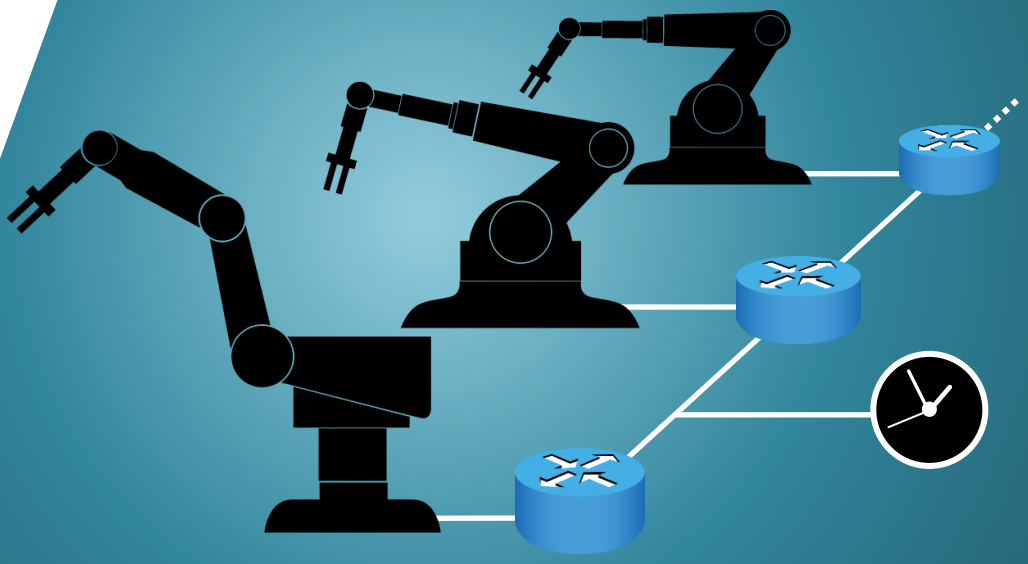
TEST PLAN

This Test Plan shows how the Calnex Paragon-X can be used to prove Time Aware Relay compliance to IEEE 802.1AS (gPTP) and provides procedures to measure noise generation and time noise tolerance.

# Time Aware Relay:
# Time Error Testing



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# Contents

# 1. Hardware and Software Required

### 1.1. Paragon-X

| | |
|---|---|
| Option 1 1 1 | 10GbE interface support (if DUT has 10G interface) |
| Option 201 | Advanced IEEE1588v2 features |
| Option 205 | Wander measurement |
| Option 206 | Phase and time measurement |
| Option 252 | IEEE 1588v2 Peer-to-Peer: One-box BC, TC & OC Test |
| Option 133 | External 1pps/ToD/frequency converter accessory (if required to match DUT outputs) |
| Software Version | X.10.32.*xx* and later |

### 1.2. Accessories

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

### 1.3. Frequency Reference Source

Option 132, Rubidium Interface (optional)

### 1.4. Document References

- IEEE Std 802.1AS Timing and Synchronization for Time-Sensitive Applications
- IEEE Std 1588™ -2008 IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- Tech Note: Cabling Considerations Document (Calnex Doc. No. CX5009)

[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 Time Aware Relay (Device-under-Test)

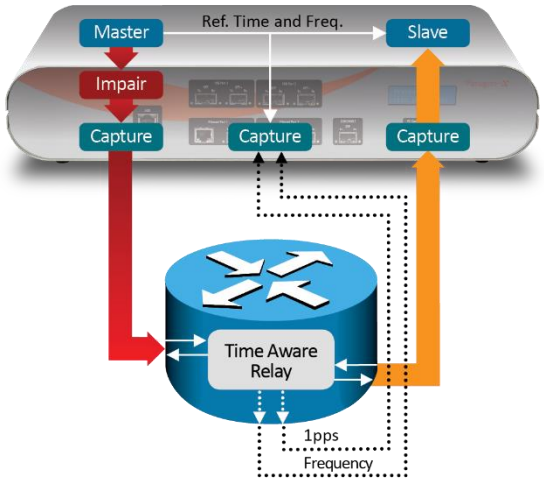
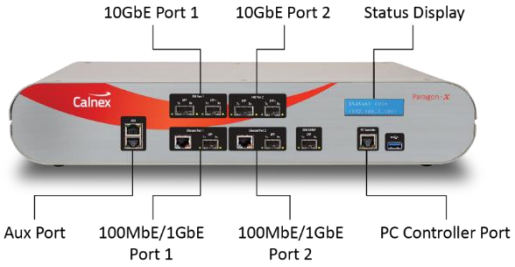



**Figure 1. Paragon-X and Time Aware Relay**

### Front Panel

- 100MbE Electrical or Optical (SGMII SFP)
- 1GbE Electrical or Optical (SFP)[2] – *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 back panel:

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

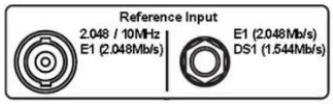



**Figure 2. Reference Inputs**

### Connections

- Connect port 1 (master side of Paragon-X) to the Time Aware Relay 'Slave' side.
- Connect port 2 (slave side of Paragon-X) to the Time Aware Relay 'Master' side.
- Connect external reference e.g. 10MHz to Paragon-X ref input.
- If provisioned on the DUT, connect 1pps output from DUT to 1pps[3] measurement port (Aux). Use converter accessory if required.
- If provisioned on the DUT, connect Freq e.g. E1 output from DUT to Freq measurement port at the rear of the Paragon-X.

[2] If using SFPs or SFP+s, both Port 1 and Port 2 optical transceivers must be inserted into Paragon-X.

[3] It is assumed that the 1pps should track the PTP output, and hence the same output limits are used for both.

# 3. How to use Paragon-X for 802.1AS Performance Tests

**Test Set-up Steps:**

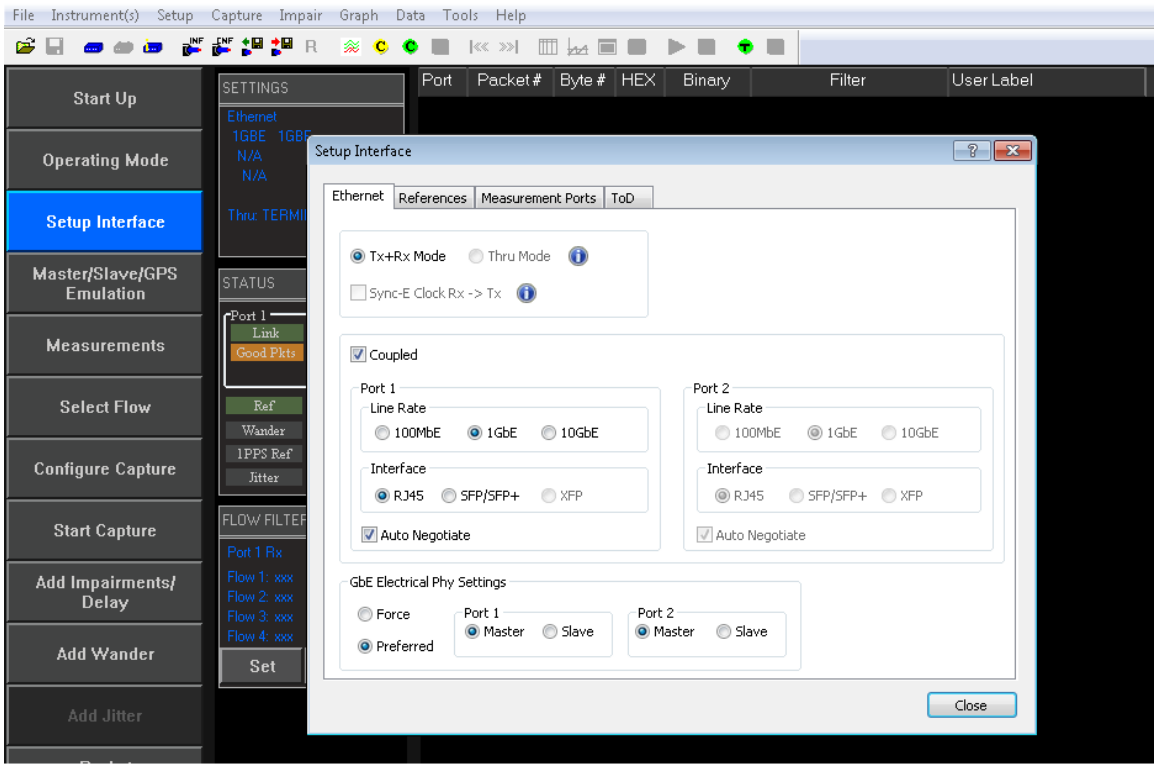
3.1 Connection to Paragon-X from GUI
3.2 Configuration of physical connections
3.3 Measurement Configuration
3.4 Preparing Master/Slave Emulation operation
3.5 Confirmation of PTP traffic on interfaces
3.6 Configuring capture filters and parameters, and enabling impairments (if desired)
3.7 Making measurements

