TEST GUIDE

CX3003

PTP Time Error for T-BC

Testing Boundary Clocks as per ITU-T G.8273.2 using Paragon-100G

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

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

This Test Guide shows how the Calnex Paragon-100G can be used to test T-BC compliance as per G.8273.2 and provides procedures to measure noise generation, time noise tolerance and transfer, packet layer transient response and holdover performance.

Contents

1. Hardware and Software Required

Paragon-100G

Option 001	100GbE interface support (if the Device-Under-Test (DUT) has 100G interfaces)
Option 002	40GbE interface support (if the Device-Under-Test (DUT) has 40G interfaces)
Option 003	25GbE interface support (if the Device-Under-Test (DUT) has 25G interfaces)
Option 004	1/10GbE interface support (if the Device-Under-Test (DUT) has 1 and/or 10G interfaces)

Option 201	Advanced IEEE1588v2 features
Option 250	IEEE 1588v2 One-box T-BC, T-TC and OC Test
Option 213	SyncE wander and ESMC

Software version: 60.05.03.xx and later.

Accessories

- Optical Transceivers as required
- Cables as required

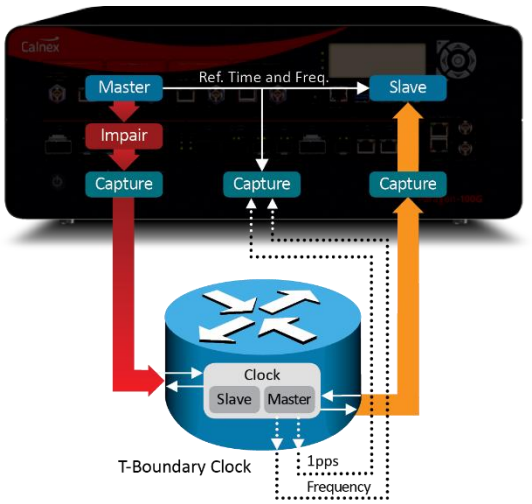
Frequency Reference Source

Option 132	GPS/Rubidium Clock (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)

2. Connecting Paragon-100G to the T-BC (Device-Under-Test)



Front Panel

Optical Interfaces:

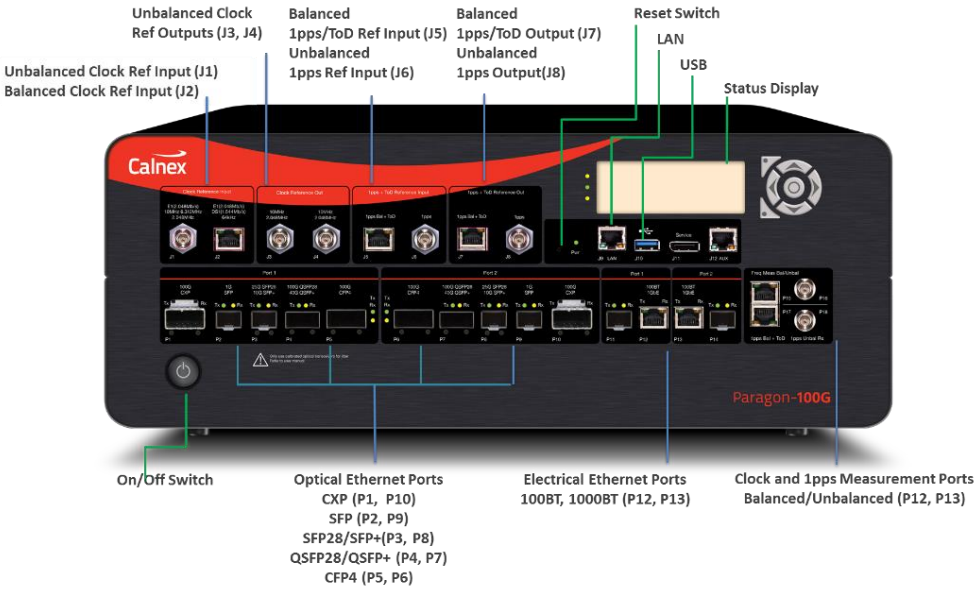
- 100GbE (QSFP28, CFP4, CXP)
- 40GbE (QSFP+)
- 25GbE (SFP28)
- 10GbE (SFP+)
- 1GbE (SFP)

Reference Clock inputs:

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

1pps measurement inputs:

- 1pps Balanced (RJ48)
- 1pps Unbalanced (BNC)



Connections

1. Connect Port 1 (Master side of Paragon-100G) to the T-BC Slave side.
2. Connect Port 2 (Slave side of Paragon-100G) to the T-BC Master side.
3. Connect the external reference, e.g. 10MHz, to the Paragon-100G Reference Input.
4. If provisioned on the DUT, connect the 1pps output from the T-BC to the Paragon-X 1pps measurement port.

3. Setting up the Paragon-100G for G.8273.2 Conformance Tests

The following steps are required to set up the Paragon-100G prior to performing G.8273.2 Conformance tests:

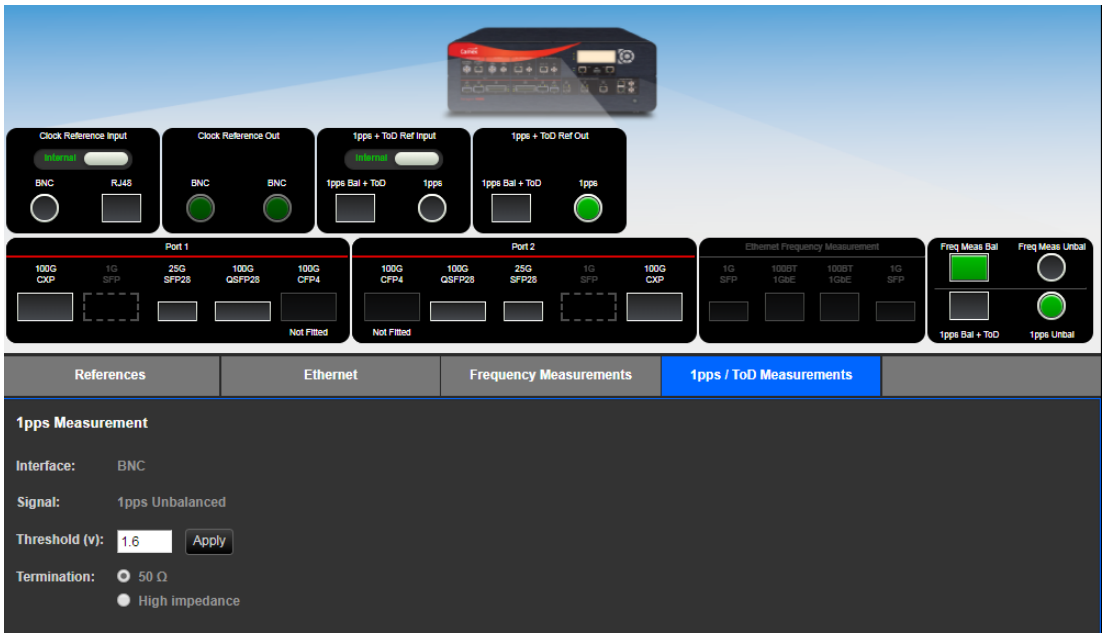
3.1. Connection to Paragon-100G
3.2. Configuration of physical connections
3.3. Test configuration
3.4. Device connection settings

3.1. Connection to Paragon-100G

1. Verify the physical connections have been completed as described in Section 2.
2. From a PC on the same network, open a browser and enter the IP address of the Paragon-100G unit.
3. From the Home Page, select ***PTP*** operating mode.
4. See the Paragon-100G Getting Started Guide for more details.

3.2 Configuration of Physical Connections

1. Select ***Setup Ports*** then from the onscreen display, select those reference and test ports to be used.
2. If required, enter ***Threshold*** and ***Termination*** information for 1pps signals.



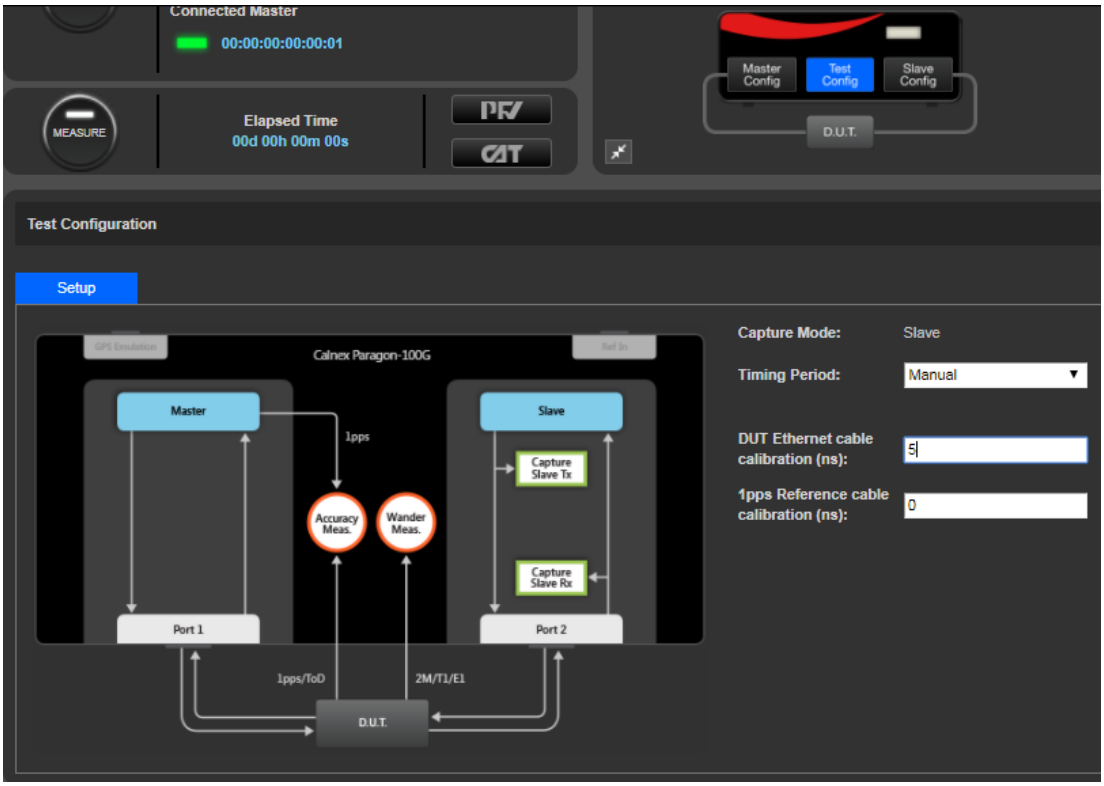
3.3. Test Configuration

1. Select ***Run Apps***, then from the ***Conformance Test*** app select ***G.8273.2***

3.4. Device Connection Settings

It is assumed that a G.8275.1 profile will be used in testing as per the G.8273.2 standard and as a result testing will be carried out using L2 encapsulation in Multicast mode. The Paragon-100G 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.

