

# USB4™ Thunderbolt3™ Compatibility Compliance Test Specification

Date: January 2021

Revision: 1.0

Copyright © 2021, USB Implementers Forum, Inc.

All rights reserved

THIS SPECIFICATION IS PROVIDED TO YOU “AS IS” WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NON-INFRINGEMENT, OR FITNESS FOR ANY PARTICULAR PURPOSE. THE AUTHORS OF THIS SPECIFICATION DISCLAIM ALL LIABILITY, INCLUDING LIABILITY FOR INFRINGEMENT OF ANY PROPRIETARY RIGHTS, RELATING TO USE OR IMPLEMENTATION OF INFORMATION IN THIS SPECIFICATION. THE PROVISION OF THIS SPECIFICATION TO YOU DOES NOT PROVIDE YOU WITH ANY LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS.

USB Type-C™, USB-C™ and USB4™ are trademarks of the Universal Serial Bus Implementers Forum (USB-IF). Thunderbolt™ is a trademark of Intel Corporation. All product names are trademarks, registered trademarks, or service marks of their respective owners.

**Revision History:**

<b>Revision</b>	<b>Comments</b>	<b>Issue Date</b>
1.0	First Release	January 2021

## Contents

1	Introduction.....	7
2	Terminology.....	8
3	Assertions .....	9
4	Test Requirements.....	14
4.1	System.....	14
5	USB4 Mode Test Setups .....	15
5.1	USB4 Host.....	15
	Setup H1 – Host Connected to a Known Good Device.....	15
	Setup H2 – Host connected to a TBT3 Known Good Device.....	15
	Setup H3 – Host connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	16
	Setup H4 – Host connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable.....	16
5.2	USB4 Hub .....	17
	Setup D1 –Hub Router connected to a Compliance Host.....	17
	Setup D2 – Hub connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	17
	Setup D3 – Hub connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable.....	18
5.3	USB4 Device .....	18
	Setup D4 – Device Router connected to a Compliance Host .....	18
5.4	Cable.....	19
	Setup C1 – Known Good Host and Device connected with USB4 Re-Driver (with TBT3) Cable.....	19
5.5	Power Delivery .....	20
	Setup P1 - Host Source Power Provisioning Setup.....	20
	Setup P2 - Host Source Power Provisioning in Sleep Mode Setup .....	21
	Setup P3 - Device Source Power Provisioning Setup (Self-powered USB4 Hub, Dock & DPD) .....	22
	Setup P4 - Device Source Power Provisioning Setup (Self-powered USB4 Peripheral Device).....	23
	Setup P5 - Current Limit for VBUS of Self-Powered Host or Device.....	24
	Setup P6 - Current Limit for VCONN of Self-powered USB4 Host or Device .....	25
	Setup P7 - Power consumption (Non-Captive Bus-Powered USB4 Device) .....	26
	Setup P8 - Power consumption (Captive Bus-Powered USB4 Device).....	26
6	Subroutines .....	28
6.1	Router Enumeration Procedure.....	28
6.2	Router Reset Procedure.....	28
	Host Router .....	28
	Device Router.....	28
7	Test Descriptions.....	29
7.1	Chapter 4 Tests.....	29

TD TBT 4.1 .....	29
TD TBT 4.2 .....	30
TD TBT 4.3 .....	31
TD TBT 4.4 .....	32
TD TBT 4.5 .....	33
TD TBT 4.6 .....	34
TD TBT 4.7 .....	35
TD TBT 4.8 .....	36
TD TBT 4.9 .....	37
TD TBT 4.10 .....	37
TD TBT 4.11 .....	38
TD TBT 4.12 .....	39
TD TBT 4.13 .....	40
7.2 Chapter 5 Tests .....	41
TD TBT 5.1 .....	41
TD TBT 5.2 .....	42
7.3 Chapter 6 Tests .....	43
7.4 Chapter 7 Tests .....	43
TD TBT 7.1 .....	43

**Figures**

Figure 5-1. Host Connected to a Known Good Device.....	15
Figure 5-2. Host connected to a TBT3 Known Good Device.....	15
Figure 5-3. Host connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	16
Figure 5-4. Host connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	16
Figure 5-5. Hub Router connected to a Compliance Host .....	17
Figure 5-6. Hub connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	17
Figure 5-7. Hub connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable .....	18
Figure 5-8. Device Router connected to a Compliance Host .....	18
Figure 5-9. Known Good Host and Device connected with USB4 Re-Driver (with TBT3) Cable.....	19
Figure 5-10. Host Source Power Provisioning Setup .....	20
Figure 5-11. Host Source Power Provisioning in Sleep Mode Setup .....	21
Figure 5-12. Device Source Power Provisioning Setup SPD Hub/Dock or DPD.....	22
Figure 5-13. Device Source Power Provisioning Setup SPD Peripheral Device .....	23
Figure 5-14. Current Limit for VBUS of Self-Powered Host or Device.....	24

Figure 5-15. Current Limit for VCONN (Self-powered USB4 Host/Device) .....	25
Figure 5-16. (Non-Captive Bus-Powered USB4 Device) .....	26
Figure 5-17. Power consumption (Captive Bus-Powered USB4 Device) .....	27

## **1 Introduction**

This specification describes the tests needed to verify that a USB4 Product is Thunderbolt3 (TBT3) Compatible as defined in “USB4™ Thunderbolt3™ Compatibility Requirements Specification”. TBT3 Compatibility CTS is meant to ensure that USB4 products are interoperable with existing TBT3 products.

Tests and test setups related to Power Delivery, connection through LRD Cable and Prohibited Product IDs have been detailed in this specification.

## 2 Terminology

The following table describes the terms used in this document.

Compliance Device	A Known Good (KG) USB4 Device that is capable of performing Transport Layer Packet loopback.  The KG USB4 Device is configured by USB4 CV (when USB4 CV is upstream of the UUT) or the Exerciser (when the Exerciser is upstream of the UUT). Unless specified otherwise, the Compliance Device is configured as an ordinary KG USB4 Device. See the USB4 Connection Manager Guide for more information on how a USB4 Device is configured.
DFP	Downstream Facing Port.
DUT	Device Under Test
Exerciser	The compliance test tool (hardware and software) that implements USB4 Port functionality and the behavior required for compliance testing.
IOP	Interop Testing. See USB4™ Interop Test Specification.
KG USB4 Device	“Known Good” USB4 Device. A USB4 Device that is known to be compliant with the USB4 Specification.
KG USB4 Host	“Known Good” USB4 Host. A USB4 Host that is known to be compliant with the USB4 Specification.
KG TBT3 Device	A Certified Thunderbolt 3 Device.
KG TBT3 Host	A Certified Thunderbolt 3 Host.
LRD Cable	Linear Re-Driver Cable
PUT	Port Under Test. The USB4 Port on a UUT that is the test point for compliance testing.
RUT	Router Under Test
TBT VID	Thunderbolt Vendor ID
UFP	Upstream Facing Port.
USB4 CV	USB4 Command Verifier software. The software that runs compliance tests and analyzes the results.
USB4 Product	Refers to a USB4 host, USB4 hub, and/or USB4 device. Includes silicon, reference platforms, and end product.
UUT	Unit Under Test. The Router Assembly that is being tested for compliance.
VIF	Vendor Information File. File provided by UUT vendor that provides information about the characteristics and capabilities of the UUT.



### 3 Assertions

Compliance criteria are provided as a list of assertions that describe specific characteristics or behaviors that must be met. Each assertion provides a reference to the USB4™ Thunderbolt™ Compatibility Requirements Specification from which the assertion was derived. In addition, each assertion provides a reference to the specific test description(s) where the assertion is tested.

Each test assertion is formatted as follows:

Assertion #	Test #	Assertion Description
-------------	--------	-----------------------

**Assertion#:** Unique identifier for each spec requirement. The identifier is in the form USB4\_SPEC\_SECTION\_NUMBER#X, where X is a unique integer for a requirement in that section.

**Assertion Description:** Specific requirement from the specification

**Test #:** A label for a specific test description in this specification that tests this requirement. Test # can have one of the following values:

- NT This item is not explicitly tested in a test description. Items can be labeled NT for several reasons – including items that are not testable, not important to test for interoperability, or are indirectly tested by other operations performed by the compliance test.
- XX This item is covered by the test described in test description X.X in this specification.
- IOP This assertion is verified by the USB4 Interoperability Test Suite.
- BC This assertion is verified as part of a background check.

Test descriptions provide a high-level overview of the tests that are performed to check the compliance criteria. The descriptions are provided with enough detail so that a reader can understand what the test does. The descriptions do not describe the actual step-by-step procedure to perform the test.

The following Table presents the USB4 Specification Chapter 1 asserts regarding reserved fields and values.

Assertion #	Test Name	Assertion Description
<b>2 USB4 Requirements</b>		
2#1	NT	A USB4 Product shall implement Chapter 13 of the USB4 Specification.
<b>3 USB Type-C Requirements</b>		
3#1	NT	A USB4 Product shall perform Thunderbolt Compatibility Discovery and Entry as described in Appendix F of the USB Type-C Specification.
<b>4 USB Power Delivery Requirements</b>		
4#1	NT	A USB4 Product shall provide power as described in the USB PD Specification and shall follow the additional Thunderbolt-specific power requirements defined in this section.

Assertion #	Test Name	Assertion Description
<b>4.1 Host Source Power Provisioning</b>		
4.1#1	NT	A USB4 Host shall support Host Power provisioning as defined in the USB PD Specification.
4.1#2	TD TBT 4.1	If a USB4 Host has one USB4 Port, it shall provide at least 15W of power after Thunderbolt Alternate Mode is entered.
4.1#3	TD TBT 4.1	When a USB4 Host provides at least 15W of power on $V_{BUS}$ , it shall meet the $V_{BUS}$ Source requirements defined in Table 4-2.
4.1#4	TD TBT 4.1	When a USB4 Host is not capable of providing at least 15W of power to each of its USB4 Ports, it shall allocate power among its USB4 Ports as described in Table 4-1.
4.1#5	TD TBT 4.1	The power rules defined in USB PD shall be followed if power greater than 15W is provided.
4.1#6	TD TBT 4.2	If the first port only provides 5V/1.5A, then second port shall make 5V/3A available.
4.1#7	TD TBT 4.2	If the first and second ports only provides 5V/1.5A each, the third port shall make 5V/3A available.
4.1#8	TD TBT 4.2	If the first, second, and third ports only provides 5V/1.5A each, the fourth port shall make 5V/3A available.
4.1#9	TD TBT 4.1	A USB4 Host shall provide 1.5W $V_{CONN}$ on each USB4 Port as described in Table 4-3.
<b>4.2 Device Source Power Provisioning</b>		
<b>4.2.1 Self-Powered Device</b>		
4.2.1#1	TD TBT 4.4	A Self-Powered Device (SPDs) that is a USB4 Hub or USB4 Dock shall provide at least 15W on $V_{BUS}$ to each USB4 Port to enable support for upstream (charging) and downstream BPDs.
4.2.1#2	TD TBT 4.5	An SPD that is a USB4 Peripheral Device shall provide at least 4.5 W $V_{BUS}$ on the upstream facing port.
4.2.1#3	TD TBT 4.4	An SPD shall meet the $V_{CONN}$ requirements defined in Table 4-3.
4.2.1#4	NT	An SPD shall follow the power rules defined in the USB PD Specification when providing power greater than 15W.
<b>4.2.2 Bus Powered Device</b>		
4.2.2#2	NT	A Bus-Powered Device (BPD) shall connect as a Sink presenting $R_d$ on both CC1 and CC2. A BPD is not required to provide $V_{CONN}$ .

