TPS6598x User Alternate Modes

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ABSTRACT

User Alternate Modes allow the developer of a USB Type-C Power Delivery system to define custom Alternate Modes to extend the functionality of the connection. This document describes the procedure for configuring a User Alternate Mode using a Texas Instruments TPS6598x USB Type-C/PD Controller and associated software tools. If enabled, a custom Vendor ID (VID) will be added to the list of supported SVIDS for the device and the mode will be available to enter upon connection, provided the devices at both ends are capable.

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1 Introduction

The User Alternate mode allows users to configure an arbitrary SVID with up to four independently configurable mode numbers. If enabled, this custom SVID is added to the list of supported SVIDs used to respond to a *Discover SVIDs* command and the modes will be entered, assuming that the SVID and mode numbers configured are also supported by the far-end device.

The User Alternate mode can be used either with or without an external microcontroller. Without an external microcontroller, the capabilities of the User Alternate mode are limited to entering the mode, optionally sending a predefined structured or unstructured VDM upon entry, and optionally reconfiguring the TPS6598x PD controller and executing up to two host interface commands upon mode entry.

The ability to send a predefined structured or unstructured VDM upon mode entry is generally used to advertise an identity. For instance, vendors can define a custom alternate mode used to communicate between supported power supplies and devices. A power supply that does not contain an external microcontroller could configure the TPS6598x PD controller to automatically send an unstructured VDM, advertising information about the power supply such as the model number, revision, serial number, and other information.

The ability to reconfigure the TPS6598x PD controller allows modification of any of the configuration registers of the host interface upon mode entry without an external microcontroller. This ability can be used, for instance, to modify the power sourcing and sinking capabilities of the PD port when recognized and supported devices are attached. After reconfiguration of host interface registers, up to two host interface commands can be executed. These commands can be used to drive a GPIO, to force a renegotiation of the power contract, or even to issue a data role or power role swap.

The primary limitation of the User Alternate mode when used without an external microcontroller is that it lacks decision-making capability. The User Alternate mode can be configured to send an arbitrary message or to change the capabilities of the TPS6598x PD port, but this is a static configuration that is based only on mode entry and exit. With the addition of an external microcontroller the capabilities of the User Alternate mode are greatly extended.

2 User Alternate Mode Host Interface Registers

- Configuration registers:
  - 0x4A, User Alternate Mode Configuration Register
  - 0x5E, Miscellaneous Configuration Register (If reconfiguring on mode entry)
- Status registers:
  - 0x57, User Alternate Mode Status Register
- Run-time registers (if using external microcontroller):
  - 0x14, Interrupt Event Register 1
  - 0x15, Interrupt Event Register 2
  - 0x16, Interrupt Mask Register 1
  - 0x17, Interrupt Mask Register 2
  - 0x60, Rx User SVID Attention VDM
  - 0x61, Rx User SVID Non-attention VDM

The User Alternate mode is configured using the User Alternate Mode Configuration Register (0x4a). If the user is enabling the User Alternate mode to reconfigure the TPS6598x PD Port Behavior or to issue Host Interface commands upon mode entry, then these capabilities are set in the Miscellaneous Configuration register (0x5e).

Register 0x57 provides status information for the User Alternate mode. This can be used for debugging or may be used by an external microcontroller for decision making at runtime.

Finally, the TPS6598x PD controller will store the last attention VDM and last nonattention VDM received in registers 0x60 and 0x61. These registers can be used by an external microcontroller to extend the capabilities of the User Alternate mode. The interrupt registers (0x14 through 0x17) can be configured to generate an interrupt to the external microcontroller whenever a new attention or nonattention VDM is received on the user SVID channel. These last attention and last non-attention received registers are dedicated to the User Alternate mode so that they cannot be overwritten by communication of other alternate modes such as DisplayPort or PDIO, which may be running concurrently.

3   User Alternate Mode Example

The TPS6598x Configuration Tool contains an example project for testing the User Alternate mode. The project template is named *TPS65982_appConfigUserAM_2_9.tpl* and it can be accessed selecting *New Project* from the *Project* drop-down menu selection of the configuration GUI.
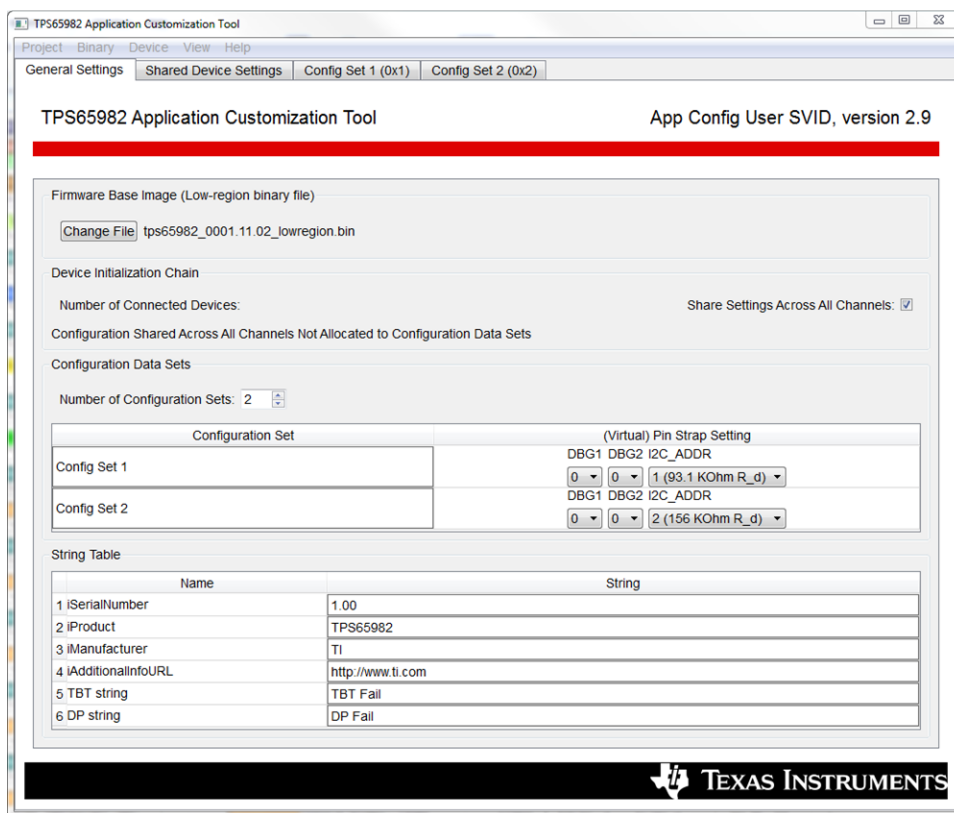

Figure 1. *TPS65982_appConfigUserAM_2_8.tpl* **General Settings Tab**

Figure 1 shows the *General Settings* tab for the TPS65982_appConfigUserAM_2_8.tpl example. This example uses three configuration sets, which are displayed in the three tabs following the *General Settings* tab. These three configuration sets are on the *Shared Device Settings* tab, the *Config Set 1 (0x1)* tab, and the *Config Set 2 (0x2)* tab.

