TimeProvider® 4500 Series Release 3.0

First Precise Timing Grandmaster With 25 GbE Support, Sub Nanosecond Accuracy and High PTP Capacity

Version 3.0 Highlights

The TimeProvider 4500 series now offers sub nanosecond accuracy that allows to extend the distance and the number of hops for nationwide distribution of time.
TimeProvider 4500 series complies with ITU-T G.8271.1/Y.1366.1 (2022) Amd.2 (01/2024) High Accuracy Time Transfer (HA-TT) class A with a max|TE| (Time Error) of only 5ns over 800km which equates to 500ps average per node (assuming 10 hops).
TimeProvider 4500 series provides a solution that minimizes dependency on GNSS; this terrestrial alternative relies on existing optical networks, off the shelf SFPs, standard Ethernet, standard PTP, is resilient, redundant and carrier grade.

Benefits and Applications

- Highly scalable PTP grandmaster implementation to serve thousands of PTP end points for customers deploying C-band gNodeBs
- sub nanosecond high accuracy time transfer (HA-TT) class A over 800 km
- Performance for highly accurate time distribution as an alternative to GNSS
- Highest network speeds on the market to ensure connectivity
- to various generations of network elements from 1 GbE to 25 GbE and beyond
- Sync solution for the mobile edge: 4G/ LTE, Cloud RAN (C-RAN), 5G, Open RAN (O-RAN)
- Ethernet backhaul, midhaul, fronthaul networks
- Cable remote physical layer (R-PHY)
- Migration from legacy synchronization (SONET/SDH) to Ethernet and IEEE® 1588 PTP for utilities, transportation and government markets

TP4500 High-Performance Hardware Platform

- Enhanced network connectivity
  - Choice of high-speed network interfaces available on the main unit
  - Configurable ports to enable 1 GbE, 10 GbE or 25 GbE
- Connecting to 100 GbE network elements: you can use a 100 GbE QSFP28 breakout cable to connect a 100 GbE port in a router or switch to a 25 GbE port on the TP4500
- All ports use hardware timestamping to ensure highest accuracy
- Hardware-accelerated PTP packet generation
- No expansion module is required to leverage 1 GbE to 25 GbE
- Standard base unit with:
  - Two RJ45 ports
  - Four SFP+ ports for 1 GbE or 10 GbE
  - Two SFP28 ports for 10 GbE or 25 GbE
  - Four E1/T1 ports
  - One craft port
  - Two 1 PPS/ToD I/O ports
  - Two high-accuracy ports: one 1 PPS output port and one 10 MHZ output port
- Optional internal expansion module with 16 E1/T1 ports for a total of 20 E1/T1 outputs per unit with support for composite clock including Japan format
- High 2,000 PTP clients capacity enabled by the latest PolarFire® SoC FPGA
  - Latest and largest Microchip FPGA SoC
  - Built-in scalability and flexibility
  - In-house source mitigates against silicon shortages
  - Thermal efficiency
  - Incorporates a quad-core deterministic, coherent RISC-V CPU cluster
- Incorporates our latest synthesizer technology to deliver best-in-class clock accuracy and stability
- Significantly exceeds Class D requirements with 1.7 ns maximum absolute time error on 1 GbE ports and 3.39 ns maximum absolute time error on 10 GbE ports

- Tightly integrated package leverages key Microchip parts including synthesizer, FPGA and state-of-the-art
- oscillators and is optimized to achieve the highest level of performance
- TDEV noise is under 5 picoseconds at 1 second; MDEV is at $5e^{-12}$ at 1 second
- Reliable passively cooled design with no fans minimizes the risks associated with rotation or moving parts
- Passive heat sinks for thermal mitigation
- Oscillator options: OCXO, super OCXO and rubidium (Rb)

Optional Expansion Module

The TimeProvider 4500 series allows you to add internal expansion modules for various capabilities. These expansion modules are an optional upgrade to the base unit.

E1/T1 Expansion Module

The E1/T1 internal module with 16 E1/T1 ports brings the unit to a total maximum of 20 E1/T1 ports (four in the base and 16 in the expansion module). This expansion module also supports CC and JCC, including two CC/JCC inputs to support cutovers from legacy SSUs.

Ports are configurable as E1, T1, CC and JCC outputs. Two ports can be configured for the CC/JCC input to use for phase alignment during cutovers from legacy Synchronization Supply Units (SSUs).

If you need more than 40 E1/T1 ports, you can connect the TP4500 grandmaster to an SSU or Building Integrated Timing Supply (BITS) system to act as a grandmaster reference with full Primary Reference Clock (PRC) traceability.

Oscillator Options

The standard TP4500 grandmaster is equipped with a crystal oscillator that enables accurate timing within nanoseconds when using GNSS-based time synchronization. However, if GNSS connectivity is lost and the TP4500 is placed in holdover, the oscillator will begin to drift, which will impact timing accuracy.

Upgrading the oscillator will significantly improve the holdover accuracy. For example, consider the drift rates listed in the table below for the OCXO, super OCXO and rubidium upgrades.

Small-Form-Factor Rubidium Oscillator

There are compelling reasons to use a rubidium oscillator instead of an OCXO, but not all rubidium oscillators are equal. Our miniature rubidium clocks are available in a unique physics package based on the Coherent Population Trapping (CPT) atomic clock. These devices consume less power, operate over a wider range of temperatures and have longer life cycles than legacy lamp-based rubidium oscillators used in other products.

Rubidium oscillators have much better power-on stabilization times than OCXOs: 24 hours after power-up versus two to five weeks. This differentiation alone is a significant reason for using rubidium-based units over OCXO-based units.

Typical Timekeeping in Holdover

Time Keeping	200 ns	400 ns	1.1 µs	1.5 µs	5 µs	10 µs
OCXO	4 hours	8 hours	14.5 hours	16.5 hours	1.5 days	2 days
Super OCXO	11 hours	18 hours	43 hours	52 hours	4.4 days	6.6 days
MAC Laser-Driven Rubidium	1 day	1.8 days	3.6 days	4.3 days	8 days	12 days

Note: The above are typical (1 Sigma Confidence) values and include initial phase and frequency errors. Assume a benign temperature environment and that the TP4500 is powered up for three weeks and locked to GNSS for 96 hours.

