CX5020 v4.0



T-TSC Time Error

Testing Time Slave Clock as per ITU-T G.8273.2 using Paragon-X

- Noise Generation
- Noise Tolerance
- Noise Transfer
- Transient Response
- Holdover Performance

The accuracy of Telecom Time Slave Clocks (T-TSCs) is essential to the successful roll-out of LTE-A and TDD-LTE. To meet the new G.8273.2 compliance limits, T-TSCs must meet a very stringent constant Time Error (cTE) limit of 20 or 50 nanoseconds. This ensures that the maximum number of nodes within the network's Time-Error budget can be deployed.

This Test Guide shows how the Calnex Paragon-X can be used to prove T-TSC compliance to G.8273.2 and provides procedures to measure noise generation, time noise tolerance and transfer, and packet layer transient response and holdover performance.

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1. Hardware and Software Required

Paragon-X

Option 111	10GbE interface support (if the Device-Under-Test (DUT) has 10G interface)
Option 201	Advanced IEEE1588v2 features
Option 205	Wander measurement
Option 206	Phase and time measurement
Option 213	SyncE wander and ESMC (if the DUT uses SyncE)
Option 250	IEEE 1588v2 One-box T-BC,T-TC and OC Test
Option 133	External 1pps/ToD/Frequency Converter accessory (if required to match the DUT outputs)

Software version: X.10.35.xx and later

Accessories

- SFP or SFP+ devices as required¹
- Cables as required
- Calnex BNC/RJ-45 adapter cable (required for 1pps accuracy/Time Error measurement)

Frequency Reference Source

Option 132 Rubidium Interface (optional)

Document References

- Recommendation ITU-T G.8273.2 Timing Characteristics of Telecom Boundary Clocks
- IEEE Std 1588TM 2008 IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- Calnex Technical Note: Cabling Considerations (CX5009)
- Calnex Noise Transfer Script Getting Started Guide (CX5036)

¹ XFP devices are not recommended for Time Error measurements as the retiming that is an integral element of the XFP introduces significant uncertainty when performing a Time Error test

2. Connecting Paragon-X to the T-TSC (Device-Under-Test)



Front Panel

- 100MbE Electrical or Optical (SGMII SFP)
- 1GbE Electrical or Optical (SFP) with option 110 fitted
- 10GbE Optical (XFP or SFP+) with option 111 fitted

Rear Panel

The Paragon-X accepts the following reference clocks which should be applied to one of the reference inputs on the rear panel of the Paragon-X:

10GbE Port 1

100MbE/1GbE

Port 1

Calney

Aux Port

10GbE Port 2

100MbE/1GbE

Port 2

🗖 . A. 🖸 . A. 🗛

Status Display

PC Controller Port

🛅 🚍

- 2.048/10MHz
- E1 (2.048Mb/s)
- DS1 (T1) (1.544Mb/s)



Connections

- 1. Connect Port 1 (Master side of Paragon-X) to the T-TSC Slave side.
- 2. Connect the external reference, e.g. 10MHz, to the Paragon-X Reference Input.
- 3. Connect the 1pps output from the T-TSC to the Paragon-X 1pps measurement port (Aux). Use Calnex's 1pps/ToD/Frequency Converter accessory if required.
- 4. If provisioned on the DUT, connect the Frequency, e.g. E1 output from T-TSC, to the Frequency measurement port at the rear of the Paragon-X.

3. Setting up the Paragon-X for G.8273.2 Conformance Tests

The following steps are required to set up the Paragon-X prior to performing the G.8273.2 Conformance tests:

- 3.1. Connection to Paragon-X from GUI
- 3.2. Configuration of physical connections
- 3.3. Measurement configuration
- 3.4. Preparing Master/Slave Emulation operation
- 3.5. Confirmation of PTP traffic on interfaces
- 3.6. Filtering capture and impairment traffic
- 3.7. Start of Master/Slave Emulation ready for test

3.1. Connection to Paragon-X from GUI

- 1. Verify the physical connections have been completed as described in Section 2.
- 2. Start the Paragon-X GUI.
- 3. Select Start Up and Connect.
- 4. Enter the IP address of the Paragon-X (displayed on Paragon-X status display).
- 5. See the Paragon-X Getting Started Guide for more details.

3.2 Configuration of physical connections

1. Select **Setup Interface** then **Line Rate** to match the T-TSC under test.

File Instrument(s) Setup	Capture Impair Graph Data Tools Help		
📽 🖬 🛲 🛲 🖉	🚰 📲 🎥 R 😹 C 🛇 🛄 💷 🚧		
Start Up	SETTINGS Port Packet # Byte : Ethemet	# HEX Binary Filter	User Label
Operating Mode	1GBE 1GBF N/A Setup Interface N/A		
Setup Interface	Thu: TERMII	ToD	
Master/Slave/GPS Emulation	TX+Rx Mode Thru Mode STATUS Sync-E Clock Rx -> Tx		
Measurements	Link Good Pkts		
Select Flow	Port 1 Line Rate Warder 0 100MbE 0 1GbE 0 10GbE	Port 2 Line Rate 100MbE @ 1GbE	◯ 10GbE
Configure Capture	IPPS Ref Jitter Interface Interface SFP/SFP+ XFP	Interface Interface SFP/SFP+	XFP
Start Capture	FLOW FILTEF Port 1 Rx	Auto Negotiate	
Add Impairments/ Delay	Flow 1: xxx GbE Electrical Phy Settings Flow 2: xxx Flow 3: xxx Flow 3: xxx Flow 3: xxx	Port 2	
Add Wander	Flow 4: xxx Set	Master Slave	
Add Jitter			Close

 Select the *References* tab to configure a stable reference for the Paragon-X. Set the *Clock Source* to *External reference* (10MHz or E1/2MHz). An external source is recommended

<u>F</u> ile Instrument(s) Setup	Capture Impair Graph Data Tools <u>H</u> elp	
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04-411-	SETTINGS Port Packet # Byte # HEX Binary	Filter User Label
Start Op	Ethernet Salura Later form	? ×
Operating Mode	IGBE TGE Setup Interface N/A N/A Ethernet References Measurement Ports ToD	
Setup Interface	Thru: TERM	
Master/Slave/GPS Emulation	STATUS Internal Internation Internatio Internation Internation Internation Intern	
Measurements	Ink 1pps Reference Input No Pkts BNC GPS D-type Internal	
Select Flow	Ref Threshold: 1.6 V (Range: 0.5 V to 2.5 V) Wander Vander V Vander Vander<	
Configure Capture	1PPS Ref Jitter	
Start Capture	FLOW FILTE Pott 2 Tx	
Add Impairments/ Delay	Flow 1: SE T Reference Output (Lower Front Aux Port) Flow 2: xxx 10 MHz and 1pps Flow 3: xxx 10 MHz and 1pps	
Add Wander	Flow 4: xxx 1pps width: 20000 µs (Range: 1 to 500,000 µs) Set	
Add Jitter		Close
Packet Generation		

3.3. Measurement configuration

1. Select Operating Mode > 1588v2 > Enable Master/Slave Emulation then Close.



2. Click on the *Measurements* button then enable *E1* and *1pps Time Error (Absolute)*.



3.4. Preparing for Master/Slave Emulation

It is assumed that a G.8275.1 profile will be used in testing to the G.8273.2 standard and as a result testing will be carried out using L2 encapsulation in Multicast mode.

1. Select Master/Slave Emulation then choose Slave Test in the Test Configuration drop down menu.



2. Select **G.8275.1** profile from the **Custom Profile** drop down menu.



3. Enter DUT to Paragon-X 1pps cable delay.

In order to correctly perform calculations, the delay caused by the cable that is used to connect the T-TSC Slave 1pps output and the Paragon-X 1pps measurement port must be factored out. Values of 5.1 ns per 1 metre of cable can be expected. Only full nanosecond values are counted, so calculated values need to be rounded up or down to the nearest full nanosecond value.



4. Start the Master/Slave emulation.

<u>F</u> ile Instrument(s) Setup	Capture Impair Graph Data	a Tools <u>H</u> elp			
📽 🖬 🛲 🛲 😹	💒 🎜 🎜 R 🛞 🗘 🍳				
Start Un	<< Results	Test Setup	G.8275.1 Phase Profile 🔹	Calne	x Master
Operating Mode	Device Configuration Master + Slave Two Masters			Mode: Multicast	1/1 < > x D-Reg Sync Ann P-to P-to P-to
Setup Interface	GPS Emulation Configure	GPS Emulation Calnex Paragoon-X	Ref In	760103	
Master/Slave/GPS Emulation	Test Configuration Slave Test	Master	Slave		
Measurements	DUT Ethernet cable (ns):	Capture Matter Iz			
Select Flow	cable (ns): 0 1pps Meas. cable (ns): 0	Tr Impairment Impairment Wander		Caln Mode: Multicast	ex Slave
Configure Capture	Capture	Capture Master Rr		Connected Master Address	D-Req Sync Ann Rate Rate Rate
Start Capture	C Slave Rx on both	Port 1	Port 2		
Add Impairments/ Delay	Measurement	1 pps/ToD 2M/T1/E1			
Add Wander	Calibration	Slave			
Add Jitter	Start			Port Link	Rx Packet
Packet Generation		\bigcirc			GOOD PACKETS
Statistics/ Results	Apply changes	Master		RefLock 🔮 1P	PS Ref 💛 1PPS Meas

3.5. Confirm PTP traffic on interfaces

1. Check the link to make sure that the PTP packets are running without error. If working successfully both Link and Packet status should show green status.

