

T-BC Time Error

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

- 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-X can be used to prove T-BC compliance to G.8273.2 and provides procedures to measure noise generation, time noise tolerance and transfer, 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

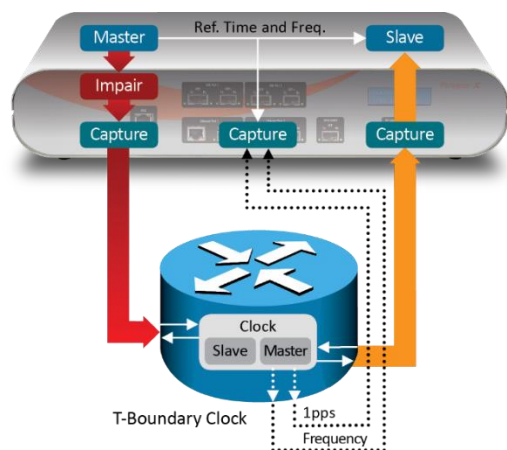
Option 132 GPS/Rubidium Clock (optional)

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)
- Calnex Noise Transfer Script - Getting Started Guide (CX5036)

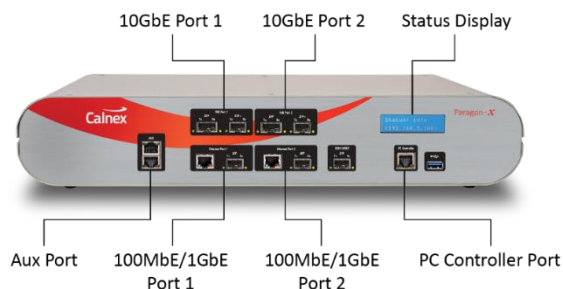
¹ XFP devices are not recommended for Time Error measurements as the retiming that is an integral element of the XFP introduces significant uncertainty when performing a Time Error test

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



Front Panel

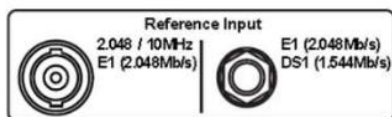
- 100MbE Electrical or Optical (SGMII SFP)
- 1GbE Electrical or Optical (SFP) – with option 110 fitted
- 10GbE Optical (XFP or SFP+) – with option 111 fitted



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:

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

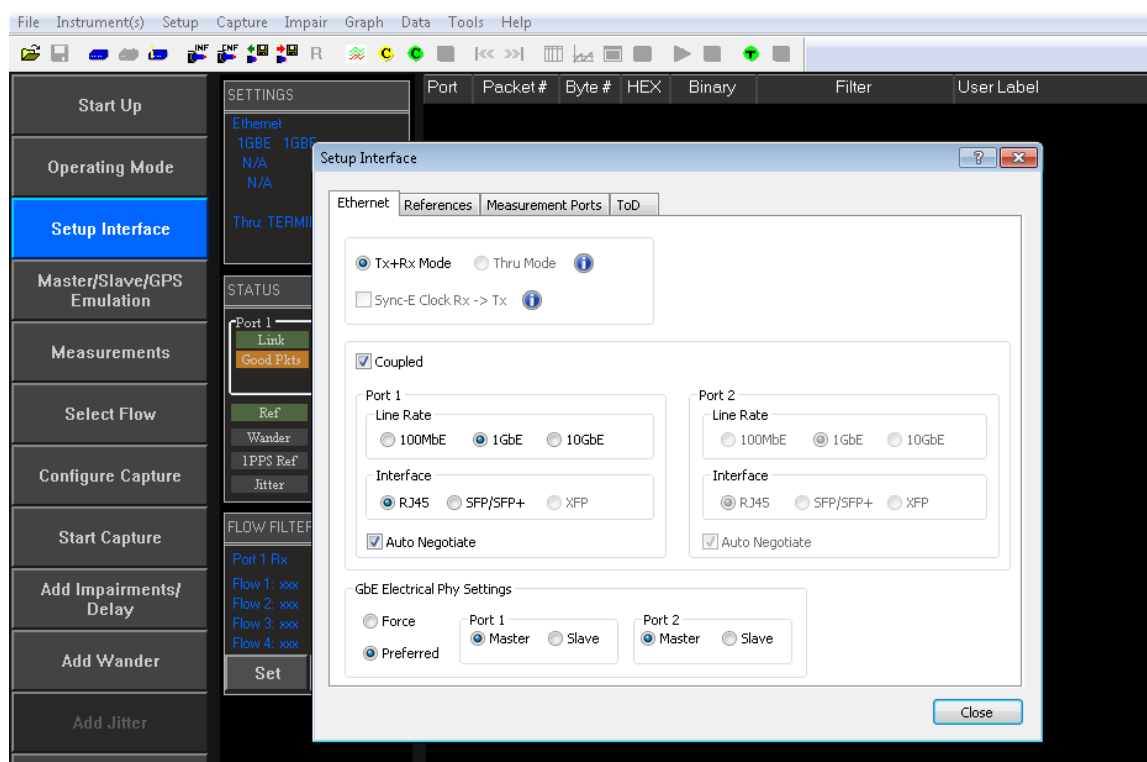
- 3.1. Connection to Paragon-X from GUI
- 3.2. Configuration of physical connections
- 3.3. Measurement configuration
- 3.4. Preparing Master/Slave Emulation operation
- 3.5. Confirmation of PTP traffic on interfaces
- 3.6. Filtering capture and impairment traffic
- 3.7. Start of Master/Slave Emulation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

3.1. Connection to Paragon-X from GUI

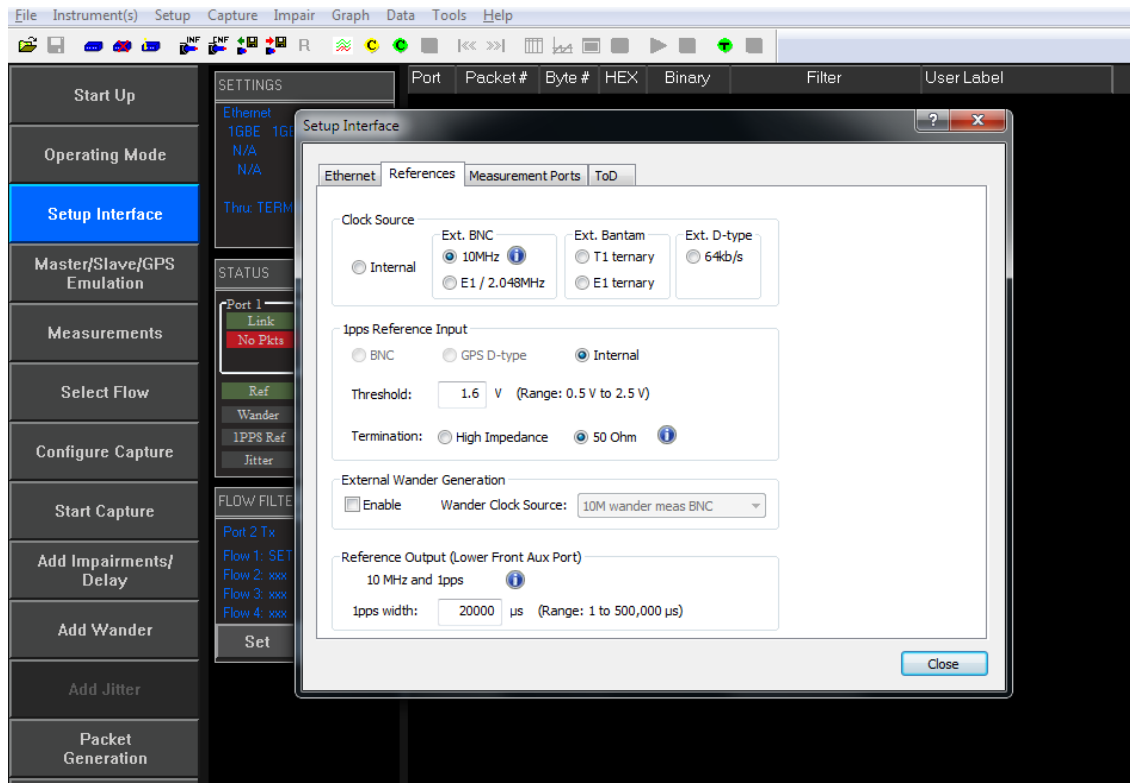
1. Verify the physical connections have been completed as described in Section 2.
2. Start the Paragon-X GUI.
3. Select **Start Up** and **Connect**.
4. Enter the IP address of the Paragon-X (displayed on Paragon-X status display). See the Paragon-X Getting Started Guide for more details.

3.2 Configuration of Physical Connections

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

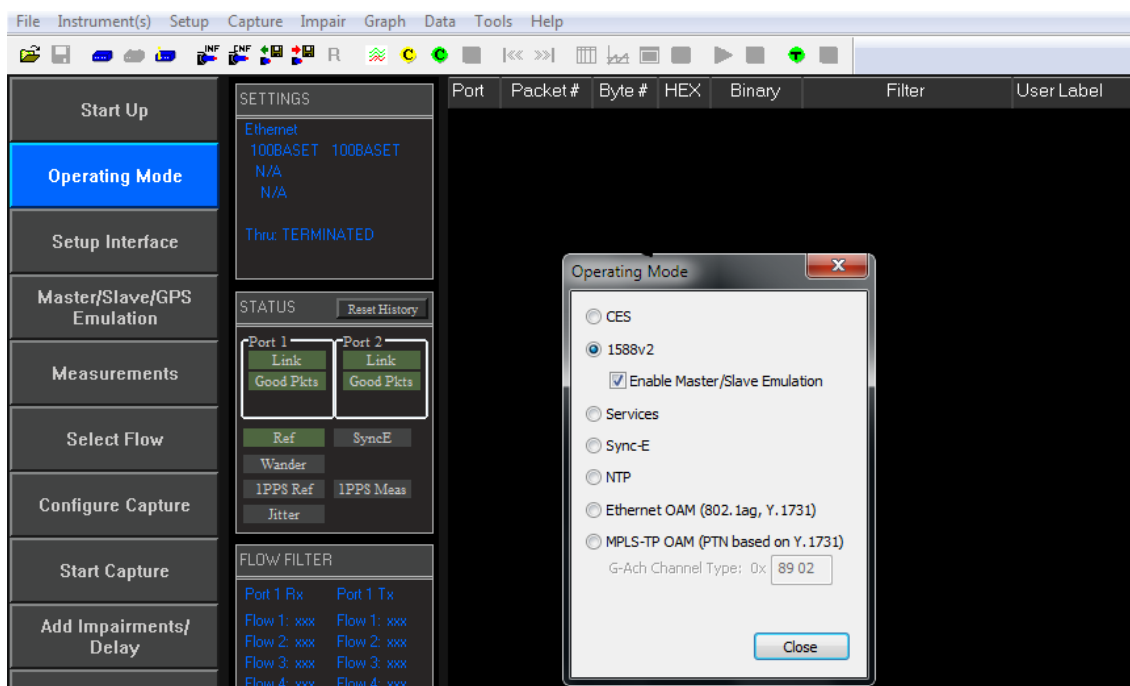


2. Select **References** tab to configure a stable reference for the Paragon-X. Set the **Clock Source** to **External reference** (10MHz or E1/2MHz). An external source is recommended.

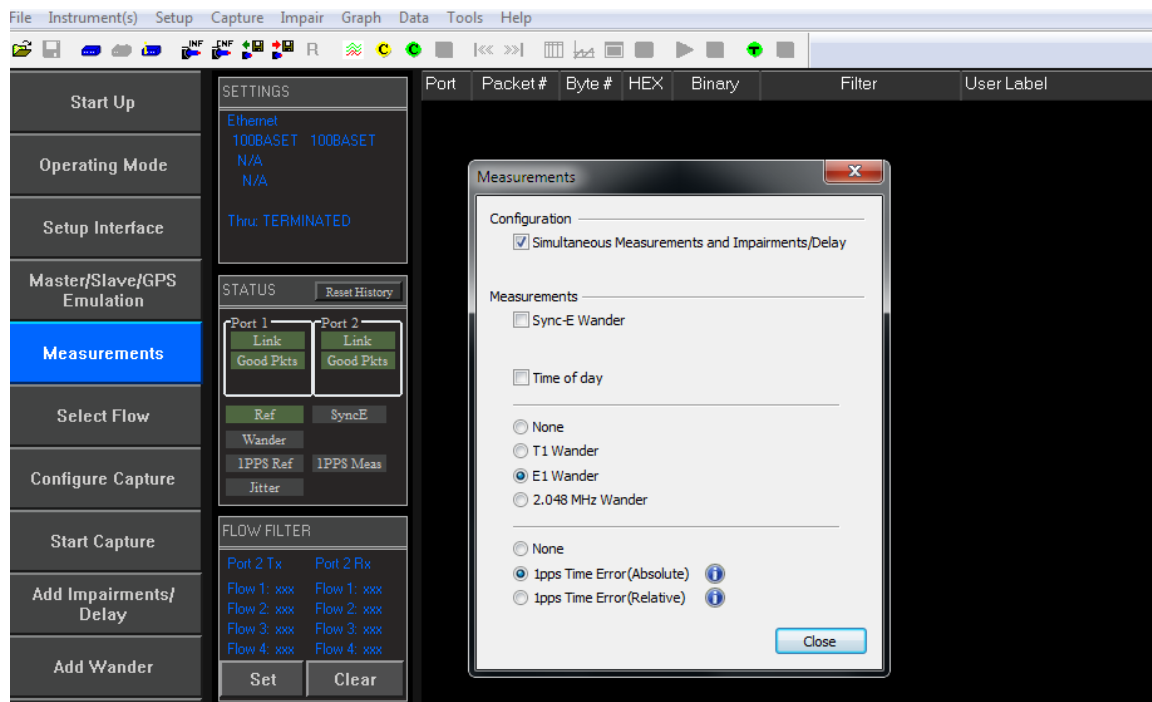


3.3. Measurement Configuration

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



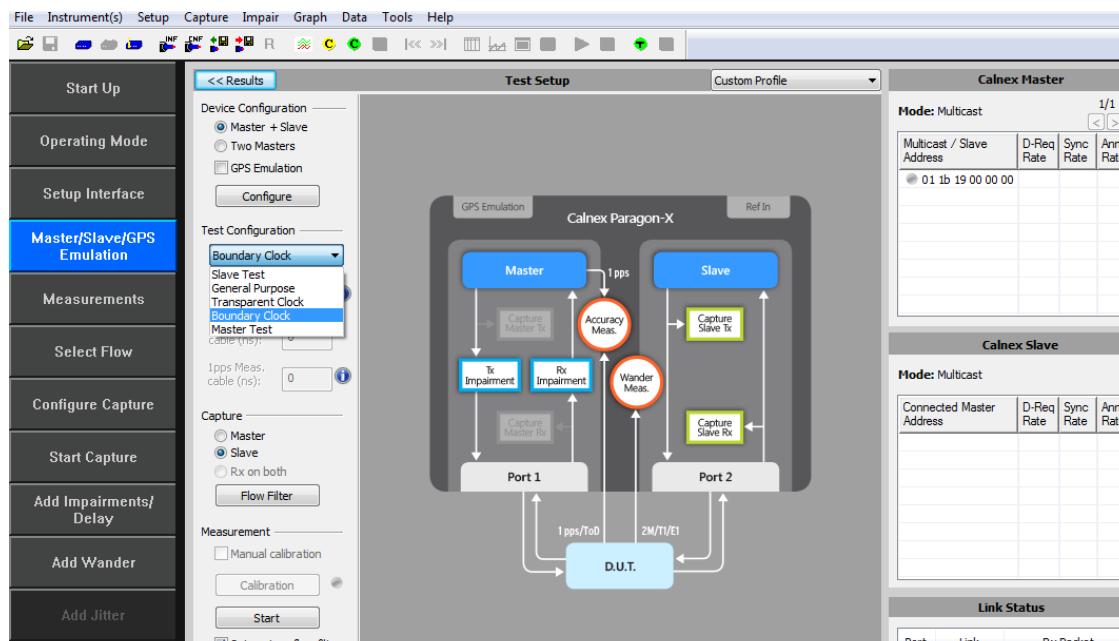
2. Select **Measurements** then any desired simultaneous measurements e.g. **1pps Accuracy** (if available from T-BC).



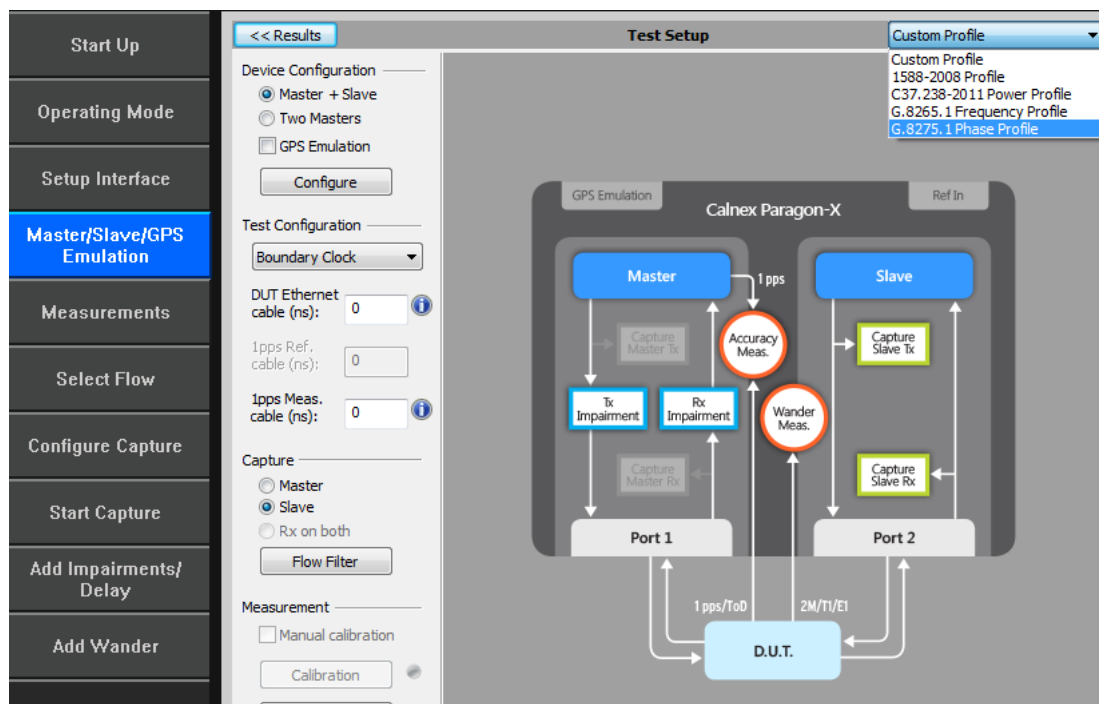
3.4. Preparing for Master/Slave Emulation

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. 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.

