USB4™ Protocol
Compliance Test Specification

Date:	December 2021
Revision:	1.5

Revision History

Revision	Issue Date	Comments
1.0	June 2020	First Release
1.1	September 2020	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 4, 2020.
1.2	January 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 4, 2020.
1.3	June 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through October 15, 2020.
1.4	October 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 19, 2021.
1.5	December 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 19, 2021.

Contents

Introduction

These tests check that the Transport Layer, Control Layer and Configuration Spaces in a Router are compliant to the USB4 specification.

The tests in this document are required for all USB4 host, hub, and device Silicon. They are not required for USB4 End Products.

Terminology

The following table describes the terms used in this document.

Analyzer	Test tool that captures and parses packets, transactions, ordered sets, etc.
Compliance Device	A KG USB4 Device that is capable of performing Transport Layer Packet loopback.
DFP	Downstream Facing Port.
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.
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 and end product.
UUT	Unit Under Test. The Router 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.

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 specification or other documents 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.
TD X.X	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 in a Background Check Procedure that is run in conjunction with other tests.

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.

Chapter 5

The following Table presents the USB4 Specification Chapter 5 asserts.

Assertion #	Test Name	Assertion Description
5 Transport Layer		
5.1 Transport Layer Packets		
5.1.1 Bit/Byte Convention		
5.1.2 Format		
5.1.2#1	NT	All Transport Layer Packets shall start with the 4-byte header described in Section 5.1.2.1.
5.1.2#2	BT	All Transport Layer Packets except Idle Packets shall carry between 1 and 256 bytes (inclusive) of payload.
5.1.2.1 Header		
5.1.2.1#1	NT	The Length field shall contain the payload size in bytes excluding the padding size.
5.1.2.1#2	NT	The Supplemental ID field shall be set to 0b in a Tunneled Packet.
5.1.2.1.1 Header Error Control (HEC)		
5.1.2.1.1#1	BT	The HEC field in a Transport Layer Packet header shall cover bits [31:8] of the Transport Layer Packet header.
5.1.2.1.1#2	BT	The HEC field in a Transport Layer Packet header shall not cover any payload.
5.1.2.1.1#3	BT	The *HEC* field consists of 8 redundancy bits, which shall be calculated from bit 31 to bit 8 as follows: Width: 8; Poly: 07h; Init: 00h; RefIn: False; RefOut: False; XorOut: 55h
5.1.2.1.1#4	TD 5.1 TD 5.2	When a Router receives a Transport Layer Packet, it shall verify the HEC field value in the packet.
5.1.2.1.1#5	TD 5.1 TD 5.2	The Router shall correct any single-bit errors in the Transport Layer Packet header.
5.1.2.1.1#6	TD 5.1 TD 5.2	After correcting an error, a Router shall continue on as if the error had never occurred.

5.1.2.1.1#7	TD 5.1 TD 5.2	When an Ingress Adapter that is a Lane Adapter detects an uncorrectable HEC error, it shall: drop the packet with the error, set the HEC Error bit in the Adapter Configuration Space to 1b, and increment the *HEC Errors* field in Adapter Configuration Space.
5.1.2.1.1#8	TD 5.2	If the Ingress Adapter that detected the uncorrectable HEC error is part of a Downstream Facing Port: 1) The Ingress Adapter shall send a Notification Packet upstream if the *HEC Error Enable* bit in the Adapter Configuration Space is set to 1b. The Notification Packet shall contain Event Code = ERR_HEC.
5.1.2.1.1#9	TD 5.2	If the Ingress Adapter that detected the uncorrectable HEC error is a Lane Adapter that is a part of a Downstream Facing Port: 2) The Lane Adapter(s) in the USB4 Port with the Ingress Adapter shall enter the Training state.
5.1.2.1.1#10	TD 5.1	If the Ingress Adapter that detected the uncorrectable HEC error is a Lane Adapter that is a part of a Upstream Facing Port: The Lane Adapter(s) in the USB4™ Port with the Ingress Adapter shall enter the Training state.
5.1.2.1.1#11	TD 5.1	If the Ingress Adapter that detected the uncorrectable HEC error is a Lane Adapter that is a part of a Upstream Facing Port: When the Lane Adapter enter CL0 state, it shall send a Notification Packet upstream if the *HEC Error Enable* bit in the Adapter Configuration Space is set to 1b. The Notification Packet shall contain Event Code = ERR_HEC.
5.1.2.2 Payload Padding		
5.1.2.2#1	BT	The Protocol Adapter Layer of a Source Adapter shall add between 0 and 3 bytes of padding to the payload of a Tunneled Packet to ensure that the Tunneled Packet is of a size that is a multiple of 4 bytes.
5.1.2.2#2	IOP	The Protocol Adapter Layer of the Destination Adapter shall remove any bytes of padding.
5.1.2.3 Error Correction Code (ECC)		
5.1.2.3#1	BT	When a Transport Layer Packet contains an ECC field, the ECC shall be calculated as described in this section.
5.1.2.3#2	BT	The ECC field consists of 8 redundancy bits, which shall be calculated from most significant bit to least significant bit as follows: Width: 8; Poly: 07h; Init: 00h; RefIn: False; RefOut: False; XorOut: 00h.
5.1.3 Transport Layer Packets		
5.1.3.1 Tunneled Packets		
5.1.3.1#1	IOP	A Tunneled Packet shall have the header defined for Transport Layer Packets in Table 5-1.

5.1.3.1#2	IOP	The Protocol Adapter Layer of a Source Adapter shall fragment Protocol Adapter Layer traffic larger than 256 bytes into multiple Tunneled Packets.
5.1.3.1#3	IOP	Re-assembly of Protocol Adapter Layer traffic from Tunneled Packets shall be performed by the Protocol Adapter Layer of the Destination Adapter.
5.1.3.1#4	IOP	A Transport Layer shall not modify any other fields (besides the HopID and HEC fields) in a Tunneled Packet header and it shall not modify the payload.
5.1.3.2 Control Packets		
5.1.3.3 Link Management Packets		
5.1.3.3.1 Idle Packets		
5.1.3.3.1#1	IOP	When a Lane is in CL0 state, the Transport Layer shall insert Idle Packets at the transmitting end of a USB4 Link if there are no other Transport Layer Packets to be transmitted.
5.1.3.3.1#2	NT	A Router shall remove Idle Packets at the receiving end of the USB4 Link.
5.1.3.3.1#3	IOP	An Idle Packet shall have the format shown in Figure 5-3.
5.1.3.3.2 Credit Grant Packet		
5.1.3.3.2#1	BT	A Credit Grant Packet shall include the header in Table 5-2 followed by one or more Credit Grant Records defined in Table 5-3.
5.1.3.3.2#2	BT	A Credit Grant Packet shall not contain more than 64 Credit Grant Records.
5.1.3.3.2#3	IOP	When more than one Credit Grant Record is sent in the same Credit Grant Packet, they shall be processed in the order received.
5.1.3.3.2#4	IOP	The HopID field indicates the HopID of the Path for which credit grant shall be applied.
5.1.3.3.2#5	IOP	The HopID field shall only be valid if L Flag= 0b.
5.1.3.3.2#6	IOP	The L Flag in a Credit Grant Record shall be set to 0b for a Path or 1b for Shared Buffers.
5.1.3.3.3 Path Credit Sync Packet		
5.1.3.3.3#1	BT	A Path Credit Sync Packet shall consist of the header in Table 5-4 followed by the payload defined in Table 5-5.

5.1.3.3.4 Shared Buffers Credit Sync Packet		
5.1.3.3.4#1	BT	A Shared Buffers Credit Sync Packet shall consist of the header in Table 5-6 followed by the payload defined in Table 5-7.
5.1.4 Effect of Link State on Transport Layer Packets		
5.1.4#1	NT	When a Link is in the Inactive State, Tunneled Packets and Control Packets shall not be sent to or received from the Logical Layer.
5.1.4#2	NT	When a Link is in the Inactive State, Credit Grant Packets, Credit Sync Packets, and Time Sync Packets shall not be sent to or received from the Logical Layer.
5.1.4#3	NT	When a Link is in the Low Power State, Tunneled Packets and Control Packets shall trigger transition of the Link to the Active State.
5.1.4#4	NT	When a Link is in the Low Power State, Credit Grant Packets shall only be sent as a result of either: increment on a packet dequeue, update on a Credit Sync due to packet loss, initial credits allocation to a Path.
5.1.4#5	NT	Sending a Credit Grant Packet shall trigger transition to Active state.
5.1.4#6	NT	When a Link is in the Low Power State, Credit Sync Packets shall not be sent.
5.1.4#7	NT	When a Link is in the Low Power State, a Time Sync Packet shall trigger transition of the Link to the Active State in time to send the Time Sync Packet.
5.1.5 Minimum Headers Gap		
5.1.5#1	IOP	A Router shall insert Idle Packets to meet the requirements defined in Table 5-9.
5.1.5#2	NT	For a Gen 2, single-Lane Link, a Router shall send no more than one non-Idle Transport Layer Header in a 64-bit Data Symbol.
5.1.5#3	BT	For a Gen 2, dual-Lane Link, a Router shall send no more than one non-Idle Transport Layer Header in the two 64-bit Data Symbols that are sent concurrently on the two Lanes of a dual-Lane Link.
5.1.5#4	NT	For a Gen 3, single-Lane Link, a Router shall send no more than one non-Idle Transport Layer Header in a 128-bit Data Symbol.
5.1.5#5	BT	For a Gen 3, dual-Lane Link, a Router shall send no more than one non-Idle Transport Layer Header in the two 128-bit Data Symbols that are sent concurrently on the two Lanes of a dual-Lane Link.

5.2 Routing		
5.2.1 Adapter Numbering Rules		
5.2.1#1	IOP	Each Adapter shall be assigned a different 6-bit Adapter Number.
5.2.1#2	IOP	The Control Adapter shall be assigned Adapter Number 0.
5.2.1#3	TD 5.5	For a Device Router, the Upstream Facing Adapter shall be assigned the lowest Adapter Number.
5.2.1#4	IOP	A USB4 Port shall have two Lane Adapters.
5.2.1#5	IOP	The Lane Adapter Numbers within a USB4 Port shall be consecutive. The Lane 0 Adapter shall have a lower number than the Lane 1 Adapter.
5.2.1#6	TD 5.5	If an Adapter Number less than the Max Adapter is unused, a Router shall use one of the following methods to indicate that the Adapter is unused: Assign a value of "Unsupported Adapter" to the Adapter Type field in Adapter Configuration Space; or Response to a Read Request or Write Request that targets the Adapter Configuration Space of the unused Adapter with a Notification Packet with Event Code = ERR_ADDR.
5.2.1#7	TD 5.5	If a Device Router supports incorporation into a fabric that tunnels PCIe traffic, then the Upstream PCIe Adapter shall be assigned the lowest Adapter number among all PCIe Adapters.
5.2.1#8	TD 5.5	If a Device Router supports incorporation into a fabric that tunnels USB3 traffic, then the Upstream USB3 Adapter shall be assigned the lowest Adapter number among all USB3 Adapters.
5.2.2 Adapter Numbering Rules HopID Rules		
5.2.3 Routing Tables		
5.2.3#1	IOP	The Egress Adapter in the Routing Table entry shall equal the *Output Adapter* field in the Path Configuration Space entry.
5.2.3#2	IOP	The Egress HopID in the Routing Table entry shall equal the *Output HopID* field in the Path Configuration Space entry.
5.2.3#3	IOP	A Host Interface Adapter shall contain Routing Table entries for Ingress HopIDs 1 through *Max Input HopID*.
5.2.3#4	IOP	All other Adapters shall contain Routing Table entries for Ingress HopIDs 8 through *Max Input HopID*.

5.2.4 Routing Rules		
5.2.4#1	IOP	Each Ingress Adapter shall have its own Routing Table.
5.2.4#2	IOP	For a single-Lane Link, the Routing Table of the Ingress Adapter that a Transport Layer Packet arrives on shall be used to route the packet.
5.2.4#3	IOP	For a dual-Lane Link, the Routing Table of the Lane 0 Adapter of the Ingress USB4 Port that a Transport Layer Packet arrives on shall be used to route the packet.
5.2.4.1 Control Packets		
5.2.4.1#1	IOP	A Lane Adapter and a Host Interface Adapter shall forward a Transport Layer Packet with a HopID value of 0 to the Control Adapter.
5.2.4.1#2	IOP	The Control Adapter shall forward the packet to an Egress Adapter as defined in Section 6.4.3.2.
5.2.4.2 Link Management Packets		
5.2.4.2#1	IOP	A Transport Layer Packet with a HopID value of 1 shall be forwarded to the Transport Layer for credit management processing. It shall not be forwarded to an Egress Adapter.
5.2.4.2#2	NT	A Transport Layer Packet with a HopID value of 2 shall be dropped and no further action shall be taken on its behalf.
5.2.4.2#3	IOP	A Transport Layer Packet with a HopID value of 3 shall be forwarded to the TMU. It shall not be forwarded to an Egress Adapter.
5.2.4.2#4	NT	A Transport Layer Packet with a HopID value of 4 through 7 shall be dropped and no further action shall be taken on its behalf.
5.2.4.3 Tunneled Packets		
5.2.4.3#1	TD 5.6	If the *Valid* bit in the Path Configuration Space for the Path of the packet is 0b, the packet shall be dropped and no further action shall be taken on its behalf.
5.2.4.3#2	NT	If the Transport Layer Packet has an Ingress HopID that is greater than Max Input HopID of the Ingress Adapter, the packet shall be dropped and no further action shall be taken on its behalf.
5.2.4.3#3	NT	If the Routing Table entry corresponding to the Ingress HopID of the Transport Layer Packet contains an Egress HopID greater than the *Max Output HopID* of the Egress Adapter, the packet shall be dropped by the Router and no further action shall be taken on its behalf

5.2.4.3#4	NT	If the Routing Table entry corresponding to the Ingress HopID of the Transport Layer Packet contains an Egress Adapter that is greater than the *Max Adapter* field in Router Configuration Space, the packet shall be dropped and no further action shall be taken on its behalf.
5.2.4.3#5	IOP	Else, the Ingress Adapter shall first replace the Ingress HopID value in the Tunneled Packet with the Egress HopID in the Routing Table entry that corresponds to the Ingress HopID.
5.2.4.3#6	IOP	Else, the Ingress Adapter shall second update the HEC field in the Tunneled Packet.
5.2.4.3#7	IOP	Else, the Ingress Adapter shall third Forward the Tunneled Packet to the Egress Adapter in the Routing Table entry that corresponds to the Ingress HopID of the Tunneled Packet
5.2.4.4 Routing Example		
5.2.5 Connectivity Rules		
5.2.5#1	IOP	A Router shall be able to forward a Control Packet received on any Lane 0 Adapter to the Control Adapter.
5.2.5#2	IOP	A Router shall be able to forward a Control Packet from the Control Adapter to any Lane 0 Adapter.
5.2.5#3	IOP	A Router shall be able to forward a Transport Layer Packet received on the Lane 0 Adapter of one USB4 Port to the Lane 0 Adapter of any other USB4 Port.
5.2.5#4	IOP	A Host Router shall be able to forward a packet received on the Host Interface Adapter to the Control Adapter and to any Lane 0 Adapter.
5.2.5#5	IOP	A Host Router shall be able to forward a packet received on any Lane 0 Adapter to the Host Interface Adapter.
5.2.5#6	IOP	A Host Router shall be able to forward a packet from the Control Adapter to the Host Interface Adapter.
5.2.5#7	IOP	A Router shall be able to forward a packet received on a DP IN Adapter to any Lane 0 Adapter.
5.2.5#8	IOP	A Router shall be able to forward packet received on a DP OUT Adapter to any Lane 0 Adapter.
5.2.5#9	IOP	A Router shall be able to forward a packet received on a Lane 0 Adapter to any DP IN Adapter or any DP OUT Adapter.

5.2.5#10	NT	A Router shall be able to forward a packet received on an Upstream PCIe Adapter to the Upstream Adapter.
5.2.5#11	NT	A Router shall be able to forward a packet received on the Upstream Adapter to the Upstream PCIe Adapter
5.2.5#12	IOP	A Router shall be able to forward a packet received on the Lane 0 Adapter of a USB4 Port to the paired PCIe Adapter.
5.2.5#13	IOP	A Router shall be able to forward a packet received on a PCIe Adapter to the Lane 0 Adapter of the paired USB4 Port.
5.2.5#14	NT	A Router shall be able to forward a packet received on an Upstream USB3 Adapter to the Upstream Adapter.
5.2.5#15	NT	A Router shall be able to forward a packet received on the Upstream Adapter to any USB3 Adapter.
5.2.5#16	IOP	A Router shall be able to forward a packet received on the Lane 0 Adapter of a USB4 Port to the matching USB3 Adapter.
5.2.5#17	IOP	A Router shall be able to forward a packet received on a USB3 Adapter to the Lane 0 Adapter of the matching USB4 Port.
5.3 Quality of Service (QoS)		
5.3.1 Packet Ordering		
5.3.1#1	IOP	A Router shall transmit Transport Layer Packets for a Path in the same order that they are received.
5.3.1#2	IOP	The ordering of Transport Layer Packets on one Path shall not affect the ordering of packets on any other Path.
5.3.2 Flow Control		
5.3.2#1	BT	Link Management Packets are not subject to flow control and shall not be stored in any of the Flow Control Buffers defined in this section.
5.3.2.1 Ingress Adapter		
5.3.2.1#1	IOP	An Ingress Adapter shall always use the Dedicated Flow Control Buffer Allocation Scheme for a Path that corresponds to HopID 0 (i.e. for Control Packets).
5.3.2.1#2	NT	Deprecated.
5.3.2.1#3	IOP	All other Paths shall be configurable during Path Setup.

5.3.2.1#4	TD 5.7	A configurable Path shall use the flow control scheme as determined by its *IFC Flag* and *ISE Flag*.
5.3.2.1.1 Buffer Allocation		
5.3.2.1.1#1	NT	An Ingress Lane Adapter shall have a buffer space that is used exclusively for incoming packets.
5.3.2.1.1#2	NT	There shall be one Dedicated Buffer for each Path that uses the Dedicated Flow Control scheme.
5.3.2.1.1#3	TD 8.17	The baMaxUSB3 Buffer Allocation Parameter shall be present if Router has a USB3 Adapter.
5.3.2.1.1#4	TD 8.17	The baMinDPaux Buffer Allocation Parameter shall be present if Router has a DP Adapter or multiple USB4 Ports.
5.3.2.1.1#5	TD 8.17	The baMinDPmain Buffer Allocation Parameter shall be present if Router has a DP OUT Adapter or multiple USB4 Ports.
5.3.2.1.1#6	TD 8.17	The baMaxPCIe Buffer Allocation Parameter shall be present if Router has a PCIe Adapter.
5.3.2.1.1#7	TD 8.17	The baMaxHI Buffer Allocation Parameter shall be present if Router is a Host Router.
5.3.2.1.1.1 Flow Control Disabled Buffer		
5.3.2.1.1.1#1	NT	An Ingress Adapter shall store Transport Layer Packets arriving on Paths that use the Flow Control Disabled scheme in the Flow Control Disabled Buffer.
5.3.2.1.1.1#2	NT	The Flow Control Disabled Buffer shall be the size set in the *Non Flow Controlled Buffers* field in Adapter Configuration Space.
5.3.2.1.1.2 Dedicated Flow Control Buffer		
5.3.2.1.1.2#1	NT	If a Path is defined with the Dedicated Flow Control Buffer scheme, an Ingress Adapter shall store any Transport Layer Packets arriving on that Path in the Dedicated Buffer for that Path.
5.3.2.1.1.2#2	TD 5.7	A Dedicated Buffer shall be the size set in the *Path Credits Allocated* field in Path Configuration Space.
5.3.2.1.1.3 Shared Flow Control Buffer		
5.3.2.1.1.3#1	NT	If a Path is defined with the Shared Flow Control Buffer scheme, an Ingress Adapter shall store any Transport Layer Packets arriving on that Path in the Shared Buffer.

5.3.2.1.1.3#2	TD 5.7	The size of the Shared Buffer shall be the size set in the *Link Credits Allocated* field in Adapter Configuration Space.
5.3.2.1.1.4 Restricted Shared Flow Control Buffer		
5.3.2.1.1.4#1	NT	If a Path is defined with the Restricted Shared Flow Control Buffer scheme, an Ingress Adapter shall store any packets arriving on that Path in the Shared Buffer.
5.3.2.1.1.4#2	TD 5.7	The Path shall not use more space in the Shared Buffer than is set forth in the *Path Credits Allocated* field in Path Configuration Space.
5.3.2.1.2 Credit Tracking		
5.3.2.1.2#1	NT	If the *IFC Flag* field is set to 0b, credits shall not be tracked for the Path
5.3.2.1.2#2	NT	If the *IFC Flag* field is set to 1b, credits shall be tracked for the Path
5.3.2.1.2#3	NT	If the *ISE Flag* field is set to 0b, credits shall not be tracked for the Path in the Shared Buffer
5.3.2.1.2#4	NT	If the *ISE Flag* field is set to 1b, credits shall be tracked for the Path in the Shared Buffers
5.3.2.1.2#5	TD 5.7	For each Path with the *IFC Flag* set to 1b, the Ingress Adapter shall initially allocate the number of credits specified in the *Path Credits Allocated* field in the Path Configuration Space
5.3.2.1.2#6	BT	The Path corresponding to HopID 0 shall be provisioned with at least 2 initial credits
5.3.2.1.2#7	TD 5.7	For the Shared Buffer, if the *Shared Buffering Capable* bit is set to 1b, the Ingress Adapter shall initially allocate the number of credits in the *Link Credits Allocated* field in the Adapter Configuration Space
5.3.2.1.2#8	NT	If an Ingress Adapter receives a packet on a flow controlled Path and the appropriate buffer (dedicated or shared) has no space for the packet, then the packet shall be discarded, the *Flow Control Error* bit in the Adapter Configuration Space shall be set to 1b, and the flow control state shall not be affected. If the *Flow Control Error Enable* bit in the Adapter Configuration Space is 1b, then a Notification Packet with Event Code = ERR_FC shall be sent upstream.
5.3.2.1.2#9	NT	Each Ingress Adapter shall track credits individually for its Shared Buffer and all of its Dedicated Buffers
5.3.2.1.2#10	TD 5.9	When an Ingress Adapter drops a packet (e.g. due to a HEC error), it shall not account for the dropped packet in its credit tracking counters

5.3.2.1.2#11	TD 5.7	Link Management Packets shall not cause credit counts to increment or decrement when received
5.3.2.1.3 Credit Grant Packets		
5.3.2.1.3#1	TD 5.7	If the *IFC Flag* field in Path Configuration Space is set to 0b, Credit Grant Packets shall not be sent for the Path.
5.3.2.1.3#2	TD 5.7	If the *IFC Flag* field in Path Configuration Space is set to 1b for a Path, an Ingress Adapter shall send Credit Grant Packets for that Path after Transport Layer Packets are dequeued.
5.3.2.1.3#3	TD 5.7	If the *IFC Flag* field in Path Configuration Space is set to 1b for the Path, an Ingress Adapter shall send a Credit Grant Packet with a Credit Grant Record for the Path when the Path is first enabled.
5.3.2.1.3#4	NT	If the *ISE Flag* field in Path Configuration Space is set to 0b, the Path shall not affect Credit Grant Packets sent for the Shared Flow Control Buffer.
5.3.2.1.3#5	NT	If an Ingress Adapter has a Path with the *ISE Flag* field in Path Configuration Space is set to 1b, the Ingress Adapter shall send Credit Grant Packets for its Shared Flow Control Buffer after Transport Layer Packets are dequeued.
5.3.2.1.3#6	TD 5.7	If the *ISE Flag* field in Path Configuration Space is set to 1b for the Path, an Ingress Adapter shall send a Credit Grant Packet with a Credit Grant Record for the Shared Buffer when the Path is first enabled.
5.3.2.1.3#7	TD 5.7	Credit Grant Packets shall be sent at least every $T_{CREDITS}$.
5.3.2.1.3#8	BT	When a Link first becomes Active, an Ingress Adapter that is a Lane 0 Adapter shall send a Credit Grant Packet with a Credit Grant Record for HopID 0.
5.3.2.1.3#9	TD 5.3	When an Egress Adapter receives a Credit Grant Packet, it shall process each Credit Grant Record and shall verify the ECC field value in the Credit Grant Record.
5.3.2.1.3#10	TD 5.3	The Egress Adapter shall correct any single-bit errors. After correcting an error, the Egress Adapter shall continue on as if the error had never occurred.
5.3.2.1.3#11	TD 5.3	If an uncorrectable error is detected, the Credit Grant Record shall be dropped, and the *ECC Error* field in the Adapter Configuration Registers shall be incremented.
5.3.2.1.3#12	NT	When an Egress Adapter receives a Credit Grant Packet, if the *HopID* in a Credit Grant Record does not match an enabled Path in the Egress Adapter, the Credit Grant Record shall be dropped and no further actions shall be taken.

5.3.2.2 Egress Adapter		
5.3.2.2#1	IOP	The Path corresponding to HopID 0 shall always use the Dedicated Flow Control scheme.
5.3.2.2#2	BT	For an Adapter that is not a Host Interface Adapter, the Paths that correspond to Paths 1 through 7 shall always use the Flow Control Disabled scheme.
5.3.2.2#3	TD 5.8	All other Paths are configurable and shall use the flow control scheme that corresponds to the EFC Flag and ESE Flag in Path Configuration Space.
5.3.2.2.1 Credit Tracking		
5.3.2.2.2 Transmission Rules		
5.3.2.2.2#1	NT	If a Path uses the Flow Control Disabled scheme (EFC = 0b and ESE = 0b), then the Egress Adapter shall not require any credits to transmit a Transport Layer Packet on that Path.
5.3.2.2.2#2	TD 5.8	If a Path uses the Dedicated Flow Control scheme (EFC = 1b and ESE = 0b), then the Egress Adapter shall require the following condition to be true before transmitting a Transport Layer packet on the Path: [(PCL-PCC > 0) and (PCL-PCC < 128)] or [(PCL-PCC < 0) and (PCC-PCL > 128)]
5.3.2.2.2#3	TD 5.8	If a Path uses the Shared Flow Control scheme (EFC = 0b and ESE = 1b), then the Egress Adapter shall require the following condition to be true before transmitting a Transport Layer packet on the Path: [(SCL-SCC > 0) and (SCL-SCC < 128)] or [(SCL-SCC < 0) and (SCC-SCL > 128)]
5.3.2.2.2#4	TD 5.8	If a Path uses the Restricted Shared Flow Control scheme (EFC = 1b and ESE = 1b), then the Egress Adapter shall require both of the following conditions be true before transmitting a Transport Layer packet on the Path: [(PCL-PCC > 0) and (PCL-PCC < 128)] or [(PCL-PCC < 0) and (PCC-PCL > 128)]; and [(SCL-SCC > 0) and (SCL-SCC < 128)] or [(SCL-SCC < 0) and (SCC-SCL > 128)]
5.3.2.3 Credit Counter Synchronization		
5.3.2.3#1	TD 5.8	An Egress Adapter shall send a Path Credit Sync Packet every T_{SYNC} for a Path with the *Egress Flow Control (EFC)* Flag field set to 1b and the Valid bit set to 1b.
5.3.2.3#2	TD 5.8	If the *Egress Shared Buffering Enable (ESE) Flag* field in Path Configuration Space is set to 1b for at least one enabled Path, an Egress Adapter shall send a Shared Buffers Credit Sync Packet every T_{SYNC}.
5.3.2.3#3	TD 5.8	The credit count in the PCC field of a Path Credit Sync Packet shall be based on the number of flow controlled Transport Layer Packets sent on the Path prior to the Path Credit Sync Packet and shall not include flow controlled Transport Layer Packets which have not yet been sent.

5.3.2.3#4	TD 5.8	The credit count in the SCC field of a Shared Credit Sync Packet shall be based on the number of Transport Layer Packets sent on all Paths that use the Shared Buffer prior to the Shared Credit Sync Packet and shall not include Transport Layer Packets which have not yet been sent.
5.3.2.3#5	TD 5.8	An Egress Adapter shall not send Path Credit Sync Packets for a Path that uses the Flow Control Disable scheme.
5.3.2.3#6	NT	An Egress Adapter shall not send a Credit Sync Packet while in a Low Power state.
5.3.2.3#7	TD 5.4	When an Ingress Adapter receives a Credit Sync Packet, it shall verify the ECC field value in the Credit Sync Packet payload as follows: The Ingress Adapter shall correct any single-bit errors. After correcting an error, the Ingress Adapter shall continue on as if the error had never occurred.
5.3.2.3#8	TD 5.4	When an Ingress Adapter receives a Credit Sync Packet, if an uncorrectable error is detected, the Credit Sync Packet shall be dropped, and the ECC Error field in the Adapter Configuration Registers shall be incremented.
5.3.3 Bandwidth Arbitration and Priority		
5.3.3#1	IOP	A Router shall enable bandwidth arbitration for a given Path when the Valid bit in the Path Configuration Space is set to 1b.
5.3.3.1 Scheduling		
5.3.3.1#2	IOP	The traffic manager for an Egress Adapter shall use the 3-layer scheduling scheme described in this section to schedule outgoing packets.
5.3.3.1.1 Path Schedulers		
5.3.3.1.1#1	IOP	There shall be one Path Scheduler for each Priority Group.
5.3.3.1.1#2	IOP	A weighted round-robin (WRR) scheduling scheme shall be implemented among the Paths that share the same Priority Group.
5.3.3.1.1#3	IOP	The Path Scheduler shall support weights in the range of 1-255.
5.3.3.1.1#4	IOP	When the Weight field changes for an enabled Path, the Path Scheduler shall use the new weight.
5.3.3.1.1#5	IOP	The weight assigned to a Path shall be determined by the Weight field in the Path Configuration Space.

5.3.3.1.1#6	IOP	When a Path is assigned a weight value of X, the Path Scheduler shall schedule X packets from that Path in one round, where a round refers to one complete iteration over all the Paths in the Priority Group. If less than X packets are available for arbitration, the scheduler shall schedule the number of available packets.
5.3.3.1.1#7	IOP	HopID 0 traffic shall be assigned to Priority Group 0.
5.3.3.1.1#8	IOP	No other traffic shall be assigned to Priority Group 0.
5.3.3.1.2 Priority Group Scheduler		
5.3.3.1.2#1	IOP	The Priority Group Scheduler shall employ a strict priority scheme between 8 Priority Groups, where Priority Group 0 has the highest priority and Priority Group 7 has the lowest priority.
5.3.3.1.3 Link Scheduler		
5.3.3.1.3#1	IOP	The Link Scheduler shall schedule traffic according to a strict priority scheme where the following priorities (from highest to lowest) are observed: Flow Control Packets; Time Sync Packets; Packets from the Priority Group Scheduler.
5.3.4 Packet Forwarding Delay Jitter		
5.3.4#1	IOP	The PFD Jitter in a Router shall be no more than tTunneledPacketJitter.
5.4 Path Tear-Down		
5.4#1	TD 5.10	After the *Valid* bit in a Path Configuration Space changes from 1b to 0b, a Router shall respond to the Write Request that sets the *Valid* bit to 0b and then tear down the Path at its Egress Adapter and Ingress Adapter.
5.4.1 Egress Adapter		
5.4.1#1	TD 5.10	For the Egress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 1. If the *ESE Flag* field in the Path Configuration Space is set to 1b for the Path, then the Router shall send a Shared Buffers Credit Sync Packet to the Link Partner.
5.4.1#2	TD 5.10	For the Egress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 2. While the Valid bit in Path Configuration Space is 0b, the Router shall not send any Path Credit Sync Packets for the Path.
5.4.1#3	NT	For the Egress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 2. While the Valid bit in Path Configuration Space is 0b, the Router shall ignore any Path credit updates for the Path received on the Egress Adapter.

5.4.1#4	TD 5.10	For the Egress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 4. After tTeardown time, the Router shall discard any remaining packets for the Path.
5.4.1#5	TD 5.10	For the Egress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 5. The Router shall block the transmission of any packets on the Path after tTeardown has elapsed since it set the Pending Packets bit to 0b and until the Valid bit in the Path Configuration Space is set again to 1b.
5.4.2 Ingress Adapter		
5.4.2#1	TD 5.11	For the Ingress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 1. The Router shall drop any packets received on the Path after the Valid bit was set to 0b.
5.4.2#2	NT	For the Ingress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: The Router shall dequeue all packets for the Path that are queued in the flow control buffers.
5.4.2#3	NT	A Router shall not transmit a partial packet.
5.4.2#4	NT	If the ISE Flag field in Path Configuration Space is set to 1b, the Ingress Adapter shall continue to increment the SCA state variable and send Credit Grant Packets.
5.4.2#5	NT	The SCA variable shall increment each time a packet is dequeued, regardless of whether the packet was discarded or transmitted.
5.4.2#6	NT	For the Ingress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed; 3. While the Valid bit in Path Configuration Space is 0b, the Router shall discard any Path Credit Sync Packets received for the Path
5.4.2#7	TD 5.11	For the Ingress Adapter of the Path being torn down, a Router shall perform the following steps in the order listed: 3. While the Valid bit in Path Configuration Space is 0b, the Router shall stop sending Path credits updates for the Path.

Chapter 6

The following Table presents the USB4 Specification Chapter 6 asserts.

Assertion #	Test Name	Assertion Description
6 Configuration Layer		
6.1 Domain Topology		
6.2 Router Addressing		
6.3 Router States		
6.3.1 Uninitialized Unplugged State		
6.3.2 Uninitialized Plugged State		
6.3.3 Sleep State		
6.3.4 Enumerated State		
6.4 Control Packet Protocol		
6.4.1 Control Adapter		
6.4.1#1	IOP	A Router shall support an internal Control Adapter that is used solely for transmitting and receiving Control Packets to and from the Transport Layer.
6.4.2 Control Packets		
6.4.2.1 Bit/Byte Conventions		
6.4.2.2 Format		
6.4.2.2#1	IOP	All Control Packets shall include a Route String.
6.4.2.2#2	NT	For Control Packets that originate from a Router and target the Connection Manager, the *TopologyID* field shall contain the TopologyID of the Router that originates the Control Packet.
6.4.2.2#3	BT	For Control Packets that originate from a Router and target the Connection Manager, bits [62:56] shall be set to 0.
6.4.2.2#4	BT	For Control Packets that originate from a Router and target the Connection Manager, the *CM* field shall be set to 1b.

6.4.2.2#5	BT	The CRC shall be calculated in increasing DW order, starting with the *Route String High* DW. Within each DW, CRC shall be calculated from bit[31] to bit[0].
6.4.2.2#6	BT	The following CRC shall be used: Width: 32; Poly: 1EDC6F41h; Init: FFFFFFFFh; RefIn: True; RefOut: True; XorOut: FFFFFFFFh.
6.4.2.3 Read Request		
6.4.2.4 Read Response		
6.4.2.4#1	IOP	A Read Response shall have the format shown in Figure 6-7.
6.4.2.4#2	IOP	Bits 12:0 in DW3 (Address field) of a Read Response shall contain the same value as the Address field in the associated Read Request.
6.4.2.4#3	TD 6.3	Bits 18:13 in DW3 (Read Size field) of a Read Response shall contain the same value as the Read Size field in the associated Read Request.
6.4.2.4#4	IOP	Bits 24:19 (Adapter Num field) in DW3 of a Read Response that targets Router Configuration Space shall contain the Adapter on which the associated Read Request arrived.
6.4.2.4#5	IOP	Bits 24:19 in DW3 (Adapter Num field) of a Read Response that does not target Router Configuration Space shall contain the *Adapter Num* value in the associated Read Request.
6.4.2.4#6	IOP	Bits 26:25 in DW3 (Configuration Space) of a Read Response shall contain the same value as the associated Read Request.
6.4.2.4#7	IOP	Bits 28:27 in DW3 (Sequence Number field) of a Read Response shall contain the same value as the Sequence Number field in the associated Read Request.
6.4.2.4#8	BT	Bits 31:29 in DW3 (reserved) are 0.
6.4.2.4#9	TD 6.3	The size of the Read Data field shall match the number of DWs in the Read Size field.
6.4.2.4#10	IOP	Data in the Read Data field shall be structured in increasing address order with bit 0 of each DW containing bit 0 of the corresponding configuration register.

