

USB4™ Time Synchronization Compliance Test Specification

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Revision History:

Revision	Issue Date	Comments
1.0	September 2020	First Release. References the USB4 Specification, Version 1.0 with Errata and ECN through May 4, 2020.
1.1	January 2021	References the USB4 Specification, Version 1.0 with Errata and ECN through October 15, 2020.
1.2	June 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through October 15, 2020.
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1.4	December 2021	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 19, 2021.
1.5	March 2022	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 19, 2021.
1.6	December 2022	With corrections and clarifications. References the USB4 Specification, Version 1.0 with Errata and ECN through May 19, 2021 and includes additional ECN through October 2022.
2.0		Revision that unites USB4 Version 1 and Version 2

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Introduction

The following tests check that a Router is compliant with Chapter 7 of the USB4 Base Specification.

System compliance purposes are:

- Test TMU standalone functionality:
 - Statistics
 - Time sync handshake
 - Time accuracy
- Check compliance of time sensitive protocols: ITP, PTM and DisplayPort over challenging setups.

Terminology

The following table describes the terms used in this document.

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.
PUT	Port Under Test. The USB4 Port on a UUT that is the test point for compliance testing.
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 Peripheral Device. Includes silicon and end product.
UUT	Unit Under Test. The Router Assembly that is being tested for compliance.
VIF	Vendor Information File. File provided by UUT vendor that provides information about the characteristics and capabilities of the UUT.

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
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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.
- 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.

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

Version 1 Assertions

Chapter 4

The following Table presents the USB4 Ver. 1 Specification Chapter 4 asserts tested in this CTS.

Assertion #	Test	Assertion Description
4.2.1.6.3 Objections		
4.2.1.6.3#1	NT	A USB4 Port shall assert an objection to enter CL2 state if: Entry to CL2 state would delay a pending Time Sync handshake.
4.2.1.6.3#2	NT	This objection shall be asserted until the Time Sync handshake is complete.
4.2.1.6.3#3	NT	A USB4 Port shall assert an objection to enter CL1 state if: Entry to CL1 state would delay a pending Time Sync handshake.
4.2.1.6.3#4	NT	The objection shall be asserted until the Time Sync handshake is complete.

Chapter 7

The following Table presents the USB4 Ver. 1 Specification Chapter 7 asserts.

Assertion #	Test	Assertion Description
7 Time Synchronization		
7#1	NT	A Router with one or more DFP shall support the USB4 Time Synchronization Protocol described in this chapter.
7#2	TBD	A Router shall implement the TMU Router Configuration Capability and the TMU Adapter Configuration Capability.
7#3	TBD	A Router that does not support the Time Synchronization Protocol shall set the Time Synchronization Protocol Not Supported bit in the TMU Router Configuration Capability to 1b.
7#4	TBD	A Host Router that does not support Inter-Domain Time Synchronization shall set the IDNS bit in the TMU Router Configuration Capability to 1b.
7.1 Time Synchronization Architecture		
7.1.1 Synchronization Hierarchy		
7.1.1.1 Intra-Domain Hierarchy		
7.1.1.2 Inter-Domain Hierarchy		
7.1.2 Time Sync Parameters		
7.1.2.1 Local Time		
7.1.2.1#1	NT	A Router shall provide a free-running clock for use in capturing the time stamps needed for the Time Synchronization Protocol.
7.1.2.1#2	NT	The Local Clock shall run at a frequency of 125 MHz or greater with an accuracy of +/- 100ppm relative to the nominal Local Clock frequency
7.1.2.1#3	NT	The Local Clock shall not be spread-spectrum.
7.1.2.1#4	Stat Sub #1	A Router shall use an 80-bit Local Time counter with the format shown in Figure 7-2 to track Local Time.
7.1.2.1#5	Stat Sub #1	The Local Time counter shall be incremented up with the Local Clock.
7.1.2.2 Time Offset		
7.1.2.2#1	NT	The TimeOffsetFromHR register shall have the format shown in Figure 7-3.
7.1.2.2#2	Stat Sub #2	The TimeOffsetFromHR register shall be updated at the conclusion of every Time Sync Handshake.

7.1.2.3 Frequency Offset		
7.1.2.3#1	NT	The frequency offset shall be computed according to Equation 7-2.
7.1.2.3#2	Stat Sub #3	The FreqOffsetFromHR register shall be updated at the conclusion of every Time Sync Handshake.
7.2 Time Stamp Measurement		
7.2#1	Protocol Check #3	USB4 Port shall generate a time stamp whenever it either sends or receives a Time Sync Notification Ordered Set (TSNOS).
7.2#2	NT	A USB4 Port shall use the value in the Local Time counter to capture time stamps.
7.2#3	NT	A time stamp shall be taken at the Time Stamp Point of the First TSNOS.
7.2#4	Protocol Check #3	If one or more back-to-back TSNOS are received immediately after the first TSNOS, they shall be ignored.
7.2#5	NT	The same transmit reference pLane shall be used for all transmitted TSNOS and the same receive reference pLane shall be used for all received TSNOS.
7.2#6	Protocol Check #3	The time stamp measurement shall have a resolution of at least 8 ns (i.e. the period of the Local Clock).
7.2#7	NT	The time stamp in a Time Sync Packet shall have the format shown in Figure 7-2.
7.2.1 Asymmetry Corrections		
7.2.1#1	Time Calculation #2	Time stamps shall be corrected for asymmetry between transmit and receive paths.
7.2.1#2	Time Calculation #2	An Upstream Facing Port (UFP) shall correct for asymmetry by performing the following computations: $t1 = \text{Delay Request Sent Time Stamp} + \text{TxTimeToWire}$; $t4 = \text{Delay Response Received Time Stamp} - \text{RxTimeToWire}$; where, TxTimeToWire is the value in the TxTimeToWire field of the TMU_ADP_CS_1 register of the UFP and RxTimeToWire is the value in the RxTimeToWire field of the TMU_ADP_CS_2 register of the UFP.
7.2.1#3	Time Calculation #2	A Downstream Facing Port (DFP) shall correct for asymmetry by performing the following computations: $t2 = \text{Delay Request Received Time Stamp} - \text{RxTimeToWire}$; $t3 = \text{Delay Response Sent Time Stamp} + \text{TxTimeToWire}$; where, TxTimeToWire is the value in the TxTimeToWire field of the TMU_ADP_CS_1 register of the DFP and RxTimeToWire is the value in the RxTimeToWire field of the TMU_ADP_CS_2 register of the DFP.

7.2.1#4	Time Calculation #2	The time duration between when a USB4 Port generates a time stamp and when it transmits first bit of a TSNOS on the wire shall be equal to the value in the TxTimeToWire field of the TMU_ADP_CS_1 register.
7.2.1#5	Time Calculation #2	The time duration between when a USB4 Port receives the first bit of a TSNOS on the wire and when it generates a time stamp shall be equal to the value in the RxTimeToWire field of the TMU_ADP_CS_2 register.
7.3 Time Sync Protocol		
7.3.1 Time Sync Handshake		
7.3.1#1	Protocol Check #1	A Router shall support Bi-Directional Time Sync Handshakes in HiFi Mode.
7.3.1#2	NT	A Router shall support Uni-Directional Time Sync Handshakes in HiFi Mode and LowRes Mode.
7.3.1#3	NT	When the USB4 Ports are connected by a Single-Lane Link, a Time Sync Handshake shall occur over that Link.
7.3.1#4	NT	When the USB4 Ports are connected by a Dual-Lane Link, the Delay Request and Delay Response Ordered Sets in the Time Sync Handshake shall be sent on both the Lane 0 and Lane 1.
7.3.1#5	NT	The Follow-Up Packet shall be sent using both Lanes (i.e. alternating bytes across Lanes).
7.3.1#6	NT	The timestamp shall be taken when the first Ordered Set from the Link Partner is received.
7.3.1#7	NT	A Receiver shall ignore a TSNOS that arrives back-to-back after another TSNOS.
7.3.1.1 Bi-Directional Time Sync Handshake		
7.3.1.1#1	Protocol Check #1	A DFP shall not initiate a Bi-Directional Time Sync Handshake
7.3.1.1#2	Protocol Check #1	A UFP shall send a Delay Request to the DFP at the interval specified in the TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space.
7.3.1.1#3	Protocol Check #1	A DFP shall transmit a Delay Response Packet within 1 μ s of receiving a Delay Request Packet.
7.3.1.1#4	Protocol Check #1	A DFP shall transmit a Follow-Up Packet within SendTimeout of transmitting the associated Delay Response Packet.
7.3.1.1#5	Stat Sub #6	A UFP shall generate time stamp t1 upon transmission of a Delay Request and shall generate time stamp t4 upon reception of a Delay Response.
7.3.1.1#6	Protocol Check #2	A DFP shall generate time stamp t2 upon receipt of a Delay Request and shall generate time stamp t3 upon transmission of a Delay Response.

7.3.1.1#7	NT	If an error occurs during the transmission or reception of a Time Sync Packet, the entire Time Sync Handshake shall be voided (i.e. neither time stamps nor values from the Follow-Up Packet shall be used).
7.3.1.1#8	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 1. Take the t2 timestamp
7.3.1.1#9	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 2. Send a Delay Response.
7.3.1.1#10	NT	Delay Response shall be sent within RespTimeout time or receiving the Delay Request
7.3.1.1#11	NT	The DFP shall take the t3 timestamp upon Delay Response transmission
7.3.1.1#12	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 3. Compute the updated TimeOffsetFromHR parameter according to Equation 7-6 using the t3 timestamp from Step 2b
7.3.1.1#13	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 4. Send Follow-Up Packet with the TimeOffsetFromHR calculated in Step 3
7.3.1.2 Uni-Directional Time Sync Handshake		
7.3.1.2#1	Protocol Check #3	When using Uni-Directional Time Sync Handshake, only the DFP shall initiate a Time Sync Handshake
7.3.1.2#2	Protocol Check #3	A DFP shall send a Delay Response to the UFP at the interval specified in the TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space.
7.3.1.2#3	Protocol Check #3	A DFP shall transmit a Follow-Up Packet within SendTimeout after transmitting the associated Delay Response Packet
7.3.1.2#4	Protocol Check #3	Uni-Directional Time Sync Handshake shall be used when the following conditions are true: Both Link Partners support Uni-Directional Time Sync Handshake; Both Link Partners have the EnableUniDirectionalMode field in the TMU_ADP_CS_3 register in Adapter Configuration Space set to 1b.
7.3.2 Inter-Domain Time Sync		
7.3.2#1	Protocol Check #1	A USB4 Port shall perform Time Sync Handshakes as described in Section 7.3.1 across the Inter-Domain Link when either the IDTR bit or IDTI bit is set to 1b.
7.3.2#2	Protocol Check #1	After completing a Time Sync Handshake across an Inter-Domain Link, the IDTI Port shall calculate the following: The Inter-Domain time stamp (see Section 7.4.2.1); The Inter-Domain frequency offset (see Section 7.4.2.2); The Inter-Domain time offset (see Section 7.4.2.3).

7.3.2#3	Protocol Check #1	After calculating the Inter-Domain time offset, Inter-Domain frequency offset and Inter-Domain time stamp, the IDTI Port shall update the InterDomainTimeStamp, FreqOffsetFromInterDomainHR and TimeOffsetFromInterDomainHR fields in Router Configuration Space.
7.3.2#4	Protocol Check #5	If the IDTI Port is part of a Device Router, it shall prepare an Inter-Domain Time Stamp Packet as described in Section 7.3.3.3.
7.3.2#5	Protocol Check #5	If the TSInterDomainInterval field in Router Configuration Space is 0, the IDTI Port shall send the Host Router an Inter-Domain Time Stamp Packet after each Inter-Domain Time Sync Handshake.
7.3.2#6	Protocol Check #5	If the TSInterDomainInterval field in Router Configuration Space is not 0, the IDTI Port shall send the Host Router an Inter-Domain Time Stamp Packet at time intervals equal to $(TSInterDomainInterval + 1) * TSPacketInterval$ number of microseconds.
7.3.2#7	NT	When a Host Router receives an Inter-Domain Time Stamp Packet: If the IDE bit in the TMU_RTR_CS_0 register of the Host Router's TMU Router Configuration Capability is set to 1b, the Host Router shall update its TimeOffsetFromInterDomainHR and FreqOffsetFromInterDomainHR registers using the time offset and frequency offset respectively contained in the Inter-Domain Time Stamp Packet.
7.3.2#8	NT	When a Host Router receives an Inter-Domain Time Stamp Packet: If the IDE bit in the Host Router is set to 0b, the Host Router shall drop the Inter-Domain Time Stamp Packet and shall not update its TimeOffsetFromInterDomainHR or FreqOffsetFromInterDomainHR registers
7.3.3 Packet Formats		
7.3.3.1 Time Sync Notification Ordered Set Format		
7.3.3.1#1	Protocol Check #1	Both a Delay Request and a Delay Response shall consist of the Time Sync Notification Ordered Set (TSNOS) defined in Section 4.4.7.
7.3.3.2 Follow-Up Packet Format		
7.3.3.2#1	Protocol Check #2	A Follow-Up Packet shall have the format shown in Figure 7-13.
7.3.3.2#2	Protocol Check #2	A Follow-Up Packet shall have the PDF field set to 1, the HopID set to 3, and the Length set to 60.
7.3.3.2#3	Protocol Check #2	The payload shall contain the fields in Table 7-3.
7.3.3.2#4	Time Calculation #2	For Bi-Directional Time Sync Handshakes: The time stamp shall include the asymmetry corrections performed at the DFP as specified in Section 7.2.1.
7.3.3.2#5	Protocol Check #2	For Bi-Directional Time Sync Handshakes: The RequestReceiptTS field shall have the format shown in Figure 7-2

7.3.3.2#6	Protocol Check #4	For Uni-Directional Time Sync Handshakes: The RequestReceiptTS field shall contain the same value as the ResponseOriginTS field.
7.3.3.2#7	Time Calculation #2	The time stamp shall include the asymmetry corrections performed at the DFP as specified in Section 7.2.1.
7.3.3.2#8	Protocol Check #2	The ResponseOriginTS field shall have the format shown in Figure 7-2.
7.3.3.2#9	Protocol Check #2	The TimeOffsetFromHR field shall have the format shown in Figure 7-3.
7.3.3.2#10	Protocol Check #2	The FreqOffsetFromHR shall have the format shown in Figure 7-4.
7.3.3.2#11	Protocol Check #2	Bits 31:16 of DW8 are reserved and shall be set to 0.
7.3.3.2#12	Protocol Check #2	For a Host Router: If IDE bit is set to 0b, then the IDTimeStamp field shall be set to 0.
7.3.3.2#13	Protocol Check #2	For a Device Router: The IDTimeStamp field shall contain the IDTimeStamp value from the last Follow-Up Packet that the IDTI Port on the Router Received.
7.3.3.2#14	Protocol Check #2	For a Host Router: If IDE bit is set to 0b, then the FreqOffsetFromInterDomainHR field shall be set to 0.
7.3.3.2#15	Protocol Check #2	For a Device Router: The FreqOffsetFromInterDomainHR field shall contain the FreqOffsetFromInterDomainHR value in the last Follow-Up Packet that the IDTI Port on the Router Received.
7.3.3.2#16	NT	The CRC32 computation shall be based on the following specification: Width: 32; Poly: 1EDC 6F41h; Init: FFFF FFFFh; RefIn: True; RefOut: True; XorOut: FFFF FFFFh;
7.3.3.3 Inter-Domain Time Stamp Packet		
7.3.3.3#1	Protocol Check #5	An Inter-Domain Time Stamp Packet shall have the format shown in Figure 7-14.
7.3.3.3#2	Protocol Check #5	An Inter-Domain Time Stamp Packet shall have the PDF set to 2, the HopID set to 3, and the Length set to 28.
7.3.3.3#3	Protocol Check #5	The payload shall contain the fields in Table 7-4.
7.3.3.3#4	Protocol Check #5	The IDTimestamp field shall have the format shown in Figure 7-2.
7.3.3.3#5	Protocol Check #5	The TimeOffsetFromInterDomainHR field shall have the format shown in Figure 7-3.
7.3.3.3#6	Protocol Check #5	The FreqOffsetFromInterDomainHR field shall have the format shown in Figure 7-4.
7.3.3.3#7	NT	The CRC32 computation shall be based on the following specification: Width: 32; Poly: 1EDC 6F41h; Init: FFFF FFFFh; RefIn: True; RefOut: True; XorOut: FFFF FFFFh;

7.4 Time Computations		
7.4#1	NT	A Router shall be able to compute the Host Router Time at any instant in time.
7.4.1 Intra-Domain Equations		
7.4.1#1	Stat Sub #3	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-1 to compute the frequency ratio between itself and its DFP.
7.4.1#2	Stat Sub #3	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-2 to compute the frequency offset. The UFP uses the frequency ratio obtained in Step 1 as input to the computation.
7.4.1#3	Stat Sub #3	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-3 to compute the frequency ratio between itself and the Host Router. The UFP uses the FreqOffsetFromHR value in the last Follow-Up Packet received from the DFP as input to the computation.
7.4.1#4	Stat Sub #3	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-4 to compute the frequency offset between itself and the Host Router. The UFP uses the frequency ratio computed in Step 3 as input to the computation.
7.4.1#5	Stat Sub #5	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-5 to compute the propagation delay of the cable between the UFP and the DFP.
7.4.1#6	Stat Sub #2	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The Link Partner (i.e. the DFP upstream of the UFP) uses Equation 7-6 to compute the most updated time offset from the Domain Host Router. The Link Partner uses the most recent result from Equation 7-9, as input to the computation.
7.4.1#7	Stat Sub #2	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-7 (Bi-Directional Time Sync Handshakes) or Equation 7-8 (Uni-Directional Time Sync Handshakes) to compute the time offset from its DFP.
7.4.1#8	Stat Sub #4	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-9 to compute the time offset from the Host Router. The UFP uses the time offset from Equation 7-7 or Equation 7-8, and the value in the last received Follow-Up Packet as input to the computation.

7.4.1#9	Time Calculation #1	A Router shall use the following series of computations to deduce the current Host Router Time within a single Domain: The UFP uses Equation 7-10 to compute the current time offset from the Host Router. The UFP uses the time offset computed in Equation 7-9 and the frequency offset computed in Equation 7-3 as input to the computation.
7.4.2 Inter-Domain Equations		
7.4.2.1 Inter-Domain Time Stamp Computation		
7.4.2.1#1	NT	Equation 7-11 is used to compute an Inter-Domain time stamp.
7.4.2.2 Inter-Domain Frequency Offset Computation		
7.4.2.2#1	NT	The frequency ratio between the Host Router in the Domain with the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-12.
7.4.2.3 Inter-Domain Time Offset Computation		
7.4.2.3#1	Stat Sub #7	The time offset of the IDTR Port that is sent in the Follow-Up Packet at the end of an Inter-Domain Time Sync Handshake is computed using Equation 7-14
7.4.2.3#2	Stat Sub #9	The time offset between the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-15.
7.4.2.3#3	Stat Sub #9	The time offset between the Host Router of the Domain with the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-16.
7.4.2.4 Inter-Domain Host Router Time Computation		
7.4.3 Filtering		
7.5 Time Synchronization Accuracy Requirements		
7.5#1	NT	A Router shall reach the required time synchronization accuracy within tConvergeTime after Time Sync Handshakes are enabled.
7.5#2	TBD	If Time Sync Handshakes are paused, a UFP shall reach the required time synchronization accuracy within tConvergeTime after receiving a Delay Response Packet.
7.5.1 Paired Measurement		
7.5.1#1	NT	For Bi-Directional Time Sync Handshake, the Static Offset between two Routers connected to one another shall not add more than 8 ns per Link.
7.5.1#2	NT	In HiFi Mode, the Dynamic Noise between two Routers connected to one another shall not add more than tHiAccuracy.
7.5.1#3	NT	In LowRes Mode, the Dynamic Noise between two Routers connected to one another shall not add more than tLowAccuracy.

7.5.2 Standalone Measurement		
7.5.2#1	NT	In HiFi Mode, the noise between measurement points and the ideal line shall not be more than tHiAccuracy.
7.5.2#2	NT	In LowRes Mode, the noise between measurement points and the ideal line shall not be more than tLowAccuracy.
7.5.2#3	NT	In order to achieve the goal of 1 ns static noise, the budget for TxTimeToWire uncertainty shall not be more than 6.4 ns dynamic noise with no more than 6.4 ns static offset that changes after each power up.
7.5.2#4	NT	RxTimeToWire shall not be more than 12.8 ns dynamic noise with no more than 6.4 ns static offset that changes after each power up.
7.5.2#5	NT	Dynamic uncertainty in TxTimeToWire and RxTimeToWire shall be filtered out during calculations by IRR or other filtering.
7.5.3 Measuring Method		
7.5.4 Accuracy Parameters		
7.6 Software Configuration		
7.6.1 Intra-Domain Time Synchronization Setup		
7.6.1#1	NT	A Router that is hot-plugged to a Domain shall only initiate the Time Sync Handshake on its UFP when the following conditions are true: The physical layer has established the Link between the hot-plugged Router and the Domain; The TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space is greater than 0.
7.6.2 Inter-Domain Time Synchronization Setup		
7.6.3 Post Time Mechanism		
7.6.3#1	NT	A Router shall update its local time when the Post Time is less than or equal to the Nanoseconds field in the Host Router Time Register.
7.6.4 Time Disruption Bit		

Chapter 8

The following Table presents the USB4 Ver. 1 Specification Chapter 8 asserts tested in this CTS.