1. Select **Master/Slave Emulation**. Choose **Boundary Clock** in the **Test Configuration** drop down menu.

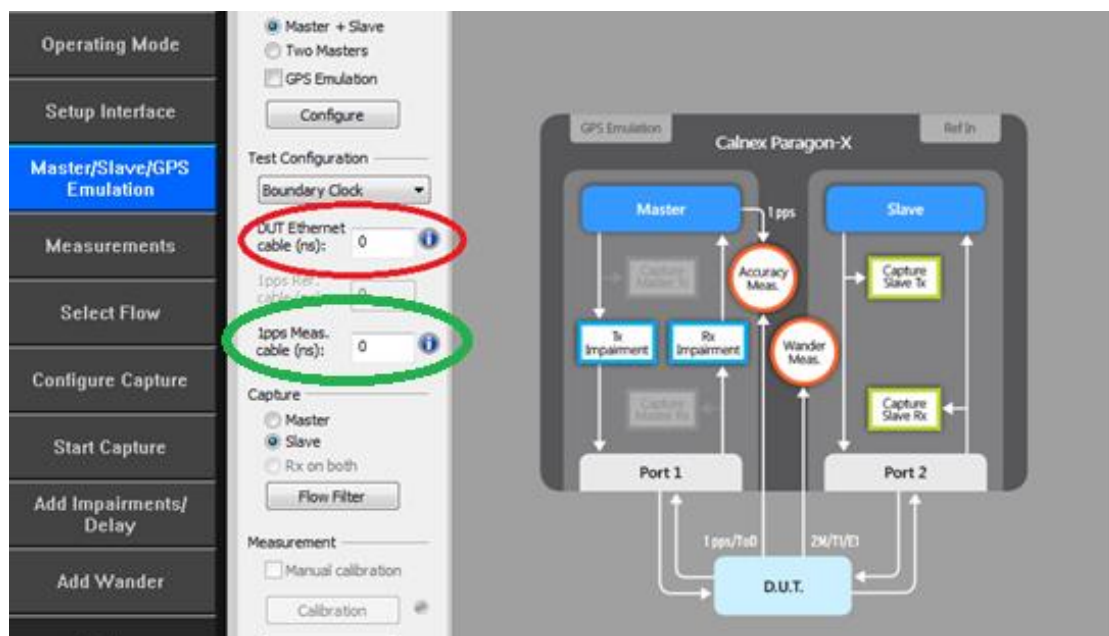


2. Select **G.8275.1** profile from the Custom Profile drop down menu.



3. Enter the DUT to Paragon-X **cable delay**.

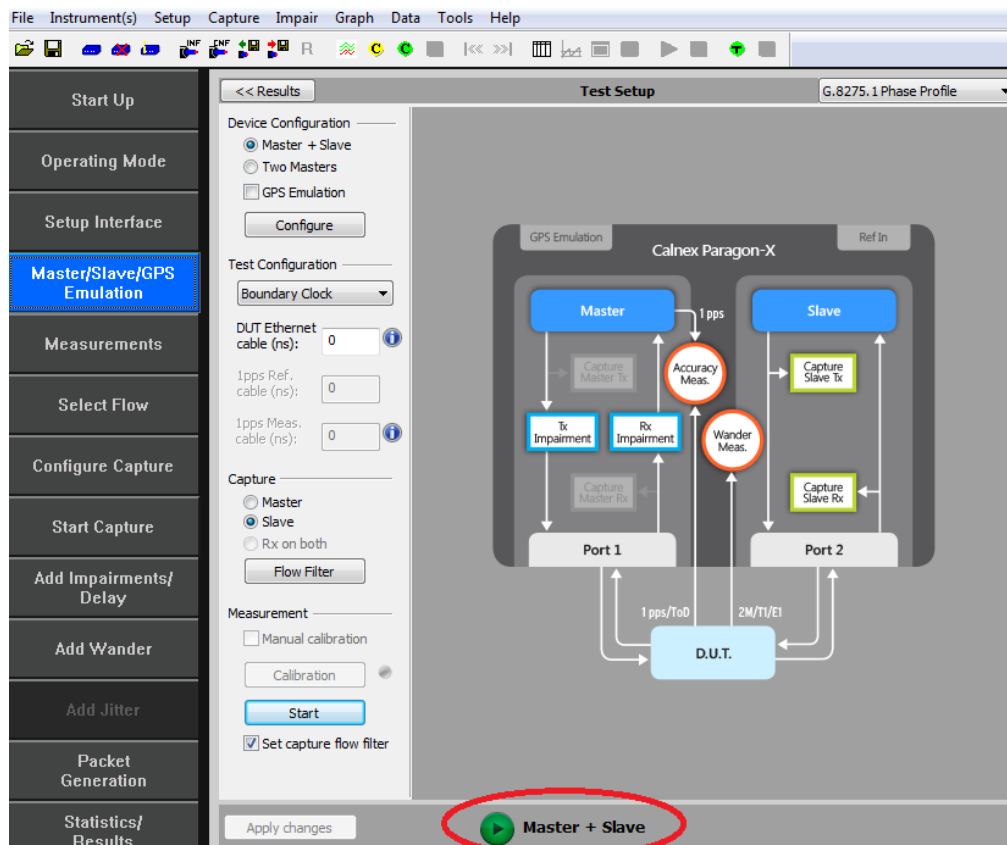
To correctly perform measurements, the delay caused by the cable that is used to connect the T-BC Master and Port 2 must be factored out. Values of 5ns per 1 metre of electrical cable and 4ns per 1 metre of optical cable can be expected.



4. If 1pps Time Error measurements are to be made, enter the **1pps Measurement cable delay**.

Values of 5ns per 1 metre of cable can be expected. See Calnex's Technical Note 'Cabling Considerations' (CX5009) for more information.

5. **Start** the Master/Slave emulation.



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			GOOD PACKETS
2			GOOD PACKETS

2. **Stop** the 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 on the generation, capture and impairment of the 1588 messages associated with T-BC 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**

By default, the capture filters are automatically enabled for the Boundary Clock test when the **Start** button is pressed in the Master/Slave emulation Test Setup pane.

However, the default filtering can be modified if required as described in Appendix 3.

- **Impairment Filtering**

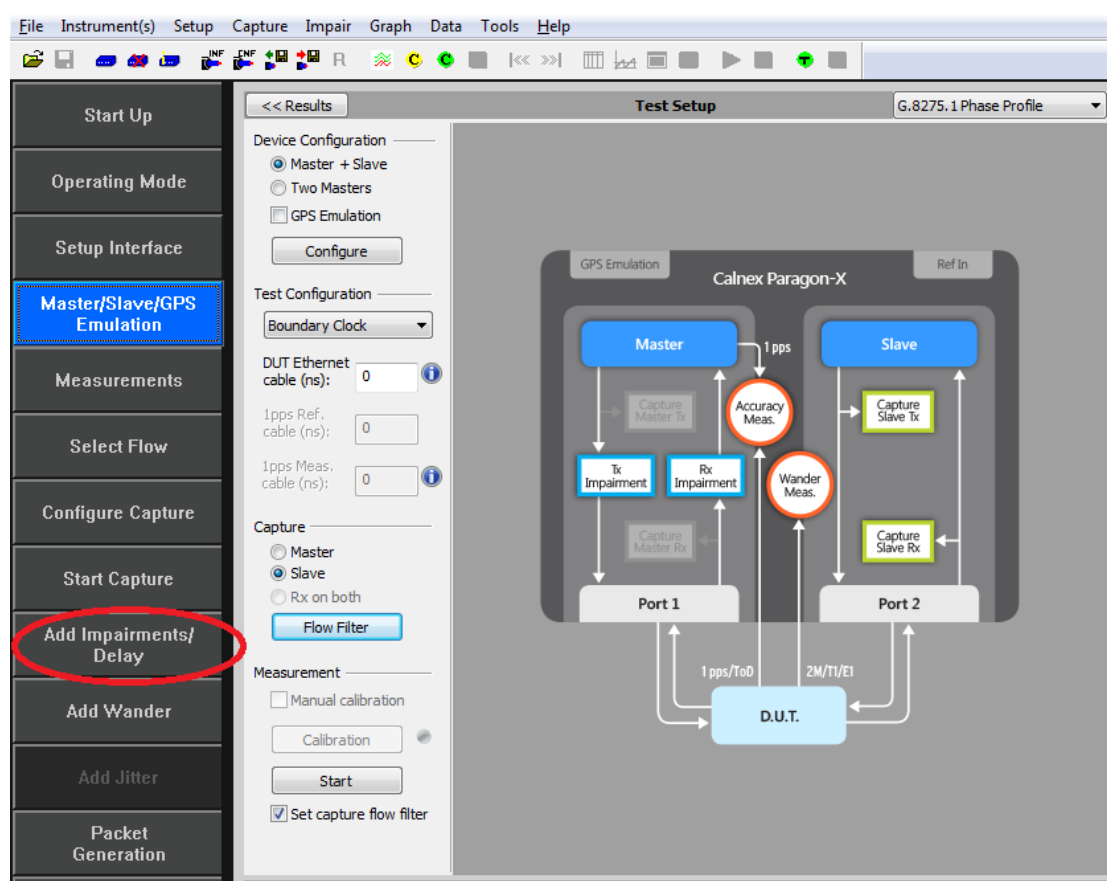
In Boundary Clock test, the impairment occurs on the **Master** side. Impairment filters must be set up before any impairment is performed.

Impairments are required in the following tests:

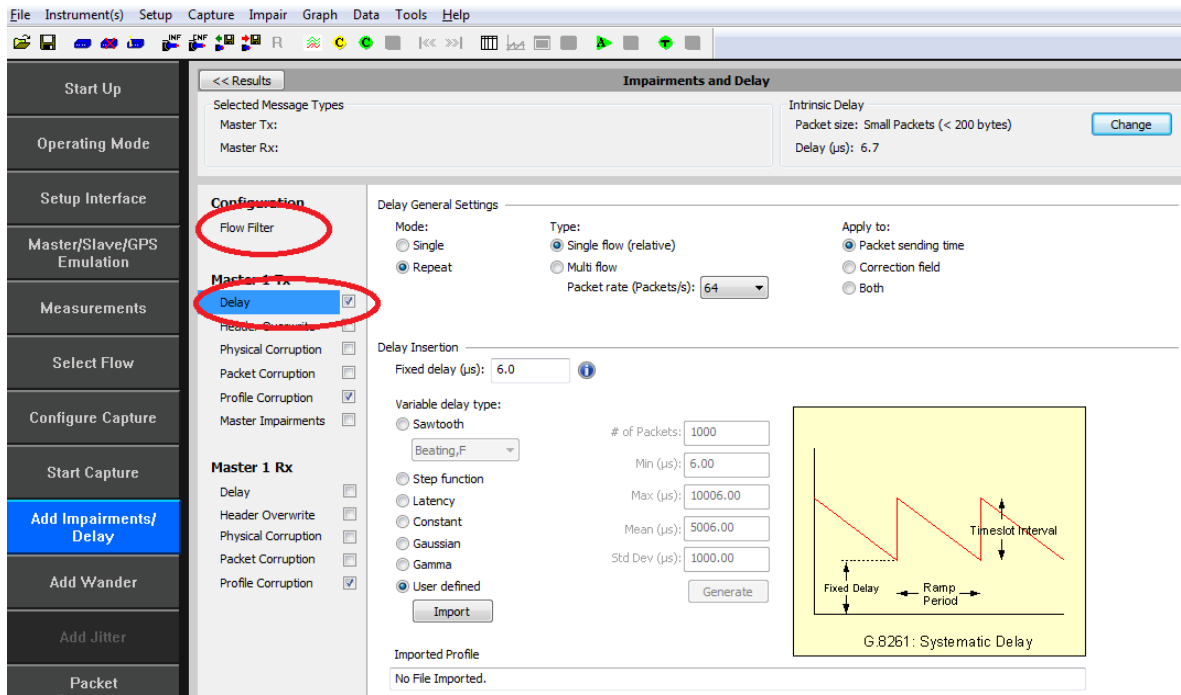
- Time Noise Tolerance – G.8273.2 Clause 7.2
- Time Noise Transfer – G.8273.2 Clause 7.3

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

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



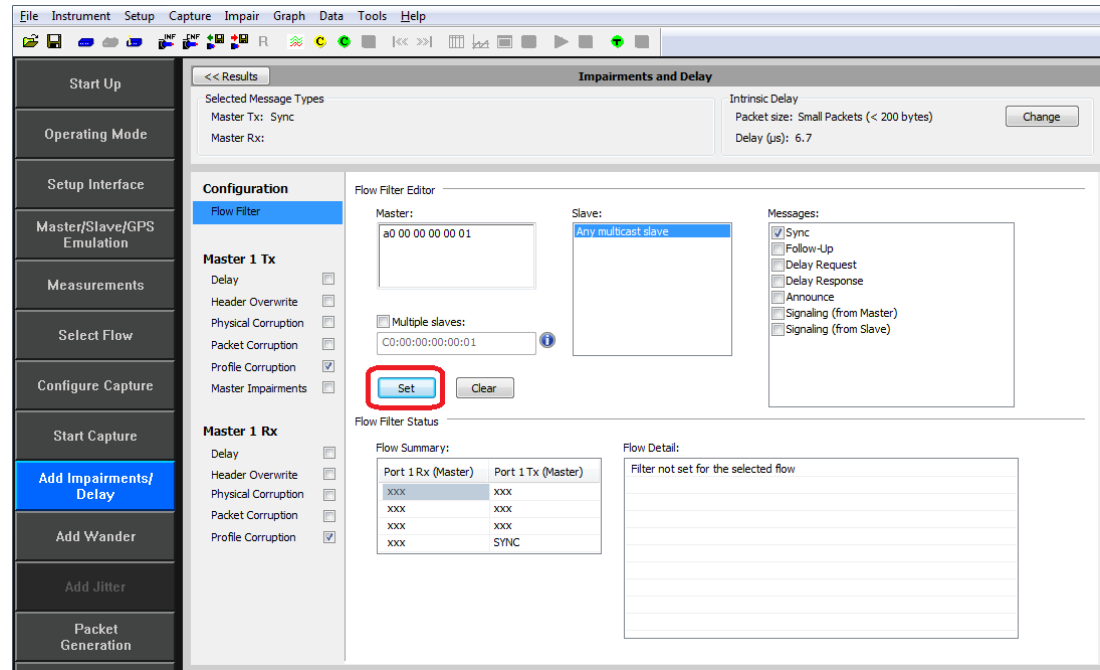
This will display the **Impairments** control screen. Impairments should be applied only in the forward direction (Master TX) to Sync messages.



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



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



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

Delay Patterns and Tools

T-BC 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

This can be accessed via the link:

https://www.calnexsol.co.uk/patternsandtools/patterns/1588/G.8273.2/G8273_2_Patterns.zip

- **Noise Transfer**

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

Enhanced Noise Transfer tool

This is installed as part of the Paragon-X software installation process and can be found in the installation directory for the Paragon-X application software under a sub-directory called **Noise Transfer**.

It is advisable to periodically check for later versions of this tool on the Calnex Solutions web-site under the following link:

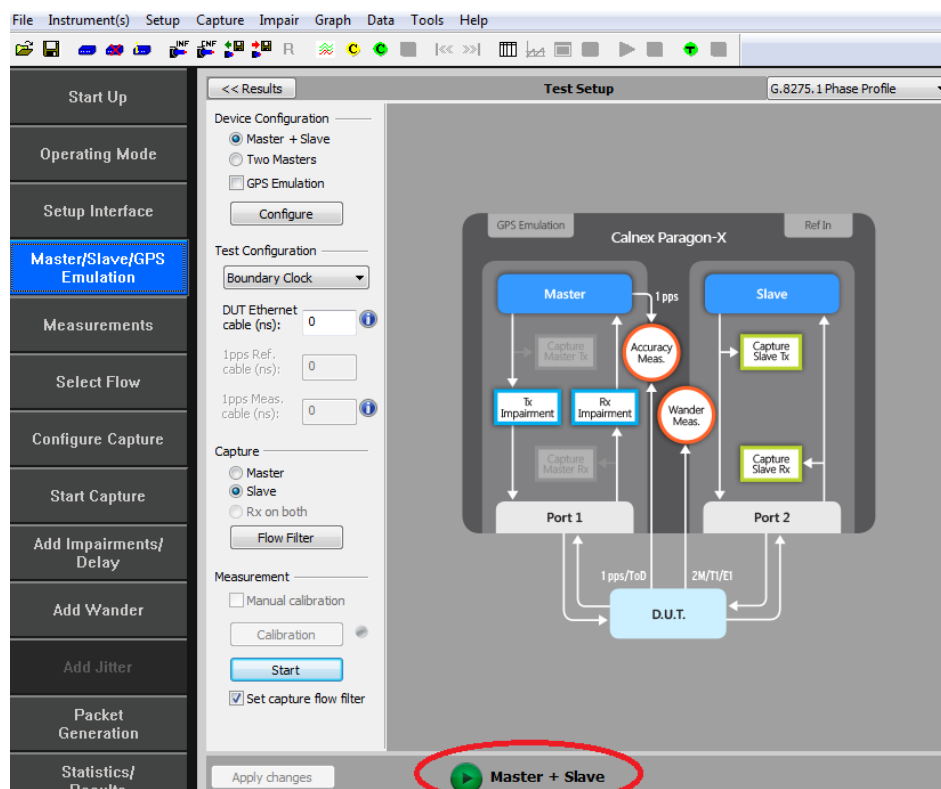
<https://www.calnexsol.co.uk/patternsandtools/tools/NoiseTransfer/>

Note: Although it is possible to run the tool from the installation location, it is recommended that it is copied to a user selected location and run from that location. The tool will try to update files within sub-directories of the base directory. The user may not have the correct permissions for such access in the Paragon-X installation directory.

3.7. Start of Master/Slave Emulation ready for test

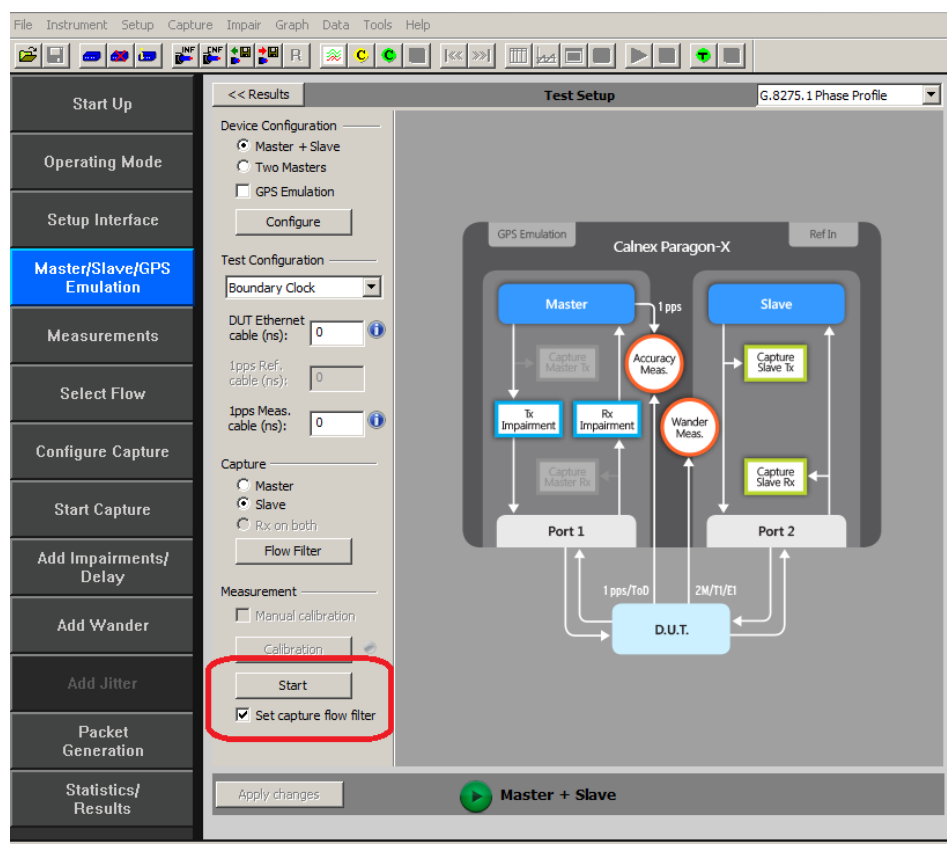
Master/Slave Emulation mode can now be re-started.

