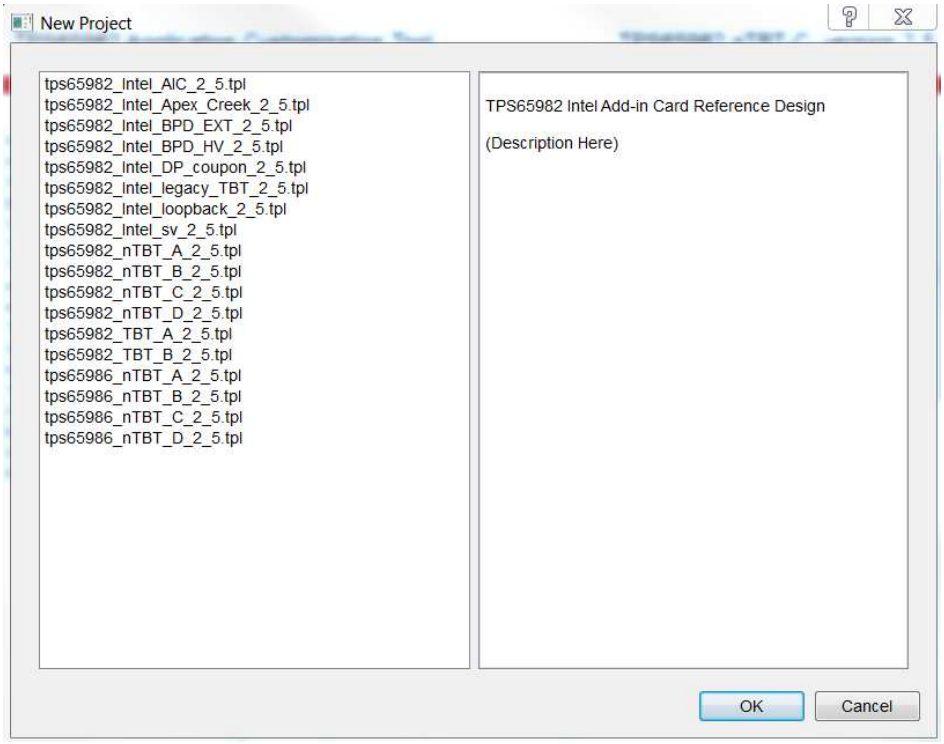


Figure 12. Load Defaults Page of TPS6598x Application Customization Tool

2.4.1 Source, Sink, and Autonegotiate Sink Capabilities

The source and sink capabilities can be directly set according to the charger capabilities found through the TPS6598x Utilities GUI. For this example, the PP_5V path was selected for the 5-V PDO and the PP_HV path was selected for the high voltage contract. The PP_EXT path could also be selected as the output path for the high-voltage contract, but it is not required because this application is less than 60 W.

Using the TPS65982-EVM, the hardware is limited to the 5-V, 12-V, and 20-V rails that exist, which means that the 14.8-V PDO described in Section 2.3.3 cannot be configured. To find an alternative-source PDO, an EVM (in Config ID 0) can be connected to a notebook or tablet on the market to learn the common sink capabilities. As shown in Figure 13, notebooks typically have a sink PDO that accepts the 12 to 20-V (up to 30 W) range. Most notebooks and tablets are configured this way to be compatible with a wide range of chargers. With this in mind, the second-source PDO will be configured at 12 V.

numPDOs	3
PDO1: MaxCurrent or Power	2400 mA
PDO1: Min Voltage or Power	5000 mV
PDO1: Max Voltage	0 PeakCurrentType_100PercentIOC
PDO1: Supply Type	Fixed
PDO2: MaxCurrent or Power	2000 mA
PDO2: Min Voltage or Power	14800 mV
PDO2: Max Voltage	0 PeakCurrentType_100PercentIOC
PDO2: Supply Type	Fixed
PDO3: MaxCurrent or Power	30000 mW
PDO3: Min Voltage or Power	10800 mV
PDO3: Max Voltage	20000 mV
PDO3: Supply Type	Battery

Figure 13. Rx Sink Cap (0x31) – Sink Capabilities of a Notebook

All data settings (USB capable, USB suspend supported) can be disabled because this port is not intended to support USB data. Autonegotiate sink functionality is not required because a charger is never a sink.