6.4.2.5 Write Request		
6.4.2.6 Write Response		
6.4.2.6#1	IOP	A Write Response shall have the format shown in Figure 6-9.
6.4.2.6#2	IOP	Bits 12:0 in DW3 (Address field) of a Write Response shall contain the same value as the Address field in the associated Write Request.
6.4.2.6#3	TD 6.3	Bits 18:13 in DW3 (Write Size field) of a Write Response shall contain the same value as the Write Size field in the associated Write Request.
6.4.2.6#4	BT	Bits 24:19 in DW3 (Adapter Num field) of a Write Response shall contain the Adapter Num value in the associated Write Request.
6.4.2.6#5	BT	Bits 26:25 in DW3 (Configuration Space field) shall contain the same value as the associated Write Request.
6.4.2.6#6	BT	Bits 28:27 in DW3 (Sequence Number field) of a Write Response shall contain the same value as the associated write Request.
6.4.2.6#7	BT	Bits 31:29 in DW3 (reserved) are 0.
6.4.2.7 Notification Packet		
6.4.2.7#1	IOP	A Notification Packet shall have the format shown in Figure 6-10 and the fields defined in Table 6-6.
6.4.2.8 Notification Acknowledgment Packet		
6.4.2.9 Hot Plug Event Packet		
6.4.2.9#1	IOP	A Hot Plug Event Packet shall have the structure defined in Table 6-8 and Figure 6-12.
6.4.2.9#2	BT	Bits 30:6 in DW3 (reserved) are 0.
6.4.2.9#3	IOP	Bit 31 in DW 3 (UPG bit) shall be set to 0b for a Hot Plug Event or 1b for a Hot Unplug Event.

6.4.2.10 Inter-Domain Request		
6.4.2.11 Inter-Domain Response		
6.4.3 Control Packet Routing		
6.4.3.1 Upstream-Bound Packets		
6.4.3.1#1	NT	An Uninitialized Router shall discard a Control Packet with the CM bit set to 1b and shall not send any packets in response.
6.4.3.1#2	IOP	An Enumerated Router shall forward a Control Packet with the *CM* bit set to 1b to its Upstream Facing Adapter.
6.4.3.2 Downstream-Bound Packets		
6.4.3.2#1	IOP	A Router that receives a Control Packet on its Upstream Facing Adapter with the CM bit set to 0b and the *TopologyID Valid* bit in Router Configuration Space set to 0b shall: If the packet is a Read Request or a Write Request that targets Router Configuration Space, the Router shall process the packet as described in Section 6.4.3.3.
6.4.3.2#2	TD 6.1	A Router that receives a Control Packet on its Upstream Facing Adapter with the CM bit set to 0b and the *TopologyID Valid* bit in Router Configuration Space set to 0b shall: If the packet is not a Read Request or a Write Request that targets Router Configuration Space, Router shall drop the packet and shall not send any packets in response.
6.4.3.2#3	IOP	Else the Router shall extract the Egress Adapter number from the Route String that corresponds to the Router's depth in the Spanning Tree.
6.4.3.2#4	IOP	If the extracted Adapter number is 0, the Control Adapter of the Router shall consume the packet. The Router shall process the packet using the Enumerated Router Flow in Section 6.4.3.2.1.
6.4.3.2#5	NT	If the extracted Adapter number refers to an Adapter, the packet shall be dropped and the Router shall send the Connection Manager a Notification Packet with Event Code = ERR_ADP as defined in Table 6-11.
6.4.3.2#6	TD 6.1	If the extracted Adapter number refers to a disconnected or disabled Adapter, the Router shall drop the packet and shall send the Connection Manger a Notification Packet with Event Code = ERR_CONN as defined in Table 6-11.
6.4.3.2#7	TD 6.1	If the extracted Adapter number refers to a connected Adapter and the Lock bit in the Adapter Configuration Space is set to 1b, the Router shall drop the packet and shall send the Connection Manager a Notification Packet with Event Code = ERR_LOCK as defined in Table 6-11.

6.4.3.2#8	IOP	Else, the Router shall forward the packet over the Egress Adapter that matches the extracted Adapter number.
6.4.3.2#9	TD 6.2	A Router that receives a Control Packet on its Downstream Facing Adapter with the CM bit set to 0b and the TopologyID Valid bit in Router Configuration Space is set to 0b, shall: If the packet is a Read Request or a Write Request, then the Router shall drop the packet and shall send the Adapter that originated the Request a Notification Packet with Event Code = ERR_NUA as defined in Table 6-11.
6.4.3.2#10	TD 6.2	A Router that receives a Control Packet on its Downstream Facing Adapter with the CM bit set to 0b and the TopologyID Valid bit in Router Configuration Space is set to 0b, shall: If the packet is not a Read Request or a Write Request, Router shall drop the packet and shall not send any packets in response.
6.4.3.2#11	IOP	Else: If the packet is an Inter-Domain Request or an Inter-Domain Response, then the Router shall modify the packet as follows, and then send the packet over the Upstream Adapter: Replace the Route String in the packet with the Route String of the receiving Router within the receiving Domain, then add the Ingress Adapter number of the Adapter connected to the inter-Domain Link
6.4.3.2#12	IOP	Else: If the packet is an Inter-Domain Request or an Inter-Domain Response, then the Router shall modify the packet as follows, and then send the packet over the Upstream Adapter: Set the CM bit to 1b.
6.4.3.2#13	IOP	Else: If the packet is an Inter-Domain Request or an Inter-Domain Response, then the Router shall modify the packet as follows, and then send the packet over the Upstream Adapter: Update the CRC field.
6.4.3.2#14	TD 6.2	If the packet is a Read Request or a Write Request, then the Router shall drop the packet and shall send the Adapter that originated the Request a Notification Packet with Event Code = ERR_ENUM as defined in Table 6-11
6.4.3.2#15	NT	Else, Router shall drop the packet and shall not send any packets in response.
6.4.3.2.1 Enumerated Router Flow		
6.4.3.2.1#1	NT	If the Control Packet is either a Read Request or a Write Request, the Router shall process the packet as described in Section 6.4.3.3.
6.4.3.2.1#2	NT	If the Control Packet is a Hot Plug Acknowledgment Packet, the Router shall process the packet as described in Section 6.8.
6.4.3.2.1#3	NT	If the Control Packet is a Notification Acknowledgment Packet, the Router shall process the packet as described in Section 6.6.
6.4.3.2.1#4	NT	Else, the Router shall drop the Control Packet and shall not send any packets in response.

6.4.3.3 Processing of Read and Write Requests		
6.4.3.3#1	TD 6.3	If the packet addresses any Configuration Space other than the Router Configuration Space, and if the *Adapter Num* field in the packet exceeds the value of the *Max Adapter* field in the Router Configuration Space: The read or write operation shall not be performed and a Response Packet shall not be sent.
6.4.3.3#2	TD 6.3	If the packet addresses any Configuration Space other than the Router Configuration Space, and if the *Adapter Num* field in the packet exceeds the value of the *Max Adapter* field in the Router Configuration Space: The Router shall send the Connection Manager a Notification Packet with Event Code = ERR_ADP as defined in Table 6-11.
6.4.3.3#3	TD 6.3	Else, if the packet is a Write Request and the Write Size field in the packet is zero, then the write operation shall not be performed. The Router shall send a Write Response.
6.4.3.3#4	NT	Else, if the packet is a Write Request for which the *Length* field in the packet header does not equal the expected length ([*Write Size* + 4] * 4): The Router shall not perform a write operation and shall not send a Write Response.
6.4.3.3#5	NT	Else, if the packet is a Write Request for which the *Length* field in the packet header does not equal the expected length ([*Write Size* + 4] * 4): The Router shall send the Connection Manager a Notification Packet with Event Code = ERR_LEN as defined in Table 6-11.
6.4.3.3#6	TD 6.3	Else, if the packet is a Write Request and if the *Address* and *Write Size* fields in the packet extend beyond the address range supported: The part of the write data that fits within the supported address range shall be written. The part of the write data that fits outside the supported address range shall be dropped.
6.4.3.3#7	TD 6.3	Else, if the packet is a Write Request and if the *Address* and *Write Size* fields in the packet extend beyond the address range supported: A Write Response shall not be sent.
6.4.3.3#8	TD 6.3	Else, if the packet is a Write Request and if the *Address* and *Write Size* fields in the packet extend beyond the address range supported: The Router shall send the Connection Manager a Notification Packet with Event Code = ERR_ADDR as defined in Table 6-11.
6.4.3.3#9	TD 6.3	Else, if the packet is a Read Request and if the *Address* and *Read Size* fields in the packet extend beyond the address range supported: A Read Response shall not be sent.

6.4.3.3#10	TD 6.3	Else, if the packet is a Read Request and if the *Address* and *Read Size* fields in the packet extend beyond the address range supported: A Router shall send the Connection Manager a Notification Packet with Event Code = ERR_ADDR as defined in Table 6-11.
6.4.3.3#11	TD 6.3	Else, if the packet is a Read Request and the Read Size field in the packet is zero then the Router shall send a Read Response without a Read Data field.
6.4.3.3#12	TD 6.3	Else, if the packet is a Read Request and *Read Size* field in the packet contains a value larger than 60: A Read Response shall not be sent.
6.4.3.3#13	TD 6.3	Else, if the packet is a Read Request and *Read Size* field in the packet contains a value larger than 60: A Router shall send the Connection Manager a Notification Packet with Event Code = ERR_LEN as defined in Table 6-11.
6.4.3.3#14	TD 6.3	Else, process the packet and send a Response Packet.
6.4.3.3#15	IOP	A Router shall send a Write Response for a Write Request to a Path Configuration Space only after it has executed the Write Request, including setting the entry in the Routing Table and in the Egress Arbiter.
6.4.4 Control Packet Reliability		
6.4.4#1	TD 6.4	Each Router along the Path of a Control Packet shall check the validity of the CRC field. If a packet fails the CRC check, the Router shall discard the packet.
6.4.4#2	BT	Unless otherwise specified, a Router that is the target of a Read Request shall send a Read Response within tCPResponse of receiving the Request.
6.4.4#3	BT	Unless otherwise specified, a Router that is the target of a Write Request shall send a Write Response within tCPResponse of receiving the Request.
6.4.4#4	TD 6.8	A Router forwarding a Control Packet shall send the packet on an Egress Adapter not later than tCPForward from the time the packet was received on an Ingress Adapter.
6.5 Notification Events		
6.6 Notification Acknowledgement		
6.6#1	TD 6.4	A Router shall retransmit a Notification Packet that requires a Notification Acknowledgment Packet if a Notification Acknowledgment Packet is not received within the time specified by the Notification Timeout field in the Router Configuration Space.
6.6#2	NT	A Router shall not send another packet that requires a Notification Acknowledgment while a previous packet that requires a Notification Acknowledgment is pending (i.e. before a Notification Acknowledgment Packet is received or a timeout occurs).

6.7 Router Enumeration and Initialization		
6.7#1	TBD	On transition to the Uninitialized state, a TBT3-Compatible Router shall: Expose USB4 Ports and PCIe Adapters as defined in Section 13.3.1.
6.7#2	TBD	On transition to Uninitialized state, a TBT3-Compatible Router shall: Set its sleep and wake behavior as defined in Section 13.2.4.
6.7#3	TBD	On transition to Uninitialized state, a TBT3-Compatible Router shall: Expose the additional registers defined in Section 13.6.
6.7#4	TBD	When the TopologyID Valid bit is set to 1b, the Router is enumerated, and a TBT3-Compatible Router shall: Expose all its USB4 Ports and PCIe Adapters (if any) to the Connection Manager.
6.7#5	TBD	When the TopologyID Valid bit is set to 1b, the Router is enumerated, and a TBT3-Compatible Router shall: Set the Lock bit to 1b on all Downstream Facing Ports.
6.7#6	TBD	When the TopologyID Valid bit is set to 1b, the Router is enumerated, and a TBT3-Compatible Router shall: Set its sleep and wake behavior as defined in Section 4.5.
6.7#7	TBD	When the TopologyID Valid bit is set to 1b, the Router is enumerated, and a TBT3-Compatible Router shall: Disable access to the additional registers defined in Section 13.6.
6.7#8	TBD	The TBT3-Compatible Router shall then set the Router Ready bit to 1b.
6.7#9	TBD	On transition to Uninitialized state, a Router that is not TBT3-Compatible shall: Expose all its USB4 Ports and PCIe Adapters (if any) to the Connection Manager.
6.7#10	TBD	On transition to the Uninitialized state, a Router that is not TBT3-Compatible shall: Set the Lock bit to 1b on all Downstream Facing Ports.
6.7#11	TBD	On transition to Uninitialized state, a Router that is not TBT3-Compatible shall: Set sleep and wake behavior to default as defined in Section 4.5.
6.7#12	TBD	The Router that is not TBT3-Compatible shall then set the Router Ready bit to 1b.
6.7#13	TBD	When the Configuration Valid bit in Router Configuration Space is set to 1b, a Device Router shall: If the USB3 Tunneling On bit is set to 1b, establish USB3 tunneling functionality.

6.7#14	TBD	When the Configuration Valid bit in Router Configuration Space is set to 1b, a Device Router shall: If the PCIe Tunneling On bit is set to 1b, establish PCIe tunneling functionality.
6.7#15	TBD	The Device Router shall then set the Configuration Ready bit in Router Configuration Space to 1.
6.8 Hot Plug and Hot Unplug Events		
6.8#1	TD 6.6	A Router shall retransmit a Hot Plug Event Packet if a Hot Plug Acknowledgment Packet acknowledging the Hot Plug or the Hot Unplug Event is not received within the time specified by the *Notification Timeout* field in the Router Configuration Space.
6.8#2	TD 6.6	A Router shall not send a Hot Plug Event Packet for a new Hot Plug Event from any Adapter until it receives a Hot Plug Acknowledgment Packet for the previous Hot Plug/Unplug Event.
6.8#3	TD 6.6	A Router shall not send a Hot Unplug Event Packet for a new Hot Plug Event from any Adapter until it receives a Hot Plug Acknowledgment Packet for the previous Hot Plug/Unplug Event.
6.8#4	TD 6.6	After receiving a Hot Plug Acknowledgment Packet, a Router shall not send any additional Hot Plug Event Packets for that Hot Plug/Unplug Event.
6.8#5	NT	A Router shall ignore a Hot Plug Acknowledgment Packet for a Hot Plug/Unplug Event that was already acknowledged.
6.8#6	TD 6.6	A Router shall not generate two consecutive Hot Plug Events or two consecutive Hot Unplug Events for a given Adapter. The next event after a Hot Plug Event for a given Adapter shall always be a Hot Unplug Event. Similarly, the next event after a Hot Unplug Event for a given Adapter shall always be a Hot Plug Event.
6.8#7	TD 6.6	A Router shall always report a Hot Plug Event or a Hot Unplug Event. When a Hot Plug Event Packet cannot be sent, the Router shall store the event and shall send Hot Plug Event Packet when conditions allow.
6.8.1 Router Hot Plug		
6.8.1.1 Enumerated Routers		
6.8.1.1#1	IOP	When a Router in the Enumerated state detects a Router Hot Plug on one of its Downstream Facing Ports, it shall perform the following steps: 1) Perform Lane Initialization on the Lanes of the Downstream Facing Port with the Hot Plugged Router

6.8.1.1#2	IOP	When a Router in the Enumerated state detects a Router Hot Plug on one of its Downstream Facing Ports, it shall perform the following steps: 2) For each Adapter in the USB4 Port that reaches CL0 state, send a Hot Plug Event Packet to the Connection Manager with the *UPG* bit set to 0b.
6.8.1.1#3	TD 8.16	When a Router in the Enumerated state detects a Router Hot Plug on one of its Downstream Facing Ports, it shall perform the following steps: 3) If none of the Adapters in the USB4 Port reaches CL0 state within tTrainingAbort1 after entering the Training state, and if the "Hot Plug Failure Indication" capability is enabled in the Router (see Section 8.3.1.3.3.1), then the Router shall send the Connection Manager a Notification Packet with Event Code = ERR_PLUG as defined in Table 6-11.
6.8.1.2 Uninitialized Routers		
6.8.1.2#1	TD 6.6	When a Router in the Uninitialized state detects a Router Hot Plug, it shall not send a Hot Plug Event Packet until it transitions to the Enumerated state.
6.8.1.2#2	IOP	After transitioning to the Enumerated state, the Router shall follow the procedure in Section 6.8.1.1.
6.8.1.3 Hot Plugged Router		
6.8.1.3#1	IOP	A hot plugged Router shall enable the following for HopID 0: Forwarding of Control Packets to and from the Control Adapter and Egress scheduling
6.8.2 Router Hot Unplug		
6.8.2.1 Hot Unplug on the Upstream Facing Port		
6.8.2.1#1	NT	If a Router is still powered on after being unplugged, it shall initiate a disconnect on the Upstream Facing Port by driving its SBTX line low.
6.8.2.2 Hot Unplug on a Downstream Facing Port		
6.8.2.2#1	NT	When a Router detects a Router Hot Unplug on a Downstream Facing Port, it shall initiate a disconnect on the Downstream Facing Port by driving its SBTX line low.
6.9 Downstream Facing Port Reset		
6.9#1	NT	When the *Downstream Port Reset* bit of a Downstream Facing Lane Adapter is set to 1b, a Router shall discard any pending Sideband transactions and initiate a disconnect event on the Downstream Facing Port by driving its SBTX line low.

6.9#2	NT	The Router shall drive the SBTX line high when the *Downstream Port Reset* bit of the Downstream Facing Port is set to 0b.
6.10 Timing Parameters		

Chapter 8

The following Table presents the USB4 Specification Chapter 8 asserts.

Assertion #	Test Name	Assertion Description
8 Registers		
8.1 Configuration Fields Access Types		
8.1#1	IOP	**Read/Write.** A field with this access type shall be capable of both read and write operations. The value read from this field shall reflect the last value written to it unless the field was reset in the interim.
8.1#2	IOP	**Read/Write Status.** A field with this access type shall be capable of both read and write operations. The value read from this field may or may not reflect the last value written.
8.1#3	IOP	**Read Only.** A write to a field with this access type shall have no effect. A read shall return a meaningful value.
8.1#4	IOP	**Read Clear.** A field with this access type shall be cleared to 0 after it is read. A write to a field with this attribute shall have no effect on its value.
8.1#5	IOP	**Write Clear.** A field with this access type shall be cleared to 0 after it is written to. A read shall return a meaningful value.
8.1#6	IOP	**Read/Write Self Clearing.** When set to 1b a field with this access type causes an action to be initiated. A field with this attribute shall read as 0b after the action is complete.
8.1#7	IOP	**Reserved.** Reserved for future implementation. A write to this field shall have no effect. A read shall return 0.
8.1#8	IOP	**Reserved and Zero**. Reserved for future implementation. A read shall return 0.
8.2 Configuration Spaces		
8.2#1	IOP	A Router shall implement Router Configuration Space.
8.2#2	IOP	A Router shall implement Adapter Configuration Spaces.
8.2#3	IOP	A Router shall implement Path Configuration Space.

8.2#4	TD 8.1 TD 8.2 TD 8.5 TD 8.7	All fields in a Configuration Space that are not Read Only (RO) shall contain their Default Values until a different value is written by a Connection Manager.
8.2.1 Router Configuration Space		
8.2.1#1	TD 8.1	A Router Configuration Space shall have the format and contain the register fields depicted in Figure 8-1.
8.2.1#2	TD 8.1	A TMU Router Configuration Capability shall be present in Router Configuration Space.
8.2.1#3	IOP	A Router that implements Vendor Specific Configuration Capabilities shall not depend on a Connection Manager's support for the Vendor Specific Configuration Capabilities.
8.2.1#4	TD 8.1	Capabilities shall be linked in the following order: 1) Required Capabilities; 2) Optional Capabilities; 3) Vendor Specific Capabilities; 4) Vendor Specific Extended Capabilities
8.2.1.1 Basic Configuration Registers		
8.2.1.1#1	IOP	Router Configuration Space registers shall have the structure and fields described in Table 8-3.
8.2.1.1#2	TD 8.1	The Vendor ID field shall identify the manufacturer of the Router silicon.
8.2.1.1#3	NT	The Product ID field shall contain a value that is assigned by the manufacturer of the Router silicon to identify the type of the Router.
8.2.1.1#4	TD 8.1	The Next Capability Pointer field shall contain the Doubleword index of the first Capability in the Router Configuration Space.
8.2.1.1#5	NT	The Max Adapter field shall contain the Adapter number of the highest numbered Adapter in the Router.
8.2.1.1#6	IOP	A Router shall support Depths up to and including 5.
8.2.1.1#7	NT	The Revision Number field shall contain the value assigned by the manufacturer to identify the revision number of the Router.
8.2.1.1#8	TD 8.1	A Router shall set the USB4 Version field to 20h.
8.2.1.1#9	TD 8.1	A Host Router shall hardwire the Enable Wake on PCIe bit to 0.
8.2.1.1#10	TD 8.1	A Host Router shall hardwire the Enable Wake on USB3 bit to 0.

8.2.1.1#11	TBD	A Host Router shall hardwire the Enable Wake on DP bit to 0.
8.2.1.1#12	NT	A Router shall ignore the CM TBT3 Not Supported bit if the *Configuration Valid* bit is set to 0b.
8.2.1.1#13	TBD	A Device Router shall ignore the PCIe Tunneling On bit if the *Configuration Valid* field is set to 0b.
8.2.1.1#14	TBD	A Device Router shall ignore the USB3 Tunneling On bit if the *Configuration Valid* field is set to 0b.
8.2.1.1#15	TBD	A Device Router shall ignore the Internal Host Controller On bit if the *Configuration Valid* field is set to 0b.
8.2.1.1#16	TD 8.1	A Router shall set the TBT3 Not Supported field to 1b if it does not support the TBT3-compatible behavior defined in Chapter 13.
8.2.1.1#17	TD 8.1	A Router shall set the TBT3 Not Supported field to 0b if it supports the TBT3-compatible behavior defined in Chapter 13.
8.2.1.1#18	NT	A Router shall set the Wake on PCIe Status bit to 1b when a PCIe Wake indication from a PCIe device connected to a PCIe downstream port causes the Router to exit from sleep.
8.2.1.1#19	NT	A Router shall set the Wake on PCIe Status bit to 0b upon entry to sleep.
8.2.1.1#20	NT	A Router shall set the Wake on USB3 Status bit to 1b when a USB Wake indication causes the Router to exit from sleep.
8.2.1.1#21	NT	A Router shall set the Wake on USB3 Status bit to 0b upon entry to sleep.
8.2.1.1#22	TBD	A Router shall set the Wake on DP Status bit to 1b when a USB Wake indication causes the Router to exit from sleep.
8.2.1.1#23	NT	A Router shall set the Wake on DP Status bit to 0b upon entry to sleep.
8.2.1.1#24	TD 8.1	A Router shall set the Internal Host Controller Implemented bit to 0b if it does not implement an internal host controller.
8.2.1.1#25	TD 8.1	A Router shall set the Internal Host Controller Implemented bit to 1b if it implements an internal host controller.
8.2.1.1#26	NT	Deprecated.
8.2.1.1#27	NT	A Device Router shall set the Configuration Ready bit to 1b when it is ready for the Protocol Tunneling enabled by the Connection Manager.

8.2.1.1#28	NT	The UUID (High) field contains bits 63:32 of the UUID value.
8.2.1.1#29	NT	The UUID (Low) field contains bits 31:0 of the UUID value.
8.2.1.1#30	NT	A Router shall process the Router Operation in the Opcode field when the value in the Operation Valid (OV) field changes from 0b to 1b.
8.2.1.1#31	NT	A Router shall set the Operation Valid field to 0b after it finishes processing the Router Operation.
8.2.1.1.1 UUID		
8.2.1.1.1#1	NT	The UUID shall have the format shown in Figure 8-4 where: Vendor ID is a 16-bit ID assigned by the USB-IF, which identifies the product vendor.
8.2.1.1.1#2	NT	Vendor ID shall contain the same value as the *Vendor ID* field in Router Configuration Space.
8.2.1.1.1#3	NT	The UUID shall have the format shown in Figure 8-4 where: Component ID is a 44-bit ID that is unique to the USB4 silicon containing the Router. Routers that reside in the same silicon shall have the same Component ID. Routers with the same Vendor ID that reside in separate silicon shall have different Component IDs.
8.2.1.1.1#4	NT	A product containing multiple Router instances shall increment the Router ID for each Router instance, starting at 0.
8.2.1.1.1#5	NT	A product containing a single Router instance shall set the Router ID field to 0.
8.2.1.2 TMU Router Configuration Capability		
8.2.1.2#1	TD 8.1	A TMU Router Configuration Capability shall have the structure depicted in Figure 8-5 and the fields defined in Table 8-4
8.2.1.2#2	TD 8.1	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Router Configuration Space.
8.2.1.2#3	TD 8.1	A Router shall set the Next Capability field to 00h if the TMU Router Configuration Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
8.2.1.2#4	TD 8.1	A Router shall set the Capability ID field to 03h indicating this is the start of a TMU Router Configuration Capability.
8.2.1.2#5	NT	The Uni-Directional Capability field shall be 0b if Uni-Directional Time Sync Handshakes are not supported and shall be 1b if Uni-Directional Time Sync Handshakes are supported.

8.2.1.2#6	NT	For a Device Router, the Inter-Domain Enable field shall have no effect.
8.2.1.2#7	NT	If TSPacketInterval field is 0b, it shall disable Time Sync Handshake initiation by the Router.
8.2.1.2#8	NT	The TimeOffsetfromHR Low field contains the least significant 32 bits of the computed time offset between the Local Clock and the Host Router's Local Clock.
8.2.1.2#9	NT	The TimeOffsetfromHR High field contains the most significant 32 bits of the computed time offset between the Local Clock and the Host Router's Local Clock.
8.2.1.2#10	NT	A Router shall calculate the time offset and described in Equation 7-9.
8.2.1.2#11	NT	The TimeOffsetFromDFP Low field contains the least significant 32 bits of the computed time offset between the DFP and UFP clocks.
8.2.1.2#12	NT	The TimeOffsetFromDFP High field contains the most significant 32 bits of the computed time offset between the DFP and UFP clocks.
8.2.1.2#13	NT	A Router shall calculate the time offset as described in Equation 7-7 for Bi-Directional Time Sync Handshakes or Equation 7-8 for Uni-Directional Time Sync Handshakes.
8.2.1.2#14	NT	The FreqOffsetFromHR field contains the computed frequency offset between the Local Clock and the Host Router's Local Clock represented using 2's complement format.
8.2.1.2#15	NT	A Router shall calculate the frequency offset in the FreqOffsetFromHR field as described in Section 7.4 Equation (4).
8.2.1.2#16	NT	The FreqOffsetFromDFP field contains the computed frequency offset between the DFP and UFP clocks, represented using 2's complement format.
NT	NT	A Router shall calculate the frequency offset in the FreqOffsetFromMaster field as described in Section 7.4 Equation (2).
8.2.1.2#18	NT	The Propagation Delay Low field contains the least significant 32 bits of the computed time delay between the Router and its upstream Link Partner. This field shall have the same format as the TimeOffsetFromHR register.
8.2.1.2#19	NT	The Propagation Delay High field contains the most significant 32 bits of the computed time delay between the Router and its upstream Link Partner. This field shall have the same format as the TimeOffsetFromHR register.

8.2.1.2#20	NT	A Router shall calculate the time delay in the Propagation Delay Low/High fields as described in Section 7.4 Equation (5).
8.2.1.2#21	NT	The Computation Time Stamp Low field shall contain the least significant 32 bits of the most recent value of the t4 time stamp ($t_4[n]$).
8.2.1.2#22	NT	The Computation Time Stamp Middle field shall contain the middle 32 bits of the most recent value of the t4 time stamp ($t_4[n]$).
8.2.1.2#23	NT	The Computation Time Stamp High field shall contain the most significant 16 bits of the most recent value of the t4 time stamp ($t_4[n]$).
8.2.1.2#24	NT	The FreqAvgConst field contains the IIR filter co-efficient that shall be used to average the frequency ratio.
8.2.1.2#25	NT	The DelayAvgConst field contains the IIR filter co-efficient that shall be used to average the propagation delay.
8.2.1.2#26	NT	The OffsetAvgConst field contains the IIR filter co-efficient that shall be used to average the time offset.
8.2.1.2#27	NT	The ErrorAvgConst field contains the IIR filter co-efficient that shall be used to average the time offset averaging error.
8.2.1.2#28	NT	For an Inter-Domain Time Initiator, the InterDomain Time Stamp Low field shall contain the least significant 32 bits of the computed value of the inter-Domain time stamp. The time stamp shall be computed as described in Section 7.4.2.1.
8.2.1.2#29	NT	For a Router that isn’t an Inter-Domain Time Initiator, the InterDomain Time Stamp High field shall contain the least significant 32 bits of the IDTimeStamp value contained in the last received Follow Up Packet.
8.2.1.2#30	NT	For an Inter-Domain Time Initiator, the InterDomain Time Stamp Middle field shall contain the middle 32 bits of the computed value of the inter-Domain time stamp. The time stamp shall be computed as described in Section 7.4.2.1.
8.2.1.2#31	NT	For a Router that isn’t an Inter-Domain Time Initiator, the InterDomain Time Stamp Middle field shall contain the middle 32 bits of the IDTimeStamp value contained in the last received Follow Up Packet.
8.2.1.2#32	NT	For an Inter-Domain Time Initiator, the InterDomain Time Stamp High field shall contain the most significant 32 bits of the computed value of the inter-Domain time stamp. The time stamp shall be computed as described in Section 7.4.2.1.

8.2.1.2#33	NT	For a Router that isn’t an Inter-Domain Time Initiator, the InterDomain Time Stamp High field shall contain the most significant 32 bits of the IDTimeStamp value contained in the last received Follow Up Packet.
8.2.1.2#34	NT	For an Inter-Domain Time Initiator, the TimeOffsetFromInterDomainHR Low field shall contain the least significant 32 bits of the computed time offset between the local Host Router clock and the inter-Domain Time Source.
8.2.1.2#35	NT	For a Router that isn’t an Inter-Domain Time Initiator, the TimeOffsetFromInterDomainHR Low field shall contain the most recent value of the TimeOffsetFromInterDomainHR field contained in the last received Follow Up Packet.
8.2.1.2#36	NT	For an Inter-Domain Time Initiator, the TimeOffsetFromInterDomainHR High field contains the most significant 32 bits of the computed time offset between the local Host Router clock and the inter-Domain Time Source. The format of this register is shown in Figure 7-4. The time offset shall be computed as described in Section 7.4.2.3.
8.2.1.2#37	NT	For a Router that isn’t an Inter-Domain Time Initiator, the TimeOffsetFromInterDomainHR High field contains the most recent value of the TimeOffsetFromInterDomainHR field contained in the last received Follow Up Packet.
8.2.1.2#38	NT	For an Inter-Domain Time Initiator, the TimeOffsetFromInterDomainHR field shall have the same format as shown in Figure 7-4 The time offset shall be computed as described in Section 7.4.2.3.
8.2.1.2#39	NT	For an Inter-Domain Time Initiator, the FreqOffsetFromInterDomainHR field shall contain the computed frequency offset between the local Host Router clock and the Inter-Domain Time Source, represented using 2’s complement format.
8.2.1.2#40	NT	The frequency offset in the FreqOffsetFromInterDomainHR field shall be computed as described in Section 7.4.2.2.
8.2.1.2#41	NT	For a Router that isn’t an Inter-Domain Time Initiator, the FreqOffsetFromInterDomainHR field shall contain the most recent value of the FrequencyOffsetFromInterDomainHR field contained in the last received Follow Up Packet.
8.2.1.2#42	NT	A Router shall set the Post Time Low field to 0 after updating its local time.
8.2.1.2#43	NT	A Router shall set the Post Time High field to 0 after updating its local time.
8.2.1.2#44	NT	The Inter-Domain Not Supported (IDNS) field shall indicate whether or not a Router supports Inter-Domain Time Synchronization.

8.2.1.2#45	NT	A Device Router shall set the Inter-Domain Not Supported field to 0.
8.2.1.2.1 Register Locking Mechanism		
8.2.1.2.1#1	CH7	A Router shall update the value in the entire field (i.e. Low Middle, and High DWs) when the Connection Manager reads the Low DW of the field.
8.2.1.2.1#2	CH7	A Router shall not change the value in the Middle and High DWs until the next time the Low DW is read.
8.2.1.2.1#3	CH7	The Register Locking Mechanism shall be implemented for following registers: LocalTime {Low, Middle, High}; TimeOffsetFromHR {Low, Middle, High}; Inter-Domain Time Stamp {Low, Middle, High}
8.2.1.2.2 Register Group Locking Mechanism		
8.2.1.2.2#1	CH7	The value of a locked register group shall change only when the Triggering DW is accessed.
8.2.1.2.2#2	CH7	Table 8-16 lists the register groups that shall be locked.
8.2.1.3 Vendor Specific Capability		
8.2.1.3#1	TD 8.1	Table 8-6 describes the fields that a Vendor Specific Capability shall contain.
8.2.1.3#2	TD 8.1	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Router Configuration Space.
8.2.1.3#3	TD 8.1	A Router shall set the Next Capability Pointer field to 00h if the Vendor-Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
8.2.1.3#4	TD 8.1	A Router shall set the Capability ID field to 05h indicating this is the start of a Vendor-Specific Capability.
8.2.1.3#5	NT	The VSC ID field shall contain the vendor-defined ID number that identifies the nature and format of the VSC structure.
8.2.1.3#6	NT	The VSC Length field shall contain the total number of Doublewords in the VSC structure including Doubleword 0 and the Vendor-Specific Doublewords that follow it.
8.2.1.4 Vendor Specific Extended Capability (VSEC)		
8.2.1.4#1	TD 8.1	Table 8-7 describes the fields that a Vendor Specific Extended Capability shall contain.

8.2.1.4#2	TD 8.1	A Router shall set the Capability ID field to 05h indicating this is the start of a Vendor-Specific Capability.
8.2.1.4#3	NT	The VSEC ID field shall contain the vendor-defined ID number that identifies the nature and format of the VSEC structure.
8.2.1.4#4	TD 8.1	A Router shall set the VSEC Header field to 00h to indicate that the Capability is an Extended Capability.
8.2.1.4#5	TD 8.1	The Next Capability Pointer field shall contains the Doubleword index of the next Capability in the Router Configuration Space.
8.2.1.4#6	TD 8.1	A Router shall set the Next Capability Pointer field to 00h if the Vendor-Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
8.2.1.4#7	NT	The VSEC Length field shall contain the total number of Doublewords in the VSEC structure including Doubleword 0, Doubleword 1, and the Vendor-Specific Doublewords that follow.
8.2.2 Adapter Configuration Space		
8.2.2#1	NT	Every Adapter (except for a Control Adapter) shall have its own Adapter Configuration Space.
8.2.2#2	TD 8.2	An Adapter Configuration Space shall have the structure depicted in Figure 8-6.
8.2.2#3	TD 8.2	A Router shall allow a Connection Manager to access Adapter Configurations Space regardless of whether or not the Adapter is connected.
8.2.2#4	TD 8.2	A Capability listed as “Required” shall be present in Adapter Configuration Space.
8.2.2#5	TD 8.2	A TMU Adapter Configuration Capability is required for Lane Adapters.
8.2.2#6	TD 8.2	A TMU Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#7	TD 8.2	A Lane Adapter Configuration Capability is Required for Lane Adapters.
8.2.2#8	TD 8.2	A Lane Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#9	TD 8.2	A USB4 Port Capability is required for the Lane 0 Adapter in a USB4 Port.
8.2.2#10	TD 8.2	A USB4 Port Capability shall not be present for any other Adapter.

8.2.2#11	TD 8.2	A PCIe Adapter Configuration Capability is required for PCIe Adapters.
8.2.2#12	TD 8.2	A PCIe Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#13	TD 8.2	A DP IN Adapter Configuration Capability is required for DP IN Adapters.
8.2.2#14	TD 8.2	A DP IN Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#15	TD 8.2	A DP OUT Adapter Configuration Capability is required for DP OUT Adapters.
8.2.2#16	TD 8.2	A DP OUT Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#17	TD 8.2	A USB3 Adapter Configuration Capability is required for USB3 Adapters.
8.2.2#18	TD 8.2	A USB3 Adapter Configuration Capability shall not be present for any other Adapter.
8.2.2#19	IOP	A Router’s operation shall not depend on a Connection Manager’s support for the Vendor Specific Capabilities and Vendor Specific Extended Capabilities.
8.2.2.1 Basic Configuration Registers		
8.2.2.1#1	TD 8.2	The first 24 Doublewords in an Adapter Configuration Space shall have the format and fields described in Figure 8-7 and Table 8-20.
8.2.2.1#2	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the first Capability in the Adapter Configuration Space.
8.2.2.1#3	TD 8.2	The Max Counter Sets field shall contain the number of counter sets provided by the Adapter in Counters Configuration Space.
8.2.2.1#4	TD 8.2	The value in the Max Counter Sets field shall be at least 1 if the CCS Flag is set to 1b.
8.2.2.1#5	TD 8.2 TD 8.7	An Adapter shall set the Counters Configuration Space Flag to 1b if the Adapter supports Counters Configuration Space. Otherwise it shall be set to 0b.
8.2.2.1#6	TD 8.2	The Adapter Type Sub-type field shall identify the Adapter sub-type using the Sub-Type encodings in Table 8-10.
8.2.2.1#7	TD 8.2	The Adapter Type Version field shall identify the Adapter version using the version encodings in Table 8-10.
8.2.2.1#8	TD 8.2	The Adapter Type Protocol field shall identify the Adapter protocol type using the Protocol encodings in Table 8-10.