Link Status									
Port	Link	Rx Packet							
1	0	GOOD PACKETS							
2	9	GOOD PACKETS							

2. Stop Master/Slave Emulation in order to configure capture characteristics and to enable impairment operation.

3.6. Filtering capture and impairment traffic

The tests detailed in Sections 4 to 7 of this document are dependent upon generation and impairment of the 1588 messages associated with T-TSC phase and sync performance. It is therefore necessary to ensure that the correct messages are handled by the Paragon-X in Master/Slave Emulation mode. This is achieved by defining a set of traffic filters which will determine the messages that are captured and impaired.

• Capture Filtering

No Capture filters are required for testing the T-TSC.

• Impairment Filtering

In Slave test, the impairment occurs on the **Master** side. Impairment filters must be set up before any impairment is performed.

Impairments are required in the following tests:

- Time Noise Tolerance G.8273.2 Clause 7.2
- Time Noise Transfer G.8273.2 Section 7.3

It is recommended that impairments are enabled prior to starting the Master/Slave Emulation mode in the Slave test.

1. To enable impairments click on the *Add Impairments/Delay* button.

File Instrument(s) Setup	Capture Impair Graph Data	Tools <u>H</u> elp	
🖻 🔲 🚥 🏘 🎃 💕	🚰 🚰 🎜 R 🚿 😋 오		
Start Up	<< Results	Test Setup	G.8275.1 Phase Profile 🔹
Operating Mode	Device Configuration Master + Slave Two Masters		
Setup Interface	Configure	GPS Emulation Collegy Paragon-V	Ref In
Master/Slave/GPS Emulation	Test Configuration Slave Test	Master	Slave
Measurements	DUT Ethernet cable (ns): 8		
Select Flow	cable (ns): 0	Twisser IX Meas	
Configure Capture	Capture	Capture Master Rx	
Start Capture	Slave	Port 1	Port 2
Add Impairments/ Delay	Flow Filter Measurement —	1 pps/ToD 2M/TI/EI	
Add Wander	Calibration	Slave	
Add Jitter	Start		
Packet Generation			
Statistics/ Results	Apply changes	🕞 Master	

This will display the **Impairments** control screen. Impairments are applied to the Sync messages in the forward direction (Master Tx).

File Instrument(s) Setup	Capture Impair Graph	Data Tools <u>H</u> elp		
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Start Up	<< Results		Impairments and Delay	
	Selected Message Type	s		Intrinsic Delay
Operating Mode	Master Tx: Master Rx:			Packet size: Small Packets (< 200 bytes) Change Delay (µs): 6.7
Setup Interface	Configuration	Delay General Settings —		
	Flow Filter	Mode:	Type:	Apply to:
Emulation	\sim	Single Report	 Single flow (relative) Multi flow 	Packet sending time Correction field
	Mactor 1 Tx	C Repeat	Packet rate (Packets/s): 64	Both
Measurements	Delay			~
	Physical Corruption	Delay Insertion		
Select Flow	Packet Corruption	Fixed delay (µs): 6.0	0	
	Profile Corruption	Variable delay type:		
Configure Capture	Master Impairments	 Sawtooth 	# of Packeter 1000	
		Beating,F 👻	# 01 Pdd(033	
Start Capture	Master 1 Rx	Step function	Min (µs): 6.00	
	Delay	Latency	Max (µs): 10006.00	
Add Impairments/	Header Overwrite	Constant	Mean (us); 5006.00	Timesint Interval
Delay	Physical Corruption	Gaussian	Std Day (us): 1000.00	
∆dd Wander	Profile Corruption	Gamma	5.4 20V (ps). 1000.00	
Add Halluci	Profile Corruption	User defined	Generate	Fixed Delay Ramp Period
A.I.I. 194		Import		<u> </u>
Add Jitter		Imported Profile		G.8261: Systematic Delay
Packet		No File Imported.		

2. Enable the *Master TX Delay* feature using the tick box shown above. Select by clicking on *Delay*. The selection will be highlighted as:



3. Select *Flow Filter* to select the Sync messages for delay impairment.

File Instrument(s) Setup	Capture Impair Graph D	Data Tools <u>H</u> elp	
📽 🖬 🛲 🛲 🂕	🚰 🎜 🕄 R 🚿 😋 🤇		
Start I In	<< Results	Impairments and Delay	
o dan op	Selected Message Types	Intrinsic Delay	
Operating Made	Master Tx:	Packet size: Small Packet	s (< 200 bytes) Change
Operating Mode	Master Rx:	Delay (µs): 32.4	
Setun Interface	Configuration		
		Flow Filter Editor	
Master/Slave/GPS	How Hiter	Master: Slave: Messages:	
Emulation	Marshau 1 Tu	Follow-Up	
	Delay	Delay Request	•
Measurements	Header Overwrite	Announce	-
	Physical Corruption	Multiple slaves: Signaling (from	Master)
Select Flow	Packet Corruption	C0:00:00:00:001	Slavey
	Profile Corruption		
Configure Capture	Master Impairments	Set Clear	
0	Master 1 Ry	Flow Filter Status	
Start Capture	Delay	Flow Summary: Flow Detail:	
Add Impairments?	Header Overwrite	Port 1 Rx (Master) Port 1 Tx (Master) Filter not set for the selected flow	
Delay	Physical Corruption	XXXX	
	Packet Corruption		
Add Wander	Profile Corruption	XXX XXX	
Add Jitter			
Destat			
Generation			
Parking I		1	
Results		Impairments	

The Impairment engine is now primed and is ready to import delay patterns when required as defined in later tests.

Delay Patterns and Tools

The test procedure for T-TSC Conformance testing has the following components:

• Noise Tolerance

This is carried out using a single traffic stimulus pattern:

G8273_2 Noise Tolerance Pattern[G8271.1Table7-1] _16pps.cpd

accessed via the link: Patterns - Calnex Product FAQ

• Noise Transfer

This comprises of a tool which exercises a set of traffic stimulus patterns for checking conformance to the standard:

Enhanced Noise Transfer

accessed via the link: Tools - Calnex Product FAQ

3.7. Start of Master/Slave Emulation ready for test

The Master/Slave Emulation mode can now be re-started.

- 1. Return to the Test Setup page by clicking on the Master/Slave Emulation button.
- 2. *Start* the Master/Slave emulation.



Notes on Measurements

The tests in Sections 4 to 7 of this document detail the measurements that must be carried out to verify performance against the ITU-T Standard's limits. Measurements are actioned using the *Start Capture* button and should be executed for the required period.



- Wait for the T-TSC Slave to lock to the Paragon-X emulated Master and stabilize before making any measurements. Clock settling time is important. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several hours dependent on the T-TSC under test. It may even be recommended to wait longer e.g. overnight.
- Once the Slave clock has settled, *Start* the capture as above and then launch the *Calnex Analysis Tool (1PPS)* to view the 1pps result metrics.

Capture Ir	mpair	Graph	Data	Tools	Help																
💒 🕼 🎥	R	🙊 😋	•	1	588 Tran	sparent Clo	ock Late	ency													
OFTENOO			⊐ s	C	Calculate	differentia	I PDV				_	_		_	_	_	_	_	_	_	
SETTINGS	<u> </u>			S	plit PDV	files															
100BASE				J	oin CSV f	iles															
N/A				F	DV Edito	r			•												
NZA				F	ile Conve	erter															
Thru: TER				S	cript Rec	order															
				N	/iew Reco	rded Scrip	t														
STATUS	R	eset History	So	F	TP Field	Verifier															
Port 1	- Pe	ort 2		L	ogging				+												
Link Cood Die		Link	1111			CDE (ULL)															
Good Pki	.15 0	IOOG PRIS		F	lot PDF/	UF/Histo	gram														
Rof		Same F			ainex An		(1995)														
Wander		-yncu		anchot	currenth	colocted	data and	d cond	to Cala												
1PPS Rei	af 1P	PS Meas	A	nalysis	Tool	sciected		u senu	to cam	~ I											
Jitter																					
FLOW FILT	IER		_	1nos Ti	ime Error :																
Port 1 Bx				(Absc	lute)		, pro		مليرية	****	 										
Flow 1: xx				Limit =	1.5µs			••••			- 4-				1 34			r Inn.			
Flow 2: xx				PA:	, <u>,</u>	سېر س														••••	
Flow 4: xx																					
Set		Clear																			[

Time Error results available with the CAT are as follows:

1. Time Error

 \circ 1PPS Time Error

2. Average Time Error (cTE)

◦ 1PPS Constant Time Error

3. Dynamic Time Error

- o 1PPS Filtered
- o 1PPS Filtered MTIE
- o 1PPS Filtered TDEV



4. Noise Generation – G.8273.2 Clause 7.1

Test Description

The noise generation of a T-TSC represents the amount of noise produced at the output of the T-TSC when there is an ideal input reference packet timing signal. The noise generation has two components, the constant time error (cTE) and the time noise generation (MaxITEI, dTE).

Measurement Process

The standard specifies that the test should be carried out with both PTP and SyncE active. It is possible to cater for non-SyncE devices (described in Section 4.2) but this is outside the remit of Standards conformance.

Note: The Master/Slave Emulation Configuration steps described in Section 3 must be performed prior to this test. **Impairments are not required for this test.**

4.1 Combined PTP and SyncE

To enable SyncE, select *Packet Generation* with SSM code of *QL_PRC*. To start ESMC generation click on the *Start* button.

