TP4100 ePRTC Performance Report

Introduction

TimeProvider 4100 is a family of precise timing devices with various operation modes that enable a customer to specify a configuration for a use case while leveraging the same hardware.

As part of this delivery strategy, an Enhanced Primary Reference Time Clock (ePRTC) license option has been defined in release 2. This enables a customer to configure the TP4100 unit as an ePRTC device connected to a GNSS source and one or two Cesium clocks in order to meet ITU-T G.8272.1 standard performance requirements.

This is the first in the series of performance reports describing the Enhanced Primary Reference Timing Clock (ITU G.8272.1) feature of the Time Provider 4100 System.

The TP4100 is architected to support multiple operating software configurable modes on a robust high-performance, fan-less 1RU hardware platform. The current operating mode configurations supported as of release 2.1 are:

- Gateway Clock
- Single-Domain, High-Performance Boundary Clock
- Multi-Domain, High-Performance Boundary Clock
- ePRTC (demo mode release in version 2.0 or 2.1; official release in version 2.1.10 scheduled for July 2020)

When configured in the ePRTC operating mode, the TP4100 is fully compliant with the controlling ITU-T Recommendation: *Timing characteristics of enhanced primary reference time clocks* G.8272.1.

The TP4100 supports not just one but optionally two autonomous atomic clock references. When configured with dual autonomous atomic clock inputs, the TP4100 supports both priority reference operation and adaptive timescale ensembling, as described later.

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1. Overview of Time Compliance Testing

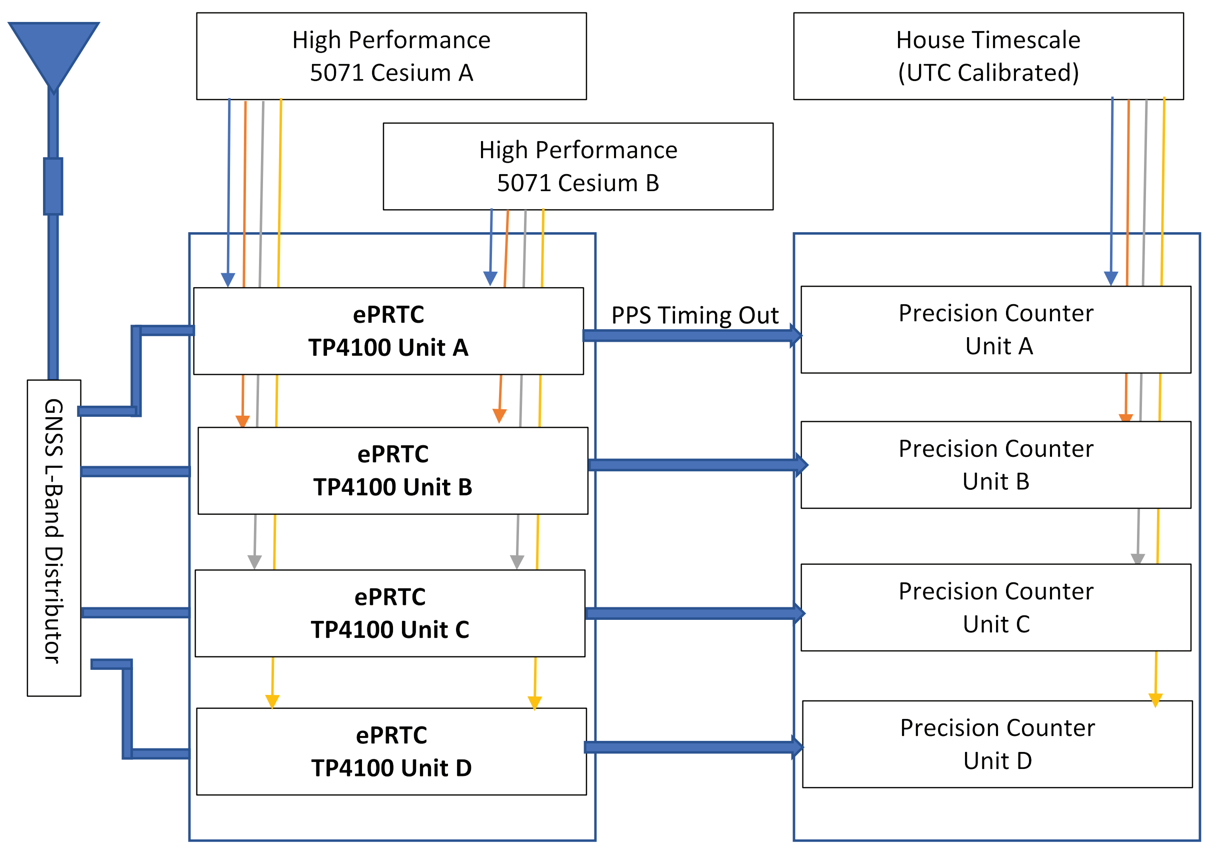
The full characterization of time accuracy compliances will be covered in this series of performance reports. In this first report, the time compliance in normal operation is the focus.