8.2.2.1#9	TD 8.2	Bits 31:24 in ADP_CS_2 shall be set to 01h.
8.2.2.1#10	IOP	The Adapter Number field shall contain the Adapter number for the Adapter.
8.2.2.1#11	TD 8.2	The Lane 1 Adapter shall set the HEC Error bit to 0b.
8.2.2.1#12	TD 8.2	The HEC Error bit is reserved in an Adapter and shall be set to 0b.
8.2.2.1#13	TD 8.2	The Lane 1 Adapter shall set the Flow Control Error bit to 0b.
8.2.2.1#14	TD 8.2	The Flow Control Error bit is reserved in an Adapter and shall be set to 0b.
8.2.2.1#15	IOP	A Lane 0 Adapter shall set the Shared Buffering Capable bit to 1b if shared buffering is supported.
8.2.2.1#16	IOP	A Lane 0 Adapter shall set the Shared Buffering Capable bit to 0b if shared buffering is not supported.
8.2.2.1#17	TD 8.2	The Lane 1 Adapter shall set the Shared Buffering Capable bit to 0b.
8.2.2.1#18	NT	The Total Buffers field shall contain the total number of ingress buffers available to a Lane Adapter as defined in Section 5.3.2.1.1.
8.2.2.1#19	TD 8.2	The Plugged field is reserved in a USB3 Adapter, a DP IN Adapter, a PCIe Adapter, and a Host Interface Adapter, and shall be set to 0.
8.2.2.1#20	TD 8.3	An Adapter shall set the *Lock* bit to 1b after the Adapter goes through a disconnect.
8.2.2.1#21	NT	Deprecated.
8.2.2.1#22	NT	Deprecated.
8.2.2.1#23	NT	The Max Input HopID field shall contain the highest HopID value the Adapter supports for incoming Packets.
8.2.2.1#24	NT	The Max Output HopID field shall contain the highest HopID value the Adapter supports for outgoing Packets.
8.2.2.1#25	NT	An Adapter that is not a Lane Adapter, a DP IN Adapter, or a DP OUT Adapter shall hardwire the Disable Hot Plug Events bit to 0b.
8.2.2.1#26	TD 5.1 TD 5.2	The HEC Errors field shall contain the number of ingress Transport Layer packets dropped due to HEC errors.

8.2.2.1#27	NT	A Lane Adapter shall increment the counter in the HEC Errors field from 0 and shall stop counting at FFFF FFFFh.
8.2.2.1#28	NT	An Adapter shall not increment the counter in the HEC Errors field and shall set this field to 0.
8.2.2.1#29	NT	The Invalid HopID Errors field shall contain the number of ingress Transport Layer packets with a HopID outside the supported range or a HopID that does not belong to an enabled Path.
8.2.2.1#30	NT	An Adapter shall increment the counter in the Invalid HopID Errors field from 0 and shall stop counting at FFFF FFFFh.
8.2.2.1#31	TD 5.3 TD 5.4	The ECC Errors field shall contain the number of Credit Sync Packets and Credit Grant Records dropped due to ECC errors.
8.2.2.1#32	NT	A Lane Adapter shall increment the counter in the ECC Errors field from 0 and shall stop counting at FFFF FFFFh.
8.2.2.1#33	NT	An Adapter shall not increment the counter in the ECC Errors field and shall set this field to 0.
8.2.2.2 TMU Adapter Configuration Capability		
8.2.2.2#1	TD 8.2	TMU Adapter Configuration Capability shall have the structure depicted in Figure 8-8 and shall contain the fields defined in Table 8-22.
8.2.2.2#2	NT	For a USB4 Port with two enabled Adapters, the values in the TMU Adapter Configuration Capability of both Adapters shall be identical. When a value in the TMU Adapter Configuration Capability of one Adapter is written to, the other Adapter in the USB4 Port shall update its value to match.
8.2.2.2#3	NT	When a value in the TMU Adapter Configuration Capability of one Adapter is written to, the other Adapter in the USB4 Port shall update its value to match.
8.2.2.2#4	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.2#5	TD 8.2	A Router shall set the Next Capability field to 00h if the TMU Adapter Configuration Capability is the final Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.2#6	TD 8.2	An Adapter shall set the Capability ID field to 03h indicating this is the start of a TMU Adapter Configuration Capability.

8.2.2.2#7	NT	The TxTimeToWire field shall contain the time duration from the instant the time stamp is taken at the Physical Layer to the instant when the first bit of the TSNOS is transmitted on the wire. The time shall be specified in nanoseconds multiplied by 2^{16}.
8.2.2.2#8	NT	The RxTimeToWire field shall contain the time duration from the instant the first bit of the TSNOS is received at the wire to the instant when the time stamp is taken at the Physical Layer. The time shall be specified in nanoseconds multiplied by 2^{16}.
8.2.2.2#9	NT	The TMU Adapter shall set the EnableUniDirectionalMode bit to 0b when its USB4 Port is disconnected.
8.2.2.2#10	NT	If the Inter-Domain Time Responder (IDTR) bit is set to 1b, the USB4 Port shall respond to Time Sync Handshakes over the Interdomain Link as initiated by the ITDI Port. Otherwise this bit shall be set to 0b.
8.2.2.2#11	NT	If the Inter-Domain Time Initiator (IDTI) bit is set to 1b, the USB4 Port shall initiate Time Sync Handshakes over the Inter-Domain Link. Otherwise this bit shall be set to 0b.
8.2.2.2#12	NT	The RX TSNOS Counter field shall contain the number of TSNOS received by TMU. The counter shall not increment past FFFFh.
8.2.2.2#13	NT	The TX TSNOS Counter field shall contain the number of TSNOS sent by TMU. The counter shall not increment past FFFFh.
8.2.2.2#14	NT	The Rx Packet Counter field shall contain the number of Time Sync Packets received by TMU. The counter shall not increment past FFFFh.
8.2.2.2#15	NT	The TX Packet Counter field shall contain the number of Time Sync Packets sent by TMU. The counter shall not increment past on FFFFh.
8.2.2.2#16	TBD	If the Disable Time Sync bit is set to 1, the Adapter shall not send any Delay Requests or Delay Responses.
8.2.2.2#17	TBD	If the Disable Time Sync bit is set to 0b, the Adapter may send Delay Requests or Delay Responses.
8.2.2.2#18	NT	The Lost TSNOS Counter field shall contain the number of times that a Delay Response was expected during a Time Sync Handshake but not received. The counter shall not increment past 3FFh.
8.2.2.2#19	NT	The Lost Packet Counter field shall contain the number of times that a Follow Up Packet was expected during a Time Sync Handshake but not received. The counter shall not increment past 3FFh.

8.2.2.2#20	NT	The Bad Packet Counter field shall contain the number of Follow Up Packets and Inter-Domain Packets received with bad CRC. The counter shall not increment past 3FFh.
8.2.2.3 Lane Adapter Configuration Capability		
8.2.2.3#1	TD 8.2	A Lane Adapter Configuration Capability shall have the structure depicted in Figure 8-10 and shall have the fields defined in Table 8-24.
8.2.2.3#2	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.3#3	TD 8.2	An Adapter shall set the Next Capability Pointer field to 00h if this Capability is the final Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.3#4	TD 8.2	An Adapter shall set the Capability ID field to 01h indicating this is a Lane Adapter Configuration Capability.
8.2.2.3#5	TD 8.2	For a USB4 host or peripheral device: An Adapter shall set bit 18 in the Supported Link Speeds field to 1b if it supports Gen 3 speed. Otherwise, bit 18 shall be 0b.
8.2.2.3#6	TD 8.2	For a USB4 host or peripheral device: An Adapter shall set bit 19 in the Supported Link Speeds field to 1b to indicate support for Gen 2 speed.
8.2.2.3#7	TD 8.2	For a USB4 hub: An Adapter shall set bit 18 in the Supported Link Speeds field to 1b to indicate support for Gen 3 speed.
8.2.2.3#8	TD 8.2	For a USB4 hub: An Adapter shall set bit 19 in the Supported Link Speeds field to 1b to indicate support for Gen 2 speed.
8.2.2.3#9	TD 8.2	The Lane 1 Adapter in a USB4 Port shall declare the same value in the Supported Link Speeds field as the Lane 0 Adapter.
8.2.2.3#10	NT	The Supported Link Widths field shall indicate which Link widths are supported by the Adapter (xN – corresponding to N Lanes).
8.2.2.3#11	TD 8.2	An Adapter shall set bit 20 to 1b to indicate support for x1 operation.
8.2.2.3#12	TD 8.2	An Adapter shall set bit 21 to 1b to indicate support for x2 operation.
8.2.2.3#13	TD 8.2	The Lane 1 Adapter in a USB4 Port shall declare the same value in the Supported Link Widths field as the Lane 0 Adapter.
8.2.2.3#14	NT	An Adapter shall set the CL0s Support field to 1b if it supports CL0s Low Power. Otherwise this bit shall be set to 0b.

8.2.2.3#15	NT	An Adapter shall set the CL1 Support field to 1b if it supports CL1 Low Power state. Otherwise this bit shall be set to 0b.
8.2.2.3#16	NT	An Adapter shall set the CL2 Support bit to 1b if it supports CL2 Low Power state. Otherwise this bit shall be set to 0b.
8.2.2.3#17	NT	Writing 0b to the Lane Bonding bit shall have no effect.
8.2.2.3#18	NT	Deprecated.
8.2.2.3#19	TD 8.2	The *Current Link Speed* field shall indicate the negotiated Link speed.
8.2.2.3#20	TD 8.2	The Lane 1 Adapter in a USB4 Port shall contain the same value in the *Current Link Speed* field as the Lane 0 Adapter.
8.2.2.3#21	TD 8.2	The Negotiated Link Width field shall indicate the negotiated Link width (xN – corresponding to N Lanes).
8.2.2.3#22	TD 8.2	The Lane 1 Adapter in a USB4 Port shall contain the same value in the Negotiated Link Width field as the Lane 0 Adapter.
8.2.2.3#23	NT	The Adapter State field shall indicate the current Adapter state.
8.2.2.4 USB4 Port Capability		
8.2.2.4#1	TD 8.2	A USB4 Port Capability shall have the structure depicted in Figure 8-11 and shall have the fields defined in Table 8-14.
8.2.2.4#2	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.4#3	TD 8.2	An Adapter shall set the Next Capability Pointer field to 00h if the Capability is the final Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.4#4	TD 8.2	An Adapter shall set the Capability ID field to 06h indicating this is USB4 Port Capability.
8.2.2.4#5	TD 8.12	After executing a read or write to the SB Register Space, a Router shall set the Length field to the value of the LEN field in the AT Response, the RT Response, or the local access.
8.2.2.4#6	TD 8.12	A Router shall set the No Response bit to 1b if it did not receive a response for the read/write (including after any retransmissions).

8.2.2.4#7	TD 8.12	For a Read operation: A Router shall set the Result Code bit to 0b if the LEN field in the AT Response or the RT Response is greater than zero, or if a local access completes successfully.
8.2.2.4#8	NT	For a Read operation: A Router shall set the Result Code bit to 1b if the LEN field in the AT Response or the RT Response is 0, or if a local access completes unsuccessfully
8.2.2.4#9	NT	For a Write: A Router shall set the Result Code bit to the value of the Result Code in the AT Response or the RT Response.
8.2.2.4#10	TD 8.12	For a local access, a Router shall set the Result Code bit to 0b if the access completes successfully. A Router shall set the Result Code bit to 1b if the access completes unsuccessfully.
8.2.2.4#11	TD 8.12	A Router shall set the Pending bit to 0b after it finishes the SB Register Space read/write.
8.2.2.4#12	TD 8.12	For a read: The Router shall set the Data[15:0] fields to contain the Doublewords read from the SB Register Space.
8.2.2.4#13	TD 8.12	Doublewords in the Data[15:0] field shall be arranged in increasing address order, starting at DW2 of the USB4 Port Capability and ending with the last Doubleword written/read.
8.2.2.4#14	NT	The Cable USB4 Version field shall identify which version of the USB4 specification is supported by the USB Type-C Cable where: Bits 7:4 identify the major version; Bits 3:0 identify the minor version.
8.2.2.4#15	NT	An Adapter shall set the Bonding Enabled bit to 1b when the conditions for Lane bonding are met. Otherwise, this bit shall be set to 0b.
8.2.2.4#16	NT	An Adapter shall set the TBT3-Compatible Mode bit to 1b when the negotiated Link speed is a TBT3-Compatible speed.
8.2.2.4#17	NT	An Adapter shall set the TBT3-Compatible Mode bit to 0b when the negotiated Link speed is not a TBT3-Compatible speed.
8.2.2.4#18	NT	A Router shall set the Link CLx Support bit to 1b if the value of the *USB4* bit in the Broadcast RT Transaction is 1b and both Routers support CLx states.
8.2.2.4#19	TD 8.2	An Adapter shall set the RS-FEC Enabled (Gen2) bit set to 1b when the USB4 Port operates in Gen 2 and RS-FEC is enabled. This bit shall be set to 0b otherwise.
8.2.2.4#20	TD 8.2	An Adapter shall set the RS-FEC Enabled (Gen 3) bit to 1b when the USB4 Port operates in Gen 3 and RS-FEC is enabled. This bit shall be set to 0b otherwise.

8.2.2.4#21	LL CTS	An Adapter shall set the Router Detected bit to 1b when the USB4 Port detects a connected Router.
8.2.2.4#22	LL CTS	An Adapter shall set the Router Detected bit to 0b upon a disconnect.
8.2.2.4#23	LL CTS	An Adapter shall set the Wake on Connect Status bit to 1b after a wake event is generated by the USB4 Port as a result of a connect to the USB4 Port.
8.2.2.4#24	LL CTS	The Wake on Connect Status bit shall not be set to 1b unless the Enable Wake on Connect bit is 1b.
8.2.2.4#25	LL CTS	The Wake on Connect Status bit shall be set to 0b on entry to sleep.
8.2.2.4#26	LL CTS	An Adapter shall set the Wake on Disconnect Status bit to 1b after a wake event is generated by the USB4 Port as a result of a disconnect from the USB4 Port.
8.2.2.4#27	LL CTS	The Wake on Disconnect Status bit shall not be set to 1b unless the Enable Wake on Disconnect bit is 1b.
8.2.2.4#28	LL CTS	The Wake on Disconnect Status bit shall be set to 0b on entry to sleep.
8.2.2.4#29	LL CTS	An Adapter shall set the *Wake on USB4 Wake Status* bit to 1b after a wake event is generated by the USB4 Port as a result of a USB4 Wake.
8.2.2.4#30	LL CTS	The *Wake on USB4 Wake Status* bit shall not be set to 1b unless the *Enable Wake on USB4 Wake* bit is 1b.
8.2.2.4#31	LL CTS	The *Wake on USB4 Wake Status* bit shall be set to 0b on entry to sleep.
8.2.2.4#32	LL CTS	An Adapter shall set the Wake on Inter-Domain Status bit to 1b after a wake event is generated by the USB4 Port as a result of an inter-Domain Wake.
8.2.2.4#33	LL CTS	The Wake on Inter-Domain Status bit shall not be set to 1b unless the Enable Wake on inter-Domain bit is 1b.
8.2.2.4#34	LL CTS	The Wake on Inter-Domain Status bit shall be set to 0b on entry to sleep.
8.2.2.4#35	NT	A Downstream Facing Adapter shall initiate a Downstream Port Reset when the Downstream Port Reset bit is set to 1b.
8.2.2.4#36	NT	Setting the Downstream Port Reset bit to 0b shall transition the Adapter out of CLd state.
8.2.2.4#37	NT	An Upstream Facing Adapter shall ignore the Downstream Port Reset bit.
8.2.2.4#38	NT	If the Request RS-FEC Gen 2 bit is set to 0b, the USB4 Port shall disable RS-FEC at Gen 2 speeds during the next Link Initialization.

8.2.2.4#39	NT	If Request RS-FEC Gen 3 bit is set to 0b, the USB4 Port shall disable RS-FEC at Gen 3 speeds during the next Link Initialization.
8.2.2.5 USB3 Adapter Configuration Capability		
8.2.2.5#1	TD 8.2	A USB3 Adapter Configuration Capability shall have the structure depicted in Figure 8-15 and shall have the fields defined in Table 8-18.
8.2.2.5#2	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.5#3	TD 8.2	An Adapter shall set the Next Capability Pointer field to 00h if the Capability is the final Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.5#4	TD 8.2	An Adapter shall set the Capability ID field to 04h indicating this is an Adapter Configuration Capability.
8.2.2.5#5	NT	When the Path Enable bit is set to 0b, the Adapter shall not send or receive Tunneled Packets.
8.2.2.5#6	NT	The Consumed Upstream Bandwidth field shall contain the amount of upstream bandwidth consumed for isochronous USB3 traffic.
8.2.2.5#7	NT	A Router shall not update the Consumed Upstream Bandwidth field when the Host Controller Ack bit is set to 1b.
8.2.2.5#8	TD 8.2	The Consumed Upstream Bandwidth field shall be hardwired to 0 for a Device Router.
8.2.2.5#	NT	The Consumed Downstream Bandwidth field shall contain the amount of downstream bandwidth consumed for isochronous USB3 traffic.
8.2.2.5#9	NT	A Router shall not update the Consumed Downstream Bandwidth field when the Host Controller Ack bit is set to 1b.
8.2.2.5#10	TD 8.2	The Consumed Downstream Bandwidth field shall be hardwired to 0 for a Device Router.
8.2.2.5#11	NT	A Router shall set this bit to 1b when a Connection Manager is allowed to read the *Consumed Upstream Bandwidth* and *Consumed Downstream Bandwidth* fields or update the *Allocated Upstream Bandwidth* or *Allocated Downstream Bandwidth* fields. Otherwise, this bit shall be set to 0b.
8.2.2.5#12	TD 8.2	The Host Controller Ack bit shall be hardwired to 0b for a Device Router.
8.2.2.5#13	NT	The Allocated Upstream Bandwidth field shall contain the amount of upstream bandwidth allocated for isochronous USB3 traffic.

8.2.2.5#14	TD 8.2	The Allocated Upstream Bandwidth field shall be hardwired to 0 for a Device Router.
8.2.2.5#15	NT	The Allocated Downstream Bandwidth field shall contain the amount of downstream bandwidth allocated for isochronous USB3 traffic.
8.2.2.5#16	TD 8.2	The Allocated Downstream Bandwidth field shall be hardwired to 0 for a Device Router.
8.2.2.5#17	TD 8.2	A Device Router shall hardwire the Scale field to 0.
8.2.2.5#18	NT	The Port Link State field shall indicate the port link state of the internal USB3 device port connected to the USB3 Adapter Layer.
8.2.2.6 DP Adapter Configuration Capability		
8.2.2.6#1	TD 8.2	A DP IN Adapter Configuration Capability shall have the structure depicted in Figure 8-13 and shall have the fields defined in Table 8-16.
8.2.2.6#2	TD 8.2	A DP OUT Adapter Configuration Capability shall have the structure depicted in Figure 8-14 and shall have the fields defined in Table 8-17.
DP IN Adapter Configuration Capability		
8.2.2.6#3	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.6#4	TD 8.2	An Adapter shall set the Next Capability Pointer field to 00h if the Capability is the last Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.6#5	TD 8.2	An Adapter shall set the Capability ID field to 04h indicating this is the start of an Adapter Capability.
8.2.2.6#6	TD 8.2	An Adapter shall set the Video HopID field to 09h.
8.2.2.6#7	NT	When the AUX Enable bit is set to 0, the Adapter shall not send or receive packets on the AUX Path.
8.2.2.6#8	NT	When the Video Enable bit is set to 0, the Adapter shall not send packets on the Video Path.
8.2.2.6#9	TD 8.2	An Adapter shall set the AUX Tx HopID field to 08h.
8.2.2.6#10	TD 8.2	An Adapter shall set the AUX Rx HopID field to 08h.
8.2.2.6#11	NT	When the SW Link Init bit transitions from 0 to 1, the Adapter shall initiate Link Init as described in Section 10.4.13

8.2.2.6#12	NT	The HPD Status field shall contain the HPD value received from the DP OUT Adapter.
8.2.2.6#13	NT	When the HPD Output Clear bit is 1b, an Adapter shall drive HPD low to cause a single event of HPD output clear.
8.2.2.6#14	NT	When the HPD Output Set bit is 1b, an Adapter shall drive HPD high to cause a single event of HPD output set.
8.2.2.6#15	TD 8.2	The Adapter Revision field shall identify which Revision of the USB4 Specification the Adapter supports.
8.2.2.6#16	NT	If the DP IN Adapter was connected as part of MFDP, the Maximal Lane Count field shall not indicate 4 lanes.
8.2.2.6#17	NT	A DP IN Adapter shall reset the fields in the DP_REMOTE_CAP register to their default values when the DP OUT Adapter is unpaired.
8.2.2.6#18	NT	The DP_COMMON_CAP fields shall be updated any time the DP_REMOTE_CAP fields are updated.
8.2.2.6#19	TD 8.2	The Adapter Revision field shall identify the highest common Revision of the USB4 Specification that is supported by both the DP IN Adapter and the DP OUT Adapter.
8.2.2.6#20	NT	An Adapter shall set the value of the DPRX Capabilities Read Done field after DPCD addresses 00001h and 00002h are read.
DP OUT Adapter Configuration Capability		
8.2.2.6#21	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.6#22	TD 8.2	An Adapter shall set the Next Capability Pointer field to 00h if the Capability is the last Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.6#23	TD 8.2	An Adapter shall set the Capability ID field to 04h indicating this is the start of an Adapter Capability.
8.2.2.6#24	NT	An Adapter shall set the Video HopID bit to 9.
8.2.2.6#x	NT	When the AUX Enable bit is set to 0, the Adapter shall not send or receive packets on the AUX Path.
8.2.2.6#25	NT	When the Video Enable bit is set to 0, the Adapter shall not receive packets on the Video Path.
8.2.2.6#26	TD 8.2	An Adapter shall set the AUX Tx HopID field to 08h.

8.2.2.6#27	TD 8.2	An Adapter shall set the AUX Rx HopID field to 08h.
8.2.2.6#28	NT	When the SW Link Init to IP bit transitions from 0b to 1b, the Adapter shall initiate Link Init as described in Section 10.4.13.
8.2.2.6#29	NT	The HPD Status field shall contain the HPD value sent to DP IN Adapter.
8.2.2.6#30	TD 8.2	The Protocol Adapter Version field shall identify which version of the USB4 Specification the DP OUT Adapter supports.
8.2.2.6#31	NT	If the DP OUT Adapter was connected as part of MFDP, the Maximal Lane Count field shall not indicate 4 lanes.
8.2.2.6#32	NT	A DP OUT Adapter shall reset the fields in the DP_REMOTE_CAP register to their default values when the DP IN Adapter is unpaired.
8.2.2.6#33	NT	The DP_COMMON_CAP fields shall be updated any time the DP_REMOTE_CAP fields are updated.
8.2.2.6#34	TD 8.2	The Protocol Adapter Version field shall identify the highest common version of the USB4 Specification that is supported by both the DP OUT Adapter and the DP IN Adapter
8.2.2.7 PCIe Adapter Configuration Capability		
8.2.2.7#1	TD 8.2	A PCIe Adapter Configuration Capability shall have the structure depicted in Figure 8-12 and shall have the fields defined in Table 8-15.
8.2.2.7#2	TD 8.2	The Next Capability Pointer field shall contain the Doubleword index of the next Capability in the Adapter Configuration Space.
8.2.2.7#3	TD 8.2	An Adapter shall set the Next Capability field to 00h if the Capability is the final Capability in the linked list of Capabilities in the Adapter Configuration Space.
8.2.2.7#4	TD 8.2	An Adapter shall set the Capability ID field to 04h indicating this is an Adapter Configuration Capability.
8.2.2.7#5	TBD	An Adapter shall set the Link bit to indicate the LinkUp state of the PCIe Physical Layer Logical Sub-block above the PCIe Adapter: 0 = Link is down; 1 = Link is up
8.2.2.7#6	TBD	An Adapter shall set the TX EI bit to indicate whether or not the PCIe Physical Layer Logical Sub-block above the PCIe Adapter is in Electrical Idle state for its transmitter: 0b = Transmitter is not in Electrical Idle state; 1b = Transmitter is in Electrical Idle state

8.2.2.7#7	TBD	An Adapter shall set the RX EI bit to indicate whether or not the PCIe Physical Layer Logical Sub-block above the PCIe Adapter is in Electrical Idle state for its receiver: 0b = Receiver is not in Electrical Idle state; 1b = Receiver is in Electrical Idle state
8.2.2.7#8	TBD	An Adapter shall set the RST bit to indicate whether or not the attached PCIe Switch Adapter is in PCIe Warm Reset/PCIe domain is active: 0b = PCIe Switch Adapter is not in reset; 1b = PCIe Switch Adapter is in reset
8.2.2.7#9	TBD	An Adapter shall set the LTSSM bit to indicate the LTSSM state in the PCIe Physical Layer Logical Sub-block above the PCIe Adapter: 0h = Detect state; 1h = Polling state; 2h = Configuration state; 3h = L0 state; 4h = Recovery state; 5h = Disabled state; 6h = Reserved; 7h = Hot Reset state; 8h-9h = Reserved; Ah = L1 state; Bh = L2 state; Ch-Fh = Reserved;
8.2.2.7#10	TBD	When the Path Enable bit is 0b, PCIe Packets shall not be sent. In-band presence is set to 0b.
8.2.3 Path Configuration Space		
8.2.3.1 Path 0 Entry		
8.2.3.1#1	TD 8.4	A Lane Adapter and a Host Interface Adapter shall support a Path for HopID 0 (referred to as “Path 0”).
8.2.3.1#2	NT	The Path Credits Allocated field shall contain the initial value of the Path Credits Allocated state variable for the Ingress Adapter of the Path.
8.2.3.1#3	TD 8.4	When the Counter Enable bit is 1b, the Adapter shall increment the counter set for the Path as defined in Table 8-22.
8.2.3.2 Lane Adapters		
8.2.3.2#1	TD 8.5	A Lane Adapter shall support Paths from HopID 8 to Max Input HopID (inclusive).
8.2.3.2#2	IOP	Each entry shall be formatted as shown in Figure 8-17.
8.2.3.2#3	IOP	When a Path is configured to route Tunneled Packets from a USB4 Port to an Adapter the following Path entry fields shall be ignored by the Router: Weight; Egress Flow Control Flag; Egress Shared Buffering Enable Flag
8.2.3.2#4	TD 8.7	When the Counter Enable bit is 1b, the Adapter shall increment the counter set for the Path as defined in Table 8-22.
8.2.3.2#5	NT	An Adapter shall set the Pending Packets field to 1b when one or more packets that belong to the Path are waiting to be dequeued. Otherwise it shall be set to zero.

8.2.3.3 Protocol Adapters		
8.2.3.3#1	TD 8.5	Host Interface Adapter shall support Paths from HopID 1 to Max Input HopID (Inclusive).
8.2.3.3#2	TD 8.5	USB3/PCIe/DP Adapter shall support Paths from HopID 8 to Max Input HopID (Inclusive).
8.2.3.3#3	IOP	Each entry shall be formatted as shown in Figure 8-18.
8.2.3.3#4	NT	When the Counter Enable bit is 1b, the Adapter shall increment the counter set for the Path as defined in Table 8-21.
8.2.3.3#5	NT	An Adapter shall set the Pending Packets field to 1b when one or more packets that belong to the Path are waiting to be dequeued. Otherwise it shall be set to zero.
8.2.3.4 Path Configuration Space Access		
8.2.3.4.1 Path Configuration Example		
8.2.4 Counters Configuration Space		
8.2.4#1	TD 8.7	An Adapter with the CCS Flag in the Adapter Configuration Space set to 1b shall implement the Counters Configuration Space depicted in Figure 8-20.
8.2.4#2	TD 8.7	A Counter Configuration Space shall contain the number of counter sets specified in the Max Counter Sets field from the Adapter Configuration Space.
8.2.4#3	TD 8.7	Each counter set shall consist of the three counters described Table 8-22.
8.2.4#4	TD 8.7	A counter set shall contain the fields defined in Table 8-22.
8.2.4#5	TD 8.7	The Received Packets Low field shall contain the lower 32 bits of a 64-bit received packets counter.
8.2.4#6	TD 8.7	The Received Packets High field contains the upper 32 bits of a 64-bit received packets counter.
8.2.4#7	TD 8.7	An Ingress Adapter shall increment the received packets counter by 1 each time it receives a packet on a Path that uses this counter set.
8.2.4#8	NT	The received packets counter shall increment from 0 and shall stop counting at FFFF FFFF FFFF FFFFh.
8.2.4#9	NT	An Ingress Adapter shall increment the dropped packets counter by 1 for every packet that is dropped due to insufficient buffer space for a Path that uses this counter set.

8.2.4#10	NT	The dropped packets counter shall increment from 0 and shall stop counting at FFFF FFFFh.
8.3 Operations		
8.3#1	NT	A Router shall handle Router Operations and Port Operations concurrently.
8.3.1 Router Operations		
8.3.1#1	NT	A Router shall process a Router Operation when the *Operation Valid* bit changes from 0b to 1b.
8.3.1#2	NT	The Router shall execute the specific Router Operation indicated by the *Opcode* field as defined in the sections below.
8.3.1#3	NT	When a Router Operation is defined to include metadata information, the Router shall fetch the information from the Metadata field in Router Configuration Space.
8.3.1#4	NT	When a Router Operation is defined to include additional information, the Router shall fetch the information from the Data DWs in Router Configuration Space.
8.3.1#5	NT	Once the Router Operation is complete, the Router shall: If the Router Operation returns completion metadata information, write the metadata information to the Metadata field in Router Configuration Space.
8.3.1#6	NT	Once the Router Operation is complete, the Router shall: 2. If the Router Operation returns additional completion information, write the additional information to the Data DWs in Router Configuration Space.
8.3.1#7	NT	Once the Router Operation is complete, the Router shall: 3. Set the *Operation Not Supported* bit to 0b if the Router supports the Operation. Set the *Operation Not Supported* bit to 1b if the Router does not support the Operation.
8.3.1#8	NT	Once the Router Operation is complete, the Router shall: 4. If the *Operation Not Supported* bit is 0b, update the *Status* field with the results of the Router Operation.
8.3.1#9	NT	Once the Router Operation is complete, the Router shall: 5. Set the Operation Valid bit to 0b.
8.3.1.1 DP Tunneling Operations		
8.3.1.1.1 Query DP Resource Availability (Conditional)		
8.3.1.1.1#1	TD 8.13	A Router shall support the Query DP Resource Availability Router Operation if it has one or more DP IN Adapters.

8.3.1.1.1#2	TD 8.13	A Router shall return the *Metadata* and *Status* fields defined in Table 8-24.
8.3.1.1.2 Allocate DP Resource (Conditional)		
8.3.1.1.2#1	TD 8.13	A Router shall support the Allocate DP Resource Availability Router Operation if it has one or more DP IN Adapters.
8.3.1.1.2#2	TD 8.13	A Router shall return the Metadata and Status fields defined in Table 8-26.
8.3.1.1.2#3	TD 8.13	If a resource was already allocated to this DP IN Adapter by a previous Allocate DP Resource Operation, then a Router shall respond with *Status* = 0h.
8.3.1.1.3 De-Allocate DP Resource (Conditional)		
8.3.1.1.3#1	TD 8.13	A Router shall support the De-Allocate DP Resource Availability Router Operation if it has one or more DP IN Adapters.
8.3.1.1.3#2	TD 8.13	A Router shall return the *Metadata* and *Status* fields defined in Table 8-28.
8.3.1.1.3#3	TBD	If no resource is allocated to this DP IN Adapter, then a Router shall respond with Status = 0h.
8.3.1.2 NVM Operations		
8.3.1.2.1 NVM Set Offset (Conditional)		
8.3.1.2.1#1	TD 8.14	A Device Router shall support the NVM Set Offset Router Operation.
8.3.1.2.1#2	TD 8.14	A Router shall return the *Metadata* and *Status* fields defined in Table 8-30.
8.3.1.2.2 NVM Write (Conditional)		
8.3.1.2.2#1	TD 8.14	A Device Router shall support the NVM Write Router Operation
8.3.1.2.2#2	NT	A Router shall increment its NVM Offset value by 16 after executing a NVM Write Router Operation.
8.3.1.2.2#3	TD 8.14	A Router shall return the *Status* field defined in Table 8-32.
8.3.1.2.3 NVM Authentication Write (Conditional)		
8.3.1.2.3#1	TD 8.14	A Device Router shall support the NVM Authenticate Write Router Operation.
8.3.1.2.3#2	TD 8.14	A Router shall return the *Status* field defined in Table 8-33.

8.3.1.2.4 NVM Read (Conditional)		
8.3.1.2.4#1	TD 8.14	A Device Router shall support the NVM Read Router Operation.
8.3.1.2.4#2	TD 8.14	A Router shall return the *Metadata* and *Status* fields defined in Table 8-35.
8.3.1.2.5 DROM Read (Conditional)		
8.3.1.2.5#1	TD 8.14	A Device Router shall support the DROM Read Router Operation.
8.3.1.2.5#2	TD 8.14	A Router shall return the *Metadata* and *Status* fields defined in Table 8-38.
8.3.1.2.5#3	TD 8.14	A Standalone AIC Host Router shall support this Router Operation.
8.3.1.2.6 Get NVM Sector Size (Conditional)		
8.3.1.2.6#1	TD 8.14	A Device Router shall support the NVM Sector Size Router Operation.
8.3.1.2.6#2	TD 8.14	A Router shall return the *Metadata* and *Status* fields defined in Table 8-40.
8.3.1.3 Router Discovery Operations		
8.3.1.3.1 Get PCIe Downstream Entry Mapping (Conditional)		
8.3.1.3.1#1	TD 8.15	A Router shall support the Get PCIe Downstream Entry Mapping Router Operation if it supports PCIe Tunneling.
8.3.1.3.1#2	TD 8.15	If a Router supports the Get PCIe Downstream Entry Mapping Router Operation, it shall return the *Metadata* and *Status* fields defined in Table 8-43.
8.3.1.3.1#3	TD 8.15	A Host Router that supports PCIe tunneling shall have one entry per Downstream PCIe Adapter.
8.3.1.3.1#4	TD 8.15	A Device Router that supports PCIe tunneling shall have one entry per PCIe Downstream Bridge.
8.3.1.3.1#5	TD 8.15	The values of the Entry Index field shall be zero to *Total Number of Entries* - 1.
8.3.1.3.1#6	TD 8.15	The first time this Operation is executed, a Router shall respond with the entry for Entry Index = 0h.
8.3.1.3.1#7	TD 8.15	On each subsequent execution of the Operation, the Router shall respond with the next entry (*Entry Index* = 01h, *Entry Index* = 02h, etc.).
8.3.1.3.1#8	TD 8.15	After the last entry is retrieved, the Router shall restart at the first entry (*Entry Index* = 0h) the next time the Operation is executed.
8.3.1.3.1#9	NT	A Router shall return the entry for a PCIe Downstream mapping in *Data* DW0 and DW1 as defined in Table 8-42.

