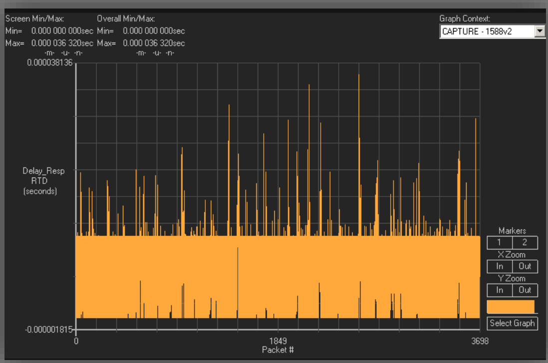
TEST GUIDE

CX5003

Testing PTP Slave Clocks

Proving PTP Slave Clock compliance as per ITU-T G.8261 using Paragon-X



ITU-T G.8261 is the International Telecommunication Union's Recommendation titled *"Timing and Synchronization Aspects in Packet Networks."*

Appendix VI of ITU-T G.8261, "Measurement Guidelines for Packet-Based Methods" provides the test methodologies to ensure that equipment is within performance limits.

This Test Guide shows how the Calnex Paragon-X can be used to prove PTP Slave Clock compliance to G.8261 and provides procedures to measure the output clock performance of such devices.

Contents

1. Testing a PTP (1588v2) Slave Clock

The Paragon-X provides two methods for testing PTP Slave Clocks for conformance to the G.8261 defined performance limits.

- **Master/Slave Emulation mode** – where the Paragon-X provides an emulated GM for the purposes of the test
- **Non Emulation mode** – where the functionality of the T-GM is provided by a 3rd party equipment

1.1 Master/Slave Emulation Mode – Equipment Required

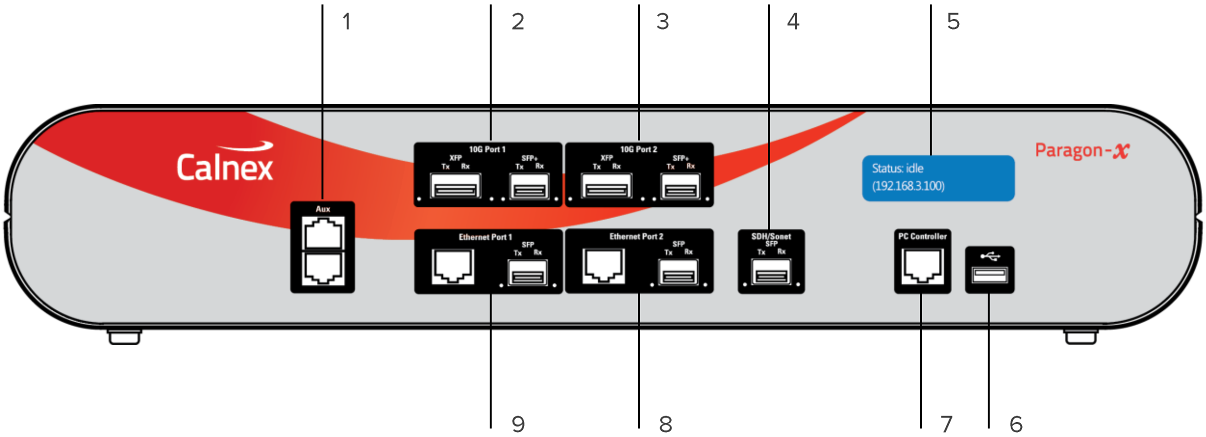
- PTP Slave Clock (Device-Under-Test, DUT)
- Common Stratum-1 (or better) GPS reference clock with frequency output (10MHz, 2MHz)
- Accessories and cabling: BNC cables with T-splitters, RJ45 Ethernet cables, SFPs, matching single-mode or multi-mode fibers
- Calnex Paragon or Paragon-X including:
  - Option 201 Advanced 1588v2 features
  - Option 250 IEEE 1588v2 End-to-End – One-box BC, TC and OC
  - Option 205 Wander Measurement (Paragon-X)
  - Option 206 Phase and Time Measurement (Paragon-X)
  - Ethernet interface rate options to match DUT

1.2 Non Emulation Mode – Equipment Required

- PTP Master Clock
- PTP Slave Clock (Device-Under-Test, DUT)
- Common Stratum-1 (or better) GPS reference clock with frequency output (10MHz, 2MHz) and phase reference (1PPS)
- Accessories and cabling: BNC cables with T-splitters, RJ45 Ethernet cables, SFPs, matching single-mode or multi-mode fibres
- Calnex Paragon or Paragon-X including:
  - Option 201 Advanced 1588v2 features
  - Option 205 Wander Measurement (Paragon-X)
  - Option 206 Phase and Time Measurement (Paragon-X)
  - Ethernet interface rate options to match DUT

2. Paragon-X Physical Connections

Figure 1: Front Panel Connections

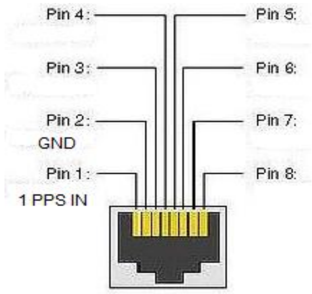


The front panel of the Paragon-X provides different connections that can be used for testing:

- 1 – Aux ports (RJ45)

  For 1PPS measurements connect to the **upper** Aux port.

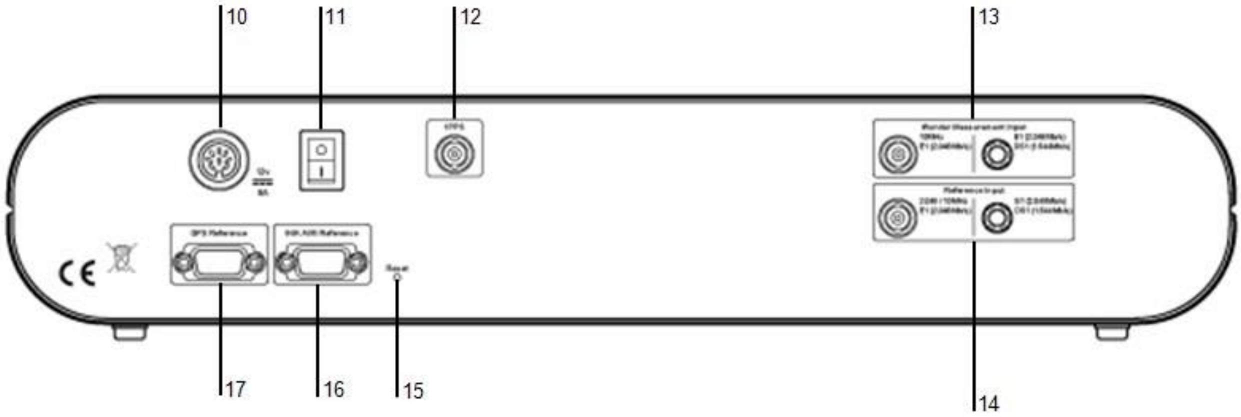
  For the pinout, refer to the figure below; pin 1 will receive the measured input while the ground (or 0V signal) is on pin 2. The other pins are not used.



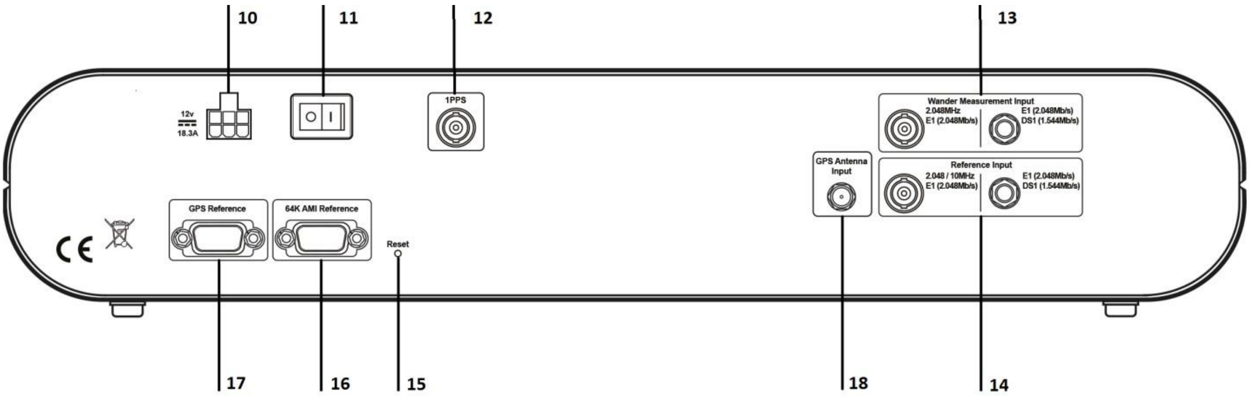
- 2 and 3 – 10G Ethernet ports.
- 4 – This connector is not used.
- 5 – Display.
- 6 – In earlier versions of the Paragon, this connector is not used and does not supply USB power. In later versions it supplies USB power to the External 1PPS/ToD Frequency Converter accessory.
- 7 – PC Controller (RJ45).
- 8 and 9 – 1GbE and 100M Ethernet ports.

Figure 2: Rear Panel Reference and Measurement Inputs to Paragon-X

Earlier Versions



Later Versions

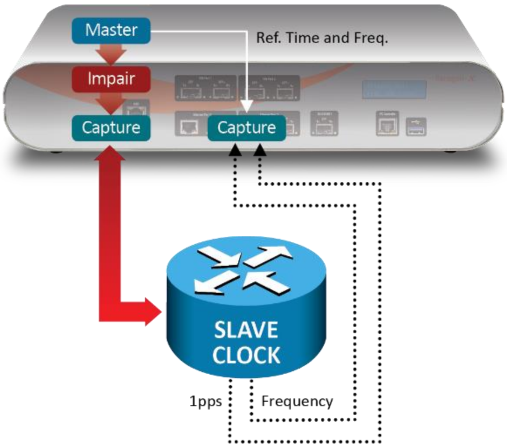


- 10 -- DC Power Input
- 11 -- Power Switch
- 12 -- 1PPS Reference Input
- 13 -- Wander Measurement Inputs
    - 2.048MHz (BNC)
    - E1 (2.048Mb/s) balanced (Bantam) or unbalanced (BNC)
    - DS1 (T1) (1.544Mb/s) balanced (Bantam)
- 14 -- Reference Inputs
    - 10MHz (BNC)
    - 2.048MHz (BNC)
    - E1 (2.048Mb/s) balanced (Bantam) or unbalanced (BNC)
    - DS1 (T1) (1.544Mb/s) balanced (Bantam)
- 15 -- Reset Switch
- 16 -- 64K AMI Reference Input
- 17 -- GPS Reference
- 18 -- GPS Antenna Input (*currently unused)*

3. Master/Slave Emulation Mode

The Paragon-X Option 250 software enables the Paragon-X to act as an Emulated PTP Master as well as providing impairment and measurement capabilities. Using this option allows the test to be carried out using solely the Paragon-X and the Slave Clock under test.

3.1 Test Setup

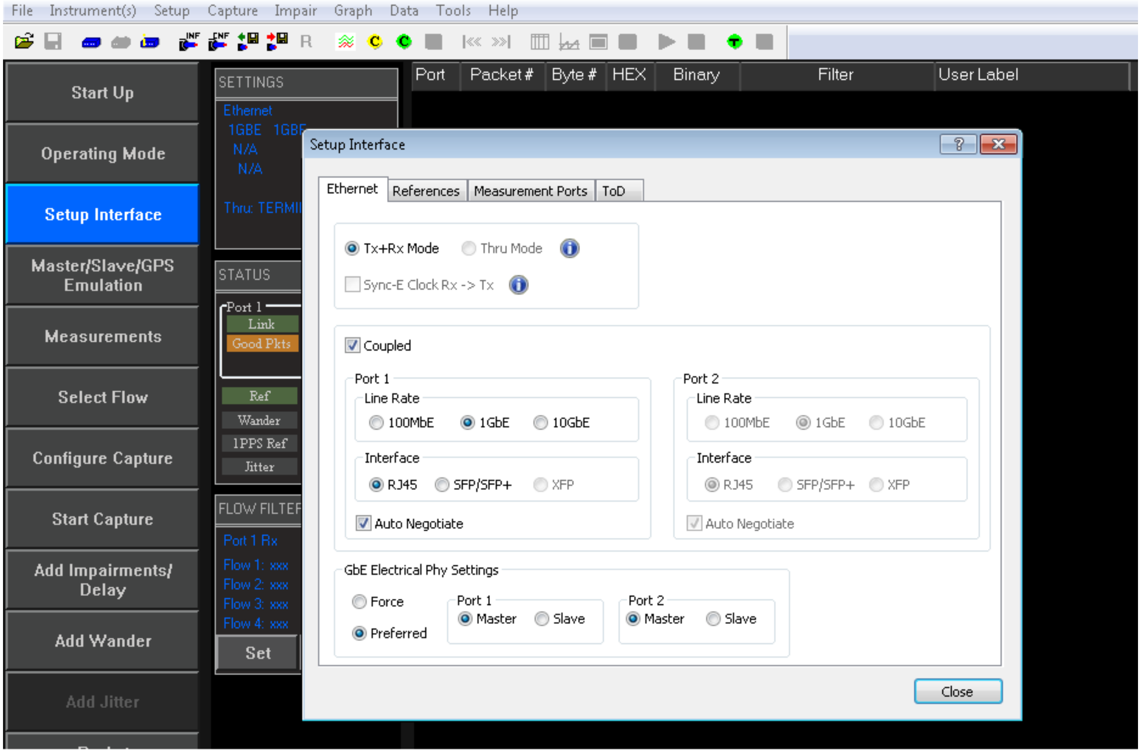


Physical connections

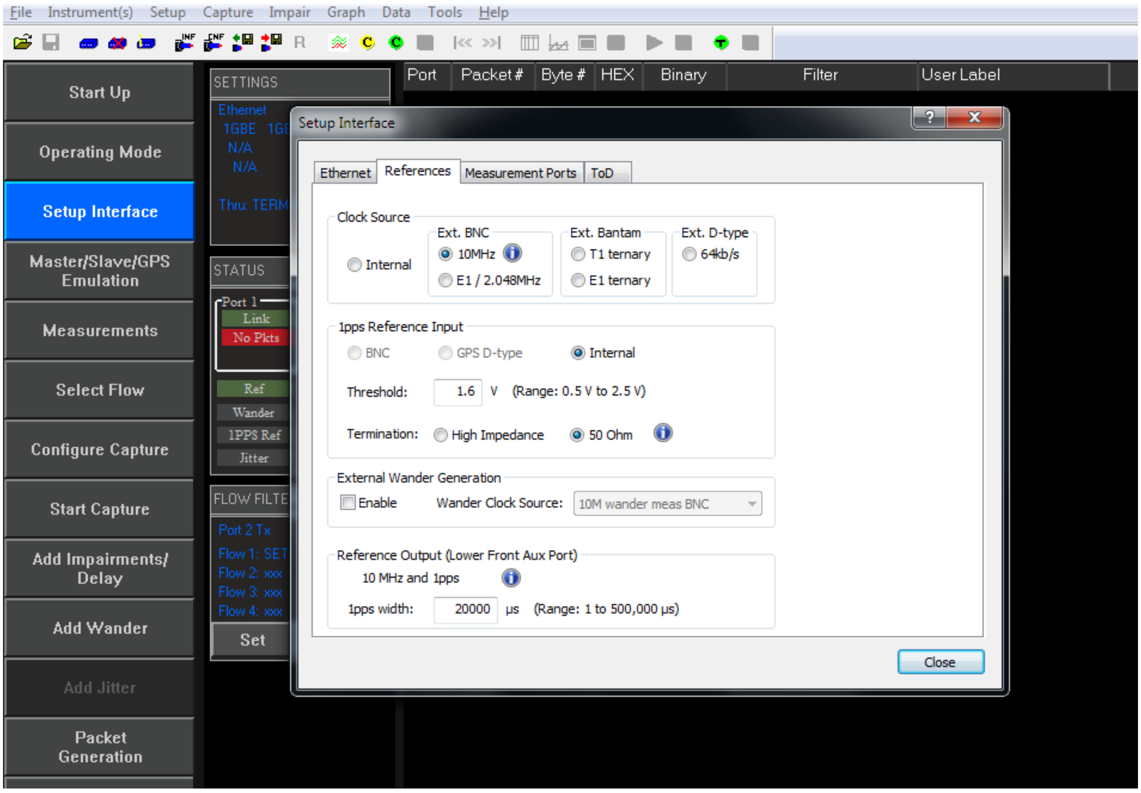
1. Connect Port 1 (Master side of Paragon-X) to the Slave Clock (Figure 1**, connectors 2 or 3**).
2. Connect the external reference, e.g. 10MHz, to the Paragon-X Reference Input (Figure 2**, connector 14**).
3. Connect the 1PPS output from the Slave Clock to the Paragon-X 1PPS measurement port (Aux). Use Calnex's 1PPS/ToD/Frequency Converter accessory if required (Figure 1**, connector 1**).
4. Connect the frequency output (e.g. E1) from the Slave Clock to the Paragon-X frequency measurement port at the rear of the Paragon-X (Figure 2**, connector 13**).

3.2 Application Setup

1. Select ***Setup Interface*** then ***Line Rate*** to match the Slave Clock under test.

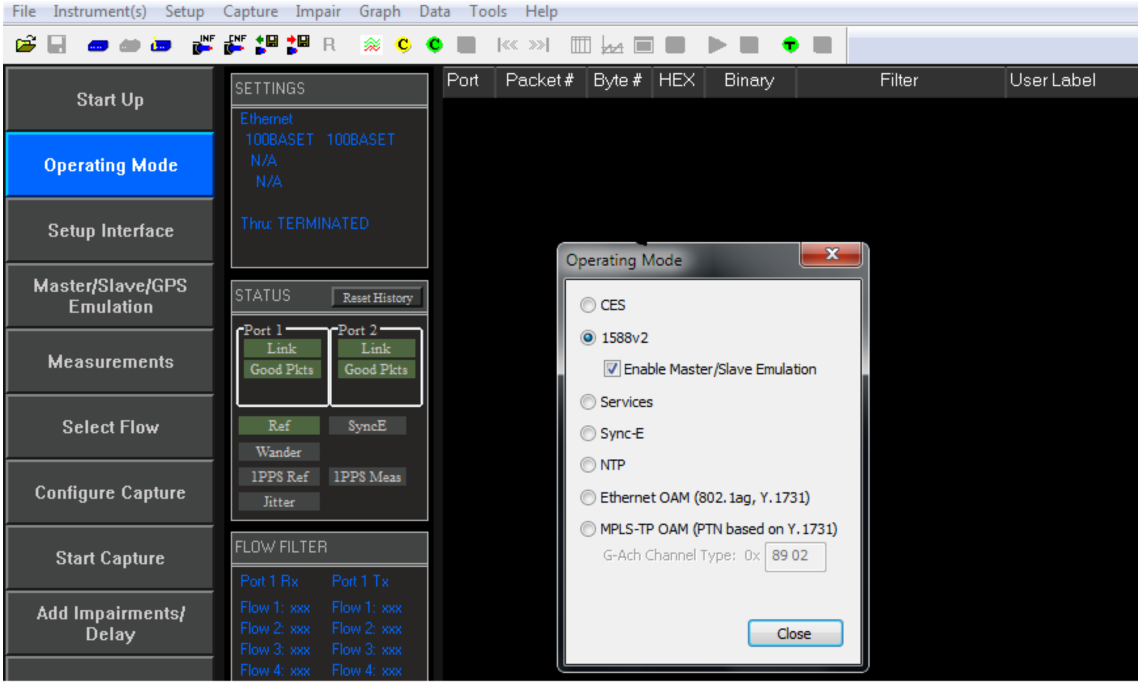


2. Select the **References** tab to configure a stable reference for the Paragon-X. Set the ***Clock Source*** to ***External reference*** (10MHz or E1/2MHz). An external source is recommended.

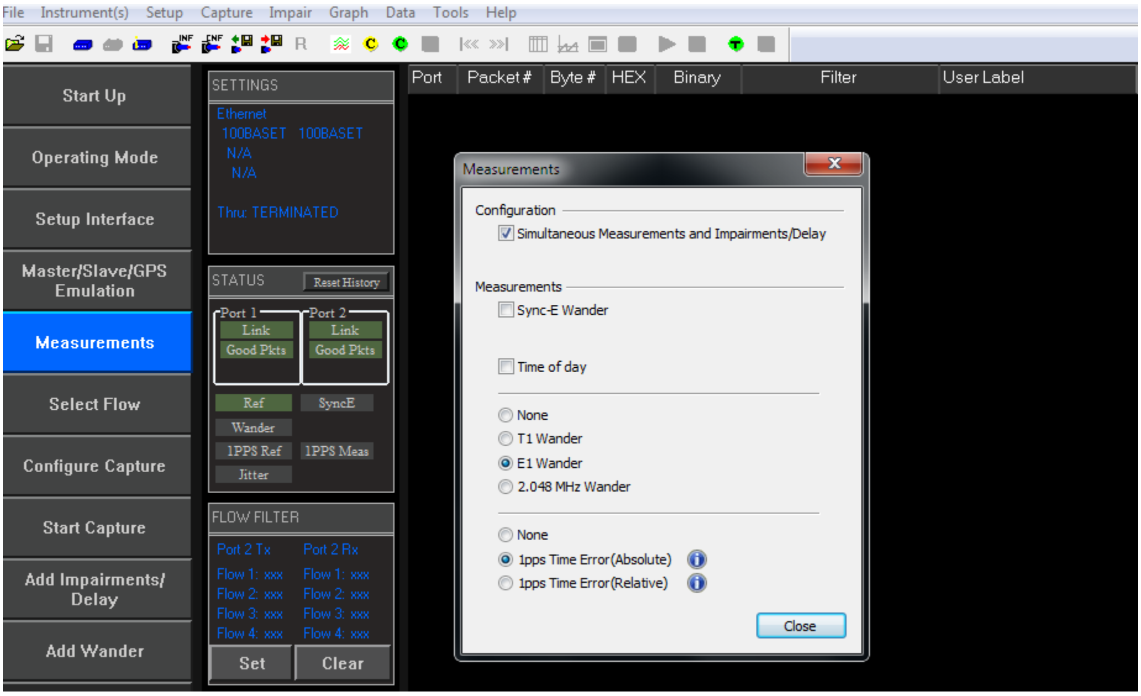


3.3 Measurement Configuration

1. Click on the ***Operating Mode*** button then enable ***1588v2*** > ***Enable Master/Slave Emulation***.

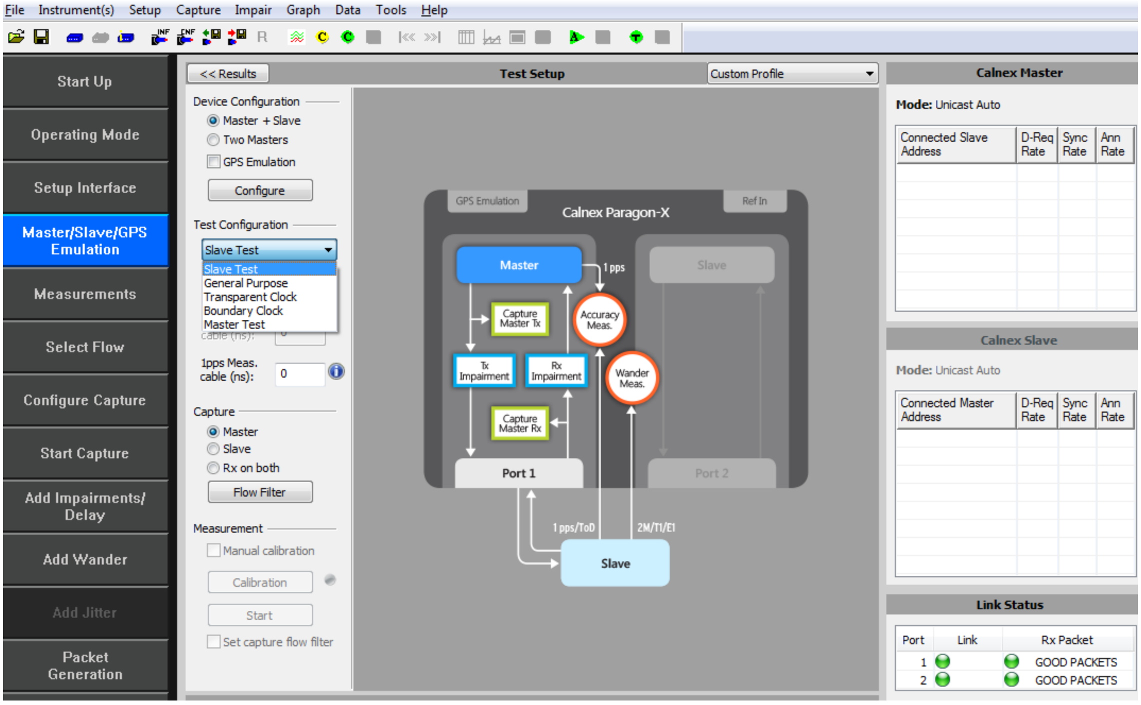


2. Click on the ***Measurements*** button then enable the required measurement either (***E1 or T1*** or ***2.048MHz)*** and ***1pps Time Error (Absolute).***

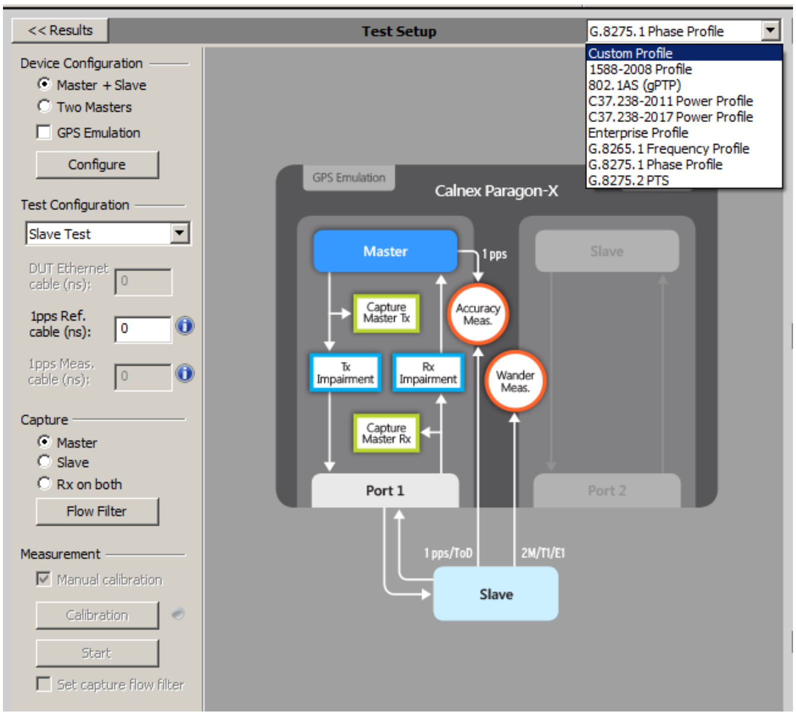


3.4 Preparing for Master/Slave Emulation

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

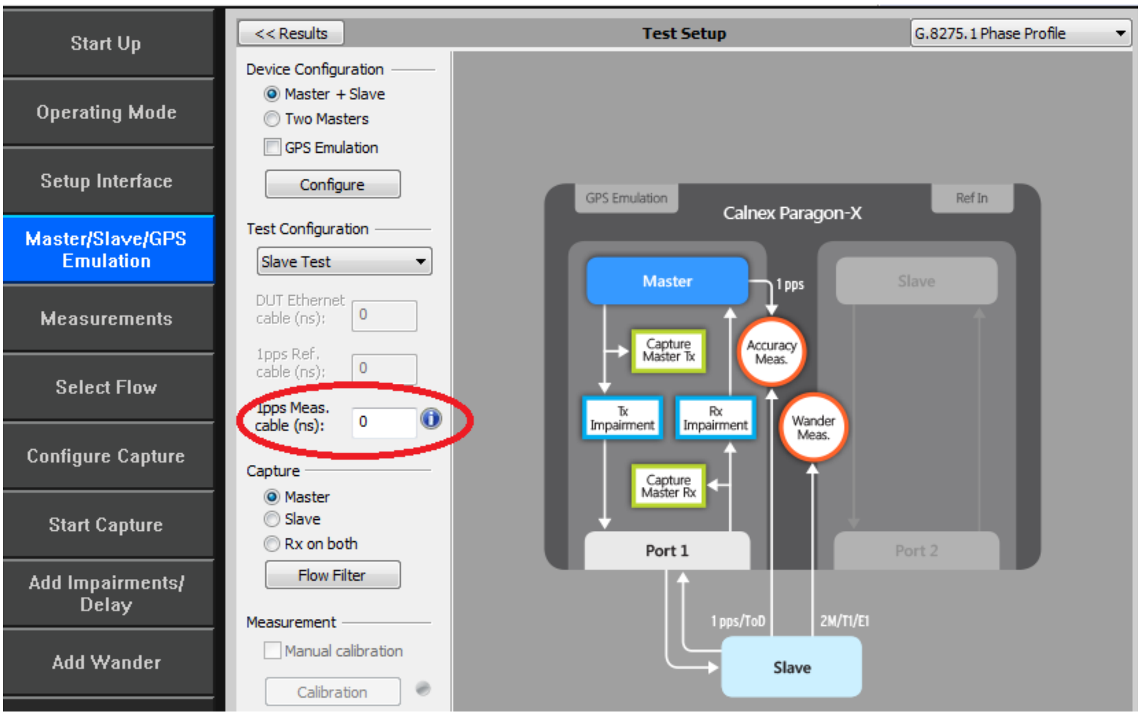


2. Now select which PTP Profile you want to use in testing the Slave Clock. The Paragon-X supports a number of pre-defined profiles, including:
   - G.8275.1 Phase Profile (Multicast, Ethenet)
   - G.8265.1 Frequency Profile (Unicast, IPV4)
3. Select which profile is supported by the Slave Clock using the ***Custom Profile*** drop down menu.