## 3.1 Paragon-X Connections

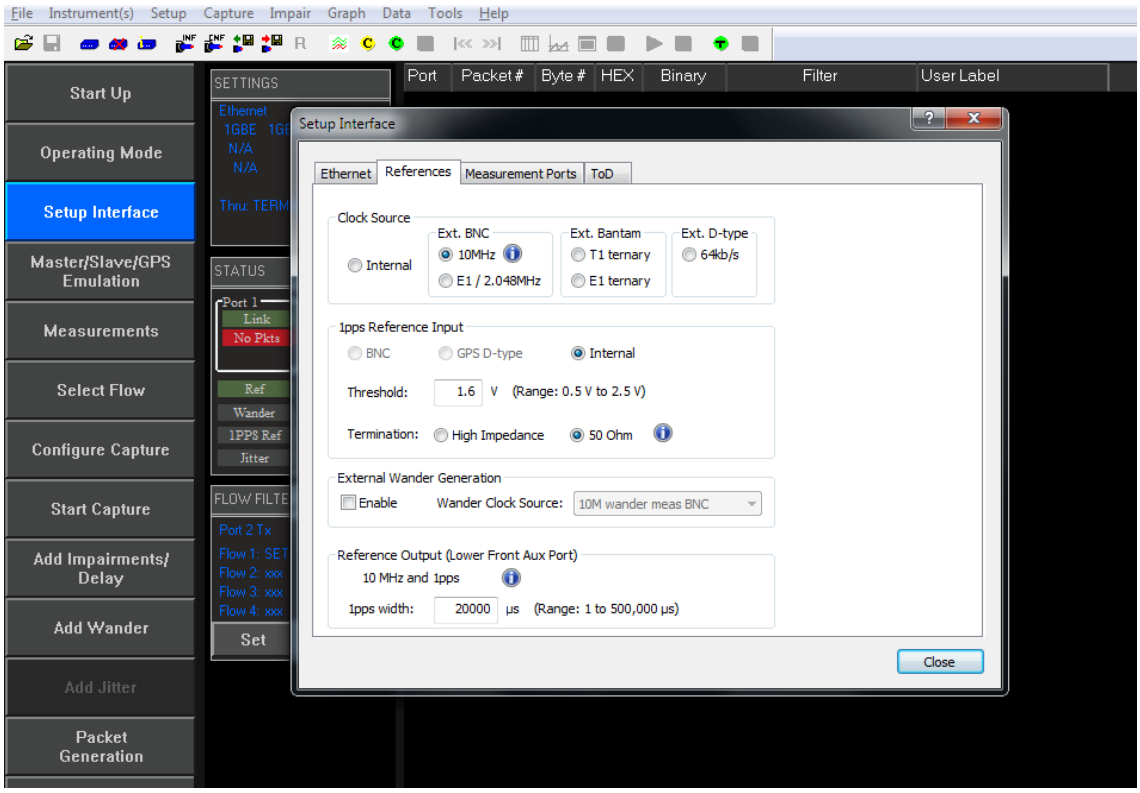
1. Verify physical connections have been completed per Section 2.
2. Start the Paragon-X GUI.
3. Select ***Start Up*** and ***Connect***.
4. Enter IP address of Paragon-X (displayed on Paragon-X status display).
5. See Paragon-X Getting Started Guide for more details.

## 3.2 Configuration of Physical Connections

1. Select ***Setup Interface*** and select ***Line Rate*** to match system under test.

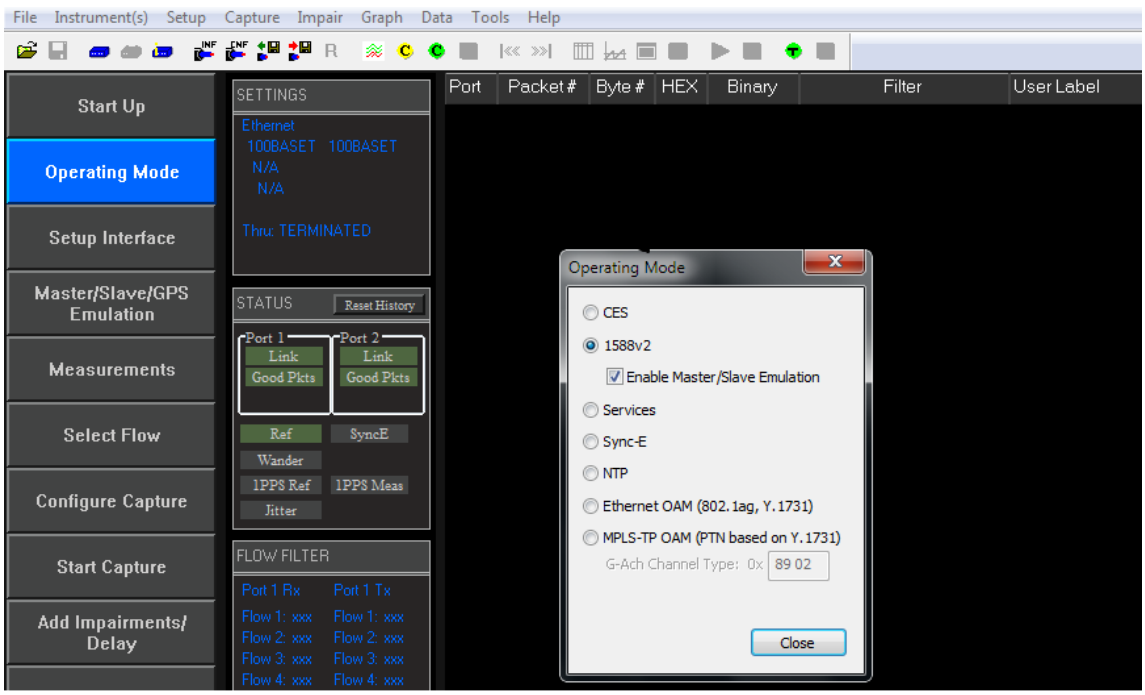


2. Select ***References*** tab to configure a stable reference for Paragon-X, set the ***Clock Source*** to ***External reference*** (10MHz or E1/2MHz). An external source is recommended. This should be the same external ref as used with the DUT.

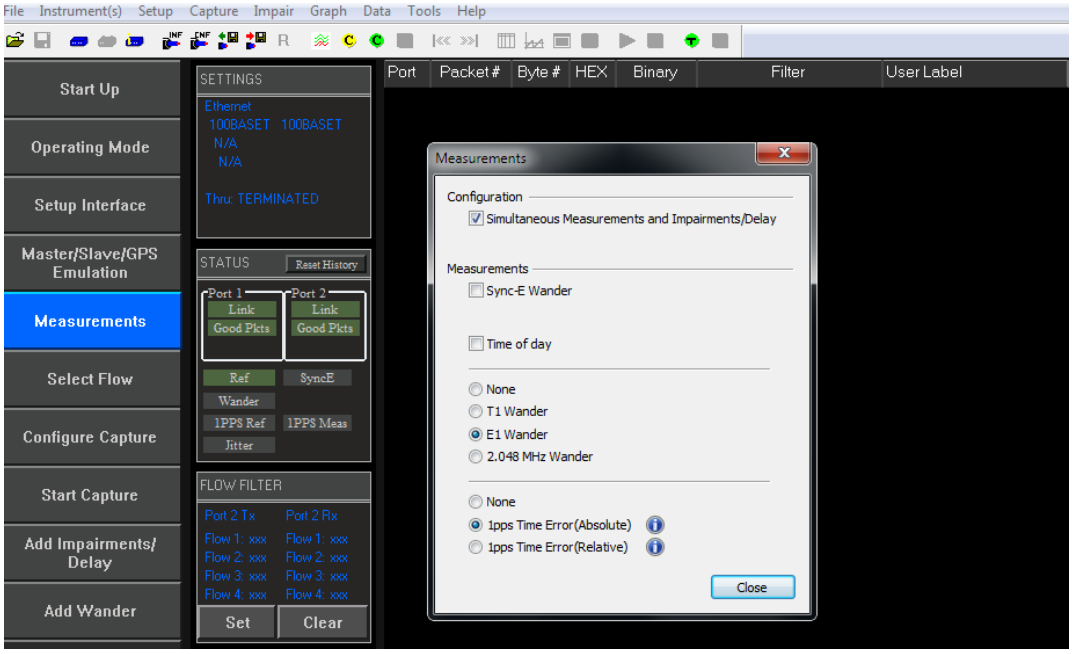



### 3.3 Measurement Configuration

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



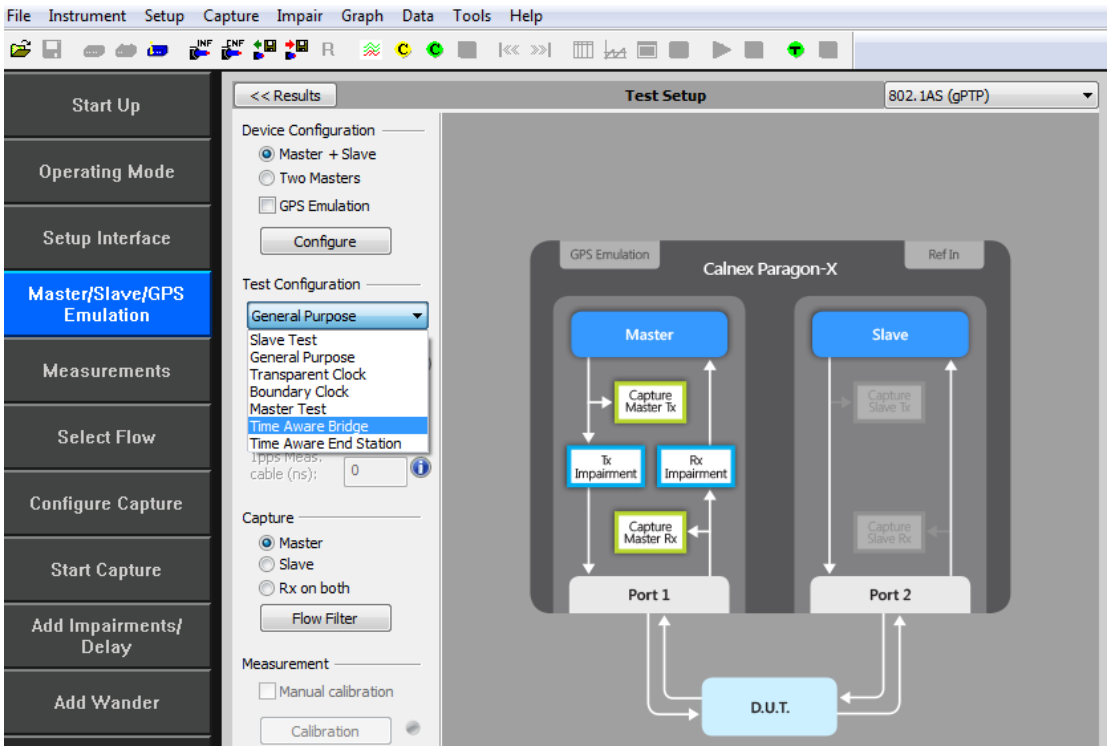
2. Select ***Measurements***, then any desired simultaneous measurements in addition to PTP based measurements, e.g. ***E1 Wander***, ***1pps Accuracy*** (if available from DUT).



