TEST GUIDE

CX5020 v4.0

T-TSC Time Error

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

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

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

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

Contents

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 required[1]
- Cables as required
- Calnex BNC/RJ-45 adapter cable (required for 1pps accuracy/Time Error measurement)

Frequency Reference Source

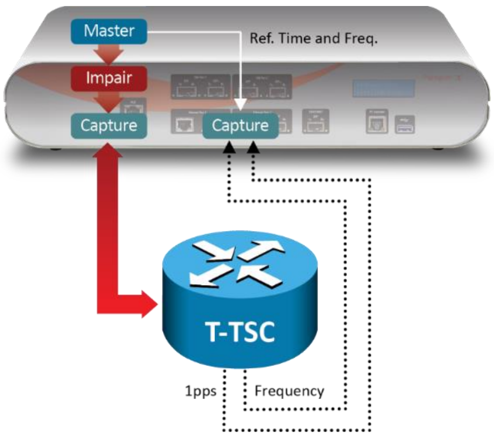
Option 132 Rubidium Interface (optional)

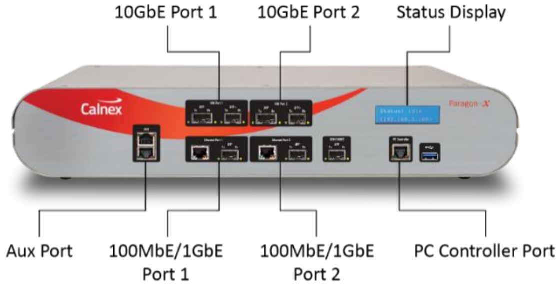
Document References

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

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

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





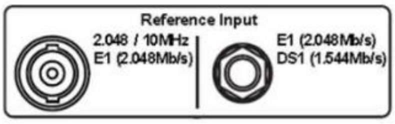
Front Panel

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

Rear Panel

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

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



Connections

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

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

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

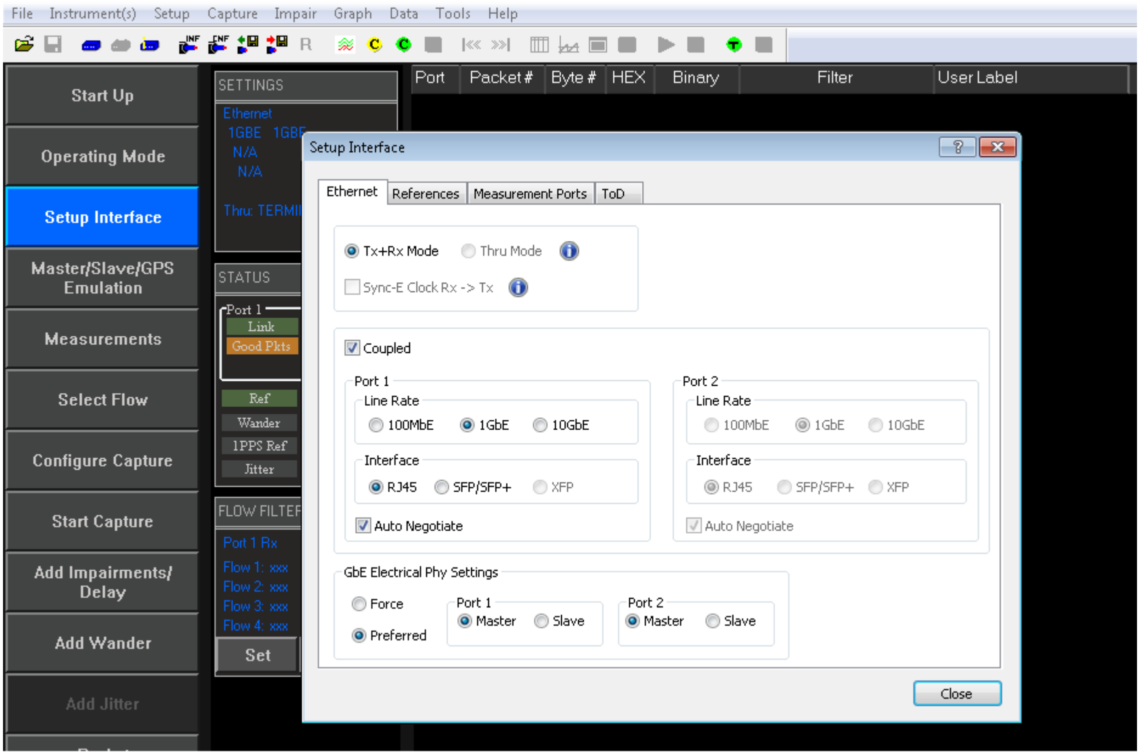
3.1. Connection to Paragon-X from GUI
3.2. Configuration of physical connections
3.3. Measurement configuration
3.4. Preparing Master/Slave Emulation operation
3.5. Confirmation of PTP traffic on interfaces
3.6. Filtering capture and impairment traffic
3.7. Start of Master/Slave Emulation ready for test

3.1. Connection to Paragon-X from GUI

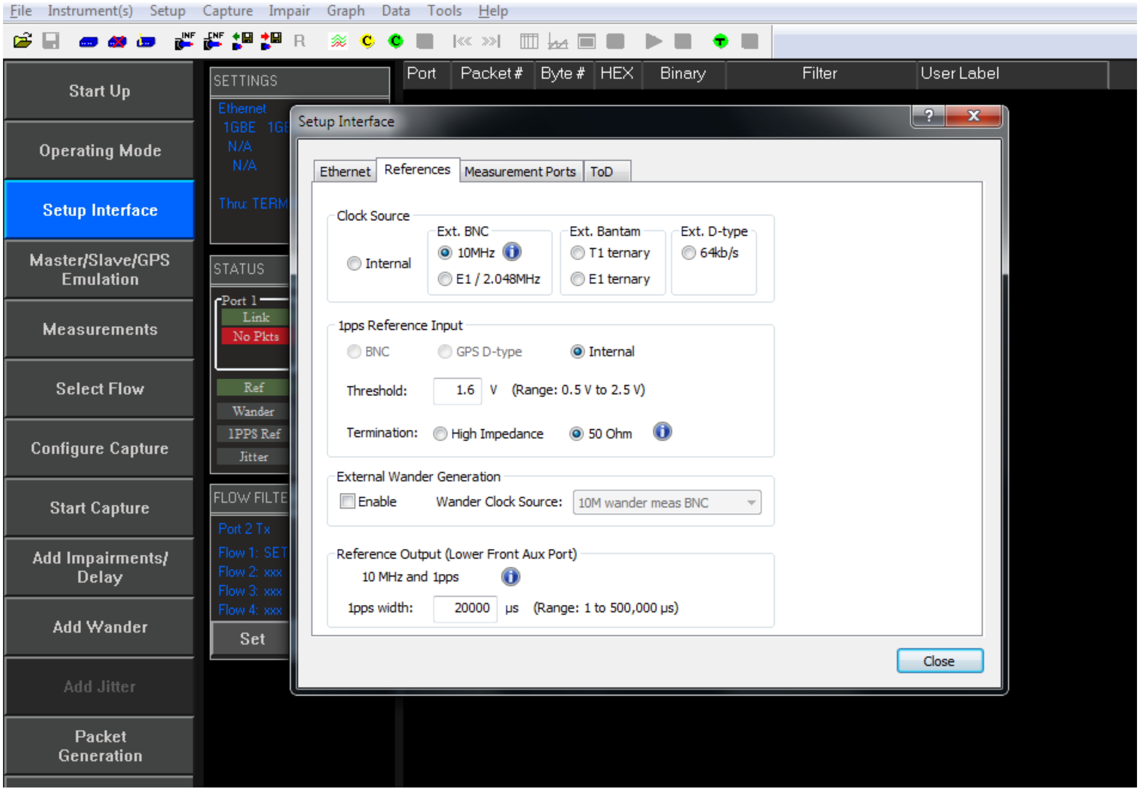
1. Verify the physical connections have been completed as described in Section 2.
2. Start the Paragon-X GUI.
3. Select ***Start Up*** and ***Connect***.
4. Enter the IP address of the Paragon-X (displayed on Paragon-X status display).
5. See the Paragon-X Getting Started Guide for more details.

3.2 Configuration of physical connections

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

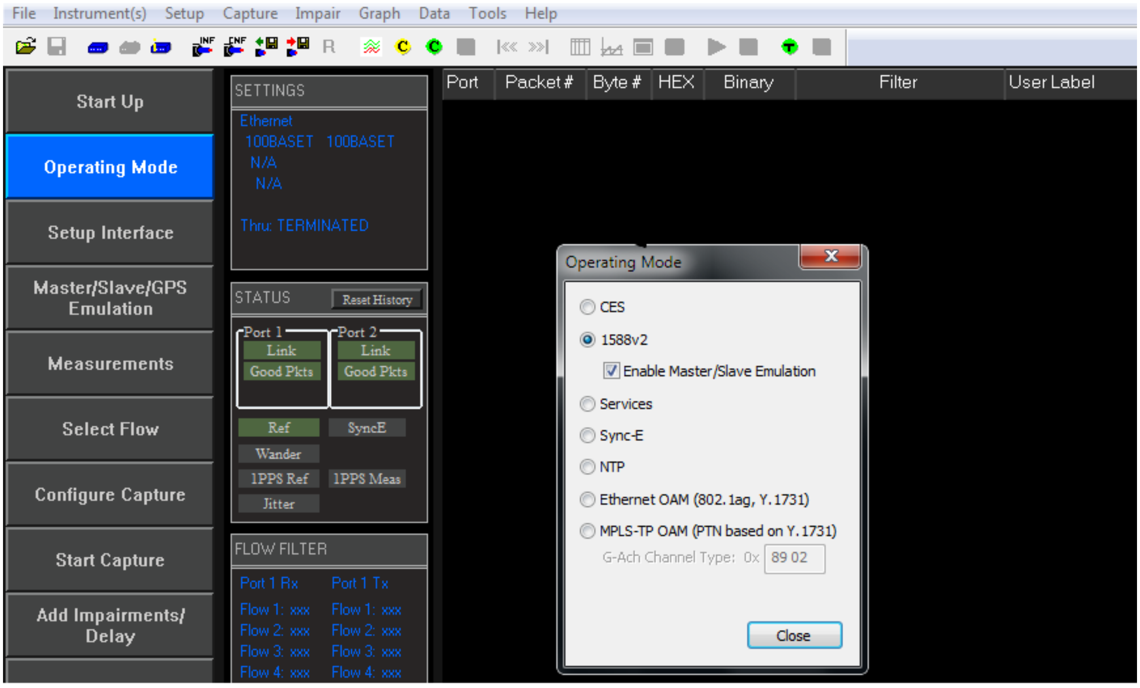


2. Select the ***References*** tab to configure a stable reference for the Paragon-X. Set the ***Clock Source*** to ***External reference*** (10MHz or E1/2MHz). An external source is recommended

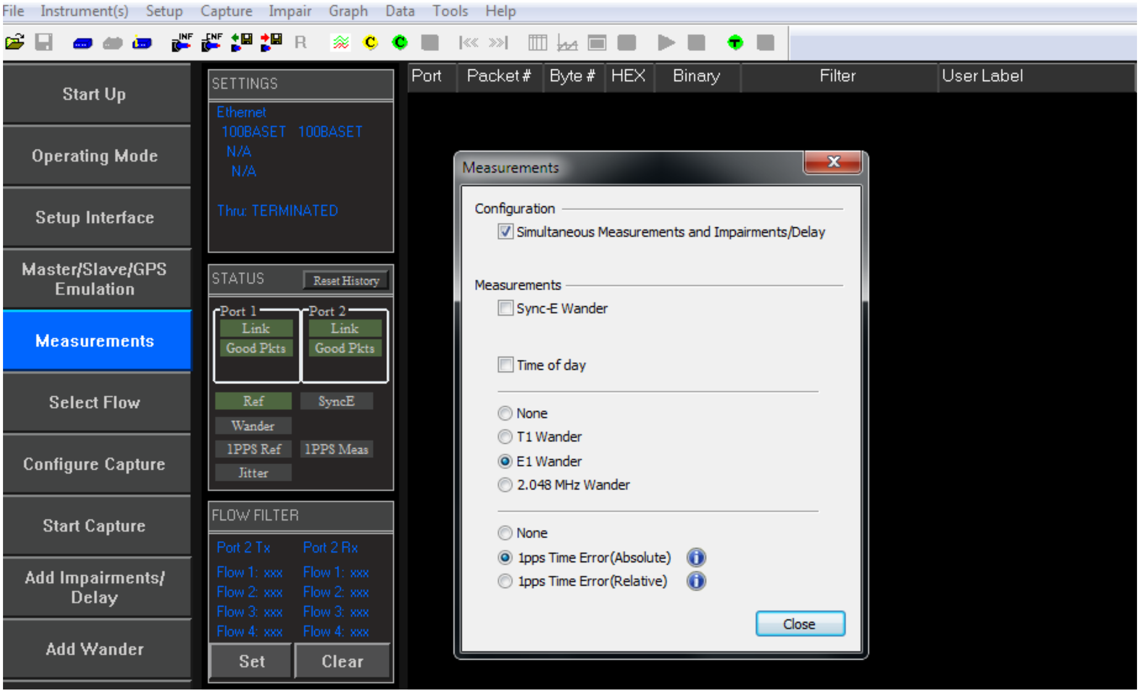


3.3. Measurement configuration

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



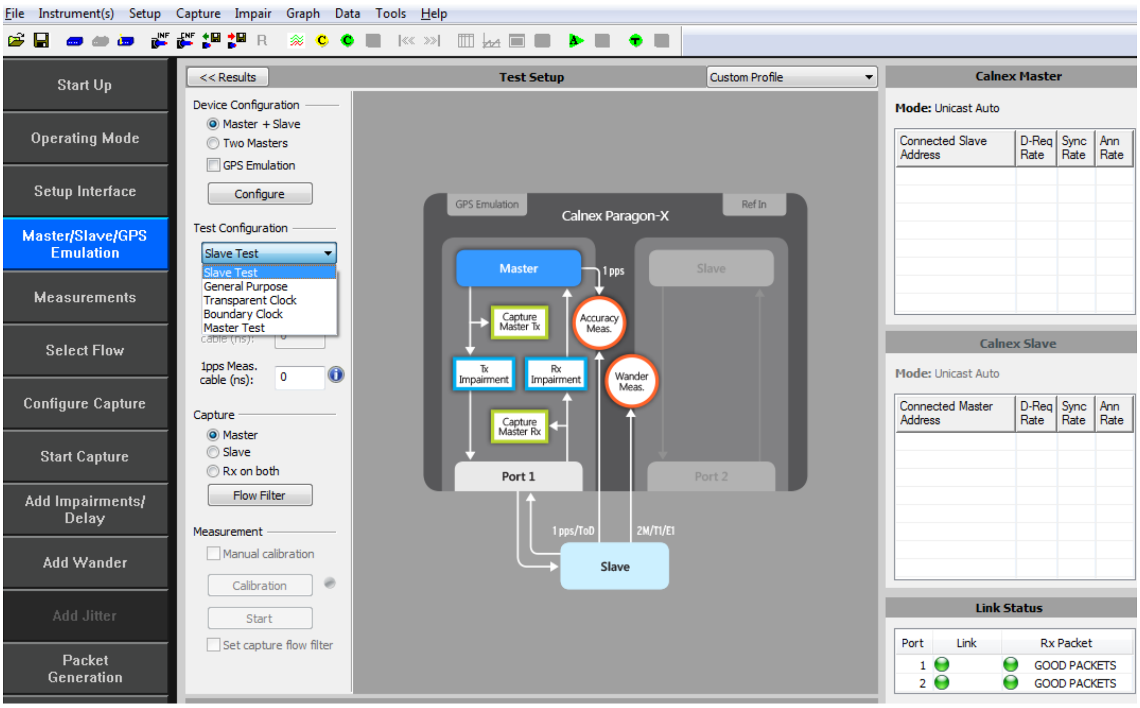
2. Click on the ***Measurements*** button then enable ***E1*** and ***1pps Time Error (Absolute)***.