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



Notes on Measurements

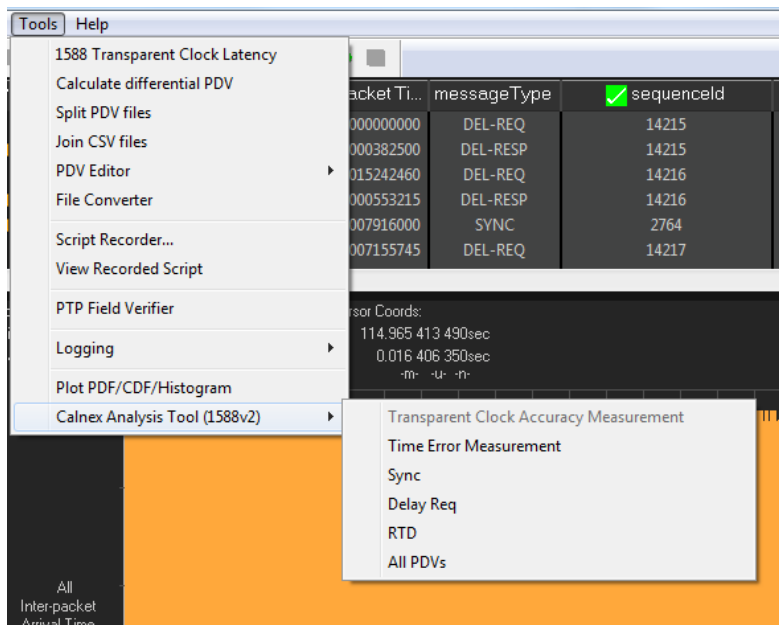
The tests in Sections 4 to 7 of this document detail the measurements that must be carried out to verify performance against the ITU-T G.8273.2 limits. Measurements are actioned using the **Start** measurement button and should be executed for the period as specified.



Wait for the T-BC 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 depending on the T-BC under test. It may even be recommended to wait longer e.g. overnight.

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

- To analyse the results select **Tools > Calnex Analysis Tool (1588v2) > Time Error Measurement**.

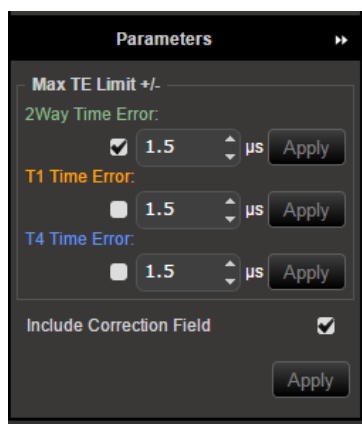


The Calnex Analysis Tool (CAT) provides G.8273.2 BC Conformance testing using the following metrics:

- **Time Error**
 - Two-way Time Error
- **Average Time Error (cTE)**
 - Two-way Constant Time Error
- **Dynamic Time Error**
 - Two way Filtered MTIE
 - Two way Filtered TDEV

- **PTP CorrectionField**

It is possible that the T-BC sends non-zero CorrectionField values as an accuracy enhancement to its own transmitted timestamps (ask vendor). Time Error results can be analysed with or without PTP CorrectionField, highlighting the impact of its implementation. Unless specifically required to exclude CorrectionField from calculations, it is recommended to leave the **Include CorrectionField** box ticked (default state).



- **1pps versus PTP**

It is important to prove performance via the egress PTP performance as this is the signal that is used downstream to recover the time. If provisioned, the 1pps output from the T-BC DUT should accurately reflect the performance of the timing being delivered by the PTP packet flow. Once in service, the T-BC performance may be monitored by using 1pps so it is important to also verify its accuracy.

4. Noise Generation – G.8273.2 Clause 7.1

Test Description

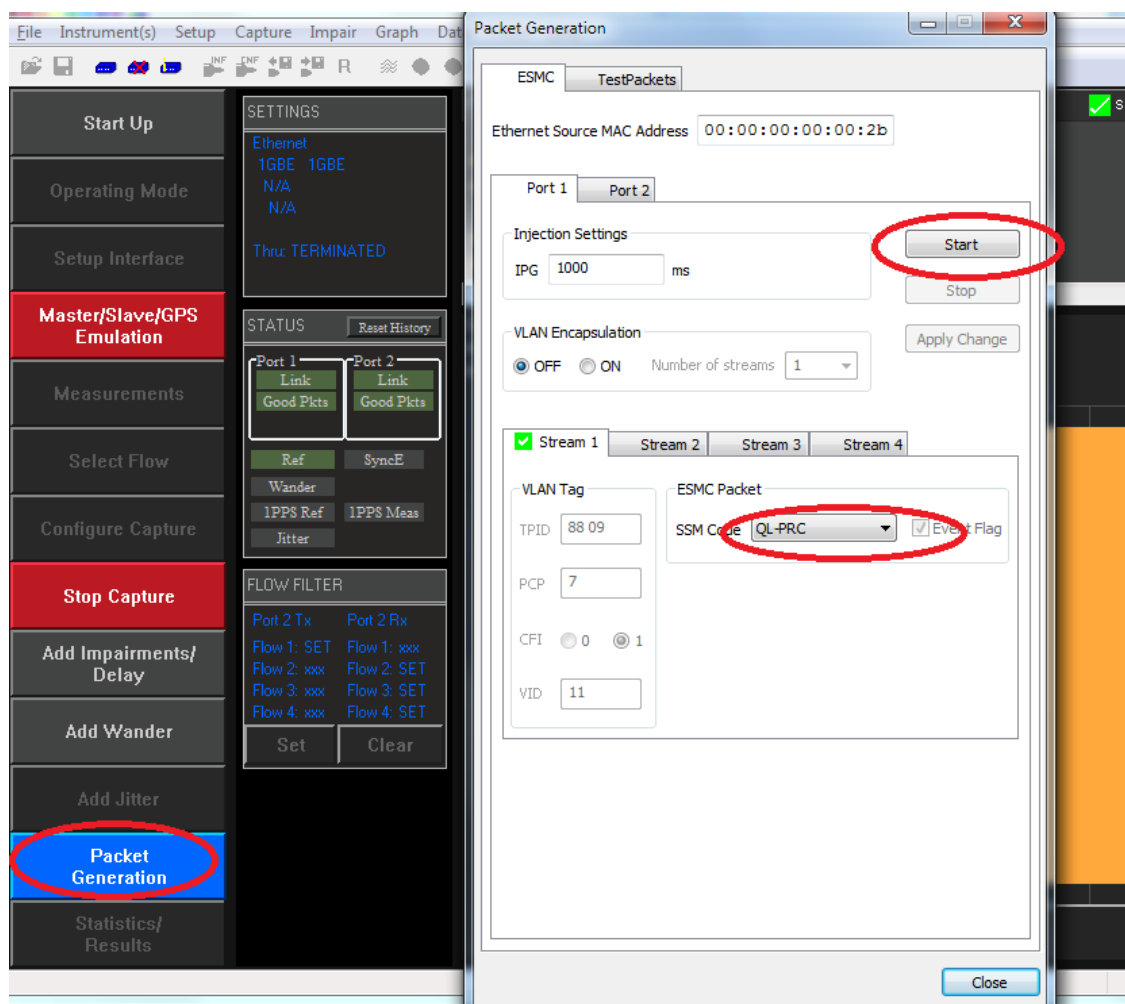
The noise generation of a T-BC is the amount of noise produced at the output of the T-BC when there is an ideal input reference packet timing signal. The noise generation has two components, the constant time error (cTE) and the dynamic time error noise generation (dTE).

Measurement Process

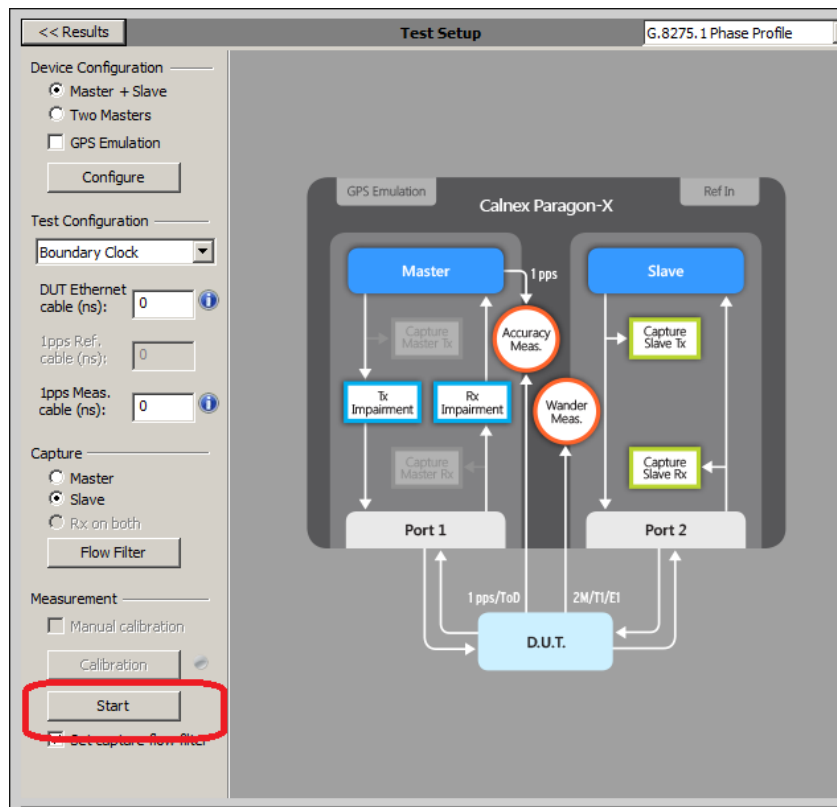
The standard specifies that the test should be carried out with both PTP and SyncE active. It is possible to cater for non-SyncE devices (described in Section 4.2) but this is outside the remit of Standards conformance.

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.**

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



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

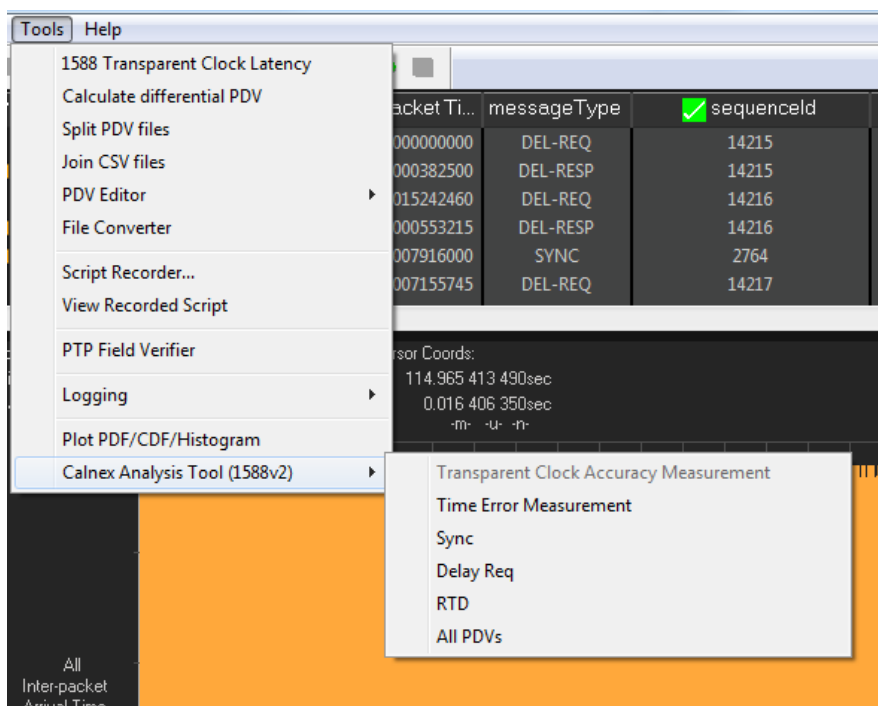


- Allow the capture to run for at least **2000s**. Then use the **Stop Capture** button to stop the capture.

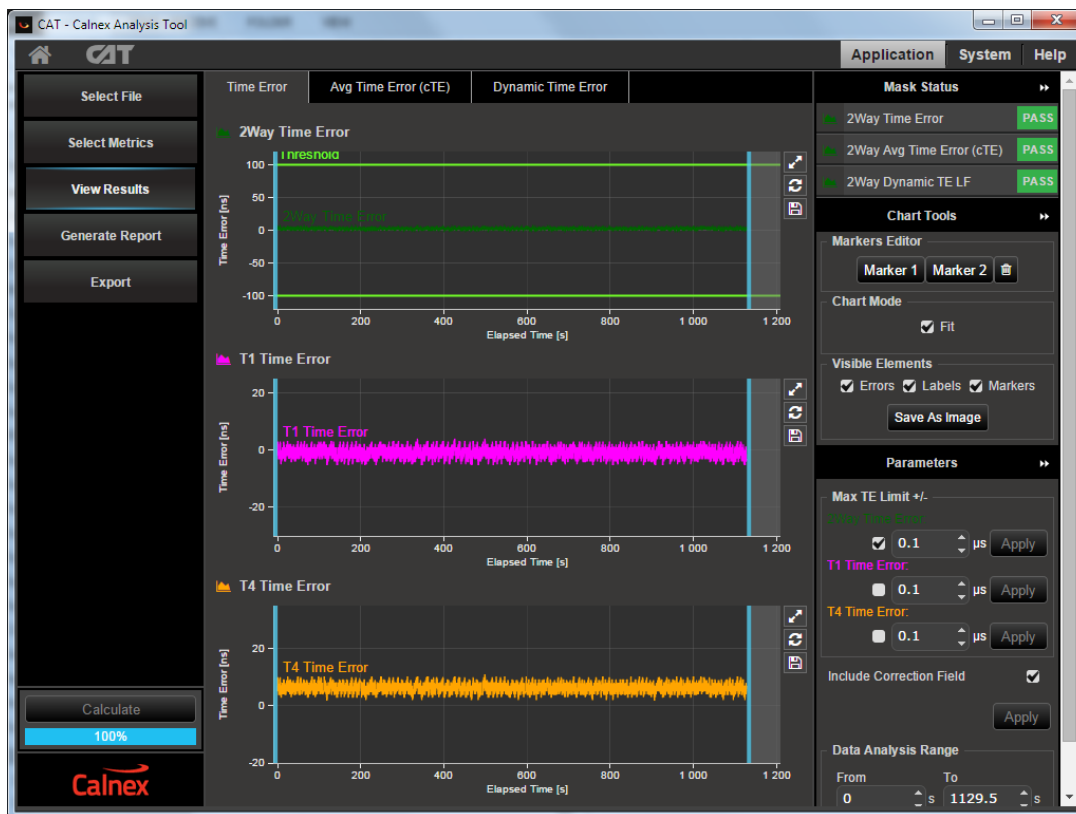
Measurements: Time Error results can either be viewed during capture or after capture has been stopped.

Time Error Results (Constant Time Error)

- Select **Tools > Calnex Analysis Tool (1588v2) > Time Error Measurement**.

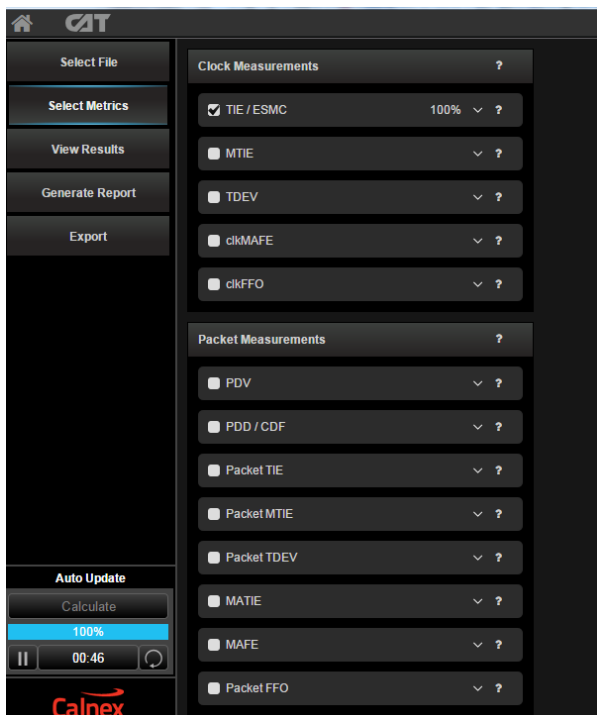


The **Calnex Analysis Tool** will launch and display the **Time Error** metrics tab.

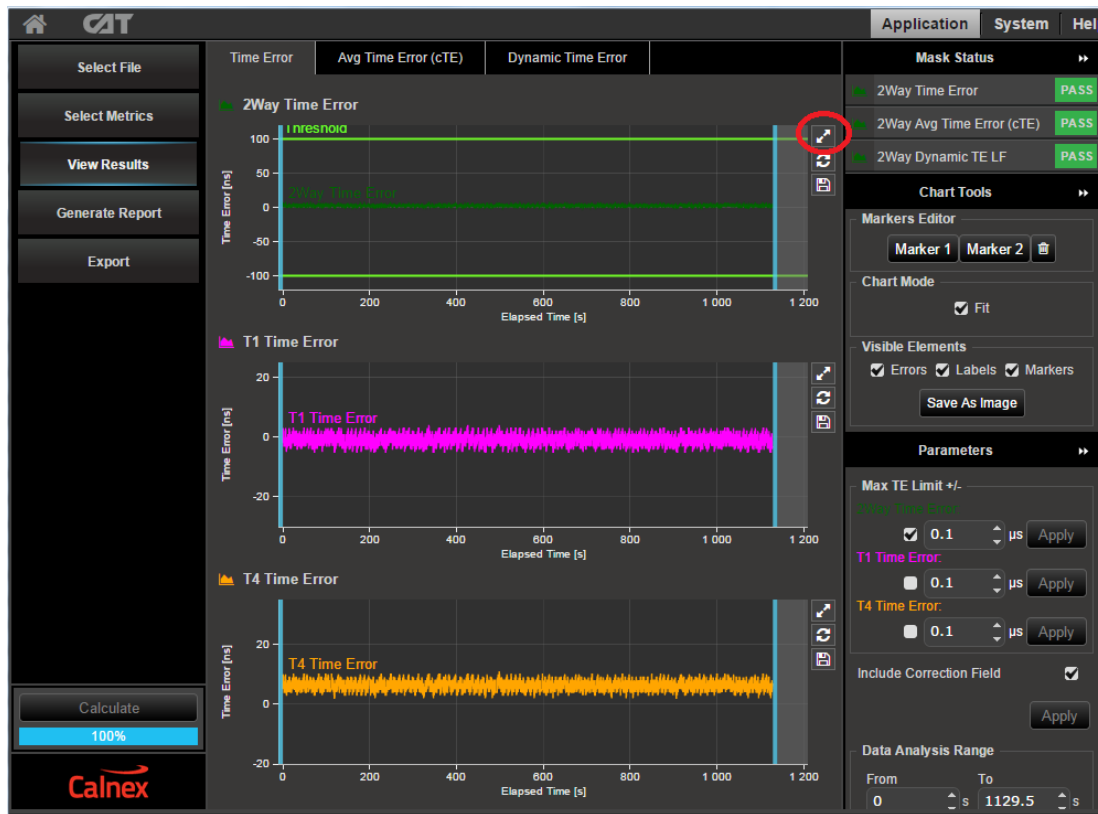


For PTP based data this will include the metrics **Time Error**, **Avg Time Error (cTE)** and **Dynamic Time Error**.