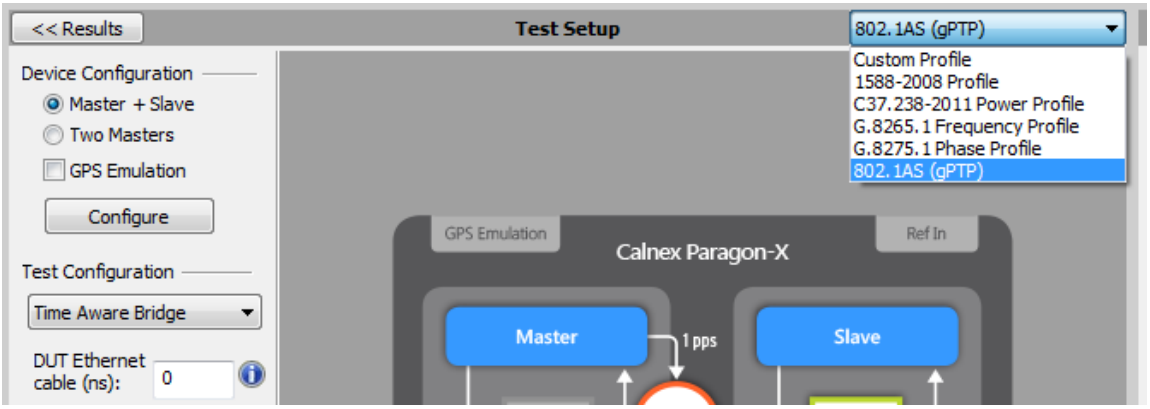

### 3.4 Prepare for Master/Slave Emulation

It is assumed that the 802.1AS profile will be used in testing 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 802.1AS standard.

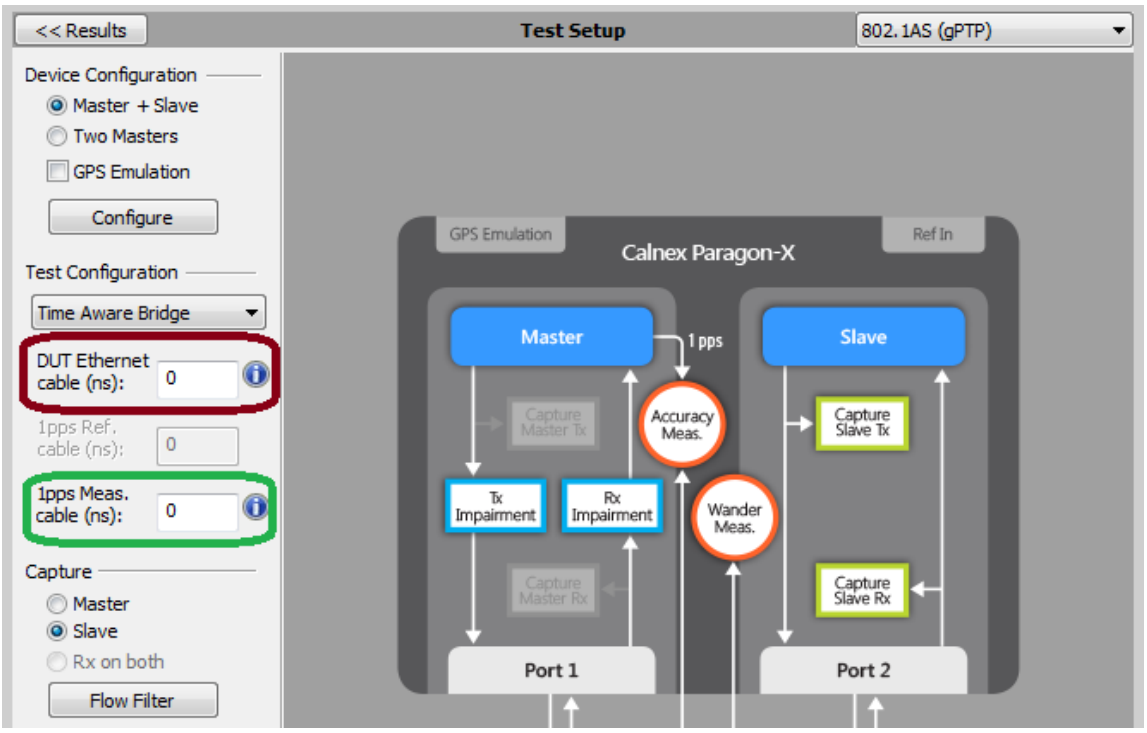
1. Select ***Master/Slave Emulation***. Choose ***Time Aware Bridge*** in the ***Test Configuration*** drop down menu.



2. Select ***802.1AS (gPTP)*** profile from the Profile Configuration drop down menu.




3. Enter **DUT to Paragon-X Cable Delay**.
In order to correctly perform calculations, the delay caused by the cable that is used to connect the DUT output 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.

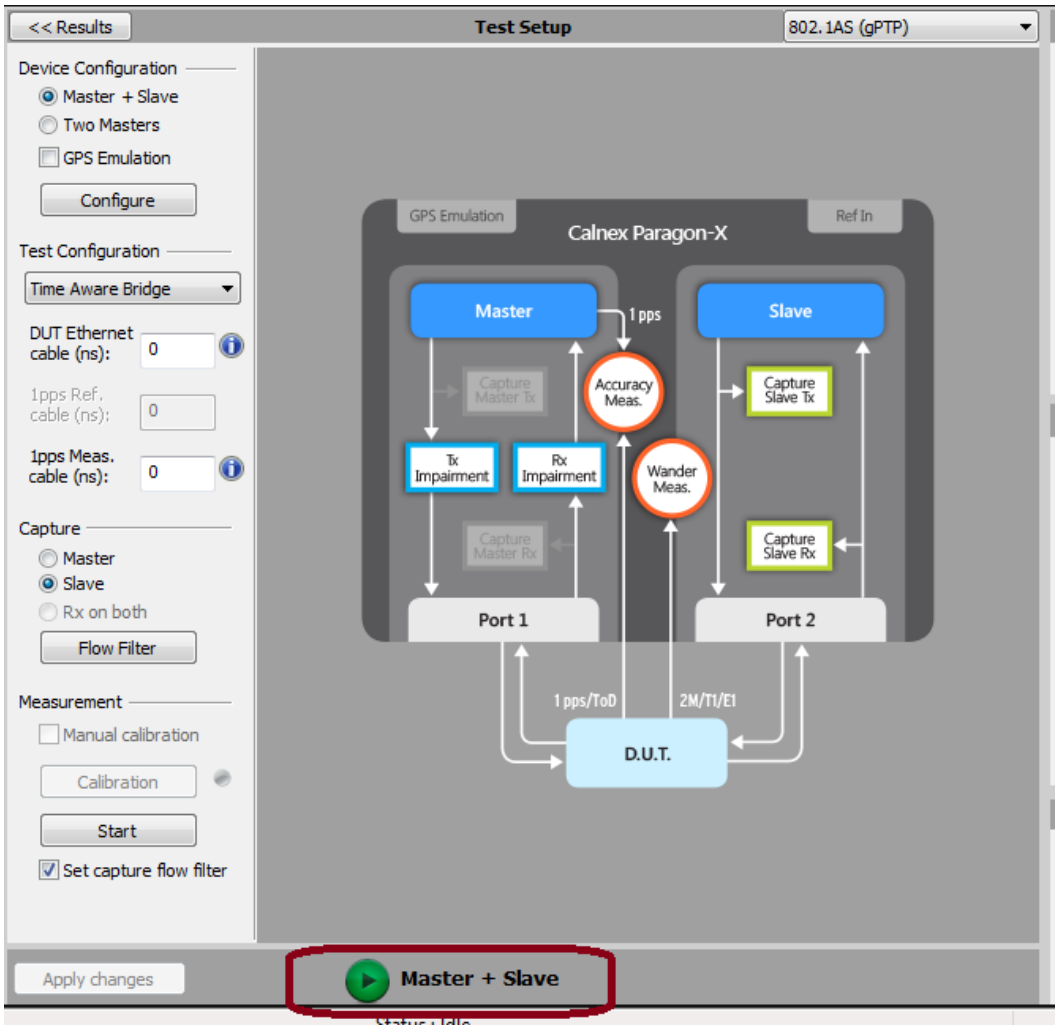



- If 1pps Time Error measurements are to be made, enter the 1pps Measurement Cable Delay

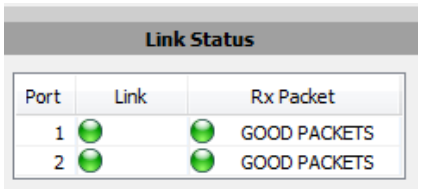
  Values of 5ns per 1 metre of cable can be expected. See the Calnex Tech Note: **Cabling Considerations Document** (Doc. No. CX5009) for more information.

