APPLICATION NOTE

This document discusses the issues that must be considered when performing high accuracy Time Error measurements. It also offers some tips on how to ensure the uncertainty due to cable delays is minimised.

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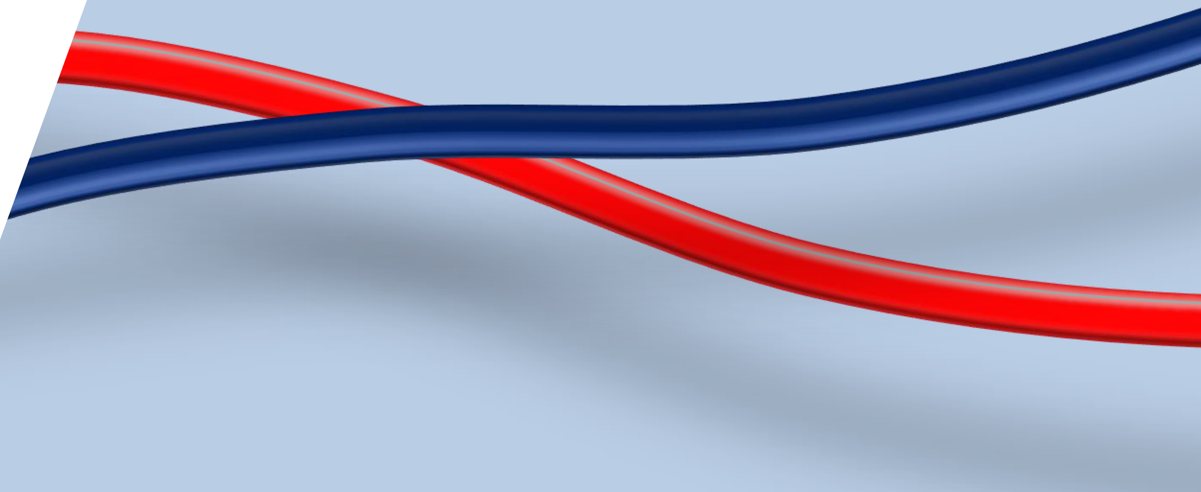
Managing the impact of CABLE DELAYS



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Contents

Cable delays and managing their impact

1. Introduction

This paper discusses issues that need to be considered when performing high accuracy Time Error measurements, and includes some tips on how to ensure errors due to cable delay are minimised.

The delay of a 1m length of cable is approximately 4.9 ns for optical cable, and 5.1 ns for electrical. In order to perform high precision Time Error measurements, cable delays need to be considered carefully for each measurement set-up used. Appropriate values need to be configured for the cables connecting reference and measurement interfaces to ensure the correct compensation is applied by the measurement equipment, which in this discussion is Calnex Paragon-X.

By design, Paragon-X offers optional integration of PTP Master and Subordinate clock functions, which further minimises potential error sources commonly associated with Time Error measurements.

2. Paragon-X compensation fields

The Test Configuration section in Paragon-X provides fields where cables, relevant to the configured set-up, can be accounted for. You can enter the delay associated with each cable[1].

a) *PTP emulation mode configuration*

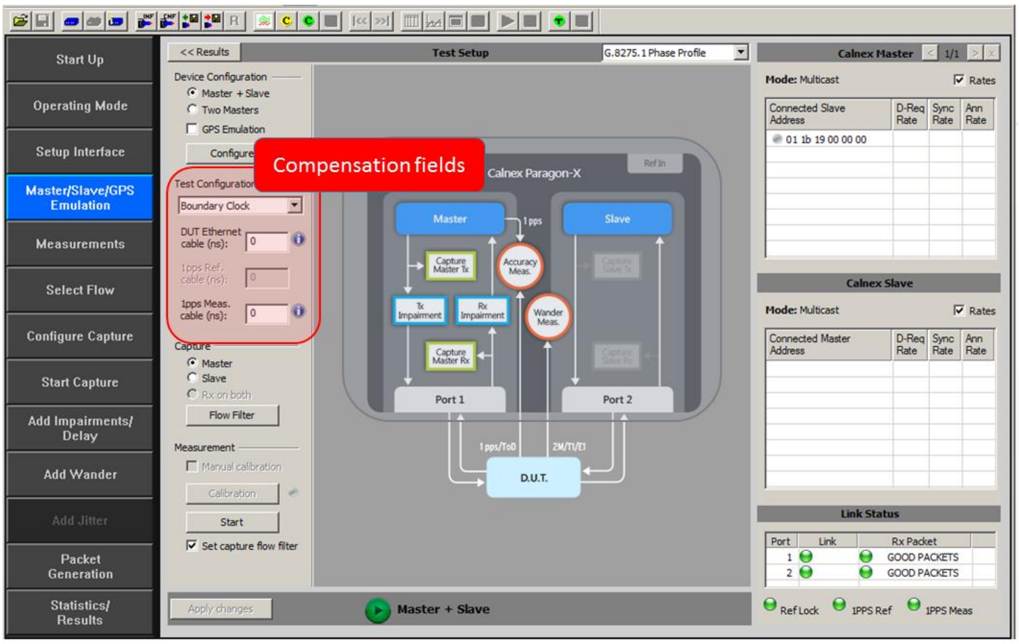

Figure 1

[1] When the 1pps output from Paragon-X is used to supply a reference to other equipment, the cable length compensation should be applied by the equipment terminating the reference signal.