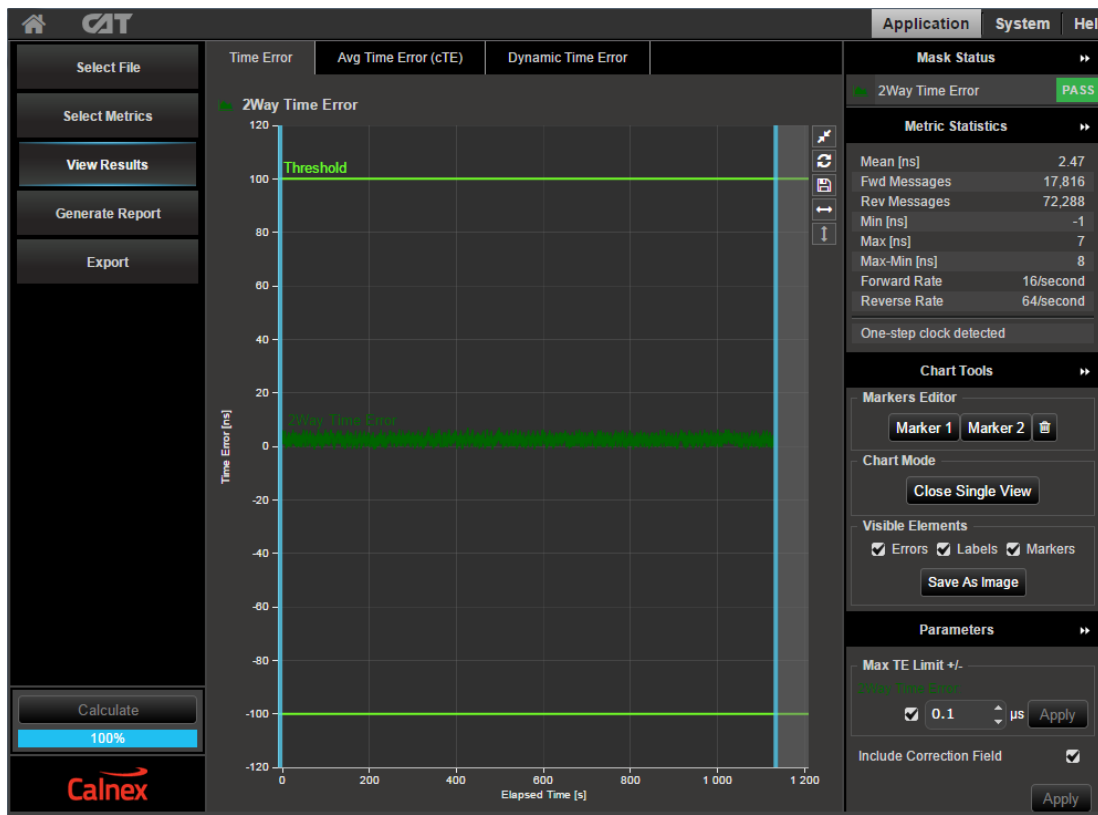
Note: The complete set of metrics can be viewed by expanding the appropriate list in the Measurement Analysis block by clicking on the + symbol against each metric.



Individual graphs can be displayed by clicking on the highlighted expand button below



This will display:



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

5. Select the '**Avg Time Error (cTE)**' metric tab and this will 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.



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

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

The Threshold can be changed in the **Avg Time Error (cTE)** tab as shown below.



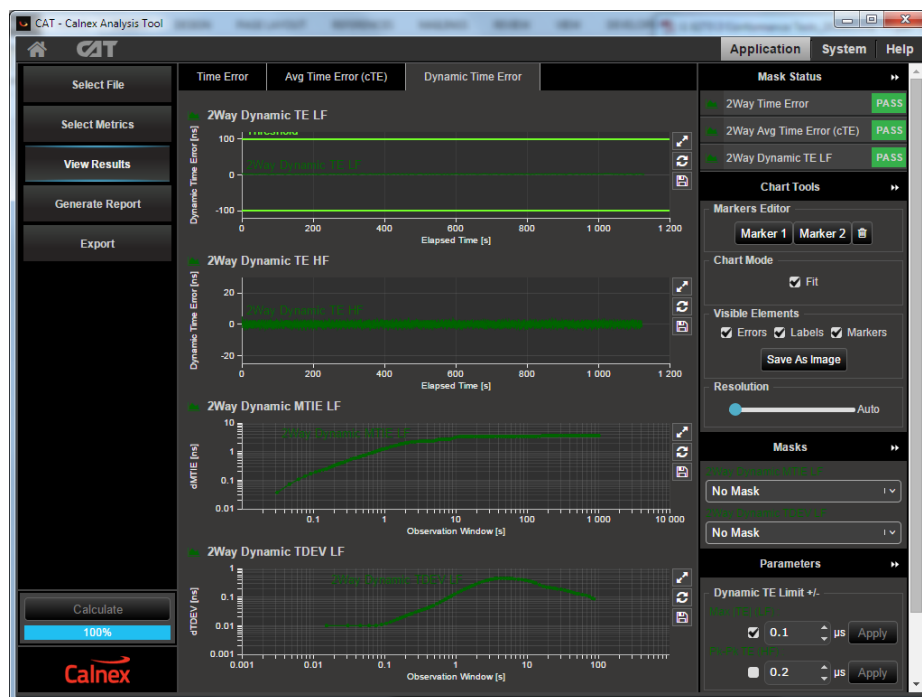
Further Analysis (Optional)

- 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.

Time Error Results (Dynamic Time Error)

1. 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.



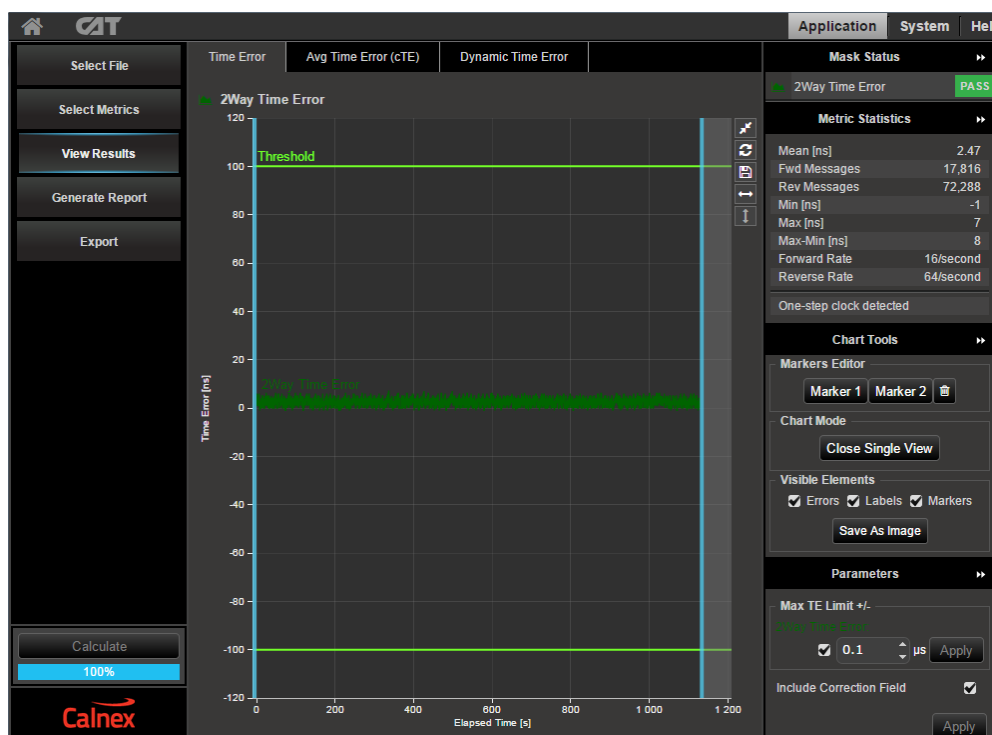
2. Compare the results against the ITU-T limits by loading the **G.8237.2 dTE Gen Const Temp** masks.



3. 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|TEI)

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



3. Set the Max|TEI limit to either **100ns** for **Class A** devices or **70ns** for **Class B** devices. This will change the **Thresholds** on the graph.
4. 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 spec 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 if the clock can maintain network limits at the output with maximum noise at the input.

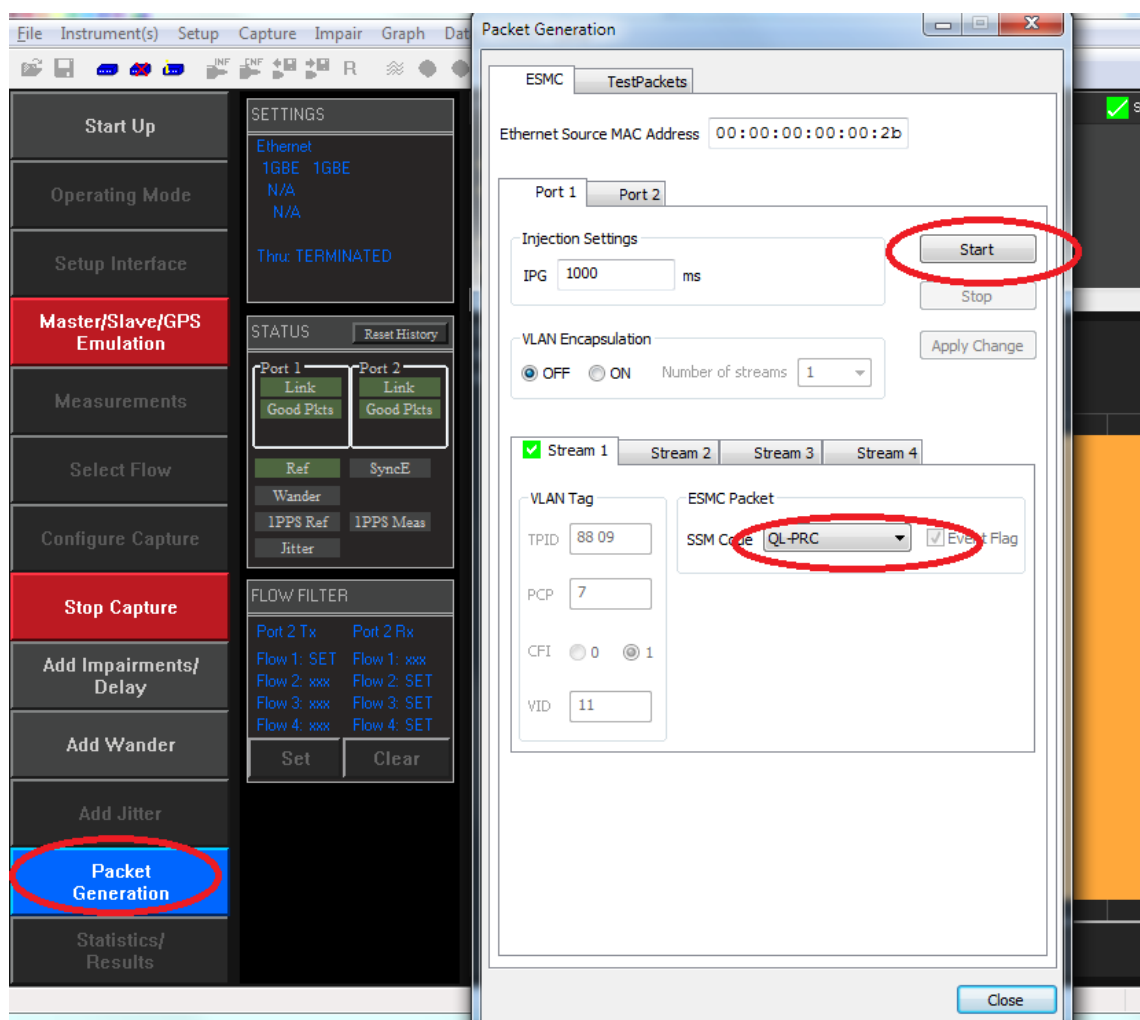
Measurement Process

The standard recommends testing in combined hybrid mode involving both PTP and SyncE input. This is reflected in the test procedure 5.1 detailed below. However, the test is also applicable to the situation where no SyncE signal is provided. This is reflected in test procedure 5.2.

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

5.1. Combined PTP and SyncE

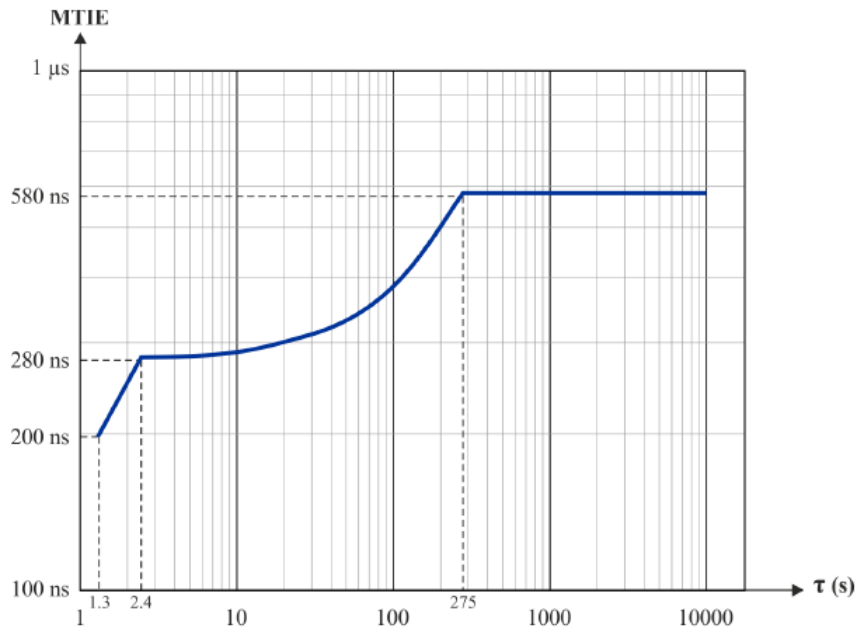
1. To enable SyncE ESMC Generation, select **Packet Generation** with **SSM code** of **QL_PRC**.
2. To start ESMC generation press the **Start** button.



Adding an Impairment Pattern

The Noise Tolerance Test in G.8273.2 Section 7.2 involves applying a known pattern to **either** the forward or reverse PTP flow in order to check that the DUT maintains its reference lock.

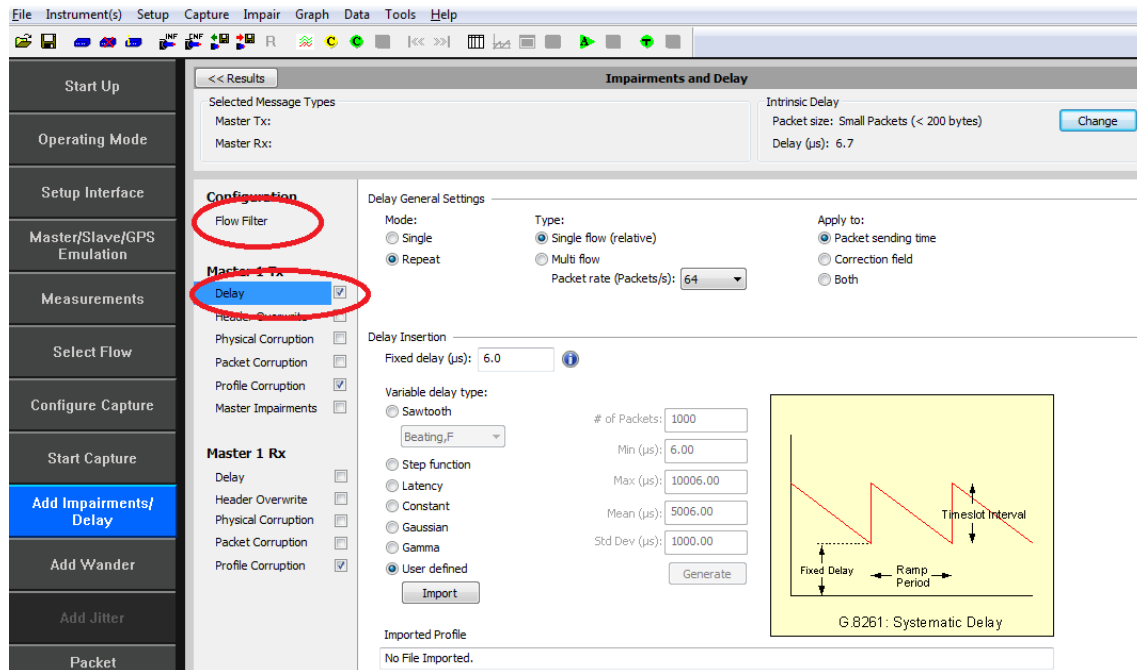
A PDV pattern with the following characteristics should be applied to the PTP input in a single direction.



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.

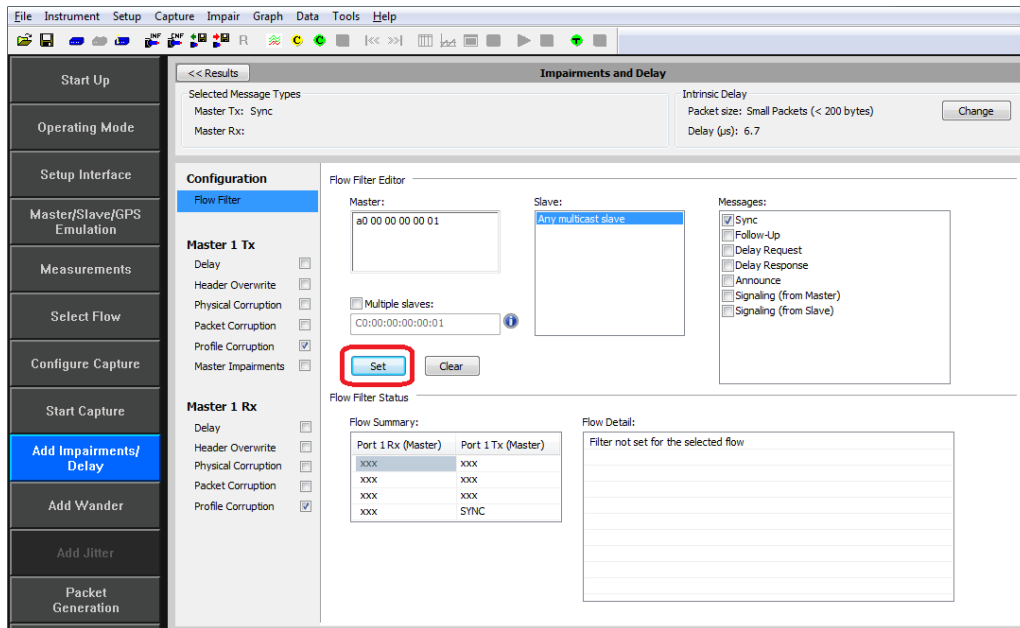
Note: Store the downloaded pattern in a known location on your PC so that you can use it to control the test.