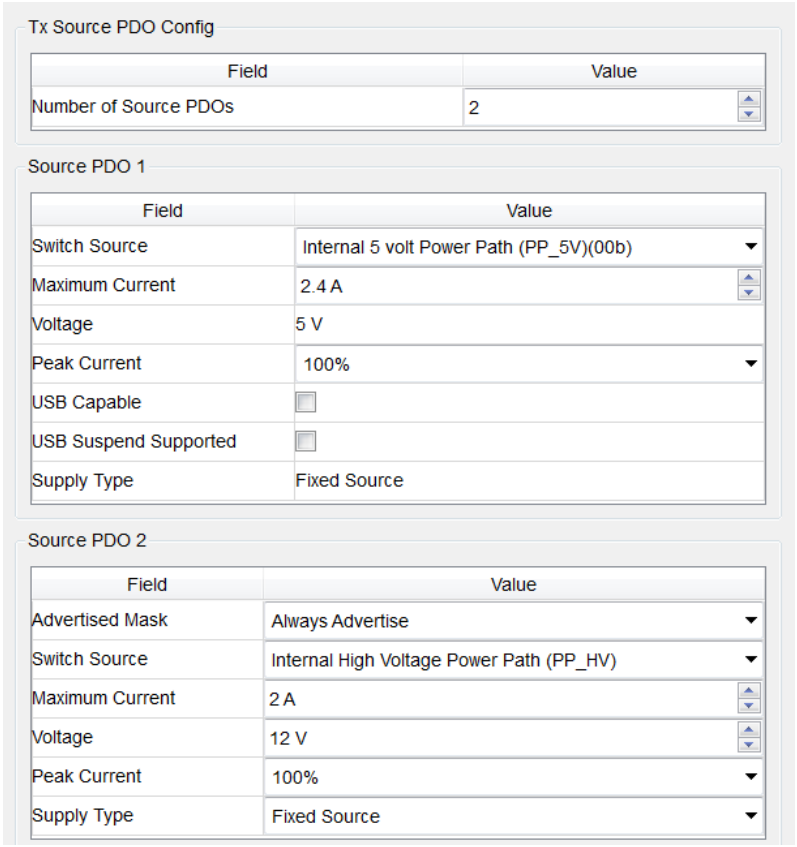


Figure 14. Transmit Source Capabilities (0x32)

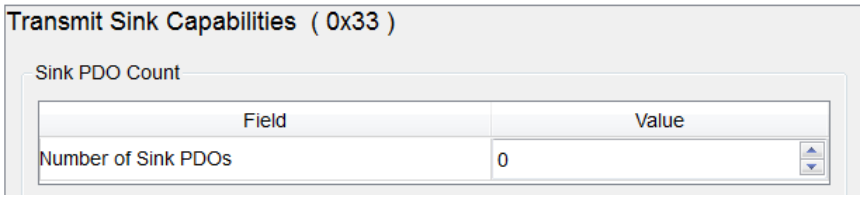


Figure 15. Transmit Sink Capabilities (0x33)

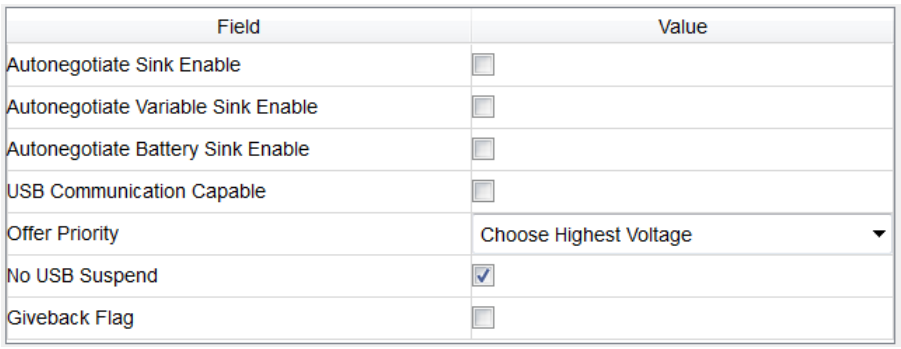


Figure 16. Autonegotiate Sink (0x37)

2.4.2 GPIO Mappings

Although GPIOs are not required to emulate a Type-C charger, they can be optionally configured to illuminate LEDs for demo and debugging purposes. The user should configure the used GPIO as shown in Table 1 and Figure 17 through Figure 19. All other configurable GPIOs can be left blank. The GPIO numbers were selected based on the routing to LEDs on the TPS65982-EVM. For more information, refer to *TPS65982 Evaluation Module*.

Table 1. GPIO Settings

GPIO	Event	Description	LED on EVM
3	Source PDO 0 Negotiated	This GPIO is driven high if Source PDO 0 (5-V contract) is negotiated	D8
7	Cable Orientation Event	This GPIO is driven high depending on the orientation of the connected Type-C cable	D2
14	Port Connected, CC1 Data Channel	This GPIO is driver high depending on the orientation of the connected Type-C cable. This is the inverse of the event mapped on GPIO 7.	D3
15	Source PDO 1 Negotiated	This GPIO is driven high is Source PDO 1 (12-V contract) is negotiated.	D9