Assertion #	Test Name	Assertion Description
<b>4.2.3 Dual-Powered Device</b>		
4.2.3#1	TD TBT 4.4	A Dual-Powered Device (DPD), shall meet the $V_{BUS}$ requirements in Table 4-2.
4.2.3#2	TD TBT 4.4	A DPD shall meet the $V_{CONN}$ requirements defined in Table 4-3.
4.2.3#3	NT	A DPD shall not have more than one USB Type-C port.
4.2.3#4	NT	A DPD shall follow the power rules defined in the USB PD Specification when providing power greater than 15W.
<b>4.3 Source <math>V_{BUS}</math> Requirements</b>		
<b>4.3.1 Electrical</b>		
4.3.1#1	TD TBT 4.1, TD TBT 4.2, TD TBT 4.3	The power requirements defined in Table 4-2 shall be met while the maximum load current is applied by the Sink.
4.3.1#2	NT	All other requirements defined in the USB PD Specification and the USB Type-C Specification for Sources (such as ramp rates, overshoot, capacitive loading, etc.) shall be met.
4.3.1#3	NT	The Source Power Rules defined in USB PD shall apply.
<b>4.4 Output Over Current Protection</b>		
4.4#1	TD TBT 4.6, TD TBT 4.7, TD TBT 4.8, TD TBT 4.9	A Source shall implement output over current protection to prevent damage from output current that exceeds the current handling capability of the Source.
<b>4.5 Source <math>V_{CONN}</math> Electrical Requirements</b>		
4.5#1	NT	All other requirements defined in the USB PD Specification and the USB Type-C Specification for Sources (such as ramp rates, overshoot, capacitive loading, etc.) shall be met.
4.5#2	TD TBT 4.8, TD TBT 4.9	The OCP (overcurrent) threshold for $V_{CONN}$ in a $V_{CONN}$ source shall be set at least 5% higher than the minimum operating current that it supports, $iV_{CONN\_MIN}$ , calculated as $iV_{CONN\_MIN} = 1.5W/V_{CONN\_MIN}$ where $V_{CONN\_MIN}$ is the lowest voltage at which the $V_{CONN}$ source will supply $V_{CONN}$ .
4.5#3	TD TBT 4.8, TD TBT 4.9	The $V_{CONN}$ source OCP shall not trip on excursions great than $iV_{CONN\_MIN} + 5\%$ of the duration less than 1ms.

Assertion #	Test Name	Assertion Description
<b>4.6 Device Sink Power Consumption</b>		
4.6#1	TD TBT 4.10, TD TBT 4.11	USB4 Non-Captive Bus-Powered Devices shall meet the power requirements defined in Table 4-4 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
4.6#2	TD TBT 4.12, TD TBT 4.13	USB4 Captive Bus-Powered Devices shall meet the power requirements defined in Table 4-5 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
<b>5 USB4 Re-Driver (with TBT3) Cable</b>		
5#1	TD TBT 5.1	When a USB4 Product is connected via a USB4 Re-Driver (with TBT3) cable, it shall do the following: Per Figure 5-1 of the USB Type-C specification, when the cable responds as a Passive Cable with USB 3.2 Gen2 as its highest supported speed, check the cable for TBT3 support.
5#2	TD TBT 5.1	When a USB4 Product is connected via a USB4 Re-Driver (with TBT3) cable, it shall do the following: When an LRD cable responds to TBT3 discovery with bit B25 set as Active Cable, proceed as follows: Use a TBT3 Cable Enter Mode Command.
5#3	TD TBT 5.1	When a USB4 Product is connected via a USB4 Re-Driver (with TBT3) cable, it shall do the following: When an LRD cable responds to TBT3 discovery with bit B25 set as Active Cable, proceed as follows: If operating in TBT3 mode, use a TBT3 Device Enter Mode Command with B25 set to 1b.
5#4	TD TBT 5.1	When a USB4 Product is connected via a USB4 Re-Driver (with TBT3) cable, it shall do the following: When an LRD cable responds to TBT3 discovery with bit B25 set as Active Cable, proceed as follows: If operating as USB4, use an Enter_USB Message with an Enter_USB Data Object that has B20..19 (Cable Type) set to 10b (Active Re-driver).
5#5	TD TBT 5.2	A USB4 Re-Driver (with TBT3) cable shall reply to SOP' Discover Identity Command as follows: <ol style="list-style-type: none"> <li>1) ID Header VDO B29..27 Product Type (Cable Plug) is set to 011b (Passive Cable).</li> <li>2) ID Header VDO Modal Operation Supported B26 is set to 1b Support Model Operation (ALT MODE).</li> <li>3) Passive Cable VDO B2..0 USB Highest Speed is set to 010b ([USB 3.2]/[USB4] Gen2).</li> </ol>

Assertion #	Test Name	Assertion Description
5#6	TD TBT 5.2	<p>A USB4 Re-Driver (with TBT3) cable shall reply to SOP' During Thunderbolt Compatibility Discovery (as described in Appendix F of the USB Type-C Specification)</p> <ol style="list-style-type: none"> <li>1) For Discover SVID: set to 0x8087 (TBT3 SVID).</li> <li>2) For TBT3 Cable Discover Mode VDO Responses: <ol style="list-style-type: none"> <li>a. Active_Passive B25:is set to 1b (Active cable).</li> <li>b. Re-timer B22: is set to 0b (Not-Re-timer).</li> <li>c. Cable Speed B18..16 is set to 011b (10 Gbps and 20 Gbps (TBT 3rd Gen active cables and 20 Gbps passive cables)).</li> </ol> </li> </ol>
<b>6 Thunderbolt VID</b>		
<b>7 Prohibited Product IDs</b>		
7#1	TD TBT 7.1	A Device Router shall not contain any of the following values in the Product ID field in Router Configuration Space: 0x1500-0x15FF; 0x0B26.

## **4 Test Requirements**

### **4.1 System**

Vendor provides the Router Under Test (RUT) in a reference system for testing. The reference system must expose one USB Type-C™ connector per USB4 Port. The USB Type-C connector is the test point for the RUT.

For a USB4™ host:

- Reference system must be x64-based, run Windows 10
- Host Router must be PCIe-based

*Note: Future versions of this specification will expand host testing to other OS and architectures.*

## 5 USB4 Mode Test Setups

This section defines the test setups for a USB4 Host, Hub, or Peripheral Device.

A USB4-Based Dock is tested as a USB4 hub.

### 5.1 USB4 Host

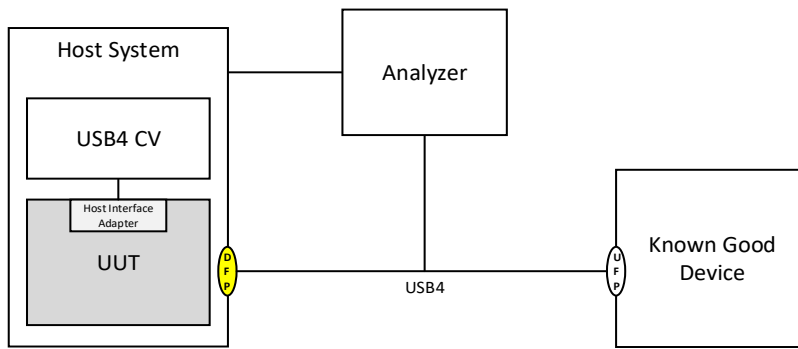
This section describes the test setups for a USB4 host. The Port Under Test (PUT) is highlighted in each figure.

#### Setup H1 – Host Connected to a Known Good Device

Description:

- The UFP of the Known good Device is connected to the DFP of the UUT
- Analyzer is connected between UUT and Compliance Device

**Figure 5-1. Host Connected to a Known Good Device**

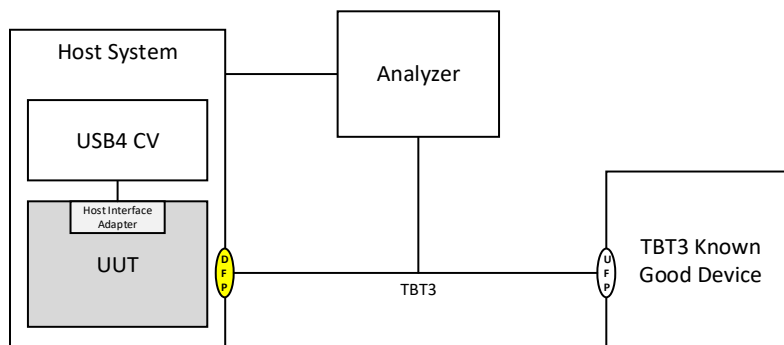


#### Setup H2 – Host connected to a TBT3 Known Good Device

Description:

- The UFP of the TBT3 Known good Device is connected to the DFP of the UUT
- Analyzer is connected between UUT and Compliance Device

**Figure 5-2. Host connected to a TBT3 Known Good Device**

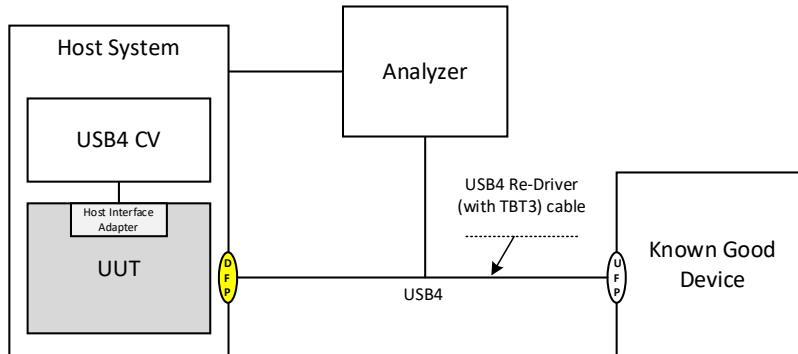


### Setup H3 – Host connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable

Description:

- The UFP of the Known good Device is connected to the DFP of the UUT through a USB4 Re-Driver (with TBT3) cable
- Analyzer is connected between UUT and Compliance Device

Figure 5-3. Host connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable

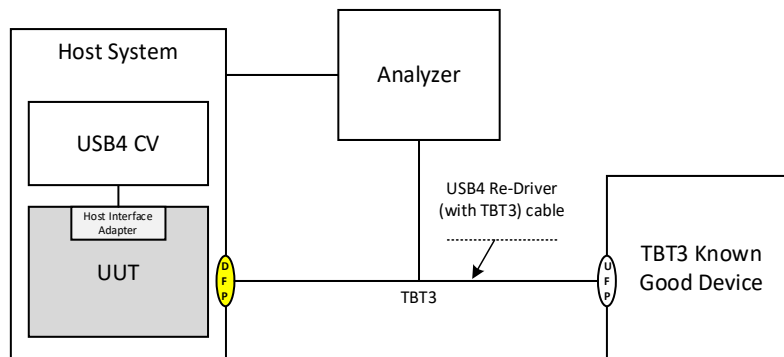


### Setup H4 – Host connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable

Description:

- The UFP of the TBT3 Known good Device is connected to the DFP of the UUT through a USB4 Re-Driver (with TBT3) cable
- Analyzer is connected between UUT and Compliance Device

Figure 5-4. Host connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable





## 5.2 USB4 Hub

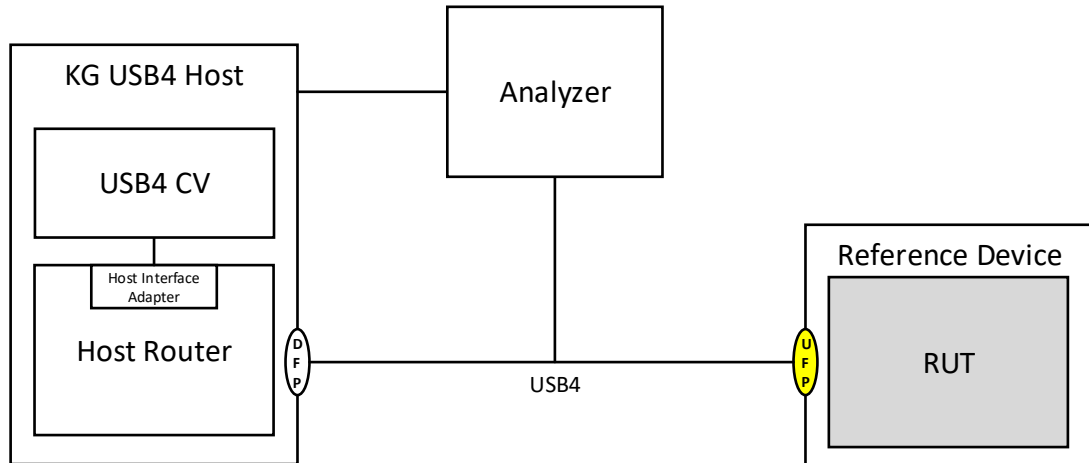
This section describes the test setups for a USB4 hub. The Port Under Test (PUT) is highlighted in each figure.