The normal operational environment is characterized by:

- The GNSS receiver function is operating in a proper surveyed-in (fix position) mode. For the TP4100, this function can be configured to be done automatically.
- The GNSS receiver function is supporting uninterrupted timing solutions. Essentially no extended period of GNSS outages.
- The temperature operating environmental is benign with daily temperature variations less than 5 °C.
- The TP4100 ePRTC is tested in GPS L1 operation for this characterization.

The following diagram shows the test configuration. The ePRTC test rack supports multiple TP4100 units that are tested simultaneously. Each TP4100 is provided a calibrated GNSS L-band input from the lab GNSS distribution. To support controlled testing, the GNSS distribution is from a common antenna, cable interconnect, and common active GNSS distribution amplifier. Two Microchip 5071 High Performance Cesium Clocks are configured to support either single or dual 10 MHz Cesium references to the ePRTC TP4100 units depending on the testing scenario.

Figure 1-1. ePRTC Timing Compliance Test Setup



Two ePRTC use cases are covered in this report:

1. **Single Cesium Input:** This is a basic configuration where a single external cesium reference clock is used to support the ITU requirement for a minimum of one co-located atomic clock.
2. **Dual Cesium Input:** The TP4100 ePRTC is designed to fully support dual cesium external clock references.

2.1. When one reference is assigned a higher priority, the TP4100 ePRTC system operates with this cesium reference assigned a 100% weight contribution to the local timescale (in steady state). The second cesium reference is operating as a hot standby to support failure or maintenance conditions.