### 3.5 Establish and Confirm Link between Paragon-X and DUT and make a Measurement

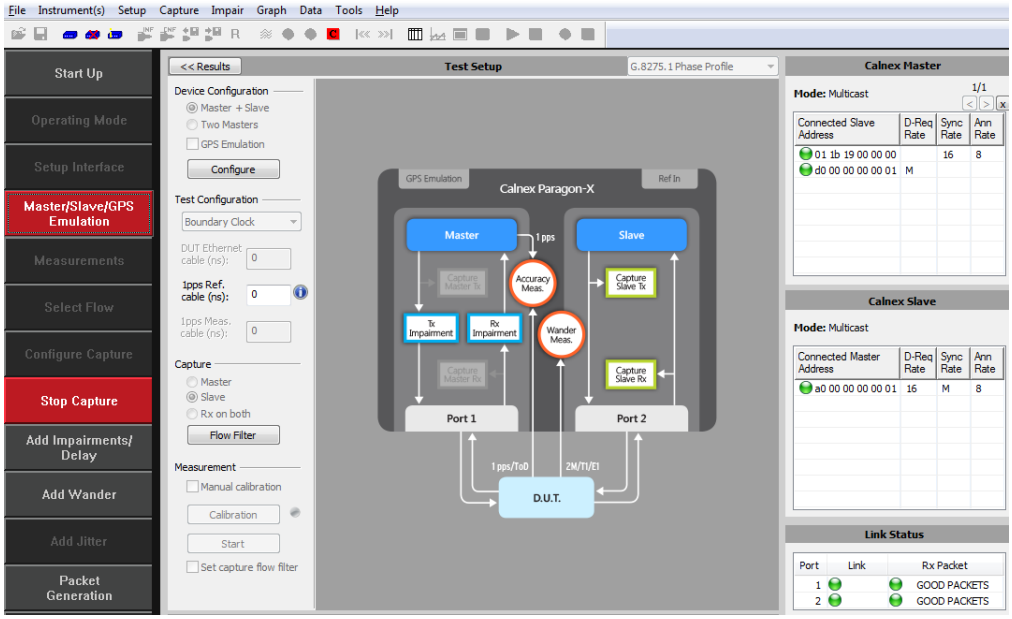
1. ***Start*** the Master/Slave emulation.




2. 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.



3. **Stop Master/Slave Emulation** in order to configure capture characteristics and to enable impairment operation, if desired.




## 3.6 Impairment Filtering and Enabling Impairments

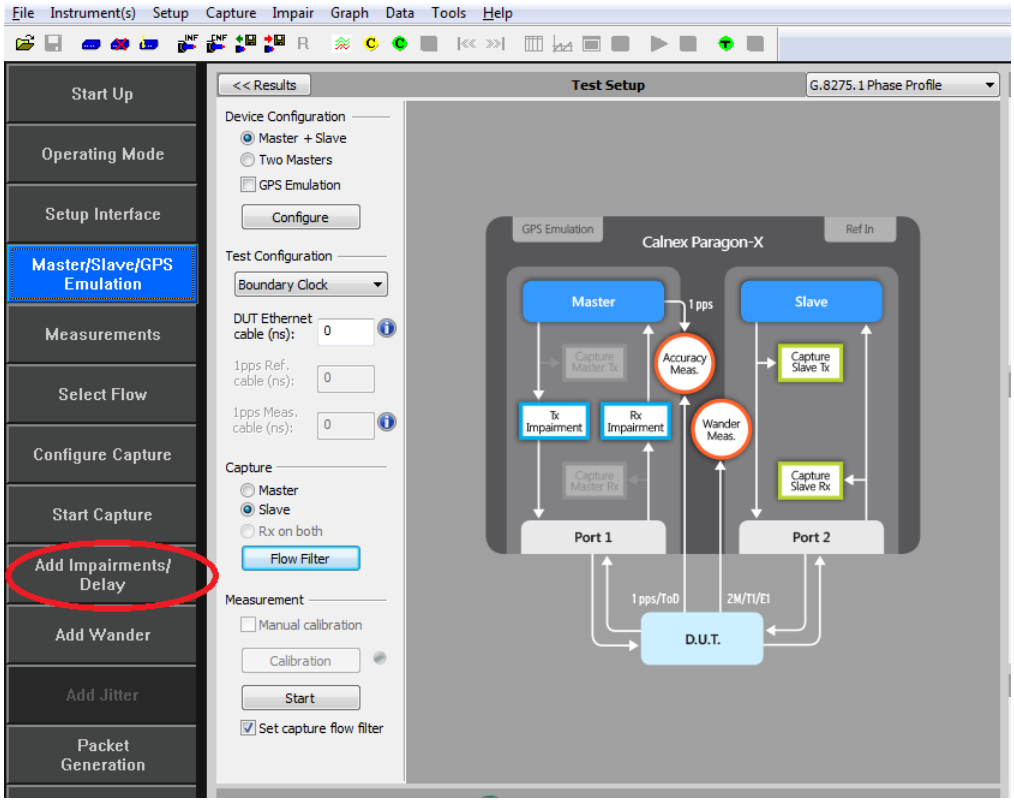
For the Time Aware device, test the **impairment** occurs on the **Master** side. Impairment filters must be set up before any impairment is performed.

Impairments are required in the following tests:

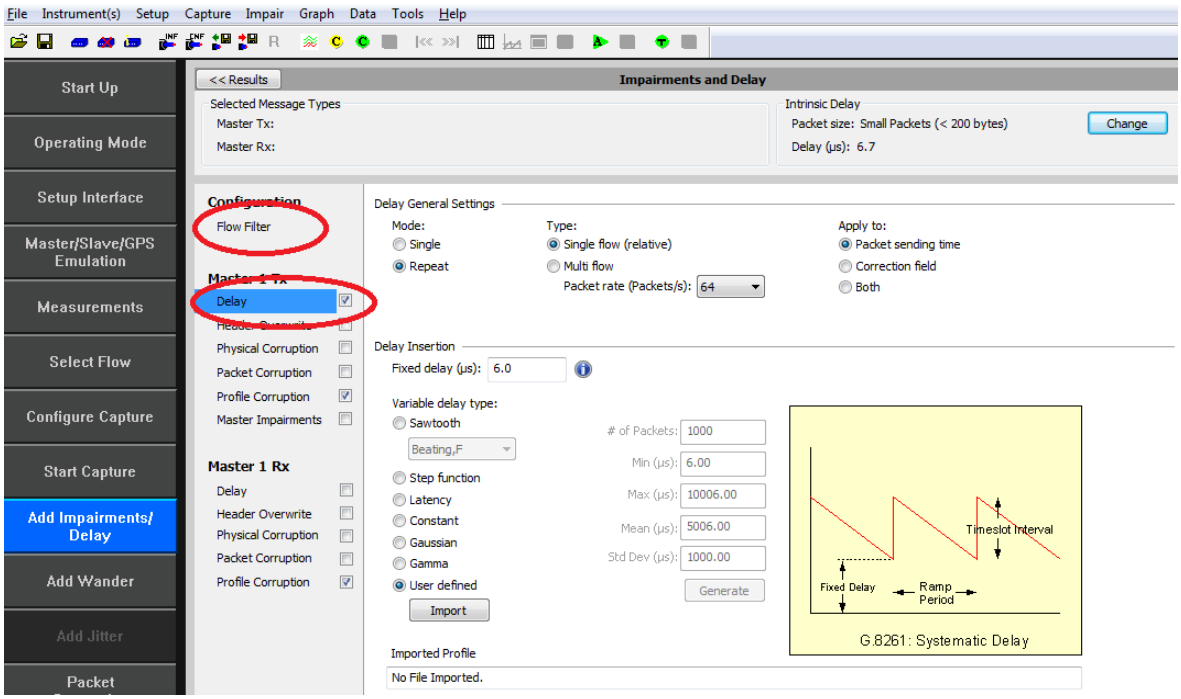
- Time Noise Tolerance

It is recommended that **Impairments** are enabled prior to starting the **Master/Slave** emulation mode.

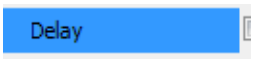
1. To enable **impairments** press the ***Add Impairments/Delay*** button.



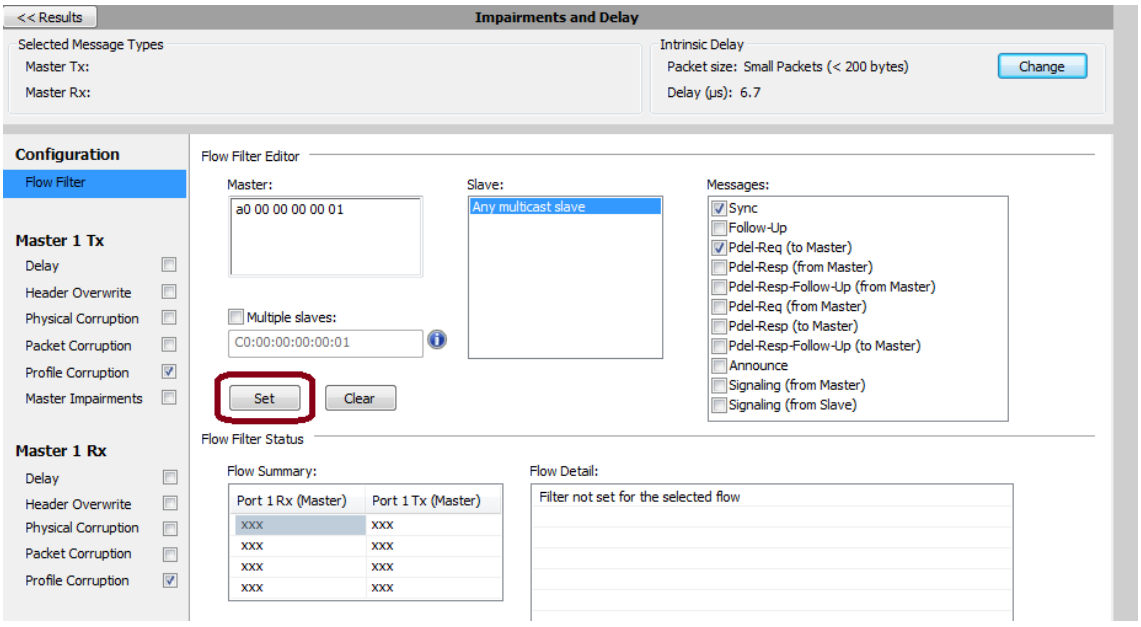
This will display the **Impairments** control screen.




