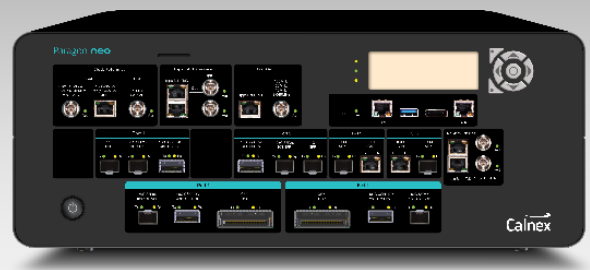


Testing a PRTC to ITU-T G.8272 using Paragon-neo



This Test Guide shows how the Calnex Paragon-neo can be used to test that a Primary Reference Time Clock (PRTC) complies to the timing requirements given in the ITU-T G.8272 standard.

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1 Introduction

A Primary Reference Time Clock (PRTC) provides the reference signal for time, phase and frequency synchronization for other clocks within a network or section of a network. Typically, the PRTC provides the reference signal to a Telecom Grandmaster (T-GM) that generates a PTP signal into the network. PRTCs are usually equipped with a GNSS receiver that provides an independent time reference traceable back to a reference standard such as UTC.

Several aspects must be considered when testing the accuracy and stability of a PRTC:

- Sourcing an accurate UTC reference in the test lab or in the field.
- Comparison against a reference GNSS receiver requires the GNSS receiver performance to be better than the PRTC under test, and its performance must be well known.
- Comparison against a PRC verifies frequency accuracy and stability, and not time/phase.
- Testing high accuracy PRTCs requires high accuracy test equipment and reference clock sources.
- Tests must run for long durations, especially holdover testing when GNSS is no longer present.

A GNSS simulator helps to address the first three items. It generates an RF signal, emulating the signals received from satellite constellations, meaning that the device under test receives a reference of known quality and performance.

PRTC performance is specified by the ITU-T G.8272 standard. A summary of G.8272 is available here: https://www.itu.int/en/ITU-T/studygroups/2022-2024/15/Documents/flyers/Flyer_ITU-T_G.8272-1.pdf.

1.1 Scope of this Test Guide

This test guide explains how to use the Calnex Paragon-neo to test PRTC and PRTC + T-GM integrated timing devices with GNSS inputs to ITU-T G.8272 Amendment 2. It is assumed that users have previously used Paragon-neo so have an understanding how to connect and configure the instrument and run tests. Please refer to the Paragon-neo Getting Started Guide for further guidance.

The test methodology described in this test guide can also be used when testing GNSS and Grandmaster clock aspects of G.8266 Packet-based Equipment Clock-Master-Frequency devices. ITU-T G.8266 specifies that for Wander in locked mode, devices must meet the limits defined in G.8272; and for Holdover Performance, the limits defined in G.812 apply. These are the same requirements as described in this test guide when testing a PRTC to G.8272.

Testing Enhanced PRTCs (ePRTC) to ITU-T G.8272.1 is not covered in this test guide.

The tests in this guide are timing performance tests that focus on the quality of the timing output from the PRTC under test as defined in the relevant standards and recommendations. During product development or qualification other aspects of device behaviour and performance may be of interest including:

- Device warm-up time and duration required to achieve optimal performance with both ideal and non-ideal reference inputs.
- Performance under various input reference impairment profiles, failure modes and the subsequent recovery times.
- Device performance changes depending on the order, concurrency, and duration of multiple fail events.
- Type and quality of events reported by the device via the management interfaces.
- Accuracy of on-device timing performance monitoring and reporting functions.

In the case of the above being required, the test procedures in this document can be used as a basis for the user to design their own tests to study those aspects.

1.2 Terminology and Abbreviations

The test guide uses the following abbreviations and acronyms:

1PPS	Pulse per Second
CAT	Calnex Analysis Tool
GNSS	Global Navigation Satellite System
GUI	Graphic User Interface
IEEE	The Institute of Electrical and Electronics Engineers
ITU-T	The International Telecommunication Union Telecommunication standardization sector
MTIE	Maximum Time Interval Error
NRZ	Non-Return to Zero
PAM4	Pulse Amplitude Modulation 4-level modulation scheme
PFV	Calnex PTP Field Verifier
PTP	Precision Time Protocol
PRC	Primary Reference Clock
PRTC, ePRTC	Primary Reference Time Clock, Enhanced Primary Reference Time Clock
RF	radio frequency (GNSS antenna signal)
T-BC	Telecom Boundary Clock
T-GM	Telecom Grandmaster
TDEV	Time Deviation
ToD	Time of Day
TR	Time Receiver (previously known as a Slave device)
TT	Time Transmitter (previously known as a Master device)
UTC	Coordinated Universal Time

The name “PRTC” is often used to refer to a device that contains both a PRTC and a T-GM (PTP Grandmaster). In this document, an integrated PRTC and T-GM will be referred to as a “PRTC + T-GM” to differentiate from a device is a PRTC only. Furthermore, in this document the names “PRTC” and “PRTC + T-GM” encompass devices designed to meet PRTC-A and PRTC-B definitions in G.8272 Amendment 2.

The name “Paragon-neo” is used in this document to include both Calnex Paragon-neo NRZ and Paragon-neo PAM4 instruments, see section 4.

1.3 References

The following documents are referenced throughout this test guide.

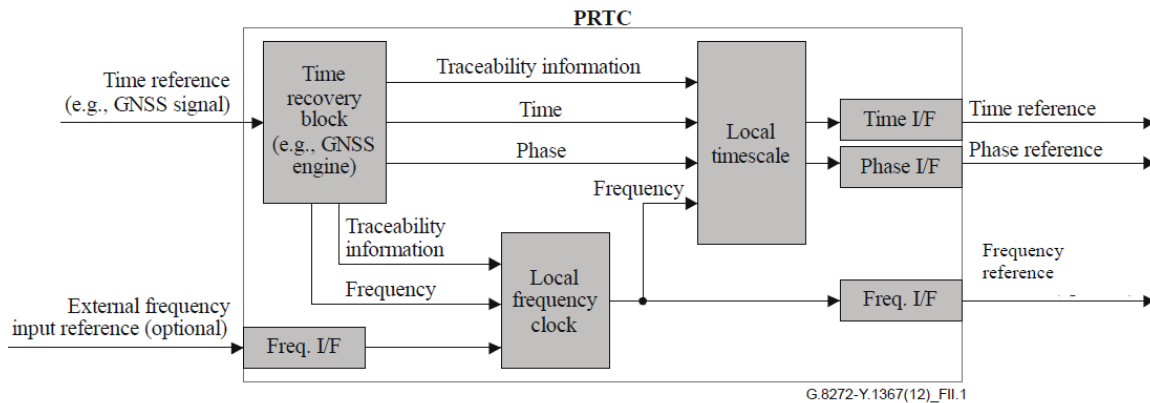
- IEEE 1588-2008 – IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.
- IEEE 1588-2019 – IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.
- ITU-T G.703 Amendment 1 2021 – Physical/Electrical Characteristics of Hierarchical Digital Interfaces.
Download here: <https://www.itu.int/rec/T-REC-G.703-202105-I!Amd1/en>
- ITU-T G.812 2004 – Timing requirements of slave clocks suitable for use as node clocks in synchronization networks. Download here: <https://www.itu.int/rec/T-REC-G.812-200406-I>
- ITU-T G.8272 Amendment 2 2022 – Recommendation ITU-T G.8272/Y.1367 (2018) Amd. 2 (11/2022), Timing characteristics of primary reference time clocks.
Download here: <https://www.itu.int/rec/T-REC-G.8272-202211-I!Amd2>
- Calnex Application Note CX5009 - Managing the Impact of Cable Delays
Download here: <https://calnexsol.com/en/resources/knowledge/techlib/timing-and-sync-lab>
- Calnex Paragon-neo Getting Started Guide. The guide is provided with Paragon-neo document set or download here: <https://calnexsolutions.atlassian.net/wiki/spaces/KB/pages/28508216/User+Guides>

IEEE standards are available for purchase at <https://www.techstreet.com/ieee>.

2 PRTC Overview

A Primary Reference Time Clock provides the reference signals for time, phase and frequency synchronization for other clocks within a network or section of a network. Typically, the PRTC provides the reference signal to a T-GM that generates a PTP signal into the network and often the PRTC and T-GM are integrated into a single device. PRTC time signals are traceable to a recognized time standard (e.g., coordinated universal time UTC). UTC can be obtained from a UTC time laboratory or, more commonly, from a global navigation satellite system.

The diagram below from G.8272 Amendment 2 illustrates the logical components of a PRTC. When integrated with a T-GM, the T-GM will use the time, phase and frequency outputs from the PRTC to generate a PTP signal for use in the network. In this case, the PRTC + T-GM will have a network connection (usually Ethernet) in addition to ToD, 1PPS and frequency outputs. A Synchronous Ethernet network connection allows one port to supply both frequency and PTP time into the network.