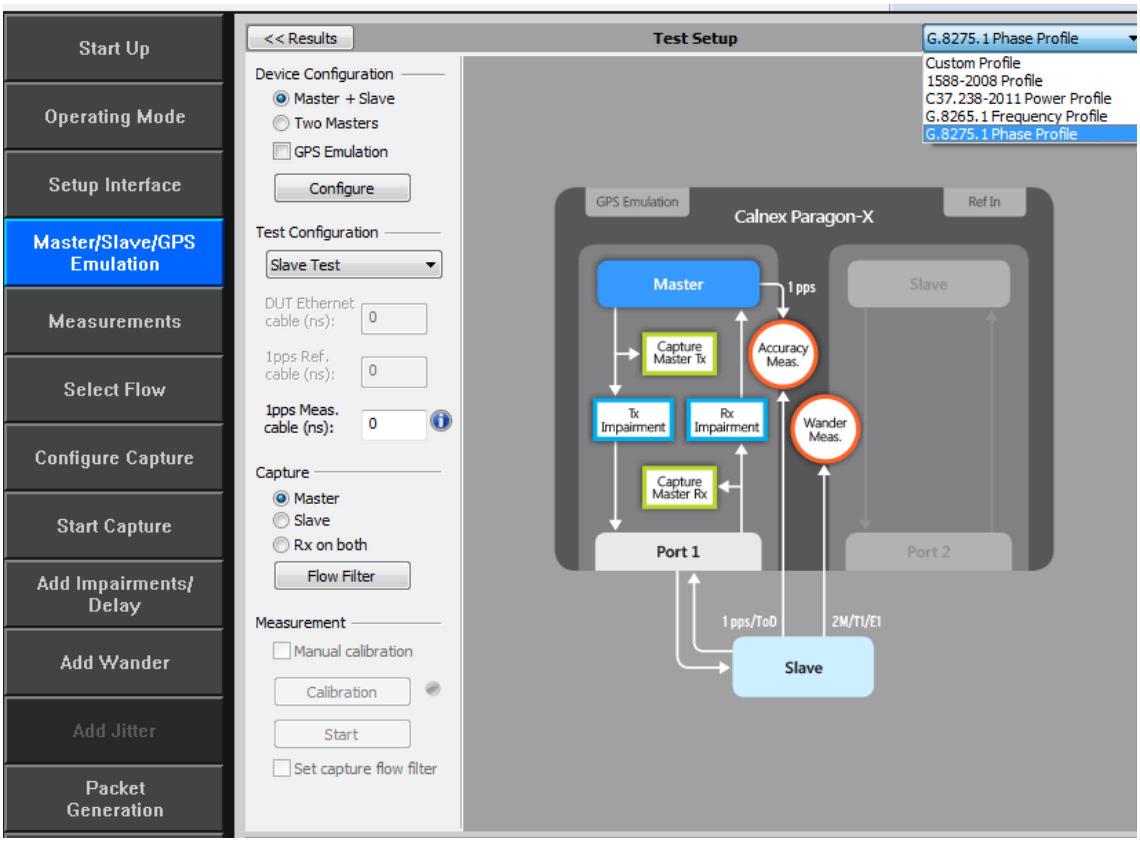
3.4. Preparing for Master/Slave Emulation

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

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

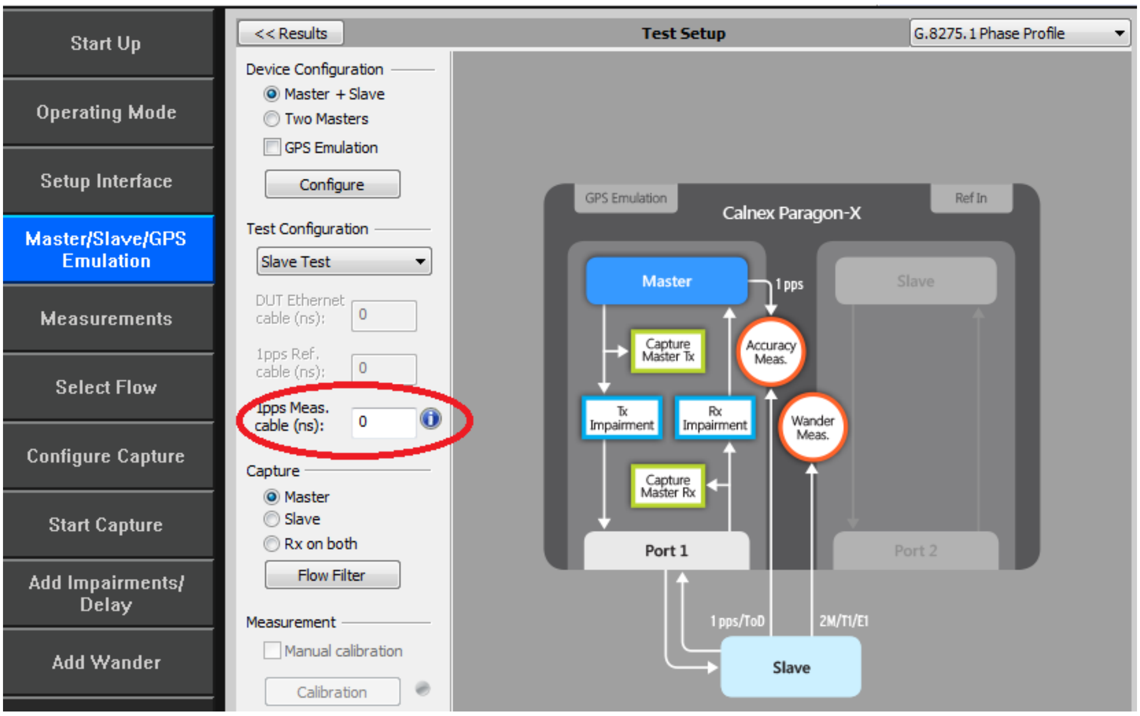


2. Select ***G.8275.1*** profile from the ***Custom Profile*** drop down menu.

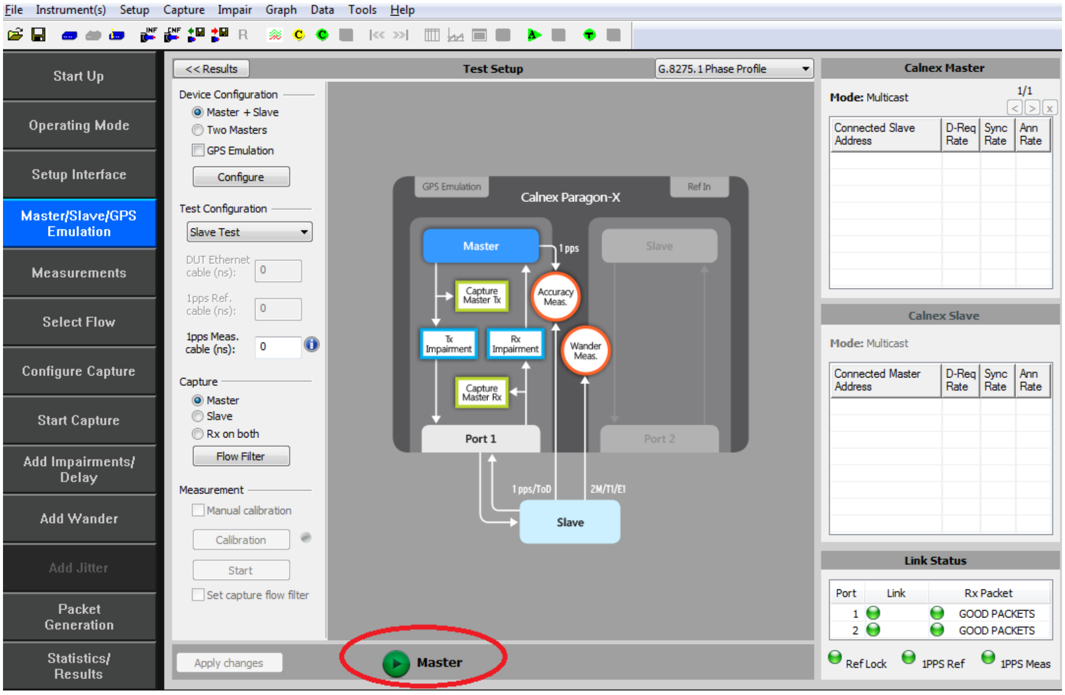


3. Enter DUT to Paragon-X 1pps **cable delay**.

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

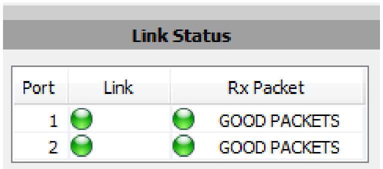


4. ***Start*** the Master/Slave emulation.



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

3.6. Filtering capture and impairment traffic

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

- **Capture Filtering**

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

- **Impairment Filtering**

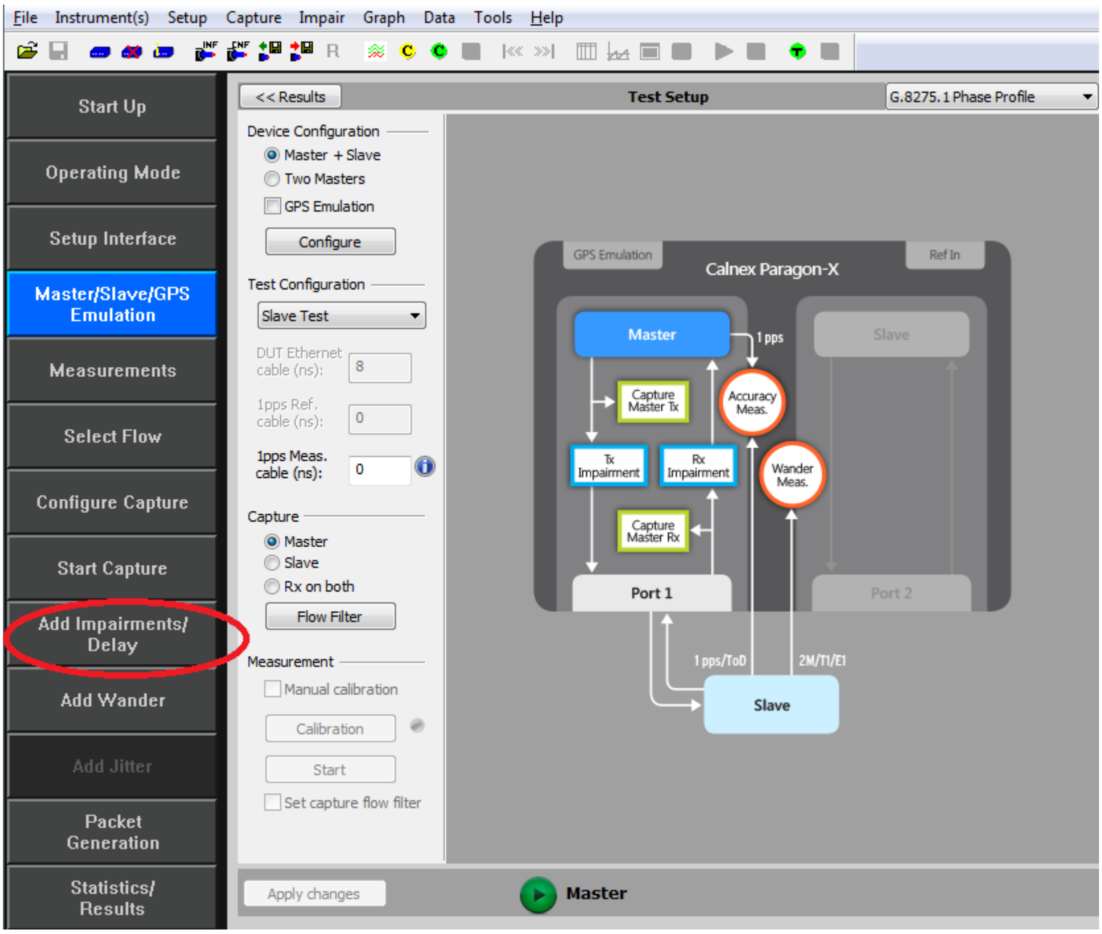
In Slave test, the impairment occurs on the **Master** side. Impairment filters must be set up before any impairment is performed.

Impairments are required in the following tests:

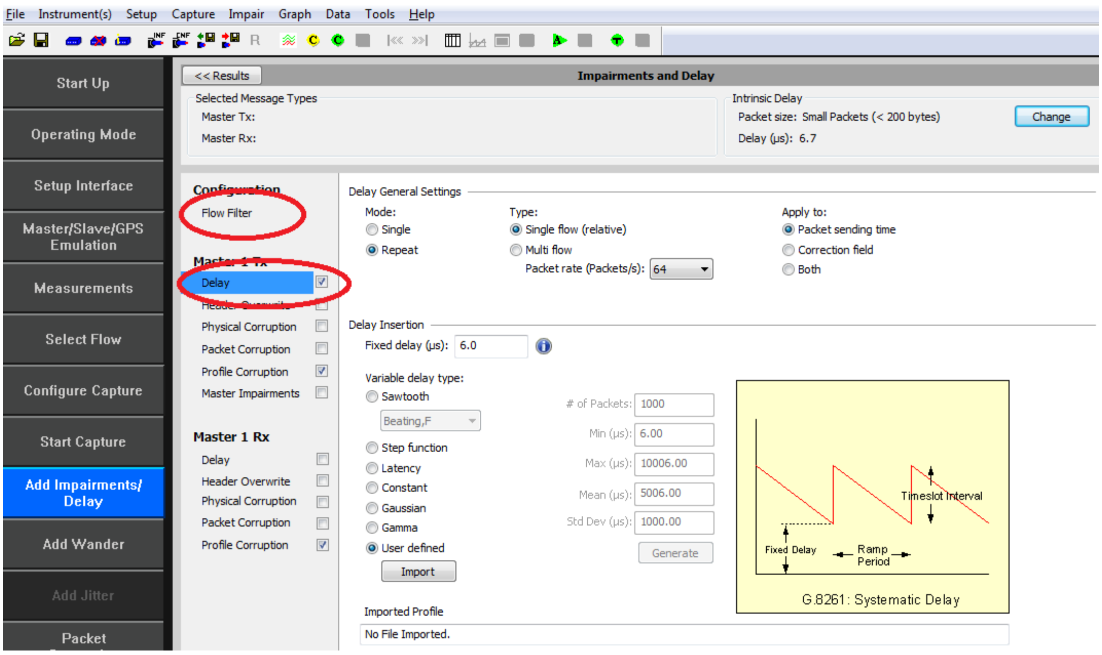
- Time Noise Tolerance – G.8273.2 Clause 7.2
- Time Noise Transfer – G.8273.2 Section 7.3

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

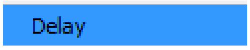
1. To enable impairments click on the ***Add Impairments/Delay*** button.



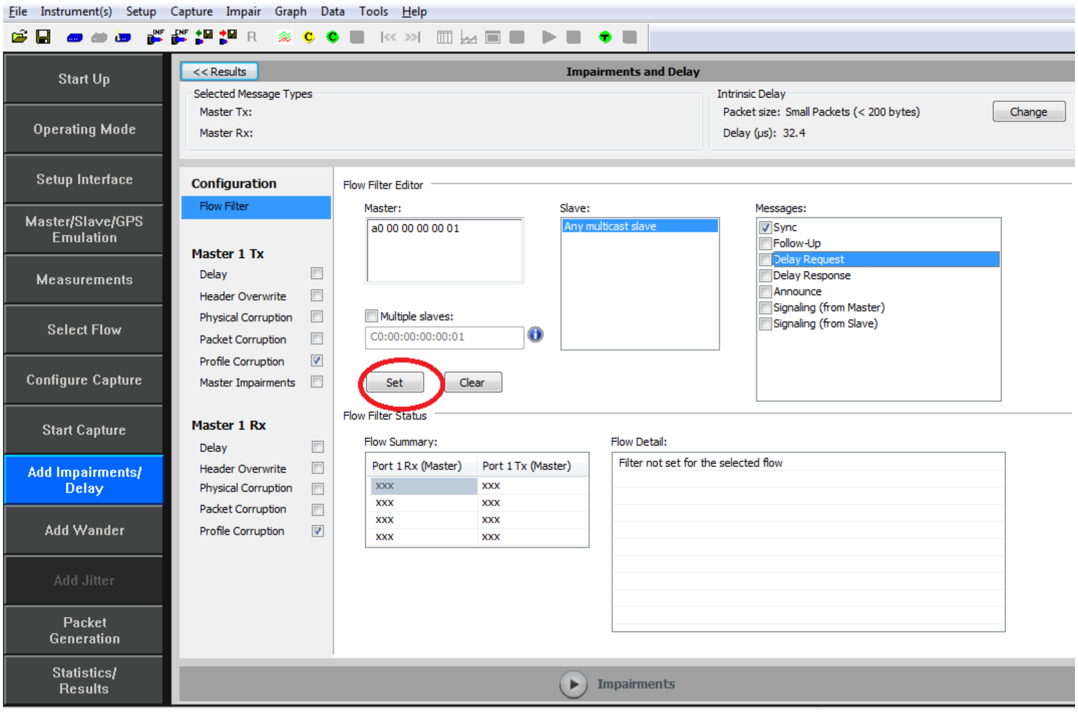
This will display the **Impairments** control screen. Impairments are applied to the Sync messages in the forward direction (Master Tx).



