USB Power Delivery - Compliance Tests

ABSTRACT
The USB Power-Delivery Certification process requires all PD end-products using Texas Instruments’ TPS6598x to comply with the USB-IF’s deterministic and communication-engine MOI, in addition to various other load and signaling tests. This application report explains the setup of three extensively used USB-PD testers and configuration of the PD Vendor Information File as per the product’s PD features or capabilities.

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1 Introduction

The TPS6598x device is a standalone, USB Type-C™, power-delivery (PD) controller that provides cable-plug and orientation detection at the USB Type-C connector. Upon cable detection, the TPS6598x device communicates on the CC wire using the USB-PD protocol. After successfully completing USB-PD negotiation, the TPS6598x enables the appropriate power paths and configures alternate mode settings for internal and external (optional) multiplexers.

The device must comply with the USB-IF’s PD specifications and test plans, and there are various USB-PD testers or examiners that test the device’s compliance. This document describes the setup of three extensively used USB-PD testers and the execution of their various compliance test suites.

2 Getting Started - Ellisys®

Ellisys® USB Explorer 350 (EX350)™ is the comprehensive protocol test and analysis system for USB 3.1, USB 2.0, and USB PD. This section lists the instructions for setting up the tester, the unit under test (UUT), and the host and control system for executing the compliance tests.

2.1 Prerequisites

- Ellisys USB Explorer 350 protocol test and analysis system
- USB VIF generator
- TPS65982 BoosterPack™ EVM
- Aardvark I2C/SPI™ adapter
- PC running Microsoft® Windows® 7
2.2 Installation

Download and install the following drivers and tools if not yet installed on the Windows PC:

- Ellisys USB Explorer 350 examiner
- Ellisys USB Explorer 350 analyzer
  - This is optional and only required for collected PD logs.
- TPS6598x Configuration Tool
- TPS6598x Host Interface (HI) Utility Tool for the device type used for the tests (also available from the access controller secure site (1))

**NOTE:** This guide assumes that all TI tools are installed at location C:\Program Files\Texas Instruments.

2.3 Test Setup

2.3.1 Preparing the UUT for the Tests

If the service pack or application binaries are already programmed on TPS6598x EVM or customer’s platform, proceed to Section 2.3.2.

Launch the latest version of the TPS6598x Configuration tool and generate a test binary to be programmed on the UUT. See TPS6598x Application-Customization Tool User Guide for detailed instructions on generating the binaries and programming the same on the UUT.

2.3.2 Generating the Ellisys® Vendor Information File

*Vendor Information File* (VIF) defines the capabilities of the UUT and is a medium for the Ellisys tester application to detect the UUT and its properties. The tester uses this information to assign some of the tests and results. For example, if the UUT is configured to *not* accept any DR Swap to DFP requests, the tester will fail the corresponding test cases if the UUT accepts such a request. Also, the tester selectively includes or excludes the tests depending on the UUT’s capabilities.

Launch the *VIF Generator* tool for creating a VIF for the tests. The format of the VIF and information about its various fields are detailed in the VIF user guide (VIF-UG), which is part of the tool’s installer. This section briefly explains these fields, and relates them to TPS65982’s configurations and features:

**Intro Fields**

- *UUT_Device_Type:* This field defines the type of UUT, and a suitable or valid option must be set for the same depending on the device’s configuration. For example, if the *Port Information* field of the System Configuration register is set as Figure 1, the field in VIF must be set to 3 : Provider Only.

![Figure 1. Port Information - System Configuration (0x28) Register](image)

**Figure 1. Port Information - System Configuration (0x28) Register**

- Other fields in this tab define the vendor and product name or ID of the UUT. Refer the VIF-UG for details and fill these fields appropriately.

(1) Contact your TI representative to request access to the secure site.
General PD Fields

- **PD_Specification_Revision**: This field defines the version of the PD specification supported by the UUT. For example, TPS65982 is PD2 compliant, so this field must be set to 1: Revision 2.0.

