Application Report
SLVAEC3–June 2019

TPS65987x, TPS65988x Power and Data Role Swaps

ABSTRACT

Power and data role swaps allow individual devices to change their roles under certain conditions. This ability allows a power source to become a sink, a data DFP (Downward Facing Port) to become a data UFP (Upward Facing Port), or both. The roles are negotiated using USB Power Delivery (PD) messaging according to the USB PD specification. This application report explains the standard implementation of data and power role swaps as well as assigning data and power preferences to individual USB Type-C ports. This application report is to be used with Texas Instruments' TPS65987x and TPS65988x families of USB Type-C and USB PD controllers and associated software tools.

Contents

List of Figures

List of Tables

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1 Introduction

The Power Delivery specification allows two connected dual-role ports to optionally switch their data role, their power role, or both roles using the power-role swap and data-role swap mechanisms.

Texas Instruments' TPS65987 and TPS65988 families of USB Type-C and USB PD controllers can be configured to automatically initiate data or power role swaps to a desired state, or the same role swaps may be initiated by an external microcontroller through host interface commands. The control configuration (0x29) register is used to specify automatically initiated role swaps. You can specify a preferred data role by using the *Initiate Swap to DFP* command instead of the *Initiate Swap to UFP* command, and can configure the device to either allow or disallow swaps through the *Process Swap to DFP* and *Process Swap to UFP* bits. The power roles have similar settings.

Using an external microcontroller to modify data and power roles using host interface commands provides an additional level of functionality. Whereas the control configuration register provides a simple preference towards one setting or the other setting, an external microcontroller can use information gathered from the TPS65987 and TPS65988 host interface status registers to make more advanced power and data role decisions. For instance, a microcontroller could use the externally powered bit of the connection partner as stored in the Rx Source Capabilities (0x30) register to make a more informed decision when setting power role orientation.

2 Role Swap Configuration in Host Interface Registers

The TPS65987 and TPS65988 registers include the following:

- Configuration registers:
  - 0x28, Port Configuration register, Type-C supported options fields
  - 0x29, Port control register, all fields
- Status registers:
  - 0x1A, Status register, *Port Role* and *Data Role* fields
  - 0x3F Power status register, Source or Sink field
  - 0x2D, Boot Status register, *Dead Battery* field
- Run-Time Host-Interface Commands:
  - SWSr, swap to source (power)
  - SWSk, swap to sink (power)
  - SWDF, swap to DFP (data)
  - SWUF, swap to UFP (data)

The Port Control register (0x29) is the primary register used to control role swap behavior. This register allows you to configure the initiation of role swaps, which causes the TPS65987 and TPS65988 PD controller to automatically initiate the given role swap, and it allows you to configure the processing of role swaps, which controls whether the TPS65987 and TPS65988 USB PD controller accepts or does not accept various role swap requests initiated by the port partner.

The Port Configuration register (0x28) can used to set what initial role the device can take when Type-C connection is made. The Port Configuration field can chose between DFP only, UFP only, or DRP. The Type-C Supported Options field selects if the DRP port has additional options as Try.Src (Try Source) or Try.Snk (Try Sink), simple no options, or it can declare it is a powered accessory. The default templates that are used in this document do not have Type-C Supported options set as "No Options", but you can modify this to Try.Src for the preferred Source project.

The Status register (0x1a) reports the current data and power role of the system. The Boot Status register (0x2d) is also important as it reports whether or not the system is currently in Dead Battery Mode, and a system that is in Dead Battery Mode does not support power role swaps. Power status register (0x3F) can be used to look at power role easily.

Finally, four host interface commands can be used to manually initiate a data or power role swap using an external controller. As discussed in this application report, certain system conditions must still be met in order for a role swap to occur. If these conditions are not met, the host interface swap command is rejected.

3 Data and Power Role Swap Examples

The TPS6598x Configuration Tool contains multiple dual-role port configurations, all of which use one of two data and power role swap settings. Refer to the *TPS6598x Application-Customization Tool User Guide* to select the appropriate template that best represents your project configuration.

When a new project is started from the Configuration Tool, it asks for following questions to select correct template -

1. Which device are you using? For example, the TPS65987DDH.
2. Which template type do you want to start with?
   - Standard
   - Advanced
3. What is the port type of the design? The choices are the following:
   - Upstream Facing Port(UFP) only
   - Downstream Facing Port (DFP) only
   - Dual Role Port (DRP), prefers data host
   - Dual Role Port (DRP), prefers power source
4. Which Super Speed data controller or mux is used?

Choices on the third question determine the behavior of the Date Role and Power Role swaps. For example, if you select "DRP, prefers power source", these generated project variants initiate a power role swap if necessary to become a power source, but the do not initiate data role swap, but instead accept any data role swap. If you select "DRP, prefers power source", these variants initiate a power role swap if they start as sink, and they do not initiate data role swap, but accept data role swap.

In the second question, if you have selected the "Standard" template configuration, the Port Control (0x29) register view relating to Power and Data role swap has a simplified view each of strategy having four options. Tools generate appropriate bit settings required for the options selected, whereas in the case of the "Advanced" template configuration, the register view shows individual bits as defined in the Host Interface TRM document. Figure 1 shows Port Control Data Role strategy settings in standard template and Figure 2 shows Port Control Power Role strategy settings in standard template.