In addition, a PRTC may include an input frequency interface to help the PRTC maintain time during GNSS outages, i.e. extend the phase/time holdover period of the clock.

Please refer to the ITU G.8272 Amendment 2 document listed in section 1.3 for further details of PRTC operation and timing requirements. When G.8272 Amendment 2 was published in 2022, it superseded G.8272 and G.8272 Amendment 1. G.8272 Amendment 2 introduced holdover performance specifications and clarified PRTC details from G.8272 and G.8272 Amendment 1.

The tests in this test guide assume that the device under test is an integrated PRTC + T-GM with the following outputs: Synchronous Ethernet carrying a PTP signal, 1PPS, ToD and a 1.544/2.048/10MHz frequency. The PTP signal is assumed to comply with the G.8275.1 profile for full timing support in a telecoms network or G.8275.2 profile for partial timing support in a telecoms network. Some PRTCs output a subset of the signals assumed in this test guide.

The focus in this test guide is testing PRTCs that are used in telecommunications networks compliant to the ITU-T standards. Other industries use similar synchronization networks and equipment that have their own standard requirements. Testing PRTC devices for these applications follows the same steps as testing a telecom PRTC but you will need to apply the relevant requirements and test limits.

2.1 PRTC Time Error in Locked Mode (G.8272 Amendment 2 Clause 6.1)

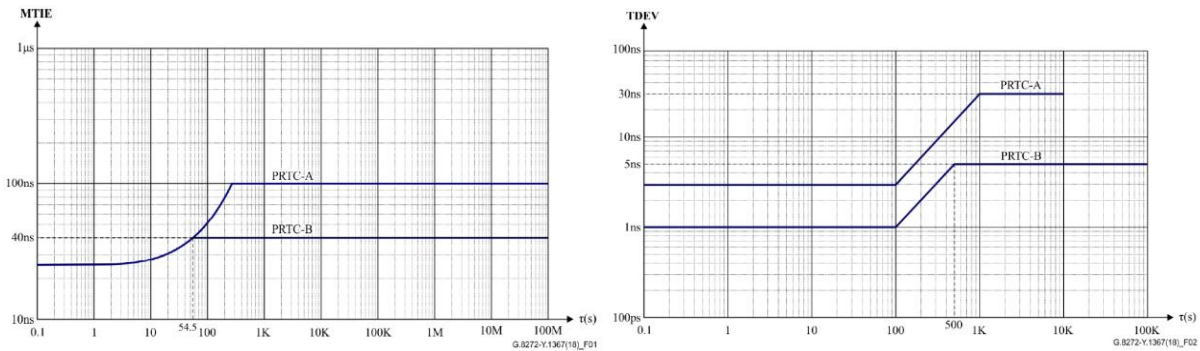
G.8272 Amendment 2 defines two classes of PRTC: PRTC-A and PRTC-B. The PRTC-B time accuracy requirements are stricter than those for PRTC-A devices.

Device	Accuracy to a primary reference standard (e.g. UTC)
PRTC-A	within 100ns
PRTC-B	within 40ns

The CAT tool will be used to analyze PRTC time error measurements and apply accuracy thresholds.

2.2 PRTC Wander in Locked Mode (G.8272 Amendment 2 Clause 6.2)

G.8272 Amendment 2 specifies the stability of the PRTC in terms of wander generation MTIE and TDEV as shown in the graphs below. The MTIE and TDEV requirements apply to all outputs of the PRTC, including SyncE frequency and the PTP signal when a PRTC and T-GM are integrated into a single device.



The CAT tool will be used to analyze PRTC wander generation measurements and apply MTIE and TDEV masks.

2.3 PRTC Jitter in Locked Mode (G.8272 Amendment 2 Clause 6.3)

Jitter performance is not specified in G.8272 Amendment 2, it is listed as a future study topic.

2.4 PRTC Wander in Holdover (G.8272 Amendment 2 Clause 7)

G.8272 Amendment 2 includes an optional specification for holdover time error performance when a PRTC loses its reference. G.8272 Amendment 2 refers to G.812 clause 11.2 where limits are defined for clock types I, II and III. The CAT tool will be used to analyze PRTC holdover performance.

3 Using a GNSS Simulator

ITU-T G.8272 Amendment 2 Appendix I.3.3 proposes that PRTC testing may use a GNSS simulator. Calnex strongly recommends that a GNSS simulator is used when testing a PRTC because a simulator provides an accurate and repeatable GNSS test signal to the device under test. A simulator also allows testing under different circumstances, for example:

- Worldwide locations away from test labs.
 - At high latitude locations. GNSS satellites have equatorial orbits in latitudes 55°N to 55°S so there are no overhead satellites at higher latitudes.
 - With attenuated and reflected RF signals to simulate different RF receiver conditions.
 - With varied simulated atmospheric and ionospheric conditions that mimic real-world conditions.
 - Operation with alternate and regional GNSS systems.
- Specific GNSS settings (location, time/date, signal attenuation, multipath effects, etc) must be chosen by equipment vendors to validate equipment across all locations and environments where the PRTC will be deployed. Such details are not specified in the ITU-T standards.

Long duration tests should run for at least 24 hours to allow a complete diurnal cycle and two 12-hour satellite cycles.

3.1 GNSS Simulator Requirements

The GNSS simulator should generate GNSS RF signals mimicking all the various GNSS systems where the PRTC under test is intended to operate. In addition to the GNSS RF signal, the GNSS simulator should output Time of Day and 1PPS signals and a 10MHz clock from which to reference Paragon-neo.

The GNSS simulator should output an unbalanced 1PPS electrical signal, ToD should be RS422 (or TOD may be RS232 if the Option 133 converter is available).

Some GNSS simulators use an external reference frequency (e.g. 10MHz) to assist with stability during for long duration tests. If used, the reference frequency must be an order of magnitude more accurate and stable than the PRTC is expected to maintain.

4 Paragon-neo Hardware and Software Requirements

Either Paragon-neo NRZ or Paragon-neo PAM4 test instruments may be used to test PRTC and PRTC + T-GM devices. Paragon-neo PAM4 is a superset of Paragon-neo NRZ with the addition of PAM4 high-speed Ethernet interfaces.

Paragon-neo software version 11.00.xx and later can be used. Calnex recommends updating test instruments to the latest available software before running equipment conformance tests.

The table below lists the Paragon-neo NRZ and Paragon-neo PAM4 options relevant to testing a PRTC or PRTC + T-GM device:

Opt. NEO-1G-10G Opt. NEO-25G Opt. NEO-40G Opt. NEO-50G Opt. NEO-100G	NRZ optical interface options.	At least one of these options must be fitted.
Opt. NEO-A-50G Opt. NEO-A-100G Opt. NEO-A-200G Opt. NEO-A-400G	PAM4 optical interface options.	
Opt. NEO-SyncE-Wander	SyncE Wander and ESMC test to ITU-T G.8262.1 and G.8262, including MTIE and TDEV analysis.	If the PRTC has SyncE interfaces.
Opt. NEO-PTP-G.8275.1	Emulation of G.8275.1 PTP timeTransmitter and timeReceiver devices, with associated Time Error Impairment and measurement capability.	At least one of these options must be fitted.
Opt. NEO-PTP-G.8275.2	Emulation of G.8275.2 PTP timeTransmitter and timeReceiver devices, with associated Time Error Impairment and measurement capability.	
Opt. NEO-E1-T1-Wander-Meas	High accuracy frequency measurement of E1 and T1 clock signals.	If the DUT has E1 or T1 interfaces.
Opt. NEO-ToD	Enables the generation, capture, and decode of time-of-day (CCSA, G.8271 and NME formats supported) on a balanced 1PPS+ToD output from a DUT.	
Opt. NEO-PFV	Enables PFV. Decodes PTP Message Fields captured with Paragon-neo and compares values for Pass/Fail to standards or user-defined parameters. Evaluate to IEEE1588, ITU-T G.8265/8275.1/8275.2/CCSA.	
Opt. 133	1PPS/ToD/Frequency Converter	If required to convert ToD RS232 to RS422.