- **USB_Comms_Capable**: This field is used by the tester to determine if the UUT is capable of USB communication. The field must be set to either YES or NO depending on the setting of USB Communication Capable bit of Autonegotiate Sink register. If this field is configured as YES, then one of its companion fields Type_C_Can_Act_As_Device or Type_C_Can_Act_As_Host in USB Type-C tab of VIF Generator tool will be set to YES.

![Figure 2. USB Communication Capability - Autonegotiate Sink (0x37) Register](image)

- **DR_Swap_To_DFP_Supported** and **DR_Swap_To_UFP_Supported**: These fields define the data-role swap capability of the UUT and must be set in accordance with the device's properties as defined in the Control Configuration register in Figure 3.

![Figure 3. Data Role Swap Capability - Control Configuration (0x29) Register](image)
- **Unconstrained_Power**: This field indicates the tester that the UUT has an external or uninterrupted source of power and must be set to either YES or NO depending on the device's properties as defined in the *Control Configuration* register in Figure 4.

![Figure 4. Externally Powered - Control Configuration (0x29) Register](image)

- **VCONN_Swap_To_On_Supported and VCONN_Swap_To_Off_Supported**: These fields define the VCONN swap capability of the device and both must be set to either YES or NO depending on the device's setting as defined in the *Control Configuration* register in Figure 5.

![Figure 5. VCONN Swap Capability - Control Configuration (0x29) Register](image)
- **Responds To Discov SOP** and **Attempts Discov SOP**: These fields define the ability of the device to respond or initiate a Discover Identity message respectively. **Responds To Discov SOP** must be set to **YES** if Transmit Identity Object register is set to a non-zero value as in Figure 6. **Attempts Discov SOP** must be set to **YES** if the device supports any **Alternate Modes**, or **NO** otherwise.

![Figure 6. Transmit Identity Data Object (0x47) Register](image)

- **SOP**: This section defines the capabilities of the device to handle the SOP protocol and must be set in accordance to the device’s properties. For TPS6598x, **SOP_Capable** and **SOP_P_Capable** must be set to **YES**.
Source Fields

- **PD_Power_as_Source**: This field defines the maximum PDP level in mW supported by the source-capable device and must be set per the settings in the Transmit Source Capabilities register. For example, if the device has two source PDOs as shown in Figure 7, this field will be set to \((3 \, \text{A} \times 12 \, \text{V}) = 36000 \, \text{mW}\).

![Figure 7. PD Power - Transmit Source Capabilities (0x32) Register](image)

- **USB_Suspend_May_Be_Cleared**: This field indicates the connected sink whether it must obey USB Suspend and must be set depending on the settings in Figure 8 in the Transmit Source Capabilities register. If the UUT (as a source) has **USB Suspend Supported** set to 0, then the VIF must set this field to **YES** or **NO** otherwise.

![Figure 8. USB Suspend Support - Transmit Source Capabilities (0x32) Register](image)
• **Num_Src_PDOs**: This field defines the number of source PDOs supported by the UUT and must be set in accordance to the device properties as defined in the Transmit Source Capabilities register in Figure 9.

![Figure 9. Total Source PDOs - Transmit Source Capabilities (0x32) Register](image)

• **Source PDOs**: The following fields represent the parameters for a single Source PDO where <X> is an integer between 1 and 7:
  - **Src_PDO_Supply_Type <X>**: This field defines the type of the source PDO and must be set to either 1: Fixed, 2: Battery, or 3: Variable depending on the settings in Figure 10 in the Transmit Source Capabilities register.

![Figure 10. Supply Type - Transmit Source Capabilities (0x32) Register](image)
– **Src_PDO_Peak_Current <X>:** This field defines the peak currents supported by the UUT for short periods and is indicated as a percent of the operating current. It must be set to one of the available options depending on the settings in Figure 11 in the Transmit Source Capabilities register.