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

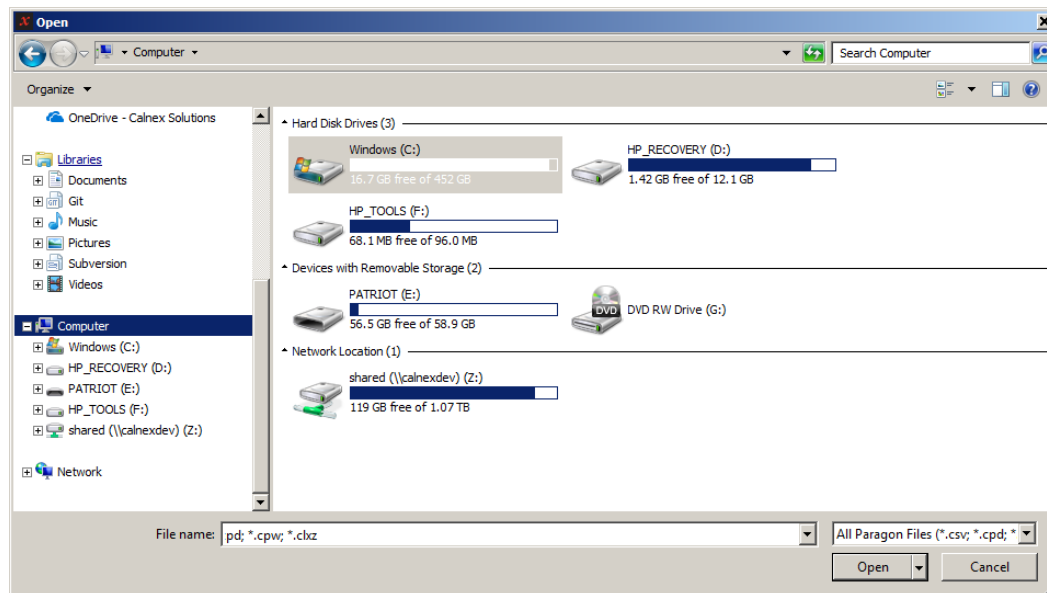


4. Enable the **Master TX Delay** feature using the tick box shown above and clicking on **Delay**.

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



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.

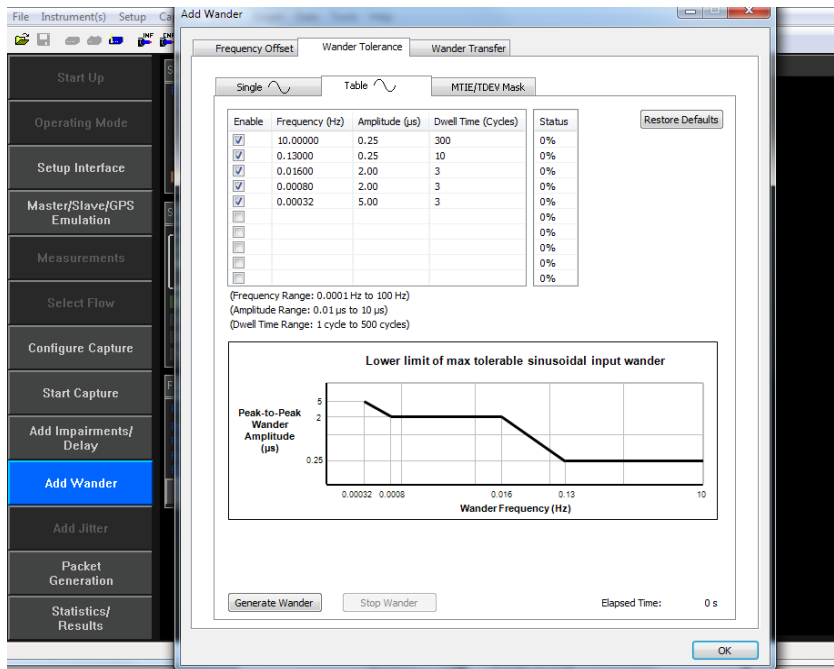


7. Once the file has been loaded, start the impairment by selecting

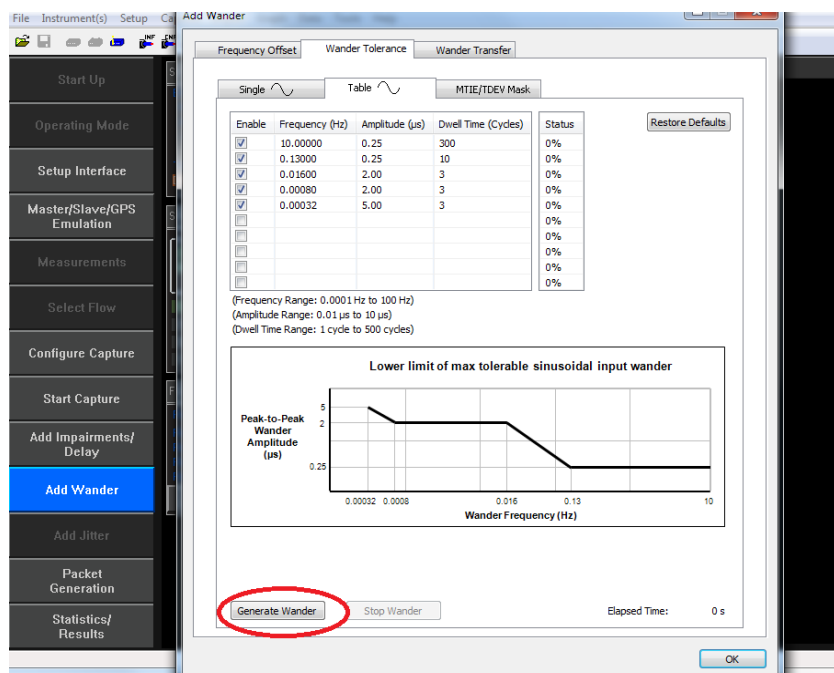


Add SyncE Wander

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.



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



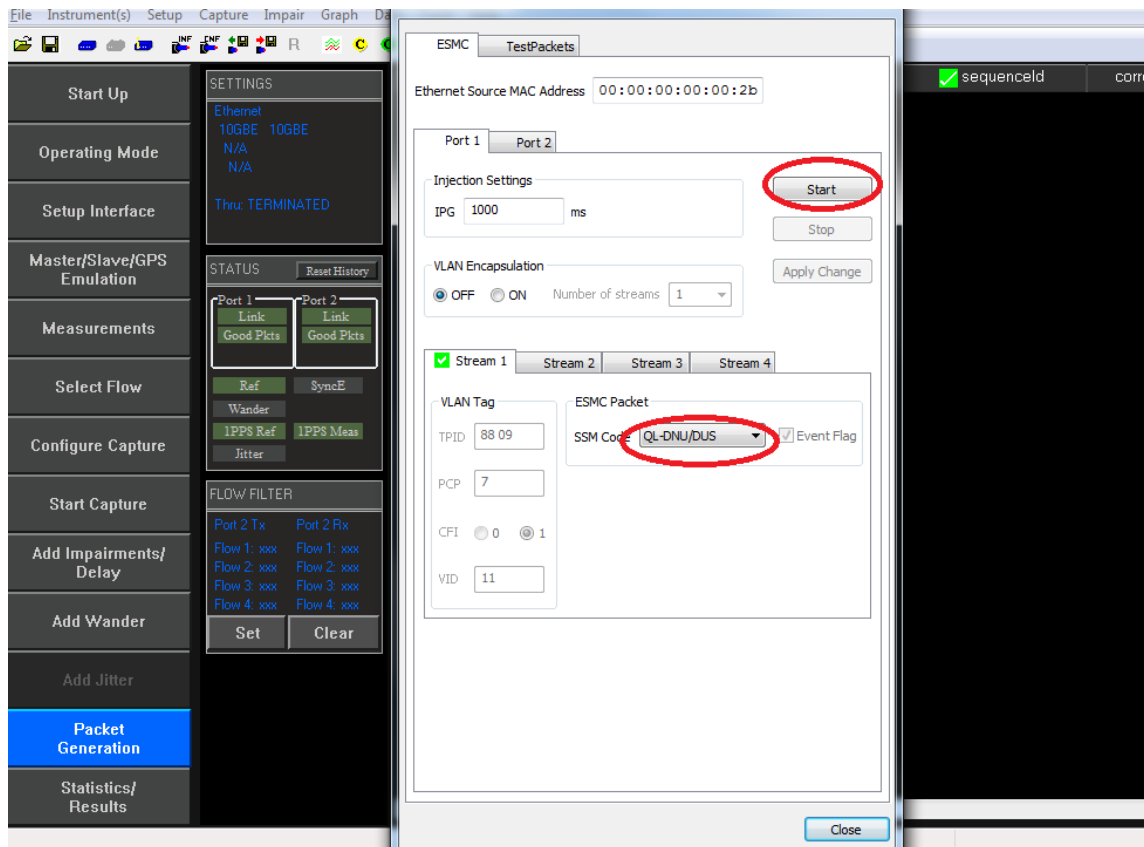
10. Select **Start Capture** to begin the measurement.
11. Once Wander Generation has finished and at least 1000s have passed, select **Stop Capture** to end the measurement.

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).

5.2. PTP only

1. Repeat steps in Section 5.1 without a SyncE reference.
2. To disable SyncE, select **Packet Generation** with **SSM code** of **QL_DNU**.
3. To start ESMC generation press the **Start** button.



6. Time Noise Transfer – G.8273.2 Clause 7.3

Test Description

This test measures how Time Error on the T-BC input is transferred to its output.

Measurement Process

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

- configures the Paragon-X
- applies the appropriate noise patterns to the T-BC input as defined in G.8273.2 Amendment 1 (Appendix VI)
- measures the T-BC 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

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 PTP 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).

Point	Test Freq (Hz)	Pk-Pk I/P Ampl (ns)	Pk-Pk O/P Ampl ± 10 ns added noise allowance (ns)		Duration (s)
			Max	Min	
0	0.00390625	200	215	130	800
1	0.0078125		215	130	
2	0.015625		215	130	400
3	0.03125		215	130	250
4	0.0615625		215	n/a	
5	0.123125		140		
6	0.24625		90		
7	0.4925		50		
8	0.985		35		
9	1.985		25		

Table 1 Maximum and Minimum Expected Output Amplitudes at Test Frequencies for PTP-to-PTP and PTP-1PPS Noise Transfer Measurement

The table lists the permitted limits for each frequency. These limits include an allowance for device noise generation and test 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.

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:

<https://www.calnexsol.co.uk/patternsandtools/>

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 sub-directories.

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

The default settings for the Tcl script are available in the **Defaults.tcl** 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.tcl** 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
GuiIp	The IP address of the PC hosting the Paragon-X application	localhost	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

Table 2. Instrument Settings

Setting	Description	Default	Allowed Values
Type	Test type to be performed (see note 4)	PTP-BOTH	PTP-BOTH, PTP-PTP, PTP-1PPS, SyncE-BOTH, SyncE-PTP, SyncE-1PPS
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 Tcl file containing configuration parameters (see Error! Reference source not found. section in the Calnex Noise Transfer Script - Getting Started Guide [CX5036])	""	Valid Tcl 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:

1. **GuiIp:** 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 5ns per metre; for optical fibre, the delay will be approximately 4ns per metre.
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.
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 "1 7". 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 vary 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 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 PTP-PTP LineRate 1GBE Interface OPTICAL
```

```
"C:\Tcl\bin\tclsh86.exe" G.8273.2.tcl InstrIp 192.168.4.100 Type PTP-PTP Reference EXT_10M
```

```
c:\Scratch\Script G.8273.2>"C:\Tcl\bin\tclsh86.exe" G.8273.2.tcl Type PTP-PTP InstrIp 192.168.207.101 SettlingTime 200
*****
Enhanced Noise Transfer 4.00.00
*****
Parameters:
  InstrIp - 192.168.207.101
  GuiIp - localhost
  GuiPort - 9000
  Type - PTP-PTP
  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: 2017-11-20 12-07-56

Results will be stored in: "Results\Results PTP-PTP 2017-11-20-T-12-07-56"
Log will be stored in: "Logs\Log PTP-PTP 2017-11-20-T-12-07-56.txt"

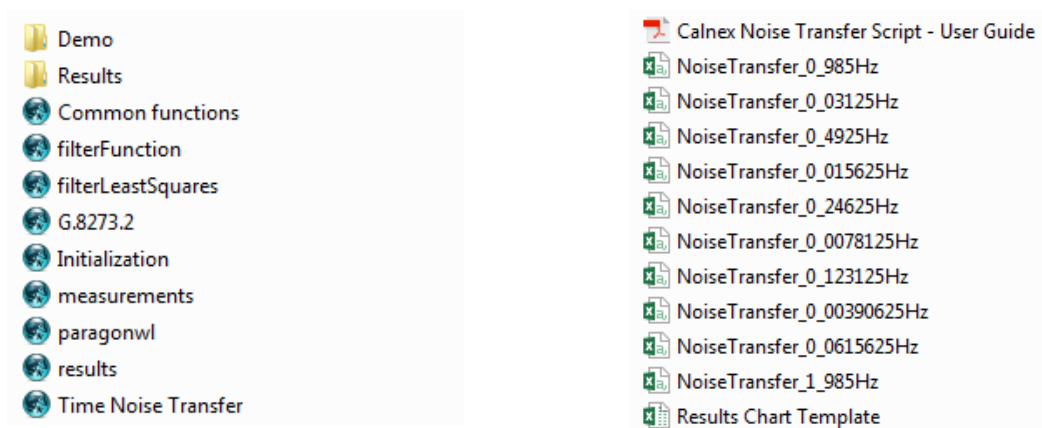
connecting to GUI localhost:9000
connected to GUI
connecting to instrument 192.168.207.101:9990
connected to instrument
X.10.38.09;FIRMWARE
CALNEX-SOLUTIONS,Paragon-X.00012054,SERVER=X.10.38.09;FIRMWARE=E.14.81;sync=C04F;sync=C04F;oam=E007;oam=E007
```

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 - 192.168.207.101
  GuiIp - localhost
  GuiPort - 9000
  Type - PTP-PTP
  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
```

Results

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



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-PTP 2017-11-20-T-11-57-41 20/11/2017 11:57 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.

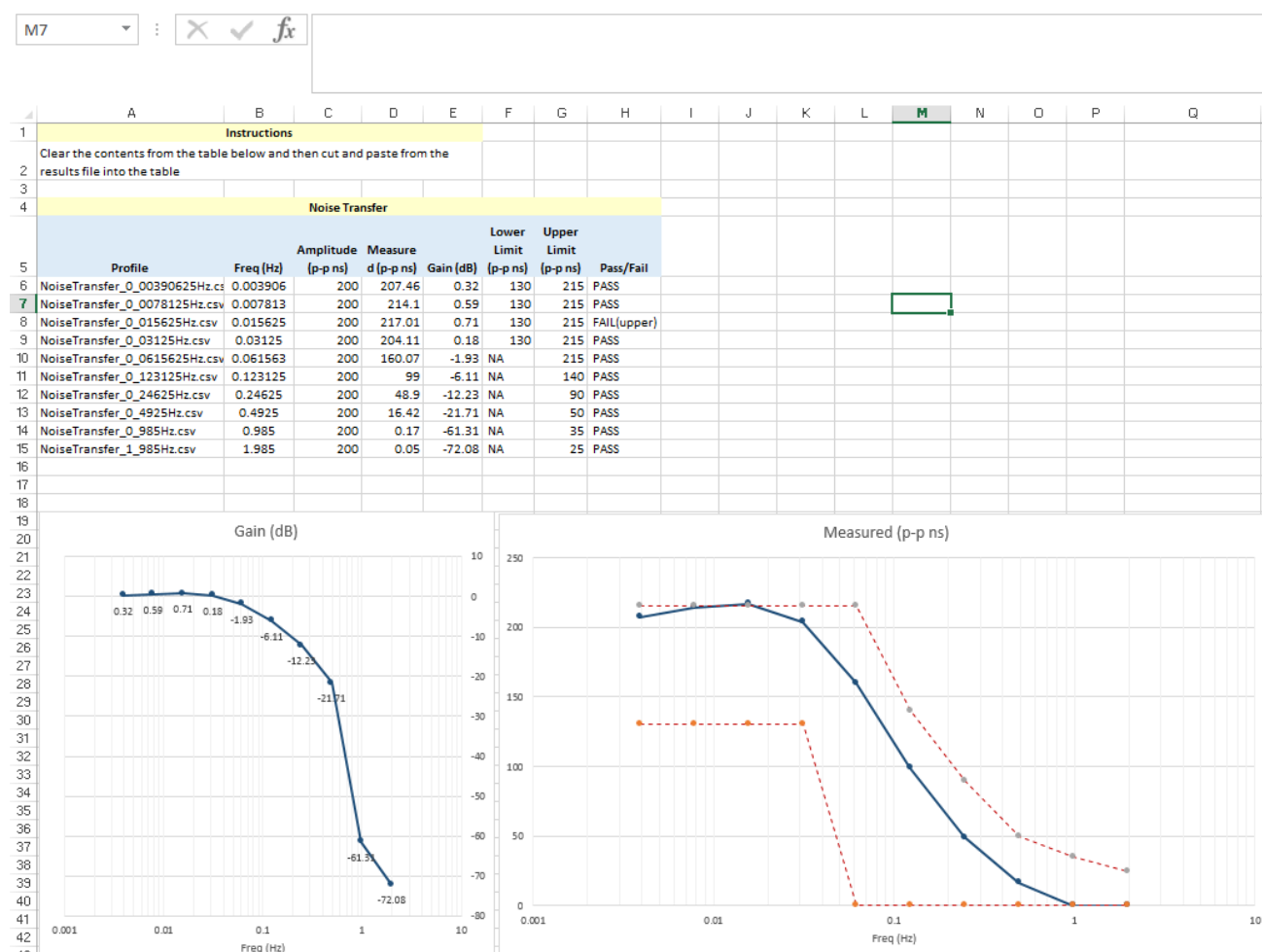
For each pattern used in the script, the following information will be recorded in the **Results.csv** file:

- Pattern filename (for **PTP-PTP** and **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-PTP** results file contains the following information:

Noise Transfer (PTP-PTP)	20/11/2017 12:08							
Profile	Freq (Hz)	Amplitude	Measured	Gain (dB)	Lower Lim	Upper Lim	Pass/Fail	
NoiseTransfer_0_00390625Hz	0.00390625	200	207.46	0.32	130	215	PASS	
NoiseTransfer_0_0078125Hz	0.0078125	200	214.1	0.59	130	215	PASS	
NoiseTransfer_0_015625Hz	0.015625	200	217.01	0.71	130	215	FAIL(upper)	
NoiseTransfer_0_03125Hz	0.03125	200	204.11	0.18	130	215	PASS	
NoiseTransfer_0_0615625Hz	0.0615625	200	160.07	-1.93	NA	215	PASS	
NoiseTransfer_0_123125Hz	0.123125	200	99	-6.11	NA	140	PASS	
NoiseTransfer_0_24625Hz	0.24625	200	48.9	-12.23	NA	90	PASS	
NoiseTransfer_0_4925Hz	0.4925	200	16.42	-21.71	NA	50	PASS	
NoiseTransfer_0_985Hz	0.985	200	0.17	-61.31	NA	35	PASS	
NoiseTransfer_1_985Hz	1.985	200	0.05	-72.08	NA	25	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.