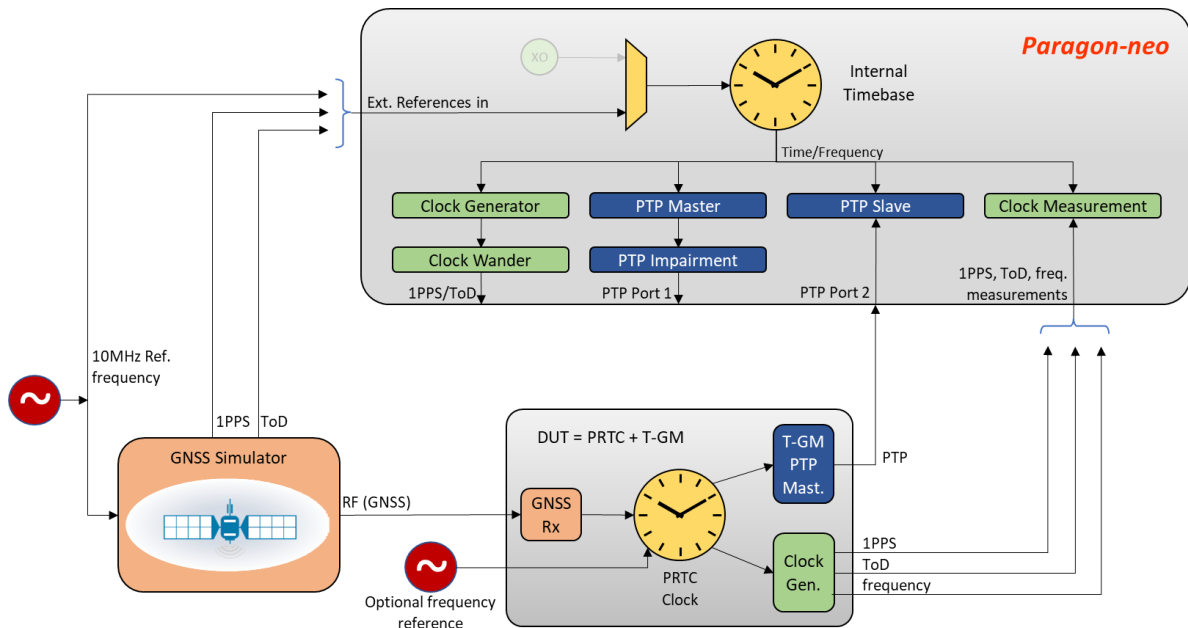
Note: 1PPS wander measurement is included in the base functionality of Paragon-neo.

Some or all the following items are needed to connect Paragon-neo to the relevant ports of the PRTC + T-GM or PRTC device under test:

- Optical Transceivers as required.
- Optical fibers and Ethernet cables as required.
- BNC and RJ-45 ToD+1PPS cables.
- E1/T1 RJ48 cables.

5 Connecting Paragon-neo to the PRTC

Connect the GNSS simulator, PRTC and Paragon-neo as shown below. Details of the Paragon-neo connector locations are given in the Paragon-neo Getting Started Guide.



1. Connect GNSS simulator RF output to the PRTC / PRTC + T-GM under test.
2. Connect Paragon-neo 10MHz reference input, either from the shared 10MHz reference or the GNSS simulator 10MHz output. Connect GNSS simulator unbalanced 1PPS and RS422 ToD reference output signals to Paragon-neo reference inputs. This ensures that the PRTC and Paragon-neo share a common source of frequency and time to avoid them drifting apart.
3. Connect the PRTC + T-GM Ethernet output to Paragon-neo port 2.
4. If SyncE is present, enable SyncE operation on the PRTC + T-GM Ethernet output so that Paragon-neo can monitor the SyncE frequency.
5. Connect the PRTC unbalanced 1PPS, RS422 ToD and frequency outputs to the Paragon-neo.
6. Note the precise cable lengths of all reference and measurement cables. These cable lengths will be needed when configuring the PRTC and Paragon-neo.

Calnex recommends the use of unbalanced 1PPS reference and measurement signals to ensure the most accurate measurements. An Option 133 converter unit may be used to convert RS232 to RS422 for the ToD signals if required.

5.1 Cabling

All cables should be kept as short as possible (less than 3m recommended) to ensure good signal integrity and timing accuracy:

- 1PPS and ToD reference cables should be short. The 1PPS reference cable delay will be compensated using the **1PPS Reference cable compensation (ns)** parameter in section 6.2 step 4.
G.703 Amendment 1 section 19 specifies ToD and 1PPS cable lengths and impedances.
- The 10MHz reference cable should be short to ensure that the high-speed clock signal edges are not degraded. G.703 Amendment 1 section 20 specifies 10MHz signal characteristics.
- The RF cable between GNSS simulator and PRTC must be in accordance with the GNSS simulator and PRTC requirements.

- Delay through the PTP Ethernet cable (or fiber optic) will be compensated using the **DUT Ethernet cable compensation Port 2 (ns)** parameter in section 6.2 step 4. The Ethernet fibers must be the same length for transmit and receive so as not to introduce asymmetry to the timing.
- 1PPS, ToD and frequency measurement cables should be short. 1PPS measurement cable delay will be compensated using the **1PPS cable compensation** parameter in section 6.3 step 9.
- Typical cable compensation values are 5.1ns/m for electrical cables and 4.9ns/m for fiber optics.

Please refer Calnex Application Note CX5009 *Managing the Impact of Cable Delays* for further details.

6 Configure Paragon-neo and Verify Operation

This section describes how to configure Paragon-neo for the PRTC test and verify test operation.

The steps and example screenshots in this section describe the complete set of measurements that Paragon-neo can run against a PRTC + T-GM device (1PPS, ToD, frequency, PTP and SyncE). Please ignore any steps that are not relevant to the PRTC + T-GM under test.

During configuration, the 1PPS reference signal will be connected from the GNSS simulator to Paragon-neo, and the 1PPS measurement signal from the PRTC under test to Paragon-neo. The Paragon-neo 1PPS reference and measurement ports can input either balanced or unbalanced signals depending on the output of the GNSS simulator and the PRTC under test. Calnex recommends using unbalanced 1PPS signals whenever possible to ensure best accuracy measurements.

6.1 Setup Paragon-neo ports

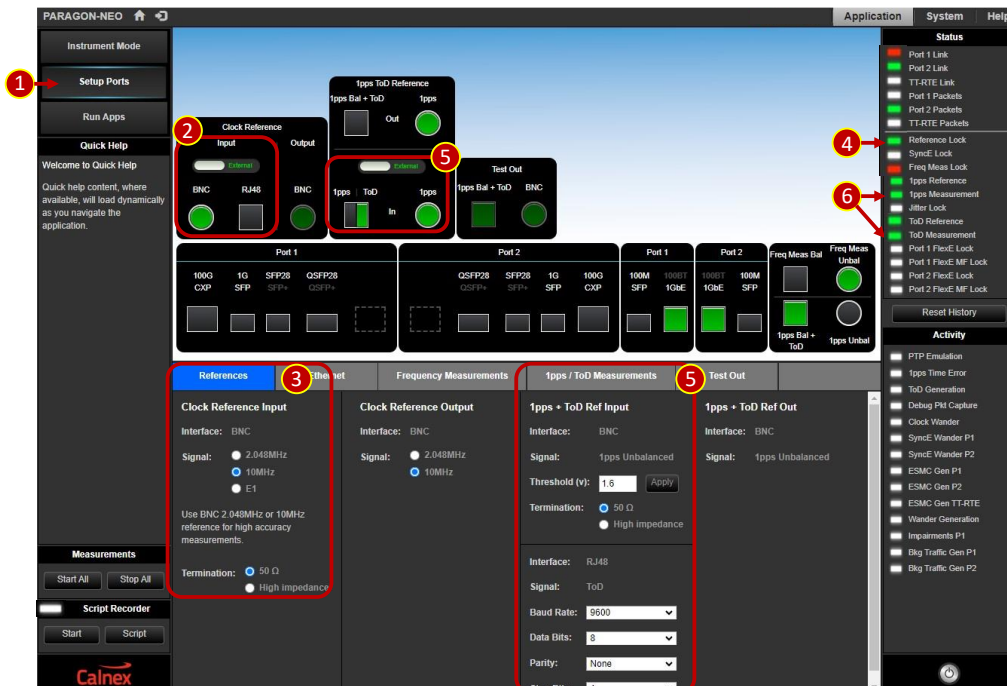
1. Click Setup Ports to show the port configuration GUI.
2. Set Paragon-neo **Clock Reference** to use an External source from either the BNC or RJ48 port.
3. Click the **References** tab, set the 10MHz reference clock frequency and set termination to 50Ω or High Impedance.
4. Check that the **Reference Lock** LED shows green to indicate a good reference signal is present.
5. Configure the 1PPS and ToD reference inputs for input from the GNSS Simulator.

Calnex recommends driving the BNC 1PPS reference port with an unbalanced signal for best accuracy, otherwise connect a balance 1PPS reference signal to the RJ48 port. The ToD reference signal is always an RS422 signal connected through the RJ48 port.