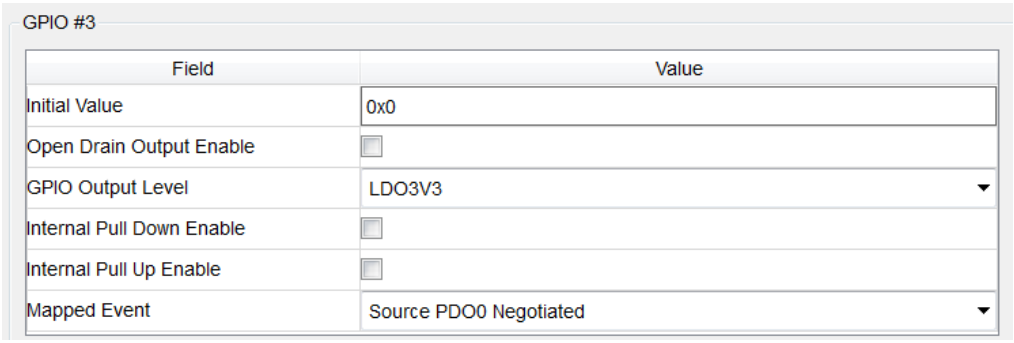


Figure 17. GPIO 3

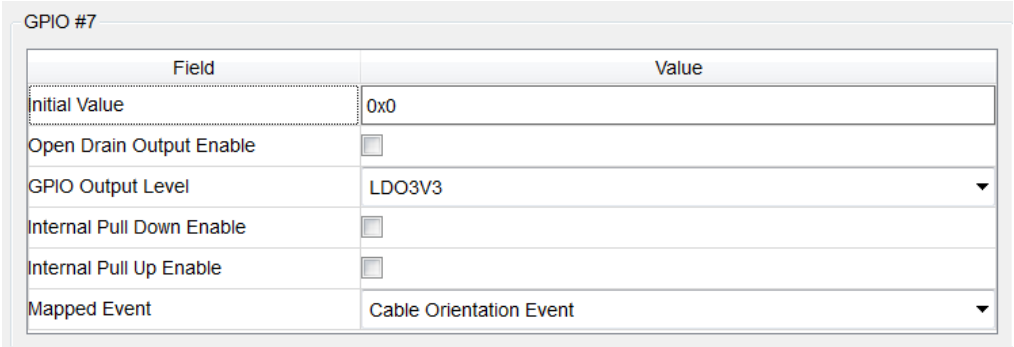


Figure 18. GPIO 7

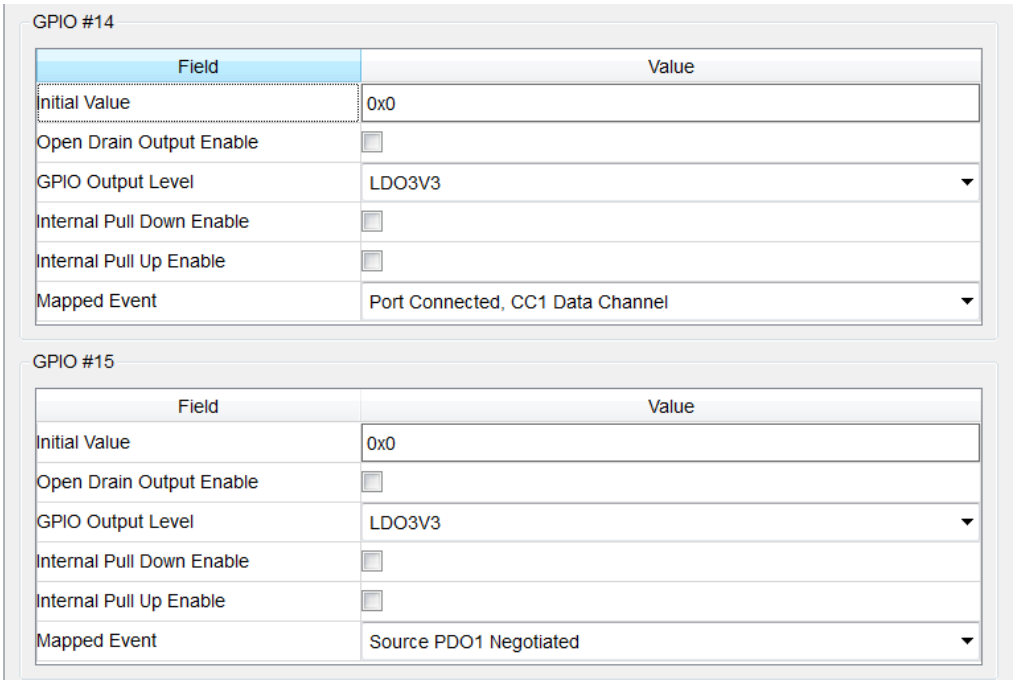


Figure 19. GPIOs 14-15

2.4.3 System Configurations

The *System Configurations* page allows the user to specify the desired port, data, accessory, and other capabilities. The port should be configured as a DFP pullup so that it is only capable of providing power. The Type-C current can be set to 1.5 A to match the pullup strength found with the TPS6598x Utilities GUI. All switches can be configured to be outputs because the device is not sinking power. All other accessory support can be disabled as shown in Figure 20.