Frequency	Aging After 30 Days	Aging With Learning	Temperature Stability
OCXO	±6e−11 per day	±3e−11 per day	±4e−10
Super OCXO	±6e−11 per day	±3e−11 per day	±4e−10
MAC Rubidium	±1e−10 per month	±2e−12 per day	±5e−11

The TP4500 is assumed to be powered up for three weeks and locked to GNSS for 96 hours for aging with learning frequency performance category.

Upgrading the oscillator ensures that the TP4500 grandmaster will continue to serve very accurate PTP and NTP services if the GNSS signal is lost. This allows plenty of time to correct the problem with no degradation or disruption in time synchronization accuracy.

You can select the OCXO, super OCXO or rubidium model depending on your deployment needs. Rubidium oscillators are unequalled for telecom applications.

Cascading of Units

The TimeProvider 4500 series is designed to enable cascading units for higher-density applications and use cases. It can leverage a subtenancy architecture which allows a client unit to subtend from a TP4500 grandmaster using a ToD input/output. The TP4500, which we recommend be upgraded to use a rubidium atomic clock, is connected to GNSS constellations while the TP4500 acting as a client can use a lower-cost oscillator without connectivity to GNSS. This architecture doubles the port count of the combined system. Units can cross connect and can also connect to GPS, which enables a second reference when GNSS goes down.

Rich Software Capabilities

- Leverages the latest TimeProvider 4100 series firmware release
- Supports all TP4100 features and adds some specific
- features unique to this hardware platform
- Includes an upgraded Linux® platform
  - Incorporate the latest security enhancements
  - Incorporates latest uboot and updated software drivers
  - New YOCTO platform
  - New Linux kernel
- ITU-T G.8273.4 APTS with patented enhanced Automatic Asymmetry Compensation (AAC) over multiple network variations with multiple PTP client inputs and majority-vote mechanism
- Three choices of redundancy mechanisms (using two units):
  - Geographical failover
  - Active/standby software redundancy
  - Active/active software redundancy
- Power profiles with grandmaster operations : IEEE C37.238-2017, IEEE C37.238-2011, IEC/IEEE 61850-9-3:2016 and PRP IEC 62439-3 support
- Time Sensitive Networks (TSN) profile : 802.1.AS-2020
- Security via enhanced Secure Shell (SSH) protocol
- Authentication, Authorization and Accounting (AAA) for Terminal Access Controller Access-Control System
- (TACACS+) and Remote Authentication Dial-In User Service (RADIUS)
- RADIUS two-factor authentication
- IEEE 1588 2.1 2019 security support for prong C (architecture guidance) and prong D (monitoring and management)
- TimePictra® Synchronization Management System support
- Support for in-band management with PTP services, device management, PTP grandmaster and PTP client on the same physical port to save cost
- Monitoring and measurement capabilities for phase (PTP) and legacy ports

Best-of-Breed grandmaster Clock

The TP4500 grandmaster is a best-in-class 1588 grandmaster complemented by extensive port fan-out for PTP, Network Time Protocol (NTP), SyncE and legacy BITS.

With multiple ports for current, legacy and future networks that can be connected to multiple base stations for 4G and 5G deployments, the device is a cost-effective solution that can be easily adapted for a wide variety of use cases.

The base model offers:

- IEEE 1588 v2 frequency, time and phase profiles such as Telecom 2008, G.8265.1, G.8275.1 and G.8275.2 and Default
- IPv6/IPv4 on all ports including Management (OAM)
- Support for multiple IEEE 1588 v2 profiles per unit and per port
- Layer 2, Layer 3 support

The TimeProvider 4500 series SyncE supports:

- Enhanced ESMC via extended QL Threshold Limit Value (TLV) formats per ITU-T G.8264 Amendment 1 (03/2018) Clause 11.3.1.2
- Enhanced SSM codes, cascaded eEECs (G.8262.1) and other extensions provided by the latest Quality Level (QL) TLV format

The TimeProvider 4500 series is based on our newest platform and our latest-generation packet engine to provide the utmost flexibility:

- Multiple packet services in the box
- Specify the service on each port (grandmaster, client, probe, NTP)
- Select management and client service on either an RJ45 or an SFP port, depending on the network and preference

This flexibility enables operators to select from the number and types of ports and interfaces for specific use cases including 5G, cRAN and Data Over Cable Service Interface Specifications (DOCSIS) remote PHYs so they can deploy and scale their equipment without compromising on performance or features.

High Performance

The TimeProvider 4500 series can support:

- 2,000 unicast clients at maximum profile rate of 128 Packets Per Second (PPS) with or without two-step clock
- NTP hardware time stamping at 20,000 Transactions Per Second (TPS) per port, for a total of 160,000 TPS per unit, or with NTPd at 500 TPS on three ports for a total NTPd performance of 1,500 TPS per unit
- High-performance multi-domain boundary clock exceeding Class D (5 ns) accuracy (1.7 ns maximum absolute time error on 1 GbE ports and 3.39 ns maximum absolute time error on 10 GbE ports)
- High-Accuracy Time Transfer (HA-TT) for sub nanosecond accuracy class A (500ps average over 800km)

Primary Reference Time Clock

The TimeProvider 4500 series meets stringent precise time standards and complies with:

- Primary Reference Time Clock (PRTC) Class A (100 ns)
- PRTC Class B (40 ns), as well as the latest time and phase standards

Power Profiles Support

- The TimeProvider 4100 series is typically deployed on the communication networks of utility companies and can act as a gateway to the substation environments.
- It supports PTP Output Power profiles IEEE. C37.238-2017, IEEE C37.238-2011, IEC/IEEE 61850-9-3:2016 Grandmaster operations.
- The TimeProvider 4100 series also supports Parallel Redundancy Protocol (PRP) IEC 62439-3 for seamless failover against failure of network elements.
- Synchronization messages are sent via multicast to subscribers whereas network delays are sent via Peer-to-Peer (P2P).

Time-Sensitive Networks (TSN)

- The TimeProvider 4100 series can act as a TSN grandmaster with its support of IEEE 802.1.AS-2020 profile which is particularly useful for private network deployments.
- It can also act as a TSN bridge to provide a gateway function between a TSN working domain and a mobile network such as 5G.