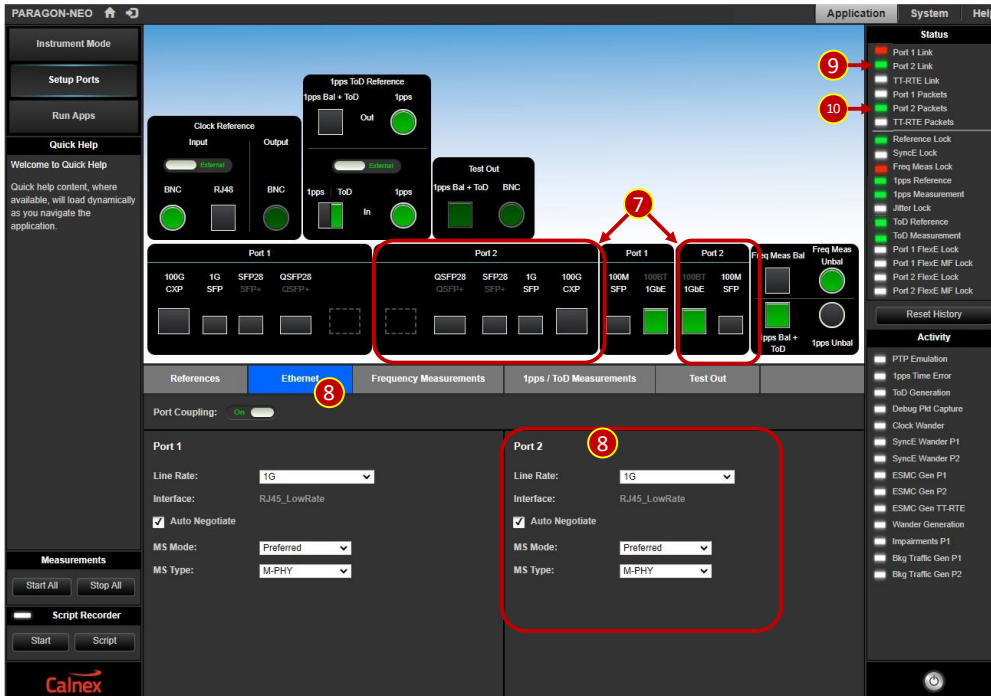
Configure the ToD Reference port parameters (baud rate, etc).

The screenshot below shows how the ToD and 1PPS are configured when an unbalanced 1PPS signal is used.

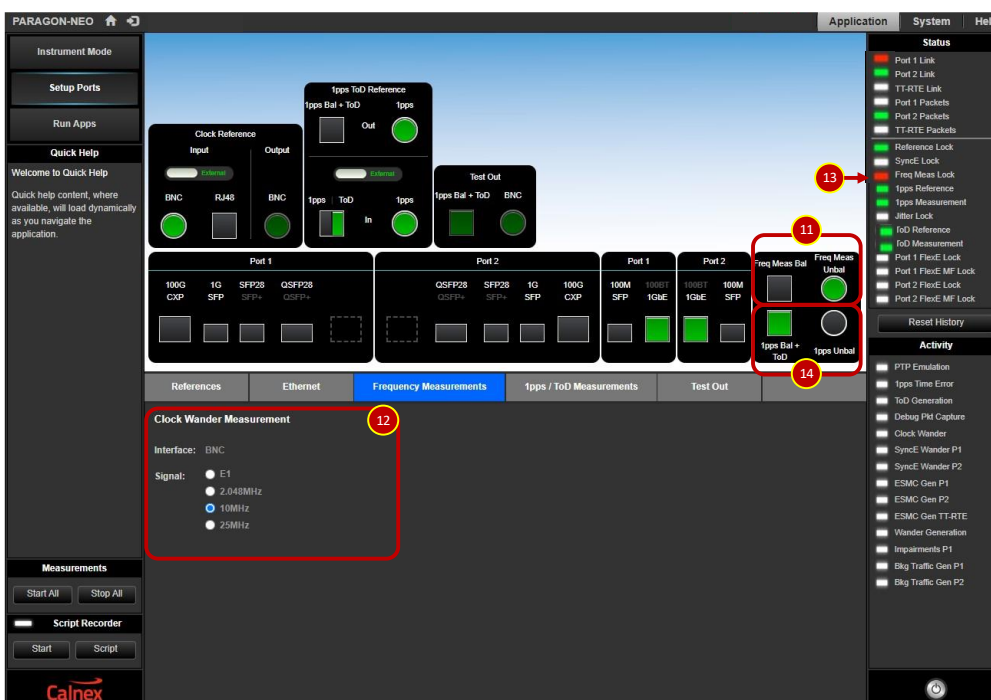
6. Check that the **1PPS Reference** and **ToD Reference** LEDs show green to indicate good reference signals are present.



- Set the Paragon-neo Ethernet **Port 2** connector to match the connection to the PRTC + T-GM.
- Configure Port 2 Ethernet settings to match the connection to the PRTC + T-GM. The example screenshot shows a 1000Base-T connection.
- Check that the **Port 2 Link** LED shows green to indicate a physical layer connection.
- If the PRTC + T-GM is already sending PTP packets, the **Port 2 Packets** LED will show green.



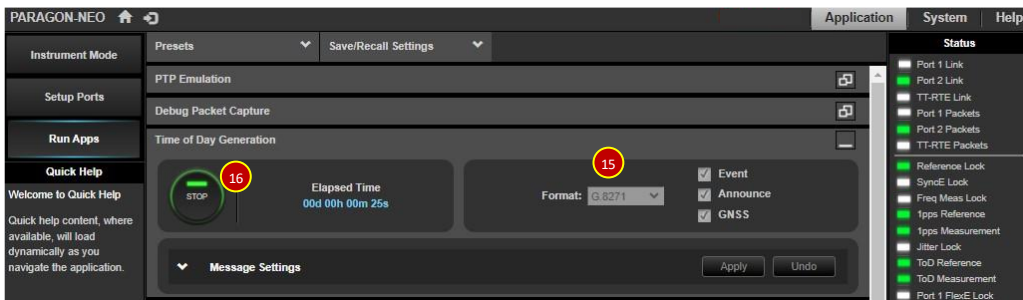
- To measure the PRTC frequency output, select the Paragon-neo **Freq Meas Bal** or **Freq Meas Unbal** port.
- Select the clock frequency that the PRTC outputs.
- Check that the **Freq Meas Lock** LED shows green to indicate the PRTC frequency output signal is detected by Paragon-neo. The example screenshot below shows that the Paragon-neo had not locked to the frequency output of the PRTC under test.



- Select either the Paragon-neo **1PPS Bal + ToD** or **1PPS Unbal** measurement port depending on the connections available on the PRTC. Calnex recommends that 1PPS time error measurements are made using the **1PPS Unbal** port if the PRTC has an unbalanced 1PPS output. ToD measurements are only available using the **1PPS Bal + ToD** port.

ToD message format on the measurement port is automatically detected.

- In the **Run Apps** GUI, set Paragon-neo time-of-day message **Format** in the **Time of Day Generation** panel to match the messages that the PRTC transmits. The time-of-day **Message Settings** are not needed during PRTC tests, just set the **Format**.
- Click the **Time of Day Generation** start button. The button illuminates green and changes to a Stop button. Time-of-day generation must be started before making time-of-day measurements even through the Paragon-neo time-of-day output is not connected in these tests.



- Configure the ToD serial port to match the PRTC ToD output.
- Check that the **1PPS Measurement** and **ToD Measurement** LEDs show green to indicate that Paragon-neo has detected 1PPS and ToD signals from the PRTC. The example screenshot below shows that Paragon-neo has detected both a 1PPS signal and a ToD signal from the PRTC.



6.2 Configure PTP Emulation for PRTC + T-GM Test

1. Click **Run Apps** to show the Paragon-neo PTP and measurements applications GUI.
2. Open the **Presets** tab and click on the **PTP** test icon. Close the **Presets** tab.



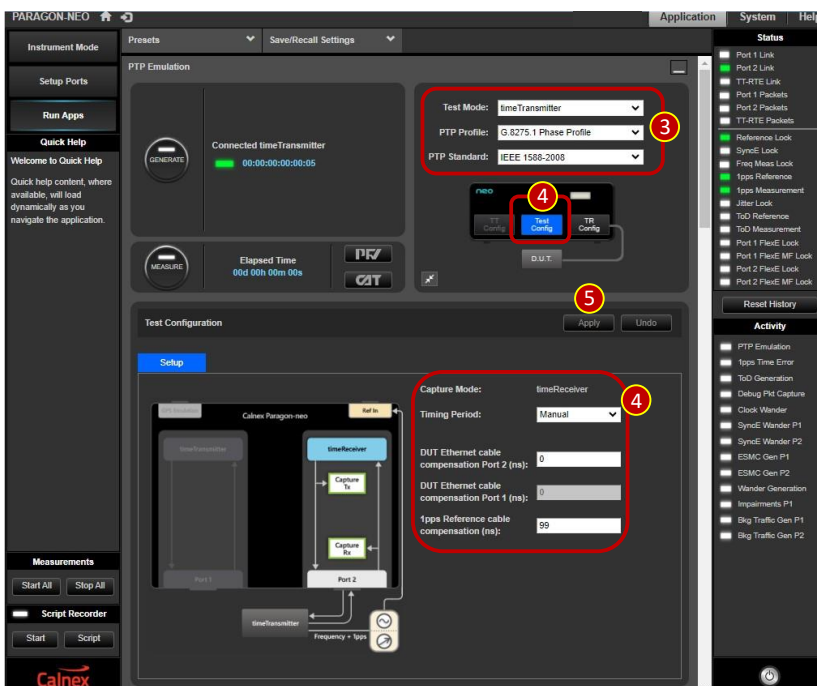
3. In the **PTP Emulation** section of the GUI –
 - set **Test Mode** = **timeTransmitter**,
 - select a **PTP Profile** from the drop-down list to match the PTP profile that the PRTC + T-GM runs,
 - select the **PTP Standard** to IEEE 1588-2008 or 1588-2019 to match the standard that the PRTC + T-GM runs.
4. Click the **Test Config** icon and enter compensation times for the Ethernet cable connected between the PRTC + T-GM and Paragon-neo port 2, and the 1PPS reference cable.