### Setup D1 –Hub Router connected to a Compliance Host

Description:

- DFP on KG USB4 Host connects to UFP of the RUT.
- Analyzer is connected between the KG USB4 Host and the RUT.

Figure 5-5. Hub Router connected to a Compliance Host

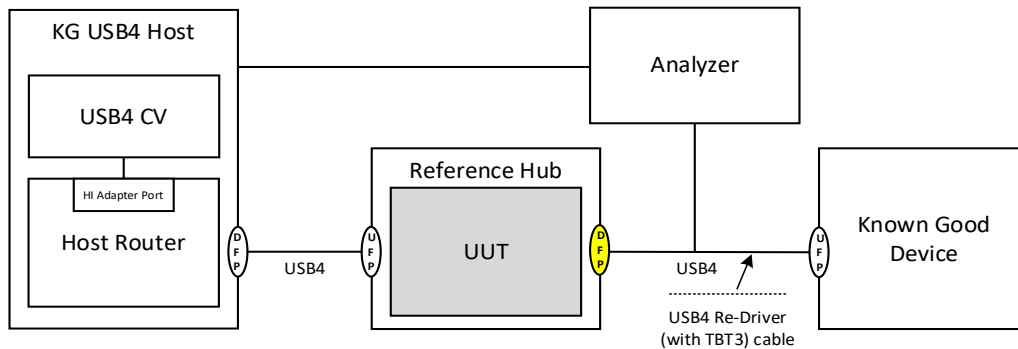


### Setup D2 – Hub connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable

Description:

- DFP on KG USB4 Host connects to UFP of the UUT
- UFP of Known good Device connects to DFP of the UUT through a USB4 Re-Driver (with TBT3) cable
- Analyzer is connected between the UUT and Compliance Device

Figure 5-6. Hub connected to a Known Good Device with USB4 Re-Driver (with TBT3) Cable

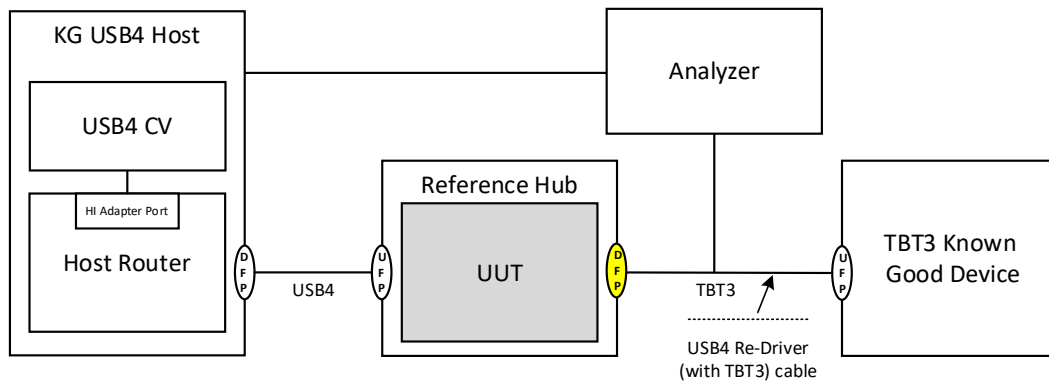


### Setup D3 – Hub connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable

Description:

- DFP on KG USB4 Host connects to UFP of the UUT
- UFP of a TBT3 Known good Device connects to DFP of the UUT through a USB4 Re-Driver (with TBT3) cable
- Analyzer is connected between the UUT and Compliance Device

**Figure 5-7. Hub connected to a TBT3 Known Good Device with USB4 Re-Driver (with TBT3) Cable**



### 5.3 USB4 Device

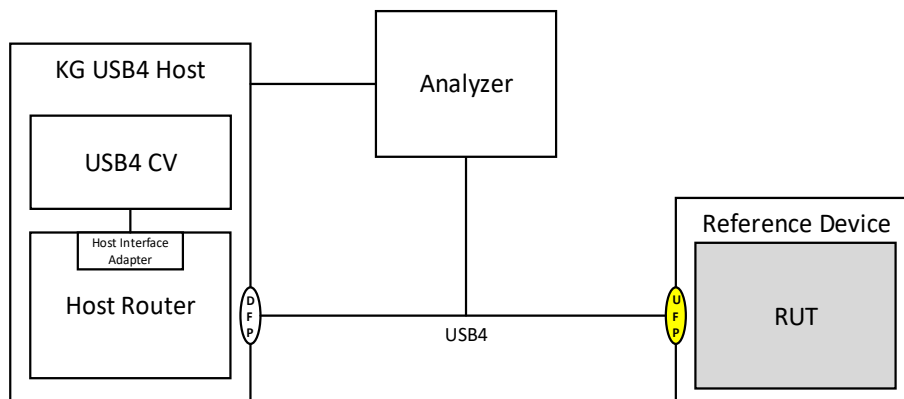
This section describes the test setup for a USB4 peripheral device. The Port Under Test (PUT) is highlighted in each figure.

#### Setup D4 – Device Router connected to a Compliance Host

Description:

- DFP on KG USB4 Host connects to UFP of the RUT.
- Analyzer is connected between the KG USB4 Host and the RUT

**Figure 5-8. Device Router connected to a Compliance Host**



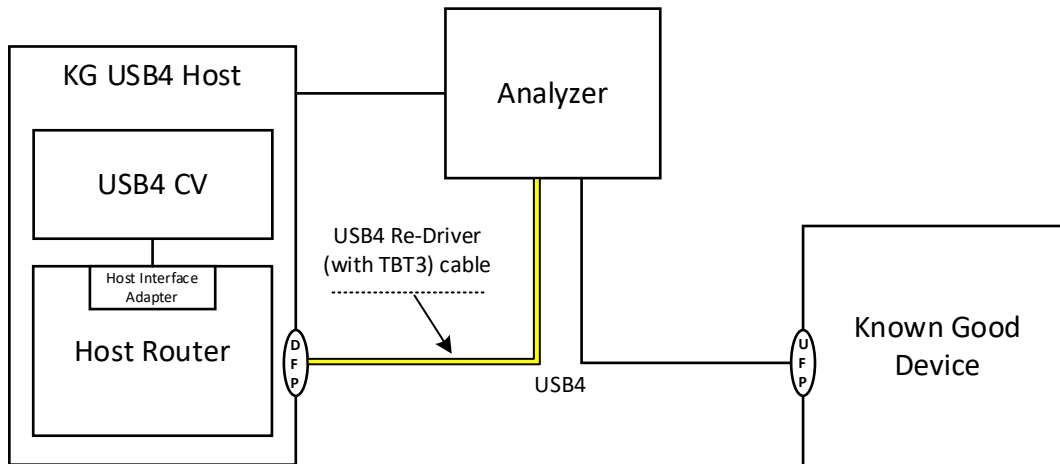
## 5.4 Cable

### Setup C1 – Known Good Host and Device connected with USB4 Re-Driver (with TBT3) Cable

Description:

- DFP of a KG USB4 Host connects to the Analyzer using a USB4 Re-Driver (with TBT3) cable.
- UFP of a KG USB4 Device connects to the Analyzer.

**Figure 5-9. Known Good Host and Device connected with USB4 Re-Driver (with TBT3) Cable**



## 5.5 Power Delivery

All test equipment requires calibration to ensure accurate and repeatable results. Equipment shall be calibrated prior to, and if necessary, during the test procedure.

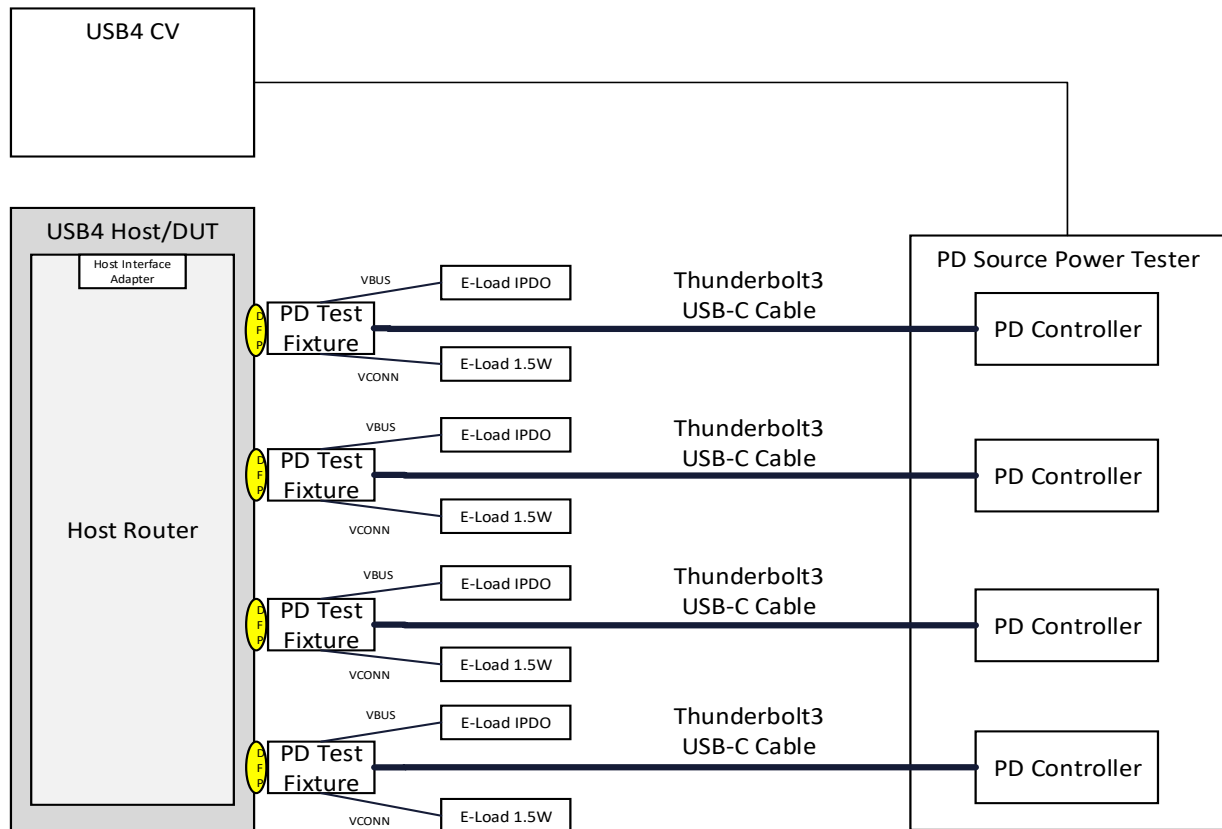
### Setup P1 - Host Source Power Provisioning Setup

This section describes the test setup for testing up to 4 power source ports on a USB4 Host.

