Calnex
Insight and Innovation

Testing Performance of the Chronos Smart SFP™ Transparent Clock using the Calnex Paragon-X

AimValley

OE SOLUTIONS

The Chronos Smart SFP™ can be configured as a Telecom Transparent Clock (T-TC), allowing Network Operators to use existing network equipment for the transfer of time and phase through the Mobile Backhaul. This Application note describes how the T-TC performance can be verified by the Calnex Paragon-X, thereby ensuring correct budgeting for Time Error (TE) in the Mobile Backhaul.

Contents

1 Project Overview

This document details a collaboration between Calnex[1] and AimValley[2] to demonstrate the capabilities of the AimValley Chronos Smart SFP™ TC and how its performance can be proven by the Calnex Paragon-X, ensuring adherence to the recommended limits for Time Error on Transparent Clocks.

The Chronos Smart SFP™ TC provides the facility to add PTP (1588) Transparent Clock functionality to an existing Switch or Router which by itself does not have 1588 capabilities (see Fig.3: Connecting Paragon-X to Chronos Smart SFP's acting as T-TC).

2 Chronos Smart SFP™ (SSFP) T-TC

OE Solutions[3] and AimValley jointly developed the Smart SFP™ portfolio, a new class of SFP's that integrate intelligent and innovative system functions into an SFP module.

Figure 1: Chronos Smart SFP™

Most LTE base-stations today use Frequency Division Duplexing (FDD-mode) which requires only frequency synchronization. However, to meet growing bandwidth demand, base-stations must switch to Time Division Duplexing (TDD-mode) which requires Time of Day (ToD) synchronization. To support this bandwidth upgrade, Telecom networks need to support Time of Day (ToD) distribution.

The ToD is distributed from a centralized 1588 Grandmaster (in ITU-T terms a T-GM) to all end nodes LTE base-stations with IEE1588 slave clock (Telecom - Time Slave Clock, T-TSC in ITU-T terms).

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[1] Supplier of test equipment, see Appendix A.
[2] Supplier of telecom and data networking solutions, see Appendix A.
[3] Supplier of optoelectronic transceiver solutions, see Appendix A.

The entire network in between the Grandmaster (T-GM) and the base-station (T-TSC) needs to be '1588 aware' to meet the stringent ToD synchronization requirements. All intermediate nodes either need to support a 1588 Boundary Clock (T-BC) or a 1588 Transparent Clock (T-TC).

Chronos Smart SFP™ TC helps operators to upgrade their network to support ToD distribution by simply swapping conventional SFPs with the Chronos Smart SFP™ TC. This instant plug & play solution is needed only on ports carrying 1588 (PTP) protocol traffic. While a T-BC solution requires provisioning and master-slave directivity, the Chronos Smart SFP™ TC reduces system and network complexity.

The 1588 Transparent Clock works 'transparent" in both directions and is 'synchronization direction" independent. The Smart SFP™ transceivers are designed in conformance with the Small Form Factor Pluggable 20-pin Multi-Source Agreement (MSA).

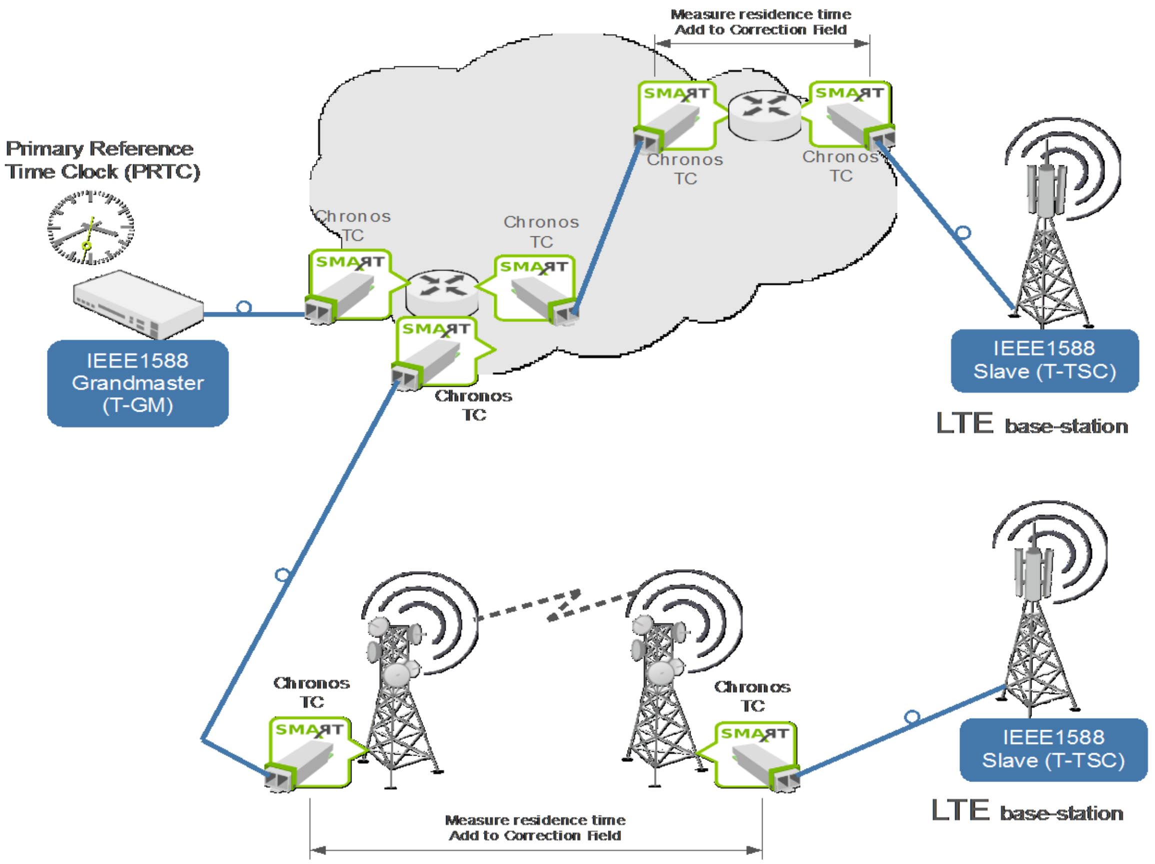


Figure 2: IEEE1588 end-to-end Transparent Clock Synchronization with Chronos Smart SFP™ TC

Networks, with equipment not supporting the 1588 protocol, can be upgraded by adding a 1588 Grandmaster and using the Chronos Smart SFP™ TC to add 1588 Transparent Clock function to all intermediate nodes.

The Chronos Smart SFP™ TC supports in real-time the 1588 TC function which means that it can handle as many PTP packet streams as the connection can carry.

3 Calnex Paragon-X

The Paragon-X is an industry leading piece of test equipment which provides verification that Ethernet-sync and packet-transport products meet industry standards and work reliably under real-world conditions.

The Paragon-X lets you capture real-world Packet Delay Variation (PDV) profiles from your existing network and replay those same profiles in a controlled lab environment, enabling you to prove your 1588, CES and NTP products will work in the complex world of Ethernet switches, routers and gateways, before deployment.

The Paragon-X is also able to measure the accuracy of the recovered Time of Day (ToD), Phase (1pps) and Frequency (MTIE/TDEV) to the specified limits.

It also has specific features designed to test 1588 Transparent Clocks and Boundary Clocks.