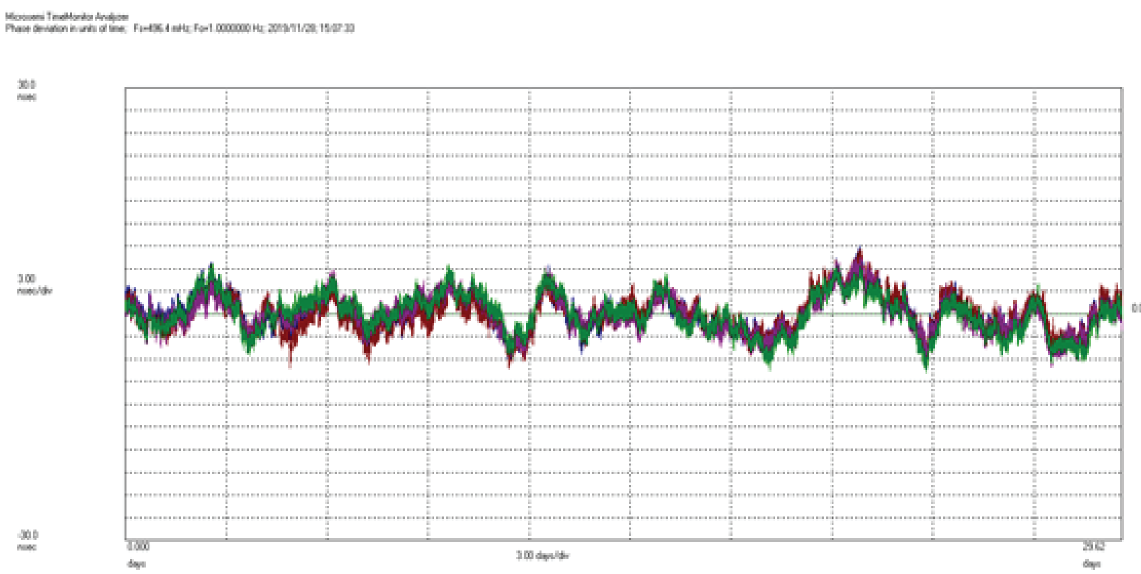
2.2. When both references are assigned equal priority, the TP4100 ePRTC system operates in adaptive timescale ensembling mode. In this mode, automatic machine learning is utilized to continuously adjust the weights of both cesium inputs to achieve the best timescale output. For the dual cesium results reported in this report, this mode is selected.

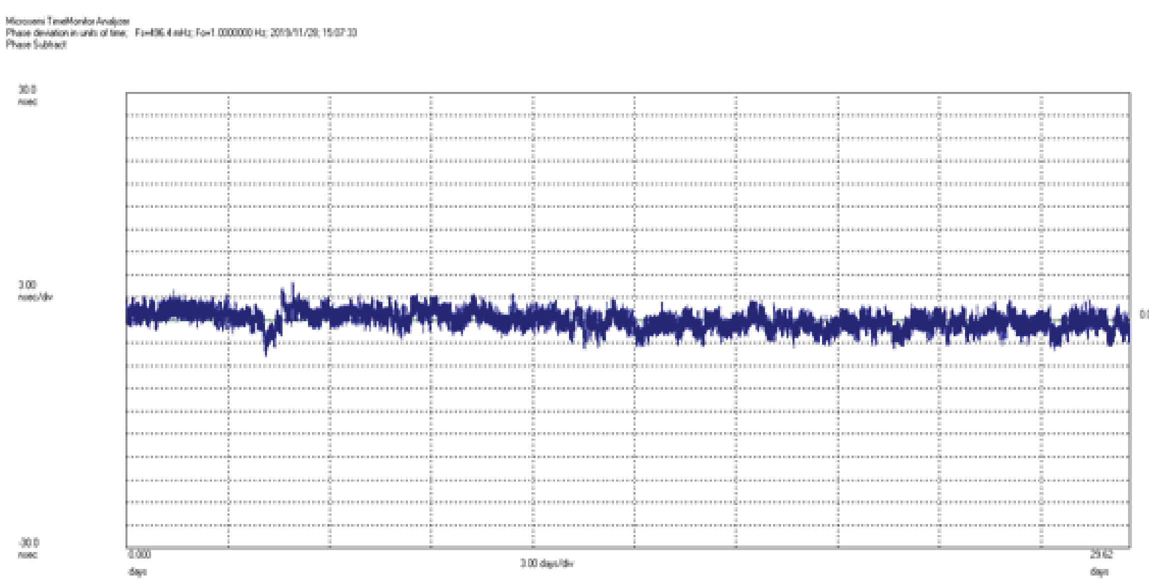
2. Single Cesium ePRTC Time Compliance Results

For this test, four ePRTC TP4100 units are configured as single cesium ePRTC systems. The test window is 30 days starting from power-up (data collection is shown 24 hours after power-up).