According to Section 4.1 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification”

- If a USB4 Host has one USB4 Port, it shall provide at least 15W of power.
- For a USB4 Host with multiple USB4 ports, power is allocated on a first-come first-serve basis between the ports. Refer Table 4-1 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”

**Figure 5-10. Host Source Power Provisioning Setup**



Description:

Figure 5-10 illustrated above consists of the following:

- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)
    - Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on V<sub>BUS</sub> and V<sub>CONN</sub>.

- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

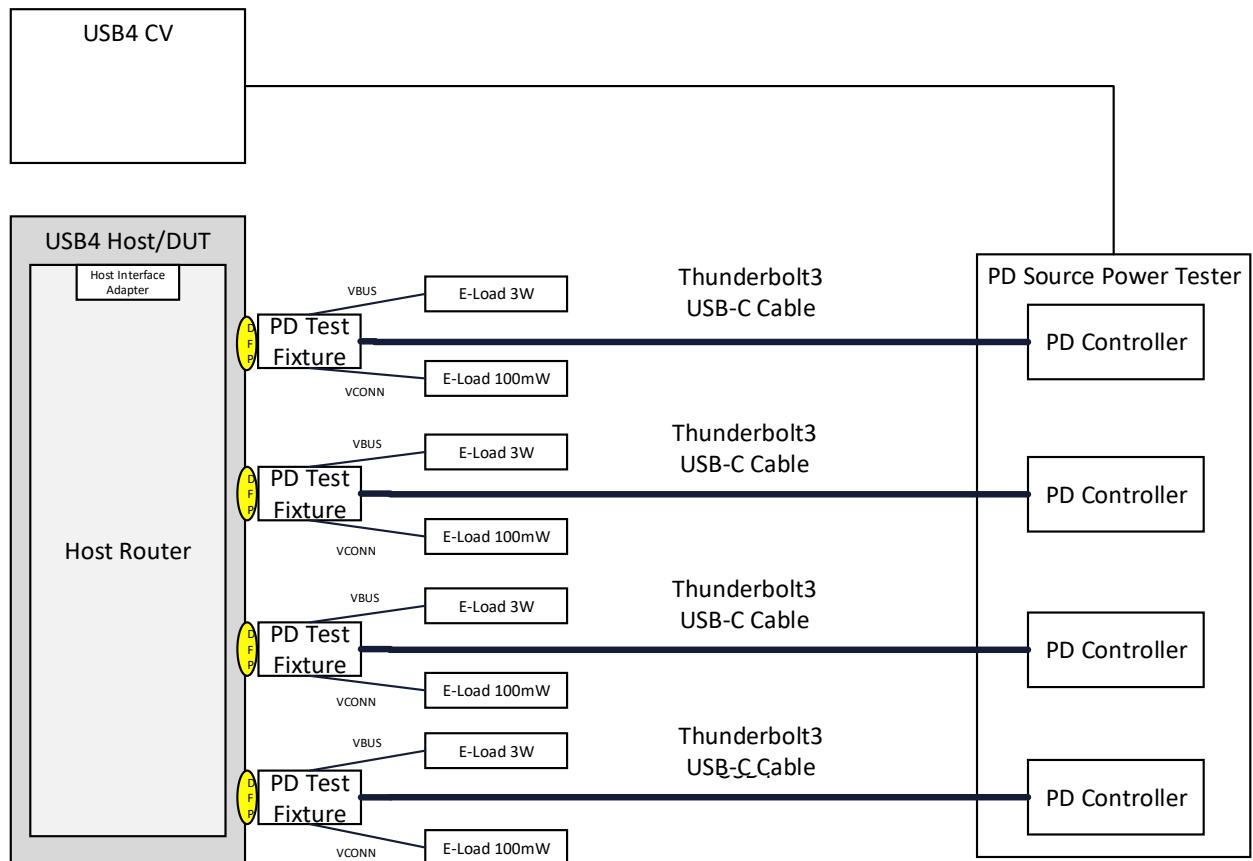
### Setup P2 - Host Source Power Provisioning in Sleep Mode Setup

This section describes the test setup for testing up to 4 power source ports on a USB4 Host in sleep mode.

According to Section 4.6 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification”

- A USB4 Host provides a minimum of 3W to all ports simultaneously when host is in sleep mode.

**Figure 5-11. Host Source Power Provisioning in Sleep Mode Setup**



Description:

Figure 5-11 illustrated above consists of the following:

- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)
    - Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on V<sub>BUS</sub> and V<sub>CONN</sub>.

- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

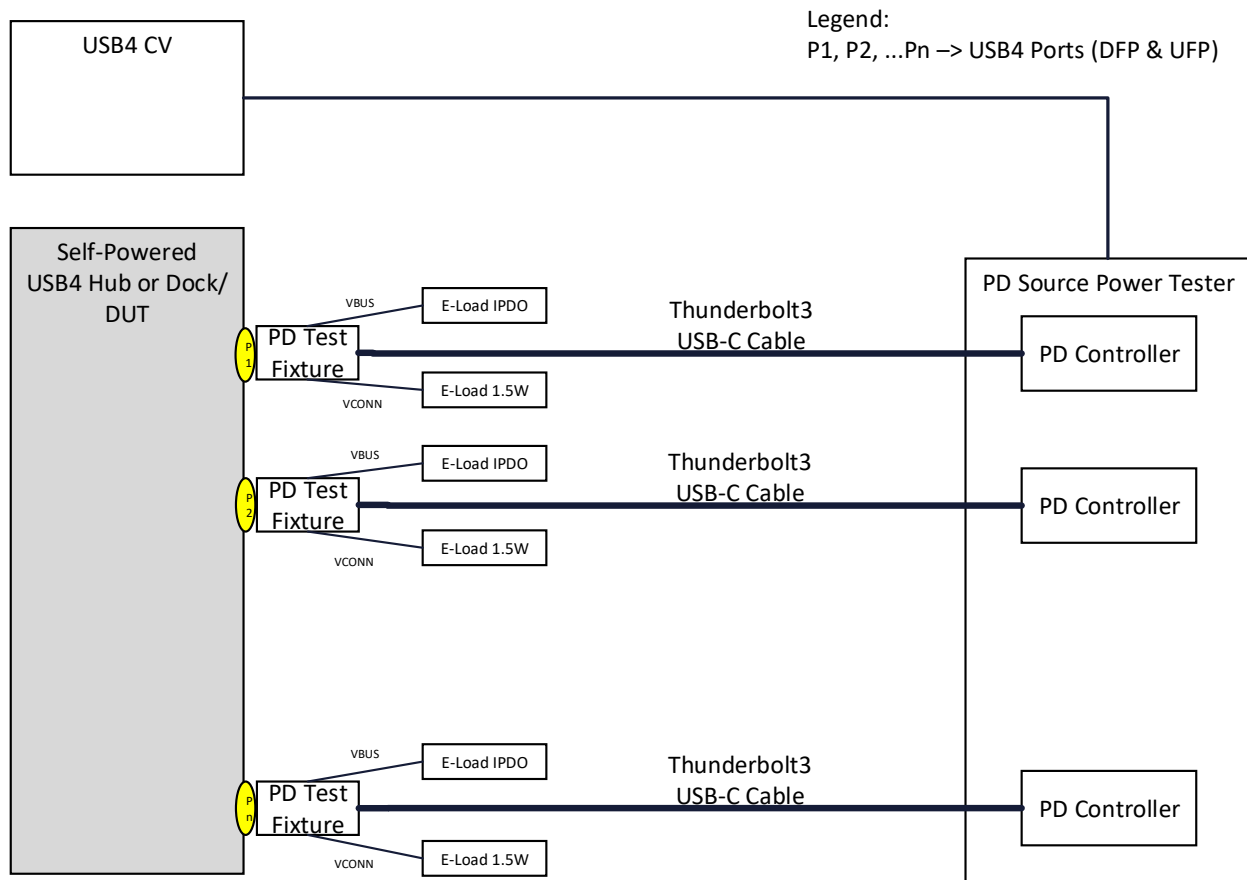
### Setup P3 - Device Source Power Provisioning Setup (Self-powered USB4 Hub, Dock & DPD)

This section describes the test setup for testing multiple USB4 ports as power source on a self-powered USB4 Hub or Dock or single USB4 port on a Dual Powered Device.

According to Section 4.2.1 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification”

- A self-powered USB4 Hub or Dock shall provide at least 15W of power on all available UFP and DFP.
- An SPD USB4 Hub or Dock shall meet VCONN requirements as specified in Table 4-3 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”

**Figure 5-12. Device Source Power Provisioning Setup SPD Hub/Dock or DPD**



Description:

Figure 5-12 illustrated above consists of the following:

- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)

- Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on  $V_{BUS}$  and  $V_{CONN}$ .
- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

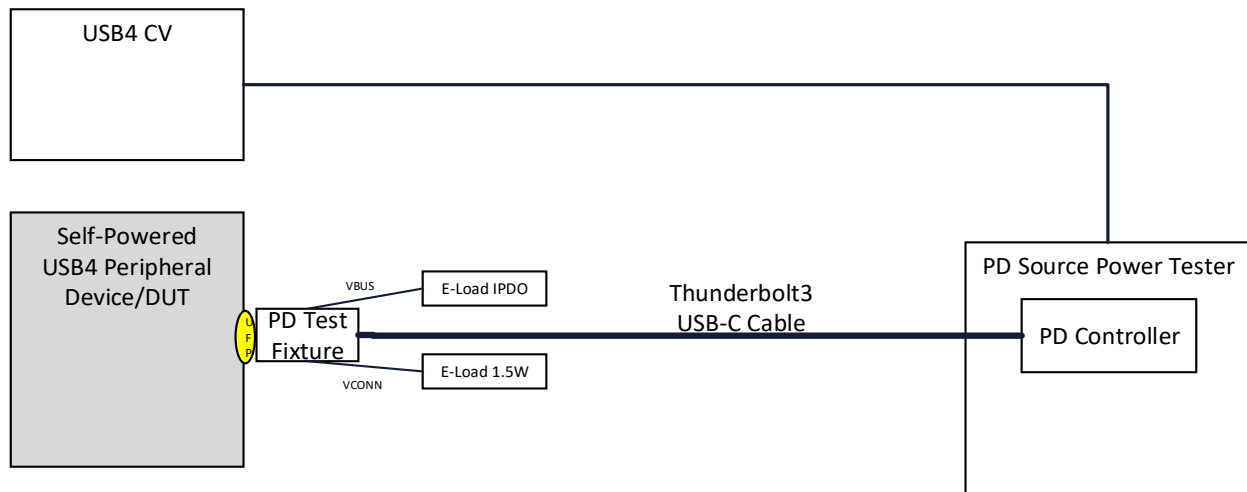
#### Setup P4 - Device Source Power Provisioning Setup (Self-powered USB4 Peripheral Device)

This section describes the test setup for testing UFP USB4 port as power source on a self-powered USB4 Peripheral Device.