2. Enable the ***Master TX Delay*** or the ***Master RX Delay*** feature using the tick boxes shown above. Select which one you want by clicking on the word ***Delay***. The selected direction will be highlighted as




3. Select ***Flow Filter*** to select the messages to apply delays against.

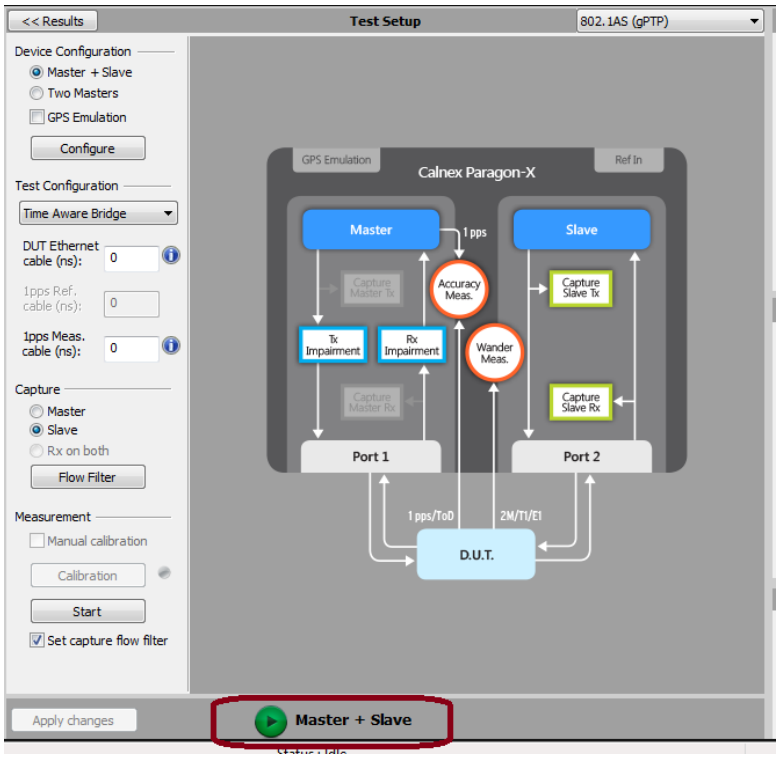



The **Impairment** engine is now primed and is ready to **import** delay profiles if required as defined in e.g. Time Noise Tolerance tests.

**Note:** Delay Profiles can be obtained from the Calnex website, captured using Paragon-X, or created using the PDV Editor tool in the GUI or directly in the ***Delay*** tab of the ***Add Impairments/Delay*** window.

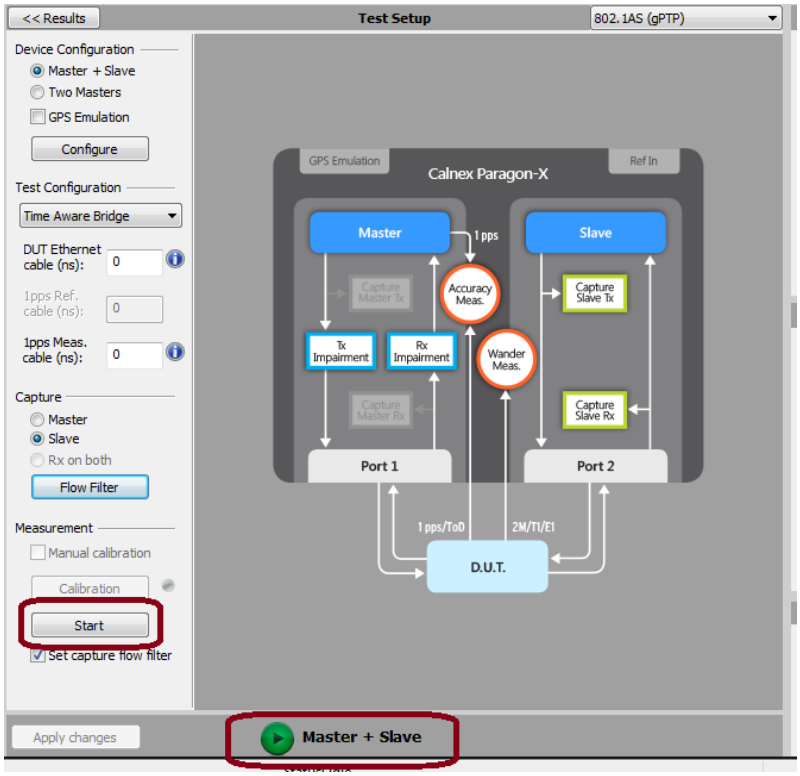
The **Master/Slave Emulation** mode can now be re-started.

4. Return to the **Test Setup page** using the ***Master/Slave Emulation*** button on the left of the display. This will display the Test setup page.
5. ***Start*** the Master/Slave emulation.




## 3.7 Making Measurements

The test recommendations in this document detail measurements that should be carried out to verify performance as defined in IEEE 802.1AS, as well as for further insight into device performance. Measurements are actioned using the ***Start*** measurement button and should be executed for the period as specified.

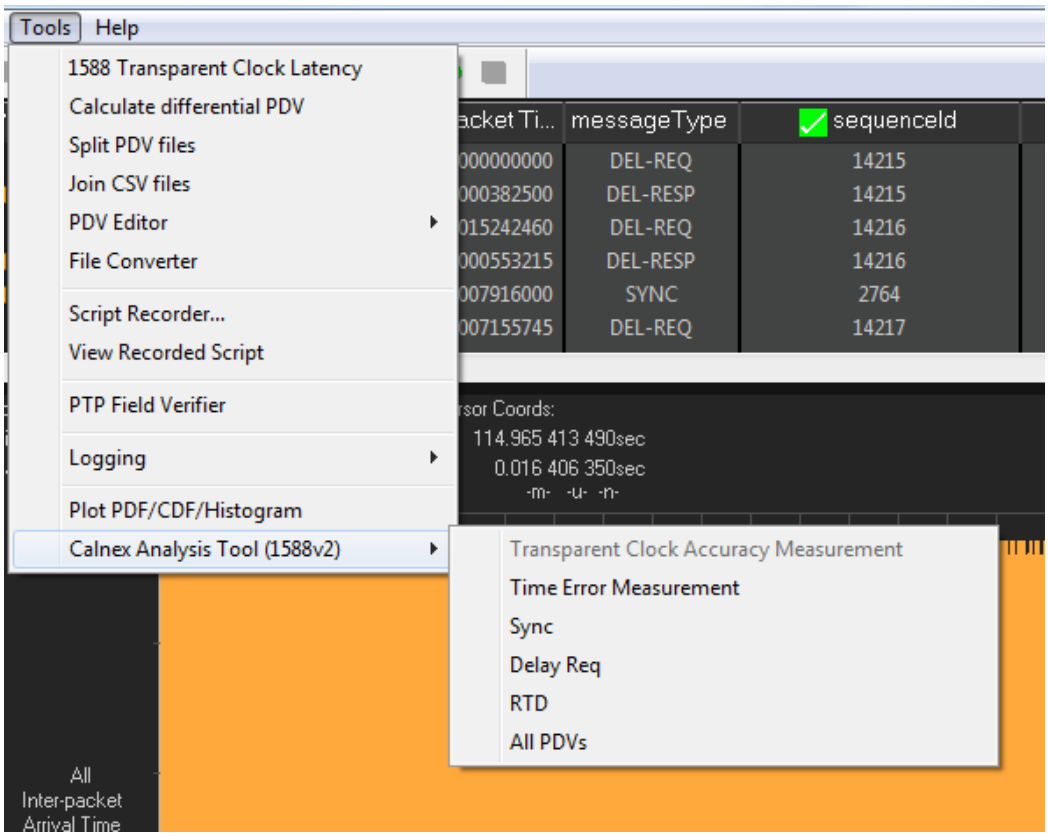


Wait for the DUT to lock to the Paragon-X emulated Master and stabilize before making any measurements**. Clock settling time is important**. Ask the vendor for advice for how long to wait or if it is possible to force a re-alignment. The wait time could be several minutes in some cases, dependent on the device under test.

If not possible to monitor this directly, using Paragon-X to view the 1pps output, if available, may provide an indication of the settling state of the DUT.

