

Configuring Transceivers

Using unqualified transceivers with Paragon-neo

- User-configured latencies
- Electrical signal conditioning



Paragon-neo provides the ability for users to apply custom compensations for transceiver transmit and receive path delays, and to modify electrical interface settings to enable the use of any transceiver.

This guide describes how to use these functions to test and use non Calnex-approved transceivers in Paragon-neo.

Warning: Using transceivers that have not been qualified by Calnex may result in poor link integrity and inaccurate timing measurements. Users do this at their own risk.

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1. Paragon-neo Transceiver Considerations

Calnex tests, characterizes and qualifies SFP type plug-in transceivers for use in Paragon-neo to ensure that repeatable and accurate timing measurements are made. Paragon-neo applies timing compensation and electrical interface settings when a qualified transceiver is detected. Transceivers that Calnex has characterized and qualified for making timing measurements with Paragon-neo are detailed on the [Calnex product FAQ website](#).

When Paragon-neo detects an unqualified transceiver, it applies a set of default electrical interface settings and timing compensation. The default settings work very well for NRZ transceivers thus avoiding the need to make changes except in extreme circumstances. PAM4 transceivers that operate at higher data rates may have variable latency and may also require adjustment to the PAM4 electrical settings before taking timing measurements. Calnex recommends using only qualified transceivers and leaving the Paragon-neo internal settings unchanged. Calnex-qualified transceivers must always be used for jitter testing.

From Release 10 onwards, Paragon-neo software provides you with the ability to adjust latency values to compensate for path delays, and to modify electrical interface settings to enable the use of unqualified transceivers.

PAM4 Transceivers

Calnex recommends using qualified PAM4 transceivers whenever possible. Follow these steps when new or unqualified transceivers must be used:

1. Test the new transceiver to determine whether Paragon-neo default settings provide error-free communication and accurate timing measurements.
2. If needed, adjust timing latencies.
3. If needed, adjust signal conditioning.

NRZ transceivers

Calnex strongly recommends that default timing and signal conditioning parameters are used. The default parameters work for all NRZ transceivers tested by Calnex to date. If you change the default parameters, follow the same steps as for PAM4 transceivers.

Jitter Testing

Calnex-qualified transceivers must always be used for jitter testing.

WARNING: Incorrect electrical signal conditioning settings and timing compensation will adversely affect your timing measurements.

This document explains how to use the Transceiver Configuration and Signal Conditioning features introduced in the Release 10 software if the Paragon-neo default internal settings are deemed inappropriate. You must make the decision to use these features in the full understanding that timing measurement accuracy may be degraded if sub-optimal settings are chosen.

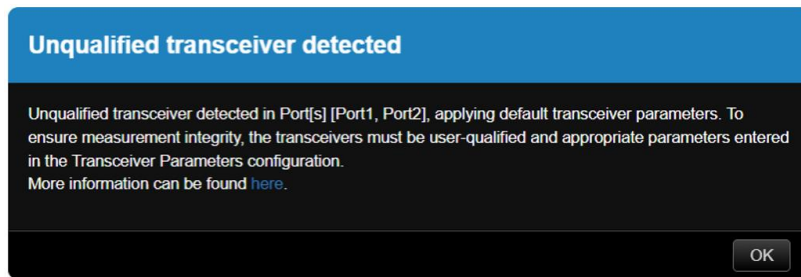
1.1. Assumptions

The following assumptions are made:

- You understand how transceivers operate and their characteristics, the details of which are beyond the scope of this document.
- You have experience of using Paragon-neo to test devices at high speed. Please refer to the Paragon-neo Getting Started Guide for more details.

1.2. Detecting Unqualified Transceivers

When Paragon-neo detects an unqualified transceiver plugged into Port 1 or Port 2, the following warning will be displayed:



1.3. Terminology

This document uses the following terminology:

Term	Description
Calnex-qualified transceivers	<p>Transceivers that have all the following characteristics:</p> <ul style="list-style-type: none"> • Been characterized and measured by Calnex and confirmed as acceptable. • Have Calnex-approved settings for Transceiver configuration and Signal Conditioning that are applied by Paragon-neo upon module insertion (a list of qualified transceivers is part of Paragon-neo software). • Have an entry on the Calnex product FAQ website for approved transceivers. <p>Calnex does not test data integrity of transceivers, only timing quality. Calnex tests transmit and receive sufficient PTP packets to check timing quality. Users must test the data integrity of all transceivers in their application.</p>
Unqualified transceivers	<p>Transceivers that have any of the following characteristics:</p> <ul style="list-style-type: none"> • Not been characterized and measured by Calnex. • Characterized and been confirmed as unacceptable for timing measurements. • Do not have an entry on the Calnex product FAQ website for approved transceivers. <p>Calnex does not test data integrity of transceivers, only timing quality. Unqualified transceivers are assumed to have good data integrity and should be tested by users.</p>
Transceiver latency	<p>Transmit Latency: the amount of time that it takes for a signal to travel from the electrical interface with Paragon-neo to the external optical interface of the transceiver.</p> <p>Receive Latency: the amount of time that it takes for a signal to travel from the external optical interface of the transceiver to the electrical interface with Paragon-neo.</p> <p>Latency is directly related to path delay.</p>
Transceiver asymmetry	The difference in latency of the transmit and receive paths of the transceiver.
Run-to-run variation	A run is a single test, run-to-run variation is the difference in results between multiple tests.
NRZ transceiver	A transceiver with Non-Return to Zero signalling on its electrical interface.
PAM4 transceiver	A transceiver with 4-level Pulse Amplitude Modulation signalling on its electrical interface.

1.4. References and Further Reading

The following Calnex document is referenced in this user guide:

- 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>

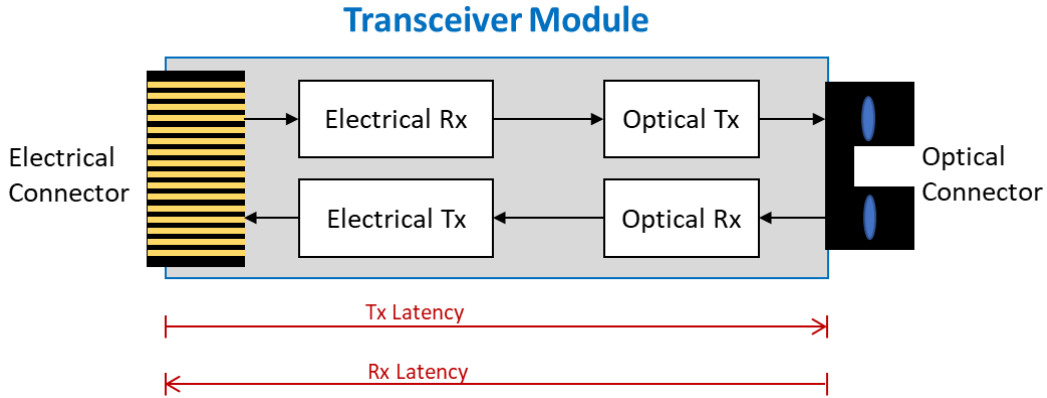
The following documents define the MSAs for a plug-in SFP type Ethernet transceiver:

- SFF-8472 rev 12.4 – *Management Interface for SFP+*.
Storage Networking Industry Association (SNIA).
Describes the management interfaces for SFP, SFP+, SFP-28 and SFP-56 transceivers.
Download here: <https://members.snia.org/document/dl/25916>
- SFF-8636 rev 2.11 – *Management Interface for 4-lane Modules and Cables*.
Storage Networking Industry Association (SNIA).
Describes the management interfaces for QSFP+ and QFP-28 transceivers.
Download here: <https://members.snia.org/document/dl/26418>
- OIF-CMIS-05.2 - *Common Management Interface Specification (CMIS)*.
Optical Internetworking Forum (OIF).
Describes the management interfaces for QSFP-56 and QSFP-DD transceivers.
Download here: <https://www.oiforum.com/wp-content/uploads/OIF-CMIS-05.2.pdf>

2. Transceiver Characterization

Two fundamental characteristics of a timing interface are timing performance and link integrity.

The diagram below shows a simplified block diagram of an SFP type plug-in transceiver module illustrating the electrical-to-optical and optical-to-electrical paths (transceiver implementation details are beyond the scope of this guide). Transceivers include active electronic circuits that introduce transmit latency to outgoing data and receive latency to incoming data. The electrical side of the transceiver carries high-speed data signals spread across one or more serial buses (lanes). Good signal integrity of these buses is critical so that the data is transferred without errors.



Transceiver modules come in multiple form factors depending on data rate. Paragon-neo supports the following module types:

SFP	1G	1 lane NRZ
SFP+, SFP28	10G, 25G	1 lane NRZ
QSFP+, QSFP28	40G, 100G	4 lanes NRZ
SFP56 and SFP-DD	50G, 100G	1, 2 lanes PAM4
QSFP56, QSFP-DD	200G, 400G	4, 8 lanes PAM4

Signal integrity requirements on the electrical buses increase with speed, especially when PAM4 modulation is used. Latency through the transceiver modules must be characterized. The more complex transceivers typically contain signal processing elements that manage the electrical buses but introduce some small timing variabilities each time they are inserted to Paragon-neo.

2.1. Timing Performance

Transceiver characteristics that affect the performance of a timing interface are:

1. Receive and transmit path delays through the transceiver.
2. Difference between receive and transmit path delays through the transceiver (asymmetry).
3. Run-to-run variations in the path delays and asymmetry.
4. Generation of timing outliers.

Section 3 describes the procedures required to test unqualified transceivers then determine and apply the appropriate latency settings for that transceiver in Paragon-neo.

2.2. Link Integrity

Link integrity on the electrical buses between Paragon-neo and transceiver becomes more critical as Ethernet speeds increase. Poor link integrity can result in unreliable link status and/or transmission/decode errors. In particular, PAM4 interfaces include active electronic components and state machines in the transceiver that must align signal quality, strength, timing and state with similar circuitry in Paragon-neo. The characteristics that determine this for a transceiver are:

- Behaviour across power cycles and re-inserts (consistent timing and state each time the link starts).
- Signal integrity on the high-speed serial buses that yield within-specification bit errors and no uncorrected FEC errors (electrical signal strength, quality and timing).
- Link reliability in operation (no link-losses after initial link-up).

The electrical buses between Paragon-neo and transceiver are part of an end-to-end communication chain so sub-optimal performance here will affect the end-to-end communication performance. In addition to transceiver link integrity, other factors such as transceiver operation, contaminated optical surfaces, and cable quality affect end-to-end communication performance.

Section 4 describes the procedures required to test unqualified transceivers then determine and apply the appropriate electrical interface tuning parameters to optimize link integrity between Paragon-neo and transceivers.

3. Transceiver Latency Configuration

Paragon-neo PTP timing functions compensate for Paragon-neo's internal latencies, transceiver latency and transceiver latency asymmetry. Paragon-neo's internal latencies are fixed and are always compensated for. Transceivers have different latencies and latency asymmetry depending on their design, speed, etc.

Calnex has qualified one or more transceivers for each port type and speed available on Paragon-neo. When Paragon-neo detects that a qualified transceiver has been inserted to one of the ports, it applies appropriate compensations. When an unqualified transceiver is detected, Paragon-neo applies default latency values and asymmetry compensation; these values may not be correct for that transceiver.

For all NRZ transceivers Calnex has tested to date, the variances (run-to-run, latency, asymmetry) between different transceivers are in the order of picoseconds. Therefore, the latency compensation values for NRZ transceivers should not need to be changed.

Latencies through PAM4 transceivers can vary by design, run-to-run, and add asymmetry that must be compensated for. Calnex has measured variations up to hundreds of nanoseconds between transceivers that have the same speed and interfaces.

The Paragon-neo **Transceiver Configuration** function allows you to override the latency parameters that Paragon-neo automatically applies. This function is useful when you want to use unqualified PAM4 transceivers. The parameters that can be set are:

- Transmit Latency in pico-seconds.
- Receive Latency in pico-seconds.

The best way to compensate transceiver latency and asymmetry is to use data provided by the transceiver vendor. When this data is available, follow the steps in section 3.1 to configure custom latencies in Paragon-neo.

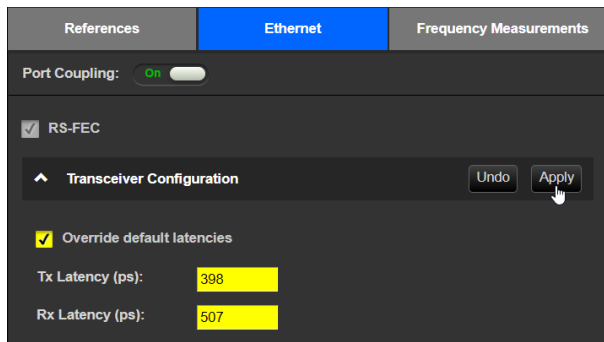
If no data is available from the transceiver vendor, section 3.4 describes a method to empirically determine transmit and receive latencies by comparison to Calnex-qualified transceivers of the same speed, form factor and interface type. A series of measurements must be run, followed by a set of calculations. The measurements are repeated multiple times so that timing variation can be understood, and timing outliers can be captured.