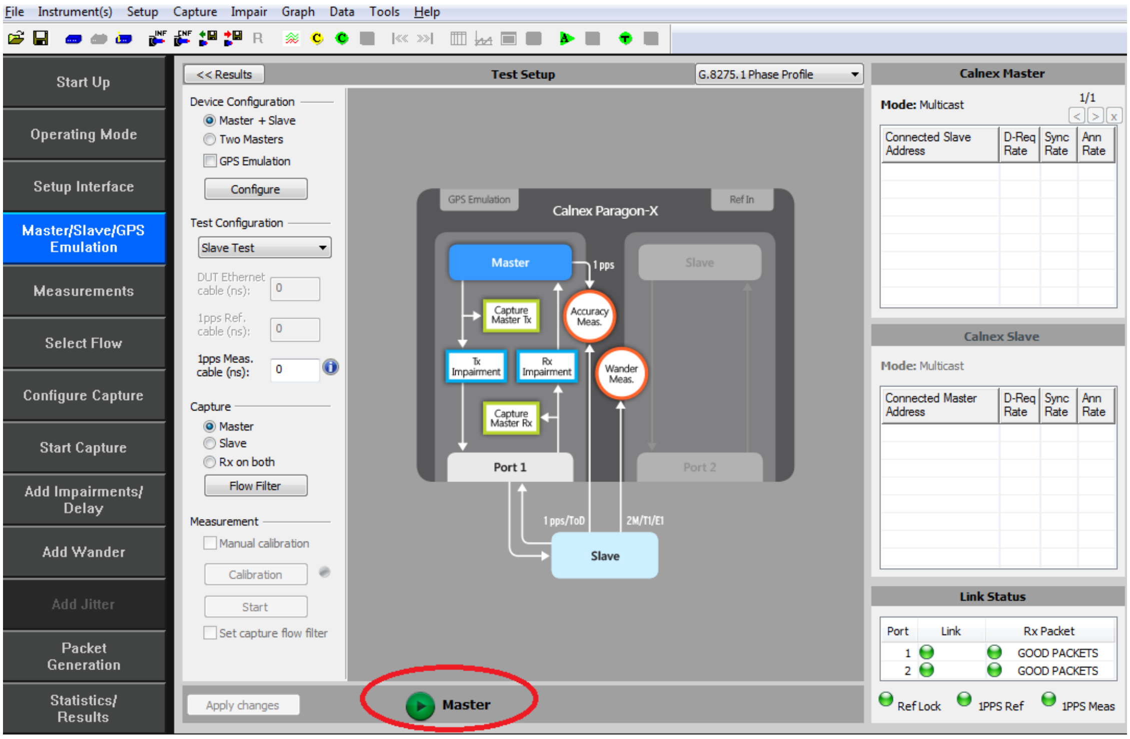


4. Enter the DUT to Paragon-X 1PPS **cable delay**.

   To correctly calculate the 1PPS measurement, the delay caused by the cable connecting the Slave Clock 1PPS output and the Paragon-X 1PPS measurement port must be removed. Values of 5.1 ns per 1 metre of cable can be used.

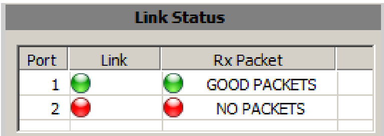


5. ***Start*** the Master/Slave emulation by clicking on the button highlighted below.



3.5 Confirming PTP Traffic on the Interfaces

Check the link to make sure that the PTP packets are being exchanged without error. If working correctly, both Link and Packet status indicators for port 1 will be green as shown below.



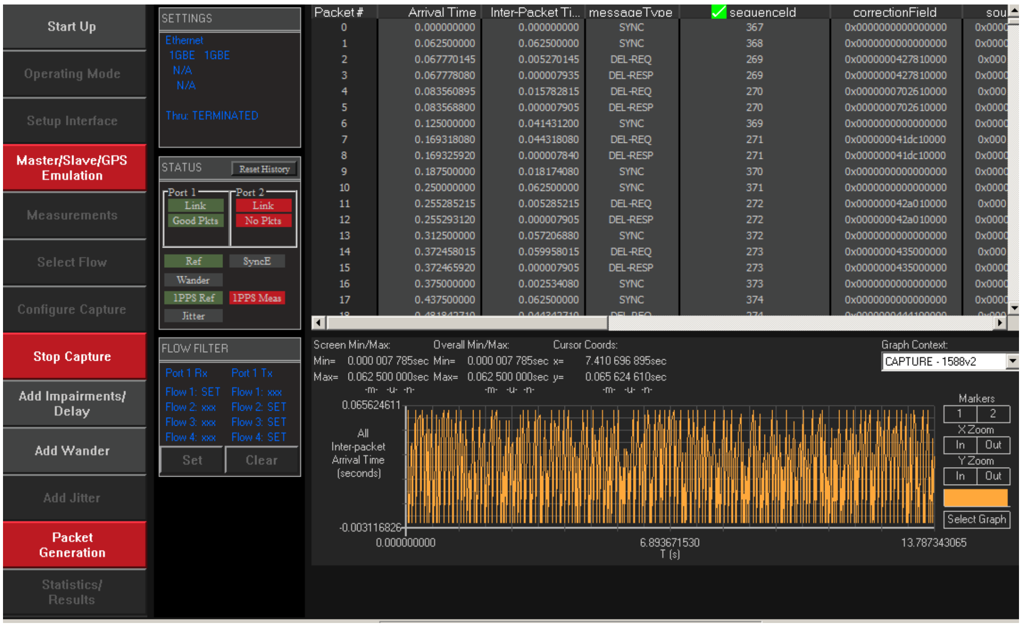
1.

No **Capture** filters are required for testing the Slave Clock output, but it is good practice to ensure that the correct traffic is being passed between the Paragon-X Master and the DUT before starting a measurement.

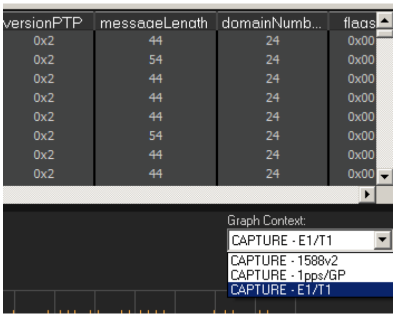
Connect the Slave Clock and clock outputs as detailed earlier in this document. With everything connected, start the Paragon-X Emulated Master running, then perform a capture using the 

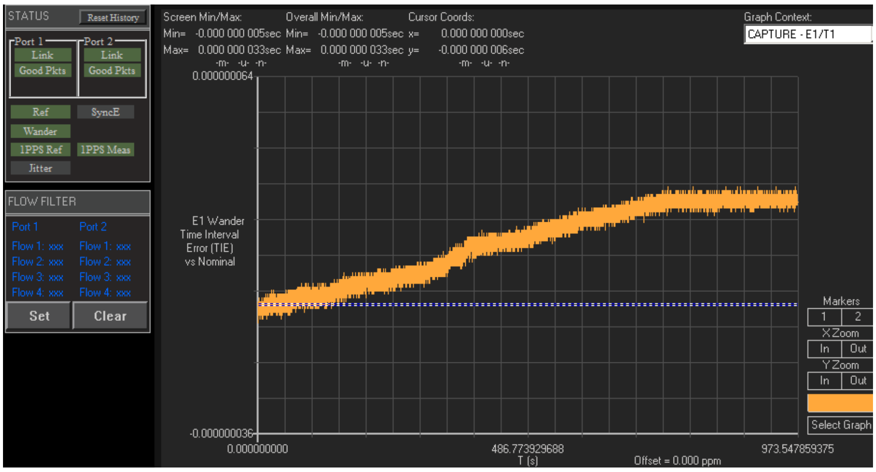
button. This will capture PTP packets between the Master and the Slave Clock and the clock outputs from the Slave Clock.

2.



3. To check the clock's frequency output use the pull down menu:





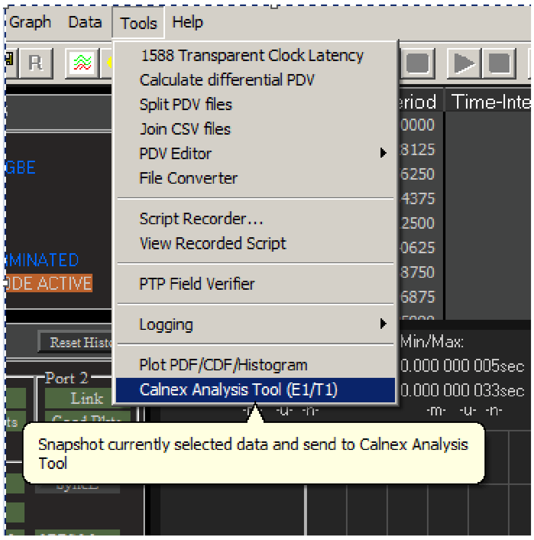
3.6 Measuring the Slave Clock Output

For performance evaluation of a G.8261 profile, the recovered clock of the Slave Clock should be measured as follows:

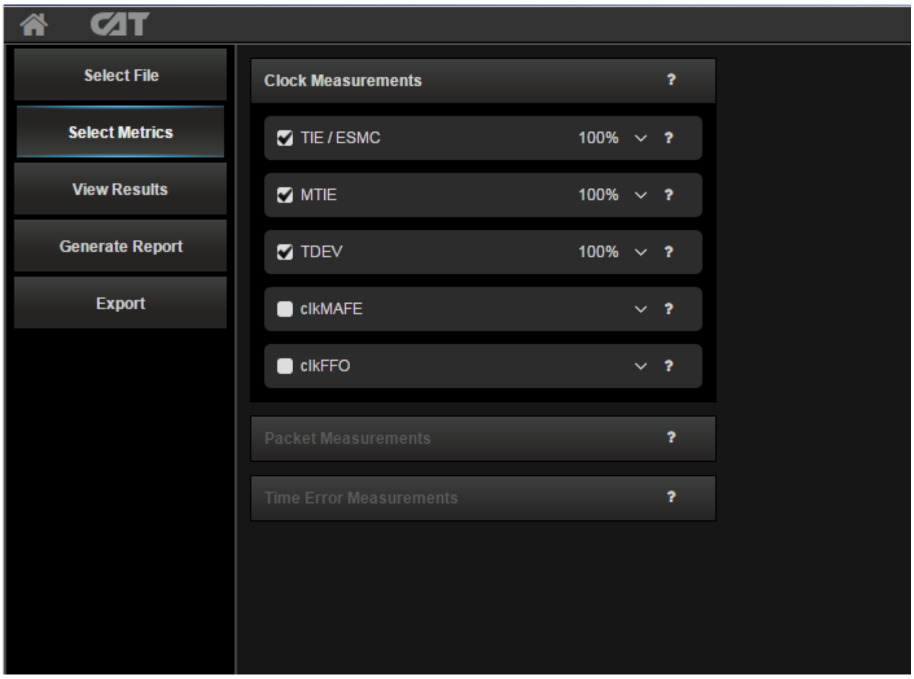
- Frequency output (MTIE/TDEV measurement) if 1588v2 is being tested for Frequency transfer.
- 1PPS Time of Day output (ToD/1PPS Error measurement) if 1588v2 is being tested for Time/Phase transfer.

3.7 Measuring the Slave Clock Output

1. From the ***Tools*** dropdown, for clock output measurements, select ***Calnex Analysis Tool (E1/T1)*** or ***Calnex Analysis Tool (2M)*** depending on which measurement you have enabled and selected in 3.5 above.



2. The Calnex Analysis Tool (CAT) will be launched to enable analysis of the TIE data metrics. Use the ***Select Metrics*** button to select ***MTIE*** and ***TDEV*** metrics.

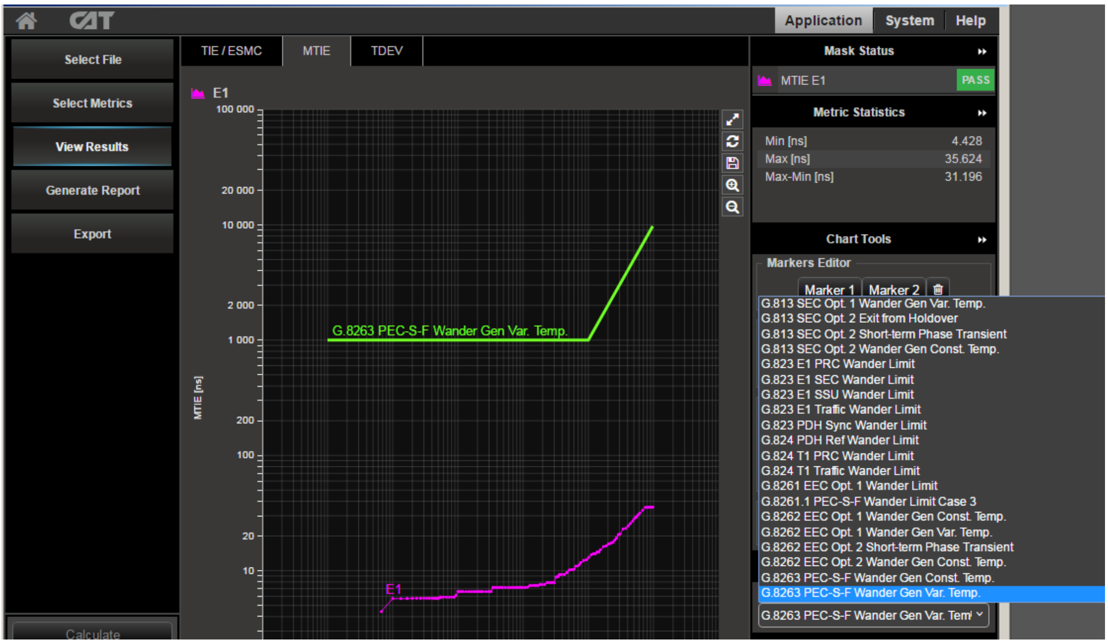


3. Use the ***View Results*** button to view the Results. ***MTIE*** and ***TDEV*** measurements are on separate tabs.

   The masks used below are defined in ITU-T Standard G.8263.

   Slave Clock Noise Generation (Clause 6.1):

- Ideal input, output mask in G.8263 Table 1 and Figure 2.

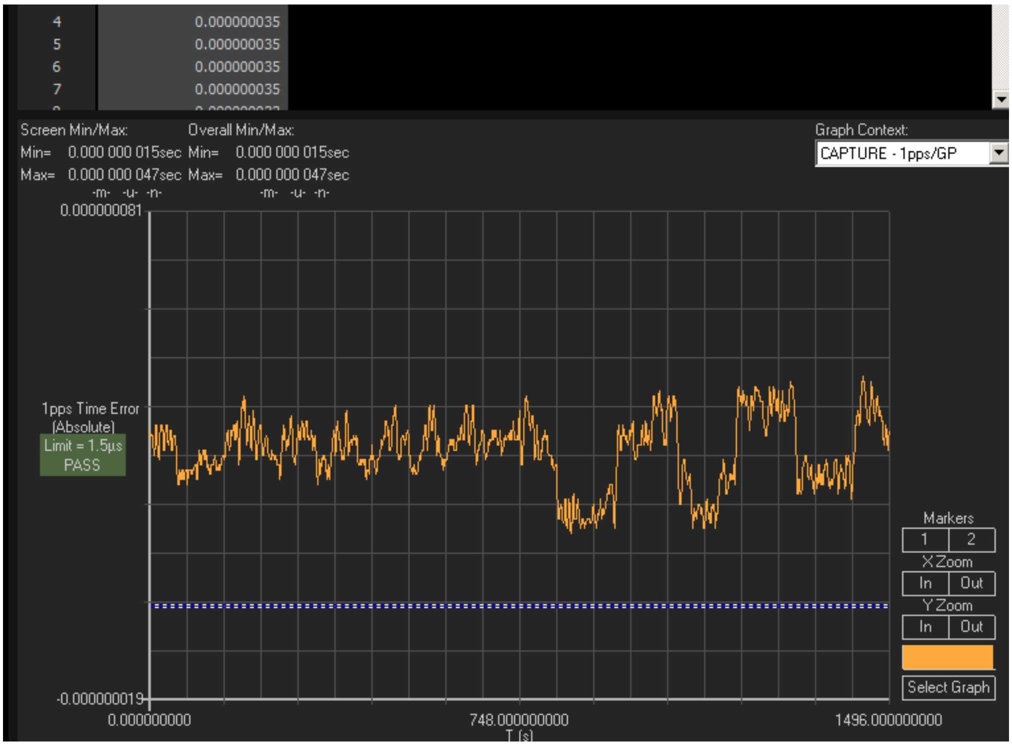


Slave Clock Noise Tolerance (clause 7.1):

- Input noise defined in clause 8.1.1 of G.8261.1 (FPP of 1% in 150us)
- Output dependent on use case:
    - For a timing a basestation: case 3 from G.8261.1 Clause 7.2.2 (Table 1 and Figure 4)
    - Output for traffic interface (e.g. timing a CES link): case 2 from G.8261.1 Clause 7.2.2

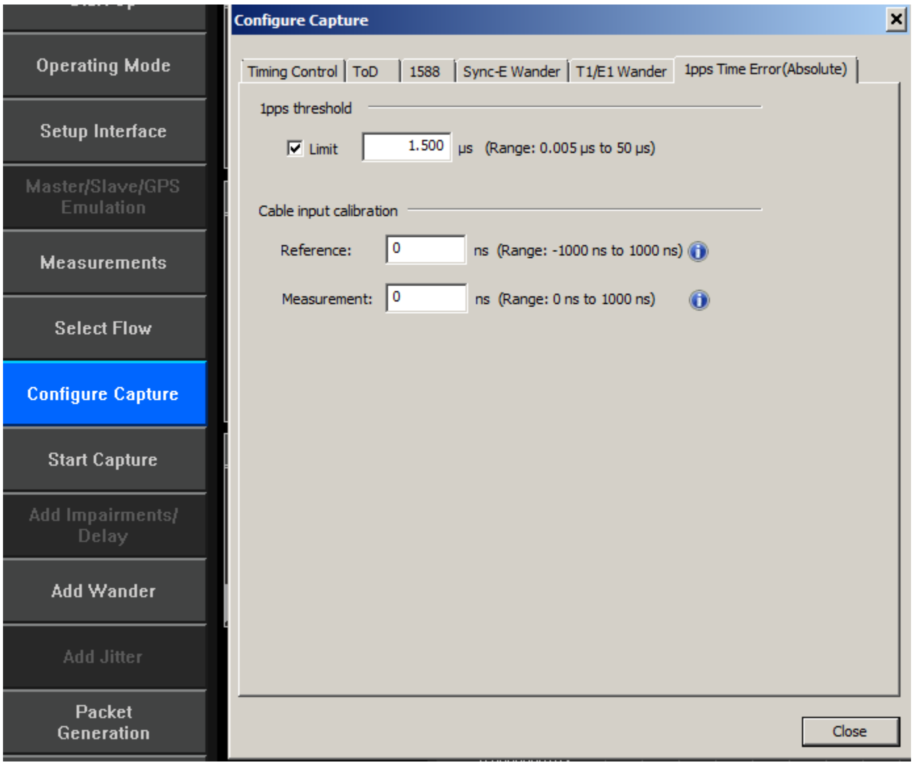
3.8 Measuring the Time/Phase Output of the Slave Clock

1. in the Paragon-X GUI graph area, select ***CAPTURE - 1pps/GP*** from the ***Graph Context*** dropdown menu:



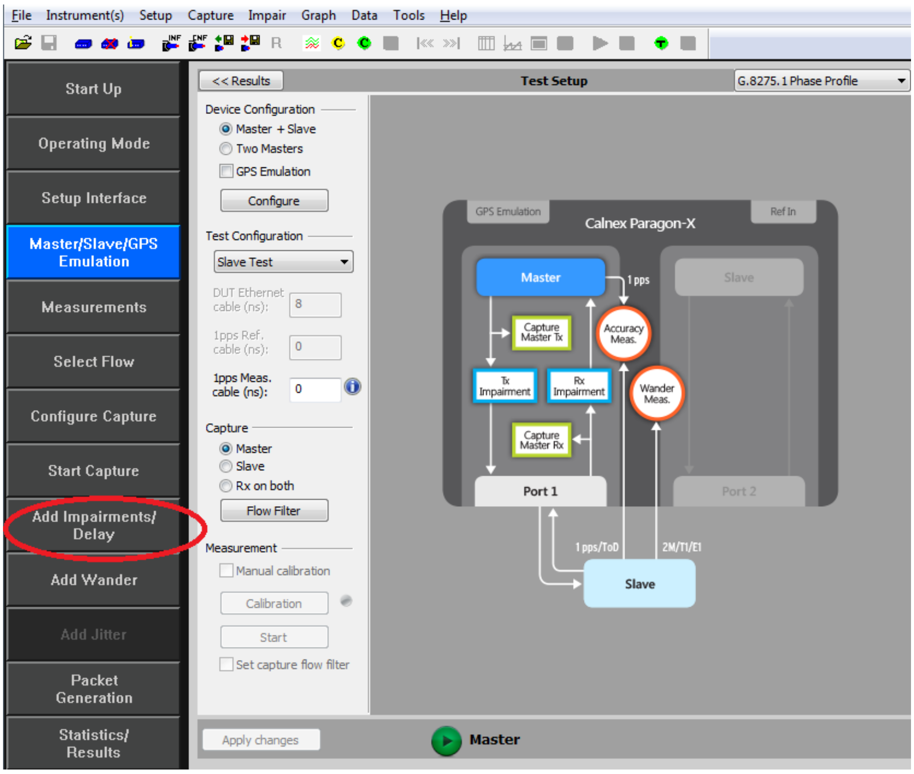
The 1PPS accuracy measurement is made at each one-second point on the rising edge of the 1PPS reference signal. The result tabulated and graphed at each 1-sec interval is the time difference between the rising edge of the measured signal from the Slave Clock and the rising edge of the reference signal. In normal conditions, this will be a positive value. However, since it is an absolute measurement, path length differences between measurement signal cabling and reference signal cabling can be significant. Make these cable lengths similar if possible, and if not then take account of the propagation error of approximately 5.1 ns per metre of cable length difference.

2. By default, the 1PPS accuracy result is compared against a limit and PASS/FAIL is displayed in a green or red box beside the graph as shown above. To disable display of the PASS/FAIL indicator, click on the ***Configure Capture*** button, select the ***1pps Time Error (Absolute)*** tab and uncheck the ***Limit*** checkbox.



3.9 Enabling Impairments for the Test Cases

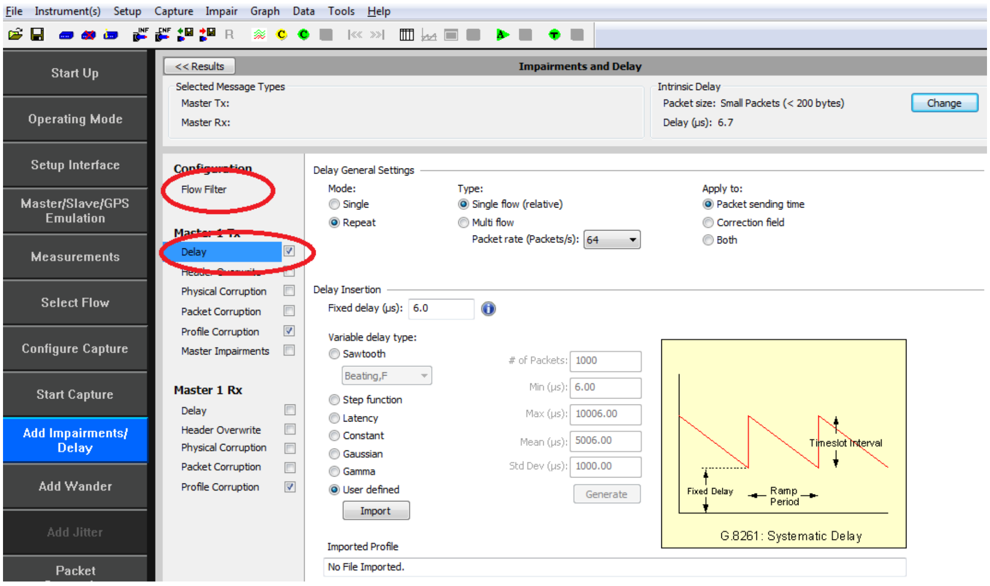
1. To enable impairments, click on the ***Add Impairments/Delay*** button highlighted below.



This will display the **Impairments** control screen. In G.8261 testing, impairments are applied to the **Sync** messages in the forward direction (**Master Tx**) and to the **Delay-Request** messages in the reverse direction (**Master Rx**).

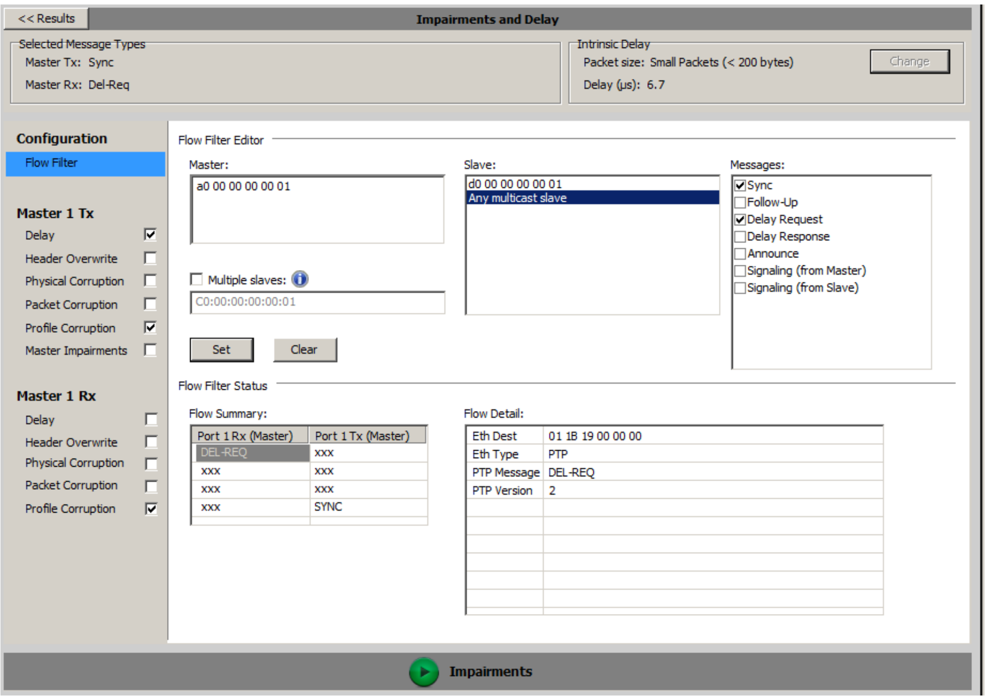
Master Tx Impairments

2. Enable the ***Master Tx Delay*** and the ***Master Rx Delay*** by ticking the associated checkboxes.



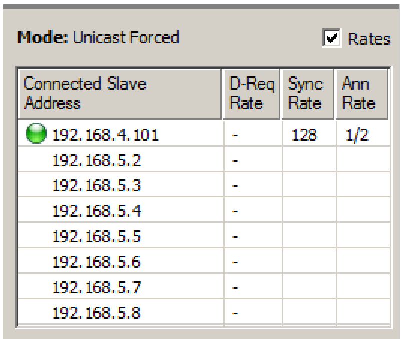
3. Click on ***Delay*** in the ***Master 1 Tx*** section to enable its configuration. The selection will be highlighted as: Delay

4. Select ***Flow Filter*** to select the ***Sync*** and ***Delay Request*** messages for delay impairment.



NOTE:

- If the PTP protocol used is a **Multicast** based protocol (e.g. G.8275.1) the filters can be set without first running a capture to determine the Slave's address.
- If a **Unicast** based protocol is used (e.g. G.8265.1) then the Paragon-X Master emulation must be started prior to setting the Flow Filter to enable the Master to discover the Slave's address. This has happened successfully when a Slave address is shown with a green status in the **Connected Slave Address** window.