NOTE: For the cases where PTP is being measured, G.8273.2 Amendment 1 (Appendix VI) also suggests that a filter is applied to the measured output to address potential measurement uncertainty due to noise on the packet interface and the intrinsic noise generation of the T-BC. The script implements the filter using least-squares estimation (one of the filter techniques listed in Amendment 1).

6.2. SyncE to PTP 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 test 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 (ns)	Pk-Pk O/P Ampl ±10 ns added noise allowance (ns)		Duration (s)
			Max	Min	
0	0.00390625	250	30	n/a	800
1	0.0078125		50		
2	0.015625		85		400
3	0.03125		145		
4	0.0615625		270	165	250
5	0.123125				
6	0.24625				
7	0.4925				
8	0.985				
9	1.985				
10	3.985				
11	7.985			n/a	

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-PTP Noise Transfer as for PTP-PTP 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 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 Instrlp 192.168.4.100 Type SyncE-PTP LineRate 1GBE Interface OPTICAL
```

```
"C:\Tcl\bin\tclsh86.exe" G.8273.2.tcl Instrlp 192.168.4.100 Type SyncE-PTP Reference EXT_10M
```

Results

As for the PTP-PTP Noise Transfer, all files are stored relative to the folder in which the script is being run. The root folder contains the Tcl script files, the PTP patterns, the Results Chart Template and the ENT user guide. 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-PTP. For example:

 Results SyncE-PTP 2017-11-21-T-12-00-47 20/12/2017 13:13 File folder

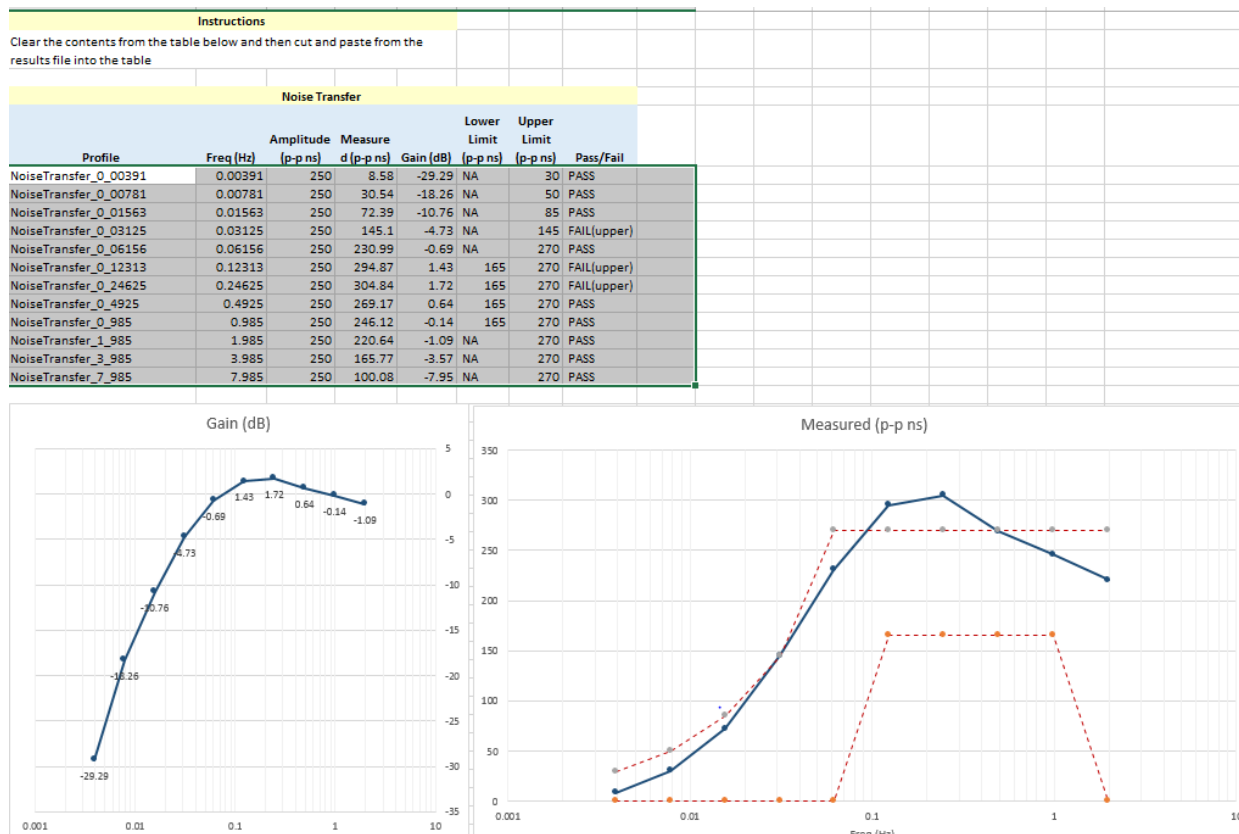
Each sub-folder will contain the capture files, the generated (interim) results files and a final results file **Results.csv**, which contains the overall results for all of the test points. For each pattern used in the script, the following information will be recorded in the **Results.csv** file:

- Pattern filename for frequency (**SyncE-PTP**, **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-PTP) #####							
Profile	Freq (Hz)	Amplitude	Measured	Gain (dB)	Lower Lim	Upper Lim	Pass/Fail
NoiseTransfer_0_00391	0.00391	250	8.58	-29.29	NA	30	PASS
NoiseTransfer_0_00781	0.00781	250	30.54	-18.26	NA	50	PASS
NoiseTransfer_0_01563	0.01563	250	72.39	-10.76	NA	85	PASS
NoiseTransfer_0_03125	0.03125	250	145.1	-4.73	NA	145	FAIL(upper)
NoiseTransfer_0_06156	0.06156	250	230.99	-0.69	NA	270	PASS
NoiseTransfer_0_12313	0.12313	250	294.87	1.43	165	270	FAIL(upper)
NoiseTransfer_0_24625	0.24625	250	304.84	1.72	165	270	FAIL(upper)
NoiseTransfer_0_4925	0.4925	250	269.17	0.64	165	270	PASS
NoiseTransfer_0_985	0.985	250	246.12	-0.14	165	270	PASS
NoiseTransfer_1_985	1.985	250	220.64	-1.09	NA	270	PASS
NoiseTransfer_3_985	3.985	250	165.77	-3.57	NA	270	PASS
NoiseTransfer_7_985	7.985	250	100.08	-7.95	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 Clause 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-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:

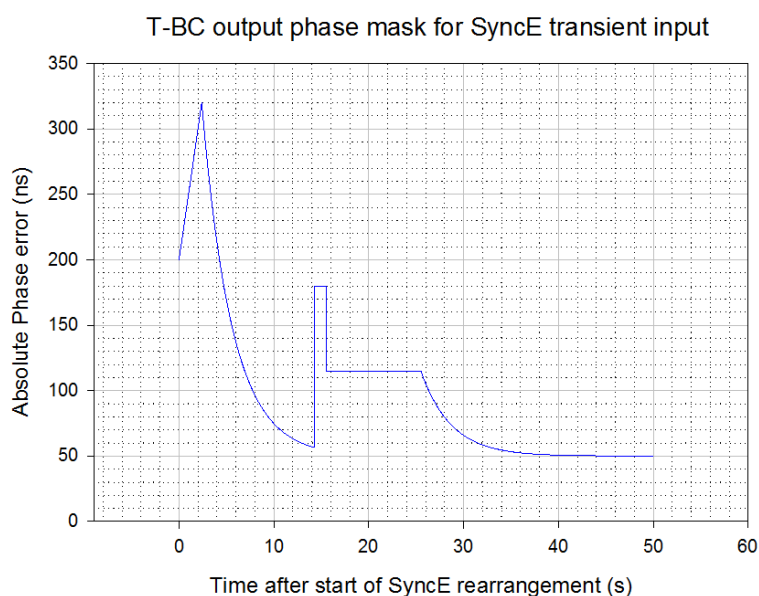


Figure B.1 from G.8273.2 Annex B – Phase error mask during a SyncE transient

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).

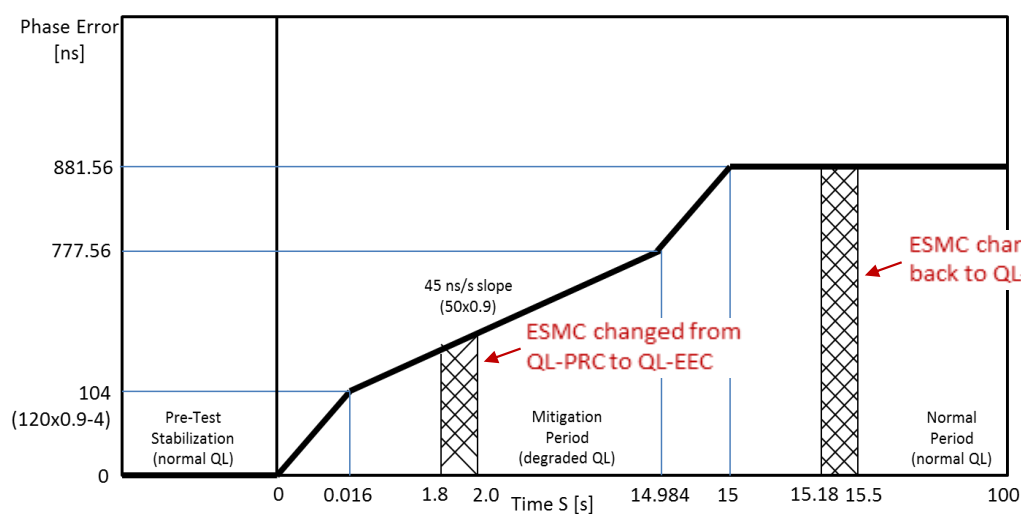


Fig. III.2 from G.8273 Appendix III – SyncE Transient Input Pattern

Measurement Process

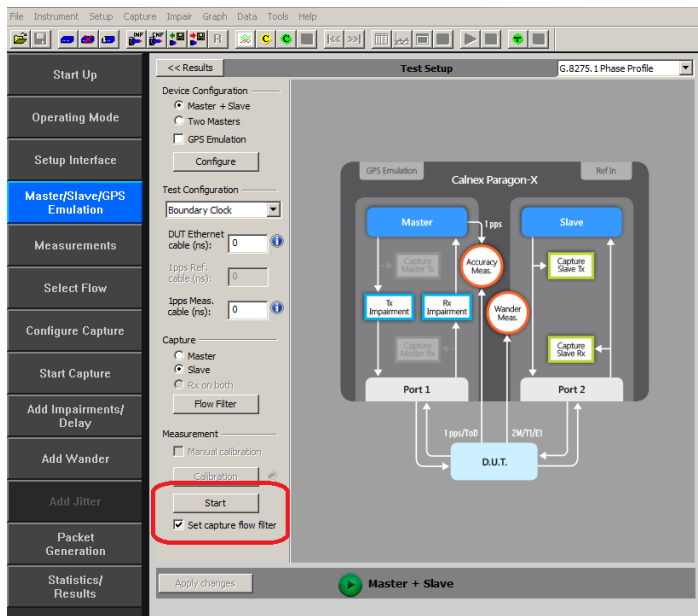
The standard requires testing in combined hybrid mode involving both PTP and SyncE input. This is reflected in the test procedure 7.1 detailed below.

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

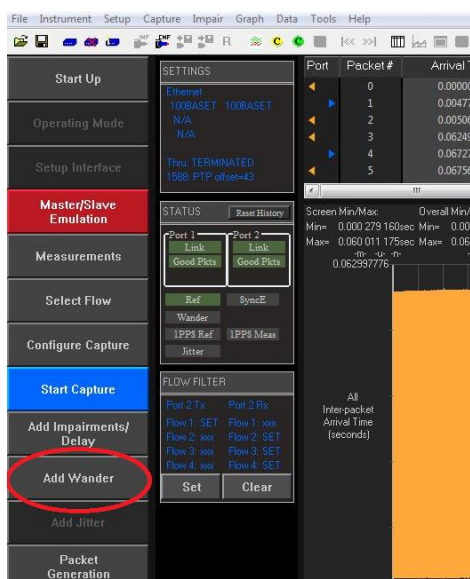
1. **Start** Master/Slave Emulation.



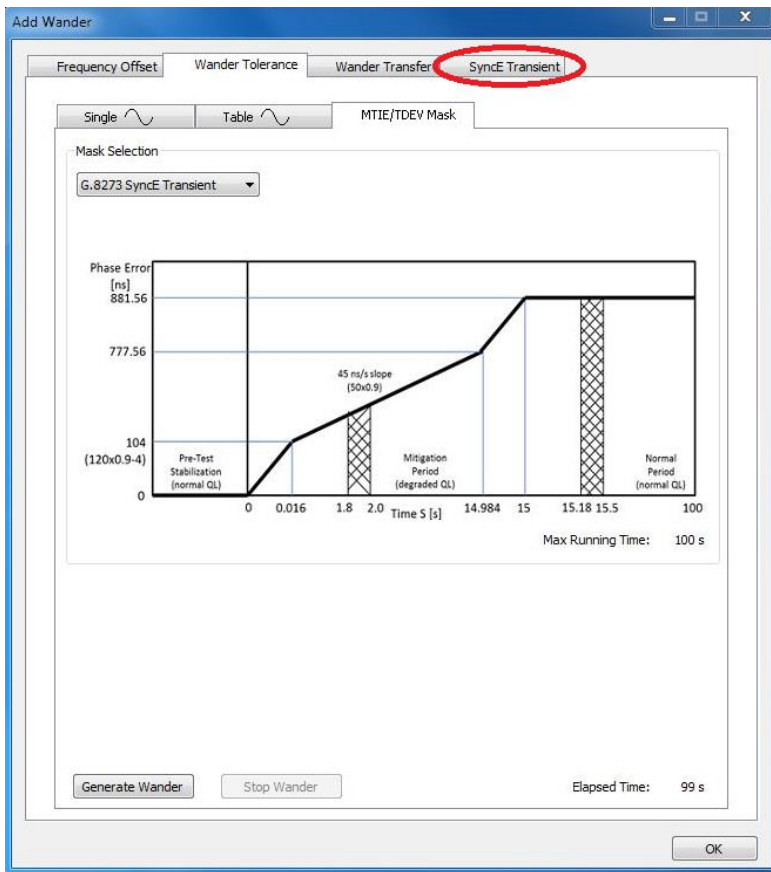
Wait for the T-BC Slave to lock to the Paragon-X emulated Master and stabilize before making any measurements. **Clock settling time is important.** Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several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

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

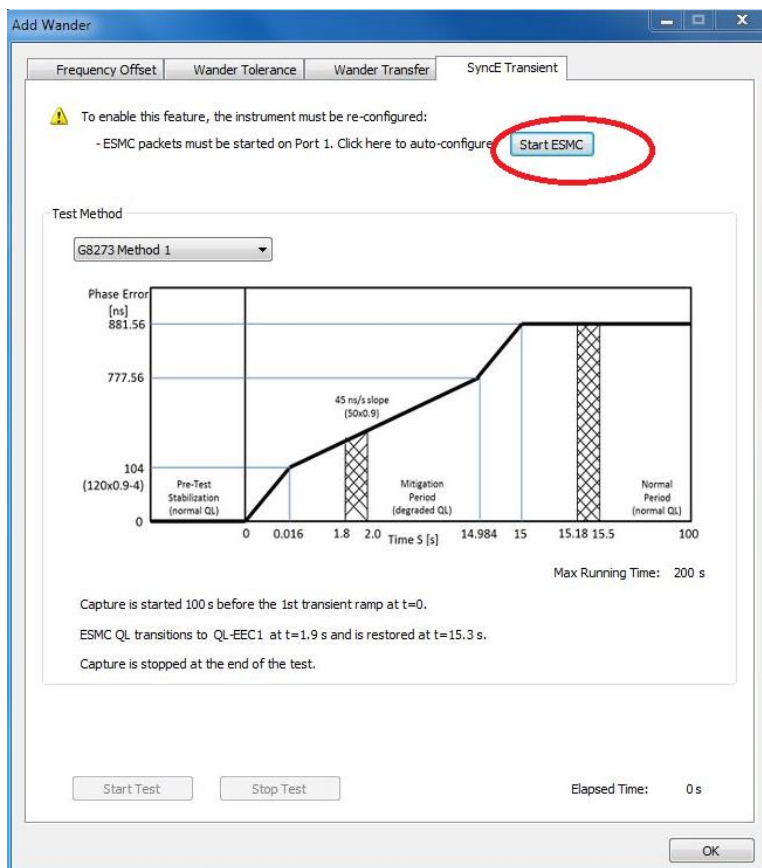
2. After device has settled select the **Add Wander** button.



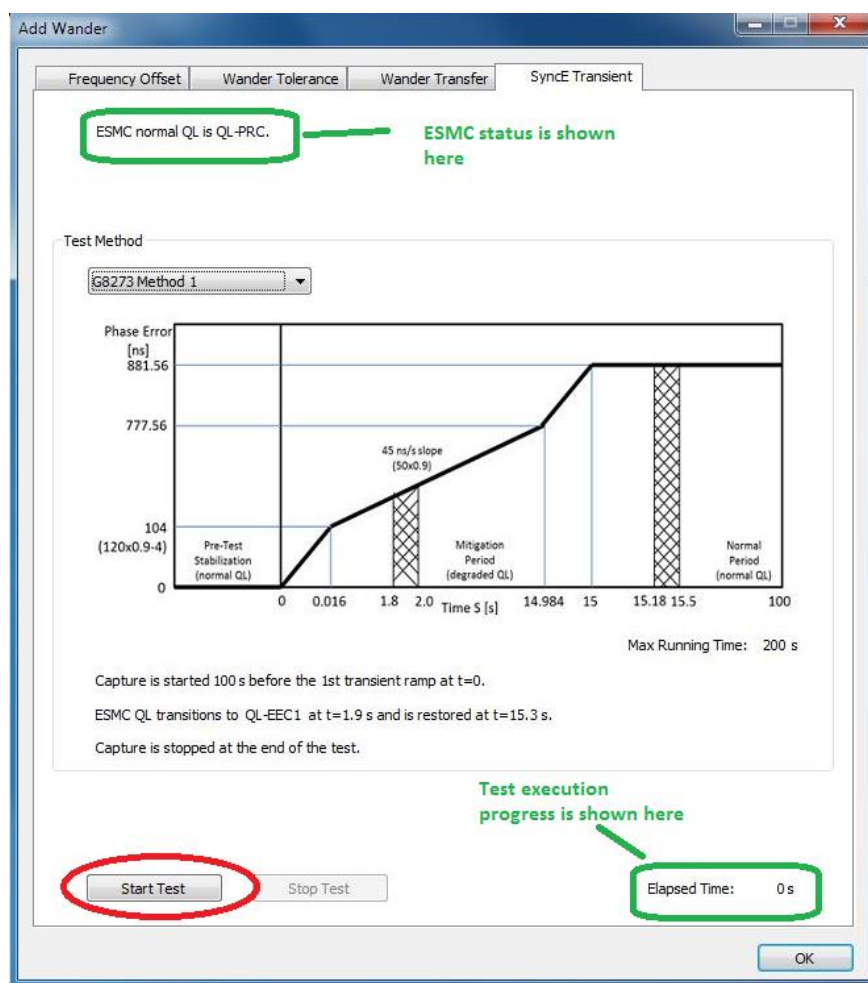
3. In the Add Wander window, select the **SyncE Transient** tab.



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

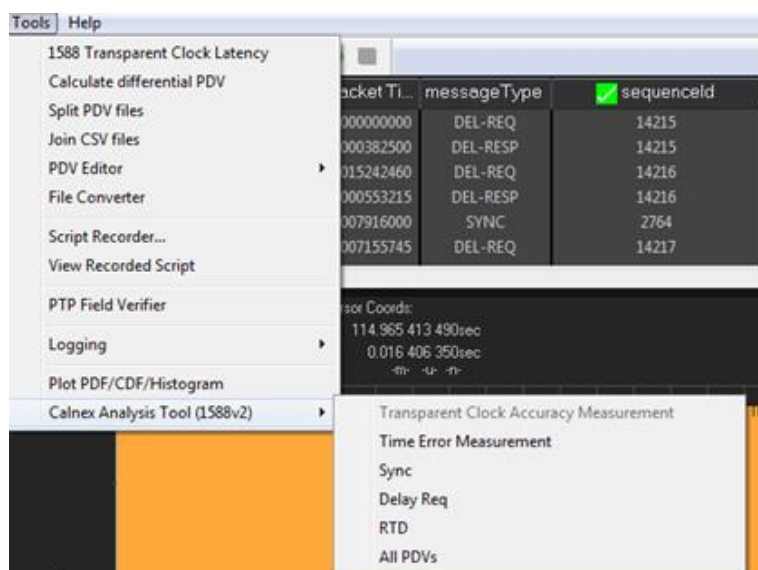


- After starting the ESMC generation the test can be started using the **Start Test** button. During the test the elapsed time is displayed, as is the current ESMC status.

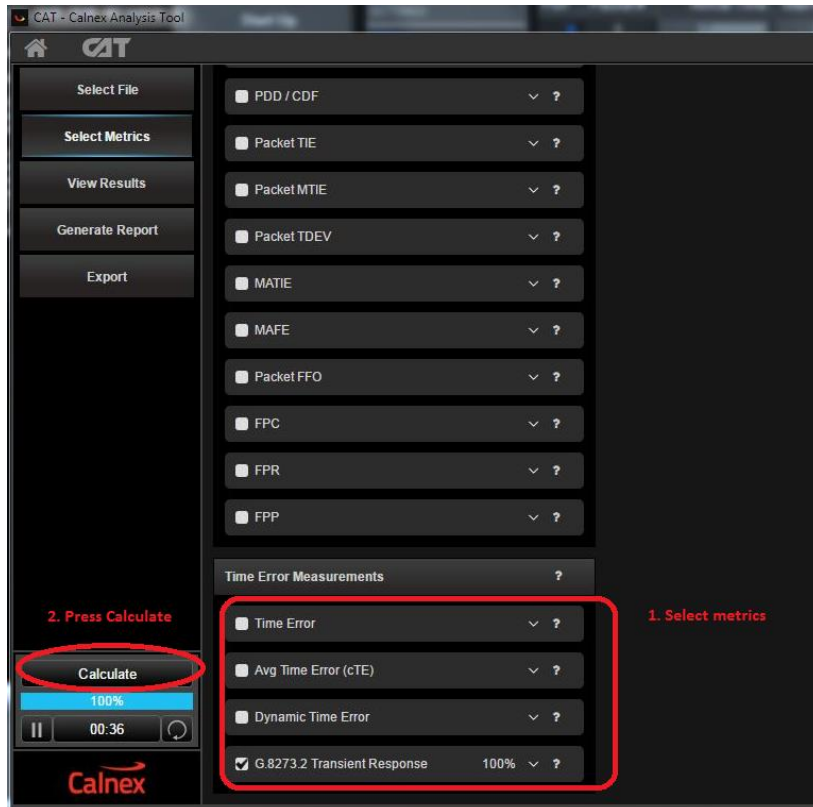