- Integrated Test Solution for ITU-T G.826x and G.827x standards
- Fully stress-test elements that deliver synchronisation over packet-based networks.
- Prove PTP (1588), Sync-E, CES, Pseudowire, NTP implementations meet ITU-T standards.
- Prove PTP (1588) to the ITU-T Telecom Profile G.8265.1.
- Comprehensive testing of 1588 Ordinary Clocks, Boundary Clocks and Transparent Clocks.
- Measure recovered Time of Day (ToD) and Frequency (MTIE/TDEV) to specified limits (G.823, G.824, and G.8261.1).
- Capture real-world PDV profiles over long periods, then replay these in a repeatable, controlled environment.
- Edit and change PDV profiles before replay to tailor-make test conditions
- Introduce packet corruption events, lost packets, misordered packets, and repeated packets.
- Validate Sync-E and ESMC to ITU-T G.8262 and G.8264.
- Stress and validate Ethernet OAM and MPLS-TP OAM (Y.1731 and 802.1ag).

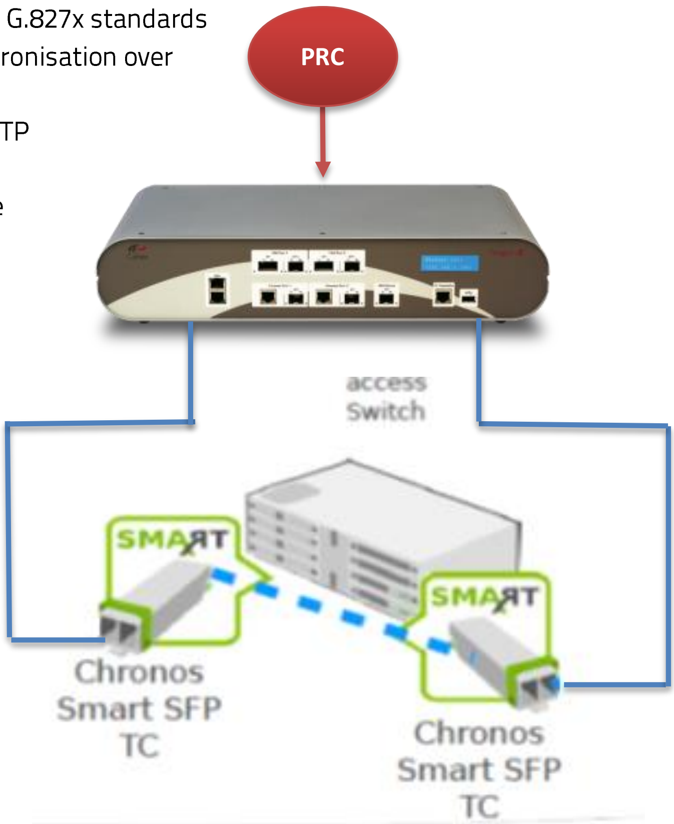


Figure 3: Connecting Paragon-X to Chronos SFPs acting as T-TCs

3.1 Connect Paragon-X to Smart SFP (Device under Test)

Connect as shown in Figure 3.

3.2 Paragon-X Front Panel

- 100MbE Electrical or Optical
- 1GbE Electrical or Optical (SFP)[4] – *with option 110 fitted*
- 10GbE Optical (XFP or SFP+) – *with option 111 fitted*

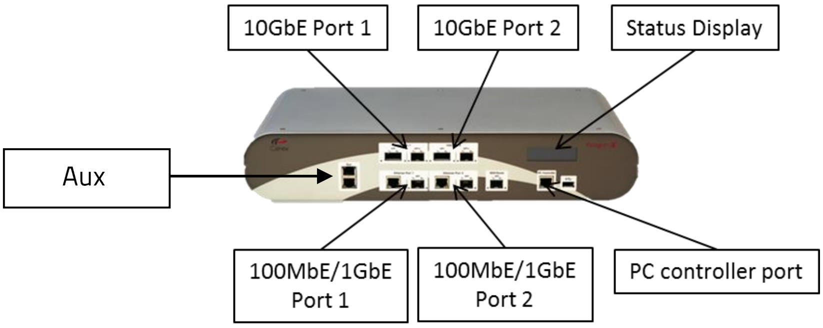


Figure 4: Paragon-X front panel

3.3 Paragon-X Rear Panel

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

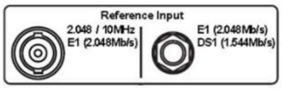


Figure 5: reference inputs

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

3.4 Paragon-X Connections

- Connect port 1 (master side of Paragon-X) to the T-TC Smart SFP Master side.
- Connect port 2 (slave side of Paragon-X) to the T-TC Smart SFP Slave side.
- Connect external reference e.g. 10MHz to Paragon-X ref input.

4 Configuring the Chronos Smart SFP™s

The Chronos Smart SFP™ TC can be considered 'plug and play".

The only requirement for the network node, in which the Chronos Smart SFP™ TCs reside, is to provide a dedicated tunnel through the network node which connects all ports of the network node which contain a Chronos Smart SFP™.

The current version requires a dedicated VLAN to provide the tunnel. Default VLAN-id = 1588.

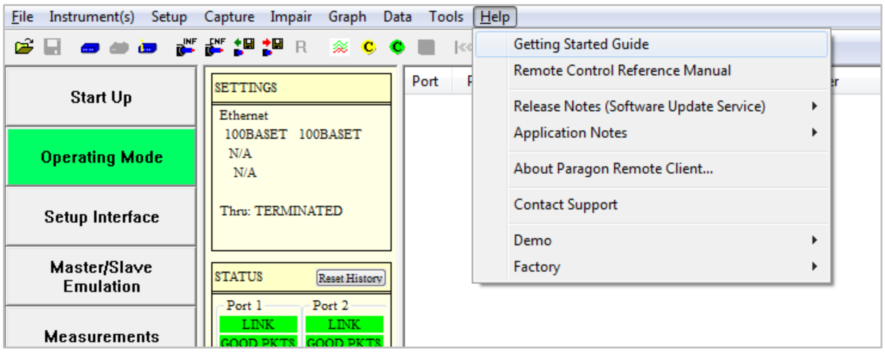
[4] If using SFPs, XFPs or SFP+s, both Port 1 and Port 2 optical transceivers must be inserted into Paragon-X.