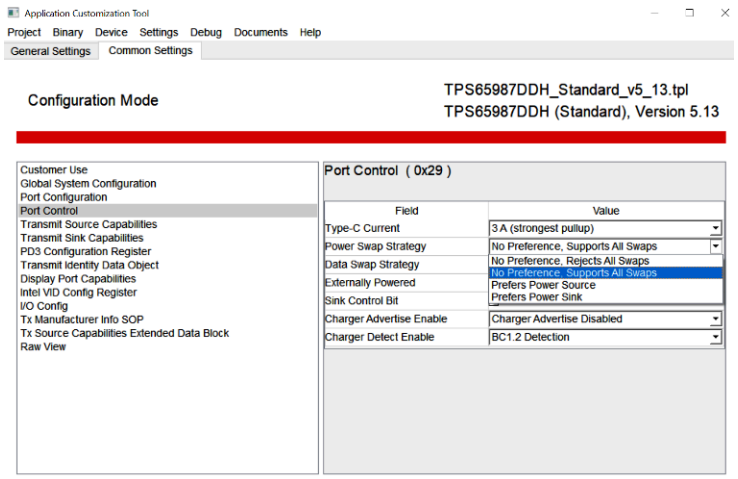

Figure 1. Port Control Data Role strategy Settings in a Standard Template

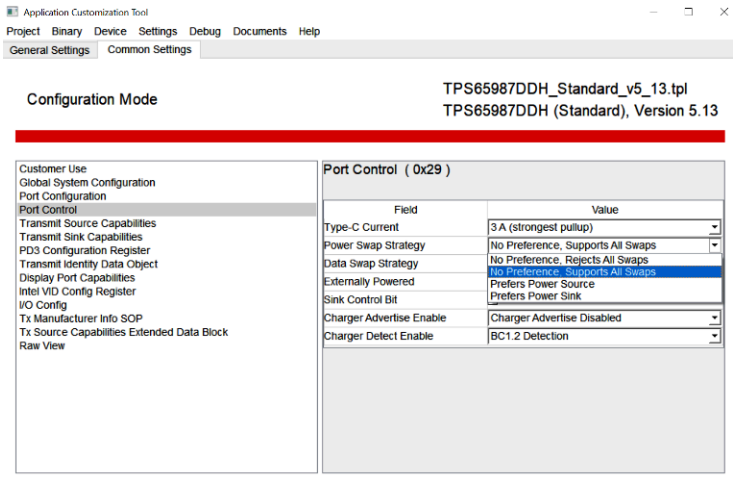

Figure 2. Port Control Power Role Strategy Settings in a Standard Template

Between Standard and Advanced, the only difference is the register view. This document limits discussion to Advanced template view of Port control register, as it is better suited to illustrate detailed functionality of power and data role swaps.

Note that the names of templates discussed below start with the last portion of the file name that points to the version of the Configuration tool being used, which gets updated whenever a newer version of configuration tool is used. For example, template*TPS65987DDH_Advanced_v5_13.tpl* is for the TPS65987DDH device and was done based on configuration tool version 5.13.

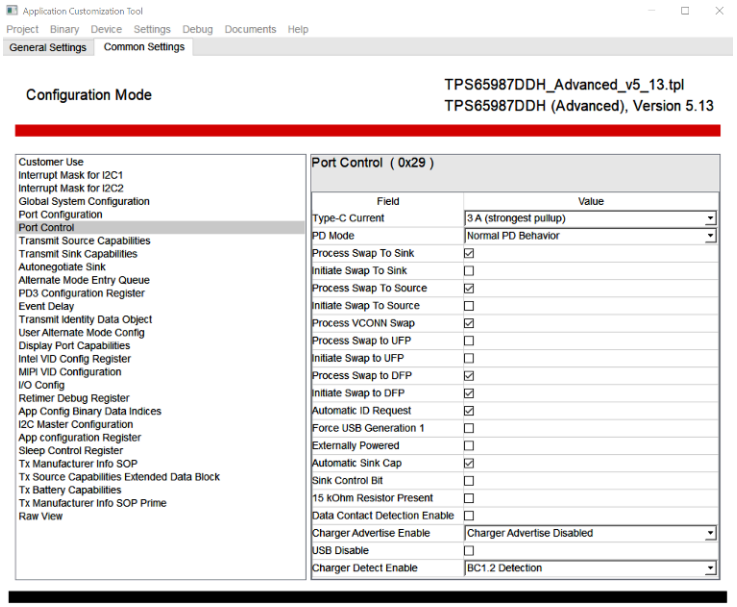

Figure 3. Port Control Register (0x29) Advanced Settings Tab for *"Preferred Host"*

Figure 3 shows the Control Configuration register (0x29) settings for the *TPS65987DDH_Advanced_v5_13.tpl* project set as *"preferred Host"*. For this project, *Process Swap to Sink*, and *Process Swap to Source* are both enabled, but *Initiate Swap to Sink* and *Initiate Swap to Source* are both disabled. This indicates that the system accepts either power role swap request from a connected device but does not (automatically) initiate a power swap request of either type. This is an agnostic configuration since it supports both power roles without driving a preference towards one or the other.

By contrast, the data role swap settings are as follows: *Initiate Swap to DFP* and *Process Swap to DFP* are both enabled, but *Initiate Swap to UFP* and *Process Swap to UFP* are both disabled. This combination indicates that the device always attempts to become the data DFP (host) in the connection.

NOTE: The *Swap to DFP* setting indicates that the device being configured swaps to become the DFP for both the *Initiate* and *Process* settings. This setting is a preferred data configuration because it drives the system towards a configuration in which the device is data DFP if possible.

When setting the initiate and process bits in the Control Configuration register, avoiding a configuration that could potentially lead to an infinite sequence of data or power role swaps is important. First, system should never be configured to initiate swaps in both directions (such as selecting *Initiate Swap to UFP* and *Initiate Swap to DFP* in the same configuration). First, this would be a meaningless configuration because it provides no preference to data or power role and therefore is swapping seemingly for the sake of swapping, but second, if the port partner accepts swaps in both directions, this configuration would lead to an infinite series of swaps.

Likewise, any configuration that initiates a data or power role swap should not process swaps in the reverse direction. Two systems that are both configured to *Initiate Swap to DFP* and *Process Swap to UFP* toggle infinitely back and forth as each system continually initiates swaps to attempt to become DFP. In any event, a system that prefers to be configured as DFP would have no reason to accept swaps to UFP since this would require relinquishing the preferred role.

Comparing the settings of Figure 3 to those of the *"preferred Source"* project as shown in Figure 4, it is seen that the latter project is configured to drive towards a power source role by selecting *Process Swap to Source* and *Initiate Swap to Source*, and deselecting *Process Swap to Sink* and *Initiate Swap to Sink*. The data role is left agnostic by enabling the *Process* settings in both directions but disabling the *Initiate* settings.