The *Shared Device Settings* tab is used to configure the TPS65982 initialization parameters. Because the *Share Settings Across All Channels* box has been selected (checked) on the *General Settings* tab, this single configuration can be used to configure multiple devices (such as a boot primary and a boot secondary that share a single flash.) This initialization will configure any device whose pin strapping does not match one of the virtual pin strappings selected for the two configuration data sets. If the *Share Settings Across All Channels* box is deselected (unchecked), entry points will appear that allow the user to select the number of devices in the boot chain and the pin strapping for each device. This selecting is required for the user to configure multiple devices and use different initialization parameters for each.

The *Config Set 1 (0x1)* and *Config Set 2 (0x2)* tabs are used to reconfigure the TPS65982 parameters upon entering and exiting User Alternate mode, respectively. The mapping of a configuration set to an event is specified in the Miscellaneous Configuration Register, 0x5e. For more information see Section 5.

> **NOTE:** Note the *(Virtual) Pin Strap Setting* column that appears on the right side of the configuration set table on the *General Settings* tab. These configuration sets do not have pin strapping because they do not correspond to the configuration of a physical device. Nonetheless, the configuration sets require a unique identifier. Therefore, a *virtual* pin strapping is used to identify the configuration. The only requirement of the 5 bits selected for this virtual pin strapping is that the virtual strapping used for the configuration set does not match the physical pin strapping of a physical device in the system, otherwise the configuration set will conflict with the initialization parameters of that device.

The TPS65982 EVM for which this example is configured has the following pin strapping: the DBG1, DBG2, and I2C_ADDR pins are grounded. This pin strapping corresponds to a 5-bit identifier of 00000b. The virtual strapping for configuration sets 1 and 2 could use any virtual pin strapping that does not exactly match this physical device. For simplicity, the next two possible 5-bit identifiers were used, 00001b and 00010b, corresponding to I2C_ADDR strappings as shown.

> **NOTE:** The I2C_ADDR pin may be strapped with various pulldown resistors and generates a 3-bit identifier.

For more information on the three configuration tabs see Section 5. The example can be evaluated by loading the same project onto two TPS65982 EVMs using the *Flash App Firmware to Device* option from the *Device* menu in the GUI.

> **NOTE:** This step must be performed twice, once for each EVMs. After flashing the EVM, the board should be power cycled or reset using the reset pushbutton to force a load of the newly flashed firmware, otherwise the previous image will continue to execute from RAM.

The PD message trace shown in Figure 2 was taken with a Teledyne LeCroy PD analyzer between two TPS65982 EVMs, each loaded with the *TPS65982_appConfigUserAM_2_8.tpl* example.
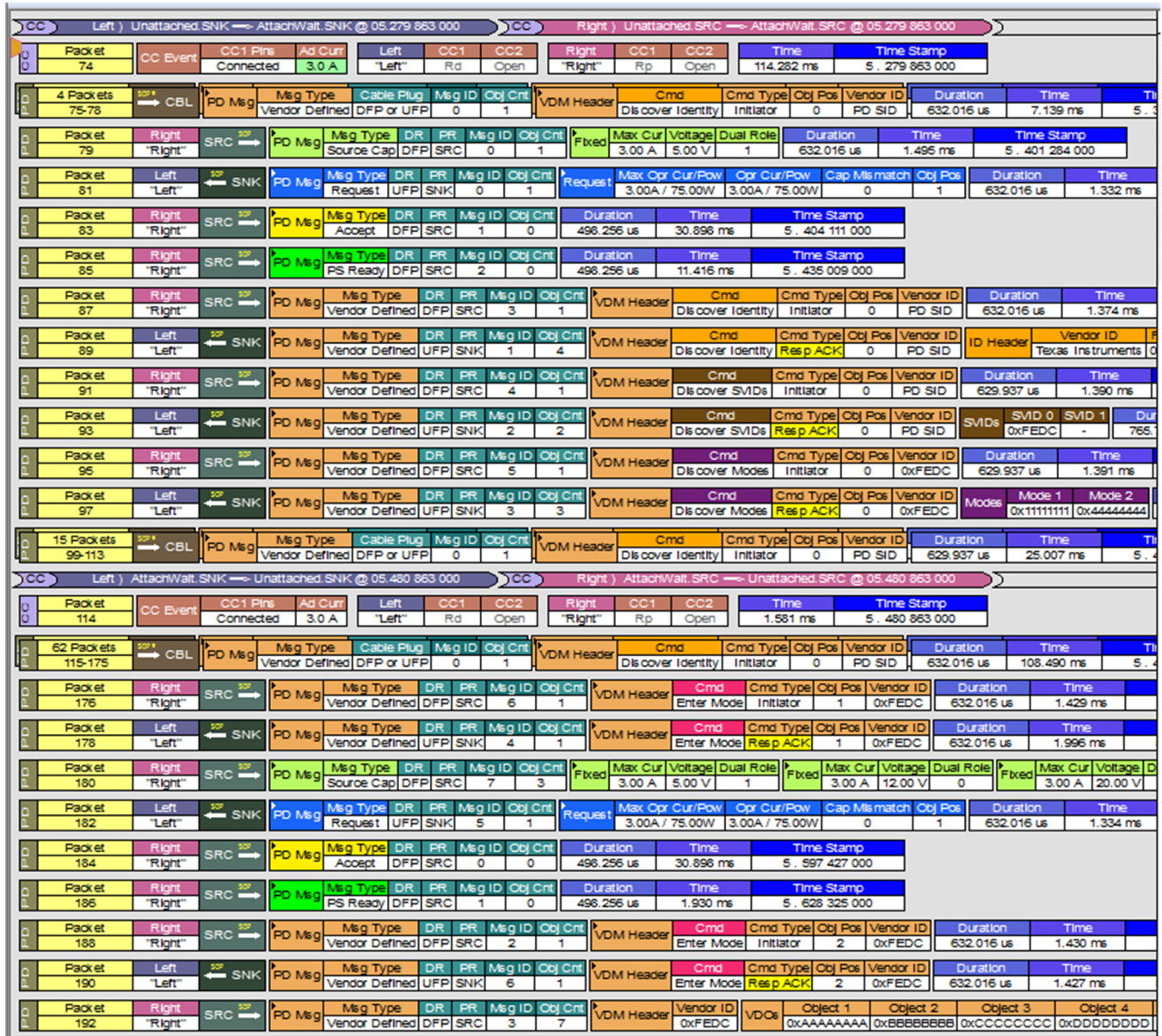
Figure 2. User Alternate Mode Full PD Trace