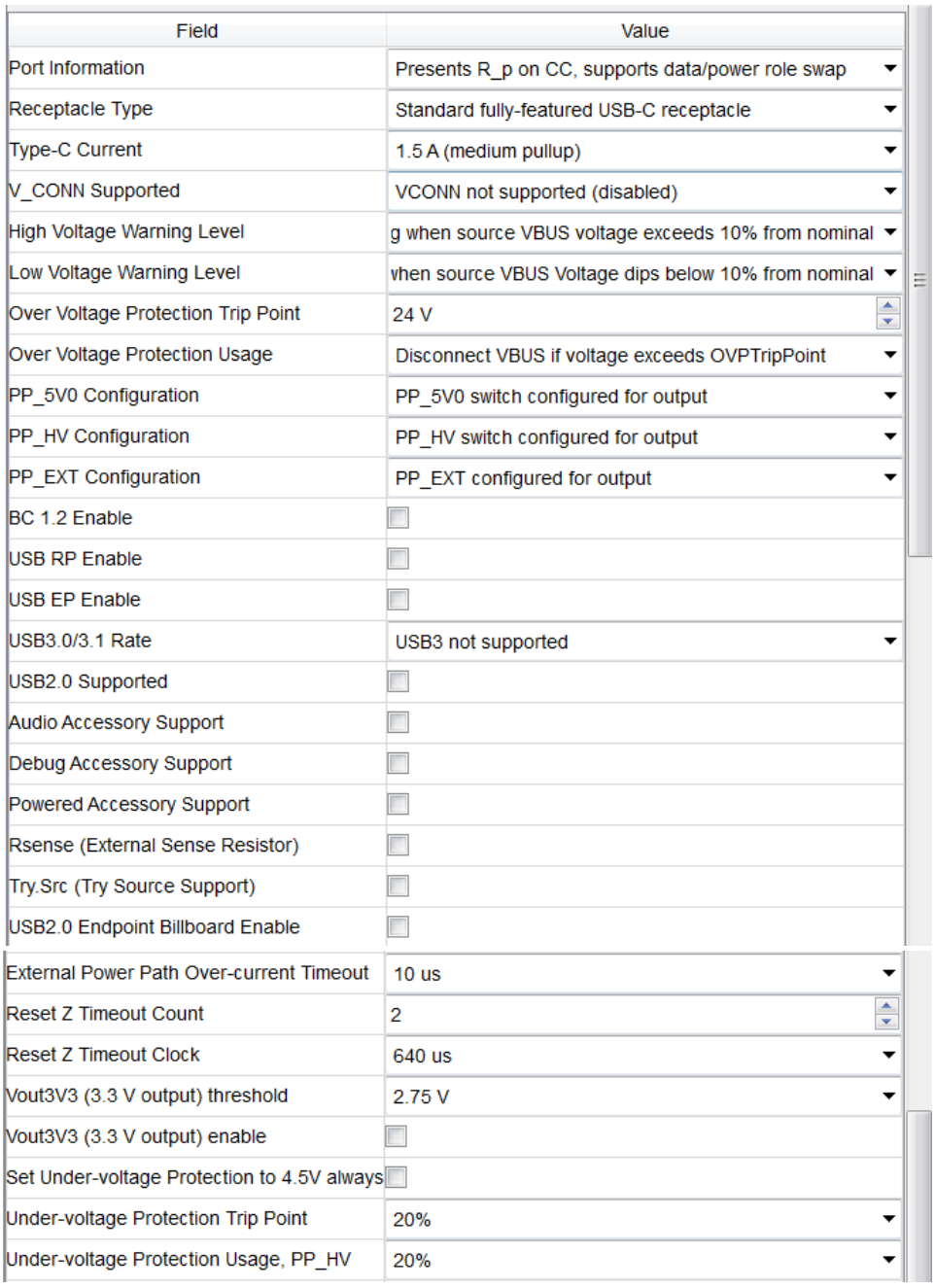


Figure 20. System Configurations

2.4.4 Control Configurations

The *Control Configurations* page allows the user to configure the types of role swaps that are initiated or permitted. A Type-C charger is intended to provide power only; therefore, the port must only be capable of swapping to source. In some applications, a data role swap is required so the tablet can request and receive authentication information. Therefore, *Initiate Swap to DFP* and *Process Swap to DFP* can also be enabled.

Field	Value
PD Mode	Normal PD Behavior
Externally Powered	☐
Process Swap To Sink	☐
Initiate Swap To Sink	☐
Process Swap To Source	☑
Initiate Swap To Source	☐
RDO Intrusive Mode	☐
PDO Intrusive Mode	☐
Process VCONN Swap	☐
Initiate VCONN Swap	☐
Process Swap to UFP	☐
Initiate Swap to UFP	☐
Process Swap to DFP	☑
Initiate Swap to DFP	☑
Automatic ID Request	☐
Intrusive Alternate Mode Support	☐
Force USB Generation 1	☐

Figure 21. Control Configuration (0x29)

2.4.5 Alternate Modes

The TPS6598x Utilities GUI showed that no Alternate Modes are required for this application. Therefore, the Alternate Mode settings and entry sequence can be disabled or cleared.