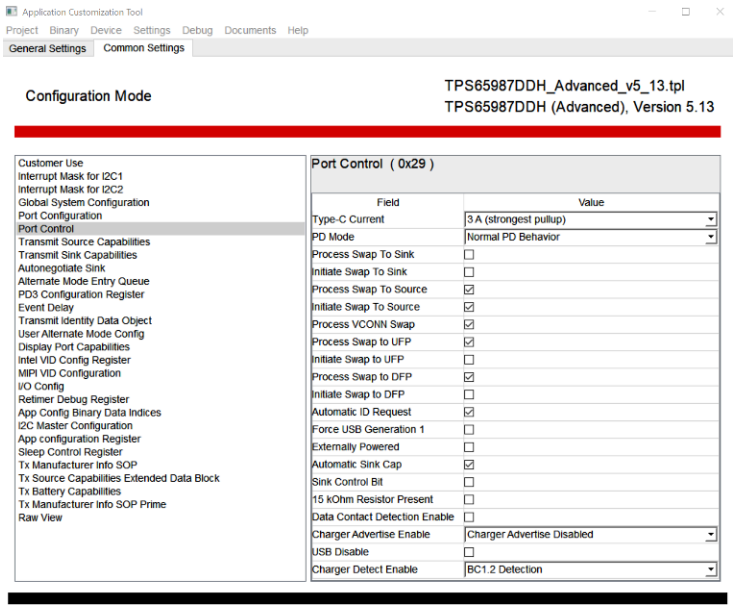

Figure 4. Port Control Advanced Settings Tab for *"preferred Source"*

The following PD message trace was taken with a Teledyne LeCroy PD analyzer between two TPS65987 EVMs, one setup as the *"preferred Source"* and the other setup as *"preferred Host"*. If the project which is set as *"preferred Source"* has the try.SRC feature enabled in port config register(0x28), the trace always follows this structure so long as either both boards are powered before connection or the board containing the source settings is powered with the host board in Dead Battery Mode. This trace was taken with both boards powered. This example also uses a non-e-marked cable, which leads to the cable resets and VConn Swap, which is discussed.

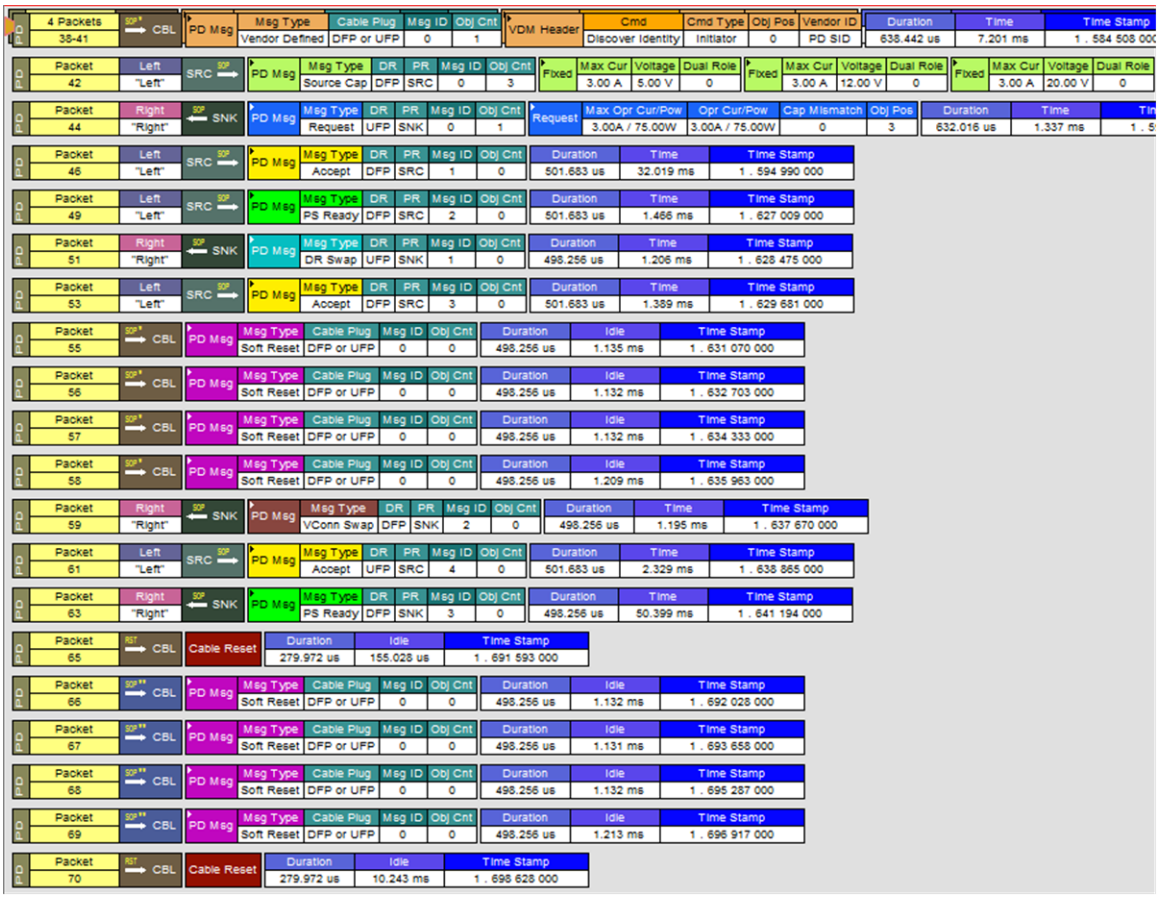

Figure 5. DRP Host Connected to DRP Source PD Trace (Excerpt)

Figure 5 shows the expected sequence of PD operations for this example. This sequence is only a partial trace. The system continues with a Discover Identity, Discover SVIDs/Modes, and mode entry.