Connected Slave Address	D-Req Rate	Sync Rate	Ann Rate
192.168.4.101	-	128	1/2
192.168.5.2	-		
192.168.5.3	-		
192.168.5.4	-		
192.168.5.5	-		
192.168.5.6	-		
192.168.5.7	-		
192.168.5.8	-		

Master emulation is started using the 

button in the Master/Slave Emulation window. After a Slave Clock is detected the Flow Filter can be set as above.

The Impairment engine is now ready to import delay patterns as described in later sections.

Impairment Patterns

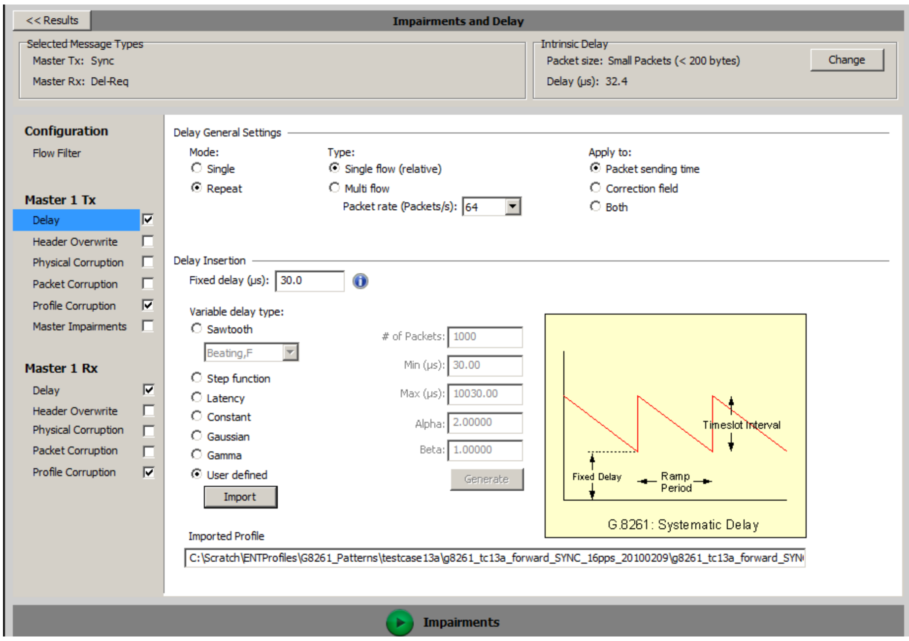
Each test case in G.8261 requires the loading of impairment patterns for both forward and reverse directions as detailed in

Appendix 1: ITU-T G.8261 Test Case Profiles for 1588v2 Testing.

Note: impairment patterns for testing to G.8261 and other ITU-T standards may be obtained from the Product Software section of the Calnex website https://calnexsol.com (registration required).

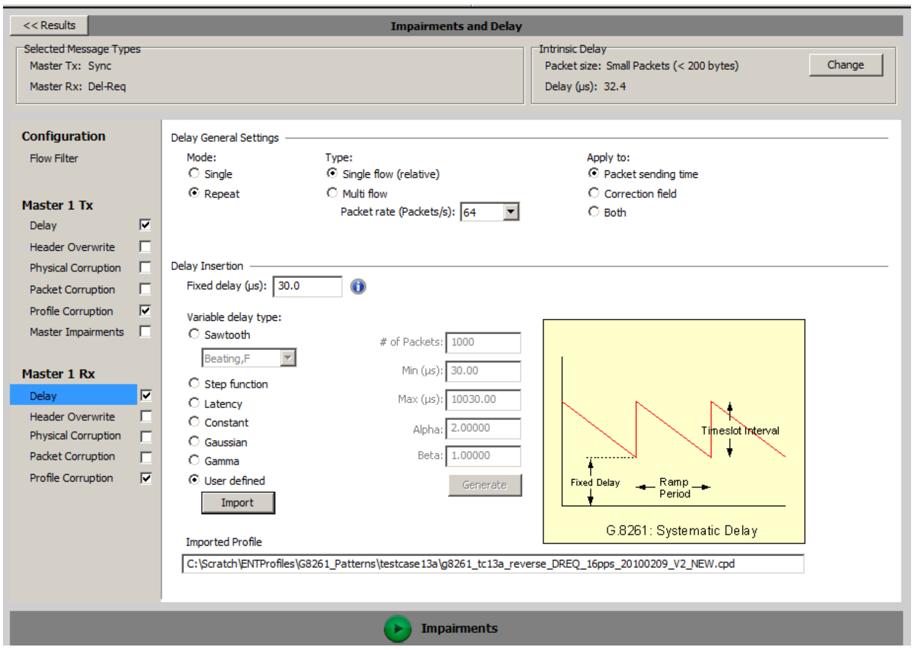
Master TX Impairments

5. In the ***Master TX - Delay*** configuration window, select the ***User defined*** option and click ***Import***. In the file browser window, navigate to the location of the desired stored pattern.



Master Rx Impairments

6. Repeat the above steps to load the desired **Master Rx** (reverse direction) delay pattern.



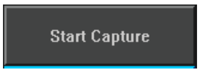
3.10Test Execution

Impairments

When ready to test your DUT, start applying the Impairments using the 

button.

Capture

The capture can then be started using the 

button:

The captured data can be analysed as described in the **Non Emulation Mode** section (see below).

Test Sequence

Each individual test case requires the following steps:

1. Import the test cases
2. Start the impairment
3. Start the capture
4. Launch the CAT to generate the metrics
5. Stop the capture
6. Repeat Steps 1 to 5

4. Non Emulation (thru) Mode

4.1 Test Setup

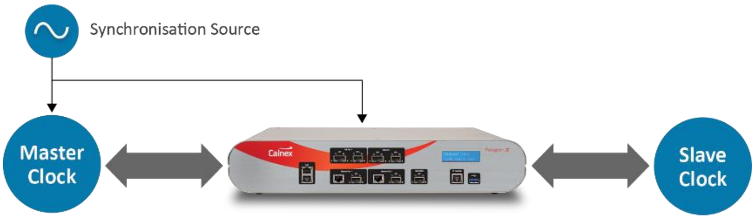


Figure 3. Test Setup for running ITU-T G.8261 performance tests with Paragon-X in non-emulation mode

Physical connections

1. Connect the PTP Master Clock to Port 1 of the Paragon-X (Figure 1**, connectors 2 or 3**).
2. Connect the PTP Slave Clock under test to Port 2 of the Paragon-X (Figure 1**, connectors 2 or 3**).

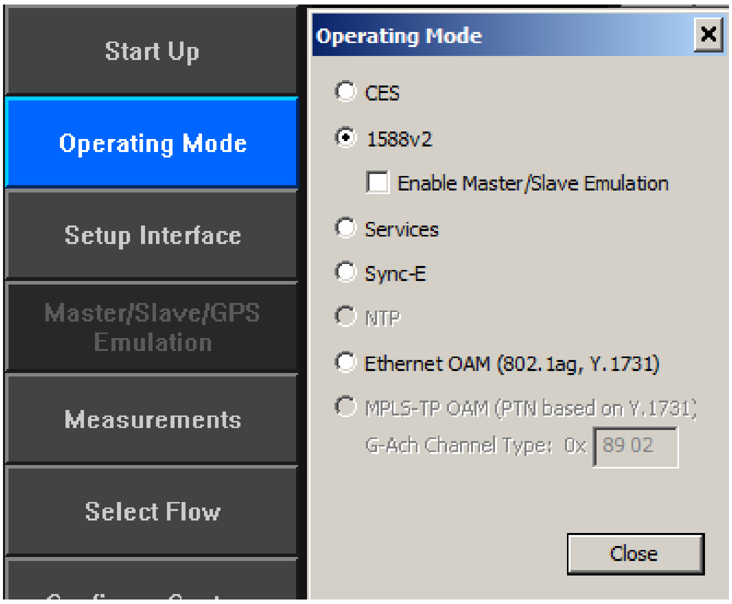
   NOTE: When using optical ports both SFP modules must be inserted into the Paragon-X to enable selection of the ***"Optical"*** option in the Physical Settings window.

   Also note both connections must be at the same rate and same media (Electrical or Optical). If the Master and Slave Clocks in your test setup are set to run at different rates, add a switch to the test set up.

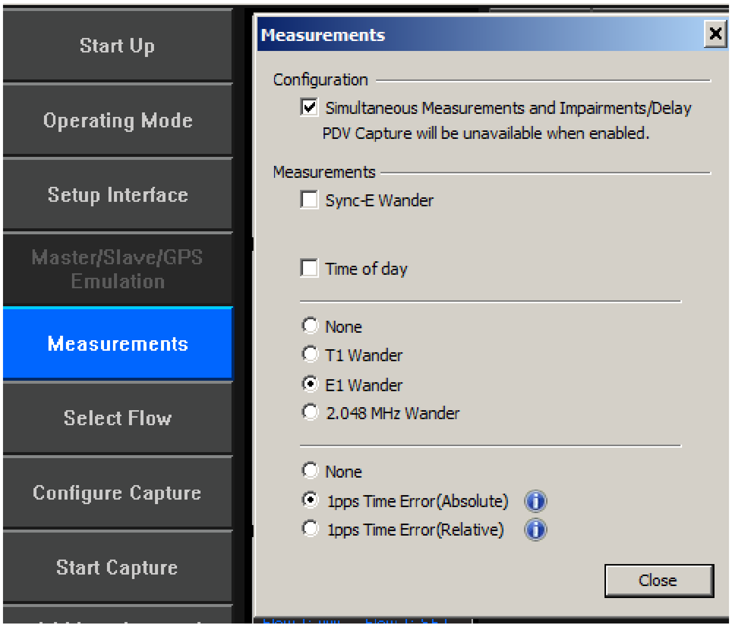
3. Connect the external reference, e.g. 10MHz, to the Paragon-X Reference Input (Figure 2**, connector 14**).
4. Connect the 1PPS output from the Slave Clock to the Paragon-X 1PPS measurement port (Aux) (Figure 1**, connector 1**). Use Calnex's 1pps/ToD/Frequency Converter accessory if required.
5. Connect the Frequency, e.g. E1 output from Slave Clock, to the Frequency measurement port at the rear of the Paragon-X (Figure 2**, connector 13**).

4.2 Application Setup

1. Verify that physical connections have been made as described above.
2. From your Windows PC, start the Paragon-X client (GUI) by clicking ***Start*** > ***All Programs*** > ***Calnex/Paragon-X*** (different Windows operating systems may vary slightly).
3. On the Paragon-X GUI, press ***Start Up*** and connect to the Paragon-X (see the *Getting Started Guide* for more details if required).
4. Click on the ***Operating Mode*** button, select ***1588v2*** mode, then click the ***Close*** button.

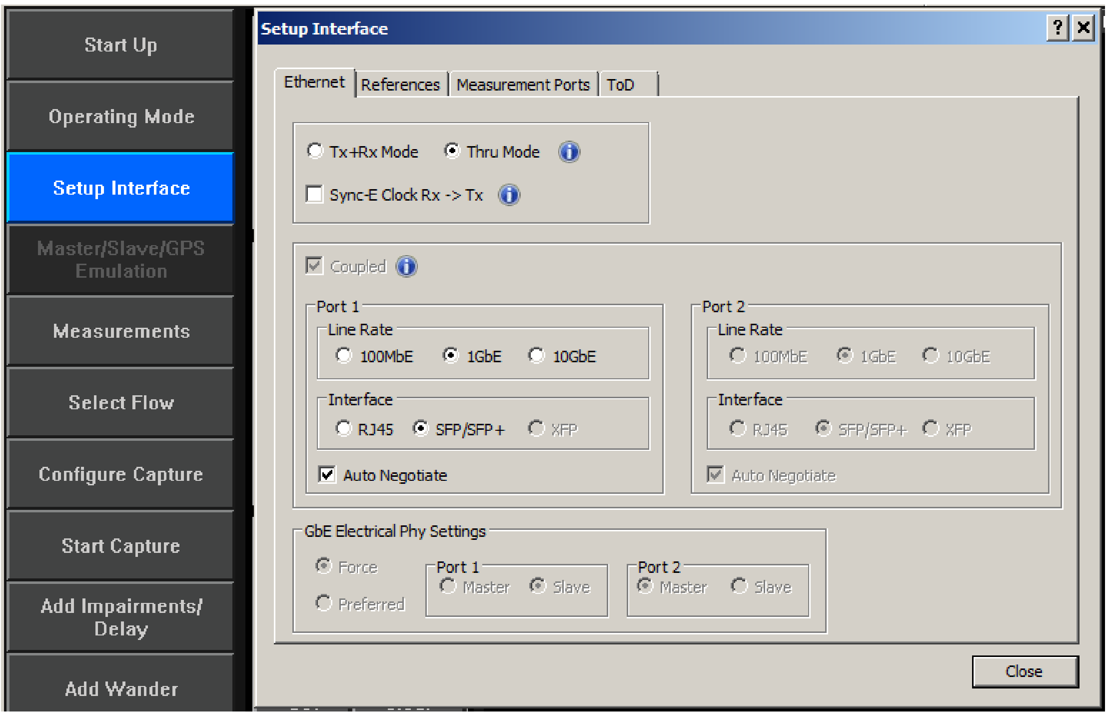


5. Click on the ***Measurements*** button and select ***E1*** (or ***T1*** or ***2.048MHz) Wander*** and ***1pps Time Error (Absolute)*** measurements. Ensure that the ***Simultaneous Measurements and Impairments/Delay*** is selected.

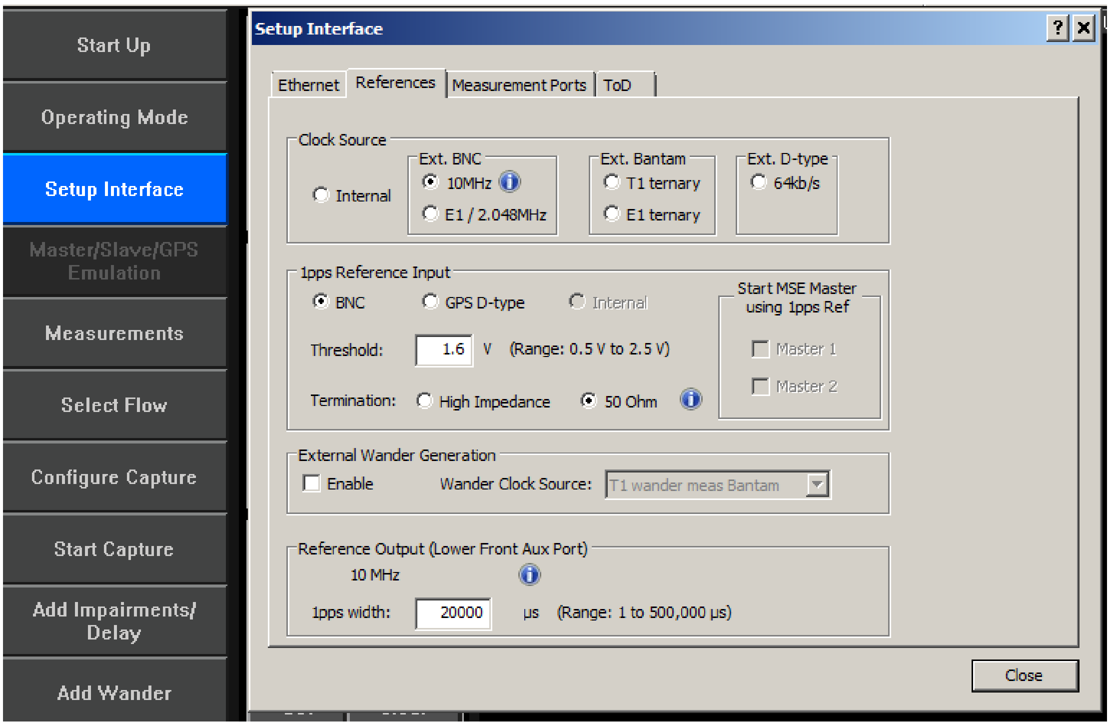


Click on the ***Setup Interface*** button. On the **Ethernet** tab, select ***Thru Mode*** then select ***Line Rate*** and ***Interface*** type.

NOTE: If using SFP/XFP devices, one must be present in both ports to be allow their selection.



6. Select the ***References*** tab and set the reference ***Clock Source*** according to rear panel reference input used. Set the ***1pps Reference Input*** selection according to the 1PPS reference input used to connect the common frequency reference or Master Clock 1PPS reference output to the Paragon-X.

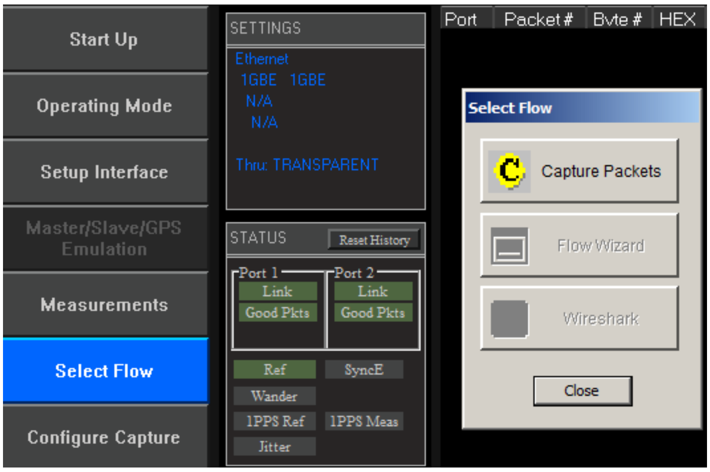


4.3 Selecting Flows and Setting Filters using Flow Wizard

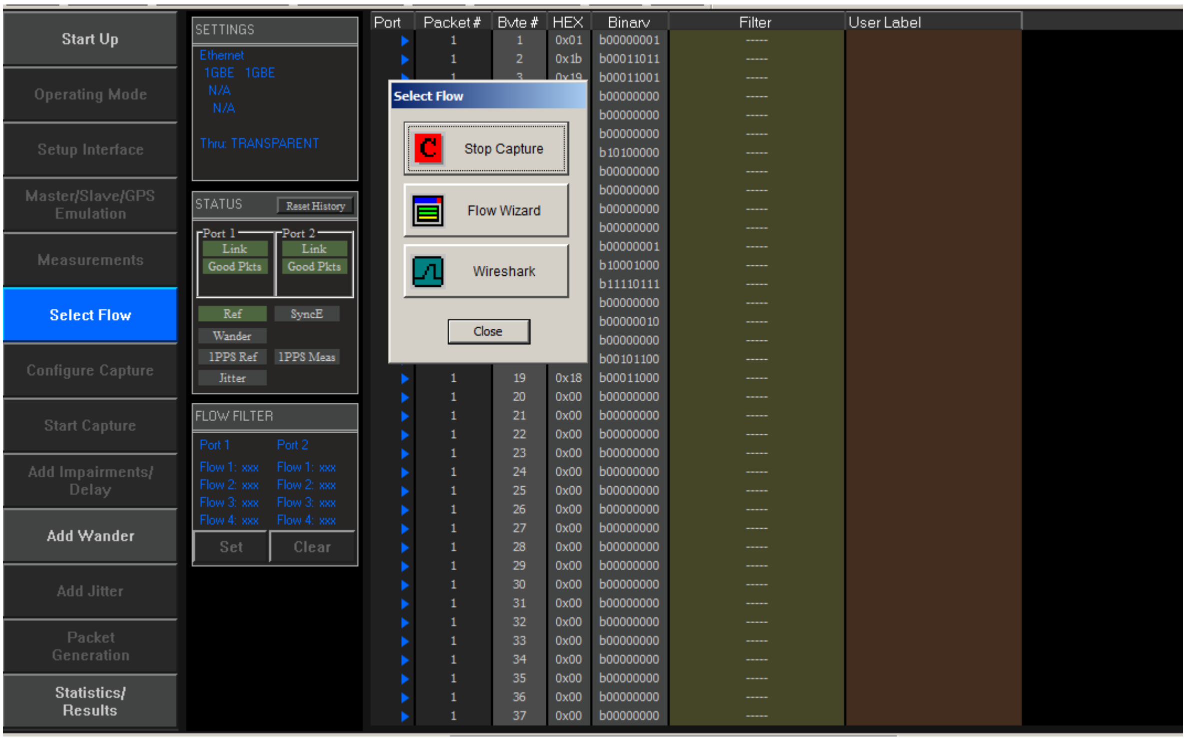
Once setup of operating mode and interfaces is complete, the correct 1588v2 flows to apply the G.8261 profiles to should be selected. This is achieved by using the Paragon-X Flow Wizard functionality.

The G.8261 Test Case PDV profiles are applied to SYNC messages in the forward direction, and to DELAY_REQ messages in the reverse direction.

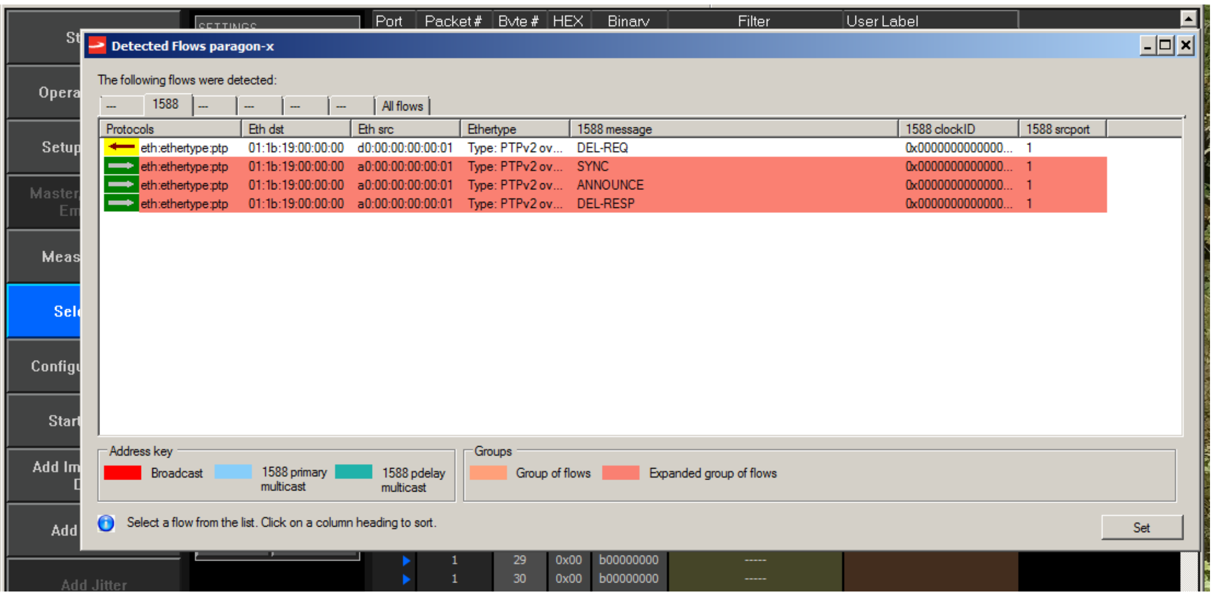
1. Click on ***Select Flow*** and the following window will appear:



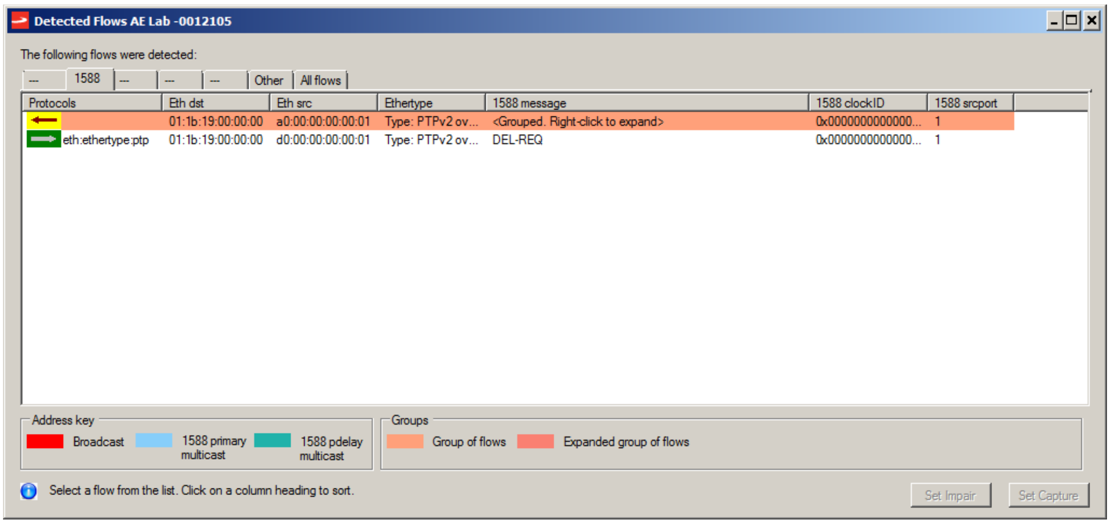
2. Click the ***Capture Packets*** button to start the capture.
3. After a short time (approximately 10 Seconds) click the ***Stop Capture*** button.



4. Click on ***Flow Wizard*** to display the following screen:



5. Flow Wizard automatically groups flows that have the same value for each of the fields displayed. To show the individual messages, right click on a pink row and then click ***"Expand row to show individual message types".***



6. Select the flows of interest. Multiple flows can be selected by using either the "Shift" and left mouse button or "Ctrl" and left mouse button. For G.8261 testing, select the **SYNC** and **DEL_REQ** flows.

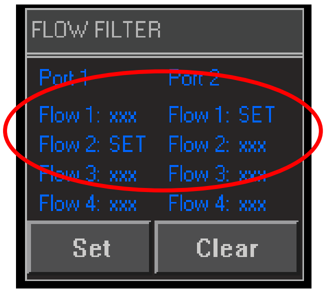
7. Click 

to set the Filters and then close the window using the Window control X in the top right corner.

8. Click 

to close the **Select Flow** window.

9. The Flow Filter Window in the main Paragon-X GUI (shown below) will now show that filters have been set.



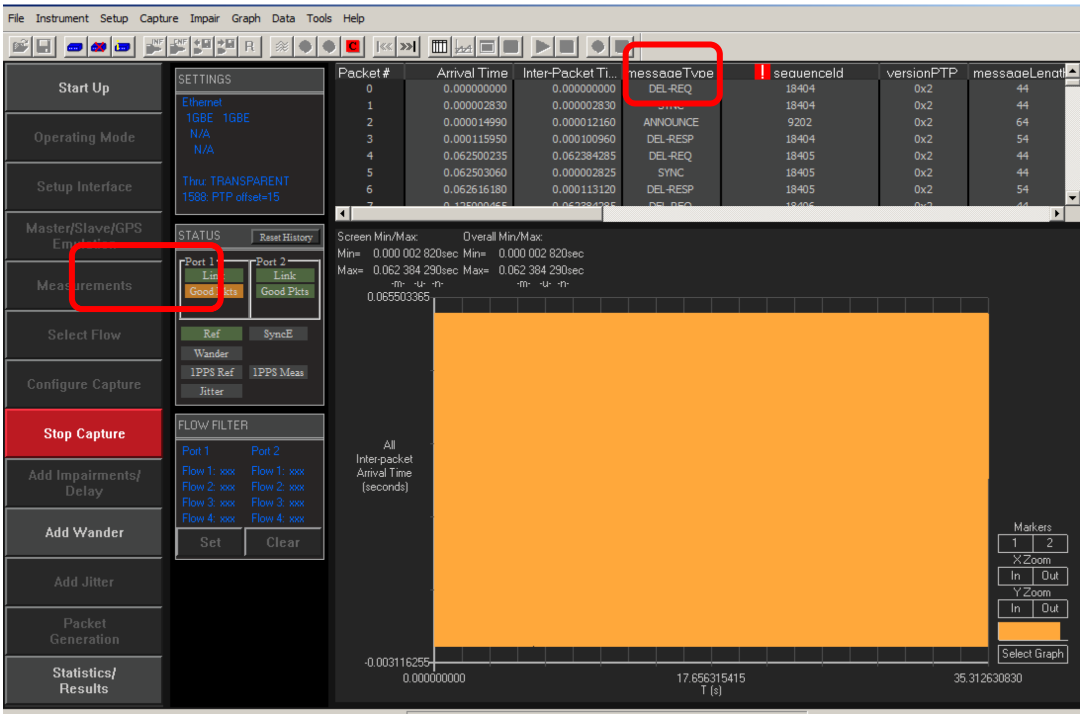
4.4 Validating the Protocol and Handshaking prior to any Impairments

1. Ensure that there is correct and regular handshaking and negotiations between the Master and Slave by looking for mis-ordered, missing, and repeated messages.
2. Ensure there are no protocol anomalies e.g. protocol errors, invalid fields.
3. Check for correct packet rates:
   - 16/32/64/etc., packets per second for SYNC and DELAY_REQ messages
   - Sync, Del_Req, Del_Resp should not exceed 128pps as specified by ITU-T for Telecom unicast applications

Messages between the Master and Slave may be validated as follows:

1. With **no filters** set, click on the ***Start Capture*** button to start the measurement.

2. If desired, stop the measurement (after a pre-defined period for running the test) by clicking on ***Stop Capture***.



The header and timing table lets you quickly determine whether there are any mis-ordered, missing or repeated packets.