Assertion #	Test	Assertion Description
8.2.1.2 TMU Router Configuration Capability		
8.2.1.2#1		A TMU Router Configuration Capability shall have the structure depicted in Figure 8-3 and the fields defined in Table 8-4.
8.2.1.2#2		Any field that spans across multiple Doublewords (e.g. LocalTime Low, LocalTime Middle, and LocalTime High) shall use the Register Locking Mechanism defined in Section 8.2.1.2.1 and the Register Group Locking Mechanism defined in Section 8.2.1.2.2.
8.2.1.2.1 Register Locking Mechanism		
8.2.1.2.1#1		In order to keep consistent values in these fields, 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		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		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		The value of a locked register group shall change only when the Triggering DW is accessed.
8.2.1.2.2#2		Table 8-5 lists the register groups that shall be locked
8.2.2.2 TMU Adapter Configuration Capability		
8.2.2.2#1		A TMU Lane Adapter Configuration Capability shall have the structure depicted in Figure 8-8 and shall contain the fields defined in Table 8-11.
8.2.2.2#2		For a USB4 Port with two enabled Adapters, the values in the TMU Lane Adapter Configuration Capability of both Adapters shall be identical.
8.2.2.2#3	TBD	When a value in the TMU Lane 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		The TMU Adapter shall set the EnableUniDirectionalMode bit to 0b when its USB4 Port is disconnected.

Version 2 Assertions

Chapter 4

The following Table presents the USB4 Ver. 2 Specification Chapter 4 asserts tested in this CTS.

Assertion #	Test	Assertion Description
4.2.1.6.3 Objections		
4.2.1.6.3#1	NT	A USB4 Port shall assert an objection to enter CL2 state if: Entry to CL2 state would delay a pending Time Sync handshake.
4.2.1.6.3#2	NT	This objection shall be asserted until the Time Sync handshake is complete.
4.2.1.6.3#3	NT	A USB4 Port shall assert an objection to enter CL1 state if: Entry to CL1 state would delay a pending Time Sync handshake.
4.2.1.6.3#4	NT	The objection shall be asserted until the Time Sync handshake is complete.

Chapter 7

The following Table presents the USB4 Ver. 2 Specification Chapter 7 asserts.

Assertion #	Test	Assertion Description
7 Time Synchronization		
7#1	NT	Deprecated.
7#2		A Router with one or more Downstream Facing Port shall support the Time Synchronization Protocol described in this chapter.
7#3		A Router that does not support the Time Synchronization Protocol shall set the Time Synchronization Protocol Not Supported bit in the TMU Router Configuration Capability to 1b.
7#4		A Router shall implement the TMU Router Configuration Capability and the TMU Adapter Configuration Capability as described in Sections 8.2.1.2 and 8.2.2.2.
7#5		Host Router that does not support Inter-Domain Time Synchronization shall set the IDNS bit in the TMU Router Configuration Capability to 1b.
7.1 Time Synchronization Architecture		
7.1.1 Synchronization Hierarchy		
7.1.1.1 Intra-Domain Hierarchy		
7.1.1.2 Inter-Domain Hierarchy		
7.1.2 Time Sync Parameters		
7.1.2.1 Local Time		
7.1.2.1#1	NT	A Router shall provide a free-running clock for use in capturing the time stamps needed for the Time Synchronization Protocol.
7.1.2.1#2	NT	The Local Clock shall run at a frequency of 125 MHz or greater with an accuracy of +/- 100ppm relative to the nominal Local Clock frequency
7.1.2.1#3	NT	The Local Clock shall not be spread-spectrum.
7.1.2.1#4	Stat Sub #1	A Router shall use an 80-bit Local Time counter with the format shown in Figure 7-2 to track Local Time.
7.1.2.1#5	Stat Sub #1	The Local Time counter shall be incremented up with the Local Clock.
7.1.2.2 Time Offset		
7.1.2.2#1	NT	The TimeOffsetFromHR register shall have the format shown in Figure 7-3.

7.1.2.2#2	Stat Sub #2	The TimeOffsetFromHR register shall be updated at the conclusion of every Time Sync Handshake.
7.1.2.3 Frequency Offset		
7.1.2.3#1	NT	The frequency offset shall be computed according to Equation 7-2.
7.1.2.3#2	Stat Sub #3	The FreqOffsetFromHR register shall be updated at the conclusion of every Time Sync Handshake.
7.2 Time Stamp Measurement		
7.2.1 Time Stamp Measurement for Gen 2 and Gen 3 Links		
7.2.1#1	Protocol Check #3	USB4 Port shall generate a time stamp whenever it either sends or receives a Time Sync Notification Ordered Set (TSNOS).
7.2.1#2	NT	A USB4 Port shall use the value in the Local Time counter to capture time stamps.
7.2.1#3	NT	A time stamp shall be taken at the Time Stamp Point of the First TSNOS.
7.2.1#4	Protocol Check #3	If one or more back-to-back TSNOS are received immediately after the first TSNOS, they shall be ignored.
7.2.1#5	NT	The same transmit reference pLane shall be used for all transmitted TSNOS and the same receive reference pLane shall be used for all received TSNOS.
7.2.1#6	Protocol Check #3	The time stamp measurement shall have a resolution of at least 8 ns (i.e. the period of the Local Clock).
7.2.1#7	NT	The time stamp in a Time Sync Packet shall have the format shown in Figure 7-2.
7.2.2 Time Stamp Measurement for Gen4 Links		
7.2.2#1		A Downstream Facing Port shall generate a Time Stamp Point periodically every AdapterTimeSyncInterval as configured in the TMU_ADP_CS_9 register.
7.2.2#2		An Upstream Facing Port shall generate a Time Stamp Point when it instructs the Logical Layer to send a Gen 4 Time Sync Notification Ordered Set (Gen 4 TSNOS).
7.2.2#3		All USB4 Ports shall generate a timestamp when they receive a Gen 4 TSNOS.
7.2.2#4		A USB4 Port shall use the value in the Local Time counter to capture timestamps.
7.2.2#5		A Downstream Facing Port shall send 24 Gen 4 TSNOS at the start of the next RS-FEC block after the Time Stamp Point.

7.2.2#6		An Upstream Facing Port shall send 24 Gen 4 TSNOS at the start of the next RS-FEC block after receiving an indication to send the Gen 4 TSNOS.
7.2.2#7		The Symbols Delay field shall have the same value in all 24 Gen 4 TSNOS.
7.2.2#8		The Symbols Delay field shall not exceed 1000.
7.2.2#9		The same transmit reference plane shall be used for all transmitted Gen 4 TSNOS.
7.2.2#10		The same receive reference plane shall be used for all received Gen 4 TSNOS.
7.2.2#11		The time stamp measurement shall have a resolution of at least 8 ns (i.e. the period of the Local Clock).
7.2.3 Asymmetry Corrections		
7.2.3#1	Time Calculation #2	Time stamps shall be corrected for asymmetry between transmit and receive paths.
7.2.3#2	Time Calculation #2	An Upstream Facing Port (UFP) shall correct for asymmetry by performing the following computations: $t1 = \text{Delay Request Sent Time Stamp} + \text{TxTimeToWire}$; $t4 = \text{Delay Response Received Time Stamp} - \text{RxTimeToWire}$; $tu1 = \text{RxTimeStamp} - \text{RxTimeToWire}$; $tu2 = \text{Delay Response Time Stamp} + \text{TxTimeToWire}$; where, TxTimeToWire is the value in the TxTimeToWire field of the TMU_ADP_CS_1 register of the UFP and RxTimeToWire is the value in the RxTimeToWire field of the TMU_ADP_CS_2 register of the UFP.
7.2.3#3	Time Calculation #2	A Downstream Facing Port (DFP) shall correct for asymmetry by performing the following computations: $t2 = \text{Delay Request Received Time Stamp} - \text{RxTimeToWire}$; $t3 = \text{Delay Response Sent Time Stamp} + \text{TxTimeToWire}$; $td1 = \text{Delay Request Time Stamp} + \text{TxTimeToWire}$; $td2 = \text{RxTimeStamp} - \text{RxTimeToWire}$; where, TxTimeToWire is the value in the TxTimeToWire field of the TMU_ADP_CS_1 register of the DFP and RxTimeToWire is the value in the RxTimeToWire field of the TMU_ADP_CS_2 register of the DFP.
7.2.3#4	Time Calculation #2	For a Gen 2 or Gen 3 Link: The time duration between when a USB4 Port generates a time stamp and when it transmits first bit of a TSNOS on the wire shall be equal to the value in the TxTimeToWire field of the TMU_ADP_CS_1 register.
7.2.3#5	Time Calculation #2	For a Gen 2 or Gen 3 Link :The time duration between when a USB4 Port receives the first bit of a TSNOS on the wire and when it generates a time stamp shall be equal to the value in the RxTimeToWire field of the TMU_ADP_CS_2 register.
7.2.3#6		For a Gen 4 Link: The time duration between when a USB4 Port generates a Time Stamp Point and when it transmits first bit of a TSNOS on the wire shall be calculated using Equation 7-1.

7.2.3#7		For a Gen 4 Link: When a USB4 Port detects the first TSNOS, it generates a time stamp that shall be equal to the current time subtracted by the value of the Symbols Delay field multiplied by the Symbol Time and RxTimeToWire.
7.3 Time Sync Protocol		
7.3.1 Time Sync Handshake		
7.3.1#1	Protocol Check #1	A Router shall support Bi-Directional Time Sync Handshakes in HiFi Mode.
7.3.1#2	NT	A Router shall support Uni-Directional Time Sync Handshakes in HiFi Mode and LowRes Mode.
7.3.1#3	NT	When the USB4 Ports are connected by a Single-Lane Link, a Time Sync Handshake shall occur over that Link.
7.3.1#4	NT	When the USB4 Ports are connected by an Aggregated Link, the Delay Request and Delay Response Ordered Sets in the Time Sync Handshake shall be sent on both the Lane 0 and Lane 1.
7.3.1#5	NT	The Follow-Up Packet shall be sent using both Lanes (i.e. alternating bytes across Lanes).
7.3.1#6	NT	The timestamp shall be taken when the first Ordered Set from the Link Partner is received.
7.3.1#7	NT	For a Gen 2 or Gen 3 Link, a Receiver shall ignore a TSNOS that arrives back-to-back after another TSNOS.
7.3.1#8		A Router shall support Enhanced Uni-Directional Time Sync Handshake in HiFi.
7.3.1.1 Bi-Directional Time Sync Handshake		
7.3.1.1#1	Protocol Check #1	A DFP shall not initiate a Bi-Directional Time Sync Handshake
7.3.1.1#2	Protocol Check #1	A UFP shall send a Delay Request to the DFP at the interval specified in the TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space.
7.3.1.1#3	Protocol Check #1	A DFP shall transmit a Delay Response Packet within 1 μ s of receiving a Delay Request Packet.
7.3.1.1#4	Protocol Check #1	A DFP shall transmit a Follow-Up Packet within SendTimeout of transmitting the associated Delay Response Packet.
7.3.1.1#5	Stat Sub #6	A UFP shall generate time stamp t1 upon transmission of a Delay Request and shall generate time stamp t4 upon reception of a Delay Response.
7.3.1.1#6	Protocol Check #2	A DFP shall generate time stamp t2 upon receipt of a Delay Request and shall generate time stamp t3 upon transmission of a Delay Response.

7.3.1.1#7	NT	If an error occurs during the transmission or reception of a Time Sync Packet, the entire Time Sync Handshake shall be voided (i.e. neither time stamps nor values from the Follow-Up Packet shall be used).
7.3.1.1#8	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 1. Take the t2 timestamp
7.3.1.1#9	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 2. Send a Delay Response.
7.3.1.1#10	NT	Delay Response shall be sent within RespTimeout time or receiving the Delay Request
7.3.1.1#11	NT	The DFP shall take the t3 timestamp upon Delay Response transmission
7.3.1.1#12	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 3. Compute the updated TimeOffsetFromHR parameter according to Equation 7-6 using the t3 timestamp from Step 2b
7.3.1.1#13	NT	When using Bi-Directional Time Sync Handshake, a DFP shall do the following upon receiving a Delay Request: 4. Send Follow-Up Packet with the TimeOffsetFromHR calculated in Step 3
7.3.1.2 Uni-Directional Time Sync Handshake		
7.3.1.2#1	Protocol Check #3	When using Uni-Directional Time Sync Handshake, only the DFP shall initiate a Time Sync Handshake
7.3.1.2#2	Protocol Check #3	A DFP shall send a Delay Response to the UFP at the interval specified in the TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space.
7.3.1.2#3	Protocol Check #3	A DFP shall transmit a Follow-Up Packet within SendTimeout after transmitting the associated Delay Response Packet
7.3.1.2#4	Protocol Check #3	Uni-Directional Time Sync Handshake shall be used when the following conditions are true: Both Link Partners support Uni-Directional Time Sync Handshake; Both Link Partners have the EnableUniDirectionalMode field in the TMU_ADP_CS_3 register in Adapter Configuration Space set to 1b.
7.3.1.3 Enhanced Uni-Directional Time Sync Handshake		
7.3.1.3#1		Enhanced Uni-Directional Time Sync Handshakes shall be used when all the following conditions are true: The Enable Enhanced Uni-Directional bit in the TMU_ADP_CS_8 register in the TMU Adapter Configuration Space is set to 1b; The AdapterTimeSyncInterval field in the TMU_ADP_CS_9 register in the TMU Adapter Configuration Space is set to 16.
7.3.1.3#2		When using Enhanced Uni-Directional Time Sync Handshakes, only the Downstream Facing Port shall initiate a Time Sync Handshake.

7.3.1.3#3		When a USB4 Port is using Enhanced Uni-Directional Time Sync Handshakes, it shall ignore the value of the TSPacketInterval in the TMU_RTR_CS_3 register.
7.3.1.3.1 Inversed Bi-Directional Mode		
7.3.1.3.1#1		A Downstream Facing Port shall send a Delay Request to the Upstream Facing Port at the interval specified in the AdapterTimeSyncInterval field in the TMU_ADP_CS_9 register in TMU Adapter Configuration Space.
7.3.1.3.1#2		An Upstream Facing Port shall transmit a Delay Response within RespTimeout time of receiving a Delay Request.
7.3.1.3.1#3		A Downstream Facing Port shall transmit a Follow-Up Packet within SendTimeout time of receiving the associated Delay Response.
7.3.1.3.1#4		Both the Downstream Facing Port and Upstream Facing Port shall assert an objection to CLx states while the Time Sync Handshakes are in Inversed Bi-Directional mode.
7.3.1.3.1#5		A Downstream Facing Port shall generate time stamp td1 upon transmission of a Delay Request and shall generate time stamp td2 upon reception of a Delay Response.
7.3.1.3.1#6		An Upstream Facing Port shall generate time stamp tu1 upon receipt of a Delay Request and shall generate time stamp tu2 upon transmission of a Delay Response.
7.3.1.3.1#7		If an error occurs during the transmission or reception of a Time Sync Packet, the entire Time Sync Handshake shall be voided (i.e. neither the time stamps nor the values from the Follow-Up Packet shall be used).
7.3.1.3.1#8		When using Inversed Bi-Directional Time Sync Handshake, a Downstream Facing Port shall do the following upon receiving a Delay Response: 1) Take the td2 timestamp; 2) Send a Follow-Up Packet with the calculated TimeOffsetFromHR.
7.3.1.3.1#9		The value of the S2U (Switch to Uni-Directional) bit in the Follow-Up Packet shall be 0b for the first DirSwitchN-1 successful Handshakes. Otherwise it shall be set to 1b.
7.3.1.3.1#10		When using Inversed Bi-Directional Time Sync Handshake, an Upstream Facing Port shall do the following upon receiving a Delay Request: 1) Take the tu1 timestamp; 2) Send a Delay Response.
7.3.1.3.1#11		Delay Response shall be sent within RespTimeout time of receiving the Delay Request.
7.3.1.3.1#12		The Upstream Facing Port shall take the tu2 timestamp upon Delay Response transmission.
7.3.1.3.2 Adaptive Bi-Directional Mode		

7.3.1.3.2#1		When the Adapters on a Link are not in a CLx state, the Downstream Facing Port shall send a Delay Response to the Upstream Facing Port at the interval specified in the AdapterTimeSyncInterval field in the TMU_ADP_CS_9 register in TMU Adapter Configuration Space.
7.3.1.3.2#2		A Downstream Facing Port shall transmit a Follow-Up Packet after the Delay Response was sent and within SendTimeout time of transmitting the associated Delay Response.
7.3.1.3.2#3		The Downstream Facing Port shall assert an objection to CLx states in the time after sending the Delay Response and before sending the Follow-Up Packet.
7.3.1.3.2#4		A Downstream Facing Port shall generate time stamp td1 upon transmission of a Delay Response.
7.3.1.3.2#5		An Upstream Facing Port shall generate time stamp tu1 upon receipt of a Delay Response. Section 7.2 defines how time stamps are measured.
7.3.1.3.2#6		If an error occurs during the transmission or reception of a Time Sync Packet, the entire Time Sync Handshake shall be voided (i.e. neither time stamps nor values from the Follow-Up Packet shall be used).
7.3.1.3.2#7		When there is a transition from “Response TSNOS” state to “Wait Sync Event” state due to the expiration of RespTimeout and SleepCyclesN<7FFFh, the Downstream Facing Port shall increment the SleepCyclesN by 1.
7.3.1.3.2#8		When there is a transition from “Send Follow-Up Packet” state to “Wait Sync Event” state due to the expiration of SendTimeout and SleepCyclesN<7FFFh, the Downstream Facing Port shall increment SleepCyclesN by 1.
7.3.1.3.2#9		SleepCyclesN shall be set to 0h after a Follow-Up Packet is sent.
7.3.1.3.2#10		The Local Time counter shall continue counting while the Adapter is in CL1 or CL0s (TX) state.
7.3.1.3.2#11		The Downstream Facing Port shall resume Time Sync Handshakes upon exiting CL1 or CL0s (TX) state keeping the same AdapterTimeSyncInterval and the updated Local Time counter value.
7.3.1.3.2#12		In the Follow-Up Packet associated with the first Time Sync Handshake after exiting CL1 or CL0s (TX), the Downstream Facing Port shall set the value of the SleepCyclesN field to match the number of handshakes missed by the Downstream Facing Port.
7.3.1.3.2#13		When an Adapter is in the CL2 state, a Downstream Facing Port shall stop Time Sync Handshakes.
7.3.1.3.2#14		When exiting CL2 state back to CL0 state, the Time Sync Handshakes shall start in Inversed Bi-Directional mode as if the TMU was enabled, including objecting to CLx states before the transition to Adaptive Uni-Directional mode.

7.3.1.3.2#15		A Router shall reach the required time synchronization accuracy within tConvergeTime after Time Sync Handshakes are resumed when exiting CL2.
7.3.2 Inter-Domain Time Sync		
7.3.2#1	Protocol Check #1	A USB4 Port shall perform Time Sync Handshakes as described in Section 7.3.1 across the Inter-Domain Link when either the IDTR bit or IDTI bit is set to 1b.
7.3.2#2	Protocol Check #1	After completing a Time Sync Handshake across an Inter-Domain Link, the IDTI Port shall calculate the following: The Inter-Domain time stamp (see Section 7.4.2.1); The Inter-Domain frequency offset (see Section 7.4.2.2); The Inter-Domain time offset (see Section 7.4.2.3).
7.3.2#3	Protocol Check #1	After calculating the Inter-Domain time offset, Inter-Domain frequency offset and Inter-Domain time stamp, the IDTI Port shall update the InterDomainTimeStamp, FreqOffsetFromInterDomainHR and TimeOffsetFromInterDomainHR fields in Router Configuration Space.
7.3.2#4	Protocol Check #5	If the IDTI Port is part of a Device Router, it shall prepare an Inter-Domain Time Stamp Packet as described in Section 7.3.3.3.
7.3.2#5	Protocol Check #5	If the TSInterDomainInterval field in Router Configuration Space is 0, the IDTI Port shall send the Host Router an Inter-Domain Time Stamp Packet after each Inter-Domain Time Sync Handshake.
7.3.2#6	Protocol Check #5	If the TSInterDomainInterval field in Router Configuration Space is not 0, the IDTI Port shall send the Host Router an Inter-Domain Time Stamp Packet at time intervals equal to $(TSInterDomainInterval + 1) * TSPacketInterval$ number of microseconds.
7.3.2#7	NT	When a Host Router receives an Inter-Domain Time Stamp Packet: If the IDE bit in the TMU_RTR_CS_0 register of the Host Router's TMU Router Configuration Capability is set to 1b, the Host Router shall update its TimeOffsetFromInterDomainHR and FreqOffsetFromInterDomainHR registers using the time offset and frequency offset respectively contained in the Inter-Domain Time Stamp Packet.
7.3.2#8	NT	When a Host Router receives an Inter-Domain Time Stamp Packet: If the IDE bit in the Host Router is set to 0b, the Host Router shall drop the Inter-Domain Time Stamp Packet and shall not update its TimeOffsetFromInterDomainHR or FreqOffsetFromInterDomainHR registers
7.3.2#9		When the IDTR is set to 1b, a USB4 Port shall behave as a Downstream Facing Port.
7.3.2#10		When the IDTI is set to 1b, a USB4 Port shall behave as an Upstream Facing Port.
7.3.3 Packet Formats		

7.3.3.1 Time Sync Notification Ordered Set Format		
7.3.3.1#1	Protocol Check #1	Both a Delay Request and a Delay Response shall consist of the Time Sync Notification Ordered Set (TSNOS) defined in Section 4.4.7.
7.3.3.2 Follow-Up Packet Format		
7.3.3.2#1	Protocol Check #2	A Follow-Up Packet shall have the format shown in Figure 7-13.
7.3.3.2#2	Protocol Check #2	A Follow-Up Packet shall have the PDF field set to 1, the HopID set to 3, and the Length set to 60.
7.3.3.2#3	Protocol Check #2	The payload shall contain the fields in Table 7-3.
7.3.3.2#4	Time Calculation #2	For Bi-Directional Time Sync Handshakes: [in the RequestTS field] The time stamp shall include the asymmetry corrections performed at the DFP as specified in Section 7.2.3.
7.3.3.2#5	Protocol Check #2	The RequestTS field shall have the format shown in Figure 7-2
7.3.3.2#6	Protocol Check #4	For Uni-Directional and Adaptive Uni-Directional Time Sync Handshakes: The RequestTS field shall contain the same value as the ResponseTS field.
7.3.3.2#7	Time Calculation #2	For Bi-Directional, Uni-Directional and Adaptive Uni-Directional Time Sync Handshakes: [in the ResponseTS field] The time stamp shall include the asymmetry corrections performed at the DFP as specified in Section 7.2.3.
7.3.3.2#8	Protocol Check #2	The ResponseTS field shall have the format shown in Figure 7-2.
7.3.3.2#9	Protocol Check #2	The TimeOffsetFromHR field shall have the format shown in Figure 7-3.
7.3.3.2#10	Protocol Check #2	The FreqOffsetFromHR shall have the format shown in Figure 7-4.
7.3.3.2#11	Protocol Check #2	For Bi-Directional and Uni-Directional, bits 31:16 of DW8 are reserved and shall be set to 0. For Enhanced Uni-directional, bits 30:16 of DW8 are the SleepCycleN and bit 31 is the S2U.
7.3.3.2#12	Protocol Check #2	For a Host Router: If IDE bit is set to 0b, then the IDTimeStamp field shall be set to 0.
7.3.3.2#13	Protocol Check #2	For a Device Router: The IDTimeStamp field shall contain the IDTimeStamp value from the last Follow-Up Packet that the IDTI Port on the Router Received.
7.3.3.2#14	Protocol Check #2	For a Host Router: If IDE bit is set to 0b, then the FreqOffsetFromInterDomainHR field shall be set to 0.
7.3.3.2#15	Protocol Check #2	For a Device Router: The FreqOffsetFromInterDomainHR field shall contain the FreqOffsetFromInterDomainHR value in the last Follow-Up Packet that the IDTI Port on the Router Received.