1. In the ***Master/Slave Emulation*** app, choose ***Test Config*** and make any necessary cable delay compensation settings the ***Test Configuration*** drop down menu.



2. In the ***1pps Absolute Time Error Measurement*** app, make any necessary cable delay compensation settings.

   Further information to assist with entering cable delay values is provided in the ***Quick Help*** in the left-hand pane within the P-100G User Interface.

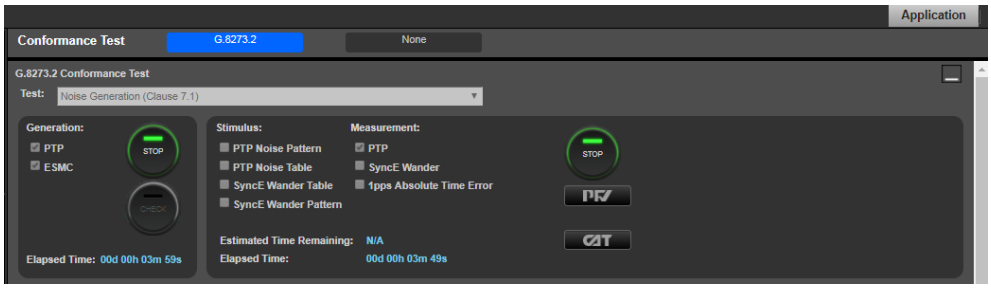
4. Noise Generation – G.8273.2 Clause 7.1

Test Description

The noise generation of a T-BC represents the amount of noise produced at the output of the T-BC 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 (Max|TE|, dTE).

Measurement Process

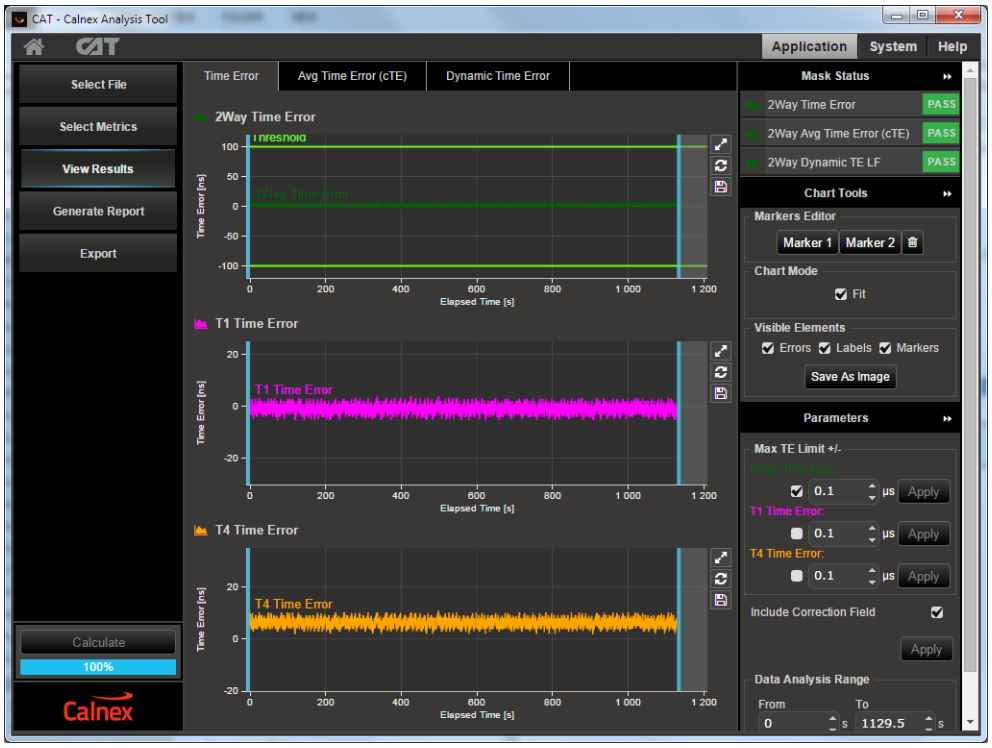
1. Confirm that preconfigured settings within Master/Slave emulation are appropriate for the current test scenario, as described in Section 3.4.
2. From the **Test:** drop-down menu, select ***Noise Generation (Clause 7.1).***
3. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the DUT to stabilize. Pressing ***Check*** will run a simultaneous data capture, after which you can open the **CAT** in a new tab to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.
4. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the Noise measurement. The measurement should be run for at least 2000s.



Measurements: Time Error results can either be viewed during capture or after capture has been stopped.

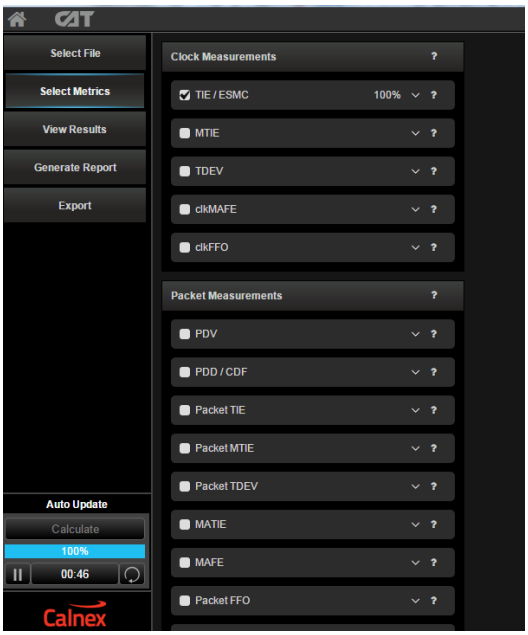
Time Error Results (Constant Time Error)

5. Select ***CAT.*** The Calnex Analysis Tool will open in a new browser tab displaying **Time Error** metrics.



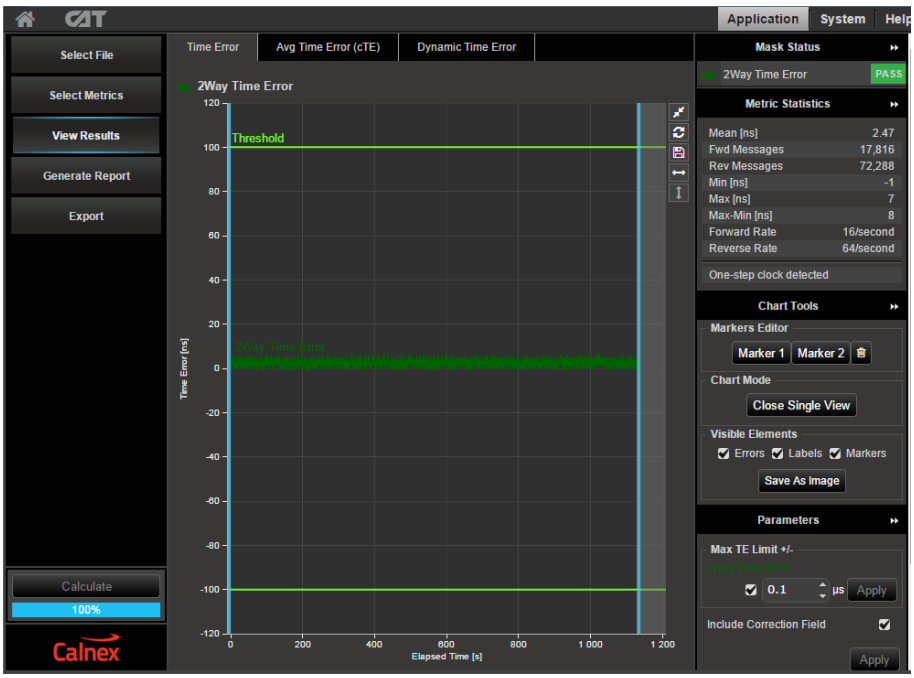
For PTP based data this will include the metrics **Time Error, Avg Time Error (cTE)** and **Dynamic Time Error**.

Note: The complete set of metrics can be viewed by expanding the appropriate list in the Measurement Analysis block by clicking on the + symbol against each metric.



Individual graphs can be displayed by clicking on the highlighted area in the display below.

This will display:



To return to the multi graph display click on the same icon in the single graph display.

6. Select the ***Avg Time Error (cTE)*** metric tab to show the ***2Way Avg Time Error (cTE)*** graph.

   This is a measure of the timing being delivered by the egress 1588 PTP flow and is the best view of the core data. The **Constant Time Error** value will be displayed. This result can expose the underlying phase movement, significant to the slave.

   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 within the T-BC.

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

   There are two classes of device:

   - Class A for devices which conform to ±50ns cTE
   - Class B for devices which conform to ±20ns cTE

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

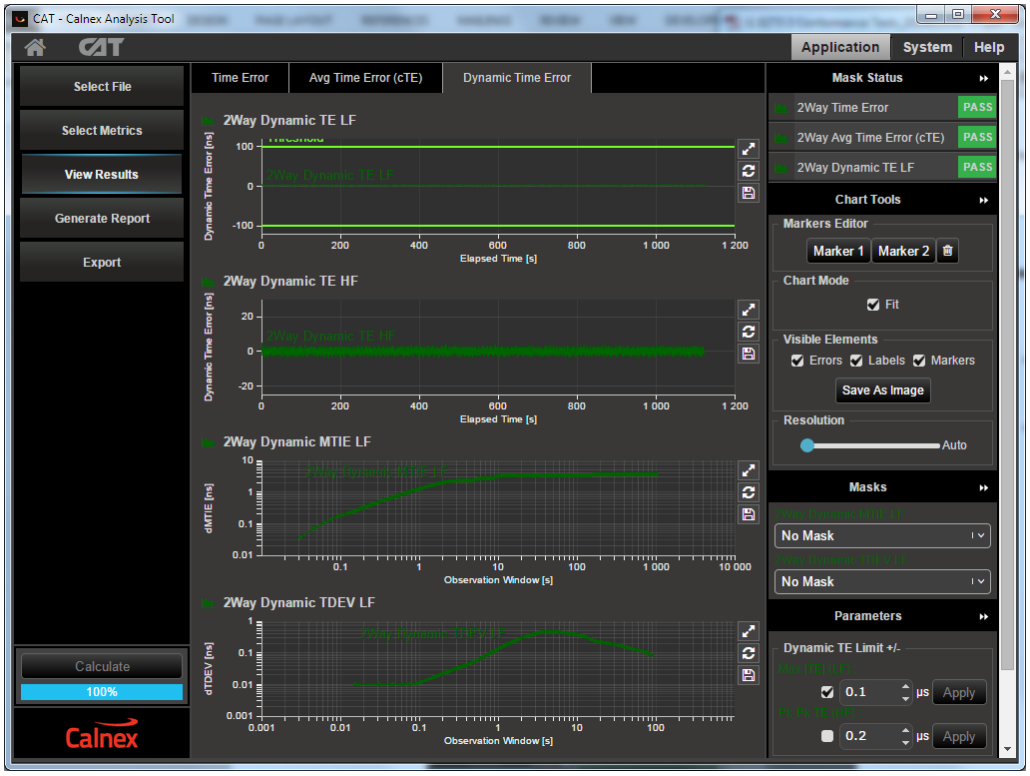
Further Analysis (Optional)

- Although not part of the standard test, further analysis can be provided by repeating the test for T1 and T4 constant Time Error to inspect for patterns and/or offsets.
- For further analysis, select the ***Time Error*** tab for unfiltered Time Error results i.e. ***2-way time error***, ***T1 Time Error (forward)*** and ***T4 Time Error (reverse)*** to further characterise the T-BC. These raw Time Error results containing both Constant and Dynamic Time Error may be useful as a troubleshooting aid.
- Launching ***PFV*** will allow you to decode and display PTP field information in a new browser tab. If the PFV option is installed on the Paragon-100G unit, conformance checking to defined PTP profiles with pass/fail analysis is also possible. For further information please refer to the ***PFV Getting Started Guide***.