b) *1588 Capture Mode Configuration*

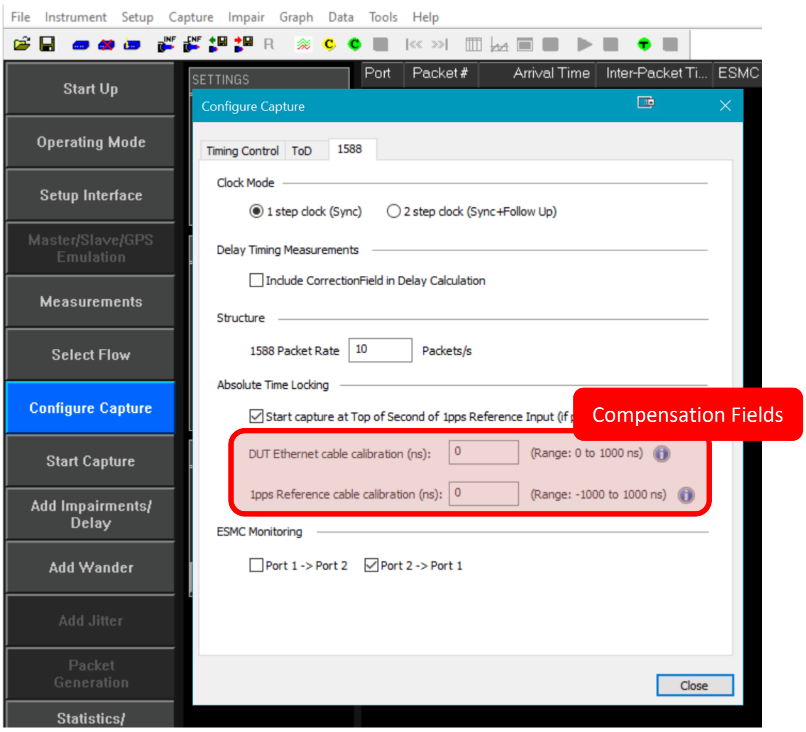

Figure 2

c) *1pps Time Error (Absolute) configuration*

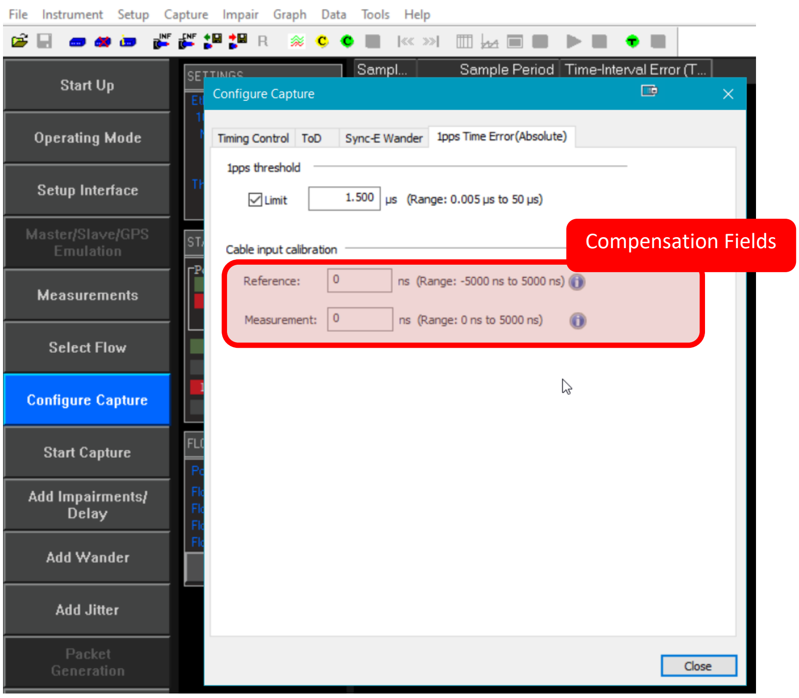

Figure 3

3. Which cables impact results?

When using Paragon-X, depending on the configuration and measurement being performed, the following cables need to be considered.

1PPS measurement mode

Consider the cable length from the 1PPS output of the Device-Under-Test (DUT) to Paragon-X's 1PPS measurement port. Figure 4 shows the user interface of the Paragon-X with the 1PPS measurement cable highlighted.