8.3.1.3.1#10	NT	If *Native PCIe Link* is set to 0, the PCIe Adapter Number field shall indicate the Adapter Number of the Downstream PCIe Adapter.
8.3.1.3.1#11	NT	Otherwise the PCIe Adapter Number field shall be set to 0.
8.3.1.3.2 Get Capabilities (Conditional)		
8.3.1.3.2#1	TD 8.16	A Router shall support the Get Capabilities Router Operation if it supports the Set Capabilities Router Operation.
8.3.1.3.2#2	TD 8.16	Otherwise, a Router shall not support this Router Operation.
8.3.1.3.2#3	NT	The value in the Capability Index field shall not exceed the Max Capability Index.
8.3.1.3.2#4	TD 8.16	A Router that supports this Operation shall return the Metadata field and the Status field defined in Table 8-44.
8.3.1.3.2#5	TD 8.16	The Capability Supported bit shall be set to 0b for *Capability Index* = 0.
8.3.1.3.2#6	TD 8.16	The Capability Enabled bit shall be set to 0b for *Capability Index* = 0.
8.3.1.3.2#7	TD 8.16	When a Router receives a Get Capabilities Operation with *Capability Index* = 0, it shall return a list of the capabilities that the Router supports and indicate which capabilities are enabled.
8.3.1.3.2#8	NT	The *Capability Supported* bit shall be set to 0b when the capability is not supported.
8.3.1.3.2#9	TD 8.16	The *Capability Supported* bit shall be set to 1b when the capability is supported.
8.3.1.3.2#10	TD 8.16	The *Capability Enabled* bit shall be set to 0b when the capability is disabled.
8.3.1.3.2#11	TD 8.16	The *Capability Enabled* bit shall be set to 1b when the capability is enabled.
8.3.1.3.2#12	NT	The list of capabilities is returned in the Data field and shall be formatted as shown in Figure 8-20.
8.3.1.3.2.1 Hot Plug Failure Indication		
8.3.1.3.3 Set Capabilities (Conditional)		
8.3.1.3.3#1	TD 8.16	A Router shall support the Set Capabilities Router Operation if it supports the Get Capabilities Router Operation.
8.3.1.3.3#2	TD 8.16	Otherwise, a Router shall not support this Router Operation.

8.3.1.3.3#3	NT	The values of the Capability Index field shall not exceed the *Max Capability Index*.
8.3.1.3.3#4	TD 8.16	If Enable Capability is 0b, Router shall disable the Capability.
8.3.1.3.3#5	TD 8.16	If Enable Capability is 1b, shall enable the Capability.
8.3.1.3.3#6	TD 8.16	A Router that supports this Operation shall return the Status field defined in Table 8-48.
8.3.1.3.3.1 Hot Plug Failure Indication		
8.3.1.3.3.1#1	TD 8.16	A Router shall enable this capability when all of the following conditions are true: The Router supports the Get Capabilities Operation and the Set Capabilities Operation; The Router supports the “Hot Plug Failure Indication” capability; The Router receives a Set Capabilities Operation with Capability Index = 1h and Enable Capability = 1b.
8.3.1.3.4 Buffer Allocation Request (Required)		
8.3.1.3.4#1	TD 8.17	A Router shall support this Router operation.
8.3.1.3.4#2	TD 8.17	A Router shall return Metadata and Status fields defined in Table 8-49.
8.3.1.3.4#3	TD 8.17	The Length field shall be equal to the number of buffer allocation parameters the Router reports.
8.3.1.3.5 Get Container-ID (Conditional)		
8.3.1.3.5#1	TD 8.18	A USB4 hub shall support this Router Operation.
8.3.1.3.5#2	TD 8.18	A USB4 peripheral device with an internal USB3 hub shall support this Router Operation.
8.3.1.3.5#3	TD 8.18	The return value for the Container-ID shall be identical to the Container-ID read from the internal USB SuperSpeed Plus hub.
8.3.1.3.5#4	TD 8.18	A Router that supports this operation shall return Status field defined in Table 8-51.
8.3.1.4 Port Control Operations		
8.3.1.4.1 Block Sideband Port Operation (Optional)		
8.3.1.4.1#1	TD 8.19	After receiving a Block Sideband Port Operations Router Operation, a Router shall change the access type for SB Registers 8, 9 and 18 in all its Ports from RW to RO when accessed by Sideband Transactions.

8.3.1.4.1#2	TD 8.19	A Router that supports this Operation shall return the Status field defined in Table 8-53.
8.3.1.4.2 Unblock Sideband Port Operation (Conditional)		
8.3.1.4.2#1	TD 8.19	If a Router supports the Block Sideband Port Operations Router Operation, it shall support this Router Operation.
8.3.1.4.2#2	TD 8.19	After receiving an Unblock Sideband Port Operations Router Operation, the Router shall change the access type for SB Registers 8, 9 and 18 from RO to RW when accessed by Sideband Transactions.
8.3.1.4.2#3	TD 8.19	A Router that supports this Operation shall return the Status field defined in Table 8-54.
8.3.2 Port Operations		
8.3.2#1	TD 8.20 TD 8.21	When the *Opcode* register in SB Register Space is written, a USB4 Port shall execute the Port Operation associated with the *Opcode* register using the information in the *Metadata* and *Data* registers.
8.3.2#2	NT	Deprecated.
8.3.2#3	TD 8.20 TD 8.21	After executing the Port Operation, the USB4 Port updates the Opcode, Metadata, and Data register as follows: If the USB4 Port successfully completed the Port Operation, it shall set the Opcode register to 0. The USB4 Port shall update the Metadata register with completion metadata (if the Port Operation is defined to return metadata), and the Data register with completion data (if the Port Operation is defined to return data).
8.3.2#4	NT	After executing the Port Operation, the USB4 Port updates the Opcode, Metadata, and Data register as follows: Else, the USB4 Port shall set the Opcode register to a FourCC value of “ERR ” (20525245h) to indicate that the Port Operation is supported, but could not be completed.
8.3.2#5	NT	After executing the Port Operation, the USB4 Port updates the Opcode, Metadata, and Data register as follows: Else, if the Port Operation is not supported, the USB4 Port shall set the Opcode register to a FourCC value of “!CMD” (444D4321h).
8.3.2#6	NT	The second byte (Opcode 1) of a vendor specific Opcode shall have a value between 61h and 7Ah (inclusive) to distinguish from Opcodes defined in this specification.
8.3.2#7	NT	All unused Opcodes (except for vendor specific Opcodes) are reserved and shall not be used.

8.3.2.1 Compliance Port Operations		
8.3.2.1.1 SET_TX_COMPLIANCE (Required)		
8.3.2.1.1#1	NT	A USB4 Port shall support the SET_TX_COMPLIANCE Port Operation.
8.3.2.1.1#2	NT	After receiving a SET_TX_COMPLIANCE Port Operation, a USB4 Port shall disable the transition from Training state to CLd state due to timeouts defined in Section 4.2.1.3.3.
8.3.2.1.1#3	NT	When the USB4 Port detects SBRX at logical low for tDisconnectRx, it shall re-enable the transition from Training state to CLd state due to timeouts.
8.3.2.1.1#4	NT	When this field is set to 111b, the pattern on the Lanes shall have skew between 16 UI and 128 UI.
8.3.2.1.2 SET_RX_COMPLIANCE (Required)		
8.3.2.1.2#1	NT	A USB4 Port shall support the SET_RX_COMPLIANCE Port Operation.
8.3.2.1.2#2	NT	After receiving a SET_RX_COMPLIANCE Port Operation, a USB4 Port shall disable the transition from Training state to CLd state due to timeouts defined in Section 4.2.1.3.3.
8.3.2.1.2#3	NT	When the USB4 Port detects SBRX at logical low for tDisconnectRx, it shall re-enable the transition from Training state to CLd state due to timeouts.
8.3.2.1.3 START_BER_TEST (Required)		
8.3.2.1.3#1	NT	A USB4 Port shall support the START_BER_TEST Port Operation.
8.3.2.1.3#2	NT	After receiving this Port Operation, a USB4 Port shall do the following for the Adapter targeted by the Operation: 1. Lock the receiver associated with the Adapter on the BER test pattern defined in the Operation Metadata.
8.3.2.1.3#3	NT	After receiving this Port Operation, a USB4 Port shall do the following for each Adapter targeted by the Operation: 2. Set the DW Count, Error Capture Count, and Burst Restart Count counters to 0.
8.3.2.1.3#4	NT	After receiving this Port Operation, a USB4 Port shall do the following for each Adapter targeted by the Operation: 3. Continue running the BER test pattern until an END_BER_TEST or an END_BURST_TEST Port Operation is received.
8.3.2.1.4 END_BER_TEST (Required)		
8.3.2.1.4#1	NT	A USB4 Port shall support the END_BER_TEST Port Operation.

8.3.2.1.4#2	NT	After receiving this Port Operation, a USB4 Port shall stop the *DW Count*, *Error Capture Count*, and *Burst Restart Count* counters associated with the Adapter in the Operation Metadata and shall update the Completion Data as defined in Table 8-60.
8.3.2.1.4#3	NT	The DW Count counter increments from 0 and shall stop counting at FF…Fh.
8.3.2.1.4#4	NT	The Error Capture Count counter increments from 0 and shall stop counting at FF…Fh.
8.3.2.1.5 END_BURST_TEST (Conditional)		
8.3.2.1.5#1	NT	A USB4 Port shall support the END_BURST_TEST Port Operation if it employs DFE with more than one tap.
8.3.2.1.5#2	NT	After receiving this Port Operation, a USB4 Port shall stop the *DW Count*, *Error Capture Count*, and *Burst Restart Count* counters associated with the Adapter(s) in the Operation Metadata and shall update the Completion Data as defined in Table 8-58.
8.3.2.1.5#3	NT	The DW Count counter increments from 0 and shall stop counting at FF…FFh.
8.3.2.1.5#4	NT	The Burst Restart Count counter increments from 0 and shall stop counting at FFFFh.
8.3.2.1.5#5	NT	The Bit Error Count counter increments from 0 and shall stop counting at FFFFh.
8.3.2.1.6 READ_BURST_TEST (Conditional)		
8.3.2.1.6#1	NT	A USB4 Port shall support the READ_BURST_TEST Port Operation if it employs DFE with more than one tap.
8.3.2.1.6#2	NT	After receiving this Port Operation, a USB4 Port shall update the Completion Data as defined in Table 8-60.
8.3.2.1.6#3	NT	The DW Count counter increments from 0 and shall stop counting at FF…FFh.
8.3.2.1.6#4	NT	The Burst Restart Count counter increments from 0 and shall stop counting at FFFFh.
8.3.2.1.6#5	NT	The Error Capture Count counter increments from 0 and shall stop counting at FFFFh.
8.3.2.1.7 ENTER_EI_TEST (Required)		
8.3.2.1.7#1	NT	A USB4 Port shall support the ENTER_EI_TEST Port Operation.

8.3.2.1.7#	NT	After receiving an ENTER_EI_TEST Port Operation, a USB4 Port shall disable the transition from Training state to CLd state due to timeouts.
8.3.2.1.7#	NT	When the USB4 Port detects SBRX at logical low for tDisconnectRx, it shall re-enable the transition from Training state to CLd state due to timeouts.
8.3.2.1.7#4	NT	A Router that receives a ENTER_EI_TEST Port Operation shall transition the Lane transmitter defined in the Operation into electrical idle state.
8.3.2.2 Service Port Operations		
8.3.2.2.1 ROUTER_OFFLINE_MODE (Required)		
8.3.2.2.1#1	TD 8.20	When in this mode, the USB4 Port shall not perform Lane Initialization.
8.3.2.2.1#2	TD 8.20	A USB4 Port shall support the ROUTER_OFFLINE_MODE Port Operation.
8.3.2.2.1#3	TD 8.20	A USB Port shall execute this Operation when delivered locally.
8.3.2.2.1#4	TD 8.20	A USB4 Port shall reject this Operation when delivered from the Sideband Channel.
8.3.2.2.1#5	TD 8.20	When the Enter Offline Mode field is set to 0b, the USB4 Port shall enter offline mode on the USB4 Port.
8.3.2.2.1#6	TD 8.20	When the Enter Offline Mode field is set to 1b, the USB4 Port shall exit offline mode on the USB4 Port.
8.3.2.2.2 ENUMERATE_RE-TIMERS (Required)		
8.3.2.2.2#1	TD 8.21	A USB4 Port shall support the ENUMERATE_RETIMERS Port Operation.
8.3.2.2.2#2	TD 8.21	A USB Port shall execute this Operation when delivered locally.
8.3.2.2.2#3	TD 8.21	A USB4 Port shall reject this Operation when delivered from the Sideband Channel.
8.3.2.3 Receiver Lane Margining Port Operations		
8.3.2.3.1 READ_LANE_MARGIN_CAP (Required)		
8.3.2.3.1#1	NT	A USB4 Port shall support the READ_LANE_MARGIN_CAP Port Operation.
8.3.2.3.1#2	NT	A Router shall set the Voltage Margin Steps – Mandatory Range field value to a minimum of 25.
8.3.2.3.1#3	NT	A Router shall set the Voltage Margin Steps – Optional Range field value to a minimum of 25.

8.3.2.3.1#4	NT	The Destructive Time Margin bit shall be set to 0b if the Time Margining bit is set to 0b.
8.3.2.3.1#5	NT	The Independent Left/Right Timing Margin field shall be set to 0b if the Time Margining bit is set to 0b.
8.3.2.3.1#6	NT	The Time Margin Steps field shall be set to 0 if the *Time Margining* bit is set to 0b.
8.3.2.3.1#7	NT	Else, the Time Margin Steps field shall be set to a value between 07h and 1Fh.
8.3.2.3.1#8	NT	The Maximum Time Offset field shall be set to 0 if the Time Margining bit is set to 0b.
8.3.2.3.1#9	NT	Else, the Maximum Time Offset field shall be set to a value between 0h and 1Eh.
8.3.2.3.2 RUN_HW_LANE_MARGINING (Conditional)		
8.3.2.3.2#1	NT	If the Port Operation completes successfully, the target of the Operation shall set the Completion Metadata listed in Table 8-70.
8.3.2.3.2#2	NT	A USB4 Port shall support the RUN_HW_LANE_MARGINING Port Operation if software margining mode is not supported.
8.3.2.3.2#3	NT	The Port Operation shall fail if the Lane Select field is set to 111b and the Router supports Lane Margining on a single Lane only as present in the Two-Lane Margining bit.
8.3.2.3.2#4	NT	The Port Operation shall fail if the Timing Margin Test field is set to 1b and the Router does not support timing margin testing.
8.3.2.3.3 RUN_SW_LANE_MARGINING (Conditional)		
8.3.2.3.3#1	NT	A USB4 Port shall support the RUN_SW_LANE_MARGINING Port Operation if hardware margining mode is not supported.
8.3.2.3.3#2	NT	The Port Operation shall fail if the Lane Select field is set to 111b and the Router supports Lane Margining on a single Lane only as present in the Two-Lane Margining bit.
8.3.2.3.3#3	NT	The Port Operation shall fail if the Timing Margin Test field is set to 1b and the Router does not support timing margin testing.
8.3.2.3.4 READ_SW_MARGIN_ERR (Conditional)		
8.3.2.3.4#1	NT	A USB4 Port shall support the READ_SW_MARGIN_ERR Port Operation if hardware margining mode is not supported.

8.3.2.3.4#2	NT	If the target of the Port Operation supports Destructive Time Margining, it shall set the Opcode register to a FourCC value of "!CMD".
8.3.2.3.4#3	NT	The counter value in the Error Counter (Lane 0) field increments from 0 and shall stop counting at 0Fh.
8.3.2.3.4#4	NT	The counter value in the Error Counter (Lane 1) field increments from 0 and shall stop counting at 0Fh.

Chapter 13

The following Table presents the USB4 Specification Chapter 13 asserts.

Assertion #	Test Name	Assertion Description
13 Interoperability with Thunderbolt™ 3 (TBT3) Systems		
13.3 Transport Layer		
13.3.1 Adapter Numbering Rules		
13.3.1#1	TD 13.1	If bits 15:12 in the *Connection Manager USB4 Version* field in the Router Configuration Space Basic Attributes are 0b (indicating a TBT3 Connection Manager), a Device Router shall expose between either one or two USB4 Ports.
13.3.1#2	TD 13.1	If the Device Router supports PCIe Tunneling, it shall only expose the PCIe Adapters that are related to the exposed USB4 Ports.
13.3.1#3	TD 13.1	The Lane Adapters in the exposed USB4 Ports shall be assigned consecutive Adapter numbers, starting from 1.
13.3.1#4	TD 13.1	A Router that exposes additional USB4 Ports and/or additional PCIe Adapters shall do so immediately when the *Connection Manager USB4 Version* field is set to a non-zero value.
13.3.2 Maximum HopID		
13.3.2#1	TD 13.2	The *Max Input HopID* and *Max Output HopID* fields in a Lane Adapter shall be at least 15 for USB4 hosts and USB4 hubs.
13.3.2#2	TD 13.2	The *Max Input HopID* and *Max Output HopID* fields in a Lane Adapter of a USB4 device supporting one DisplayPort tunneled stream shall be at least 11.
13.3.2#3	TD 13.2	The *Max Input HopID* and *Max Output HopID* fields in a Lane Adapter of a USB4 device supporting two DisplayPort tunneled streams shall be at least 14.
13.3.3 Connectivity Rules		
13.3.3#1	IOP	A Device Router shall support the Connectivity rules defined in Section 5.2.5 for both the Lane 0 Adapter and Lane 1 Adapter in a USB4 Port.

13.4 Configuration Layer		
13.4.1 Notification Packet		
13.4.2 Bit Banging Interface		
13.4.2#1	TD 13.6	A Router shall support the "bit banging" interface defined in Vendor Specific 1 Capability.
13.4.2#2	TD 13.6	A Router shall return the value 00000080h when the 32 bits at addresses [78h:75h] are read.
13.4.2#3	TD 13.6	A Router shall return the value 01h when the byte at address 0148h is read.
13.4.2#4	TD 13.6	A Router shall return the value 00000111h when the 32 bits at addresses [1A7h:1A4h] are read.
13.4.3 Control Packet Routing		
13.4.3.1 Downstream-Bound Packets		
13.4.3.1#1	NT	A Router that receives a Control Packet with the *CM* bit set to 0b, shall route the packet according to the following rules.
13.4.3.1#2	TD 13.3 TD 13.4	If the packet arrived on the Upstream Adapter, then: If the Router is a Host Router and the TopologyID Valid bit in Router Configuration Space is set to 0b, then the Router shall process the packet using the Uninitialized Router Flow in Section 13.4.3.2.
13.4.3.1#3	IOP	If the packet arrived on the Upstream Adapter, then: Else the Router shall extract the Egress Adapter number from the Route String that corresponds to the Router's depth in the Spanning Tree (as present in the *Depth* field in the Router Configuration Space).
13.4.3.1#4	IOP	If the extracted Adapter number is 0, the Control Adapter of the Router shall consume the packet. The Router shall process the packet using the Enumerated Router Flow in Section 6.4.3.2.1.
13.4.3.1#5	NT	If the extracted Adapter number refers to a Protocol Adapter, the packet shall be dropped and the Router shall send the Connection Manager a Notification Packet with Event Code = ERR_ADP as defined in Table 6-11.
13.4.3.1#6	NT	If the extracted Adapter number refers to a disconnected or disabled Adapter, the Router shall drop the packet and shall send the Connection Manger a Notification Packet with Event Code = ERR_CONN as defined in Table 6-11.
13.4.3.1#7	NT	If the extracted Adapter number refers to a connected Adapter and the *Lock* bit in the Adapter Configuration Space is set to 1b, the Router shall drop the packet and shall send the Connection Manager a Notification Packet with Event Code = ERR_LOCK as defined in Table 6-11.

13.4.3.1#8	IOP	Else, the Router shall forward the packet over the Egress Adapter that matches the extracted Adapter number.
13.4.3.1#9	NT	If the packet arrived on an Adapter that is not the Upstream Adapter, then: If the *Upstream Adapter* field in Router Configuration Space is 0, then the Router shall process the packet using the Uninitialized Router Flow in Section 13.4.3.2.
13.4.3.1#10	IOP	If the packet arrived on an Adapter that is not the Upstream Adapter, then: Else: If the packet is an Inter-Domain Request or an Inter-Domain Response, then the Router shall modify the packet as follows, and then send the packet over the Upstream Adapter: Replace the Route String in the packet with the Route String of the receiving Router within the receiving Domain, then add the Ingress Adapter number of the Adapter connected to the inter-Domain Link; Set the CM bit to 1b.
13.4.3.1#11	NT	If the packet arrived on an Adapter that is not the Upstream Adapter, then: Else: If the packet is a Read Request or a Write Request and the TopologyID *Valid* bit in the Router Configuration Space is set to 1b, then the Router shall drop the packet and shall send the Adapter that originated the Request a Notification Packet with Event Code = ERR_ENUM as defined in Table 6-11.
13.4.3.1#12	NT	If the packet arrived on an Adapter that is not the Upstream Adapter, then: Else: If the Router is a Host Router and the packet is a Read Request or a Write Request and the *TopologyID Valid* bit in the Router Configuration Space is set to 0b, then the Router shall drop the packet and shall send the Adapter that originated the Request a Notification Packet with Event Code = ERR_NUA as defined in Table 6-11.
13.4.3.1#13	NT	If the packet arrived on an Adapter that is not the Upstream Adapter, then: Else: Else, Router shall drop the packet and shall not send any packets in response.
13.4.3.2 Uninitialized Router Flow		
13.4.3.2#1	IOP	If the packet is a Read Request or a Write Request that targets Router Configuration Space, the Router shall process the packet as described in Section 6.4.3.3.
13.4.3.2#2	TD 13.3 TD 13.4	Else, Router shall drop the packet and shall not send any packets in response.
13.6 Configuration Spaces		
13.6#1	NT	**TBT3-Compatible.** A write to this field shall have no effect.
13.6.1 Router Configuration Space		
13.6.1#1	TD 13.5	A Router shall support the Router Configuration Space Basic Attributes defined in Table 13-12.

13.6.1#2	TD 13.5	A Capability listed as “Required” shall be present in Router Configuration Space.
13.6.1.1 Vendor Specific 1 Capability		
13.6.1.1#1	TD 13.5	A Vendor Specific 1 Capability shall have the structure depicted in Figure 13-3 and the fields defined in Section 13.6.1.4.1.
13.6.1.1#2	TD 13.5	The Absolute address of the VSC_CS_0 register shall be 0x28.
13.6.1.1#3	NT	The Next Capability Pointer field shall be set to 00h if the Vendor Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
13.6.1.1#4	TD 13.5	The Capability ID field shall contain the value 05h indicating this is the start of a Vendor Specific Capability.
13.6.1.1#5	TD 13.5	The VSC ID field shall contain the value 01h indicating this is a Vendor Specific 1 Capability.
13.6.1.1#6	NT	The VSC Length field shall contain the total number of Doublewords in the VSC structure including Doubleword 0 and the Vendor Specific Doublewords that follow.
13.6.1.1#7	TBD	When a bit in the Plug Event Disable field is set to 1b, a Router shall not send a Hot Plug Event Packet when a Hot Plug or a Hot Unplug takes place on an Adapter with the Adapter Type specified by the bit
13.6.1.1#8	TBD	A Router shall set the Link Errors – Adapter A field to 1b when the Link Errors Enable – Adapter A bit is 1b and one of the bits in the Logical Layer Errors of Adapter A is set to 1b.
13.6.1.1#9	TBD	A Router shall set the HEC Error – Adapter A field to 1b when the *Link Errors Enable – Adapter A* bit is 1b and a Transport Layer Packet is received on Adapter A with an uncorrectable HEC error in the header.
13.6.1.1#10	TBD	A Router shall set the Flow Control Error – Adapter A field to 1b when the *Link Errors Enable – Adapter A* bit is 1b and a Transport Layer Packet is received on Adapter A for a flow controlled Path where the appropriate buffer (dedicated or shared) has no space for the Packet or is not enabled.
13.6.1.1#11	TBD	A Router shall set the Link Errors – Adapter B field to 1b when the Link Errors Enable – Adapter B bit is 1b and one of the bits in the Logical Layer Errors of Adapter B is set to 1b.
13.6.1.1#12	TBD	A Router shall set the HEC Error – Adapter B field to 1b when the *Link Errors Enable – Adapter B* bit is 1b and a Transport Layer Packet is received on Adapter B with an uncorrectable HEC error in the header.

13.6.1.1#13	TBD	A Router shall set the Flow Control Error – Adapter B field to 1b when the *Link Errors Enable – Adapter B* bit is 1b and a Transport Layer Packet is received on Adapter B for a flow controlled Path where the appropriate buffer (dedicated or shared) has no space for the Packet or is not enabled.
13.6.1.1#14	TBD	A Router shall set the Link Errors – Adapter C field to 1b when the Link Errors Enable – Adapter C bit is 1b and one of the bits in the Logical Layer Errors of Adapter C is set to 1b.
13.6.1.1#15	TBD	A Router shall set the HEC Error – Adapter C field to 1b when the *Link Errors Enable – Adapter C* bit is 1b and a Transport Layer Packet is received on Adapter C with an uncorrectable HEC error in the header.
13.6.1.1#16	TBD	A Router shall set the Flow Control Error – Adapter C field to 1b when the *Link Errors Enable – Adapter C* bit is 1b and a Transport Layer Packet is received on Adapter C for a flow controlled Path where the appropriate buffer (dedicated or shared) has no space for the Packet or is not enabled.
13.6.1.1#17	TBD	A Router shall set the Link Errors – Adapter D field to 1b when the Link Errors Enable – Adapter D bit is 1b and one of the bits in the Logical Layer Errors of Adapter D is set to 1b.
13.6.1.1#18	TBD	A Router shall set the HEC Error – Adapter D field to 1b when the *Link Errors Enable – Adapter D* bit is 1b and a Transport Layer Packet is received on Adapter D with an uncorrectable HEC error in the header.
13.6.1.1#19	TBD	A Router shall set the Flow Control Error – Adapter D field to 1b when the *Link Errors Enable – Adapter D* bit is 1b and a Transport Layer Packet is received on Adapter D for a flow controlled Path where the appropriate buffer (dedicated or shared) has no space for the Packet or is not enabled.
13.6.1.1#20	TD 13.5	When the *Bit Banging Enable* bit is set to 1b, a Router shall drive the value of the FL_SK bit to the clock pin of the Flash memory device.
13.6.1.1#21	TD 13.5	When the *Bit Banging Enable* bit is set to 1b, a Router shall drive the value of the FL_CS bit to the chip select pin of the Flash memory device.
13.6.1.1#22	TD 13.5	When the *Bit Banging Enable* bit is set to 1b, a Router shall drive the value of the FL_DI bit to the data input pin of the Flash memory device.
13.6.1.1#23	TD 13.5	When the *Bit Banging Enable* bit is set to 1b, a Router shall set the value of the FL_DO bit to reflect the data output pin of the Flash memory device.
13.6.1.1#24	TD 13.5	A Router shall set the Invalid Flash Memory bit to 0b if it has a Flash Memory that can be accessed via bit banging. Otherwise, this bit shall be set to 1b.
13.6.1.1#25	TD 13.5	The DROM Base Address field shall contain the base address (in bytes) of the DROM within the Flash Memory address space.

13.6.1.2 Vendor Specific 3 Capability		
13.6.1.2#1	TD 13.5	A Vendor Specific 3 Capability shall have the structure depicted in Figure 13-4 and the fields defined in Table 13-15.
13.6.1.2#2	NT	The Next Capability Pointer field shall be set to 00h if the Vendor Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
13.6.1.2#3	TD 13.5	The Capability ID field shall contain the value 05h indicating this is the start of a Vendor Specific Capability.
13.6.1.2#4	TD 13.5	The VSC ID field shall contain the value 03h indicating this is a Vendor Specific 3 Capability.
13.6.1.2#5	NT	The VSC Length field shall contain the total number of Doublewords in the VSC structure including Doubleword 0 and the Vendor Specific Doublewords that follow.
13.6.1.3 Vendor Specific 4 Capability		
13.6.1.3#1	NT	If a Router implements Vendor Specific 4 Capability, the first 11 Doublewords shall have the structure depicted in Figure 13-5 and the fields defined in Table 13-16.
13.6.1.3#2	NT	The Next Capability Pointer field shall be set to 00h if the Vendor Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
13.6.1.3#3	NT	The Capability ID field shall contain the value 05h indicating this is the start of a Vendor Specific Capability.
13.6.1.3#4	NT	The VSC ID field shall contain the value 04h indicating this is a Vendor Specific 4 Capability.
13.6.1.3#5	NT	The VSC Length field shall contain the total number of Doublewords in the VSC structure including Doubleword 0 and the Vendor Specific Doublewords that follow.
13.6.1.4 Vendor Specific Extended 6 Capability		
13.6.1.4#1	TD 13.5	A Vendor Specific Extended 6 Capability shall have the structure depicted in Figure 13-6 and the fields defined in Section 13.6.1.4.1 and Section 13.6.1.4.2.
13.6.1.4#2	TD 13.5	A USB4 Port Region shall exist for each USB4 Port.
13.6.1.4#3	NT	The first USB4 Port Region (USB4 Port Region 0) shall contain information about the USB4 Port with the lowest Adapter Number.

13.6.1.4#4	NT	Each subsequent USB4 Port Region shall contain information about the USB4 Port with the next highest Adapter Number.
13.6.1.4.1 Common Region		
13.6.1.4.1#1	TD 13.5	A Common Region shall have the structure depicted in Figure 13-7 and the fields defined in Table 13-17.
13.6.1.4.1#2	TD 13.5	The Capability ID field shall contain the value 05h indicating this is the start of a Vendor Specific Capability.
13.6.1.4.1#3	TD 13.5	The VSEC ID field shall contain the value 06h indicating this is a Vendor Specific Extended 6 Capability.
13.6.1.4.1#4	TD 13.5	The VSEC Header field shall be set to 00h to indicate that the Capability is an Extended Capability.
13.6.1.4.1#5	NT	The Next Capability Pointer field shall be set to 00h if the Vendor Specific Capability is the final Capability in the linked list of Capabilities in the Router Configuration Space.
13.6.1.4.1#6	NT	The VSEC Length field shall contain the total number of Doublewords in the VSEC structure including Doubleword 0, Doubleword 1, and the Vendor-Specific Doublewords that follow.
13.6.1.4.1#7	TD 13.5	The USB4 Ports field shall contain the number of USB4 Ports supported by the Router.
13.6.1.4.1#8	TD 13.5	The Common Region Length field shall contain the size (in Doublewords) of the Common Region.
13.6.1.4.1#9	TD 13.5	The USB4 Port Region Length field shall contain the size (in Doublewords) of a single USB4 Port Region.
13.6.1.4.2 USB4 Port Regions		
13.6.1.4.2#1	TD 13.5	A USB4 Port Region shall have the structure depicted in Figure 13-8 and the fields defined in Table 13-18.
13.6.1.4.2#2	NT	For an Upstream Facing Port: A read or write to the Downstream Port Reset bit shall have no effect.
13.6.1.4.2#3	IOP	An Adapter shall set the Bonding Enabled bit to 1b when the conditions for Lane bonding are met.
13.6.1.4.2#4	IOP	An Adapter shall set the Bonding Enabled bit to 0b when the conditions for Lane bonding are not met.

13.6.1.4.2#5	TBD	When a bit in the Enable Wake Events field is set to 1b, the corresponding event shall cause a Router to exit from sleep.
13.6.1.4.2#6	TBD	When a bit in the Enable Wake Events field is set to 0b, the corresponding event shall not cause a Router to exit from sleep
13.6.1.4.2#7	TBD	The Connection Manager sets the Lane 0 Configured bit to 1b to indicate that the Router connected to Lane 0 of the USB4 Port is configured and that entry to Sleep State and exit from Sleep State shall be supported on the Lane.
13.6.1.4.2#8	TBD	The Connection Manager sets the Lane 1 Configured bit to 1b to indicate that the Router connected to Lane 1 of the USB4 Port is configured and that entry to Sleep State and exit from Sleep State shall be supported on the Lane.
13.6.1.4.2#9	TBD	When the Start Link Initialization bit is 1b, the USB4 Port shall start Lane Initialization.
13.6.1.4.2#10	TBD	When the Start Link Initialization bit is 0b, the USB4 Port shall not start Lane Initialization.
13.6.1.4.2#11	IOP	An Adapter shall set the RS_FEC Enabled (Gen 2) bit to 1b when the USB4 Port is operating at Gen 2 speed and RS-FEC is enabled.
13.6.1.4.2#12	IOP	An Adapter shall set the RS_FEC Enabled (Gen 3) bit to 1b when the USB4 Port is operating at Gen 3 speed and RS-FEC is enabled.
13.6.1.4.2#13	TD 13.5	An Adapter shall set the TBT3-Compatible Mode bit to 1b when the Link is operating in TBT3-Compatible Mode.
13.6.1.4.2#14	TBD	An Adapter shall set the CLx Protocol Support bit to 1b if the Sideband Channel operates as a USB4 Sideband Channel and the Cable supports CLx states.
13.6.1.4.2#15	TBD	Otherwise, an Adapter shall set the CLx Protocol Support bit to 0b.
13.6.1.4.2#16	IOP	If the Request RS-FEC Gen 2 bit is set to 1b, the Router shall enable RS-FEC encoding at 10G speeds on the Links of this USB4 Port during the next Lane Initialization.
13.6.1.4.2#17	IOP	If the Request RS-FEC Gen 3 bit is set to 0b, the Router shall enable RS-FEC encoding at 20G speeds on the Links of this USB4 Port during the next Lane Initialization.
13.6.2 Adapter Configuration Space		
13.6.2#1	TD 13.7	The Absolute address of the ADP_DP_CS_0 register in a DP Adapter Configuration Capability shall be 0x39.
13.6.2#2	TD 13.8	A Device Router shall ignore an attempt to modify bit 8 in ADP_DP_CS_3 register of a DP OUT Adapter.

13.6.2#3	TD 13.8	When a DP OUT Adapter receives a Write Request that targets address 0x10, it shall send a Write Response.
13.6.2#4	TD 13.7	A DP OUT Adapter shall not implement a Capability Register at address 0x10 in its Adapter Configuration space.
13.6.2#5	TD 13.7	A DP IN Adapter shall not have a Vendor Specific Capability with VSC ID = 0 or VSC ID = 1.
13.6.2#6	TD 13.7	A DP OUT Adapter shall not have a Vendor Specific Capability with VSC ID = 1.
13.6.2.1 Basic Attributes		
13.6.2.1#1	TD 13.7	An Adapter shall support the Adapter Configuration Space Basic Attributes in Table 13-19.
13.6.2.1#2	TD 13.7	The Vendor ID field shall contain the same value as the Vendor ID field in Router Configuration Space.
13.6.2.1#3	TD 13.7	The Product ID field shall contain the same value as the Product ID field in Router Configuration Space.
13.6.2.1#4	TD 13.7	The Revision Number field shall contain the same value as the Revision Number field in Router Configuration Space.
13.6.2.1#5	TD 13.7	The Max Credits field shall be equal to the Total Buffers Field.
13.6.2.2 USB4 Port Capability		
13.6.2.2#1	TD 13.7	An Adapter shall support the USB4 Port Capability fields in Table 13-20.
13.6.2.2#2	IOP	If the Request RS-FEC Gen 2 bit is set to 1b, the USB4 Port shall enable RS-FEC at Gen 2 speeds during the next Lane Initialization.

Test Requirements

Vendor provides the UUT 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 UUT.

For a USB4™ host:

- Reference system must be x64-based, run Windows 10
- Host Router must be PCIe-based
- The Reference System must include a way to connect to the Analyzer/Exerciser through a controller that is separate from the USB4 controller. This is to allow the Analyzer/Exercise hardware and software to operate concurrently on the same system with USB4 CV while USB4 CV controls the USB4 hardware

Note: In the future, will expand host testing to other OS and architectures.

USB4 Mode Test Setups

This section defines the test setups for a USB4™ Host, Dock, Hub, or Peripheral Device. The test setups in this section are used for the USB4 Mode Tests.

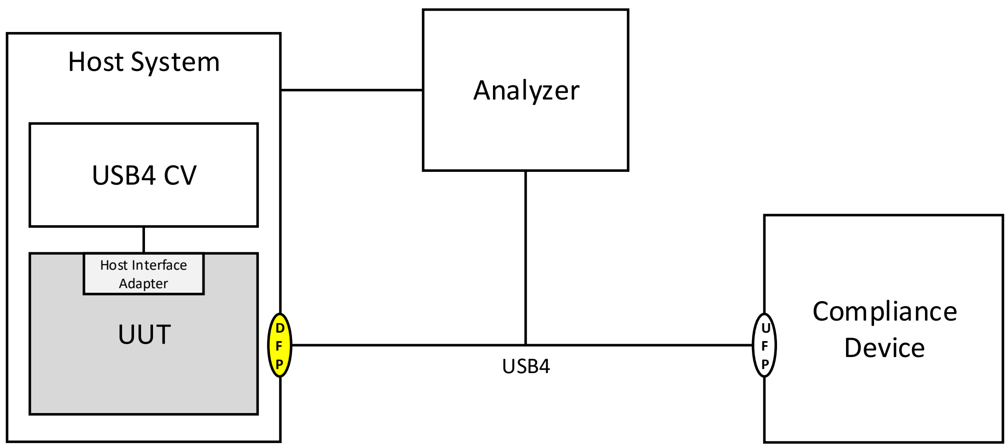
Host

This section defines the test setups for testing a USB4 Host. The PUT is highlighted in each figure.