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



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



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

Delay Patterns and Tools

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

- **Noise Tolerance**

  This is carried out using a single traffic stimulus pattern:

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

  accessed via the link: [Patterns - Calnex Product FAQ]

- **Noise Transfer**

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

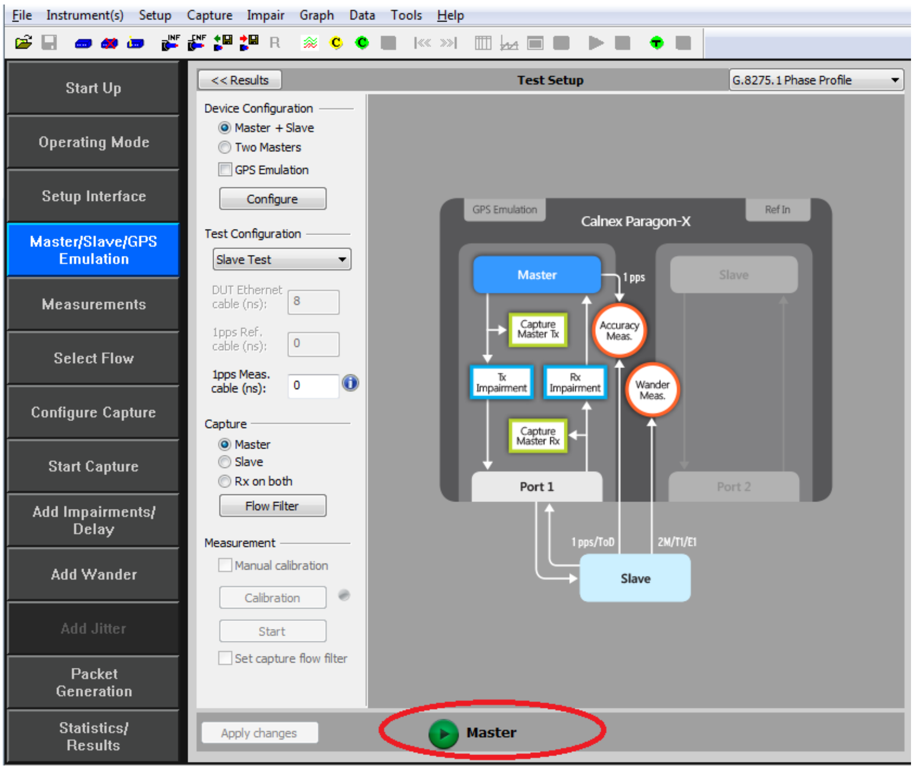
  Enhanced Noise Transfer

  accessed via the link: [Tools - Calnex Product FAQ]

3.7. Start of Master/Slave Emulation ready for test

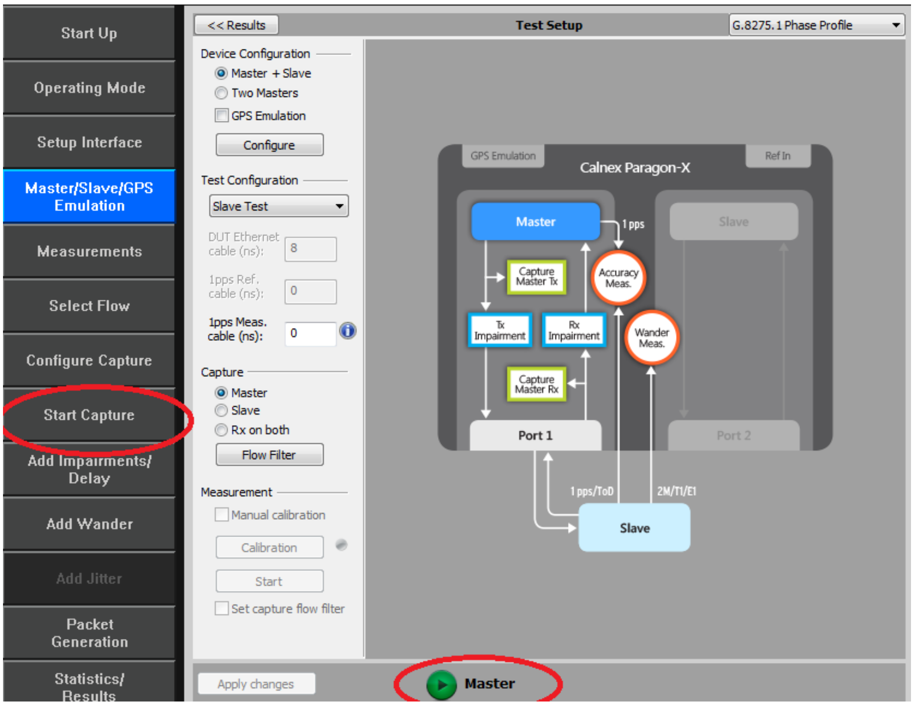
The **Master/Slave Emulation** mode can now be re-started.

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



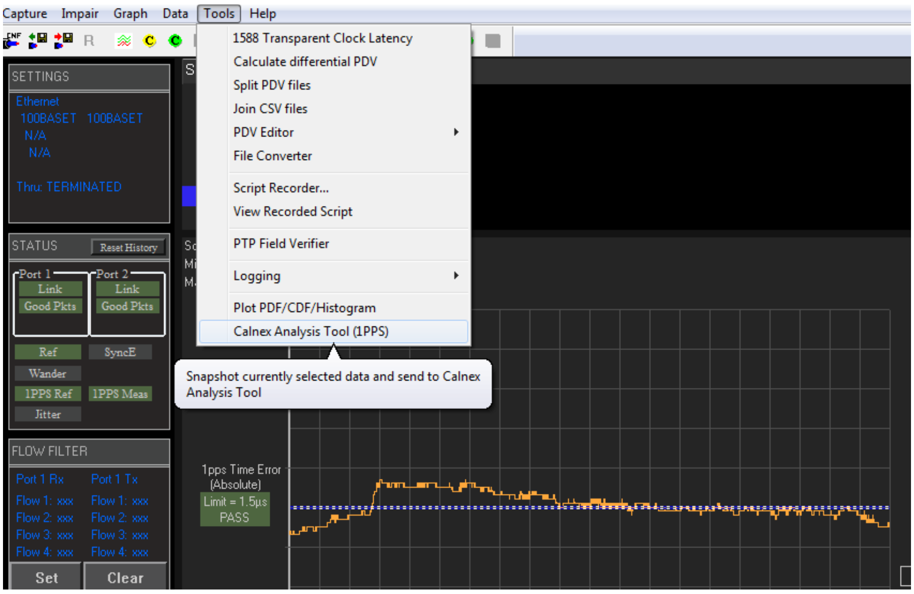
Notes on Measurements

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



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

- Once the Slave clock has settled, ***Start*** the capture as above and then launch the ***Calnex Analysis Tool (1PPS)*** to view the 1pps result metrics.



Time Error results available with the CAT are as follows:

1. **Time Error**
   - 1PPS Time Error
2. **Average Time Error (cTE)**
   - 1PPS Constant Time Error
3. **Dynamic Time Error**
   - 1PPS Filtered
   - 1PPS Filtered MTIE
   - 1PPS Filtered TDEV

4. Noise Generation – G.8273.2 Clause 7.1

Test Description

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

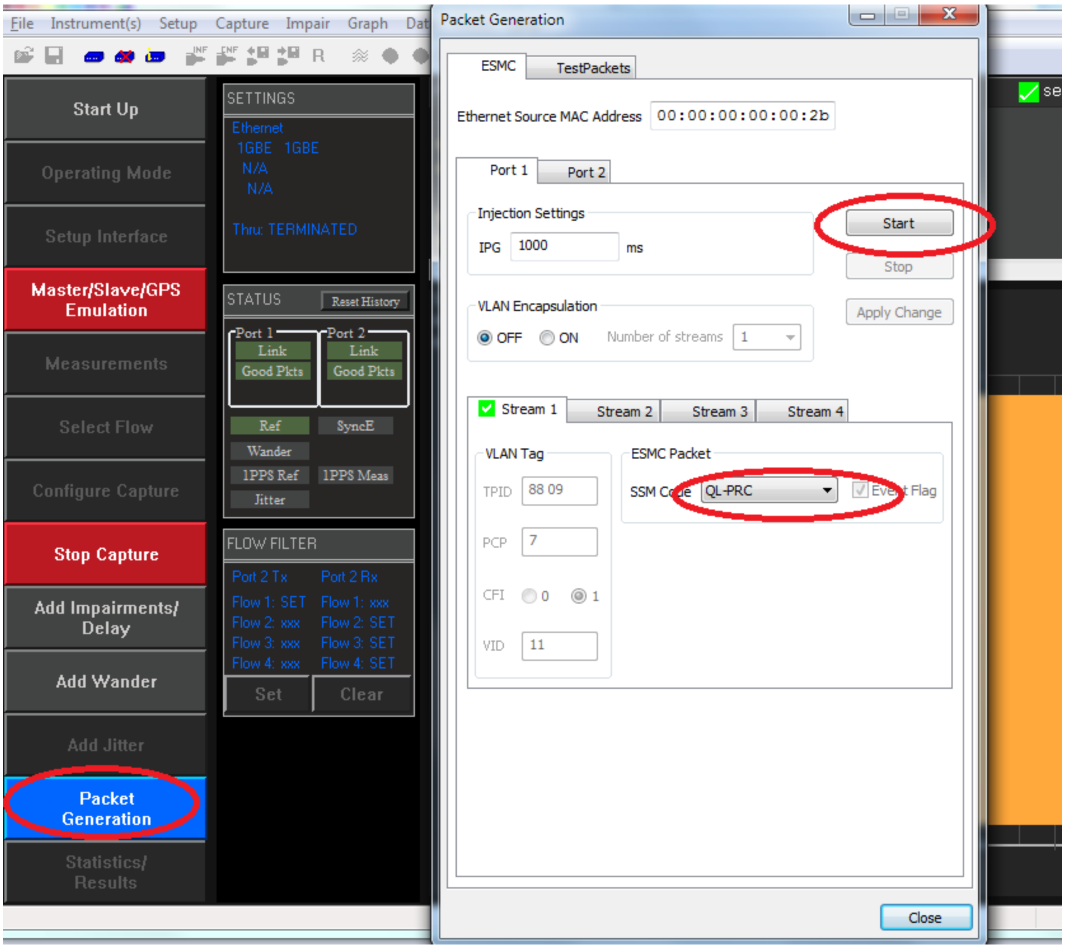
Measurement Process

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

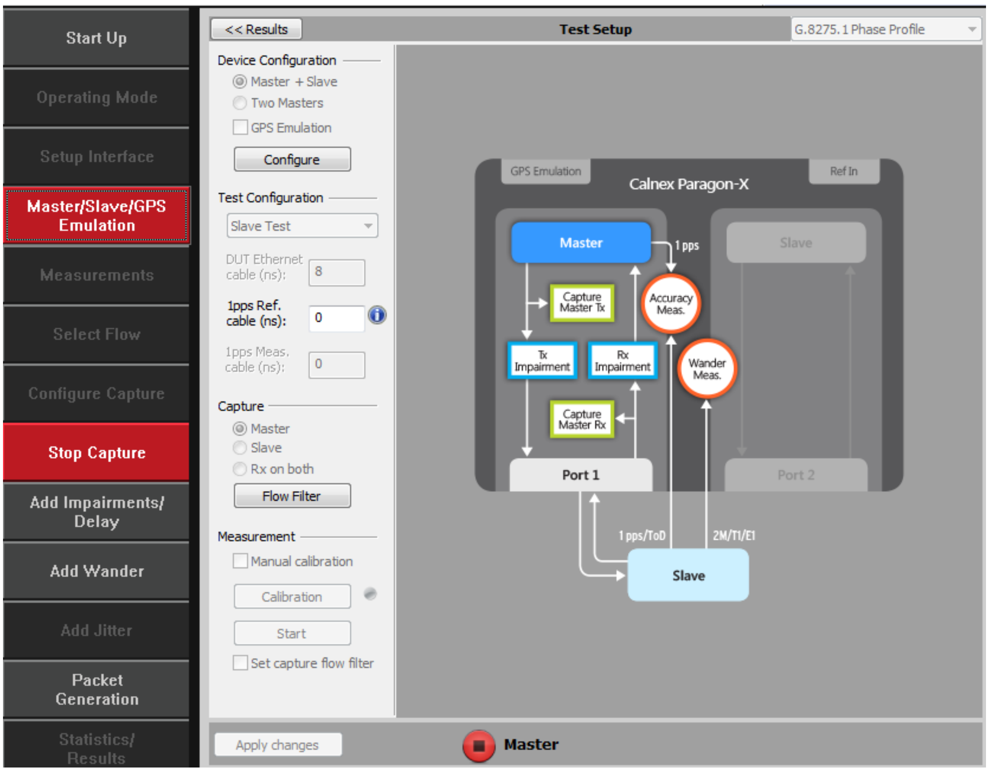
Note: The Master/Slave Emulation Configuration steps described in Section 3 must be performed prior to this test. **Impairments are not required for this test.**

4.1 Combined PTP and SyncE

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



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

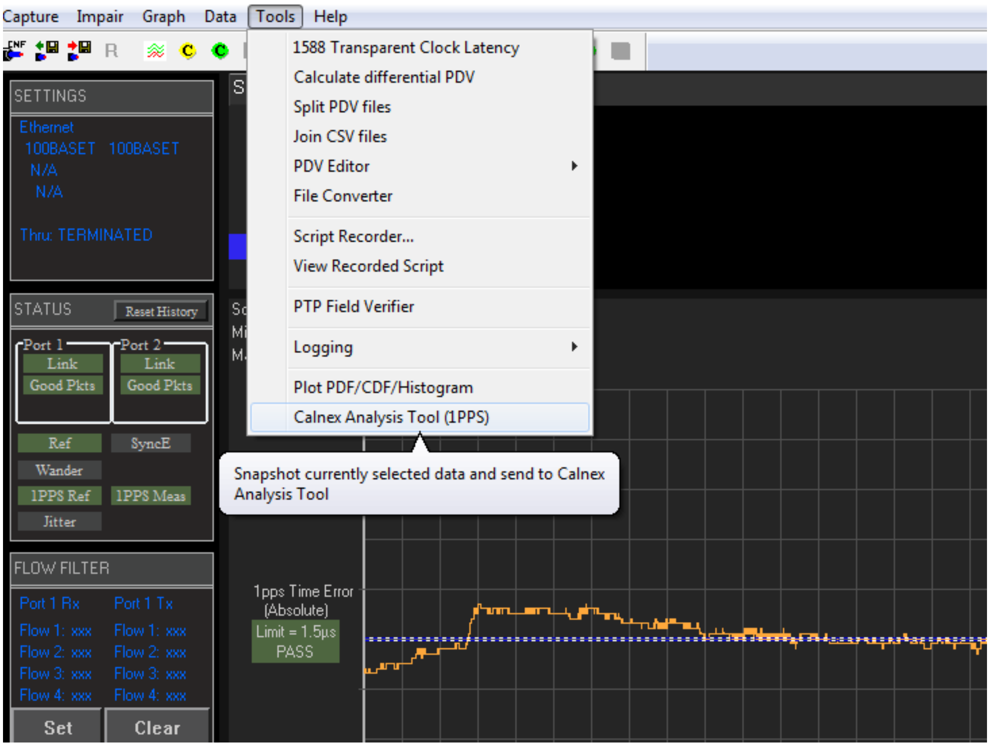


3. Allow the capture to run for at least **2000s.** Then use the ***Stop Capture*** button to stop the capture.

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

Time Error Results (Constant Time Error)