<u>F</u> ile Instrument(s) Setup	Capture Impair Graph Dat	Packet Generation	
📽 🔲 🛲 🏘 🏣 🕌	📲 🎜 🎜 R 🛞 🔶 🌢	ESMC TestPackets	
Start Up Onerating Mode	SETTINGS Ethemet 1GBE 1GBE N/A	Ethernet Source MAC Address 00:00:00:00:00:2b	s s
Setup Interface	N/A Thru: TERMINATED	Injection Settings IPG 1000 ms	Start
Master/Slave/GPS Emulation	STATUS Reset History	VLAN Encapsulation	Apply Change
Measurements	Port 1 Port 2 Link Link Good Pkts Good Pkts	OFF ON Number of streams 1	
Select Flow	Ref SyncE Wander	Stream 1 Stream 2 Stream 3 Stream	4
Configure Capture	1PPS Ref 1PPS Meas Jitter	TPID 88 09 SSM Coze QL-PRC -	Evert Flag
Stop Capture	FLOW FILTER	PCP 7	
Add Impairments/ Delay	Flow 1: SET Flow 1: xxx Flow 2: xxx Flow 2: SET Flow 3: xxx Flow 3: SET	CFI 0 0 1 VID 11	
Add Wander	Flow 4: xxx Flow 4: SET		
Add Jitter			
Packet Generation			
Statistics/ Results			
			Close

2. With Master Slave Emulation mode running, start a capture using the *Master* button in the Master/Slave *Test Setup* page.

Start Up	<< Results	Test Setup	G.8275.1 Phase Profile 🔹
	Oevice Configuration Omega Master + Slave		
Operating Mode	 Two Masters GPS Emulation 		
Setup Interface	Configure	GPS Emulation Calnex Paragon-X	Ref In
Master/Slave/GPS Emulation	Test Configuration		
Measurements	DUT Ethernet acable (ns);	Master 1 pps	Slave
Select Flow	1pps Ref. cable (ns): 0 0		
Configure Capture	cable (ns); 0 Capture	Impairment Impairment Meas.	
Stop Capture	 Master Slave Rx on both 	Port 1	Port 2
Add Impairments/ Delay	Flow Filter	1 nns/TaD 2W/T1/F1	
Add Wander	Manual calibration		
Add Jitter	Start		
Packet Generation	Set capture flow filter		
Statistics/ Results	Apply changes	🖲 Master	

- 3. Allow the capture to run for at least 2000s. Then use the Stop Capture button to stop the capture.
- 4. Measurements: Time Error results can either be viewed during capture or after capture has been stopped.

Time Error Results (Constant Time Error)

1. Select Tools > Calnex Analysis Tool (1PPS).



The Calnex Analysis Tool will launch and display the Time Error metrics tab.

CAT - Calnex Analysis Tool	2 3 20		6 L R		
₩ 6 21 T					Application System Help
Select File	Time Error A	vg Time Error (cTE)			Mask Status 🔹 🍝
	1 1pps TF Absol	ute			🕍 Avg Time Error 1pps cTE 🛛 PASS
Select Metrics	40 1				🕍 Time Error 1pps TE 🛛 PASS
View Results	30 -			0	Metric Statistics
	20 -			E	Mean [ns] 0.415
Generate Report	101000 TE 4	broluto		a	Min [ns] -7 Max [ns] 7
Export		/www.www.utemb	Production of the local division of the loca		Max-Min [ns] 14
	1				Chart Tools >>>
	F -10-				Markers Editor
	-20 -				Marker 1 Marker 2 🖻
	-30 -				Chart & Zoom mode
	-40 -				
	o	10 000 20 000	30 000 Elapsed Time [s]	40 000 50 000	Visible Elements
				C	🖌 Errors 🖌 Labels 🏹 Markers
	Sample #	Timestamp	TIE	*	Save As Image
	56604	56605	-4		Darameters
		56606		*	Dynamic TE Limit +/
		56607	-4		1pps TE Absolute:
		56608	-4		🗹 1.5 🌲 🗘 🗸 Apply
Calculate		56609	-4		Zero 1pps
		56610	-4		Offset: -6 ns
		56611	-4		Data Analysis Range(s)
Calnex		30011			From 10 0 ↓ 56611 ↓s ♂ ↓

- By default only the *Time Error* and *Avg Time Error* metrics can be enabled. To enable MTIE and TDEV metrics, you must first click on the *Select Metrics* button followed by enabling the *MTIE* and *TDEV* metric tick boxes under *Dynamic Time Error*.
- Click on the *Calculate* button. On reaching 100%, the metrics are available for selection by clicking on the appropriate tabs.

CAT - Calnex Analysis Tool	the lot a loss a low a hadron				storing being and	-		×
A (21						Application	System	Help
Select File	Clock Measurements							
Select Metrics				?				
View Results				?				
Generate Report	ClkFFO			?				
Export								
	Time Error Measurements							
	Avg Time Error (cTE)	100%		?				
	Time Error	100%		?				
	 Dynamic Time Error 1pps TE Absolute LF 1pps TE Absolute HF 1pps TE Absolute Dynamic 1pps TE Absolute Dynamic 	MTIE LF TDEV LF	^ 10 10	? 6% 0% 0%				
Calculate								
Calnex								

4. Select the Avg Time Error (cTE) metric tab.



Min and Max values are displayed to the right of the graph in the Metric Statistics display area.

The G.8273.2 spec [1.4.1] refers to Constant Time Error stating:

"It is expected that for the type of measurements implied by the G.8273.x series of recommendations it should always be possible to identify a stable, consistent observation interval when performing a cTE measurement. In general a value of 1000s or greater is recommended."

To cater for this definition, the Constant Time Error displayed is a result of a moving average of 1000s being applied to the raw Time Error results. This removes packet-to-packet noise that will be filtered out by the terminating slave.

5. Check your result conforms to the G.8273.2 spec [1.4.1].

There are 2 classes of device:

- Class A for devices which conform to ± 50 ns cTE
- Class B for devices which conform to $\pm 20 \text{ns} \text{ cTE}$

Check with the vendor which class of device is being tested.

Time Error Results (MTIE and TDEV)

6. Select the Dynamic Time Error tab to display the filtered Time Error results. Note that these results are filtered at 0.1Hz.



- Compare the results against the ITU-T limits by applying the appropriate mask to the 2Way Dynamic MTIE LF and 2Way Dynamic TDEV LF metrics to match the class of the device under test:
 - G.8273.2 T-BC Class A Dynamic TE LF Const. Temp
 - G.8273.2 T-BC Class B Dynamic TE LF Const. Temp



8. Check for PASS/FAIL versus masks. If the masks pass then the status in the **Mask Status** Block will indicate PASS. Mask failure will be indicated by FAIL.

Time Error Results (MaxITEI)

9. Select the *Time Error* tab to display the raw unfiltered Time Error results.

CAT - Calnex Analysis Tool	N N M		6 LA 19			
₩ 62 T						Application System Help
Select File	Time Error Av	g Time Error (cTE)				Mask Status 🔹 🐣
Select Metrics	🗠 1pps TE Absolu	ıte			-	Avg Time Error 1pps cTE PASS
	40				2	Time Error 1pps TE PASS
View Results	30 -				2	Mean Ins) 0.415
Generate Report	20 -				0	Min [ns] -7
Export	10 - 1pps TE A	bsolute /ˈwww.www.udv.ww	Page and and			Max-Min [ns] 14
	ر المربي الم			W-WWW.Con-Contraction of the Contraction of the Con		Chart Tools >>
	10 -					Markers Editor
	-20 -					Chart & Zoom mode
	-30 -					↔1 0 ⊕
	-40 - 4	10 000 20 000	30 000 Elapsed Time [s]	40 000 50 000		Fit
					2	Visible Elements
	Sample #	Timestamp	TIE		*	Save As Image
	56604	56605			\sim	Parameters >>
	56605	56606			*	Dynamic TE Limit +/-
	56606	56607				1pps TE Absolute:
Calculate	56607	56608				Zero 1pps
100%	56608	56609				1pps Offset -6 ns
	56609	56610				Data Analysis Range(s)
Calnex	56610	56611	-4	<u> </u>		From To 0 1 56611 1 s

- Set the Dynamic TE Limit to either 100ns for Class A devices or 70ns for Class B devices. This will change the Thresholds on the graph.
- 11. Compare the results against the thresholds.



NOTE: The graph attempts to show metrics at the highest resolution to add visibility. Display of the graph thresholds will only occur if the resolution allows.

5. Time Noise Tolerance – G.8273.2 Clause 7.2

Test Description

Checks if the clock can maintain network limits at the output with maximum noise at the input.

Measurement Process

The standard recommends testing in combined hybrid mode involving both PTP and SyncE input. This is reflected in the test procedure detailed below.

Note: The Master/Slave Emulation Configuration steps described in Section 3 must be performed prior to this test.

Combined PTP and SyncE

- 1. To enable SyncE ESMC Generation, select *Packet Generation* with **SSM code** of *QL_PRC*.
- 2. To start ESMC generation press the **Start** button.