Two Calnex-qualified transceivers are required to empirically determine the latencies of unqualified transceivers.

3.1. Configuring Custom Transceiver Latencies

When the transmit and receive latencies of an unqualified transceiver are known, either receiving information direct from the transceiver vendor or determined through empirical testing, the values can be configured in the Paragon-neo GUI.

In the **Transceiver Configuration** settings for the port(s) where unqualified transceivers are used, check the **Override default latencies** checkbox, and enter the values determined for transmit and receive latencies for the unqualified transceiver in the associated port, then click **Apply**.



A yellow warning banner appears in the **Run Apps** GUI when custom transceiver latencies are used during measurements to make you aware that their PTP timing measurements will be offset by the custom latencies.

When the **Override default latencies** checkbox is checked, the custom latencies are applied to whatever transceiver is inserted into the port. You must uncheck the **Override default latencies** checkbox to stop using the custom latencies.

The custom transceiver latency settings are saved in Paragon-neo's internal configuration data and persist through power cycles and instrument restarts. Paragon-neo only saves the current custom latency settings so you must record the latency information separately if multiple different unqualified transceivers are to be used.

3.2. Clearing Custom Transceiver Latencies

Several actions will clear custom transceiver latency values:

- Uncheck the **Override default latencies** checkbox.
- Click the **Restore to Defaults** button in the **Run Apps > Save/Recall Settings** panel.

3.3. Saving Custom Transceiver Latencies

The current custom transceiver latency values are stored in Paragon-neo when the instrument is shut down and will be used again when the instrument is restarted.

Custom transceiver latency values are saved in user-configuration files with other instrument settings.

3.4. Empirically Determining Transceiver Latencies

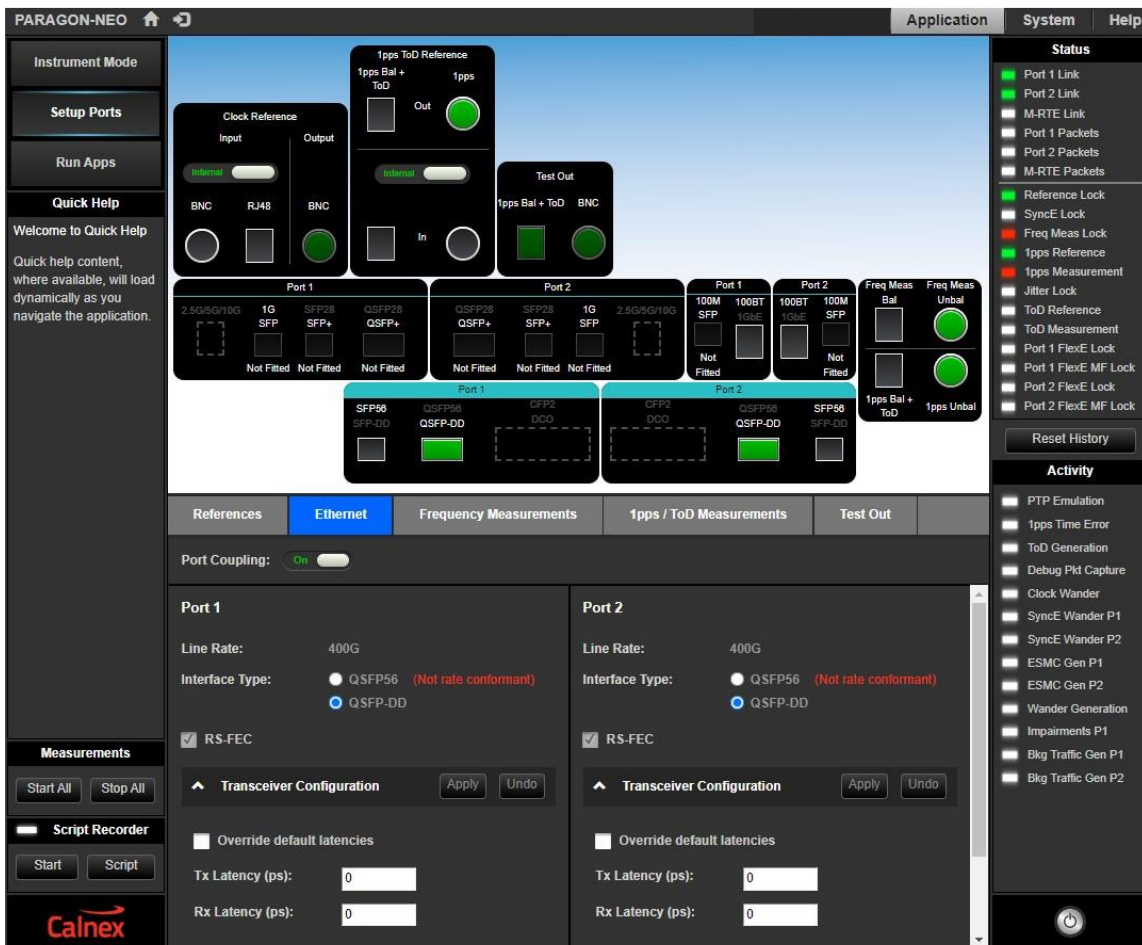
There are four stages in the process to empirically determine transceiver latencies:

1. Set up Paragon-neo.
2. Configure Paragon-neo to test the latencies.
3. Run latency characterization tests and record results.
4. Calculate transceiver latencies from the characterization test results.

3.4.1. Set up Paragon-neo

1. Insert two Calnex-qualified transceivers into Port 1 and Port 2
2. Connect the two transceivers to give a bidirectional Port 1 to Port 2 back-to-back connection. The fibers between both the Tx/Rx connections must be of identical length and as short as possible to ensure accurate measurements and no timing asymmetry.
3. Open the GUI and click **Setup Ports** to show the Paragon-neo port configurations.
4. Set **Clock Reference = Internal**.
5. Set **1PPS + ToD reference = Internal**.
6. Select the relevant interfaces for Port 1 or Port 2.
7. Click the Ethernet tab and expand the ▼ **Transceiver Configuration** details.

The example screenshot below shows that two QSFPDD 400G PAM4 transceivers have been selected. The **Override default latencies** checkboxes are unchecked, indicating that both ports are using default latency values.