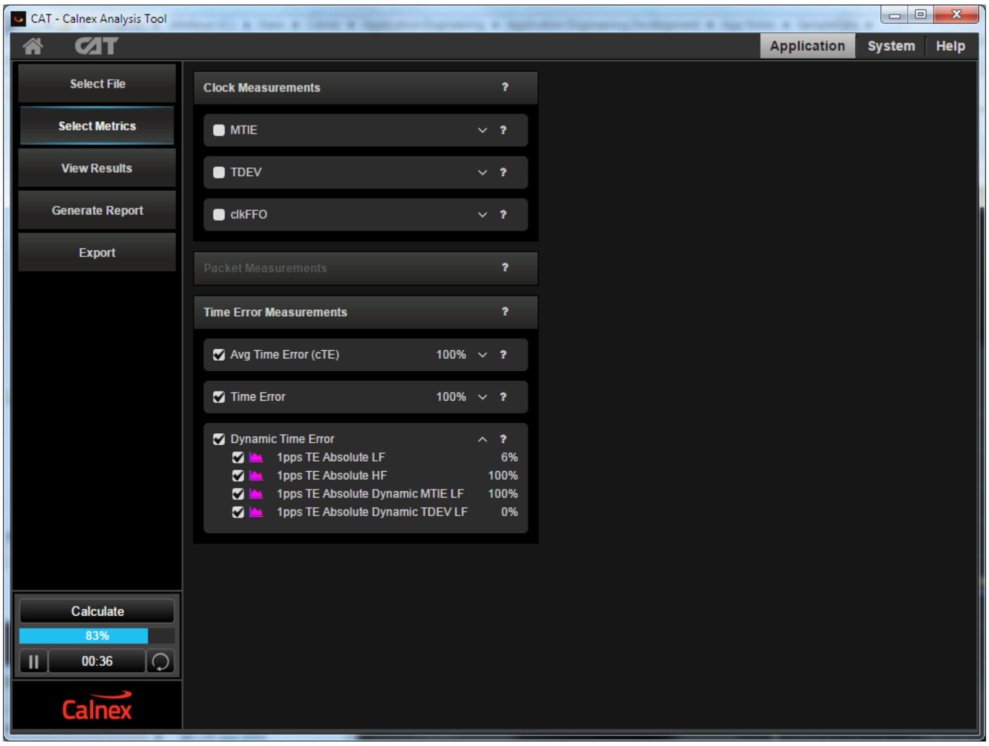
1. Select ***Tools*** > ***Calnex Analysis Tool (1PPS)***.



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

2. By default only the ***Time Error*** and ***Avg Time Error*** metrics can be enabled. To enable **MTIE** and **TDEV** metrics, you must first click on the ***Select Metrics*** button followed by enabling the ***MTIE*** and ***TDEV*** metric tick boxes under ***Dynamic Time Error***.

3. Click on the ***Calculate*** button. On reaching 100%, the metrics are available for selection by clicking on the appropriate tabs.



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

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

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

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

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

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

There are 2 classes of device:

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

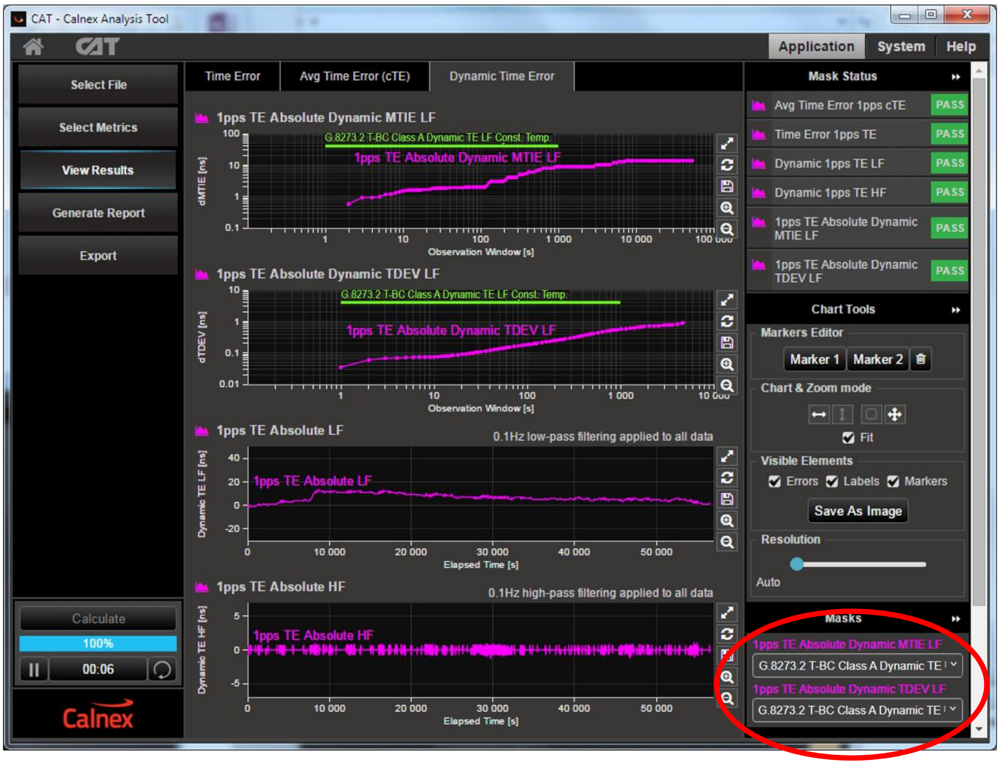
Check with the vendor which class of device is being tested.

Time Error Results (MTIE and TDEV)

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

7. Compare the results against the ITU-T limits by applying the appropriate mask to the ***2Way Dynamic MTIE LF*** and ***2Way Dynamic TDEV LF*** metrics to match the class of the device under test:

- ***G.8273.2 T-BC Class A Dynamic TE LF Const. Temp***
- ***G.8273.2 T-BC Class B Dynamic TE LF Const. Temp***



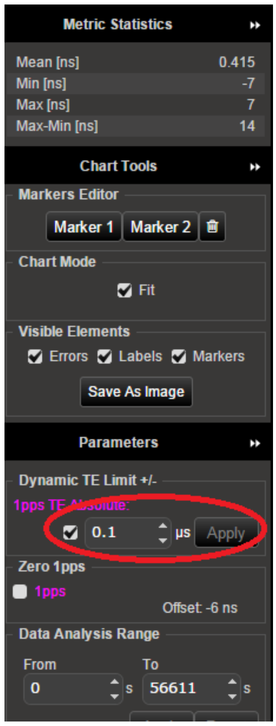
8. Check for PASS/FAIL versus masks. If the masks pass then the status in the **Mask Status** Block will indicate PASS. Mask failure will be indicated by FAIL.

Time Error Results (Max|TE|)

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

10. Set the Dynamic TE Limit to either ***100ns*** for **Class A** devices or ***70ns*** for **Class B** devices. This will change the **Thresholds** on the graph.

11. Compare the results against the thresholds.



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

5. Time Noise Tolerance – G.8273.2 Clause 7.2

Test Description

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

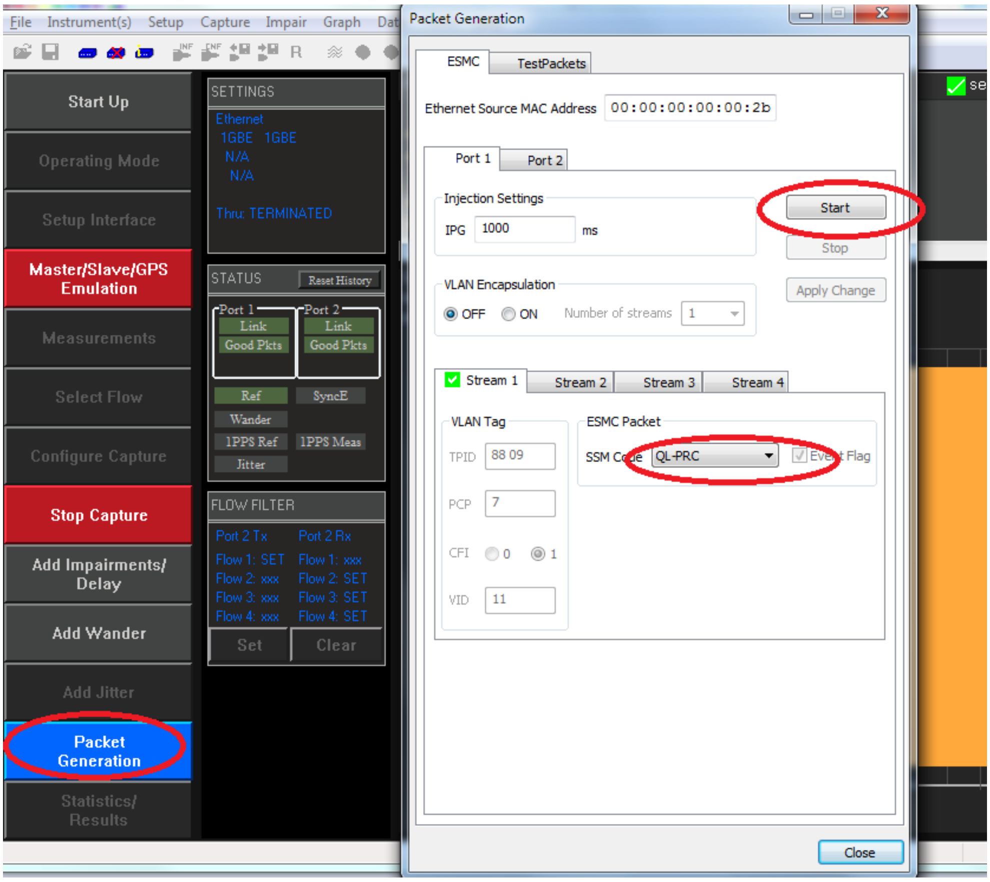
Measurement Process

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

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

Combined PTP and SyncE

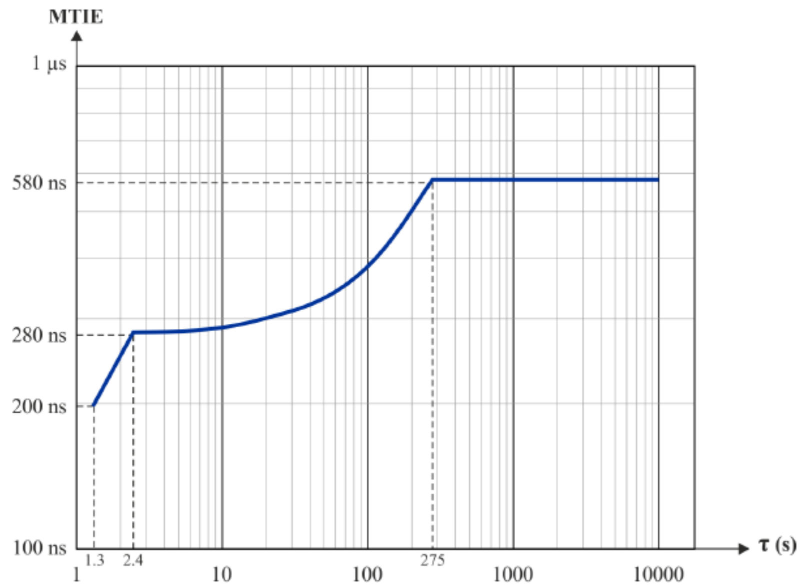
1. To enable SyncE ESMC Generation, select ***Packet Generation*** with **SSM code** of ***QL_PRC***.
2. To start ESMC generation press the ***Start*** button.



Add Impairment Pattern

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

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

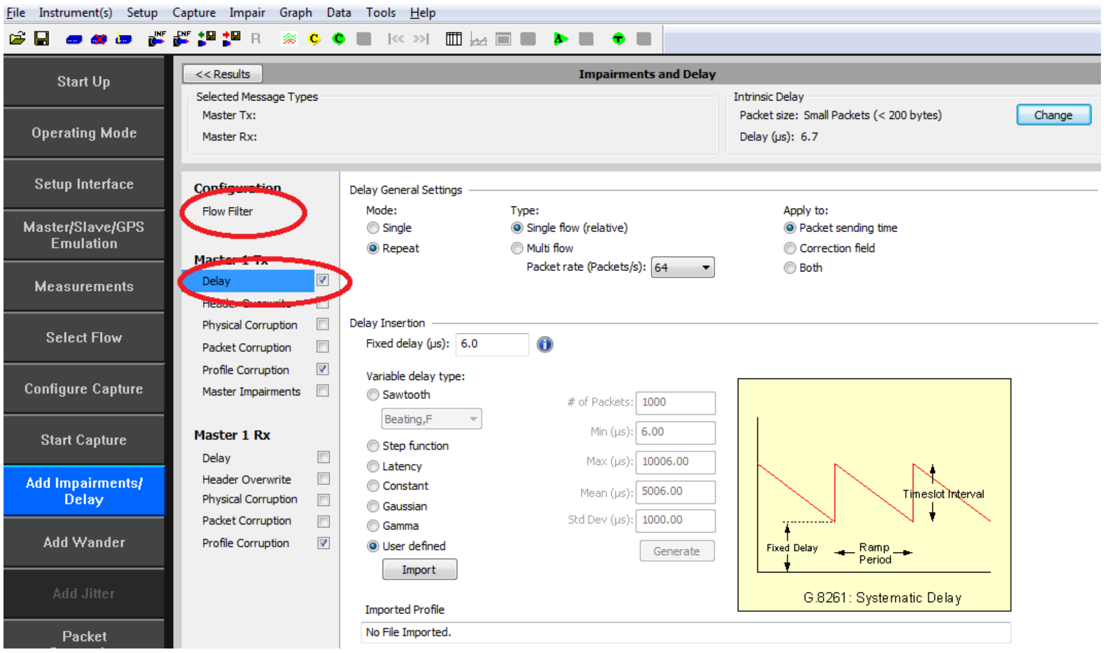


This pattern is called ***G8273_2 Noise Tolerance Pattern[G8271.1Table7-1] _16pps.cpd*** and is available for download as part of the G.8273.2 suite of impairment patterns.