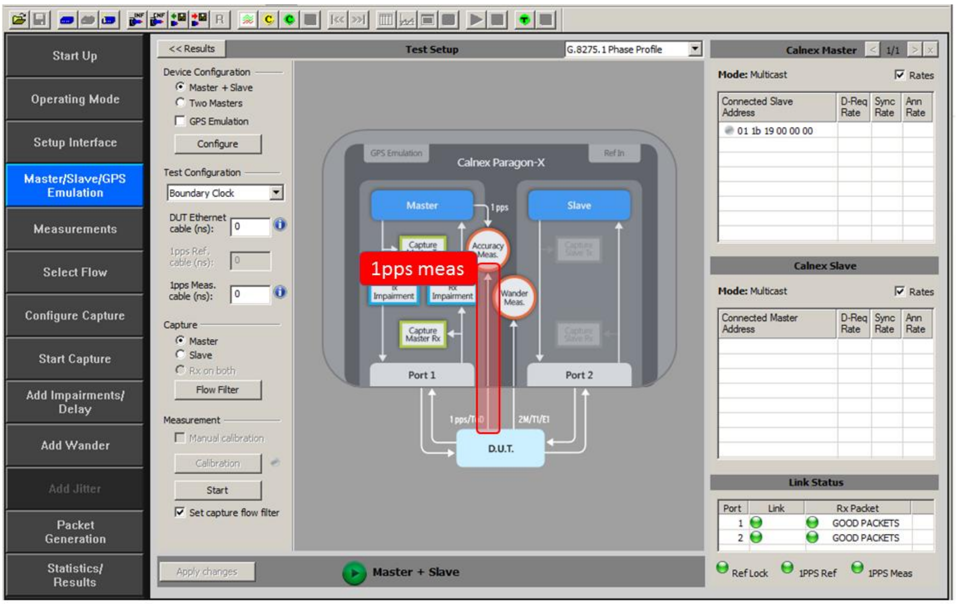

Figure 4

Figure 5 below shows the compensation field for the 1PPS measurement.

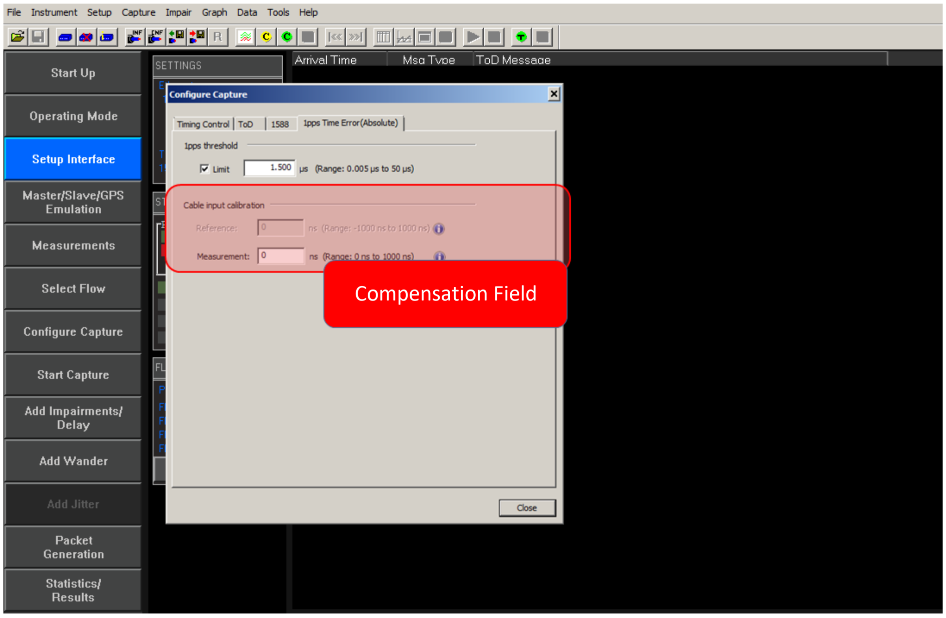

Figure 5

1588 surement mode

a) *PTP emulation configuration*

Consider the cable connecting the egress 1588 from the DUT to the emulated subordinate clock in Paragon-X i.e. connected to Paragon-X Port 2, and the cable connecting the 1PPS output from the DUT to the Paragon's 1PPS measurement input. See Figure 6 below.

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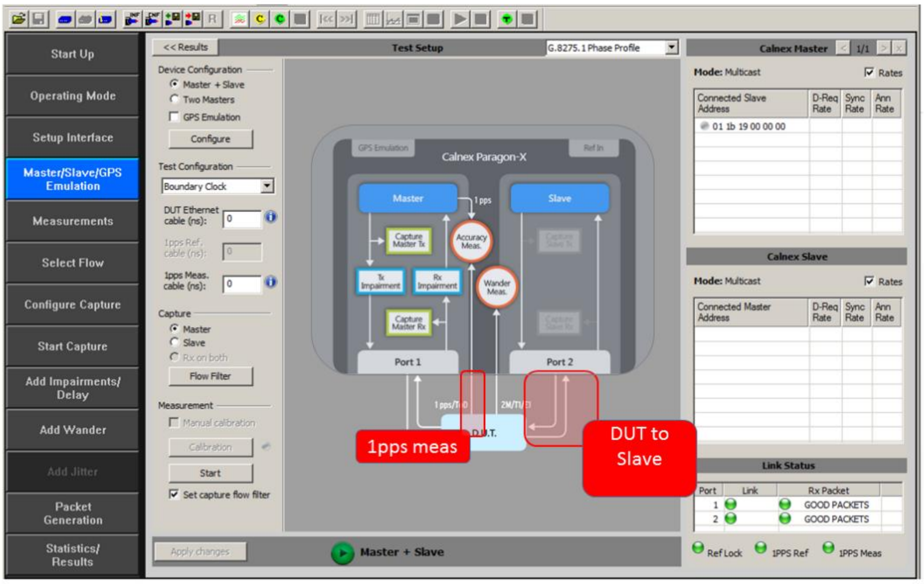


Figure 6

b) *Master configuration*

Consider the cable connecting the egress 1588 from the DUT to Paragon-X Port 2, and the cable connecting the 1PPS reference to the Paragon's 1PPS reference input. See Figure 7 below.