<u>F</u> ile Instrument(s) Setup	Capture Impair Graph Dat	Packet Generation		
📽 🔲 🛲 🍻 🔐	₽ 18 18 R ⊗ ● ●	ESMC TestPackets		
Start Up	Ethernet	Ethernet Source MAC Address 00:00:00:00:00:2b		<u> </u>
Operating Mode	N/A N/A	Port 1 Port 2		
Setup Interface	Thru: TERMINATED	Injection Settings IPG 1000 ms	Start	
Master/Slave/GPS Emulation	STATUS Reset History	VLAN Encapsulation	Apply Change	
Measurements	Port 1 Link Good Pkts Good Pkts	OFF ON Number of streams 1		
Select Flow	Ref SyncE Wander	Stream 1 Stream 2 Stream 3 Stream 4		
Configure Capture	1PPS Ref 1PPS Meas Jitter	TPID 88 09 SSM COLE QL-PRC	Evert Flag	
Stop Capture	FLOW FILTER	PCP 7		
Add Impairments/ Delay	Flow 1: SET Flow 1: xxx Flow 2: xxx Flow 2: SET Flow 3: xxx Flow 3: SET	CFI 0 0 1 VID 11		
Add Wander	Flow 4: xxx Flow 4: SET			
Add Jitter				
Packet Generation				
Statistics/ Results				
			Close	

Add Impairment Pattern

The Noise Tolerance Test in G.8273.2 Section C.2.2 involves applying a known pattern to **either** the forward or reverse PTP flow in order to check that the DUT maintains its reference lock.

A PDV pattern with the following characteristics should be applied to the PTP input in a single direction.



This pattern is called **G8273_2** Noise Tolerance Pattern[G8271.1Table7-1]_16pps.cpd and is available for download as part of the G.8273.2 suite of impairment patterns.

Note: Store the downloaded pattern in a known location on your PC so that you can use it to control the test.

Adding the Pattern

3. Select Add Impairments/Delay. This will display the following:



4. Enable the *Master TX Delay* feature using the tick box shown above and clicking on the word *Delay*.

5. Select *Flow Filter* to set up the Sync messages for delay impairment.

<u>File</u> Instrument Setup Ca	apture Impair Graph Dat	a Tools <u>H</u> elp			
🛎 🖬 🚥 🖮 💕	🚰 🎾 🎥 R 🚿 C	• 🔲 < ») 🛄 🚧 🔳 📕			
Start Up	<< Results		Impairments and Delay		
· ·	Selected Message Types			Intrinsic Delay	
	Master Tx: Sync			Packet size: Small Packets (< 200 bytes)	Change
Uperating Mode	Master Rx:			Delay (µs): 6.7	
		1			
Setup Interface	Configuration	Flow Filter Editor			
	Flow Filter	Master:	Slave:	Messages:	_
Master/Slave/GPS		a0 00 00 00 00 01	Any multicast slave	✓ Sync	
Lindiduon	Master 1 Tx			Ellow-Up	
Measurements	Delay 📃			Delay Response	
	Header Overwrite			Announce	
0.1. I.F.	Physical Corruption	Multiple slaves:		Signaling (from Master)	
Select Flow	Packet Corruption	C0:00:00:00:01			
	Profile Corruption				
Configure Capture	Master Impairments 📃	Set Clear			
		Flow Filter Status			
Start Capture	Master 1 Rx	Flow Summary:	Flow Detail:		
	Delay	Dest 1 De (Master) Dest 1 Te (Filter not set for	the selected flow	7
Add Impairments/	Header Overwrite		naster)		-
Delay	Physical Corruption	XXX XXX			
Add Wander	Profile Corruption	XXX XXX			-
	Profile Corruption	XXX SYNC			-
					-
Add Jitter					-
					-
Packet					-
conoration					

6. Select the *Master TX Delay* again, then *User defined* and *Import*. In the file browser window navigate to the location of the stored pattern and select the *Pattern* obtained from Calnex.

- Open		Name and Andreas (1988)	net Liter.	×
🚱 🗢 🖳 🕨 Computer 🕨			✓ 4 Search Computer	٩
Organize 🔻			_= ¥=	
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▷ ≦ Windows (C:) ▷ ⊟ HP_RECOVERY (I ▷ = HP_RECOVERY (I ▷ = HP_RECOVERY (I ▷ = HP_RECOVERY (I ▷ = HP_TOOLS (F:) ▷ = ZEN Stone (H:)	2// US free of 452 GB Devices with Removable Storage (3) KINGSTON (E) 516 MB free of 14.5 GB Network Location (1)	1.46 GB tree of 12.1 GB	ZEN Stone (H:)	
Service (\calmexc Service (\calmexc Service (\calmexc) Service (\calmexc)	shared (\\calnexdev) (Z:)			
File <u>n</u> ame:	pd; *.cpw; *.cbz			*.cpd; * ▼ Cancel

7. Once the file has been loaded, start the impairment by selecting



Add SyncE Wander

8. Select *Add wander* > *Wander Tolerance* > *Table* to apply sinusoidal wander to the SyncE input based on G.8262 Section 9.1.1 Table 9.

e Instrument(s) Setup Ca A	dd Wander				
ê 🖬 🛲 🛲 🖬 🛍	Frequency Offset Wand	ler Tolerance	Wander Transfer		
Start Up	Single 🔨	Table 🔨	MTIE/TDEV Mask		
Operating Mode	Enable Frequency (Hz)	Amplitude (µs)	Dwell Time (Cycles)	Status	Restore Defaults
Setup Interface	Image: Construction Image: Construction	0.25	10 3	0%	
Aaster/Slave/GPS	 ✓ 0.00080 ✓ 0.00032 	2.00 5.00	3	0% 0%	
Measurements				0% 0%	
	(Frequency Range: 0.000)	. Hz to 100 Hz)		0%	
Select Flow	(Amplitude Range: 0.01 µs (Dwell Time Range: 1 cycle	to 10 µs) to 500 cycles)			
onfigure Capture		Lower lim	it of max tolerable	sinusoidal	input wander
Start Capture	Peak-to-Peak	\mathbf{i}			
Add Impairments/ Delay	Wander 2 Amplitude (µs)				
Add Wander	0.25	00022 0 0008	0.016		
Add Jitter			Wander Frequ	ency (Hz)	
Packet					
Generation Statistics/	Generate Wander	Stop Wander			Elapsed Time: 0 s
Results					
					UK

9. Select *Generate Wander* to stress the SyncE input accordingly.

S S				_		
start Op	Single	\sim – T	able \sim	MTIE/TDEV Mask		
rating Mode	Enable	Frequency (Hz)	Amplitude (us)	Dwell Time (Cycles)	Status	Restore Defaults
		10.00000	0.25	300	0%	
		0.13000	0.25	10	0%	
p Interface		0.01600	2.00	3	0%	
		0.00080	2.00	3	0%	
		0.00032	5.00	3	0%	
slave/GPS	[III]	0100002	0.00		0%	
ration _					0%	
ſ					0%	
ements					0%	
	[0 /0	
re Capture	(Frequen (Amplitud (Dwell Tir	cy Range: 0.0001 le Range: 0.01µs ne Range: 1 cycle	Hz to 100 Hz) to 10 µs) to 500 cycles) Lower limi	t of max tolerable	0%	nput wander
Iect Flow	(Frequen (Amplitud (Dwell Tir Peak-t War	cy Range: 0.0001 le Range: 0.01 µs ne Range: 1 cycle o-Peak 2 der 2	Hz to 100 Hz) to 10 µs) to 500 cycles) Lower limi	t of max tolerable	sinusoidal i	nput wander
lect Flow jure Capture et Capture pairments/ Delay	(Frequen (Amplitud (Dwell Tir Peak-t War Ampj (µ	cy Range: 0.0001 le Range: 0.01 µs ne Range: 1 cyde 5 o-Peak 1der 2 itude s)	Hz to 100 Hz) to 10 µs) to 500 cycles)	t of max tolerable	sinusoidal i	nput wander
lect Flow jure Capture rt Capture npairments/ Delay	(Frequen (Amplitud (Dwell Tir Peak-t War Ampl (µ	cy Range: 0.0001 µs ne Range: 1 cyde o-Peak 2 ider istude s) 0.25	Hz to 100 Hz) to 10 µs) to 500 cycles)	t of max tolerable	sinusoidal i	nput wander
lect Flow jure Capture rt Capture mpairments/ Delay d Wander	(Frequen (Amplitud (Dwell Tir Peak-t War Ampj (µ	cy Range: 0.0001 ls le Range: 0.01 ls ne Range: 1 cycle o-Peak 2 der itude s) 0.25 0.25	Hz to 100 Hz) to 10 µs) to 500 cycles) Lower limi	t of max tolerable	0% sinusoidal i 0.13 ency (Hz)	nput wander
lect Flow jure Capture et Capture npairments; Delay d Wander Id Jitter	(Frequen (Amplituc (Dwell Tir Peak-t War Ampju (µ	cy Range: 0.0001 le Range: 0.01 µs ne Range: 1 cycle o-Peak 2 inder is) 0.25 0.25	Hz to 100 Hz) to 10 µs) to 500 cycles) Lower limi	t of max tolerable	sinusoidal i	nput wander
elect Flow gure Capture rt Capture pairments/ Delay d Wander dd Jitter Packet eneration	(Frequen (Amplitu (Owel Tir Peak-t Way Ampl (µ	cy Range: 0.0001 µs he Range: 0.01 µs he Range: 1 cyde	Hz to 100 Hz) to 10 µs) to 500 cycles) Lower limi	t of max tolerable	sinusoidal i	nput wander

10. Select

to begin the measurement.

11. Once Wander Generation has finished and at least **1000s** have passed, select **Stop Capture** to end the measurement.

Expected Outcome

The Vendor DUT should maintain reference and not be subjected to switching reference or enter holdover state. This must be determined from the device itself (e.g. via the management interface).