Figure 2 shows the expected sequence of PD operations for this example:

1. Packets 75–78: The DFP makes a discover identity request to the cable. Because a cable that is not e-marked was used in this example, no response is returned.
2. Packets 79–85: The PD power contract is negotiated. For an explanation of the configuration of this stage of PD negotiation see Section 4.
3. Packets 87–89: The DFP makes a discover identity request and the identity of the UFP is returned. for an explanation of the configuration of this stage of PD negotiation see Section 7.
4. Packets 91–97: The DFP discovers all supported SVIDs and Modes, which for this example are the user SVID of 0xFEDC (currently unassigned by USB-IF), modes 0x11111111 and 0x44444444. This interaction is described at length in Section 4.
5. Packets 99–175: The DFP attempts again to discover the identity of the cable. This is the first step in a sequence that would discover the SVIDs and modes supported by the cable if the cable were e-marked.

6. Packets 176–186: The user SVID mode at position 1 (0x11111111) is entered. Immediately after entering the alternate mode a new set of source capabilities is sent and a new PD contract is made. This interaction is described at length in Section 4.

7. Packets 188–192: The user SVID mode at position 2 (0x44444444) is entered. Immediately after entering the alternate mode, an unstructured VDM is sent. This interaction is described at length in Section 4.

4   Basic Configuration of the User Alternate Mode

The basic configuration of the User Alternate mode is handled in the User Alternate Mode Configuration Register (0x4A).
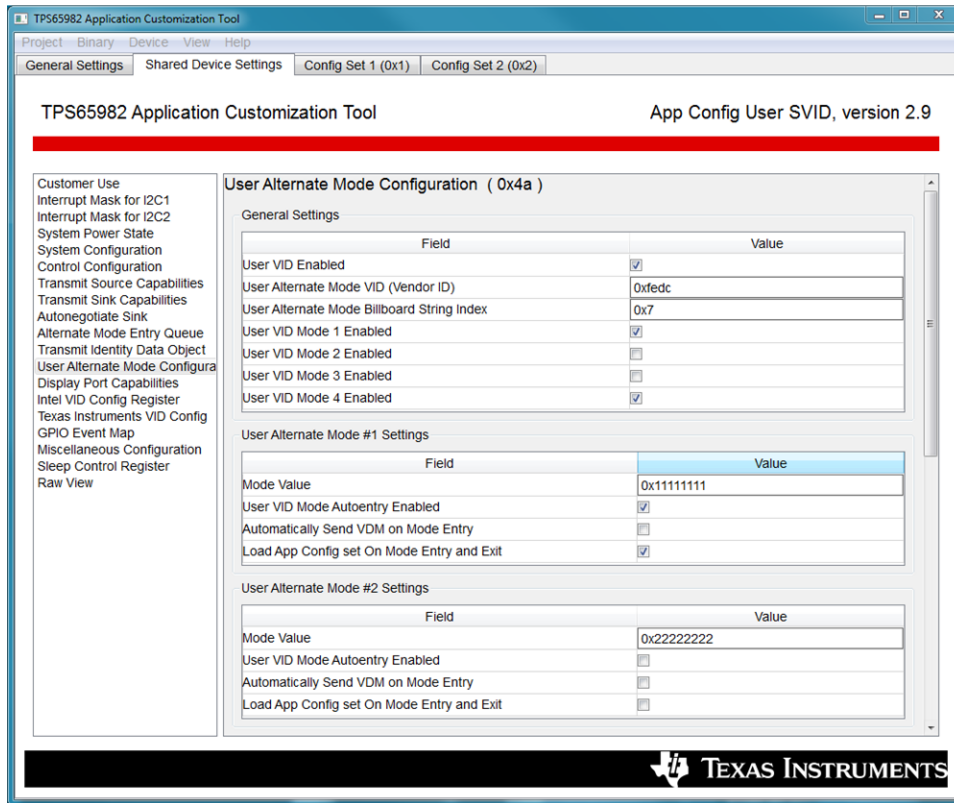

Figure 3. User Alternate Mode Configuration Register, Part 1

In the *Shared Device Settings* section of this register, as shown in Figure 3, the user VID is enabled, and the vendor ID is configured as 0xFEDC. Configuration of these two items enables the TPS65982 PD controller to respond with SVID 0xFEDC to the discover SVIDs request of the far end, shown in Figure 4 (packets 91 and 93 of Figure 2).

Figure 4. PD Trace Highlighting *Discover SVIDs* **Messages**

Also under the *Shared Device Settings* section, modes 1 and 4 are enabled, and modes 2 and 3 are disabled. Under the *User Alternate Mode #1 Settings* section, mode 1 is configured with the mode value 0x11111111, auto-entry is enabled, and it is configured to load an application configuration set upon mode entry and exit.