The **DUT Ethernet cable compensation Port 2(ns)** parameter can be used to compensate any known asymmetry in the cable between the PRTC and Paragon-neo (e.g. optic fiber has a repair spliced into transmit or receive path).

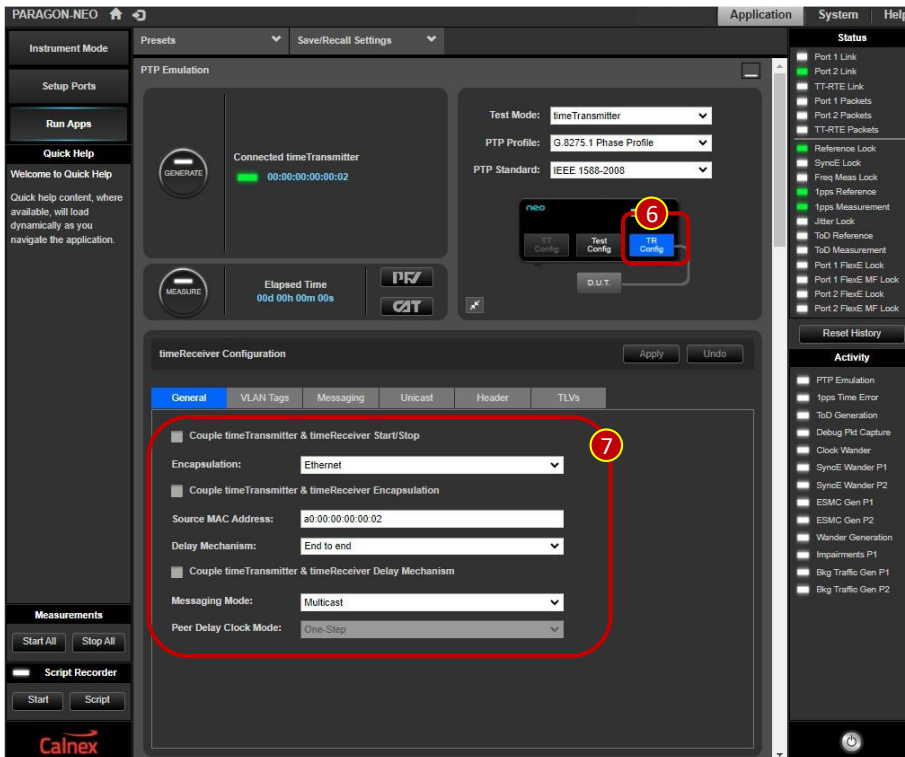
Delay through the 1PPS reference connection between the GNSS simulator and Paragon-neo must be compensated for using the **1PPS Reference cable compensation** parameter. This compensation time must be accurate to avoid any offset between Paragon-neo and the PRTC under test (i.e. constant time error).

The **Timing Period** can be set to automatically end the test after some hours if required (default is that test runs must be stopped manually).

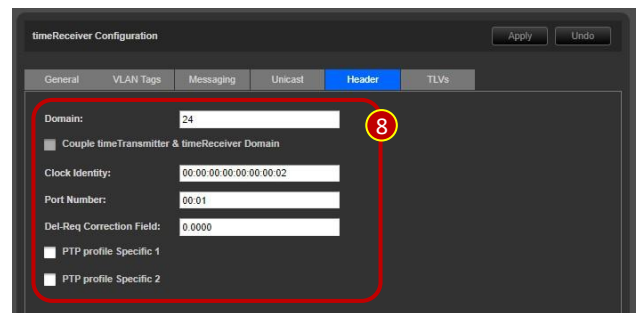
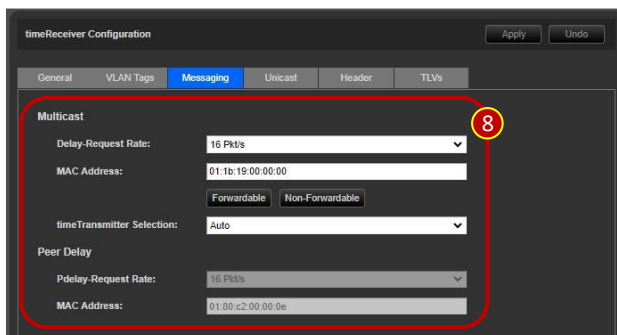
5. Click the **Apply** button.



- Click the **TR Config** icon to open the Paragon-neo **timeReceiver Configuration** panel where PTP parameters are configured to match the PRTC + T-GM.
- The example screenshot below shows the timeReceiver **General** configuration tab and the default settings for when using the G.8275.1 PTP Profile.



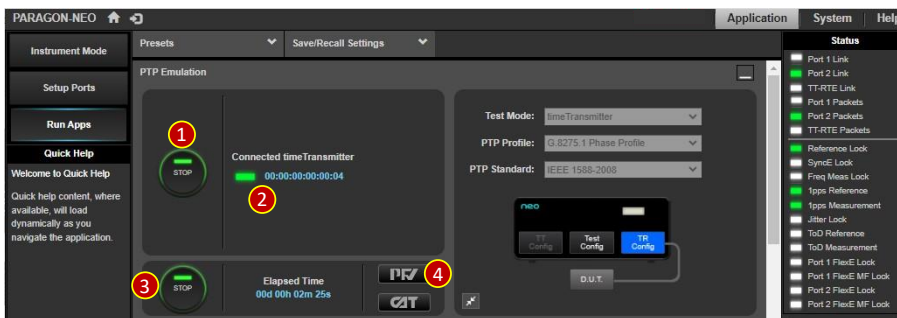
- Other timeReceiver configuration parameters can be set in the **VLAN Tags**, **Messaging**, **Unicast**, **Header** and **TLVs** tabs depending on the PTP profile that the PRTC + T-GM uses. The two example screenshots below show the G.8275.1 message rates and multicast MAC address used, and the Domain, Clock Identity and Port Number.



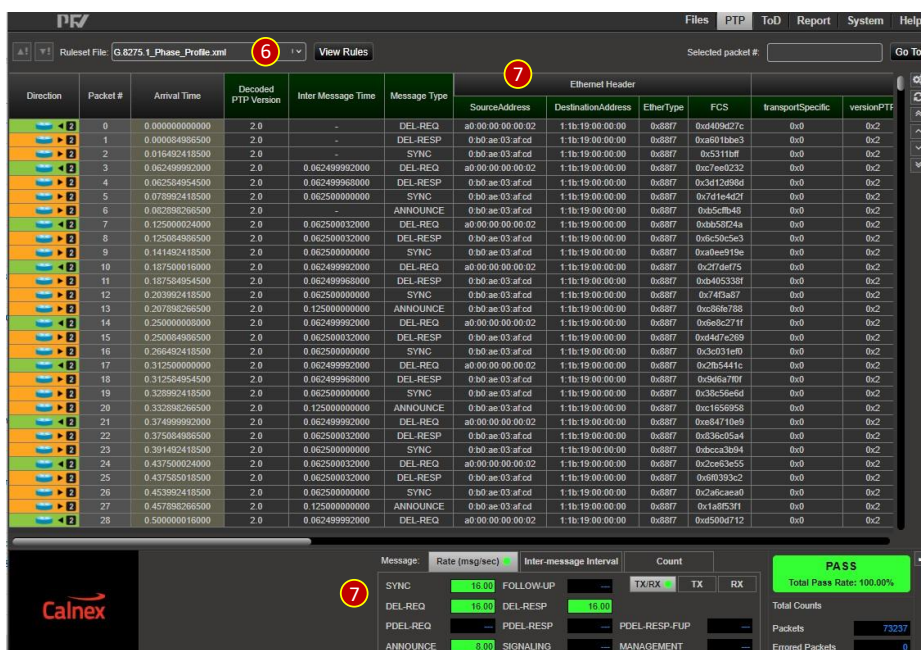
6.3 Verify Operation of PRTC and Paragon-neo

Before running long duration tests on a PRTC, a short test run will verify that the connections are correct, Paragon- neo and PRTC + T-GM are interoperating, and there are no significant timing errors.

1. In the Paragon- neo **Run Apps** GUI, click the PTP Emulation **Generate** button. The button illuminates green to show that the PTP timeReceiver in Paragon- neo is running and changes to a **Stop** button.
2. Check that Paragon- neo has connected to the PRTC + T-GM timeTransmitter. The T-GM address will be displayed, and the **Port 2 Packets** LED will show green.
3. Click the PTP **Measure** button. The button illuminates green to show that a PTP measurement is underway and changes to a **Stop** button.
4. Click the **PFV** button. A PFV window will open in your browser.