GNSS Support

The TimeProvider 4500 series includes a 72-channel GNSS receiver coupled with our patented active thermal compensation technology. Its GNSS satellite input provides flexible support for constellations of choice depending on the region:

- Global Positioning System (GPS)
- Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS)
- BeiDou Navigation Satellite System (BDS)
- Quasi-Zenith Satellite System (QZSS)
- Galileo
- Satellite-Based Augmentation System (SBAS) support

The TP4500 grandmaster also provides multi-band support with an enhanced GNSS receiver. It is configured to support a single band by default.

Ionospheric conditions depend on time, season and solar activity. These ionospheric conditions can lead to substantial errors (around 50 ns in some cases) which need to be compensated. A multi-band GNSS receiver allows you to mitigate these error conditions. A multi-band receiver can also mitigate jamming. If one frequency is being jammed, the other band can be used for continued operation.

The webGUI on a TP4500 unit displays bar charts with the respective satellite signal values for all five constellations in parallel and for dual frequencies as well. The TP4500 also supports multi-band L1/L2/E5B frequencies.

Anti-Spoofing and Jamming

The multi-band GNSS support features two indicators for monitoring and protection against jamming. The Automatic Gain Control (AGC) and the continuous wave values can be used for guidance on recommended mitigation and actions that are documented in the User Guide.

The TimeProvider 4100 series utilizes advanced algorithms that observe each signal and utilizes knowledge linked to the superior oscillator of the unit compared to data provided by its GNSS receiver. The TP4100 series can detect and mitigate abnormal subtle patterns and offer ultra-high protection of the output timescale.

Embedded BlueSky Firewall

The TimeProvider 4100 series embeds BlueSky GNSS firewall technology for the best GNSS protection. The BlueSky technology is a software option that does not require additional hardware modules. It includes an extensive set of detectors for monitoring GNSS. These detectors include tracking, jamming/spoofing, RF health and navigation message content. Consistency checks are performed to detect possible attacks. Automatic actions can be configured restrict GNSS if the signal has been compromised. Results can be charted and saved for further analysis.

Resilient Solution

The TimeProvider 4500 series features layered protection:

- Accepts three PTP inputs with our enhanced asymmetry compensation to provide best-in-class Assisted Partial Timing Support (APTS) to back up the GNSS signal
- by correcting for up to 96 network paths or behavior variations
- APTS is a key technology that accounts for high packet
- delay variation, timing jitter variation and asymmetry challenges
- Majority-vote mechanism (part of IEEE 1588 2.1 2019
- prong C) to select the best input for APTS
- Provides dual Direct Current (DC) input for power redundancy and geographical network redundancy for failover

Redundancy

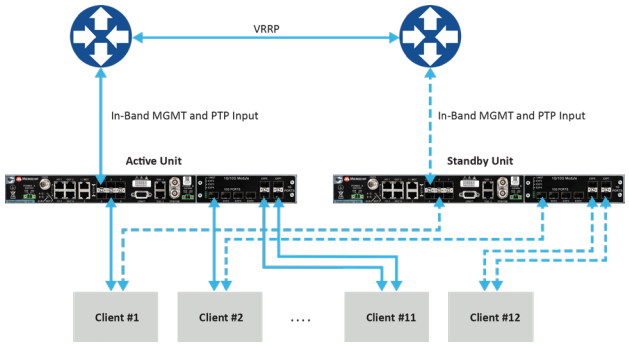
Software redundancy enables a cost-effective architecture, flexibility, resiliency and investment protection.

In this software redundancy schema, two units effectively act as a single coordinated system for high availability of Ethernet timing services. One unit is configured as active while the second unit is set up as standby. Both hardware units need to be similar except for the oscillator grade, which can be a lower grade on the standby unit. License options need to be equivalent on both units.

Both units need to be connected via a direct fiber and an additional RJ45 cable connection and co-located at a maximum of 100 meters.

Typically, the two units will be used in conjunction with Virtual Router Redundancy Protocol (VRRP) to achieve seamless transfer of PTP client sessions between the two grandmaster units. This is quite important as PTP clients do not need to reset their internal clock state-machine which happens when connecting to a new grandmaster. In this case both redundant grandmaster units announce the identical session information upon switchover.

Redundancy is offered in Gateway-Clock and ePRTC modes.



Use Case - Aggregation

Accuracy is the relative offset between the active and standby units and is lower than 5 ns relative to the 1 PPS output on the active unit. A single IP management address is used.

Health metrics and check mechanisms ensure proper monitoring of units to trigger the redundancy mechanism (switchover event). The redundancy schema is non-revertive. Manual intervention is required if the user decides to switch back to the original active unit once it is back in operation.

Switchover of timing services is very performant. It is completed in less than 3 seconds for any profiles (aside from G.8275.1) with recovery of the full list of connected clients. For the G.8275.1 profile, switchover is performed in less than 0.375 seconds.

Legacy ports have different behaviors than Ethernet. Squelch or Active-Active modes enable the user to decide whether the behavior of the output ports should switch over or not, depending on the user's needs and redundancy strategy.

Redundancy has been extended to the enhanced PRTC (ePRTC) when both active and standby units are set in ePRTC operation mode.

The user is offered more flexibility for the ports that are dedicated to the redundancy function, not just ETH4.

Active/Active Mechanism

The other redundancy mechanism features two units that act as completely separate and distinct units that do not need to have the same hardware configuration nor the same licenses installed, but these two units need to be synchronized.

Operation Modes

The TimeProvider 4500 series can support multiple modes of operations:

- Gateway Clock mode
- Single Domain or Multi-Domain High-Performance Boundary Clock mode
- ePRTC mode

Each operation mode is defined by a very specific set of inputs that are used as reference signal references. From an output standpoint, all features of the grandmaster clock are available as well as monitoring of external timing inputs.

Gateway Clock Mode

The TP4500 grandmaster is a gateway clock, a new class of synchronization product that accepts multiple inputs and generates a variety of outputs using sophisticated mapping algorithms.

Inputs can be GNSS, SyncE, IEEE 1588 PTP, TOD, 1PPS, 10 MHz, 5 MHz and E1/T1 digital transmission links that distribute timing flows to multiple endpoints such as base stations. A gateway clock benefits from multiple layers of protection by leveraging other assets in the core of the network.