6. Time Noise Transfer – G.8273.2 Section 7.3

Test Description

Measures how Time Error on the input is transferred to the output.

Measurement Process

Noise Transfer test conformance for T-TSCs, in line with ITU-T G.8273.2 (Clause 7.3), is performed using an Enhanced Noise Transfer (ENT) Tcl or Python script which automatically:

configures the Paragon-X

applies the appropriate noise patterns to the T-TSC input as defined in G.8273.2 Amendment 1 (Appendix VI) measures the T-TSC response to the applied noise patterns

provides a pass / fail indication for measured output based on the limits defined in G.8273.2 Amendment 1 (Appendix VI)

Requirements

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The Script requirements are defined in the Calnex Noise Transfer Script - Getting Started Guide [CX5036].

The PC requirements for the Paragon-X and associated tools are described in "Minimum PC Requirements" installed with the Paragon-X Application.

6.1 PTP to 1PPS Transfer

Table 1 below shows the stimulus frequencies and amplitudes of the noise applied to the PTP input of the DUT. Note that 200ns of sinusoidal time error is achieved by applying a sinusoidally varying delay in the forward direction with an amplitude of 400ns (the overall time error is an average of the error in both directions).

The table lists the permitted limits for each frequency. These limits include an allowance for device noise generation and tests equipment uncertainty. An allowance of 10ns (n=10) has been added based on the use of the least squares method being applied to the results.

Point Test Freq (Hz		Pk-Pk I/P	Pk-Pk O/P Amj noise allo	Duration (s)	
		Ampi (ns)	Max	Min	
0	0.00390625		215	130	800
1	0.0078125		215	130	800
2	0.015625		215	130	400
3	0.03125		215	130	
4	0.0615625	200	215		
5	0.123125	200	140		
6	0.24625		90	2/2	250
7	0.4925		50	li/d	
8	0.985		35		
9 1.985			25		

Table 1. Maximum and Minimum Expected Output Amplitudes atTest Frequencies for PTP-1PPS Noise Transfer Measurement

Procedure

The Enhanced Noise Transfer script is delivered as a part of the Paragon-X install procedure and is located in the same installation directory as the Paragon-X software.

NOTE: It is recommended that users check for updated versions of the ENT script prior to testing. The URL is:

Tools - Calnex Product FAQ

It is possible to execute the script from the installation directory. However, it is recommended that the script is copied to a user's home directory (or other user preferred location), as execution of the script causes result files to be created in subdirectories.

The ENT script is a Tcl or Python script which uses a set of configurable command line parameters to control the execution of the test.

The default settings for the script are available in the *Defaults* file. These defaults contain sufficient information to enable execution of the script. However, there are certain parameters that require to be overridden on the command line for the customer environment, e.g. Instrument IP address. The table below lists the set of customer configurable parameters which might require to be set at run-time.

These can either be set by passing in the specific parameter token and value pair on the command line, or all of the user parameters can be passed in to the Script in the form of a configuration file.

A user configuration file can be created by copying the **Defaults** file to a user named file then amending the contents to the user preferred settings within this file. The configurable parameters control the behaviour of the Paragon-X or the behaviour of the script itself. These parameters are listed in the tables below. Note that the parameters and settings are **case-sensitive**. Additional parameters can be seen in the **Calnex Noise Transfer Script - Getting Started Guide [CX5036]**, which is delivered with the script.

There are two sets of information required:

- Instrument Settings which define the physical set up of the Paragon-X
- Script Control Settings which define how the script will execute

Setting	Description	Default	Allowed Values
Instrip	The IP address of the Paragon-X management port	192.168.3.100	Valid IP address
Guilp	IIpThe IP address of the PC hosting the Paragon- X application		Valid IP address
GuiPort	The TCP port for script to application software commands	9000	Valid TCP port
LineRate	Line rate to be used by the Paragon-X	1GBE	100BASET, 1GBE, 10GBE
Interface	Interface used for the test	ELECTRICAL	XFP, SFPPLUS, ELECTRICAL, OPTICAL
TwoStep	Enables/disables two-step operation	FALSE	TRUE, FALSE
AutoNegotiate	Enables/disables auto negotiation	FALSE	TRUE, FALSE
SyncE	Enable/disable SyncE measurement during the test	TRUE	TRUE, FALSE
Reference	Source of the Paragon-X frequency reference	INT	EXT_10M, EXT_R75_E1, EXT_R100_T1, EXT_R100_E1, EXT_K64, INT
CableDelay	Cable delay between the DUT and Paragon-X port 2. (See note 3)	5	Type: Integer Range: 0 to 1000 Unit: ns
1ppsThreshold	When Type = PTP-1PPS or SyncE-1PPS	1.0	Type: Float Range: 0.5 to 2.5 Units: Volts

Setting	Description	Default	Allowed Values
Туре	Test type to be performed (see note 4)	PTP-BOTH	PTP-BOTH, PTP-PTP, PTP-1PPS, SyncE-BOTH, SyncE-PTP, SyncE-1PPS (see note 4)
PtpPoints	Specifies which frequency points are to be tested with PTP input	ALL	ALL or list of points (see note 5)
SyncEPoints	Specifies which frequency points are to be tested with SyncE input	ALL	ALL or list of points (see note 5)
ConfigFile	Specifies a file containing configuration parameters (see the "Executing the Enhanced Noise Transfer" section) in the Calnex Noise Transfer Script - Getting Started Guide [CX5036]	<i>u</i> "	Valid configuration file
SettlingTime	Time for the device to lock to PTP supplied from the P-X Master (see note 6).	120	Type: Integer Range: Positive Unit: Seconds
RecoveryTime	Time for the device to recover after a change to the applied input noise (see note 7).	50	Type: Integer Range: Positive Unit: Seconds

Table 3. Script Control Settings

Notes

For execution of the script in customer environments the following is a list of parameters which might require user selection when running the script:

- Guilp: If the IP address of the GUI (Paragon-X application) is not "localhost", then it is assumed that the Paragon-X application is running on a remote host. This will change the behaviour of the script and may also change the locations of saved files (see the Calnex Noise Transfer Script Getting Started Guide [CX5036]).
- 2. **GuiPort:** The GUI (Paragon-X application) listens on this port for commands from active scripts. By default port 9000 is used by all instances of the GUI. You can override this for individual GUI instances using a command line option when launching the GUI. See the **Paragon-X Remote Control Reference Manual** for details.
- 3. **CableDelay:** This is not required since noise transfer measures peak-to-peak output and this is not affected by cable delay. However, if used, for electrical interfaces, the delay due to the cable will be approximately 5.1 ns per metre; for optical fibre, the delay will be approximately 4.9 ns per metre. Only full nanosecond values are counted, so calculated values need to be rounded up or down to the nearest full nanosecond value.
- 4. **Type:** Specifies the stimulus (PTP or SyncE) to be applied to the DUT input and the measurements to be performed on the DUT output. The measurements can be PTP, 1pps or BOTH. **This should be set to PTP-1PPS.**
- 5. **PtpPoints / SyncEPoints:** A subset of frequencies can be selected using a space delimited string of numbers indexed from 0. For example, to test only 0.0071825Hz and 0.4925Hz, set PtpPoints to "17". To test all frequencies (as defined in the tables above), then set PtpPoints and SyncEPoints to ALL.
- 6. **SettlingTime:** This should be long enough for the time error measurement to become stable, otherwise the results will be incorrect. This time will vary between DUTs.
- 7. **RecoveryTime:** A fixed period of time to allow the DUT to recover from each change of noise on the DUT input (i.e. for each frequency point). This time will very between DUTs. This recovery time will not be included in the measurement.
- 8. LineRate: The interface Line Rate to be used (e.g. 1GBE, 10GBE etc.). Default is 1GBE.
- 9. Interface: The selected interface. Please select LineRate if changing Interface.

Execution

Launch the Paragon-X application and run *cmd.exe* to launch a shell. Change the working directory (*cd*) to the script location. For example:

cd "C:\scripts\Script G.8273.2"

The script should now be run by launching a Tcl or Python shell passing the script name with the required arguments as command line parameters.

The arguments are passed to the script as a simple list of <argument value> pairs (separated by spaces). Some examples are shown below:

"C:\Tcl\bin\tclsh86.exe" G.8273.2.tc/ Instrlp 192.168.4.100 Type PTP-1PPS LineRate 1GBE Interface OPTICAL

"C:\Python38\python3.8.exe" G.8273.2.py Instrlp 192.168.4.100 Type PTP-1PPS Reference EXT_10M



The settings being used by the script (the defaults plus those set on the command line) will be printed to the console before the test begins.