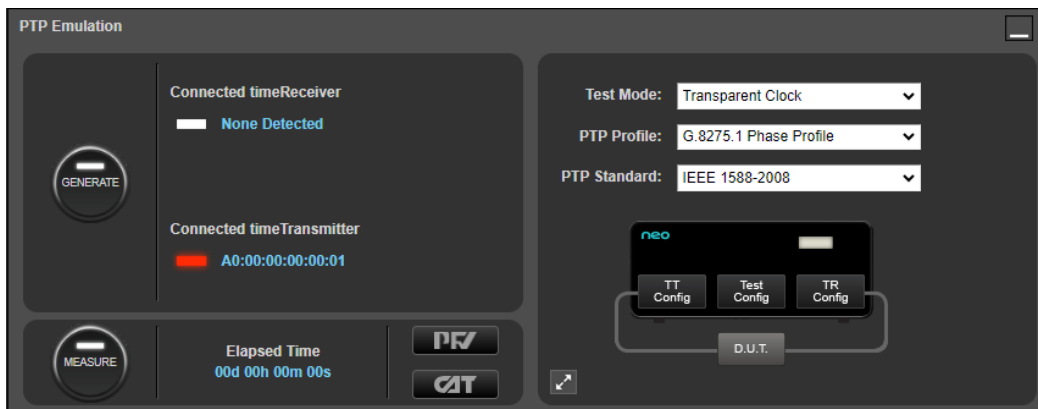


3.4.2. Test Configuration

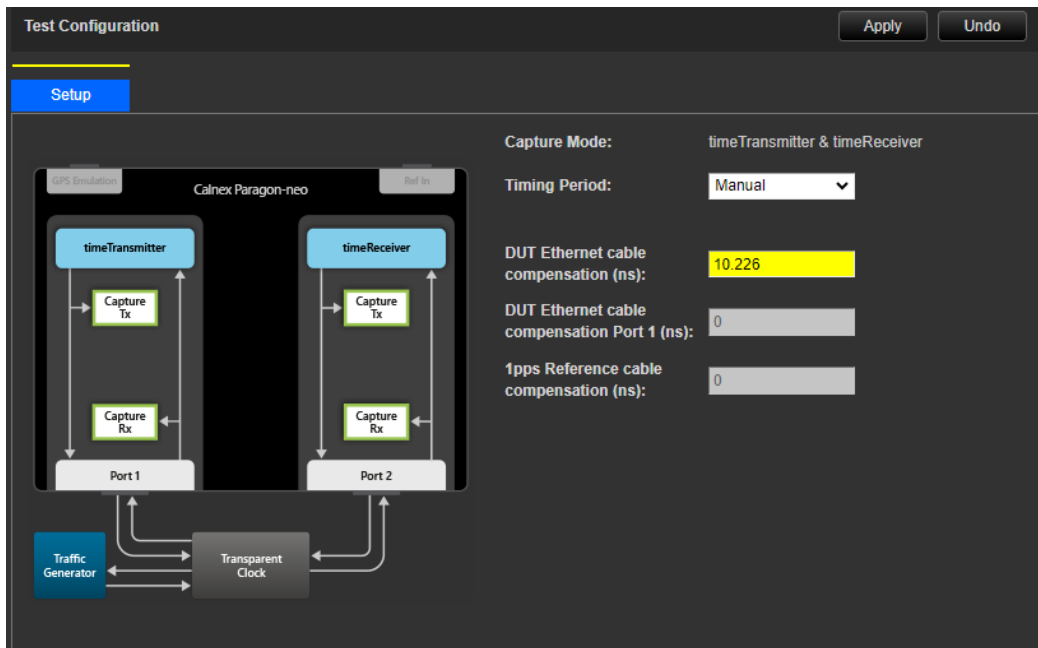
1. Click the **Restore to Defaults** button in the **Run Apps > Save/Recall Settings** panel to clear any previous configuration.
2. Open the **Presets** panel and click the **PTP** icon.



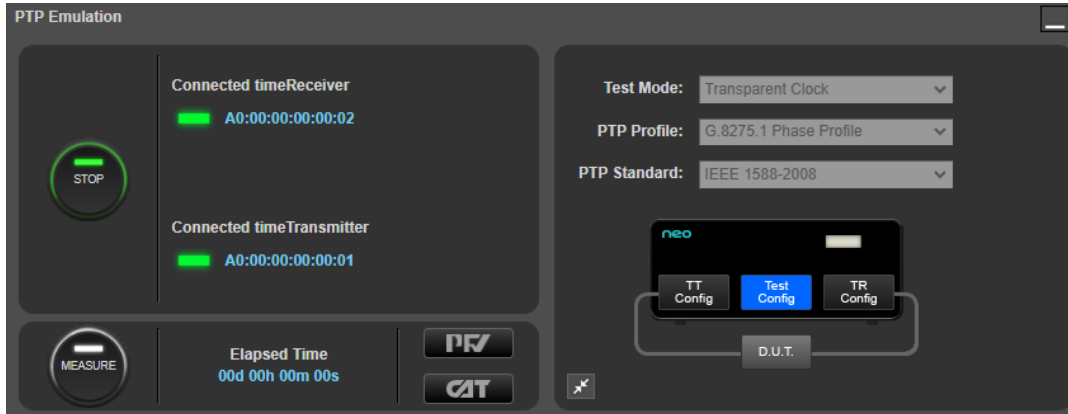
3. In the **PTP Emulation** app:
 - a. select **Test Mode = Transparent Clock**
 - b. select an End-to-End PTP Profile (e.g. G.8275.1 or G.8275.2) from the **PTP Profile** list
 - c. the **PTP Standard** is not relevant and can be either IEEE 1588-2008 or IEEE 1588-2019



4. Click **Test Config** and enter a cable delay compensation for the cable connecting ports 1 and 2.
5. Click **Apply**.



- In the **PTP Emulation** app, click **Generate** and confirm that a back-to-back PTP session is running.



- Click **Measure** then click **CAT** to launch the Calnex Analysis Tool in a new browser tab.
- In CAT, confirm that a **T1 Time Error** measurement is active.

The T1 Time Error should be within a few nanoseconds of zero due to run-to-run variances.



- After confirming the measurement is being made correctly, stop the measurement by clicking the measurement **Stop** button in the **PTP Emulation** app.