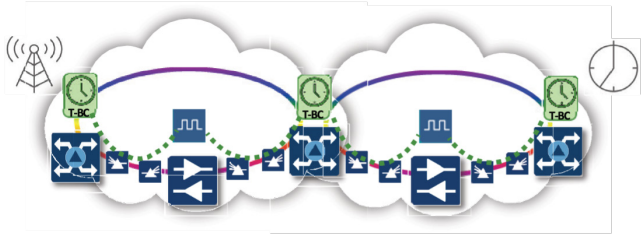
The TimeProvider 4500 series supports hybrid operation, which allows the frequency reference to come from only one frequency source (e.g., SyncE) and the time reference to come from another source (e.g., PTP).

Multiple IEEE 1588 PTP enhancements are available in v2.3, including:

- Support for up to three PTP clients with
- asymmetry correction and majority vote to select the best channel for APTS in Gateway Clock mode
- Support for two PTP grandmaster profiles per port
- Support for two timing services per port

High-Performance Boundary Clock Mode

An optional license can enable High-Performance Boundary Clock (HPBC) mode. This mode is used to enable boundary clock with Class C (10 ns) and Class D (5 ns) performance levels.



Optical Timing Channel

One license can enable two different operation modes: Single-Domain HPBC (SD HPBC) or Multi-Domain HPBC (MD HPBC). A typical MD HPBC mode architecture is a horseshoe. An ePRTC placed at each end of the horseshoe transfers precise time to a chain of HPBC units providing PRTC Class

A (100 ns) service to gateway clock units. This architecture is redundant as both directions of the horseshoe design can serve as a backup in case of failure in one specific direction.

With SD HPBC, the chromatic dispersion calculator was designed for a single PTP client. This has been enhanced in MD HPBC mode to support two PTP clients with respective fiber length fields. Two different chromatic dispersion offset values can be calculated.

High-Accuracy Time Transfer Clock Mode

An optional license can enable HA-TT clock operation mode (5 ns max|TE| (Time Error) over 800 km, equates to 500 ps average per node, assuming 10 hops). The application or use case is similar to MD HP BC, enabling the creating of chain of nodes for nationwide distribution of accurate time in a vPRTC architecture. This operation mode enables a sub nanosecond enhanced vPRTC..

ePRTC Mode

Mitigates Threat of GNSS Vulnerabilities

Concerned about GNSS vulnerabilities—such as signal anomalies, regional disruptions and even global outages—governments around the world are asking their primary network infrastructure providers to defend against this serious threat. The TimeProvider 4500 series' ePRTC goes far beyond mitigating the threat of GNSS vulnerabilities. It enables an operator to deploy an autonomous time source that is impervious to GNSS disruptions and outages.

Meets ITU-T G.8272.1 Requirements

ITU-T G.8272.1 specifies the requirements for ePRTCs. This standard describes stringent time, phase and frequency requirements. It also requires that an ePRTC has frequency output performance levels that will set the foundation input that can be fed with an autonomous primary reference clock.

Available as an operation mode, the ePRTC enables an operator to configure a TP4500 grandmaster as an ePRTC device that meets the 30 ns standard's requirement.

Since the ePRTC is available via software upgrade, there's no need to purchase new hardware. Any grandmaster in the TimeProvider product family manufactured after July 2019 is factory calibrated to meet PRTC-A, PRTC-B and ePRTC requirements. The grandmaster can be upgraded to the latest firmware to operate in ePRTC mode if configured accordingly.

The output signal generator of the TP4500 grandmaster's ePRTC system provides several formats including PTP, SyncE, 10 MHz, TOD and 1 PPS and traditional timing formats such as E1.

Cesium Atomic Clock System

The TimeProvider 4500 series' innovative, and high-performance design meets the ITU-T G.8272.1 30 ns accuracy requirement for ePRTC with either a standard cesium atomic clock, such as the TimeCesium® 4400/4500 primary frequency references, or with a high-performance atomic clock such as the 5071A or B.
TimeCesium 4x00 and CsIII products have one 10 MHz output and one 5 MHz output. The TP4500 grandmaster supports a 5 MHz or 10 MHz signal. Since it can sense if the incoming frequency is 10 MHz or 5 MHz, no additional configuration is necessary.

The user can select the right cesium source system based on requirements and budget.

Ensemble Function

The Ensemble function is available when there are two cesium clocks connected to the system. The ensemble algorithm measures and compares the stability of the individual cesium clocks and uses these measurements to produce a higher level of accuracy. Using two cesium clocks also provides operational advantages, as one of the cesium clocks can be removed from service while the system is in operation without any degradation in performance. The ePRTC Output Weight metric for each of the cesium clocks is based on the algorithm quality assessment for each clock. This ePRTC Output Weight metric is visible via CLI and the TimePictra software suite.

Fully Protected Time Scale

The TimeProvider 4500 series' ePRTC generates time by producing its own autonomous time scale, which provides time, phase and frequency that are aligned and calibrated to the GNSS signal over time. Using patented measurement algorithms, the ePRTC engine evaluates and measures its own autonomous time scale relative to GNSS. It then adjusts its timescale as needed, rather than following the GNSS time regardless of its accuracy. The cesium clocks and GNSS help maintain the accuracy of the ePRTC time scale.

In addition to being used for holdover backup, the local atomic clock provides protection against real-world GNSS events that happen during normal day-to-day tracking operation. The TimeProvider 4500 series' ePRTC has the best protection decoupling in the market, providing a full day of isolation to mitigate real-world jamming and spoofing and unsurpassed detection of anomalous GNSS measurements.

The TimeProvider 4500 series' ePRTC does not simply lock to one atomic clock, but locks to two clocks actively and seamlessly in a properly weighted time scale ensemble.

For example, if one atomic clock degrades in performance, the ePRTC will effectively de-weight it from influencing the outgoing time and frequency services.

We provide simple and intuitive dashboard metrics on our ePRTC availability and timescale performance to support proactive management of the ePRTC in your network.

Holdover Gas Gauge

Based on our extensive expertise in real-life deployments, we know that systems not only need day-to-day protection from GNSS issues, but they also need the assurance that the timescale will support the 14-day holdover current standard requirement as well as 40-day holdover for the upcoming standard revision.

We maintain a simple holdover estimate (similar to a gas gauge) so you can know what the current time error accumulation is during holdover and can predict the holdover period that the TP4500 ePRTC system is capable of maintaining an accuracy of 100 ns to UTC without GNSS.

Our product experts and channel partners can assist you with deploying a TP4500 grandmaster, including enabling the ePRTC mode and setting up the GNSS antenna and cabling.