Time Error Results (Dynamic Time Error)

8. Select the ***Dynamic Time Error*** tab to display the **filtered** Time Error results. This will display the Dynamic Time Error results as Low Frequency measurements and High Frequency measurements.

   Note that these results are filtered at 0.1Hz.

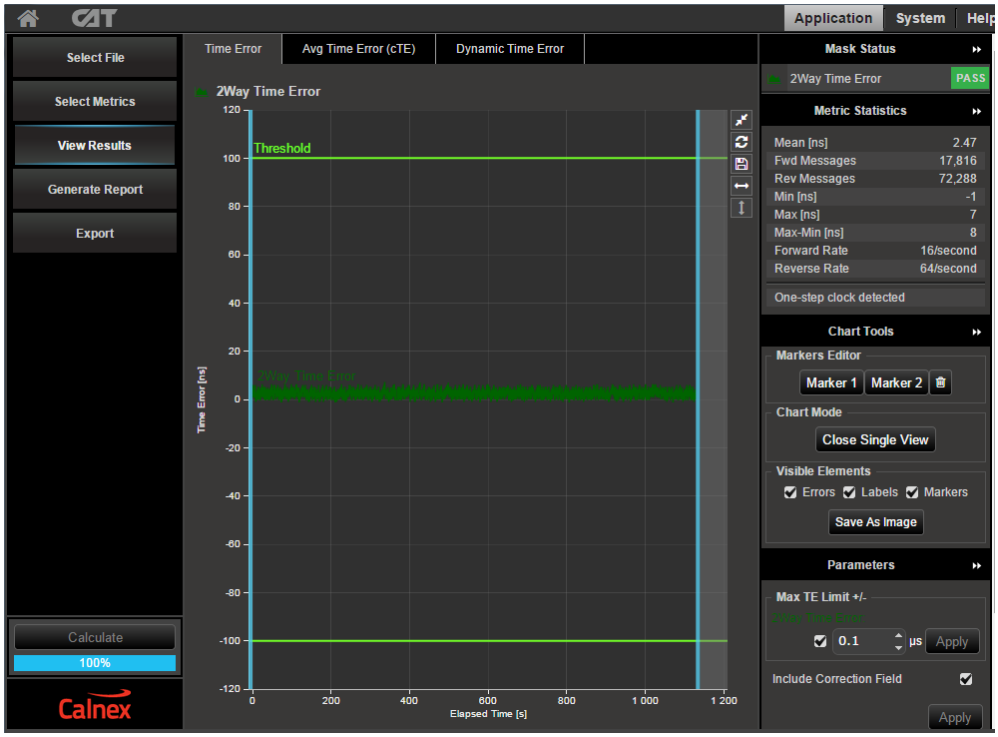


9. Compare the results against the ITU-T limits by loading the ***G.8237.2 dTE Gen Const Temp*** masks.

10. 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 (Max|TE|)

11. Select the ***Time Error*** tab to display the **raw unfiltered** Time Error results.
12. Select the ***2-way Time Error*** metric only. This will display the following graph:



13. Set the Max|TE| limit to either ***100ns*** for **Class A** devices or ***70ns*** for **Class B** devices. This will change the **Thresholds** on the graph.

14. Compare the results against the thresholds.

Compare PTP with 1pps (if available)

If the T-BC has a 1pps output, check that it is within specification and similar shape to the egress PTP packet flow result i.e. the peak-to-peak Time Error on the 1pps should be similar to that of the PTP Time Error. Once in service, the performance could be monitored by the 1pps port so it is important to prove it is an accurate reflection of performance on the line.

Note: Verification by the 1pps only is NOT recommended since it is the 1588v2 flow that the downstream device will use.

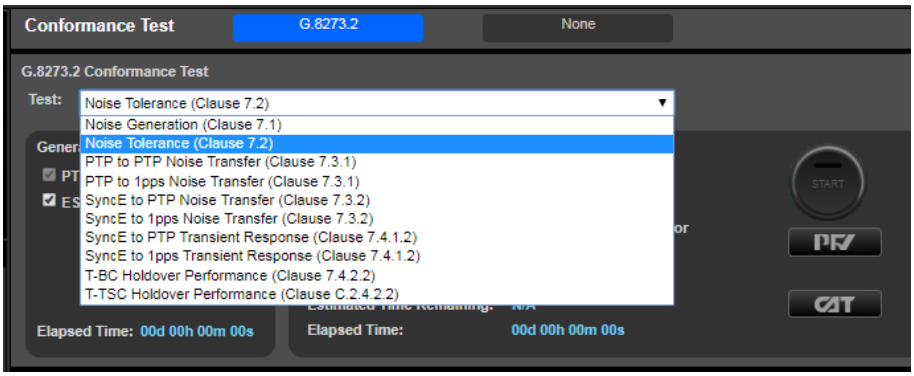
5. Time Noise Tolerance – G.8273.2 Clause 7.2

Test Description

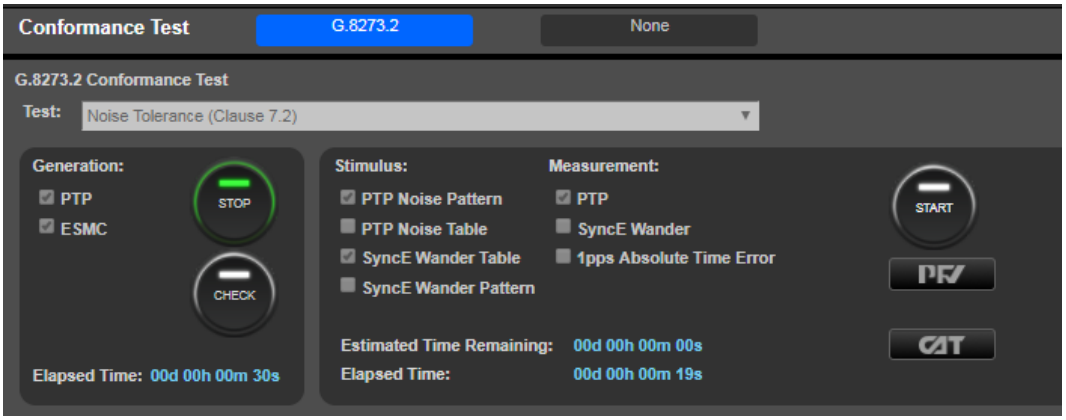
This test checks whether the clock can maintain network limits at the output with maximum noise at the input.

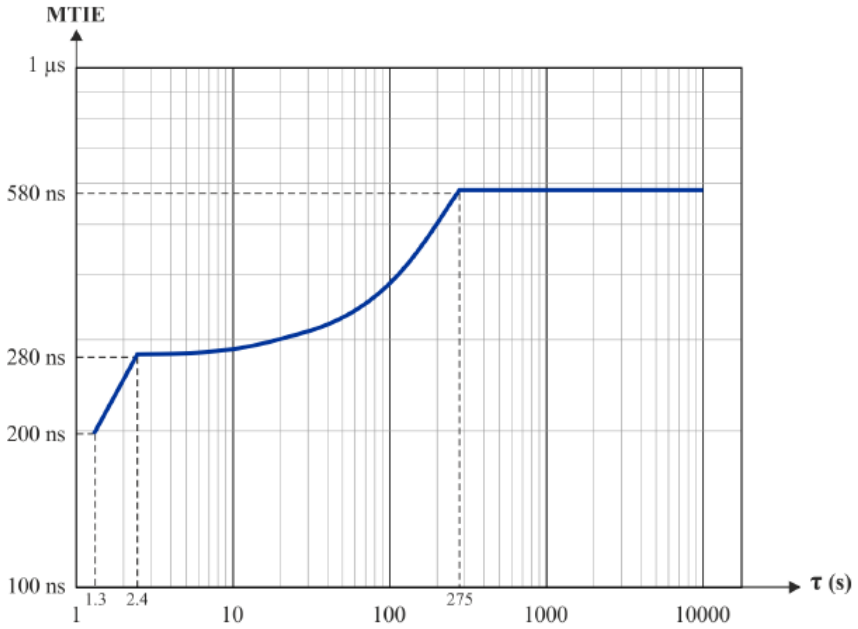
Measurement Process

1. Confirm that preconfigured settings within Master/Slave emulation are appropriate for the current test scenario, as described in Section 3.4.
2. From the **Test:** drop-down menu, select ***Noise Tolerance (Clause 7.2)***.



3. From the ***Generation*** section of the conformance test app, press ***Generate***. This starts PTP and ESMC message generation, allowing the DUT to stabilize. Pressing ***Check*** will open the CAT in a new tab to allow you to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.
4. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the Noise Tolerance test. PTP and SyncE Stimulus as per the relevant clause of G.8273.2 will be applied, and capture will be started.





5. Once the test stimuli have finished and at least 1000s has 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).

Further Analysis (Optional)

As a simultaneous PTP measurement is run by Paragon-100G during this test, indication of DUT lock can be determined by viewing Time Error performance in CAT – in addition, the timing behaviour of the DUT under the tolerance conditions can be further analysed.

Furthermore, launching ***PFV*** will allow you to decode and display PTP field information in a new browser tab. If the PFV option is installed on the Paragon-100G unit, conformance checking to defined PTP profiles with pass/fail analysis is also possible. For further information please see ***PFV Getting Started Guide***.

6. Time Noise Transfer – G.8273.2 Clause 7.3

Test Description

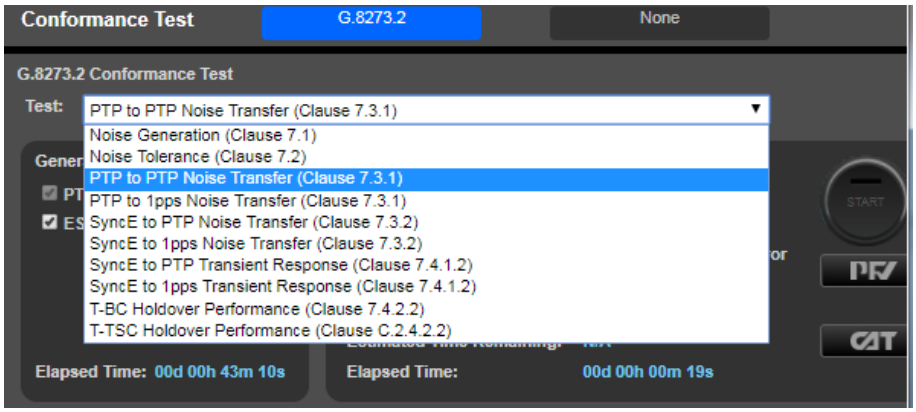
This test measures how Time Error on the input is transferred to the output.