3.4.3. Test Method

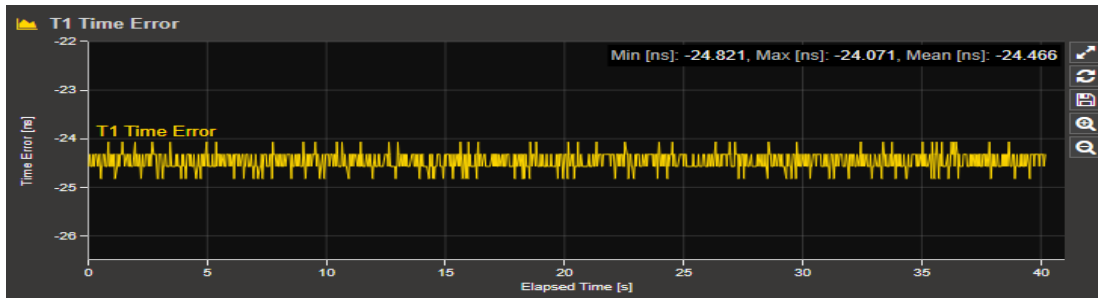
- Setup Paragon-neo as described in section 3.4.1.
- Configure Paragon-neo as described in section 3.4.2.
- Insert an unqualified transceiver into port 1 and a qualified transceiver into port 2. Connect transceivers back-to-back using the same cable that was previously compensated for (section 3.4.2 step 4).
- In the Port 1 **Transceiver Configuration** settings, check the **Override default latencies** checkbox, and enter the values of 0 ps for transmit (Tx) and receive (Rx) latencies. Click **Apply**.

Ensure that the **Override default latencies** checkbox for port 2 is unchecked so that Paragon-neo uses the latencies for the qualified transceiver. Click **Apply**.

- Run a PTP measurement for 30 seconds. Record the minimum, maximum and mean **T1 Time Error** and **T4 Time Error** statistics shown by CAT.
 - Repeat measurements 200 times, with the unqualified transceiver power-cycled after each test (see Note 1).
 - Review the 200 measurements for variance and outliers. Discard any outliers and rerun tests if there is too much variance.

- The Transmit Latency of the unqualified transceiver is -1 multiplied by the average of the 200 **mean T1 Time Error** measurements.

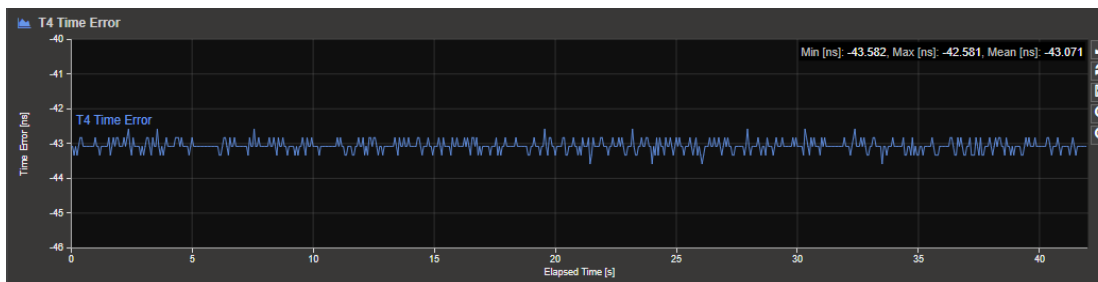
The example below is a single T1 Time Error measurement showing the transmit latency of an unqualified transceiver is approximately 24.5ns. This is a single measurement; the value will change after calculating the average of the mean T1 Time Error statistics over 200 runs.



- The Receive Latency of the unqualified transceiver is the average of the 200 **mean T4 Time Error** measurements.

The example below is a single T4 Time Error measurement showing the receive latency of an unqualified transceiver is approximately 43.1ns. This is a single measurement; the value will change after calculating the average of the mean T4 Time Error statistics over 200 runs.

Typically, the receive latency is larger than the transmit latency, depending on the specific transceiver design.

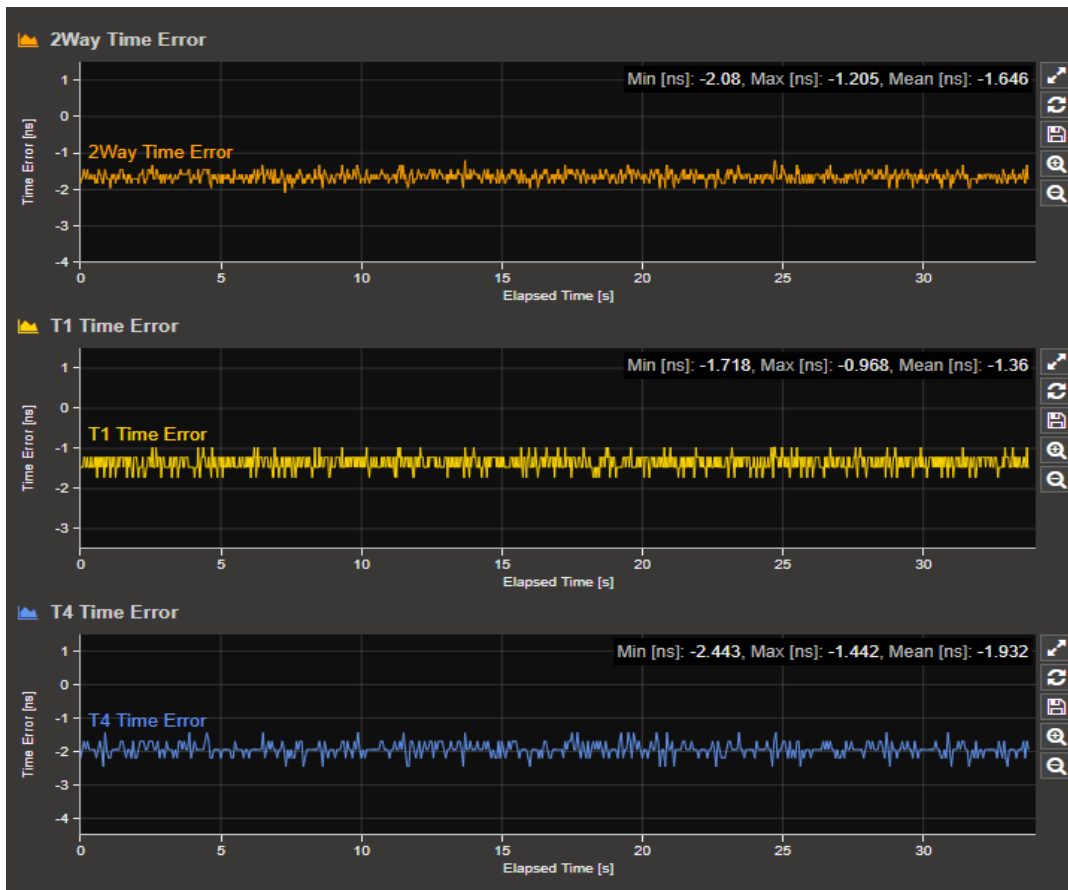


- Change transceivers: insert two unqualified transceivers into port 1 and port 2. Connect transceivers back-to-back using the same cable as step 3.
- In both Port 1 and Port 2 **Transceiver Configuration** settings, check the **Override default latencies** checkboxes, and enter the transmit and receive latency values calculated in steps 6 and 7. Click **Apply** for both ports.
- Run a PTP measurement for 30 seconds. Record the minimum, maximum and mean **2Way Time Error**, **T1 Time Error** and **T4 Time Error** statistics shown by CAT.