SSU Operation Mode

SSU Operation Mode is required in a use case where the primary frequency input into the TimeProvider 4100 unit is a line legacy signal such as E1 or T1. In this case, there is a need to filter for jitter and wander. Typically GNSS is not used as a reference in this use case as a TimeProvider 4100 using GNSS as primary would be configured as a gateway clock not in SSU mode.

However a TimeProvider that uses SSU mode can of course have its Ethernet ports used for PTP profiles and using GNSS. For jitter and wander filtering to continue operating on E1/T1 input ports, it is critical to have E1/T1 as primary and GNSS as secondary input priority.

Security

Access Control Lists (ACL) are supported for white lists and black lists.

Hardware-level security enables the system to avoid denial of service scenarios for synchronization traffic as well. The TP4100 supports Secure Shell Protocol (SSH). It also has firewall features that can block specific protocols such as Simple Network Management Protocol (SNMP), SSH, Internet Control Message Protocol (ICMP) and more.

Full Authentication, Authorization and Accounting (AAA) is supported for both TACACS+ and Radius for up to five external servers. Radius also now supports Two-Factor Authentication (2FA).

The IEEE 1588 2.1 2019 security standard is now supported for two prongs: prong C (architecture guidance) and prong D (monitoring and management).

Prong C provides more resilient operation of PTP inputs for APTS by using a majority-vote mechanism that also detects tampering of timing packets.

Prong D is used for detection of potential tampering by measuring unusual offsets, PTP link delays and other events.

New SSH extensions can be used to secure a profile. The security level can be configured via a Command Line Interface (CLI) or the TimePictra software suite to enable or disable high-security mode. Stringent password complexity requirements can be enforced.

Common Vulnerabilities and Exposures (CVEs) and the cross-site scripting vulnerability have been addressed to protect the unit from these security exposures.

The TimeProvider 4500 series utilizes advanced algorithms that observe each signal as well as measurements from the superior oscillator of the unit compared to data provided by its GNSS receiver. The TP4500 series can detect and mitigate subtle or abnormal patterns and offer ultra-high protection to the output timescale.

Monitoring

The TimePictra software suite offers intuitive feedback for ease of use. The Microchip-branded webGUI that is available on the TP4500 grandmaster is a user-friendly interface for monitoring results, measurements and calculations. Key benefits include:

- webGUI-based real-time metric updates
- Graphing of any metric vs. user-configured thresholds
- Selectable generic alarm generation for any metrics that support thresholds
- Storage of time metrics for 24 hours
- Support for Time Interval Error (TIE)
- Simple download for every metric (compatible with TimeMonitor software)
- 1 ns resolution

Originally developed to help customers with phase deployments, the TimeProvider 4500 series features Time Error calculation for monitoring PTP traffic as well as 1 PPS monitoring.

Monitoring supports legacy options including E1/T1, SyncE and 10 MHz signals. Frequency TIE monitoring, presented as Maximum Time Interval Error (MTIE) is offered for observation periods of 1, 10, 100, 1000, 10000 and 100000 seconds.

Other enhancements include performance monitoring of multiple PTP clients. SyncE signal monitoring uses the same physical port as PTP monitoring.

TDEV Support

The TimeProvider 4500 series takes advantage of multi-band GNSS support with metrics such as Peak Time deviation (TDEV) noise, which is lower than single-band GNSS.

Management

When deployed with our TimePictra Synchronization Management System, a TP4500 grandmaster offers superior monitoring information and management capabilities.

It features full Fault, Configuration, Accounting, Performance, Security (FCAPS) capabilities using the Command Line Interface (CLI) and the TimePictra software suite. A separate management port can be selected either as RJ45 or as an SFP+ port. In-band management is also supported. Internal logging, SNMP traps and alarms and Light-Emitting Diodes (LEDs) provide additional insight into the status of the unit.

Configuration changes made after an upgrade and before a reboot are now preserved. Support for NTP client and local time assures time alignment for system logs.

A new communication system between the grandmaster and the TimePictra software suite significantly improves system performance and the user experience. It leverages autonomous messaging, which combines status changes or configuration changes without requiring multiple polling messages from the TimePictra software suite.