7.3.3.2#16	NT	The CRC32 computation shall be based on the following specification: Width: 32; Poly: 1EDC 6F41h; Init: FFFF FFFFh; RefIn: True; RefOut: True; XorOut: FFFF FFFFh;
7.3.3.2#17		For Inversed Bi-Directional Time Sync Handshakes: [in the RequestTS field] The time stamp shall include the asymmetry corrections performed at the Downstream Facing Port as described in Section 7.2.3.
7.3.3.2#18		For Inversed Bi-Directional Time Sync Handshakes: [in the ResponseTS field] The time stamp shall include the asymmetry corrections performed at the Downstream Facing Port as specified in Section 7.2.3.
7.3.3.2#19		[The S2U] bit shall be set to 1b after Enhanced Uni-Directional Time Sync Handshakes are enabled and DirSwitchN – 1 number of Follow-Up packets have been sent. Otherwise it shall be set to 0b.
7.3.3.2#20		When Adaptive Uni-Directional mode is enabled, [the SleepCyclesN] field shall contain the number of missed Time Sync Handshakes. It shall be set to 0h when no Time Sync Handshakes were missed.
7.3.3.2#21		In Bi-Directional, Uni-Directional, and Inversed Bi-Directional modes, [the SleepCyclesN] field shall be set to 0h
7.3.3.3 Inter-Domain Time Stamp Packet		
7.3.3.3#1	Protocol Check #5	An Inter-Domain Time Stamp Packet shall have the format shown in Figure 7-14.
7.3.3.3#2	Protocol Check #5	An Inter-Domain Time Stamp Packet shall have the PDF set to 2, the HopID set to 3, and the Length set to 28.
7.3.3.3#3	Protocol Check #5	The payload shall contain the fields in Table 7-4.
7.3.3.3#4	Protocol Check #5	The IDTimestamp field shall have the format shown in Figure 7-2.
7.3.3.3#5	Protocol Check #5	The TimeOffsetFromInterDomainHR field shall have the format shown in Figure 7-3.
7.3.3.3#6	Protocol Check #5	The FreqOffsetFromInterDomainHR field shall have the format shown in Figure 7-4.
7.3.3.3#7	NT	The CRC32 computation shall be based on the following specification: Width: 32; Poly: 1EDC 6F41h; Init: FFFF FFFFh; RefIn: True; RefOut: True; XorOut: FFFF FFFFh;
7.4 Time Computations		
7.4#1	NT	A Router shall be able to compute the Host Router Time at any instant in time.
7.4.1 Intra-Domain Equations		

7.4.1#1	Stat Sub #3	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-1 to compute the frequency ratio between itself and its DFP.
7.4.1#2	Stat Sub #3	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-2 to compute the frequency offset. The UFP uses the frequency ratio obtained in Step 1 as input to the computation.
7.4.1#3	Stat Sub #3	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-3 to compute the frequency ratio between itself and the Host Router. The UFP uses the FreqOffsetFromHR value in the last Follow-Up Packet received from the DFP as input to the computation.
7.4.1#4	Stat Sub #3	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-4 to compute the frequency offset between itself and the Host Router. The UFP uses the frequency ratio computed in Step 3 as input to the computation.
7.4.1#5	Stat Sub #5	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-5 to compute the propagation delay of the cable between the UFP and the DFP.
7.4.1#6	Stat Sub #2	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The Link Partner (i.e. the DFP upstream of the UFP) uses Equation 7-6 to compute the most updated time offset from the Domain Host Router. The Link Partner uses the most recent result from Equation 7-9, as input to the computation.
7.4.1#7	Stat Sub #2	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-7 (Bi-Directional Time Sync Handshakes) or Equation 7-8 (Uni-Directional Time Sync Handshakes) to compute the time offset from its DFP.
7.4.1#8	Stat Sub #4	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-9 to compute the time offset from the Host Router. The UFP uses the time offset from Equation 7-7 or Equation 7-8, and the value in the last received Follow-Up Packet as input to the computation.
7.4.1#9	Time Calculation #1	A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: The UFP uses Equation 7-10 to compute the current time offset from the Host Router. The UFP uses the time offset computed in Equation 7-9 and the frequency offset computed in Equation 7-3 as input to the computation.
7.4.1#10		A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: When Enhanced Uni-Directional mode is enabled, the equations use $t_3 = td_1$ and $t_4 = tu_1$

7.4.1#11		A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: An Upstream Facing Port uses Equation 7-11 (Time Offset Delta) to calculate the current change in Time Offset between two consecutive handshakes.
7.4.1#12		A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: An Upstream Facing Port uses the Time Offset Delta in Equation 7-12 (First Time Offset from Downstream Facing Port) on the first handshake after a “pause”. This calculation shall not be filtered.
7.4.1#13		A Router shall use the following series of computations to calculate the current Host Router Time within a single Domain: When using Equation 7-9 in Adaptive Uni-Directional mode, the Const value is the average T_{pd} calculated using Equation 7-7 in Inversed Bi-Directional mode.
7.4.2 Inter-Domain Equations		
7.4.2.1 Inter-Domain Time Stamp Computation		
7.4.2.1#1	NT	Equation 7-11 is used to compute an Inter-Domain time stamp.
7.4.2.2 Inter-Domain Frequency Offset Computation		
7.4.2.2#1	NT	The frequency ratio between the Host Router in the Domain with the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-12.
7.4.2.3 Inter-Domain Time Offset Computation		
7.4.2.3#1	Stat Sub #7	The time offset of the IDTR Port that is sent in the Follow-Up Packet at the end of an Inter-Domain Time Sync Handshake is computed using Equation 7-14
7.4.2.3#2	Stat Sub #9	The time offset between the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-15.
7.4.2.3#3	Stat Sub #9	The time offset between the Host Router of the Domain with the IDTI Port and the Inter-Domain Time Source is computed using Equation 7-16.
7.4.2.4 Inter-Domain Host Router Time Computation		
7.4.3 Filtering		
7.5 Time Synchronization Accuracy Requirements		
7.5#1	NT	A Router shall reach the required time synchronization accuracy within tConvergeTime after Time Sync Handshakes are enabled.
7.5#2	TBD	If Time Sync Handshakes are paused, a UFP shall reach the required time synchronization accuracy within tCLxConvergeTime after receiving a Delay Response Packet.
7.5.1 Paired Measurement		

7.5.1#1	NT	For Bi-Directional and Enhanced Uni-Directional Time Sync Handshake, the Static Offset between two Routers connected to one another shall not add more than 8 ns per Link.
7.5.1#2	NT	In HiFi Mode, the Dynamic Noise between two Routers connected to one another shall not add more than tHiAccuracy.
7.5.1#3	NT	In LowRes Mode, the Dynamic Noise between two Routers connected to one another shall not add more than tLowAccuracy.
7.5.2 Standalone Measurement		
7.5.2#1	NT	In HiFi Mode, the noise between measurement points and the ideal line shall not be more than tHiAccuracy.
7.5.2#2	NT	In LowRes Mode, the noise between measurement points and the ideal line shall not be more than tLowAccuracy.
7.5.2#3	NT	In order to achieve the goal of 1 ns static noise, the budget for TxTimeToWire uncertainty shall not be more than 6.4 ns dynamic noise with no more than 6.4 ns static offset that changes after each power up.
7.5.2#4	NT	RxTimeToWire shall not be more than 12.8 ns dynamic noise with no more than 6.4 ns static offset that changes after each power up.
7.5.2#5	NT	Dynamic uncertainty in TxTimeToWire and RxTimeToWire shall be filtered out during calculations by IRR or other filtering.
7.5.3 Measuring Method		
7.5.4 Accuracy Parameters		
7.6 Software Configuration		
7.6.1 Intra-Domain Time Synchronization Setup		
7.6.1#1	NT	A Router that is hot-plugged to a Domain shall only initiate the Time Sync Handshake on its UFP when the following conditions are true: The physical layer has established the Link between the hot-plugged Router and the Domain; The TSPacketInterval field in the TMU_RTR_CS_3 register in Router Configuration space is greater than 0.
7.6.2 Inter-Domain Time Synchronization Setup		
7.6.3 Post Time Mechanism		
7.6.3#1	NT	A Router shall update its local time when the Post Time is less than or equal to the Nanoseconds field in the Host Router Time Register.

7.6.4 Time Disruption Bit

Chapter 8

The following Table presents the USB4 Ver. 2 Specification Chapter 8 asserts tested in this CTS.

Assertion #	Test	Assertion Description
8.2.1.2 TMU Router Configuration Capability		
8.2.1.2#1		A TMU Router Configuration Capability shall have the structure depicted in Figure 8-3 and the fields defined in Table 8-4.
8.2.1.2#2		Any field that spans across multiple Doublewords (e.g. LocalTime Low, LocalTime Middle, and LocalTime High) shall use the Register Locking Mechanism defined in Section 8.2.1.2.1 and the Register Group Locking Mechanism defined in Section 8.2.1.2.2.
8.2.1.2.1 Register Locking Mechanism		
8.2.1.2.1#1		In order to keep consistent values in these fields, 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		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		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		The value of a locked register group shall change only when the Triggering DW is accessed.
8.2.1.2.2#2		Table 8-5 lists the register groups that shall be locked
8.2.2.2 TMU Adapter Configuration Capability		
8.2.2.2#1		A TMU Lane Adapter Configuration Capability shall have the structure depicted in Figure 8-8 and shall contain the fields defined in Table 8-11.
8.2.2.2#2		For a USB4 Port with two enabled Adapters, the values in the TMU Lane Adapter Configuration Capability of both Adapters shall be identical.
8.2.2.2#3	TBD	When a value in the TMU Lane 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		The TMU Adapter shall set the EnableUniDirectionalMode bit to 0b when its USB4 Port is disconnected.

Test Requirements

Testing Approach

The USB4 Time Synchronization Protocol is tested using the following methods:

- Indirect measurement by reading and analyzing statistics (TMU registers in Router and Adapter Configuration Spaces)
- Direct measurement by letting KG USB4 Devices synchronize with the UUT and then extracting the system time via Time Serial Interface from the KG USB4 Device
- Protocol testing with USB4 Protocol analyzer
- Functional compliance of time sensitive protocols: ITP, PTM and DisplayPort over different setups

Hardware

Testing TMU requires:

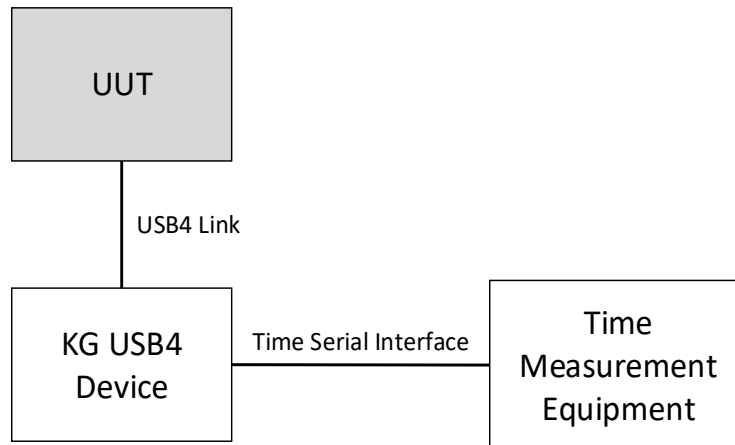
- KG USB4 Host
- KG USB4 Hub
- KG USB4 Device
- TMU CLK OUT Analyzer
- USB4 Link Analyzer
- USB4 CV SW

Measurement Methods

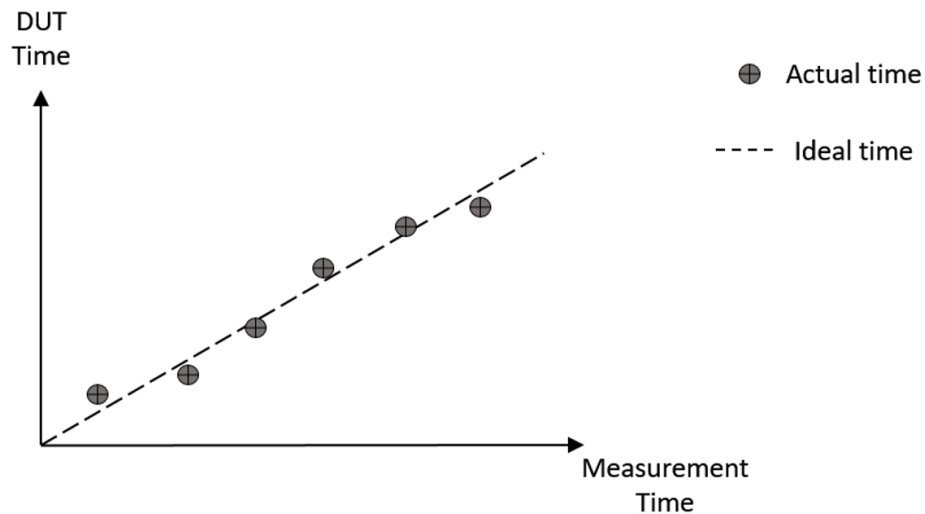
Direct Time Measurement Method

Standalone Time Stream

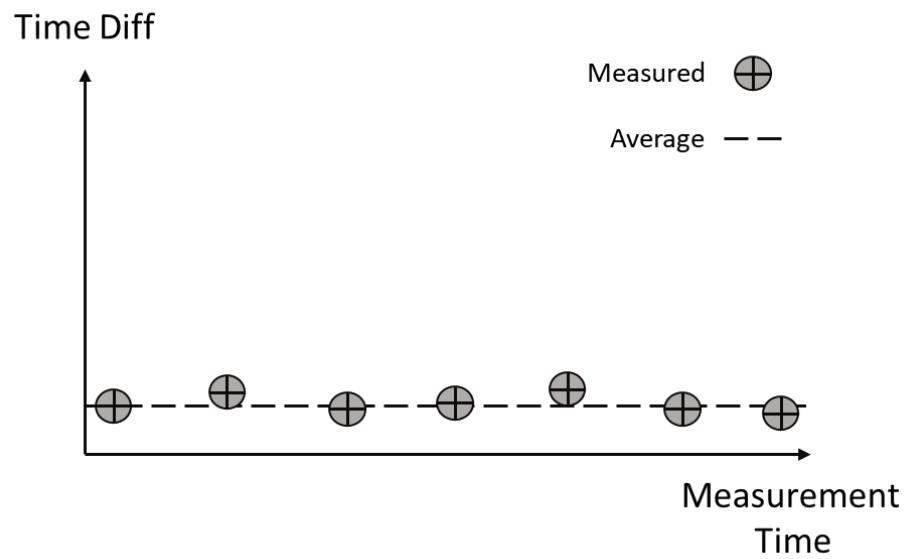
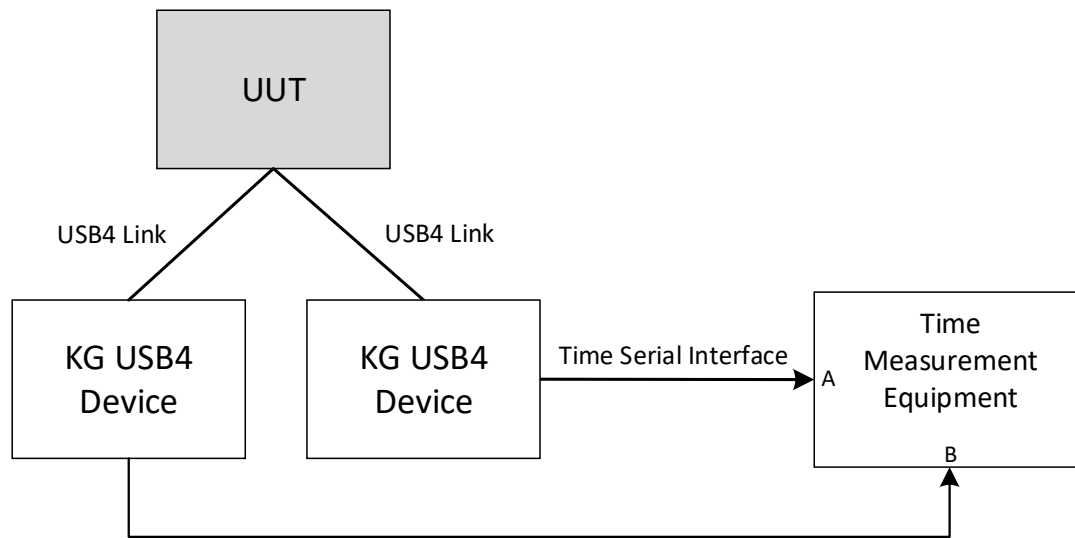
When applicable, time synchronization is measured via Time Serial Interface (TMU CLK OUT) of a KG USB4 Host, KG USB4 Hub or KG USB4 Device in the following manner:



The KG USB4 Device synchronizes to UUT and then extracts the computed Host Router time over Time Serial interface, which in turn is fed to Serial Protocol Analyzer. After Host Router time is extracted, it is analyzed for consistency.



Comparative Time Measurement



Time Measurement Equipment

The TMU FPGA is used to capture the time stream on the Time Serial Interface. The FPGA is operated through executable (outside the scope of this document).

The command format is:

1. To capture PA input in standalone mode
 > TMU_FPGA.bat PA
2. To capture PA input in standalone mode
 > TMU_FPGA.bat PB
3. To capture in comparative mode
 > TMU_FPGA.bat TDIFF

The output will be in the file “**dump.txt**”

The file location shall be in folder "C:\Users\Public\Documents\TMU_FPGA\USB4_Compliance\"

The file format is list of timestamps in hexadecimal:

```
00000010001
00000050002
000000a0003
000000f0004
00000140005
```

The time format is as specified in Figure 7-2. Local Time Counter Format of the USB4 Specification and shall have exactly 16 hexadecimal digits.

Indirect Measurement Method (SW)

This section describes the registers that participate in analyzing time sync using Indirect method.

\ Device Type Variable	Host Router	Hub	Endpoint
LocalTime	✓	✓	✓
TimeOffsetFromHR	X	✓	✓
TimeOffsetFromDFP	X	✓	✓
FreqOffsetFromHR	X	✓	✓
FreqOffsetFromDFP	X	✓	✓
Propagation Delay	X	✓	✓
Computation Timestamp	X	✓	✓
InterDomain Computation Timestamp	✓	✓	✓
TimeOffsetFromInterDomainHR	✓	✓	✓
FreqOffsetFromInterDomainHR	✓	✓	✓

\ Statistics Port Direction	RX TSNOS Counter	TX TSNOS Counter	RX Packet Counter	TX Packet Counter
Upstream Bidirectional	✓	✓	✓	X
Downstream Bidirectional	✓	✓	X	✓
Upstream Unidirectional	✓	X	✓	X
Downstream Unidirectional	X	✓	X	✓
Upstream Enhanced Unidirectional	✓	DirSwitchN	✓	X
Downstream Enhanced Unidirectional	DirSwitchN	✓	X	✓

Where:

X - Register is expected to remain 0

✓ - Register is expected to change

DirSwitchN – Register is expected to increase until getting to DirSwitchN value

Reading and analyzing relevant registers in different setups gives basic insight into Time Sync functionality using different setups. The exact function are described further.

Testing Subroutines

This section defines subroutines with the test steps that are repeated for multiple tests. The USB4 Test Descriptions reference the subroutines defined in this section.

USB4 Link Configuration

Note: See the USB4 Connection Manager Guide for how to perform a DFP reset, initiate Lane Bonding, and enumerate Routers.

Link Configuration #1 Dual-Lane Link

1. If not defined specifically by the test, set highest supported speed on the Host Router Target Link Speed
2. USB4 CV performs a Downstream Port Reset on the DFP of the Host Router
3. If the Link is not Gen 4, USB4 CV initiates Lane Bonding
4. USB4 CV enumerates all Routers in the topology
5. Execute [Time Posting #5](#)

Link Configuration #2 Single Lane Links

1. USB4 CV disables Gen 4 Link in the DFP
2. USB4 CV performs a Downstream Port Reset on the DFP of the Host Router
3. USB4 CV does not initiate Lane Bonding
4. USB4 CV disabled Lane 1 Adapter
5. USB4 CV enumerates all Routers in the topology
6. Execute [Time Posting #5](#)

Direct Time Measurement

The deviation noise from ideal line is expected to be less than 1 ns per hop in HiFi mode and less than 4 ns in LowRes mode.