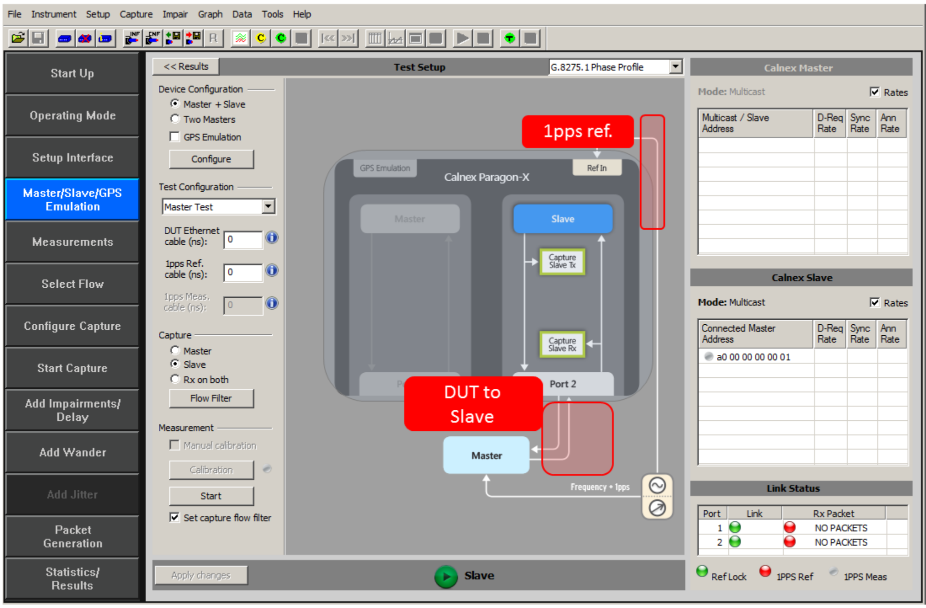
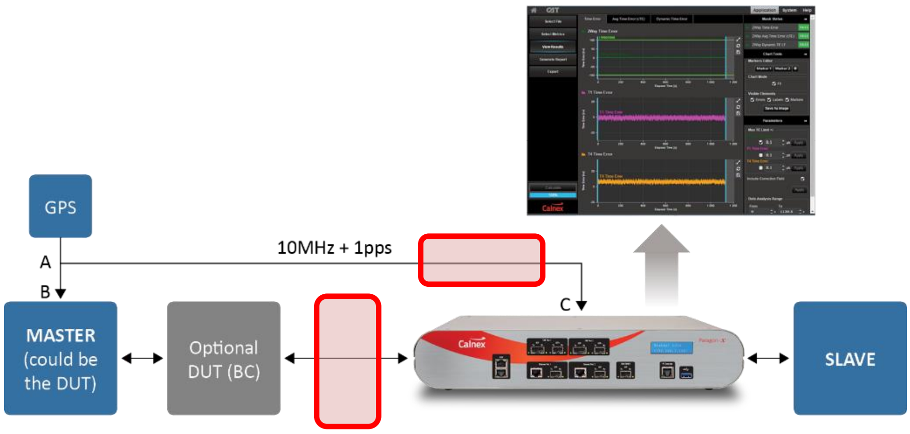


Figure 7

c) *Thru Mode configuration*

Consider the cable connecting the upstream network/DUT to Paragon-X i.e. connected to Port 1, and the cable connecting the 1PPS reference to the Paragon 1PPS reference input.



1PPS reference

When locking to an external time reference, consider the cable connecting the Reference source to the Paragon-X 1PPS Reference input port. See A in Figure 8 below.