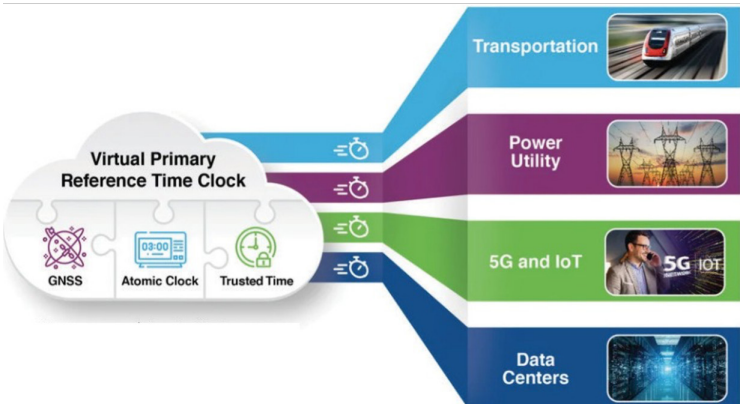
Virtual PRTC (vPRTC) Architecture

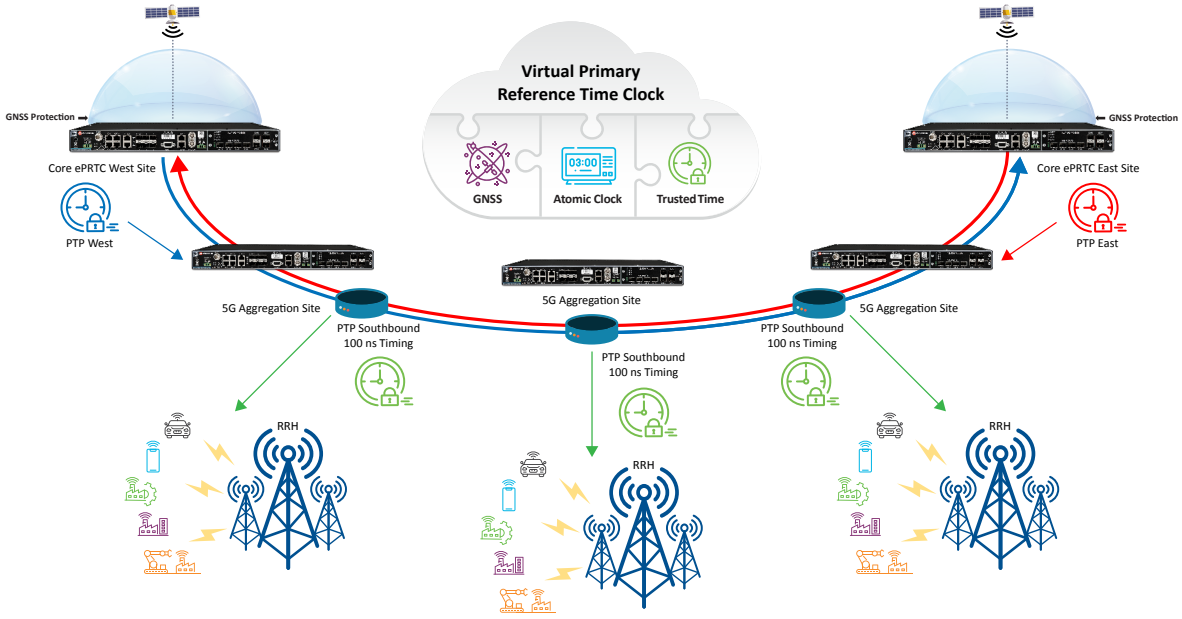
This architecture prescribes:

- Leveraging the existing optical network to avoid using expensive dark fiber
- Using dedicated lambda to transport time in the most rapid way and provide the utmost resiliency
- Using a redundant source of time based on the ePRTC, which can deliver 30 ns performance and use a combination of cesium clocks and GNSS as the source of time
- Offering east and west flows of time to provide a redundant path from source to endpoint
- Offering a chain of high-precision MD HPBCs that can meet the highest level of performance defined by T-BC Class D 5 ns standards

Optical Timing Channel

This vPRTC multi-domain architecture is currently the only solution available for delivering affordable, high-performance, state-of-the-art, redundant sub 5 ns distribution of precise time over hundreds of miles optical links, using a state-of-the-art Optical Timing Channel (OTC) for highest accuracy.





Specifications

Mechanical

- Size: 1 RU
- Height: 1.73 in. (44 mm)
- Width: 17.24 in. (438 mm)
- Depth: 9.50 in. (241 mm)
- Depth with connectors on faceplate: 10.21 in. (259 mm)
- 1.75 in. (H) × 17.5 in. (19 in. with handle bracket) (W) × 9.5 in. (10.5 in with BNC connector)
- Rack mounts: 19-inch; optional kits for 21-inch and 23-inch rack installations
- Weight: 12.5 pounds (14.5 pounds with shipping box)

Power

- DC power models: dual-power feeds, –38.4 Vdc to –72 Vdc
- Power consumption: OCXO and super OCXO models with DC supply: 38 Watts (max), 30 Watts (typical)
- Rubidium model with DC supply: 45 Watts (max), 38 Watts (typical)

Oscillator

- Oscillator options: OCXO, super OCXO and rubidium

GNSS

- Multi-constellations: GPS, GLONASS, BeiDou, QZSS and Galileo
- SBAS support
- Multi-band support
- GPS L1/L2C
- Galileo E1/E5b
- Glonass L1/L2
- BeiDou B1I/B2I
- QZSS L1/L2C
- User-configurable GNSS RX survey parameters
- User-configurable AGC and CW range (0%–100% seconds)
- Antenna GNSS cable delay range ±100 (us) GPS over fiber at locations up to 15 miles

PTP client (PTP Input)

- Three PTP client inputs with majority vote for best APTS channel selection and Figure of Merit metric
- Two PTP clients in MD HPBC mode of operation
- Profiles: Telecom-2008, ITU-T G.8265.1, ITU-T G.8275.1 and ITU-T
- G.8275.2
- Best grandmaster Clock Algorithm (BTCA) (IEEE 1588 v2), alternate BTCA (ITU-T G.8275.1/2) and Global Best grandmaster Clock Algorithm (G-BTCA) 1.0

Timing Services

- Profiles: Ethernet default, Telecom-2008, ITU-T G.8265.1, ITU-T
- G.8275.1, ITU-T G.8275.2 and default (IPv4)
- ITU-T G.8263
- Multiple PTP profiles support per box
- Dual PTP grandmaster profiles per port
- Multiple timing services (PTP, NTP, grandmaster, client) per port
- G.8275.1 PTP grandmaster profile on 10 GbE expansion module is sourced from main unit packet engine per default
- PTP client list for all ports
- Configuration of PTP client load percentage threshold for the entire system with alarm when exceeded
- PTP client timing service can be set on any one of the ports or ETH5 and ETH6 ports together in MD HPBC operation mode
- NTPr v4 and v6 and NTPd with MD5 security
- NTP client mode for setting log files – NTPv4&v3 (RFC5905)
- NTP or PTP support per port
- Main unit: total of eight ports can operate in parallel with any packet engine services
- In-band or out-of-band management from ETH1 or ETH3 ports
- MGMT port: ETH1, ETH3 are capable of PTP client as well as PTP grandmaster and NTPr
- Ports ETH2 and ETH4–8 can operate as packet engine services (PTP GM, NTP, PTP probe)
- PTP client timing service can be set on any one of the ports or ETH7 and ETH8 ports together in MD HPBC operation mode
- Power grandmaster Profiles: IEC/IEEE 61850-9-3:2016, IEEE C37.238-2011, IEEE C37.238-2017
- Parallel Redundancy Protocol (PRP) IEC 62439-3 with maximum of four PRP instances
- IEEE 802.1.AS-2020 PTP grandmaster profile support for Time Sensitive Networks (TSNs)