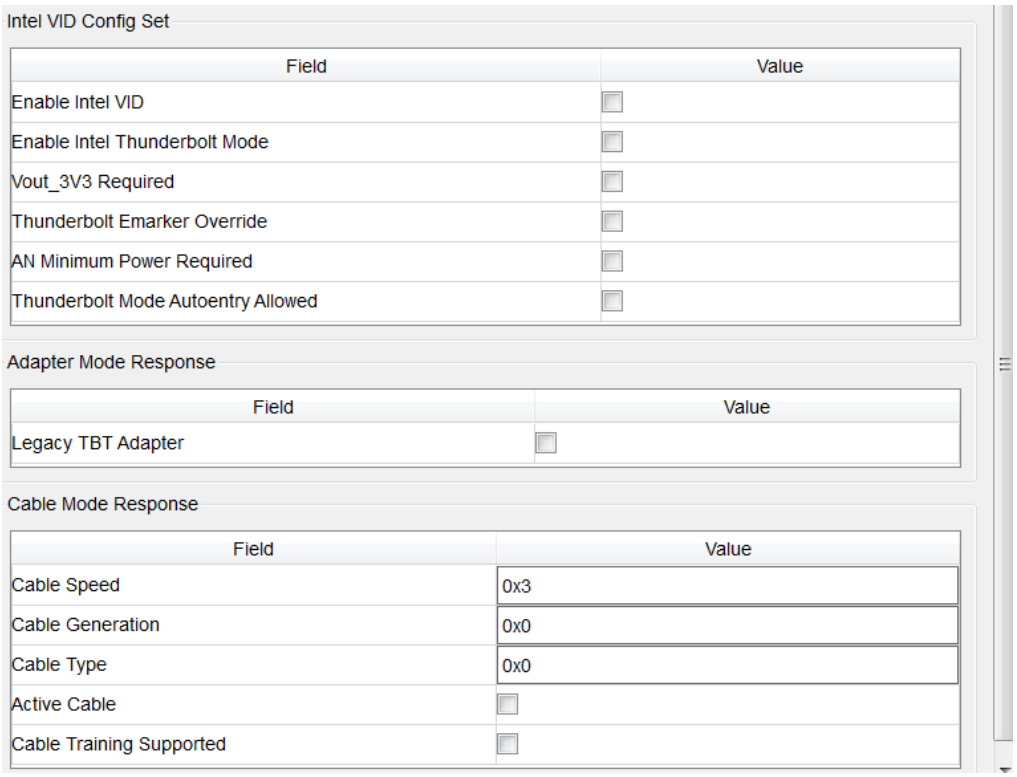


Figure 22. Intel VID Config Register (0x52)

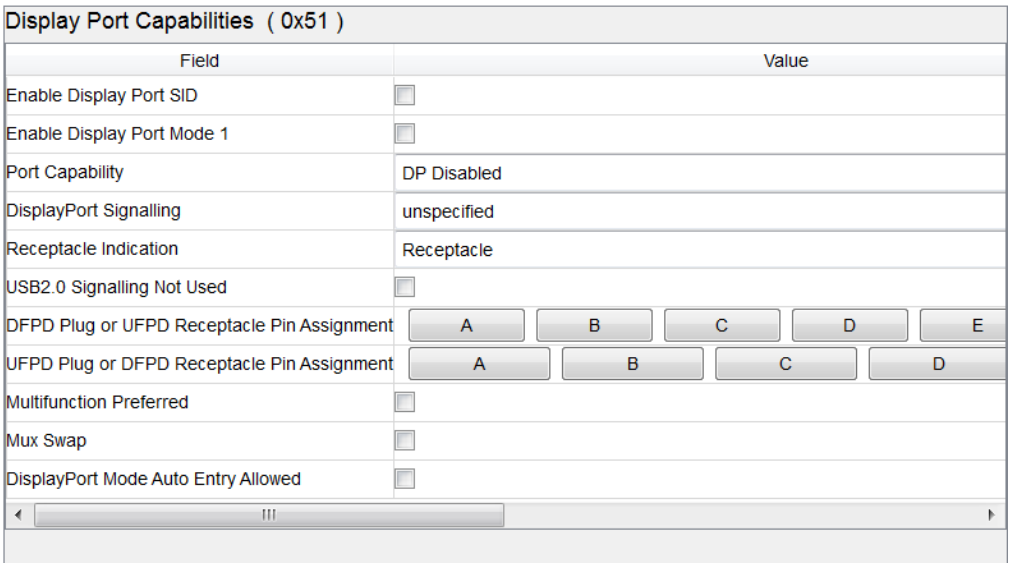


Figure 23. Display Port Capabilities (0x51)

Figure 24. Texas Instruments VID Config (0x54)

Alternate Mode Entry Queue record #1

Field	Value
SVID (Standard or Vendor ID)	0x0
Mode Number	0x0

Alternate Mode Entry Queue record #2

Field	Value
SVID (Standard or Vendor ID)	0x0
Mode Number	0x0

Alternate Mode Entry Queue record #3

Field	Value
SVID (Standard or Vendor ID)	0x0
Mode Number	0x0

Figure 25. Alternate Mode Entry Queue (0x38)

2.4.6 All Other Configuration Pages

All remaining configuration pages are not pertinent to this example and can remain with default settings. These pages include *Sleep Control Register*, *Interrupt Mask for I2C1*, *Interrupt Mask for I2C2*, *System Power State*, *Transmit Identity Data Object*, and *Miscellaneous Configuration*.

2.5 Load Firmware on to EVM to Create a Charger

The user has now created a firmware image that can be directly loaded onto a TPS65982-EVM using the TPS6598x Utilities GUI. This firmware enables the TPS65982-EVM to actually emulate the Type-C charger. Follow these steps to load the firmware image onto an EVM:

Step 1. Connect a second TPS65982-EVM to the Aardvark.

Step 2. Connect the barrel-jack charger to the TPS65982-EVM

Step 3. Connect the USB standard-B to -A cable from the Aardvark to a computer.