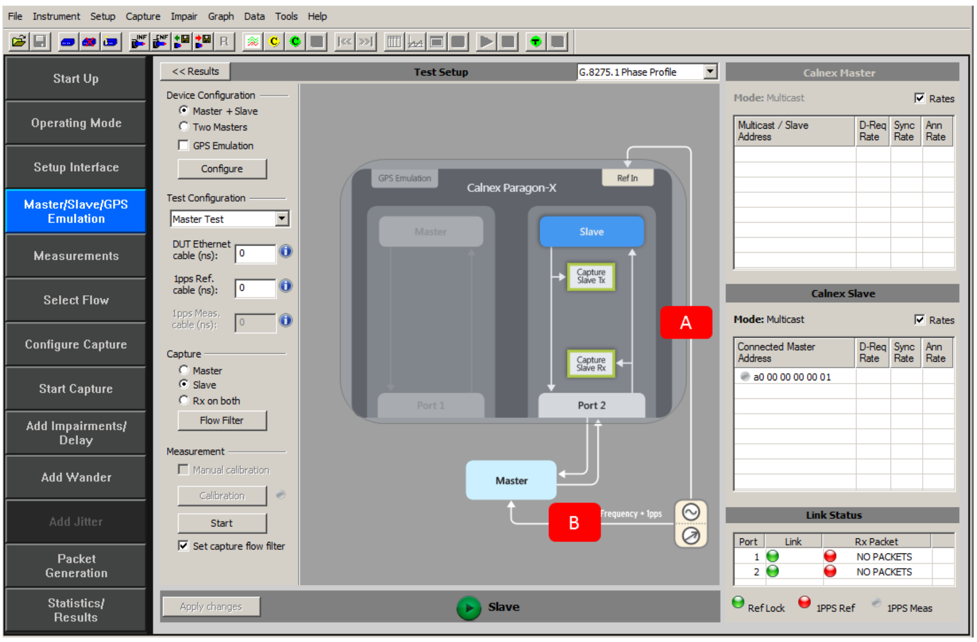


Figure 8

Note that if the 1588 master in the test set-up does **not** provide compensation for cable delay, the length of the cable from the Reference to the 1588 master under test (B) should be subtracted from the cable length between the reference and Paragon-X (A). A negative value should be entered in the field when the cable to the 1588 master is longer than that to Paragon-X. Refer to the *Complex Cabling of the 1PPS Reference* section later in this document on for further information.

4. Determining the delay value for a cable

An optical cable typically creates a delay of 4.9 ns per metre, while an electrical cable is around. 5.1 ns per metre. Wherever possible, very short cables should be used as these will reduce the total delay as well as the uncertainty in the delay estimation. If long cables are used and/or it is important to minimise uncertainty, it is suggested that a test is performed using Paragon-X to determine the *actual* delay produced by the specific cable.

Ethernet cables (Optical or Electrical)

a) Enable Master/Slave Emulation mode of Paragon-X then connect Port 1 to Port 2 with the cable to measured. See Figure 9.

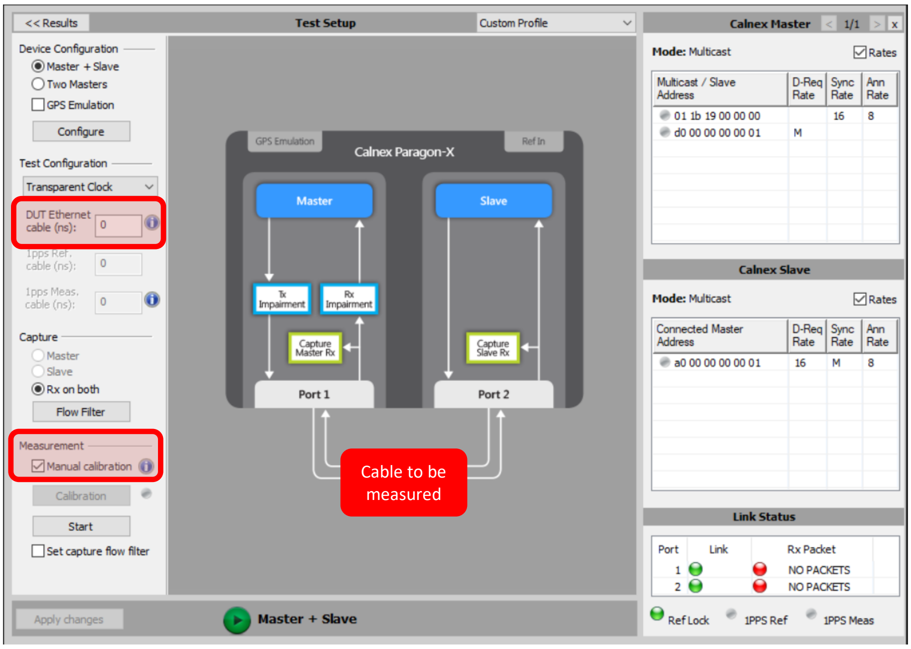


Figure 9

b) In the **Master/Slave/GPS Emulation** screen, select *Transparent Clock* in the **Test Configuration** and any end-to-end profile (e.g. G.8275.1) depending on available options. Check “Manual Calibration” checkbox and ensure the DUT Ethernet Cable (ns) value is set to “0”. Start PTP emulation, then perform a capture for 30s, stop the capture, and launch the Calnex Analysis Tool (CAT) for Transparent Clock Accuracy Measurement.

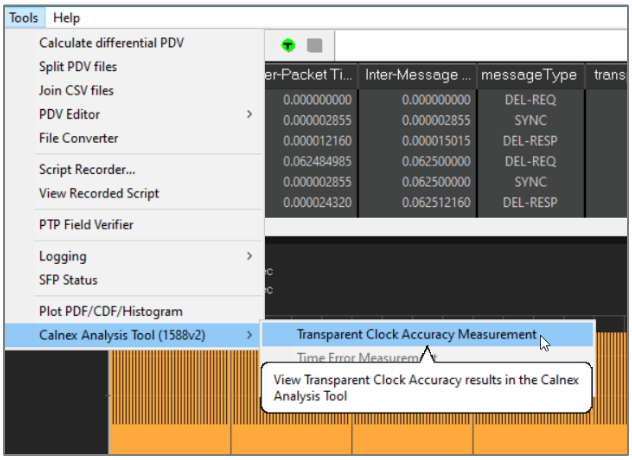


Figure 10

c) Record the *Mean [ns]* value for the *Fwd Latency* and *Rev Latency* metrics shown below in Figure 11.