Enhanced Noise Transfer 4.00.00

Parameters:
InstrIp - 192.168.3.100
GuiIp - localhost
GuiPort - 9000
Type - PTP-1PPS
CableDelay - 5
LineRate - 1GBE
Interface - ELECTRICAL
Reference - INT
SettlingTime - 200
RecoveryTime - 50
1ppsThreshold - 1.0
AutoNegotiate - FALSE
SyncE - TRUE
RemoteCaptureFolder - C:/Desktop
RemoteProfileFolder - C:/Desktop
Debug - FALSE
ReProcess - FALSE
Filter - LSQ
SimulatedData - FALSE
Graphing - FALSE
Start: 2017-12-21 10-39-35

Results

All files are stored relative to the folder in which the script is being run. The root folder contains the script files, the PTP patterns, the Results Chart Template and the ENT user guide:

퉲 Demo	🗾 Calnex Noise Transfer Script - User Guide
Results	🔊 NoiseTransfer_0_985Hz
🐼 Common functions	🔊 NoiseTransfer_0_03125Hz
ilterFunction	🔊 NoiseTransfer_0_4925Hz
filterLeastSquares	🔊 NoiseTransfer_0_015625Hz
G.8273.2	NoiseTransfer_0_24625Hz
Nitialization	NoiseTransfer_0_0078125Hz
measurements	NoiseTransfer_0_123125Hz
🗑 paragonwl	NoiseTransfer_0_00390625Hz
R results	NoiseTransfer_0_0615625Hz
🗑 Time Noise Transfer	NoiseTransfer_1_985Hz
•	Results Chart Template

All results files and capture files will be stored in the **Results** folder in the same directory as the script files. Each execution of the script will create a sub-folder using the following naming convention:

Results <Type> <YYYY-MM-DD-T-HH-MM-SS>

Where **<Type**> is the test type e.g. PTP-PTP. For example:

Results PTP-1PPS 2017-11-27-T-16-47-48 30/11/2017 13:13 File folder

Each sub-folder will contain the capture files, the generated (interim) results files and a final results file **Results.csv**, which contains the overall results for all of the test points.

For each pattern used in the script, the following information will be recorded in the *Results.csv* file:

- Pattern filename (for **PTP-1PPS**)
- Frequency (Hz)
- Input Amplitude (pk-pk ns)
- Measured Amplitude (pk-pk ns): The noise transferred to the output of the DUT
- Gain (dB): The ratio of measured amplitude (output from the DUT) to input amplitude (generated by Paragon-X)
- Lower Limit (pk-pk ns): The lower limit from G.8273.2 Amendment 1
- Upper Limit (pk-pk ns): The upper limit from G.8273.2 Amendment 1
- Pass / Fail: Will be one of Pass, Fail (lower), Fail (upper)

For example, a **PTP-1PPS** results file contains the following information:

Noise Transfer (PTP-1PPS)	******							
Profile	Freq (Hz)	Amplitud	Measured	Gain (dB)	Lower Lim	Upper Lim	Pass/Fail	
NoiseTransfer_0_00390625Hz	0.00390625	200	224	0.98	130	215	FAIL(upp	er)
NoiseTransfer_0_0078125Hz	0.0078125	200	237	1.47	130	215	FAIL(upp	er)
NoiseTransfer_0_015625Hz	0.015625	200	231	1.25	130	215	FAIL(upp	er)
NoiseTransfer_0_03125Hz	0.03125	200	211	0.47	130	215	PASS	
NoiseTransfer_0_0615625Hz	0.0615625	200	166	-1.62	NA	215	PASS	
NoiseTransfer_0_123125Hz	0.123125	200	109	-5.27	NA	140	PASS	
NoiseTransfer_0_24625Hz	0.24625	200	70	-9.12	NA	90	PASS	
NoiseTransfer_0_4925Hz	0.4925	200	102	-5.85	NA	50	FAIL(upp	er)
NoiseTransfer_0_985Hz	0.985	200	173	-1.26	NA	35	FAIL(upp	er)
NoiseTransfer_1_985Hz	1.985	200	64	-9.9	NA	25	FAIL(upp	er)

To analyse the data, copy the entries from the **Results.csv** file into the **Template file Results Chart Template.xlsx**. This has macros which will draw a chart of the measured results versus the expected filter mask.



6.2. SyncE to 1PPS Transfer

Table 4 below shows the stimulus frequencies and amplitudes of the noise applied to the SyncE input of the DUT. Note that 200ns of sinusoidal time error is achieved by applying a sinusoidally varying delay in the forward direction with an amplitude of 400ns (the overall time error is an average of the error in both directions).

The table lists the permitted limits for each frequency. These limits include an allowance for device noise generation and tetst equipment uncertainty. An allowance of 10ns (n=10) has been added based on the use of the least squares method being applied to the results.

Point	Test Freq (Hz)	Pk-Pk I/P Ampl	Pk-Pk O/P Ampl ±25 ns added noise allowance (ns)		Duration (s)	
		(115)	Max	Min		
0	0.00391		225		800	
1	0.00781	2000	340		800	
2	0.01563		630	n/a	400	
3	0.03125	1000	565			
4	0.06156	500	545			
5	0.12313					
6	0.24625			15.0		
7	0.4925			150	250	
8	0.985	250	285			
9	1.985					
10	3.985			n/a		
11	7.985					

Table 4. Maximum and Minimum Expected Output Amplitudes at Test

 Frequencies for SyncE-to-PTP and SyncE-to-1pps Noise Transfer Measurement

Procedure

The same procedure is carried out for SyncE-1PPS Noise Transfer as for PTP-1PPS Noise Transfer.

Execution

Launch the Paragon-X application and run *cmd.exe* to launch a shell. Change the working directory (*cd*) to the script location. For example:

cd "C:\scripts\Script G.8273.2"

The script should now be run by launching a Tcl or Python shell passing the script name with the required arguments as command line parameters. The arguments are passed to the script as a simple list of <argument value> pairs (separated by spaces). Some examples are shown below:

"C:\Tcl\bin\tclsh86.exe" *G.8273.2.tcl* **Instrip** 192.168.4.100 **Type** SyncE-1PPS **LineRate** 1GBE **Interface** OPTICAL "C:\Python38\python3.8.exe" *G.8273.2.py* **Instrip** 192.168.4.100 **Type** PTP-1PPS **Reference** EXT_10M

Results

As for the PTP-1PPS Noise Transfer all files are stored relative to the folder in which the script is being run.

The root folder contains the script files, the PTP patterns, the Results Chart Template and the ENT user guide:

퉬 Demo
퉬 Results
🔞 Common functions
🗑 filterFunction
🐼 filterLeastSquares
🔞 G.8273.2
🐼 Initialization
🔞 measurements
🐼 paragonwl
🔞 results
🐼 Time Noise Transfer

Execution of the script will create a sub-folder using the following naming convention:

Results <Type> <YYYY-MM-DD-T-HH-MM-SS>

Where **<Type**> is the test type e.g. SyncE-1PPS. For example:

Results SyncE-1PPS 2017-11-21-T-10-04-31 21/12/2017 11:15 File folder

Each sub-folder will contain the capture files, the generated (interim) results files and a final results file **Results.csv**, which contains the overall results for all of the test points.

For each pattern used in the script, the following information will be recorded in the **Results.csv** file:

- Pattern filename for frequency (SyncE-1PPS)
- Frequency (Hz)
- Input Amplitude (pk-pk ns)
- Measured Amplitude (pk-pk ns): The noise transferred to the output of the DUT
- Gain (dB): The ratio of measured amplitude (output from the DUT) to input amplitude (generated by Paragon-X)
- Lower Limit (pk-pk ns): The lower limit from G.8273.2 Amendment 1
- Upper Limit (pk-pk ns): The upper limit from G.8273.2 Amendment 1
- Pass / Fail: Will be one of Pass, Fail (lower), Fail (upper)

The *Results.csv* produced will look like:

Noise Transfer (SyncE-1PPS)	21/11/2017 10:04							
Profile	Freq (Hz)	Amplitud	Measured	d Gain (dB)	Lower Lim	Upper Lim	Pass/Fail	
NoiseTransfer_0_00391	0.00391	250	26	-19.66	NA	30	PASS	
NoiseTransfer_0_00781	0.00781	250	38	-16.36	NA	50	PASS	
NoiseTransfer_0_01563	0.01563	250	80	-9.9	NA	85	PASS	
NoiseTransfer_0_03125	0.03125	250	146	-4.67	NA	145	FAIL(upper)	
NoiseTransfer_0_06156	0.06156	250	237	-0.46	NA	270	PASS	
NoiseTransfer_0_12313	0.12313	250	303	1.67	165	270	FAIL(upper)	
NoiseTransfer_0_24625	0.24625	250	319	2.12	165	270	FAIL(upper)	
NoiseTransfer_0_4925	0.4925	250	328	2.36	165	270	FAIL(upper)	
NoiseTransfer_0_985	0.985	250	326	2.31	165	270	FAIL(upper)	
NoiseTransfer_1_985	1.985	250	236	-0.5	NA	270	PASS	
NoiseTransfer_3_985	3.985	250	186	-2.57	NA	270	PASS	
NoiseTransfer_7_985	7.985	250	138	-5.16	NA	270	PASS	

To analyse the data, copy the entries from the **Results.csv** file into the **Template file Results Chart Template.xlsx**. This has macros which will draw a chart of the measured results versus the expected filter mask.



7. Packet Layer Transient Response and Holdover Performance – G.8273.2 Section 7.4

Test Description

Short-term transient response refers to the time error generated when a clock switches from one input reference to another e.g. in the event of a reference failure.

A reference switch in the physical layer frequency reference at the node prior to the T-TSC can generate a large transient in the T-TSC input, therefore a T-TSC must reject this transient. It can achieve this by monitoring the ESMC messages on the SyncE interface. On receipt of a degraded QL, the T-TSC must either stop using the SyncE signal, or turn off the low-pass filter, allowing the PTP to correct the time error more quickly. When traceability of the SyncE signal is restored, the T-TSC can go back to using the SyncE signal.