Time Calculation #1 System Time Consistency (Parameter N)

1. Parse Serial Time stream.
2. Capture each N -th Serial packet, extract system time.
3. Capture 32K samples of system time.
4. Create data regression on the time stream.
5. Measure system time deviation from average line.
6. Expected deviation is calculated by the following algorithm:

```
// TimeArr [0:L-1] is the array that contains all the values from the sample
// L is the length of the array

//Step#1: compute average step
AvStep=(TimeArr[L-1]-TimeArr[0])/(L-1);

//Step#2: build ideal array
IdealArr[0]=TimeArr[0];
```

```

for(i=1;i<L;i++) {
IdealArr[i]=IdealArr[i-1] + AvStep;
};

#Step#2: compute deviation from ideal
for(i=0;i<L;i++) {
Diff[i]=TimeArr[i]-IdealArr[i];
};

//Step#3: find max and min of the Diff
TMin = min(Diff);
TMax = max(Diff);

//Step#4: compute absolute error
AbsError = Tmax - Tmin;

```

7. Verify that AbsError: (7.4.1#9)
 - a. In HiFi mode less than 1 ns per hop
 - b. In LowRes mode less than 4 ns per hop
 - c. In MedRes mode less than 2 ns per hop

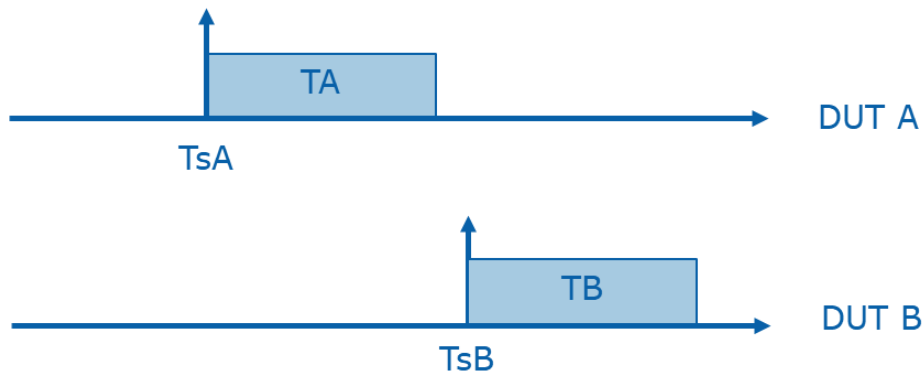
Assertions checked:

- 7.4.1#9

Comparative Time Measurement

Time Calculation #2 System Time Diff (Parameter N)

1. Parse Serial Time stream from UUT A.
2. Parse Serial Time stream from UUT B.
3. Capture each N-th pair.
4. Capture 32K samples.
5. Calculate Time Diff according to the following method:



$$\text{Time Diff} = (TB - TA) - (TsB - TsA)$$

Where TsA and TsB are the timestamps of serial packets

6. The following method is used to calculate the average Time Diff:

//TimeDiff[0:L-1] is an array containing the samples
// L is the length of the array

```
for (i=0;i<L;i++) {  
    TimeSum = TimeSum + TimeDiff[i];  
}  
TimeAv = TimeSum/L;
```

7. Verify that TimeDiff doesn't cross the expected amplitude: (7.2.1#1-#5, 7.3.3.2#4, 7.3.3.2#7)
 - a. In HiFi mode less than 2 ns per hop, TimePass = 2
 - b. In LowRes less than 10 ns per hop, TimePass = 10

The method:

```
for(i=0;i<L;i++) {  
    if (abs(TimeDiff[i] - TimeAV) > TimePass) {  
        error = 1;  
    }  
    if (abs(TimeDiff[i]) < 16 ns) {  
        error = 1;  
    }  
}
```

Note: The TimeDiff value is represented as a 32-bit 2's compliment signed integer.

Assertions checked:

- 7.2.1#1, 7.2.1#2, 7.2.1#3, 7.2.1#4, 7.2.1#5
- 7.3.3.2#4, 7.3.3.2#7

Protocol Validation

The steps in this section are performed by parsing a trace from the USB4 protocol analyzer.

Protocol Check #1: Bi-Directional

Verify that a Bi-Directional Time Sync Handshake is performed according to Figures 7-7 and 7-8 in USB4 specification:

1. Take sample of 250ms.
2. If the Link is Inter-Domain, then:
 - a. If IDTI bit in the Inter-Domain Time Initiator is not set and Bi-Directional mode is set, no handshake should be initiated
3. UFP initiates handshake every TSPacketInterval (+/- 1%). (7.3.1.1.#2, 7.3.2#1)
4. DFP does not initiate any handshakes. (7.3.1.1.#1, 7.3.2#1)
5. DFP responds by TSNOS within RespTimeout. (7.3.1.1.#3, 7.3.2#1)
6. DFP sends Follow-Up Packet within FPTimeout after OS. (7.3.1.1.#4, 7.3.2#1)

Assertions checked:

- 7.3.1#1
- 7.3.1.1#1, 7.3.1.1#2, 7.3.1.1#3, 7.3.1.1#4
- 7.3.2#1, 7.3.2#2, 7.3.2#3
- 7.3.3.1#1

Protocol Check #2: Bi-Directional

Take sample of 250ms.

Check the contents of each Follow-Up Packet:

1. Verify that:
 - a. PDF field is set to 1. (7.3.3.2#2)
 - b. HopID is set to 3. (7.3.3.2#2)
 - c. Length is set to 60. (7.3.3.2#2)
2. Verify that T2 and T3 are consistently growing between every two consecutive packets by TSPacketInterval. (7.3.1.1#6)
3. Verify that $\text{Max}(\Delta T2) - \text{Min}(\Delta T2)$ is less than 32 ns. (7.3.1.1#6)
 - a. Obtain a list of all follow up packets
 - b. Calculate all the T2 Deltas
 - i. A T2 Delta is $T2_{\text{Packet N}} - T2_{\text{Packet N-1}}$
 - c. Find the Minimum and maximum of T2 Delta
 - d. Verify the maximum delta minus the minimum delta is not bigger than 32 ns
4. Set a warning if $\text{Max}(T3-T2) - \text{Min}(T3-T2) > 32\text{ns}$
 - a. Obtain a list of all follow up packets
 - b. Calculate all the response delay deltas between T3 and T2
 - i. A response delay delta is $T3_{\text{Packet N}} - T2_{\text{Packet N}}$
 - c. Find the minimum and maximum of the response delay deltas.
 - d. Warn if the maximum minus the minimum is bigger than 32 ns
5. If a packet is sent by Hub Router on the downstream port, verify that:
 - a. TimeOffsetFromHR is consistently growing like in Stat Sub #2. (7.3.3.2#9)
 - b. FreqOffsetFromHR is constant like in Stat Sub #3. (7.3.3.2#10)
 - c. There is correlation between TimeOffsetFromHR and FreqOffsetFromHR same as in Stat Sub #4. (TBD)
6. If a packet is sent by Inter-Domain Time Responder or any DFP in Inter-Domain Time Initiator's Domain, verify that the following fields are 0 when IDE bit is set to 0 in Host Router:
 - a. IDTimeStamp. (7.3.3.2#12)
 - b. TimeOffsetFromInterDomainHR. (TBD)
 - c. FreqOffsetFromInterDomainHR. (TBD)
 - d. FreqOffsetFromInterDomainHR. (7.3.3.2#14)
7. Otherwise (IDE bit is set to 1), verify that:
 - a. IDTimeStamp is constantly growing between every two consecutive packets. (7.3.3.2#13)
 - b. TimeOffsetFromInterDomain is consistently growing like in Stat Sub #8. (TBD)
 - c. FreqOffsetFromInterDomain is constant like in Stat Sub #9. (7.3.3.2#15)
 - d. There is correlation between TimeOffsetFromInterDomain and FreqOffsetFromInterDomain same as in Stat Sub #10. (TBD)

Assertions checked:

- 7.3.1.1#6
- 7.3.3.2#1
- 7.3.3.2#2
- 7.3.3.2#3
- 7.3.3.2#5
- 7.3.3.2#8
- 7.3.3.2#9
- 7.3.3.2#10
- 7.3.3.2#11
- 7.3.3.2#12
- 7.3.3.2#13
- 7.3.3.2#14

- 7.3.3.2#15

Protocol Check #3: Uni-Directional

Verify that a Uni-Directional Time Sync Handshake is performed according to Figure 7-10 and 7-11 in the USB4 Specification:

1. Take sample of 250ms.
2. Verify that the DFP sends a TSNOS every TSPacketInterval (+/-1%). (7.3.1.2#2)
3. Verify that the DFP sends a Follow-Up Packet within SendTimeout time after sending the TSNOS. (7.3.1.2#3)

Assertions checked:

- 7.2#1
- 7.2#4
- 7.2#6
- 7.3.1.2#1
- 7.3.1.2#2
- 7.3.1.2#3
- 7.3.1.2#4

Protocol Check #4: Uni-Directional

Check the contents of a Follow-Up Packet:

1. Verify that:
 - a. PDF field is set to 1. (7.3.3.2#2)
 - b. HopID is set to 3. (7.3.3.2#2)
 - c. Length is set to 60. (7.3.3.2#2)
2. Verify that T2 is equal to T3 and is consistently growing between every two consecutive packets by TSPacketInterval. (TBD)
3. Verify that T2 is equal to T3 and $\text{Max}(\Delta T2) - \text{Min}(\Delta T2)$ is less than 32 ns.
 - a. Obtain a list of all follow up packets
 - b. Calculate all the T2 Deltas
 - i. A T2 Delta is $T2_{\text{Packet } N} - T2_{\text{Packet } N-1}$
 - c. Find the Minimum and maximum of T2 Delta
 - d. Verify the maximum delta minus the minimum delta is not bigger than 32 ns
4. If a packet is sent by Hub Router on the downstream port, verify that:
 - a. TimeOffsetFromHR is consistently growing like in Stat Sub #2.
 - b. FreqOffsetFromHR is constant like in Stat Sub #3.
 - c. There is correlation between TimeOffsetFromHR and FreqOffsetFromHR same as in Stat Sub #4.
5. If a packet is sent by Inter-Domain Time Responder or any DFP in Inter-Domain Time Initiator's Domain, verify that the following fields are 0 when IDE bit is set to 0 in Host Router:
 - a. IDTimeStamp. (TBD)
 - b. TimeOffsetFromInterDomain. (TBD)
 - c. FreqOffsetFromInterDomain. (TBD)
6. Otherwise (IDE bit is set to 1), verify that:
 - a. IDTimeStamp is constantly growing between every two consecutive packets. (TBD)
 - b. TimeOffsetFromInterDomain is consistently growing like in Stat Sub #8. (TBD)
 - c. FreqOffsetFromInterDomain is constant like in Stat Sub #9. (TBD)
 - d. There is correlation between TimeOffsetFromInterDomain and FreqOffsetFromInterDomain same as in Stat Sub #10. (TBD)

Assertions checked:

- 7.3.3.2#2, 7.3.3.2#6

Protocol Check #5: Inter-Domain Timestamp Packet

1. Verify that Inter-Domain TimeStamp packet is sent every $[(TSInterDomainInterval + 1) * TSPacketInterval]$ μs . (7.3.2#6)
2. Verify that:
 - a. PDF is set to 2. (7.3.3.3#2)
 - b. HopID is set to 3. (7.3.3.3#2)
 - c. Length is set to 28. (7.3.3.3#2)
3. Verify that Bits 31:16 of DW 0 are set to 0 (reserved). (7.3.3.3#3)
4. Verify that the IDTimeStamp field (DW 2:0) has the format shown in Figure 7-6. (7.3.3.3#4)
5. Verify that:
 - a. IDTimeStamp is constantly growing between every two consecutive packets.
 - b. TimeOffsetFromInterDomain is consistently growing like in Stat Sub #8.
 - c. FreqOffsetFromInterDomain is constant like in Stat Sub #9.
 - d. There is correlation between TimeOffsetFromInterDomain and FreqOffsetFromInterDomain same as in Stat Sub #10.

Assertions checked:

- 7.3.2#4
- 7.3.2#5
- 7.3.2#6
- 7.3.3.3#1
- 7.3.3.3#2
- 7.3.3.3#3
- 7.3.3.3#4
- 7.3.3.3#5
- 7.3.3.3#6

Protocol Check #6: Enhanced Uni-Directional (Ver. 2 Only)

Verify that an Enhanced Uni-Directional Time Sync Handshake is performed according to Figure 7-14 and 7-17 in the USB4 Specification:

1. Take sample of 250ms that is triggered on the first TSNOS
2. Enable Enhanced Uni-Directional Time Sync Handshakes
3. Verify that the DFP starts with Inversed Bi-directional by sending TSNOS every TSPacketInterval (+/-1%)
4. While in Inversed Bi-directional, verify that the DFP sends a Follow-Up Packet within SendTimeout time after receiving the TSNOS.
5. Verify that the first (DirSwitchN-1) packets have the S2U field set to 0b
6. Verify that after the S2U field in the Follow-Up Packet is set to 1b the DFP uses Adaptive Uni-Directional Time Sync Handshakes.
7. While in Adaptive Uni-directional, verify that the DFP sends a Follow-Up Packet within SendTimeout time after sending the TSNOS.

Protocol Check #7: Enhanced Uni-Directional (Ver. 2 Only)

Check the contents of a Follow-Up Packet:

1. Verify that:
 - a. PDF field is set to 1
 - b. HopID is set to 3
 - c. Length is set to 60
2. While S2U is 0b verify that:
 - a. Td1 and Td2 is consistently growing between every two consecutive packets by TSPacketInterval.
 - b. Verify that $\text{Max}(\Delta\text{Td1}) - \text{Min}(\Delta\text{Td1})$ is less than 32 ns
 - i. Obtain a list of all follow up packets
 - ii. Calculate all the Td12 Deltas
 1. A Td1 Delta is $\text{Td1}_{\text{Packet N}} - \text{Td1}_{\text{Packet N-1}}$
 - iii. Find the Minimum and maximum of Td1 Delta
 - iv. Verify the maximum delta minus the minimum delta is not bigger than 32 ns
3. While S2U is 1b verify that:
 - a. Td1 is equal to Td2 is consistently growing between every two consecutive packets by TSPacketInterval.
 - b. Verify that $\text{Max}(\Delta\text{Td1}) - \text{Min}(\Delta\text{Td1})$ is less than 32 ns
 - i. Obtain a list of all follow up packets
 - ii. Calculate all the Td12 Deltas
 1. A Td1 Delta is $\text{Td1}_{\text{Packet N}} - \text{Td1}_{\text{Packet N-1}}$
 - iii. Find the Minimum and maximum of Td1 Delta
 - c. Verify the maximum delta minus the minimum delta is not bigger than 32 ns
4. Verify that SleepCyclesN equals to the number of missed handshakes with the following rules:
 - a. If CLx is disabled, SleepCyclesN shall be equal to 0.
 - b. If CLx is enabled, SleepCyclesN shall be equal to $([\text{time passed from previous handshake}] / 16\text{us} - 1)$
5. If a packet is sent by Hub Router on the downstream port, verify that:
 - a. TimeOffsetFromHR is consistently growing like in Stat Sub #2.
 - b. FreqOffsetFromHR is constant like in Stat Sub #3.
 - c. There is correlation between TimeOffsetFromHR and FreqOffsetFromHR same as in Stat Sub #4.
6. If a packet is sent by Inter-Domain Time Responder or any DFP in Inter-Domain Time Initiator's Domain, verify that the following fields are 0 when IDE bit is set to 0 in Host Router:
 - a. IDTimeStamp. (TBD)
 - b. TimeOffsetFromInterDomain. (TBD)
 - c. FreqOffsetFromInterDomain. (TBD)
7. Otherwise (IDE bit is set to 1), verify that:
 - a. IDTimeStamp is constantly growing between every two consecutive packets. (TBD)
 - b. TimeOffsetFromInterDomain is consistently growing like in Stat Sub #8. (TBD)
 - c. FreqOffsetFromInterDomain is constant like in Stat Sub #9. (TBD)
 - d. There is correlation between TimeOffsetFromInterDomain and FreqOffsetFromInterDomain same as in Stat Sub #10. (TBD)

Protocol Check #8: Enhanced Uni-Directional Replenish (Ver. 2 Only)

Verify that an Adaptive Uni-Directional Time Sync Handshake is performed according to Figure 7-20 in the USB4 Specification:

1. Take sample of 250ms that is triggered on the last TSNOS before CL_OFF Ordered Sets
2. Enable Enhanced Uni-Directional Time Sync Handshakes
3. If there is a CLx entry, go over the capture and verify:
 - a. The maximum time in CLx is shorter than *Replenish Timeout* times 16us.
 - b. After each entry to CLx, verify that the Link is in CL0 for *tCLxConvergeTime*.
 - c. If the Link was in CLx for more than *Replenish Threshold* times 16us, there are at least *ReplenishN* consecutive Handshakes before another entry to CLx

Statistics Functions

Stat Sub #1 LocalTime Consistency

1. Local Time is checked for consistency.
2. Read LocalTime in loop every second, 60 times.
3. Verify that the Average Time diff between the reads is 1 second (+/- 1%). (7.1.2.1#4, 7.1.2.1#5)

31						0
I D E	U C A P	Rsvd	Freq Measurement Window	Capability ID	Next Capability Pointer	0
LocalTime Low 31:0						1
LocalTime High 63:32						2

Assertions checked:

- 7.1.2.1#4
- 7.1.2.1#5

Stat Sub #2 Time Offset

1. Read in loop 60 times with 1 sec delay.
2. Average slope is calculated per read:

$$T_{avgN} = \frac{T_{off}[N] - T_{off}[1]}{N - 1}$$

$$T_{avgN+1} = \frac{T_{off}[N + 1] - T_{off}[1]}{N}$$

$$T_{avgSlopeDrift} = \frac{T_{avgN+1}}{T_{avgN}} - 1$$

3. Verify that:
 - a. Expected behavior is a consistent linear incline or decline (accuracy of 1%). (7.4.1#6, 7.4.1#7)

$$|T_{avgSlopeDrift}| \leq 0.01$$

- b. For 1st hop, TimeOffsetFromHR is 0. (TBD)
 - c. For 2nd hop, TimeOffsetFromHR == TimeOffsetFromDFP. (7.1.2.2.#2)

TimeOffsetFromHR 31:0	4
TimeOffsetFromHR 63:32	5
TimeOffsetFromDFP 31:0	6
TimeOffsetFromDFP 63:32	7

Assertions checked:

- 7.1.2.2#1
- 7.1.2.2#2
- 7.1.2.2#3
- 7.4.1#6
- 7.4.1#7

Stat Sub #3 Frequency Offset

Repeat 60 times. For each step:

1. Read FreqOffsetFromHR. Save value to temporary variable FrequencyOffsetFromReg
2. To convert the value to ppm:

```
Polarity = FrequencyOffsetFromReg >> 31
If (Polarity == 1) { // negative value
    FrequencyOffset = ConvertTwosCompliment(FrequencyOffsetFromReg)
}
Else {
    FrequencyOffset = FrequencyOffsetFromReg
}
FrequencyOffsetPPM = FrequencyOffset * 106/241
```
3. Verify that:
 - a. Expected behavior is a constant FrequencyOffsetFromReg value with not more than 1 ppm deviation from the average. (7.4.1#1-#4)
 - b. For 1st hop, FreqOffsetFromHR is 0. (TBD)
 - c. For 2nd hop, FreqOffsetFromHR == FreqOffsetFromDFP. (7.1.2.3#2)

FreqOffsetFromHR	8
FreqOffsetFromDFP	9

Assertions checked:

- 7.4.1#1
- 7.4.1#2
- 7.4.1#3
- 7.4.1#4

Stat Sub #4 Correlation between Frequency and Time Offsets

For both OffsetFromDFP and OffsetFromHR, the following correlation is checked:

- The slope of TimeOffset is expected to be the equal to FreqOffset +/- 10%.
- TimeOffset is read 60 times once per second.
- Average slope is calculated:
 - $\text{Toff}[1]$ – time offset from first read.
 - $\text{Toff}[n]$ – time offset from last read.
 - $A = (\text{Toff}[n] - \text{Toff}[1]) / ((n-1) * 1e9)$.
 - Average Slope = $A * 1e6$ // the units are ppm.
- Compare Average Slope to Frequency Offset from Stat Sub #3 in ppm units.
- Verify the that correlation between the calculated and measured Frequency offset are less than 10.
(7.4.1#8):
 - $\text{Abs}(\text{Average Slope} / \text{Frequency Offset} - 1) * 100 < 10$.

Assertions checked:

- 7.4.1#8

Stat Sub #5 Propagation Delay

1. Read Propagation Delay 100 times. Compute average.
2. Verify that the Propagation Delay is constant (+/- 1%) (7.4.1#5).
3. Test with KG USB4 Host/Hub/Device.