3. To do this, look at the top of the sequenceId column and check the soft LED icon.

✓ sequenceId	Indicates no error
! sequenceId	Indicates there is an error

4. To go to the first error use the »| icon, and the first/next error will appear at the top of the screen. Errors are identified by messages being highlighted in red.

Packet #	Arrival Time	Inter-Packet Ti...	messageType	! sequenceId	versionPTP	messageLeng
1721	23.875014990	0.000012160	FOLLOW-UP	3734	0x2	44
1722	23.875027150	0.000012160	ANNOUNCE	1867	0x2	64
1723	23.875039310	0.000012160	DEL-RESP	45590	0x2	54
1724	23.937500000	0.062460690	DEL-REQ	45591	0x2	44
1725	23.937502830	0.000002830	SYNC	3735	0x2	44
1726	23.937514990	0.000012160	FOLLOW-UP	3735	0x2	44
1727	23.937527150	0.000012160	DEL-RESP	45591	0x2	54
1728	24.000000000	0.062472850	DEL-REQ	45592	0x2	44
1729	24.000014990	0.000014990	FOLLOW-UP	3736	0x2	44
1730	24.000027150	0.000012160	ANNOUNCE	1868	0x2	64
1731	24.000039310	0.000012160	DEL-RESP	45592	0x2	54
1732	24.062500000	0.062460690	DEL-REQ	45593	0x2	44
1733	24.062502830	0.000002830	SYNC	3737	0x2	44
1734	24.062514990	0.000012160	FOLLOW-UP	3737	0x2	44
1735	24.062527150	0.000012160	DEL-RESP	45593	0x2	54
1736	24.125000000					

5. In the screenshot above, it can be seen that there is a missing Sync message between sequence Id of 3735 and sequence id 3737 sent by the Master.

6. To go back to the previous error use the |« icon, and the previous error will appear at the top of the screen.

7. If no errors are seen during a short run (1 minute), you are ready to start the G.8261 performance tests. If errors are seen, the most likely cause is a mismatch in settings between the Master and Slave – this is particularly likely in mixed-supplier situations.

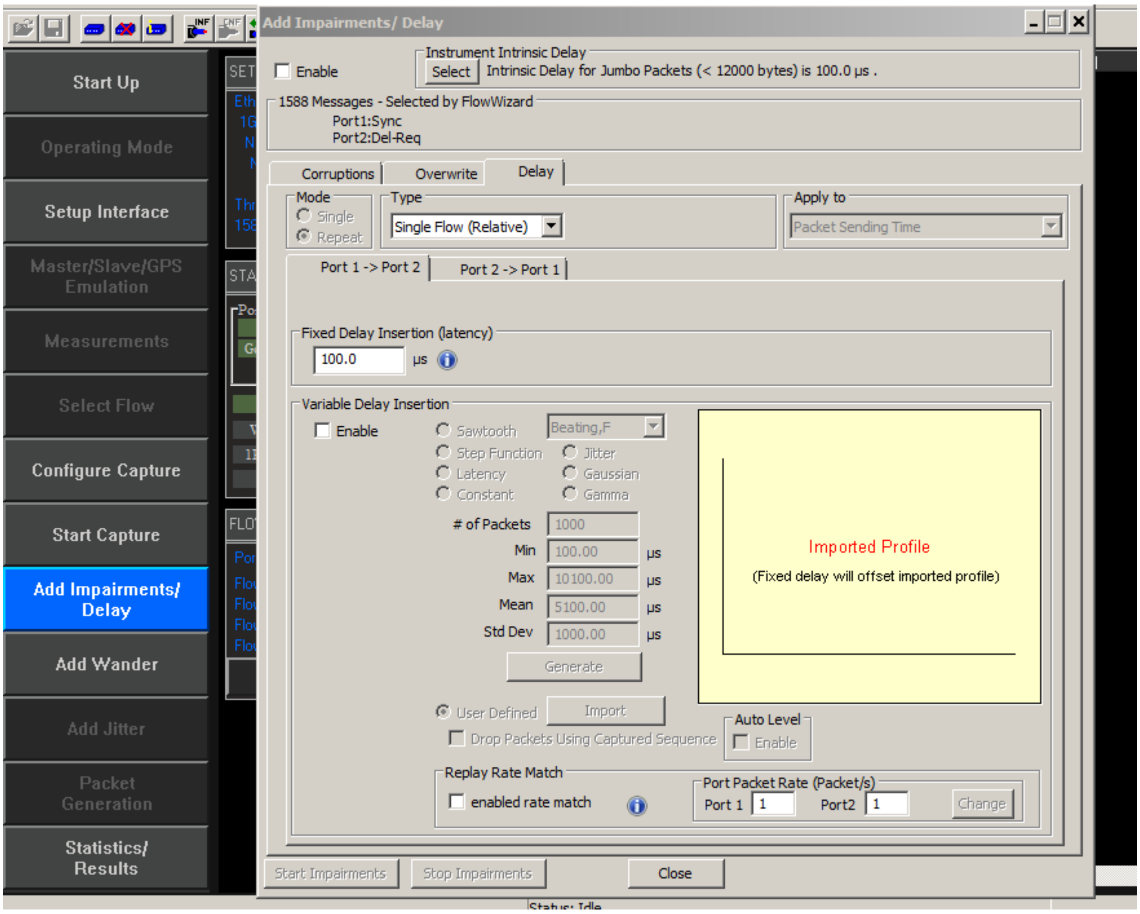
4.5 Importing and Replaying a G.8261 Test Case

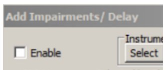
For G.8261 testing, it is required to load two profiles; one for the ***forward*** direction (for SYNC messages from the Master to the Slave), and one for the ***reverse*** direction (for DEL_REQUEST messages from Slave to Master).

NOTE: *For testing 1588v2 in accordance with G.8261, bidirectional test cases 12-17 are used. Calnex has a library of these profiles at each relevant packet rate (from 2 packets per second to 128packets per second). These may be obtained from the Product Software section of the Calnex website https://calnexsol.com registration required).*

To load the G.8261 profiles:

1. Click on ***Add Impairments/Delay*** and the following window will appear:

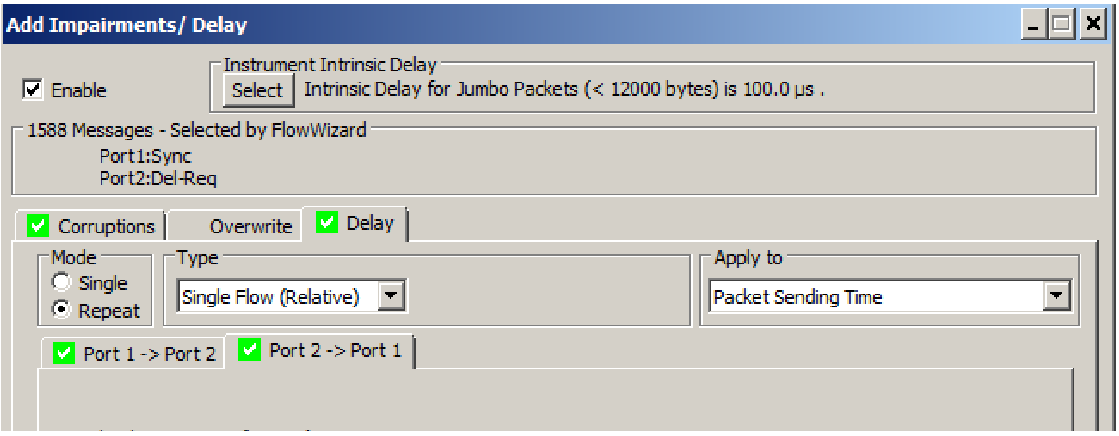


2. Tick the ***Enable***  box.

NOTE: *Immediately the Enable box is checked, the Instrument Intrinsic delay is applied to ALL traffic. This might cause the Slave to lose lock and further settling time might be required before the application of PDV.*

3. In the **Add Impairments/Delay** window, tick the box to ***Enable*** "*Variable Delay Insertion*" in both directions (**Port 1 > Port 2** and **Port 2 > Port 1**).

4. When “Variable Delay Insertion” is enabled in both directions, the “Delay” and each of the port direction tabs display green tick boxes:



NOTE: *Imported profiles are designed to be replayed against Sync and Delay Request messages only. If Flow Wizard was used earlier to select multiple messages for analysis, Flow Wizard must be used again so that only Sync and Delay Request messages are selected.*

5. G.8261 test case profiles may now be imported, one for each direction. The G.8261 profiles from the Calnex website are labeled to identify their direction and packet rateAn example pair is:

   - g8261_tc12_forward_SYNC_32pps
   - g8261_tc12_reverse_DREQ_32pps

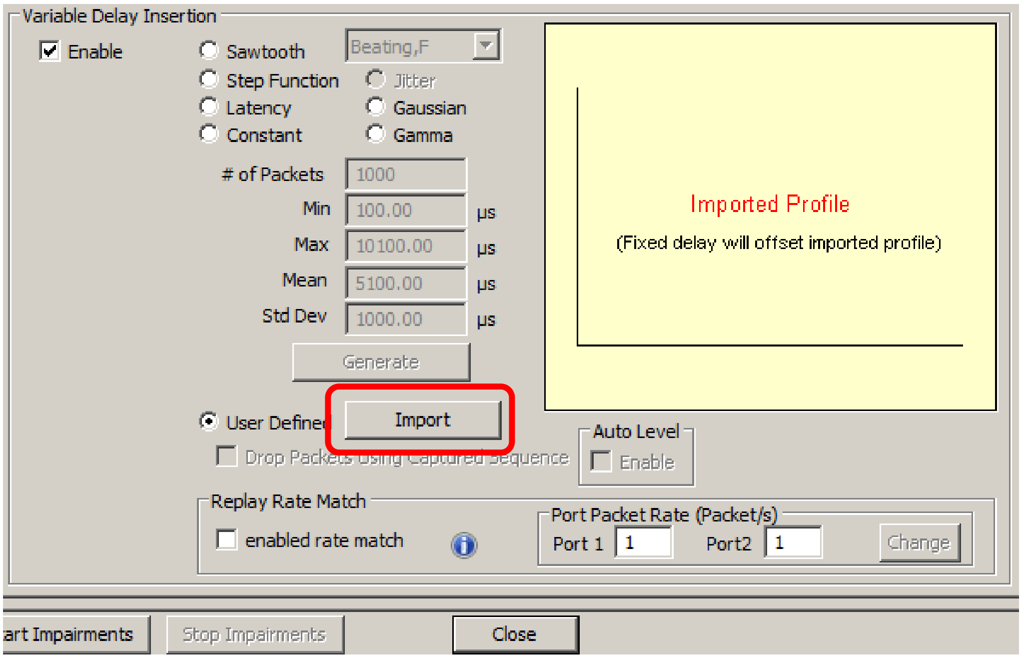
   Where:

   “*g8261_tc12*” identifies the specific ITU-T G.8261 test to be performed, in this instance testcase 12,

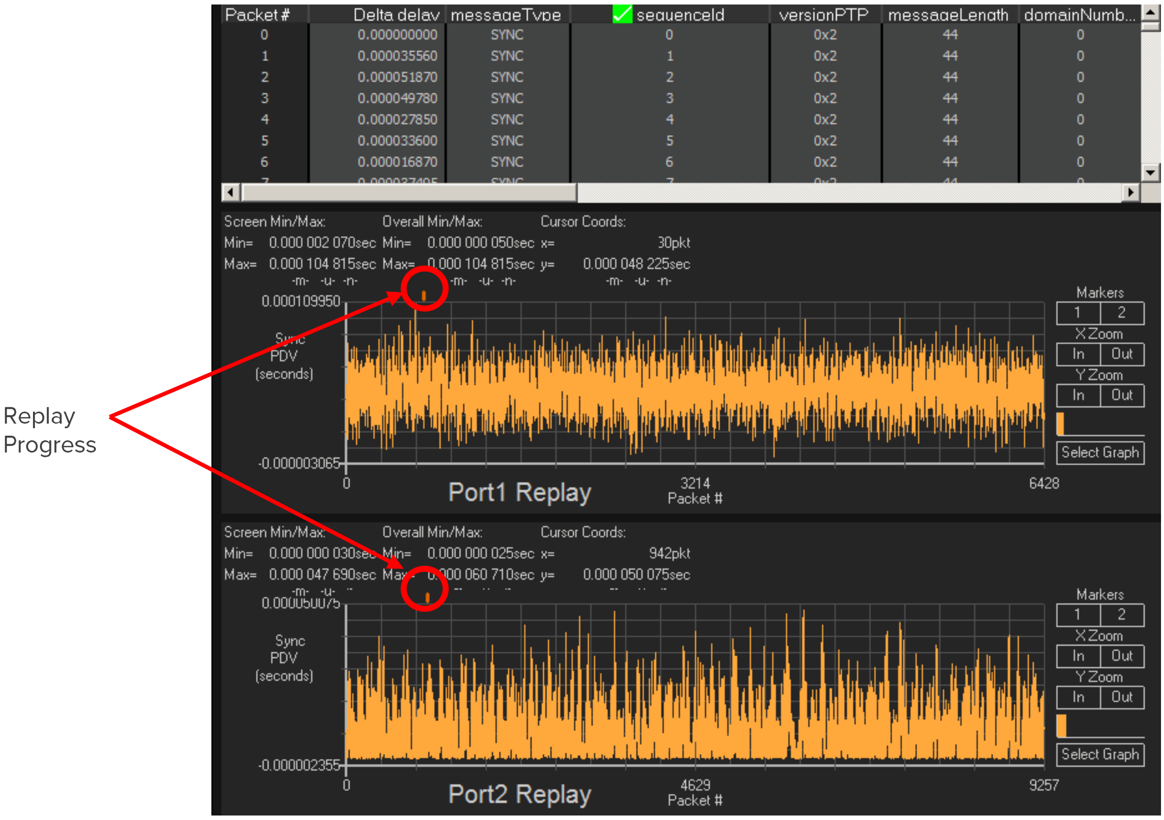
   “*forward_SYNC*” identifies the direction and 1588v2 messages within the profile, and

   “*32pps*” identifies the packet rate.

6. Import the forward profile for the **Port 1 > Port 2** direction by clicking on the ***Import*** button within the **Add Impairments/Delay** window. (Note: if this selection is greyed out, ensure that the “*Variable Delay Insertion*” **Enable** box is checked.)



7. On clicking the ***Import*** button, browse your PC for the location of the forward profile you want to load.
8. Click ***Open.*** The profile is now enabled for the **Port 1 > Port 2** direction.
9. Click on the **Port 2 > Port 1** tab and repeat steps 6 to 8.
10. To start the overwrite, click on the ***Start Impairments*** button and the following screen is shown:



The replayed profile for each direction is displayed. Each graph has a red vertical bar above it which shows the progress of the replay of the delay profile.

For G.8261 testing, there is a required amount of time that each test must run before checking the results. Review Appendix 2 for further information.

11. The replay can be stopped by clicking on the ***Stop Impairments*** button.

NOTE: *The G.8261 Test case must be started before the measurements on the Slave Clock. There is a stabilisation period allowed in G.8261 (900 seconds or 15 minutes). The Calnex G.8261 Test Case profiles have a stabilisation period of 15 minutes at the beginning, so start the profiles as shown above but only start the performance measurement steps after 15 minutes.*

15 minutes is a suggested stabilisation period, but some equipment might take longer than this. Individual equipment designers should be able to advise the appropriate settling time. If a greater period is required, profiles can be modified by using the PDV Editor tool as described in Appendix 1.

Performance measurement should generally start after the stabilisation period, but exact timings depend on the profile being used. Details are provided for each profile in Appendix 2.

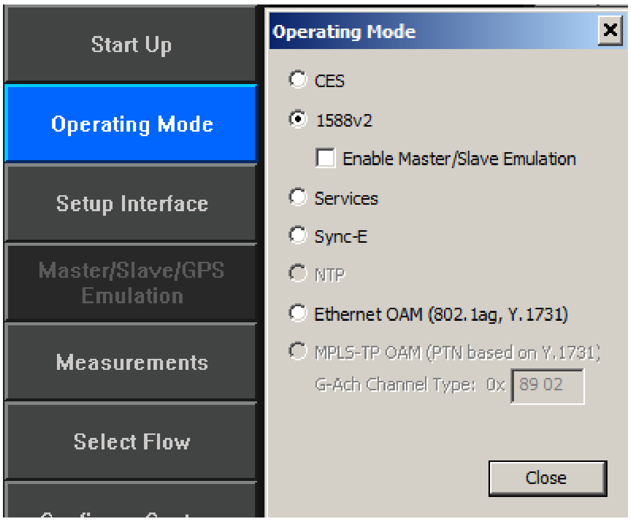
4.6 Measuring the Slave Clock Output

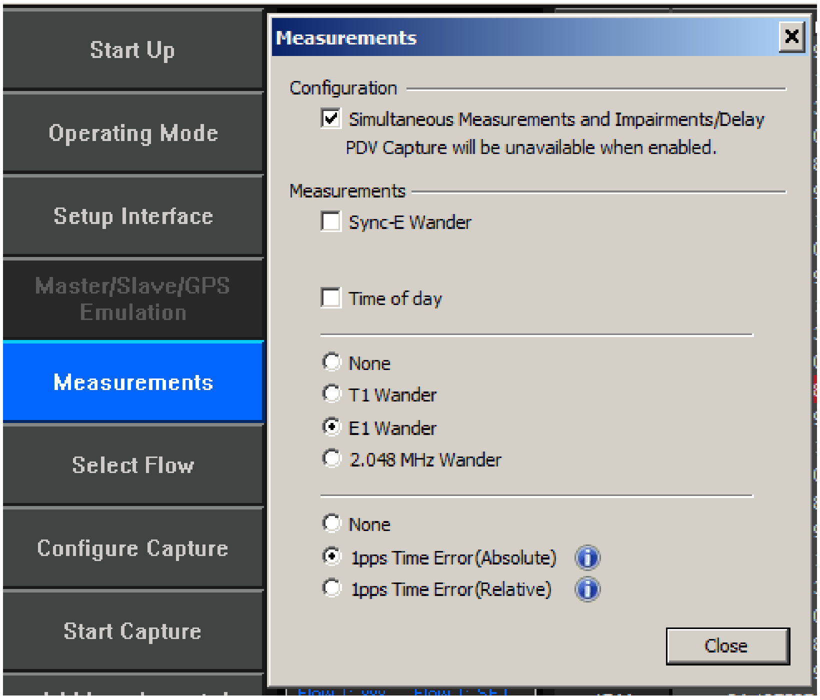
For performance evaluation of a G.8261 profile, the recovered clock of the Slave should be measured as follows:

- Frequency output (MTIE/TDEV measurement) if 1588v2 is being tested for Frequency transfer.
- 1PPS Time of Day output (ToD/1PPS Error measurement) if 1588v2 is being tested for Time/Phase transfer.

4.7 Configuring Paragon-X to Measure the Slave Clock Output

Verify that **1588v2** mode is selected and **E1/T1 /2.048MHz Wander** and **1pps Time Error (Absolute)** measurements are selected:

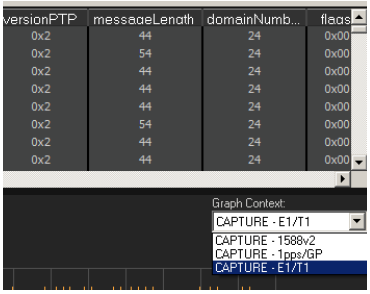




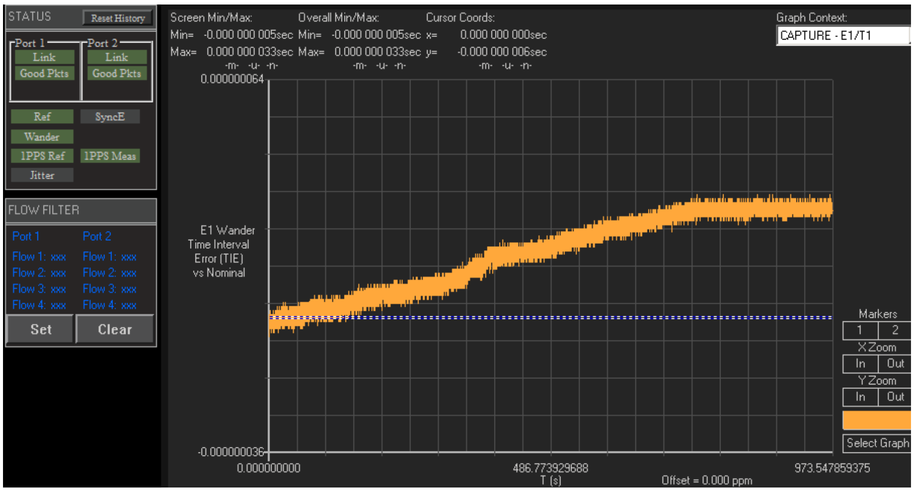
4.8 Measuring the Frequency Output (E1/T1 Wander) of the Slave Clock

1. Click on the ***Start Capture*** button.

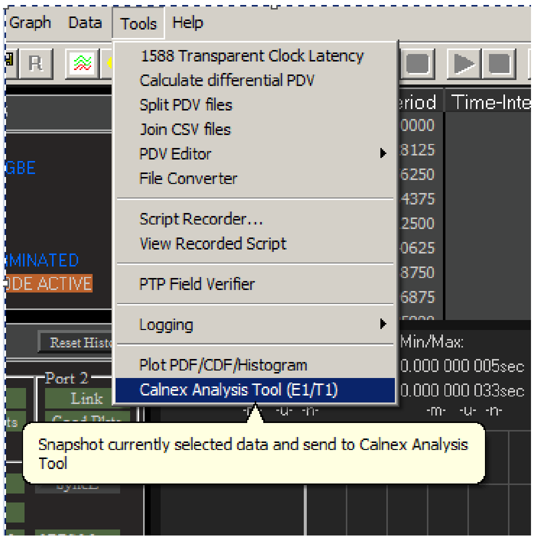
2. From the graph, select the measurement data from the ***Graph Context*** pull down menu.



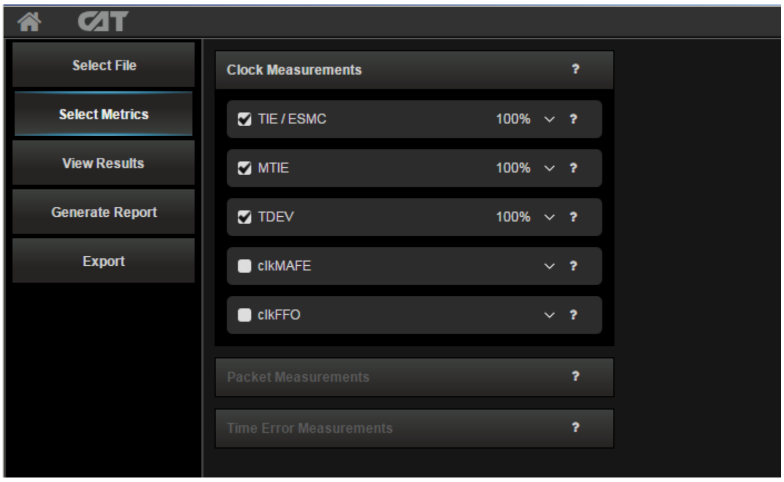
3. The E1/T1 Wander graph (TIE) will be displayed.



4. From the **Tools** dropdown, select ***Calnex Analysis Tool (E1)*** – or T1 if configured.



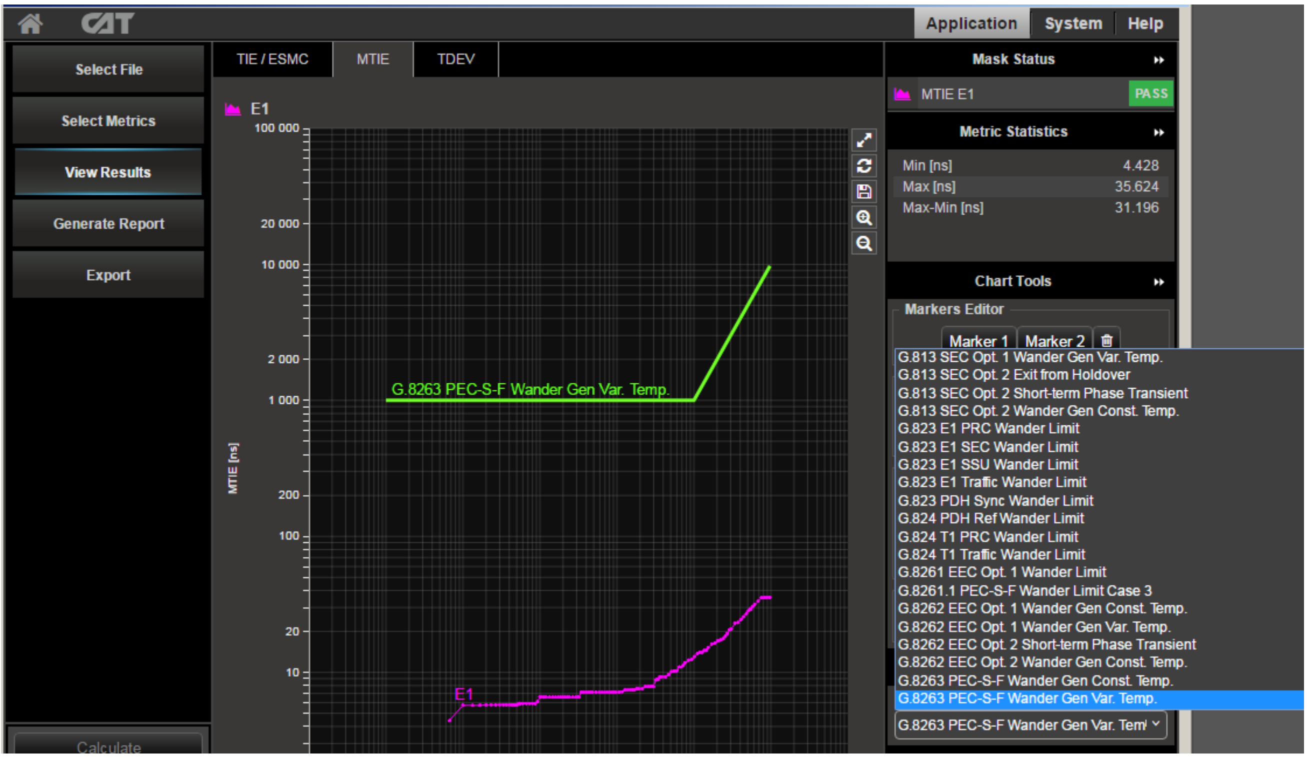
5. The Calnex Analysis Tool (CAT) will be launched to provide metric analysis of the TIE data. Use the ***Select Metrics*** button to enable the **MTIE** and **TDEV** metrics.