Annex B of G.8273.2 Amd. 2 defines the following mask for the clock output in the event of a transient on the SyncE input:



T-BC output phase mask for SyncE transient input

Figure B.1 from G.8273.2 Annex B – Phase error mask during a SyncE transient

The method to verify compliance with the mask shown above is described in **G.8273 Appendix III**. The phase transient to be applied to the input SyncE signal is shown below. During the transient, the input QL-value in the ESMC messages is changed from QL-PRC to QL-EEC in the first shaded area (from 1.8s to 2.0s), and back to QL-PRC in the second shaded area (from 15.18s to 15.5s).



Fig. III.2 from G.8273 Appendix III – SyncE Transient Input Pattern

Measurement Process

The standard requires testing in combined hybrid mode involving both PTP and SyncE input. This is reflected in the test procedure 7.1.1 detailed below.

The methodology required to align all stimuli and measurements requires controlled timing of physical events, transmitted values, and captured data – this is facilitated with step-by-step control in Paragon-X.

Note: The Master/Slave Emulation Configuration steps described in Section 3 must be performed prior to this test.

7.1 Packet Layer Transient Response

1. Start Master/Slave Emulation.



Wait for the T-TSC to lock to the Paragon-X emulated Master and stabilize before making any measurements. **Clock settling time is important**. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several hours dependent on the T-TSC under test.

If it is not possible to monitor the lock state directly on the T-TSC under test, then an indication of the settling state could be determined by monitoring the 1pps output from the T-TSC under test, if this is available.

2. After device has settled select the *Add Wander* button.



3. In the Add Wander window, select the *SyncE Transient* tab.

equency Offset	Wander Tolerance	Wander Transfer	SyncE Transient	
Single 🔨	Table 🔨	MTIE/TDEV Mask		
Mask Selection				
G.8273 SyncE Tran	sient 🔻			
Phase Error				
[ns] 881.56				
777.56				
		45 ns/s slope (50x0.9)		
104 (120x0.9-4) Pr	e-Test	Mitigation		Normal
0 (nor	mal QL)	(degraded QL)		(normal QL)
	0 0.016	1.8 2.0 Time S [s]	14.984 15 15.18 15.5	100
			Max Running Tir	ne: 100 s
Generate Wander	Stop Wande	r.	Elapsed Tin	me: 99 s

4. Selecting this will display the SyncE Transient test page. To start the test, **ESMC generation** from the Master must be enabled.

Frequency Offset	Wander Tolerance	Wander Transfer	SyncE Transie	nt	
To enable this fe	ature, the instrument m ts must be started on Po	ust be re-configured: rt 1. Click here to auto	-configure Start	ESMC	
est Method					
G8273 Method 1	•				
120-11-11-11-11-11-11-11-11-11-11-11-11-11					
Phase Error					
881.56					_
				XX	
				88	
777.56				×	
		45 ns/s slope		₩	
		(50x0.9)		\approx	
				\otimes	
				\otimes	
104	1			XXX	
(120x0.9-4)	Pre-Test	Mitigation	on	Nor Part	mal
(normal QL)	(degraded	QL)	(norm	al QL)
0	0 0.016	18 20	14.984 15	15.18 15.5	100
		Time 5 [s	1 1.000 10		
				Max Running Time	. 200 -
				Hax Running Time	. 200 3
Capture is starte	d 100 s before the 1st t	ansient ramp at t=0.			
FOLG OF L		6	45.0		
ESMC QL transit	ons to QL-EEC1 at t=1.	9 s and is restored at	t=15.3 S.		
Capture is stopp	ed at the end of the tes	t.			
					323
Start Test	Stop Test			Elapsed Time:	0 s

5. After starting the ESMC generation the test can be started using the *Start Test* button. During the test the elapsed time is displayed, as is the current ESMC status.



Test execution takes 200s. The first 100s are used to analyse the underlying Constant Time Error (cTE) without the application of the transient. As per the standard, the mask for Phase Noise response to the generated transient requires the results to be adjusted for cTE – this step therefore allows the Calnex Analysis Tool to calculate and make that adjustment.

6. On completion of the test, the test results can be analysed using the *Calnex Analysis Tool*.



7. In the Calnex Analysis Tool, *Select Metrics* and enable the **G.8273.2 Transient Response** metric followed by the *Calculate* button.

TL>> &		
Select File	Clock Measurements	?
Select Metrics	Time of Day	100% 🗸 ?
View Results		× ?
Generate Report		× ?
Export	ClkFFO	~ ?
		2
	Time Error Measurements	?
	Time Error	100% 🗸 ?
	Avg Time Error (cTE)	100% 🗸 ?
	Dynamic Time Error	~ ?
	G.8273.2 Transient Response	~ ?
Calculate		
100%		

8. Once the calculation has reached 100% the results and associated Pass/Fail information can be viewed using the *View Results* button.



7.2 Holdover Performance

Holdover performance is checked by measuring the phase/time output in the event of the loss of the PTP input to the T-TSC.

It is assumed that a G.8275.1 profile will be used in testing to the G.8273.2 standard and, consequently, testing will be carried out using L2 encapsulation in Multicast mode.

The Master/Slave Emulation can be configured to use other profiles e.g. Unicast UDP/IPV4 etc., however, it should be noted that these profiles will not conform to the G.8273.2 standard.

Measurement process – Master/Slave Configuration

1. Select Master/Slave Emulation. Choose Slave Test in Test Configuration drop down menu.



2. Select G.8275.1 Phase Profile from the Custom Profile drop down menu.



3. Enter DUT to Paragon-X 1pps cable delay.

In order to correctly perform calculations, the delay caused by the cable that is used to connect the T-TSC Slave and Port 1 must be factored out. Values of 5.1 ns per 1 metre of can be expected. Only full nanosecond values are counted, so calculated values need to be rounded up or down to the nearest full nanosecond value.

Start Un	<< Results	Test Setup	G.8275.1 Phase Profile 🔹
	Device Configuration		
Operating Mode	Master + Slave		
operating mode	Two Masters ODC Fruidation		
0-1	GPS Emulation		
Setup Interrace	Configure	GPS Emulation	Ref In
Master/Slave/GPS	Test Configuration ———	Callex Paragon-X	
Emulation	Slave Test 🔹		
	DUT Ethernet	Master 1pps	Slave
Measurements	cable (ns);		
	1pps Ref.	Master Tx Accuracy Meas.	
Select Flow	Cable (risy)		
	cable (ns): 0	Tx Impairment Impairment Wander Meas	
Configure Capture	Capture		
	Master	Capture Master Rx	
Start Capture	🔘 Slave		
	© Rx on both	Port 1	Port 2
Add Impairments/	Flow Filter	L ↑	
Delay	Measurement	1 pps/ToD 2M/T1/E1	
Add Wander	Manual calibration		
	Calibration	Slave	

4. Start the Master/Slave emulation.

<u>F</u> ile Instrument(s) Setup	Capture Impair Graph Dat	a Tools <u>H</u> elp			
📽 🖬 🛲 🗰 💕	🚰 🎜 🎜 R 🚿 😋 🔍				
Start Up	<< Results	Test Setup	G.8275.1 Phase Profile 🔹	Calne	x Master
Operating Mode	Device Configuration			Mode: Multicast Connected Slave Address	1/1 < > x D-Req Sync Ann Rate Rate Rate
Setup Interface	Configure	GPS Emulation Calney Paragon-X	Ref In		
Master/Slave/GPS Emulation	Test Configuration	Master 1 pos	Slave		
Measurements	DUT Ethernet cable (ns): 1pps Ref.	Capture Accuracy			
Select Flow	cable (ns): 0 1pps Meas. cable (ns): 0	Tx Rx Impairment Impairment Wander		Calne Mode: Multicast	ex Slave
Configure Capture	Capture	Capture Master Rx		Connected Master Address	D-Req Sync Ann Rate Rate Rate
Start Capture	Slave Rx on both	Port 1	Port 2		
Add Impairments/ Delay	Flow Filter	1 pps/ToD 2M/T1/E1			
Add Wander	Calibration	Slave			
Add Jitter	Start			Link S	Status
Packet Generation	Set capture flow filter			1 0 2 0	GOOD PACKETS GOOD PACKETS
Statistics/ Results	Apply changes	Master		⊖ _{RefLock} ⊖ _{1PF}	PS Ref \varTheta 1PPS Meas

Confirm PTP traffic on interfaces

- With Master/Slave emulation running, start a capture using the Start Capture button to capture traffic
- Check the link to make sure that the PTP packets are running without error. If working successfully both Link and Packet status should show green status.
- Wait for the T-TSC to lock to the Paragon-X emulated Master and stabilize before making any measurements.

Clock settling time is important. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several hours dependent on the T-TSC under test. It may even be recommended to wait longer e.g. overnight.

Measurement Steps

With the T-TSC in a stable state:

- 1. Press the Stop Capture button to ready the test.
- 2. When ready to proceed press the Start Capture button.



- 3. With the capture active, select the *Add Impairments/Delay* button.
 - When displayed select Master TX Packet Corruption
 - Select Lost Packet Periodicity: Continuous and Distribution: Constant

<< Results	In	ipairments and Delay	
Selected Message Types		Intrinsic Delay	
Master Tx: Sync, Del-Re	esp	Packet size: Small Packets (< 200 bytes) Change	
Master Rx:		Delay (µs): 6.7	
Configuration	Packet Corruption		_
Flow Filter	Type:		
	lost packet		
Master 1 Tx	Repeated packet		
Delay	Misorder events to a depth: 1		
Header Overwrite			
Physical Corruption			
Packet Corruption	Distribution	Desite dialation	_
Profile Corruption	Single	Periodicity:	
Master Impairments			
	Burst of packets:	On for (s): 0.1	
Master 1 Rx	Percentage rate: 0.00001	Repeat for (s): 1.0	
Delay	Ratio: 1 E- 7		
Header Overwrite			
Physical Corruption	Constant		
Packet Corruption	Symbol rate: 1		
Profile Corruption			

4. Select *Flow Filter* to choose the messages to apply delays against – *Sync, Follow-Up, Delay-Request* and *Delay Response* messages.