Measurement Process

Confirm that preconfigured settings within Master/Slave emulation are appropriate for the current test scenario, as described in Section 3.4.

6.1 PTP to PTP Transfer

1. From the **Test:** drop-down menu, select ***PTP to PTP Noise Transfer (Clause 7.3.1).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.



3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the prescribed PTP Noise Stimulus and simultaneous measurement.

   PTP Noise (Time Error) is applied as per G.8273.2 Amendment 1 (Appendix VI).

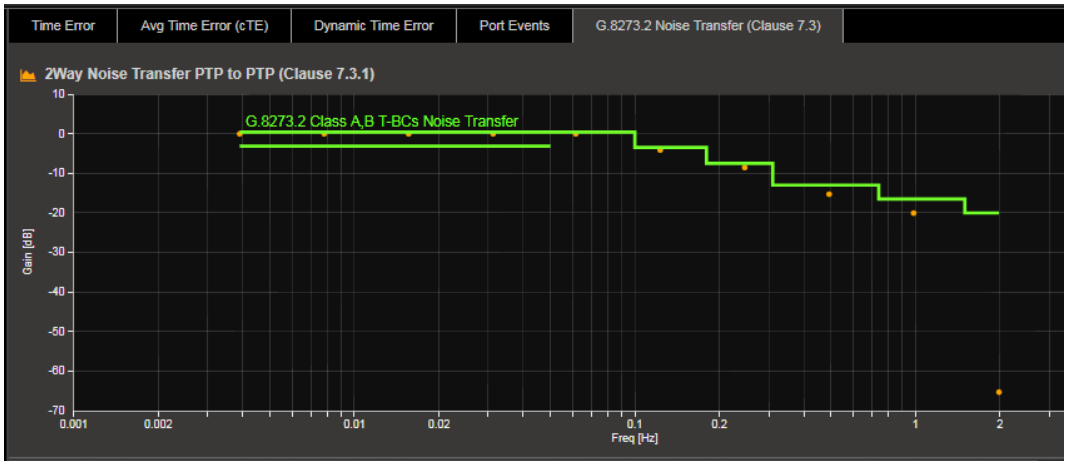
   A least-squares filter technique as suggested in Amendment 1 is applied to the PTP signal to be measured (to address potential measurement uncertainty due to noise on the packet interface and the intrinsic noise generation of the T-BC).

   For more information on the test considerations and the approach to test in the ITU-T recommendation, please see the Calnex application note *Time Error Transfer for BCs.*

4. During or after the test, CAT can be launched to view the results – complete PTP-PTP transfer results are available in the ***G.8273.2 Noise Transfer (Clause 7.3)*** tab. A baud plot is displayed, along with a table of applied stimulus vs. gain. If a test step is still underway, this will be highlighted in orange on the table.

Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)
4	0.03125	200	224.30	200.01	0.00
5	0.0615625	200	243.95	200.19	0.01
6	0.123125	200	203.35	124.77	-4.10
7	0.24625	200	203.35	75.05	-8.51
8	0.4925	200	203.35	34.49	-15.27
9	0.985	200	203.35	19.91	-20.04
10	1.985	200	201.81	0.11	-65.31

By selecting ***G.8273.2 Class A,B T-BC Noise Transfer*** in ***Masks*** from the right-hand side of the CAT, max/min pk-pk values as per the standard will be displayed in the table, along with limit lines on the graph.

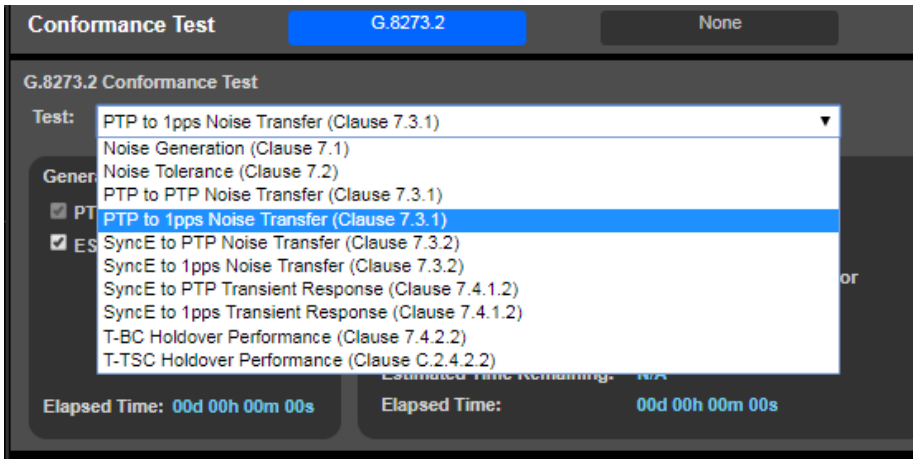


Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)	Upper Pk-Pk Limit (ns)	Lower Pk-Pk Limit (ns)
4	0.03125	200	224.30	200.01	0.00	210	135
5	0.0615625	200	243.95	200.19	0.01	210	-
6	0.123125	200	203.35	124.77	-4.10	135	-
7	0.24625	200	203.35	75.05	-8.51	85	-
8	0.4925	200	203.35	34.49	-15.27	45	-
9	0.985	200	203.35	19.91	-20.04	30	-
10	1.985	200	201.81	0.11	-65.31	20	-

Note that the Pk-Pk limits as defined in G.8273.2 are defined as a value +*n* to allow for measurement uncertainty. As Paragon-100G performs with better than 5ns accuracy, a value of 5ns is used as ***n*** for the pass/fail limits.

6.2 PTP to 1pps Transfer

1. From the **Test:** drop-down menu, select ***PTP to 1pps Noise Transfer (Clause 7.3.1).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab, to allow you to check current timing performance. In this case, you should wait for a **1pps TE Absolute measurement** graph moving from a ramp to stable condition to indicate lock has been achieved



3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the prescribed PTP Noise Stimulus and simultaneous 1pps measurement.

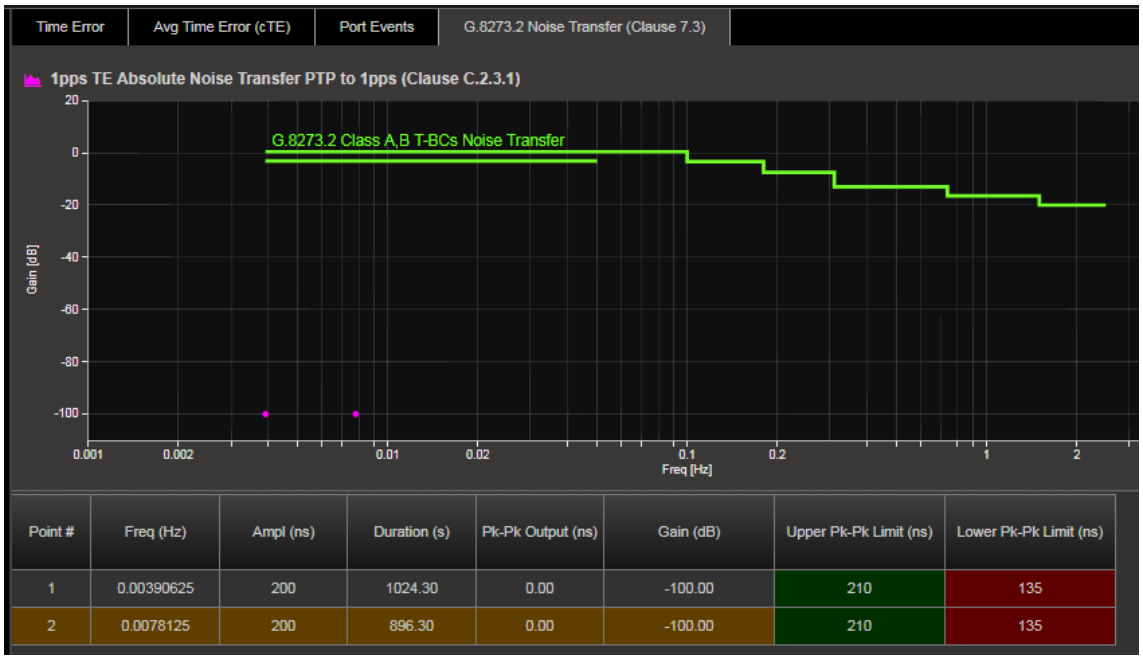
   PTP Noise (Time Error) is applied as per G.8273.2 Amendment 1 (Appendix VI).

   For more information on the test considerations and the approach to test in the ITU-T recommendation, please see the Calnex application note *Time error transfer for BCs.*

4. During or after the test, CAT can be launched to view the results – complete PTP-1pps transfer results are available in the ***G.8273.2 Noise Transfer (Clause 7.3)*** tab. A baud plot is displayed, along with a table of applied stimulus vs. gain. If a test step is still underway, this will be highlighted in orange on the table.

Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)
1	0.00390625	200	1024.30	0.00	-100.00
2	0.0078125	200	896.30	0.00	-100.00

5. By selecting ***G.8273.2 Class A,B T-BC Noise Transfer*** in ***Masks*** from the right-hand side of the CAT, max/min pk-pk values as per the standard will be displayed in the table, along with limit lines on the graph.

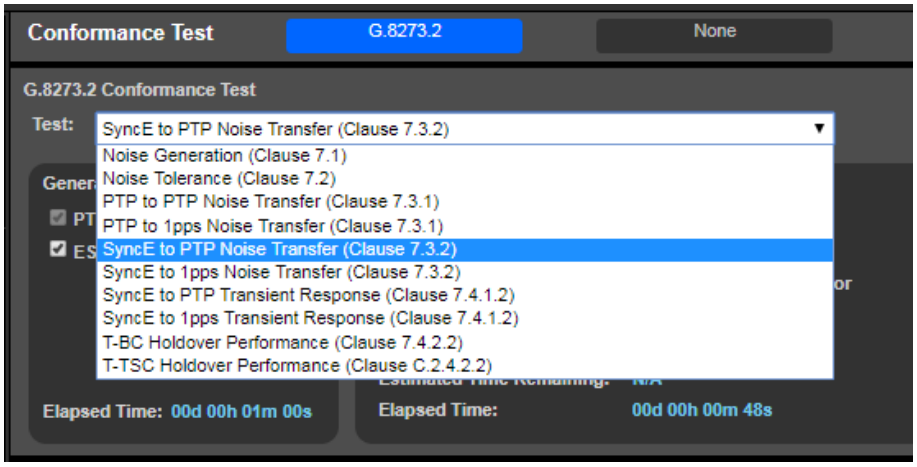


Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)	Upper Pk-Pk Limit (ns)	Lower Pk-Pk Limit (ns)
1	0.00390625	200	1024.30	0.00	-100.00	210	135
2	0.0078125	200	896.30	0.00	-100.00	210	135

Note that the Pk-Pk limits as defined in G.8273.2 are defined as a value *+n* to allow for measurement uncertainty. As Paragon-100G performs with better than 5ns accuracy, a value of 5ns is used as ***n*** for the pass/fail limits.