Test execution takes 200s. The first 100s are used to analyse the underlying Constant Time Error (cTE) without the application of the transient. As per the standard, the mask for Phase Noise response to the generated transient requires the results to be adjusted for cTE – this step therefore allows the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

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

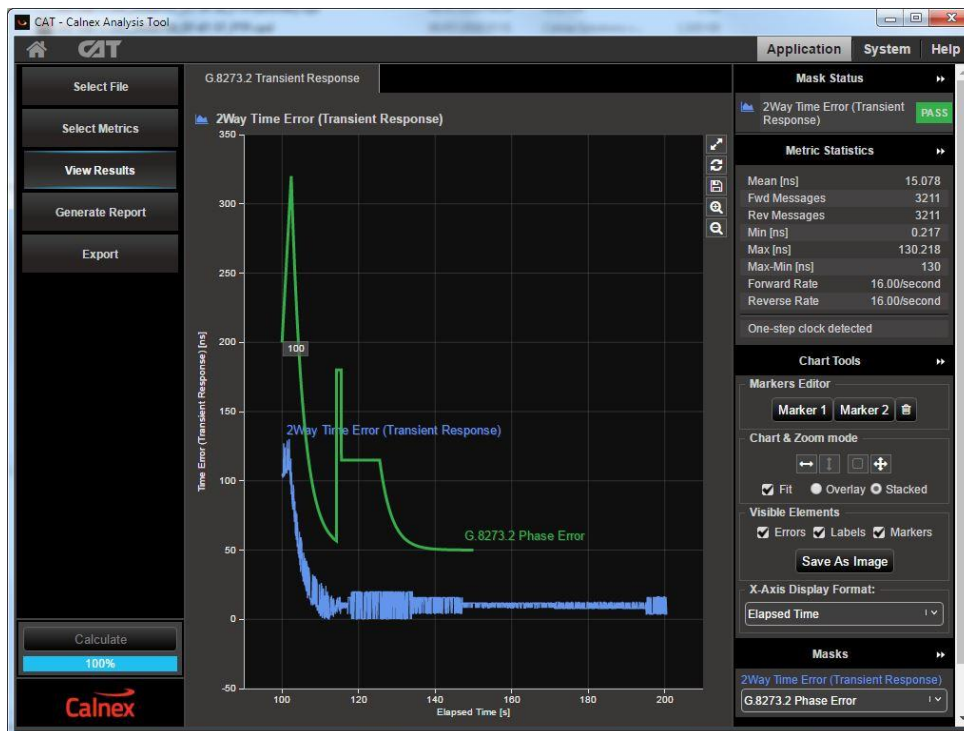


7. In the Calnex Analysis Tool, **Select Metrics** and enable the **G.8273.2 Transient Response** metric followed by the **Calculate** button.



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.

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



7.2 Packet Layer – Holdover Performance

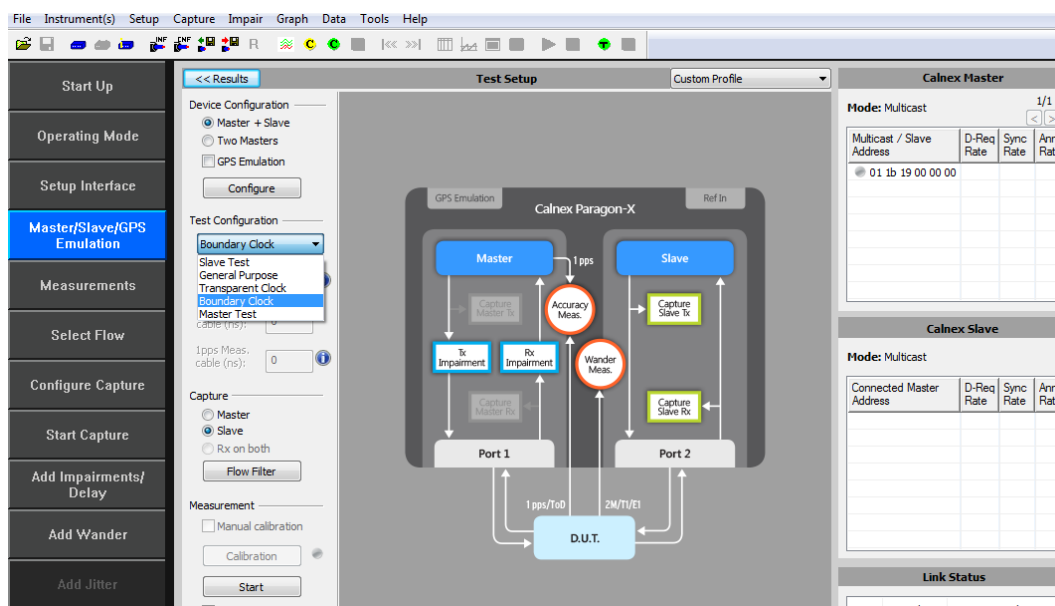
Holdover performance is checked by measuring the phase/time output in the event of the loss of the PTP input to the T-BC.

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.

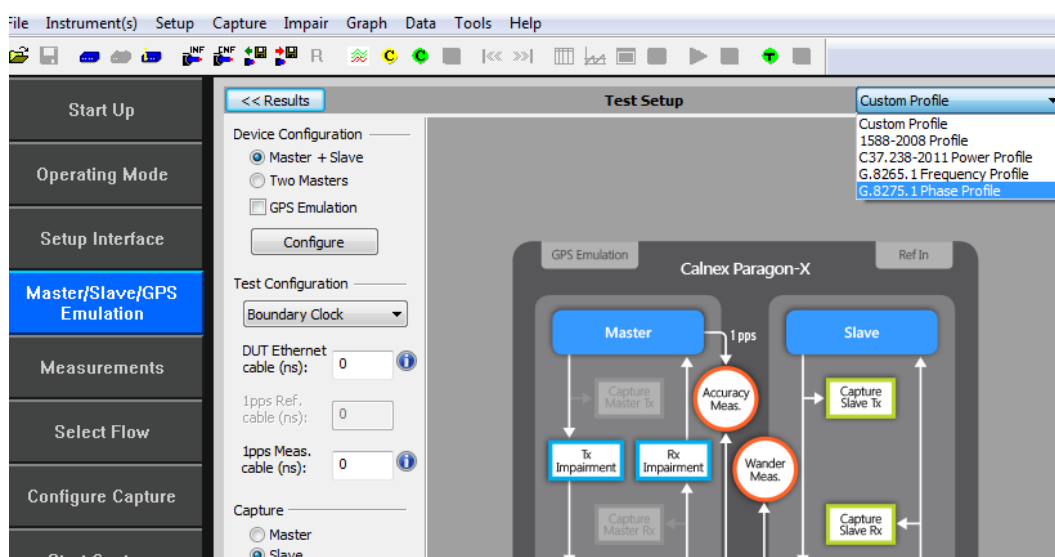
The Master/Slave Emulation can be configured to use other profiles e.g. Unicast UDP/IPV4 etc., however, it should be noted that these profiles will not conform to the G.8273.2 standard.

Measurement Process – Master/Slave Configuration

1. Select **Master/Slave Emulation**. Choose **Boundary Clock** from the Test Configuration drop down menu.

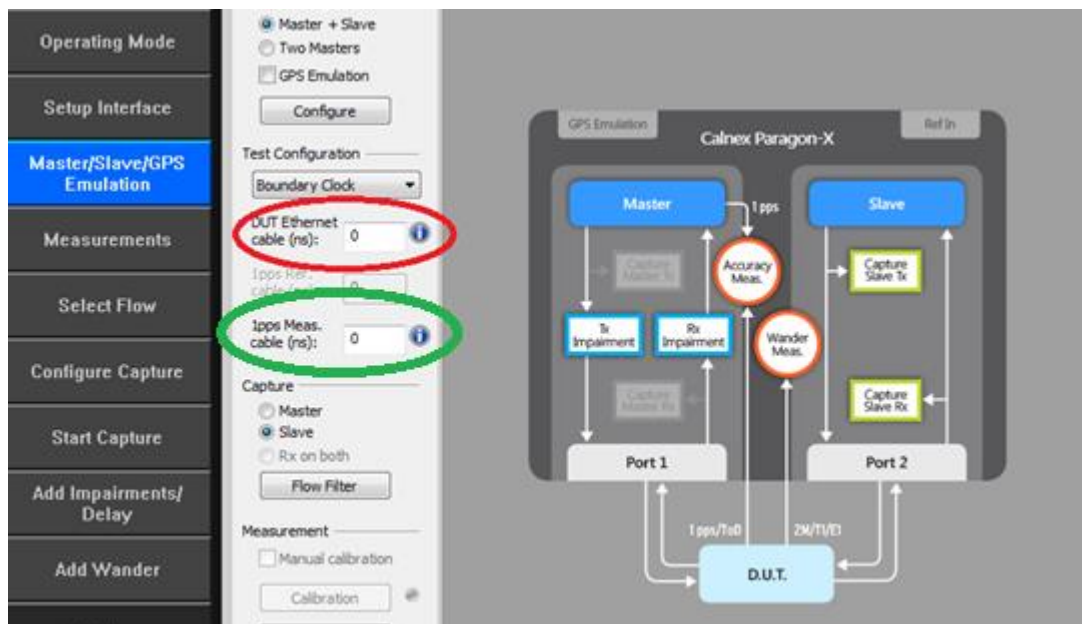


2. Select **G.8275.1 Phase Profile** from the Custom Profile drop down menu.



3. Enter DUT to Paragon-X Cable Delay

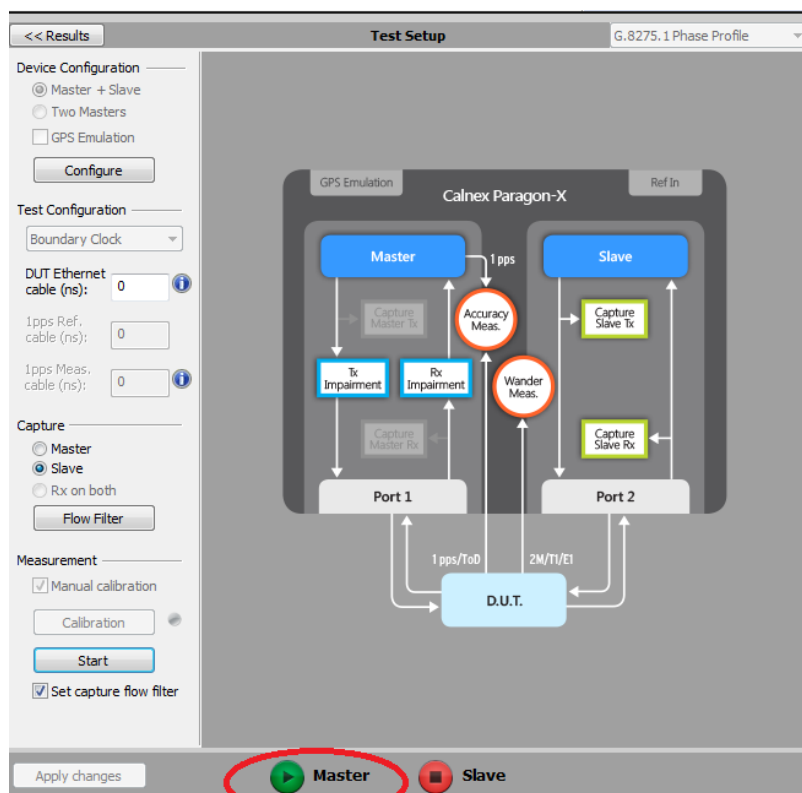
To correctly perform measurements, the delay caused by the cable that is used to connect the T-BC Slave and Port 2 must be factored out. Values of 5ns per 1 metre of electrical cable and 4ns per 1 metre of optical cable can be expected.



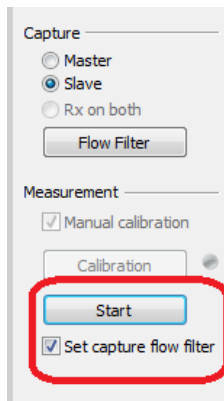
4. If 1pps Time Error measurements are to be made, enter the 1pps Measurement cable delay.

Values of 5ns per 1 metre of cable can be expected. See Calnex's Technical Note 'Cabling Considerations' (CX5009) for more information.

5. Start the Paragon-X Master using the **Master** button.



- With Master/Slave emulation running, start a capture using the **Start** button which will set the correct capture filters.

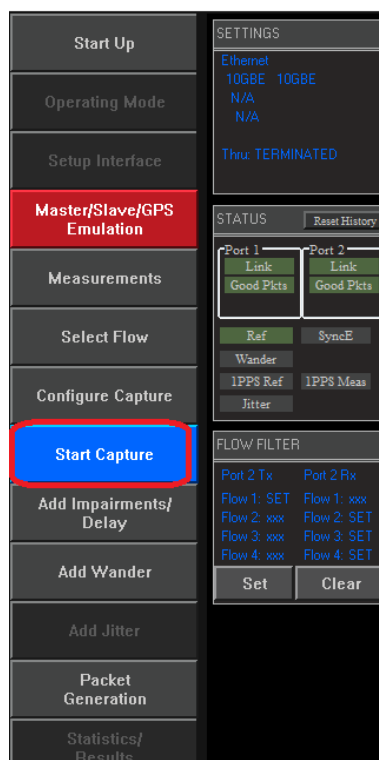


- Check the link to make sure that the PTP packets are running without error. If working successfully both Link and Packet status should show green status.
- Wait for the T-BC Slave to lock to the Paragon-X emulated Master and stabilize before making any measurements. **Clock settling time is important.** 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-BC under test. It may even be recommended to wait longer e.g. overnight.

Measurement Steps

With the T-BC in a stable state:

- Press the **Stop Capture** button to ready the test.
- 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**.

Impairments and Delay

Selected Message Types
Master Tx: Sync, Del-Resp
Master Rx:

Intrinsic Delay
Packet size: Small Packets (< 200 bytes)
Delay (µs): 6.7 Change

Configuration

Flow Filter

Master 1 Tx

Delay ☐
Header Overwrite ☐
Physical Corruption ☐
Packet Corruption ☒
Profile Corruption ☒
Master Impairments ☐

Master 1 Rx

Delay ☐
Header Overwrite ☐
Physical Corruption ☐
Packet Corruption ☐
Profile Corruption ☒

Packet Corruption

Type:
☐ Errored packet
☒ Lost packet
☐ Repeated packet
☐ Misorder events to a depth:

Distribution

Type:
☐ Single
☐ Burst of packets:
☐ Percentage rate:
☐ Ratio: E-
☒ Constant
☐ Symbol rate:

Periodicity:
☒ Continuous
☐ On for (s):
☐ Repeat for (s):

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

Impairments and Delay

Selected Message Types
Master Tx: Sync, Follow-Up, Del-Resp
Master Rx: Del-Req

Intrinsic Delay
Packet size: Small Packets (< 200 bytes)
Delay (µs): 6.7 Change

Configuration

Flow Filter

Master 1 Tx

Delay ☐
Header Overwrite ☐
Physical Corruption ☐
Packet Corruption ☒
Profile Corruption ☒
Master Impairments ☐

Master 1 Rx

Delay ☐
Header Overwrite ☐
Physical Corruption ☐
Packet Corruption ☐
Profile Corruption ☒

Flow Filter Editor

Master:
☐ Multiple slaves:
Set Clear

Slave:

Messages:

☒ Sync
☒ Follow-Up
☒ Delay Request
☒ Delay Response
☐ Announce
☐ Signaling (from Master)
☐ Signaling (from Slave)

Flow Filter Status

Flow Summary:

Port 1 Rx (Master)	Port 1 Tx (Master)
DEL-REQ	xxx
xxx	DEL-RESP
xxx	FOLLOW-UP
xxx	SYNC

Flow Detail:

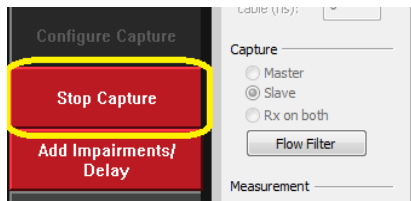
Eth Dest	01 1B 19 00 00 00
Eth Type	PTP
PTP Message	DEL-REQ
PTP Version	2

5. Now start the impairment by selecting

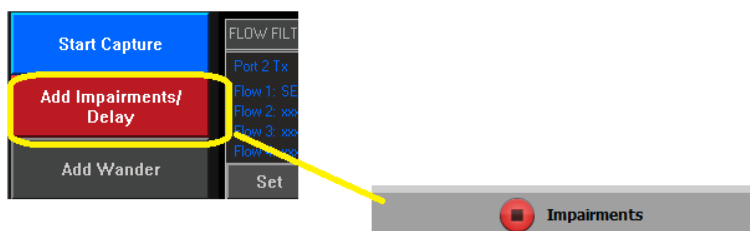


This will stop all Sync and Delay Response messages from reaching the Boundary Clock. The Boundary Clock should drop into the holdover state at this point.