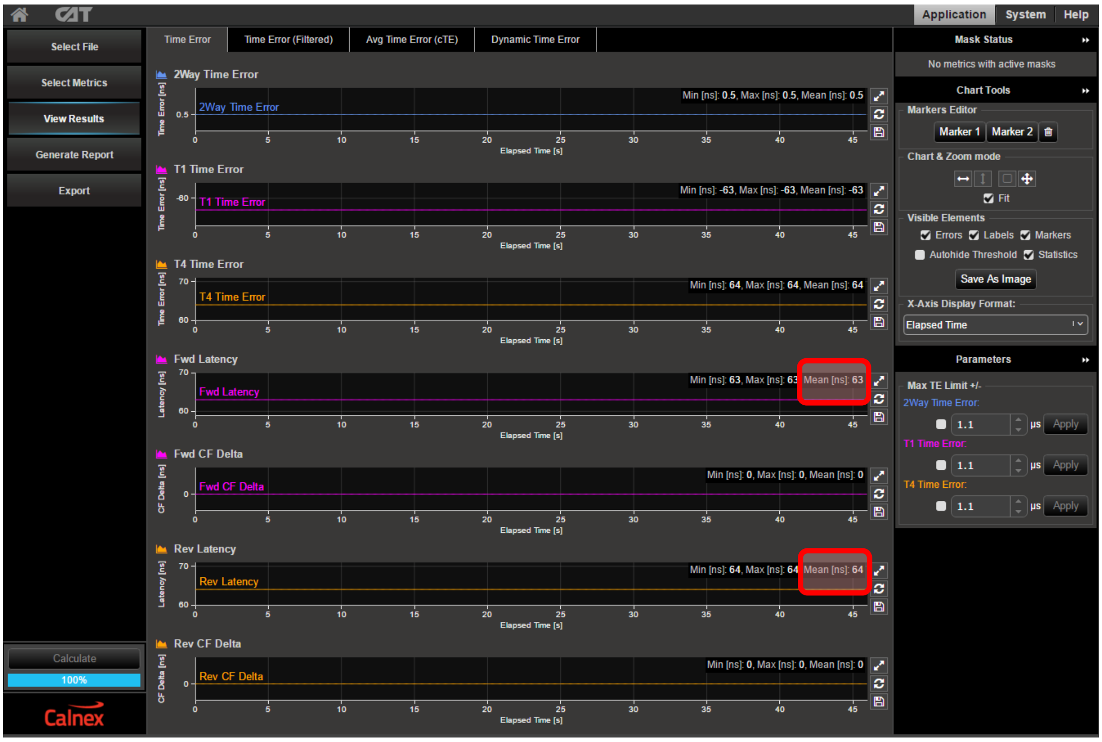


Figure 11

d) The Paragon X has a 5ns measurement resolution, in order to achieve the most accurate estimate of the measured cable delay use both measurement points by performing the calculation below:

(Fwd Latency + Rev Latency) / 2

Example: (64+63)/2 = 63.5 ns

The result should be rounded to the nearest whole nanosecond then entered into the Paragon X GUI.

1PPS cables

Configure Paragon-X in Master/Slave mode and connect the Paragon-X 1PPS reference output (from the lower Aux port on the front panel) directly to the 1PPS measurement input (with the cable intended for use in the measurement. Early versions of Paragon X require user selection of the 1PPS output on the Lower AUX port via the Paragon X GUI.

Start a 1PPS accuracy measurement. The measured result gives the delay associated with the cable.

5. Complex cabling of the reference 1PPS

When an external Reference is being supplied to Paragon-X and also to the source of the 1588, when that source is not configured to compensate for the delay of that 1PPS reference cable, then the difference in the cable length should be entered.

1pps cable from GPS/PRTC to Paragon-X = A m

1pps cable from GPS/PRTC to GM = B m

Cable compensation required = (A-B) m

The calculated cable compensation value should be converted to nanoseconds, and, depending on the measurement type, entered in the *1pps Reference cable calibration (ns)* field shown in Figure 12, or the *1pps Ref. cable (ns)* field shown in Figure 13.

The examples below show the 3 scenarios that may be encountered, and the correct compensation value for each.