![Figure 11. Peak Current - Transmit Source Capabilities (0x32) Register](image)

– **Src_PDO_Voltage <X>:** This field defines the output voltage of a source PDO in the units of 50 mV and must be set per the Figure 12 configuration in the Transmit Source Capabilities register. For example, for Figure 12 settings of PDO-1, this field must be set to 5000 mV / 50 mV = 100. The VIF Generator tool takes care of this conversion when generating the vendor information file.

![Figure 12. PDO Voltage - Transmit Source Capabilities (0x32) Register](image)

– **Src_PDO_Max_Current:** This field defines the maximum operating current of a source PDO in units of 10 mA and must be set per the Figure 13 configuration in the Transmit Source Capabilities register. For example, for Figure 13 settings of PDO-1, this field must be set to 3000 mA / 10 mA = 300. The VIF Generator tool takes care of this conversion when generating the vendor information file.

![Figure 13. Maximum PDO Current - Transmit Source Capabilities (0x32) Register](image)
– **Src_PDO_Min_Voltage <X>** and **Src_PDO_Max_Voltage <X>**: These fields define the minimum and maximum output voltage of a source PDO in units of 50 mV and must be set per the Figure 14 configuration in the *Transmit Source Capabilities* register. For example, for Figure 14 settings of PDO-2, these fields must be set to \( \frac{5000 \text{ mV}}{50 \text{ mV}} = 100 \) and \( \frac{12000 \text{ mV}}{50 \text{ mV}} = 240 \), respectively. The *VIF Generator* tool takes care of this conversion when generating the vendor information file.

![Figure 14. Minimum and Maximum Voltage - Transmit Source Capabilities (0x32) Register](image-url)
– **Src_PDO_Max_Power <X>:** This field defines the maximum operating power of a source PDO in units of 250 mW and must be set as per the Figure 15 configuration in the *Transmit Source Capabilities* register. For example, for Figure 15 settings of PDO-2, this field must be set to 75000 mW / 250 mW = 300. The *VIF Generator* tool takes care of this conversion when generating the vendor information file.

**Figure 15. Maximum PDO Power - Transmit Source Capabilities (0x32) Register**

**Sink Fields**

- **PD_Power_as_Sink:** This field defines the maximum PDP level in mW supported by the sink-capable device and must be set per the Figure 16 settings in the *Transmit Sink Capabilities* register. For example, if the device has two sink PDOs as shown in Figure 16, this field must be set to (3 A × 12 V) = 36000 mW.

**Figure 16. PD Power - Transmit Sink Capabilities (0x33) Register**
• **No_USB_Suspend_May_Be_Set**: This field indicates the sink device’s intent not to obey **USB Suspend** and must be set depending on the Figure 17 settings in the **Autonegotiate Sink** register. If the UUT (as a sink) has **No USB Suspend** set to 1, then the VIF must set this field to **YES** or **NO** otherwise.

![Figure 17. No USB Suspend - Autonegotiate Sink (0x37) Register](image)

• **GiveBack_May_Be_Set**: This field indicates if a sink is prepared to lower its operating current to its minimum supported operating current, on demand, and must be set depending on the Figure 18 settings in the **Autonegotiate Sink** register. If the UUT (as a sink) has **Giveback Flag** set to 1, then the VIF must set this field to **YES** or **NO** otherwise.

![Figure 18. Giveback Flag - Autonegotiate Sink (0x37) Register](image)

• **Higher_Capability_Set**: This field indicates that the sink requires more than vSafe5V to provide full functionality and must be set to **YES** if the UUT has more than one sink PDO.
• **Num_Snk_PDOs**: This field defines the number of sink PDOs supported by the UUT and must be set in accordance to the device properties as defined in the Transmit Sink Capabilities register in Figure 19.

![Figure 19. Total Sink PDOs - Transmit Sink Capabilities (0x33) Register](image)

• **Sink PDO**: The below fields represent the parameters for a single Sink PDO where <X> is an integer between 1 and 7:
  - **Snk_PDO_Supply_Type <X>**: The field defines the type of the sink PDO and must be set to either 1: Fixed, 2: Battery, or 3: Variable depending on the Figure 20 settings in Transmit Sink Capabilities register.