5 Configuring the Paragon-X for T-TC tests

5.1 Test Set up.

5.1.1 Verify physical connections have been completed per Section 3.

5.1.2 Start the Paragon-X GUI. PC interface connection information is available in the Getting Started Guide.

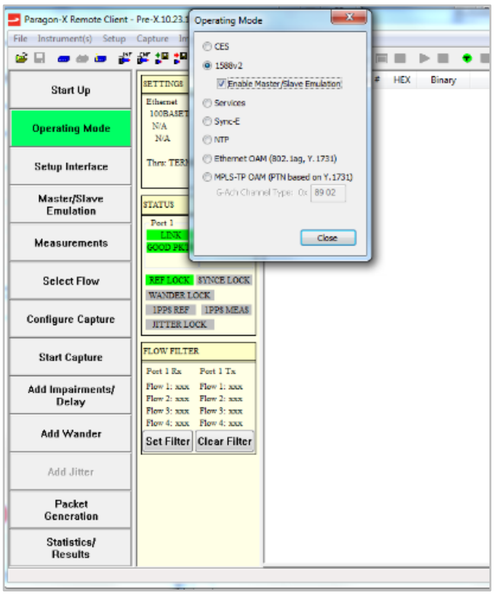


5.1.3 Select Start Up and Connect.

5.1.4 Enter IP address of Paragon-X (displayed on Paragon-X status display)[5]

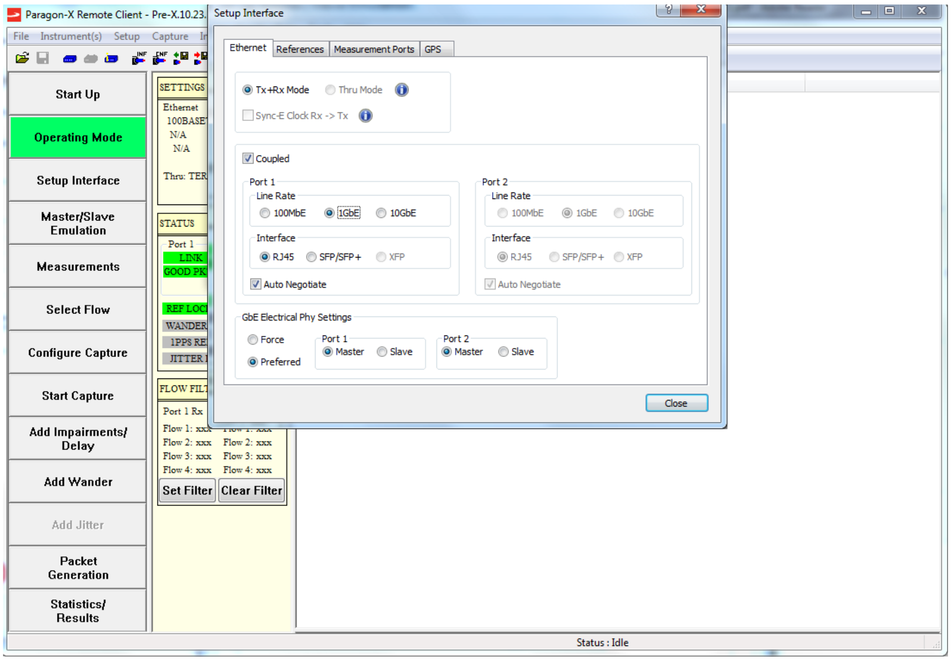
5.2 Set up Master Slave Emulation.

5.2.1 Select Operating Mode, 1588v2, Enable Master/Slave Emulation then Close.

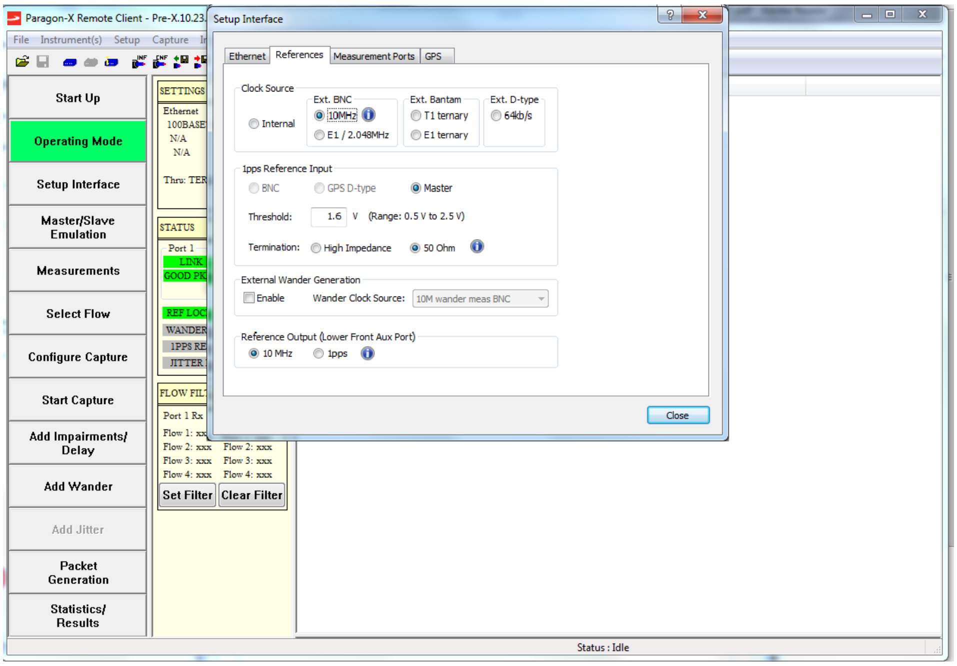


[5] See Paragon-X Getting Started User Guide for more information.

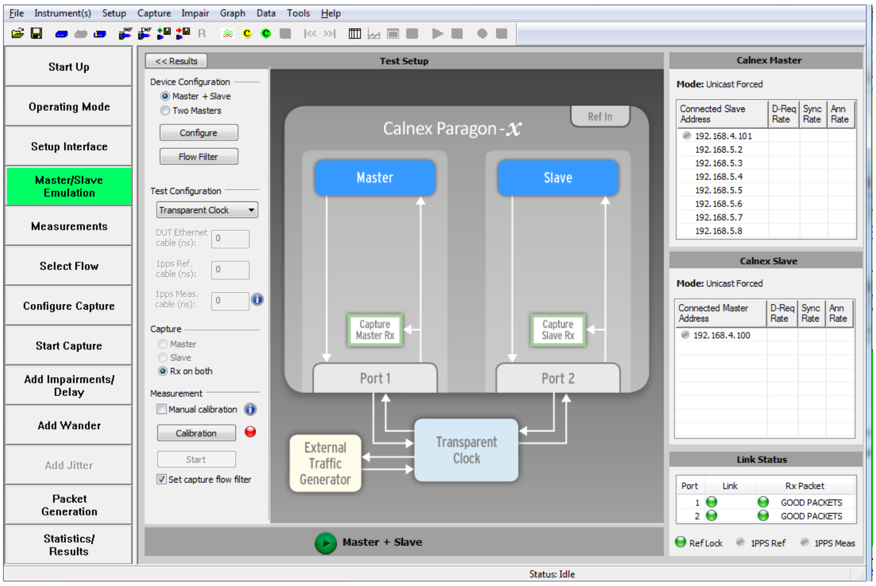
5.2.2 Select *Setup Interface* and select *Line Rate* to match the T-TC Smart SFP under test.



5.2.3 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.