6. Click on the ***View Results*** button to view the results. Note that **MTIE** and **TDEV** are on separate tabs.

   Note: Masks to be used are defined in ITU-T Standard G.8263;

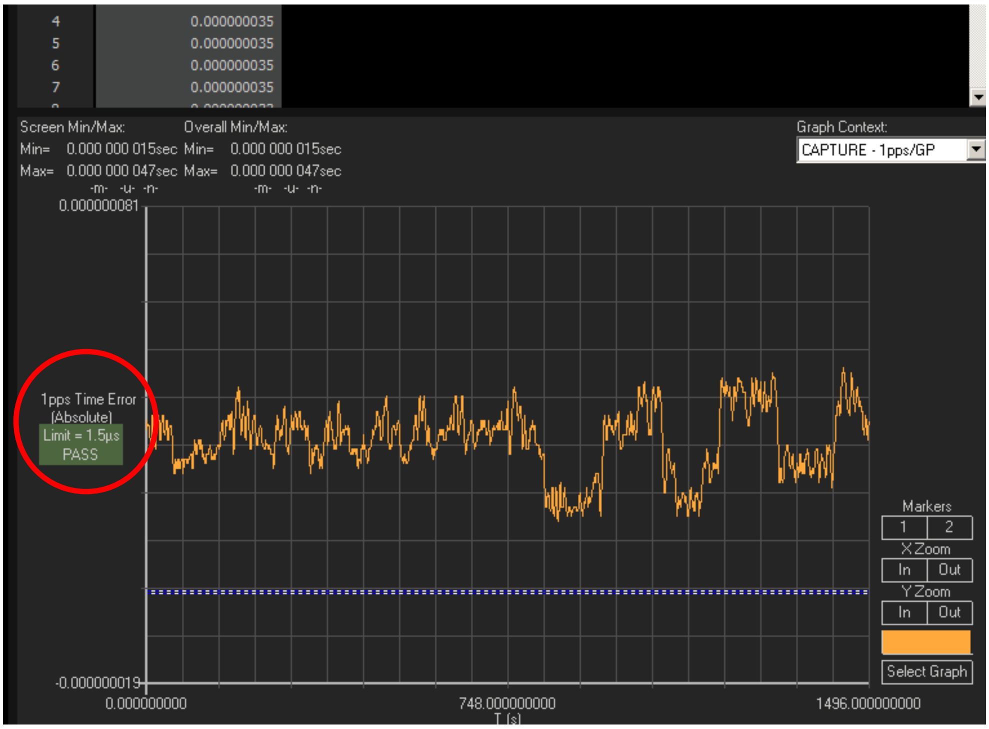
   - Slave Clock Noise Generation (clause G.8363 Clause 6.1):
     - ideal input, output mask in Table1/Figure 2 of G.8263



   - Slave Clock Noise Tolerance (clause 7.1):
     - Input noise defined in clause 8.1.1 of G.8261.1 (FPP of 1% in 150us)
     - Output depends on use case:
       - For a timing a base station: case 3 from G.8261.1/Clause 7.2.2 (Table 1/Figure 4)
       - Output for traffic interface (e.g. timing a CES link): case 2 from G.8261.1/Clause 7.2.2

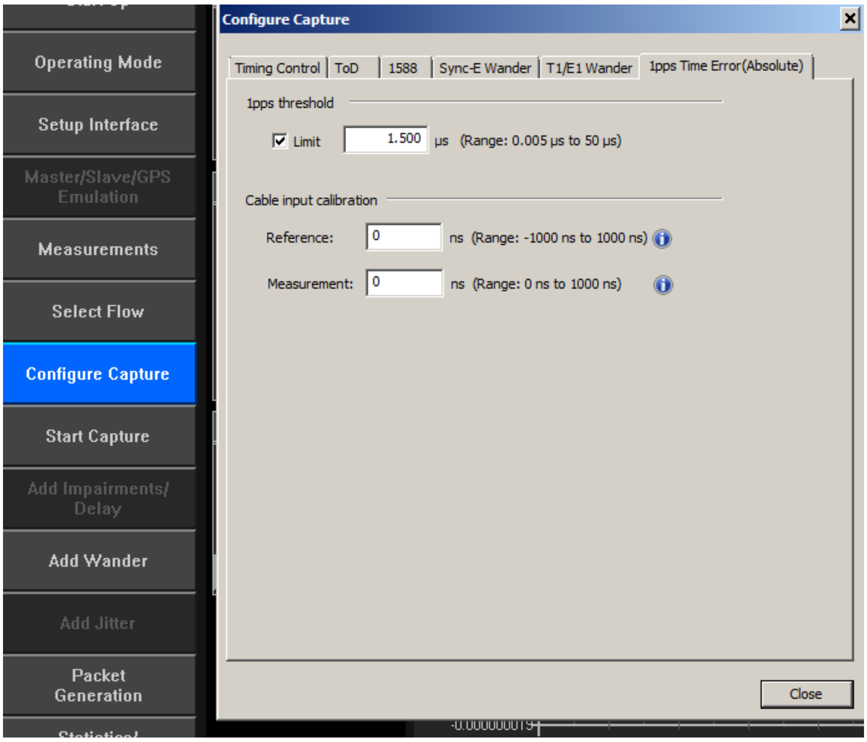
4.9 Measuring the Time/Phase Output of the Slave Clock

1. Select ***Graph Context*** and choose ***CAPTURE - 1pps/GP.***



NOTE: The 1PPS accuracy measurement is made at each 1-second point on the rising edge of the 1PPS reference signal. The result tabulated and graphed at each 1-second interval is the time difference between the rising edge of the measured signal (from the Slave Clock) and the rising edge of the reference signal. In normal conditions, this will be a positive value. However, since it is an absolute measurement, path length differences between measurement signal cabling and reference signal cabling can be significant. Make these cable lengths similar if possible, and if not, allow for the propagation error of approximately 5.1 ns per metre of cable length difference.

2. The 1PPS accuracy result is compared against a limit and PASS/FAIL is displayed in a green or red box on the graph as shown above (circled). Limit checking is enabled and the limit set under **Configure Capture** as shown below.



4.10 Analysis of Failing Test Results

If the Slave Clock output fails the MTIE/TDEV or 1PPS measurements, the next step is to identify the cause of the failure. This can be challenging for G.8261 tests as there may be a number of contributing factors. Some possible factors are listed below. This is not an exhaustive list, and is provided for guidance only:

- **Noise Floor Delay Raised during Peak Traffic** – During periods of high traffic, the noise floor may rise, which can increase the likelihood of test failure.

  (**Adjusting Delay Floor** – It may be possible to adjust the Delay Floor using the Paragon's "PDV Editor" function. Appendix 1 describes the PDV Editor in greater detail.)

- **Check Quality of Clock Oscillator** – The clock oscillator (crystal) should be of at least "carrier-grade" quality
- **Check the Line Rate** – confirm the packet rate configured for the test matches the packet rate of the applied delay profiles: failure to do so will result in a test failure.
- **Algorithm working as expected?** – Check your test parameters and verify correct operation.

Appendix 1: ITU-T G.8261 Test Case Profiles for 1588v2 Testing

Network Traffic Models Used for G.8261

Traffic over mobile networks can never be assumed to operate in a pre-defined mode. According to one mobile network authority, access traffic is composed of conversational (voice), streaming (audio/video), interactive (e.g., http) and background (sms, email). It is known that in wireless networks, 80% to 90% of the traffic is conversational, with the average call lasting from 1 minute to 2 minutes.

Two traffic models have been defined in G.8261, identified as Network Traffic Model 1 and Network Traffic Model 2. A synopsis of each model is provided below:

Network Traffic Model 1

Network Traffic Model 1 assumes 80% of the load should be based on packets of fixed small size constant bit rate, and 20% based on packets with a mix of medium and maximum size. The packet size profile is:

- 80% of the load must be minimum size packets (64 octets)
- 15% of the load must be maximum size packets (1518 octets)
- 5% of the load must be medium size packets (576 octets)

Maximum size packets will occur in bursts lasting between 0.1s and 3s.

Network Traffic Model 2

Bigger packets compared with the Network Traffic Model 1 compose the Network that handles more data traffic. To be able to model this traffic, 60% of the load should be based on packets of maximum size, and 40% on packets with a mix of minimum and medium size. The packet size profile is:

- 60% of the load must be maximum size packets (1518 octets)
- 30% of the load must be minimum size packets (64 octets)
- 10% of the load must be medium size packets (576 octets)

Maximum size packets will occur in bursts lasting between 0.1s and 3s.

> **NOTE:** *The G.8261 Test Case must be started before the measurements on the Slave Clock. There is a stabilisation period allowed in G.8261 (900 seconds or 15 minutes). The Calnex G.8261 Test Case profiles have a stabilisation period of 15 minutes at the beginning, so start the profiles as shown above but only start the performance measurement steps after 15 minutes.*
>
> *15 minutes is a suggested stabilisation period, but some equipment might take longer than this. Individual equipment designers should be able to advise the appropriate settling time. If a greater period is required, profiles can be modified by using the PDV Editor tool as described in Appendix 1.*
>
> *Performance measurement should generally start after the stabilisation period, but exact timings depend on the profile being used. Details are provided for each profile below.*

G.8261 Test Case 12

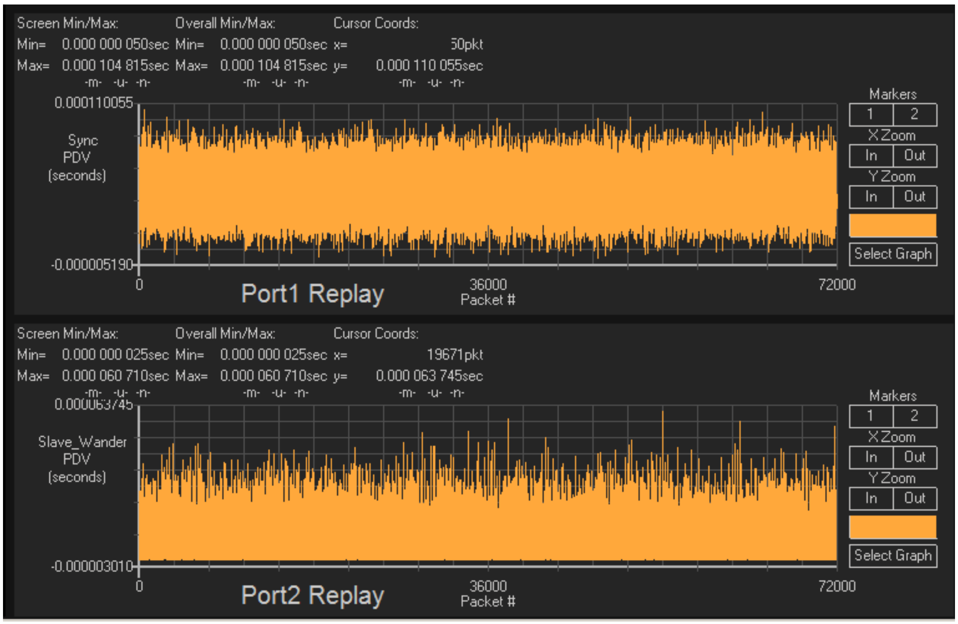
Test case 12 models the "Static" Packet load. Test Case 12 must use the following network conditions:

- Network disturbance load with 80% for the forward direction (Server to Client) and 20% in the reverse direction (Client to Server) for 1 hour.

The test measurements should start after the clock recovery is in a stable condition. Guidance on stabilisation period is provided in Appendix II of G.8261 and should be a minimum of 900s. The disturbance background traffic to load the network must use Network Traffic Model 2 as defined below:

PDV Graphs Test Case 12

The two diagrams below show Sync PDV and Slave Wander PDV respectively:



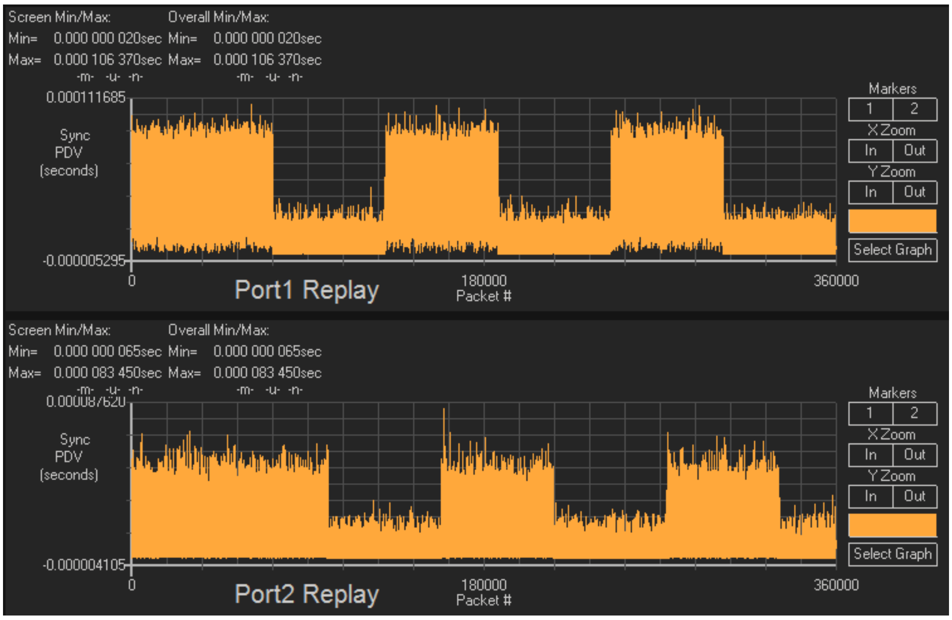
Test Case 12 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period. After this time, start capturing E1/T1 and 1PPS accuracy. These measurements should remain within the specified limits for the duration of the replay, which is 1 hour after initial stabilisation.*

G.8261 Test Case 13a/b

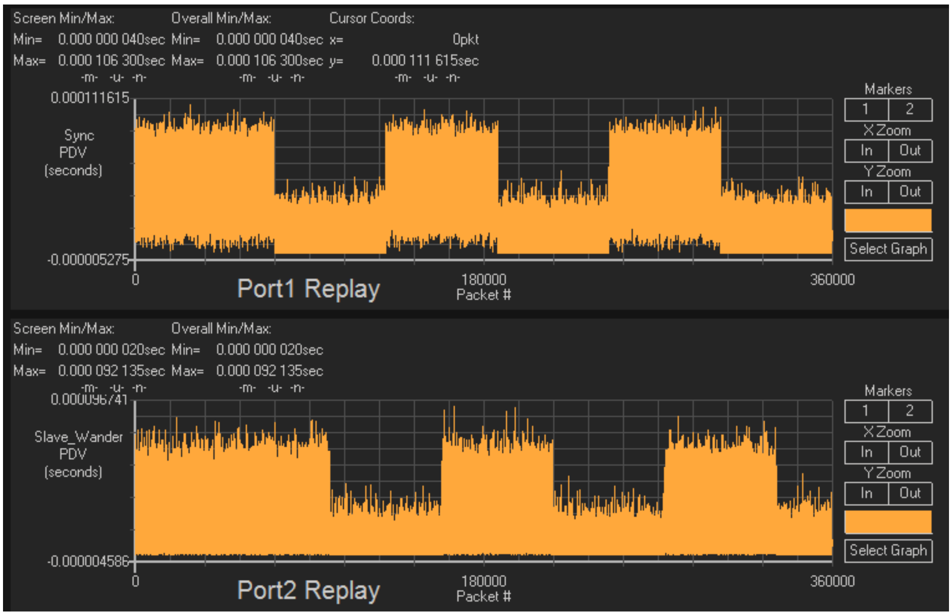
Test Case 13 models sudden large, and persistent changes in the network load. It demonstrates stability on sudden large changes in network conditions, and wander performance in the presence of low frequency PDV. Test Case 13 must use the following network conditions:

- The packets to load the network must use Network Traffic Model 1 (Test Case 13a) as defined in ITU-T G.8261.
- Allow a stabilisation period according to Appendix II for the clock recovery process to stabilise before doing the measurements
- In the **forward** direction: Start with network disturbance load at 80% for 1 hour, drop to 20% for an hour, increase back to 80% for an hour, drop back to 20% for an hour, increase back to 80% for an hour, drop back to 20% for an hour. Simultaneously, in the **reverse** direction: Start with network disturbance load at 50% for 1.5 hours, drop to 10% for an hour, increase back to 50% for an hour, drop back to 10% for an hour, increase back to 50% for an hour, drop back to 10% for 0.5 hour (see Figure VI.11/G.8261). Repeat the test using the Network Traffic Model 2 (Test Case 13b) as defined above to load the network

PDV Graphs Test Case 13a (Network Traffic Model #1)



PDV Graphs Test Case 13b (Network Traffic Model #2)



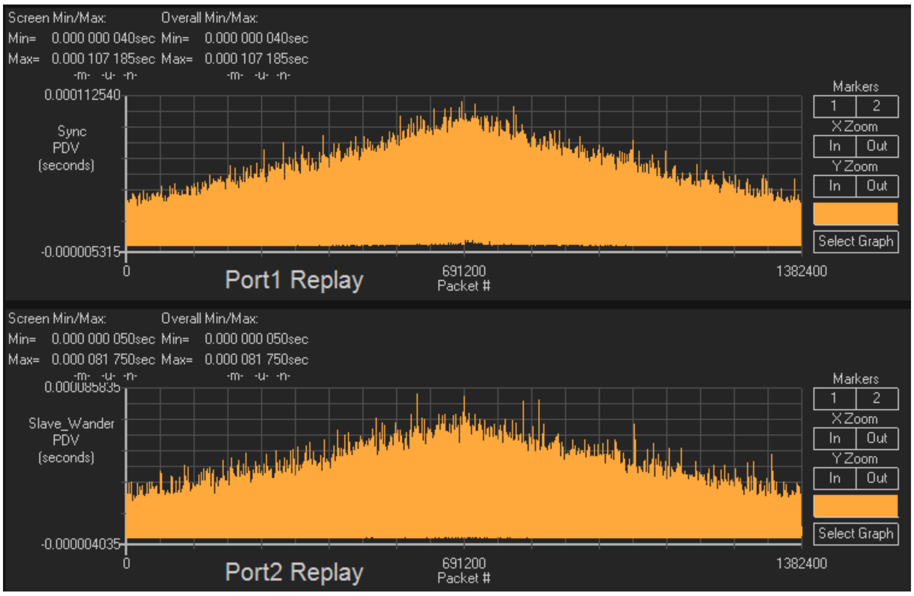
Test Case 13 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period. After this time, start capturing E1/T1 and 1PPS accuracy. These measurements should remain within the specified limits for the duration of the replay, which is 6 hours after initial stabilisation.*

G.8261 Test Case 14a/b

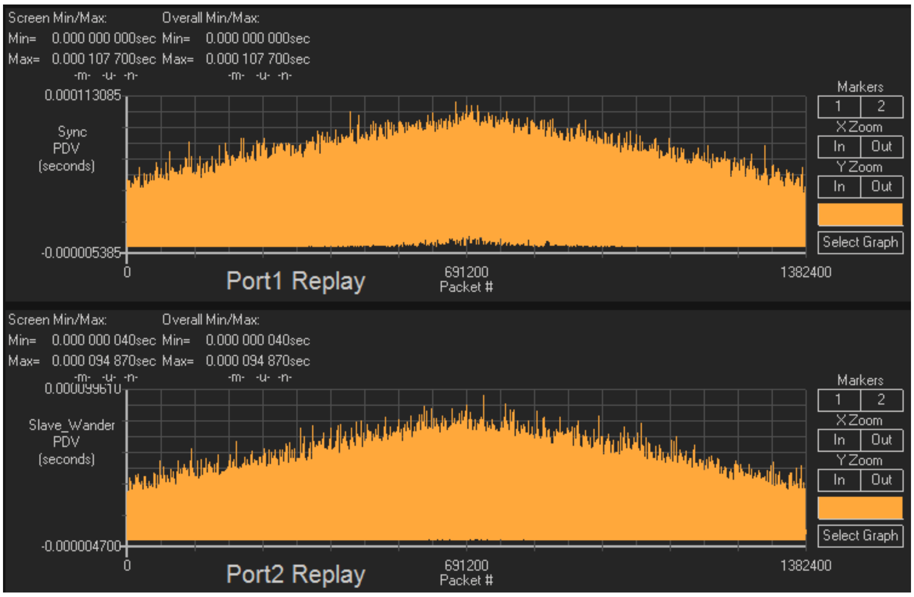
Test case 14 models the slow change in network load over an extremely long timescale (24 hours). It demonstrates stability with very slow changes in network conditions, and wander performance in the presence of extremely low frequency PDV. Test Case 14 must use the following network conditions:

- The packets to load the network must use Network Traffic Model 1 (test case 14a) as defined above.
- Allow a stabilisation period according to Appendix II for the clock recovery process to stabilise before doing the measurements.
- In the forward direction: Vary network disturbance load smoothly from 20% to 80% and back over a 24-hour period. Simultaneously, in the reverse direction: Vary network disturbance load smoothly from 10% to 55% and back over a 24-hour period (see PDV graphs below).

PDV Graphs Test Case 14a (Network Traffic Model #1)



PDV Graphs Test Case 14b (Network Traffic Model #2)



Test Case 14 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period. After this time, start capturing E1/T1 and 1PPS accuracy. These measurements should remain within the specified limits for the duration of the replay, which is 23 hours 45 minutes after initial stabilisation.*

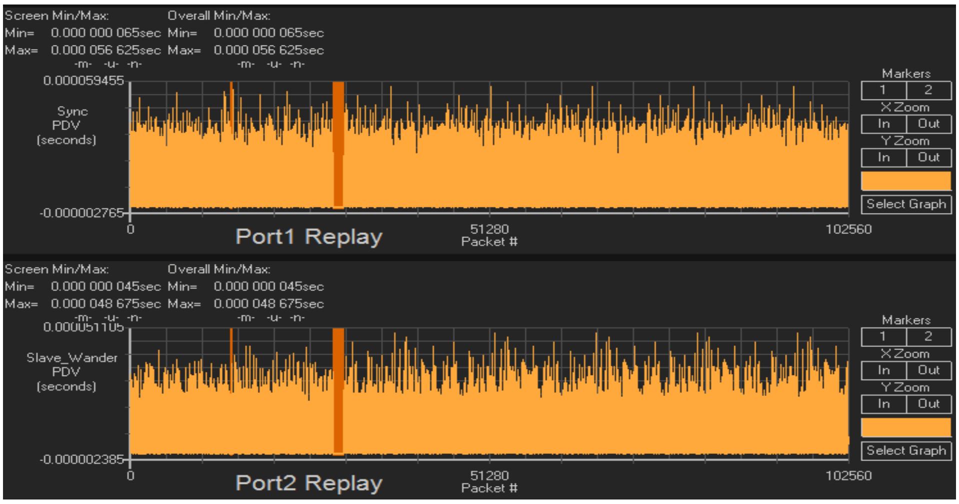
G.8261 Test Case 15a/b

Test case 15 is a test that models temporary network outages and restoration for varying amounts of time within the network. It demonstrates ability to survive network outages and recover on restoration.

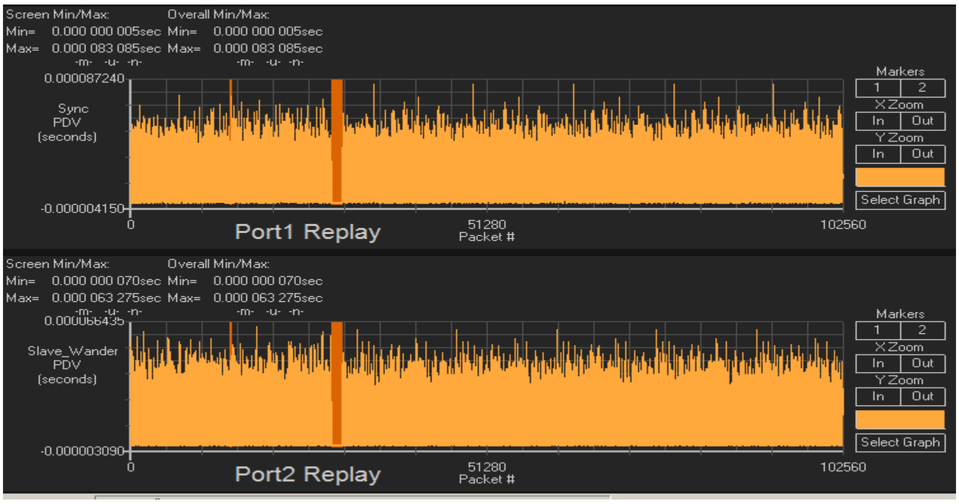
Test Case 15 must use the following network conditions:

- The packets to load the network must use Network Traffic Model 1 as defined in VI.2.1.
- Start with 40% of network disturbance load in the forward direction and 30% load in the reverse direction. After a stabilisation period according to Appendix II, remove network connection for 10s, then restore. Allow a stabilisation period according to Appendix II for the clock recovery process to stabilise. Repeat with network interruptions of 100s.
- Repeat the test using the Network Traffic Model 2 as defined in VI.2.2 to load the network.

PDV Graphs Test Case 15a (Network Traffic Model #1)

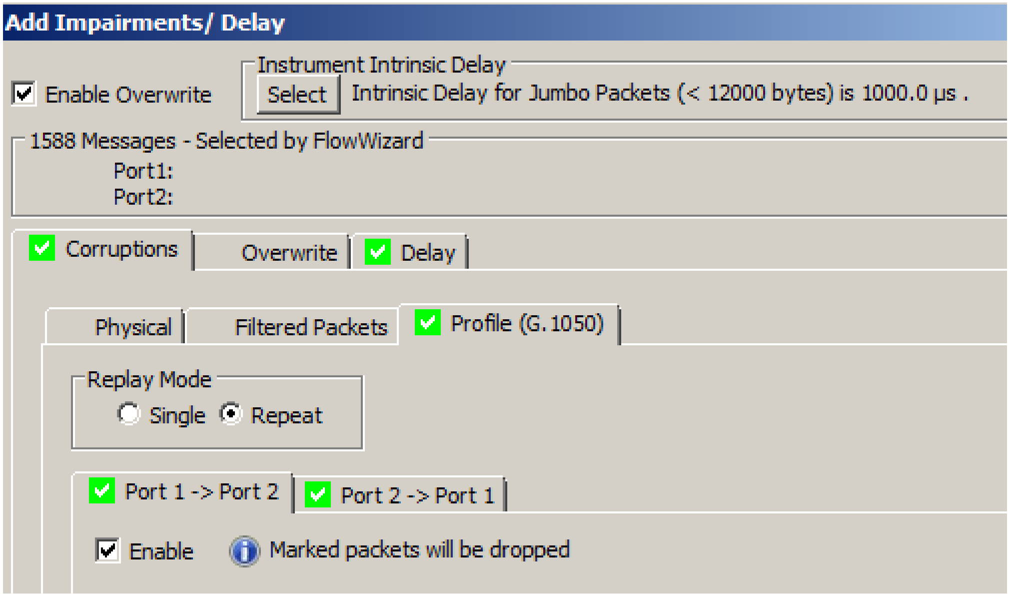


PDV Graphs Test Case 15b (Network Traffic Model #2)



NOTE: *The outage periods are represented by the orange regions of the graph. This indicates that during these periods, packets will be dropped to simulate traffic outage. In order for the packets to be dropped, the G.1050 Corruption function must be enabled.*

Profile (G.1050) enabled on both ports:



Test Case 15 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period, followed by a 10 second outage, a 15 minute recovery period, a further 100second outage and another 15 minute recovery period. After this final recovery period, start capturing E1/T1 and 1PPS accuracy. Continue capture for 1 hour, during which measurements should remain within the specified limits.*

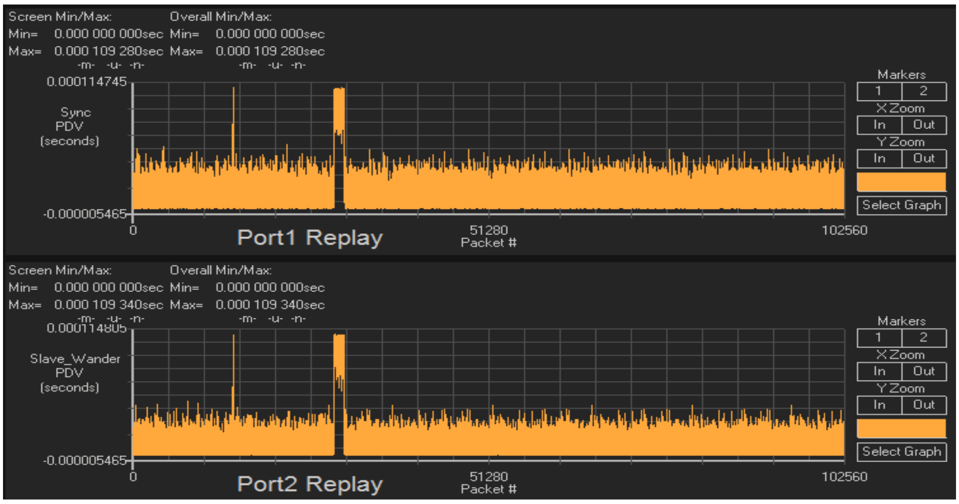
G.8261 Test Case 16a/b

Test case 16 models temporary network congestion and restoration for varying amounts of time, it demonstrates ability to survive temporary congestion in the packet network.

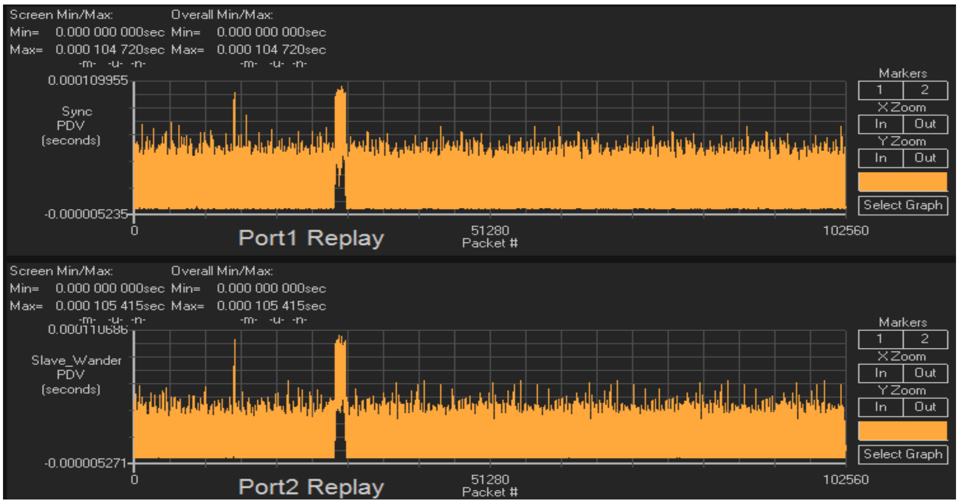
Test Case 16 must use the following network conditions:

- The packets to load the network must use Network Traffic Model 1 as defined in VI.2.1.
- Start with 40% of network disturbance load in the forward direction and 30% load in the reverse direction. After a stabilisation period according to Appendix II, increase network disturbance load to 100% in both directions, inducing severe delays and packet loss for 10s, then restore. Allow a stabilisation period according to Appendix II for the clock recovery process to stabilise. Repeat with a congestion period of 100s.
- Repeat the test using the Network Traffic Model 2 as defined in VI.2.2 to load the network.