![Figure 20. Supply Type - Transmit Sink Capabilities (0x33) Register](image)
- **Snk_PDO_Voltage <X>**: This field defines the output voltage of a sink PDO in the units of 50 mV and must be set per the Figure 21 configuration in the Transmit Sink Capabilities register. For example, for Figure 21 settings of PDO-1, this field must be set to 5000 mV / 50 mV = 100. The VIF Generator tool takes care of this conversion when generating the vendor information file.

- **Snk_PDO_Op_Current <X>**: This field defines the operating current of a sink PDO in units of 10 mA and must be set per the Figure 21 configuration in Transmit Sink Capabilities register. For example, for Figure 21 settings of PDO-1, this field must be set to 900 mA / 10 mA = 90. The VIF Generator tool takes care of this conversion when generating the vendor information file.

![Figure 21. Operating Current and Voltage - Transmit Sink Capabilities (0x33) Register](image1)

- **Snk_PDO_Op_Power<X>**: This field defines the operating power of a sink PDO in units of 250 mW and must be set per the Figure 22 configuration in Transmit Sink Capabilities register. For example, for Figure 22 settings of PDO-2, this field must be set to 22500 mW / 250 mW = 90. The VIF Generator tool takes care of this conversion when generating the vendor information file.

![Figure 22. Operating Power - Transmit Sink Capabilities (0x33) Register](image2)
- **Snk(PDO) Min Voltage <X>** and **Snk(PDO) Max Voltage <X>**: These fields define the minimum and maximum voltage of a sink PDO in units of 50 mV and must be set per the Figure 23 configuration in **Transmit Sink Capabilities** register. For example, for Figure 23 settings of PDO-2, these fields must be set to \((12000 \text{ mV} / 50 \text{ mV}) = 240\) and \((20000 \text{ mV} / 50 \text{ mV}) = 400\), respectively. The **VIF Generator** tool takes care of this conversion when generating the vendor information file.

![Figure 23. Minimum and Maximum Voltage - Transmit Sink Capabilities (0x33) Register](image)

**Dual Role Fields**

- **Accepts_PR_Swap_As_Src** and **Accepts_PR_Swap_As_Snk**: These fields define the power-role swap capability of the device and must be set in accordance to the device properties as defined in the **Control Configuration** register in Figure 24.

![Figure 24. Power Swap Capabilities - Control Configuration (0x29) Register](image)

- **Requests_PR_Swap_As_Src** and **Requests_PR_Swap_As_Snk**: These fields define the ability of the device to request for power-role swaps and must be set in accordance to the device properties as defined in the **Control Configuration** register in Figure 25.

![Figure 25. Power Swap Capabilities - Control Configuration (0x29) Register](image)
SOP Discovery Fields

- The fields in *Part One* tab define the identity of the UUT and must be set in accordance with the Figure 26 configuration as defined in the Transmit Identity Data Object register. 
  *Data Capable as USB Host SOP* and *Data Capable as USB Device SOP*: These fields are automatically set by the tool depending on the corresponding settings in USB Type-C fields.

![Figure 26. Transmit Identity Data Object (0x47) Register](image)

- The *self-explanatory* fields in *Part Two* tab define the alternate modes supported by the UUT and must be set in accordance with the configurations in registers as indicated in Figure 27. VIF-UG has detailed description of these fields.

![Figure 27. Alternate Mode Configuration Registers](image)
USB Type-C Fields

- **Type_C_State_Machine**: This field indicates the type of Type-C state machine implemented on the UUT. For some of the configurations of UUT_Device_Type, this field is set automatically by the tool.

- **Rp_Value**: This field defines the Rp value that the UUT (as a source) will present upon a connection and must be set depending on the Figure 28 configuration in the System Configuration register.

![Figure 28. Type-C Current - System Configuration (0x28) Register](image)

- **Type_C_Implements_Try_SRC** and **Type_C_Implements_Try_SNK**: These fields define the ability of the UUT to support Try.SRC and Try.SNK state when transitioning out of AttachWait.SNK and AttacheWait.SRC respectively. Type_C_Implements_Try_SRC must be set in accordance with Figure 29 configuration in System Configuration register and Type_C_Implements_Try_SNK must be always set to NO for TPS6598x.