6.3 SyncE to PTP Transfer

1. From the **Test:** drop-down menu, select ***SyncE to PTP Noise Transfer (Clause 7.3.2).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.



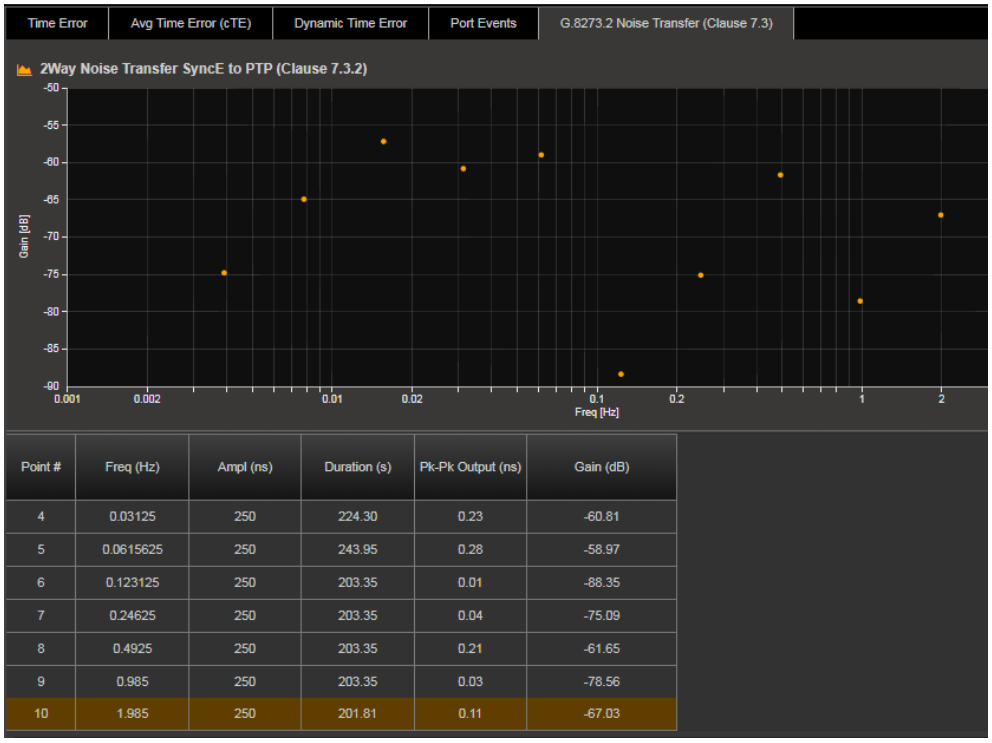
3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press **Start** to run the prescribed SyncE Noise Stimulus and simultaneous PTP measurement.

   PTP Noise (Time Error) is applied as per G.8273.2 Amendment 1 (Appendix VI).

   A least-squares filter technique as suggested in Amendment 1 is applied to the PTP signal to be measured (to address potential measurement uncertainty due to noise on the packet interface and the intrinsic noise generation of the T-BC).

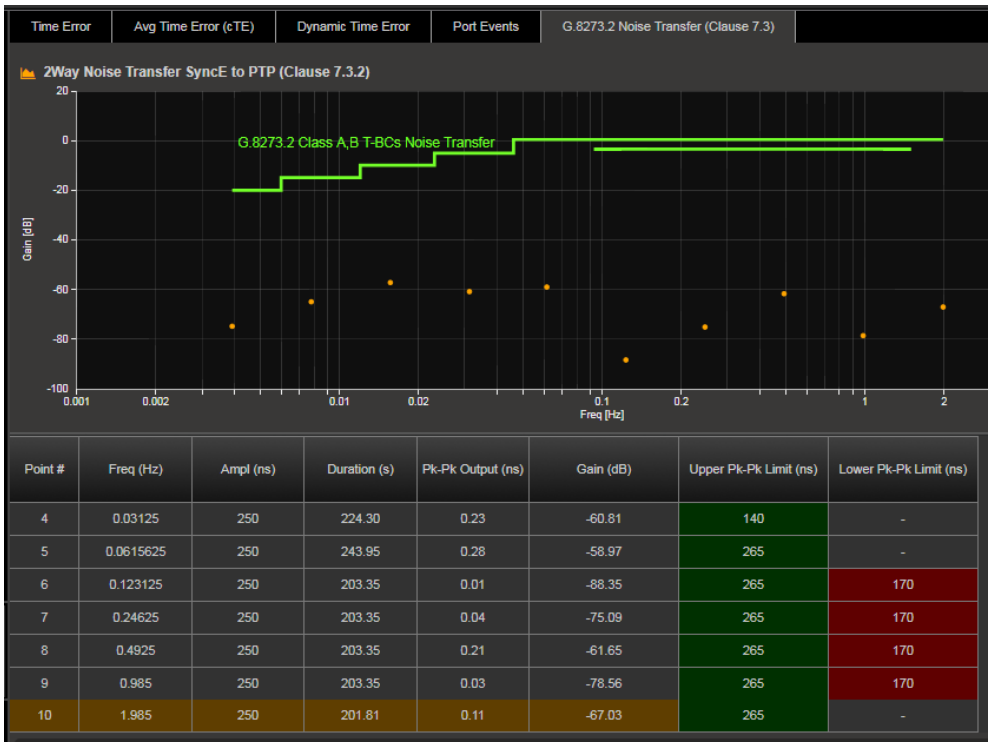
   For more information on the test considerations and the approach to test in the ITU-T recommendation, please see the Calnex application note *Time error transfer for BCs*.

During or after the test, CAT can be launched to view the results – complete SyncE-PTP transfer results are available in the ***G.8273.2 Noise Transfer (Clause 7.3)*** tab. A baud plot is displayed, along with a table of applied stimulus vs. gain. If a test step is still underway, this will be highlighted in orange on the table.



Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)
4	0.03125	250	224.30	0.23	-60.81
5	0.0615625	250	243.95	0.28	-58.97
6	0.123125	250	203.35	0.01	-88.35
7	0.24625	250	203.35	0.04	-75.09
8	0.4925	250	203.35	0.21	-61.65
9	0.985	250	203.35	0.03	-78.56
10	1.985	250	201.81	0.11	-67.03

By selecting ***G.8273.2 Class A,B T-BC Noise Transfer*** in ***Masks*** from the right-hand side of the CAT tool, max/min pk-pk values as per the standard will be displayed in the table, along with limit lines on the graph.

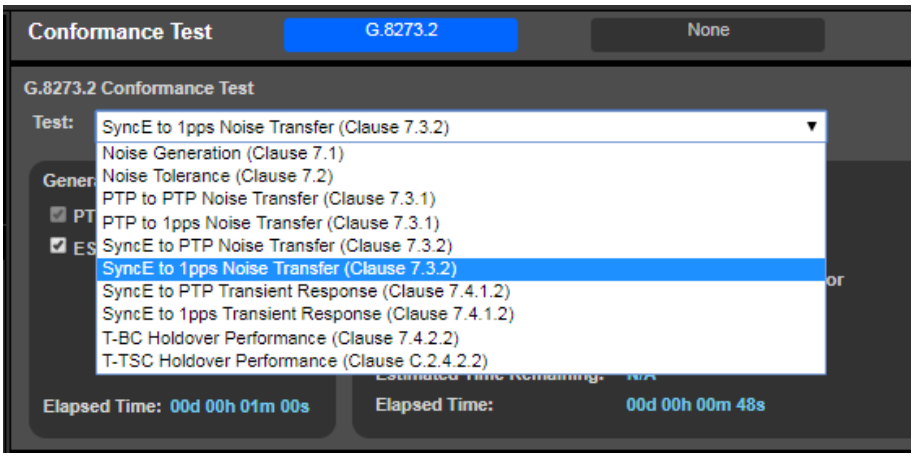


Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)	Upper Pk-Pk Limit (ns)	Lower Pk-Pk Limit (ns)
4	0.03125	250	224.30	0.23	-60.81	140	-
5	0.0615625	250	243.95	0.28	-58.97	265	-
6	0.123125	250	203.35	0.01	-88.35	265	170
7	0.24625	250	203.35	0.04	-75.09	265	170
8	0.4925	250	203.35	0.21	-61.65	265	170
9	0.985	250	203.35	0.03	-78.56	265	170
10	1.985	250	201.81	0.11	-67.03	265	-

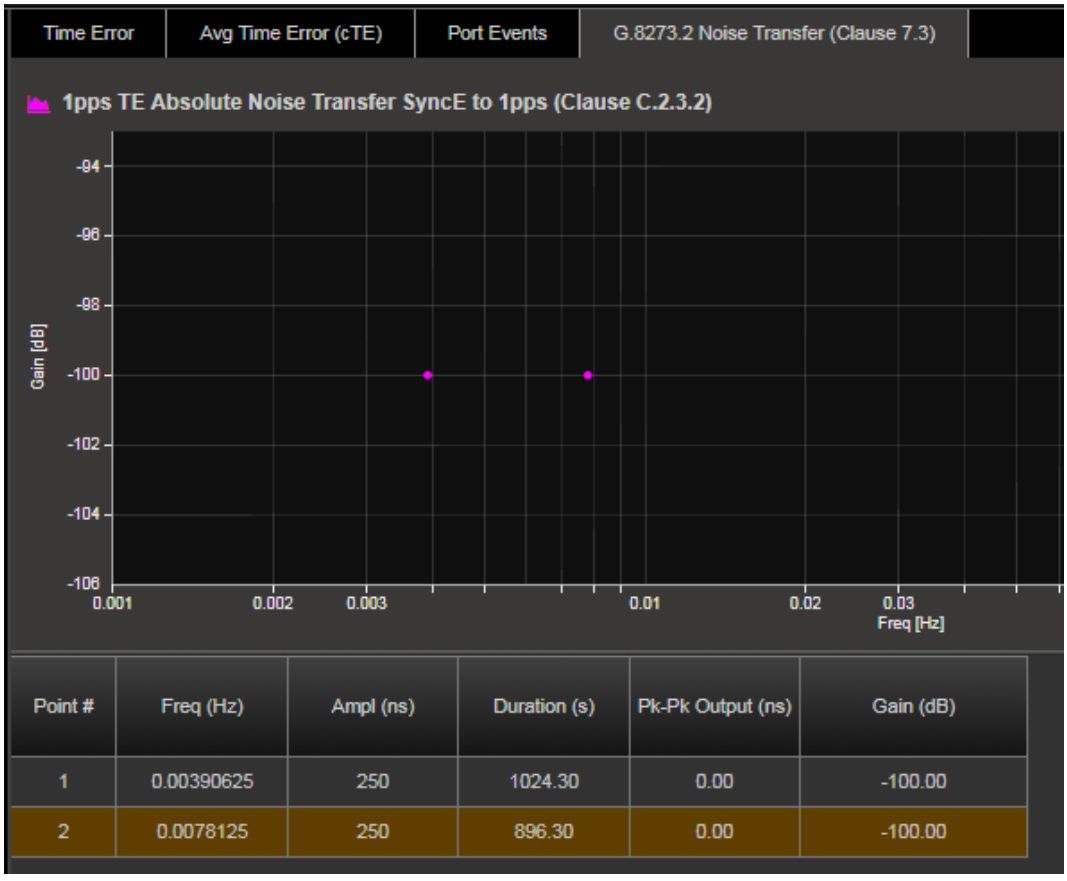
Note that the Pk-Pk limits as defined in G.8273.2 are defined as a value *+n* to allow for measurement uncertainty. As Paragon-100G performs with better than 5ns accuracy, a value of 5ns is used as ***n*** for the pass/fail limits.