5. In the PFV browser window, check that the PTP profile used by the PRTC + T-GM conforms to the required PTP Profile.
6. Select the PFV **Ruleset** (G.8275.1 in the example screenshot below).
7. Check that there are no fields highlighted red indicating protocol or profile errors. Fields of each message are displayed across the screen (horizontal scroll to see all the fields). The bottom of the screen shows the result of checking the message rates. The example screenshot shows no protocol or profile errors.
8. Errors flagged in PFV should be fixed before continuing to run performance tests.

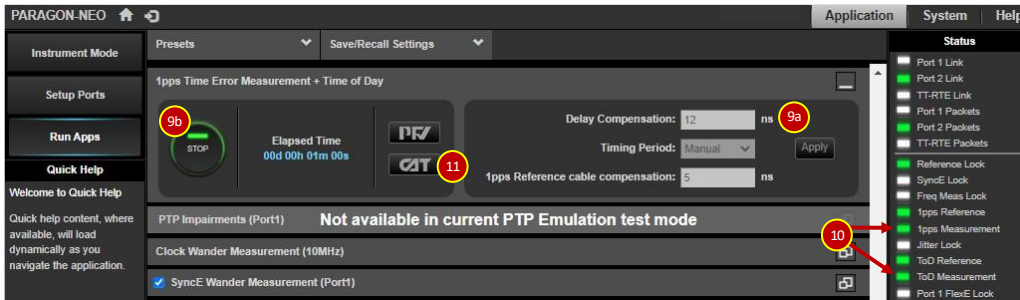


9. Configure and start 1PPS measurements:

- a) Enter compensation for the 1PPS measurement cable in the **Delay compensation** field and click **Apply**. This compensation time must be accurate to avoid any offset between Paragon-neo and the PRTC under test (i.e. constant time error).
- b) Click the 1PPS **Measure** button. The button illuminates green to show that a 1PPS measurement is underway and changes to a **Stop** button.

10. Check that the **1PPS Measurement LED** and **ToD Measurement LED** are green to indicate good measurements.

11. Click the **CAT** button. A CAT window will open in your browser.



12. In the CAT browser window, check PTP and 1PPS timing performance.

13. When CAT first opens, default time error limits of $\pm 1.5\mu\text{s}$ are applied to the PTP and 1PPS time error measurements. Disable the limits by unchecking the **Dynamic TE Limit +/-** checkboxes and clicking the relevant **Apply** button.

14. The CAT screenshot below shows that the PRTC + T-GM under test had not been configured accurately –

- a) The PTP signal shows a two-way time error of approximately -80ns.
- b) The 1PPS signal shows a time error between 5 and 20ns.

Some settings in the PRTC + T-GM configuration were found to be incorrect during this verification run and corrected before running long duration tests.



15. Leave the verification test running for 1000sec or 1hr to ensure that the test system is stable and running correctly.

16. Stop the verification test by clicking the green 1PPS and PTP measurement **STOP** buttons. Click the green PTP Emulation **STOP** button.

7 PRTC Locked Mode Performance Test (G.8272 Amendment 2 Clause 6)

G.8272 Amendment 2 defines PRTC performance requirements when the PRTC is locked to its incoming GNSS signal, but the standard does not define test conditions.

To test the full utility of the PRTC, the following simulated GNSS scenarios are recommended at a minimum –

- GNSS ideal conditions.
- GNSS emulating a high latitude location (higher than 60°N or 60°S).
- GNSS degraded signal (low satellite strength, high multipath, low number of satellites in view).
- Leap Second (leap second handling is vendor dependant and may cause steps that exceed MTIE/TDEV masks).

The steps in section 7.1 should be followed for each GNSS scenario run. Calnex recommends that each locked mode test should last at least 24 hours, the longer the better.

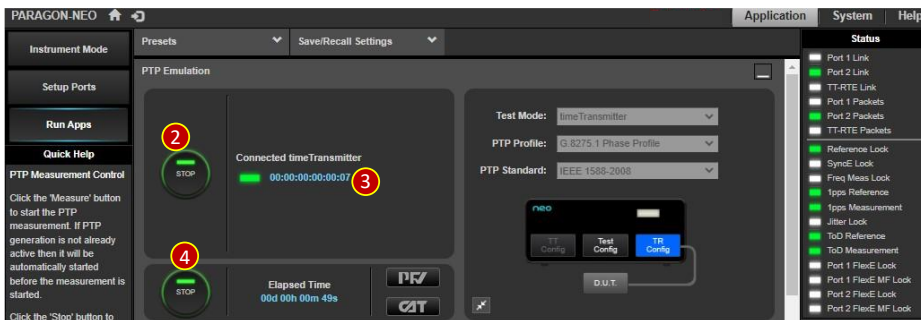
Time error and wander generation requirements for PRTC-A and PRTC-B devices in locked mode are summarised in the table below and detailed in sections 2.1 and 2.2. CAT includes pre-set time error thresholds and MTIE/TDEV masks for wander generation that will be used to verify PRTC performance when locked to an incoming reference signal.

Metric	PRTC-A	PRTC-B
Time Error	within 100ns	within 40ns
Wander Generation MTIE		
Wander Generation TDEV		

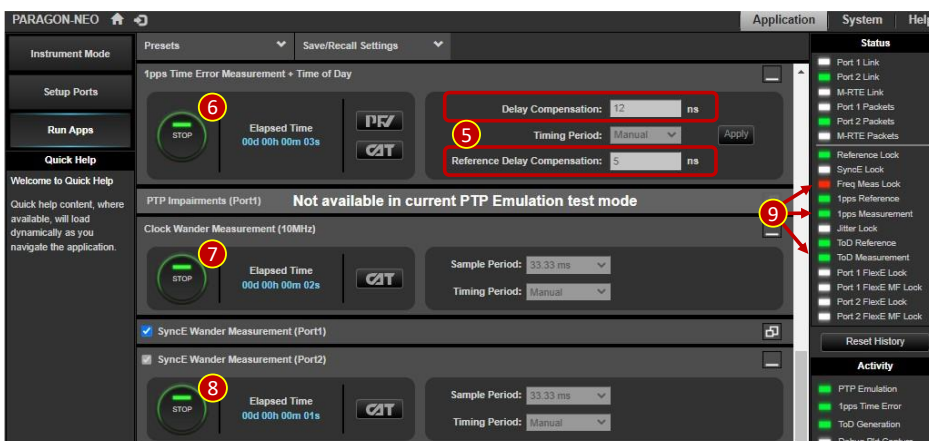
7.1 Test Steps

The descriptions below start all measurements – PTP, 1PPS, SyncE wander, frequency, and ToD. Please ignore any measurement steps for signals that the PRTC + T-GM under test does not output.

1. Setup the GNSS simulator as required, start the test scenario, and allow the PRTC + T-GM to synchronize to the new GNSS signal. Settling time is equipment specific.
2. In the Paragon-neo **Run Apps** GUI, click the PTP Emulation **Generate** button. The button illuminates green to show that the PTP timeReceiver in Paragon-neo is running and changes to a Stop button.
3. Check that Paragon-neo has connected to the PRTC + T-GM – the **Connected timeTransmitter** address will be displayed with a green indicator.
4. Click the PTP **Measure** button. The button illuminates green to show that a PTP measurement is underway and changes to a Stop button.



5. In the **1PPS Time Error Measurement + Time of Day** panel, the **1PPS Reference cable compensation** value was set during the verification test to compensate for the signal delay through the 1PPS measurement cable.
 Note: Time of Day Generation must be running for Time of Day measurement to be taken. Time of Day generation was previously enabled while configuring the ToD port in section 6.1.
6. Click the **1PPS Time Error Measurement MEASURE** button to start the 1PPS measurement. The button illuminates green to show a measurement is running and changes to a Stop button.
7. Click the **Clock Wander Measurement MEASURE** button to start the clock wander measurement. The button illuminates green to show a measurement is running and changes to a Stop button.
8. Click the **SyncE Wander Measurement (Port 2) MEASURE** button to start the SyncE wander measurement. The button illuminates green to show a measurement is running and changes to a Stop button. The default SyncE Sample Period of 33.33ms is a good balance between measurement accuracy and collecting more measurements than needed.
9. Check the measurement status LEDs. In the example screenshot below, the **Freq Meas Lock** LED is red because the PRTC under test was not outputting a 10MHz frequency signal.



10. While the test is running, click one of the **CAT** buttons in the GUI to see the results live.



11. Either manually stop the test by clicking the green measurement **STOP** buttons or allow the test to run to completion if you configured an automatic test duration.

Paragon-neo saves all test measurements in session files that CAT accesses live during a test run, or after a test run has completed. Additional memory is consumed in Paragon-neo when CAT displays the measurement data live. If the allocated memory fills during a multi-day test run, CAT stops updating the live display. No data is lost when this occurs, the measurement data is continually saved into session files that can be imported into CAT after the test has ended. Alternately, Remote CAT Live may be used to visualise live measurement results when Paragon-neo stops updating the live CAT display (refer to the Paragon-neo Getting Started Guide for details).