### Understanding Measurements

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



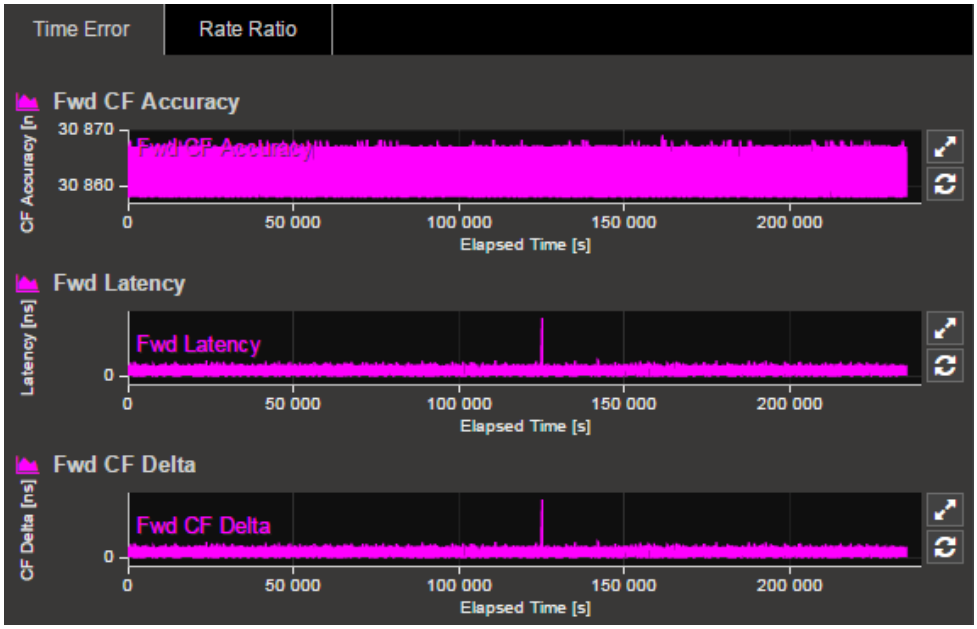

### Calnex Analysis Tool (Time Error Measurement) Notes

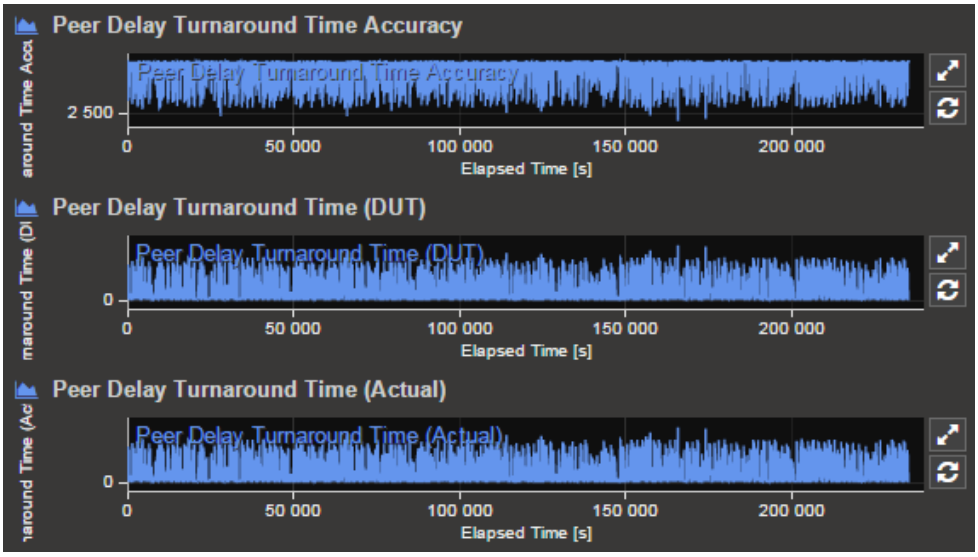
Time Aware Bridge measurements available with the CAT:

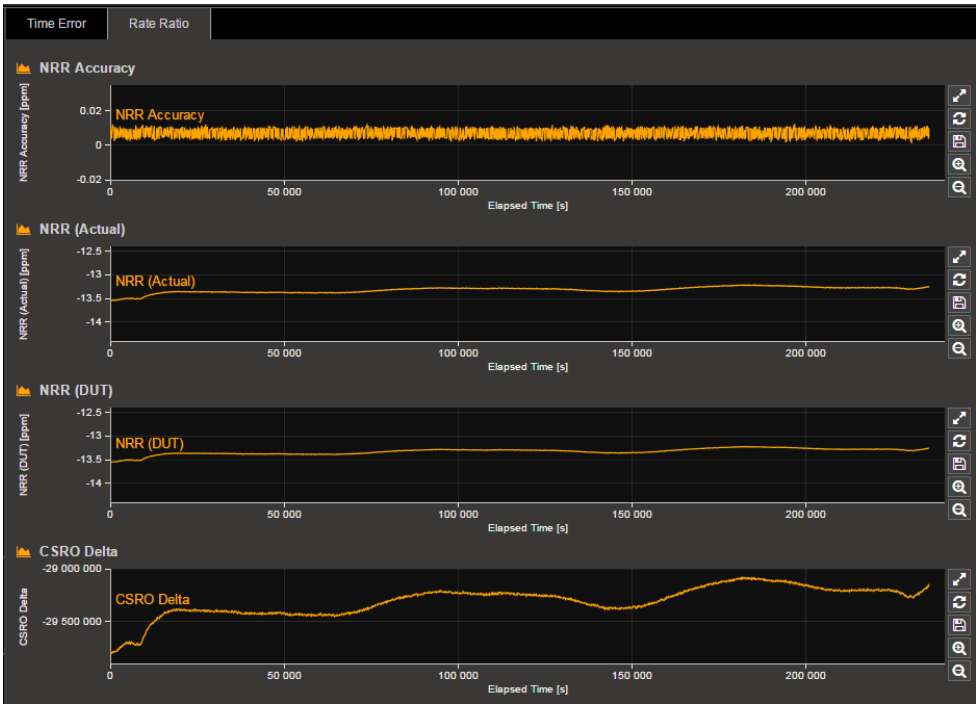
- **Time Error**
  - Forward Correction Field Accuracy (T1 Time Error )
  - Forward Latency
  - Forward Correction Field delta
- **Peer Delay**
  - Peer Delay Turnaround Time Accuracy
  - Peer Delay Turnaround Time (DUT)
  - Peer Delay Turn-Around Time (Actual)
- **Rate Ratio**
  - Neighbour Rate Ratio (NRR) Accuracy
  - Neighbour Rate Ratio (NRR) Actual
  - Neighbour Rate Ratio (NRR) DUT
  - CumulativeScaledRateOffset (CSRO) Delta

**1pps versus PTP**

It is important to prove performance via the egress PTP as this is the signal that is used downstream to recover the time. If provisioned, the 1pps output from the DUT should accurately reflect the performance of the timing being delivered by the egress PTP packet flow. Once in service, the performance can be monitored by this 1pps output so it is important to also prove it is an accurate reflection of performance on the line.


Time Error
Rate Ratio
Fwd CF Accuracy
CF Accuracy [n
30 870
30 860
Fwd CF Accuracy
0
50 000
100 000
150 000
200 000
Elapsed Time [s]
Fwd Latency
Latency [ns]
Fwd Latency
0
Elapsed Time [s]
Fwd CF Delta
CF Delta [ns]
Fwd CF Delta
0
Elapsed Time [s]


Peer Delay Turnaround Time Accuracy
2 500
Peer Delay Turnaround Time Accuracy
0
50 000
100 000
150 000
200 000
Elapsed Time [s]
Peer Delay Turnaround Time (DUT)
Peer Delay Turnaround Time (DUT)
0
Elapsed Time [s]
Peer Delay Turnaround Time (Actual)
Peer Delay Turnaround Time (Actual)
0
Elapsed Time [s]


Time Error
Rate Ratio
NRR Accuracy
NRR Accuracy [ppm]
0.02
0
-0.02
NRR Accuracy
0
50 000
100 000
150 000
200 000
Elapsed Time [s]
NRR (Actual)
NRR (Actual) [ppm]
-12.5
-13
-13.5
-14
NRR (Actual)
Elapsed Time [s]
NRR (DUT)
NRR (DUT) [ppm]
NRR (DUT)
Elapsed Time [s]
CSRO Delta
CSRO Delta
-29 000 000
-29 500 000
CSRO Delta
Elapsed Time [s]

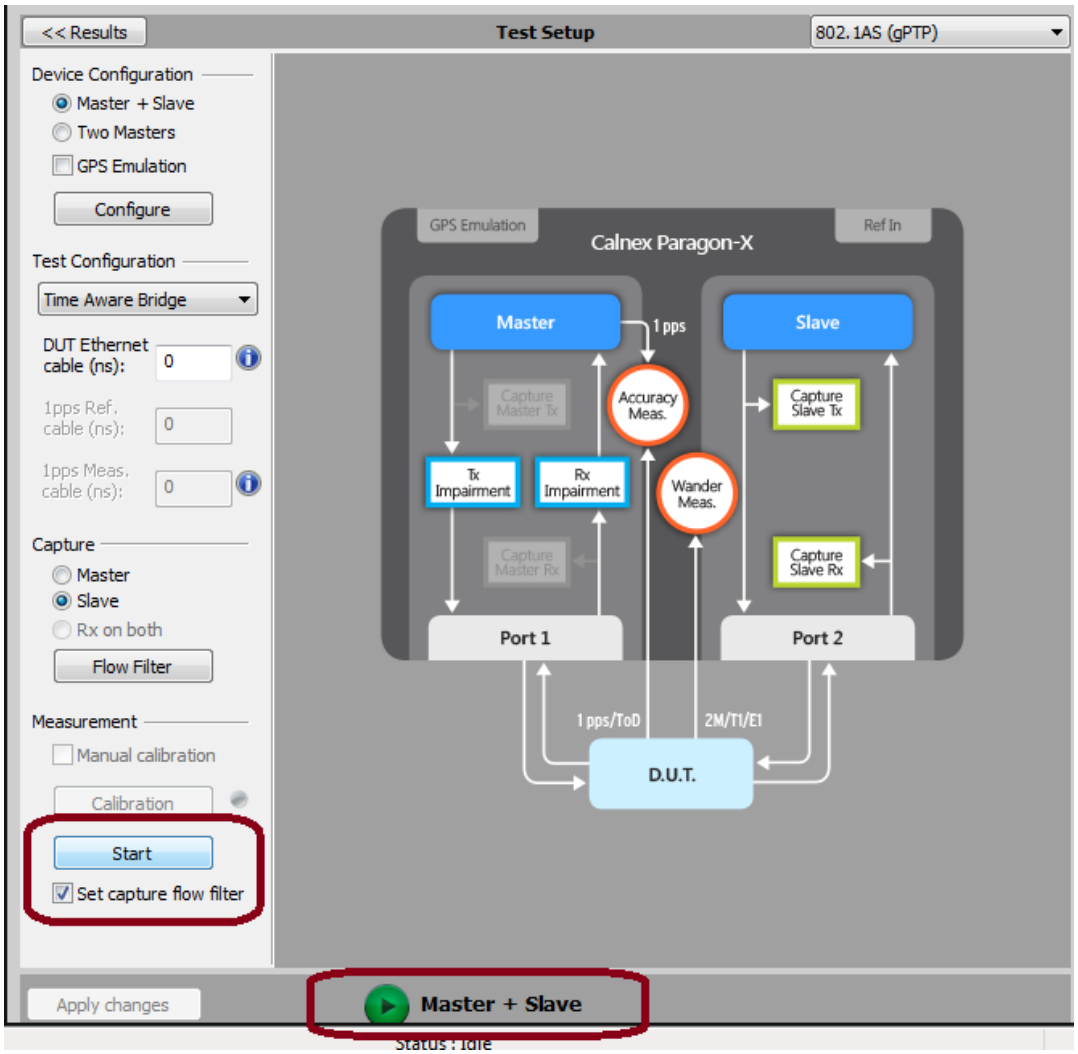
# 4. Noise Generation

**Test background**
The noise generation of a device represents the amount of noise produced at the output 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).