2.1 ITU G.8272.1 Time Accuracy Compliance

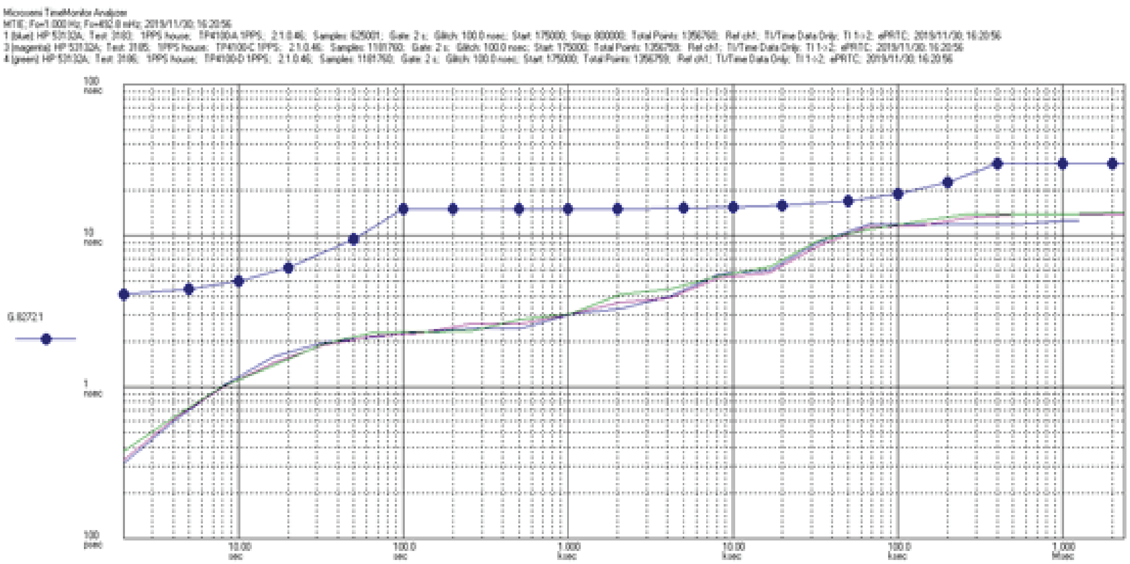
The following graph shows the PPS time error overlay (note the ±30 ns graph bounds are the compliance limit). The PPS time error performance is well within the 30 ns requirement (<10 ns over the 30-day test window). One important observation is that all four units are exhibiting essentially the same time error performance with respect to the house timescale reference This dominant common mode term includes the true common mode bias of the units plus the common mode bias of the house timescale (which is less than 5 ns). The differential time accuracy error between two units (Units A and B) shown in the second graph is significantly smaller. The differential time error associated with the units is observed to be 1.1 ns (1 sigma).





2.2 ITU G.8272.1 MTIE Compliance

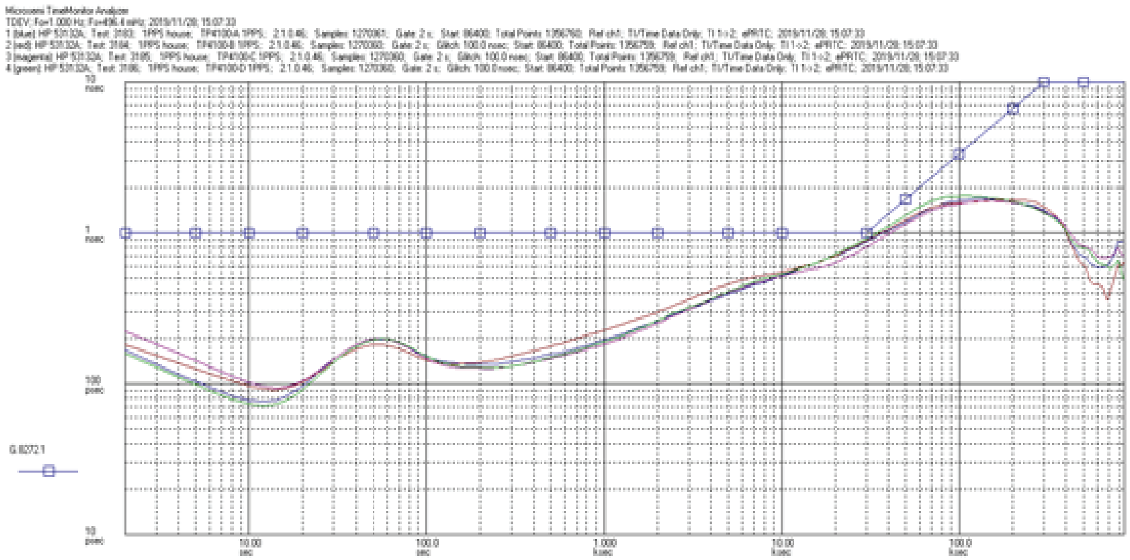
The following overlay graph shows the compliance of the ePRTC TP4100 units with respect to the ITU Maximum Time Interval Error Requirement. As already discussed, the House Timescale reference has an uncertainty of 5 ns which contributes to the overall MTIE performance.