Timekeeping and Holdover

- Maintains ITU-T G8271.1 400 ns GMC holdover specification for up to 43 hours
- Maintains performance levels for a period until technician
- can reestablish GNSS or fix the disruption
- Several levels of oscillators (hold 200 ns for full day) to enable remediation
- ITU-T G.8273.4 APTS with enhanced patented automatic asymmetry compensation providing extended phase alignment protection for up to 96 network variations
- Configurable bridging time
- Geographical redundancy through network topology and failover

ePRTC

- ePRTC ITU-T G.8272.1 30 ns accuracy with support for either 10 MHz or 5 MHz input from cesium clock
- Enhanced holdover from 14 days to 40 days to meet latest
- revision of ITU-T G.8272.1 standard
- Time reference inputs can be GNSS, ToD-1 and ToD-2
- Frequency reference inputs can be GNSS, PPS10M-1 and PPS10M-2
- Other references, such as 1 PPS, for monitoring
- ePRTC ensembling for use of dual cesium feeds in parallel
- ePRTC default bridging period: 14 days, configurable from 5–80 days
- Support for redundancy (with OCXO or better oscillator)
- Provides autonomous time scale for time, phase and frequency that operates even without GNSS availability
- Exceeds requirements as defined by ITU G.8272.1
- Operates with one or two cesium clock inputs
- PTP IEEE 1588 grandmaster or integration with external grandmasters such as the TP5000 and TP4100
- Meets standard with either standard cesium or high-performance cesium source systems
- Time error in locked mode: accuracy to within 30 ns when verified against the applicable primary time standard (such as UTC)
- Wander in locked mode: better than MTIE and TDEV masks as defined by G.8272.1
- Holdover over 14 days: meets or exceeds 100 ns when verified against the applicable primary time standard (such as UTC)
- Holdover gas gauge
- Intuitive dashboard metrics

Scalability

- 2,000 PTP clients at 128 pps per box in unicast profiles
- NTPr up to 20,000 tps per port, for a total of 160,000 tps per unit
- NTPd up to 500 tps per port up to three ports for a total of 1,500 tps per unit

Licensing

- Base unicast client count of 64 clients and software upgrade options through licensing to 128, 256, 512, 790, 1,000 and 2,000 clients at 128 packets per second
- NTP license
- HPBC license
- HA-TT sub nanosecond license
- ePRTC license
- Multiband GNSS operation license
- Ultra resilience for multi-PTP clients with three PTPc and majority-vote mechanism for enhanced APTS
- 1 PPS + NTP time reference license
- Power profile license
- 802.1.AS TSN profile licenses

Management

- Separate management port from other traffic (such as PTP grandmaster, NTP server and more)
- In-band management (from PTP client interface)
- IPv4 or IPv6 support for management traffic
- FCAPS on TimePictra platform
- Internal log
- SNMP traps (v2 and v3)
- CLI through SSHv2
- webGUI through Hypertext transfer protocol secure (HTTPS) for monitoring performance
- Custom CLI banner
- Syslog RFC5424

Security

- Firewall limits specific protocols such as SNMP, SSH, ICMP and more
- Avoid traffic port denial of service scenarios including sync
- and announce packet receptions for GM port in hardware level
- Status in CLI and TimePictra software suite – three NTP
- servers (configurable)
- Support for TACACS+ AAA
- Maximum five external TACACS+ servers, Name Service Switch (NSS)
- Configuration via SSH or TimePictra software suite
- Support for RADIUS AAA (maximum five external)
- RADIUS servers: configuration via SSH or TimePictra software suite
  - Support for RADIUS 2FA
- Support for IEEE 1588 2.1 2019 security prong C (architecture guidance) and prong D (monitoring and management)
- Vulnerabilities fixed in TimeProvider 4500 series:
  - CVE-2019-15921
  - CVE-2019-15916
  - CVE-2019-10639
  - CVE-2018-20856
  - CVE-2019-8912
  - CVE-2019-11477/11478/11479
  - CVE-2019-5599
  - CVE-2020-11868
- Cross-site scripting
- Enhanced password complexity requirements
- Access Control List (ACL) for black lists and white lists
- High-security profile for secured mode configuration (SSH extensions)
- Encryption Algorithms (Ciphers):
  - High Profile: aes256- gcm@ openssh.com, aes128-gcm@openssh.com, aes256-ctr, aes192-ctr, aes128-ctr
  - Default profile: (In addition) chacha20-poly1305@ openssh.com
  - Medium Profile: (In addition) 3des-cbc, aes128-cbc, aes192-cbc, aes256-cbc

- Key Exchange Algorithms (Kex)
  - High Profile: curve25519-sha256@libsshorg, diffie-hellman-group18-sha512, diffie-hellman-group16-sha512, diffie-hellman-group-exchange-sha256, sntrup761x25519-sha512@openssh.com
  - Default profile: (In addition) curve25519-sha256, ecdh-sha2-nistp256, ecdh-sha2-nistp384, ecdh-sha2-nistp521, diffie-hellman-group14-sha256, (remove) sntrup761x25519-sha512@openssh.com
  - Medium Profile: (In addition) diffie-hellman-group1-sha1, diffie-hellman-group14-sha1, diffie-hellman-group-exchange-sha1, (remove) diffie-hellman-group-exchange-sha256, diffie-hellman-group-exchange-sha256
- Message Authentication Code Algorithms (MACs)
  - High Profile: hmac-sha2-512-etm@openssh.com, hmac-sha2-256-etm@openssh.com
  - Default profile: (In addition) hmac-sha2-512, hmac-sha2-256, umac-64-etm@openssh.com, umac-128-etm@ openssh.com, hmac-sha1-etm@openssh.com, umac-64@ openssh.com, umac-128@openssh.com, hmac-sha1
  - Medium Profile: (In addition) hmac-md5-96, hmac-sha1-96, hmac-md5-96-etm@openssh.com, hmac-sha1-96-etm@openssh.com, hmac-md5-etm@ openssh.com, hmac-md5 (Remove) hmac-sha2-512, hmac-sha2-256, umac-64@openssh.com, umac-128@ openssh.com

Redundancy

- Software solution
- Active/standby method uses two units that act as single coordinated system
- Active/active method uses two units that are synchronized but do not require the same hardware nor the same licenses and that act as two separate systems
- Supported in Gateway Clock operation mode, ePRTC operation mode as well as SSU operation mode
- Direct fiber and RJ45 connections; less than 100 meters between redundant pair units
- Accuracy: < 5 ns relative to 1 PPS output of active unit
- ETH2 (secondary link) and full range of ETH3–ETH8 (main link) redundancy links
- Unique IP address for active/standby model, separate IP addresses for active/active method
- Non-revertive schema
- Heartbeat message exchange and clock state sync
- Very performant switchover: < 0.375s for G.8275.1; < 3s for all other timing profiles
- Squelch or On modes for legacy ports