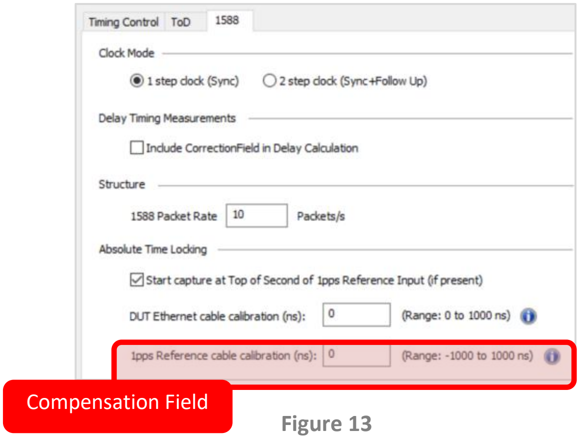


Figure 13

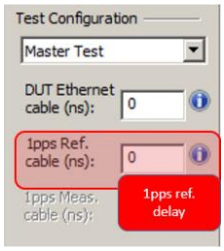
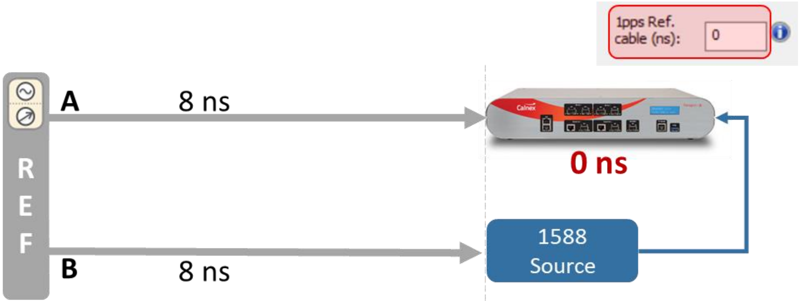
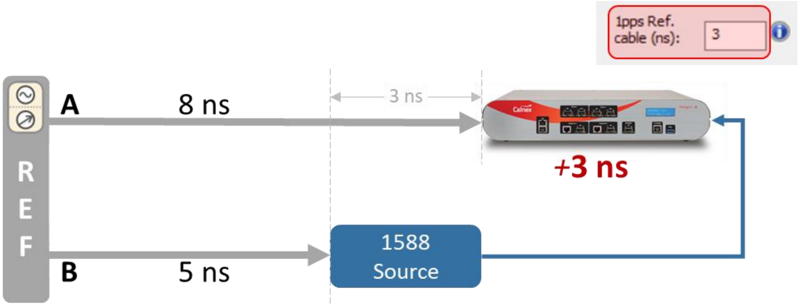


Figure 12

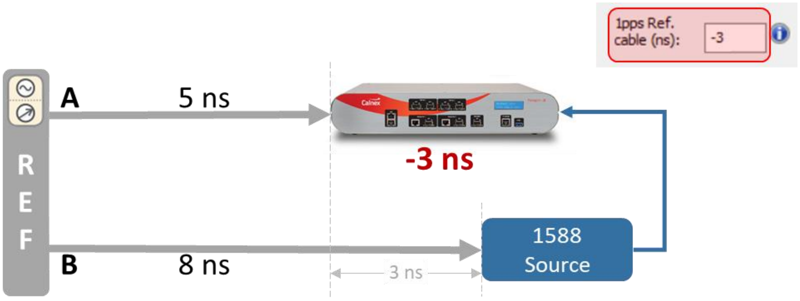
Example 1 – Identical cable lengths:



Example 2 – Paragon X cable is longer:



Example 3 – Paragon X cable is shorter:



6. 1PPS cable termination

G.8271 Annex A indicates that there is a 10ns uncertainty associated with the rising edge of the 1PPS pulse. It is important that the Paragon X termination impedance is correctly matched to the source signal impedance, and that the interconnecting cable used has the correct impedance, or the rising edge of signal will degrade, leading to greater measurement uncertainty.

It is recommended for TTL signals that 50Ω coaxial cable is used for the majority of the cable run.

Later versions of Paragon-X termination for 1PPS input may be configured as 'High Impedance' or 50Ω to match the signal requirements. Earlier versions support 50Ω termination only.

7. 1PPS threshold levels

It is important to ensure the input signal integrity when using 1PPS. G.8271 Annex A suggests the uncertainty of the rising edge of a 1PPS signal may be up to 10ns. If the signal level is not correct, this uncertainty can significantly increase.

If there is concern regarding the signal integrity of a 1PPS pulse, it should be checked using an oscilloscope, with careful attention paid to the rise time and amplitude of the signal. Measuring the amplitude allows a suitable threshold value to be configured in Paragon-X. By convention this threshold should be set at 50%; configuration of this on Paragon-X is as shown in Figure 14.

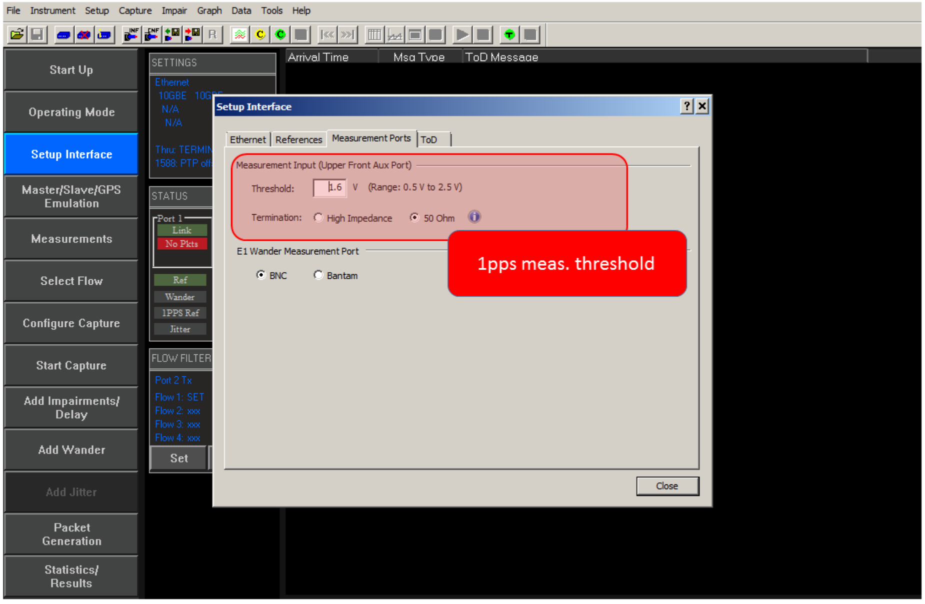


Figure 14

The 1PPS reference input can also be adjusted as shown in Figure 15.