Under the *User Alternate Mode #4 Settings* section, mode 4 is configured with the mode value 0x44444444 and this mode is configured to *Automatically Send VDM on Mode Entry* (shown in Figure 5).
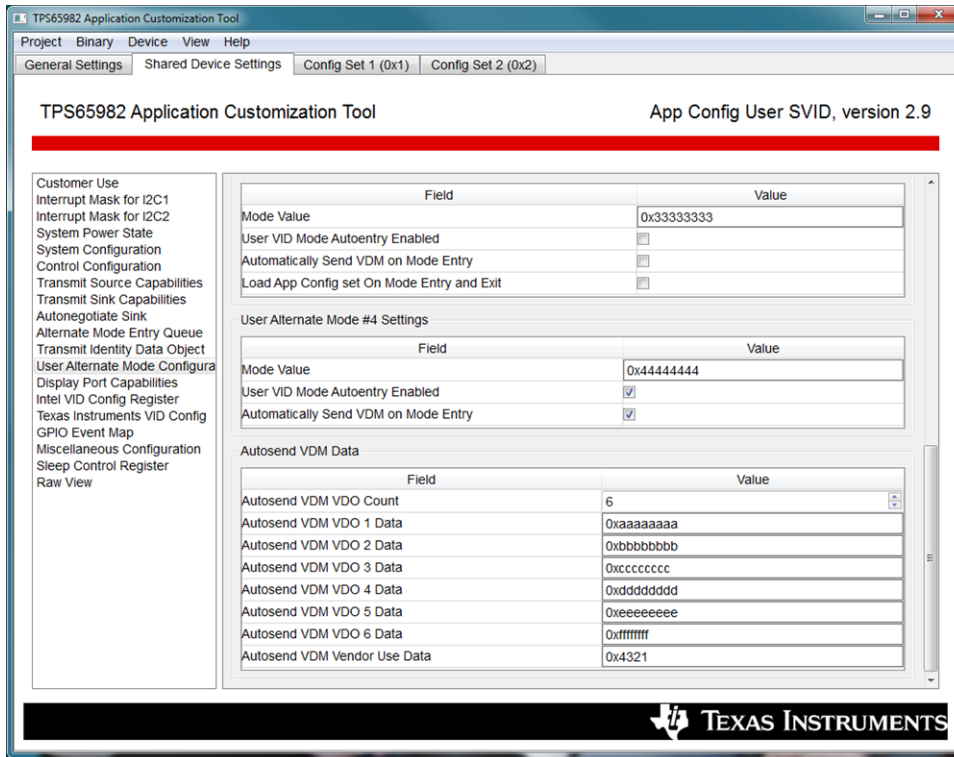
Figure 5. User Alternate Mode Configuration Register, part 2

When the DFP issues a discover modes request on the user SVID (configured as 0xfedc as previously described), the UFP responds with two modes, 0x11111111 and 0x44444444.

NOTE: Because modes 2 and 3 in the User Alternate Mode Configuration register are not enabled, they are not part of the supported modes response of the UFP. The mode numbers returned by the UFP correspond to the *Mode Value* fields as configured in the configuration tool, as shown in Figure 6.

Figure 6. PD Trace Highlighting *Discover Modes* **Messages**

Next, because the *User VID Mode Auto-entry* is enabled for both modes 1 and 4, the DFP will issue an Enter Mode request, first for 0x11111111 and then for 0x44444444. Packets 176-186 (Figure 7) show the entry into mode 1, followed by the sending of new source capabilities by the power source and ultimately the negotiation of a new PD contract.

Figure 7. PD Trace Highlighting *Enter Mode 1* **Messages**

The new source capabilities are specified in Config Set 2 of the configuration tool. These new source capabilities are then issued by the SSrC host interface command. Note that entry into this mode also drives GPIO 7 high, lighting an LED on the EVM.

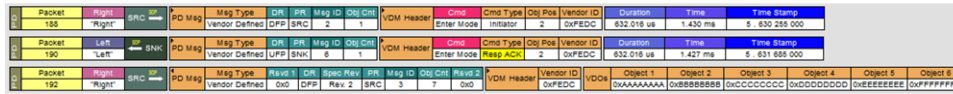After entry into mode 1 completes, mode 4 is entered (Figure 8).

Figure 8. PD Trace Highlighting *Enter Mode 4* **Messages**

After the mode is entered, an unstructured VDM is sent. The payload of this VDM is as specified in the *Auto-send VDM Data* section of the User Alternate Mode Configuration Register.

5   Register Reconfiguration on Mode Entry and Exit

In addition to advertising and automatically entering the SVID and mode numbers configured in the User Alternate Mode Configuration Register, the User Alternate mode can be configured to load configuration sets and issue up to two host interface commands on mode entry and exit.

The loading of configuration sets is enabled by the *Load App Config set on Mode Entry and Exit* flag of the *User Alternate Mode #N Settings* section of the User Alternate Mode Configuration register in Section 4. The actual configuration set that is loaded, as well as the optional host interface commands to be executed after the configuration set is loaded, are specified in the Miscellaneous Configuration Register (0x5E) and shown in Figure 9.
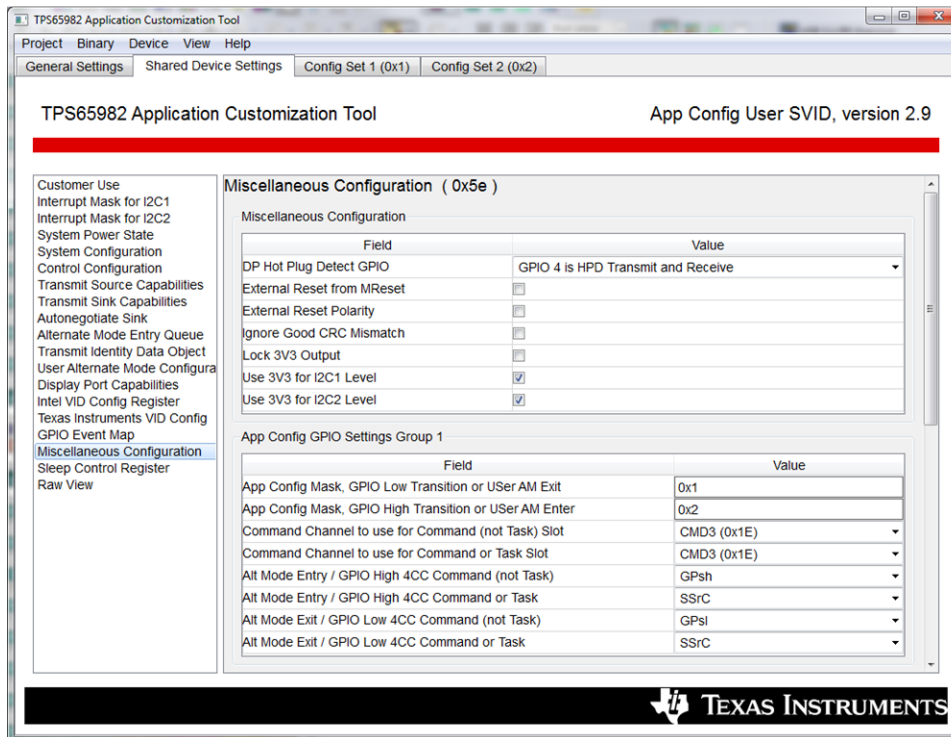
Figure 9. Miscellaneous Configuration Register

The first section of this register (Miscellaneous Configuration) is not directly relevant to the User Alternate mode or configuration sets.

Following this initial section, there are three additional sections of the register, *App Config GPIO Settings Group 1*, *App Config GPIO Settings Group 2*, and *App Config GPIO Settings Group 3*. These three sections allow the user to add configuration sets to be loaded on the entry or exit of User Alternate modes 1, 2 and 3, respectively. User Alternate mode 4 does not support configuration set loading.