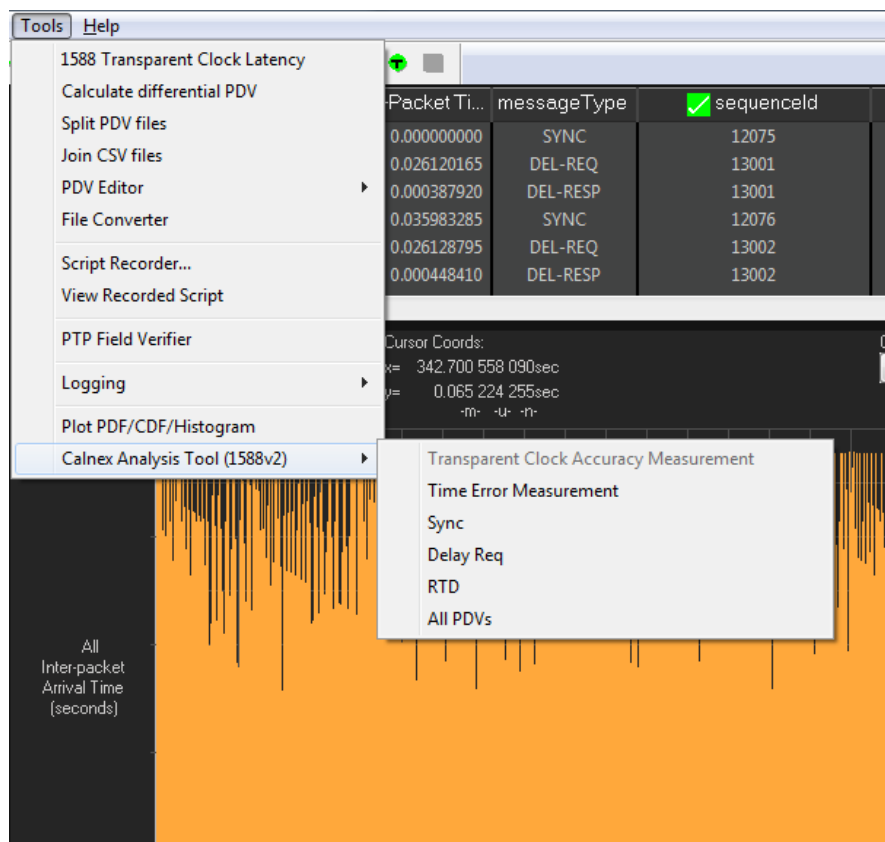
6. After **1000s** select the **Stop Capture** button.



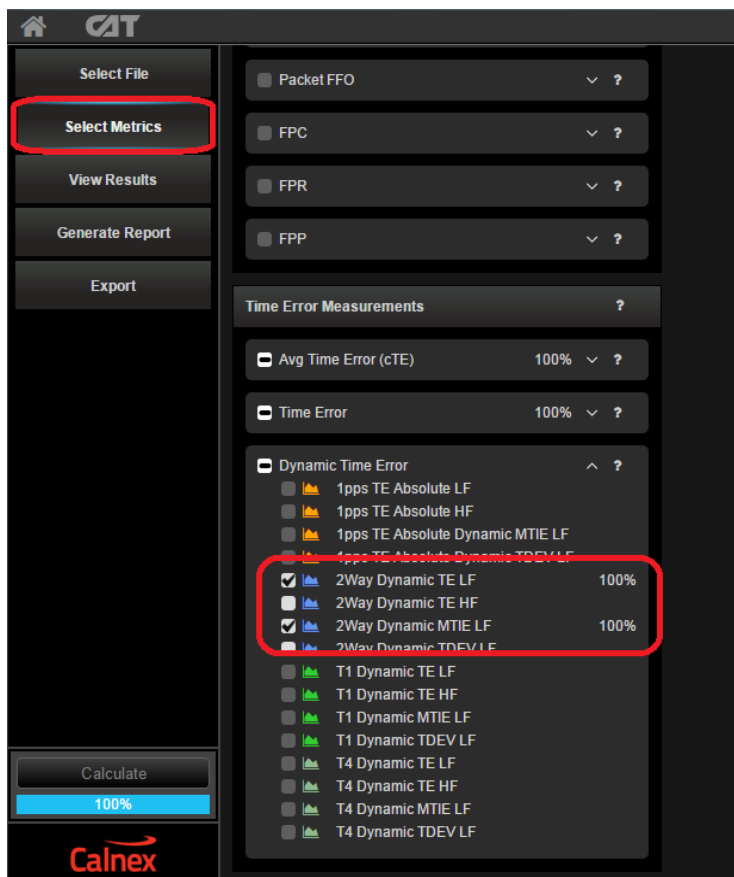
7. Select the **Add Impairments/Delay** and **Stop** the impairment.



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



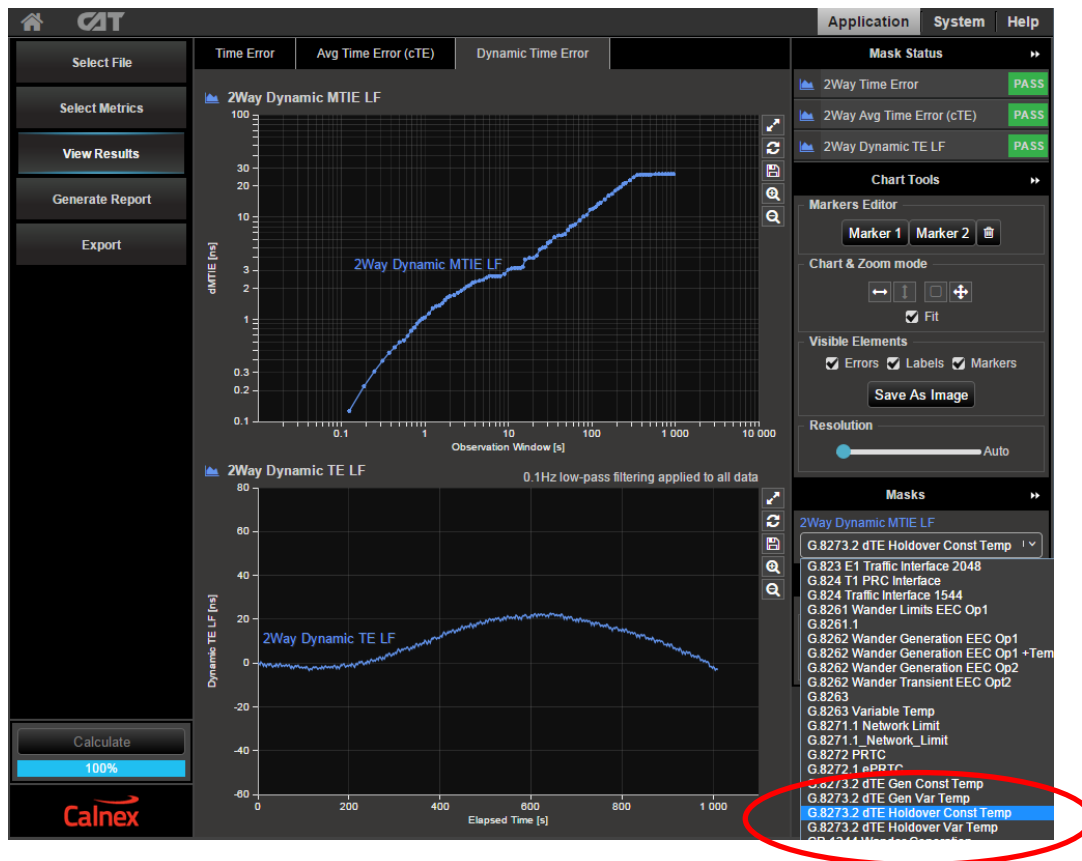
9. The key metrics to be examined are the **2way Dynamic TE LF** metrics. Enable these in the Metrics block and disable the **Average Time Error (cTE)** metrics and the remainder of the **Dynamic TE** metrics.



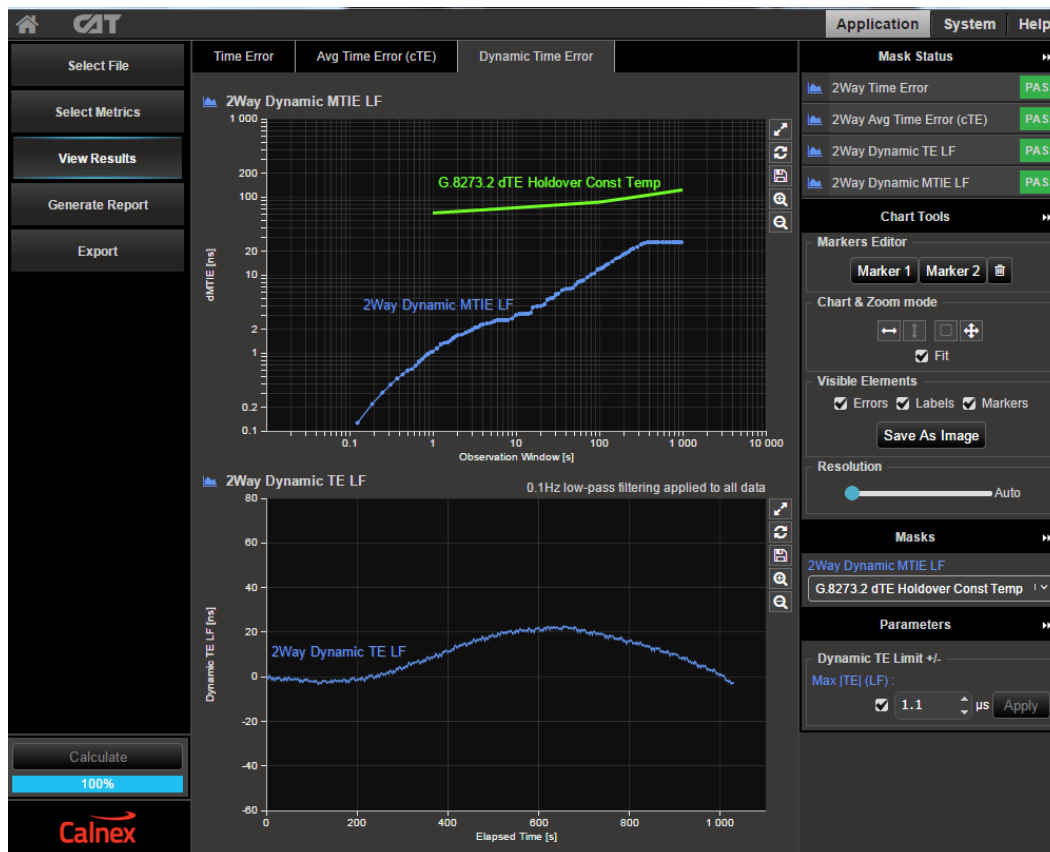
10. Select the **Dynamic Time Error** tab.



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



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



Appendix 1 – G.8271.1 Time Error Budget Example

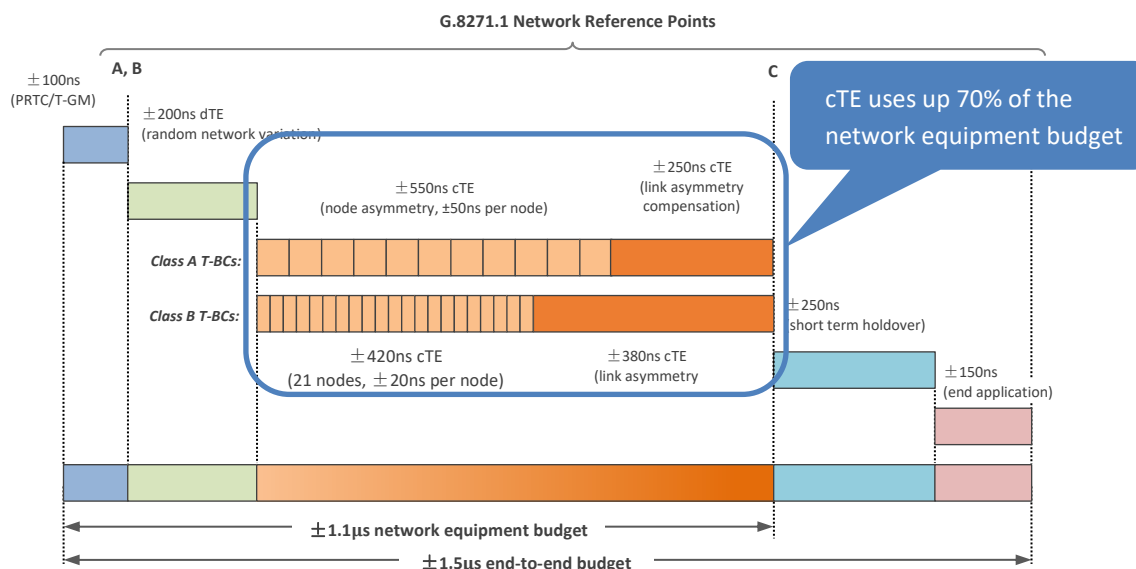


Table V1.1/G.8271.1 – Example of Time Error Allocation

Budget Component	Failure scenario a)	Failure scenario b)	Long Holdover periods (e.g. 1 day)
PRTC (ce_{ref})	100 ns	100 ns	100 ns
Holdover and Rearrangements in the network (TE_{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_{link_asym}) (Note2)	250 ns	100 ns	100 ns
Rearrangements and short Holdover in the End Application (TE_{REA})	250 ns	NA	NA
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-BC

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

² 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.

³ 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.

⁴ Max|TE| is calculated on the raw, unfiltered time error data.

⁵ MTIE and TDEV are calculated after low-pass filtering by 0.1Hz. Same values apply to both Class A and Class B devices.

⁶ TIE is measured after high-pass filtering by 0.1Hz. Same values apply to both Class A and Class B devices.

⁷ 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 (PTP and 1pps) ¹
Noise 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 .	Tone frequencies and amplitudes defined in Appendix VI of G.8273.2 (Amendment 1, August 2017)
		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.	Tone frequencies and amplitudes defined in Appendix VI of G.8273.2 (Amendment 1, August 2017)
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

Appendix 3 – Changing Capture Filters

The **Capture** Flow Filters are used to limit the captured traffic to 1588 **Sync**, **Follow up**, **Delay Request** and **Delay Response** messages and are set up automatically when the **Start** button is pressed on the **Test Setup** screen.

The **Capture Flow** Filters can, however, be amended if required using the **Flow** Filter button on the display below.

By default in the Boundary Clock Test the filters are applied on the **Slave** side of the emulation. However, these can be applied to the **Master** side of the emulation if it is required to check that the Paragon-X Master is generating the correct input into the Slave side of the Boundary Clock.

The screenshot displays the Calnex Paragon-X software interface. The main window is titled "Test Setup" and shows a diagram of the "Calnex Paragon-X" system with "Master" and "Slave" components. The "Flow Filter" button is highlighted in the "Capture" section of the left sidebar. A secondary window, "Capture Flow Filter", is open, showing the "Flow Filter Editor" and "Flow Filter Status" sections.

The "Flow Filter Editor" section contains two text boxes for "Master" and "Slave" MAC addresses. The "Slave" box contains the address "d0 00 00 00 00 01". Below these boxes are "Set" and "Clear" buttons.

The "Flow Filter Status" section contains a "Flow Summary" table and a "Flow Detail" table.

Flow Summary:	
Port 2 Tx (Slave)	Port 2 Rx (Slave)
DEL-REQ	xxx
xxx	DEL-RESP
xxx	FOLLOW-UP
xxx	SYNC

Flow Detail:	
Eth Dest	01 1B 19 00 00 00
Eth Source	D0 00 00 00 00 01
Eth Type	PTP
PTP Message	DEL-REQ
PTP Version	2

The "Messages" section on the right of the "Capture Flow Filter" window lists various message types with checkboxes:

- ☒ Sync
- ☒ Follow-Up
- ☒ Delay Request
- ☒ Delay Response
- ☐ Announce
- ☒ Signaling (from Master)
- ☒ Signaling (from Slave)

The **Flow Filter** button can be used to display the filter selection window to examine the capture flow filters.

Individual message types can be included or excluded from the capture by ticking/unticking the appropriate message boxes on the upper right followed by use of the **Set** button.



Calnex Solutions Ltd
Oracle Campus
Linlithgow
EH49 7LR
United Kingdom

t: +44 (0) 1506 671 416
e: info@calnexsol.com

calnexsol.com

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