2.3 ITU G.8272.1 TDEV Compliance

The ITU ePRTC requirements set a tight limit on the permitted time error stability. This can be seen in the first feature of the TDEV compliance mask which requires better than 1 ns stability for observation windows up to 30,000 seconds. This stringent requirement enforces the need for the local atomic timescale to be loosely coupled to the external GNSS reference. While the vast majority of GNSS based timing products operate with generally tight coupling to the GNSS reference, an ePRTC caliber timescale must be loosely coupled to protect the outgoing timing services from GNSS related vulnerabilities such as intended an unintended spoofing and jamming including space weather.

The following overlay plot shows the TP4100 is designed to be compliant to this stringent requirement. Note the House timescale contributes TDEV noise at the critical 30K observation point so the pass margin is actually better than shown in this instrumented test.

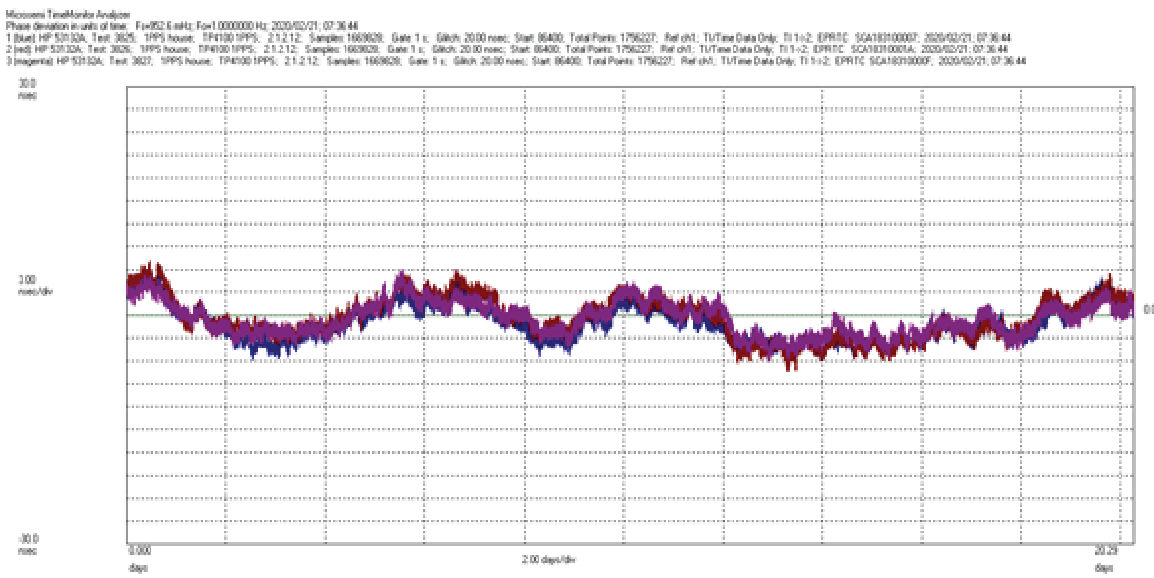


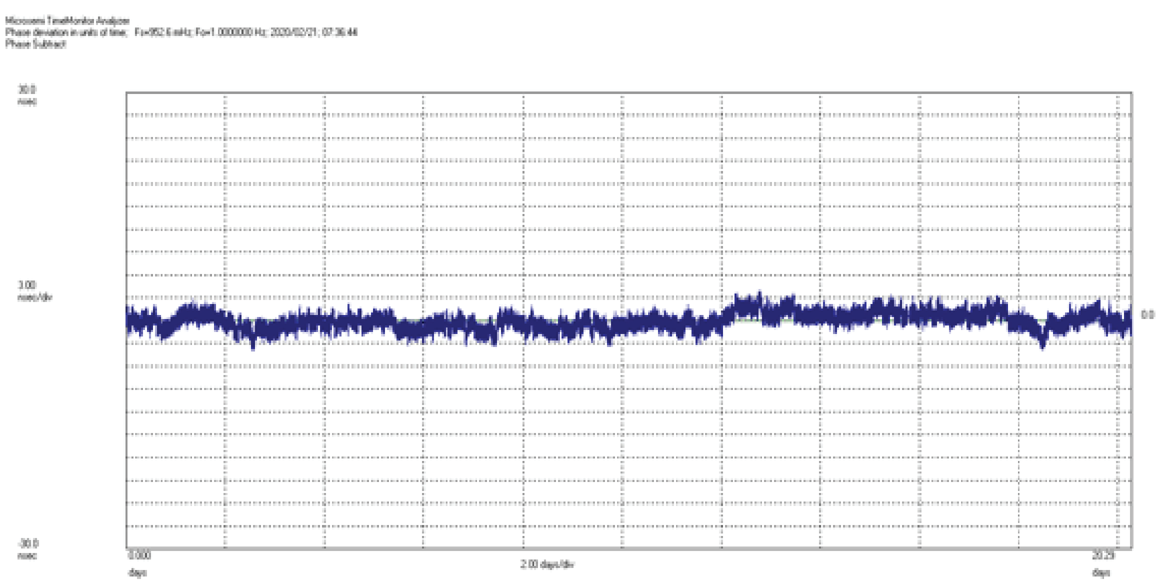
3. Dual Cesium ePRTC Time Compliance Results

For this test scenario, three ePRTC TP4100 units are configured as dual cesium ePRTC systems (note that the TP4100 included in the first single cesium test was re-purposed for other testing). The test window is 21 days starting from power-up (data collection is shown 24 hours after power-up).