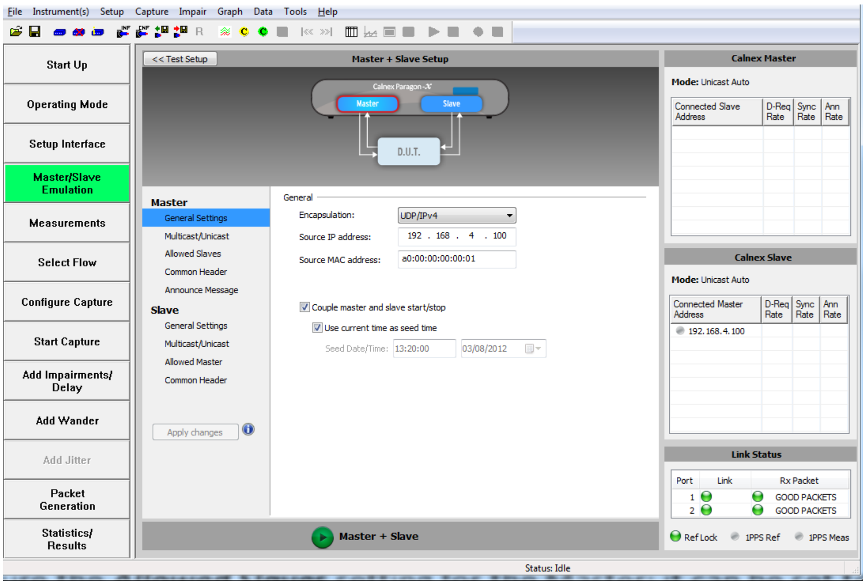


5.2.4 Select Master/Slave Emulation. Choose Transparent Clock in Test Configuration drop down menu.



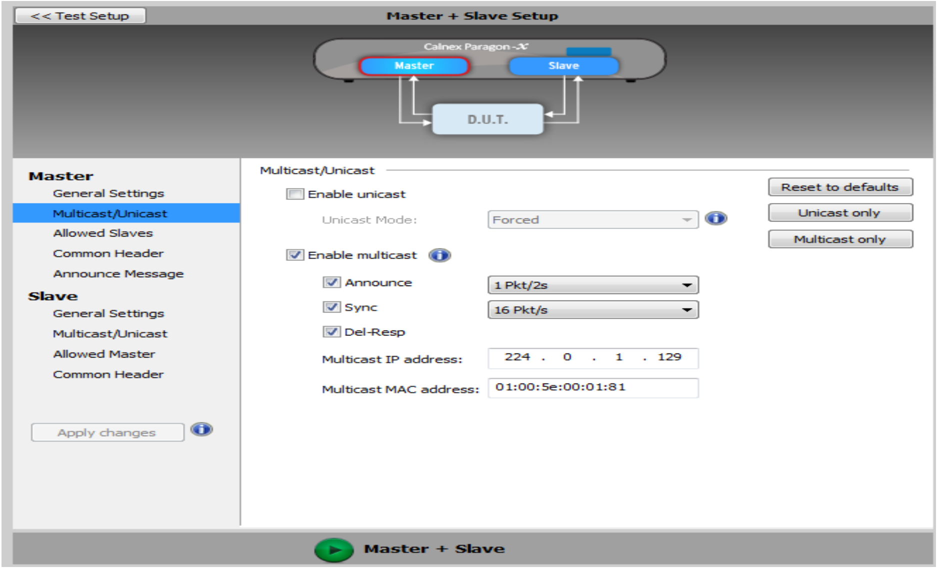
5.3 Configure the Master

5.3.1 Select *Configure* and enter the general settings of the Paragon-X emulated Master. Select the Encapsulation to match that of the T-TC (both *UDP/IPv4* and *Ethernet* are supported)



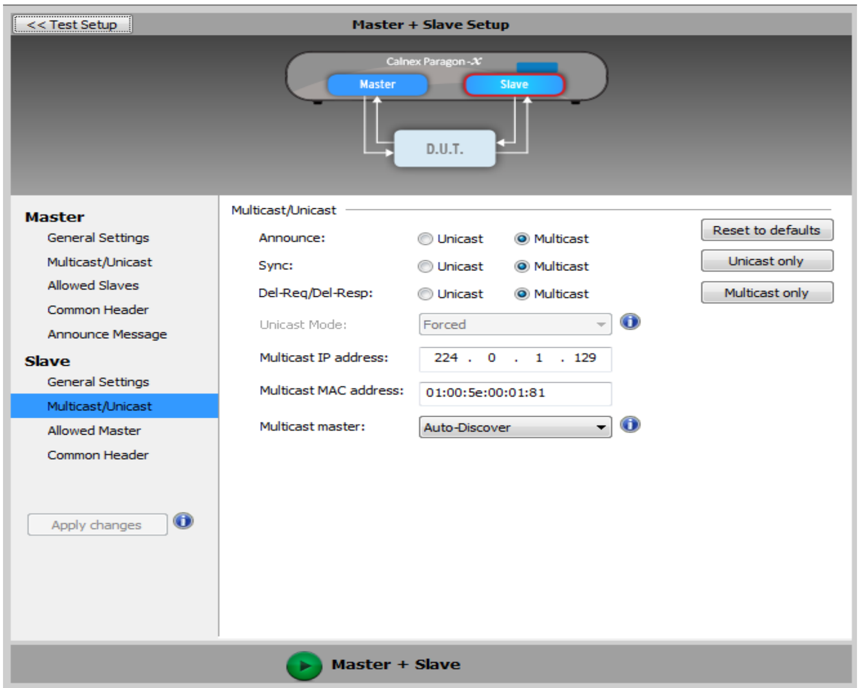
NOTE: Enter the delay based on the total length of all cables used to connect the Smart SFPs to the Paragon-X

5.3.2 Select multicast operation. Set Master mode.

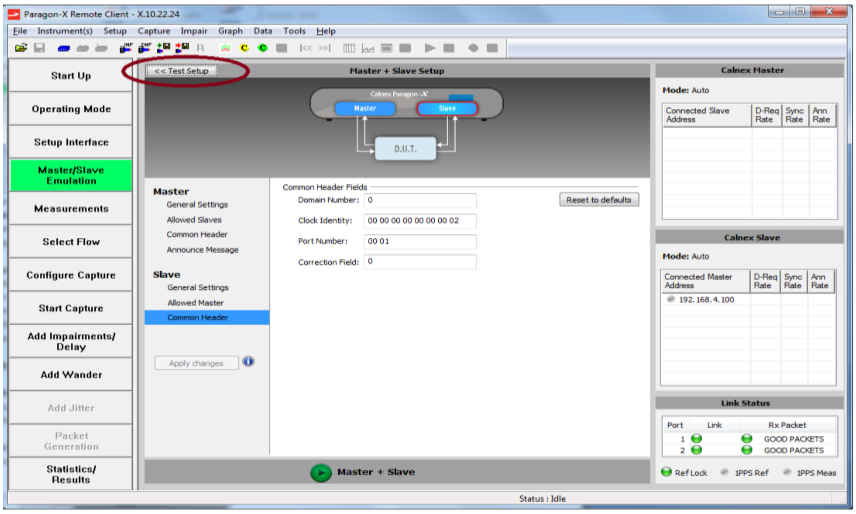


5.4 Configure the Slave.

5.4.1 Since the test uses the Master Slave emulated Master and Slave default settings will suffice for all Slave settings other than selection of *Multicast/Unicast* mode to match that of the Master settings.



5.4.2 Return to Master Slave test setup.

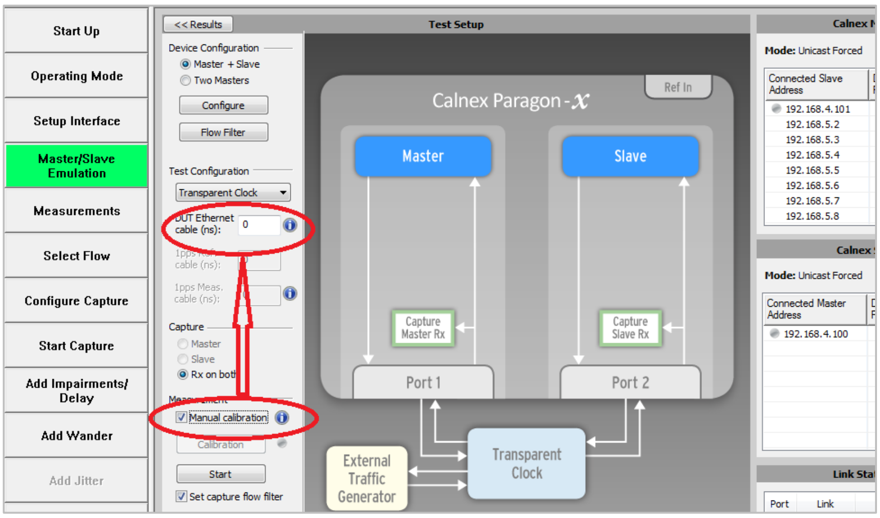


5.5 Calibrate Smart SFP to Paragon-X Cable Delay.

In order to correctly perform calculations, the delay caused by the cable that is used to connect the T-TC Smart SFPs to the Paragon-X must be factored out. Values of 5nS per 1 metre of electrical cable and 4nS per 1 metre of optical cable can be expected. The calibrated cable delays can either be manually entered or can be automatically detected.