Repeat measurements at least 200 times, with both unqualified transceivers power-cycled after each test (see Note 1).

- This step validates the measurements and calculations made so far:
 - Confirm that the average of the 200 mean **2Way Time Error** is zero.
 - Confirm that the average of the 200 mean **T1 Time Error** values equals -1 multiplied by the average of the 200 mean **T4 Time Error** values.

The example below is a single run of the validation step showing that the transmit and receive latencies of the unqualified transceivers have been calculated correctly. This is a single measurement; the values will change after calculating the averages over 200 runs.



Note 1: Power-cycling a transceiver is easily achieved by toggling from an SFP type port to the RJ45 electrical port, then back again to the transceiver being tested.

Transceivers often include stateful logic on the electrical interface that starts up in a different state when the transceiver is powered up (especially PAM4 transceivers). This results in slightly different timing each time the transceiver is powered and explains why transceivers must be power cycled and the time averaged across multiple runs when finding the latencies.

4. Transceiver Signal Conditioning

Paragon-neo has built-in sets of electrical parameters that optimize signal integrity on the high-speed serial buses between Paragon-neo and transceivers plugged into Ports 1 and 2. When a user selects an SFP type Ethernet transceiver port in the Setup Ports GUI, Paragon-neo applies the relevant set of electrical parameters depending on the port used.

For most transceivers, especially NRZ transceivers, the built-in sets of electrical parameters provided by Calnex ensure optimal signal integrity between Paragon-neo and transceiver. For unqualified PAM4 transceivers, adjusting the electrical parameters may improve signal integrity between Paragon-neo and the transceiver. If signal integrity is not properly maintained, timing and bit errors on the buses will lead to incorrect timing measurements. For this reason, Calnex recommends using the default electrical parameters unless there is a specific need to change them.

The **Signal Conditioning** function allows you to override Paragon-neo's built-in electrical parameters. This function is useful when you want to use unqualified transceivers. The **Signal Conditioning** function is available for all module types and is particularly useful when optimizing performance with PAM4 higher speed modules.

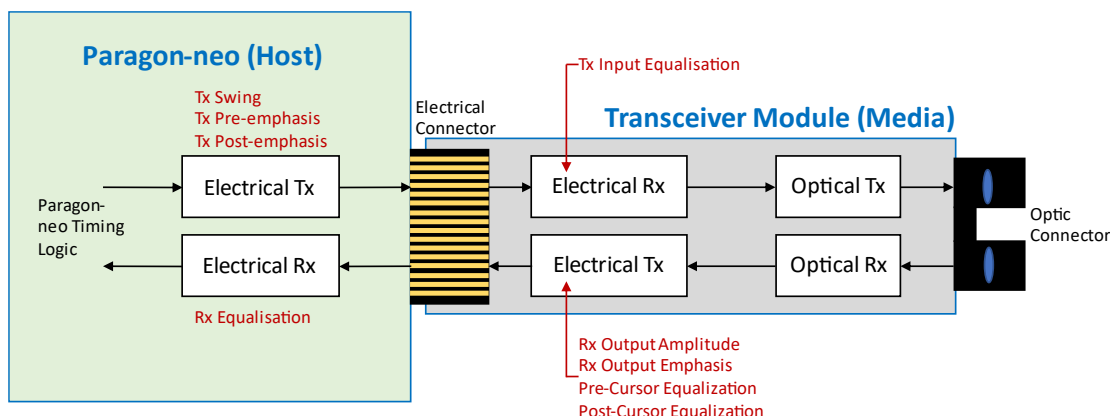
The table below shows the electrical parameters that can be adjusted for NRZ transceivers. The Host parameters refer to the Paragon-neo hardware while the Media parameters are defined in the transceiver MSAs. Please refer to the MSAs for more details of the electrical parameters applicable to specific transceiver types.

NRZ Interface	Host	Media
1G SFP	Tx Swing Tx Pre-Emphasis Tx Post-Emphasis	Tx Input Equalization (SFF-8472 table 9-18) Rx Output Emphasis (SFF-8472 table 9-19)
SFP28 and SFP+	Tx Swing Tx Pre-Emphasis Tx Post-Emphasis Rx Equalization ¹	Tx Input Equalization (SFF-8472 table 9-18) Rx Output Emphasis (SFF-8472 table 9-19)
QSFP28 and QSFP+	Tx Swing Tx Pre-Emphasis Tx Post-Emphasis Rx Equalization ¹	Tx Input Equalization (SFF-8636 table 6-32) Receiver Output Amplitude (SFF-8636 table 6-31) ² Rx Output Emphasis (SFF-8636 table 6-33)
Notes:		
1. Receive Equalization is only available on Paragon-neo Port 1.		
2. Rx Output Amplitude refers to the Receiver Output Amplitude Control in SFF-8636 table 6-31.		

The table below shows the electrical parameters that can be adjusted for PAM4 transceivers.

PAM4 Interface	Host	Media
SFP56 and SFP-DD	Tx Swing Tx Pre-Emphasis Tx Post-Emphasis	Tx Input Equalization (SFF-8472 table 9-18) Rx Output Emphasis (SFF-8472 table 9-19)
QSFP56 and QSFP-DD	Tx Swing Tx Pre-Emphasis Tx Post-Emphasis Rx Equalization (Port 1 only)	Tx Input Equalization (OIF-CMIS-05.2 table 6-6) ¹ Receiver Output Amplitude (OIF-CMIS-05.2 table 6-8) Pre-Cursor Equalization (OIF-CMIS-05.2 table 6-7) Post-Cursor Equalization (OIF-CMIS-05.2 table 6-7)
Notes:		
1. OIF-CMIS-05.2 table 6-6 defines more possible values for Tx Input Equalization provided in the GUI.		

The diagram below is a simplified block diagram of an optical transceiver connected to Paragon-neo. The parameters shown in red indicate the location in Paragon-neo and the transceiver where the Signal Conditioning electrical parameters apply. The parameters shown in red are the superset of all electrical parameters that control signal integrity on the electrical connections; the tables above show which parameters are relevant to which transceiver type.



4.1. When to Use the Signal Conditioning Function

Calnex recommend using the default electrical parameters unless you have a specific need to change them, that is, an unqualified transceiver where there is a suspected signal integrity issue.