According to Section 4.2.1 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification”

- A self-powered USB4 Peripheral Device shall provide at least 4.5W of power on its UFP.
- An SPD USB4 Peripheral Device shall meet  $V_{CONN}$  requirements as specified in Table 4-3 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”

**Figure 5-13. Device Source Power Provisioning Setup SPD Peripheral Device**



Description:

Figure 5-13 illustrated above consists of the following:

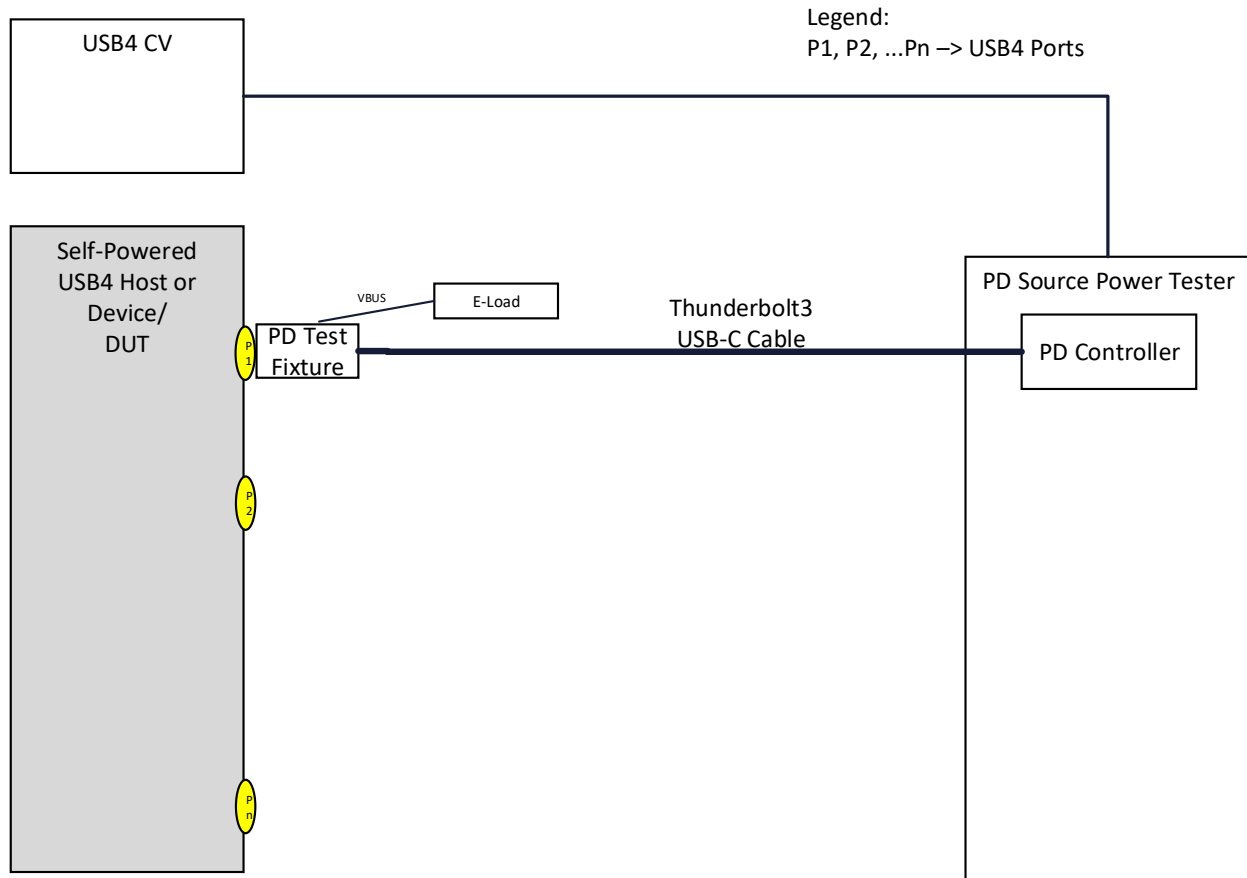
- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)
    - Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on  $V_{BUS}$  and  $V_{CONN}$ .
- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

### Setup P5 - Current Limit for VBUS of Self-Powered Host or Device

This section describes the test setup for testing VBUS Current Limits on all USB4 ports of a self-powered USB4 Host or a Device.

Refer Section 4.3.1, Table 4-2 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification” for the VBUS Current Limit requirements.

**Figure 5-14. Current Limit for VBUS of Self-Powered Host or Device**



Description:

Figure 5-14 illustrated above consists of the following:

- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)
    - Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on VBUS.
- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

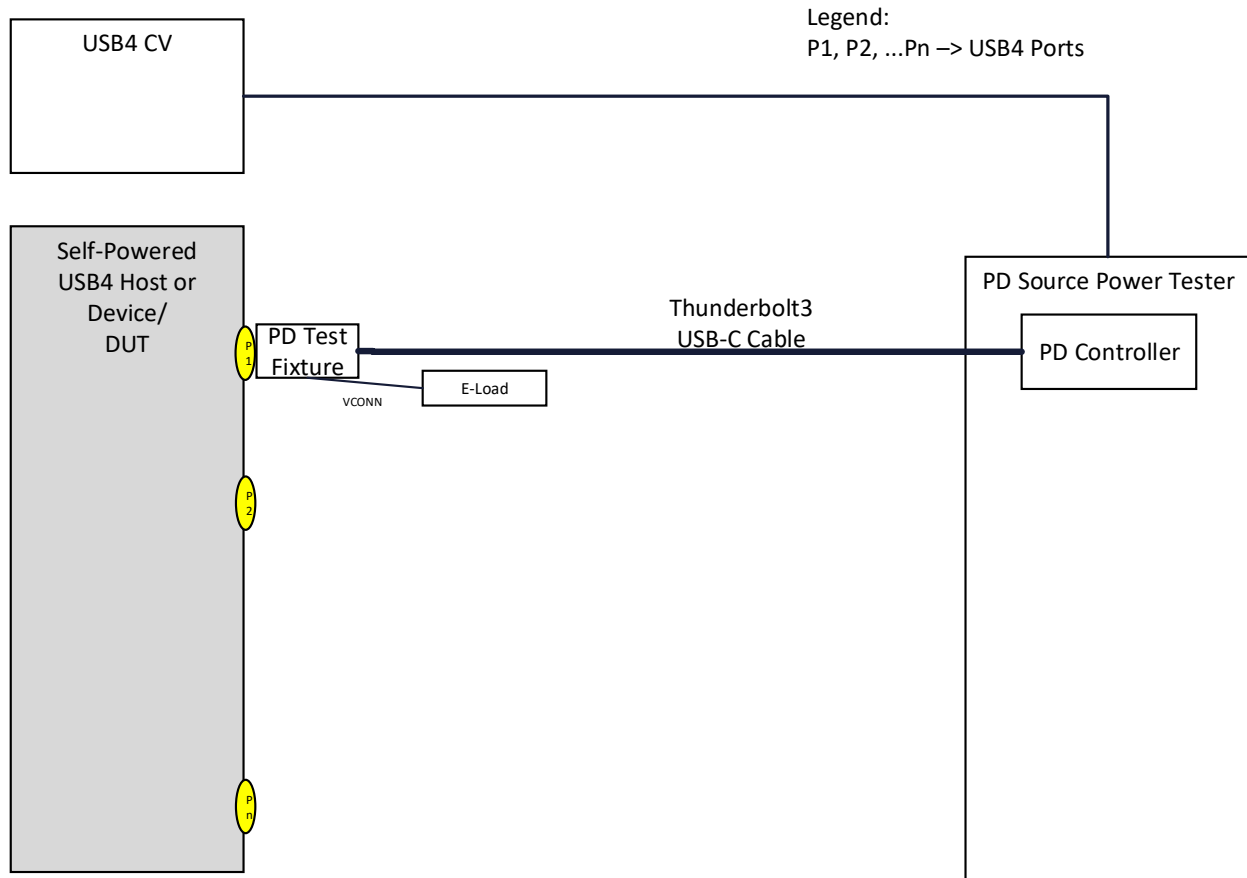


## Setup P6 - Current Limit for VCONN of Self-powered USB4 Host or Device

This section describes the test setup for testing VCONN Current Limits on all USB4 ports of a self-powered USB4 Host or a Device.

Refer Section 4.5, Table 4-3 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification” for the VCONN Current Limit requirements.

**Figure 5-15. Current Limit for VCONN (Self-powered USB4 Host/Device)**



Description:

Figure 5-15 illustrated above consists of the following:

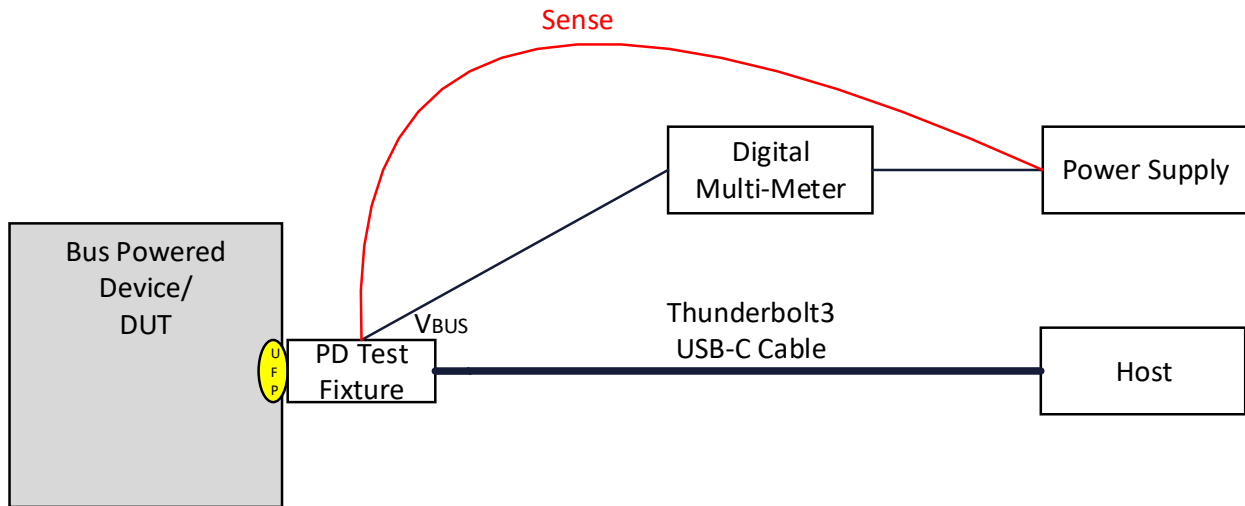
- Presence of PD controller in the “PD Source Power Tester”.
- Ability in “PD Source Power Tester” to negotiate specific PDO.
- Method to verify the Voltage and Current of negotiated PDO.
  - Recommended Test equipment:
    - QuadraMax 4 port Source Power Tester (Protocol Analyzer and PD Controller in setup)
    - Wilder USB4 microcontroller and Test Adapters (USB4-TPA-UC-K)
- Ability either through a “PD Test Fixture” or the “PD Source Power Tester” to apply Load on VCONN.
- A host as USB4 CV connected to “PD Source Power Tester” to verify PD messages, advertised PDOs, Negotiated PDO, Voltage and Current graphs.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

### Setup P7 - Power consumption (Non-Captive Bus-Powered USB4 Device)

This section describes the test setup for testing maximum power consumption by a Bus-Powered USB4 Device.

Refer Section 4.6, Table 4-4 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification” for the maximum power consumption in normal operation and in sleep conditions.