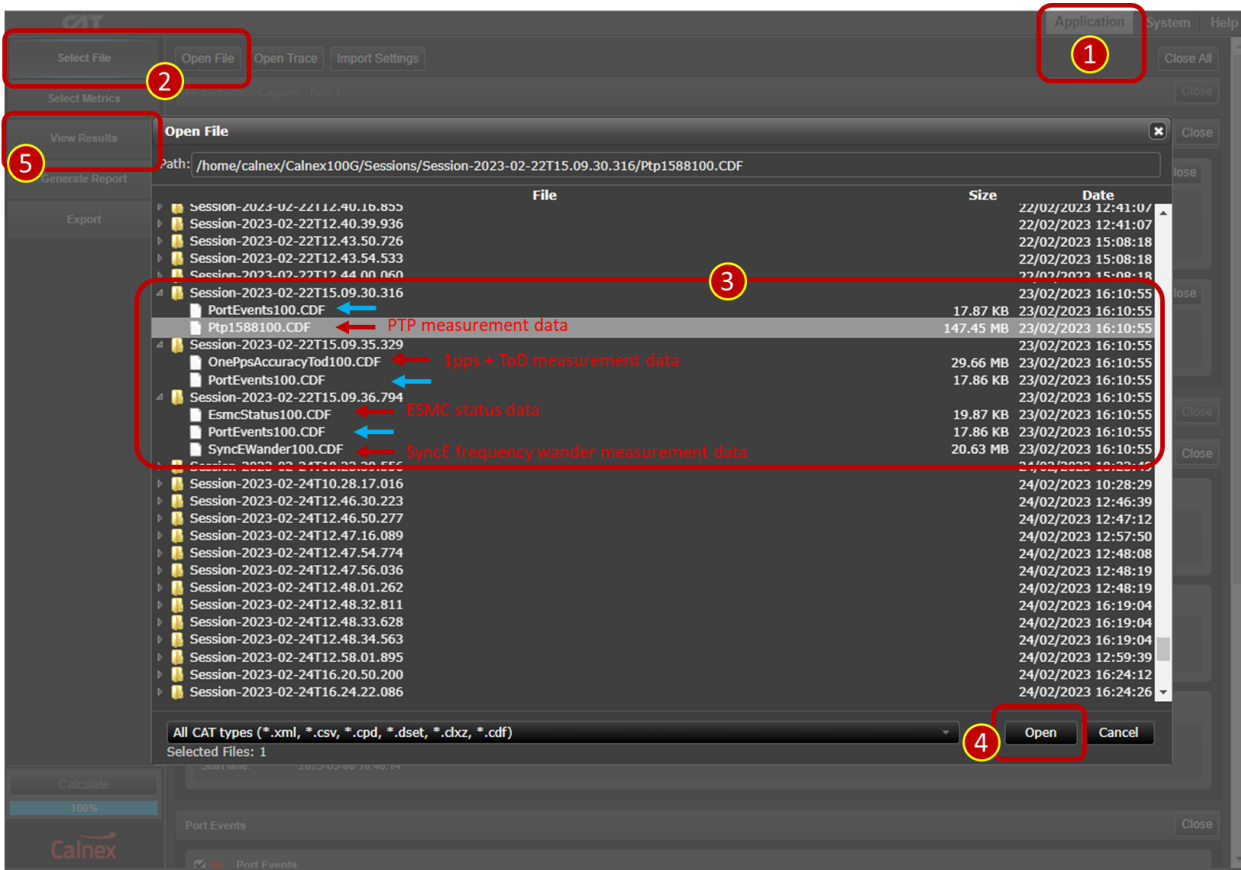
After stopping the test, session files can be copied from Paragon-neo and saved elsewhere if required.

7.2 Analyzing Test Results

Session files can be opened in CAT as follows:

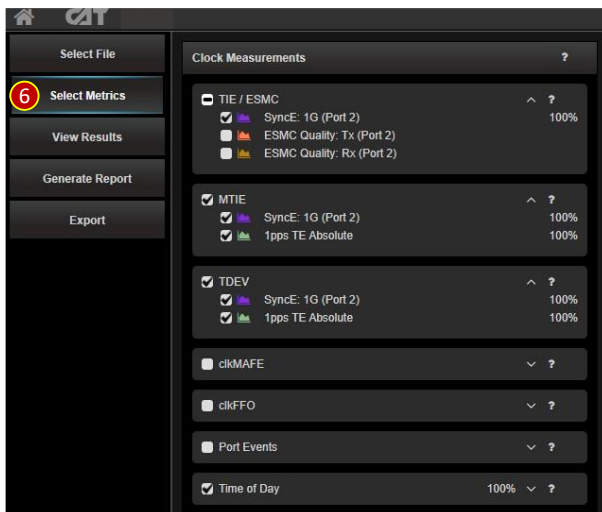
1. Open the CAT browser window at the **Application** GUI.
2. Click **Select File** then click **Open File** to show file list.
3. Select the relevant session file(s). The example screenshot below shows measurement session files captured during a 25-hour test.
 - Session files are stored in folders where the folder name includes the date and start time of the measurement. In this example, measurements were started a few seconds apart so there are multiple session files.
 - Each session folder contains one or more data files (red arrows) and one Port Events file (blue arrows). The session file filenames include the measurement type.
 - You only need to select one of the port events files. These files record the port state through the whole test duration.
 - Multiple session files are created when tests are started sequentially. The example screenshot shows that PTP measurement started first, followed by 1PPS + ToD measurements and finally the SyncE measurement. The three session files all pertain to the same 25-hour test.

- Click **Open**.
- Click **View Results** and CAT display the measurement results.



- Click **Select Metrics** and select required metrics for analysis. Useful metrics are:

Time Error – Two-way Time Error and 1PPS TE Absolute
 Time of Day
 TIE – SyncE
 MTIE – SyncE and 1PPS TE Absolute
 TDEV – SyncE and 1PPS TE Absolute
 Packet MTIE and Packet TDEV for Sync packets



7. Click **View Results**, select the **Time Error** tab and apply Time Error thresholds. Change the default time error limits from $\pm 1.5\mu\text{s}$ as required for the class of PRTC under test:

PRTC-A 100ns

PRTC-B 40ns

Click **Apply** after changing the limits.



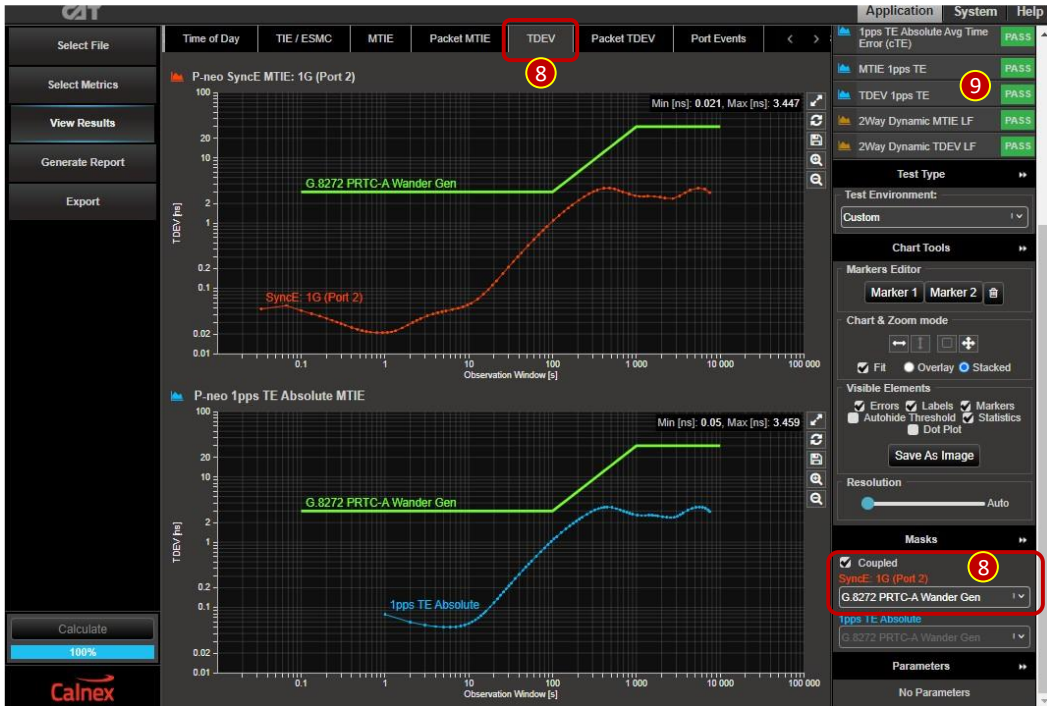
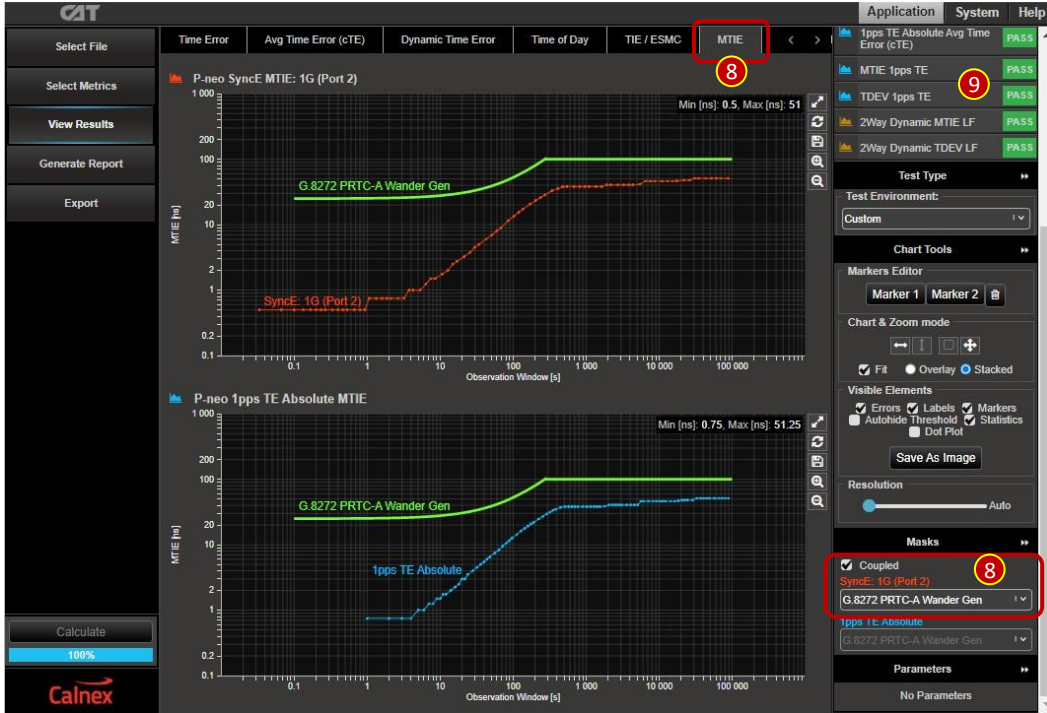
- Click **View Results**, select the **MTIE** and **TDEV** tabs and apply MTIE and TDEV masks.