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

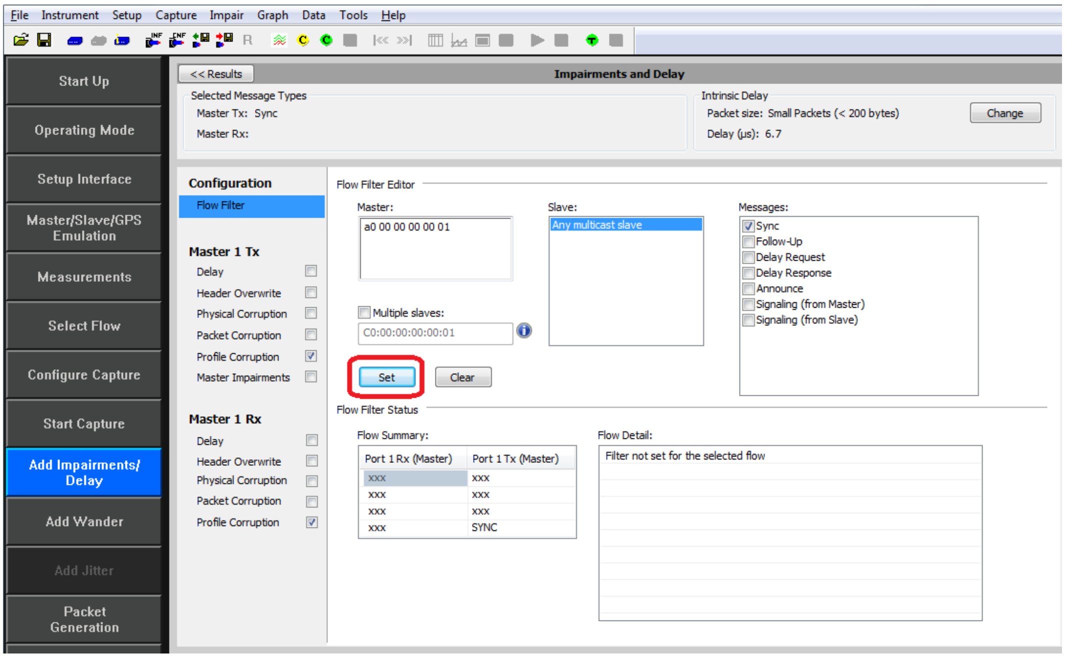
Adding the Pattern

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

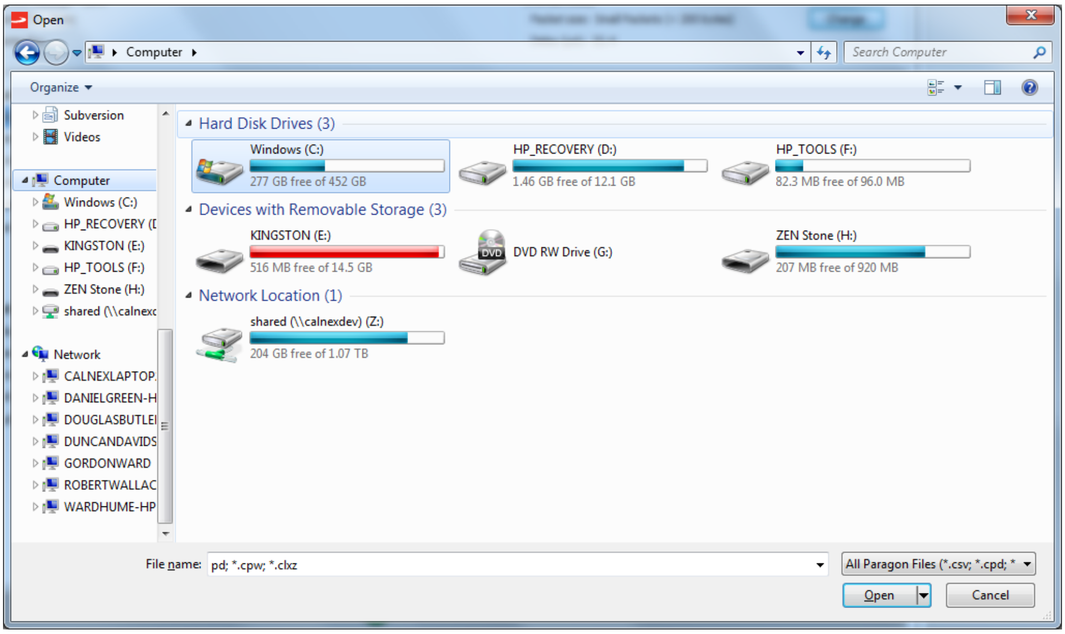


4. Enable the ***Master TX Delay*** feature using the tick box shown above and clicking on the word ***Delay***.

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



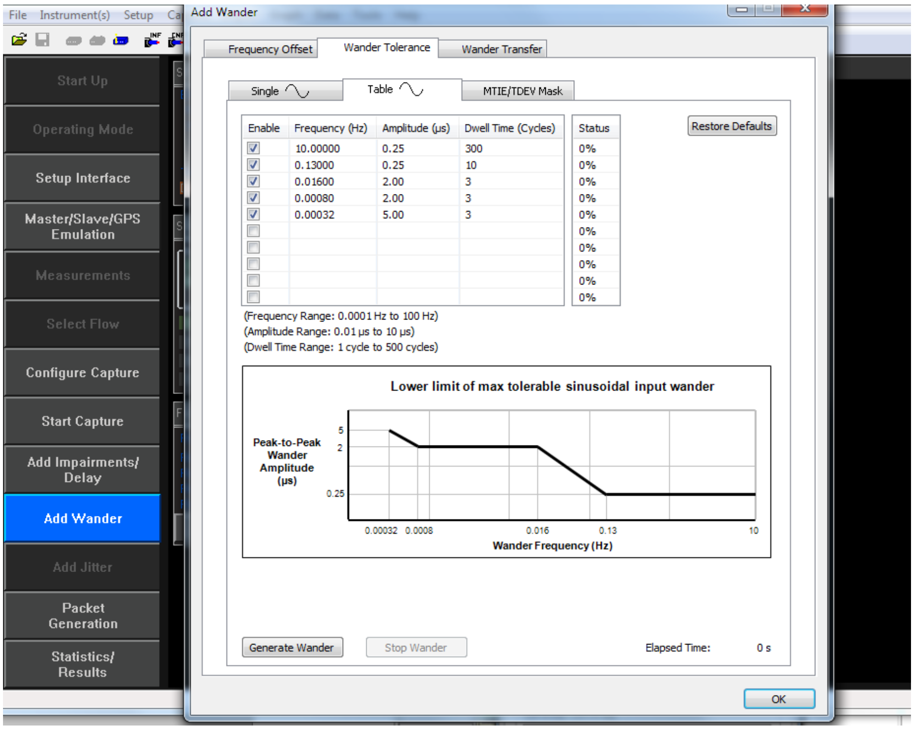
6. Select the ***Master TX Delay*** again, then ***User defined*** and ***Import***. In the file browser window navigate to the location of the stored pattern and select the ***Pattern*** obtained from Calnex.



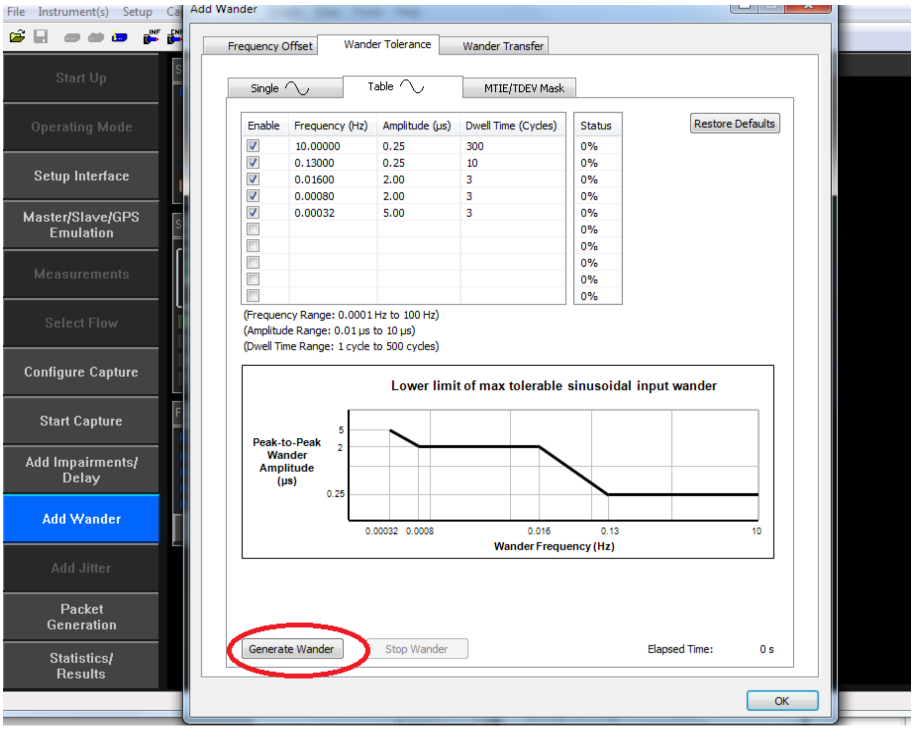
7. Once the file has been loaded, start the impairment by selecting 

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).

6. Time Noise Transfer – G.8273.2 Section 7.3

Test Description

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

Measurement Process

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

- configures the Paragon-X
- applies the appropriate noise patterns to the T-TSC input as defined in G.8273.2 Amendment 1 (Appendix VI)
- measures the T-TSC response to the applied noise patterns
- provides a pass / fail indication for measured output based on the limits defined in G.8273.2 Amendment 1 (Appendix VI)

Requirements

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

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

6.1 PTP to 1PPS Transfer

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

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

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

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

Procedure

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

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

Tools - Calnex Product FAQ

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

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

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

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

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

There are two sets of information required:

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

Setting	Description	Default	Allowed Values
InstrIp	The IP address of the Paragon-X management port	192.168.3.100	Valid IP address
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 (see note 4)
PtpPoints	Specifies which frequency points are to be tested with PTP input	ALL	ALL or list of points (see note 5)
SyncEPoints	Specifies which frequency points are to be tested with SyncE input	ALL	ALL or list of points (see note 5)
ConfigFile	Specifies a file containing configuration parameters (see the **"Executing the Enhanced Noise Transfer"** section) in the **Calnex Noise Transfer Script - Getting Started Guide [CX5036]**	""	Valid configuration file
SettlingTime	Time for the device to lock to PTP supplied from the P-X Master (see note 6).	120	Type: Integer Range: Positive Unit: Seconds
RecoveryTime	Time for the device to recover after a change to the applied input noise (see note 7).	50	Type: Integer Range: Positive Unit: Seconds

Table 3. Script Control Settings

Notes

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

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 5.1 ns per metre; for optical fibre, the delay will be approximately 4.9 ns per metre. Only full nanosecond values are counted, so calculated values need to be rounded up or down to the nearest full nanosecond value.
4. **Type:** Specifies the stimulus (PTP or SyncE) to be applied to the DUT input and the measurements to be performed on the DUT output. The measurements can be PTP, 1pps or BOTH. **This should be set to PTP-1PPS.**
5. **PtpPoints / SyncEPoints:** A subset of frequencies can be selected using a space delimited string of numbers indexed from 0. For example, to test only 0.0071825Hz and 0.4925Hz, set PtpPoints to "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 very between DUTs. This recovery time will not be included in the measurement.
8. **LineRate:** The interface Line Rate to be used (e.g. 1GBE, 10GBE etc.). Default is 1GBE.
9. **Interface:** The selected interface. **Please select LineRate if changing Interface.**

Execution

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

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

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

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

"C:\Tcl\bin\tclsh86.exe" *G.8273.2.tcl* **InstrIp** 192.168.4.100 **Type** PTP-1PPS **LineRate** 1GBE **Interface** OPTICAL

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

```
"C:\Tcl\bin\tclsh86.exe" G.8273.2.tcl Type PTP-1PPS InstrIp 192.168.3.100 SettlingTime 200 ReProcess TRUE
*************************************
Enhanced Noise Transfer 4.00.00
*************************************
Parameters:
        InstrIp - 192.168.3.100
        GuiIp - localhost
        GuiPort - 9000
        Type - PTP-1PPS
        CableDelay - 5
        LineRate - 1GBE
        Interface - ELECTRICAL
        Reference - INT
        SettlingTime - 200
        RecoveryTime - 50
        1ppsThreshold - 1.0
        AutoNegotiate - FALSE
        SyncE - TRUE
        RemoteCaptureFolder - C:/Desktop
        RemoteProfileFolder - C:/Desktop
        Debug - FALSE
        ReProcess - FALSE
        Filter - LSQ
        SimulatedData - FALSE
        Graphing - FALSE

Start: 2017-12-21 10-39-35

Results will be stored in:      "Results\Results PTP-1PPS Demo"
Log will be stored in:  "Logs/Log PTP-1PPS Demo.txt"
Existing demo folder "Results/Results PTP-1PPS Demo" has been deleted

connecting to GUI localhost:9000
connected to GUI
connected to instrument
X.10.38.33;FIRMWARE
CALNEX-SOLUTIONS,Paragon-X,00012054,SERVER=X.10.38.33;FIRMWARE=E.14.92;sync=C04F;sync=C04F;oam=E007;oam=E007


*** Stimulus = PTP ---> DUT ---> Measure = 1PPS ***

2017-12-21 10-39-46     Step 0 Stimulus:         0.00390625 200.0 16.0 800 130 215 "NoiseTransfer_0_00390625Hz.csv"
```

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

```
*************************************
Enhanced Noise Transfer 4.00.00
*************************************
Parameters:
        InstrIp - 192.168.3.100
        GuiIp - localhost
        GuiPort - 9000
        Type - PTP-1PPS
        CableDelay - 5
        LineRate - 1GBE
        Interface - ELECTRICAL
        Reference - INT
        SettlingTime - 200
        RecoveryTime - 50
        1ppsThreshold - 1.0
        AutoNegotiate - FALSE
        SyncE - TRUE
        RemoteCaptureFolder - C:/Desktop
        RemoteProfileFolder - C:/Desktop
        Debug - FALSE
        ReProcess - FALSE
        Filter - LSQ
        SimulatedData - FALSE
        Graphing - FALSE

Start: 2017-12-21 10-39-35
```

Results

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

- Demo
- Results
- Common functions
- filterFunction
- filterLeastSquares
- G.8273.2
- Initialization
- measurements
- paragonwl
- results
- Time Noise Transfer

- Calnex Noise Transfer Script - User Guide
- NoiseTransfer_0_985Hz
- NoiseTransfer_0_03125Hz
- NoiseTransfer_0_4925Hz
- NoiseTransfer_0_015625Hz
- NoiseTransfer_0_24625Hz
- NoiseTransfer_0_0078125Hz
- NoiseTransfer_0_123125Hz
- NoiseTransfer_0_00390625Hz
- NoiseTransfer_0_0615625Hz
- NoiseTransfer_1_985Hz
- Results Chart Template

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

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

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

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

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

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

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

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

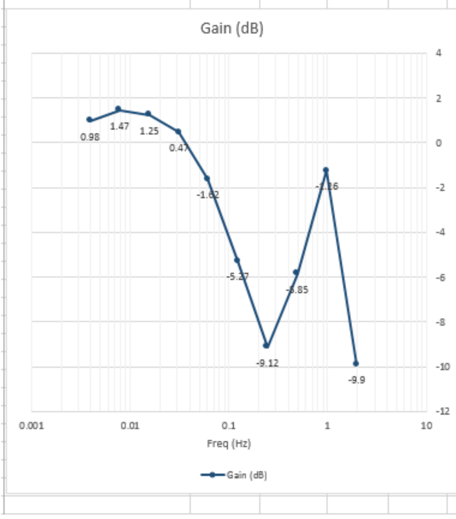
Noise Transfer (PTP-1PPS)	#############						
Profile	Freq (Hz)	Amplitud	Measured	Gain (dB)	Lower Lim	Upper Lim	Pass/Fail
NoiseTransfer_0_00390625Hz	0.00390625	200	224	0.98	130	215	FAIL(upper)
NoiseTransfer_0_0078125Hz	0.0078125	200	237	1.47	130	215	FAIL(upper)
NoiseTransfer_0_015625Hz	0.015625	200	231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

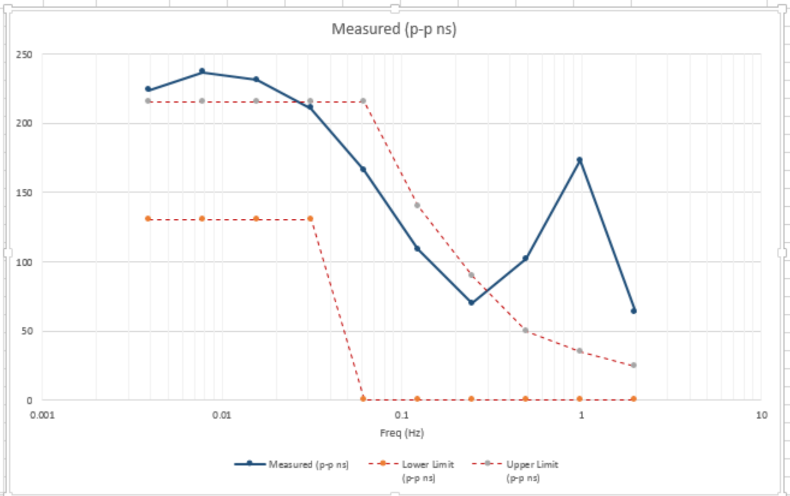
To analyse the data, copy the entries from the **Results.csv** file into the **Template file Results Chart Template.xlsx**. This has macros which will draw a chart of the measured results versus the expected filter mask.