Figure 5-16. (Non-Captive Bus-Powered USB4 Device)



Description:

Figure 5-16 illustrated above consists of the following:

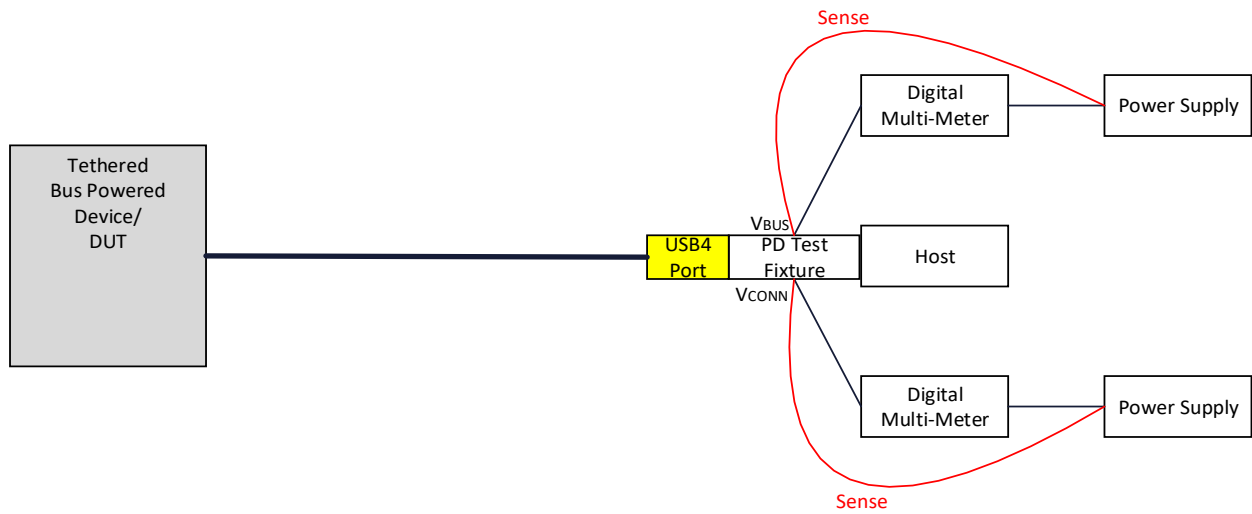
- Presence of a Host that is wake capable from a USB4 Device connection.
- Ability through a “PD Test Fixture”, Digital Multi-Meter (DMM) and DC Power Supply connected in series to alter voltage from power supply and current from DMM on  $V_{BUS}$  of port under test.
- 0.8m Passive TBT3 (40Gbps) USB-C cable e-marked as a 5A cable to connect ports under test to the Tester.

### Setup P8 - Power consumption (Captive Bus-Powered USB4 Device)

This section describes the test setup for testing maximum power consumption by a Bus-Powered tethered USB4 Device in normal operation and in sleep conditions.

Refer Section 4.6, Table 4-5 of “USB4™ Thunderbolt3™ Compatibility Requirements Specification” for the maximum power consumption.

**Figure 5-17. Power consumption (Captive Bus-Powered USB4 Device)**



Description:

Figure 5-17 illustrated above consists of the following:

- Presence of a Host that is wake capable from a USB4 Device connection.
- Ability through a "PD Test Fixture", Digital Multi-Meter (DMM) and DC Power Supply connected in series to alter voltage from power supply and current from DMM on  $V_{BUS}$  and  $V_{CONN}$  of port under test.

## 6 Subroutines

### 6.1 Router Enumeration Procedure

The steps in this section are performed whenever a test step calls for a Router to be enumerated.

1. Wait for a Hot Plug Event Packet with UPG=0 for Lane 0 and Lane 1
2. Send the UUT a Write Request that writes the following fields:
  - a. *Connection Manager USB4 Version* = 1.0 (for a USB4 Connection Manager)
  - b. *Connection Manager USB4 Version* = 0.0 (for a TBT3 Connection Manager)
  - c. *Topology ID* = Router TopologyID (assigned per USB4 Specification)
  - d. *Depth* = Router depth (0 for a Host Router, or 1 for a Device Router)
  - e. *Valid* = 1b

### 6.2 Router Reset Procedure

The steps in this section are performed whenever a test calls for the UUT to be reset.

#### Host Router

1. Teardown any Paths in the RUT
2. Disable, then enable all Transmit and Receive Rings
3. Perform a DFP Reset in each of the Downstream Facing Ports
4. Reset the Host Interface using the Host Interface Reset Register

#### Device Router

Perform the following steps in the DFP of the USB4 Host that is connected to the UUT:

1. Set the Downstream Port Reset bit to 1b
2. Read the *Lock* bits for the Lane 0 and Lane 1 Adapters
3. Poll the *Lock* bits until both are 1b
4. Set the Downstream Port Reset bit to 0b

## 7 Test Descriptions

### 7.1 Chapter 4 Tests

#### TD TBT 4.1

- A. Purpose:
- Verify the USB4 Host supports power provisioning as defined in USB PD specification.
  - Verify USB4 Host provides at least 15W of power after USB4 Mode is entered.
  - Verify USB4 Host meets the  $V_{BUS}$  source requirements as defined in Table 4-2 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
  - Verify the USB4 Host provides power to each of its USB4 ports as described in Table 4-1 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
  - Verify USB4 Host provides greater than 15W as per the power rules defined in USB PD.
  - Verify USB4 Host provides 1.5W  $V_{CONN}$  as described in Table 4-3 of the “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
- 4.1#2
  - 4.1#3
  - 4.1#4
  - 4.1#5
  - 4.1#9
  - 4.3.1#1
- C. Test Setups:
- P1
  - This test applies to all DFP of USB4 Host/DUT.
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat steps 1 through 5 for all available USB4 ports.
  - Repeat steps 6 through 27 for all available PDOs in the port under test.
  - Repeat steps 6 through 27 for with  $V_{CONN}$  provided on the second CC line in the port under test.
  - Repeat steps 6 through 27 for all available USB4 ports.
- F. Procedure:
1. Connect a PD controller to the USB4 port under test.
  2. Use the “PD Source Power Tester” to issue Get\_Source\_Cap Message to get the source PDOs.
  3. Record all available source PDOs.
  4. Verify 5V/3A PDO is available.
  5. Disconnect the PD controller
  6. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to the port under test using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  7. Using a PD controller negotiate a 5V/3A PDO.
  8. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to the rest of the available USB4 ports of the DUT using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  9. For the rest of the available USB4 ports - using PD controllers - negotiate the highest available PDOs (first-come, first-serve basis).

10. Verify rest of the ports present a 5V/1.5A PDO or higher.
11. Record  $V_{BUS}$  voltage of the port under test.
12. Verify  $V_{BUS}$  is not greater than 5.5V.
13. Verify  $V_{BUS}$  is not less than 4.75V.
14. Record  $V_{CONN}$  voltage of the port under test
15. Verify  $V_{CONN}$  is not greater than 5.5V.
16. Verify  $V_{CONN}$  is not less than 4.25V.
17. Set a 3A or a 1.5A constant current (CC) load on each E-load that is connected to  $V_{BUS}$  (per the negotiated PDO).
18. Set a 1.5W constant power (CP) load on each E-load that is connected to  $V_{CONN}$ .
19. Turn ON the load on all E-loads and wait for as long as necessary for the voltages to stabilize.
20. Record  $V_{BUS}$  voltage of the port under test.
21. Verify  $V_{BUS}$  is not greater than 5.5V.
22. Verify  $V_{BUS}$  is not less than 4.75V.
23. Record  $V_{CONN}$  voltage of the port under test.
24. Verify  $V_{CONN}$  is not greater than 5.5V.
25. Verify  $V_{CONN}$  is not less than 4.25V.
26. Record the lowest voltage value of  $V_{CONN}$  during testing as  $V_{CONN\_min}$
27. Turn OFF the load on all E-loads and disconnect all ports.

#### TD TBT 4.2

- A. Purpose:
  - Verify if the first USB4 port on the USB4 Host provides 5V/1.5A then second port makes 5V/3A PDO available.
  - Verify if the first and second USB4 ports on the USB4 Host provides 5V/1.5A then the third port makes 5V/3A PDO available.
  - Verify if the first, second and third USB4 ports on the USB4 Host provides 5V/1.5A then the fourth port makes 5V/3A PDO available.
- B. Asserts:
  - 4.1#6
  - 4.1#7
  - 4.1#8
  - 4.3.1#1
- C. Test Setups:
  - P1
  - This test applies to all DFP of USB4 Host/DUT. Any available port can be chosen as “First Port” when the test is initiated.
- D. Pre-Condition:
  - None
- E. Repetitions:
  - Repeat test procedure on all available USB4 ports of the DUT.
- F. Procedure:
  1. Connect a PD controller to the first USB4 port.
  2. Record all available source PDOS.
  3. Verify a 5V/3A PDO is available.
  4. Using a PD controller negotiate a 5V/1.5A PDO.

5. Connect a PD controller on the second available USB4 port.
6. Record all available source PDOs on the second port.
7. Verify a 5V/3A PDO is available
8. Using a PD controller negotiate a 5V/3A PDO.
9. Connect a PD controller on remaining two USB4 ports (if ports are available).
10. For the remaining two USB4 ports - using PD controllers - negotiate the highest available PDOs (first-come, first-serve basis)
11. Verify rest of the ports present a 5V/1.5A PDO or higher.
12. Disconnect PD controllers from all available ports.
13. Connect a PD controller to the first USB4 port.
14. Record all available source PDOs.
15. Verify a 5V/3A PDO is available.
16. Using a PD controller negotiate a 5V/1.5A PDO.
17. Connect a PD controller on the second available USB4 port.
18. Record all available source PDOs on the second port.
19. Verify a 5V/3A PDO is available.
20. Using a PD controller negotiate a 5V/1.5A PDO.
21. Connect a PD controller on the on the third USB4 port if available.
22. Record all available source PDOs on the third port.
23. Verify a 5V/3A PDO is available
24. Using a PD controller negotiate a 5V/3A PDO.
25. Connect a PD controller on the fourth USB4 port.
26. Using PD controller, negotiate the highest available PDO.
27. Verify fourth port presents a 5V/1.5A PDO or higher.
28. Disconnect PD controllers from all available ports.
29. Connect a PD controller to the first USB4 port.
30. Record all available source PDOs.
31. Verify a 5V/3A PDO is available.
32. Using a PD controller negotiate a 5V/1.5A PDO.
33. Connect a PD controller on the second available USB4 port.
34. Record all available source PDOs on the second port.
35. Verify a 5V/3A PDO is available.
36. Using a PD controller negotiate a 5V/1.5A PDO.
37. Connect a PD controller on the on the third USB4 port if available.
38. Record all available source PDOs on the third port.
39. Verify a 5V/3A PDO is available.
40. Using a PD controller negotiate a 5V/1.5A PDO
41. Connect a PD controller on the fourth USB4 port.
42. Record all available source PDOs on the fourth USB4 port.
43. Verify a 5V/3A PDO is available.
44. Using PD controller, negotiate a 5V/3A PDO.
45. Verify fourth port presents a 5V/3A PDO or higher.

#### **TD TBT 4.3**

- A. Purpose:
  - Verify the USB4 Host provides at a minimum of 3W on  $V_{BUS}$  and 100mW on  $V_{CONN}$  per port simultaneously in sleep mode as defined in Table 4-2 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
  - 4.3.1#1
- C. Test Setups:

- P2
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat test procedure with  $V_{CONN}$  provided on the second CC line on each port under test
- F. Procedure:
1. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to each USB4 port of the Host/DUT using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  2. Use the “PD Source Power Tester” to issue Get\_Source\_Cap Message to get the source PDOs.
  3. Record all available source PDOs.
  4. Verify 5V/1.5A PDO is available.
  5. Using the PD controllers negotiate the highest available PDO on all ports.
  6. Verify all the ports present a 5V/1.5A PDO or higher.
  7. Set a 3W constant power (CP) load on each E-load that is connected to  $V_{BUS}$ .
  8. Set a 100mW constant power (CP) load on each E-load that is connected to  $V_{CONN}$ .
  9. Turn ON the load on all E-loads and wait for as long as necessary for the voltages to stabilize.
  10. Put Host in sleep mode (S3).
  11. Verify power provided on  $V_{BUS}$  of each port is 3W at minimum.
  12. Verify power provided on  $V_{CONN}$  of each port is 100mW at minimum.
  13. Verify the DUT stays in sleep mode (S3).
  14. Disconnect all PD controllers from the ports.