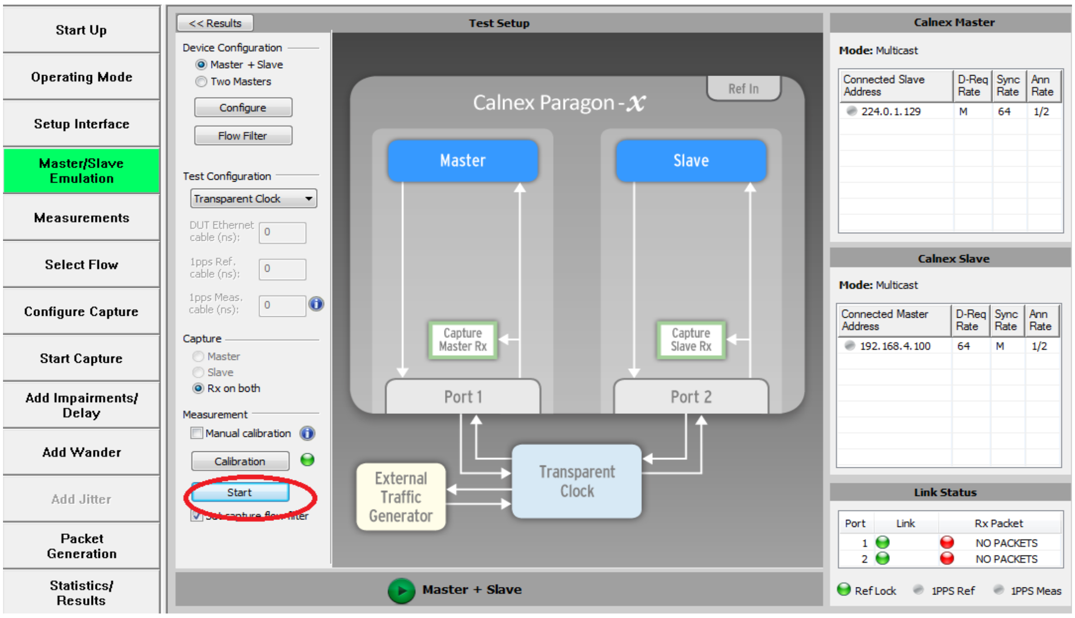
5.5.1 To manually enter the delay values tick the *Manual Calibration* check box and enter the delay value in *DUT Ethernet Cable* field.

✋ **NOTE:** Enter the delay based on the total length of all cables used to connect the Smart SFPs to the Paragon-X



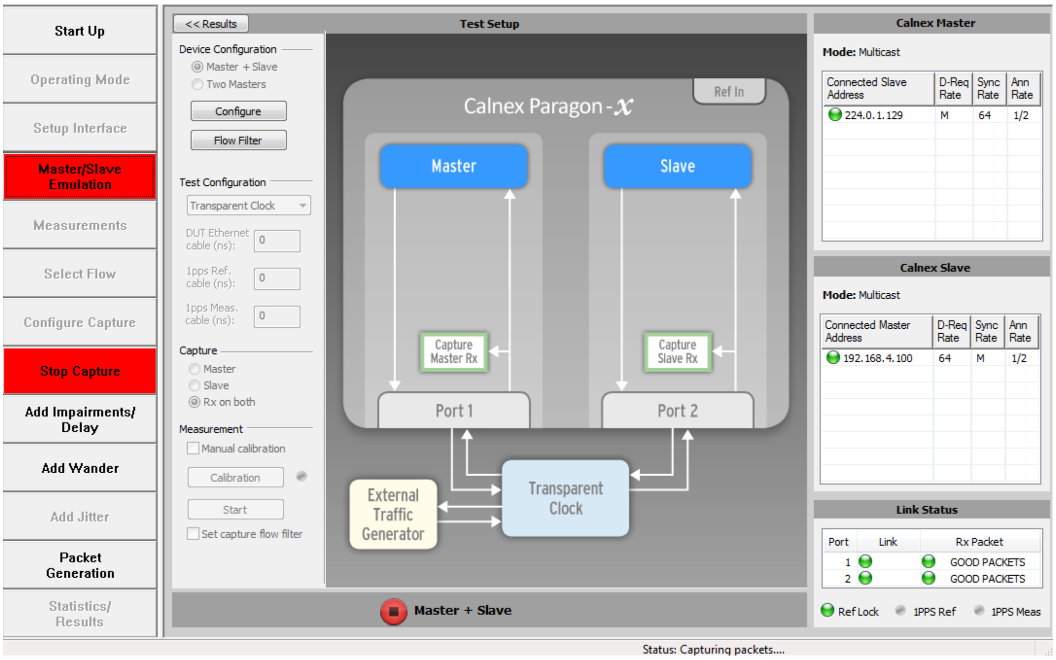
5.5.2 Establish link between Paragon-X and Smart SFP T-TC & make measurement

5.5.3 Connect the Smart SFPs to the SFPs in Ports 1 and 2 of the Paragon-X.

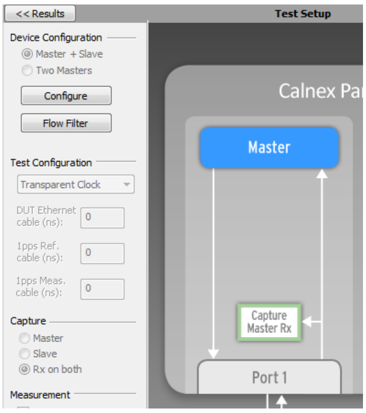


5.5.4 *Start* the Capture Master/Slave emulation.

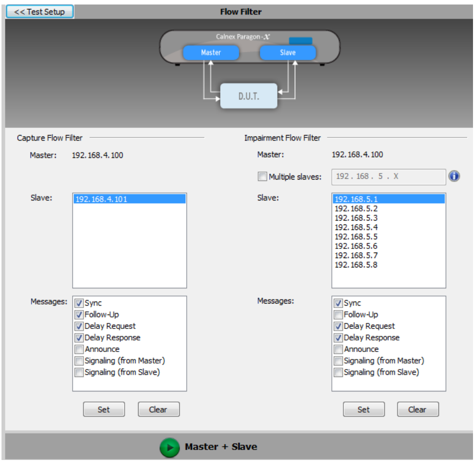
5.5.5 Check the link to make sure that the PTP packets are running without error. Check the link Status window for green status on Link and Good Packets. (See Paragon-X 1588 emulation connection guide for troubleshooting information if there is any difficulty in establishing a PTP session with the DUT).