![Figure 29. Try.SRC Capability - System Configuration (0x28) Register](image)

- **Type_C_Is_Debug_Target_SRC**, **Type_C_Is_Debug_Target_SNK**, and **Type_C_Supports_Audio_Accessory**: These fields define the ability of the device to support Debug Accessory Mode and Audio Accessory Mode respectively and must be set per the Figure 30 configuration in the System Configuration register.

![Figure 30. Accessory Support - System Configuration (0x28) Register](image)

**NOTE:** Some device variants do not have support for the accessory modes. Contact your TI representative for more details.
• **Type_C_Sources_VCONN and Type_C_Supports_VCONN_PoweredAccessory**: These fields indicate whether the UUT sources VCONN and supports communication with a VCONN powered accessory and must be set per the configuration in the **System Configuration** register. These fields are automatically set by the tool if **VCONN_Swap_To_XXX** is set as **YES** in **General PD Settings** tab.

![Figure 31. VCONN Support - System Configuration (0x28) Register](image)

• **Type_C_BC_1_2_Support**: This field indicates whether the UUT supports **USB Battery Charging v1.2** and must be set per the **Figure 32** configuration in the **System Configuration** register.

![Figure 32. BC1.2 Support - System Configuration (0x28) Register](image)

• **Type_C_Can_Act_As_Host and Type_C_Can_Act_As_Device**: These fields indicate whether the UUT can communicate with USB 2.0 or USB 3.1 as a host or device respectively and must be set per the **Figure 33** configuration in the **Transmit Identity Data Object** register.

![Figure 33. Test Equipment and UUT Connections](image)
• **Type_C_Host_Speed** and **Type_C_Device_Speed**: These fields indicate which USB speed is supported when communicating as a host or a device respectively.

![Figure 34. Data Capability as USB Device and Host - Transmit Identity (0x47) Register](image)

*Type_C_Is_Alt_Mode_Controller* and *Type_C_Is_Alt_Mode_Device*: These fields indicate whether the UUT is capable to act as an **Alternate Mode Controller** or **Alternate Mode Device** respectively and must be set to **YES** if the device supports alternate modes.

### 2.3.3 Connection and Test Execution

Connect the test-equipment and UUT to the PC as shown in **Figure 35**.

![Figure 35. Ellisys® Examiner and UUT - Connection Diagram](image)

1. Connect the test equipment to the Windows PC.
2. Launch the tester GUI, and select the tests that are to be executed.
3. Upload the VIF that was created in above, and run the selected tests.
4. After the tests are completed, the results can be found under **Results** tab.

**Figure 37. Vendor Information File - Ellisys® Examiner**
Figure 38. Test Results - Ellisys® Examiner
2.3.4 Notes and Known Issues

- Some PD test-cases like TD.4.10.3 require the UUT to have the USB EP or Billboard capabilities and might fail if these features are not enabled in the device’s System Configuration register.

![Figure 39. USB EP Capability - System Configuration (0x28) Register](image)

- Sometimes the tester incorrectly responds to the DR-Swap requests of the UUT. This may cause some PD test cases like TD.4.10.2 and TD.PD.VNDI.E10 to fail if the device is configured to initiate such requests.

![Figure 40. Initiating Data Role Swaps - System Configuration (0x28) Register](image)

- Some tests like TD.PD.VNDI.E4 SOP* might fail if SOP_P_Capable is set to YES in VIF because the tester wrongly marks the test case as Failed if the tester does not detect a Good-CRC from the UUT, and instead the tester must have checked if the device sent any VDM response as against the set configuration for this particular test-case. Though TPS65982 supports SOP’ and SOP” handling, the device monitors messages from plug only when expecting a response.

3 Getting Started – GRL

*This section will be updated in a future revision.*

4 Getting Started – MQP

*This section will be updated in a future revision.*
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