It was shown in the previous section that the *Load App Config Set on Mode Entry and Exit* setting was enabled for User Alternate Mode #1 Settings. Because User Alternate Mode #1 always maps to *App Config GPIO Settings Group 1*, this is the section that is used to specify the reconfiguration parameters for Mode 1 entry and exit.

The step is to map a configuration data set to the alternate mode entry and a second configuration data set to the alternate mode exit. As shown in Figure 9, *App Config Mask, GPIO Low Transition or User AM Exit* has been mapped to Config Set 1, which has the identifier 0x1 (00001b) and *App Config Mask, GPIO High Transition or User AM Enter* has been mapped to Config Set 2, which has the identifier 0x2 (00010b). These identifiers are determined from the *(Virtual) Pin Strap Setting* field associated with each configuration set on the *General Settings* tab, as described in Section 3. The identifier associated with each configuration set is displayed in parenthesis following the name in the selection tab.

Examination of the settings of the *Config Set 1 (0x1)* and *Config Set 2 (0x2)*, Figure 10 and Figure 11, respectively, configuration set tabs shows that they specify settings for the CMD3 Data Register (0x1F) and the Transmit Source Capabilities Register (0x32). Registers can be added to or removed from this set by selecting the *Adjust Registers* button that appears above the register list in the left pane.
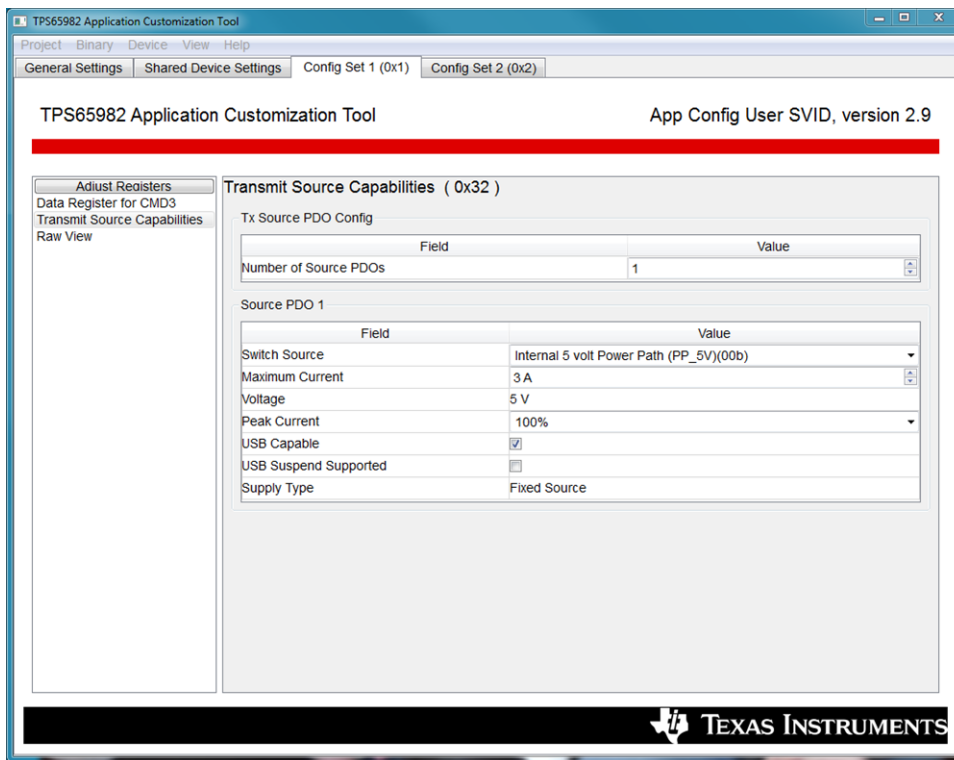

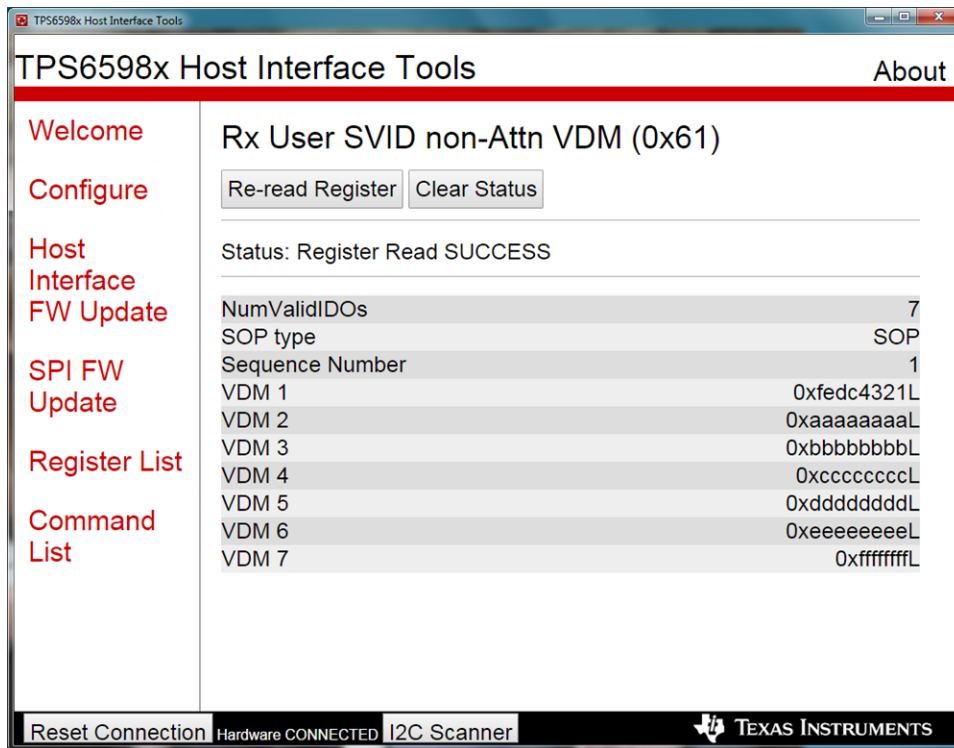**Figure 10. Config Set 1, Transmit Source Capabilities**

Figure 11. Config Set 2, Transmit Source Capabilities

Comparison of the Transmit Source Capabilities registers as specified in Config Set 1 and Config Set 2 shows that upon entry into the User Alternate Mode 1 (0x11111111), the Transmit Source Capabilities register will be populated with 3 source PDOs (fixed 5 V, 12 V and 20 V), and upon exit from User Alternate Mode 1, the Transmit Source Capabilities register will be populated with one source PDO (fixed 5 V). The initialization parameters for this register, specified in the *Shared Device Settings* tab can be verified to match those of Config Set 2 because the system is always initialized in a state where no alternate modes have been entered.