Class of Service (CoS) and VLANs

- Up to 256 VLANs for PTP grandmaster, both for IPv4 and IPv6
- One VLAN for management
- Total number of VLANs is 260 per system (256 PTP grandmaster, two PTP clients, one management and one spare)

Time and Frequency Accuracy

- PRTC: fully compliant with ITU-T G.8272
- L1 calibrated PRTC Class B (40 ns)
- Designed with ToD input that is fully compliant with TimeSource® ePRTC system
- Frequency accuracy: conforms with ITU-T G.811
- Multi-domain, high-performance boundary clock (MD HPBC) function with G.8273.2 performance [Class C (< 10 ns) and Class D (< 5 ns)]
- Enhanced high-performance boundary clock exceeding class D (15 ns accuracy for a chain of 15 boundary clocks) with 1.7 ns maximum absolute time error on 1 GbE ports and 3.39 ns maximum absolute time error on 10 GbE ports
- High Accuracy Time Transfer (HA-TT) class A accuracy G.8271.1/Y.1366.1 (2022) Amd 2. (01/2024) 5 ns max|TE| (Time Error) over 800 km (equates to 500ps average assuming 10 hops), MTIE (Maximum time interval error) peak to peak better than 5 ns, TDEV (Time deviation) better than 1 ns

Monitoring

- Presentation of network accuracy with all available data through local webGUI
- Four channel measurements
- PTP packet probing and monitoring with threshold level
- 1 PPS measurement (two channels)
- 10 MHz measurement (two channels)
- E1/T1 measurement (two channels)
- Frequency TIE and MTIE (Maximum time interval error)
- MTIE thresholds and alarms support
- Input support for TDEV monitoring, TDEV status and TDEV graphing
- SyncE monitoring on same physical port as PTP
- Up to two SyncE inputs
- Monitoring resolution ≤ 1 ns and accuracy ≤ 2 ns
- Jitter and wander measurements comply with ITU-T O.172/O.174 for frequency
- Monitoring sample frequency of 40 Hz for up to 100,000 seconds
- PTP monitoring as well as NTPr supported on expansion module ports

SyncE

- SyncE can be used as a frequency input and generated as an output (as a parent)
- Conforms to relevant sections of ITU-T G.8261, G.8262 and
- G.8264
- Ethernet Synchronization Message Channel (ESMC)
- Automatic SyncE switchover feature in MD HPBC mode
- SyncE switchover between ports
- Extended QL TLV format as per ITU-T G.8264 Amendment 1 (03/2018) clause 11.3.1.1 including enhanced SSM codes

Physical Interfaces

- Two shielded RJ45 1 GbE, 100/1000BASE-T Ethernet ports
- Four SFP+ GbE ports support either:
  - SFP (optical), 1000BASE-X
  - SFP+ (optical), 10 GbE
- Two SFP28 25 GbE ports support either:
  - SFP+ (optical), 10 GbE
  - SFP28 (optical), 25 GbE
- Four E1/T1: two input/output ports and two output ports over balanced RJ48c connectors, 120Ω/100Ω impedance
- Optional legacy expansion module:
  - 16 E1/T1 output ports over balanced RJ48c connectors, 120Ω/100Ω impedance
  - 16 outputs each separately configurable as E1/T1/2048 kHz/1544 kHz/composite-clock (64 kHz)/JCC two inputs
- CC-IN1 and CC-IN2 can be configured as CC/JCC inputs to module (outputs phase alignment)
- Two 10 MHz/1 PPS input/output ports, user configurable, over single-ended BNC connectors, 50Ω impedance
- One 1 PPS high-accuracy output
- One 10 MHz high-accuracy output
- 10 Mhz clock sigma rms performance values at 5 ps (500% better than TP4100)
- Two ToD/1 PPS inputs/outputs over RJ45 connectors, according to ITU-T V.11-based time/phase distribution interface
- ToD formats: ITU-T G.8271, China Mobile V2, NTP4
- Support for bidirectional SFPs
- Support for G.703 for all physical interfaces including ToD/E1/ T1/10 MHz

Network Support

- DHCP
- SSHv2
- SNMPv2, SNMPv3
- NTPv3, NTPv4

Regulatory and Environmental Requirements

Compliance Marks

- NRTL — North America Safety
- CB Scheme — International Safety
- CE — EU Safety and EMC
- UKCA — UK Conformity Assessed
- FCC — USA EMC
- VCCI — Japan EMC
- RCM — Australia/New Zealand EMC
- KC — Korea EMC
- TR9 level 2 Class A — Germany

Safety Compliance

- UL 62368-1
- CAN/CSA-22.2 No. 62368-1
- IEC 62368-1
- EU Safety Directive 2014/35/EU
- EN 62368-1

Emissions Compliance

- FCC Part 15 (Class A)
- ICES 003 (Class A)
- VCCI (Class A)
- CISPR32
- KS C 9832
- EU EMC Directive 2014/30/EU
- EN55032
- Radio Equipment Directive (RED) 2014/53/EU
- EN 301 489-1, 489-19
- EN 303 413
- EN 300 386
- AS/NZS CISPR 32
- Deutsche Telekom EMC Spec (1 TR 9)

Immunity Compliance

- KS C 9835 (Criteria A)
- EU EMC Directive 2014/30/EU
- EN55035
- Deutsche Telekom EMC Spec (1 TR 9)
- British Telecom GS7 Issue V1

Environmental

- Acoustic noise level: 0 dBA
- Operating temperature: –5°C to 55°C for Rb, –5°C to 65°C for OCXO and super OCXO
- Storage temperature: –40°C to 70°C
- Relative humidity: 5% to 90% non-condensing, 100% with condensation under ETSI EN 300 019-2-3 T3.2
- ETSI EN 300-019-2-3, Operating, Class T3.2
- ETSI EN 300 019-2-2 (1999) – Transportation, Class T2.3
- ETSI EN 300 019-2-1 (2000) – Storage, Class T1.2
- GR-63
- Ingress Protection Rating: IP20
- RoHS EU Directive 2011/65/EU and the (EU) 2015/863 amendment

Network Equipment Building System

- NEBS Level 3*, GR-1089
- ATT-TP-76200
- VZ.TPR.9305, Issue 10

*When following deployment guidelines as specified in the user manual

TimeProvider 4500 Series Physical Outline