Propagation Delay 31:0	10
Propagation Delay 63:32	11

Assertions checked:

- 7.4.1#5

Stat Sub #6 Computation Timestamp

1. Read 10 times with period of 1 sec between the reads.
2. Verify that the Computation Timestamp grows by approximately 1 sec relative to previous read value (+/- 5%). (7.3.1.1.#5)

Computation Timestamp 31:0		12
Computation Timestamp 63:32		13
Reserved	Computation Timestamp 79:64	14

Assertions checked:

- 7.3.1.1#5

Stat Sub #7 Inter-Domain Computation Timestamp

1. Read 10 times with period of 1 sec between the reads.
2. Verify that the Computation Timestamp grows by approximately 1 sec relative to previous read value (+/- 1%). (7.4.2.3#1)

InterDomain Computation Timestamp 31:0		16
InterDomain Computation Timestamp 63:32		17
Reserved	InterDomain Computation Timestamp 79:64	18

Assertions checked:

- 7.4.2.3#1

Stat Sub #8 Inter-Domain Time Offset

1. Read in loop 60 times with 1 sec delay.
2. Average slope is calculated per read.
3. Verify that:
 - a. Expected behavior is a consistent linear incline or decline (accuracy of 1%). (TBD)
 - b. For 1st hop, TimeOffsetFromInterDomainHR is 0. (TBD)
 - c. For 2nd hop, TimeOffsetFromInterDomainHR == TimeOffsetFromInterDomainDFP. (TBD)

Assertions checked:

- TBD

Stat Sub #9 Inter-Domain Frequency Offset

Repeat 60 times. For each step:

1. Read FreqOffsetFromHR. Save value to temporary variable FrequencyOffsetFromReg.
2. To convert the value to ppm:

```
Polarity = FrequencyOffsetFromReg >> 31
If (Polarity == 1) { // negative value
    FrequencyOffset = ConvertTwosCompliment(FrequencyOffsetFromReg)
}
Else {
    FrequencyOffset = FrequencyOffsetFromReg
}
FrequencyOffsetPPM = FrequencyOffset * 106/241
```
3. Verify that:
 - a. Expected behavior is a constant FrequencyOffsetFromReg value with not more than 1 ppm deviation from the average. (TBD)
 - b. For 1st hop, FreqOffsetFromInterDomainHR is 0. (TBD)
 - c. For 2nd hop, FreqOffsetFromInterDomainHR == FreqOffsetFromInterDomainDFP. (TBD)

Assertions checked:

- 7.4.2.3#2
- 7.4.2.3#3

Stat Sub #10 Correlation between Inter-Domain Frequency and Inter-Domain Time Offsets

For both OffsetFromInterDomainDFP and OffsetFromInterDomainHR, the following correlation is checked:

- The slope of TimeOffset is expected to be the equal to FreqOffset.

Test Example:

1. TimeOffset is read every second 60 times once every second.
2. If after averaging out the slope is ~100 ns per second, then the calculated Freq offset should be:

$$219902 = \frac{100}{10^9} * 2^{41}$$

3. FreqOffset is read and compared with calculated value.
4. Verify that the correlation between the calculated and measured Frequency offset are less than 1ppm.
(TBD)

Assertions checked:

- TBD

Stat Sub #11 Port Statistics for Bi-Directional DFP

1. Read first time to clear.
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi, verify that:
 - a. RX TSNOS counter changes.
 - b. TX TSNOS counter changes.
 - c. TX Packet counter changes.
4. Verify that the change of the three parameters is more than 20,000 counts per second in HiFi mode.
5. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

TX TSNOS counter	RX TSNOS counter	4
TX Packet counter	RX Packet counter	5

Assertions checked:

- TBD

Stat Sub #12 Port Statistics for Bi-Directional UFP

1. Read first time to clear.
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi or LowRes, verify that:
 - a. RX TSNOS counter changes.
 - b. TX TSNOS counter changes.
 - c. RX Packet counter changes.
4. Verify that the change of the three parameters is more than 20,000 counts per second in HiFi mode.
5. Verify that the change of the three parameters is more than 250 counts per second in LowRes mode.
6. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

Assertions checked:

- TBD

Stat Sub #13 Port Statistics for Uni-Directional DFP

1. Read first time to clear.
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi or LowRes, verify that:
 - a. TX TSNOS counter changes.
 - b. TX Packet counter changes.
4. Verify that the change of the two parameters is more than 20,000 counts per second in HiFi mode.
5. Verify that the change of the two parameters is more than 250 counts per second in LowRes mode.
6. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

Assertions checked:

- TBD

Stat Sub #14 Port Statistics for Uni-Directional UFP

1. Read first time to clear.
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi or LowRes, verify that:
 - a. RX TSNOS counter changes.
 - b. TX TSNOS counter changes.
 - c. RX Packet counter changes.
4. Verify that the change of the two parameters is more than 20,000 counts per second in HiFi mode.
5. Verify that the change of the two parameters is more than 250 counts per second in LowRes mode.
6. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

Assertions checked:

- TBD

Stat Sub #15 Port Statistics for Inter-Domain Timestamp Packets

Use Stat Sub #13 or Stat Sub #14 depending on TMU mode on inter-Domain Link.

Apply the Sub on the inter-Domain port.

Assertions checked:

- TBD

Stat Sub #16 Port Statistics for Enhanced Uni-Directional DFP

1. Read first time.
 - a. Verify that RX TSNOS counter equals DirSwitchN value
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi, verify that:
 - a. TX TSNOS counter changes.
 - b. TX Packet counter changes.
4. Verify that the change of the last two parameters is more than 20,000 counts per second in HiFi mode.
5. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

TX TSNOS counter	RX TSNOS counter	4
TX Packet counter	RX Packet counter	5

Assertions checked:

- TBD

Stat Sub #17 Port Statistics for Enhanced Uni-Directional UFP

1. Read first time.
 - a. Verify that TX TSNOS counter equals DirSwitchN value
2. Read 10 times with period of less than 500ms between the reads.
3. If TMU mode is HiFi, verify that:
 - a. RX TSNOS counter changes.
 - b. RX Packet counter changes
4. Verify that the change of the last two parameters is more than 20,000 counts per second in HiFi mode.
5. If TMU mode is OFF, verify that all four counters are 0 after 1st read.

TX TSNOS counter	RX TSNOS counter	4
TX Packet counter	RX Packet counter	5

Assertions checked:

- TBD

Time Posting Functions

Time Posting #1: Immediate Posting – 15 days

1. Read Local time in Host Router.
2. Write value of 15 days to Local time:
 - a. Value 0x83A10000 to Post Local Time Low.
 - b. Value 0x49AB4 to Post Local Time High.
 - c. Value 0xFFFFFFFF to Post Time High.
 - d. Value 0x1 to Post Time Low.
 - e. Value 0x0 to Post Time High.
3. Poll Post Time Low until it becomes 0x0.
4. Read Local time.
5. Verify that values are greater than:
 - a. LocalTime High[63:32] = 0x9AB483XX. (TBD)
 - b. LocalTime High[79:64] = 0x4. (TBD)

Note: LocalTime Low can be any value.

This function only used before enabling TMU in Hub and or Device.

Assertions checked:

- TBD

Time Posting #2: Immediate Posting – 1 hour

1. Read Local time in Host Router
2. Write value of 15 days to Local time:
 - a. Value 0xffff0000 to Post Local Time Low.
 - b. Value 0x0346 to Post Local Time High.
 - c. Value 0xFFFFFFFF to Post Time High.
 - d. Value 0x1 to Post Time Low.
 - e. Value 0x0 to Post Time High.
3. Poll Post Time Low until it becomes 0x0.
4. Read Local time.
5. Verify that values are greater than:
 - a. LocalTime High[63:44] = 0x03470. (TBD)
 - b. LocalTime High[79:64] = 0x0. (TBD)

Note: LocalTime Low can be any value.

This function only used before enabling TMU in Hub and or Device.

Assertions checked:

- TBD

Time Posting #3: Future Posting – 15 days

1. Read Local time in Host Router, Store it in LTH variable.
2. Add 10 sec to LTH.
3. Read current filters values: Freq Measurement Window , DelayAvgConst , OffsetAvgConst, ErrorAvgConst.
4. Set All setup to LowRes Mode
5. Configure all the devices in the setup with following:
 - a. Write value of 15 days to Local time:
 - i. Value 0x83A10000 to Post Local Time Low.
 - ii. Value 0x49AB4 to Post Local Time High.
 - iii. Value 0xFFFFFFFF to Post Time High.
 - iv. Value LTH & 0xFFFFFFFF to Post Time Low.
 - v. Value (LTH >> 32) to Post Time High.
6. Poll Post Time Low in UUT until it becomes 0x0:
 - a. Timeout after 12 seconds (system time) if the posting hasn't occurred. Report error.
 - b. Report error if time posting occurred earlier than 8 seconds (system time).
7. Read Local time in UUT and verify that values are greater than:
 - a. LocalTime High[63:32] = 0x9AB48XXX. (TBD)
 - b. LocalTime High[79:64] = 0x4. (TBD)
8. Restore filters to values from #3.

Note: LocalTime Low can be any value.

This function only used on the whole tree – Host, Hubs, and Peripheral Devices.

Assertions checked:

- TBD

Time Posting #4: Future Posting – 1 hour

1. Read Local time in Host Router, Store it in LTH variable.
2. Add 10 sec to LTH.
3. Read current filters values: Freq Measurement Window , DelayAvgConst , OffsetAvgConst, ErrorAvgConst.
4. Set Filters to low level:
 - a. Freq Measurement Window = 30.
 - b. DelayAvgConst = 4.
 - c. OffsetAvgConst = 4.
 - d. ErrorAvgConst = 4.
5. Configure all the devices in the setup with following:
 - a. Write value of 15 days to Local time:
 - i. Value 0xffff0000 to Post Local Time Low.
 - ii. Value 0x00384 to Post Local Time High.
 - iii. Value 0xFFFFFFFF to Post Time High.
 - iv. Value LTH & 0xFFFFFFFF to Post Time Low.
 - v. Value (LTH >> 32) to Post Time High.
6. Read values of filters from TMU_RTR_CS_15 and store for future reference.
7. Write new filter value to TMU_RTR_CS_15.
8. Poll Post Time Low in UUT until it becomes 0x0.
 - a. Timeout after 12 seconds (system time) if the posting hasn't occurred. Report error.
 - b. Report error if time posting occurred earlier than 8 seconds (system time).
9. Read Local time in UUT and verify that values are greater than:
 - a. LocalTime High[63:44] = 0x03470. (TBD)
 - b. LocalTime High[79:64] = 0x0. (TBD)
10. Restore filters to values from #3.

Note: LocalTime Low can be any value.

This function only used on the whole tree – Host, Hubs, and Peripheral Devices.

Assertions checked:

- TBD

Time Posting #5: Immediate Time Posting Upon Configuration

1. Read Local time in Host Router, Store it in LTH variable.
2. Configure all the devices in the setup with following:
 - a. Write following values to Local time:
 - i. Value LTH & 0xffffffff to Post Local Time Low.
 - ii. Value LTH >> 32 to Post Local Time High.
 - iii. Value 0xFFFFFFFF to Post Time High.
 - iv. Value 0x1 to Post Time Low.
 - v. Value 0x0 to Post Time High.
3. Poll Post Time Low in UUT until it becomes 0x0.
4. Read Local time in UUT.
5. Verify that LocalTime is within 100msec away from LTH

Test Setups

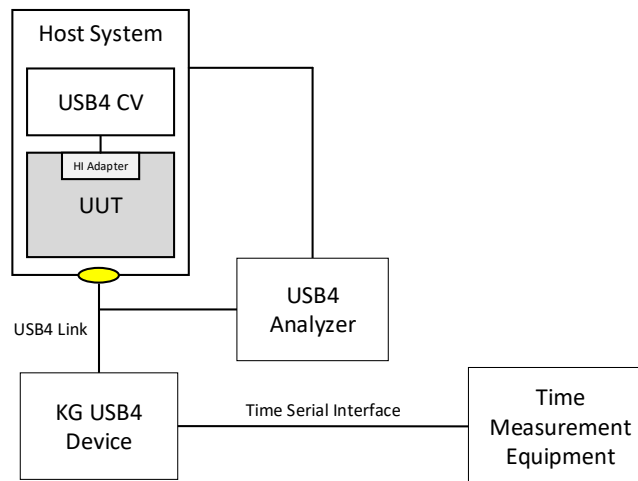
This section describes the test setups for USB4 Hosts, Hubs, and Peripheral Devices.

Single-Port Host

This section describes the test setups for a Host Router with one USB4 Port.

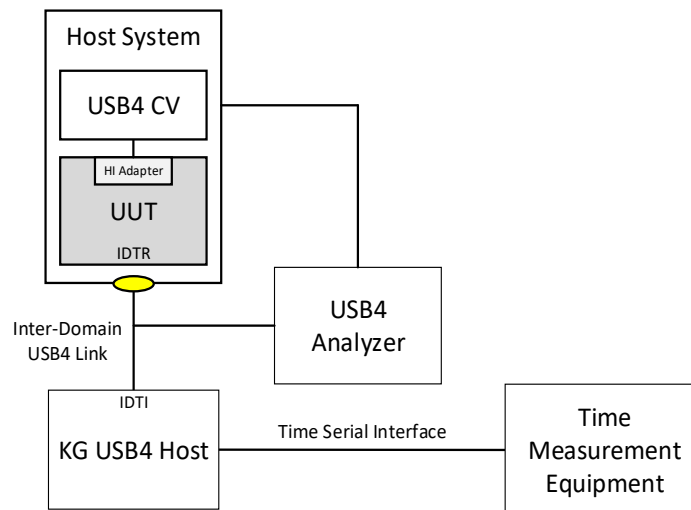
Single Domain (SD)

SD_HOST_DFP_TMU_01

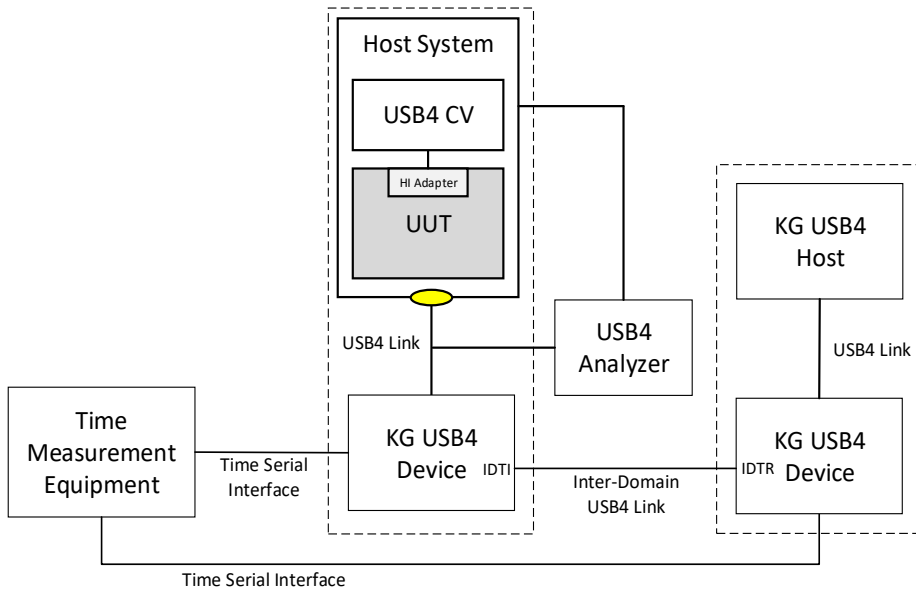


Inter-Domain (ID)

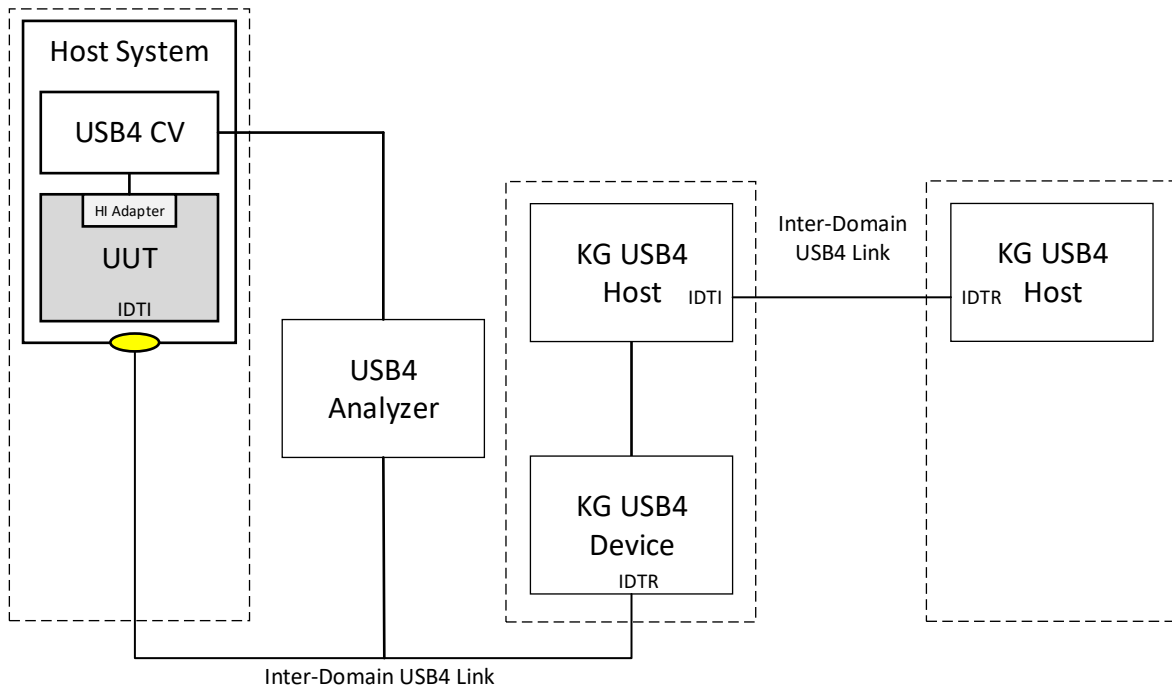
ID_HOST_DFP_TMU_02



ID_HOST_DFP_TMU_03



ID_HOST_DFP_TMU_04

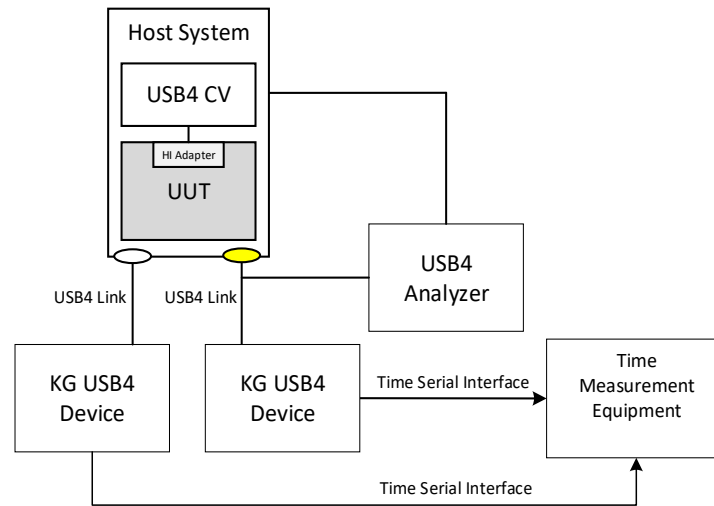


Multi-Port Host

This section describes the test setups for a Host Router with more than one USB4 Port.