6.4 SyncE to 1pps Transfer

1. From the **Test:** drop-down menu, select ***SyncE to 1pps Noise Transfer (Clause 7.3.2).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **1pps TE Absolute measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.

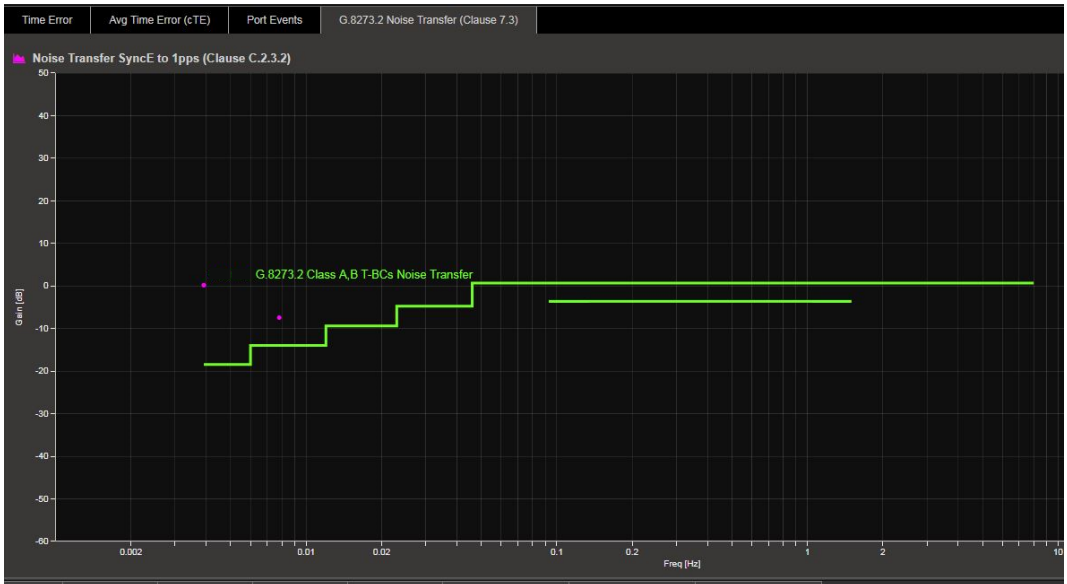


3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press start to run the prescribed SyncE Noise Stimulus and simultaneous 1pps measurement.
4. During or after the test, CAT can be launched to view the results – complete SyncE-1pps transfer results are available in the ***G.8273.2 Noise Transfer (Clause 7.3)*** tab. A baud plot is displayed, along with a table of applied stimulus vs. gain. If a test step is still underway, this will be highlighted in orange on the table.



Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)
1	0.00390625	250	1024.30	0.00	-100.00
2	0.0078125	250	896.30	0.00	-100.00

5. By selecting ***G.8273.2 Class A,B T-BC Noise Transfer*** in ***Masks*** from the right-hand side of the CAT tool, max/min pk-pk values as per the standard will be displayed in the table, along with limit lines on the graph.



Point #	Freq (Hz)	Ampl (ns)	Duration (s)	Pk-Pk Output (ns)	Gain (dB)	Upper Pk-Pk Limit (ns)	Lower Pk-Pk Limit (ns)
1	0.00390625	250	1024.30	255.75	0.20	30	-
2	0.0078125	250	896.30	106.25	-7.43	50	-

Note that the Pk-Pk limits as defined in G.8273.2 are defined as a value *+n* to allow for measurement uncertainty. As Paragon-100G performs with better than 5ns accuracy, a value of 5ns is used as ***n*** for the pass/fail limits.

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 over 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 previous node to the T-BC can generate a large transient in the T-BC input, therefore a T-BC 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-BC 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-BC 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:

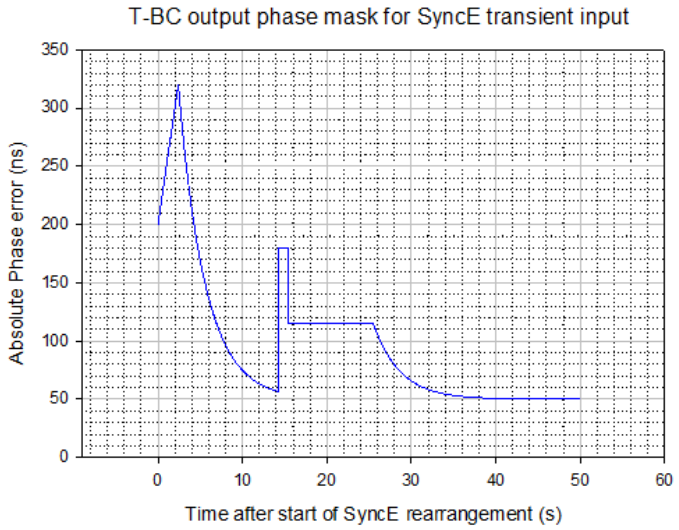


Figure B.1 from G.8273.2 Annex B – Phase error mask during a SyncE transient

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).

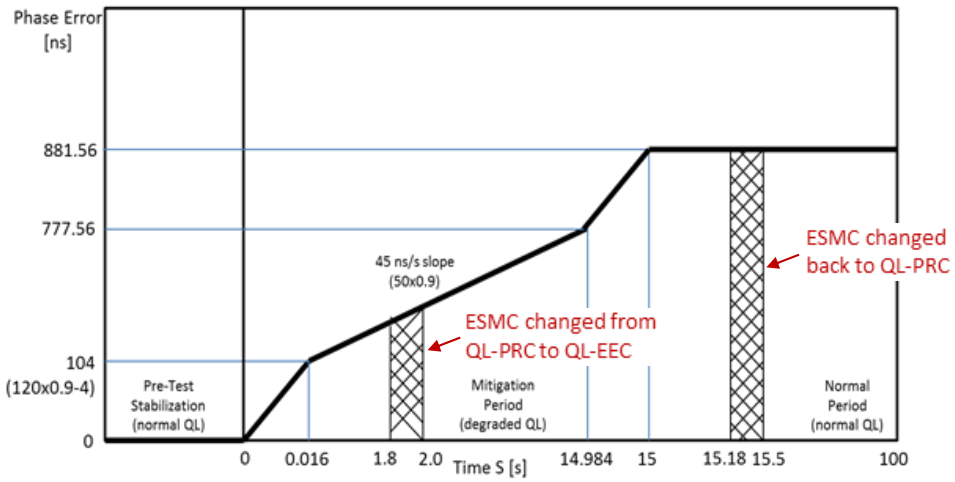


Fig. III.2 from G.8273 Appendix III – SyncE Transient Input Pattern

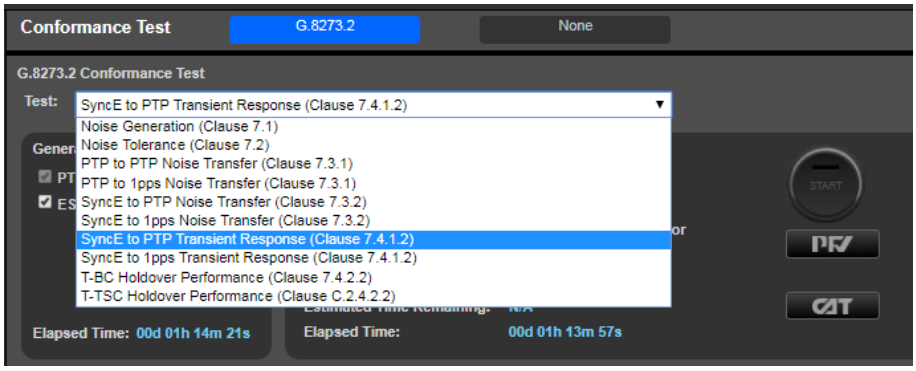
Measurement Process

Confirm that preconfigured settings within Master/Slave emulation are appropriate for the current test scenario, as described in Section 3.4.

7.1 SyncE to PTP Transient Response (Clause 7.4.1.2)

1. From the **Test:** drop-down menu, select ***SyncE to PTP Transient Response (Clause 7.4.1.2).***

2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.

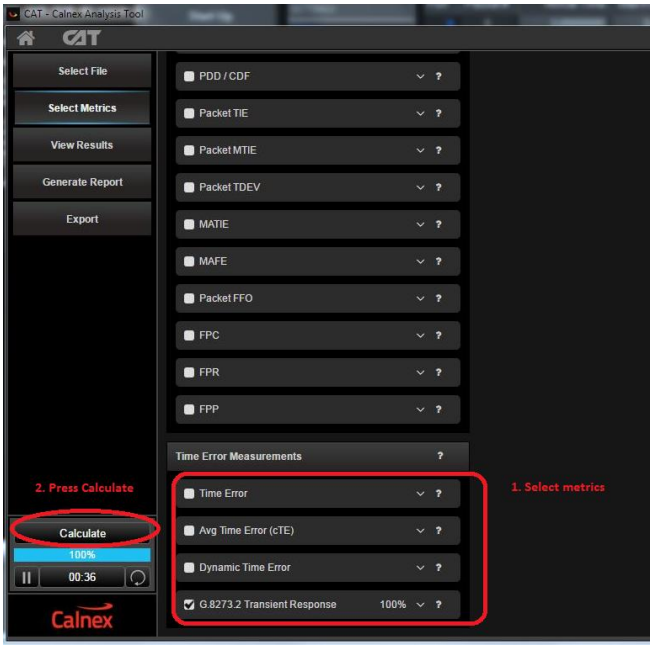


3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the prescribed SyncE wander and ESMC state change stimulus and simultaneous PTP measurement.

   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 CAT to calculate and make that adjustment.