AN_HOST_DFP1

Description:

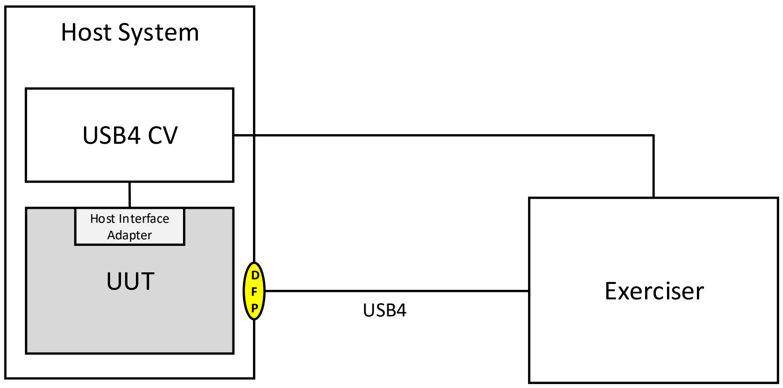
- The UFP of the Compliance Device is connected to the DFP of the UUT
- Analyzer is connected between UUT and Compliance Device



EX_HOST_DFP1

Description:

- The Exerciser is connected to the DFP of the UUT
- Unless specified otherwise, the Exerciser is in USB4 device mode and presents as UFP



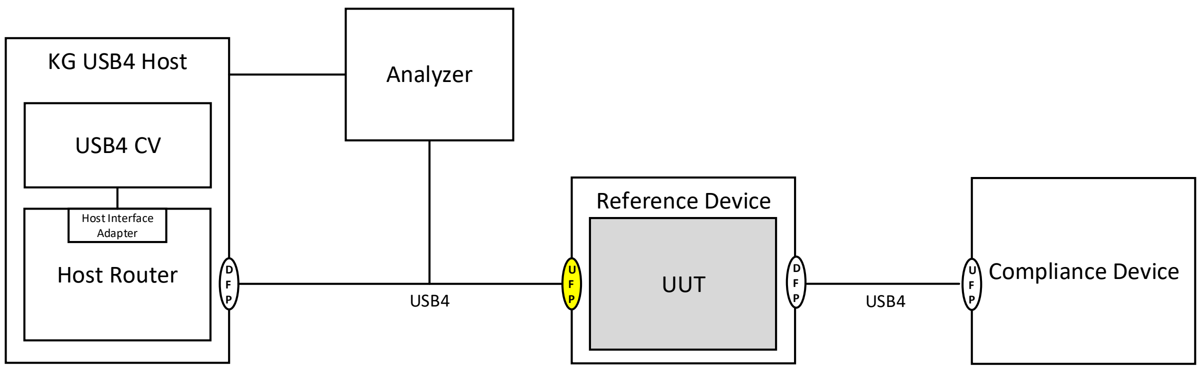
Hub/Dock

This section describes the test setups for a USB4 Hub or Dock. The PUT is highlighted in each figure.

AN_HUB_UFP2

Description:

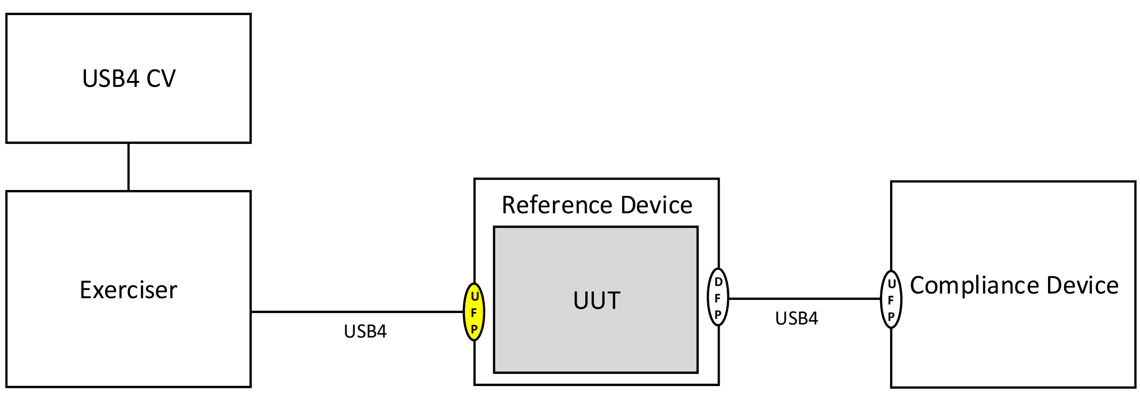
- DFP on KG USB4 Host connects to UFP of the UUT
- Analyzer is connected between the KG USB4 Host and the UUT
- DFP of UUT connects to Compliance Device



EX_HUB_UFP2

Description:

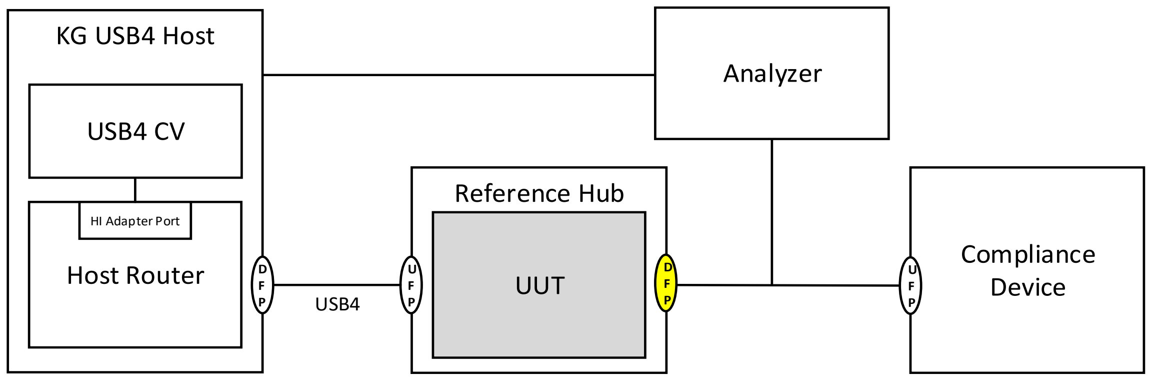
- Exerciser connects to UFP of the UUT
- Unless specified otherwise, Exerciser is in USB4 Host mode and presents as DFP
- DFP of UUT connects to a Compliance Device



AN_HUB_DFP1

Description:

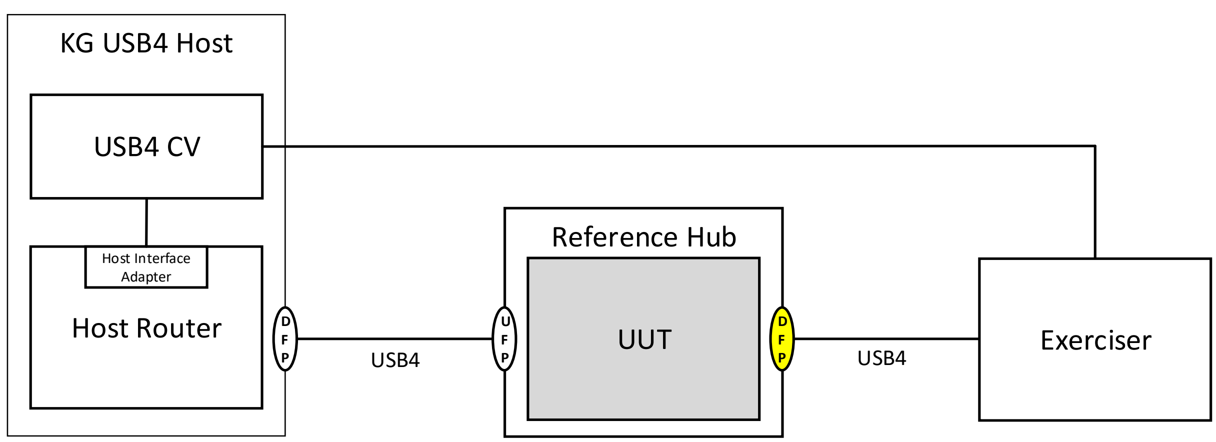
- DFP on KG USB4 Host connects to UFP of the UUT
- UFP of Compliance Device connects to DFP of the UUT
- Analyzer is connected between the UUT and Compliance Device



EX_HUB_DFP1

Description:

- DFP on KG USB4 Host connects to UFP of the UUT
- Exerciser connects to DFP of the UUT
- Unless specified otherwise, the Exerciser is in USB4 Host mode and presents as DFP



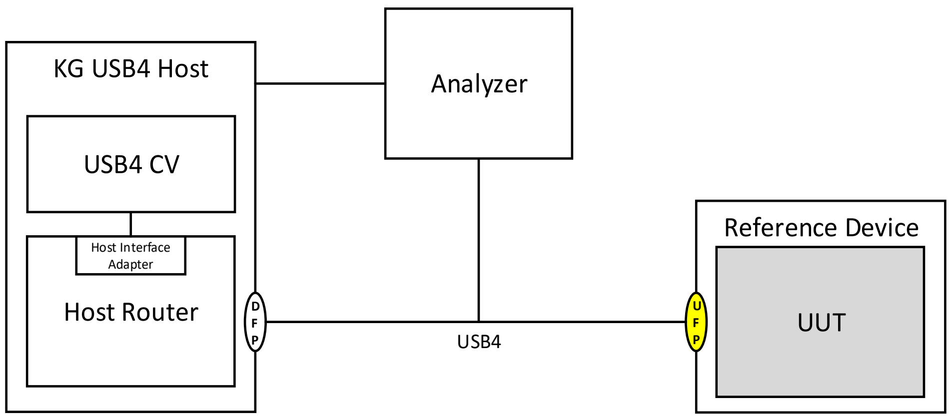
Peripheral Device

This section describes the test setups for a USB4 Peripheral Device. The PUT is highlighted in each figure.

AN_DEV_UFP1

Description:

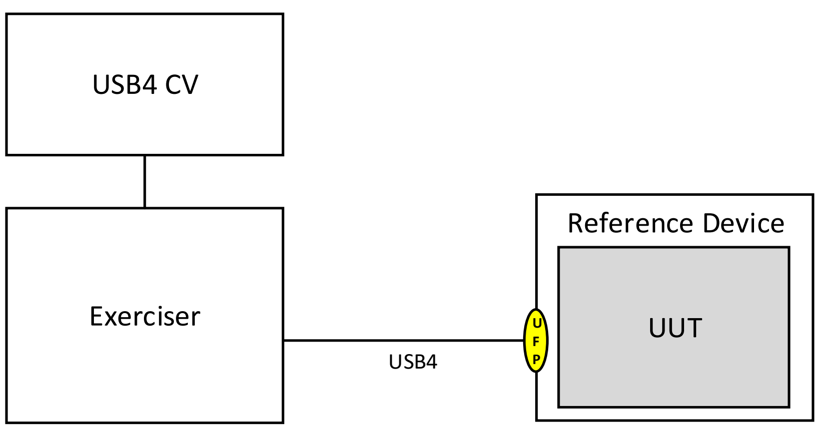
- DFP on KG USB4 Host connects to UFP of the UUT
- Analyzer is connected between the KG USB4 Host and the UUT



EX_DEV_UFP1

Description:

- Exerciser connects to UFP of the UUT
- Unless specified otherwise, Exerciser is in USB4 Host mode and presents as DFP



TBT3-Compatibility Mode Test Setups

This section defines the test setups for a USB4™ Host, Dock, Hub, or Peripheral Device. The test setups in this section are used for the TBT3-Compatibility Mode Tests.

Note: In the test setups below, a USB4 Compliance Device can be used instead of a KG TBT3 Device. If a USB4 Compliance Device is used, USB4 CV will enumerate it as a TBT3 device.

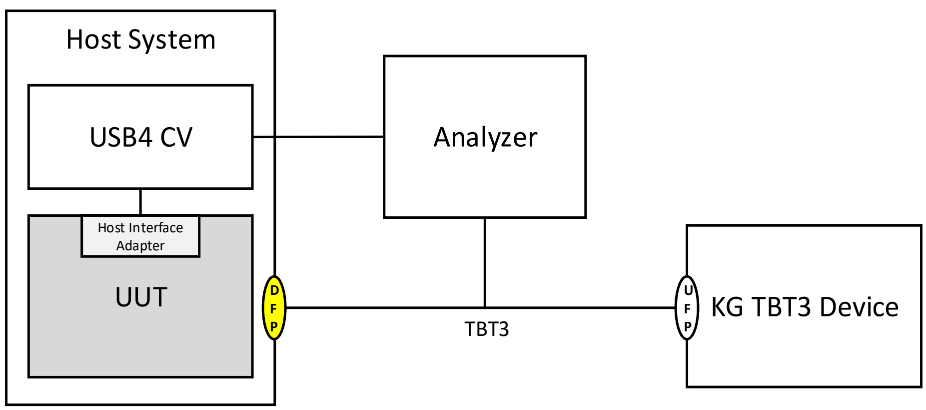
Host

This section defines the test setups for testing a USB4 Host. The PUT is highlighted in each figure.

AN_HOST_DFP1—TBT3_01

Description:

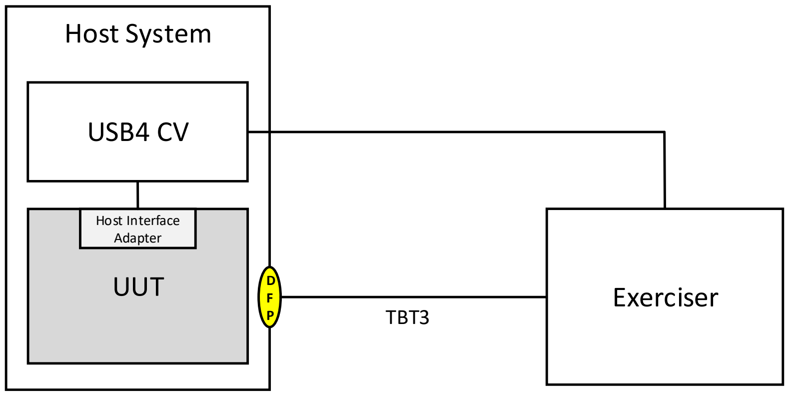
- The UFP of the KG TBT3 Device is connected to the DFP of the UUT
- Analyzer is connected between UUT and KG TBT3 Device
- USB4 CV runs in TBT3 Compatible Mode



EX_HOST_DFP1—TBT3_02

Description:

- The Exerciser is connected to the DFP of the UUT
- Unless specified otherwise, Exerciser is in TBT3 Device mode and presents as UFP
- USB4 CV runs in TBT3 Compatible Mode



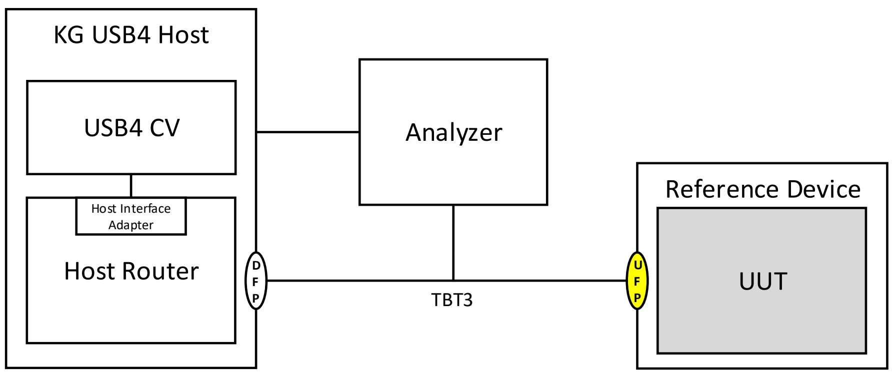
Hub/Dock

This section describes the test setups for a USB4 Hub or Dock. The PUT is highlighted in each figure.

AN_HUB_UFP1—TBT3_01

Description:

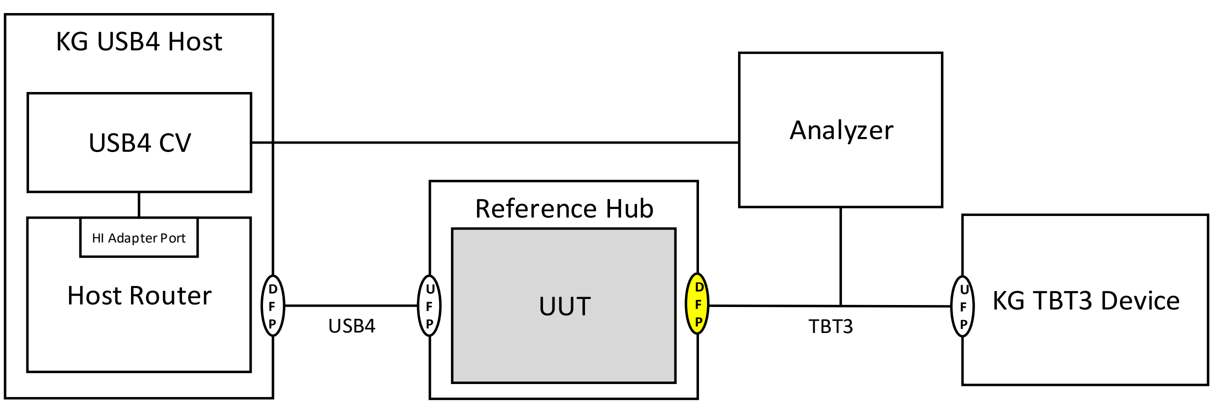
- DFP on Compliance Device connects to UFP of the UUT
- Analyzer is connected between the Compliance Device and the UUT
- USB4 CV runs in TBT3 Compatible Mode



AN_HUB_DFP1—TBT3_03

Description:

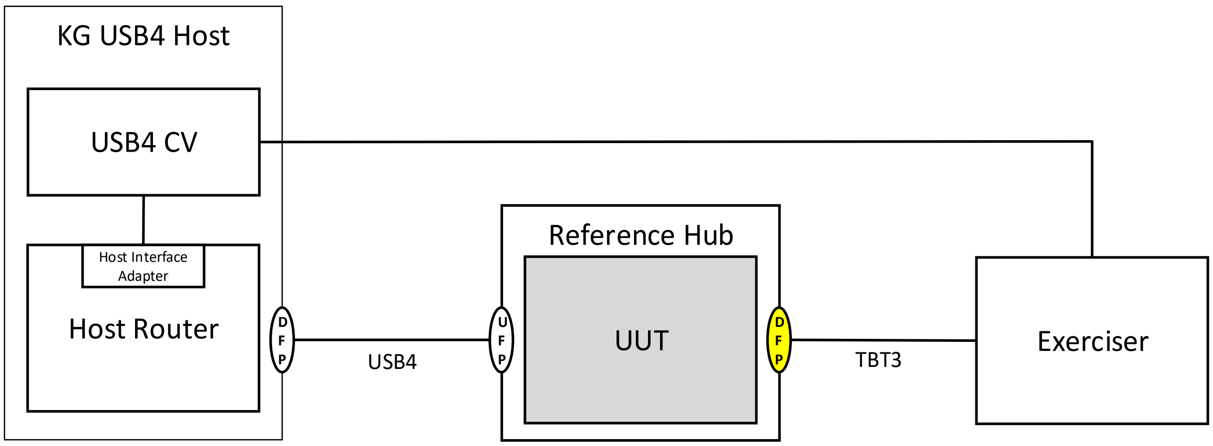
- DFP on KG USB4 Host connects to UFP of the UUT
- UFP of KG TBT3 Device connects to DFP of the UUT
- Analyzer is connected between the UUT and KG TBT3 Device
- USB4 CV runs in TBT3 Compatible Mode



EX_HUB_DFP1—TBT3_04

Description:

- DFP on KG USB4 Host connects to UFP of the UUT
- Exerciser connects to DFP of the UUT
- Unless specified otherwise, Exerciser is in TBT3 Device mode and presents as UFP
- USB4 CV runs in TBT3 Compatible Mode



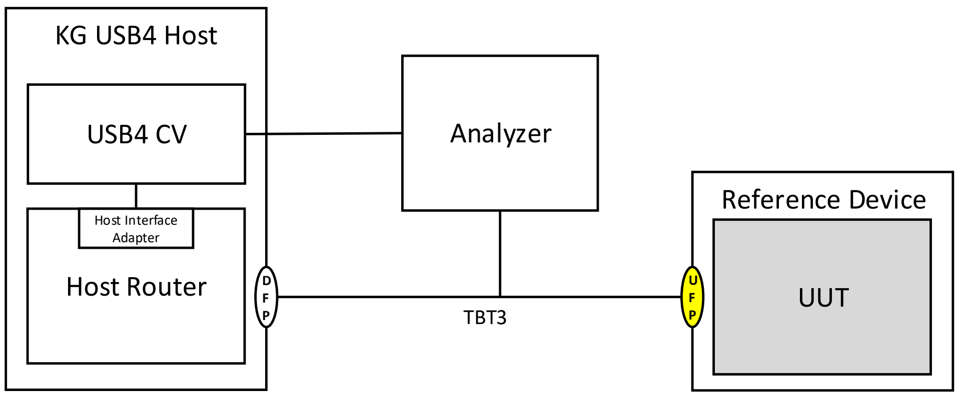
Peripheral Device

This section describes the test setups for a USB4 Peripheral Device. The PUT is highlighted in each figure.

AN_DEV_UFP1—TBT3_01

Description:

- DFP on Compliance Device connects to UFP of the UUT
- Analyzer is connected between the Compliance Device and the UUT
- USB4 CV runs in TBT3 Compatible Mode



Subroutines

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

Lane Bonding Initiation Procedure

The steps in this section are performed after Router Enumeration Procedure is done unless stated otherwise.

1. Send the UUT a Write Request that writes the following fields:
    a. *Target Link Width* = 1b
2. Send the Link Partner of the UUT a Write Request that writes the following fields:
    a. *Target Link Width* = 1b
3. Send the Lane 0 Adapter in the DFP (whether it's the UUT or its Link Partner) a Write Request that writes the following fields:
    a. *Lane Bonding* = 1b
4. Wait for a Hot Plug Packet with UPG=1 for Lane 1

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

Router Connect Procedure

The steps in this section are performed whenever a test calls for a USB4 device or the Exerciser to be connected to a UUT. The Adapters in the DFP being connected are enabled, which simulates a new connection.

Performs the following steps in the DFP that is being connected:

1. Set the *Lane Disable* bit in the Lane 0 Adapter to 0b
2. Wait at least tDisabled time (10ms)
3. Set the *Lane Disable* bit in the Lane 1 Adapter to 0b
4. Set the *Lock* bit in the DFP to 0b

Note *This step assumes that the USB4 device/Exerciser is physically connected to the DFP and the DFP Adapters have been disabled using the Router Assembly Disconnect Procedure below.*

Router Disconnect Procedure

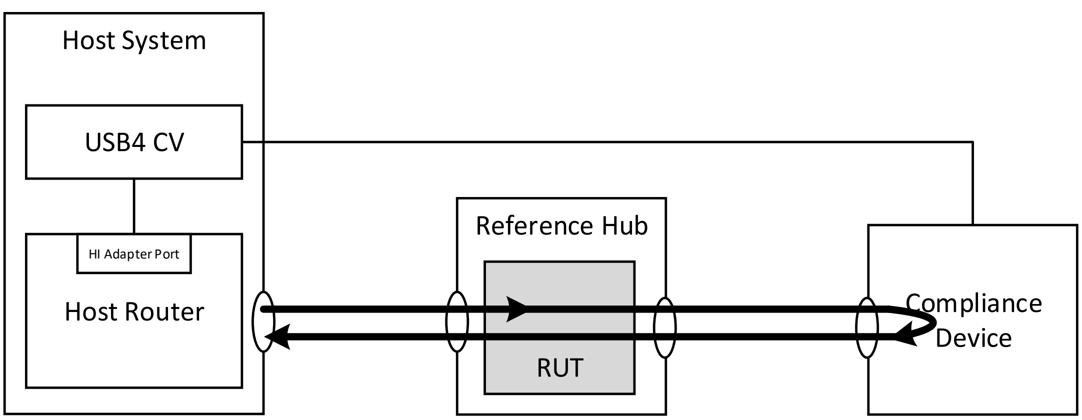
The steps in this section are performed whenever a test calls for a USB4 device or the Exerciser to be disconnected from a UUT. The Adapters in the DFP being disconnected are disabled, which simulates a disconnect.

Performs the following steps in the DFP that is connected to the device being disconnected:

1. Set the *Lane Disable* bit in the Lane 1 Adapter to 1b
2. Wait for a Hot Plug Event Packet with UPG=1 for Lane 1
3. Set the *Lane Disable* bit in the Lane 0 Adapter to 1b
4. Wait for a Hot Plug Event Packet with UPG=1 for Lane 0

Loopback Path Setup

A Loopback Path allows USB4 CV to inject traffic into a USB4 fabric by sending itself USB4 Packets using Host-to-Host Tunneling. The USB4 Packets are generated by USB4 CV and routed through the UUT out to the Compliance Device and back through the UUT. The loopback Path uses Ring 1.



The steps in this section are performed whenever a test calls for a loopback path to be setup.

Note: When Lanes are bonded, only Lane 0 Path Configuration Space needs to be configured.

Part 0 – Configure Adapters Credits fields

Upstream of the UUT, in each Lane Adapter along the loopback Path configure the following:

- If loopback path is set for Flow Control Disabled, set *Non-Flow Controlled Buffers* in the Adapter Configuration Space to: *Total Buffers – Path Credits Allocated* for Path 0
- If loopback path is set for Restricted Shared or Shared, set *Link Credits Allocated* in the Adapter Configuration Space to: MIN(*Total Buffers – Path Credits Allocated* for Path 0, 127)

Part 1 – Configure the Path Segments

Upstream of the UUT, in each Adapter along the loopback Path starting with the Source Adapter and ending with the Destination Adapter:

1. For all Adapters, configure the HopID/routing table using the following fields in Path Configuration Space:
    a. *Output Adapter*
    b. *Output HopID*
    c. *Priority*
    d. *Weight*
2. If Adapter is Lane Adapter, set the Flow Control parameters using the following fields in Path Configuration Space:
    a. *Path Credits Allocated*
    b. *ESE*
    c. *ISE*
    d. *EFC*
    e. *IFC*
3. Set the *Valid* bit in Path Configuration Space to 1b

Part 2 – Enable Loopback

After all Path segments are configured, do the following in each Protocol Adapter along the loopback Path starting with the Source Adapter and ending with the Destination Adapter

4. Set the *Enable* bit in Adapter Configuration Space to 1b

Loopback Teardown

The steps in this section are performed whenever a test calls for a loopback Path to be torn down.

Part 1 – Disable Loopback

Upstream of the UUT, in each Protocol Adapter along the loopback Path starting with the Destination Adapter and ending with the Source Adapter:

1. Set the *Enable* bit in Adapter Configuration Space to 0b

Part 2 – Teardown Path Segments

Upstream of the UUT in each Adapter along the loopback Path starting with the Destination Adapter and ending with the Source Adapter:

2. Set the *Valid* bit in Path Configuration Space to 0b
3. Read the *Pending Requests* bit in Path Configuration Space
4. Poll the *Pending Requests* bit until it is 0b
5. Wait tTeardown time

USB4 Mode Tests

The tests in this section are performed in USB4 mode where all connected USB4 Ports negotiate and enter USB4 operation as described in the USB Type-C Specification and the USB PD Specification. USB4 CV enumerates the Router as a USB4 Connection Manager.

Tests are performed at the highest signaling speed that the UUT supports. Unless specified otherwise, Lanes are bonded and RS-FEC is enabled. When Lanes are bonded, the configuration Space of the Lane 0 Adapter is used to perform the tests.

Unless otherwise noted, a test will timeout if it takes more than 500ms to go from one step to the next step. It is a test failure if a test times out.

If a USB4 Product contains multiple Routers, all Routers in the USB4 Product are tested.

Background Check Procedure

The test steps in this section are performed by the Analyzer (test setup starts with "AN_") or the Exerciser (test setup starts with "EX_") in the background while the rest of the tests in this document are performed.

A UUT must pass all of the Background Check Procedure steps, each time a test is performed. If the UUT fails any of the Background Check Procedure steps, it fails the full Background Check.

1. Parse each non-Idle Transport Layer Packet from the UUT and verify that:
    a. It contains between 1 and 256 bytes of payload (5.1.2#2)
    b. The HEC field is valid (5.1.2.1.1#1, 5.1.2.1.1#2, 5.1.2.1.1#3)
2. Parse each Credit Grant Packet received from the UUT and verify:
    a. The value in the *Length* field is a multiple of 4 (5.1.2.2#1)
    b. The packet contains one or more Credit Grant Records after header (5.1.3.3.2#1)
    c. The packet does not contain more than 64 Credit Grant Records (5.1.3.3.2#2)
3. Verify that the ECC is valid in each Credit Grant Record from the UUT (5.1.2.3#1, 5.1.2.3#2)
4. Parse each Path Credit Sync Packet from the UUT and verify:
    a. The *HEC* field is valid (5.1.3.3.3#1)
    b. The *Length* field is 04h (5.1.3.3.3#1)
    c. The *ECC* is valid (5.1.2.3#1, 5.1.2.3#2)
5. Parse each Shared Buffers Credit Sync Packet from the UUT and verify:
    a. The *HEC* field is valid (5.1.3.3.4#1)
    b. The *Length* field is 04h (5.1.3.3.4#1)
    c. The *ECC* is valid (5.1.2.3#1, 5.1.2.3#2)
6. If Link is Gen 2, verify that the UUT sends no more than one Transport Layer Header in the two 64-bit Data Symbols that are sent concurrently on the two Lanes of a Dual-Lane Link. (5.1.5#2)
7. If Link is Gen 3, verify that a Router sends no more than one Transport Layer Header in the two 128-bit Data Symbols that are sent concurrently on the two Lanes of a Dual-Lane Link. (5.1.5#4)
8. Verify that the UUT does not send Credit Grant Records or Credit Sync Packets for the Paths that correspond to HopIDs 1 through 7. (5.3.2#1) (5.3.2.2#2)
9. Verify that the first Credit Grant Packet from the UUT is from Lane 0 and has a Credit Grant Record for HopID 0. (5.3.2.1.3#8)
10. Verify that the first Credit Grant Record for Path 0 allocates at least 2 credits for Path 0 (5.3.2.1.2#6)
11. Verify that all Control Packets from the UUT have:
    a. Bits 62:56 (Rsvd) set to 0 (6.4.2.2#3)
    b. Bit 63 (CM) set to 1b (6.4.2.2#4)
12. Verify that the CRC in each Control Packet is valid (6.4.2.2#5, 6.4.2.2#6)
13. Parse each Read Response from the UUT and verify that bits 31:29 in DW3 (reserved) are 0 (6.4.2.4#8)
14. Parse each Write Response from the UUT and verify that bits 31:29 in DW3 (reserved) are 0 (6.4.2.6#7)
15. Parse each Hot Plug Event Packet from the UUT and verify that bits 30:6 in DW3 (reserved) are 0 (6.4.2.9#2)
16. For each Read Response from the UUT, verify that it was send within tCPResponse of when the UUT received the corresponding Read Request (6.4.4#2)
17. For each Write Response from the UUT, verify that it was send within tCPResponse of when the UUT received the corresponding Write Request (6.4.4#3)

Transport Layer Tests

Unless noted otherwise, the tests in this section are repeated for each USB4 Port on the UUT.

TD 5.1 UFP HEC Error Test (Devices and Hubs Only)

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

A. Purpose:
   - Verify that the UUT handles HEC errors correctly in Control Packets received on the UFP

B. Asserts:
   - 5.1.2.1.1#4-7, 5.1.2.1.1#10-11
   - 8.2.2.1#26

C. Test Setup:
   - EX_HUB_UFP2 (Hub UFP)
   - EX_DEV_UFP1 (Device UFP)

D. Repetitions:
   - Repeat test with HEC error notifications enabled and disabled

E. Procedure:

The Exerciser performs all the following test steps:

Part 0 - Setup

1. Reset UUT
2. Enumerate UUT
3. Read the *HEC Error* bit in Adapter Configuration Space

   Note: the read will clear the HEC Error bit to 0b

4. Read the *HEC Errors* field in the Adapter Configuration Space of the PUT and record the value
5. Write to the *HEC Error Enable* bit in the Adapter Configuration Space of the PUT:
   a. Write 1b to enable HEC error notifications
   b. Write 0b to disable HEC error notifications

Part 1 – Single Bit Error

6. Send the PUT a Read Request with a single-bit HEC error
7. Verify that the PUT sends a Read Response (5.1.2.1.1#5)
8. Read the *HEC Error* bit and *HEC Errors* field in the Adapter Configuration Space of the PUT
9. Verify that the *HEC Error* bit is 0b (5.1.2.1.1#6)
10. Verify that the *HEC Errors* field did not increment (5.1.2.1.1#6)

Part 2 – Multi-Bit Error

11. Send the PUT a Read Request with a multi-bit HEC error
12. Verify that the PUT Adapters enter the Training state (PUT sends SLOS1) (5.1.2.1.1#10)
13. Wait 1 second (for PUT Adapters to come back to CL0 state)
14. Read the *HEC Error* bit and *HEC Errors* field in the Adapter Configuration Space of the PUT
15. Verify that the *HEC Error* bit is 1b (5.1.2.1.1#7)
16. Verify that the *HEC Errors* field has incremented (5.1.2.1.1#7, 8.2.2.1#26)
17. If HEC error notifications are enabled (*HEC Error Enable* = 1b), verify that the PUT sends a Notification Packet with Event Code = ERR_HEC (5.1.2.1.1#11)

TD 5.2 DFP HEC Error Test (Hosts and Hubs Only)

Note: This test is only performed on the DFP(s) of the UUT.

A. Purpose:
   - Verify that the UUT handles HEC errors correctly in Control Packets received on a DFP

B. Asserts:
   - 5.1.2.1.1#4-9
   - 8.2.2.1#26

C. Test Setup:
   - EX_HOST_DFP1 (Host DFP)
   - EX_HUB_DFP1 (Hub DFP)

D. Repetitions:
   - Repeat test with HEC error notifications enabled and disabled

E. Procedure:

Part 0 - Setup

USB4 CV performs the following steps:

1. Reset UUT
2. Enumerate UUT
3. Read the *HEC Error* bit in Adapter Configuration Space

   Note: the read will clear the HEC Error bit to 0b

4. Read the *HEC Errors* field in Adapter Configuration Space of the PUT and record the value
5. Write to the *HEC Error Enable* bit in the Adapter Configuration Space of the PUT (see repetitions):
   a. Write 1b to enable HEC error notifications
   b. Write 0b to disable HEC error notifications

Part 1 – Single Bit Error

6. Configure the Exerciser Configure the Exerciser to insert a single-bit HEC error in any Read Responses that it sends

   Note: This step can be performed manually by the user if needed

7. Send the Exerciser a Read Request to Adapter Configuration Space with:
   a. Adapter Number = 1h
   b. Address = 0h

   Note: Exerciser will send a Read Response with a single-bit HEC error

8. Verify that a Read Response is received (i.e. PUT corrected error and forwarded Read Response to USB4 CV) (5.1.2.1.1#5, 5.1.2.1.1#6)
9. Read the *HEC Error* bit and *HEC Errors* field in the Adapter Configuration Space of the PUT
10. Verify that the *HEC Error* bit is 0b (5.1.2.1.1#6)
11. Verify that the *HEC Errors* field did not increment (5.1.2.1.1#6)

Part 2 – Multi Bit Error

12. Configure the Exerciser to do the following:
    a. insert a multi-bit HEC error in any Read Responses that it sends
    b. When SLOS1 are received, retrain the Link and bring Lane Adapters back to CL0 state

    Note: This step can be performed manually by the user if needed

13. Send the Exerciser a Read Request to Adapter Configuration Space with:
    a. Adapter Number = 1h
    b. Address = 0h

    Note: Exerciser will send a Read Response with a multi-bit HEC error

14. Wait 1 second (for PUT Adapters to come back to CL0 state)
15. Read the *HEC Error* bit and *HEC Errors* field in the Adapter Configuration Space of the PUT
16. Verify that the *HEC Error* bit is 1b (5.1.2.1.1#7)
17. Verify that the *HEC Errors* field has incremented (5.1.2.1.1#7, 8.2.2.1#26)
18. If HEC error notifications are enabled (*HEC Error Enable* = 1b), verify that the PUT sends a Notification Packet with Event Code = ERR_HEC (5.1.2.1.1#8)
19. Parse the Trace from the Exerciser and verify that the PUT sent SLOS1 (entered Training state) after receiving the Read Response from the Exerciser (5.1.2.1.1#9)

TD 5.3 Credit Grant ECC Error Test (Hosts and Hubs Only)

A. Purpose:
   - Verify that the UUT handles ECC Errors correctly on an Egress Adapter

B. Asserts:
   - 5.3.2.1.3#9-11
   - 8.2.2.1#31

C. Test Setup
   - EX_HOST_DFP1 (Host DFP)
   - EX_HUB_UFP2 (Hub UFP)
   - EX_HUB_DFP1 (Hub DFP)

D. Procedure:

Note: When performing this test on an UFP, the exerciser performs both the test steps that are defined "Upstream of the UUT" and the test steps that are defined "On the PUT". When this test is performed on a DFP, USB4 CV performs the tests steps that are defined "Upstream of the UUT" and the Exerciser performs the test steps that are defined "On the PUT".