Before adjusting the Signal Conditioning parameters, follow the steps below to check for signal integrity issues:

1. Clean optic surfaces and optical fibers to ensure that dirty optics do not impact link integrity.
2. Insert a single unqualified transceiver module to Paragon-neo Port 1 or Port 2.
3. Insert a single short optical fiber looping back the transceiver transmit to receive.
4. Open the **Setup Ports** configuration GUI and expand the **▼Details** panel.
5. With the optical loopback in place, Paragon-neo will attempt to link the port transmitter and receiver. Look for physical layer errors:
 - For NRZ transceivers, look at the **BIP Error** counter.
 - For PAM4 transceivers, look at the **FEC Corrected** and **FEC Uncorrected** counters.

Rapidly increasing error counters may indicate a signal integrity issue between Paragon-neo and the transceiver module or may simply mean that the transceivers optic surfaces need cleaning.

When using PAM4 modules, a certain rate of corrected FEC errors is expected. However, rapidly increasing corrected FEC error and uncorrected FEC error counts indicate that there may be a signal integrity issue on the electrical buses between Paragon-neo and the transceiver.

Signal Conditioning parameters for Paragon-neo ports 1 and 2 must be adjusted individually – parameters will be different so do not copy between the ports. Follow this sequence to check and adjust the signal conditioning parameters for unqualified transceivers:

1. Check physical layer error counters for Port 1. If required, adjust Port 1 signal conditioning following the detailed steps in sections 4.4 and 4.5.
2. Check physical layer error counters for Port 2. If required, adjust Port 2 signal conditioning following the detailed steps in sections 4.4 and 4.5.
3. Interconnect Ports 1 and 2 back-to-back and verify that the changes made have not increased error counts.

When an unqualified transceiver is to be used in only one Paragon-neo port (timeTransmitter test or timeReceiver test) either step 1 or 2 can be omitted as appropriate.

4.2. Defining Electrical Parameters for good Signal Integrity

Defining values for the signal conditioning parameters that yield good signal integrity is a complex task that requires intimate knowledge of the transceiver electronics. Please refer to the relevant MSAs and transceiver datasheets before adjusting electrical parameters.

The Calnex default electrical parameters are a good starting point from which to work, from which adjustments to one parameter can be tested at a time. A certain amount of trial and error is required to refine the electrical parameters for unqualified transceivers to achieve good signal integrity.

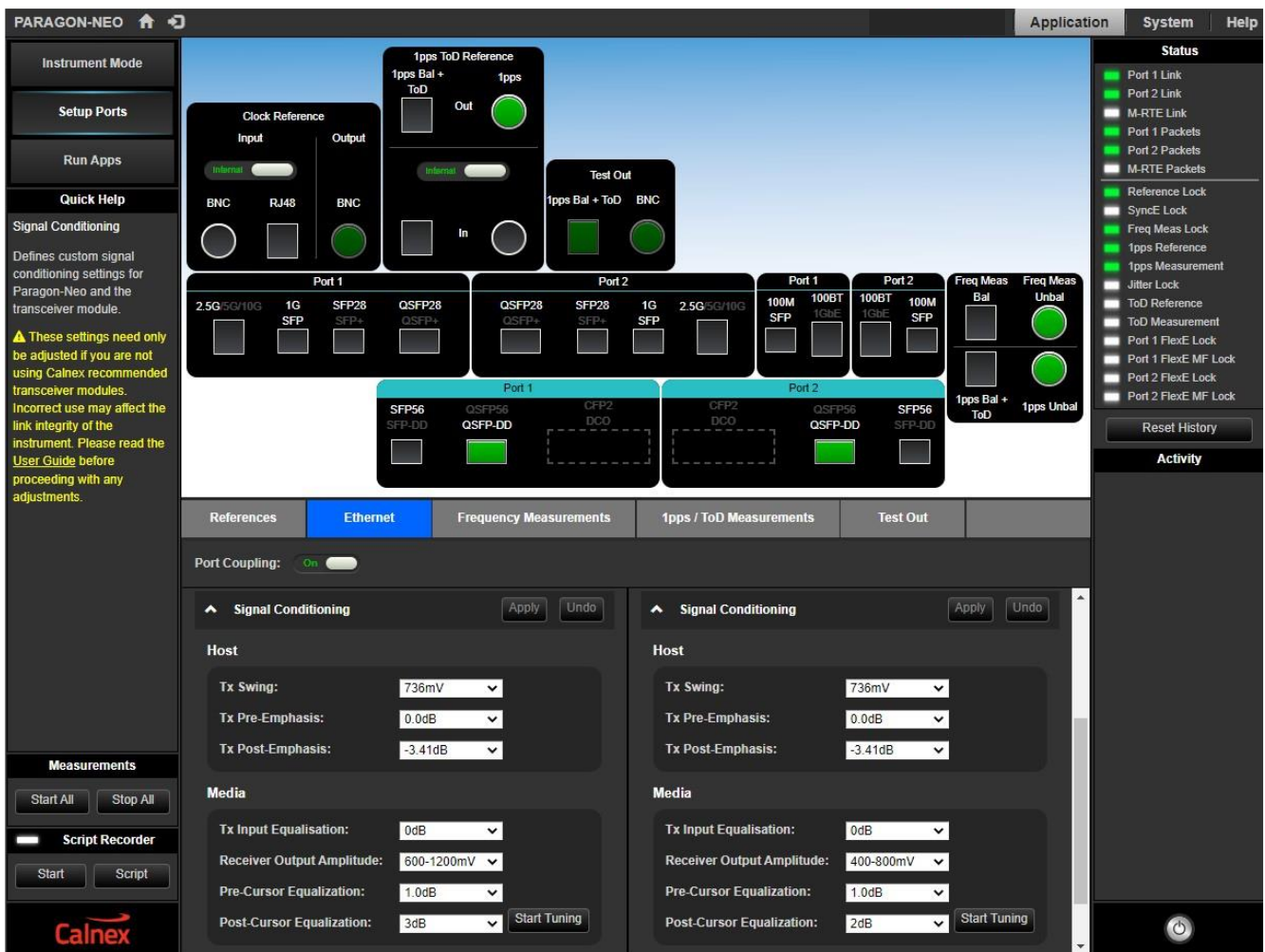
4.3. Signal Conditioning GUI

The screenshot below shows the **Signal Conditioning** GUI when Paragon-neo Ports 1 and 2 have 100G QSFP28 NRZ transceivers plugged in and selected. The **Signal Conditioning** GUI is similar when other types of NRZ transceiver are selected, only the specific parameters change depending on the transceiver type (see relevant MSA for details).

The screenshot shows the default electrical parameters for 100G NRZ QSFP28 modules on both Port 1 and 2. The parameters have different default values for each port due to the Paragon-neo internal hardware design. Port 2 does not have a receiver equalizer so no Rx Equalization parameter.