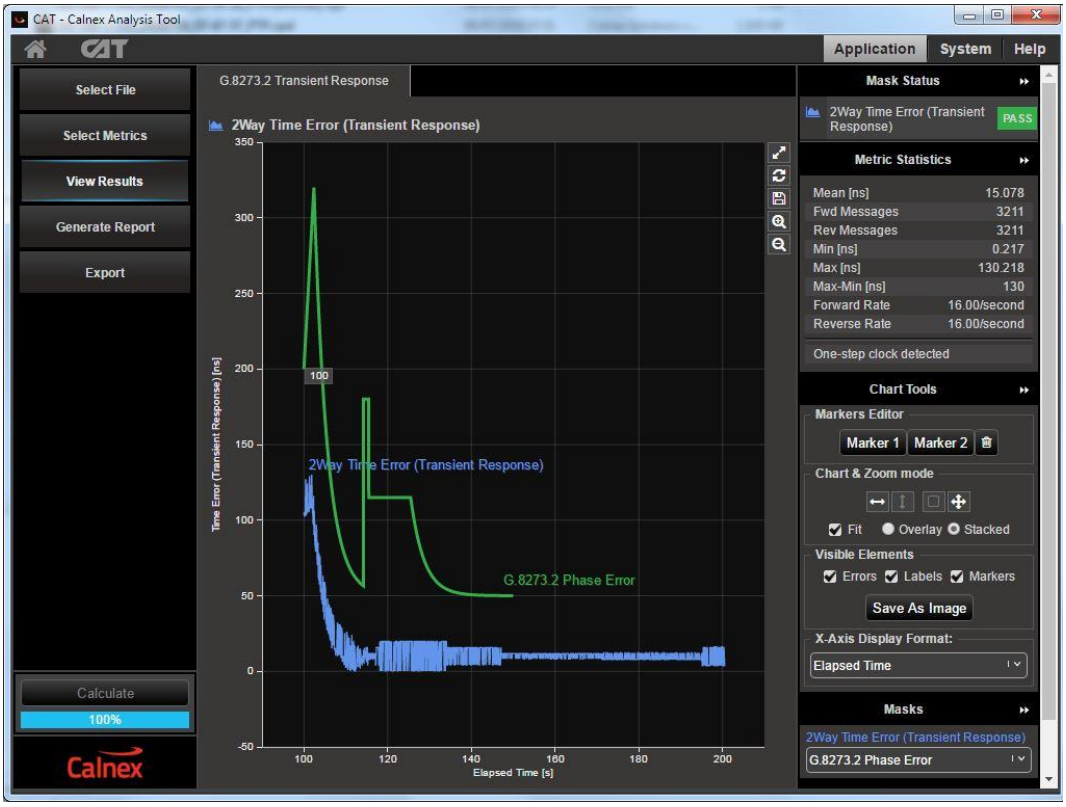
   On completion of the test, the test results can be analysed using the CAT.

4. In the CAT, select ***Select Metrics*** and enable the **G.8273.2 Transient Response** metric followed by the ***Calculate*** button.



   NOTE: Due to the application of the transient event the other Time Error results will be impacted and thus cannot be relied upon to provide representative results – other aspects of Time Error performance should be analysed in separate test runs.

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



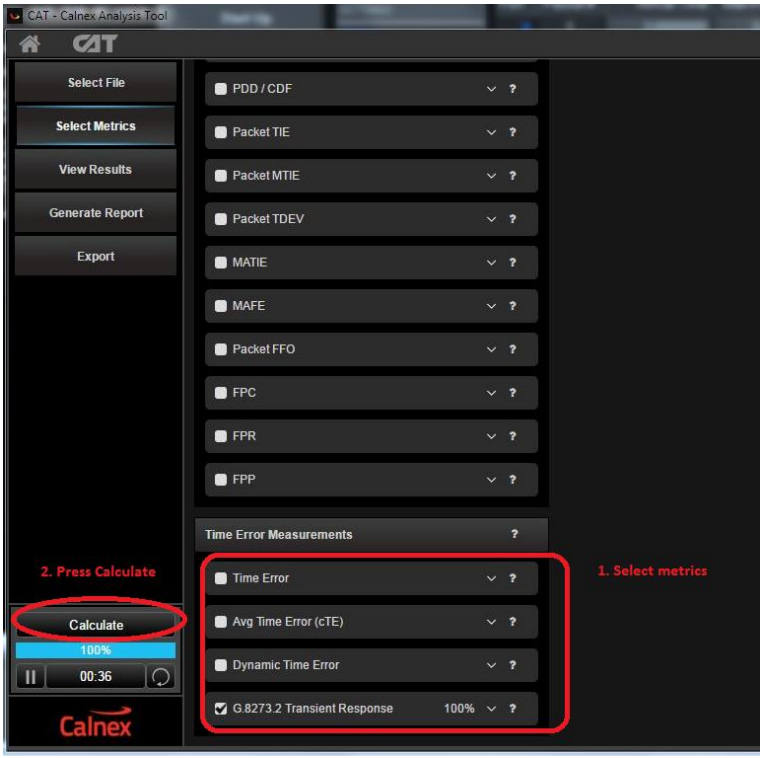
7.2 SyncE to 1pps Transient Response (Clause 7.4.1.2)

1. From the **Test:** drop-down menu, select ***SyncE to 1pps Transient Response (Clause 7.4.1.2).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **1pps TE Absolute measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.

3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to run the prescribed SyncE wander and ESMC state change stimulus and simultaneous 1pps measurement.

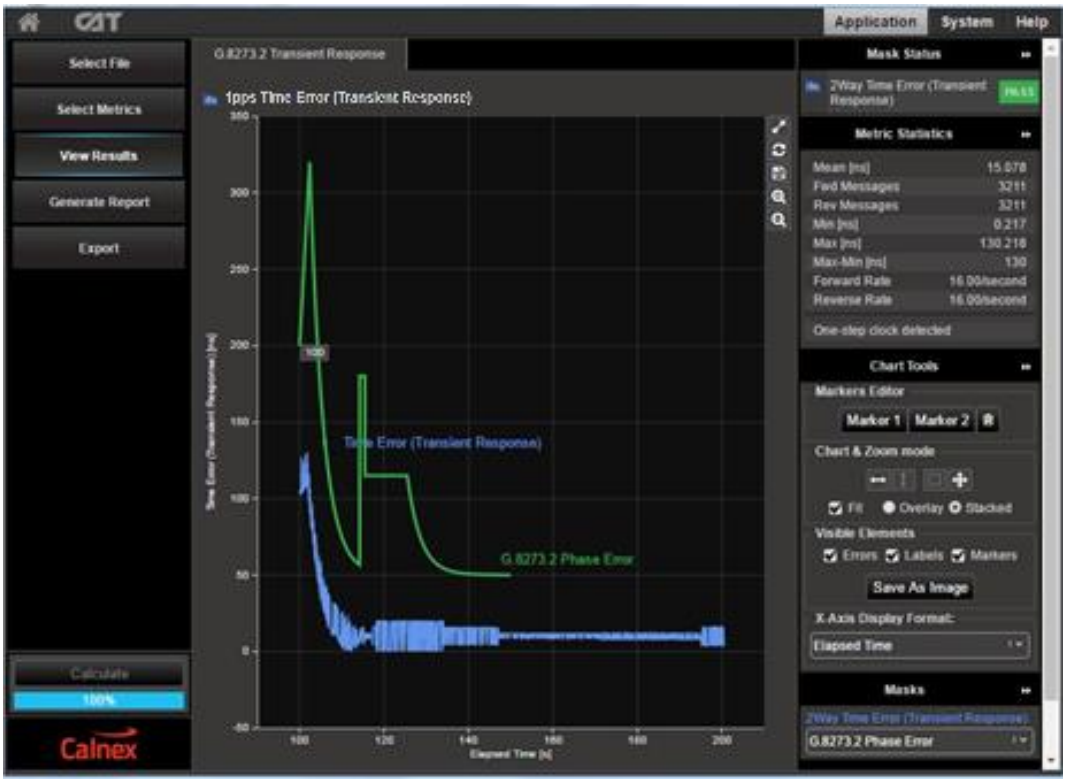
   Test execution takes 200s. The first 100s are used to analyse the underlying Constant Time Error (cTE) without the application of the transient. As per the standard, the mask for Phase Noise response to the generated transient requires the results to be adjusted for cTE – this step therefore allows the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

4. On completion of the test, the test results can be analysed using the CAT.
5. In the CAT, click on ***Select Metrics*** and enable the **G.8273.2 Transient Response** metric followed by the ***Calculate*** button.



NOTE: Due to the application of the transient event the other Time Error results will be impacted and thus cannot be relied upon to provide representative results – other aspects of Time Error performance should be analysed in separate test runs.

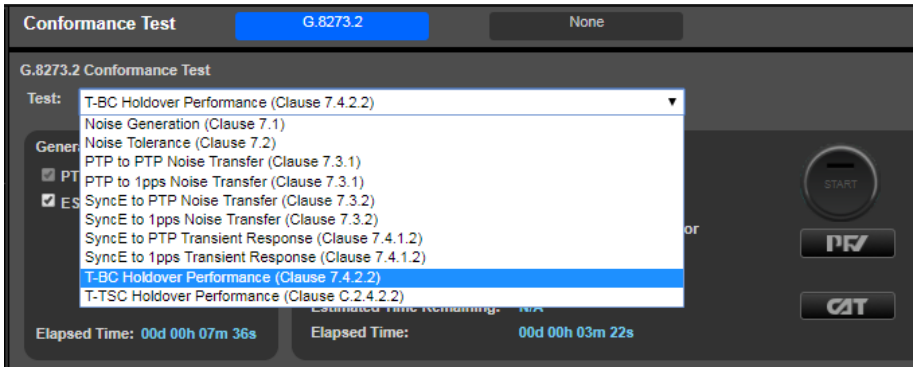
6. Once the calculation has reached 100% the results and associated Pass/Fail information can be viewed using the ***View Results*** button.



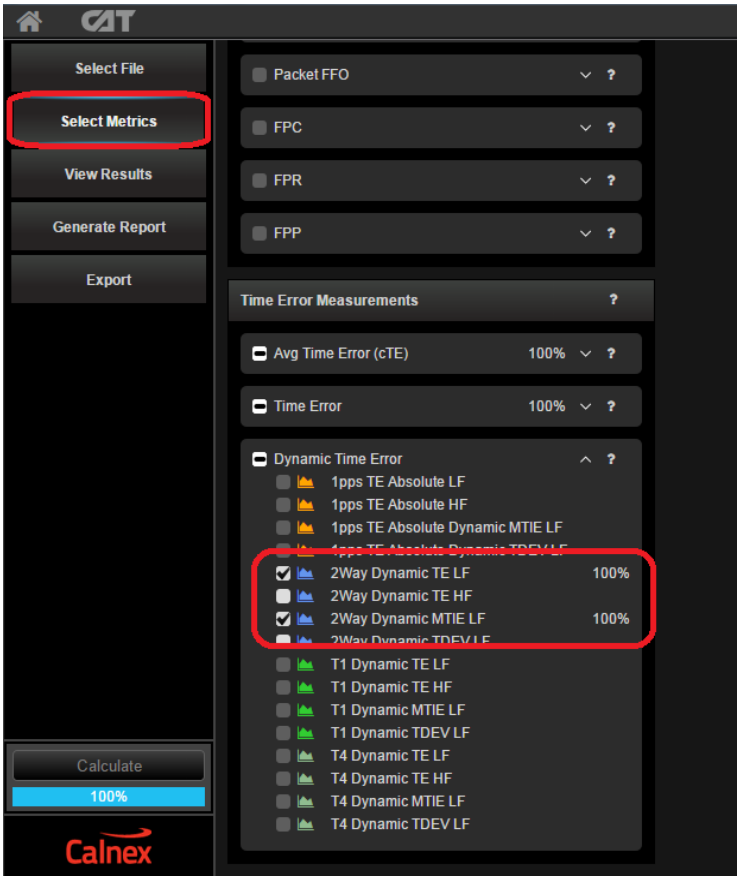
7.3 Holdover Performance

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

1. From the **Test:** drop-down menu, select ***T-BC Holdover performance (Clause 7.4.2.2).***
2. From the ***Generation*** section of the conformance test app, press ***Generate.*** This starts PTP and ESMC message generation, allowing the device under test to stabilize. Pressing ***Check*** will open the **CAT** in a new tab to allow you to check current timing performance. In this case, you should wait for a **2WayTE measurement** graph moving from a ramp to stable condition to indicate lock has been achieved.