Compared to the PD trace of Figure 2, the initialization parameters (Shared Device Settings or Config Set 1) are advertised upon connection. Figure 12 shows this portion of the PD trace.

Figure 12. PD Trace Showing Shared Device Settings and Config Set 1 Source Capabilities

After the User Alternate Mode 1 is entered, the advertised source capabilities match those specified in Config Set 2. Figure 13 shows this portion of the PD trace

Figure 13. PD Trace Showing Config Set 2 Source Capabilities

6   Host Interface Commands on Mode Entry and Exit

Section 5 explains the method for automatically reconfiguring the settings for the host interface register upon entry into or exit from User Alternate modes. In the example presented, the Transmit Source Capabilities register was modified upon entry into and exit from User Alternate Mode 1 (Mode Value 0x11111111).

Overwriting the Transmit Source Capabilities register does not, however, force a retransmission of source capabilities. Overwriting this register is accomplished by issuing the host interface command SSrC (send source capabilities).

As many as one host interface command and one host interface task can be executed upon User Alternate mode entry and exit. These comments can be individually specified for entry and exit. For instance, a mode could issue the SWSr (swap to source) task upon entering a given mode but issue the SWSk (swap to sink) task upon exiting the same mode.

The host interface command and task for each mode are specified in the Miscellaneous Configuration Register (0x5e). For convenience, the settings of the App Config User SVID example are reprinted in Figure 14, which is identical to Figure 9.
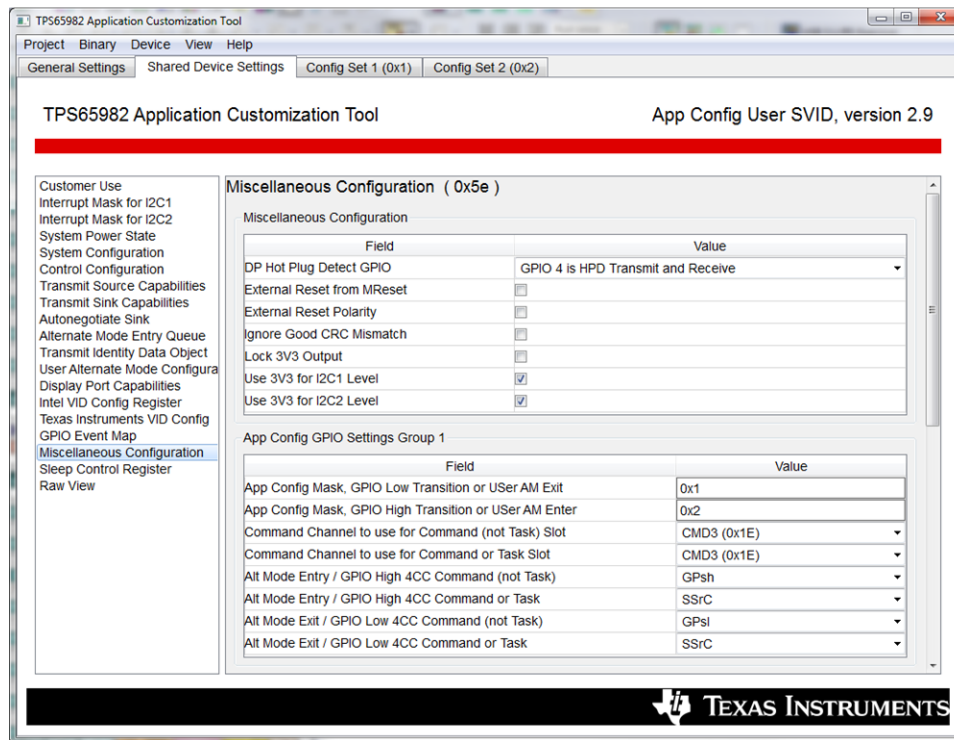
Figure 14. Miscellaneous Configuration Register

Figure 14 shows that upon entry in to User SVID mode 1 the TPS65982 will execute the GPsh (GPIO set high) command followed by the SSrC task, and upon exit from the User SVID mode 1, the TPS65982 will execute the GPsl (GPIO set low) command followed by the SSrC task.

> **NOTE:**   If one or both of the command or task slots is not required, !CMD (not command) should be selected from the pulldown menu.

The *TPS65981, TPS65982, and TPS65986 Host Interface Technical Reference Manual* (SLVUAN1) indicates that the SSrC task takes no parameters, but that the GPsh and GPsl commands take a single byte parameter to indicate which GPIO should be set high or low. As with host interface commands and tasks that are issued by an external microcontroller, commands and tasks that are issued through the application configuration (App Config) mechanism use one of three CMD and data register pairs: CMD1 (0x08) and Data1 (0x09), CMD2 (0x10) and Data2 (0x11), or CMD3(0x1E) and Data3 (0x1E). Which CMD and data pair the command and task are executed using is selected by the *Command Channel to use for Command (not Task) Slot* and *Command Channel to use for Command or Task Slot* fields, respectively.

Note that it is possible for the CMD and data channel in use by the App Config mechanism to conflict with a CMD/Data channel in use by an external microcontroller. The system integrator responsible for selecting a CMD and data channel which is not already in use. The CMD3 and Data3 channel are dedicated to App Config and are not available to external devices through the I^{2}C Channel as commands written into the CMD3 register through I^{2}C are not processed. This generally makes the CMD3 and Data3 channel the recommended channel for use by the App Config mechanism.

The GPsh and GPsl commands that are configured for User Alternate Mode 1 is entry and exit are configured to use the CMD3 and Data3 channel. To specify the GPIO number to set or clear through the Data3 register, Config Set 1 (mode exit) or Config Set 2 (mode entry) is used. Figure 15 shows the Data3 Register (0x1F) for CMD3.