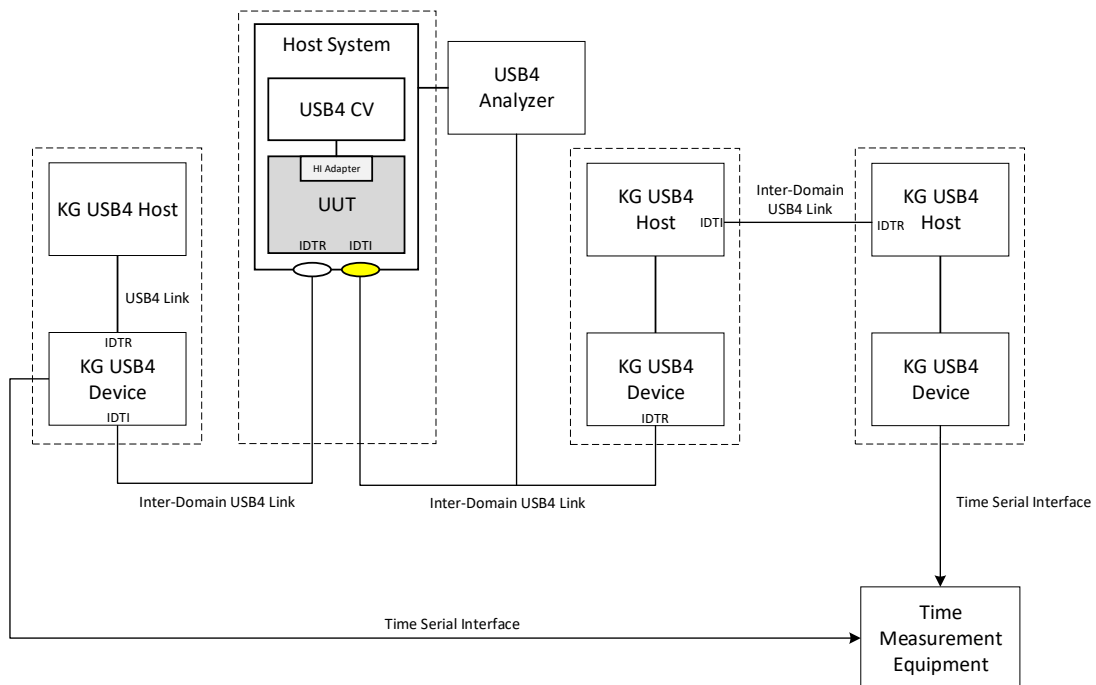
Single Domain (SD)

SD_HOST_DFP_TMU_05

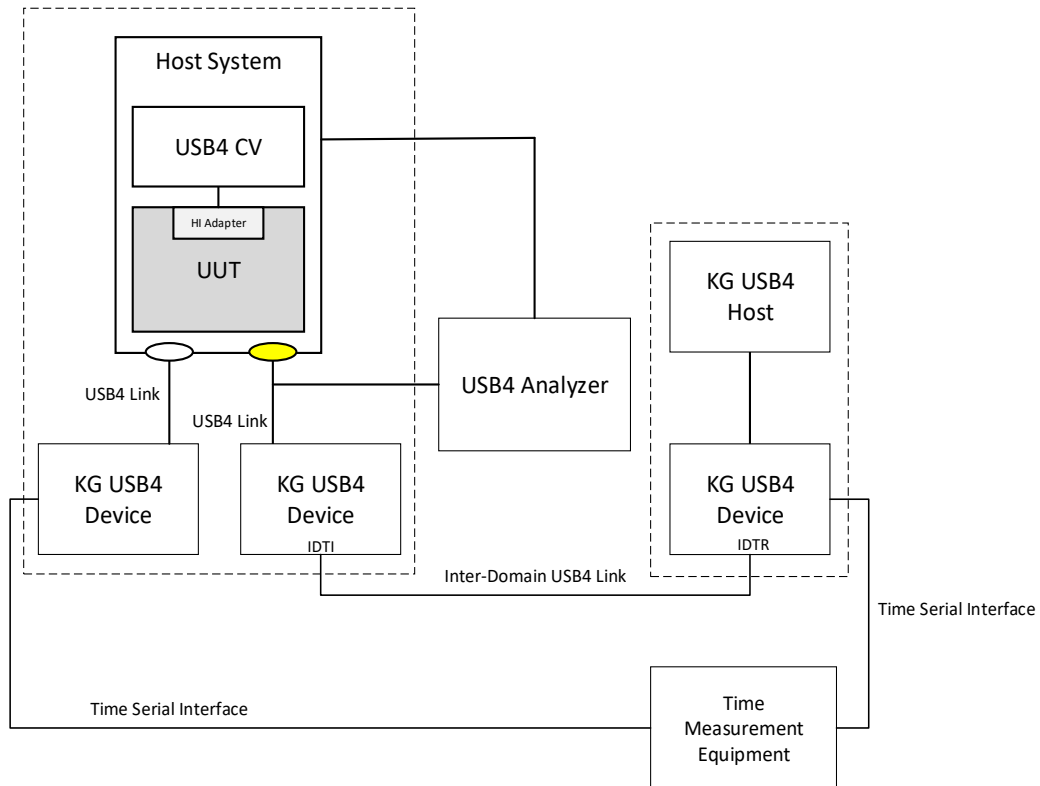


Inter-Domain (ID)

ID_HOST_DFP_TMU_06



ID_HOST_DFP_TMU_07

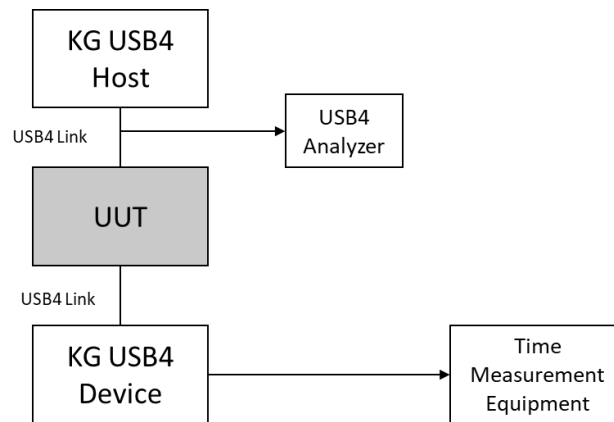


Hub

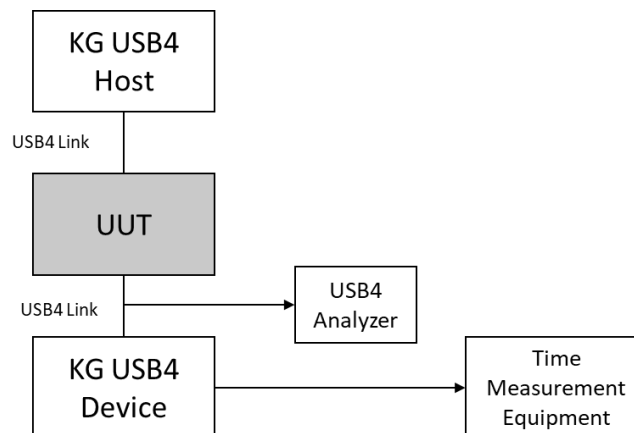
This section describes the test setups for a USB4 Hub.

Single Domain (SD)

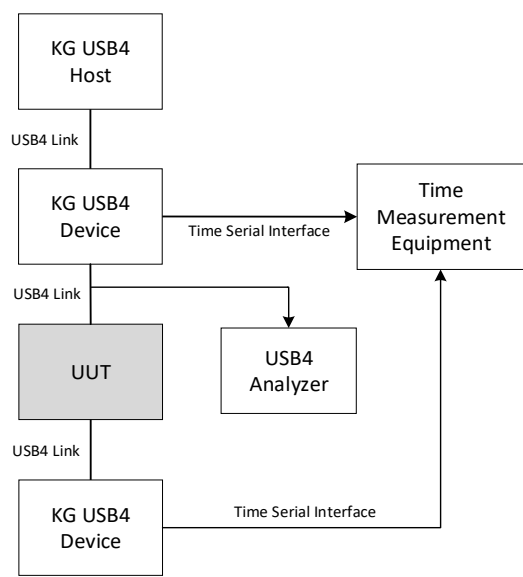
SD_HUB_UFP_TMU_08



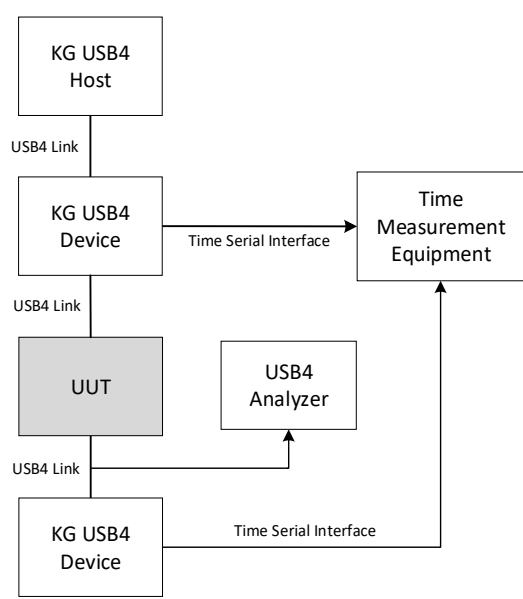
SD_HUB_DFP_TMU_09



SD_HUB_UFP_TMU_10

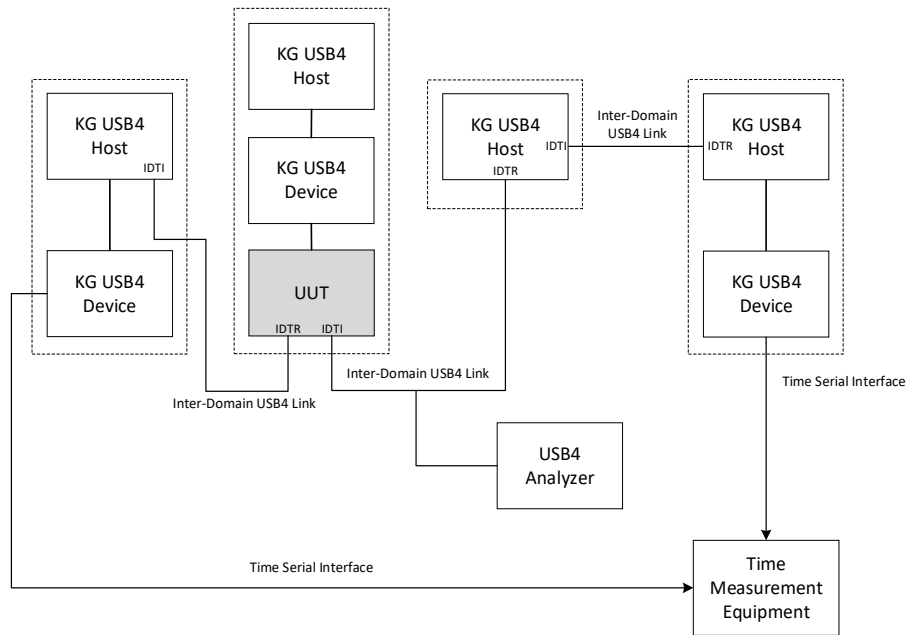


SD_HUB_DFP_TMU_11

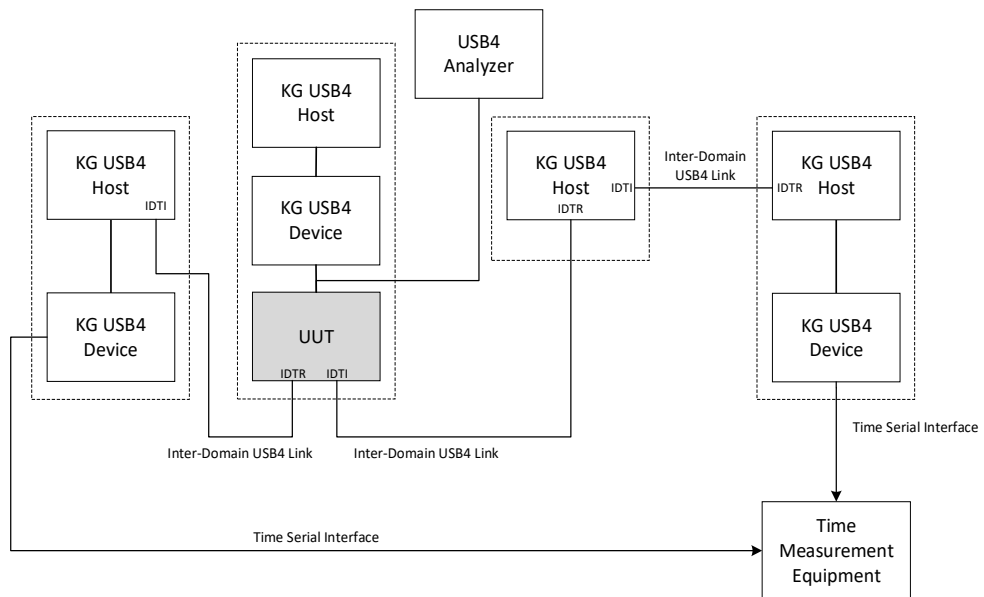


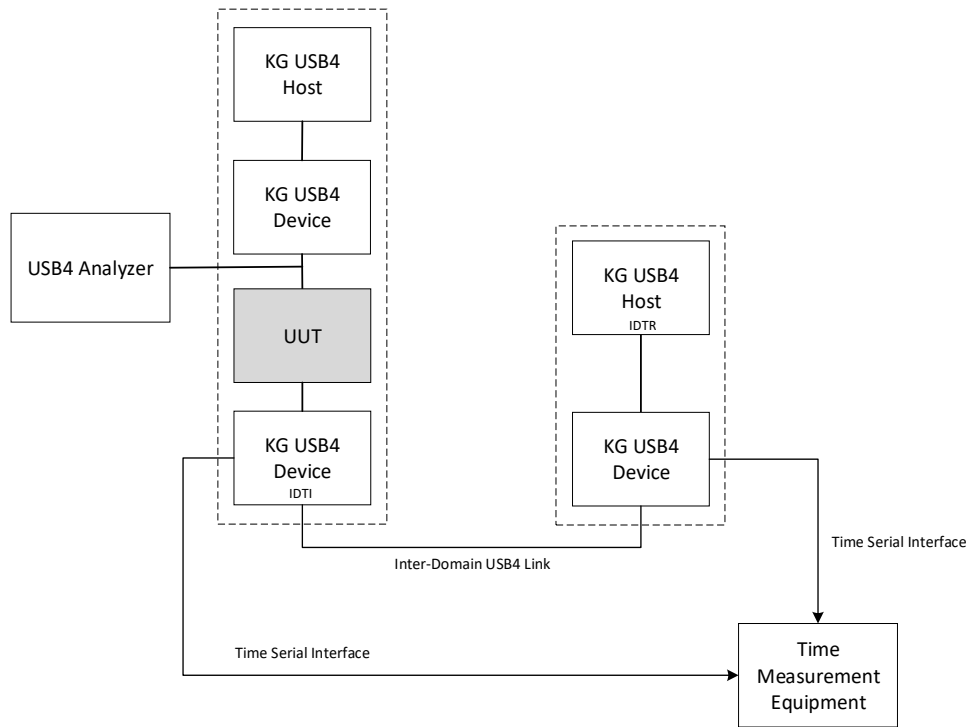
Inter-Domain (ID)

ID_HUB_DFP_TMU_12



ID_HUB_UFP_TMU_13



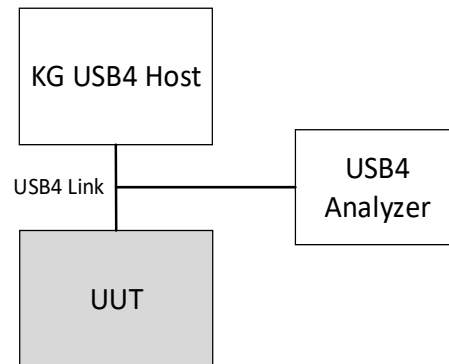


Peripheral Device

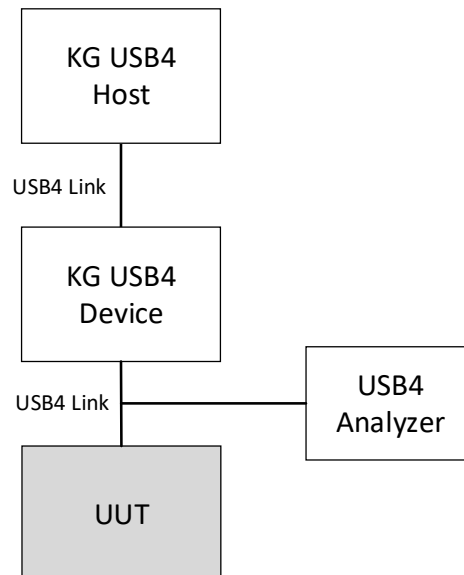
This section describes the test setups for a USB4 Peripheral Device.

Single Domain (SD)

SD_DEV_UFP_TMU_15

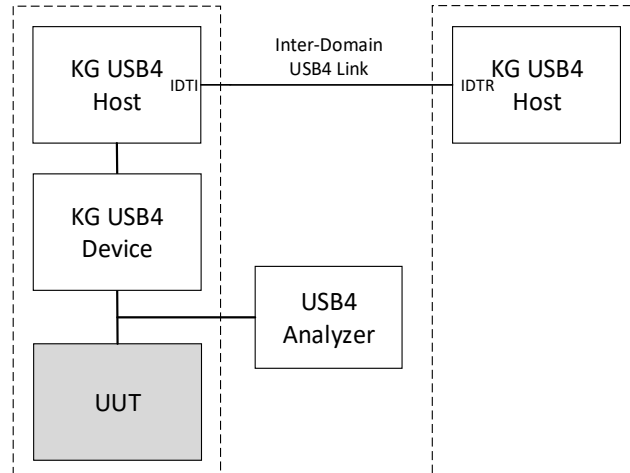


SD_DEV_UFP_TMU_16



Inter-Domain (ID)

ID_DEV_UFP_TMU_17



USB4 Test Descriptions

Note: After each test, the TMU Mode is set to Off (i.e. the TMU is disabled) throughout the topology.

Single-Port Host

The tests in this section apply to a USB4 Host that has one USB4 Port.

Intra-Domain

TD 7.001 Bi-Directional HiFi Mode Test (Single-Port Host)

- A. Purpose:
 - Verify that the TMU in a USB4 Host behaves as expected in Bidirectional HiFi Mode
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
 - Repeat test at Gen 2 and Gen 3 speeds (if supported)
- C. Procedure:
 1. Connect SD_HOST_DFP_TMU_01
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode in UUT
 4. Configure TMU to Bi-Directional HiFi mode in KG USB4 Device
 5. Run Time Calculation #1, N=1
 6. Run Stat Sub #1 on Host Router
 7. Run Stat Sub #2 on KG USB4 Device
 8. Run Stat Sub #3 on KG USB4 Device
 9. Run Stat Sub #4 on KG USB4 Device
 10. Run Stat Sub #5 on KG USB4 Device
 11. Run Stat Sub #6 on KG USB4 Device
 12. Run Stat Sub #11 on Host Router
 13. Run Stat Sub #12 on KG USB4 Device
 14. Run Protocol Check #1
 15. Run Protocol Check #2

TD 7.002 Uni-Directional HiFi Mode Test (Single-Port Host)

A. Purpose:

- Verify that the TMU in a USB4 Host behaves as expected in Unidirectional HiFi Mode.

B. Procedure:

1. Connect SD_HOST_DFP_TMU_01
2. Configure USB4 Link according to Link Configuration #1
3. Configure KG USB4 Device to Unidirectional HiFi mode
4. Configure UUT to Unidirectional HiFi mode
5. Run Time Calculation #1, N=1
6. Run Stat Sub #1 on Host Router
7. Run Stat Sub #2 on KG USB4 Device
8. Run Stat Sub #3 on KG USB4 Device
9. Run Stat Sub #4 on KG USB4 Device
10. Run Stat Sub #6 on KG USB4 Device
11. Run Stat Sub #13 on Host Router
12. Run Stat Sub #14 on KG USB4 Device
13. Run Protocol Check #3
14. Run Protocol Check #4

TD 7.101 Enhanced Uni-Directional HiFi Mode Test (Single-Port Host)

- A. Purpose:
- Verify that the TMU in a USB4 Host behaves as expected in Enhanced Unidirectional HiFi Mode.
- B. Repetitions:
- Repeat test at Gen 2 and Gen 4 (if supported) speeds (Dual Lane Link only)
 - Repeat test with CLx (CL0s and CL1) enabled and disabled
- C. Procedure:
1. Connect SD_HOST_DFP_TMU_01
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure KG USB4 Device to Enhanced Unidirectional HiFi mode
 4. Configure UUT to Enhanced Unidirectional HiFi mode
 5. Run Time Calculation #1, N=1
 6. Run Stat Sub #1 on Host Router
 7. Run Stat Sub #2 on KG USB4 Device
 8. Run Stat Sub #3 on KG USB4 Device
 9. Run Stat Sub #4 on KG USB4 Device
 10. Run Stat Sub #6 on KG USB4 Device
 11. When CLx is disabled, run Stat Sub #13 on Host Router
 12. When CLx is disabled, run Stat Sub #14 on KG USB4 Device
 13. Run Protocol Check #6
 14. Run Protocol Check #7
 15. When CLx is enabled run Protocol Check #8

TD 7.003 Uni-Directional LowRes Mode Test (Single-Port Host)

A. Purpose:

- Verify that the TMU in a USB4 Host behaves as expected in LowRes Mode

B. Procedure:

1. Connect SD_HOST_DFP_TMU_01
2. Configure USB4 Link according to Link Configuration #1
3. Configure KG USB4 Device to Unidirectional LowRes mode
4. Configure UUT to Unidirectional LowRes mode
5. Proceed to the next steps as in TD 7.002 starting from step #5

TD 7.102 Enhanced Uni-Directional MedRes Mode Test (Single-Port Host)

- A. Purpose:
 - Verify that the TMU in a USB4 Host behaves as expected in MedRes Mode
- B. Repetitions:
 - Repeat test at Gen 2 and Gen 4 (if supported) speeds (Dual Lane Link only)
 - Repeat test with CL0s and CL1 enabled and disabled
- C. Procedure:
 1. Connect SD_HOST_DFP_TMU_01
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure KG USB4 Device to Enhanced Unidirectional MedRes mode
 4. Configure UUT to Enhanced Unidirectional MedRes mode
 5. Proceed to the next steps as in TD 7.002 starting from step #5

TD 7.004 TMU Mode Change Test (Single-Port Host)

A. Purpose:

- Verify that the TMU Mode change works properly in a USB4 Host

B. Procedure:

1. Connect SD_HOST_DFP_TMU_01
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Bi-Directional HiFi mode in UUT
4. Configure TMU to Bi-Directional HiFi mode in KG USB4 Device
5. Run Time Calculation #1, N=1
6. Run Stat Sub #1 on Host Router
7. Run Stat Sub #2 on KG USB4 Device
8. Run Stat Sub #3 on KG USB4 Device
9. Run Stat Sub #4 on KG USB4 Device
10. Run Stat Sub #5 on KG USB4 Device
11. Run Stat Sub #6 on KG USB4 Device
12. Run Stat Sub #11 on Host Router
13. Run Stat Sub #12 on KG USB4 Device
14. Run Protocol Check #1
15. Run Protocol Check #2
16. Change TMU mode to Uni-directional HiFi mode both in UUT and Device according to CM mode change flow (see CM guide)
17. Wait 1 sec
18. Repeat steps #5 to #11
19. Run Stat Sub #13 on Host Router on both ports
20. Run Stat Sub #14 on KG USB4 Device on both ports
21. Run Protocol Check #3
22. Run Protocol Check #4
23. Change TMU mode to Uni-directional LowRes mode both in UUT and Device according to CM mode change flow (see CM guide)
24. Wait 1 sec
25. Repeat steps #5 to #11
26. Run Stat Sub #13 on Host Router on both ports
27. Run Stat Sub #14 on KG USB4 Device on both ports
28. Run Protocol Check #3
29. Run Protocol Check #4
30. Change TMU mode to TMU OFF mode both in UUT and Device according to CM mode change flow (see CM guide)
31. Run Stat Sub #11
32. Change TMU mode to Uni-directional LowRes mode both in UUT and Device according to CM mode change flow (see CM guide)
33. Wait 1 sec
34. Repeat steps #5 to #11
35. Run Stat Sub #13 on Host Router on both ports
36. Run Stat Sub #14 on KG USB4 Device on both ports
37. Run Protocol Check #3
38. Run Protocol Check #4
39. Change TMU mode to Bi-Directional HiFi mode both in UUT and Device according to CM mode change flow (see CM guide)
40. Wait 1 sec
41. Repeat steps #5 to #15

TD 7.005 Future Time Posting Test – 15 days (Single-Port Host)

A. Purpose:

- Verify that Future Time posting works correctly in a USB4 Host

B. Procedure:

1. Connect SD_HOST_DFP_TMU_01
2. Configure USB4 Link according to Link Configuration #1
3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
5. Run Time Posting #3
6. Run Time Calculation #1, N=1
7. Run Stat Sub #1 on Host Router
8. Run Stat Sub #2 on KG USB4 Device
9. Run Stat Sub #3 on KG USB4 Device
10. Run Stat Sub #4 on KG USB4 Device
11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

TD 7.006 Future Time Posting Test – 1 Hour (Single-Port Host)

- A. Purpose:
 - Verify that Future Time posting works correctly in a USB4 Host
- B. Procedure:
 1. Connect SD_HOST_DFP_TMU_01
 2. Configure USB4 Link according to Link Configuration #1
 3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
 4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
 5. Run Time Posting #4
 6. Run Time Calculation #1, N=1
 7. Run Stat Sub #1 on Host Router
 8. Run Stat Sub #2 on KG USB4 Device
 9. Run Stat Sub #3 on KG USB4 Device
 10. Run Stat Sub #4 on KG USB4 Device
 11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

Inter-Domain

Note: The tests in this section are only run if the UUT supports Inter-Domain Time Synchronization.