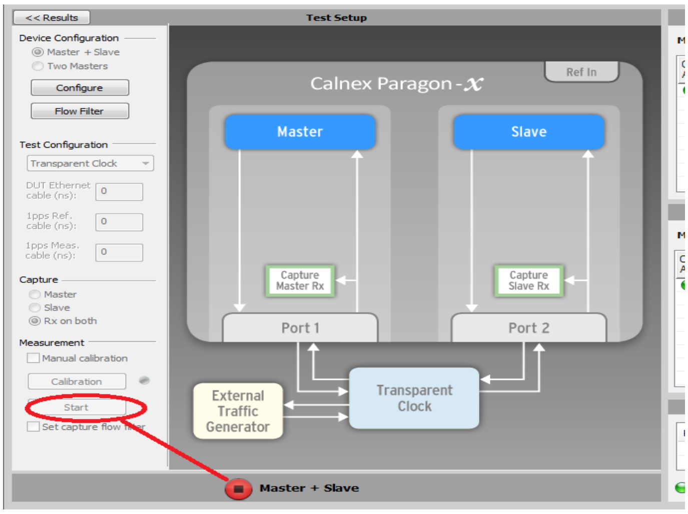
5.5.6 Capture flow filters are set to default values automatically.



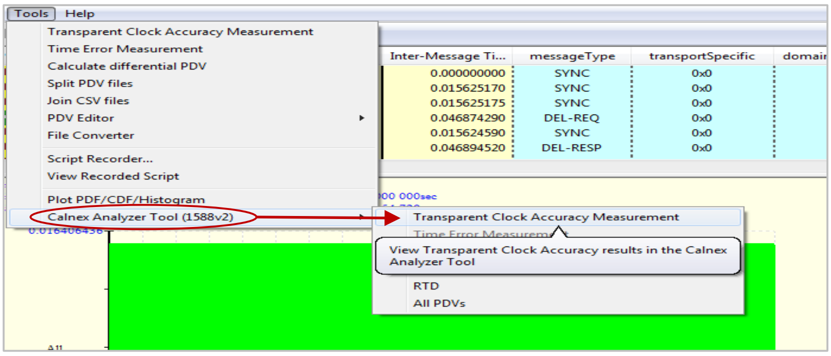
5.5.7 If required to change the details of which message types are included in the filter then use flow filter button.



5.5.8 Filters are only actioned if the *Set* button is pressed. If manually setting filters, once set *Start* measurement and run the measurement for the required period. Recommendation is to capture for a minimum of 300s.



5.5.9 Select Tools, Calnex Analyzer Tool (1588) and Transparent Clock Accuracy Measurement tool.



5.6 Transparent Clock Accuracy Measurement Notes - CAT

5.6.1 Transparent Clock Accuracy Results available with Calnex Analyzer Tool (CAT).

Time Error

- Forward Correction Field Accuracy (Sync)
- Forward Latency
- Forward Correction Field
- Forward Correction Field Delta.
- Reverse Correction Field Accuracy (Delay Request)
- Reverse Latency
- Reverse Correction Field
- Reverse Correction Field Delta.
- Two – way Correction Field Accuracy

5.6.2 PTP Correction Field.

The T-TC should use the Correction Field values to inform other network elements of the dwell time of messages passing through in the Forward direction (Sync) and Reverse direction (Delay Request) in order to correctly compensate for any delay within the T-TC. In addition the T-TC must **add** to any existing Correction Field values to ensure that the delays through intermediate network elements are correctly catered for at the Master and the Slave.

The Time Error results provide the means of determining the behaviour of the T-TC with respect to the correct identification of delays and should provide an accurate representation of the performance of the T-TC.

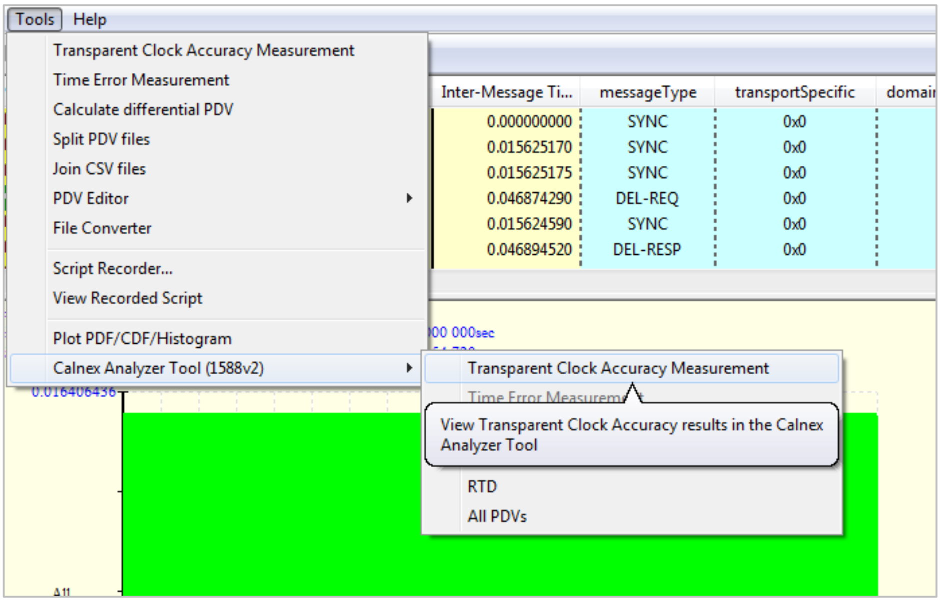
6 Test Procedure

The purpose of the test is to measure the accuracy of the **Correction Field** adjustment carried out by the T-TC capability of the Smart SFPs to provide verification that the performance meets that of the relevant ITU-T specification.

6.1 Without Load

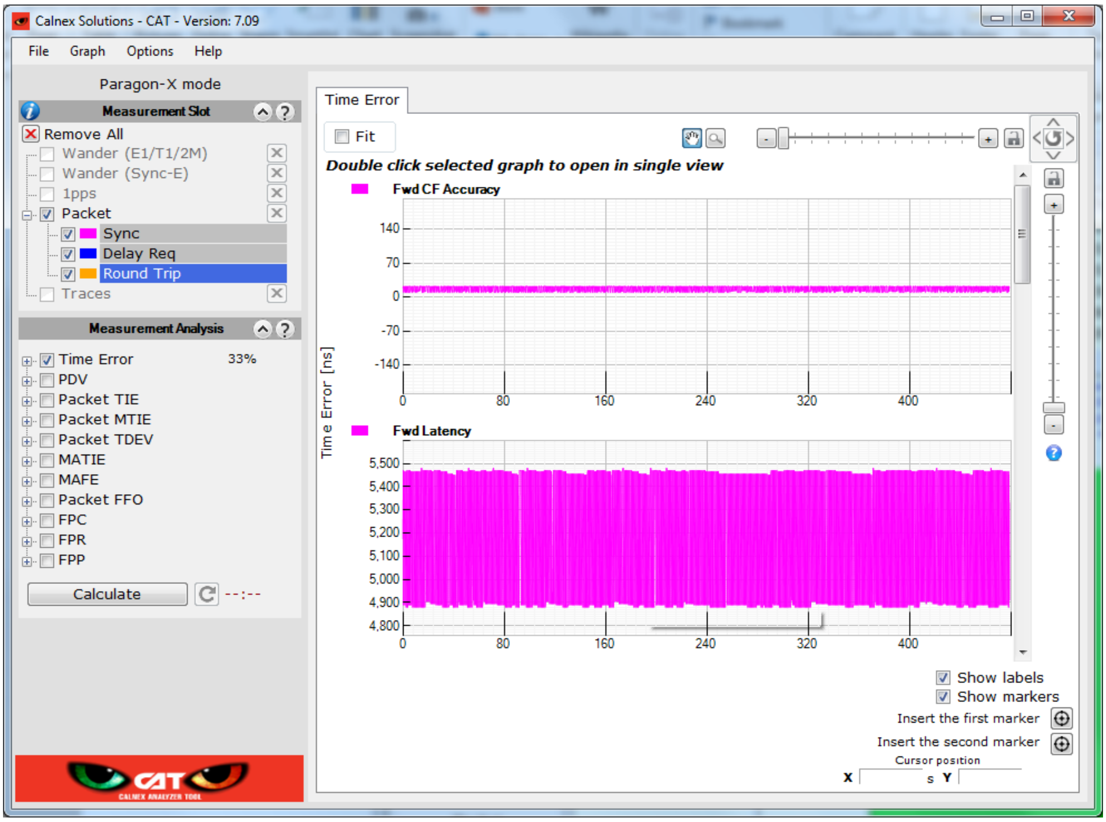
Perform configuration steps defined in paragraphs 4 (Configuring the Chronos Smart SFP™s) and 5 (Configuring the Paragon-X for T-TC tests).