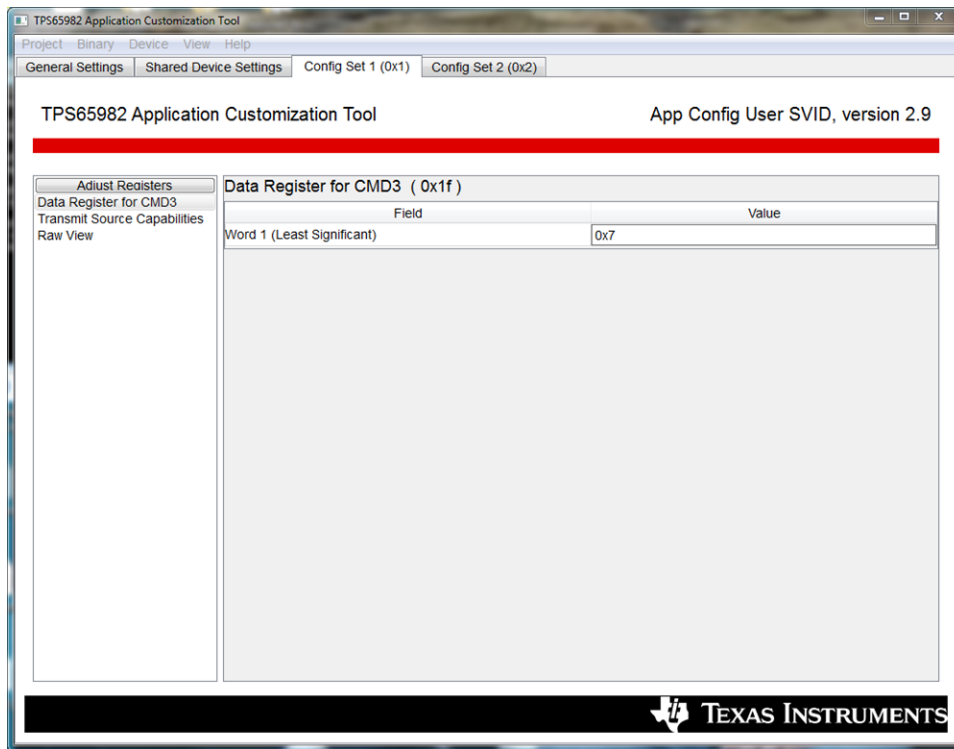**Figure 15. Data3 Register Setting for GPsl Command on User Alternate Mode 1 Exit**

The value specified for the CMD3 data register is 7. This value is read into the Data3 Register (0x1F) during the register write phase, alongside the update of the Transmit Source Capabilities register. After all registers are updated, the GPsh (mode entry) or GPsl (mode exit) command is executed on the CMD3 Register (0x1E).

7 Verification of the User Alternate Mode

The first step in verification of the User Alternate mode settings is to verify that the settings read from the device match those that were input into the configuration tool. These settings are stored in the User VID Confg Register (0x4A). These settings to be modified at runtime by an external microcontroller, so checking to make sure that the settings read as expected is useful.
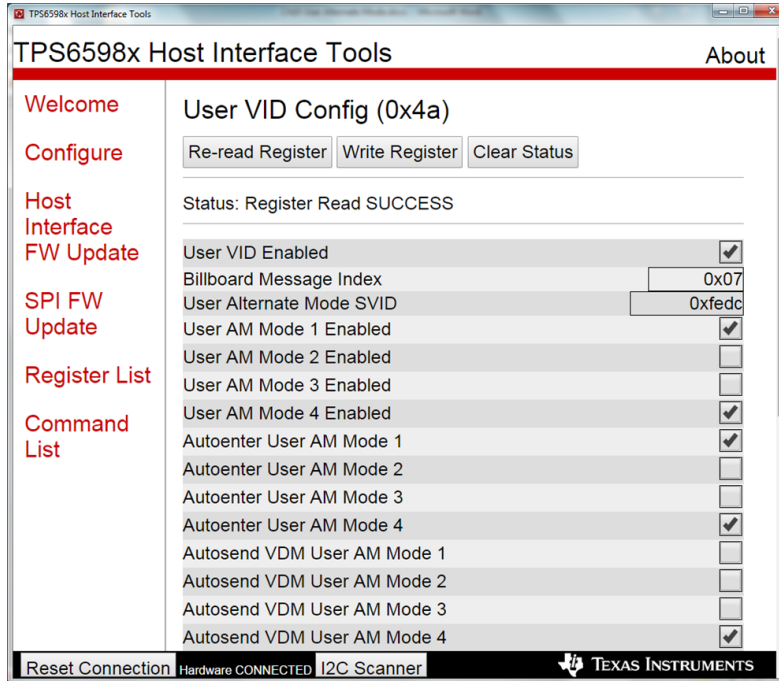

Figure 16. User VID Config Register as Read Through Host Interface (1 of 2)

The settings shown in Figure 16 and Figure 17 are verified to match those of the configuration tool as shown in Figure 3 and Figure 5.
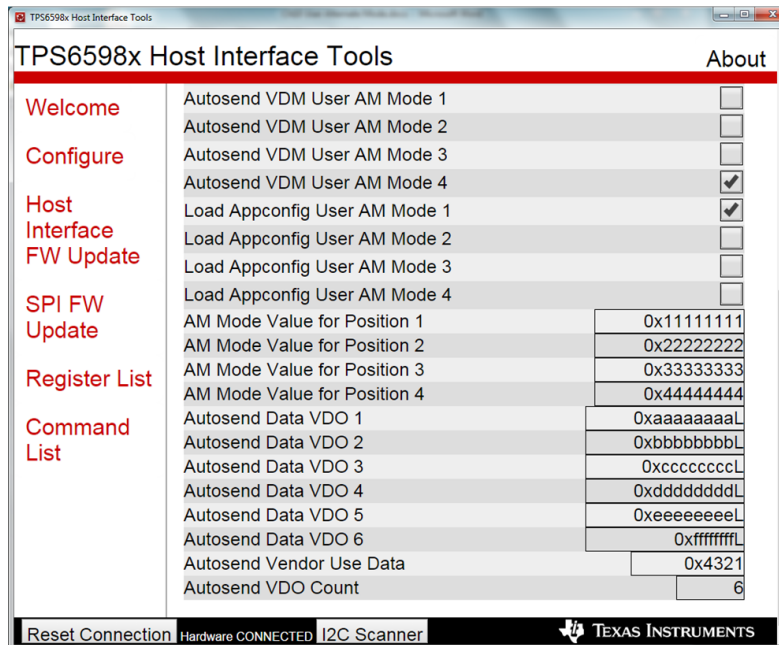

Figure 17. User VID Config Register as read via Host Interface (2 of 2)

After verifying that the configuration of the User Alternate mode is as expected, the device may be tested. The User Alternate Mode Status register can be read through the host interface utilities GUI and indicates which modes of the User VID have been entered.