PDV Graphs Test Case 16a (Network Traffic Model #1)



PDV Graphs Test Case 16b (Network Traffic Model #2)



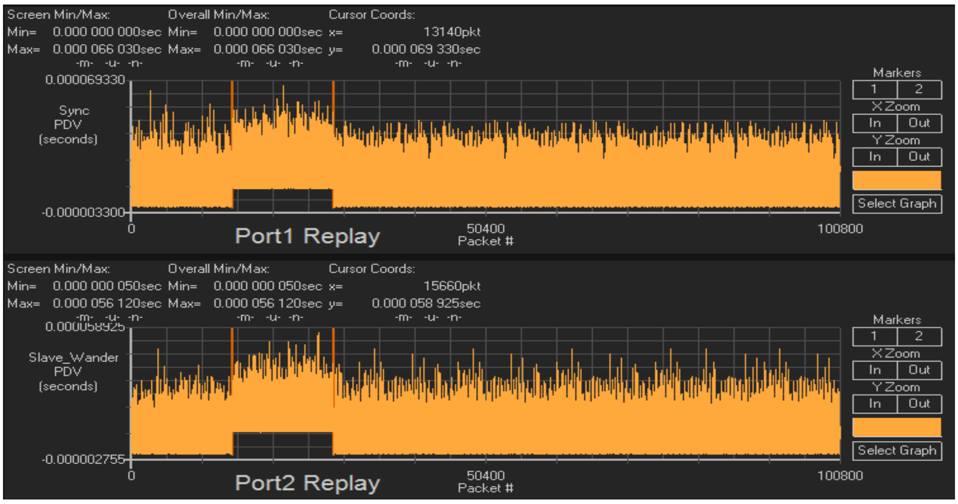
Test Case 16 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period, followed by a 10 second period of congestion, a 15 minute recovery period, a further 100 second period of congestion and another 15 minute recovery period. After this final recovery period, start capturing E1/T1 and 1PPS accuracy. Continue capture for 1 hour, during which measurements should remain within the specified limits.*

G.8261 Test Case 17a/b

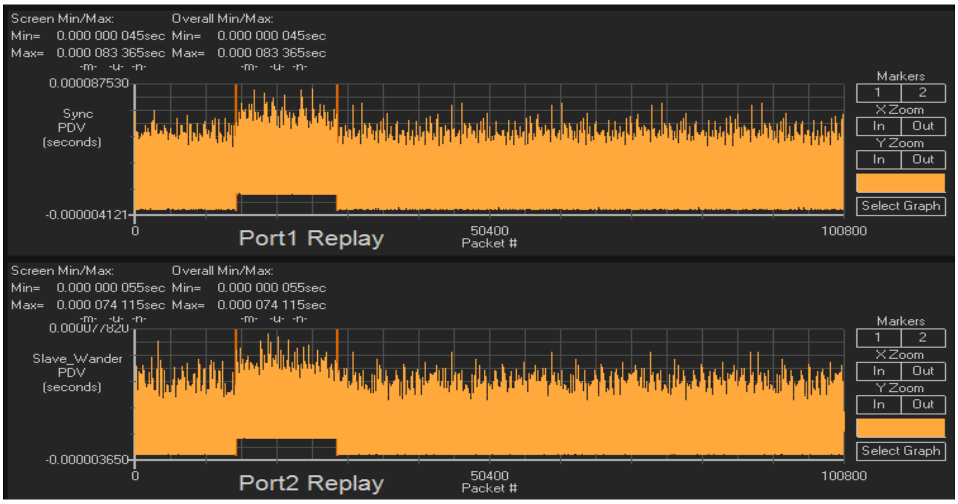
Test case 17 models routing changes caused by failures in the network. The test case must use the following network conditions:

- Change the number of switches between the DUTs, causing a step change in packet network delay.
- The packets to load the network must use Network Traffic Model 1 as defined in VI.2.1.
- Start with 40% of network disturbance load in the **forward** direction and 30% load in the **reverse** direction. After a stabilisation period according to Appendix II, reroute the traffic (in both directions) to bypass one switch in the traffic path. This shall be done by updating the test set up in figure VI.10/G.8261 adding a cable from switch in position “n” to switch in position “n+2” and either using a fibre spool or adding an impairment box able to simulate different cable lengths (10 µs and 200 µs can be simulated as typical examples). The configuration shall be done so that the traffic flow under test is routed directly from switch in position “n” via the new link to switch in position “n+2”. After disconnecting the cable from switch “n” to switch “n+2” (so that traffic under test will then be routed from switch in position “n” to switch in position “n+1”), allow a stabilisation period according to Appendix II for the clock recovery process to stabilise, and then reconnect the link that was disconnected in order to restore the traffic on the original path.
- Start with 40% of network disturbance load in the forward direction and 30% load in the reverse direction. After a stabilisation period according to Appendix II, reroute the traffic to bypass three switches in the traffic path.

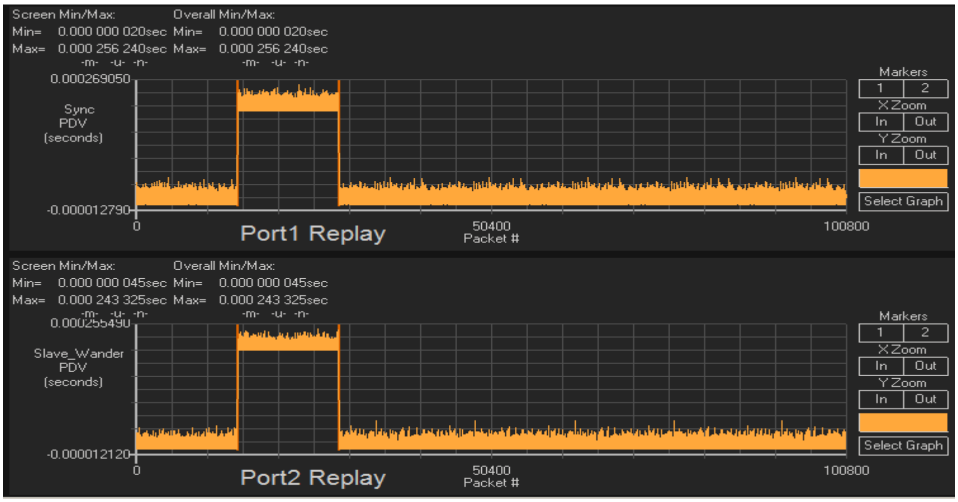
PDV Graphs Test Case 17a (10µS Traffic Model #1)



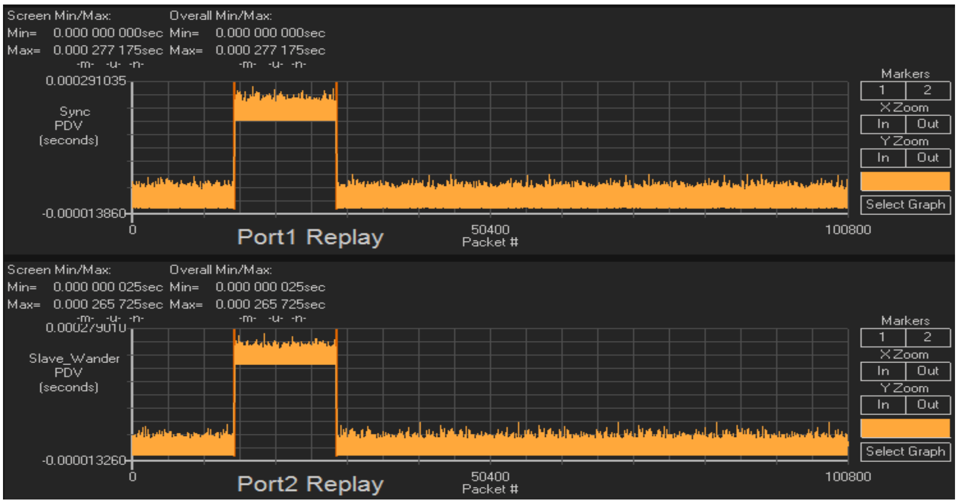
PDV Graphs Test Case 17b (10µS Traffic Model #2)



PDV Graphs Test Case 17a (200µS Traffic Model #1)



PDV Graphs Test Case 17b (200µS Traffic Model #2)



NOTE: *At each step or discontinuity, there is short period when packets are lost. This is represented by the narrow orange regions of the graph. In order for these packets to be dropped, the G.1050 Corruption function must be enabled as for Test Case 15.*

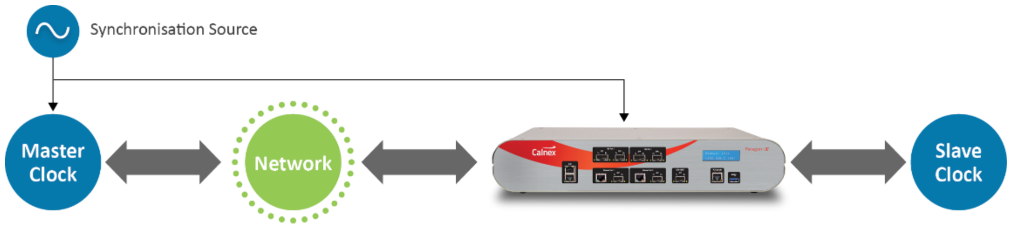
Test Case 17 Performance Evaluation: *The first 15 minutes of the profile is a stabilisation period, followed by a network discontinuity, a 15 minute recovery period, a further network discontinuity and another 15 minute recovery period. After this final recovery period, start capturing E1/T1 and 1PPS accuracy. Continue capture for 1 hour, during which measurements should remain within the specified limits.*

Appendix 2: Capturing and Analysing 1588v2 Messages from a Live Network

Paragon-X can be used to capture 1588v2 packet delay data and Slave Clock output wander/1PPS accuracy from a live network as a troubleshooting tool for problems existing in the network. The network capture can be saved and then analyzed in the lab for troubleshooting purposes. The Paragon-X further allows you to edit the PDV capture, increasing or decreasing the PDV, then replaying that file to narrow in on the fault and determine the performance margin.

Placement of Paragon within the Network for Live Capture

For live network capture the Paragon unit should always be placed next to the Slave Clock as shown below:



Calculating PDV in a 1588v2 Network

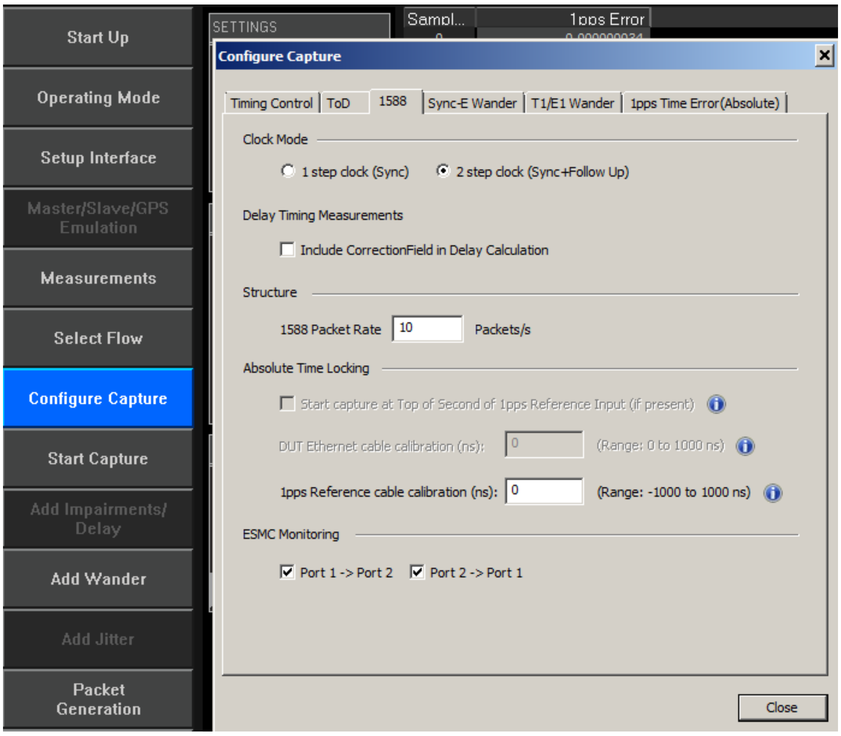
Transmission of IEEE 1588v2 packets may require each node to process a time stamp, which incurs delay. As a result, the number of hops in a network can cause accumulated delay and have a direct impact on the accuracy of time synchronization signals. As a store-and-forwarding mechanism is used in the network, Packet Delay Variation (PDV) may have a significant impact on accuracy. Signal degradation, temperature, and frequency synchronization are other factors that may impact accuracy.

Connect Paragon-X and proceed up to the end of section ***"4.3 Select flows and set filters using Flow Wizard***" above.

Configure Capture: IEEE 1588

If required, the **1588 Settings** window allows additional settings for 1588v2 capture.

1. Click on the ***Configure Capture*** button.



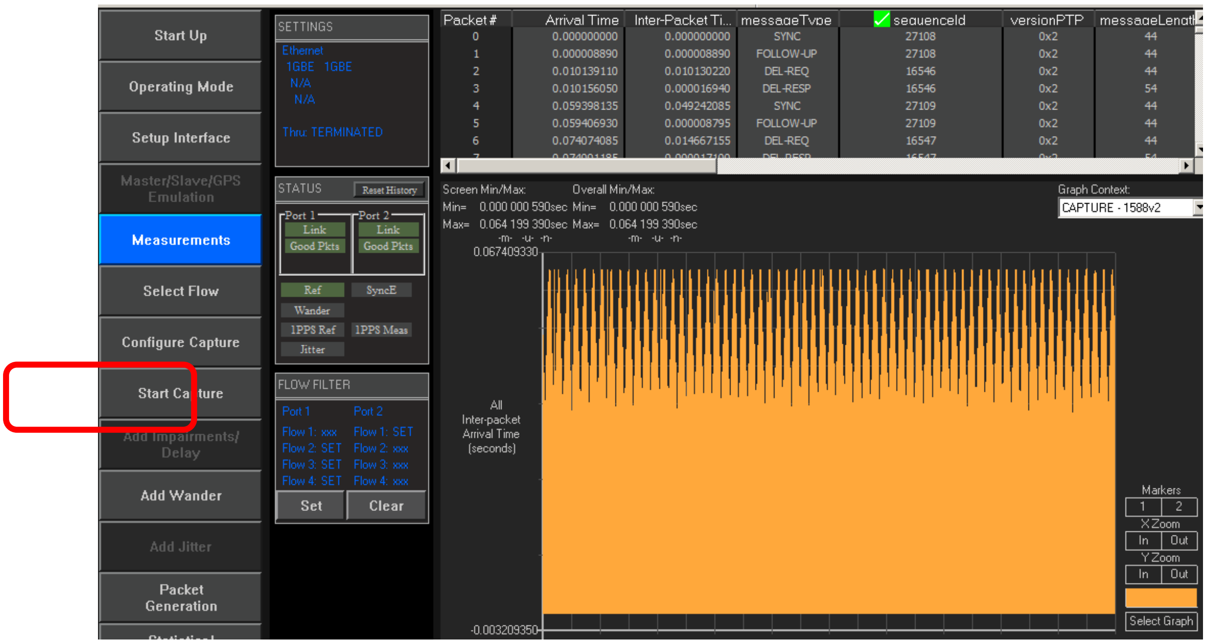
2. Select either ***1 step*** (Sync only) or ***2 step*** (Sync + Follow_Up) clock mode.
3. Tick the box if the ***CorrectionField*** value contained in the Sync message is to be included in the calculation of the captured PDV. This is typically used when testing a 1588v2 Transparent Clock.

4. Enter the 1588 Packet rate – this is used if captured data is exported to Symmetricom TimeMonitor.
5. ESMC Rx Monitoring – the instrument will capture ESMC messages in one direction when in 1588 mode.

Capturing IEEE1588 Header and Timing Information

Once a live capture is started, 1588v2 packets will be displayed in the main body of the Paragon GUI, and a graph will automatically start that defaults to the inter-packet gap for all messages.

1. Click on the ***Start Capture*** button. The Timing Header and directional information for each message will be displayed in the table and the graph will show the inter-packet arrival time. The table continues to update in real-time with the captured bi-directional 1588v2 messages.



2. Click on the ***Stop Capture*** button to stop the capture.
3. By default the Paragon shows all the fields in a 1588 message header. It is possible to reduce the number of fields displayed to those of interest by selecting the **1588 Column sorter** that can be found under **Data** in the top menu.
4. Export the capture, using ***File Export***, as a .cpd or .csv file.

Analyzing the IEEE 1588v2 Capture

Once you have completed a capture of your live network data, the data can be imported, edited and analysed either in the field or in a laboratory environment.

Evaluation of 1588v2 Capture

Paragon-X will measure the PDV captured throughout the network, providing the data required to prove performance in the mobile backhaul network (mobile network requirements are listed in the chart below). Live network capture on Paragon-X can also be saved and brought back to the lab for further analysis and troubleshooting.

Base Station Application	Frequency	Time
CDMA2000	±50 ppb	Goal: <3μs Must Meet: <10μs
GSM	50 ppb	N/A
WCDMA	50 ppb	N/A
TD-SCDMA	50 ppb	3μs inter-cell phase difference
LTE (FDD)	50 ppb	N/A
LTE (TDD)	50 ppb	**3μs inter-cell phase difference
LTE MBMS	50 ppb	**5μs inter-cell phase difference
FemtoCell	250 ppb	N/A
WiMAX (TDD)	2 ppm absolute, ~50 ppb between base stations	Typically 1 – 1.5 μs
Backhaul N/W	16 ppb	N/A

By identifying the cause of the failure, operators and clock manufacturers can re-engineer their network or equipment to prevent similar failures in the future. There are two strategies that operators and network equipment manufacturers can use to re-engineer their equipment to better cope with these network events:

1. Re-calibrate or re-engineer their clock equipment to better cope with the PDV profiles that causes a clock recovery failure.
2. Re-engineer the network such that these catastrophic PDV patterns do not appear again in the network. Operators can do the following depending on the cause of the PDV pattern:
   - Re-route the PTP traffic to a less congested path (forward and reverse direction).
   - Reduce the number of nodes between the Master and Slave by rerouting the PTP traffic (forward and reverse direction).
   - Re-route traffic to ensure forward and reverse paths are more symmetrical if asymmetry is causing the problem.
   - Implement transparent or boundary clocks to reduce PDV seen by the slave.

Using PDV Graphs in Paragon-X

The Paragon offers extensive graphing facilities to analyze the 1588 Master – Slave timing.

1. To access the graphs click on ***Select Graph***. This brings up a menu that allows:

- Graph Display Mode – access to the different graphs for analysis

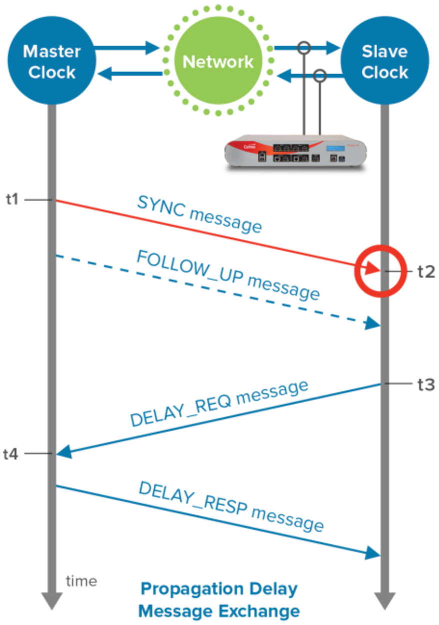
Menu option	Description
PDV Graphs – 1588	• Sync PDV • Slave Wander • Pdelay_Req PDV • Pdelay_Resp PDV • Follow_Up PDV • Delay_Resp RTD • Delay_Req PDV • Round Trip PDV
Inter-packet Arrival Time vs Time	Displays the Inter-packet arrival time for a specific message against time. • Sync • Delay_Req • Pdelay_Req • Pdelay_Resp • Follow_Up • Delay_Resp
Inter-packet Arrival Time vs Packet #	Displays the Inter-packet arrival time against packet number.

- Auto-graph refresh – the graph refreshes approximately every 10 seconds
- Graph Format – Chose between line or dot graph format
- Show 2nd Graph – A second graph is displayed of the same data
- Lock Graphs – If second graph is selected above locks x axis zoom position.
- Open in New Window – Graph is opened in a new window

A description of each graph with examples is provided on the following pages. Note that all PDV graphs show the *variation between values* and not absolute values.

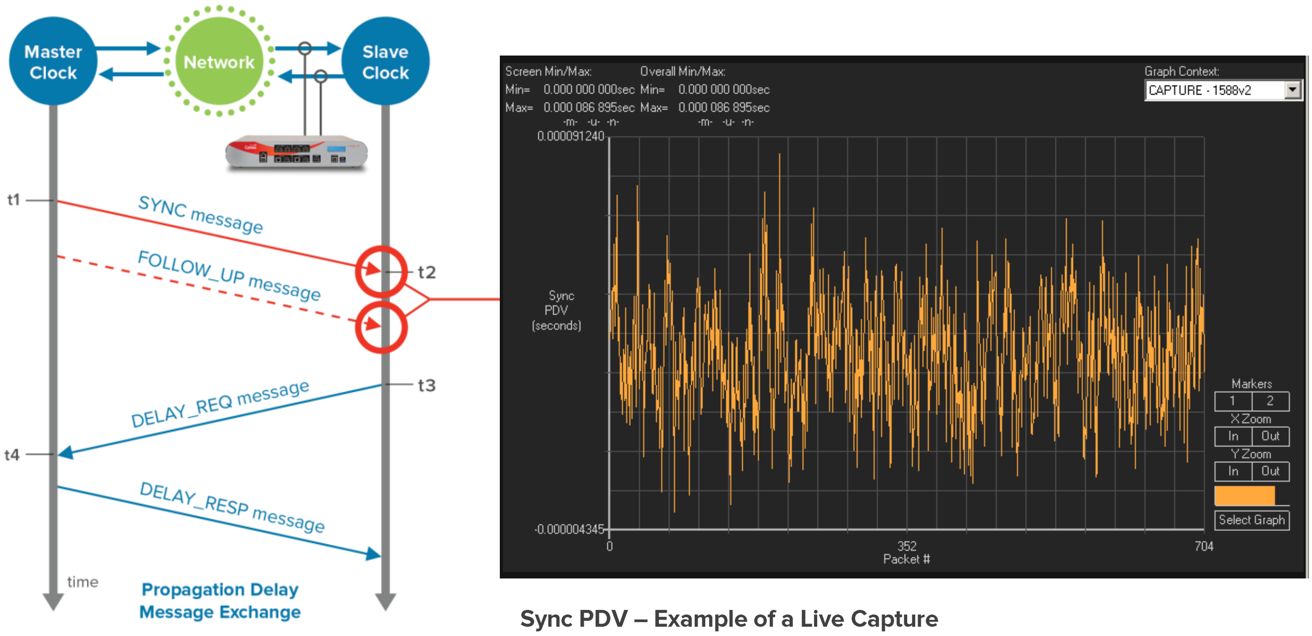
Sync PDV (1 step)

The Paragon uses the arrival time of the Sync message at the Paragon and the timestamp from the Sync message to calculate Sync PDV.



Sync PDV (2 step)

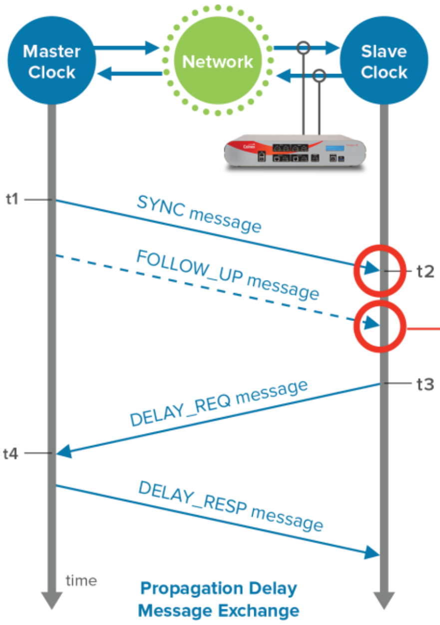
The Paragon uses the arrival time of the Sync message at the Paragon and the timestamp from the Follow-Up message to calculate Sync PDV (see PacketSync Settings Specific to 1588v2 to select 1-step or 2-step). The correction field from a transparent clock can be used in the calculation.