#### TD TBT 4.4

- A. Purpose:
- Verify if a Self-Powered Device (SPD) USB4 Hub/ USB4 Dock or a Dual Powered Device (DPD) provides at least 15W on  $V_{BUS}$  to each USB4 Port.
  - Verify if an SPD USB4 Hub/ USB4 Dock or a Dual Powered Device (DPD) provides the  $V_{CONN}$  as described in Table 4-3 of the “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
- 4.2.1#1
  - 4.2.1#3
  - 4.2.3#1
  - 4.2.3#2
- C. Test Setups:
- P3
  - This test applies to all UFP and DFP of USB4 Self Powered Hub or Dock and single port of Dual Powered Device.
- D. Pre-Condition:
- None



- E. Repetitions:
- Repeat test steps 1 through 5 on all available USB4 ports of the SPD Hub or Dock.
  - Repeat steps 6 through 26 for all available PDOs in the port under test.
  - Repeat steps 6 through 26 for with  $V_{CONN}$  provided on the second CC line in the port under test.
  - Repeat steps 6 through 26 for all available USB4 ports
- F. Procedure:
1. Connect a PD controller to the single USB4 port.
  2. Use the PD controller to issue Get\_Source\_Cap Message to get the source PDOs.
  3. Record all available source PDOs.
  4. Verify a 5V/3A PDO is available.
  5. Disconnect the PD controller.
  6. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to the port under test using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the "PD Source Power Tester".
  7. Using a PD controller negotiate a 5V/3A PDO.
  8. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to the rest of the available USB4 ports of the DUT using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the "PD Source Power Tester".
  9. Using the PD controllers negotiate a 5V/3A PDO on all available USB4 ports.
  10. Verify all ports present a 5V/3A PDO or higher.
  11. Record  $V_{BUS}$  voltage of the port under test.
  12. Verify  $V_{BUS}$  is not greater than 5.5V.
  13. Verify  $V_{BUS}$  is not less than 4.75V.
  14. Record  $V_{CONN}$  voltage of the port under test
  15. Verify  $V_{CONN}$  is not greater than 5.5V.
  16. Verify  $V_{CONN}$  is not less than 4.25V.
  17. Set a 3A constant current (CC) load on each E-load that is connected to  $V_{BUS}$ .
  18. Set a 1.5W constant power (CP) load on each E-load that is connected to  $V_{CONN}$ .
  19. Turn ON the load on all E-loads and wait for as long as necessary for the voltages to stabilize.
  20. Verify  $V_{BUS}$  is not greater than 5.5V.
  21. Verify  $V_{BUS}$  is not less than 4.75V.
  22. Record  $V_{CONN}$  voltage of the port under test
  23. Verify  $V_{CONN}$  is not greater than 5.5V.
  24. Verify  $V_{CONN}$  is not less than 4.25V.
  25. Record the lowest voltage value of  $V_{CONN}$  during testing as  $V_{CONN\_min}$
  26. Turn OFF the load on all E-loads and disconnect all ports

#### TD TBT 4.5

- A. Purpose:
- Verify UFP of SPD USB4 Peripheral Device provides at least 4.5W on the  $V_{BUS}$ .
- B. Asserts:
- 4.2.1#2
- C. Test Setups:
- P4
  - This test applies to the UFP of Self Powered USB4 Peripheral Device.
- D. Pre-Condition:

- None
- E. Repetitions:
- None
- F. Procedure:
1. Connect a PD controller to a UFP port of DUT.
  2. Use the PD controller to issues Get\_Source\_Cap Message to get the source PDOs.
  3. Record all available source PDOs.
  4. Verify a 5V/0.9A PDO or higher is available.
  5. Disconnect PD controller.
  6. Connect a PD controller with two E-loads (one to  $V_{BUS}$  and one to  $V_{CONN}$ ) to the UFP of DUT using a Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  7. Using the PD controllers negotiate a 5V/0.9A PDO.
  8. Verify the port present a 5V/0.9A PDO or higher.
  9. Record  $V_{BUS}$  voltage of the port under test.
  10. Verify  $V_{BUS}$  is not greater than 5.5V.
  11. Verify  $V_{BUS}$  is not less than 4.75V.
  12. Record  $V_{CONN}$  voltage of the port under test
  13. Verify  $V_{CONN}$  is not greater than 5.5V.
  14. Verify  $V_{CONN}$  is not less than 4.25V.
  15. Set a 0.9A constant current (CC) load on the E-load that is connected to  $V_{BUS}$ .
  16. Set a 1.5W constant power (CP) load on the E-load that is connected to  $V_{CONN}$ .
  17. Turn ON the load on all E-loads and wait for as long as necessary for the voltages to stabilize.
  18. Verify  $V_{BUS}$  is not greater than 5.5V.
  19. Verify  $V_{BUS}$  is not less than 4.75V.
  20. Record  $V_{CONN}$  voltage of the port under test
  21. Verify  $V_{CONN}$  is not greater than 5.5V.
  22. Verify  $V_{CONN}$  is not less than 4.25V.
  23. Record the lowest voltage value of  $V_{CONN}$  during testing as  $V_{CONN\_MIN}$
  24. Turn OFF the load on all E-loads and disconnect the port.

#### TD TBT 4.6

- A. Purpose:
- Verify all USB4 ports of a Self-Powered USB 4 Host or Device meets the over current protection for  $V_{BUS}$  as defined in Table 4-2 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
- 4.4#1
- C. Test Setups:
- P5
  - This test applies to all USB4 ports of USB4 Host or USB4 ports of a Self-Powered Device.
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat the test procedure for all available PDOs.

- Repeat the test procedure for all available USB4 ports.

F. Procedure:

1. Connect a PD controller in the “PD Source Power Tester” to the port under test using a Type-C PD test fixture or directly if the “PD Source Power Tester” provides the capability to apply E-loads.
2. Connect an E-load to VBUS using the Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
3. Use the PD controller to issue Get\_Source\_Cap Message to get the source PDOs
4. Record all available source PDOs.
5. Using a PD controller negotiate a 5V/3A PDO.
6. Set a load sweep (CC) with the following settings:
  - i. Starting current:  $I_{PDO} - 1A$
  - ii. End current:  $2 * I_{PDO} + 1A$
  - iii. Number of steps: 1000
  - iv. Dwell time: 100mSec
7. Sweep the load until the DUT’s over current protection turns on.
8. Record the load current at which the over current protection turned on.
9. Verify the Maximum value of the current is not greater than  $2 * I_{PDO}$ .
10. Verify that the DUT is undamaged.
11. Disconnect the PD controller and E-load from DUT.

**TD TBT 4.7**

A. Purpose:

- Verify damages to all USB4 ports of a Self-Powered USB 4 Host or Device are prevented from any short circuit conditions on VBUS as Table 4-2 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.

B. Asserts:

- 4.4#1

C. Test Setups:

- P5
- This test applies to all USB4 ports of USB4 Host or USB4 ports of a Self-Powered Hub or Dock.

D. Pre-Condition:

- None

E. Repetitions:

- Repeat the test procedure for all available PDOs.
- Repeat the test procedure for all available USB4 ports.

F. Procedure:

1. Connect a PD controller in the “PD Source Power Tester” to the port under test using a Type-C PD test fixture or directly if the “PD Source Power Tester” provides the capability to apply E-loads.
2. Connect an E-load to VBUS using the Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
3. Using a PD controller negotiate a 5V/3A PDO.

4. Depending on capability of PD Source Power Tester, either Set the DC load to short function and Turn ON the short for 60 seconds; or use a fixture to apply short.
5. Verify that the over current protection is turned on.
6. Verify that the DUT is undamaged.
7. Disconnect the PD controller and E-load from DUT.

#### TD TBT 4.8

- A. Purpose:
  - Verify all USB4 ports of a Self-Powered USB 4 Host or Device meets the over current protection for  $V_{CONN}$  as defined in Table 4-3 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
  - 4.4#1
  - 4.5#2
  - 4.5#3
- C. Test Setups:
  - P6
  - This test applies to all USB4 ports of USB4 Host or USB4 ports of a Self-Powered Hub or Dock.
- D. Pre-Condition:
  - None
- E. Repetitions:
  - Repeat the test procedure for CC2.
  - Repeat the test procedure for all available USB4 ports.
- F. Procedure:
  1. Connect a PD controller in the “PD Source Power Tester” to the port under test using a Type-C PD test fixture or directly if the “PD Source Power Tester” provides the capability to apply E-loads.
  2. Connect an E-load to CC1 ( $V_{CONN}$ ) using the Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  3. Using a PD controller negotiate a 5V/3A PDO.
  4. Set a load sweep (CC) with the following settings:
    - i. Starting current: 0.25A
    - ii. End current: 0.95A
    - iii. Number of steps: 1000
    - iv. Dwell time: 100mSec
  5. Sweep the load until the DUT’s over current protection turns on.
  6. Record the load current at which the over current protection turned on.
  7. Verify the Maximum value of the current is not greater than 900mA.
  8. Verify Maximum value of the current is not less than  $1.05 * i V_{CONN\_MIN}$ .
  9. Verify that the DUT is undamaged.
  10. Disconnect the PD controller and E-load from DUT

#### **TD TBT 4.9**

- A. Purpose:
- Verify damages to all USB4 ports of a Self-Powered USB 4 Host or Device are prevented from any short circuit conditions on  $V_{CONN}$  as Table 4-3 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
- 4.4#1
  - 4.5#2
  - 4.5#3
- C. Test Setups:
- P6
  - This test applies to all USB4 ports of USB4 Host or USB4 ports of a Self-Powered Hub or Dock.
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat the test procedure for CC2.
  - Repeat the test procedure for all available USB4 ports
- F. Procedure:
1. Connect a PD controller in the “PD Source Power Tester” to the port under test using a Type-C PD test fixture or directly if the “PD Source Power Tester” provides the capability to apply E-loads.
  2. Connect an E-load to  $V_{CONN}$  using the Type-C PD test fixture (Note: Remote sense wires must be used with all E-loads.) or E-loads from the “PD Source Power Tester”.
  3. Using a PD controller negotiate a 5V/3A PDO.
  4. Depending on capability of PD Source Power Tester, either Set the DC load to short function and Turn ON the short for 60 seconds; or use a fixture to apply short.
  5. Verify that the over current protection is turned on.
  6. Verify that the DUT is undamaged
  7. Disconnect the PD controller and E-load from DUT

#### **TD TBT 4.10**

- A. Purpose:
- Verify power consumption by Non-Captive Bus Powered USB4 Devices in normal operational mode does not exceed the maximum limit of  $pSnk\_BPD5f$  as specified in Table 4-4 of “USB4™ Thunderbolt™ Compatibility Requirements Specification”.
- B. Asserts:
- 4.6#1
- C. Test Setups:
- P7

- This test applies to all Non-Captive Bus Powered USB4 Devices in normal operational mode.
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat test procedure with DC power supply output set to 4.75V and 5.5V.
- F. Procedure:
1. Connect a PD controller to the DUT's USB4 port.
  2. Use the PD controller to issues Get\_Sink\_Cap Message to get the sink PDO.
  3. Record the available sink PDOs
  4. Verify  $V_{PDO}$  is not greater than 5V
  5. Verify  $I_{PDO}$  is not greater than 3A.
  6. Disconnect the DUT
  7. Connect the DUT to a type-C PD test fixture (plug side).
  8. Connect the Fixture's  $V_{BUS}$  (plug side) to a DC power supply and a Digital Multi-Meter (DMM) current input in series. Note: Power supply's remote sense wires must be used
  9. Set DC power supply's output to 4V with no current limit (set to the maximum)  
Note: if DUT fails to establish a link, power supply may be set to 4.75V and lowered to 4V after link has been established
  10. Set the DMM to 10A manual range.
  11. Set the DMM measurement aperture to 20uSec.
  12. Connect the type-C PD test fixture to a powered-on host (receptacle side).
  13. Turn the DC power supply output ON.
  14. Functionally stress the DUT
    - i. If the DUT is a storage device, then data integrity tool should be used.
    - ii. If the DUT is a display adapter, then maximum resolution and refresh rate display/s must be used.
    - iii. If the DUT is an Ethernet adapter, then Ethernet communication must be stressed with iPerf and with a maximum length Ethernet cable.
    - iv. If the DUT is an AV device, then AV must be generated/captured at max resolution and bitrate.
    - v. If the DUT contains ports that can supply power (USB/DP/other peripherals) then each port must be loaded with an E-load up to its maximum supply current by its specification.