## 4.1 Measurement Process

1. Perform the **Master Slave Emulation Configuration** steps described in Section 3.
   **NOTE: impairments are not required for this test.**

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

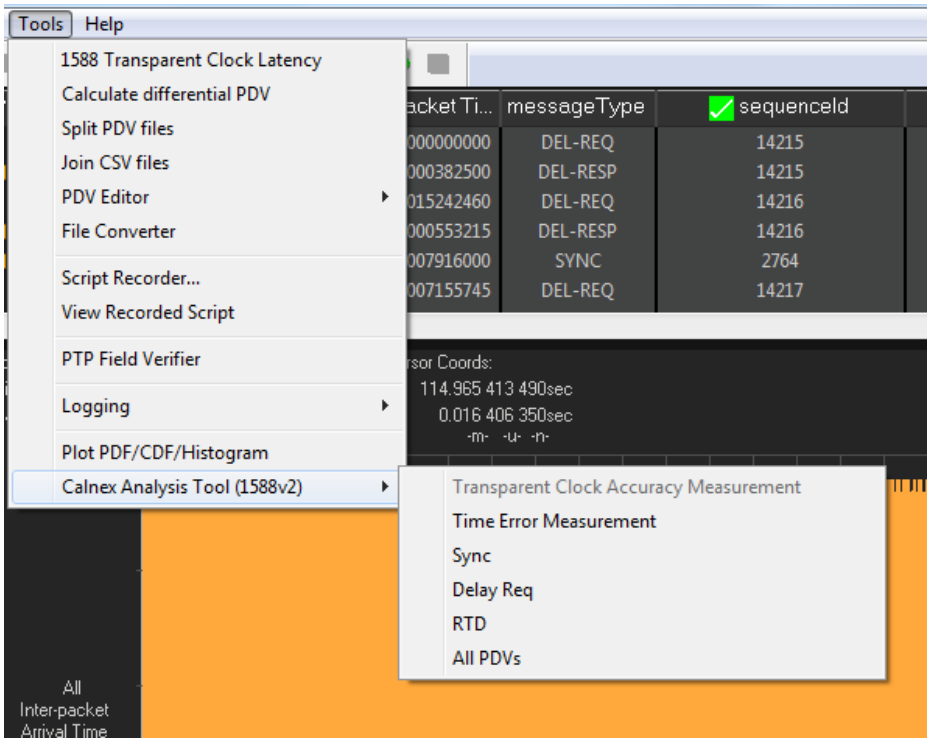



3. Allow the capture to run for the desired period. Then use the ***Stop Capture*** button to stop the capture.

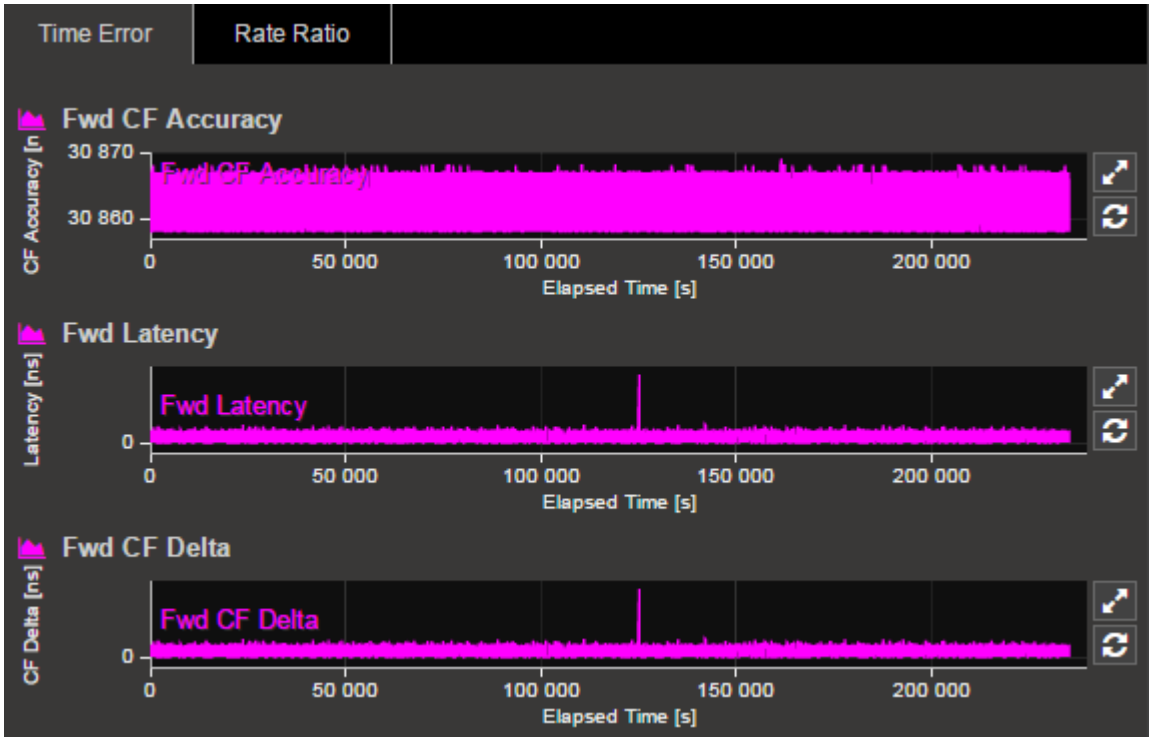
   **Measurements:** Time error results can be viewed live during capture or after capture has been stopped.

### 4.2 Time Error Results

1. Select ***Tools*** > ***Calnex Analysis Tool (1588v2) and Time Error Measurement*** tool.




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




For PTP based data this will include the metrics ***Fwd CF Accuracy (T1 Time Error), Fwd Latency*** and ***Fwd CF Delta***.

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


This will display a single graph view, including additional statistics on the chosen measurement.

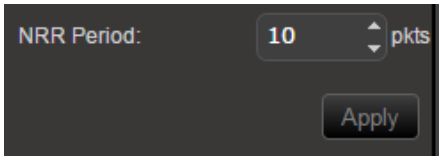
To return to the multi-graph display, click on the same icon in the single graph display.

**NOTES:**

- **Fwd CF Accuracy** (**T1 Time Error)** shows the accuracy of the transmitted PTP time information, including correctionfield, when compared to the reference time provided by Paragon-X. It is, therefore, the key metric for verifying the ability of the DUT to compensate for network and device propagation delays – limits can be set for automatic pass/fail on screen or in generated reports.
- **Fwd Latency** shows the actual propagation delay from transmission at Paragon-X to receipt.
- **Fwd CF Delta** shows the value of change made to the CorrectionField value by the DUT.
- If limits or masks have been selected, 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 in Fail.

## 4.3 Rate Ratio Results

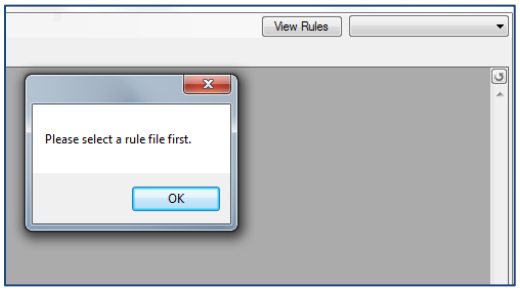

- **Neighbour Rate Ratio Accuracy** shows the accuracy of the DUT in updating the CumulativeScaledRateOffset field to reflect the rate offset from the upstream device. Inaccuracies will have an effect on the ability of downstream devices to accurately calculate a stable frequency. **Default Limit is set to 0.1ppm, as per 802.1AS**
- **Neighbour Rate Ratio (Actual)** shows the actual rate ratio between the DUT and the upstream device (Paragon-X). This is calculated using Peer delay messages, and the user can modify the number of packets over which to average, to most closely match the calculation used by the DUT.



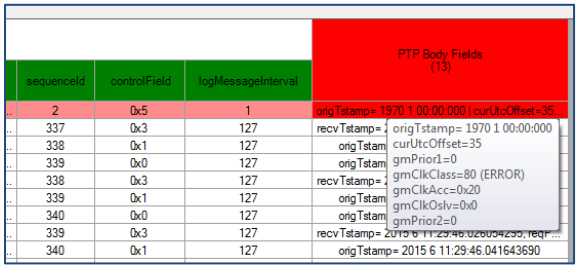

- **Neighbour Rate Ratio (DUT)** shows the DUT estimation of Neighbour Rate ratio, as indicated in the CumulativeScaledRateOffset field.
- **CumulativeScaledRateOffset Delta** shows the change made by the DUT to the CSRO field, without converting to Rate Ratio, for direct analysis of the magnitude of change.