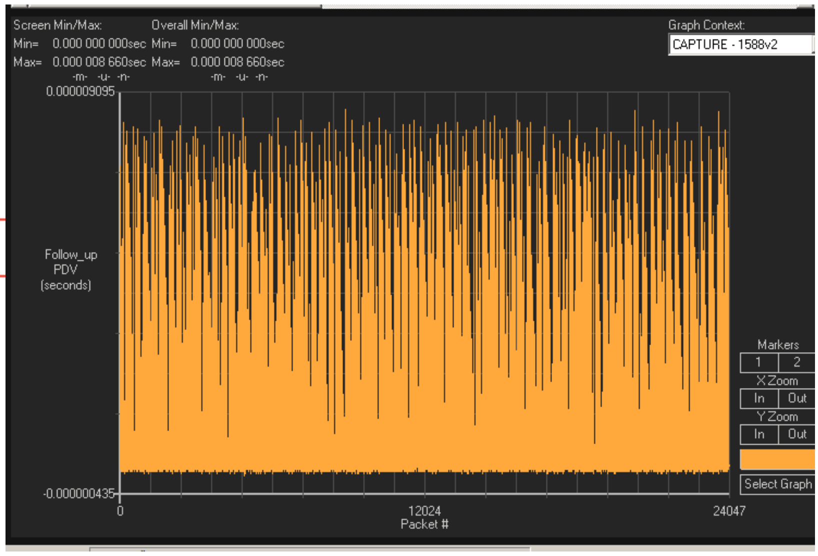


Sync PDV – Example of a Live Capture

Follow_Up PDV

The Paragon graphs the variation in arrival time of the Follow_Up message with respect to the Sync message as shown below:

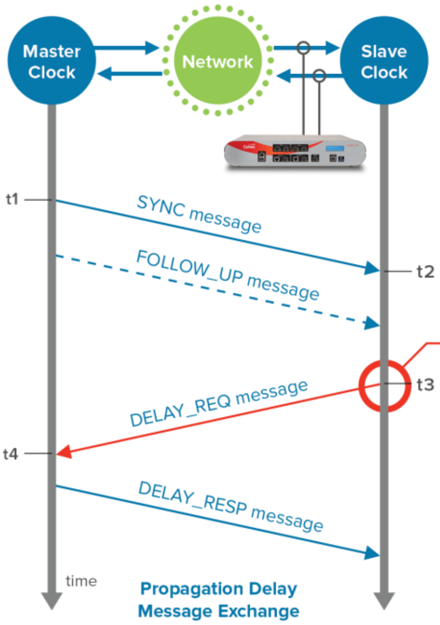


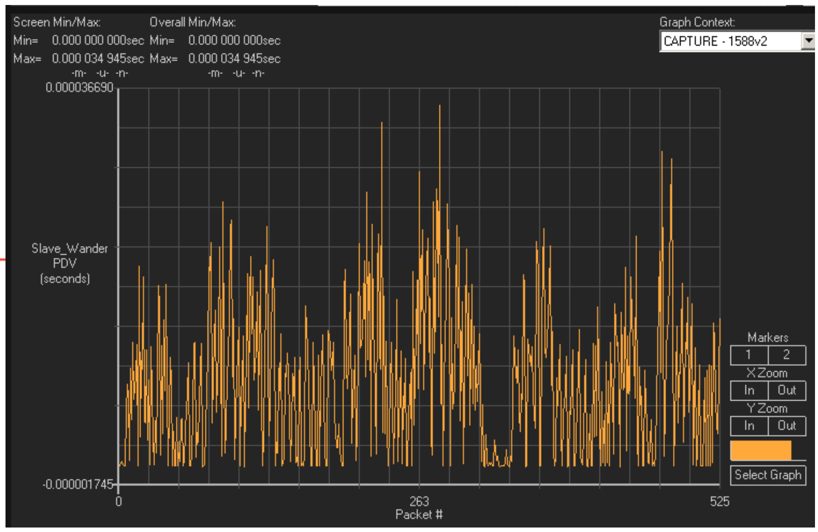


Follow_Up PDV – Example of a Live Capture

Slave Wander

The Paragon extracts the embedded timestamp within the Delay_Req message and compares it to the Master Reference, the variation is then graphed to provide the Slave Wander output as shown below:

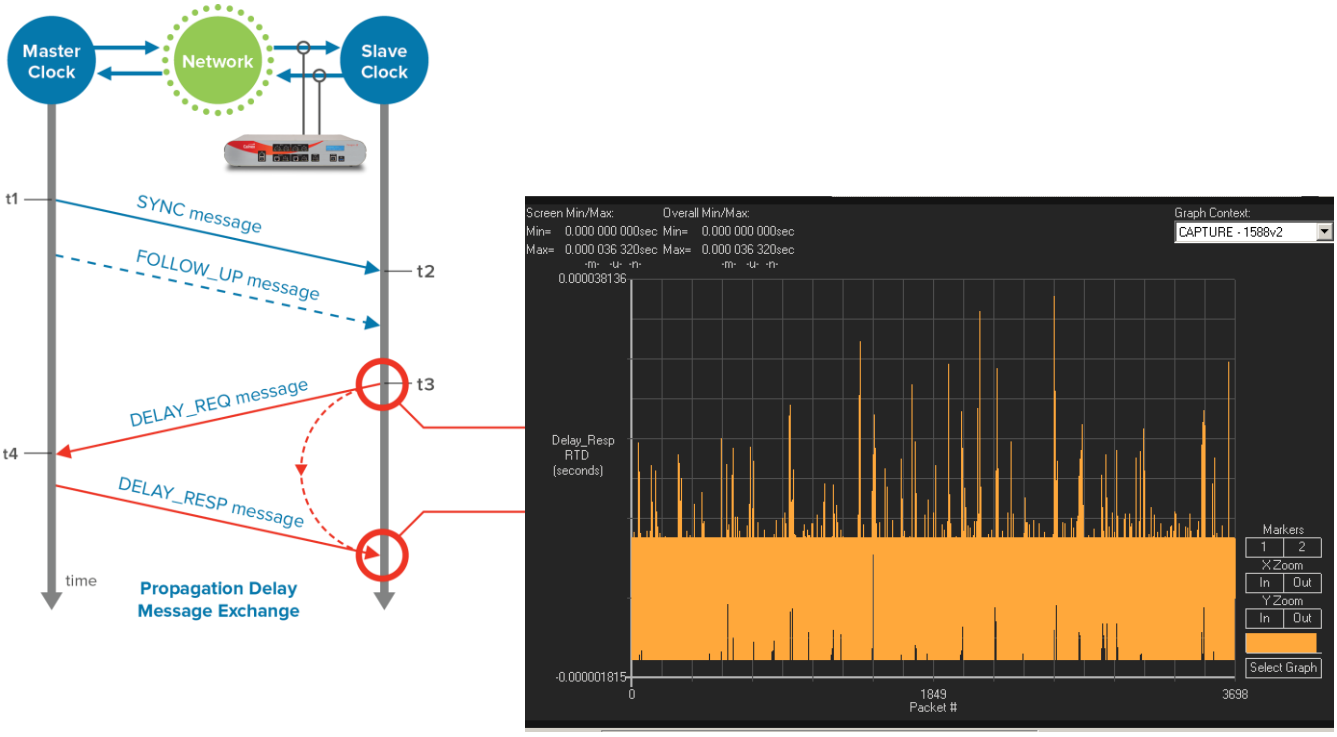




Slave Wander – Example of a Live Capture

Delay_Resp Round Trip Delay (RTD)

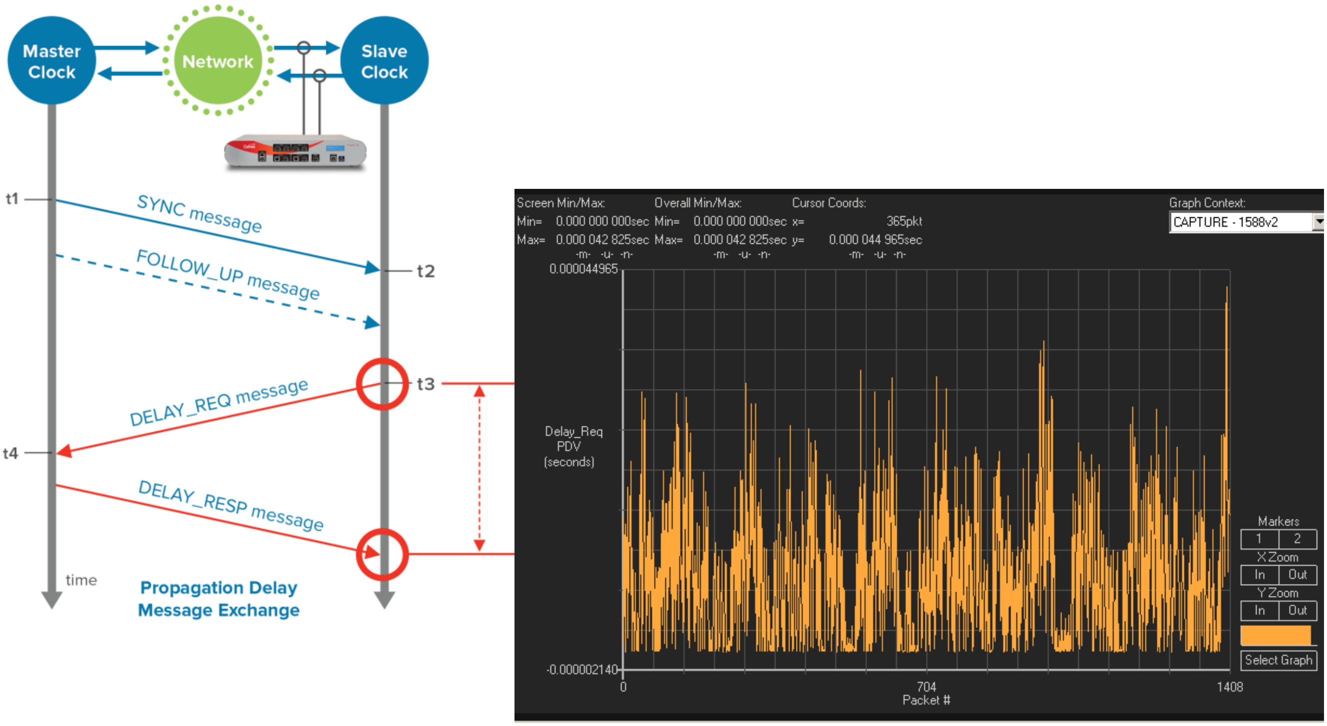
The Paragon calculates and graphs the time difference between the arrival time of the Delay_Req message and the corresponding Delay_Resp message as shown below:



Delay_Resp Round Trip Delay (RTD) – Example of a Live Capture

Delay_Req PDV

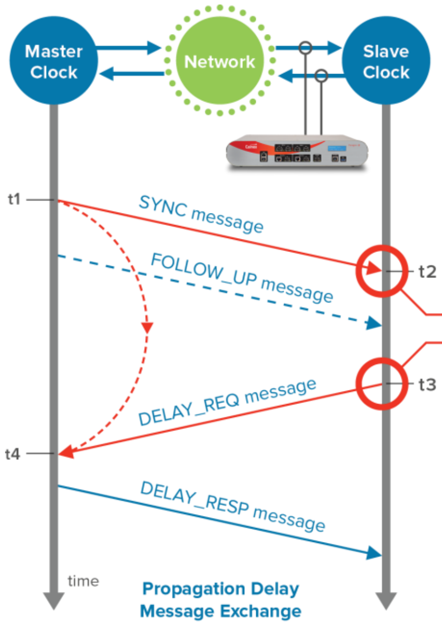
The Paragon graphs the variation between the launch time (arrival time at the Paragon) of the Delay_Req message and the embedded timestamp, t4, in the Delay_Resp message as shown below:

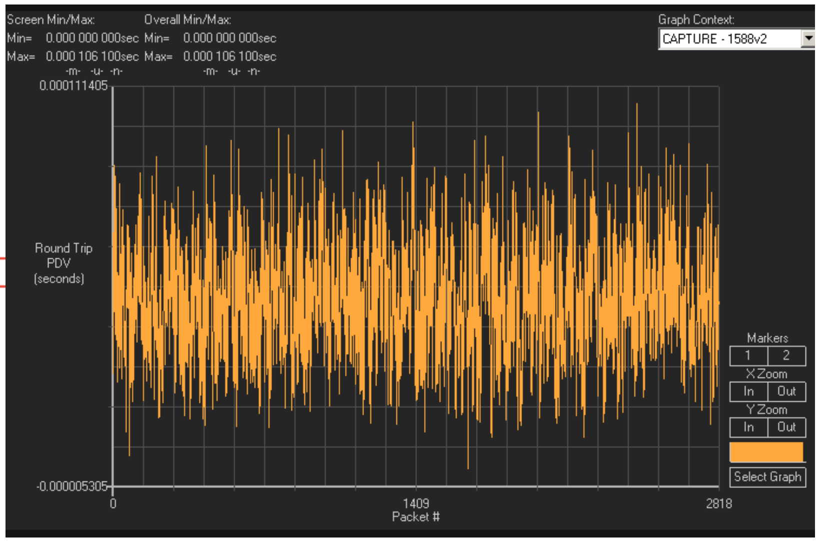


Delay_Req PDV – Example of a Live Capture

Round Trip Delay

The Paragon graphs the variation in (t2 – t1) + (t4 – t3) Round Trip Delay i.e. the calculation performed by the Slave as shown below:

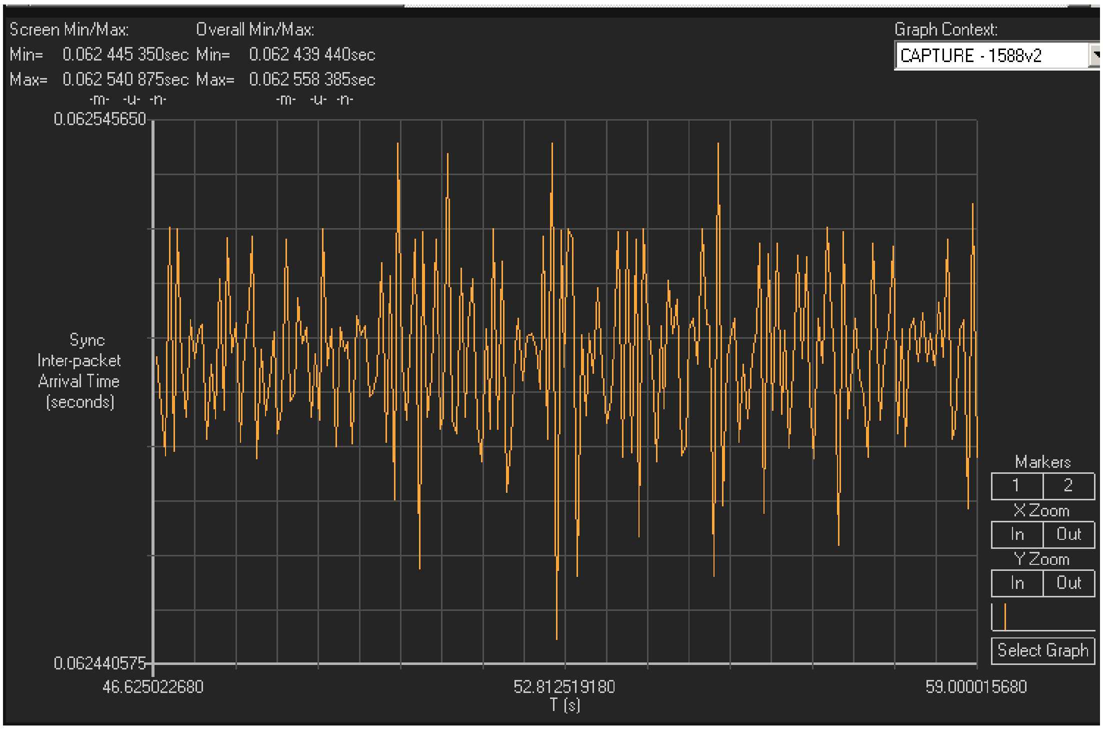




Round Trip Delay – Example of a Live Capture

Description of Inter-packet Arrival Time vs Time Graphs

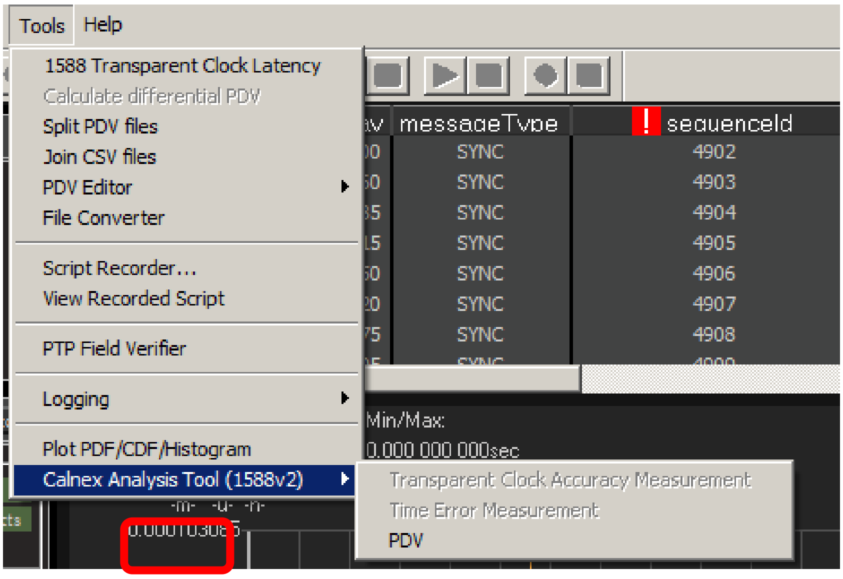
For each of the 1588 messages it is possible to graph the Inter-packet arrival time versus time. This will allow you to have enhanced visibility of the 1588 network by determining if the messages are arriving at regular intervals and/or if they are being delayed by the network, Master Clock or Slave Clock.



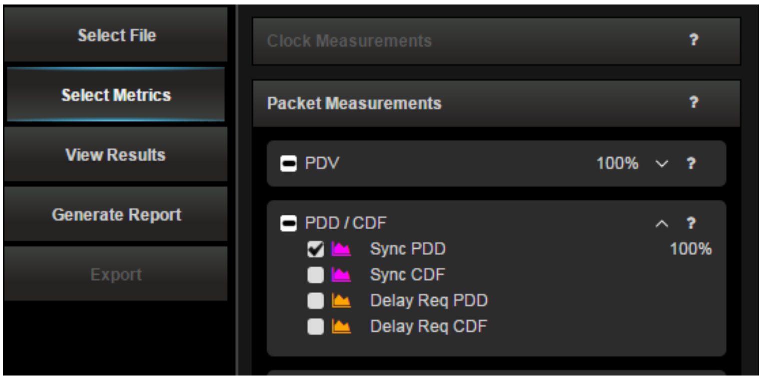
Paragon Packet Distribution Charts

The packet distribution function allows the analysis of a delay data set from a capture to be analysed and presented graphically as a Probability Density Function. The data to be analysed must be present in the GUI of the instrument either from a capture or from loading in a previous capture of profile. The tool is accessed in the following manner:

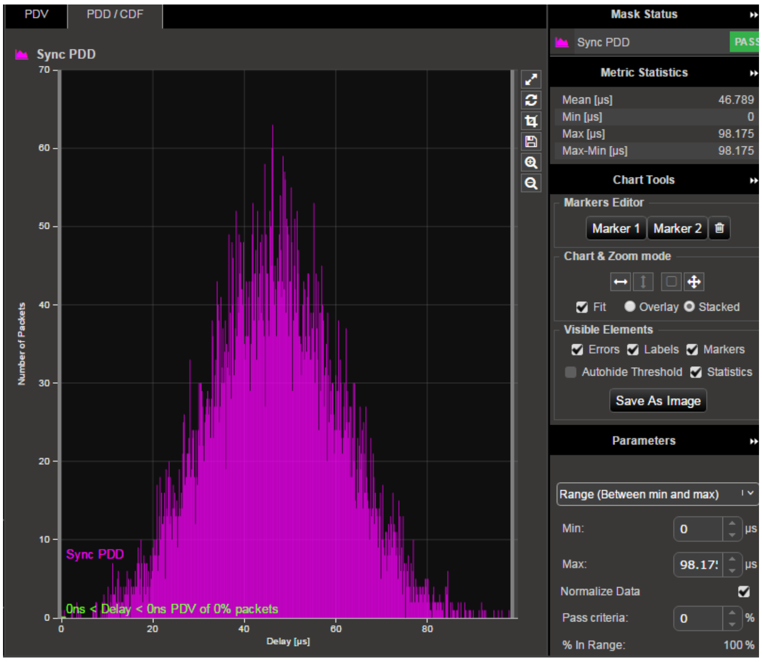
1. Once a capture has been loaded select the ***Graph*** menu item from the Paragon main menu.
2. From the **Tools** dropdown, select ***Calnex Analysis Tool (1588v2)*** > ***PDV***.



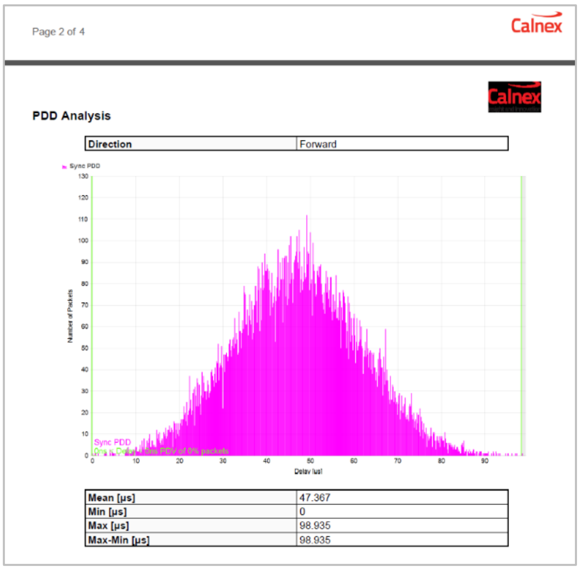
3. This launches the CAT. Select the ***Sync PDD*** metric.



4. Click on the ***View Results*** button to display the metric. This will provide a Pass/Fail indication based on the limits set.



5. A record of the result can be obtained using the ***Generate Report*** button. This will produce a PDF report file which will contain the PDD analysis data.


Page 2 of 4

Calnex

PDD Analysis

Direction	Forward

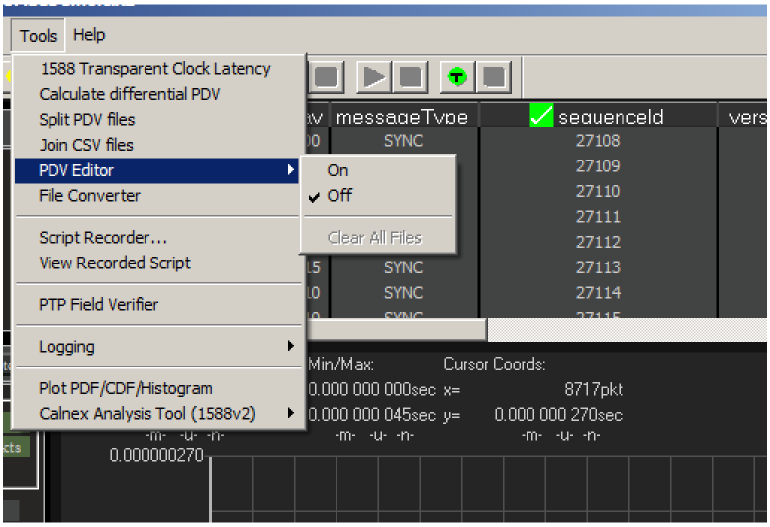
Mean [µs]	47.367
Min [µs]	0
Max [µs]	98.935
Max-Min [µs]	98.935

Appendix 3: Using the PDV Editor

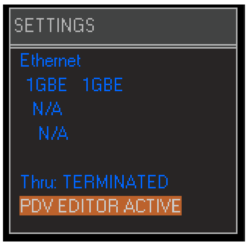
This feature allows captured timing profiles to be manipulated in a number of ways. It is intended to aid experimentation to establish limits of operation and margin testing, and to allow network events to be combined to produce a composite profile which will speed up testing. The tool operates on all profiles captured by Paragon when in IEEE 1588 or Services modes of operation, and the supplied G.8261 test case profiles.

The G8261 Test case 13b profile is used as an example in the rest of this Appendix.

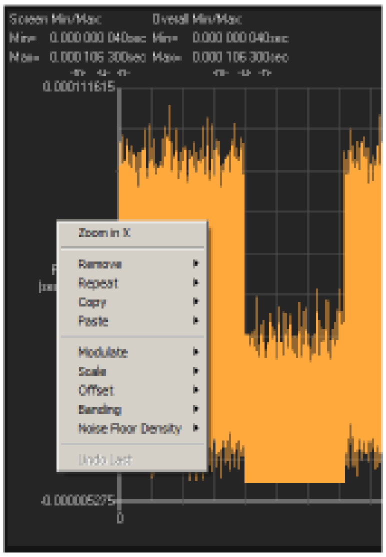
1. Disconnect the Paragon-X GUI from the instrument.
2. Click on ***File*** and ***Import*** from the menu bar to import a .cpd file to edit.
3. From the **Tools** dropdown, select ***PDV Editor*** > ***On***.



When the profile editing mode is enabled, the **SETTINGS** status section on the GUI will show:



4. Edit the profile by placing the cursor on the graph display and pressing the left mouse button. This will display the menu shown below.

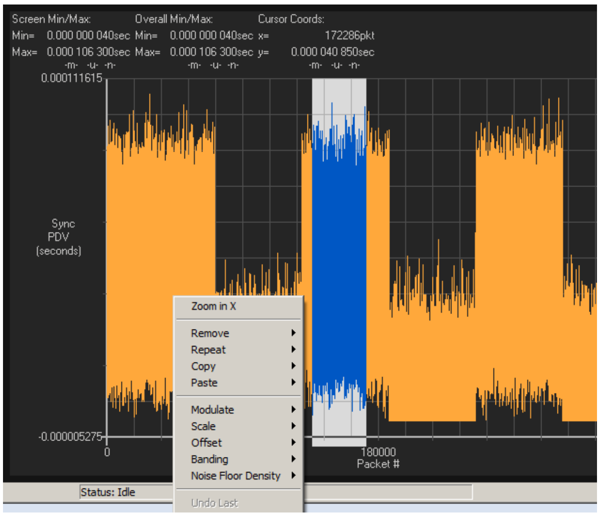


5. The editing functions that can be carried out from this menu are:

a. **Remove** – allows part of the timing profile to be cut out and disposed of or to retain part of the profile and dispose of the rest. One use of this feature is to extract a short part of the profile to allow it to be replayed to determine if it is a stressful section of a replay which causes a Slave Clock failure.

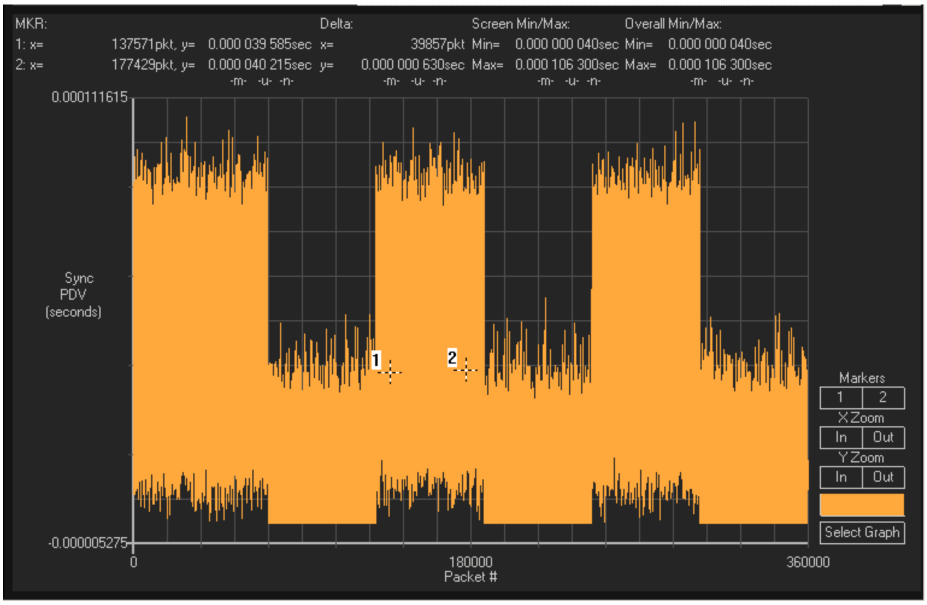
There are two methods of delimiting the section of interest.

The first is to use the mouse. Place the cursor at the start of the section of interest then left button down and drag the mouse to the end of the section of interest. This will highlight the area.

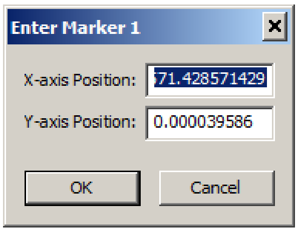


The second way is to use markers. These are set using the **Markers** buttons shown on the screen below.

There are two methods of placing the markers; using the mouse and using the location. In each case both markers should be set. These are marked on the graph as 1 and 2 as shown below.



To use the mouse, click the **Markers** button **1** or **2** and a menu will appear. Select ***Set Marker*** using the mouse then place the cursor at the desired position and left click. The marker will appear as shown in the previous screen shot.



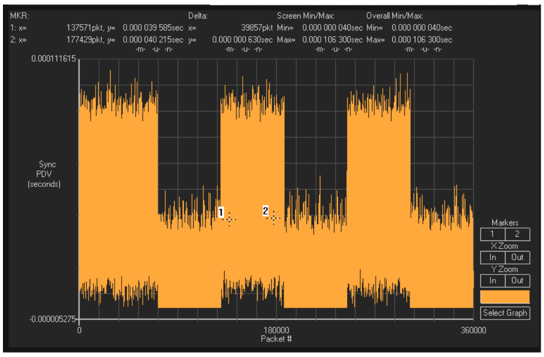
To use the location, click the **Markers** button ***1*** or ***2*** and a menu will appear. Select ***Enter Marker*** manually. A pop-up window will appear as shown opposite. The parameters can then be entered.

Once the area of interest is selected the left mouse should be clicked and then ***Remove*** either the ***Marked*** or ***Non-Marked*** area.

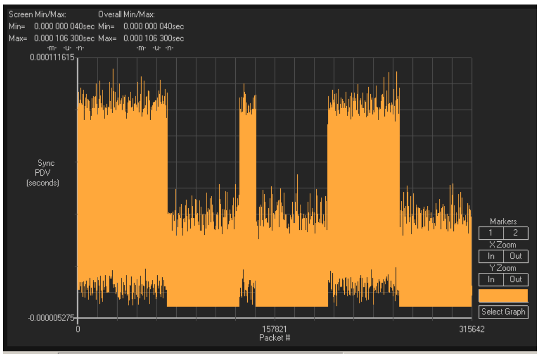
If **Marked** is selected then only the area highlighted is removed and the rest of the profile retained.

If **Non-Marked** is selected then only the highlighted section is retained with the rest being removed of and the rest is kept.

Example of highlighted area deleted from original



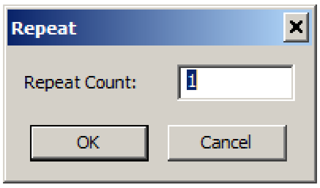
Original Profile



Edited Profile – with section removed

b. Repeat – allows a section of a profile to be be repeated a controlled number of times. The whole profile may be repeated or a section repeated within the overall profile.

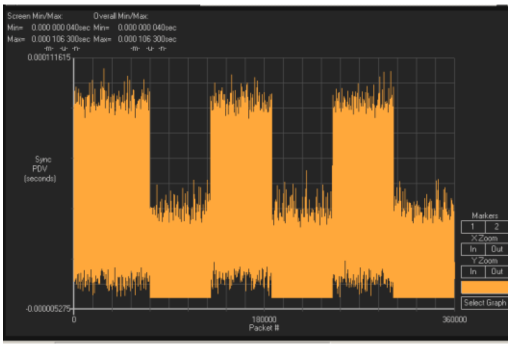
There are 3 sub-selections:



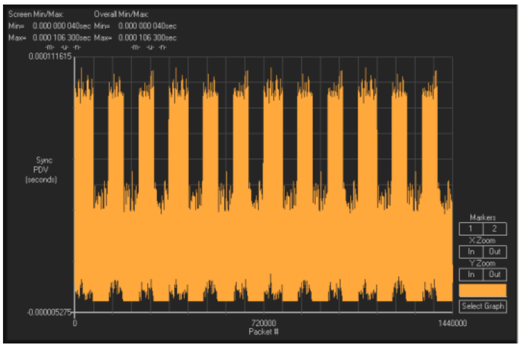
All where the overall profile is repeated the selected number of times. When the All selection is made the pop-up screen opposite is displayed to allow the repeat number to be set.