Instructions

Clear the contents from the table below and then cut and paste from the results file into the table

Noise Transfer							
Profile	Freq (Hz)	Amplitude (p-p ns)	Measured (p-p ns)	Gain (dB)	Lower Limit (p-p ns)	Upper Limit (p-p ns)	Pass/Fail
NoiseTransfer_0_00390625Hz	0.003906	200	224	0.98	130	215	FAIL(upper)
NoiseTransfer_0_0078125Hz	0.007813	200	237	1.47	130	215	FAIL(upper)
NoiseTransfer_0_015625Hz	0.015625	200	231	1.25	130	215	FAIL(upper)
NoiseTransfer_0_03125Hz	0.03125	200	211	0.47	130	215	PASS
NoiseTransfer_0_0615625Hz	0.061563	200	166	-1.62	NA	215	PASS
NoiseTransfer_0_123125Hz	0.123125	200	109	-5.27	NA	140	PASS
NoiseTransfer_0_24625Hz	0.24625	200	70	-9.12	NA	90	PASS
NoiseTransfer_0_4925Hz	0.4925	200	102	-5.85	NA	50	FAIL(upper)
NoiseTransfer_0_985Hz	0.985	200	173	-1.26	NA	35	FAIL(upper)
NoiseTransfer_1_985Hz	1.985	200	64	-9.9	NA	25	FAIL(upper)





6.2. SyncE to 1PPS Transfer

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

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

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

Table 4. Maximum and Minimum Expected Output Amplitudes at Test Frequencies for SyncE-to-PTP and SyncE-to-1pps Noise Transfer Measurement

Procedure

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

Execution

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

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

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

"C:\Tcl\bin\tclsh86.exe" *G.8273.2.tcl* **InstrIp** 192.168.4.100 **Type** SyncE-1PPS **LineRate** 1GBE **Interface** OPTICAL

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

Results

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

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

- Demo
- Results
- Common functions
- filterFunction
- filterLeastSquares
- G.8273.2
- Initialization
- measurements
- paragonwl
- results
- Time Noise Transfer

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

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

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

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

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

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

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

The ***Results.csv*** produced will look like:

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

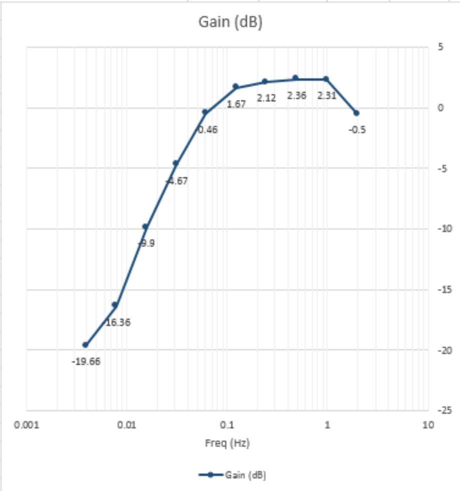
To analyse the data, copy the entries from the **Results.csv** file into the **Template file Results Chart Template.xlsx**. This has macros which will draw a chart of the measured results versus the expected filter mask.

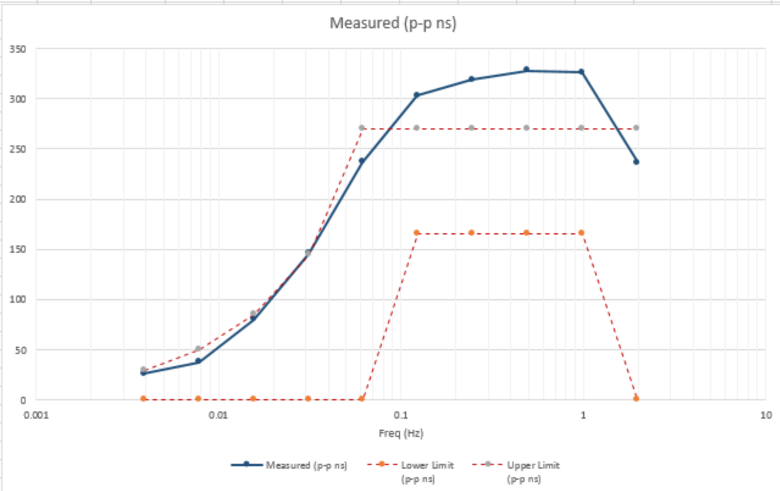
Instructions

Clear the contents from the table below and then cut and paste from the results file into the table

Noise Transfer

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





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

Test Description

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

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

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

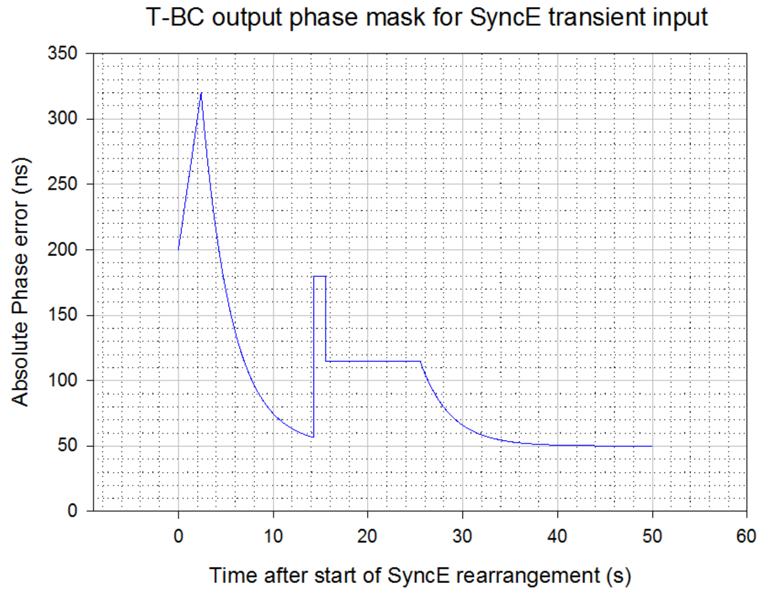


Figure B.1 from G.8273.2 Annex B – Phase error mask during a SyncE transient

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

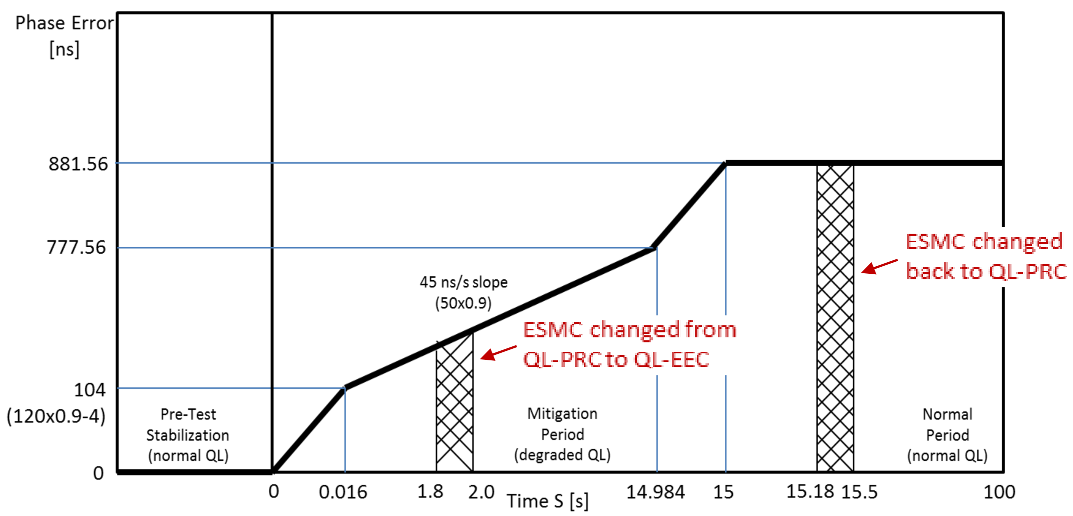


Fig. III.2 from G.8273 Appendix III – SyncE Transient Input Pattern

Measurement Process

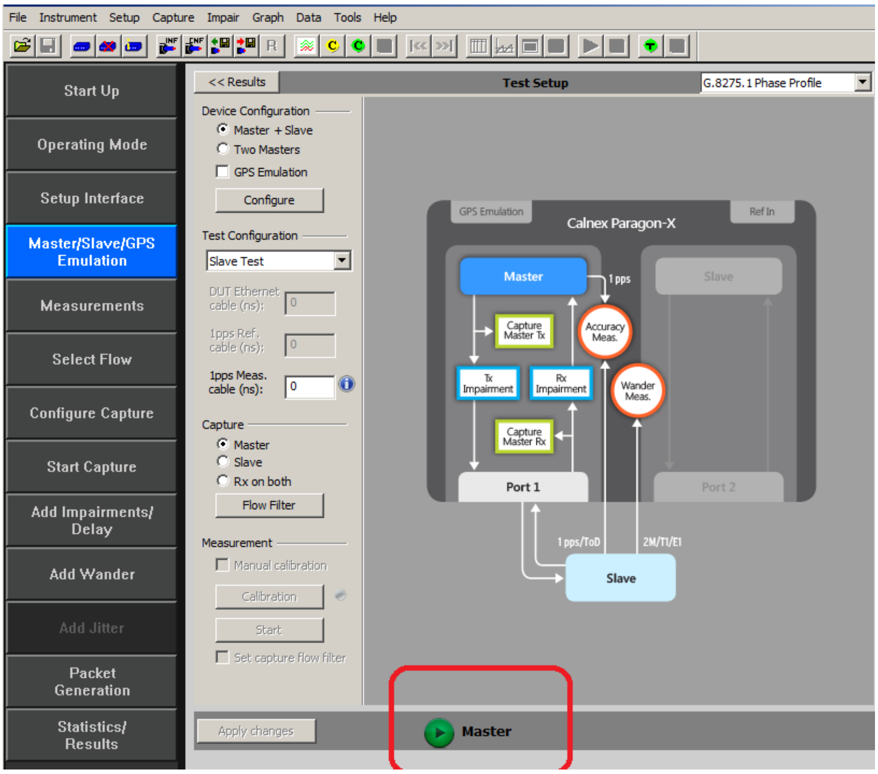
The standard requires testing in combined hybrid mode involving both PTP and SyncE input. This is reflected in the test procedure 7.1.1 detailed below.

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

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

7.1 Packet Layer Transient Response

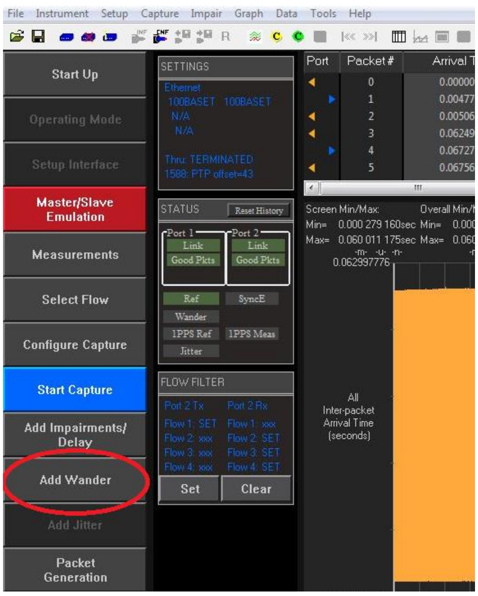
1. Start Master/Slave Emulation.



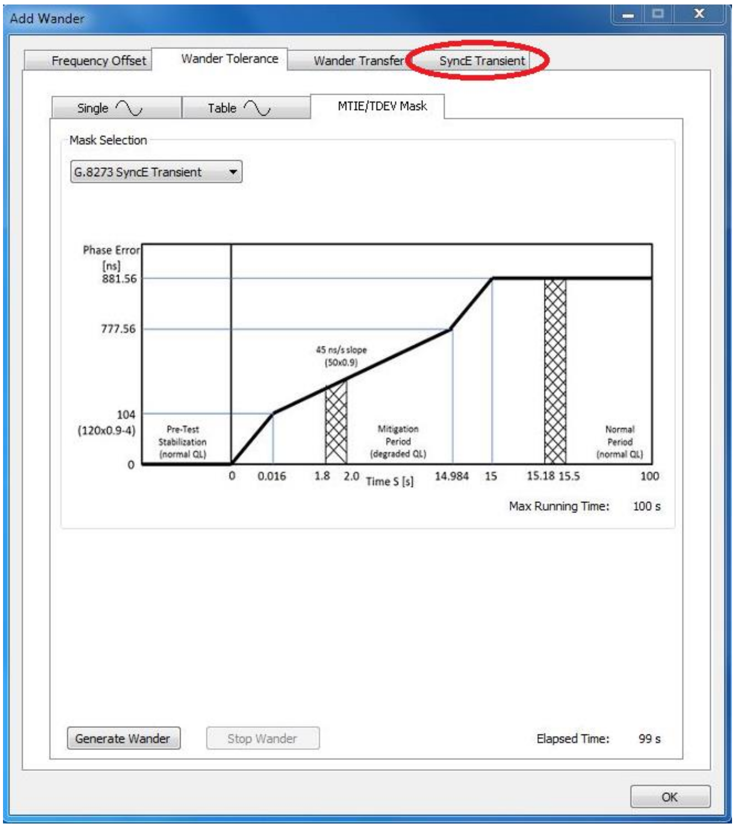
Wait for the T-TSC to lock to the Paragon-X emulated Master and stabilize before making any measurements**. Clock settling time is important**. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several hours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

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

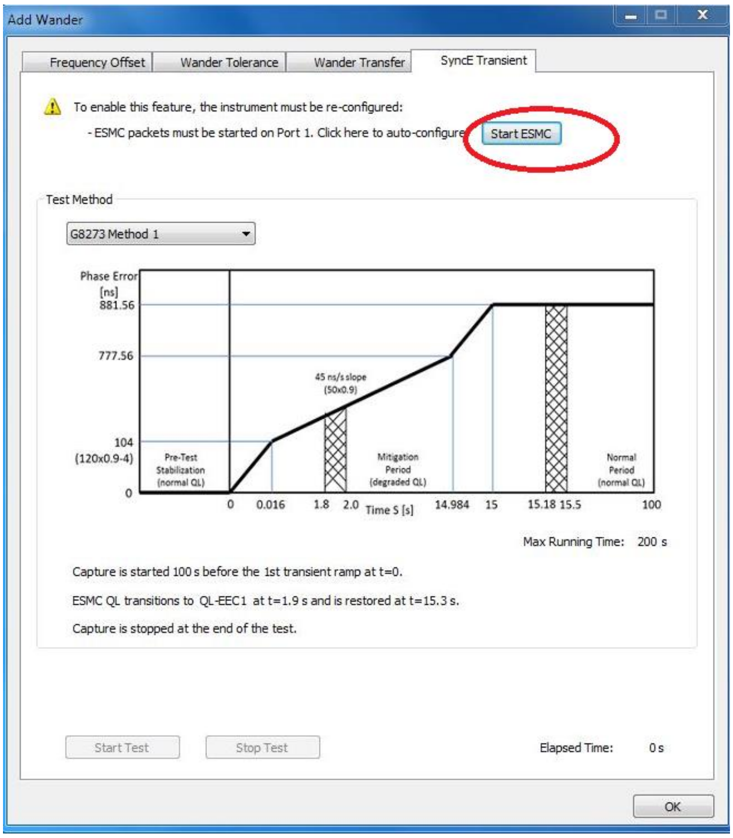
2. After device has settled select the ***Add Wander*** button.