TD 7.007 Inter-Domain Time Responder in Bi-Directional HiFi Mode Test (Single-Port Host)

- A. Purpose:
 - Verify that a USB4 Host behaves properly as Inter-Domain Time Responder
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HOST_DFP_TMU_02
 2. Configure USB4 Link according to Link Configuration #1
 3. Set KG Host Router as Inter-Domain Time Initiator by setting IDTI bit to 1
 4. Set UUT as Inter-Domain Time Responder by setting IDTR bit to 1
 5. Configure KG Host Router to Bi-Directional HiFi mode
 6. Configure UUT to Bi-Directional HiFi mode
 7. Run Time Calculation #1, N=1 on endpoint
 8. Run Stat Sub #7 on KG USB4 Device
 9. Run Stat Sub #8 on KG USB4 Device
 10. Run Stat Sub #9 on KG USB4 Device
 11. Run Stat Sub #10 on KG USB4 Device
 12. Run Stat Sub #11 on Host Router
 13. Run Stat Sub #12 on KG USB4 Device
 14. Run Protocol Check #1
 15. Run Protocol Check #2

TD 7.008 Host Router in Inter-Domain Time Initiator Domain in Bi-Directional HiFi Mode Test (Single-Port Host)

- A. Purpose:
 - Verify that a USB4 Host behaves properly in a time following Domain
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HOST_DFP_TMU_03
 2. Configure USB4 Link according to Link Configuration #1
 3. Set KG USB4 Device as Inter-Domain Time Initiator by setting IDTI bit to 1
 4. Set KG Host Router as Inter-Domain Time Responder by setting IDTR bit to 1
 5. Configure UUT to Bi-Directional HiFi mode
 6. Configure KG USB4 Device to Bi-Directional HiFi mode
 7. Configure KG Host Router to Bi-Directional HiFi mode
 8. Set IDE bit to 1 in UUT
 9. Run Time Calculation #2, N=1 on endpoints
 10. Run Stat Sub #7 on KG USB4 Device
 11. Run Stat Sub #8 on KG USB4 Device
 12. Run Stat Sub #9 on KG USB4 Device
 13. Run Stat Sub #10 on KG USB4 Device
 14. Run Stat Sub #11 on Host Router
 15. Run Stat Sub #12 on KG USB4 Device
 16. Run Protocol Check #1
 17. Run Protocol Check #2

A. Purpose:

- Verify that a USB4 Host behaves properly in a time Following Domain

B. Procedure:

1. Connect ID_HOST_DFP_TMU_04
2. Configure USB4 Link according to Link Configuration #1
3. Set KG USB4 Device as Inter-Domain Time Initiator by setting IDTI bit to 1
4. Set KG Host Router as Inter-Domain Time Responder by setting IDTR bit to 1
5. Configure UUT to Bi-Directional HiFi mode
6. Configure KG USB4 Device to Bi-Directional HiFi mode
7. Configure KG Host Router to Bi-Directional HiFi mode
8. Set IDE bit to 1 in UUT
9. Run Stat Sub #7 on KG USB4 Device
10. Run Stat Sub #8 on KG USB4 Device
11. Run Stat Sub #9 on KG USB4 Device
12. Run Stat Sub #10 on KG USB4 Device
13. Run Stat Sub #11 on Host Router
14. Run Stat Sub #12 on KG USB4 Device
15. Run Protocol Check #1
16. Run Protocol Check #2

TD 7.010 Host Router in Inter-Domain Time Initiator Domain in Bi-Directional HiFi Mode Test (Single-Port Host)

A. Purpose:

- Verify that a USB4 Host behaves properly as Inter-Domain Time Responder

B. Procedure:

1. Connect ID_HOST_DFP_TMU_06
2. Configure USB4 Link according to Link Configuration #1
3. Set KG USB4 Device as Inter-Domain Time Initiator by setting IDTI bit to 1
4. Set KG Host Router as Inter-Domain Time Responder by setting IDTR bit to 1
5. Configure UUT to Bi-Directional HiFi mode
6. Configure KG USB4 Device to Bi-Directional HiFi mode
7. Configure KG Host Router to Bi-Directional HiFi mode
8. Set IDE bit to 1 in UUT
9. Run Time Calculation #2, N=1 on devices
10. Run Stat Sub #7 on KG USB4 Device
11. Run Stat Sub #8 on KG USB4 Device
12. Run Stat Sub #9 on KG USB4 Device
13. Run Stat Sub #10 on KG USB4 Device
14. Run Stat Sub #11 on Host Router
15. Run Stat Sub #12 on KG USB4 Device
16. Run Protocol Check #1
17. Run Protocol Check #2

Multi-Port Host

The tests in this section apply to a USB4 Host that has more than one USB4 Port.

Intra-Domain

TD 7.011 Bi-Directional HiFi Mode Test (Multi-Port Host)

- A. Purpose:
 - Verify that the TMU in a USB4 Host behaves as expected in Bi-Directional HiFi Mode
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
 - Repeat test at Gen 2 and Gen 3 speeds (if supported)
- C. Procedure:
 1. Connect SD_HOST_DFP_TMU_05
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on both KG USB4 Devices
 5. Run Time Calculation #2, N=1 between the KG USB4 Devices
 6. Run Stat Sub #1 on Host Router
 7. Run Stat Sub #2 on KG USB4 Device
 8. Run Stat Sub #3 on KG USB4 Device
 9. Run Stat Sub #4 on KG USB4 Device
 10. Run Stat Sub #5 on KG USB4 Device
 11. Run Stat Sub #6 on KG USB4 Device
 12. Run Stat Sub #11 on Host Router on both ports
 13. Run Stat Sub #12 on KG USB4 Device on both ports
 14. Run Protocol Check #1
 15. Run Protocol Check #2

- A. Purpose:
- Verify that the TMU in a USB4 Host behaves as expected in Uni-Directional HiFi Mode
- B. Procedure:
1. Connect SD_HOST_DFP_TMU_05
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on both KG USB4 Devices
 5. Run Time Calculation #2, N=1 between the two KG USB4 Devices
 6. Run Stat Sub #1 on Host Router
 7. Run Stat Sub #2 on KG USB4 Device
 8. Run Stat Sub #3 on KG USB4 Device
 9. Run Stat Sub #4 on KG USB4 Device
 10. Run Stat Sub #6 on KG USB4 Device
 11. Run Stat Sub #13 on Host Router on both ports
 12. Run Stat Sub #14 on KG USB4 Device on both ports
 13. Run Protocol Check #3
 14. Run Protocol Check #4

TD 7.013 Uni-Directional LowRes Mode Test (Multi-Port Host)

A. Purpose:

- Verify that the TMU in a USB4 Host behaves as expected in LowRes Mode

B. Procedure:

1. Connect SD_HOST_DFP_TMU_05
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Unidirectional LowRes mode in UUT and KG USB4 Devices
4. Proceed the next steps as in TD 7.012 starting from step #4

TD 7.103 Enhanced Uni-Directional HiFi Mode Test (Multi-Port Host)

A. Purpose:

- Verify that the TMU in a USB4 Host behaves as expected in Enhanced Uni-Directional HiFi Mode

B. Repetitions:

- Repeat test at Gen 2 and Gen 4 (if supported) speeds (Dual Lane Link only)
- Repeat test with CLx (CL0s and CL1) enabled and disabled

C. Procedure:

1. Connect SD_HOST_DFP_TMU_05
2. Configure USB4 Link according to Link Configuration #1
3. Configure KG USB4 Device to Enhanced Unidirectional HiFi mode
4. Configure UUT to Enhanced Unidirectional HiFi mode
5. Run Time Calculation #1, N=1
6. Run Stat Sub #1 on Host Router
7. Run Stat Sub #2 on KG USB4 Device
8. Run Stat Sub #3 on KG USB4 Device
9. Run Stat Sub #4 on KG USB4 Device
10. Run Stat Sub #6 on KG USB4 Device
11. If CLx is disabled, run Stat Sub #13 on Host Router
12. If CLx is disabled, run Stat Sub #14 on KG USB4 Device
13. Run Protocol Check #3
14. Run Protocol Check #4
15. If CLx is enabled, run Protocol Check #8

A. Purpose:

- Verify that the TMU in a USB4 Host behaves as expected in Bi-Directional HiFi Mode

B. Procedure:

1. Connect SD_HOST_DFP_TMU_05
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Bi-Directional HiFi mode
4. Run Time Calculation #1, N = 1 on both KG USB4 Devices
5. Run Time Calculation #2, N = 1 between the KG USB4 Devices
6. Run Stat Sub #1 on Host Router
7. Run Stat Sub #2 on KG USB4 Device
8. Run Stat Sub #3 on KG USB4 Device
9. Run Stat Sub #4 on KG USB4 Device
10. Run Stat Sub #5 on KG USB4 Device
11. Run Stat Sub #6 on KG USB4 Device
12. Run Stat Sub #11 on Host Router on both ports
13. Run Stat Sub #12 on KG USB4 Device on both ports
14. Run Protocol Check #1
15. Run Protocol Check #2
16. Change TMU mode to Uni-directional HiFi mode both in UUT and Device according to CM mode change flow (see CM guide)
17. Wait 1 sec.
18. Repeat steps #5 to #11
19. Run Stat Sub #13 on Host Router on both ports
20. Run Stat Sub #14 on KG USB4 Device on both ports
21. Run Protocol Check #3
22. Run Protocol Check #4
23. Change TMU mode to Uni-directional LowRes mode both in UUT and Device according to CM mode change flow (see CM guide)
24. Wait 1 sec
25. Repeat steps #5 to #11
26. Run Stat Sub #13 on Host Router on both ports
27. Run Stat Sub #14 on KG USB4 Device on both ports
28. Run Protocol Check #3
29. Run Protocol Check #4
30. Change TMU mode to TMU OFF mode both in UUT and Device according to CM mode change flow (see CM guide)
31. Run Stat Sub #11
32. Change TMU mode to Uni-directional LowRes mode both in UUT and Device according to CM mode change flow (see CM guide)
33. Wait 1 sec
34. Repeat steps #5 to #11
35. Run Stat Sub #13 on Host Router on both ports
36. Run Stat Sub #14 on KG USB4 Device on both ports
37. Run Protocol Check #3
38. Run Protocol Check #4
39. Change TMU mode to Bi-Directional HiFi mode both in UUT and Device according to CM mode change flow (see CM guide)
40. Wait 1 sec
41. Repeat steps #5 to #15

TD 7.015 Future Time Posting Test – 15 days (Multi-Port Host)

- A. Purpose:
 - Verify that Future Time posting is working as expected in a USB4 Host
- B. Procedure:
 1. Connect SD_HOST_DFP_TMU_05
 2. Configure USB4 Link according to Link Configuration #1
 3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
 4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to enhanced Uni-Directional HiFi mode
 5. Run Time Posting #3
 6. Run Time Calculation #1, N=1
 7. Run Stat Sub #1 on Host Router
 8. Run Stat Sub #2 on KG USB4 Device
 9. Run Stat Sub #3 on KG USB4 Device
 10. Run Stat Sub #4 on KG USB4 Device
 11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

TD 7.016 Future Time Posting Test – 1 hour (Multi-Port Host)

A. Purpose:

- Verify that Future Time posting is working as expected in a USB4 Host

B. Procedure:

1. Connect SD_HOST_DFP_TMU_05
2. Configure USB4 Link according to Link Configuration #1
3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to enhanced Uni-Directional HiFi mode
5. Run Time Posting #4
6. Run Time Calculation #1, N=1
7. Run Stat Sub #1 on Host Router
8. Run Stat Sub #2 on KG USB4 Device
9. Run Stat Sub #3 on KG USB4 Device
10. Run Stat Sub #4 on KG USB4 Device
11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

Inter-Domain

Note: The tests in this section are only run if the UUT supports Inter-Domain Time Synchronization.

TD 7.017 Inter-Domain Time Initiator and Time Responder in Bi-Directional HiFi Mode Test

- A. Purpose:
 - Verify that a USB4 Host behaves properly as Inter-Domain Time Responder
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HOST_DFP_TMU_06
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure the topology to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on Inter-Domain Time Initiator (KG Host Router)
 5. Run Time Calculation #2, N=1 between Inter-Domain Time Initiator (KG Host Router) and Inter-Domain Host Router
 6. Run Stat Sub #7 on UUT
 7. Run Stat Sub #8 on UUT
 8. Run Stat Sub #9 on UUT
 9. Run Stat Sub #10 on UUT
 10. Run Stat Sub #11 on UUT all ports
 11. Run Stat Sub #12 on KG USB4 Device
 12. Run Protocol Check #1 on UUT ports
 13. Run Protocol Check #2 on UUT ports

Hub

The tests in this section apply to a USB4 Hub.

Intra-Domain

TD 7.018 Bi-Directional HiFi Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
 - Repeat test at Gen 2 and Gen 3 speeds (if supported)
- C. Procedure:
 - 1. Connect SD_HUB_UFP_TMU_08
 - 2. Configure USB4 Link according to Link Configuration #1
 - 3. Configure TMU to Bi-Directional HiFi mode
 - 4. Run Time Calculation #1, N=1 on KG USB4 Device
 - 5. Run Stat Sub #1 on UUT

Measurements on Hub as DFP:

- 6. Run Stat Sub #2 on UUT
- 7. Run Stat Sub #3 on UUT
- 8. Run Stat Sub #4 on UUT
- 9. Run Stat Sub #5 on UUT upstream port
- 10. Run Stat Sub #6 on UUT
- 11. Run:
 - If mode is Bi-directional, Stat Sub #11 on KG Router above UUT
 - If mode is Uni-directional, Stat Sub #13 on KG Router above UUT
 - If mode is Enhanced Uni-directional, Stat Sub #16 on KG Router above UUT
- 12. Run:
 - If mode is Bi-directional, Stat Sub #12 on UUT on upstream port
 - If mode is Uni-directional, Stat Sub #14 on KG Router above UUT
 - If mode is Enhanced Uni-directional, Stat Sub #17 on KG Router above UUT
- 13. Run:
 - If mode is Bi-directional, Protocol Check #1 on UUT upstream port
 - If mode is Uni-directional, Protocol Check #3 on UUT upstream port
 - If mode is Enhanced Uni-directional, Protocol Check #6 on UUT upstream port
- 14. Run:
 - If mode is Bi-directional, Protocol Check #2 on UUT upstream port
 - If mode is Uni-directional, Protocol Check #4 on UUT upstream port
 - If mode is Enhanced Uni-directional, Protocol Check #7 on UUT upstream port

TD 7.019 Bi-Directional HiFi Mode as 2nd Hop Test (Hub DFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
 - Repeat test at Gen 2 and Gen 3 speeds (if supported)
- C. Procedure:
 - 1. Connect SD_HUB_DFP_TMU_09
 - 2. Configure USB4 Link according to Link Configuration #1
 - 3. Configure TMU to Bi-Directional HiFi mode
 - 4. Run Time Calculation #1, N=1 on KG USB4 Device
 - 5. Run Stat Sub #1 on UUT

Measurements of the effect of Hub as DFP:

- 6. Run Stat Sub #2 on KG USB4 Device
- 7. Run Stat Sub #3 on KG USB4 Device
- 8. Run Stat Sub #4 on KG USB4 Device
- 9. Run Stat Sub #5 on KG USB4 Device
- 10. Run Stat Sub #6 on KG USB4 Device
- 11. Run:
 - If mode is Bi-directional, Stat Sub #11 on UUT on downstream port
 - If mode is Uni-directional, Stat Sub #13 on UUT on downstream port
 - If mode is Enhanced Uni-directional, Stat Sub #16 on KG Router above UUT
- 12. Run:
 - If mode is Bi-directional, Stat Sub #12 on UUT on upstream port
 - If mode is Uni-directional, Stat Sub #14 on KG USB4 Device
 - If mode is Enhanced Uni-directional, Stat Sub #16 on KG Router above UUT
- 13. Run:
 - If mode is Bi-directional, Protocol Check #1 on KG USB4 Device
 - If mode is Uni-directional, Protocol Check #3 on KG USB4 Device
 - If mode is Enhanced Uni-directional, Protocol Check #6 on UUT upstream port
- 14. Run:
 - If mode is Bi-directional, Protocol Check #2 on KG USB4 Device
 - If mode is Uni-directional, Protocol Check #4 on KG USB4 Device
 - If mode is Enhanced Uni-directional, Protocol Check #7 on UUT upstream port

TD 7.020 Uni-Directional HiFi Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional HiFi Mode
- B. Procedure:
 - 1. Same as TD 7.018 only with UUT and KG Router below the UUT configured to Uni-Directional HiFi mode
 - 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-Directional HiFi mode (Ver. 2)

TD 7.021 Uni-Directional HiFi Mode as 2nd Hop Test (Hub DFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional HiFi Mode
- B. Procedure:
 1. Same as TD 7.019 only with UUT and KG Router below the UUT configured to Uni-Directional HiFi mode
 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-Directional HiFi mode (Ver. 2)

TD 7.022 Uni-Directional LowRes Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional LowRes Mode
- B. Procedure:
 1. Same as TD 7.018 only with UUT and KG Router above the UUT configured to Uni-Directional LowRes mode
 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-Directional HiFi mode (Ver. 2)

TD 7.023 Uni-Directional LowRes Mode as 2nd Hop Test (Hub DFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional LowRes Mode
- B. Procedure:
 1. Same as TD 7.019 only with UUT and KG Router above the UUT configured to Uni-Directional LowRes mode
 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-Directional HiFi mode (Ver. 2)

TD 7.104 Enhanced Uni-Directional HiFi Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Enhanced Uni-Directional HiFi Mode
- B. Procedure:
 - 1. Same as TD 7.0198 only with UUT and Host configured to Enhanced Uni-Directional HiFi mode
 - 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-directional HiFi mode (Ver. 2).

TD 7.105 Enhanced Uni-Directional HiFi Mode as 2nd Hop Test (Hub DFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Enhanced Uni-Directional HiFi Mode
- B. Procedure:
 - 1. Same as TD 7.019 only with UUT and Host configured to Enhanced Uni-Directional HiFi mode
 - 2. All the rest of the tree is configured to Enhanced Uni-Directional HiFi mode (Ver. 1) or Enhanced Uni-directional HiFi mode (Ver. 2).

TD 7.106 Enhanced Uni-Directional MedRes Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional MedRes Mode
- B. Procedure:
 - 1. Same as TD 7.018 only with UUT and Host configured to Enhanced Uni-Directional MedRes mode
 - 2. All the rest of the tree is configured to Enhanced Uni-Directional HiFi mode (Ver. 1) or Enhanced Uni-directional HiFi mode (Ver. 2).

TD 7.107 Enhanced Uni-Directional MedRes Mode as 2nd Hop Test (Hub UFP)

- A. Purpose:
 - Verify that the TMU in a USB4 Hub behaves as expected in Uni-Directional MedRes Mode
- B. Procedure:
 - 1. Same as TD 7.018 only with UUT and Host configured to Enhanced Uni-Directional MedRes mode
 - 2. All the rest of the tree is configured to Bi-Directional HiFi mode (Ver. 1) or Enhanced Uni-directional HiFi mode (Ver. 2).