The range of the repeat number is 1 to 9.

As an example, the following profile will have three additional repeats inserted as shown in the second screen shot.



Original Profile



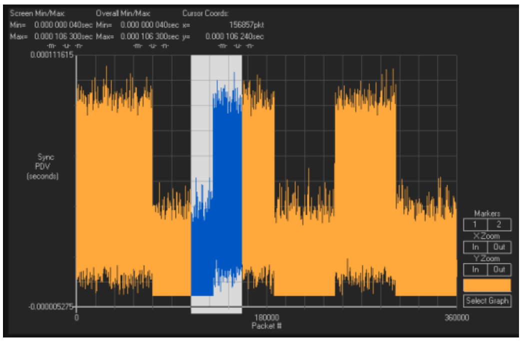
Edited Profile – with repeat count of three

The other two sub-selections allow parts of the profile to be repeated within the overall capture.

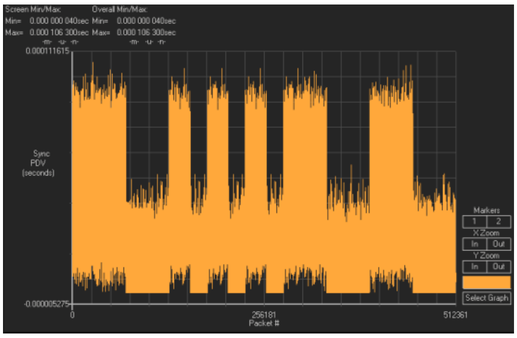
The selections allow the marking of the sections to be performed either using the mouse or using markers as introduced in the **Remove** section.

The following illustrates the repeating of partial profile three times.

Original profile with section highlighted using the mouse click and drag.



Original Profile



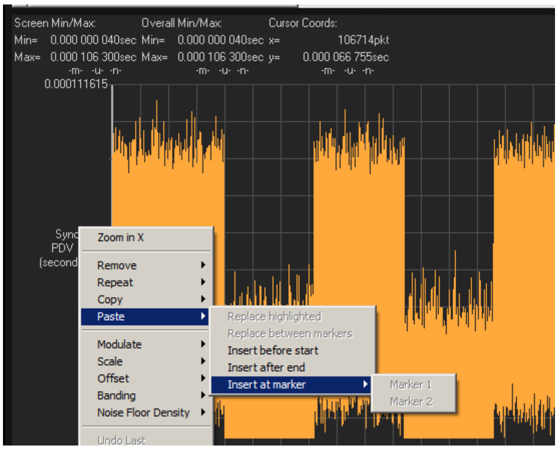
After repeating three times

c. Copy and Paste – allow parts of the profile to be copied then inserted into a later part of the profile.

The modes for Copy are:

- **All** where the whole profile is copied
- **Highlighted** where the section identified by using the mouse click and drag is copied
- **Marked** where the two markers identify the section to be copied

The modes for Paste are shown below.



- **Replace highlighted** allows the data in the copy buffer to replace the highlighted area.
- **Replace between markers** allows the data in the copy buffer to replace the data between the two markers. Operation of the markers is explained in the **Remove** section.
- **Insert before start** inserts the data in the copy buffer before the start of the data.
- **Insert after end** inserts the data in the copy buffer after the end of the currently loaded data.
- **Insert at marker** inserts the data in the copy buffer at the point marked by the appropriate marker. Operation of the markers is explained in the **Remove** section.

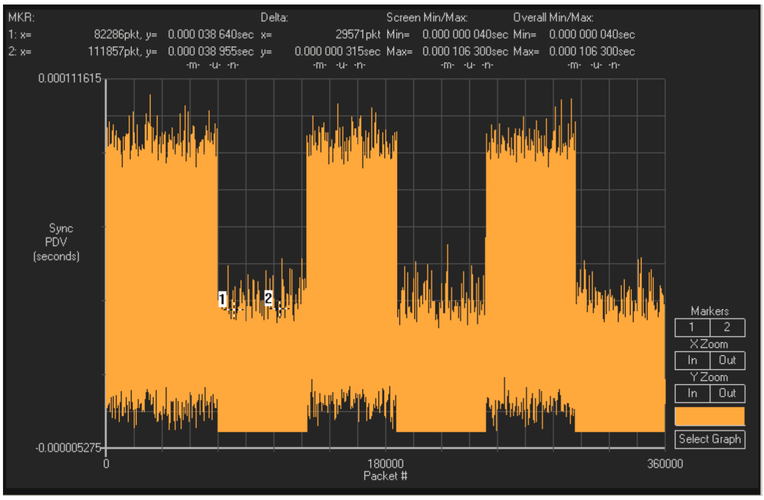
d. Modulate – allows sections of the data (graph) to be edited by adding a:

- Step in amplitude
- Sawtooth increase in the values
- Triangle increase in the values

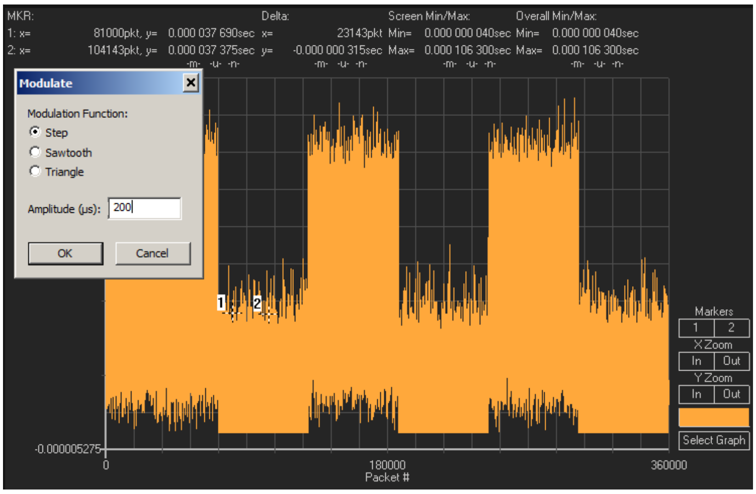
The range over which this change is applied is selectable as **All**, **Highlighted** or **Marked**. These are set as described in the **Remove** section.

As an illustration, the following shows how to apply a step offset to part of a profile.

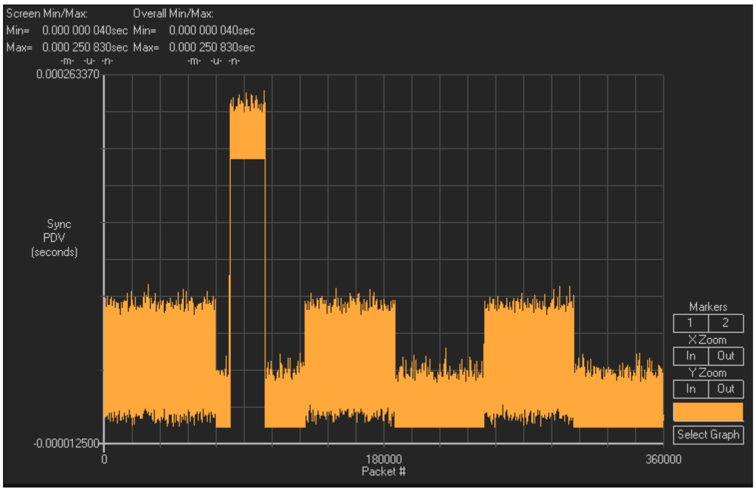
Original profile with section selected using markers.



Add step of 200 microseconds to this section.

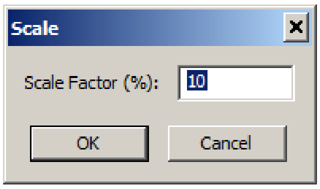


The resultant profile with the 200 microsecond step.



The range of the Modulation Amplitude is 0.1 microseconds to 1 second.

e. **Scale** – allows you to increase or decrease the PDV.

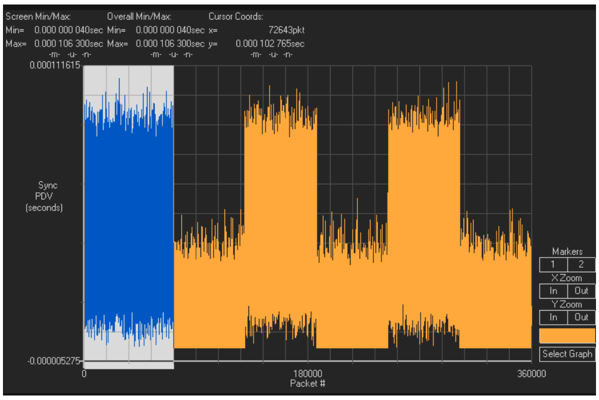


Again, the packets to be impacted are selected from **All**, **Highlighted** or **Marker**. The level of the scaling is set on the pop-up screen shown opposite.

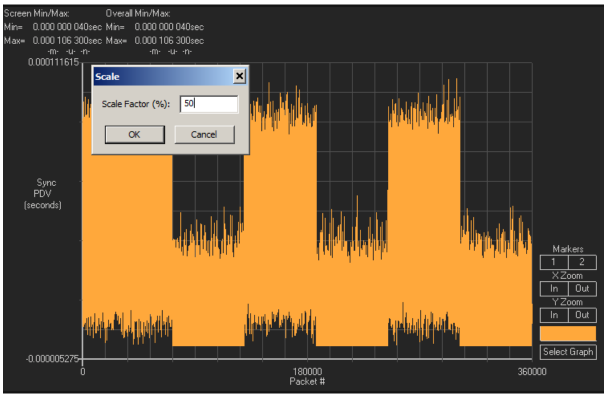
The range of the scaling is 10 – 1000%

As an example, the following will have the first part of the profile scaled to 50% of its original value.

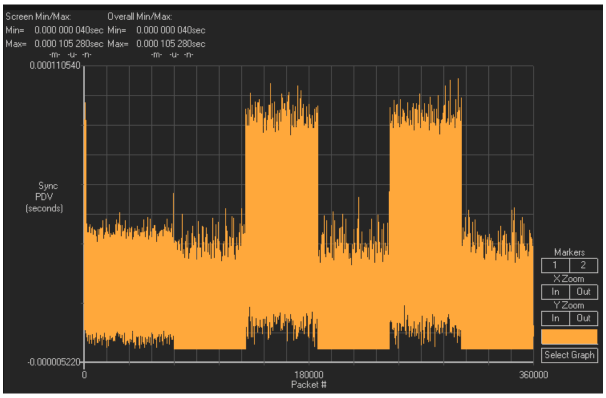
Initial profile with the highlighted section.



With the scale factor set.



The final result is shown below.

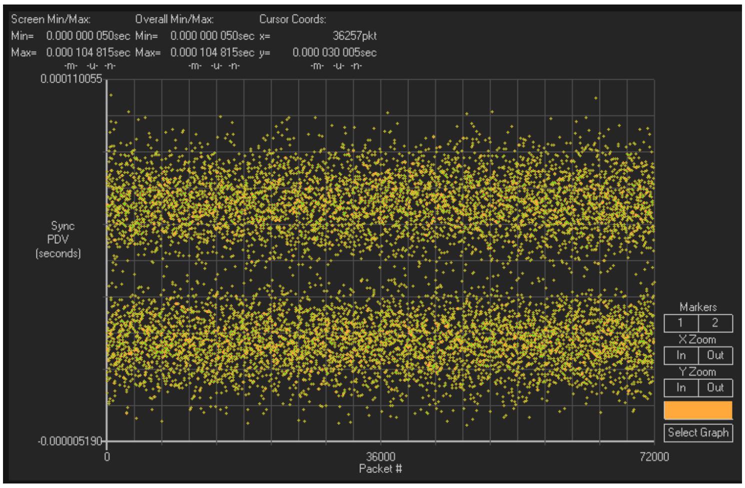


f. Banding – allows the packet timings to be gathered into bands or excluded from a band of timing.

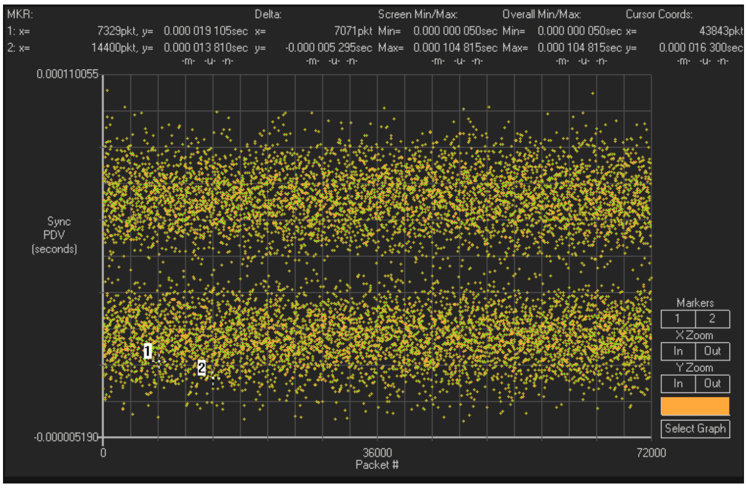
For a clearer view of the data it is recommended that the graph be viewed in scatter graph mode rather than line mode.

The scatter graph mode is selected using the ***Select Graph*** > ***Graph Format*** > ***Dot*** controls located at the right hand side of the graph display.

The scatter graph display for Testcase 12a 16pps is shown below.

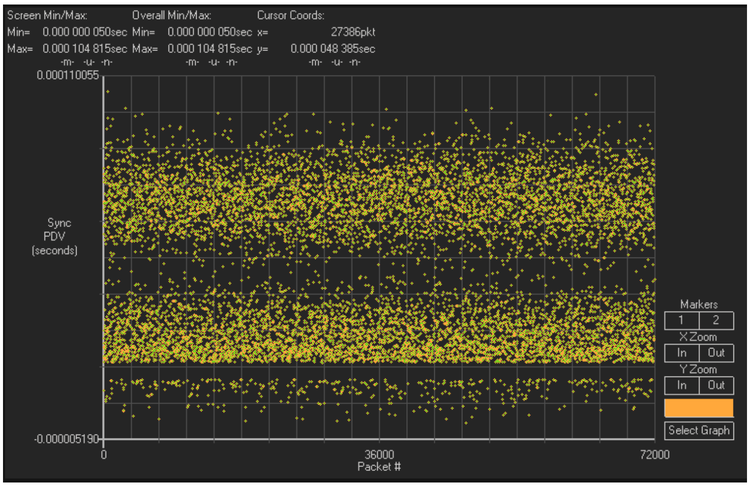


To define a band, the **Markers** are used. Note that they set the band in the **Y-axis**.



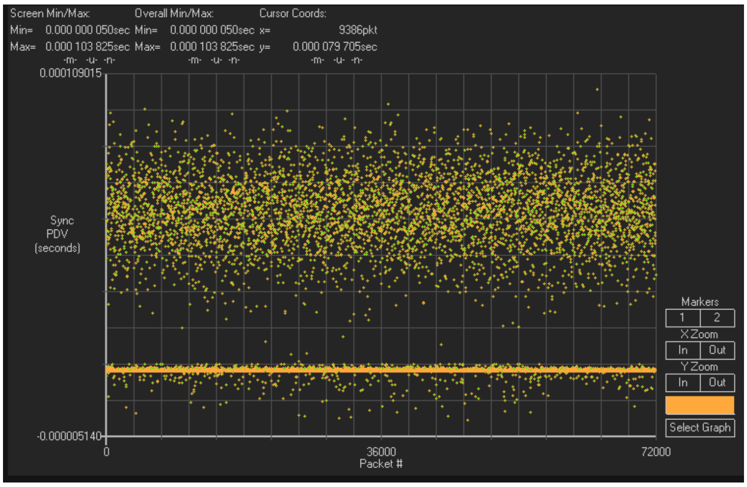
The data in the defined band may now be **depleted** or **concentrated**.

If ***Deplete*** > ***All*** is selected, the packets in the band are moved out by adding an offset equal to the band height to each of the packets to be moved as shown below.



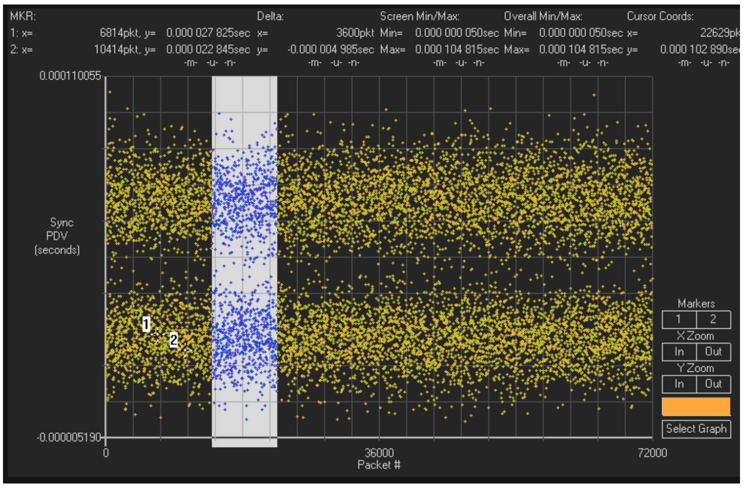
If ***Concentrate*** > ***All*** is selected, you will be prompted for a **percentage**. This is the percentage of all packets in the profile that will be concentrated into the band defined by the two markers.

The packets selected to be moved into the band are picked at random and given a randomised value within the band set. The result will be as shown below where **50%** of the packets have been concentrated into the define band.

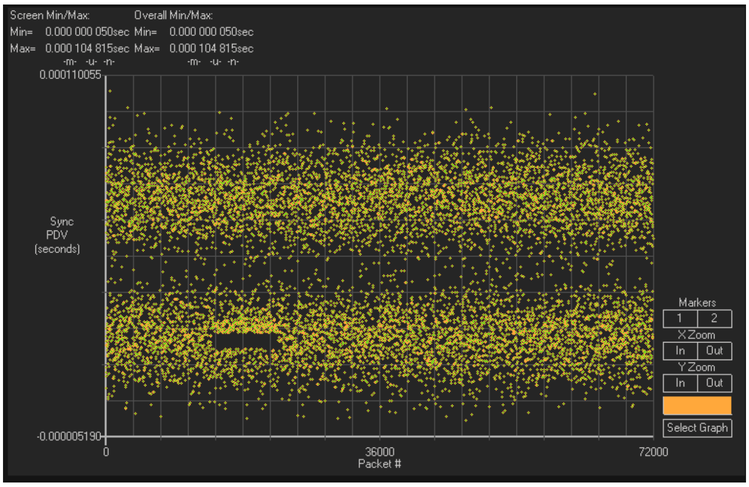


It is possible to apply the **Banding** over a section of the profile by **highlighting the X-axis range** over which the Depletion or Concentration is required.

For example the screenshot below shows the markers defining the band to be adjusted and the highlighting to define an X-axis section to be manipulated.



Resulting in the following when ***Deplete*** > ***Highlighted*** is selected.



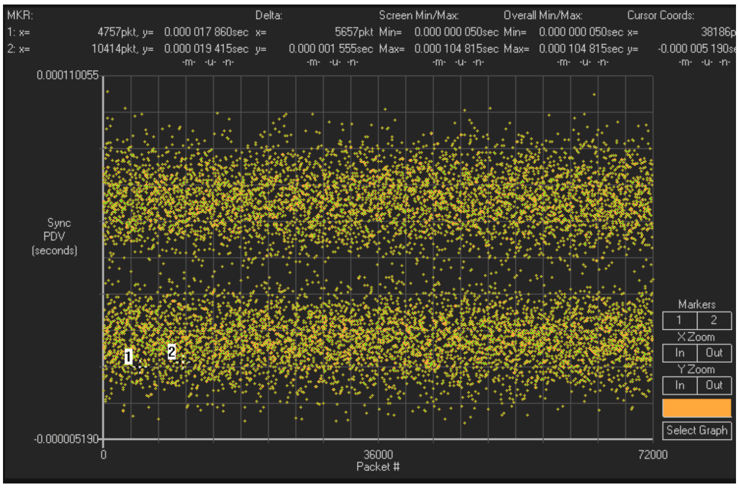
g. **Noise Floor Density** – allows the profile to be adjusted to change the density of packets to be found in the noise floor i.e. lucky packets.

There are two dimensions that can be defined. If only a limited section of the profile is required to be adjusted, then that section should be highlighted using the mouse click and drag as defined in the **Remove** section.

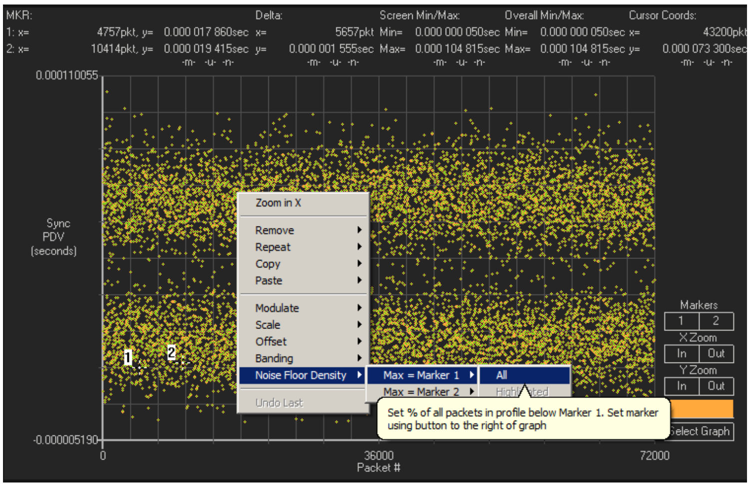
The band of interest is defined between the packet with the minimum delay and one of the markers. Based on the requested %, the number of desired packets within the noise band is then calculated.

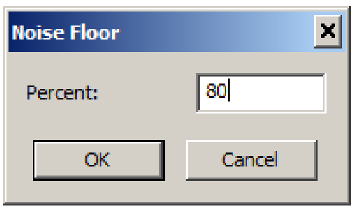
- If there are less packets than requested, packets out with the band are linearly selected and reassigned a new random value in between the marker and the minimum profile value.
- If there are more packets in the band than requested then packets within the band are linearly selected and offset by the difference between the marker and the minimum profile value.

Example 1: If you are making an adjustment across all of the packets, you need to define the top of the band using the marker (Marker 2 in this case). This is shown below.



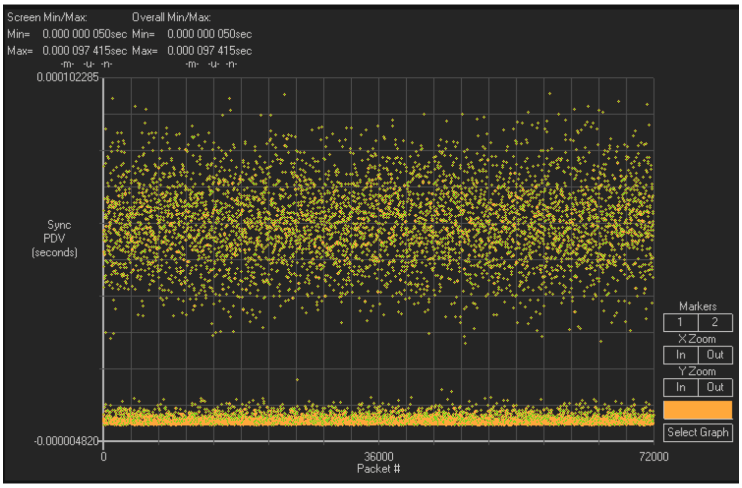
The Banding and the Marker are selected as shown below. Since there is no highlighting, the only choice is **All** i.e. across the whole set of packets.





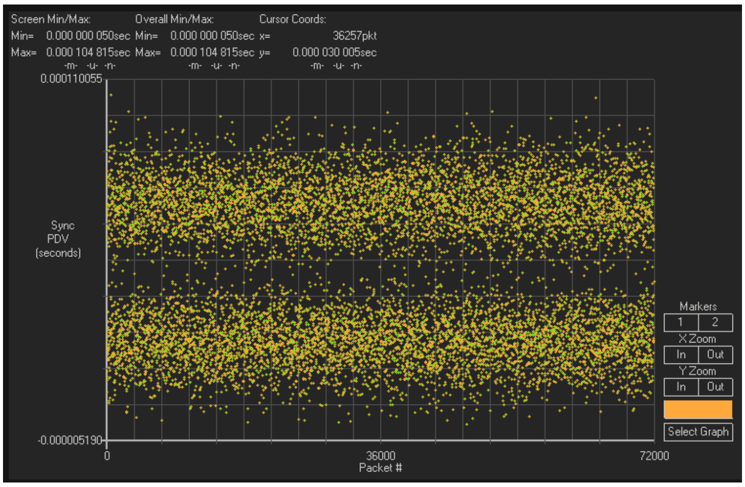
The percentage of packets to be placed in this band is now user-selectable via the pop-up screen.

The following shows the effect when 80% of the packets are moved into the band.

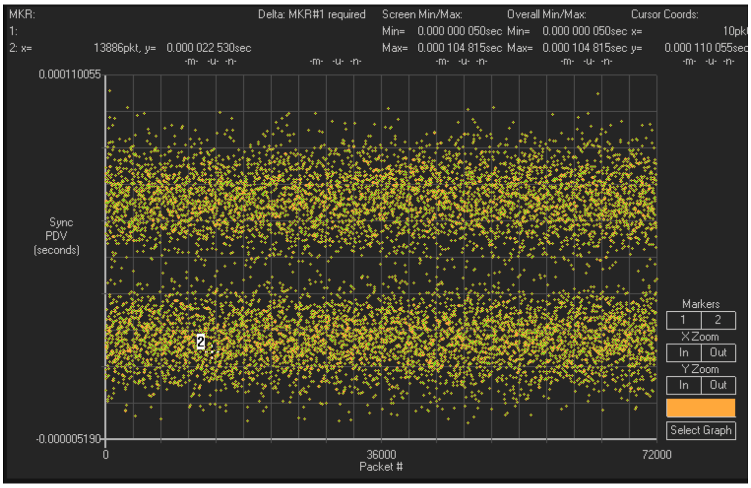


Example 2: Where the manipulation is applied over part of the packet set using the highlighting feature.

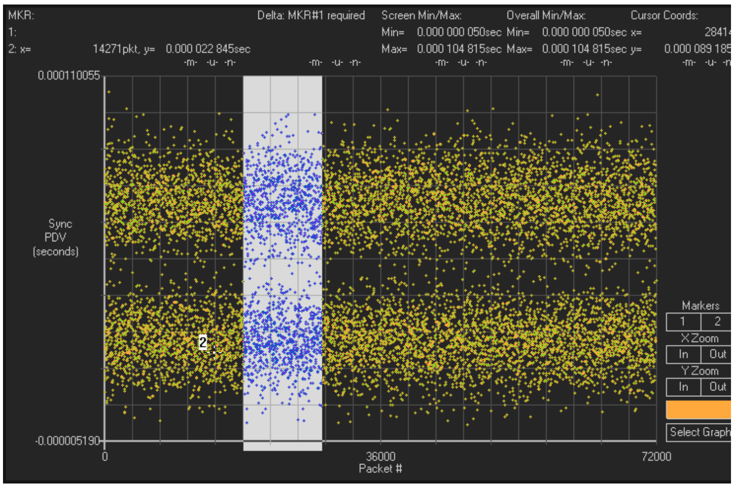
Initial data set is shown below.



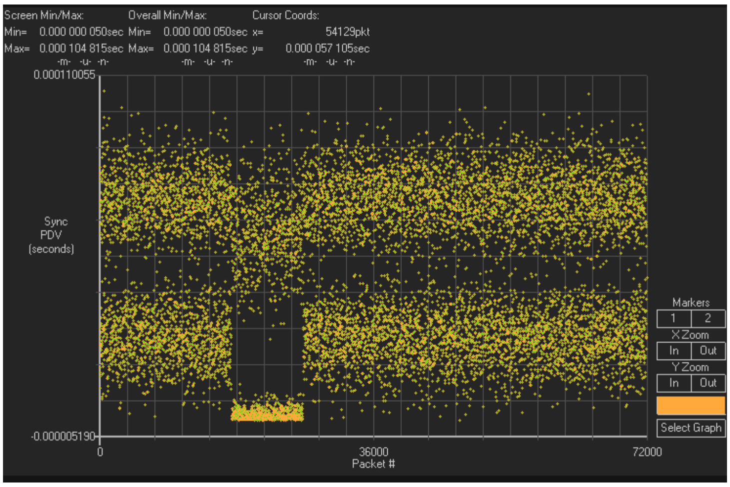
Set the marker.



Set the range of the area to be adjusted.



Apply the **Noise Floor Density** adjustment as described in Example 1, **Noise Floor Density, Max** = **Marker 2 , Highlighted**.



h. Undo Last – allows you to return to the data set prior to the last operation.

Note that several windows may be opened to allow cutting and pasting of parts of several profiles to provide a final composite data set for replay. This is invoked by using the ***File*** > ***Import*** selection from the application toolbar menu.

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