- Perform **Capture** for at least 300 seconds.
- **Measurements: Time error** results can either be viewed during capture or after capture has been stopped.
- Select Tools, Calnex Analyzer Tool (1588) and Transparent Clock Accuracy Measurement tool.

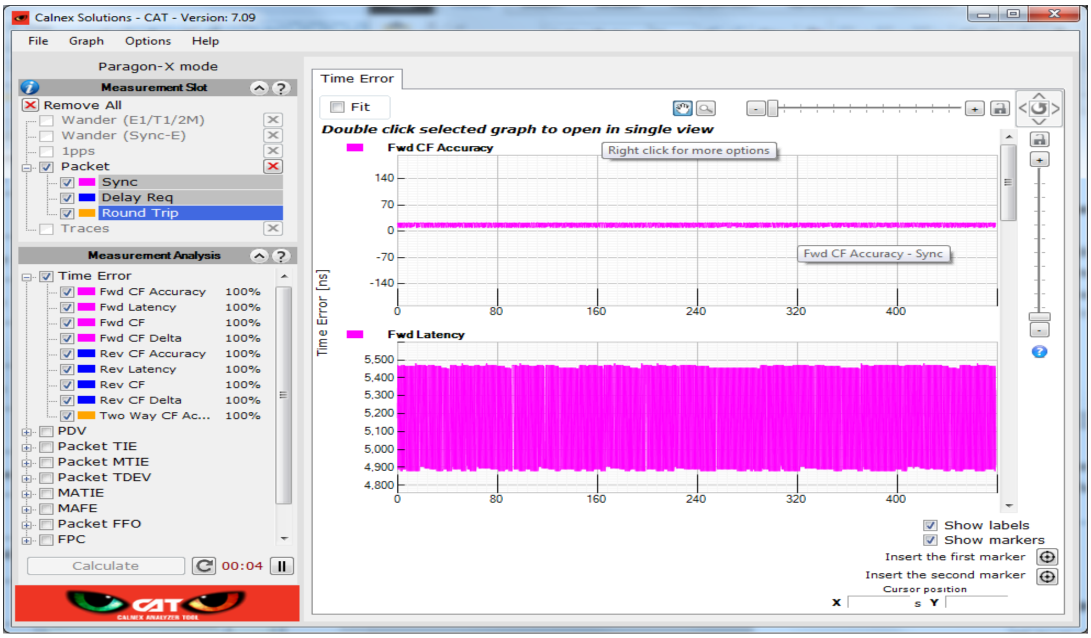


6.1.1 Time Error Results (Transparent Clock Accuracy)

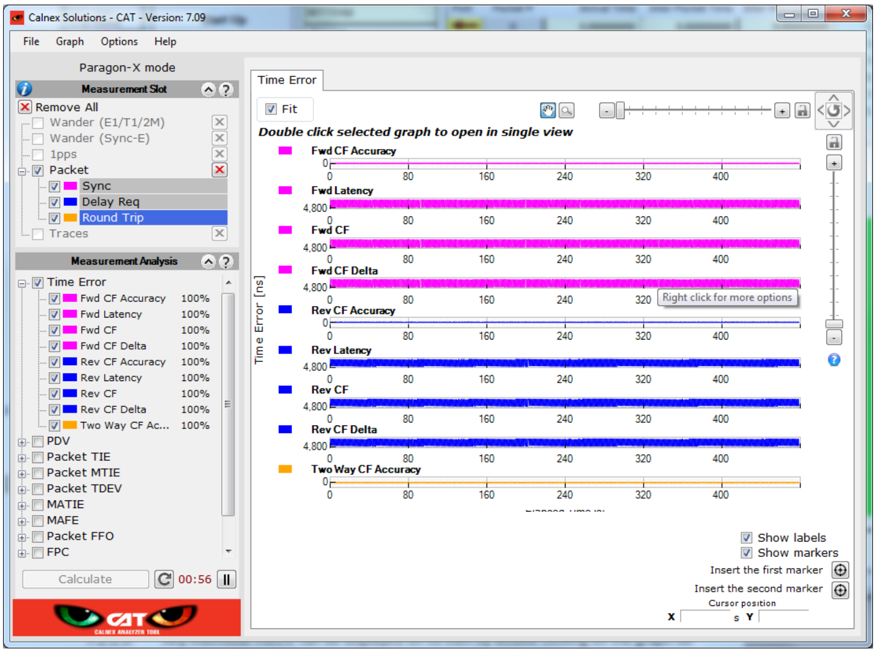
The *Calnex Analyzer Tool* will launch and display the *Time Error* metrics tab.



6.1.2 Click on the + next to Time Error in Measurement Analysis block to expand the selection of metrics available.



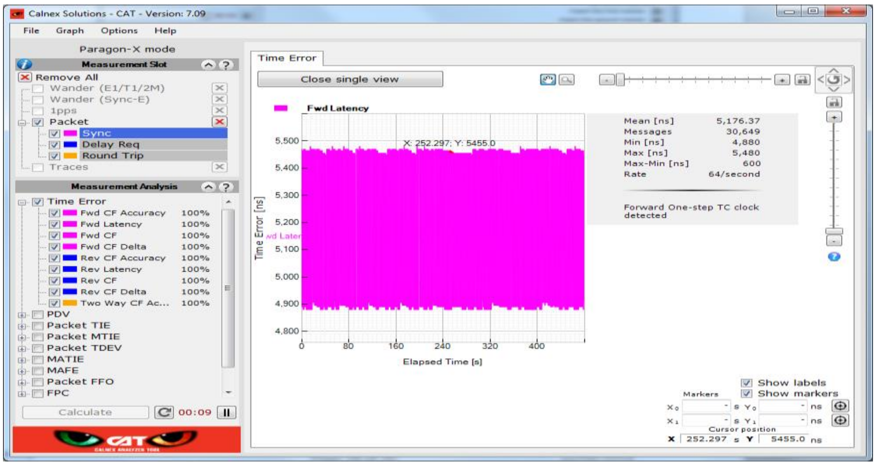
6.1.3 All the metric graphs are available and can be accessed via the scroll bar on the right of the display. Alternatively selection of the *Fit* tick box will result in all metrics for Transparent Clock being displayed.



6.1.4 The set of displayed metrics can be enabled/disabled by ticking/un-ticking the relevant measurement in the *Measurement Analysis* set.