1. Packets 01 through 37 (not displayed in Figure 5) — The EVM set up as *"preferred Source"* connects as the *DFP and "preferred Host"* connects as the UFP. This always happens, so long as the EVM programmed with the source settings is powered, and try.SRC is enabled and the host settings are not.
2. Packets 38 through 41 — A Discover Identity request and three retries are sent to the cable. Because it is a non-e-marked cable, there is no response.
3. Packets 42 through 49 — The PD power contract is negotiated. See Section 3 of this document for an explanation of the configuration of this stage of PD negotiation.
4. Packet 51 — The EVM configured as "preferred Host" makes a data role swap request. This occurs because *Initiate Swap to DFP* is enabled in the Control Configuration register of this project and it is currently the UFP. Additional conditions are required for this to occur, as shown in .
5. Packet 53 — The EVM configured as *"preferred Source"* accepts the data role swap request. This occurs because *Process Swap to UFP* is enabled in the Control Configuration register of this project and it is currently the DFP. Additional conditions are required for this to occur, as listed in Table 1.
6. Packets 55 through 58 — The EVM configured as *"preferred Host"* issues a soft reset command to the cable with three retries. The new DFP always attempts a soft reset to the cable following a data-role swap to reset the message ID to 0. The cable used in this example does not respond because it is not e-marked.
7. Packet 59 — The EVM configured as *"preferred Host"* issues a VConn swap. The PD spec requires that a PD port must provide power to the connection cable in order to issue a cable reset. This VConn swap request is preliminary to the cable reset of packet 65.
8. Packets 61 and 63 — The VConn swap is accepted and then the EVM configured with *preferred Host*

issues a *PS Ready* command when it is providing power to the cable.

9. Packets 65 through 70 — The host-configured port issues a *Cable Reset* command. Because the cable is not e-marked, it does not return a *Good CRC* message to this *Cable Reset* (all *Good CRC* messages have been removed from this trace to reduce its size). When no *Good CRC* message is received from the cable, the DFP (host) issues one soft reset and three retries to the cable as a result of not receiving *Good CRC* for the soft reset request. After four *Soft Reset* requests with no *Good CRC*, the port issues one final *Cable Reset* and then continues with the rest of its PD negotiation (not shown).

4 Requirements for Data and Power Role Swaps

A number of conditions must be met for the TPS6598x USB PD controller issues or accepts a power or data role swap. If a swap request is not issued or accepted as you expect, these conditions should be checked.

Table 1 summarizes the requirements for each type of swap to be issued or accepted. The combination of conditions in the *Required Conditions* column must be met as specified in the table for the swap to occur. If any of the conditions in the *Blocking Conditions* column are met, the swap does not occur.

Table 1. Data-Role and Power-Role Swap Requirements

ACTION	TYPE	REQUIRED CONDITIONS	BLOCKING CONDITIONS
Issue swap to source	Power	Port is currently a Sink AND Initiate Swap to Source == 1 OR SWSr 4CC command issued	A previous swap-to-source request was NAK'd by the far-end PD port controller. Dead Battery flag is set in the Boot Status register (0x2D). The *Port Information* field in the System Configuration register does not support PR swap.
Accept swap to source	Power	Port is currently a Sink AND Process Swap to Source == 1	The *Port Information* field in the System Configuration register does not support PR swap. Dead Battery flag is set in Boot Status register (0x2D).
Issue swap to sink	Power	Port is currently a Source AND Initiate Swap to Sink == 1 OR SWSk 4CC command issued	A previous swap-to-sink request was NAK'd by the far-end PD port controller. The *Port Information* field in the System Configuration register does not support PR swap.
Accept swap to sink	Power	Port is currently a Source AND Process Swap to Sink == 1	The *Port Information* field in the System Configuration register does not support PR swap.
Issue swap to DFP	Data	Port is currently a UFP (Device) AND Issue Swap to DFP == 1 OR SWDF 4CC command issued	A previous swap-to-DFP request was NAK'd by the far-end PD port controller. The *Port Information* field in the System Configuration register does not support DR swap. An Alternate Mode is Active (has been entered and not exited). A Source or Sink Capabilities message has been received from port partner that does not have Dual Role Data bit set.
Accept swap to DFP	Data	Port is currently a UFP (device) AND Process Swap to DFP == 1	The *Port Information* field in the System Configuration register does not support DR. An Alternate Mode is Active (has been entered and not exited).
Issue swap to UFP	Data	Port is currently a DFP (Host) AND Initiate Swap to UFP == 1 OR SWUF 4CC command issued	A previous Swap to UFP request was NAK'd by the far-end PD port controller. The *Port Information* field in the System Configuration register does not support DR. An Alternate Mode is active (has been entered and not exited). A source or sink capabilities message has been received from port partner that does not have Dual Role Data bit set.
Accept swap to UFP	Data	Port is currently a DFP (Host) AND Process Swap to UFP == 1	The *Port Information* field in the System Configuration register does not support DR. An Alternate Mode is Active (has been entered and not exited).

5 Verification of Data-Role and Power-Role Swaps

The first step in verification of the data-role and power-role swaps is to verify that the settings read from the device match those that were input into the configuration tool. The relevant settings are stored in the Control Configuration register (0x29) and the System Configuration register (0x28). These settings can be modified at runtime by an external microcontroller and therefore ensuring that the settings read as expected is useful.

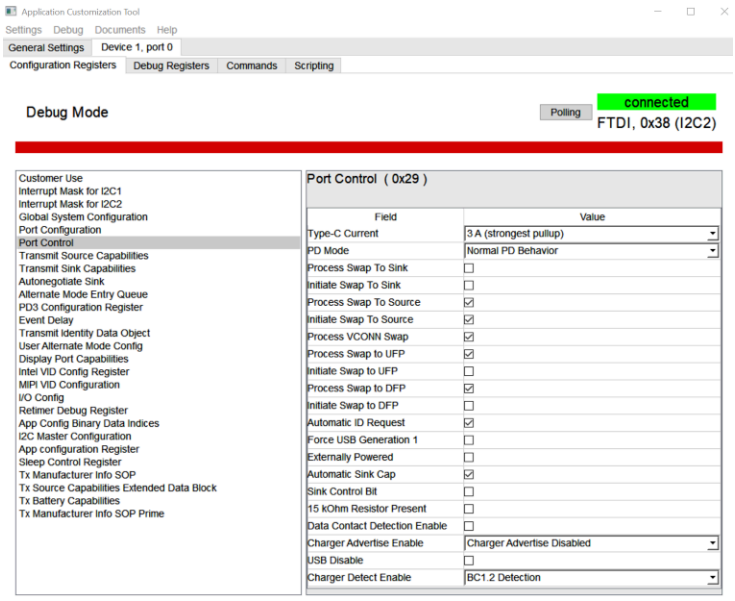

Figure 6. Port Control Register *"preferred_Source"*

The settings shown in Figure 6 are verified to match those of the configuration tool as shown in Figure 4. Even when this is the case, you may find cases where swaps do not occur as expected. This section provides two common examples (see Section 5.1 for example 1 and Section 5.2 for example 2) and a walkthrough of a typical debug procedure for these scenarios using the TPS6598x Configuration Tool.