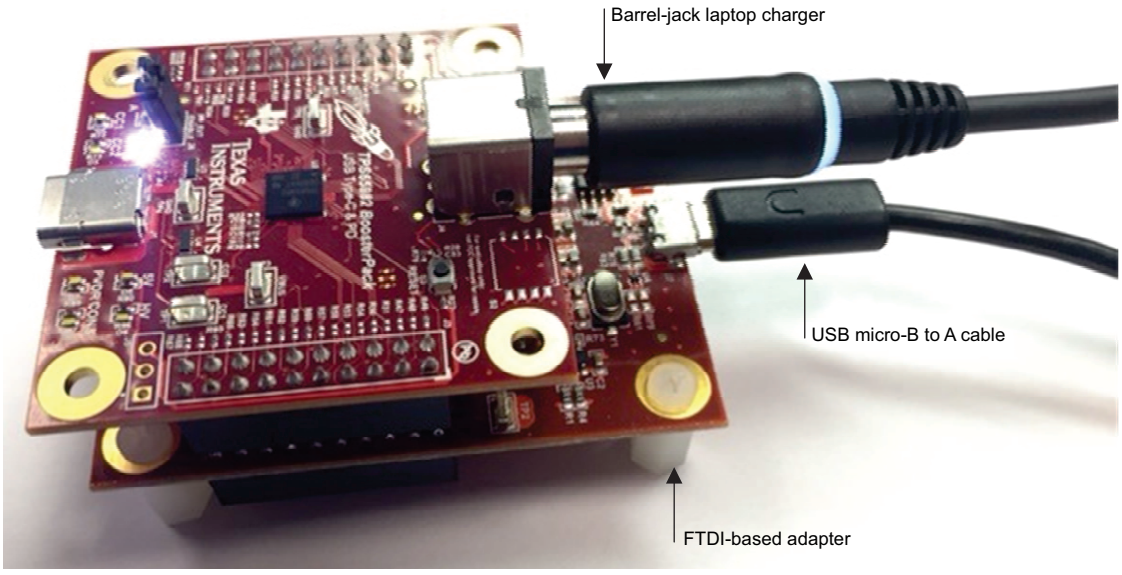


Figure 26. System Set-Up for Firmware Loading

Step 4. Open the TPS6598x Utilities GUI and click the *SPI FW Update* link.

Step 5. Click the *Choose File* button to load a full-flash FW image.

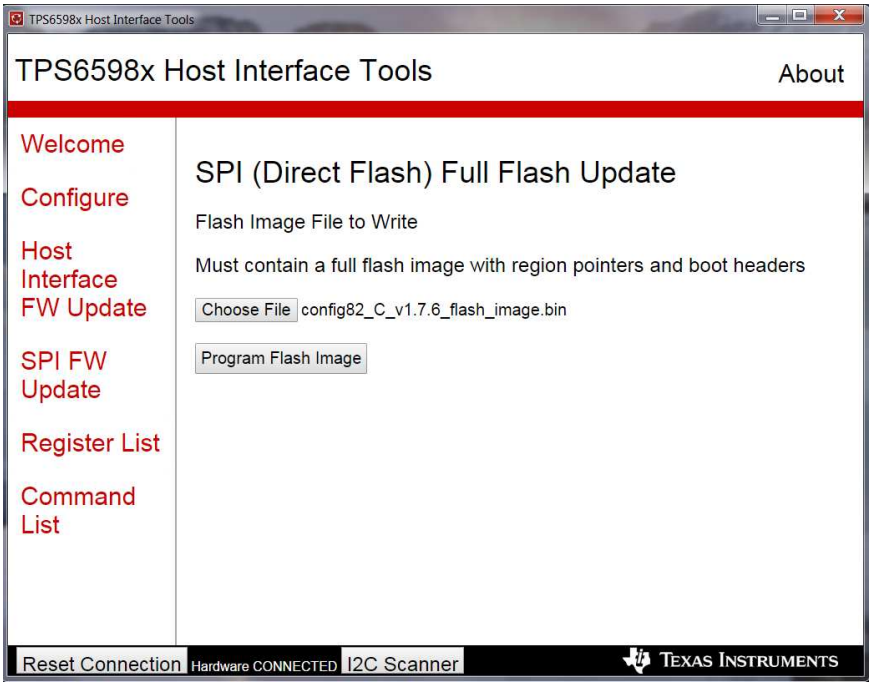


Figure 27. SPI FW Update on TPS65982 Utilities GUI

Step 6. Click the *Program Flash Image* button and wait for a successful firmware update.

Step 7. Power-cycle the EVM by pressing the reset button or disconnecting the power.

Step 8. (Optional) Check virtual registers in “Register List” page to confirm new capabilities

3 System Demo

After completing the procedure described in Section 2, the user now has an EVM that emulates a Type-C charger and an EVM that emulates a tablet. These EVMs can now be connected to demo the Type-C and PD system by following these steps:

Step 1. Connect the charger EVM to the Aardvark.

Step 2. Connect the barrel-jack to the charger EVM.

Step 3. Connect the tablet EVM to the charger EVM using a Type-C cable.

Step 4. Connect the USB standard-B to -A cable from the Aardvark to a computer.