3.1 ITU G.8272.1 Time Accuracy Compliance

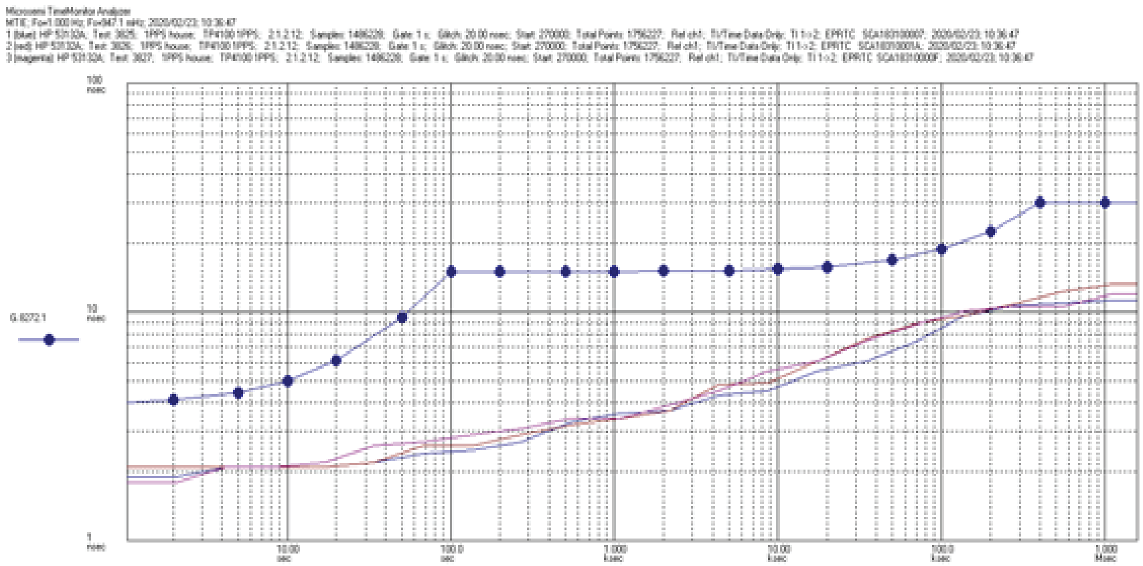
The following graph shows the PPS time error overlay (note the ±30 ns graph bounds are the compliance limit). The PPS time error performance is well within the 30 ns requirement (<7 ns over the 21-day test window). One important observation is that all units are exhibiting essentially the same time error performance with respect to the house timescale reference This dominant common mode term includes the true common mode bias of the units plus the common mode bias of the house timescale (which is less than 5 ns). The differential time accuracy error between two units (Units A and B) is shown in the second graph is significantly smaller. The differential time error associated with the units is observed to be 1.0 ns (1 sigma).





3.2 ITU G.8272.1 MTIE Compliance

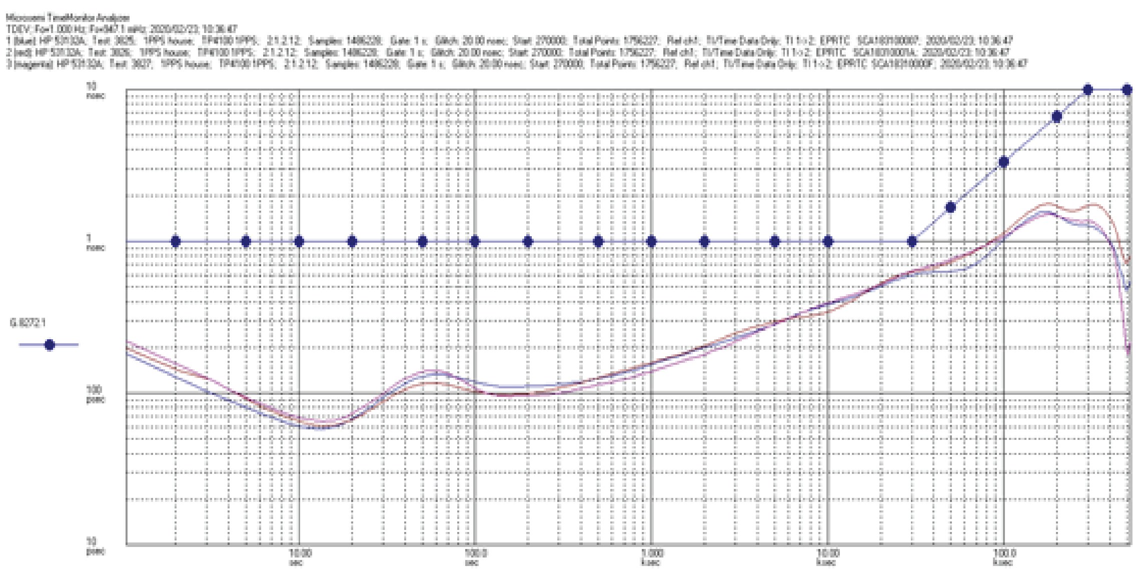
The following overlay graph shows the compliance of the ePRTC TP4100 units with respect to the ITU Maximum Time Interval Error Requirement. The MTIE performance shows a small but consistent improvement when operating in dual cesium adaptive timescale ensembling mode. The advantage is this mode is more statistically evident in the TDEV compliance results discussed later.