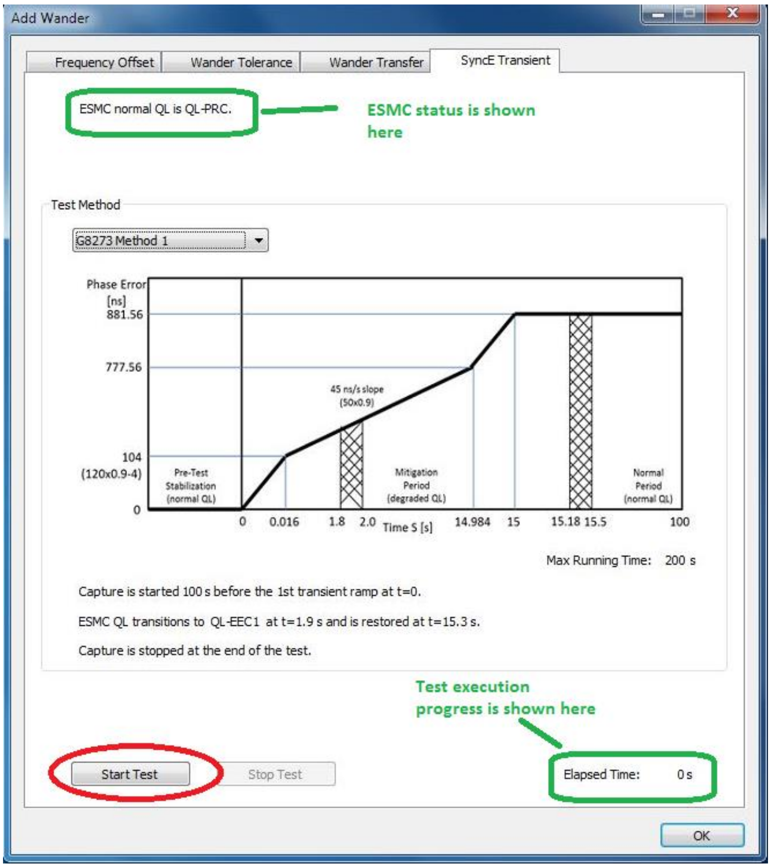
3. In the Add Wander window, select the ***SyncE Transient*** tab.



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

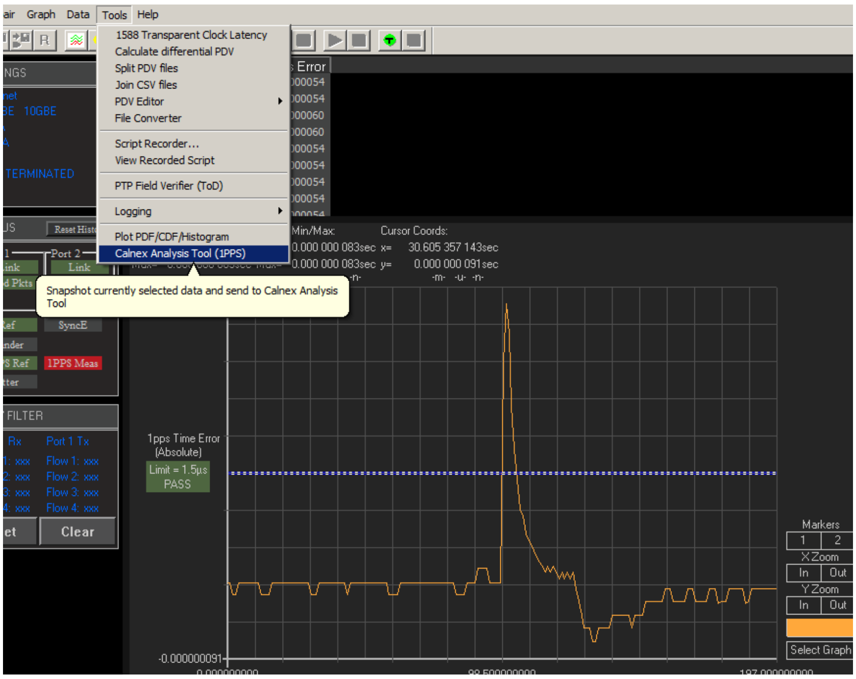


5. After starting the ESMC generation the test can be started using the ***Start Test*** button. During the test the elapsed time is displayed, as is the current ESMC status.

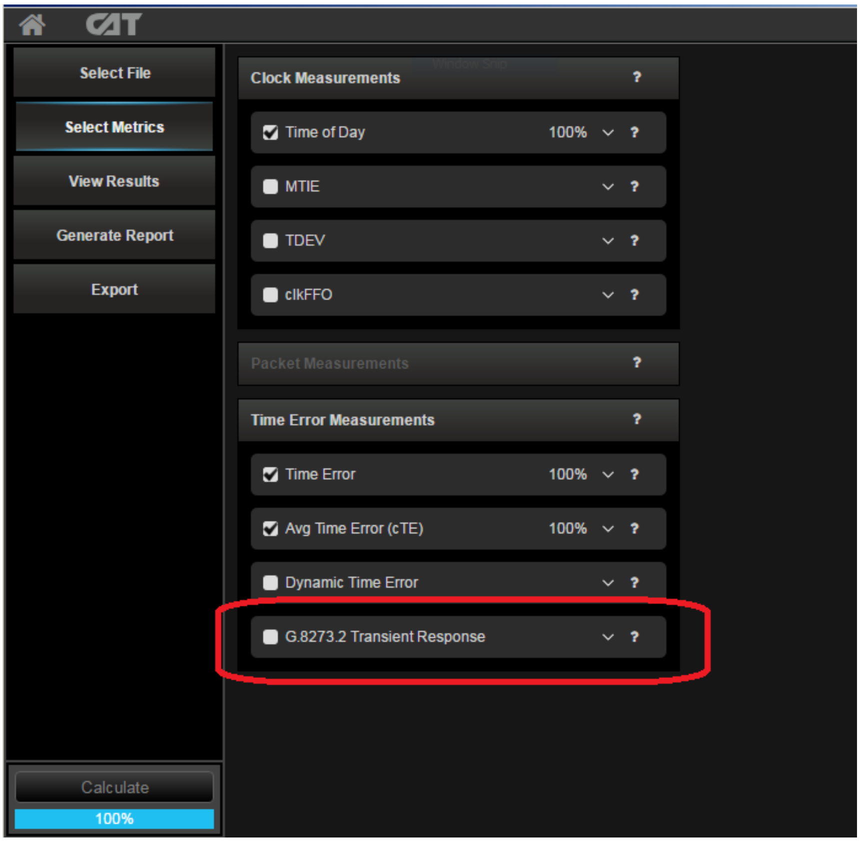


Test execution takes 200s. The first 100s are used to analyse the underlying Constant Time Error (cTE) without the application of the transient. As per the standard, the mask for Phase Noise response to the generated transient requires the results to be adjusted for cTE – this step therefore allows the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

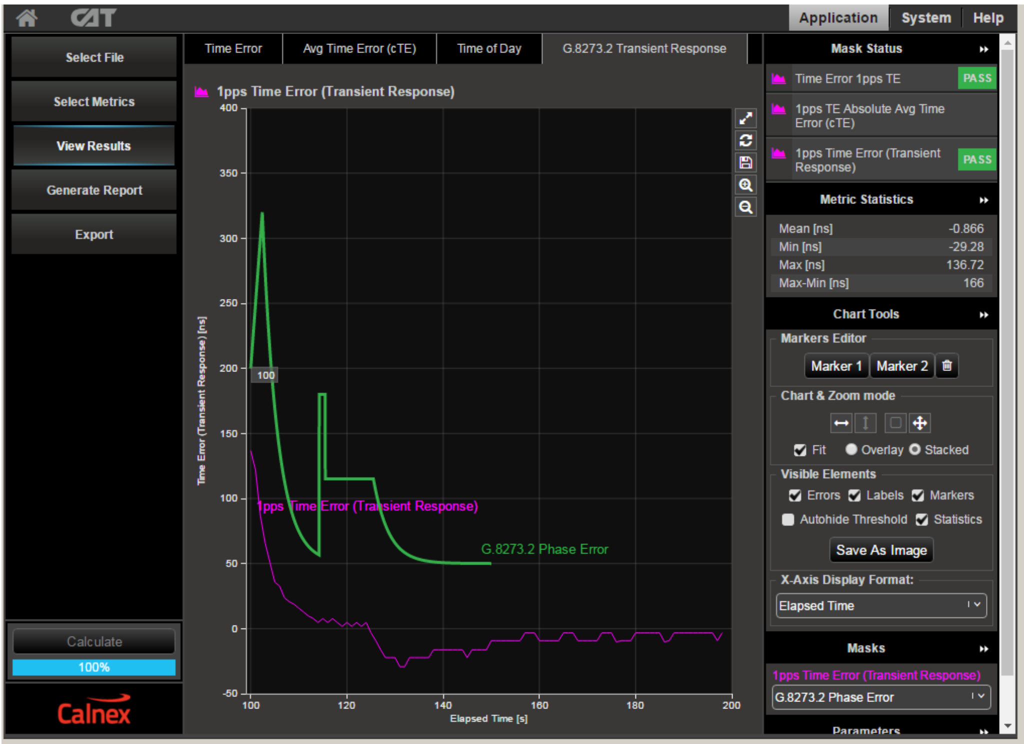
6. On completion of the test, the test results can be analysed using the ***Calnex Analysis Tool***.



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



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



7.2 Holdover Performance

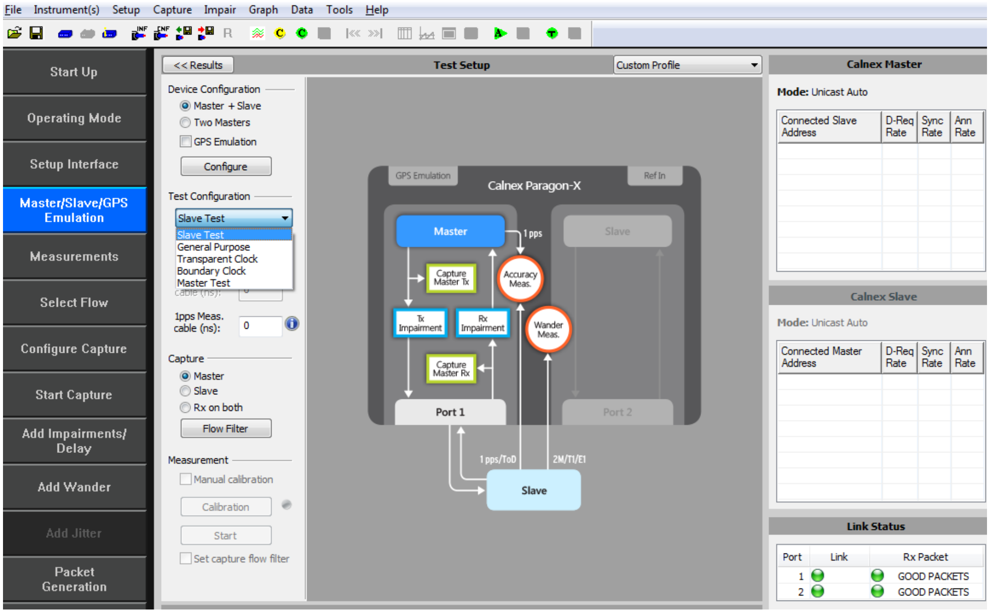
Holdover performance is checked by measuring the phase/time output in the event of the loss of the PTP input to the T-TSC.

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

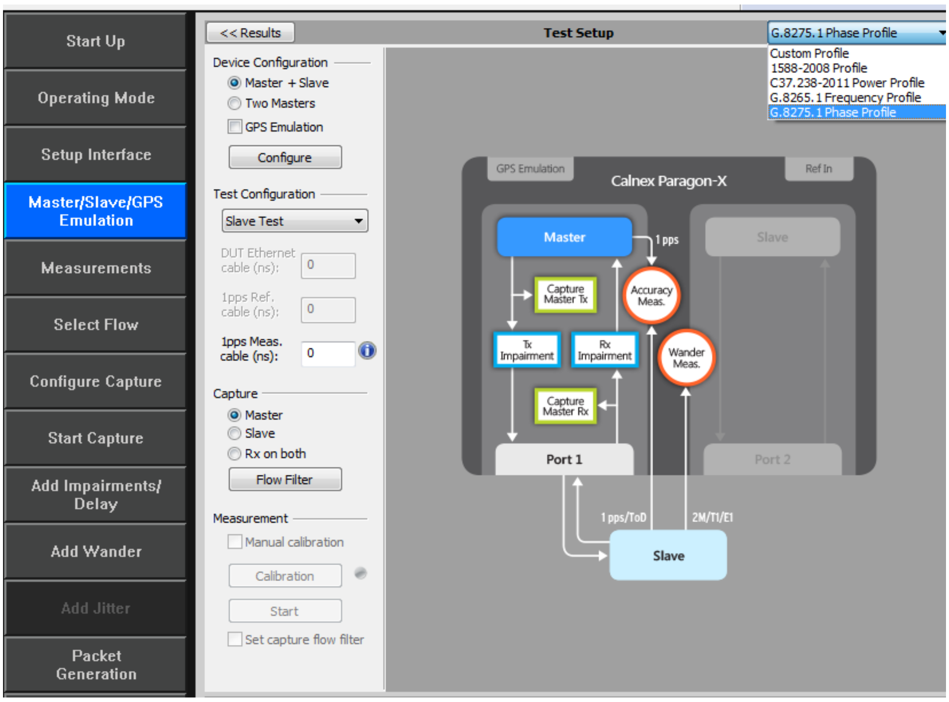
The Master/Slave Emulation can be configured to use other profiles e.g. Unicast UDP/IPV4 etc., however, it should be noted that these profiles will not conform to the G.8273.2 standard.