5.1 Example 1: Debugging Power Role Swap Exiting Dead Battery Mode Operation

For the first experiment, use the two TPS65987 EVMs programmed as *preferred Source* and *preferred Host* settings from the earlier example. The *preferred Source* EVM is left unpowered, while the *preferred Host* EVM is powered.

As shown in Figure 7, no power-role swap is initiated by the *preferred Source* system, even though it is a sink and has *Initiate Swap to Source* enabled.

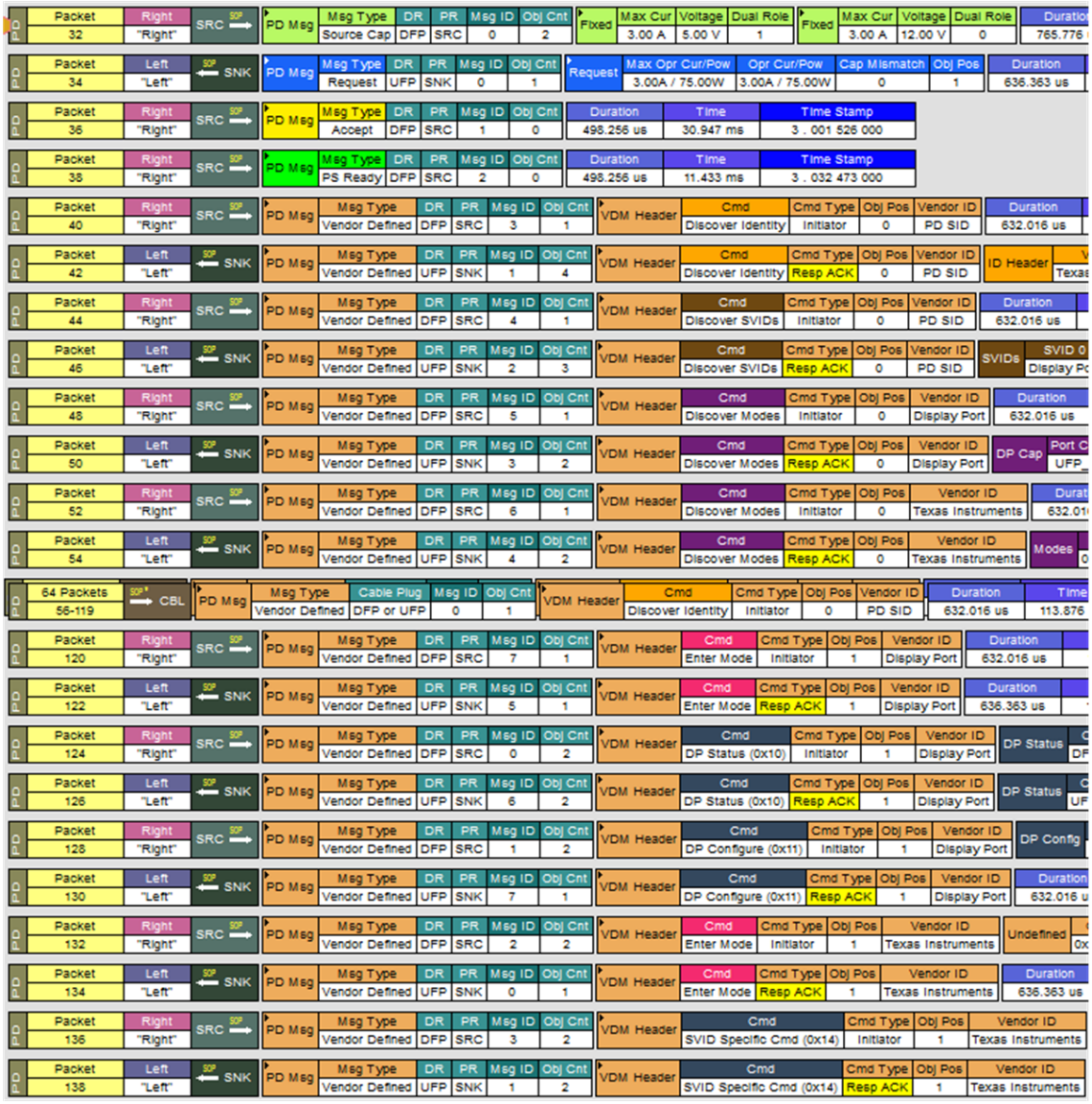

Figure 7. PD Flow With DRP Source Unpowered

If the system settings have been verified, but a data-role or power-role swap is not occurring as expected, initiate the role swap manually through the TPS6598x Configuration Tool.

Because the *preferred Source* EVM is not issuing the expected swap request, use debug mode on the TPS6598x configuration tool to this EVM and issue the SWSr command.