3.3 ITU G.8272.1 TDEV Compliance

As already discussed, the ITU ePRTC requirements set a tight limit on the permitted time error stability.

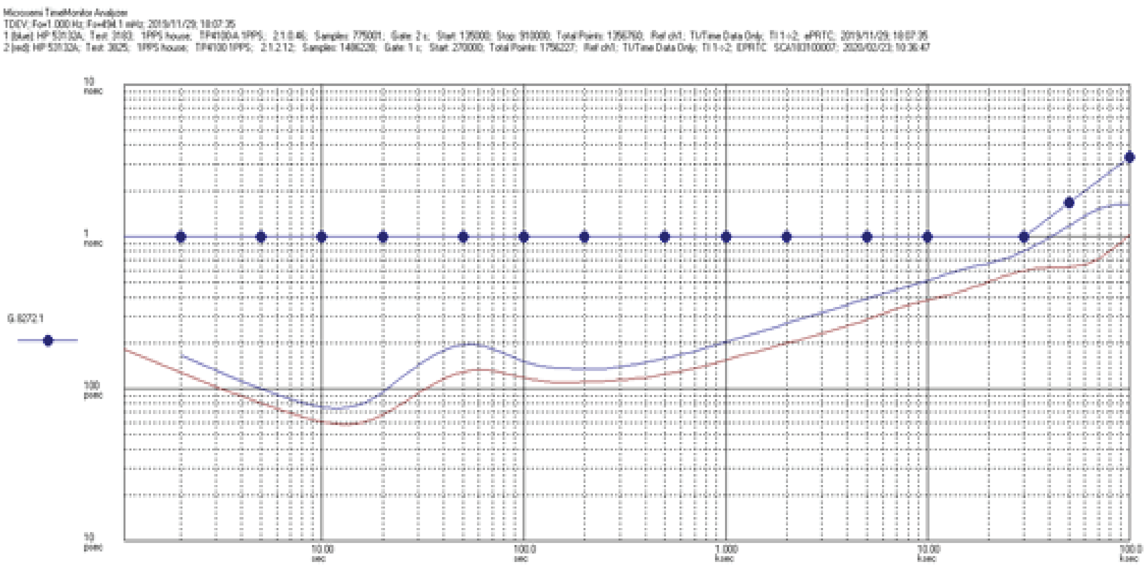
The following overlay plot shows the TP4100 is designed to be compliant to this stringent requirement. Note the House timescale contributes TDEV noise at the critical 30K observation point so the pass margin is actually better than shown in this instrumented test.



4. Adaptive Timescale Ensembling Advantage

For both test cases, the same unit (A) is configured with either one high performance cesium (5071) or two.

The blue graph shows the TDEV performance with respect to the ITU ePRTC compliance mask for the single cesium and the red graph shows the advantage of the using the dual cesium input adaptive timescale mode. This comparison demonstrates the performance advantage of this mode. One key benchmark is the margin compared to the ITU compliance mask at the key 30,000 second corner. In single cesium operation, the observed margin is 1.1 dB while with dual cesium adaptive timescale operation the observed performance margin is 4.4 dB. As a point of reference under the simple case where both cesium standards have identical performance the expected performance improvement would be 3 dB. Perhaps equally useful is the ability to detect a cesium that is degrading and de-weight it out of the ensemble.



5. Contacting Technical Support

If you encounter any difficulty installing the update or operating the product, contact Microsemi Frequency and Time Division (FTD) Services and Support.

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6. Revision History

Revision	Date	Section	Description
A	04/2020		Initial Revision

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