Measurement process – Master/Slave Configuration

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

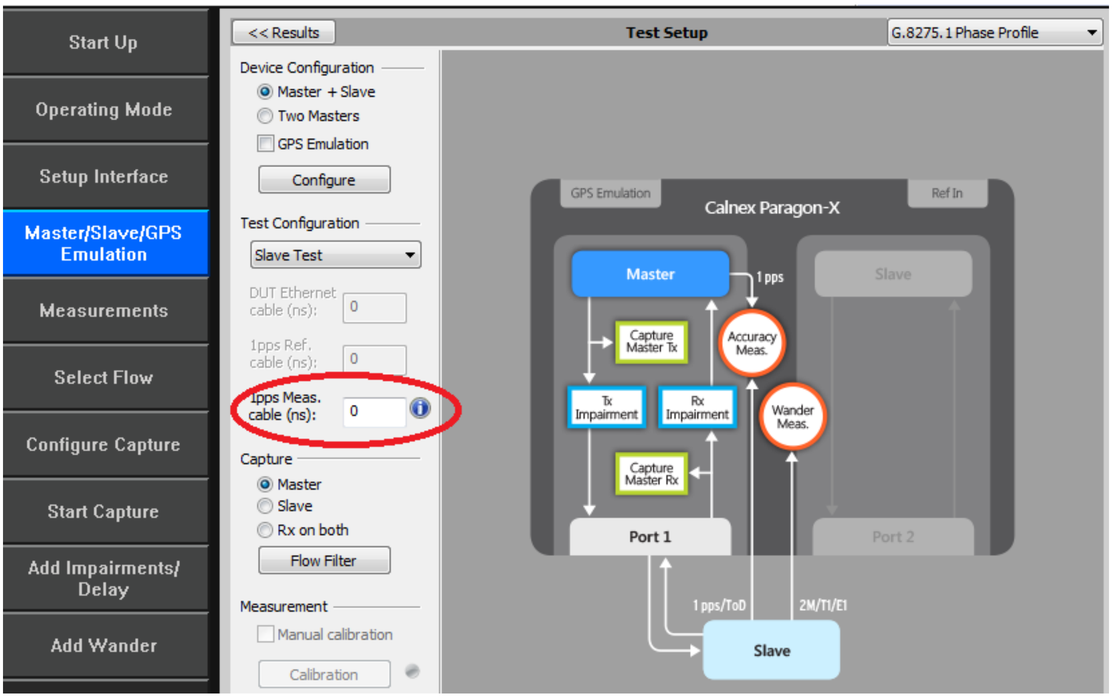


2. Select ***G.8275.1 Phase Profile*** from the Custom Profile drop down menu.

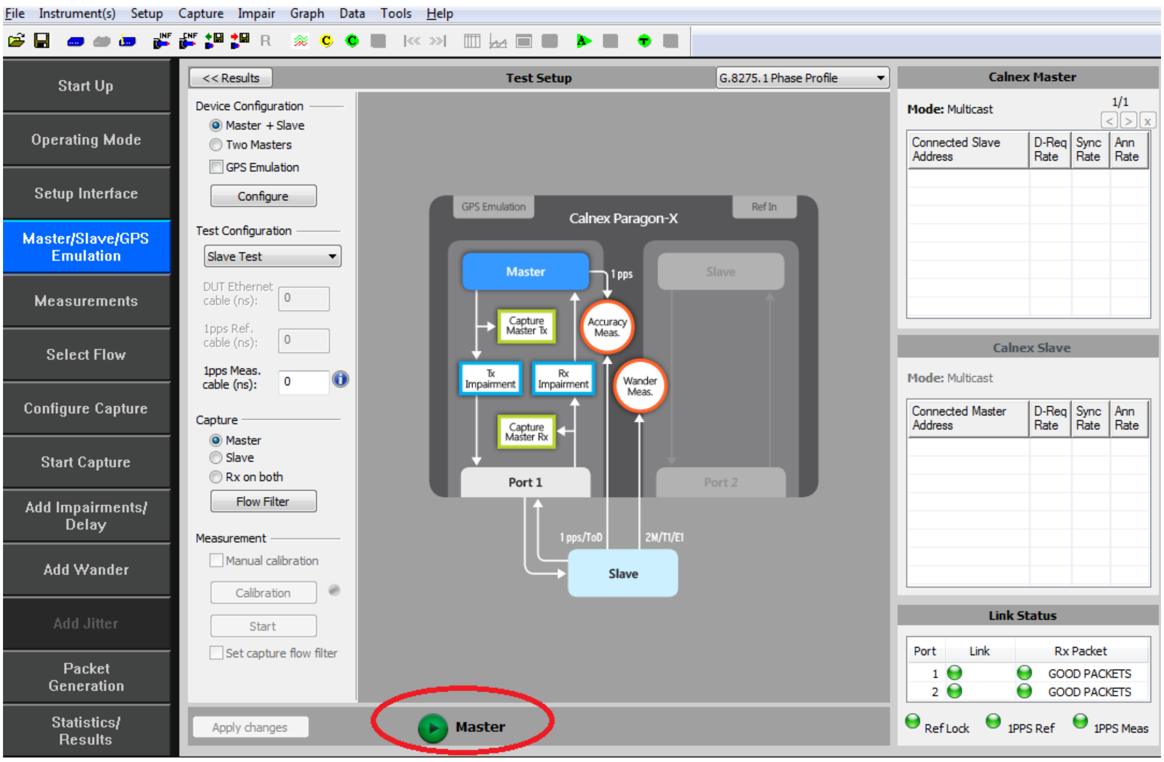


3. Enter DUT to Paragon-X 1pps **cable delay**.

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



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



Confirm PTP traffic on interfaces

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

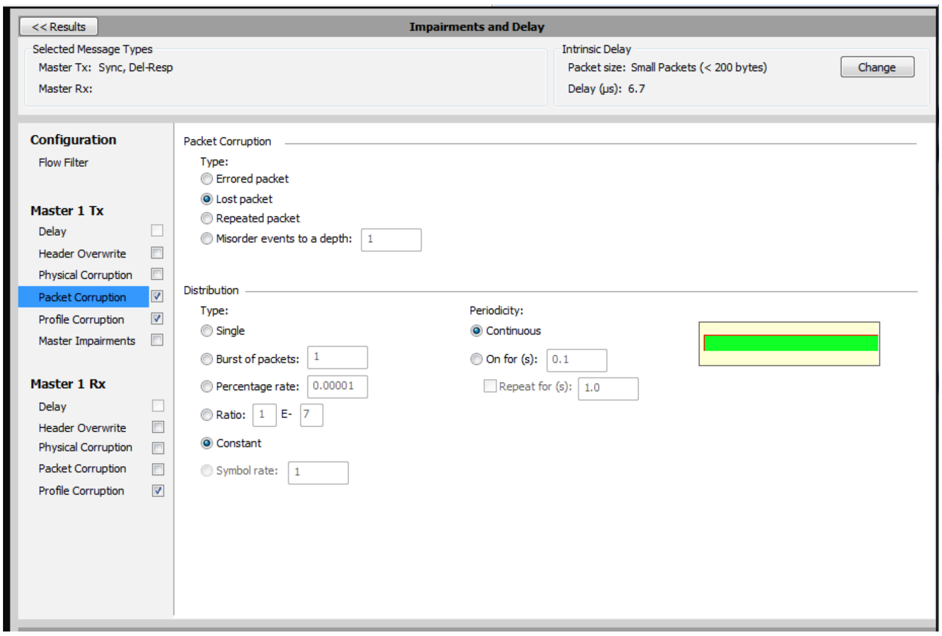
Clock settling time is important. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be anywhere from a few minutes to several hours dependent on the T-TSC under test. It may even be recommended to wait longer e.g. overnight.

Measurement Steps

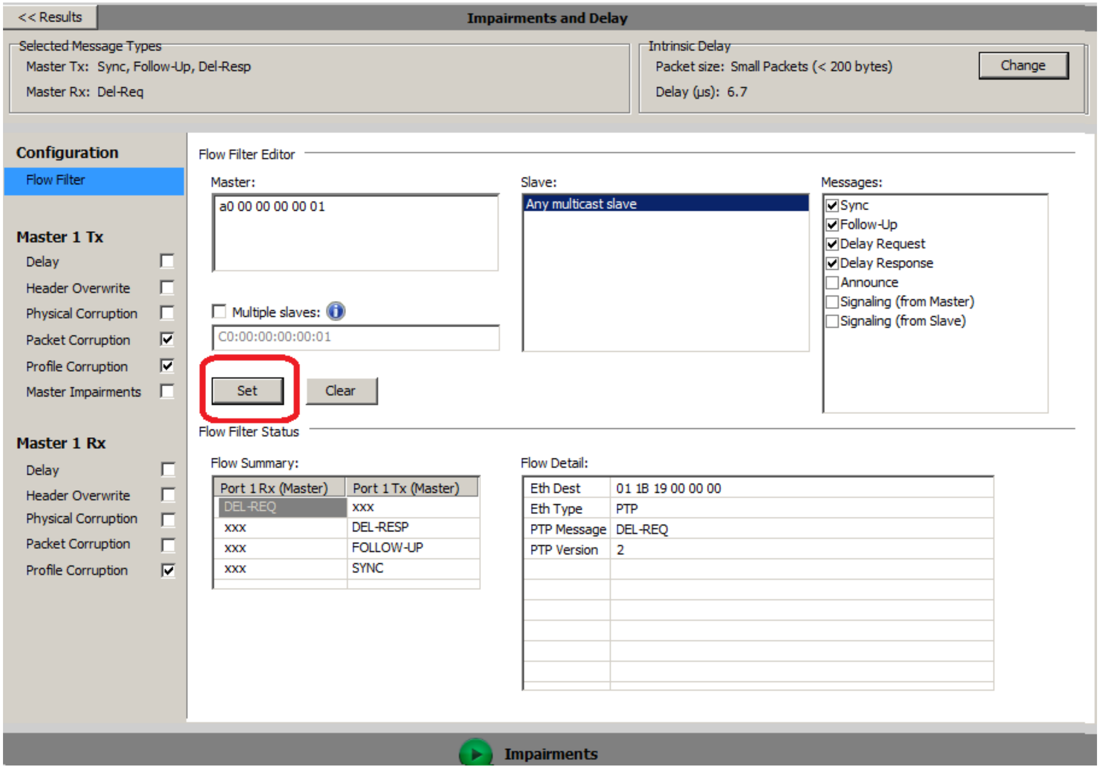
With the T-TSC in a stable state:

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

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



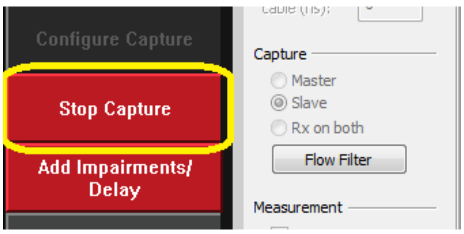
4. Select ***Flow Filter*** to choose the messages to apply delays against – ***Sync, Follow-Up, Delay-Request*** and ***Delay Response*** messages.



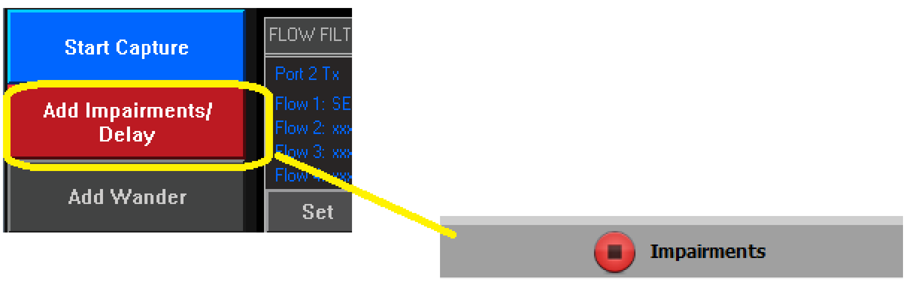
5. Now start the impairment by selecting 

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

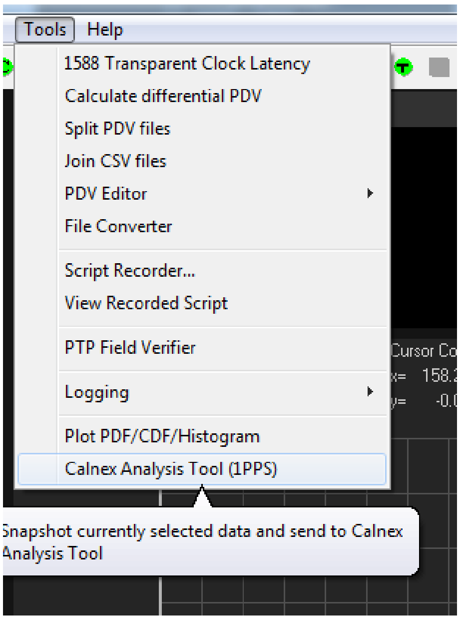
6. After **1000s** select the ***Stop Capture*** button.



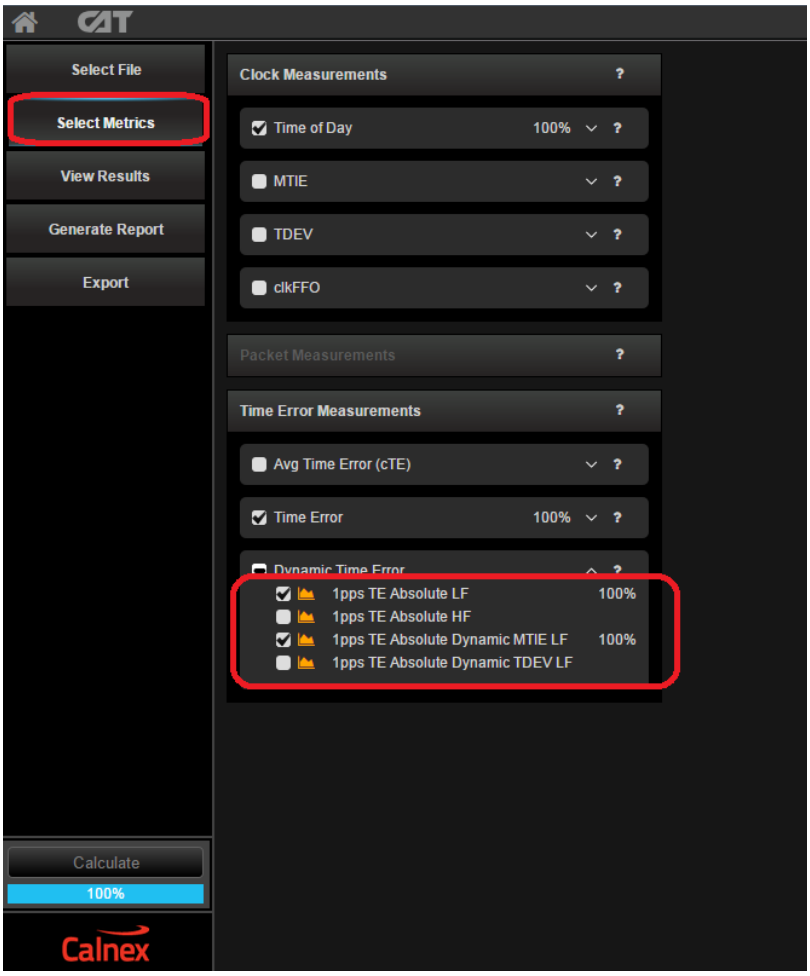
7. Select the **Add Impairments/Delay** and stop the impairment



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



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



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

11. Apply the appropriate mask to the ***2Way Dynamic MTIE LF*** metric depending on the class of the device under test:

- ***G.8273.2 T-BC Class A Time Holdover Const. Temp***
- ***G.8273.2 T-BC Class B Time Holdover Const. Temp***

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

Appendix 1 – G.8271.1 Time Error Budget Example

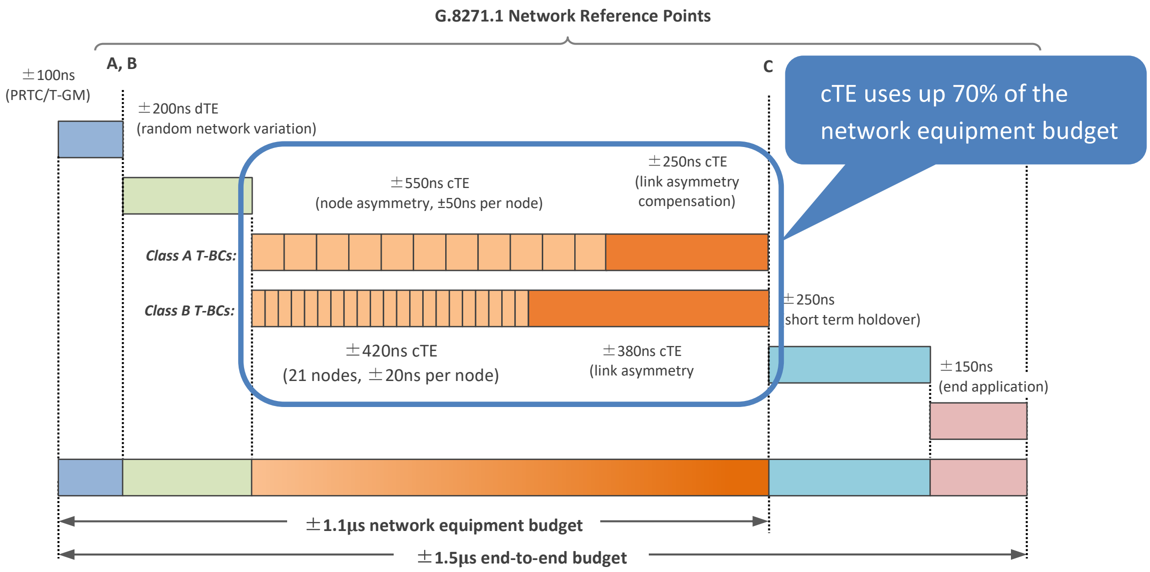


Table V1.1/G.8271.1 – Example of Time Error Allocation

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-TSC

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

<table>
<tr><th>Test</th><th>Objective</th><th>Test method</th><th colspan="3">Output Limit (1pps signal)</th></tr>
<tr><td rowspan="5">Time Error Noise Generation
(G.8273.2, Annex C.2.1)</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>Noise Tolerance
(G.8273.2, Annex C.2.2)</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 Pattern to the PTP input[6].
Simultaneously apply sine wave phase wander to the SyncE input according to G.8262, Table 9.</td><td colspan="3">No output performance limit.
Clock under test should not:
• generate alarms
• switch reference
• go into holdover</td></tr>
</table>

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

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

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

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