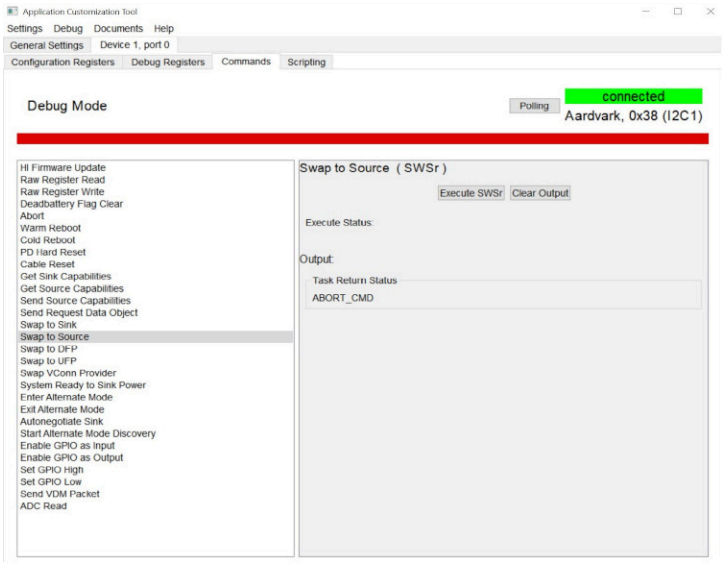

Figure 8. Failed SWSr When Dead Battery flag is Set to 1 (True)

Figure 8 shows the feedback from the host interface tools. The tool reports that the SWSr command was aborted. You can read Boot flags register (0x2D) to check if the Dead Battery Flag is set.

To correct this, you can power the board and then issue the DBfg command from the host interface which clears the Dead Battery flag as shown in Figure 9. Clearing of the Dead Battery flag should also be verified by reading the Boot Status register (0x2D) as shown in Figure 10.

The board must be powered before clearing the Dead Battery flag otherwise the device resets and reboots again in Dead Battery Mode operation.

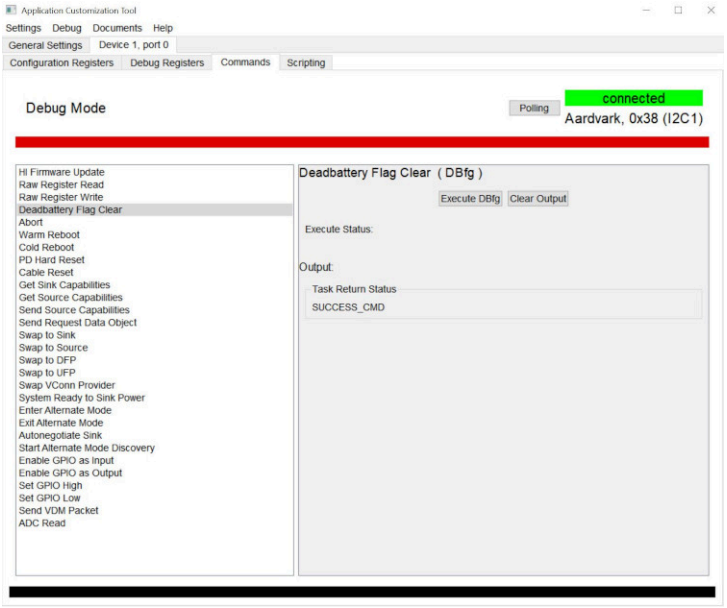

Figure 9. Successful DBfg Command to Clear Dead Battery Flag

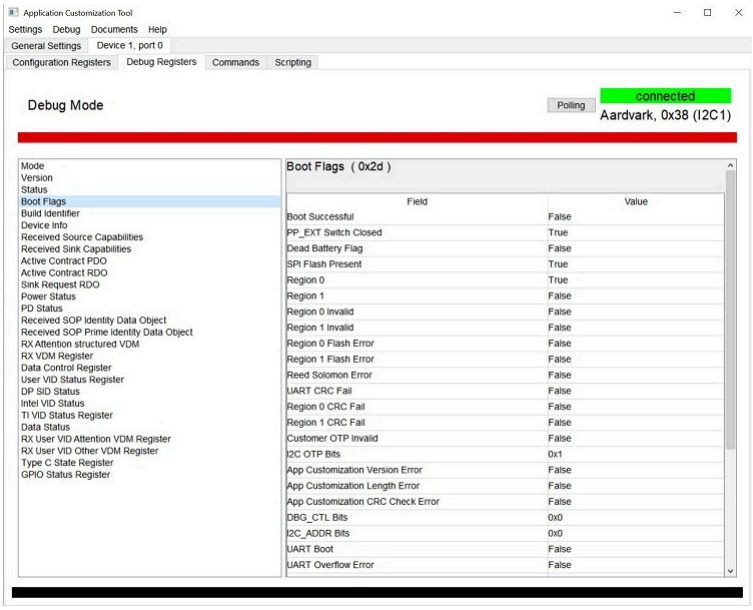

Figure 10. Verified Dead Battery flag Cleared to 0 (False)

When the Dead Battery flag has been cleared, the EVM programmed as *preferred Source* can be swapped to the power source by issuing the SWSr host interface command as shown in Figure 11.

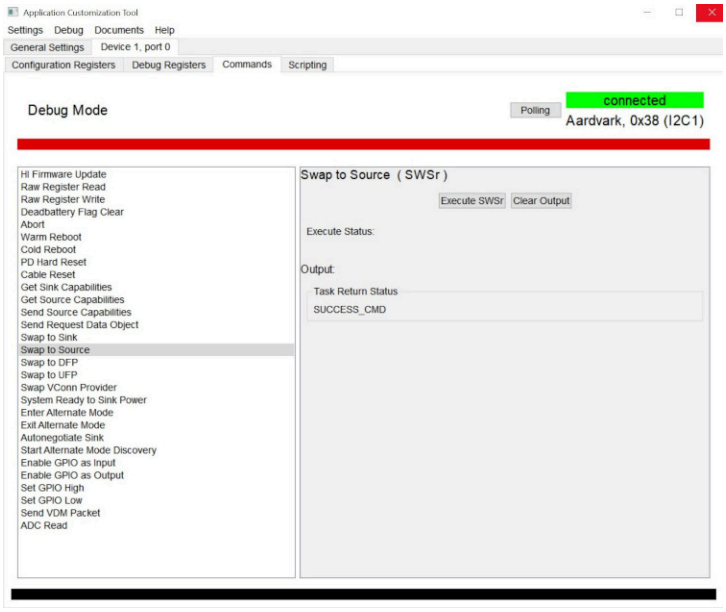

Figure 11. Successful Swap to Source

5.2 Example 2: Debugging Swap Reversal from non-Persistent Swap Conditions

Using the TPS65987 EVMs programmed as *preferred Source* and *preferred Host* settings from the earlier example, the host interface tools may be used to issue a power-role swap.