Figure 18 shows the User VID Status Register (0x57) reading after connecting two TPS65982 EVMs that have both been programmed with the *TPS65982_appConfigUserAM_2_9.tpl* example project discussed in this section. The register shows that the User SVID is active (one or more modes have been entered) and that modes 1 and 4 are currently entered, and that modes 2 and 3 have not been entered which matches the PD trace shown in Figure 2.

The User VID Status register is useful both as a debugging tool and as a real-time status register that may be read by an external microcontroller.
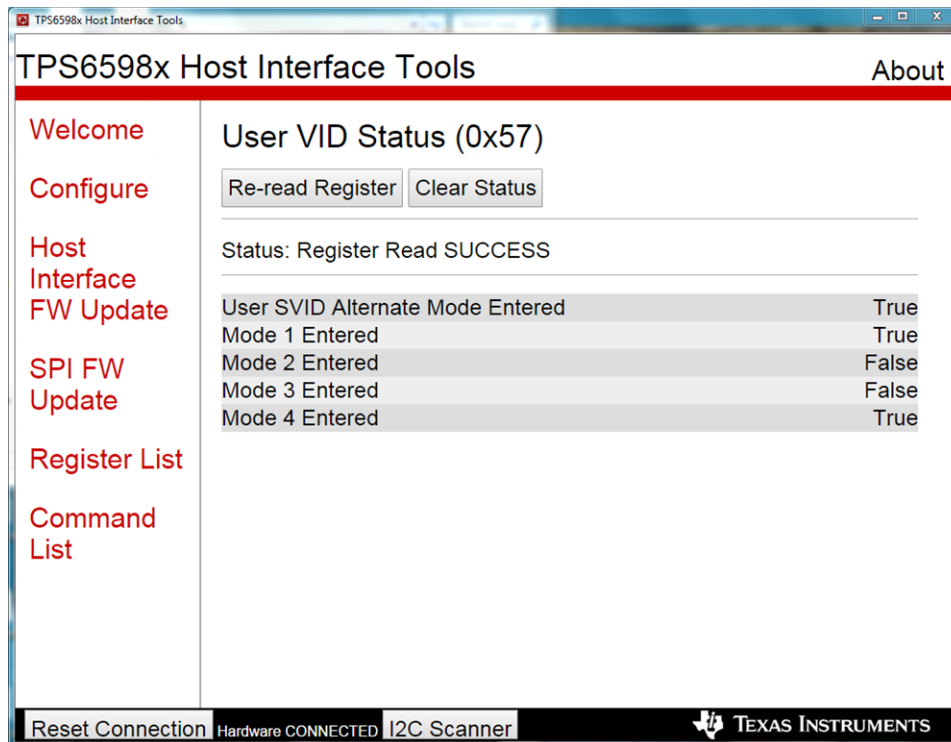

Figure 18. User VID Status Register

After reading the User SVID Status register to verify that all modes have been entered as expected, the final verification steps for the TPS65982_appConfigUserAM_2_9.tpl example are to ensure that the *Load App Config* functionality for User Alternate Mode 1 and the *Auto-send VDM* functionality for User Alternate Mode 4 have executed correctly.

Verifying the *Load App Config* functionality is accomplished by reading the appropriate registers before and after connection and verifying appropriate settings for mode entry and exit. In this example, the Transmit Source Capabilities register is updated based on entry into or exit from User Alternate Mode 1.

Verification of the *Auto-send VDM* functionality may be verified using the Rx User SVID Attention VDM (0x60) and Rx User SVID non-Attn VDM (0x61) registers. The auto-send message specified in the configuration of this project is not an attention message, so it will be filtered into the Rx User SVID non-Attn VDM Register (0x61).
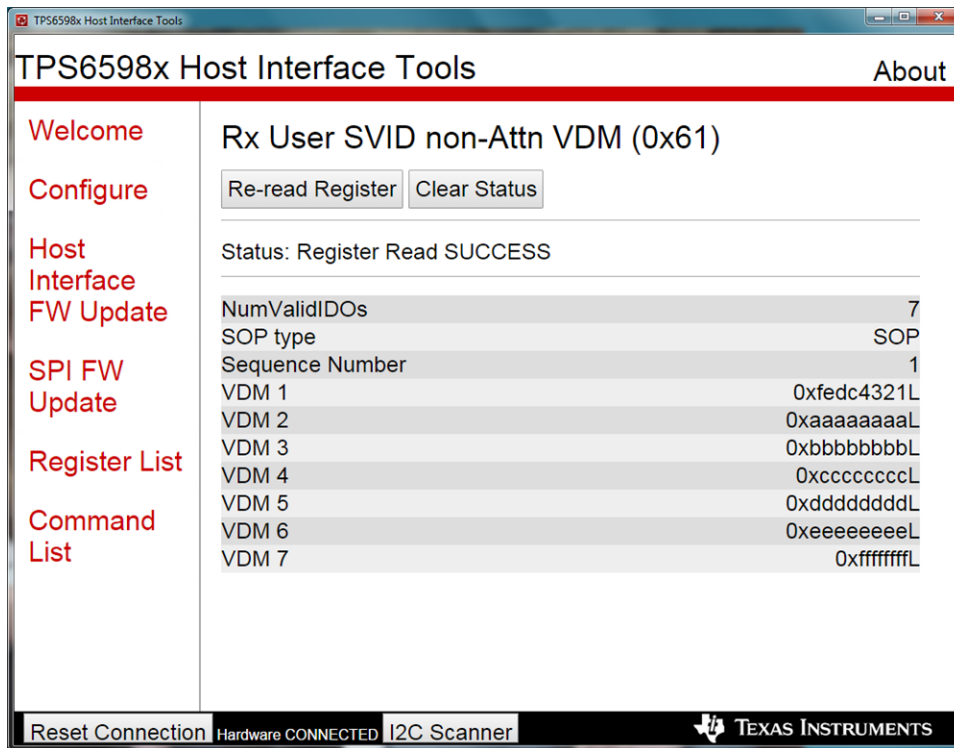
Figure 19. Verification of User Alternate Mode Auto-send Data using Register 0x61

Finally, make sure to read the Rx User SVID non-ATTN VDM Register (0x61) on the UFP that receives the VDM message sent from the DFP. The DFP that sends the VDM does not save the outgoing message, it is only saved on the receiving side. Figure 19 shows a received VDM message on the User SVID (read from the UFP) that matches the expected message as configured in the Miscellaneous Configurations Register (0x4A) of the DFP shown in Figure 5.

In summary, the successful entry of two User Alternate modes has been verified, and all of the feature configurations have been confirmed by examining the PD Traces, data in the TPS6598X Host Interface Utility Tool, or both.

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