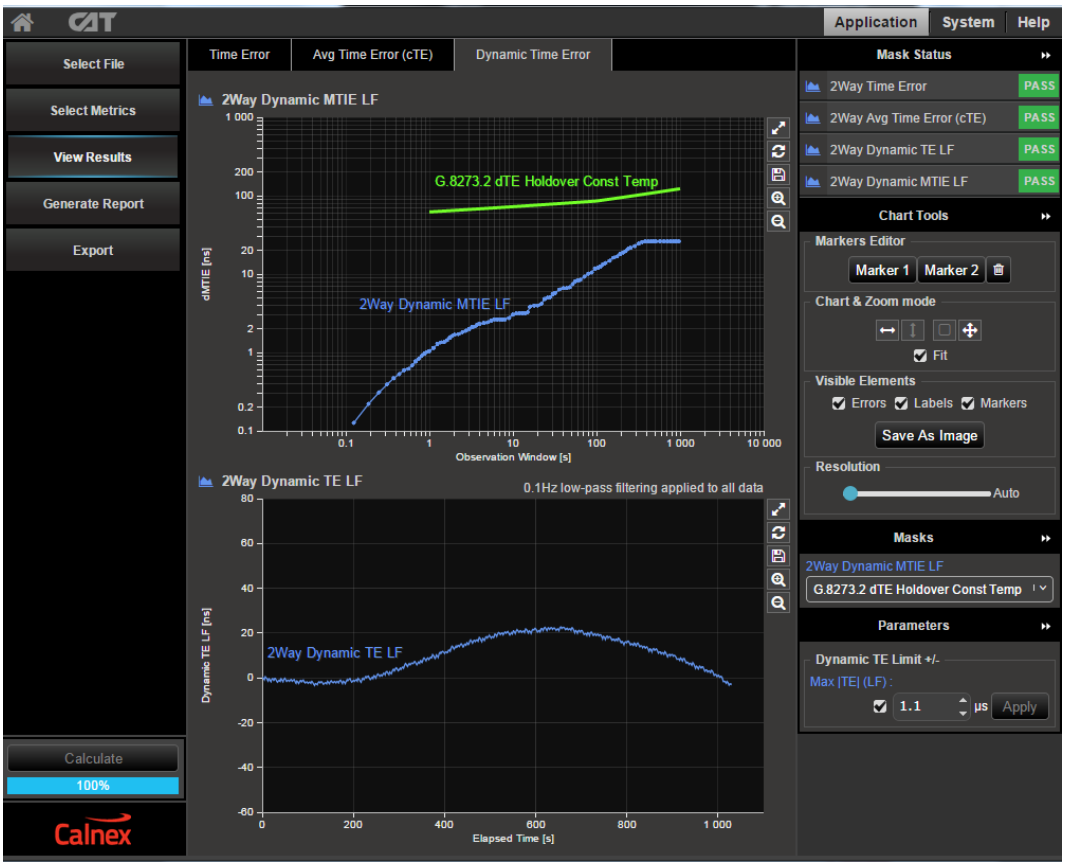
3. Once the DUT is stable, in the ***Stimulus/Measurement*** section, press ***Start*** to simulate loss of PTP input signal to the device and make simultaneous PTP performance measurements.
4. On completion of the test, the test results can be analysed using the CAT.
5. The key metrics to be examined are the **2way 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.



6. Select the ***Dynamic Time Error*** tab.

7. Select the ***G.8273.2 dTE Holdover Const Temp*** mask.

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



Appendix 1 – G.8271.1 Time Error Budget Example

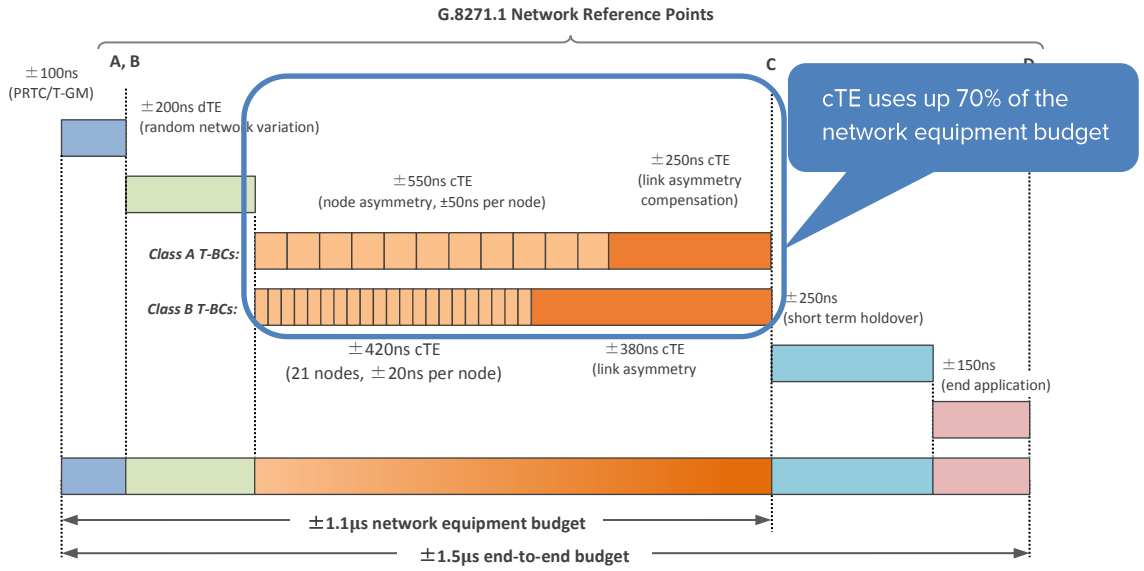


Table V1.1/G.8271.1 – Example of Time Error Allocation

Budget Component	Failure scenario a)	Failure scenario b)	Long Holdover periods (e.g. 1 day)
PRTC (ce_{ref})	100ns	100ns	100ns
Holdover and Rearrangements in the network (TE_{HO})	NA	400ns	2400ns
Random and error due to SyncE rearrangements (dTE')	200ns	200ns	200ns
Node Constant including intrasite (ce_{ptp_clock}) (Note1)	550ns	550ns	550ns
Link Asymmetries (ce_{link_asym}) (Note2)	250ns	100ns	100ns
Rearrangements and short Holdover in the End Application (TE_{REA})	250ns	NA	NA
End application (TE_{EA})	150ns	150ns	150ns
Total (TE_D)	1500ns	1500ns	3500ns (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-BC

<table>
<tr><th>Test</th><th>Objective</th><th>Test Method</th><th colspan="3">Output Limit (PTP and 1pps)[1]</th></tr>
<tr><td rowspan="5">Time Error Generation
(G.8273.2, Section 7.1)</td><td rowspan="5">With stable input references, measure the inherent time error (Max|TE|, cTE and dTE) produced by the internal clock.</td><td rowspan="5">Apply a stable time reference to the PTP input.
Apply a stable frequency reference to the SyncE input.
Repeat without a SyncE reference[2].</td><td></td><td>Class A</td><td>Class B</td></tr>
<tr><td>Max|TE|:[3]</td><td>≤100ns</td><td>≤70ns</td></tr>
<tr><td>cTE:</td><td>≤50ns</td><td>≤20ns</td></tr>
<tr><td>dTE_{LF}:[4]</td><td colspan="2">40ns MTIE, 4ns TDEV</td></tr>
<tr><td>dTE_{HF}:[5]</td><td colspan="2">70ns p-p</td></tr>
<tr><td>Time Error Tolerance
(G.8273.2, Section 7.2)</td><td>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
• switch reference
• go into holdover</td><td>Combined PTP and SyncE tolerance:
Apply Calnex noise tolerance profile to the PTP input[6].
Simultaneously apply sine wave phase wander to the SyncE input according to G.8262, Table 9.
Repeat without a SyncE reference[7].</td><td colspan="3">No output performance limit.
Clock under test should not:
• generate alarms
• switch reference
• go into holdover</td></tr>
</table>

[1] Same limits apply to 1pps and PTP outputs. It is assumed that the 1pps should track the PTP output closely, although there is no specification for how closely they should track.

[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] Max|TE| 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 profile is derived from the dTE network limit MTIE mask, defined in G.8271.1 Figure 7-2.

[7] Values assume a first order, 20dB/decade filter, with ±35ns (70ns p-p) noise from the output packet interface. For higher-order or digital filters, or for lower noise different values will apply.

Test	Objective	Test method	Output Limit (PTP and 1pps)[1]	
Time Error Transfer (G.8273.2, Section 7.3)	Measures how time error on the input is transferred to the output. **PTP-to-PTP transfer function**: • Low-pass filter (undefined order or shape) • Bandwidth from 0.05 to 0.1Hz **SyncE-to-PTP transfer function**: • Band-pass filter (undefined order or shape) • Lower cut-off from 0.05 to 0.1Hz • Upper cut-off from 1 to 10Hz	**PTP to PTP:** 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[2].	Frequency	Output Amplitude[7]
			0.01Hz	>160ns p-p (min), <230ns p-p (max)
			1Hz	<55ns p-p (max)
		SyncE to PTP: 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.	0.005Hz	<55ns p-p (max)
			0.33Hz	>145ns p-p (min), <230ns p-p (max)
Transients and Holdover (G.8273.2, Section 7.4, plus Annex B, Appendix 1)	Measure the transient caused by a switch between PTP masters.	No test method defined.	No performance limit defined	
	Measure the 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-BC 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-BC has locked onto the inputs and stabilised, stop the flow of PTP packets, and monitor the output for up to 1000s.	MTIE mask defined in G.8273.2, Table 7-6	

[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.

[7] Values assume a first order, 20dB/decade filter, with ±35ns (70ns p-p) noise from the output packet interface. For higher-order or digital filters, or for lower noise different values will apply.

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CX3003 v4.4 April 18