Taking the lesson learned from Section 5.1, power both EVMs and then connect. The PD flow should be as was already shown in Figure 5.

As a next step, use the host interface tool to issue a *Swap to Sink* PD message to the port partner.

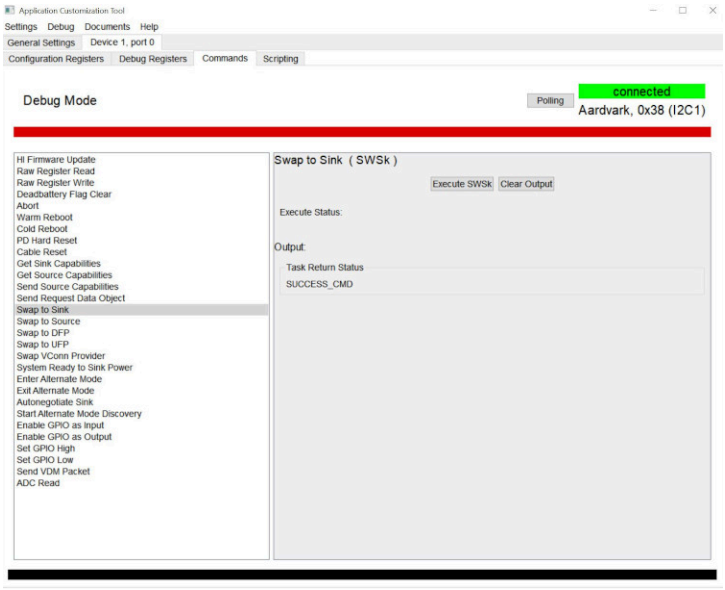

Figure 12. SWSk Command Page Before Execution

Figure 12 shows the command page for the SWSk (swap to sink) host interface command. The tools are attached to the EVM that have been configured with *preferred Source*, which comes up as the power source always if it has the *try.SRC* feature enabled.

Before issuing SWSk, the PD Status register, displayed at the bottom of the command page, shows that the system is currently the power source (*Source-Sink* field).

After pressing the *Execute Function* button, the tool indicates a successful execution as shown in Figure 13; however, the PD Status register still indicates that the device is the power source, just as it was before issuing the SWSk command. This scenario is referred to as a *swap reversal* which is an accidental scenario that arises from configuring the TPS65987 device with non-persistent swap conditions.

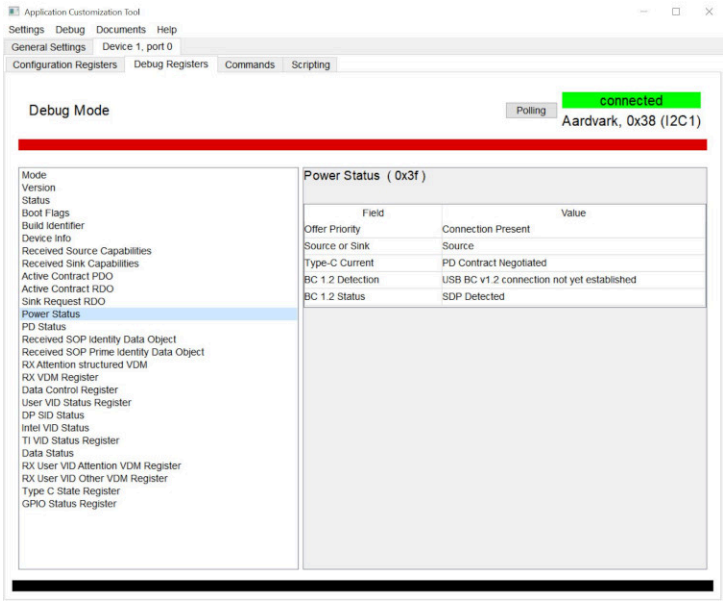

Figure 13. SWSk Power-Role Swap to Sink Attempt (Inconclusive Result)

As shown in Figure 13, the host interface tool reports a successful completion of the *Swap to Source* command, but the Power Status register reports that the device is still a source. The reason that the device is still a source after a *Swap to Sink* command that is reported as successful is shown in Figure 14. This PD capture is started at the point in which the SWSk command is issued from the host interface tool. The trace shows that, in fact, a successful *Swap to Sink* PD message sequence operation does occur (packets 1 through 15); however, the system immediately issues another swap request. The reason is shown by revisiting the Port Control register on the device programmed as *preferred Source*.