Note: Allow device to warm up by leaving it running while being stressed for at least 30min.
  15. Measure the maximum current over stress time.
  16. Verify maximum current at any time does not exceed  $I_{PDO}$ .
  17. Turn off the DC power supply and disconnect the type-C PD test fixture from the host.

#### **TD TBT 4.11**

- A. Purpose:
- Verify power consumption by Non-Captive Bus Powered USB4 Devices in sleep mode does not exceed the maximum limit of pSnkSleep as specified in Table 4-4 of "USB4™ Thunderbolt™ Compatibility Requirements Specification".
- B. Asserts:
- 4.6#1

C. Test Setups:

- P7
- This test applies to all Non-Captive Bus Powered USB4 Devices in sleep mode.

D. Pre-Condition:

- None

E. Repetitions:

- None

F. Procedure:

1. Connect the DUT to a type-C PD test fixture (plug side)
2. Connect the Fixture's  $V_{BUS}$  (plug side) to a DC power supply and a Digital Multi-Meter (DMM) current input in series.

*Note: Power supply's remote sense wires must be used*

3. Set DC power supply's output to 5V with no current limit (set to the maximum).
4. Set the DMM to 10A manual range.
5. Set the DMM measurement aperture to 20uSec.
6. Connect the type-C PD test fixture to a powered-on host (receptacle side) that supports wake from USB4 device.
7. Turn the DC power supply output ON
8. Put the host into sleep mode (S3)
9. Measure the maximum current  $I_{Max}$ .
10. Verify the maximum power  $P_{Max} = 5 * I_{Max}$  does not exceed 2.8W.
11. Verify the DUT stays in sleep mode (S3).
12. Turn off the DC power supply and disconnect the type-C PD test fixture from the host.

#### **TD TBT 4.12**

A. Purpose:

- Verify power consumption by Captive Bus Powered USB4 Devices in normal operation mode does not exceed the maximum limit of pSnk\_CBPd5f as specified in Table 4-5 of "USB4™ Thunderbolt™ Compatibility Requirements Specification".

B. Asserts:

- 4.6#2

C. Test Setups:

- P8
- This test applies to all Captive Bus-Powered USB4 Devices in normal operation mode.

D. Pre-Condition:

- None

E. Repetitions:

- Repeat test steps 7 through 20 with DC power supplies output set to 5.5V.
- Repeat test steps 7 through 20 with  $V_{BUS}$  DC power supply output set to 4.75V and  $V_{CONN}$  DC power supply set to 3V.

F. Procedure:

1. Connect a PD controller to the DUT's USB4 port.
2. Use the PD controller to issues Get\_Sink\_Cap Message to get the sink PDO.
3. Record the available sink PDO.
4. Verify  $V_{PDO}$  is not greater than 5V.
5. Verify  $I_{PDO}$  is not greater than 3A.
6. Disconnect the DUT.
7. Connect the DUT to a type-C PD test fixture (receptacle side).
8. Connect the Fixture's  $V_{BUS}$  (receptacle side) to a DC power supply and a Digital Multi-Meter (DMM) current input in series.

*Note: Power supply's remote sense wires must be used.*

9. Connect the Fixture's  $V_{CONN}$  (receptacle side) to a DC power supply and a DMM current input in series.

*Note: Power supply's remote sense wires must be used*

10. Set both DC power supplies output to 4.75V with no current limit (set to the maximum).
11. Set the  $V_{BUS}$  DMM to 10A manual range.
12. Set the  $V_{BUS}$  DMM measurement aperture to 20uSec.
13. Set the  $V_{CONN}$  DMM to 1A manual range.
14. Set the  $V_{CONN}$  DMM measurement aperture to 100uSec.
15. Connect the type-C PD test fixture to a host (plug side).
16. Turn the DC power supply output ON.
17. Functionally stress the DUT
  - i. If the DUT is a storage device, then data integrity tool should be used.
  - ii. If the DUT is a display adapter, then maximum resolution and refresh rate display/s must be used.
  - iii. If the DUT is an Ethernet adapter, then Ethernet communication must be stressed with iPerf and with a maximum length Ethernet cable.
  - iv. If the DUT is an AV device, then AV must be generated/captured at max resolution and bitrate.
  - v. If the DUT contains ports that can supply power (USB/DP/other peripherals) then each port must be loaded with an E-load up to its maximum supply current by its specification.

*Note: Allow device to warm up by leaving it running while being stressed for at least 30min.*

18. Measure the maximum current over stress time.
19. Verify maximum current at any time does not exceed  $I_{PDO}$ .
20. Verify maximum  $V_{CONN}$  power  $P_{Vconn\_Max} = V_{CONN}$  (power supply voltage) \*  $I_{Vconn\_Max}$  does not exceed 1.5W.
21. Turn off the DC power supply and disconnect the type-C PD test fixture from the host.

#### **TD TBT 4.13**

- A. Purpose:
  - Verify power consumption by Captive Bus Powered USB4 Devices in sleep mode does not exceed the maximum limit of pSnkSleep as specified in Table 4-5 of "USB4™ Thunderbolt™ Compatibility Requirements Specification".
- B. Asserts:
  - 4.6#2



C. Test Setups:

- P8
- This test applies to all Captive Bus-Powered USB4 Devices in sleep mode.

D. Pre-Condition:

- None

E. Repetitions:

- None

F. Procedure:

1. Connect the DUT to a type-C PD test fixture (receptacle side).
2. Connect the Fixture's  $V_{BUS}$  (receptacle side) to a DC power supply and a Digital Multi-Meter (DMM) current input in series.

*Note: Power supply's remote sense wires must be used.*

3. Connect the Fixture's  $V_{CONN}$  (receptacle side) to a DC power supply and a DMM current input in series.

*Note: Power supply's remote sense wires must be used*

4. Set both DC power supplies output to 5V with no current limit (set to the maximum).
5. Set the  $V_{BUS}$  DMM to 10A manual range.
6. Set the  $V_{BUS}$  DMM measurement aperture to 20uSec.
7. Set the  $V_{CONN}$  DMM to 1A manual range.
8. Set the  $V_{CONN}$  DMM measurement aperture to 100uSec.
9. Connect the type-C PD test fixture to a powered-on host (plug side) that supports wake from USB4 Device.
10. Turn the DC power supply output ON.
11. Put the host into sleep mode (S3)
12. Measure the maximum current  $I_{VBUS\_Max}$   $I_{Vconn\_Max}$
13. Verify maximum  $V_{BUS}$  power  $P_{VBUS\_Max} = 5 * I_{VBUS\_Max}$  is not greater than 3W.
14. Verify maximum  $V_{CONN}$  power  $P_{Vconn\_Max} = 5 * I_{Vconn\_Max}$  is not greater than 70mW.
15. Verify the DUT stays in sleep mode (S3).
16. Turn off the DC power supply and disconnect the type-C PD test fixture from the host.

## 7.2 Chapter 5 Tests

### TD TBT 5.1

*Note: This is Router Assembly DFP Test.*

A. Purpose:

- Verify that RUT meets the USB4 Re-Driver (with TBT3) cable discover flow

B. Asserts:

- 5#1
- 5#2
- 5#3
- 5#4

C. Test Setups:

- H3
  - H4
  - D2
  - D3
- D. Pre-Condition:
- None
- E. Repetitions:
- Repeat with a TBT3 Known good Device
- F. Procedure:
1. Reset RUT
  2. Start Analyzer
  3. Plug the Known good Device and the USB4 Re-Driver (with TBT3) cable to the RUT
  4. RUT will send SOP' discover identity request.
  5. Cable sends SOP' discover identity response with the following attributes:
    - a. ID header VDO - B26 (model operation) is set to 1b (alt mode)
    - b. ID header VDO - B29..27 (product type) are set to 011b (passive cable)
    - c. Cable VDO - B2..0 (USB highest speed) are set to 010b (USB3.2/USB4 Gen 2)
  6. Verify that RUT sends SOP' TBT discover mode command (5#1)
  7. Cable sends SOP' TBT discover mode response with the following attributes:
    - a. B20..19 (rounded/rounded & none) set to 01b (both)
    - b. B21 (Optical/none) set to 0 (none)
    - c. B22 (Re-timer/Re-driver) set to 0b (Re-driver)
    - d. B23 (Uni/Bi-directional) set to 1b (Uni)
    - e. B25 (Active/Passive) to 1b (Active)
  8. If Device replies with SOP discover identity response indicating USB4 support:
    - a. Verify that RUT sends SOP enter\_USB with the following attributes: (5#3)
      - i. B20..19 (cable type) set to 10b (Active Re-driver)
 Else:
    - b. Verify that RUT sends SOP TBT3 enter mode with the following attributes (5#2):
      - i. B20..19 (rounded/rounded & none) set to 01b (both)
      - ii. B21 (Optical/none) set to 0 (none)
      - iii. B22 (Re-timer/Re-driver) set to 0b (Re-driver)
      - iv. B23 (Uni/Bi-directional) set to 1b (Uni)
      - v. B25 (Active/Passive) to 1b (Active)

## TD TBT 5.2

*Note: This is USB4 Re-Driver (with TBT3) cable Test*

- A. Purpose:
- Verify that LRD cable exposes all mandatory values to meet the USB4 Re-Driver (with TBT3) cable discover flow
- B. Asserts:
- 5#5
  - 5#6
- C. Test Setups:

- C1
- D. Pre-Condition:
- None
- E. Repetitions:
- None
- F. Procedure:
1. Reset Host
  2. Start Analyzer
  3. Plug the Setup
  4. Host sends SOP' discover identity request.
  5. Verify that USB4 Re-Driver (with TBT3) cable sends SOP' discover identity response with the following bits values (5#5):
    - a. ID header VDO - B26 (model operation) is set to 1b (alt mode)
    - b. ID header VDO - B29..27 (product type) are set to 011b (passive cable)
    - c. Cable VDO - B2..0 (USB highest speed) are set to 010b (USB3.2/USB4 Gen 2):
  6. Host sends SOP' TBT discover mode command
  7. Verify that USB4 Re-Driver (with TBT3) cable sends SOP' discover mode response with the following bits values (5#6):
    - a. B20..19 (rounded/rounded & none) set to 01b (both)
    - b. B21 (Optical/none) set to 0 (none)
    - c. B22 (Re-timer/Re-driver) set to 0b (Re-driver)
    - d. B23 (Uni/Bi-directional) set to 1b (Uni)
    - e. B25 (Active/Passive) to 1b (Active)

### 7.3 Chapter 6 Tests

Verifying that a valid TBT-VID is present in the DROM, is checked in USB4 Protocol CTS.

### 7.4 Chapter 7 Tests

#### TD TBT 7.1

*Note: This test is only performed on the UFP of the RUT.*

- A. Purpose:
- Verify that the RUT's Product ID does not implement a prohibited Product ID.
- B. Asserts:
- #7.1
- C. Test Setups:
- D1
  - D4
- D. Pre-Condition:
- None
- E. Repetitions:
- None

F. Procedure:

1. Reset RUT
2. Enumerate RUT
3. Read the *Product ID* in the Router Configuration Space of the RUT
4. Verify that the *Product ID* value is not equal to 0x0B26
5. Verify that the *Product ID* value is not with in the following range [0x1500-0x15FF]