Part 0 - Setup

Upstream of the UUT:

1. Reset UUT
2. Enumerate UUT
3. Configure a loopback Path:
   a. Loopback Path uses Dedicated Flow Control scheme (IFC=1b, ISE=0b, EFC=1b, ESE=0b, Path Credits Allocated = 5, HopID = 8)
4. Read the *ECC Error* field in the Adapter Configuration Space of the PUT and record the value

Part 1 – Correctable error

On PUT:

5. Upon every reception of Tunneled Packet with HopID = 8:
   a. If Exerciser act as a Device, it loops back the packet as it receives it.
   b. Sends back a Credit Grant Packet with Credit Grant Record which has a single-bit error in its ECC field.

Upstream of the UUT:

6. Send 10 Tunneled Packets on the loopback Path
7. Verify that all 10 Tunneled Packets sent on the loopback Path are received back (5.3.2.1.3#9, 5.3.2.1.3#10)
8. Read the *ECC Error* field in Adapter Configuration Space of the PUT
9. Verify that the *ECC Error* field value did not change. (5.3.2.1.3#10, 8.2.2.1#31)

Part 2 – Uncorrectable Error

On PUT:

10. Upon every reception of Tunneled Packet with HopID = 8:
    a. If Exerciser act as a Device, it loops back the packet as it receives it.
    b. Sends back a Credit Grant Packet with Credit Grant Record which has a two-bit error in its ECC field.

Upstream of the UUT:

11. Send 10 Tunneled Packets on the loopback Path
12. Verify that the first 5 and only the first 5 Tunneled Packet sent on the loopback Path is received back (5.3.2.1.3#9)
13. Read the *ECC Error* field in Adapter Configuration Space of the PUT
14. Query the Exerciser to get the number of Credit Grant Packets sent with multi-bit errors
15. Verify that the *ECC Error* field value is equal to 5 (5.3.2.1.3#11, 8.2.2.1#31)

TD 5.4 Credit Sync ECC Error Test (Hosts and Hubs Only)

A. Purpose:
   - Verify that the UUT handles ECC Errors correctly on an Ingress Adapter

B. Asserts:
   - 5.3.2.3#7-8
   - 8.2.2.1#31

C. Test Setup
   - EX_HOST_DFP1 (Host DFP)
   - EX_HUB_DFP1 (Hub DFP)
   - EX_HUB_UFP2 (Hub UFP)

D. Procedure:

Note: When performing this test on an UFP, the exerciser performs both the test steps that are defined "Upstream of the UUT" and the test steps that are defined "On the PUT". When this test is performed on a DFP, USB4 CV performs the tests steps that are defined "Upstream of the UUT" and the Exerciser performs the test steps that are defined "On the PUT".

Part 0 - Setup

Upstream of the UUT:

1. Reset UUT
2. Enumerate UUT
3. Configure a Loopback Path:
   a. Loopback Path uses Dedicated Flow Control scheme (IFC=1b, ISE=0b, EFC=1b, ESE=0b, Path Credits Allocated = 5, HopID = 8)
4. Read the *ECC Error* field in Adapter Configuration Space of the PUT and record the value

Part 1 – Correctable error

Upstream of the UUT:

5. Verify that Credit Grant Records sent by UUT for HopID=8 equal to 5 (Initial value)

On PUT:

6. Exerciser sends 10 Path Credit Sync Packet with the following parameters:
   a. HopID = 8
   b. Has a single-bit ECC error
   c. Increment the PCC by 1 from the previous packet (should send values 1 -> 10)
7. Wait 1 second
8. Read the *ECC Error* field in Adapter Configuration Space of the PUT and verify that the value did not change. (5.3.2.3#7, 8.2.2.1#31)
9. Verify that Credit Grant Records sent by UUT for HopID=8 equal to 15 (Incremented despite the errors) (5.3.2.3#7)

Part 2 – Uncorrectable Error

On PUT:

10. Exerciser sends 10 Path Credit Sync Packet with the following parameters:
    a. HopID = 8
    b. Has a two-bit ECC error
    c. Increment the PCC by 1 from the previous packet (should send values 11 -> 20)

Upstream of the UUT:

11. Wait 1 second
12. Read the *ECC Error* field in Adapter Configuration Space of the PUT
13. Verify that the *ECC Error* field incremented by10. (5.3.2.3#8, 8.2.2.1#31)
14. Verify that Credit Grant Records sent by UUT for HopID=8 equal to 15 (Did not increment, due to the errors) (5.3.2.3#8)

TD 5.5 Adapter Enumeration Test

Note: This test is only performed once on the UUT.

A. Purpose:
  - Verify that the UUT Adapters are numbered correctly

B. Asserts:
  - 5.2.1#3-4, 5.2.1#5-8

C. Test Setup:
  - AN_HOST_DFP1 (Host)
  - AN_HUB_UFP2 (Hub)
  - AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the following fields from Router Configuration Space of UUT:
    a. *Max Adapter*
    b. *Upstream Adapter*
5. For each UUT Adapter (i.e. Adapters numbered 1 through *Max Adapter)*, send a Read Request to read the following fields from Adapter Configuration Space:
    a. *Adapter Number*
    b. *Adapter Type Sub-Type*
    c. *Adapter Type Version*
    d. *Adapter Type Protocol*
6. For each Read Request:
    a. Verify that the UUT either returns a Read Response or a Notification Packet with Error Code = ERR_ADDR. (5.2.1#6)
    b. Verify that the Adapter has one of the Adapter Types defined in Table 8-10 in the USB4 Specification.
7. For a Device Router, verify that the *Upstream Adapter* field contains the value of the Lane Adapter with the lowest Adapter Number (5.2.1#3)
8. If UUT is a Device Router:
    a. If the UUT has an Upstream PCIe Adapter, verify that the PCIe Upstream Adapter has the lowest Adapter number of all the PCIe Adapters (5.2.1#7)
    b. If the UUT has an Upstream USB3 Adapter, verify that the USB3 Upstream Adapter has the lowest Adapter number of all USB3 Adapters (5.2.1#8)
9. Stop Analyzer

TD 5.6 Unconfigured Path Test (Hosts and Hubs Only)

A. Purpose:
  - Verify that the UUT does not forward packets on a Path with *Valid* bit = 0b

B. Asserts:
  - 5.2.4.3#1

C. Test Setup:
  - AN_HOST_DFP1 (Host DFP)
  - AN_HUB_DFP1 (Hub DFP)
  - AN_HUB_UFP2 (Hub UFP)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the following fields from Adapter Configuration Space:
    a. *Max Input HopID*
    b. *Max Output HopID*
    c. *Max Adapter*
5. Setup up a loopback Path
    a. Set the *Valid* bit to 1b in each Adapter that the Path traverses except the PUT Adapters

    Note: Valid bit should be 0b by default in PUT

6. Send 10 Tunneled Packets on the loopback Path
7. Wait 10 seconds
8. Verify that no Tunneled Packets were received back on the loopback Path (5.2.4.3#1)
9. Stop Analyzer

TD 5.7 Ingress Adapter Flow Control Test (Hosts and Hubs Only)

A. Purpose:
  - Verify that the UUT uses the correct flow control scheme in an Ingress Adapter

B. Asserts:
  - 5.3.2.1#4, 5.3.2.1.1.2#2, 5.3.2.1.1.3#2, 5.3.2.1.1.4#2, 5.3.2.1.2#5, 5.3.2.1.2#7, 5.3.2.1.2#11, 5.3.2.1.3#1, 5.3.2.1.3#2, 5.3.2.1.3#3, 5.3.2.1.3#6, 5.3.2.1.3#7

C. Test Setup:
  - AN_HOST_DFP1 (Host DFP)
  - AN_HUB_DFP1 (Hub DFP)
  - AN_HUB_UFP2 (Hub UFP)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the *Shared Buffering Capable* bit from the Adapter Configuration Space of the PUT
    a. If *Shared Buffering Capable* = 0b, do not perform Part 3 and Part 4
5. Read the following fields from Adapter Configuration Space of the PUT:
    a. *Total Buffers*
    b. *Non Flow Controlled Buffers*
    c. *Link Credits Allocated*
6. Read the *Path Credits Allocated* field from Path Configuration Space

Part 1 – Flow Control Disabled

7. Configure a loopback Path:
    a. Path has Flow Control Disabled (*IFC* = 0b, *ISE* = 0b , *EFC* = 0b, *ESE* = 0b)
    b. *Valid* bit = 1b
8. Send 140 Tunneled Packets on the loopback Path
9. Verify reception of the 140 Tunneled Packets
10. Stop Analyzer and read trace
11. Verify that the UUT did not send any Credit Grant Packets for the Path (5.3.2.1.3#1)

Part 2 – Dedicated Flow Control

12. Start Analyzer
13. Reset UUT
14. Enumerate UUT
15. Configure a loopback Path:
    a. Path has Dedicated Flow Control (*IFC* = 1b, *ISE* = 0b, *EFC* = 1b, *ESE* = 0b)
    b. *Valid* bit = 1b
16. Marker 1 – Read address 1h from Router CS at the Compliance Device
17. Wait 2 x tCredits
18. Marker 2 – Read address 2h from Router CS at the Compliance Device
19. Send 140 Tunneled Packets on the loopback Path
20. Verify reception of the 140 Tunneled Packets
21. Marker 3 – Read address 3h from Router CS at the Compliance Device
22. Wait 2 x tCredits
23. Marker 4 – Read address 4h from Router CS at the Compliance Device
24. Stop Analyzer and read trace

25. Verify that:
    a. UUT sent a Credit Grant Packet with a Credit Grant Record for the Path after the *Valid* bit for the Path was set to 1b (5.3.2.1.3#3)
    b. UUT sent a Credit Grant Packet with a Credit Grant Record for the Path every tCredits (5.3.2.1.3#2, 5.3.2.1.3#7)
26. Parse each Credit Grant Record between Marker 1 and Marker 2 for the Path and verify that the *Flow Control Credits* field has the same value as the *Path Credits Allocated* field in Path Configuration Space (5.3.2.1.1.2#2, 5.3.2.1.2#5, 5.3.2.1.2#11)
27. Parse each Credit Grant Record between Marker 3 and Marker 4 for the Path and verify that the *Flow Control Credits* field equals to (*Path Credits Allocated* + 140)%256. (5.3.2.1.1.2#2, 5.3.2.1.2#5, 5.3.2.1.2#11)

Part 3 – Restricted Shared

28. Start Analyzer
29. Reset UUT
30. Enumerate UUT
31. Configure a loopback Path:
    a. Path has Restricted Shared Flow Control (*IFC* = 1b, *ISE* = 1b, *EFC* = 1b, *ESE* = 1b)
    b. *Valid* bit = 1b
32. Marker 1 – Read address 1h from Router CS at the Compliance Device
33. Wait 2 x tCredits
34. Marker 2 – Read address 2h from Router CS at the Compliance Device
35. Send 140 Tunneled Packets on the loopback Path
36. Verify reception of the 140 Tunneled Packets
37. Marker 3 – Read address 3h from Router CS at the Compliance Device
38. Wait 2 x tCredits
39. Marker 4 – Read address 4h from Router CS at the Compliance Device
40. Stop Analyzer and read trace
41. Verify that:
    a. UUT sent a Credit Grant Packet with a Credit Grant Record for the Path after the *Valid* bit for the Path is set to 1b (5.3.2.1.3#3)
    b. UUT sent a Credit Grant Packet with a Credit Grant Record for the Shared Buffer after the *Valid* bit for the Path is set to 1b (5.3.2.1.3#6)
    c. UUT sent a Credit Grant Packet with a Credit Grant Record for the Path every tCredits (5.3.2.1.3#2, 5.3.2.1.3#7)
    d. UUT sent a Credit Grant Packet with a Credit Grant Record for the shared buffer every tCredits (5.3.2.1.3#7)
42. Parse each Credit Grant Record between Marker1 and Marker 2:
    1. Verify the Path Records Flow Control Credits field has the same value as the *Path Credits Allocated* field in Path Configuration Space (5.3.2.1.1.4#2, 5.3.2.1.2#5, 5.3.2.1.2#11)
    2. Verify the Shared Records Flow Control Credits field has the same value as the *Link Credits Allocated* field in Adapter Configuration Space (5.3.2.1.1.4#2, 5.3.2.1.2#7, 5.3.2.1.2#11)
43. Parse each Credit Grant Record between Marker3 and Marker 4:
    1. Verify the Path Records Flow Control Credits field equals to (*Path Credits Allocated* + 140)%256 (5.3.2.1.1.4#2, 5.3.2.1.2#5, 5.3.2.1.2#11)
    2. Verify the Shared Records Flow Control Credits field equals to (*Link Credits Allocated + 140)%256* (5.3.2.1.1.4#2, 5.3.2.1.2#7, 5.3.2.1.2#11)

Part 4 – Shared

44. Start Analyzer
45. Reset UUT
46. Enumerate UUT
47. Configure a loopback Path:
    a. Path has Shared Flow Control (*IFC* = 0b, *ISE* = 1b, *EFC* = 0b, *ESE* = 1b)
    b. *Valid* bit = 1b
48. Marker 1 – Read address 1h from Router CS at the Compliance Device
49. Wait 2 x tCredits
50. Marker 2 – Read address 2h from Router CS at the Compliance Device
51. Send 140 Tunneled Packets on the loopback Path
52. Verify reception of the 140 Tunneled Packets
53. Marker 3 – Read address 3h from Router CS at the Compliance Device
54. Wait 2 x tCredits
55. Marker 4 – Read address 4h from Router CS at the Compliance Device
56. Stop Analyzer and read trace
57. Verify that:
    a. UUT sent a Credit Grant Packet with a Credit Grant Record for the Shared Buffer when the Path is first enabled (5.3.2.1.3#6)
    b. UUT sent a Credit Grant Packet with a Credit Grant Record for the shared buffer every tCredits (5.3.2.1.3#7)
    c. UUT did not send any Credit Grant Records for the Path (5.3.2.1.3#1)
58. Parse each Credit Grant Record between Marker1 and Marker 2 for the shared buffer and verify that the *Flow Control Credits* field had the same value as the *Link Credits Allocated* field in Adapter Configuration Space (5.3.2.1.1.3#2, 5.3.2.1.2#7, 5.3.2.1.2#11)
59. Parse each Credit Grant Record between Marker3 and Marker 4 for the shared buffer and verify that the *Flow Control Credits* field equals to (*Link Credits Allocated + 140)%256*. (5.3.2.1.1.3#2, 5.3.2.1.2#7, 5.3.2.1.2#11)

TD 5.8 Egress Adapter Flow Control Test (Hosts and Hubs Only)

A. Purpose:
  - Verify that the UUT uses the correct flow control scheme in an Egress Adapter

B. Asserts:
  - 5.3.2.2#3, 5.3.2.2.2#2, 5.3.2.2.2#3, 5.3.2.2.2#4, 5.3.2.3#1-5
  - 5.3.2.3#3-5

C. Test Setup:
  - AN_HOST_DFP1 (Host DFP)
  - AN_HUB_DFP1 (Hub DFP)
  - AN_HUB_UFP2 (Hub UFP)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the *Shared Buffering Capable* field from Router Configuration Space of the UUT
    a. If *Shared Buffering Capable* = 0b, do not perform Part 3 and Part 4

Part 1 – Flow Control Disabled

5. Configure a loopback Path:
    a. Path has Flow Control Disabled (*IFC* = 0b, *ISE* = 0b , *EFC* = 0b, *ESE* = 0b)
    b. *Valid* bit = 1b
6. Wait 1 second
7. Stop Analyzer and read trace
8. Verify that the UUT did not send any Credit Sync Packets for the Path (5.3.2.2#3, 5.3.2.3#5)

Part 2 – Dedicated Flow Control

9. Start Analyzer
10. Reset UUT
11. Enumerate UUT
12. Configure a loopback Path:
    a. Path has Dedicated Flow Control (*IFC* = 1b, *ISE* = 0b , *EFC* = 1b, *ESE* = 0b)
    b. *Valid* bit = 1b
    c. In the Ingress Adapter connected to the PUT, *Path Credits Allocated* = 1
    d. In the rest of the Adapters along the loopback Path, *Path Credits Allocated* = 3
13. Send 140 Tunneled Packets on the loopback Path
14. Wait 1 second
15. Stop Analyzer and read trace
16. Verify that:
    a. UUT sent a Path Credit Sync Packet for the loopback Path every tSync (5.3.2.2#3, 5.3.2.3#1)
    b. UUT did not transmit a Tunneled Packet on the loopback Path until the Ingress Adapter reported available credits (5.3.2.2.2#2)
    c. The PCC field in each Path Credit Sync Packet from the UUT is based on the number of Transport Layer Packets forwarded by the UUT (5.3.2.3#3)

Part 3 – Restricted Shared

17. Start Analyzer
18. Reset UUT
19. Enumerate UUT
20. Configure a Loopback Path:
    a. Path has Restricted Shared Flow Control (*IFC* = 1b, *ISE* = 1b , *EFC* = 1b, *ESE* = 1b)
    b. *Valid* bit = 1b
    c. In the Ingress Adapter connected to the PUT:
        i. *Path Credits Allocated* = 1
        ii. *Link Credits Allocated* = 1
    d. In the rest of the Adapters along the loopback Path:
        i. *Path Credits Allocated* = 3
        ii. *Link Credits Allocated* = 3
21. Send 140 Tunneled Packets on the loopback Path
22. Wait 1 second
23. Stop Analyzer and read trace
24. Verify that:
    a. UUT sent a Path Credit Sync Packet every tSync (5.3.2.2#3, 5.3.2.3#1)
    b. UUT sent a Shared Credit Sync Packet every tSync (5.3.2.2#3, 5.3.2.3#2)
    c. UUT did not transmit a Tunneled Packet on the Loopback Path until the Ingress Adapter reported available credits (5.3.2.2.2#4)
    d. The PCC field in each Path Credit Sync Packet from the UUT is based on the number of Transport Layer Packets forwarded by the UUT (5.3.2.3#3)
    e. The SCC field in Shared Credit Sync is based on number of Transport Layer Packets forwarded by the UUT (5.3.2.3#4)

Part 4 – Shared

25. Start Analyzer
26. Reset UUT
27. Enumerate UUT
28. Configure a Loopback Path:
    a. Path has Shared Flow Control (*IFC* = 0b, *ISE* = 1b , *EFC* = 0b, *ESE* = 1b)
    b. *Valid* bit = 1b
    c. In the Ingress Adapter connected to the PUT, *Link Credits Allocated* = 1
    d. In the rest of the Adapters along the loopback Path, *Link Credits Allocated* = 3
29. Send 140 Tunneled Packets on the loopback Path
30. Wait 1 second
31. Stop Analyzer and read trace
32. Verify that:
    a. UUT sent a Shared Credit Sync Packet every tSync (5.3.2.2#3, 5.3.2.3#2)
    b. UUT did not transmit a Tunneled Packet on the Loopback Path until the Ingress Adapter reported available credits (5.3.2.2.2#3)
    c. The *SCC* field in Shared Credit Sync is based on number of Transport Layer Packets forwarded by the UUT (5.3.2.3#4)

TD 5.9 Credit Error Test (Hosts and Hubs Only)

A. Purpose:
   - Verify that the UUT tracks flow control credits correctly after receiving a Tunneled Packet with an error

B. Asserts:
   - 5.3.2.1.2#10

C. Test Setup:
   - EX_HOST_DFP1 (Host DFP)
   - EX_HUB_UFP2 (Hub UFP)
   - EX_HUB_DFP1 (Hub DFP)

D. Repetitions:
   - Repeat test with Dedicated Flow Control and Shared Flow Control

E. Procedure:

Note: When performing this test on an UFP, the exerciser performs both the test steps that are defined "Upstream of the UUT" and the test steps that are defined "On the PUT". When this test is performed on a DFP, USB4 CV performs the tests steps that are defined "Upstream of the UUT" and the Exerciser performs the test steps that are defined "On the PUT".

Part 0 - Setup

Upstream of the UUT:

1. Reset UUT
2. Enumerate UUT

Part 1 – HEC Error (Dedicated Flow Control)

3. Configure a loopback Path:
   a. For Dedicated Flow Control: Path uses Dedicated Flow Control scheme (*IFC* = 1b, *ISE* = 0b, *EFC* = 1b, *ESE* = 0b, Path Credits Allocated = 5, HopID = 8)
   b. For Shared Flow Control: Path uses Dedicated Flow Control scheme (*IFC* = 0b, *ISE* = 1b, *EFC* = 0b, *ESE* = 1b, Link Credits Allocated = 5, HopID = 8)
   c. *Valid* bit = 1b

On the PUT:

4. If Exerciser acts as a Device, it loops back the Tunneled Packets it receives at HopID=8. If it acts as a Host, it generates the Tunneled Packets for HopID=8. In both cases the Exerciser sends the Tunneled Packets with multiple-bit HEC errors.
5. The Exerciser doesn't send any Credit Sync Packet
6. If SLOS1 received retrain the link to CL0

Upstream of the UUT:

7. Send 3 Tunneled Packets in a 1 second interval on the loopback Path

   Note: the Adapters on the Link will go to Training state after detecting the HEC error

8. Query the Exerciser to verify that the *Flow Control Credits Count* field in the Credit Grant Record for the loopback Path did not change (5.3.2.1.2#10)

TD 5.10 Egress Adapter Path Tear-Down Test (Hosts and Hubs Only)

A. Purpose:
  - Verify that the UUT tears down Paths correctly in an Egress Adapter

B. Asserts:
  - 5.4#1, 5.4.1#1, 5.4.1#2, 5.4.1#4, 5.4.1#5

C. Test Setup:
  - AN_HOST_DFP1 (Host DFP)
  - AN_HUB_DFP1 (Hub DFP)
  - AN_HUB_UFP2 (Hub UFP)

D. Repetitions
  - Repeat for the following flow control schemes:
    - Flow Control Disabled (*IFC* = 0b, *ISE* = 0b, *EFC* = 0b, *ESE* = 0b)
    - Dedicated Flow Control (*IFC* = 1b, *ISE* = 0b, *EFC* = 1b, *ESE* = 0b)
  - If *Shared Buffering Capable* = 1b, repeat for the following flow control schemes:
    - Restricted Shared Flow Control (*IFC* = 1b, *ISE* = 1b, *EFC* = 1b, *ESE* = 1b)
    - Shared Flow Control (*IFC* = 0b, *ISE* = 1b, *EFC* = 0b, *ESE* = 1b)

E. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Configure a Loopback Path:
    a. Configure flow control scheme (see repetitions)
    b. *Valid* bit = 1b
5. Send 10 Tunneled Packets on the loopback Path
6. Send a Read Request to the most downstream Router
    a. *Address* = 0h
    b. *Read Size* = 1
    c. *Adapter Num* = 0 (Router)
    d. *Configuration Space* = 10b (Router Configuration Space)
7. Send a Write Request to the RUT that sets the *Valid* bit in Path Configuration Space to 0b for the segment of the loopback Path that goes PUT→Compliance Device (For Host RUT: from HI to PUT in the RUT; For Hub UUT: from Lane Adapter to PUT in the RUT)
    a. *Valid* bit remains 1b for the rest of the loopback Path segments
8. Send a Read Request to the most downstream Router
    a. *Address* = 0h
    b. *Read Size* = 1
    c. *Adapter Num* = 0 (Router)
    d. *Configuration Space* = 10b (Router Configuration Space)
9. Wait for 128ms
10. Verify that UUT sends a Write Response to the Write Request that set the Valid bit to 0b (5.4#1)
11. Verify that UUT:
    a. Sends a Shared Buffers Credit Sync Packet if ESE = 1b (5.4.1#1)
    b. Does not send any Path Credit Sync Packets for the Path (5.4.1#2)
12. Send a Read Request to read the *Pending Packets* bit in the Path Configuration Space of the PUT
    a. If the *Pending Packets* bit is 1b, repeat read until *Pending Packets* = 0b
13. Wait tTeardown time
14. Send 4 Tunneled Packets on the loopback Path
15. Verify that the Tunneled Packets are not returned back on the loopback Path (5.4.1#4, 5.4.1#5)
16. Stop Analyzer

TD 5.11 Ingress Adapter Path Tear-Down Test (Hosts and Hubs Only)

A. Purpose:
  - Verify that the UUT tears down Paths correctly in an Ingress Adapter

B. Asserts:
  - 5.4.2#1, 5.4.2#7

C. Test Setup:
  - AN_HOST_DFP1 (Host DFP)
  - AN_HUB_DFP1 (Hub DFP)
  - AN_HUB_UFP2 (Hub UFP)

D. Repetitions
  - Repeat with for each supported flow control scheme:
    - Flow Control Disabled (IFC = 0b, ISE = 0b, EFC = 0b, ESE = 0b)
    - Dedicated Flow Control (IFC = 1b, ISE = 0b, EFC = 1b, ESE = 0b)
    - Restricted Shared Flow Control (IFC = 1b, ISE = 1b, EFC = 1b, ESE = 1b)
    - Shared Flow Control (IFC = 0b, ISE = 1b, EFC = 0b, ESE = 1b)

E. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Configure a loopback Path
    a. Configure flow control scheme (see repetitions)
    b. *Valid* bit = 1b
5. Send 10 Tunneled Packets on the loopback Path
6. Send a Write Request to the RUT that sets the *Valid* bit in Path Configuration Space to 0b for the segment of the loopback Path that goes Compliance Device-to-PUT (For Host RUT: from PUT to HI in RUT ; For Hub RUT: from PUT to Lane Adapter in RUT)
    a. *Valid* bit remains 1b for the rest of the loopback Path segments
7. Verify that UUT sends a Write Response to the Write Request that set the Valid bit to 0b (5.4#1)
8. Send a Read Request to read the *Pending Packets* bit in the Path Configuration Space of the PUT
    a. If the *Pending Packets* bit is 1b, repeat read until *Pending Packets* = 0b
9. Verify that the UUT does not send any Path Credit Grant Packets for the Path (5.4.2#7)
10. Wait tTeardown time
11. Send 4 Tunneled Packets on the loopback Path
12. Verify that the Tunneled Packets are not returned back on the loopback Path (5.4.2#1)
13. Stop Analyzer

Configuration Layer Tests

Unless otherwise noted, the tests in this section are performed once per Router.

TD 6.1 UFP Downstream-Bound Control Packet Test

A. Purpose:
- Verify that the UUT handles Control Packets with CM=0b correctly when Router is Uninitialized
- Verify that the UUT handles Control Packets with CM=0b correctly when Router is Enumerated

B. Asserts:
- 6.4.3.2#2, 6.4.3.2#6, 6.4.3.2#7

C. Test Setup:
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Repetitions:
- If the UUT is a Hub, repeat Part 2 and Part 3 on each DFP

E. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Do not enumerate UUT

Part 1 – Uninitialized Router

4. Send the PUT a Read Request that targets Adapter Configuration Space
5. Wait at least tCPResponse (2 ms) to let the Read Request time out
6. Verify that the PUT does not send a Read Response (6.4.3.2#2)
7. Send the PUT a Write Request that targets Path Configuration Space
8. Wait at least tCPResponse (2 ms) to let the Write Request time out
9. Verify that the PUT does not send a Write Response (6.4.3.2#2)

Part 2 – Enumerated Router - Disconnected Port (Hubs only)

10. Enumerate the UUT
11. Disconnect the Compliance Device
12. Send the UUT a Read Request that targets the Router Configuration Space of the Compliance Device
13. Wait at least tCPResponse (2 ms) to let the Read Request time out
14. Verify that no Read Response is received (i.e. UUT dropped the Read Request) (6.4.3.2#6)
15. Verify that the UUT sends a Notification Packet with Event Code= ERR_CONN (6.4.3.2#6)

Part 3 – Enumerated Router – Locked Port (Hubs only)

16. Connect the Compliance Device
17. Read the *Lock* bit in the Adapter Configuration Space of the UUT DFP that is connected to the Compliance Device
18. Verify that the *Lock* bit is 1b
19. Send the UUT a Read Request that targets the Compliance Device
20. Wait at least tCPResponse (2 ms) to let the Read Request time out
21. Verify that no Read Response is received (i.e. UUT dropped the Read Request) (6.4.3.2#7)
22. Verify that the UUT sends a Notification Packet with Event Code= ERR_LOCK (6.4.3.2#7)
23. Stop Analyzer

TD 6.2 DFP Downstream-Bound Control Packet Test

Note: This test is performed on each DFP of the UUT.

A. Purpose:
   - Verify that DFP handles Control Packet with CM=0b correctly

B. Asserts:
   - 6.4.3.2#9, 6.4.3.2#10, 6.4.3.2#14, 6.4.3.2#15

C. Test Setup:
   - EX_HOST_DFP1 (Host)
   - EX_HUB_DFP1 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Reset UUT
2. Do not enumerate UUT
3. Configure the Exerciser to behave as a DFP (i.e. Exerciser is in USB4 Host mode)
4. Tell Exerciser to perform Part 1

Exerciser performs the following test steps:

Part 1 – Uninitialized Router

5. Send the UUT a Read Request that targets Router Configuration Space
6. Verify that the UUT:
   a. Does not send a Read Response (6.4.3.2#9)
   b. Sends a Notification Packet with Event Code=ERR_NUA (6.4.3.2#9)
7. Send a Write Request that targets the Adapter Configuration Space of the PUT
8. Verify that the UUT:
   a. Does not send a Read Response (6.4.3.2#9)
   b. Sends a Notification Packet with Event Code=ERR_NUA (6.4.3.2#9)
9. Send an Inter-Domain Request to the UUT
10. Verify that the UUT:
    a. Does not send an Inter-Domain Response (6.4.3.2#10)
    b. Does not send a Notification Packet (6.4.3.2#10)

Part 2 – Initialized Router – Read/Write Request

USB4 CV performs the following test steps:

11. Enumerate UUT
12. Tell the Exerciser to perform Part 2

Exerciser performs the following test steps:

13. Send a Read Request to the UUT
14. Verify that:
    a. UUT does not send a Read Response (6.4.3.2#14)
    b. UUT sends a Notification Packet with Event Code=ERR_ENUM (6.4.3.2#14)
15. Send a Write Request to the UUT
16. Verify that:
    a. UUT does not send a Write Response (6.4.3.2#14)
    b. UUT sends a Notification Packet with Event Code=ERR_ENUM (6.4.3.2#14)

TD 6.3 Read/Write Errors Test

A. Purpose:
  - Verify that the UUT handles Read Requests correctly
  - Verify that the UUT handles Write Requests correctly

B. Asserts:
  - 6.4.3.3#1, 6.4.3.3#2, 6.4.3.3#3, 6.4.3.3#6, 6.4.3.3#7, 6.4.3.3#8, 6.4.3.3#9, 6.4.3.3#10, 6.4.3.3#11, 6.4.3.3#12, 6.4.3.3#13

C. Test Setup:
  - AN_HOST_DFP1 (Host)
  - AN_HUB_UFP2 (Hub)
  - AN_DEV_UFP1 (Device)

D. Repetitions:
  - Repeat Part 2 through Part 6 with:
    - Router Configuration Space as the target
    - Each Adapter Configuration Space as the target
    - Each Path Configuration Space as the target

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Adapter Num > Max Adapter

4. Read the *Max Adapter* field from UUT Router Configuration Space
5. Send the UUT a Read Request with the *Adapter Num* field greater than *Max Adapter*
6. Verify that:
    a. UUT does not send a Read Response (6.4.3.3#1)
    b. UUT sends a Notification Packet with Event Code=ERR_ADP (6.4.3.3#2)
7. Send the UUT a Write Request with the *Adapter Num* field greater than *Max Adapter*
8. Verify that:
    a. UUT does not send a Write Response (6.4.3.3#1)
    b. UUT sends a Notification Packet with Event Code=ERR_ADP (6.4.3.3#1)

Part 2 – Zero Length Read

9. Send the UUT a Write Request with *Write Size* = 0
10. Verify that the UUT sends a Write Response (6.4.3.3#3)

Part 3 – Out of Bounds Read

11. Send the UUT a Read Request
    a. If target is Router Configuration Space:
        i. *Address* = TMU_DEV_CS_23 (start of *Post Local Time* registers)
        ii. *Read Size* = 4 DW
    b. If target is Adapter Configuration Space:
        i. *Address* = ADP_CS_5
        ii. *Read Size* = 6 DW
    c. If target is Path Configuration Space:
        i. *Address* = last Path Entry
        ii. *Read Size* = 5 DW

12. Verify that:
    a. UUT does not send a Read Response (6.4.3.3#9)
    b. UUT sends a Notification Packet with Event Code=ERR_ADDR (6.4.3.3#10)

Part 4 – Out of Bounds Write

13. Send the UUT a Write Request
    a. If target is Router Configuration Space:
        i. *Address* = TMU_DEV_CS_23 (start of *Post Local Time* registers)
        ii. *Write Size* = 4 DW
    b. If target is Adapter Configuration Space:
        i. *Address* = ADP_CS_5
        ii. *Write Size* = 6DW
    c. If target is Path Configuration Space:
        i. *Address* = last Path Entry
        ii. *Write Size* = 5 DW
14. Verify that:
    a. UUT does not send a Write Response (6.4.3.3#7)
    b. UUT sends a Notification Packet with Event Code=ERR_ADDR (6.4.3.3#8)
15. Send the UUT a Read Request that reads the Configuration Space targeted by the Write Request in Step 13
16. Verify that the R/W fields within the supported address range were written to (6.4.3.3#6)
    a. If target is Router Configuration Space, first 3 DW are written and last DW is dropped
    b. If target is Adapter Configuration Space, first 4 DW are written and last 2 DW are dropped
    c. If target is Path Configuration Space, first 2 DW are written and last 3 DW are dropped

Part 5 – Zero Length Read

17. Send the UUT a Read Request with *Read Size* = 0
18. Verify that the UUT does sends a Read Response with no Read Data (6.4.3.3#11)

Part 6 – Read > 60

19. Send the UUT a Read Request with *Read Size* = 61
20. Verify that:
    a. UUT does not send a Read Response (6.4.3.3#12)
    b. UUT sends a Notification Packet with Event Code =ERR_LEN (6.4.3.3#13)
21. Send the UUT a Read Request with *Read Size* = 63
22. Verify that:
    a. UUT does not send a Read Response (6.4.3.3#12)
    b. UUT sends a Notification Packet with Event Code =ERR_LEN (6.4.3.3#13)
23. Stop Analyzer

TD 6.4 Bad CRC Test (Hosts and Hubs Only)

A. Purpose:
   - Verify that the UUT discards Control Packets with a bad CRC

B. Asserts:
   - 6.4.4#1

C. Test Setup:
   - EX_HOST_DFP1 (Host)
   - EX_DEV_UFP1 (Hub)

D. Repetitions:
   - Repeat with the following Control Packets:
     - Hot Plug Event Packet
     - Notification Packet with Even Code = ERR_LINK

E. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Tell the Exerciser to send the UUT a Control Packet with a bad CRC
5. Query the Exerciser to see if UUT sent a Response to the Control Packet
6. Verify that the UUT did not respond to the Control Packet (6.4.4#1)
7. Stop Analyzer

TD 6.5 Notification Acknowledgement Test (Hosts and Hubs Only)

Note: This test is performed on each DFP of the UUT.