TD 7.024 HiFi Mode as 3rd Hop Test (Hub UFP)

- A. Purpose:
- Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode (Ver. 1)
 - Verify that the TMU in a USB4 Hub behaves as expected in Enhanced Uni-Directional HiFi Mode (Ver. 2)
- B. Repetitions:
- Repeat test at Gen 2 and Gen 4 (if supported) speeds (Dual Lane Link only)
 - On Ver. 2 Routers, repeat test with CLx (CL0s and CL1) enabled and disabled
- C. Procedure:
1. Connect SD_HUB_UFP_TMU_10
 2. Configure USB4 Link according to Link Configuration #1
 3. If Router is Ver. 1, configure TMU to Bi-Directional HiFi mode
 4. If Router is Ver. 2, configure TMU to Enhanced Uni-Directional HiFi mode
 5. Run Time Calculation #1, N=1 on KG USB4 Device
 6. Run Time Calculation #2, N=1 between the KG Router and KG USB4 Device
 7. Run Stat Sub #1 on UUT
- Measurements on Hub as DFP:
8. Run Stat Sub #2 on UUT
 9. Run Stat Sub #3 on UUT
 10. Run Stat Sub #4 on UUT
 11. For a Ver. 2 Router:
 - Run Stat Sub #6 on UUT
 - If CLx is disabled, run Stat Sub #16 on KG Router above UUT
 - If CLx is disabled, run Stat Sub #17 on UUT on upstream port
 - Run Protocol Check #6 on UUT upstream port
 - Run Protocol Check #7 on UUT upstream port
 - If CLx is enabled, run Protocol Check #8 on UUT upstream port
 12. For a Ver. 1 Router:
 - Run Stat Sub #11 on KG Router above UUT
 - Run Stat Sub #12 on UUT on upstream port
 - Run Protocol Check #1 on UUT upstream port
 - Run Protocol Check #2 on UUT upstream port

TD 7.025 HiFi Mode as 3rd Hop Test (Hub DFP)

- A. Purpose:
- Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode(Ver. 1)
 - Verify that the TMU in a USB4 Hub behaves as expected in Enhanced Uni-Directional HiFi Mode (Ver. 2)
- D. Repetitions:
- Repeat test at Gen 2 and Gen 4 (if supported) speeds (Dual Lane Link only)
 - On Ver. 2 Routers, repeat test with CLx (CL0s and CL1) enabled and disabled
- B. Procedure:
1. Connect SD_HUB_DFP_TMU_11
 2. Configure USB4 Link according to Link Configuration #1
 3. If Router is Ver. 1, configure TMU to Bi-Directional HiFi mode
 4. If Router is Ver. 2, configure TMU to Enhanced Uni-Directional HiFi mode
 5. Run Time Calculation #1, N=1 on KG USB4 Device
 6. Run Time Calculation #2, N=1 between the KG Router and KG USB4 Device
 7. Run Stat Sub #1 on UUT
- Measurements of the effect of Hub as DFP:
8. Run Stat Sub #2 on KG USB4 Device
 9. Run Stat Sub #3 on KG USB4 Device
 10. Run Stat Sub #4 on KG USB4 Device
 11. For a Ver. 2 Router:
 - Run Stat Sub #6 on KG USB4 Device
 - If CLx is disabled, run Stat Sub #16 on UUT on downstream port
 - If CLx is disabled, run Stat Sub #17 on KG USB4 Device
 - Run Protocol Check #6 on KG USB4 Device
 - Run Protocol Check #7 on KG USB4 Device
 - If CLx is enabled, run Protocol Check #8 on KG USB4 Device
 12. For a Ver. 1 Router:
 - Run Stat Sub #11 on UUT on downstream port
 - Run Stat Sub #12 on KG USB4 Device
 - Run Protocol Check #1 on KG USB4 Device
 - Run Protocol Check #2 on KG USB4 Device

TD 7.026 TMU Mode Change Test (Hub UFP)

- A. Purpose:
- Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode
- B. Procedure:
1. Connect SD_HUB_UFP_TMU_08
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on KG USB4 Device
 5. Run Stat Sub #1 on UUT

Measurements on Hub as DFP:

6. Run Stat Sub #2 on UUT
7. Run Stat Sub #3 on UUT
8. Run Stat Sub #4 on UUT
9. Run Stat Sub #5 on UUT upstream port
10. Run Stat Sub #6 on UUT
11. Run:
 - If in Bi-directional mode Stat Sub #11 on KG Router above UUT
 - If in Uni-directional mode Stat Sub #13 on KG Router above UUT
12. Run:
 - If in Bi-directional mode Stat Sub #12 on UUT on upstream port
 - If in Uni-directional mode Stat Sub #14 on UUT on upstream port
13. Run:
 - If in Bi-directional mode Protocol Check #1 on UUT upstream port
 - If in Uni-directional mode Protocol Check #3 on UUT upstream port
14. Run:
 - If in Bi-directional mode Protocol Check #2 on UUT upstream port
 - If in Uni-directional mode Protocol Check #4 on UUT upstream port
15. Change TMU mode to Uni-Directional HiFi mode both in Host and UUT according to CM mode change flow (see CM guide)
16. Wait 1 sec
17. Repeat steps #4 to #24
18. Change TMU mode to Uni-Directional LowRes mode both in Host and UUT according to CM mode change flow (see CM guide)
19. Wait 1 sec
20. Repeat steps #4 to #24
21. Change TMU mode to OFF mode both in Host and UUT according to CM mode change flow (see CM guide)
22. Wait 1 sec
23. Run Stat Sub #11
24. Change TMU mode to Uni-Directional LowRes mode both in Host and UUT according to CM mode change flow (see CM guide)
25. Wait 1 sec
26. Repeat steps #4 to #24

TD 7.027 TMU Mode Change Test (Hub DFP)

- A. Purpose:
- Verify that the TMU in a USB4 Hub behaves as expected in Bi-Directional HiFi Mode
- B. Procedure:
1. Connect SD_HUB_DFP_TMU_09
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on KG USB4 Device
 5. Run Stat Sub #1 on UUT

Measurements of the effect of Hub as DFP:

6. Run Stat Sub #2 on KG USB4 Device
7. Run Stat Sub #3 on KG USB4 Device
8. Run Stat Sub #4 on KG USB4 Device
9. Run Stat Sub #5 on KG USB4 Device
10. Run Stat Sub #6 on KG USB4 Device
11. Run:
 - If in Bi-directional mode Stat Sub #11 on UUT on downstream port
 - If in Uni-directional mode Stat Sub #13 on UUT on downstream port
12. Run:
 - If in Bi-directional mode Stat Sub #12 on KG USB4 Device
 - If in Uni-directional mode Stat Sub #14 on KG USB4 Device
13. Run:
 - If in Bi-directional mode Protocol Check #1 on KG USB4 Device
 - If in Uni-directional mode Protocol Check #3 on KG USB4 Device
14. Run:
 - If in Bi-directional mode Protocol Check #2 on KG USB4 Device
 - If in Uni-directional mode Protocol Check #4 on KG USB4 Device
15. Change TMU mode to Uni-Directional HiFi mode both in Host and UUT according to CM mode change flow (see CM guide)
16. Wait 1 sec
17. Repeat steps #4 to #24
18. Change TMU mode to Uni-Directional LowRes mode both in Host and UUT according to CM mode change flow (see CM guide)
19. Wait 1 sec
20. Repeat steps #4 to #24
21. Change TMU mode to OFF mode both in Host and UUT according to CM mode change flow (see CM guide)
22. Wait 1 sec
23. Run Stat Sub #11
24. Change TMU mode to Uni-Directional LowRes mode both in Host and UUT according to CM mode change flow (see CM guide)
25. Wait 1 sec
26. Repeat steps #4 to #24

TD 7.028 Immediate Time Posting Test – 15 days (Hub)

A. Purpose:

- Verify that Immediate Time posting is working as expected in a in a USB4 Hub

B. Procedure:

1. Connect SD_HUB_UFP_TMU_08
2. Run Time Posting #1 on Host
3. Configure USB4 Link according to Link Configuration #1
4. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
5. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
6. Run Time Calculation #1, N=1
7. Run Stat Sub #1 on Host Router
8. Run Stat Sub #2 on KG USB4 Device
9. Run Stat Sub #3 on KG USB4 Device
10. Run Stat Sub #4 on KG USB4 Device
11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

TD 7.029 Immediate Time Posting – 1 hour (Hub)

- A. Purpose:
 - Verify that Immediate Time posting is working as expected in a USB4 Hub
- B. Procedure:
 1. Connect SD_HUB_UFP_TMU_08
 2. Run Time Posting #2 on Host
 3. Configure USB4 Link according to Link Configuration #1
 4. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
 5. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
 6. Run Time Calculation #1, N=1
 7. Run Stat Sub #1 on Host Router
 8. Run Stat Sub #2 on KG USB4 Device
 9. Run Stat Sub #3 on KG USB4 Device
 10. Run Stat Sub #4 on KG USB4 Device
 11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

TD 7.030 Future Time Posting Test – 15 days (Hub)

A. Purpose:

- Verify that Future Time posting is working as expected in a USB4 Hub

B. Procedure:

1. Connect SD_HUB_UFP_TMU_08
2. Configure USB4 Link according to Link Configuration #1
3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
5. Run Time Posting #3 on whole setup
6. Run Time Calculation #1, N=1
7. Run Stat Sub #1 on Host Router
8. Run Stat Sub #2 on KG USB4 Device
9. Run Stat Sub #3 on KG USB4 Device
10. Run Stat Sub #4 on KG USB4 Device
11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

TD 7.031 Future Time Posting Test – 1 hour (Hub)

- A. Purpose:
 - Verify that Future Time posting is working as expected in a USB4 Hub
- B. Procedure:
 1. Connect SD_HUB_UFP_TMU_08
 2. Configure USB4 Link according to Link Configuration #1
 3. For a Ver. 1 Router:
 - a. Configure UUT to Bi-Directional HiFi mode
 - b. Configure KG USB4 Device to Bi-Directional HiFi mode
 4. For a Ver. 2 Router:
 - a. Configure UUT to Enhanced Uni-Directional HiFi mode
 - b. Configure KG USB4 Device to Enhanced Uni-Directional HiFi mode
 5. Run Time Posting #4 on whole setup
 6. Run Time Calculation #1, N=1
 7. Run Stat Sub #1 on Host Router
 8. Run Stat Sub #2 on KG USB4 Device
 9. Run Stat Sub #3 on KG USB4 Device
 10. Run Stat Sub #4 on KG USB4 Device
 11. For a Ver. 2 Router, run Stat Sub #6 on KG USB4 Device

Inter-Domain

TD 7.032 Inter-Domain Time Initiator and Time Responder in Bi-Directional HiFi Mode Test (Hub DFP)

- A. Purpose:
 - Verify that a USB4 Hub DFP behaves properly as Inter-Domain Time Initiator and Time Responder
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HUB_DFP_TMU_12
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure the topology to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on Inter-Domain Time Initiator (KG Host Router)
 5. Run Time Calculation #2, N=1 between Inter-Domain Time Initiator (KG Host Router) and Inter-Domain Host Router
 6. Run Stat Sub #7 on UUT
 7. Run Stat Sub #8 on UUT
 8. Run Stat Sub #9 on UUT
 9. Run Stat Sub #10 on UUT
 10. Run Stat Sub #15 on UUT IDTI port
 11. Run Protocol Check #1 on UUT IDTI port
 12. Run Protocol Check #2 on UUT IDTI port
 13. Run Protocol Check #4 on UUT IDTI port

- A. Purpose:
 - Verify that a USB4 Hub UFP behaves properly as Inter-Domain Time Initiator and Time Responder
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HUB_UFP_TMU_13
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure the topology to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on Inter-Domain Time Initiator (KG Host Router)
 5. Run Time Calculation #2, N=1 between Inter-Domain Time Initiator (KG Host Router) and Inter-Domain Host Router
 6. Run Stat Sub #7 on UUT
 7. Run Stat Sub #8 on UUT
 8. Run Stat Sub #9 on UUT
 9. Run Stat Sub #10 on UUT
 10. Run Stat Sub #15 on UUT IDTI port
 11. Run Protocol Check #1 on UUT IDTI port
 12. Run Protocol Check #2 on UUT IDTI port
 13. Run Protocol Check #4 on UUT IDTI port
 14. Run Protocol Check #5 on UUT upstream port

- A. Purpose:
 - Verify that a USB4 Hub forwards Interdomain Timestamp packets properly
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
- C. Procedure:
 1. Connect ID_HUB_DFP_TMU_14
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure the topology to Bi-Directional HiFi mode
 4. Run Time Calculation #1, N=1 on Inter-Domain Time Initiator (KG Host Router)
 5. Run Time Calculation #2, N=1 between Inter-Domain Time Initiator (KG Host Router) and Inter-Domain Host Router
 6. Run Stat Sub #7 on the upstream KG USB4 Device
 7. Run Stat Sub #8 on the upstream KG USB4 Device
 8. Run Stat Sub #9 on the upstream KG USB4 Device
 9. Run Stat Sub #10 on the upstream KG USB4 Device
 10. Run Stat Sub #11 on the Host Router
 11. Run Stat Sub #12 on the downstream KG USB4 Device
 12. Run Stat Sub #15 on UUT IDTI port
 13. Run Protocol Check #1 on UUT upstream port
 14. Run Protocol Check #2 on UUT upstream port
 15. Run Protocol Check #5 on UUT upstream port

Peripheral Device

The tests in this section apply to a USB4 Peripheral Device that supports TMU. If the USB4 Peripheral Device is not supporting TMU, verify that Time Synchronization Not Supported (TSNS) bit in TMU_RTR_CS_0 register is set to 1b.

Intra-Domain

TD 7.035 Bi-Directional HiFi Mode as 2nd Hop Test (Peripheral Device)

- A. Purpose:
 - Verify that the TMU in a USB4 Peripheral Device behaves as expected in Bidirectional HiFi Mode
- B. Repetitions:
 - Repeat test with Single-Lane Link and Dual-Lane Link
 - Repeat test at Gen 2 and Gen 3 speeds (if supported)
- C. Procedure:
 1. Connect SD_DEV_UFP_TMU_15
 2. Configure USB4 Link according to Link Configuration #1
 3. Configure TMU to Bi-Directional HiFi mode
 4. Run Stat Sub #1 on UUT
 5. Run Stat Sub #2 on UUT
 6. Run Stat Sub #3 on UUT
 7. Run Stat Sub #4 on UUT
 8. Run Stat Sub #5 on UUT
 9. Run Stat Sub #6 on UUT
 10. Run Stat Sub #11 on KG upstream Router
 11. Run Stat Sub #12 on UUT
 12. Run Protocol Check #1 on UUT
 13. Run Protocol Check #2 on UUT

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Uni-Directional HiFi Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Uni-Directional HiFi mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #14 on UUT
10. Run Protocol Check #3 on UUT
11. Run Protocol Check #4 on UUT

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Uni-Directional LowRes Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Uni-Directional HiFi mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #14 on UUT
10. Run Protocol Check #3 on UUT
11. Run Protocol Check #4 on UUT

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Uni-Directional HiFi Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_16
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Uni-Directional HiFi mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #14 on UUT
10. Run Protocol Check #3 on UUT
11. Run Protocol Check #4 on UUT

TD 7.108 Enhanced Uni-Directional HiFi Mode as 2nd Hop Test (Peripheral Device)

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Enhanced Uni-Directional HiFi Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Enhanced Uni-Directional HiFi mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #17 on UUT
10. Run Protocol Check #6 on UUT
11. Run Protocol Check #7 on UUT

TD 7.109 Enhanced Uni-Directional MedRes Mode as 2nd Hop Test (Peripheral Device)

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Enhanced Uni-Directional MedRes Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Enhanced Uni-Directional MedRes mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #17 on UUT
10. Run Protocol Check #6 on UUT
11. Run Protocol Check #7 on UUT

TD 7.110 Enhanced Uni-Directional HiFi Mode as 3rd Hop Test (Peripheral Device)

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves as expected in Enhanced Uni-Directional HiFi Mode

B. Procedure:

1. Connect SD_DEV_UFP_TMU_16
2. Configure USB4 Link according to Link Configuration #1
3. Configure TMU to Enhanced Uni-Directional HiFi mode
4. Run Stat Sub #1 on UUT
5. Run Stat Sub #2 on UUT
6. Run Stat Sub #3 on UUT
7. Run Stat Sub #4 on UUT
8. Run Stat Sub #6 on UUT
9. Run Stat Sub #14 on UUT
10. Run Protocol Check #3 on UUT
11. Run Protocol Check #4 on UUT

TD 7.039 Immediate Time Posting Test – 15 days (Peripheral Device)

A. Purpose:

- Verify that Immediate Time posting is working as expected in a USB4 Peripheral Device.

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Run Time Posting #1 on Host
3. Configure USB4 Link according to Link Configuration #1
4. For a Ver. 1 Router, configure UUT to Bi-Directional HiFi mode
5. For a Ver. 2 Router, configure UUT to Enhanced Uni-Directional HiFi mode
6. Run Stat Sub #1 on UUT
7. Run Stat Sub #2 on UUT
8. Run Stat Sub #3 on UUT
9. Run Stat Sub #4 on UUT
10. For a Ver. 2 Router, run Stat Sub #6 on UUT
11. Run Stat Sub #12 on UUT
12. Run Protocol Check #1 on UUT
13. Run Protocol Check #2 on UUT

TD 7.040 Immediate Time Posting Test – 1 hour (Peripheral Device)

- A. Purpose:
 - Verify that Immediate Time posting is working as expected in a USB4 Peripheral Device
- B. Procedure:
 1. Connect SD_DEV_UFP_TMU_15
 2. Run Time Posting #2 on Host
 3. Configure USB4 Link according to Link Configuration #1
 4. For a Ver. 1 Router, configure UUT to Bi-Directional HiFi mode
 5. For a Ver. 2 Router, configure UUT to Enhanced Uni-Directional HiFi mode
 6. Run Stat Sub #1 on UUT
 7. Run Stat Sub #2 on UUT
 8. Run Stat Sub #3 on UUT
 9. Run Stat Sub #4 on UUT
 10. For a Ver. 2 Router, run Stat Sub #6 on UUT
 11. For a Ver. 1 Router, run Stat Sub #12 on UUT
 12. Run Protocol Check #1 on UUT
 13. Run Protocol Check #2 on UUT

TD 7.041 Future Time Posting Test – 15 days (Peripheral Device)

A. Purpose:

- Verify that Immediate Time posting is working as expected in a USB4 Peripheral Device

B. Procedure:

1. Connect SD_DEV_UFP_TMU_15
2. Configure USB4 Link according to Link Configuration #1
3. For a Ver. 1 Router, configure UUT to Bi-Directional HiFi mode
4. For a Ver. 2 Router, configure UUT to Enhanced Uni-Directional HiFi mode
 - a. Configure UUT to Bi-Directional HiFi mode
5. Run Time Posting #3 on whole setup
6. Run Stat Sub #1 on UUT
7. Run Stat Sub #2 on UUT
8. Run Stat Sub #3 on UUT
9. Run Stat Sub #4 on UUT
10. For a Ver. 2 Router, run Stat Sub #6 on UUT
11. For a Ver. 1 Router, run Stat Sub #12 on UUT
12. Run Protocol Check #1 on UUT
13. Run Protocol Check #2 on UUT

TD 7.042 Future Time Posting Test – 1 hour (Peripheral Device)

- A. Purpose:
- Verify that Immediate Time posting is working as expected in a USB4 Peripheral Device
- B. Procedure:
1. Connect SD_DEV_UFP_TMU_15
 2. Configure USB4 Link according to Link Configuration #1
 3. For a Ver. 1 Router, configure UUT to Bi-Directional HiFi mode
 4. For a Ver. 2 Router, configure UUT to Enhanced Uni-Directional HiFi mode
 5. Run Time Posting #4 on whole setup
 6. Run Stat Sub #1 on UUT
 7. Run Stat Sub #2 on UUT
 8. Run Stat Sub #3 on UUT
 9. Run Stat Sub #4 on UUT
 10. For a Ver. 2 Router, run Stat Sub #6 on UUT
 11. For a Ver. 1 Router, run Stat Sub #12 on UUT
 12. Run Protocol Check #1 on UUT
 13. Run Protocol Check #2 on UUT

Inter-Domain

TD 7.043 Bi-Directional HiFi Mode Test (Peripheral Device) on Inter-Domain Link

A. Purpose:

- Verify that the TMU in a USB4 Peripheral Device behaves properly as Inter-Domain Time Initiator

B. Procedure:

1. Connect ID_DEV_UFP_TMU_17
2. Configure USB4 Link according to Link Configuration #1
3. Configure the topology to Bi-Directional HiFi mode
4. Run Stat Sub #7 on UUT
5. Run Stat Sub #8 on UUT
6. Run Stat Sub #9 on UUT
7. Run Stat Sub #10 on UUT
8. Run Stat Sub #12 on UUT

TBT3-Compatibility Test Descriptions

The tests in this section are only performed if the USB4 Product implements TBT3-Compatibility as defined in Chapter 13 of the USB4 Specification. There are no TBT3-Compatibility tests for a USB4 Host.

Note: After each test, the TMU Mode is set to Off (i.e. the TMU is disabled) throughout the topology.

Hub

Intra-Domain

TD 7.044 Intra-Domain Two Single-Lane Links Test (Hub UFP)

- A. Purpose:
 - Verify that a USB4 Hub behaves properly with Two Single-Lane Links
- B. Procedure:
 1. Connect SD_HUB_UFP_TMU_08
 2. Configure upstream USB4 Link according to Link Configuration #2
 3. Configure downstream USB4 Link according to Link Configuration #2
 4. Configure Lane 0 and Lane 1 to be active
 5. Continue as in TD 7.018 from step #3

TD 7.045 Intra-Domain Two Single-Lane Links Test (Hub DFP)

- A. Purpose:
 - Verify that a USB4 Hub behaves properly with Two Single-Lane Links
- B. Procedure:
 1. Connect SD_HUB_DFP_TMU_09
 2. Configure upstream USB4 Link according to Link Configuration #2
 3. Configure downstream USB4 Link according to Link Configuration #2
 4. Configure Lane 0 and Lane 1 to be active
 5. Continue as in TD 7.019 from step #3

TD 7.046 Intra-Domain One Single-Lane Link Test (Hub)
Same as TD 7.044 only with Lane 1 active

Inter-Domain

TD 7.047 Inter-Domain Two Single-Lane Links Test (Hub)

A. Purpose:

- Verify that a USB4 Hub behaves properly with Two Single-Lane Links

B. Procedure:

1. Connect ID_HUB_DFP_TMU_12
2. Configure upstream USB4 Link according to Link Configuration #2
3. Configure inter-Domain USB4 Link according to Link Configuration #2
4. Configure Lane 0 and Lane 1 to be active
5. Configure Bi-Directional mode
6. Continue as in TD 7.032 from step #4

TD 7.048 Inter-Domain One Single-Lane Link Test (Hub)
Same as TD 7.047 only with Lane 1 active