✋ **NOTE**: if a metric is un-ticked and then ticked again the ***Calculate*** button must be pressed to recalculate that metric.

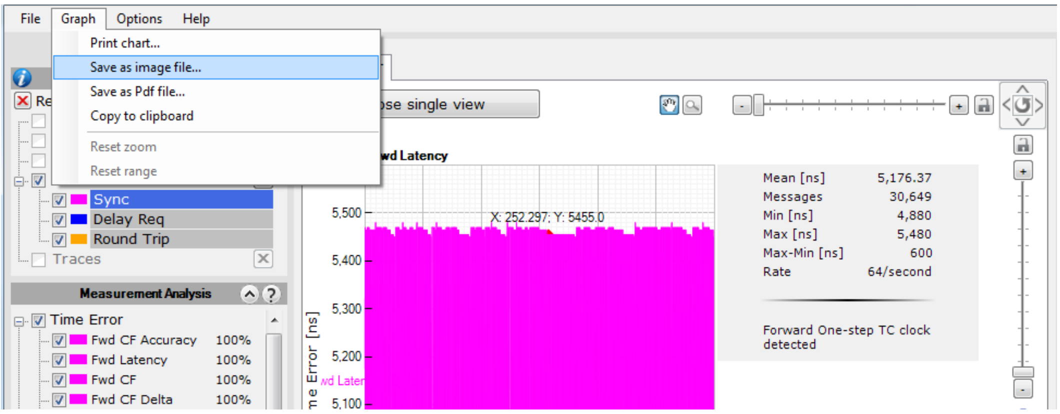
6.1.5 Any individual metric can be displayed on its own by double clicking on the appropriate graph.



6.2 Records of Results

Individual graph images can be saved in either PDF or JPEG formats as evidence of the outcome of any given measurement. To save a metric select the ***Graph->Save as*** menu choices.

Measurements:



Fwd. /Reverse Latency provides a measure of the time individual packet spend in the T-TC by the Paragon-*X* time stamping the packets on ingress to and egress from the DUT then measuring the difference between the two.

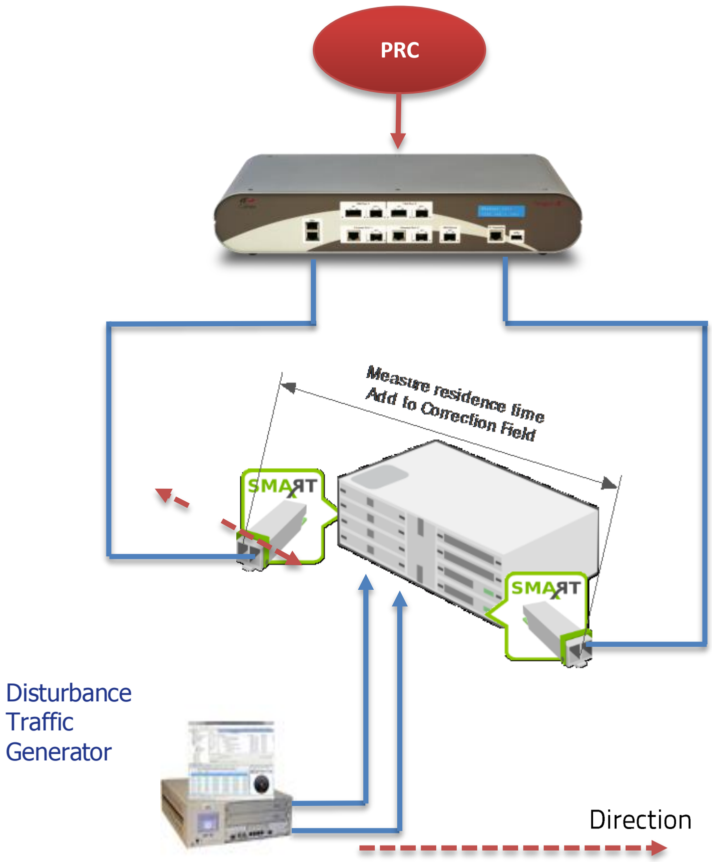
Fwd. /Reverse CF provides a graphing of Correction Field values from individual packets on egress from the DUT.

Fwd. /Reverse CF Delta provides a measurement of the change in Correction Field within the DUT on egress of the device by measuring the Correction Field value on egress in comparison to the value on ingress to the device.

Fwd. /Reverse CF Accuracy provides a measurement of the accuracy of the Correction Field by measuring **Latency – Correction Field** on individual packets.

6.3 Network Loading

Repeat Test 1 but with differing Network loading.



Test	Forward Direction	Reverse direction	Duration	Result
(a)	80% load	20% load	1200s	
(b)	20% load then 80% load		600s at 20% then 1200s at 80% load	
		10% load then 50% load	900s at 10% then 1200s at 80% load	
(c)	100% load	100% load	1200s	
(d)	97% load	97% load	1200s	

6.3.1 Connect Traffic Generator to provide congestion traffic on output port.

6.3.2 Check Time Error results for Forward, Reverse and Two-way measurements fall within the recommended 50nS limit.

7 Test Results Analysis

Loading	Measurement	Min	Max	Mean
0%	Fwd Latency			
	Fwd CF			
	Fwd CF Delta			
	Fwd CF Accuracy			
	Reverse Latency			
	Reverse CF			
	Reverse CF Delta			
	Reverse CF Accuracy			
80%	Fwd Latency			
	Fwd CF			
	Fwd CF Delta			
	Fwd CF Accuracy			
20%	Reverse Latency			
	Reverse CF			
	Reverse CF Delta			
	Reverse CF Accuracy			
20% then 80%	Fwd Latency			
	Fwd CF			
	Fwd CF Delta			
	Fwd CF Accuracy			
10% then 50 %	Reverse Latency			
	Reverse CF			
	Reverse CF Delta			
	Reverse CF Accuracy			
100%	Fwd Latency			
	Fwd CF			
	Fwd CF Delta			
	Fwd CF Accuracy			
100%	Reverse Latency			
	Reverse CF			
	Reverse CF Delta			
	Reverse CF Accuracy			
97%	Fwd Latency			
	Fwd CF			
	Fwd CF Delta			
	Fwd CF Accuracy			
97%	Reverse Latency			
	Reverse CF			
	Reverse CF Delta			
	Reverse CF Accuracy			

Appendix A: Company Overview

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Calnex Solutions are the world leaders in test & measurement solutions to prove and monitor the performance and reliability of Ethernet synchronization and OAM technologies – PTP (1588), NTP, SyncE, CES, E-OAM and MPLS-TP OAM. Customers developing equipment with these technologies can use the Calnex equipment to prove performance to rigorous standards for R&D, System and Field test. Customers deploying these technologies in their networks can use the Calnex equipment to test performance during trials and to troubleshoot problems in their networks.

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AimValley is a global supplier of telecom and data networking solutions that enable network operators to provide services with optimized quality of experience. With its innovative solutions for Ethernet demarcation, Circuit Emulation and Carrier Class switching, AimValley addresses the demands of next generation packet based networks, supporting applications ranging from legacy based services to bandwidth demanding data and video.

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OE Solutions is a leading supplier of optoelectronic transceiver solutions for both broadband wireless and wireline markets, including wireless backhaul, Metropolitan Area Networks (MANs), Local Area Networks (LANs), Storage Area Networks (SANs), Passive Optical Networks (PONs) and HD Video Transport.

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