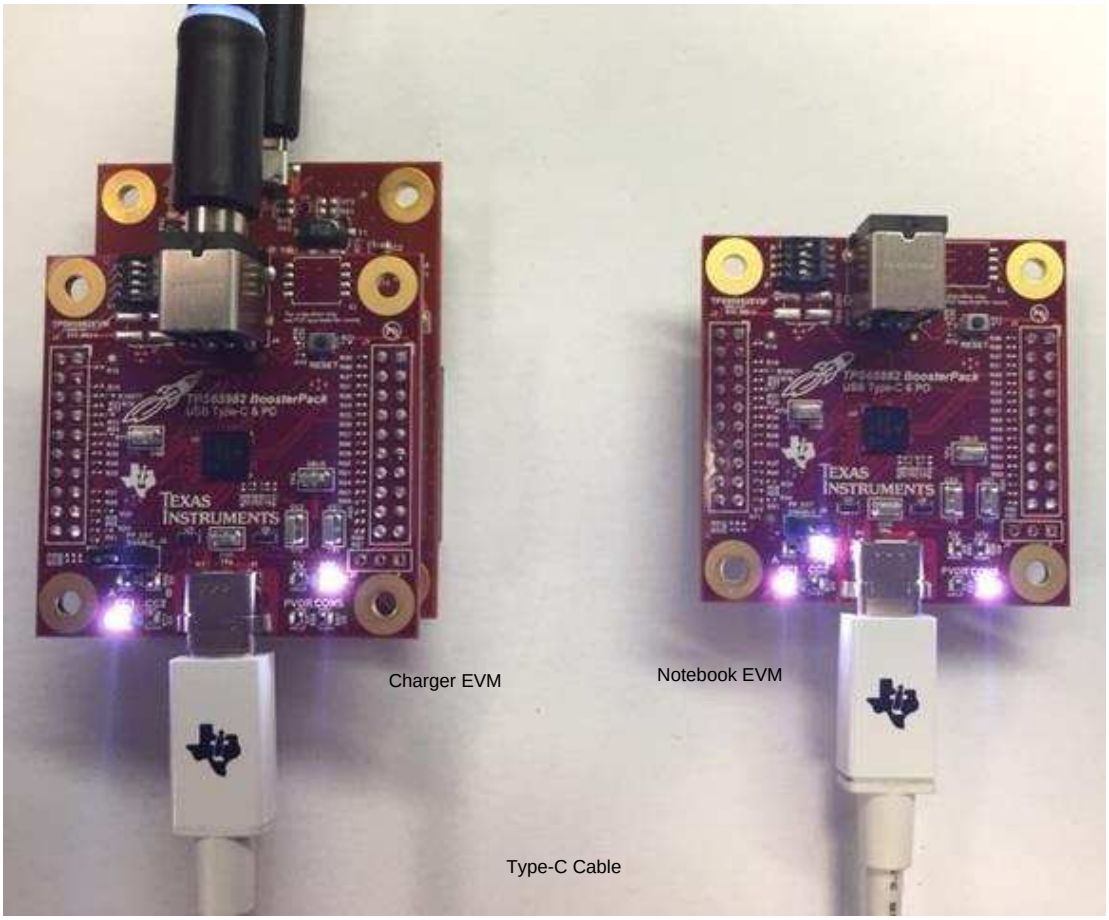


Figure 28. Type-C and PD System Demo

Step 5. View the LEDs on the charger EVM, which indicate the following events:

- Type-C cable is right-side up (using CC1)
- 12-V PD contract has been negotiated

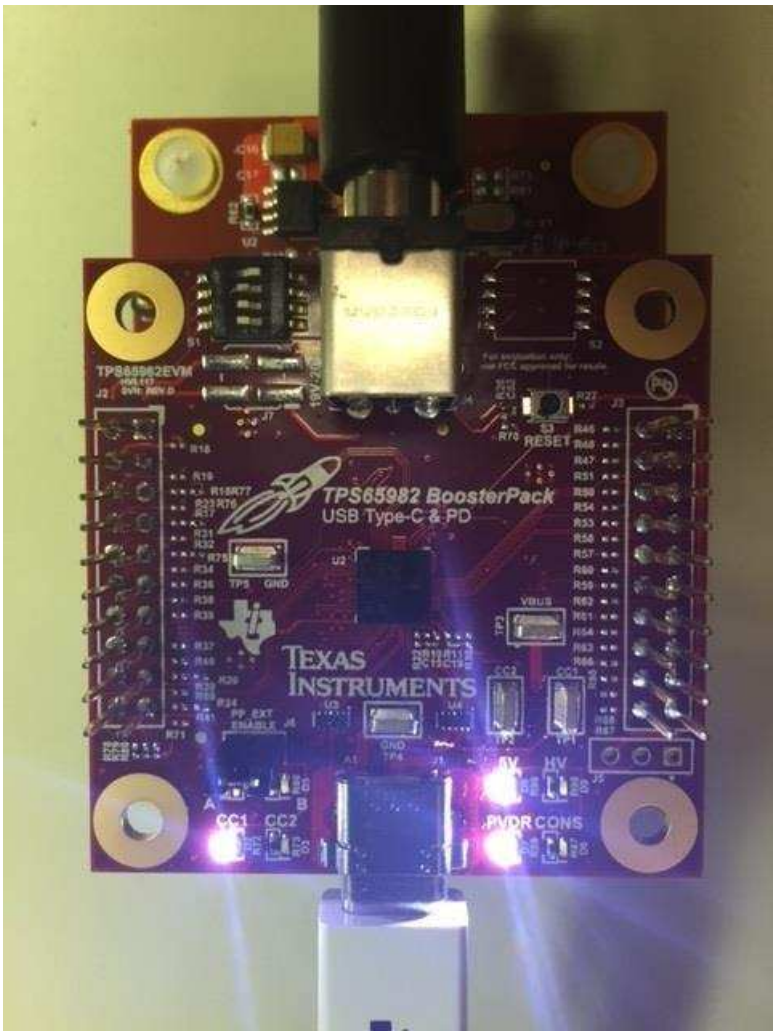


Figure 29. LED Indicators on the Charger EVM

Step 6. Open the TPS6598x Utilities GUI to verify system capabilities in the virtual registers