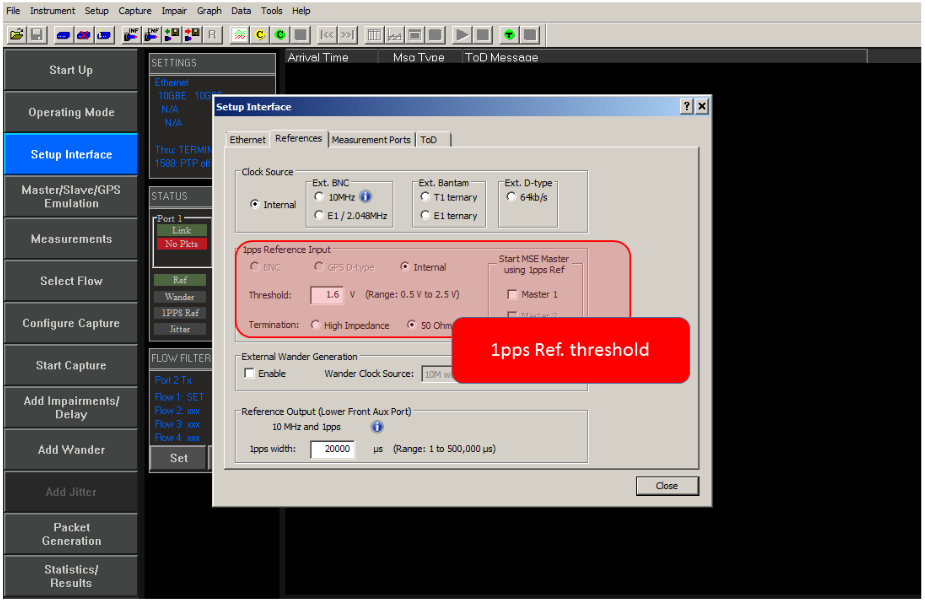


Figure 15

8. Connector Type Conversion

In some situations, the connector type on the source or terminating equipment are not of the same type and therefore an adaptor or conversion cable will be required to facilitate interoperability, these can be purchased or constructed. These should be well made and must not affect the voltage levels and/or pulse shape of the 1PPS signal. In particular, it is vital the rising edge of the pulse is not affected as this is the edge used to register the top-of-second event. If in doubt, examine the pulse shape using an oscilloscope.

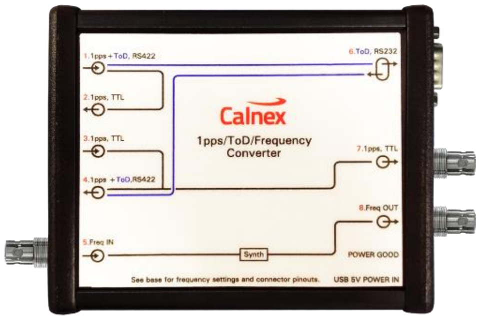
For example, if it is necessary to construct a 1PPS conversion, between a BNC connector and a RJ45 connector, it is recommended that the majority of the length of the cable uses a coaxial 50Ω single-ended cable (as typically used with BNC connectors). The length of twisted pair Ethernet cable joining the coaxial cable to the RJ45 should be as short as possible to reduce additional skew on the rising edge of the 1PPS pulse caused by impedance mismatch.

9. 1PPS/ToD/frequency convertor

Calnex offers a convertor accessory (option 133) to ease interconnection issues.

The following table provides the nominal delay values through this device depending on the ports in use. Additional reference frequency conversion ratios may be available, contact Calnex for more information.

Size: 140 x 35 x 105mm
Weight: 320g



Functions	Input	Output
Combined differential 1PPS+ToD serial signal conversion to separate 1PPS TTL and ToD RS-232 signals	RJ-45 connector (see port 1 pinout above). Combined differential (RS-422) 1PPS and ToD. Normally connected to subordinate clock output.	1PPS TTL (single-ended) pulse on RJ-45 connector (port 2) and ToD RS-232 signal on DB9 connector (port 6). Normally connected to Paragon 1PPS and GPS inputs. Use crossover (null modem cable) to connect ToD RS-232 cable from accessory to Paragon. Port 1 to Port 2 delay = 40ns
1PPS TTL signal connector adapter	RJ45 connector (port 3), TTL high impedance	BNC female connector (port 7), TTL 50Ω Port 3 to Port 7 delay = 52ns
1PPS TTL signal format converter	RJ45 connector (port 3), TTL high impedance	RJ-45 connector (port 4), RS-422 Port 3 to Port 4 delay = 13ns
10MHz wander measurement vs. 10MHz reference on Paragon	10MHz on BNC female connector (port 5). Normally connected to subordinate clock output.	2MHz on BNC female connector (port 8), which tracks input 10MHz wander. Normally connected to Paragon 2MHz wander measurement input.
5/15MHz reference signal to 10MHz conversion. Switch selectable.	5/15MHz on BNC female connector (port 5). Normally connected to 5/15MHz reference source.	10MHz on BNC female connector (port 8), frequency locked to input. Normally connected to Paragon 10MHz reference input.

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