The **Signal Conditioning** GUI for PAM4 interfaces is shown in the screenshot below where 400G PAM4 QSFP-DD transceivers are plugged into Ports 1 and 2.



Note: while **Port Coupling** affects the port selection, the electrical signal conditioning parameters are always separate for Ports 1 and 2.

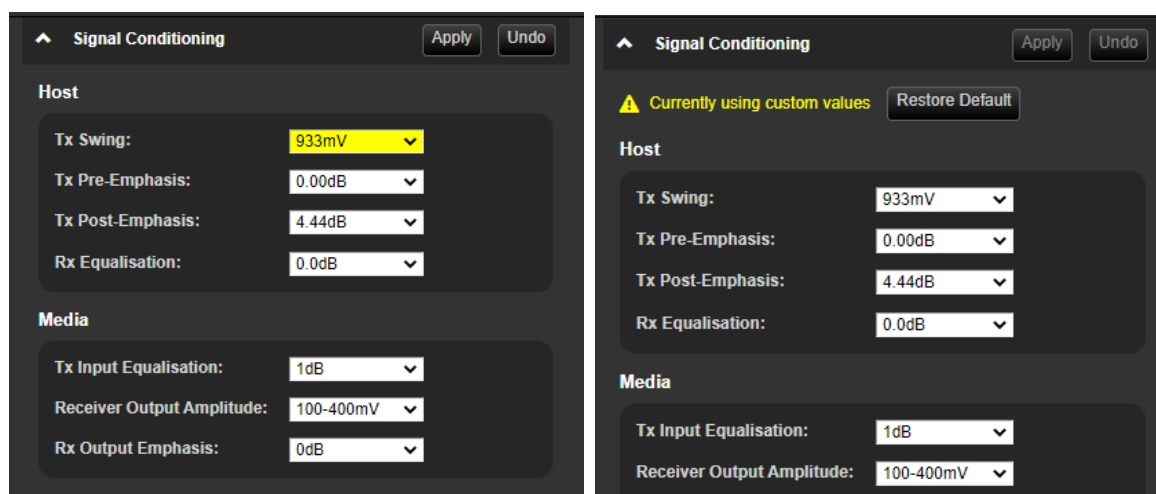
4.4. Changing Electrical Parameters for NRZ Transceivers

NRZ transceiver signal conditioning parameters should be adjusted one at a time, testing each change to assess the impact. Adjust the Amplitude Control parameters (TX Swing, Rx Swing) before adjusting the Emphasis and Equalization values. The adjustment process involves trial and error until values are found that give the lowest error counts.

1. Plug an NRZ transceiver into Paragon-neo Port 1 or Port 2.
2. Connect a single short optical fiber to loopback transmit and receive ports of the transceiver.
3. Click **Setup Ports** to show the Paragon-neo port configuration GUI.
4. Select the relevant interfaces for Port 1 or Port 2.
5. Click the **Ethernet** tab and expand the **▼ Signal Conditioning** details.
6. Using the **Host** and **Media** drop down lists, select new parameter values as required. The new parameters will be highlighted yellow. Click **Undo** to return to the default set of electrical parameters.
7. Click **Apply**.
8. A warning is displayed that the port is currently using custom values. To clear all custom values for the port, click the **Restore Default** button.

9. Check the **BIP Error** counter in the port **Details** panel to judge the impact of the change.

The examples below show the **Signal Conditioning** panel for Port 1 when a new value has been selected for the **Tx Swing** parameter but has not yet applied (left) and after applying the new value (right).



4.5. Changing Electrical Parameters for PAM4 Transceivers

PAM4 transceiver signal conditioning parameters should be adjusted one at a time, testing each change to assess the impact. Adjust the Amplitude Control parameters (TX Swing, Rx Amplitude) before adjusting the Emphasis and Equalization values. The adjustment process involves trial and error until values are found that give the lowest error counts.

A function is provided to automatically tune the Media Receive parameters for PAM4 transceivers – the Media Transmit and all Host parameters must be updated manually. Automatic tuning cycles through all combinations of the Media Receive values hunting for the best combination to minimize uncorrected FEC errors.

1. Plug a PAM4 transceiver into Paragon-neo Port 1 or Port 2.
2. Connect a single short optical fiber to loopback transmit and receive ports of the transceiver.
3. Click **Setup Ports** to show the Paragon-neo port configuration GUI.
4. Select the relevant interfaces for Port 1 or Port 2.
5. Click the **Ethernet** tab and expand the **▼ Signal Conditioning** details.
6. Using the **Host** drop down lists, select new parameter values as required. The new parameters will be highlighted yellow. Click **Undo** to return to the default set of electrical parameters.
7. Click **Apply**.
8. Electrical parameters for the transceiver can be configured in two ways:
 - a. Either use the **Media** drop down lists to select custom parameters and click **Apply**.
 - b. Or click the **Start Tuning** button to automatically select appropriate electrical parameters. Automatic tuning may take several hours to complete. The GUI displays a progress page while automatic tuning is underway.
9. A warning is displayed that the port is currently using custom values. To clear all custom values for the port, click the **Restore Default** button.
10. Check the **FEC Corrected** and **FEC Uncorrected** counters in the port **Details** panel to judge the impact of the change.

4.6. Clearing Custom Electrical Parameters

Several actions will clear custom electrical parameter values:

- Click the Signal Conditioning **Restore Default** button.
- Click the **Restore to Defaults** button in the **Run Apps > Save/Recall Settings** panel.

4.7. Saving Custom Electrical Parameters

Custom electrical parameter values are stored in Paragon-neo when the instrument is shut down and will be used again when the instrument is restarted.

Custom electrical parameter values are currently not saved in user configuration files with other instrument settings. A future software update will add the custom parameters when configuration files are saved.

5. Troubleshooting

Adjusting the signal conditioning and timing latency parameters associated with transceivers inherently impacts the stability of the link between Paragon-neo and the transceiver and the timing calculations based on PTP messages passing through the transceiver. Unexpected behaviour can be resolved as follows:

1. Ensure that all optic surfaces on transceivers and fibers are thoroughly cleaned. Contaminated optical surfaces can cause additional physical layer errors.
2. Verify Paragon-neo back-to-back operation with qualified transceivers:
 - Remove all custom timing and signal conditioning parameters.
 - Remove unqualified transceivers and replace with qualified transceivers of the same speed and interface type.
 - Run a back-to-back timing test between Paragon-neo ports 1 and 2 to verify that the instrument works correctly.
3. Re-run timing latency tests to validate the timing latency changes.
4. Re-run signal conditioning alterations using smaller changes. If possible, use the default signal conditioning parameter values.



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