When MTIE and TDEV measurements are displayed, the bottom right corner of the CAT View Results GUI shows the **Masks** selection list. Select the relevant **PRTC-A Wander Gen** or **PRTC-B Wander Gen** mask from the list. Ticking the **Coupled** checkbox applies the same mask to both metrics shown on the GUI.

The screenshots below show examples of SyncE and 1PPS TE MTIE and TDEV measurements with the PRTC-A mask applied.

- Check Pass/Fail flags shown at the top right side of the screen.

Failing tests will show a red FAIL flag and the measurement trace in the graph will cross the threshold or mask line.

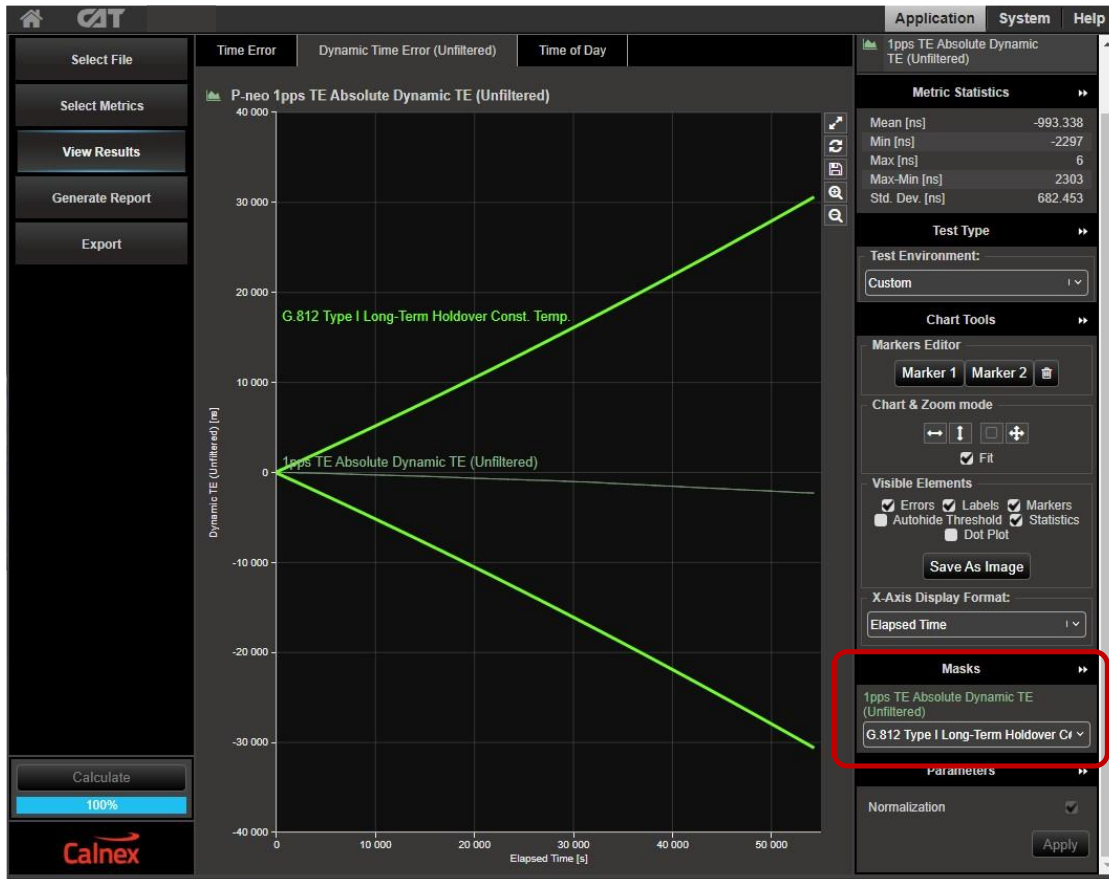


8 PRTC Holdover Mode Performance Test (G.8272 Amendment 2 Clause 7)

PRTC time error requirements during holdover are outlined in section 2.4 and reference G.812 clause 11.2. CAT includes pre-set time error masks following the G.812 clause 11.2 Type I and Type III Long Term Holdover at Constant Temperature specifications. These masks will be used to verify PRTC holdover performance.

Holdover tests are run following the same test steps as locked mode tests described in section 7.1 except that that the GNSS signal must be removed after the PRTC + T-GM has synchronized.

Holdover test results are displayed and analyzed in CAT following the same test steps as locked mode tests described in section 7.2 except that G.812 holdover mask must be applied to Sync Packet TIE, SyncE TIE and two-way unfiltered DTE. The example screenshot below shows 1PPS time error performance during holdover with a G.812 Type I mask applied.



9 Further Analysis Using CAT

The previous sections showed a selection of time measurement metrics displayed by CAT, many other metrics can be calculated and displayed as follows:

1. In the CAT browser window, click **Select Metrics** to show the list of metrics available.
2. Check or uncheck the individual test metrics from the list. The metrics are listed in groups that can be expanded by clicking the ▼ symbol.
3. Click the **Calculate** button to calculate metrics that show 0% in the metric list.
4. Click the ? symbol to show help related to any of the metrics.
5. Click the **View Results** button to return to the results GUI.

The screenshot shows the CAT software interface. On the left, the 'Select Metrics' panel is visible, with a 'Calculate' button at the bottom showing a progress bar at 74%. The main area displays the 'MTIE' help page. The help page includes the following information:

MTIE – Maximum Time Interval Error

Standards Reference
ITU-T Recommendation G.810 Appendix II (03/1996)

Estimation Formula
MTIE(nT_0) can be estimated by:

$$MTIE(nT_0) \approx \max_{1 \leq i \leq n} \left(\max_{k \leq j \leq k+n} x_j - \min_{k \leq j \leq k+n} x_j \right)$$

$n = 1, 2, \dots, N-1$

The above is a point estimate, and is obtained for measurements over a single measurement period - see Figure:

where:

- T_0 is the sample period;
- n is the number of samples in each observation interval;
- T is the observation interval, equal to nT_0 ;
- N is the total number of samples;
- T is the measurement period;
- kT_0 is the k -th time error sample;
- x_{ppk} is the peak-to-peak x_j within k -th observation;
- $MTIE(t)$ is the maximum x_{pp} for all observations of length t within T .

Frequency offset and drift
For observation intervals t where a constant frequency offset dominates, the $MTIE(t)$ behaves as t .
For observation intervals t where a linear frequency drift dominates, the $MTIE(t)$ is not theoretically bounded. From the measurement viewpoint this circumstance is expected to cause increasing value of estimated $MTIE(t)$ as the total observation time, (i.e. the length N of the x_j data) is increased.



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