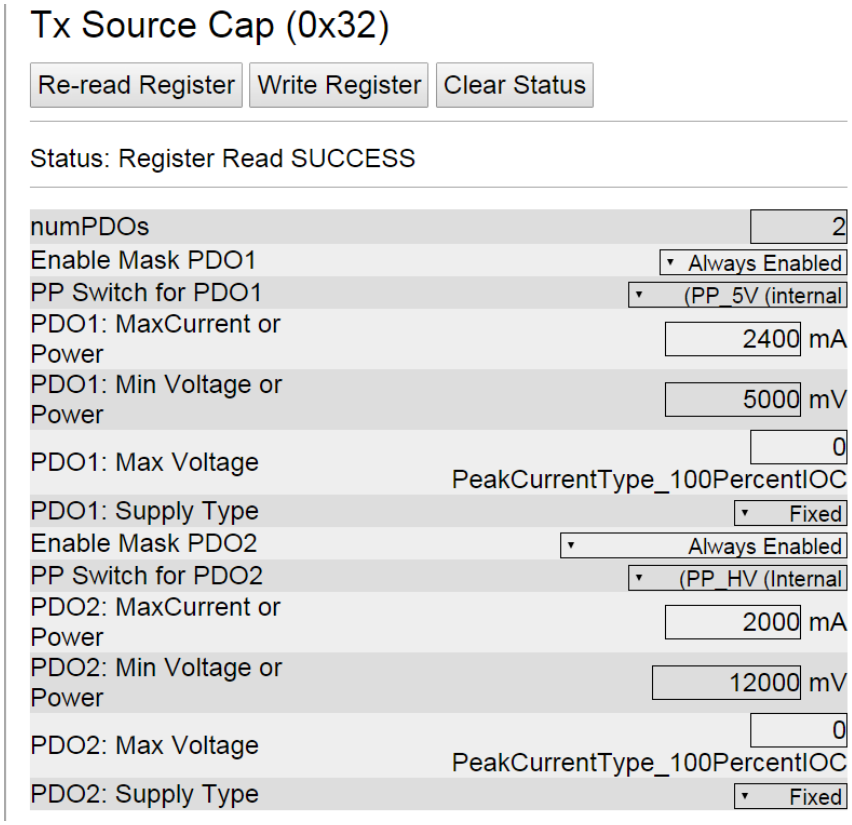


Figure 30. Tx Source Capabilities Register

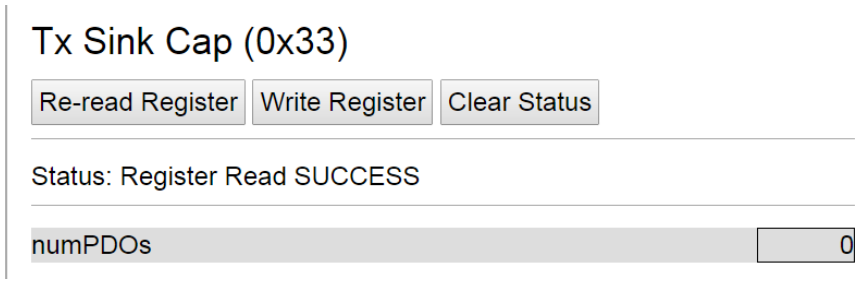


Figure 31. Tx Sink Capabilities Register

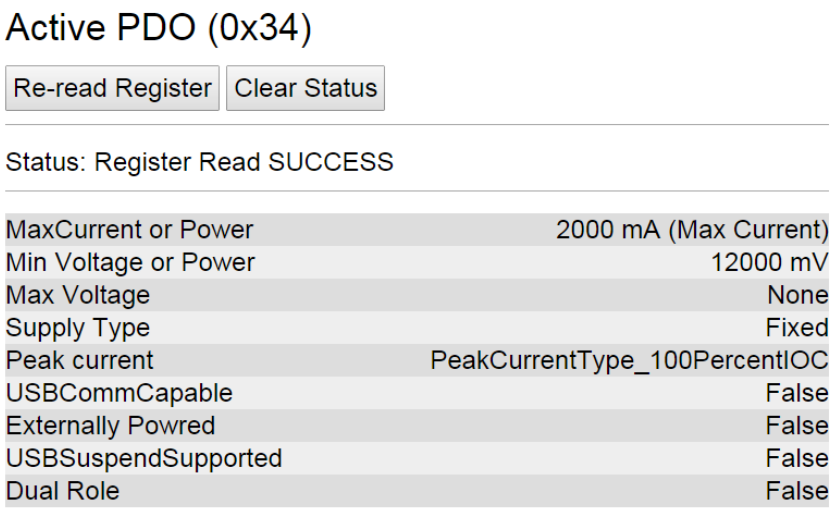


Figure 32. Active PDO Register

4 Conclusion

This application report describes the process of using TPS6598x EVMs to interface with and emulate a Type-C charger. The same process can be extended to any Type-C and PD product on the market, which can be very useful when developing a product with a Type-C interface. For example, a user developing a notebook can test compatibility to other products by creating firmware to emulate various applications (dongle, chargers, and others). This capability is very important in designs with Type-C receptacles or plugs because the range of products that can be connected.

Texas Instrument's portfolio of TPS6598x EVMs, reference designs, documentation, and support provide the tools necessary for development of a compatible and compliant Type-C and PD product. For any questions regarding TI's USB Type-C and Power Delivery solutions, go to TI's USB Forum (https://e2e.ti.com/support/interface/usb).

Revision History

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

Changes from Original (June 2016) to A Revision	Page
• Changed references to the *USB2MANY* board and replaced them with *Aardvark* or *FTDI-based adapter*	3

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