<< Results	Impa	irments and Delay	
Selected Message Types Master Tx: Sync, Follow-U Master Rx: Del-Req	p, Del-Resp	Intrinsic Delay Packet size: Small Packet Delay (μs): 6.7	s (< 200 bytes) Change
Configuration	Flow Filter Editor		
Flow Filter	Master:	Slave:	Messages:
Master 1 Tx Delay Header Overwrite Physical Corruption Profile Corruption Master Janziment	a0 00 00 00 00 01	Any multicast slave	Sync Follow-Up Delay Request Delay Response Announce Signaling (from Master) Signaling (from Slave)
Master Impairments	Flow Filter Status		
Delay 🗌	Flow Summary:	Flow Detail:	
Header Overwrite	DEL-REQ XXX	Eth Type PTP	
Physical Corruption	xxx DEL-RESP	PTP Message DEL-REQ	
Profile Corruption	XXX FOLLOW-UP XXX SYNC	PTP Version 2	
	8	Impairments	
		pairmants	

5. Now start the impairment by selecting

This will stop all Sync and Delay Response messages from reaching the T-TSC. The T-TSC clock will be forced to enter the holdover state at this point. DUT administrative reporting of status is out of scope for this test.

6. After **1000s** select the *Stop Capture* button.

Configure Capture	Capture
Stop Capture	 Master Slave Rx on both
Add Impairments/ Delay	Flow Filter Measurement

7. Select the Add Impairments/Delay and stop the impairment



8. Launch the Calnex Analysis Tool then select Time Error Measurement.



9. The key metrics to be examined are **the 1pps Dynamic TE LF metrics.** Enable these in the Metrics block and disable the **Average Time Error (cTE) metrics** and the remainder of the **Dynamic TE metrics.**

₩ 1 2		
Select File	Clock Measurements ?	
Select Metrics	✓ Time of Day 100% ∨ ?	
View Results	MTIE V?	
Generate Report	TDEV v ?	
Export	ClkFFO v ?	
	Packet Measurements ?	
	Time Error Measurements ?	
	Avg Time Error (cTE) V ?	
	✓ Time Error 100% ∨ ?	
	Dynamic Time Error A 2 Z 1pps TE Absolute LF 100% 1pps TE Absolute HF	
	 Ipps TE Absolute Dynamic MTIE LF 100% Ipps TE Absolute Dynamic TDEV LF 	
Calculate 100%		
Calnex		

10. Select the *Dynamic Time Error* tab.



- 11. Apply the appropriate mask to the 2Way Dynamic MTIE LF metric depending on the class of the device under test:
 - G.8273.2 T-BC Class A Time Holdover Const. Temp
 - G.8273.2 T-BC Class B Time Holdover Const. Temp



12. Show results and check the Pass/Fail status.



Appendix 1 – G.8271.1 Time Error Budget Example



G.8271.1 Network Reference Points

Table V1.1/G.8271.1 – Example of Time Error Allocation

Budget Component	Failure scenario a)	Failure scenario b)	Long Holdover periods (e.g. 1 day)
PRTC (ce _{ref})	100 ns	100 ns	100 ns
Holdover and Rearrangements in the network (TE $_{\mbox{\scriptsize Ho}}$)	NA	400 ns	2400 ns
Random and error due to SyncE rearrangements (dTE')	200 ns	200 ns	200 ns
Node Constant including intrasite (ce _{ptp_clock}) (Note1)	550 ns	550 ns	550 ns
Link Asymmetries (ce _{llink_asym}) (Note2)	250 ns	100 ns	100 ns
Rearrangements and short Holdover in the End Application (TE _{REA})	250 ns	NA	ΝΑ
End application (TE _{EA})	150 ns	150 ns	150 ns
Total (TE _D)	1500 ns	1500 ns	3500 ns (Note3)

Note 1: it is assumed in these examples that all T-BCs contribute constant TE of 50ns.

In Deployment Case 1 the HRM is composed of: 10 T-BCs, 1 T-GM and 11 links, and it can be assumed that the. T-GM and one of the links contribute 50ns in total.

In Deployment Case 2 the HRM is composed of: 1 T-GM, 1 T-TSC, 9 T-BCs, 1 intra-site link, and 10 links. The time error budget allocated to the time synchronization distribution in the intra-site connection between the Packet Clock and the End Application in the worst case is 50ns. In order to get the same constant Time Error limit as per Deployment case 1, it can be assumed that the T-GM, the T-TSC, and the intra-site connection contribute 100ns in total.

Note 2: in order to simplify the comparison between Deployment cases 1 and 2, 10 links can be assumed in both deployment cases 1 and 2, The additional link of the Deployment case 1 model, as indicated in Note 1, is associated with the T-GM 50ns budget.

Note 3: exceeding the TE_D limit of 1500ns is related to the operator requirements in terms of service degradation.

Appendix 2 – Tests for a G.8273.2 T-TSC

NOTE: The performance for a T-TSC is largely identical to that of the T-BC, with the exception is that it is measured at the 1pps output since the T-TSC doesn't have a PTP output. The performance requirements are defined in G.8273.2 Annex C.

Test	Objective	Test method	Output Limit (1pps signal)		
Time Error With stable input references, Noise measure the inherent time error	With stable input references, measure the inherent time error	es, Apply a stable time reference e error to the PTP input. oduced Apply a stable frequency reference to the SyncE input.		Class A	Class B
Generation (G.8273.2,	(maxITEI, cTE and dTE) produced by the internal clock.		Max TE : ³	≤ 100ns	≤ 70ns
Annex C.2.1)	Repeat without a SyncE reference ² .	cTE:	≤ 50ns	≤ 20ns	
			dTE _{LF} : ⁴	40ns MTIE, 4ns TDEV	
			dTE _{HF} :⁵	70n:	s p-p
Noise Tolerance (G.8273.2, Annex C.2.2)	Measures whether the clock can operate correctly with maximum noise input at the input. The test must be carried out with noise on both the PTP and SyncE inputs. Clock under test should not: • generate alarms	Combined PTP and SyncE tolerance: Apply Calnex noise tolerance Pattern to the PTP input ⁶ . Simultaneously apply sine wave phase wander to the SyncE input according to G.8262, Table 9.	No output performance limit. Clock under test should not: • generate alarms • switch reference • go into holdover		
	switch referencego into holdover				

² G.8273.2 doesn't currently specify the performance in the absence of SyncE, therefore repeating the test without the use of SyncE input reference is optional.

³ MaxITEI is calculated on the raw, unfiltered time error data.

⁴ MTIE and TDEV are calculated after low-pass filtering by 0.1Hz. Same values apply to both Class A and Class B devices.

⁵ TIE is measured after high-pass filtering by 0.1Hz. Same values apply to both Class A and Class B devices.

⁶ This pattern is derived from the dTE network limit MTIE mask, defined in G.8271.1 Figure 7-2.

Test	Objective	Test method	Output Limit (1pps signal)
Noise Transfer (G.8273.2, Annex C.2.3)	Measures how time error on the input is transferred to the output. PTP-to-1pps transfer function : • (undefined order or shape) • Bandwidth from 0.05 to 0.1Hz	PTP to 1pps: Apply a set of sine wave PDV modulations of 400ns p-p amplitude (i.e. 200ns time error when applied in one direction) at several different frequencies. Apply a stable frequency reference to the SyncE input. Repeat without a SyncE reference. ⁴	Tone frequencies and amplitudes defined in Appendix VI of G.8273.2 (Amendment 1, August 2017)
	 SyncE-to-1pps transfer function: High-pass filter (undefined order or shape)⁷ Bandwidth from 0.05 to 0.1Hz 	SyncE to 1PPS: Apply a stable time reference to the PTP input. Apply a set of sine wave phase modulations of 200ns p-p amplitude at several different frequencies.	Tone frequencies and amplitudes defined in Appendix VI of G.8273.2 (Amendment 1, August 2017)
Transients and Holdover (G.8273.2, Annex C.2.4)	Measure the transient caused by a switch between PTP masters	No test method defined	No performance limit defined
	Measure the T-TSC response to a SyncE rearrangement transient.	Apply a stable time reference to the PTP input. Apply a stable frequency reference to the SyncE input. After the T-TSC has locked onto the inputs and stabilised, apply the transient defined in G.8273 Figure III.2 to the SyncE input, coupled with changing the ESMC QL values at the times defined in G.8273 Appendix III.	Phase mask defined in G.8273.2 Annex B
	Measures the response to entry into holdover caused by loss of packets at PTP input.	Apply a stable time reference to the PTP input. Apply a stable frequency reference to the SyncE input. After the T-TSC has locked onto the inputs and stabilised, stop the flow of PTP timing packets, and monitor the output for up to 1000s.	MTIE mask defined in G.8273.2, Table 7-6

⁷ Theoretically, this should be a band-pass filter with the low-pass cut-off between 1 and 10Hz, but since a 1pps interface can only carry frequencies of < 0.5Hz, it is effectively a high-pass filter.



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