### Further Analysis (Optional)

- PFV tool can be launched to check captured PTP data for conformance to 802.1AS profile
- Once data has been captured, launch PFV from ***Tools > PTP Field Verifier***
- Once launched, if not already selected, choose ***IEEE 802.1AS*** from the dropdown list

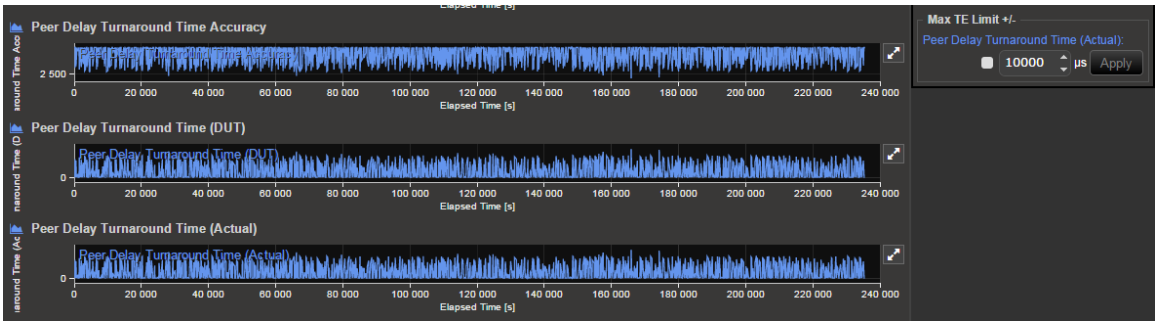


- Areas of non-conformance will automatically be highlighted in red, with details of the failure provided via hover-over.




- For further details on using PFV, including Report Generation, see ***the PFV Getting Started Guide*** available in the GUI from ***Help.***

### 4.4 Time Error Results (Peer Delay)




- **Peer Delay Turnaround Time Accuracy** shows the accuracy of the DUT in updating Peer Delay messages to reflect it's own Turnaround Time. Inaccuracies will have an effect on the ability of downstream devices to accurately compensate for network path delays.
- **Peer Delay Turnaround Time (DUT)** shows the value of change made to Peer Delay messages by the DUT – it's own estimation of Turnaround Time
- **Peer Delay Turnaround Time (Actual)** shows the actual Turnaround Time through the DUT, measured by Paragon-X. This can be analysed against defined limits for maximum allowed delay.

**Compare PTP with 1pps (if available).**

If the DUT 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 gPTP flow that the downstream device will use.**

# 5. Time Noise Tolerance

**Test Background**

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

## 5.1 Measurement Process

1. Perform Master Slave Emulation Configuration steps described in Section 3.
2. Choose an Impairment profile.

   The Noise Tolerance Test involves applying a known varying delay (Time Error) profile to the gPTP flow in order to check that the DUT maintains its reference lock.

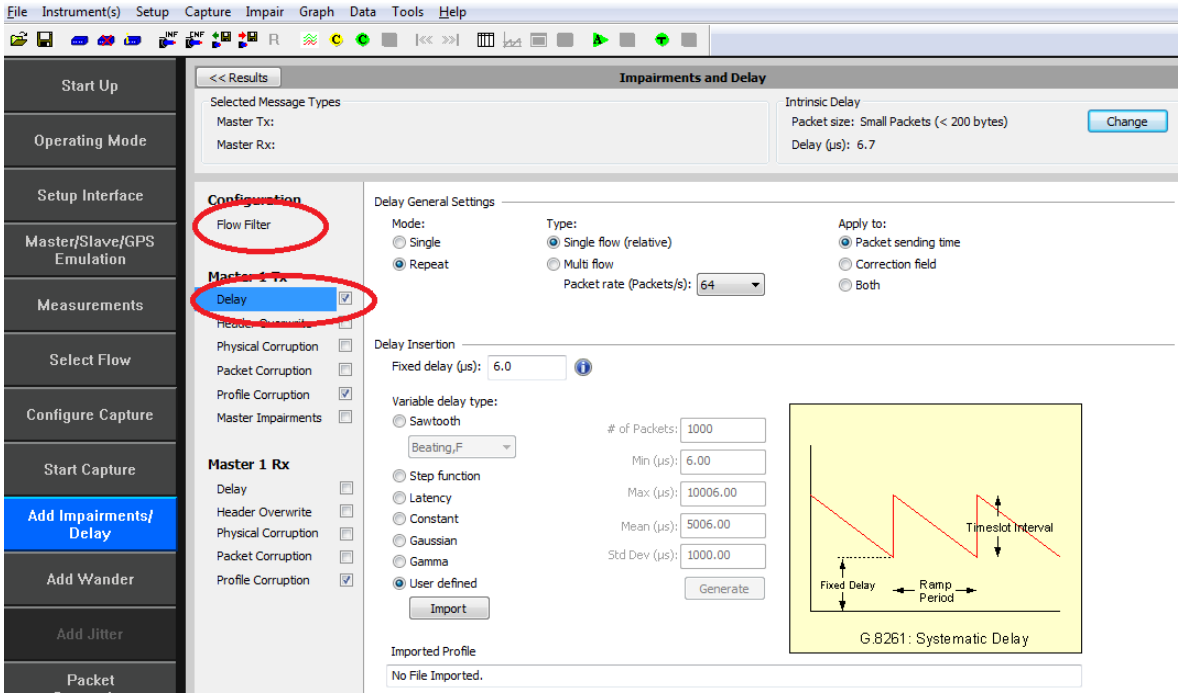
   Suitable test profiles to reflect realistic and challenging situations from real-world deployments are for further investigation.

   An example is a Time Error/Packet Delay Variation profile with a sinusoidal pattern, to test the ability of the DUT to tolerate fluctuating network conditions, which could be particularly challenging.

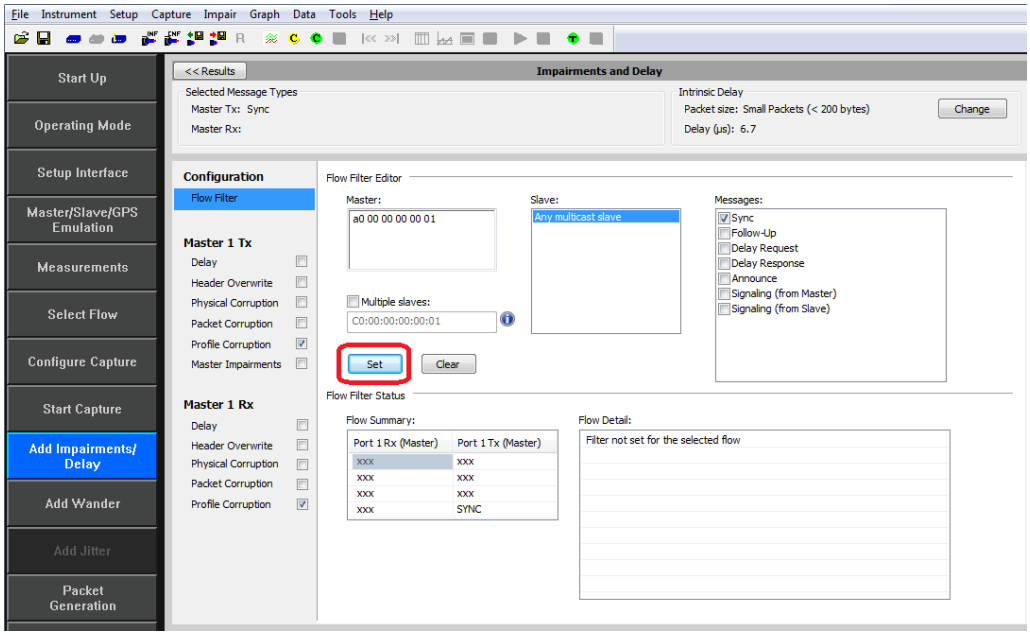
   Example sinusoidal (and other) Time Error/PDV profiles are available to download from the Calnex website, from the Product Software Download page.

   **NOTE: Store the downloaded profile in a known location on the PC that will be used to control the test.**
   **Adding the chosen Profile.**

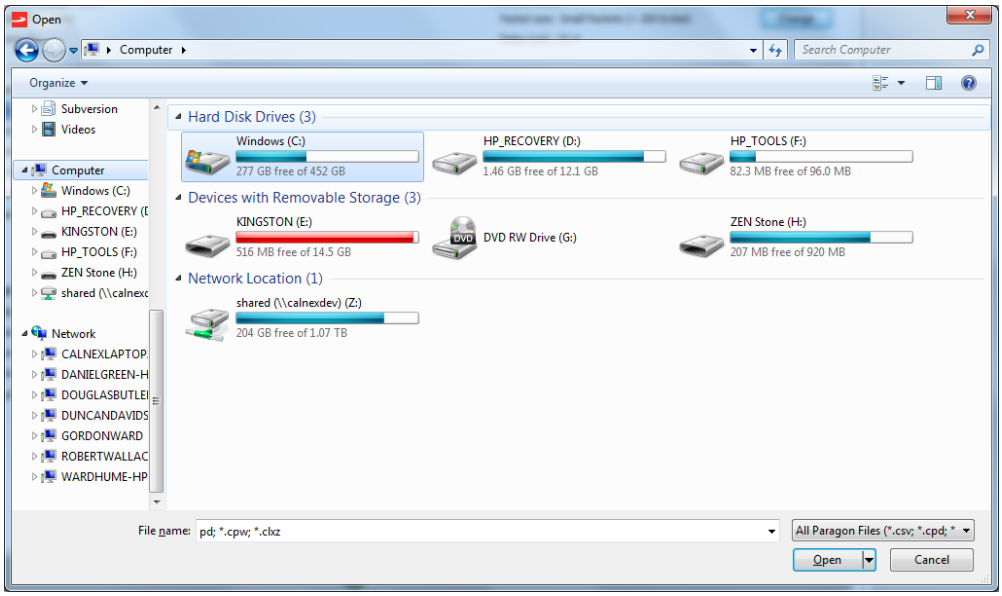
3. Select ***Add Impairments/Delay***. This will display the following:




4. Enable the ***Master TX Delay*** feature using the tick boxes shown above.
5. Select ***Flow Filter*** to choose the messages to applied delays against, e.g. Sync.




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




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


## 5.2 Expected Outcome

- 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).
- By simultaneously running a Capture/Measurement, performance of PTP (and 1pps if available) output can be tested as per the Noise Generation method described earlier in this document, although expected performance may vary.
- If desired Noise Transfer performance is known, then defined impairment profiles and measurement masks/limits can be used to confirm that the DUT meets these requirements.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