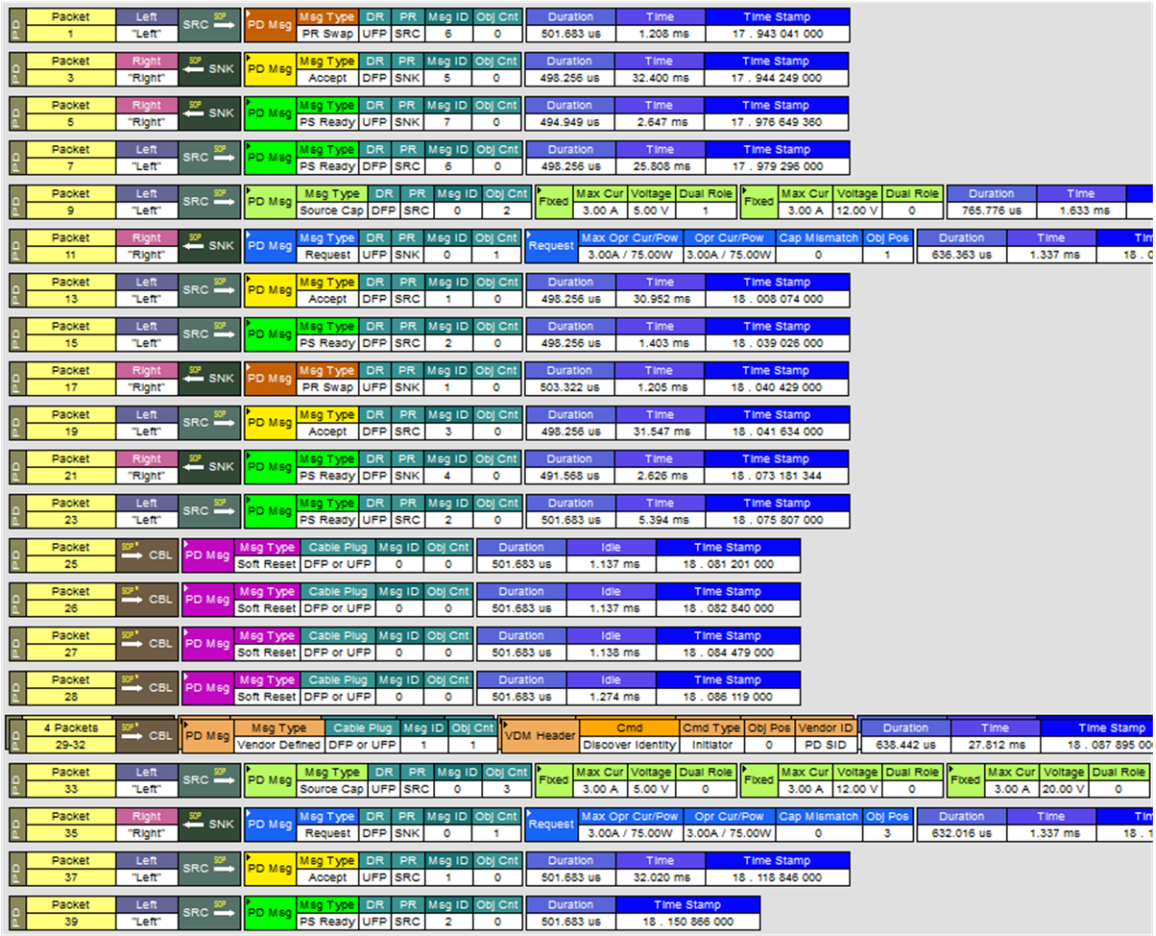

Figure 14. PD Trace of Manual Power-Role Swap Followed by Automatic Power-Role Swap

Referring back to Figure 6, recall that the source device has the *Initiate Swap to Source* setting enabled. The behavior of this setting is that it initiates a *Swap to Source* request at any time that the device is a sink and none of the blocking conditions of Table 1 are present. So, in this system, when the manual swap requests swaps power roles, the *Initiate Swap to Source* setting immediately swaps the power role back. In fact, any number of *Swap to Sink* requests are immediately swapped back as long as this setting is enabled.

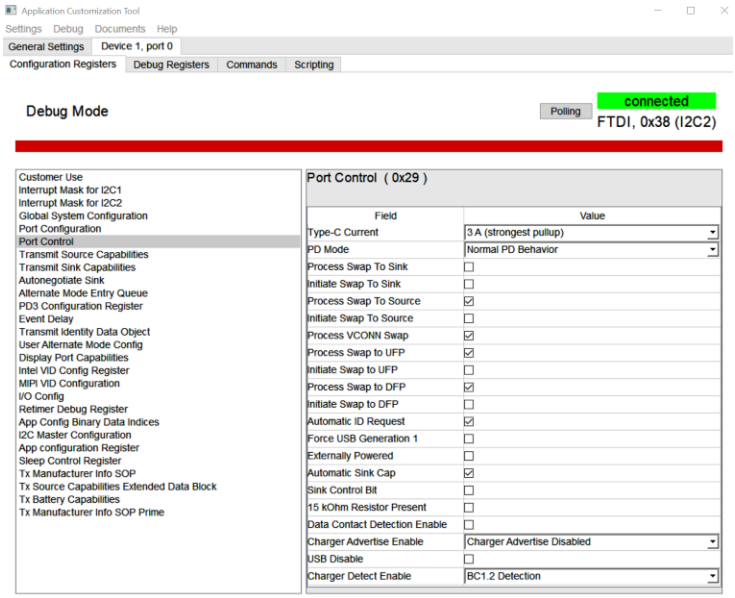

Figure 15. *"preferred Source"* **With** *InitSwapToSource* **Disabled**

A simple means of completing this test is to use the host interface tools to disable *Initiate Swap to Sink* in the Control Configuration register (0x29) of the EVM that has been configured with *preferred Source*.

NOTE: Register changes made with the host interface tools are made only in the device RAM, not the system FLASH, and is therefore reset back to their default values if there is a device reset or power cycle.

Do not forget to click the *Write Register* button after making this change.

The *Process Swap to Sink* field does not need to be enabled for the SWSk command to work properly. This field is only used to evaluate swap requests that are initiated by the port partner.

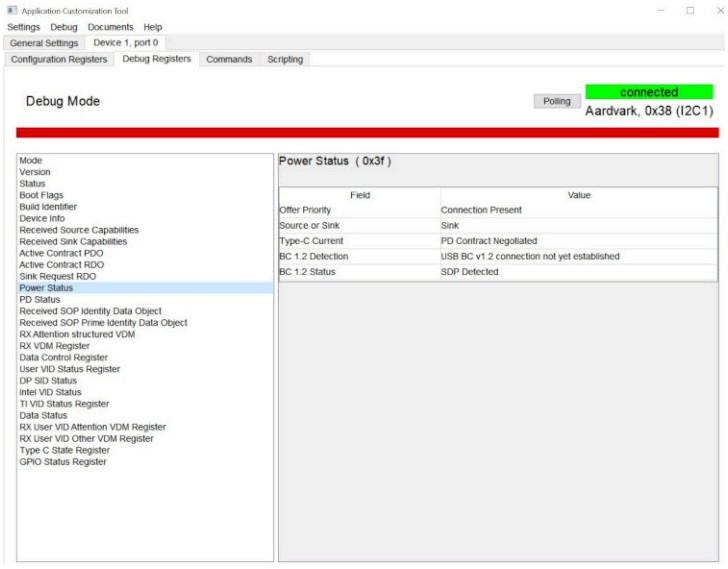

Figure 16. Manual Swap to Sink (Successful and Persistent)

Figure 16 shows the successful completion of the SWSk host interface command after disabling *Initiate Swap to Source* field in Control Configuration register (0x29). The Power Status register now shows the device is the power sink in the connection.

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