A. Purpose:
    - Verify that the UUT resends a Notification Packet that requires a Notification Acknowledgement Packet
    - Verify that the UUT uses timeout specified in Notification Timeout field
B. Asserts:
    - 6.6#1
C. Test Setup:
    - EX_HOST_DFP1 (Host DFP)
    - EX_HUB_DFP1 (Hub DFP)
D. Repetitions:
    - Repeat with *Notification Timeout* field set to:
        - 0x0A (default)
        - 0x01 (minimum value)
        - 0xFF (maximum value)
E. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Reset UUT
2. Enumerate UUT

Part 1 – ERR_LINK

3. Configure UUT with:
    a. *OSE* bit in the *Logical Layers Enable* field set to 1b
    b. *HEC Error Enable* bit = 1b
    c. *Notification Timeout* field = (see repetitions)
4. Tell Exerciser to send an Ordered Set with unknown contents
5. Wait for UUT to send a Notification Packet with Event Code = ERR_LINK
6. Do not send a Notification Acknowledgement Packet
7. Wait for Notification Timeout to expire
8. Verify that the UUT resends ERR_LINK Notification Packet after timeout expires (6.6#1)
9. Send a Notification Acknowledgement Packet for the ERR_LINK Notification Packet

Part 2 – ERR_HEC

10. Reset UUT
11. Configure UUT with:
    a. *OSE* bit in the *Logical Layers Enable* field set to 1b
    b. *HEC Error Enable* bit = 1b
    c. *Notification Timeout* field = (see repetitions)
12. Tell Exerciser to send a Control Packet with a multi-bit HEC error
13. Wait for UUT to send a Notification Packet with Event Code = ERR_HEC
14. Do not send a Notification Acknowledgement Packet
15. Wait for Notification Timeout to expire
16. Verify that the UUT resends Notification Packet after timeout expires (6.6#1)
17. Send a Notification Acknowledgement Packet for the ERR_HEC Notification Packet

TD 6.6 Hot Plug Event Acknowledgement Test (Hosts and Hubs Only)

Note: This test is performed on each DFP of the UUT.

A. Purpose:
   - Verify that the UUT resends a Hot Plug Event Packet if it does not receive a Hot Plug Acknowledgement Packet within timeout

B. Asserts:
   - 6.8#1-4, 6.8#6, 6.8#7

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_DFP1 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT

Part 1 – Single Hot Plug

3. Do not send a Hot Plug Acknowledgement Packet
4. Verify that the UUT resends the Hot Plug Event Packet (6.8#1)
5. Send the UUT a Hot Plug Acknowledgement Packet
6. Verify that the UUT does not send another Hot Plug Event Packet with UPG=0 (6.8#4)

   Note: After receiving the Hot Plug Acknowledgement packet, the UUT is allowed (but not required) to send a Hot Plug Event Packet with UPG=1, followed by a Hot Plug Event with UPG=0.

7. If the UUT sends any additional Hot Plug Event Packets, send a Hot Plug Acknowledgement Packet to UUT for each Hot Plug Event Packet

Part 2 – Multiple Hot Plugs (if UUT has two or more DFPs)

8. Disconnect the Compliance Device
9. Wait for a Hot Plug Event Packet with UPG=1 from the UUT
10. Send a Hot Plug Acknowledgement Packet to the UUT
11. Connect the Compliance Device
12. Wait for a Hot Plug Event Packet with UPG=0 from the UUT
13. Do not send a Hot Plug Acknowledgement Packet
14. Connect a second Compliance Device to a DFP of the UUT
15. Verify that UUT does not send a Hot Plug Event Packet for the second Compliance Device (6.8#2)
16. Wait for the UUT to retry the first Hot Plug Event Packet
17. Send a Hot Plug Acknowledgement Packet
18. Verify that the UUT sends a Hot Plug Event Packet for the second Compliance Device (6.8#2)
19. Disconnect the second Compliance Device
20. Wait for a Hot Plug Event Packet with UPG=1 from the UUT
21. Do not send a Hot Plug Acknowledgement Packet
22. Disconnect the first Compliance Device
23. Verify that UUT does not send a Hot Plug Event Packet for the first Compliance Device (6.8#3)
24. Wait for the UUT to retry the Hot Plug Event Packet for the second Compliance Device
25. Send a Hot Plug Acknowledgement Packet
26. Verify that the UUT sends a Hot Plug Event Packet for the first Compliance Device (6.8#3)

TD 6.7 Uninitialized Router Hot Plug Test (Hosts and Hubs Only)

Note: This test is performed on each DFP of the UUT.

A. Purpose:
   - Verify that uninitialized Router does not send Hot Plug Event Packet until after it is enumerated

B. Asserts:
   - 6.8.1.2#1

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_DFP1 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Do not enumerate the UUT

Part 1 – Plug then Unplug

4. Connect the Compliance Device
5. Verify that the UUT does not send a Hot Plug Event Packet (6.8.1.2#1)
6. Disconnect the Compliance Device
7. Verify that the UUT does not send a Hot Plug Event Packet (6.8.1.2#1)

Part 2 – Plug then Enumerate

8. Connect the Compliance Device
9. Verify that the UUT does not send a Hot Plug Event Packet (6.8.1.2#1)
10. Enumerate the UUT
11. Verify that the UUT sends a Hot Plug Event Packet with UPG=0 (6.8.1.2#1)

TD 6.8 Control Packet Forwarding Timing Test (Hubs Only)

Note: This test is performed on each DFP of the UUT.

A. Purpose:
    - Verify that the UUT forwards a Control Packet within tCPForward time

B. Asserts:
    - 6.4.4#4

C. Test Setup:
    - AN_HUB_DFP1 (Hub)

D. Repetitions:
    - Repeat with the following Control Packets:
        - Read Request
        - Write Request

E. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
2. Enumerate UUT
3. Start Analyzer on both Upstream Link and Downstream Link

    Note: Analyzers will need to have common notion of time so that time stamps between the two are consistent

4. Send a Control Packet to the Compliance Device (see repetitions)
5. Wait for the Compliance Device to send a Response
6. Stop the Analyzers
7. Parse Analyzer traces
8. Compare timestamp of when a Control Packet was received by the UUT and when it was forwarded by the UUT
9. Verify that the UUT forwarded each Control Packet within tCPForward (500 µs) of receiving it (6.4.4#4)

TD 6.9 Max Length Read/Write Test

A. Purpose:
  - Verify that the UUT handles Read Requests correctly
  - Verify that the UUT handles Write Requests correctly

B. Asserts:
  - 6.4.2.4#3, 6.4.2.4#9
  - 6.4.2.6#3

C. Test Setup:
  - AN_HOST_DFP1 (Host)
  - AN_HUB_UFP2 (Hub)
  - AN_DEV_UFP1 (Device)

D. Repetitions:
  - Repeat Part 1 and 2 with the following targets:
    - Router Configuration Space Basic Attributes
      - Read Size/Write Size = 27 (all registers)
      - Configuration Space = 10b (Router)
      - Target Field = Data[0-15]
    - The USB4 Port Capability in each Lane 0 Adapter
      - Read Size/Write Size = 20 (all registers)
      - Configuration Space = 01b (Adapter)
      - Target Field = Data[0-15]
  - If the UUT is TBT3-Compatible, repeat Part 1 and 2 with the following target:
    - VSEC6 USB4 Port Region
      - Read Size/Write Size = 60 (first 60 registers)
      - Configuration Space = 10b (Router)
      - Target Field = Enable Wake on Inter-Domain

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Max Length Read

4. Send the UUT a Read Request (see repetitions)
5. Verify that:
    a. UUT sends a Read Response (6.4.3.3#14)
    b. The *Read Size* field in the Read Response is the same as in the Read Request (6.4.2.4#3)
    c. Read Data in Read Response is *Read Size* DW in length (6.4.2.4#9)
6. Record the value of the Target Field (see repetitions)

Part 2 – Max Length Write

7. Send the UUT a Write Request (see repetitions)
    a. Target will be the same as in Part 1
    b. *Write Data* inverses the value of Target Field that was read in Part 1 (e.g. if value read was 0101 1111b, inverse is 1010 0000b)

8. Verify that:
    a. UUT sends a Write Response (6.4.3.3#14)
    b. The Write Size field in the Write Response is the same as in the Write Request (6.4.2.6#3)
9. Send the UUT a Read Request that targets the Configuration Space that was just written to
10. Wait for a Read Response from the UUT
11. Verify that the value in the Target Field matches what was written by the Write Request in Step 7 (6.4.3.3#14)

Register Tests

Unless otherwise noted, the tests in this section are performed once per Router.

TD 8.1 Default Router Configuration Space Test

A. Purpose:
   - Verify that Router Configuration Space contains proper default values

B. Asserts:
   - 8.2#4
   - 8.2.1#1, 8.2.1#2, 8.2.1#4
   - 8.2.1.1#2, 8.2.1.1#4, 8.2.1.1#8-10, 8.2.1.1#16, 8.2.1.1#17, 8.2.1.1#24, 8.2.1.1#25
   - 8.2.1.2#1, 8.2.1.2#2, 8.2.1.2#3, 8.2.1.2#4
   - 8.2.1.3#1, 8.2.1.3#2, 8.2.1.3#3, 8.2.1.3#4
   - 8.2.1.4#1, 8.2.1.4#2, 8.2.1.4#4, 8.2.1.4#5, 8.2.1.4#6

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)
   - AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

2. Start Analyzer
3. Reset UUT
   a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values

~~3.~~4. Do not enumerate UUT

~~4.~~5. Do not write to any fields in UUT Configuration Space

~~5.~~6. Download the USB-IF list of VIDs from www.usb.org

~~6.~~7. Read the full Router Configuration Space of the UUT

~~7.~~8. Verify that:
   a. UUT has a TMU Router Configuration Capability (8.2.1#2)
   b. The TMU Router Configuration Capability is the first Capability (8.2.1#4)
   c. If the UUT has any Vendor Specific Capabilities, they come after the TMU Router Configuration Capability (8.2.1#4)
   d. If the UUT has any Vendor Specific Extended Capabilities, they come after the Vendor Specific Capabilities (8.2.1#4)
   e. UUT does not have any undefined Capabilities

~~8.~~9. Verify the following for the Basic Configuration Registers: (8.2#4, 8.2.1#1)
   a. *Vendor ID* field contains:
      i. Router Silicon vendor's VID (8.2.1.1#2) (See VIF)
   b. Next Capability Pointer points to the TMU Router Configuration Capability (8.2.1.1#4)
   c. *Depth* field is set to 0
   d. *TopologyID Low* field is 0
   e. *TopologyID High* field is 0
   f. *Topology Valid* bit is 0
   g. *Notification Timeout* field is 0Ah
   h. *Connection Manager USB4 Version* field is 0
   i. *USB4 Version* field is 20h (8.2.1.1#8)

j. *Enter Sleep* bit is 0
k. *Enable Wake on PCIe* is 0 (8.2.1.1#9)
l. *Enable Wake on USB3* is 0 (8.2.1.1#10)
m. *PCIe Tunneling On* bit is 0
n. *Internal Host Controller On* bit is 0
o. *Configuration Valid* bit is 0
p. *TBT3 Not Supported* bit is 1b if Router does not support TBT3-Combatibility (8.2.1.1#15) (see VIF)
q. *TBT3 Not Supported* bit is 0b if Router supports TBT3-Combatibility (8.2.1.1#16) (see VIF)
r. *Data*[0] through *Data* [15] are 0
s. *Metadata* field is 0
t. *Opcode* field in 0
u. *Status* field is 0
v. *Operation Not Supported* field is 0
w. *Operation Valid* field is 0

~~9.~~10. Verify the following for the TMU Router Configuration Capability: (8.2#4, 8.2.1#1, 8.2.1.2#1)
   a. If UUT does not have any Vendor Specific Capabilities, *Next Capability Pointer* is 00h (8.2.1.2#2, 8.2.1.2#3)
   b. *Capability ID* is 03h (8.2.1.2#4)
   c. *Freq Measurement Window* is 800
   d. *Inter-Domain Enable* bit is 0
   e. *TSPacketInterval* field is 0
   f. *FreqAvgConst* field is 8
   g. *DelayAvgConst* is 8
   h. *OffsetAvgConst* is 8
   i. *ErrorAvgConst* is 8
   j. *TSInterDomainInterval* is 0

~~10.~~11. Verify the following for any Vendor Specific Capabilities: (8.2.1.3#1)
   a. *Next Capability Pointer* points to another Vendor Specific Capability, a Vendor Specific Extended Capability, or is 00h (8.2.1.3#2, 8.2.1.3#3)
   b. *Capability ID* field is 05h (8.2.1.3#4)

~~11.~~12. Verify the following for any Vendor Specific Extended Capabilities: (8.2.1.4#1)
   a. *Capability ID* field is 05h (8.2.1.4#2)
   b. *VSEC Header* is 00h (8.2.1.4#4)
   c. *Next Capability Pointer* points to another Vendor Specific Extended Capability or is 00h (8.2.1.4#5, 8.2.1.4#6)

~~12.~~13. Verify that all Rsvd and RsvdZ bits and fields in Router Configuration Space are 0

~~13.~~14. Stop Analyzer

TD 8.2 Default Adapter Configuration Space Test

A. Purpose:
- Verify that Adapter Configuration Space contains proper default values

B. Asserts:
- 8.2#4
- 8.2.2#2-19
- 8.2.2.1#1-9, 8.2.2.1#11-14, -8.2.2.1#17, 8.2.2.1#19
- 8.2.2.2#4-6
- 8.2.2.2#1-4
- 8.2.2.3#1-5, 8.2.2.3#11-13, 8.2.2.3#19-22
- 8.2.2.4#1-4, 8.2.2.4#19-20
- 8.2.2.5#1-4, 8.2.2.5#8, 8.2.2.5#10, 8.2.2.5#12, 8.2.2.5#14, 8.2.2.5#16-17
- 8.2.2.6#1-6, 8.2.2.6#9-10, 8.2.2.6#15, 8.2.2.6#19, 8.2.2.6#21-23, 8.2.2.6#28, 8.2.2.6#30
- 8.2.2.7#1-4

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Repetitions:
- Repeat for Adapter Numbers 1 through *Max Adapter*

Note: Only need to perform setup once at beginning of test repetitions

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
   a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values

~~2.~~3. Enumerate UUT
~~3.~~4. Do not write to any fields in Adapter Configuration Space of the PUT
~~4.~~5. Read the *Max Adapter* field from Router Configuration Space of the UUT
~~5.~~6. Read the *Current Link Speed* and *Negotiated Link Width* fields from the Adapter Configuration Space of the Adapters in the Compliance Device that are connected to the PUT Adapters.

Part 1 – Adapter Configuration Space Verification

~~6.~~7. Send a Read Request to the Adapter (see repetitions for Adapter Number) that reads the Basic Configuration Registers in Adapter Configuration Space
~~7.~~8. End test repetition here and move on to next Adapter Number if either of the following occur:
   a. *Adapter Type* = Unsupported Adapter
   b. UUT returns a Notification Packet with Event Code = ERR_ADDR

~~8.~~9. Read the all the Configuration Capabilities in Adapter Configuration Space
~~9.~~10. If Adapter is a Host Interface Adapter, verify that it does not have any Configuration Capabilities. (8.2.2#5, 8.2.2#6, 8.2.2#8, 8.2.2#10, 8.2.2#12, 8.2.2#14, 8.2.2#16, 8.2.2#18)
~~10.~~11. If Adapter is a Lane Adapter, verify that:
   a. It has a TMU Adapter Configuration Capability (Capability ID = 03h) (8.2.2#5)
   b. It has a Lane Adapter Configuration Capability (Capability ID = 01h) (8.2.2#7)

    c. It does not have any other Adapter Configuration Capabilities (8.2.2#12, 8.2.2#14, 8.2.2#16, 8.2.2#18)
    d. If Adapter is a Lane 0 Adapter, it has a USB4 Port Capability (Capability ID = 06h) (8.2.2#9)

~~11.~~12. If Adapter is a DP IN Adapter, verify that:

    a. It has a DP IN Adapter Configuration Capability (Capability ID = 04h) (8.2.2#13)
    b. It does not have a TMU Adapter Configuration Capability (Capability ID = 03h) (8.2.2#6)
    c. It does not have a Lane Adapter Configuration Capability (Capability ID = 01h) (8.2.2#8)
    d. It does not have a USB4 Port Configuration Capability (Capability ID = 06h) (8.2.2#10)
    e. It does not have any other Adapter Configuration Capabilities (8.2.2#12, 8.2.2#16, 8.2.2#18)

~~12.~~13. If Adapter is a DP OUT Adapter, verify that:

    a. It has a DP OUT Adapter Configuration Capability (Capability ID = 04h) (8.2.2#15)
    b. It does not have a Lane Adapter Configuration (Capability ID = 01h) (8.2.2#8)
    c. It does not have a USB4 Port Configuration Capability (Capability ID = 06h) (8.2.2#10)
    d. It does not have any other Adapter Configuration Capabilities (8.2.2#12, 8.2.2#14, 8.2.2#18)

~~13.~~14. If Adapter is a USB3 Adapter, verify that:

    a. It has a USB3 Adapter Configuration Capability (Capability ID = 04h) (8.2.2#17)
    b. It does not have a TMU Adapter Configuration Capability (Capability ID = 03h) (8.2.2#6)
    c. It does not have a Lane Adapter Configuration (Capability ID = 01h) (8.2.2#8)
    d. It does not have a USB4 Port Configuration Capability (Capability ID = 06h) (8.2.2#10)
    e. It does not have any other Adapter Configuration Capabilities (8.2.2#12, 8.2.2#14, 8.2.2#16)

~~14.~~15. If Adapter is a PCIe Adapter, verify that:

    a. It has a PCIe Adapter Configuration Capability (Capability ID = 04h) (8.2.2#11)
    b. It does not have a TMU Adapter Configuration Capability (Capability ID = 03h) (8.2.2#6)
    c. It does not have a Lane Adapter Configuration (Capability ID = 01h) (8.2.2#8)
    d. It does not have a USB4 Port Configuration Capability (Capability ID = 06h) (8.2.2#10)
    e. It does not have any other Adapter Configuration Capabilities (8.2.2#14, 8.2.2#16, 8.2.2#18)

~~15.~~16. If the UUT has any Vendor Specific Capabilities, verify that they come after the required capabilities

~~16.~~17. If the UUT has any Vendor Specific Extended Capabilities, verify that they come after any Vendor Specific Capabilities

~~17.~~18. Verify the following for the Basic Configuration Registers: (8.2#4, 8.2.2.1#1)

    a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.1#2)
    b. *Max Counter Sets* field is 0 if Counters Configuration Space Flag is 0b (8.2.2.1#3, 8.2.2.1#5)
    c. *Max Counter Sets* field is 1 or higher if *Counters Configuration Space Flag* is 1b (8.2.2.1#4, 8.2.2.1#5)
    d. *Adapter Type*, *Sub-Type*, *Adapter Type*, *Version*, and *Adapter Type Protocol* fields do not contain undefined values (see Table 8-10 in USB4 Base Spec) (8.2.2.1#6, 8.2.2.1#7, 8.2.2.1#8)
    e. Bits 24-31 in DW2 are 01h (8.2.2.1#9)
    f. If Adapter is a Lane 1 Adapter:
        i. *HEC Error* field is 0 (8.2.2.1#11)
        ii. *Flow Control Error* field is 0 (8.2.2.1#13)
        iii. *Shared Buffering Capable* bit is 0 or an (8.2.2.1#17)
    g. If Adapter is a Protocol Adapter:
        i. *HEC Error* field is 0 (8.2.2.1#12)
        ii. *Flow Control Error* field is 0 (8.2.2.1#14)
        iii. *Plugged* bit is 0 (8.2.2.1#19)
    h. *Non-Flow Controlled Buffers* field is set to 0
    i. *Link Credits Allocated* field is 0

j. *HEC Error Enable* field is 0
k. *Flow Control Error Enable* field is 0
l. *Disable Hot Plug Events* field is 0

~~18.~~19. Verify the following for a TMU Adapter Configuration Capability: (8.2#4, 8.2.2.2#1)

a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.2#4, 8.2.2.2#5)
b. *Capability ID* is 03h (8.2.2.2#6)
c. *EnableUniDirectionalMode* bit is 0
d. *Inter-Domain Time Responder* bit is 0
e. *Inter-Domain Time Initiator* bit is 0
f. *RX TSNOS Counter* bit is 0
g. *TX TSNOS Counter* bit is 0
h. *RX Packet Counter* bit is 0
i. *TX Packet Counter* bit is 0
j. *Lost TSNOS Counter* is 0
k. *Lost Packet Counter* is 0
l. *Bad Packet Counter* is 0

~~19.~~20. Verify the following for a Lane Adapter Configuration Capability: (8.2#4, 8.2.2.3#1)

a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.3#2, 8.2.2.3#3)
b. *Capability ID* is 01h (8.2.2.3#4)
c. If UUT is not a Hub Router:
   i. *Supported Link Speeds* field indicates support for Gen 3 (bit 19 in DW0 is 1b) if Gen 3 speed is supported (8.2.2.3#5)
   ii. *Supported Link Speeds* field does not indicate support for Gen 3 (bit 19 in DW0 is 0b) if Gen 3 speed is not supported (8.2.2.3#5)
   iii. *Supported Link Speeds* field indicates support for Gen 2 (bit 18 in DW0 is 1b) (8.2.2.3#6)
d. If UUT is a Hub Router:
   i. *Supported Link Speeds* field indicates support for Gen 3 (bit 18 in DW0 is 1b) (8.2.2.3#7)
   ii. *Supported Link Speeds* field indicates support for Gen 2 (bit 19 in DW0 is 1b) (8.2.2.3#8)
e. If Adapter is a Lane 1 Adapter, the value in the *Supported Link Speeds* field is the same as the Lane 0 Adapter (8.2.2.3#9)
f. Rsvd bits in the *Supported Link Speeds* field (bits 16-17 in DW0) are 0 (8.2.2.3#5, 8.2.2.3#9)
g. *Supported Link Widths* field indicates support for x1 Link width (bit 20 in DW0 is 1b) (8.2.2.3#11)
h. *Supported Link Widths* field indicates support for x2 Link width (bit 21 in DW0 is 1b) (8.2.2.3#12)
i. If Adapter is a Lane 1 Adapter, the value in the *Supported Link Widths* field is the same as the Lane 0 Adapter (8.2.2.3#13)
j. Rsvd bits in the *Supported Link Widths* field (bits 22-25 in DW0) are 0 (8.2.2.3#10)
k. *Target Link Width* field is set to 000 01h
l. *CL0s Enable* bit set to 0
m. *CL1 Enable* bit set to 0
n. *CL2 Enable* bit set to 0
o. *Lane Disable* bit is 0
p. *Lane Bonding* bit is 0

q. *Current Link Speed* field is the same as read from the Compliance Device (8.2.2.3#19)
r. If Adapter is a Lane 1 Adapter, the *Current Link Speed* field is the same as in the Lane 0 Adapter. (8.2.2.3#20)
s. *Negotiated Link Width* field is the same as read from the Compliance Device (8.2.2.3#21)
t. If Adapter is a Lane 1 Adapter, the *Negotiated Link Width* field is the same as in the Lane 0 Adapter. (8.2.2.3#22)
u. *PM Secondary* bit is 1b
v. *Logical Layer Errors Enable* field is 00h

~~20.~~21. Verify the following for a USB4 Port Capability: (8.2#4, 8.2.2.4#1)

a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.4#2, 8.2.2.4#3)
b. *Capability ID* is 06h (8.2.2.4#4)
c. *Address* field is 0
d. *Length* field is 0
e. *Target* field is 0
f. *Retimer Index* field is 0
g. *WnR* field is 0
h. *No Response* field is 0
i. *Result Code* field is 0
j. *Pending* bit is 0
k. *Data* [15:0] are 0
l. If Link is Gen 2 speed:
    i. *RS-FEC Enabled (Gen 2)* bit is 1 (8.2.2.4#19)
    ii. *RS-FEC Enabled (Gen 3)* bit is 0 (8.2.2.4#20)
m. If Link is Gen 3 speed:
    i. *RS-FEC Enabled (Gen 2)* bit is 0 (8.2.2.4#19)
    ii. *RS-FEC Enabled (Gen 3)* bit is 1 (8.2.2.4#20)
n. *Downstream Port Reset* bit is 0
o. *Request RS-FEC Gen 2* bit is 1
p. *Request RS-FEC Gen 3* bit is 1
q. *USB4 Port is Configured* bit is 0
r. *USB4 Port is Inter-Domain* bit is 0
s. *Enable Wake on Connect* bit is 0
t. *Enable Wake on Disconnect* bit is 0
u. *Enable Wake on USB4 Wake* bit is 0
v. *Enable Wake on Inter-Domain* bit is 0

~~21.~~22. Verify the following for a USB3 Adapter Configuration Capability: (8.2#4, 8.2.2.5#1)

a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.5#2, 8.2.2.5#3)
b. *Capability ID* field is 04h (8.2.2.5#4)
c. *Valid* bit is 0
d. *Path Enable* bit is 0
e. If UUT is a Device Router:
    i. *Consumed Upstream Bandwidth* field is 0 (8.2.2.5#8)
    ii. *Consumed Downstream Bandwidth* field is 0 (8.2.2.5#10)
    iii. *Host Controller Ack* bit is 0 (8.2.2.5#12)
    iv. *Allocated Upstream Bandwidth* field is 0 (8.2.2.5#14)
    v. *Allocated Downstream Bandwidth* field is 0 (8.2.2.5#16)
    vi. *Connection Manger Request* bit is 0b
    vii. *Scale* bit is 0 (8.2.2.5#17)
f. If UUT is Host Router:
    i. *Connection Manger Request* bit is 0b

ii. *Scale* bit is 0b

~~22.~~23. Verify the following for a DP IN Configuration Capability: (8.2#4, 8.2.2.6#1)
  a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.6#3, 8.2.2.6#4)
  b. *Capability ID* field is 04h (8.2.2.6#5)
  c. *Video HopID* field is 9 (8.2.2.6#6)
  d. *AUX Enable* bit is 0
  e. Video Enable bit is 0
  f. *AUX Tx HopID* field is 8 (8.2.2.6#9)
  g. *AUX Rx HopID* field is 8 (8.2.2.6#10)
  h. *SW Link Init* bit is 0
  i. *HPD Output Clear* bit is 0
  j. *HPD Output Set* bit is 0
  k. In the DP_LOCAL_CAP register (DW4):
    i. *Protocol Adapter Version* field is 4h (8.2.2.6#15, 8.2.2.6#19)
    ii. *Maximal DPCD Rev* field is a value between 0 and 3 (inclusive)
    iii. *Maximal Link Rate* field is a value between 0 and 3 (inclusive)
    iv. *Maximal Lane Count* field is a value between 0 and 2 (inclusive)
  l. DP_REMOTE_CAP register (DW5) is 0
  m. DP_STATUS register (DW6) is 0
  n. DP_COMMON_CAP register (DW7) is 0

~~23.~~24. Verify the following for a DP OUT Adapter Configuration Capability: (8.2#4, 8.2.2.6#2)
  a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.6#21, 8.2.2.6#22)
  b. *Capability ID* field is 04h (8.2.2.6#23)
  c. *Video HopID* field is 9 (8.2.2.6#24)
  d. *AUX Enable* bit is 0
  e. *Video Enable* bit is 0
  f. *AUX Tx HopID* field is 8 (8.2.2.6#26)
  g. *AUX Rx HopID* field is 8 (8.2.2.6#27)
  h. *SW Link Init* bit is 0In the DP_LOCAL_CAP register (DW4):
    i. *Protocol Adapter Version* field is 4h (8.2.2.6#30, 8.2.2.6#34)
    ii. *Maximal DPCD Rev* field is a value between 0 and 3 (inclusive)
    iii. *Maximal Link Rate* field is a value between 0 and 3 (inclusive)
    iv. *Maximal Lane Count* field is a value between 0 and 2 (inclusive)
    v. Bit 23 is 1
  i. DP_REMOTE_CAP register (DW5) is 0
  j. DP_STATUS register (DW6) is 0
  k. DP_COMMON_CAP register (DW7) is 0

~~24.~~25. Verify the following for a PCIe Adapter Configuration Capability: (8.2#4, 8.2.2.7#1)
  a. *Next Capability Pointer* points to another Adapter Configuration Capability or is 00h (8.2.2.7#2, 8.2.2.7#3)
  b. *Capability ID* set to 04h (8.2.2.7#4)
  c. *Path Enable* bit set to 0

~~25.~~26. Verify that all Rsvd and RsvdZ bits and fields are 0

~~26.~~27. Stop Analyzer

TD 8.3 Lane Adapter Lock Test (Hosts and Hubs Only)

A. Purpose:
   - Verify that the UUT correctly sets Lock bit

B. Asserts:
   - 8.2.2.1#20

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)

D. Repetitions:
   - Repeat for each DFP on the UUT

E. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the *Lock* bit in the Adapter Configuration Space of the target DFP
5. Verify that the Lock bit is 1b (8.2.2.1#20)
6. Send a Read Request to the Compliance Device
7. Wait for UUT to send a Notification Packet with Event Code= ERR_LOCK
8. Set the *Lock* bit to 0b in the Adapter Configuration Space of the target DFP
9. Send a Read Request to the Compliance Device
10. Verify a Read Response is received from the Compliance Device
11. Disconnect the Compliance Device from the target DFP
12. Read the *Lock* bit from the Adapter Configuration Space of the target DFP
13. Verify that the *Lock* bit is 1b (8.2.2.1#20)
14. Write 0b to the *Lock* bit in the Adapter Configuration Space of the target DFP
15. Read the *Lock* bit from the Adapter Configuration Space of the target DFP
16. Verify that the *Lock* bit is 1b (8.2.2.1#20)
17. Stop Analyzer

TD 8.4 Path 0 Configuration Space Test

Note: This test is only performed once on the UUT.

A. Purpose:
   - Verify that Path Configuration Space entry for Path 0 is implemented correctly
   - Verify that the Counter Configuration Space for Path 0 is correctly implemented

B. Asserts:
   - 8.2.3.1#1, 8.2.3.1#3

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)
   - AN_DEV_UFP1 (Device)

D. Repetitions:
   - Repeat for each Lane Adapter in the UUT
   - If UUT is a Host Router, repeat for the Host Interface Adapter

Note: Only need to perform setup once at beginning of test repetitions.

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset PUT
3. Enumerate UUT
4. Do not write to any fields in Path Configuration Space

Part 1 – Path Configuration Space

5. Read the Path Configuration Space entry for Path 0 in each Lane Adapter
6. If UUT is a Host Router, read the Path Configuration Space entry for Path 0 in the Host Interface Adapter.
7. Verify that the UUT sends a Read Response for each Read to Path Configuration Space (8.2.3.1#1)
8. Verify that the *Valid* bit is 1b in each Path 0 entry.

Part 2 – Counter Configuration Space (if UUT implements Counters Configuration Space)

9. In the Path 0 Entry:
   a. Set the *Counter ID* field (see repetitions)
   b. Set the *Counters Enable* bit to 1b
10. Send 5 Read Requests and 5 Write Requests
11. Read the Counter Set from Path Configuration Space and verify that:
    a. *Received Packet* field = 10 (8.2.3.1#3)
    b. *Dropped Packets* field = 0 (8.2.3.1#3)
12. Stop Analyzer

TD 8.5 Lane Adapter Default Path Configuration Space Test

A. Purpose:
- Verify that Path Configuration Space entries for all Paths contain default values

B. Asserts:
- 8.2#4
- 8.2.3.2#1
- 8.2.3.3#1-3

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
    a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values

~~2.~~3. Enumerate UUT

~~3.~~4. Do not write to any fields in Path Configuration Space

Part 1 – Lane Adapter Configuration Space

~~4.~~5. For each Lane Adapter:
    a. Read the *Max Input HopID* field from Adapter Configuration Space
    b. Read the Path Configuration Space entries for Paths 8 through *Max Input HopID*
    c. Verify that the UUT returns Read Data for all the Path entries (length = 2 * number of entries) (8.2.3.2#1)
    d. Verify that the *Valid* bit is 0b (default value) (8.2#4)

~~5.~~6. Stop Analyzer

TD 8.6 Protocol Adapter Default Path Configuration Space Test

Note: This test is only performed once on the UUT.

A. Purpose:
- Verify that Path Configuration Space for an Adapter contains proper default values

B. Asserts:
- 8.2#4, 8.2.3.3#1-3

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Repetitions:
- Repeat for each Protocol Adapter in the UUT

Note: Only need to perform setup once at beginning of test repetitions

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset ~~PUT~~UUT
   a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values

~~2.~~3. Enumerate UUT

~~3.~~4. Do not write to any fields in Path Configuration Space

Part 1 – Path Configuration Space

~~4.~~5. Read the *Max Input HopID* field from Adapter Configuration Space of each Protocol Adapter

~~5.~~6. For a Host Interface Adapter (Host Router only):
   a. Read the Path Configuration Space entries for Paths 1 to *Max Input HopID*
   b. Verify that the UUT returns Read Data for all the Path entries (length = 2 * number of entries) (8.2.3.3#1)

~~6.~~7. For a PCIe, DP, or USB3 Adapter:
   a. Read the Path Configuration Space entries for Paths 8 through *Max Input HopID*
   b. Verify that the UUT returns Read Data for all the Path entries (length = 2 * number of entries) (8.2.3.3#2)

~~7.~~8. Verify that the *Valid* bit in each entry is 0b (default value) (8.2#4)

~~8.~~9. Stop Analyzer

TD 8.7 Reserved

TD 8.8 Reserved

TD 8.9 Reserved

TD 8.10 Reserved

TD 8.11 Counters Configuration Space Test

A. Purpose:

- Verify that Counter Configuration Space has the correct default values
- Verify that the counters in Counter Configuration Space function increment correctly
- Verify that counters in Counters Configuration Space only increment when enabled

B. Asserts:

- 8.2#4,
- 8.2.2.1#5
- 8.2.3.2#4
- 8.2.4#1-7

C. Test Setup:

- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Repetitions:

- Repeat Part 1 for all Adapters in UUT that support Counters Configuration Space
- Repeat Part 2 and Part 3 for all Lane Adapters in UUT that support Counters Configuration Space
- Repeat Part 2 and Part 3 with the loopback Path using *Counter ID* = 0 through *Counter ID* = (*Max Counter Sets* – 1) (8.2.4#2)

Note: Only need to perform setup once at beginning of test repetitions.

E. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

2. Start Analyzer
3. Reset UUT
    a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values
~~3.~~4. Enumerate UUT
~~4.~~5. For each Adapter in UUT:
    a. Read the *CCS Flag* and *Max Counter Sets* field in Adapter Configuration Space
    b. If *CCS Flag* = 0b, Adapter does not support Counters Configuration Space and test is not performed for Adapter

Part 1 – Default Values

~~5.~~6. Send a Read Request to the UUT that reads Counter Sets 0 through (*Max Counter Sets* – 1)
~~6.~~7. Verify that all 3 DW in each Counter Set are 0 (8.2#4)

Part 2 – Counter Disabled (Host and Hub Only)

~~7.~~8. Set up a loopback Path with the following:
    a. *Counter Enable* bit = 0b
    b. *Counter ID* field = 0b
    c. Buffer scheme = dedicated
~~8.~~9. Send 100 Tunneled Packets on the loopback Path
~~9.~~10. Read Counter Set 0 from Path Configuration Space and verify that:
    a. Received Packet field = 0
    b. Dropped Packets field = 0
~~10.~~11. Tear down the loopback Path

Part 3 – Counter Enabled (Host and Hub Only)

~~11.~~12. Set up a loopback Path through the Adapter with the following:
   a. Counter Enable bit = 1b
   b. *Counter ID* field = 0b
   c. Buffer scheme = dedicated

~~12.~~13. Send 100 Tunneled Packets on the loopback Path

~~13.~~14. Read Counter Set 0 from Path Configuration Space and verify that:
   a. *Received Packet* field = 100 (8.2.3.2#4, 8.2.4#7)
   b. *Dropped Packets* field = 0 (8.2.3.2#4)

~~14.~~15. Tear down the loopback Path

~~15.~~16. Stop Analyzer

TD 8.12 SB Register Read/Write Test

A. Purpose:
- Verify that the UUT performs SB Register Read when initiated by a Connection Manager
- Verify that the UUT performs SB Register Write when initiated by a Connection Manager

B. Asserts:
- 8.2.2.4#5-7, 8.2.2.4#10-13
- 8.2.2.4#9-12

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Repetitions:
- Repeat Part 1 and Part 2 with the following values in the *Target* field in the USB4 Port Capability:
  - 000b (UUT)
  - 001b (Link Partner)

E. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Write

4. Write the following to the USB4 Port Capability of the Lane 0 Adapter
   a. *Address* = 9 (Metadata)
   b. *Length* = 4 (bytes)
   c. *Target* = (see repetitions)
   d. *WnR* = 1b (Write)
   e. Data = FFFFh
5. Set the *Pending* bit to 1b in the USB4 Port Capability to initiate the write to SB Register Space
6. Poll the *Pending* bit and wait for the UUT to set it to 0b (8.2.2.4#11)
7. Read the USB4 Port Capability of the Lane 0 Adapter and verify the following:
   a. *Result Code* is 0 (success) (8.2.2.4#7, 8.2.2.4#10)
   b. *No Response* bit it is 0b
   c. *Length* is 4 (8.2.2.4#5)

Part 2 – Read

8. Write the following to the USB4 Port Capability of the Lane 0 Adapter
   a. *Address* = 9 (Metadata)
   b. *Length* = 4 (bytes)
   c. *Target* = (see repetitions)
   d. *WnR* = 0b (read)
9. Set the *Pending* bit to 1b in the USB4 Port Capability to initiate the read to SB Register Space
10. Poll the *Pending* bit and wait for the UUT to set it to 0b (8.2.2.4#11)
11. Read the USB4 Port Capability of the Lane 0 Adapter and verify the following:
    a. *Result Code* is 0 (success) (8.2.2.4#7, 8.2.2.4#10)
    b. *No Response* bit it is 0b
    c. *Length* is 4 (8.2.2.4#5)
    d. *Data* contains FFFFh (8.2.2.4#12, 8.2.2.4#13

Part 3 – No Response

12. Write the following to the USB4 Port Capability of the Lane 0 Adapter
    a. *Address field* = 0 (Vendor ID)
    b. *Length* = 4 (bytes)
    c. *Target* = 010b (Retimer)
    d. *WnR* = 0b (read)
    e. Retimer Index = 7
13. Set the *Pending* bit to 1b in the USB4 Port Capability to initiate a read from SB Register Space
14. Poll the *Pending* bit and wait for the UUT to set it to 0b (8.2.2.4#11)
15. Read the USB4 Port Capability and verify that the *No Response* bit it is 1b (8.2.2.4#6)
16. Stop Analyzer

Router Operation Tests

Unless otherwise noted, the tests in this section are performed once per Router.

TD 8.13 DP Tunneling Operations Test

Note: This test is only performed in the UUT has one or more DP Adapters

A. Purpose:
   - Verify that a Router with one or more DP IN Adapters supports DP Tunneling Operations
   - Verify that a Router without a DP IN Adapter handles DP Tunneling Operations correctly

B. Asserts:
   - 8.3.1.1.1#1-2
   - 8.3.1.1.2#1-3
   - 8.3.1.1.3#1-2

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)
   - AN_DEV_UFP1 (Device)

D. Repetitions:
   - Repeat for each DP Adapter

E. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Query DP Resource Availability

4. Initiate a QUERY_DP_RESOURCE_AVAILABILITY Operation
5. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
6. Verify that:
   a. *Operation Not Supported* bit is 0b (8.3.1.1.1#1)
   b. *Metadata* field value did not change (8.3.1.1.1#2)
   c. *Status* field is 0h or (8.3.1.1.1#2)

Part 2 – Allocate DP Resource

7. Initiate an ALLOCATE_DP_RESOURCE Operation
8. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
9. Verify that:
   a. *Operation Not Supported* bit is 0b (8.3.1.1.2#1)
   b. *Metadata* field value did not change (8.3.1.1.2#2)
   c. *Status* field is 0h (8.3.1.1.2#2)
10. Initiate a second ALLOCATE_DP_RESOURCE Operation that is identical to the first.
11. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
12. Verify that the *Status* field is 0h (8.3.1.1.2#3)

Part 3 – De-Allocate DP Resource

13. Initiate an DEALLOCATE_DP_RESOURCE_ Operation
14. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
15. Verify that:
    a. *Operation Not Supported* bit is 0b (8.3.1.1.3#1)
    b. *Metadata* field value did not change (8.3.1.1.3#12)
    c. *Status* field is 0h (8.3.1.1.3#2)

TD 8.14 NVM Operations Test

A. Purpose:
- Verify that a Device Router supports NVM Operations
- Verify that a Host Router handles NVM Operations correctly

B. Asserts:
- 8.3.1.2.1#1, 8.3.1.2.1#2
- 8.3.1.2.2#1, 8.3.1.2.2#3
- 8.3.1.2.3#1, 8.3.1.2.3#2
- 8.3.1.2.4#1, 8.3.1.2.4#2
- 8.3.1.2.5#1-3
- 8.3.1.2.6#1, 8.3.1.2.6#2

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – NVM Set Offset

4. Initiate a NVM_SET_OFFSET Operation
5. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
6. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.1#1)
7. If *Operation Not Supported* bit is 0b, verify that:
    a. *Metadata* field value did not change (8.3.1.2.1#2)
    b. *Status* field is 0h,(8.3.1.2.1#2)

Part 2 – NVM Write

8. Initiate a NVM_WRITE Operation
9. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
10. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.2#1)
11. If *Operation Not Supported* bit is 0b, *Status* field is 0h (8.3.1.2.2#3)

Part 3 – NVM Authenticate Write

12. Initiate a NVM_AUTHENTICATE_WRITE Operation
13. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
14. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.3#1)
15. If *Operation Not Supported* bit is 0b, *Status* field is a value between 0h and 3h (inclusive) (8.3.1.2.3#2)

Part 4 – NVM Read

16. Initiate a NVM_READ Operation
17. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
18. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.4#1)
19. If *Operation Not Supported* bit is 0b:
    a. *Metadata* field value did not change (8.3.1.2.4#2)
    b. *Status* field is 0h (8.3.1.2.4#2)

Part 5 – DROM Read

20. Initiate a DROM_READ Operation
21. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
22. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.5#1)
23. If UUT is a Standalone AIC Host Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.5#3)
24. If *Operation Not Supported* bit is 0b:
    a. Verify that the *Metadata* field value did not change (8.3.1.2.5#2)
    b. Verify that the *Status* field is 0h (8.3.1.2.5#2)
    a. Read the Data DW and parse according to the DROM Specification
    b. Verify that DROM contains an Unused Adapter Entry for each unused Adapter (see VIF)
    c. Verify that DROM contains a DP Adapter Entry for each DP Adapter (see VIF)
    d. Verify that the Vendor Name Entry contains the correct vendor name (See VIF)
    e. Verify that the Model Name Entry contain the correct Model Name (see VIF)
    f. Verify the following in the Product descriptor Entry:
        i. bcdUSBSpec field is 400h (USB4)
        ii. VID is correct (see VIF)
        iii. TID is correct (see VIF)
    g. If UUT is a hub, verify that it contains a USB Ports Mapping Entry

Part 6 – Get NVM Sector Size

25. Initiate a GET_NVM_SECTOR_SIZE Operation
26. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
27. If UUT is a Device Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.2.6#1)
28. If *Operation Not Supported* bit is 0b:
    a. *Metadata* field is a non-zero value (indicates sector size) (8.3.1.2.6#2)
    b. *Status* field is a value between 0h and 2h (inclusive) (8.3.1.2.6#2)

TD 8.15 Get PCIe Downstream Mapping Operation Test

A. Purpose:
   - Verify that a Router handles Get PCIe Downstream Mapping Operation correctly

B. Asserts:
   - 8.3.1.3.1#1-8

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)
   - AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the number of PCIe Bridges and PCIe Adapters from the VIF
5. Initiate a GET_PCIE_DOWNSTREAM_MAPPING Operation
6. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
7. If UUT supports PCIe Tunneling, verify that the *Operation Not Supported* bit is 0b (8.3.1.3.1#1)
8. If the *Operation Not Supported* bit is 1b, end test here
9. Else, if *Operation Not Supported* bit is 0b, continue test
10. Read the Total Number of Entries in the *Metadata* field (bits 7:0) and verify that:
    a. There is one entry per downstream PCIe Adapter (8.3.1.3.1#3)
    b. There is one entry per PCIe downstream Bridge (8.3.1.3.1#4)
11. Read the Entry Index in the *Metadata* field (bits 15:8) and verify that it is 0h (8.3.1.3.1#6)
12. Repeat the following N times, where N=Total Number of Entries returned by UUT:
    a. Initiate a GET_PCIE_DOWNSTREAM_MAPPING Operation
    b. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
    c. Verify that:
       i. Total Number of Entries in the *Metadata* field value did not change (8.3.1.3.1#2)
       ii. Entry Index in the *Metadata* field incremented up by 1 since the last GET_PCIE_DOWNSTREAM_MAPPING Operation (8.3.1.3.1#7)
       iii. *Status* field is 0h (8.3.1.3.1#2)
13. After completing the GET_PCIE_DOWNSTREAM_MAPPING Operation with Entry Index = (Total Number of Entries – 1), verify that the next Operation returns Entry Index = 0h (8.3.1.3.1#5, 8.3.1.3.1#8

TD 8.16 Get/Set Capabilities Operation Test

A. Purpose:
- Verify that a Router correctly handles Get Capabilities and Set Capabilities Operations

B. Asserts:
- 8.3.1.3.2#1-2, 8.3.1.3.2#4-7, 8.3.1.3.2#9-11
- 8.3.1.3.3#1-2, 8.3.1.3.3#4-6
- 6.8.1.1#3

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Disable Lane Initialization in Compliance Device

Part 1 – Read Capabilities

5. Initiate a GET_CAPABILITIES Operation with Capability Index = 0
6. Read the ROUTER_CS_25, ROUTER_CS_26 bytes, and Data DW 0 from Router Configuration Space
7. If the *Operation Not Supported* bit is 1b, end Part 1 and go to Part 2
8. If the *Operation Not Supported* bit is 0b, verify that:
    a. Max Capability Index in Metadata field (bits 7:0) is 1 (8.3.1.3.2#4)
    b. Capability Index in Metadata field (bits 15:8) is 0 (8.3.1.3.2#4)
    c. Capability Supported in Metadata field (bit 30) is 0 (8.3.1.3.2#5)
    d. Capability Enabled in Metadata field (bit 31) is 0 (8.3.1.3.2#6)
    e. Status field is 0h (8.3.1.3.2#4)
    f. In Data DW 0:
        i. Verify that bit 2 (Capability Supported) is 1b (8.3.1.3.2#9)
        ii. Record the value of Bit 3 (Capability Enabled)
        iii. Verify that all other bits are 0 (8.3.1.3.2#7)
9. Send the UUT a GET_CAPABILITIES Operation with Capability Index = 1
10. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
11. Verify that:
    a. Max Capability Index in Metadata field (bits 7:0) is 1 (8.3.1.3.2#4)
    b. Capability Index in Metadata field (bits 15:8) is 1 (8.3.1.3.2#4)
    c. Capability Enabled in Metadata field (bit 31) is the same as the Capability Enabled bit recorded in Step 8.f.ii (8.3.1.3.2#10, 8.3.1.3.2#11)
    d. Status field is 0h (8.3.1.3.2#4)
12. If Capability Supported in the Metadata field (bit 30) is 0, end test here.

Part 2 – Enable Hot Plug Failure Capability

13. Initiate a SET_CAPABILITIES Operation with:
    a. Capability Index = 1
    b. Enable Capability = 1

14. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
15. Verify that the *Operation Not Supported* bit is 0b if it was 0b in Part 1 (8.3.1.3.2#1, 8.3.1.3.3#1)
16. Verify that the *Operation Not Supported* bit is 1b if it was 1b in Part 1 (8.3.1.3.2#2, 8.3.1.3.3#2)
17. If the *Operation Not Supported* bit is 1b, end test here
18. If *Operation Not Supported* bit is 0b, verify that the Status field is 0 (8.3.1.3.3#6)
19. Initiate a GET_CAPABILITIES Operation with Capability Index = 1
20. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
21. Verify that:
    a. Capability Enabled in Metadata field (bit 31) is 1b (8.3.1.3.2#11, 8.3.1.3.3.1#1)
    b. Status field is 0h (8.3.1.3.2#4)
22. Connect the Compliance Device
23. Verify that the UUT sends a Notification Packet with Event Code = ERR_PLUG (6.8.1.1#3, 8.3.1.3.3.1#1)
24. Disconnect the Compliance Device

Part 3 – Disable Hot Plug Failure Capability

25. Initiate a SET_CAPABILITIES Operation with:
    a. Capability Index = 1
    b. Enable Capability = 0
26. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
27. Verify that the Status field is 0h (8.3.1.3.3#6)
28. Initiate a GET_CAPABILITIES Operation with Capability Index = 1
29. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
30. Verify that:
    a. Capability Enabled in Metadata field (bit 31) is 0b (8.3.1.3.2#10)
    b. Status field is 0h (8.3.1.3.2#4)
31. Connect the Compliance Device
32. Wait 1 second
33. Verify that the UUT did not send a Notification Packet with Event Code = ERR_PLUG (6.8.1.1#3)
34. Disconnect the Compliance Device

TD 8.17 Buffer Allocation Request Test

A. Purpose:
- Verify that UUT performs a Buffer Allocation Request Correctly (if supported) or returns an error (if not supported)
- Verify that UUT returns the correct Buffer Allocation Parameters

B. Asserts:
- 5.3.2.1.1#3-7
- 8.3.1.3.4#1-3

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)
- AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Initiate a BUFFER_ALLOCATION_REQUEST Operation
5. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
6. Verify that the *Operation Not Supported* bit is 0b (8.3.1.3.4#1)
7. Verify that:
    a. *Length* in the Metadata field (bits 7:0) is equal to the buffer allocation parameters that the UUT supports (8.3.1.3.4#3)
    b. *Status* field is 0h (8.3.1.3.4#2)
8. Read the number of Data DW indicated by the Length (bits 7:0) in the Metadata field
9. Look at the Parameter Index (bits 15:0) of each Data DW
10. If UUT has a USB3 Adapter, verify that it returned a baMaxUSB3 Buffer Allocation Parameter (5.3.2.1.1#3)
11. If UUT has a DP Adapter, verify that it returned a baMinDPaux Buffer Allocation Parameter (5.3.2.1.1#4)
12. If UUT has more than one USB4 Port, verify that it returned a baMinDPaux Buffer Allocation Parameter (5.3.2.1.1#4)
13. If UUT has a DP OUT Adapter, verify that it returned a baMinDPmain Buffer Allocation Parameter (5.3.2.1.1#5)
14. If UUT has more than one USB4 Port, verify that it returned a baMinDPmain Buffer Allocation Parameter (5.3.2.1.1#5)
15. If UUT has a PCIe Adapter, verify that it returned a baMaxPCIe Buffer Allocation Parameter (5.3.2.1.1#6)
16. If UUT is a Host Router, verify that it returned a baMaxHI Buffer Allocation Parameter (5.3.2.1.1#7)

TD 8.18 Get Container ID Test (Hub or Device Only)

A. Purpose:
    - Verify that Router handles a Get Container ID Operation correctly

B. Asserts:
    - 8.3.1.3.5#1-4

C. Test Setup:
    - AN_HUB_UFP2 (Hub)
    - AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT
4. Read the Container ID from the internal USB 3.2 hub
5. Initiate a GET_CONTAINER_ID Operation
6. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
7. If UUT is a Hub Router, verify that the *Operation Not Supported* bit is 0b (8.3.1.3.5#1)
8. If UUT is a Device Router with an internal USB SuperSpeed Plus hub, verify that the *Operation Not Supported* bit is 0b (8.3.1.3.5#2)
9. If the *Operation Not Supported* bit is 1b, end test here
10. If *Operation Not Supported* bit is 0b, verify that:
    a. *Status* field is 0h (8.3.1.3.5#4)
11. Read Data DW 0 through Data DW 4
12. Verify that the Data DWs contain the same Container ID as read from the internal USB 3.2 hub (8.3.1.3.5#3)

TD 8.19 Block/Unblock Sideband Port Test

A. Purpose:
   - Verify that Router handles a Block Sideband Port correctly
   - Verify that Router handles an Unblock Sideband Port correctly

B. Asserts:
   - 8.3.1.4.1#1, 8.3.1.4.1#2
   - 8.3.1.4.2#1-3

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_UFP2 (Hub)
   - AN_DEV_UFP1 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 – Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Block Sideband

4. Initiate a BLOCK_SIDEBAND_PORT Operation
5. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
   a. If the *Operation Not Supported* bit is 1b, end test here
6. Verify that the *Status* field is 0h (8.3.1.4.1#2)
7. For each UUT Port:
   a. Tell the Compliance Device to read SB Register 9
   b. Verify that PUT sends a Read Response (8.3.1.4.1#1)
   c. Record the value of the Read Data in the Read Response
   d. Tell the Compliance Device to write to SB Register 9
   e. Verify that PUT sends a Write Response with the Result Code set to 01h (ERROR) (8.3.1.4.1#1)
   f. Tell the Compliance Device to read SB Register 9
   g. Wait for a Read Response from the PUT
   h. Verify that the Read Data in the Read Response is the same as recorded in Step 8c (8.3.1.4.1#1)

Part 2 – Unblock Sideband

8. Initiate an UNBLOCK_SIDEBAND_PORT Operation
9. Read the ROUTER_CS_25 and ROUTER_CS_26 bytes from Router Configuration Space
10. If the *Operation Not Supported* bit was 0b in Part 1 (i.e. UUT Supported BLOCK_SIDEBAND_PORT Operation), verify that *Operation Not Supported* bit is 0b (8.3.1.4.2#1)
11. Verify that the *Status* field is 0h (8.3.1.4.2#3)
12. For each UUT Port:
    a. Tell the Compliance Device to initiate a Port Operation that is not a Service Port Operation
    b. Verify that the Port Operation is executed (8.3.1.4.2#2)

Port Operation Tests

Unless noted otherwise, the tests in this section are repeated for each USB4 Port on the UUT.

TD 8.20 Router Offline Test (Hosts and Hubs only)

Note: This test is only performed on the DFP.

A. Purpose:
   - Verify that a Router correctly handles a ROUTER_OFFLINE_MODE Port Operation

B. Asserts:
   - 8.3.2#1, 8.3.2#3
   - 8.3.2.2.1#1-6

C. Test Setup:
   - AN_HOST_DFP1 (Host)
   - AN_HUB_DFP1 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Enter Offline Mode (Sideband Channel)

4. Disconnect the Compliance Device
5. Wait for a Hot Unplug Event Packet
6. Tell the Compliance Device to initiate a ROUTER_OFFLINE_MODE Port Operation in the PUT
   a. In Metadata field, Enter Offline Mode = 0
   b. Target = PUT
7. Reconnect the Compliance Device
8. Verify that UUT sends a Hot Plug Event Packet (8.3.2.2.1#4)
9. Read the Plugged field in Adapter Configuration Space
10. Verify that Plugged field is 1b (8.3.2.2.1#4)

Part 2 – Enter Offline Mode (Local Access)

11. Disconnect the Compliance Device
12. Wait for a Hot Unplug Event Packet
13. Initiate a ROUTER_OFFLINE_MODE Port Operation
    a. In Metadata field, Enter Offline Mode = 0
    b. Target field = 000b
14. Verify that Operation completes successfully (8.3.2.2.1#2, 8.3.2.2.1#3)
15. Reconnect the Compliance Device
16. Verify that UUT does not send a Hot Plug Event Packet (8.3.2.2.1#1, 8.3.2.2.1#5)
17. Read the Plugged field in Adapter Configuration Space
18. Verify that Plugged field is 0b (8.3.2.2.1#1, 8.3.2.2.1#5)

Part 3 – Exit Offline Mode (Sideband Channel)

19. Tell the Compliance Device to initiate a ROUTER_OFFLINE_MODE Port Operation in the PUT
    a. In Metadata field, Enter Offline Mode = 1
    b. Target = PUT
20. Disconnect the Compliance Device
21. Read the Plugged field in Adapter Configuration Space
22. Verify that Plugged field is 0b (8.3.2.2.1#4)

Part 4 – Exit Offline Mode (Local Access)

23. Initiate a ROUTER_OFFLINE_MODE Port Operation
    a. In Metadata field, Enter Offline Mode = 1
    b. Target field = 000b
24. Verify that Operation completes successfully (8.3.2.2.1#2, 8.3.2.2.1#3)
25. Reconnect the Compliance Device
26. Verify that UUT sends a Hot Plug Event Packet (8.3.2.2.1#6)
27. Read the Plugged field in Adapter Configuration Space
28. Verify that Plugged field is 1b (8.3.2.2.1#6)

TD 8.21 Enumerate Re-Timers Test (Hosts and Hubs only)

A. Purpose:
- Verify that a Router correctly handles an ENUMERATE_RE-TIMERS Port Operation

B. Asserts:
- 8.3.2#1, 8.3.2#3
- 8.3.2.2.2#1-3

C. Test Setup:
- AN_HOST_DFP1 (Host)
- AN_HUB_UFP2 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Start Analyzer
2. Reset UUT
3. Enumerate UUT

Part 1 – Initiated Locally

4. Initiate an ENUMERATE_RE-TIMERS Operation
5. Verify that completes successfully (8.3.2.2.2#1)
6. Verify that UUT sends a Broadcast RT Transaction (8.3.2.2.2#2)

Part 2 – Initiated Remotely

7. Tell the Compliance Device to initiate an ENUMERATE_RE-TIMERS Operation
8. Verify that UUT does not send a Broadcast RT Transaction (8.3.2.2.2#3)

TBT3-Compatibility Mode Tests

The tests in this section are performed in TBT3-Compatible mode where all connected USB4 Ports negotiate and enter TBT3-Compatible operation as described in the USB Type-C Specification and the USB PD Specification. Unless specified otherwise, USB4 CV enumerates the Router as a TBT3 Connection Manager.

Tests are performed at the highest signaling speed that the UUT supports. Unless specified otherwise, Lanes are bonded and RS-FEC is enabled.

Unless otherwise noted, a test will timeout if it takes more than 500ms to go from one step to the next step. It is a test failure if a test times out.

If a USB4 Product contains multiple Routers, all Routers in the Product are tested.

Transport Layer Tests

Unless otherwise noted, the tests in this section are performed once per Router.

TD 13.1 TBT3 Adapter Enumeration Test

A. Purpose:
  - Verify that Adapter numbering rules are implemented correctly

B. Asserts:
  - 13.3.1#1-4

C. Test Setup:
  - AN_HUB_UFP1—TBT3_01 (Hub)
  - AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Reset UUT
2. Enumerate UUT as TBT3 Connection Manager

Part 1 – TBT3 Connection Manager

3. Read the *Max Adapter* field from Router Configuration Space of UUT:
4. For each UUT Adapter (i.e. Adapters numbered 1 through *Max Adapter)*, send a Read Request to read the following fields from Adapter Configuration Space:
    a. *Adapter Number*
    b. *Adapter Type Sub-Type*
    c. *Adapter Type Version*
    d. *Adapter Type Protocol*
5. Verify that UUT has either two Lane Adapters or four Lane Adapters (i.e. one or two USB4 Ports) (13.3.1#1)
6. Verify that the UUT has no more than one PCIe UP Adapter (13.3.1#2)
7. Verify that the UUT has no more than one PCIe DN Adapter (13.3.1#2)
8. Verify that a Lane Adapter is either preceded or followed by another Lane Adapter (e.g. If Adapter Number 2 is a Lane Adapter, either Adapter number 1 or Adapter Number 3 is a Lane Adapter) (13.3.1#3)

Part 2 – USB4 Connection Manager

9. Reset UUT
10. Enumerate UUT as USB4 Connection Manager
11. Read the *Max Adapter* field from Router Configuration Space of UUT
12. For each UUT Adapter (i.e. Adapters numbered 1 through *Max Adapter)*, send a Read Request to read the following fields from Adapter Configuration Space:
    a. *Adapter Number*
    b. *Adapter Type Sub-Type*
    c. *Adapter Type Version*
    d. *Adapter Type Protocol*
13. Verify that UUT exposes additional Lane Adapters and/or PCIe Adapters if supported (see VIF) (13.3.1#4)

TD 13.2 TBT3 Max HopID Test

A. Purpose:
  - Verify that Router supports required maximum HopIDs

B. Asserts:
  - 13.3.2#1-3

C. Test Setup:
  - AN_HOST_DFP1—TBT3_01 (Host)
  - AN_HUB_UFP1—TBT3_01 (Hub)
  - AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
2. Enumerate UUT as TBT3 Connection Manager
3. Read the following fields in the Adapter Configuration Space of each Lane Adapter:
    a. *Max Input HopID*
    b. *Max Output HopID*
4. If UUT is a Host Router or a Device Router with a DFP, verify that:
    a. *Max Input HopID* is at least 15 (13.3.2#1)
    b. *Max Output HopID* is at least 15 (13.3.2#1)
5. If UUT is a Device Router without a DFP, verify that:
    a. *Max Input HopID* is at least 11 (13.3.2#2)
    b. *Max Output HopID* is at least 11 (13.3.2#2)
6. If UUT is a Device Router that supports at least two DisplayPort tunneled streams, verify that:
    a. *Max Input HopID* is at least 14 (13.3.2#3)
    b. *Max Output HopID* is at least 14 (13.3.2#3)
7. Read the Path Configuration Space of each Lane Adapter
8. Verify that the Path Configuration Space of each Lane Adapter contains entries for HopID=8 through HopID=*Max Input HopID*

TD 13.3 TBT3 UFP Downstream-Bound Control Packet Test

A. Purpose:
- Verify that the UUT handles Control Packets with CM=0b correctly when Router is Uninitialized

B. Asserts:
- 13.4.3.1#2
- 13.4.3.2#2

C. Test Setup:
- AN_HOST_DFP1—TBT3_01 (Host)
- AN_HUB_UFP1—TBT3_01 (Hub)
- AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Start Analyzer
2. Reset UUT
3. Do not enumerate UUT
4. Send the PUT a Read Request that targets Adapter Configuration Space
5. Wait at least tCPResponse (2 ms) to let the Read Request time out
6. If UUT us a Host Router, verify that the PUT sends a Read Response (13.4.3.1#2)
7. If UUT is a Device Router, verify that PUT does not send a Read Response (13.4.3.2#2)
8. Send the PUT a Write Request that targets Path Configuration Space
9. Wait at least tCPResponse (2 ms) to let the Write Request time out
10. If UUT us a Host Router, verify that the PUT sends a Write Response (13.4.3.1#2)
11. If UUT is a Device Router, verify that PUT does not send a Write Response (13.4.3.2#2)

TD 13.4 TBT3 DFP Downstream-Bound Control Packet Test

Note: This test is performed on each DFP of the UUT.

A. Purpose:
- Verify that DFP handles Control Packet with CM=0b correctly when Router is Uninitialized

B. Asserts:
- 13.4.3.1#2
- 13.4.3.2#2

C. Test Setup:
- EX_HOST_DFP1—TBT3_02 (Host)
- EX_HUB_DFP1—TBT3_04 (Hub)

D. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
2. Do not enumerate UUT
3. Configure the Exerciser to behave as a DFP (i.e. Exerciser is in USB4 Host mode)
4. Tell Exerciser to perform Part 1

Exerciser performs the following test steps:

5. Send the UUT a Read Request that targets Router Configuration Space
6. If UUT is a Host Router, verify that UUT sends a Read Response (13.4.3.1#2)
7. If UUT is a Device Router, verify that the UUT:
    a. Does not send a Read Response (13.4.3.2#2)
    b. Sends a Notification Packet with Event Code=ERR_NUA
8. Send a Write Request that targets the Adapter Configuration Space of the PUT
9. If UUT is a Host Router, verify that UUT sends a Read Response (13.4.3.1#2)
10. If UUT is a Device Router, verify that the UUT:
    a. Does not send a Read Response (13.4.3.2#2)
    b. Sends a Notification Packet with Event Code=ERR_NUA
11. Send an Inter-Domain Request to the UUT
12. If UUT is a Host Router, verify that UUT sends a Read Response (13.4.3.1#2)
13. If UUT is a Device Router, verify that the UUT:
    a. Does not send an Inter-Domain Response (13.4.3.2#2)
    b. Does not send a Notification Packet (13.4.3.2#2)

Register Tests

Unless otherwise noted, the tests in this section are performed once per Router.

TD 13.5 TBT3 Default Router Config Space Test

A. Purpose:
- Verify that Router Configuration Space contains the correct default values

B. Asserts:
- 13.6.1#1-2
- 13.6.1.1#1-2, 13.6.1.1#4-5
- 13.6.1.2#1, 13.6.1.2#3-4
- 13.6.1.4#1-2
- 13.6.1.4.1#1-4, 13.6.1.4.1#7-9
- 13.6.1.4.2#1, 13.6.1.4.2#113

C. Test Setup:
- AN_HOST_DFP1—TBT3_01 (Host)
- AN_HUB_UFP1—TBT3_01 (Hub)
- AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
    a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values
2. Do not enumerate UUT
3. Do not write to any fields in UUT Configuration Space
4. If UUT is a Device Router:
    a. Read the Upstream Adapter field in Router Configuration Space
    b. Verify that the Upstream Adapter field is 0 (13.6.1#1)
5. Read all of the Capabilities in Router Configuration Space of the UUT
6. Verify that the UUT has all of the following Capabilities: (13.6.1#2)
    a. TMU Router Configuration
    b. Vendor Specific 1
    c. Vendor Specific 3
    d. Vendor Specific Extended 6

    Note: UUT may also optionally contain a Vendor Specific 4 Capability
7. Parse the Vendor Specific 1 Capability and verify the following: (13.6.1.1#1)
    a. Absolute address of VSC_CS_0 register is 28h (13.6.1.1#2)
    b. Capability ID field is 05h (13.6.1.1#4)
    c. VSEC ID field is 01h (13.6.1.1#5)
    d. Plug Event Disable field is 0
    e. DW 3 is 0
    f. FL_SK is 0
    g. FL_CS is 0
    h. FL_DI is 0
    i. Bit Banging Enable is 0

8. Parse the Vendor Specific 3 Capability and verify the following: (13.6.1.2#1)
    a. Capability ID field is 05h (13.6.1.2#3)
    b. VSEC ID field is 03h (13.6.1.2#4)
    c. DW 4 through DW 7 are 0
    d. Time Disruption field is 0
9. Parse the Vendor Specific Extended 6 Capability and verify the following: (13.6.1.4#1)
    a. For the Common Region: (13.6.1.4.1#1)
        i. Capability ID field is 05h (13.6.1.4.1#2)
        ii. VSEC ID field is 06h (13.6.1.4.1#3)
        iii. VSEC Header field is 00h (13.6.1.4.1#4)
        iv. USB4 Ports field contains the number of USB4 Ports on the UUT (13.6.1.4.1#7)
        v. Common Region Length is 14h (13.6.1.4.1#8)
        vi. USB4 Port Region Length is 100h (13.6.1.4.1#9)
    b. It contains a USB4 Port Region for each USB4 Port on the UUT (13.6.1.4#2)
    c. For each Port Region: (13.6.1.4.2#1)
        i. Downstream Port Reset bit is 0
        ii. Enable Wake on Inter-Domain is 0
        iii. Inter-Domain Disconnect on Sleep is 0
        iv. If UUT is a Host Router, Enable Wake Events = 180h
        v. If UUT is a Device Router, Enable Wake Events = 140h
        vi. Lane 0 Configured is 0
        vii. Lane 0 is Inter-Domain is 0
        viii. Lane 1 Configured is 0
        ix. Lane 1 is Inter-Domain is 0
        x. Start Link Initialization is 0
        xi. TBT3-Compatible Mode bit is 1 (13.6.1.4.2#13)
        xii. Enter Sleep is 0
        xiii. Request RS-FEC Gen 2 is 0
        xiv. Request RS-FEC Gen 3 is 1

TD 13.6 TBT3 Bit Banging Test (Hubs and Devices Only)

A. Purpose:
- Verify that Router implements bit banging mechanism correctly
- Verify that a Router implements a TBT3-Compatible DROM

B. Asserts:
- 13.4.2#1-4
- 13.6.1.1#20-25

C. Test Setup:
- AN_HUB_UFP1—TBT3_01 (Hub)
- AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
2. Enumerate UUT
3. Read the UUID from Router Configuration Space
4. Use the "bit banging" mechanism defined in Chapter 13 of the USB4 Specification to read the DROM of the UUT
5. Verify that DROM contains a TBT3 Identification Section
6. Verify that the UUID in the TBT3 Identification Section is the same as the UUID read from Router Configuration Space
7. Verify that DROM contains a TBT3 Header Section
8. Verify that the TBT3 Header Section contains the TBT3 VID (see VIF)
9. Verify that each Lane Adapter has a TBT3 Lane Adapter Entry in the DROM
10. Verify that DROM has a TBT3 PCIe Upstream Adapter Entry
11. Verify that each PCIe DN Adapter has a TBT3 PCIe Downstream Adapter Entry in the DROM

TD 13.7 TBT3 Default Adapter Configuration Space Test

A. Purpose:
  - Verify that Adapter Configuration Space has the correct default values

B. Asserts:
  - 13.6.2.1#1-5
  - 13.6.2.2#1
  - 13.6.2#1, 13.6.2#4-6

C. Test Setup:
  - AN_HOST_DFP1—TBT3_01 (Host)
  - AN_HUB_UFP1—TBT3_01 (Hub)
  - AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

1. Reset UUT
    a. If UUT is a Host Router, tell the user to manually restart the host system in order to set the Router Configuration Space back to its default values
2. Enumerate UUT
3. Read the following fields from Router Configuration Space:
    a. *Vendor ID*
    b. *Product ID*
    c. *Revision Number*
    d. *Total Buffers*
4. Read the Adapter Configuration Space of each Adapter
5. Verify the following for the Basic Attributes of each Adapter: (13.6.2.1#1)
    a. Vendor ID is the same as the Vendor ID in Router Configuration Space (13.6.2.1#2)
    b. Product ID is the same as the Product ID in Router Configuration Space (13.6.2.1#3)
    c. Revision Number is the same as the Revision Number field in Router Configuration Space (13.6.2.1#4)
    d. Max Credits field = Total Buffers field in Router Configuration Space (13.6.2.1#5)
6. Verify the following in the USB4 Port Capability of each Lane 0 Adapter: (13.6.2.2#1)
    a. Target field is 0
    b. Request RS-FEC Gen 2 is 1
7. Verify the following for the Adapter Configuration Space of any DP OUT Adapters:
    a. The absolute address of the ADP_DP_CS_0 register in a DP Adapter Configuration Capability is be 0x39 (13.6.2#1)
    b. There is no Capability Register at address 10h in Adapter Configuration Space (13.6.2#4)
    c. The DP OUT Adapter does not contain any Vendor Specific Extended Capability with VSEC ID = 1 (13.6.2#6)
8. Verify the following for the Adapter Configuration Space of any DP IN Adapters:
    a. The absolute address of the ADP_DP_CS_0 register in a DP Adapter Configuration Capability is be 0x39 (13.6.2#1)
    b. The DP IN Adapter does not contain any Vendor Specific Extended Capability with VSEC ID = 0 (13.6.2#5)
    c. The DP IN Adapter does not contain any Vendor Specific Extended Capability with VSEC ID = 1 (13.6.2#5)

TD 13.8 TBT3 DP OUT Adapter Write Test

A. Purpose:
   - Verify that a DP OUT Adapter handles specific Write cases to Adapter Configuration Space

B. Asserts:
   - 13.6.2#2, 13.6.2#3

C. Test Setup:
   - AN_HOST_DFP1—TBT3_01 (Host)
   - AN_HUB_UFP1—TBT3_01 (Hub)
   - AN_DEV_UFP1—TBT3_01 (Device)

D. Procedure:

USB4 CV performs the following test steps:

Part 0 - Setup

1. Reset UUT
2. Enumerate UUT
3. Repeat Part 1 and Part 2 for each DP OUT Adapter

Part 1 – ADP_DP_3 Register

4. Send UUT a Read Request that targets the ADP_DP_3 register in Adapter Configuration Space
5. Wait for a Read Response and read the value in the ADP_DP_3 register
6. Send the UUT a Write Response that targets the ADP_DP_3 register in Adapter Configuration Space and writes a value different than what was previously read
7. Wait for a Write Response or timeout
8. Verify that UUT is still functional (13.6.2#2)

Part 2 – Address 10h

9. Send a Write Request that targets address 10h
10. Verify that UUT sends a Write Response (13.6.2#3)