TimeProvider® 4100 Series Release 2.4

Precise Timing Grandmaster With Gateway Clock, High-Accuracy and Redundancy

New 2.4 Version Highlights

- Upgraded Linux software platform
- Embedded GNSS firewall (BlueSky™ technology) for anti-jamming, anti-spoofing protection
- Precision Time Protocol (PTP) enhancements with higher capacity up to 2,000 PTP clients
- Enhanced security with password complexity requirements, support for Access Control Lists (ACL) and resolved Common Vulnerabilities Exposures (CVEs)
- Added support for PTP power profiles grandmaster operations as well as Parallel Redundancy Protocol (PRP)
- Added support for Time Sensitive Networks (TSN) profile for private networks
- New operation mode for Synchronization Supply Unit (SSU) function including input filtering for jitter and wander
- New active/active redundancy mode
- New models with support for L5 frequencies used by NavIC/IRNSS constellation in India
- Added support for TimeProvider XT to provide legacy signals port fan out to up to 200 E1/T1/CC/JCC ports

Key Features

- IEEE® 1588 v2 PTP grandmaster
- Reliable fanless passive thermal operation
- Oscillator options: oven-controlled crystal oscillator (OCXO), super OCXO and rubidium (Rb)
- Standard base unit with eight Ethernet ports, four E1/T1 ports, one craft port, two 1 PPS/ToD ports, two 1 PPS/ 10 MHz ports
- Optional internal expansion module with 16 E1/T1/CC/JCC ports for a total of 20 E1/T1 outputs per unit with support for composite clock including Japan format
- Configuration, status monitoring and integration with up to five TimeProvider XT legacy signals fan-out extension shelves for a maximum number of 200 E1/T1/CC/JCC output ports
- Optional internal expansion module with four Small Form-Factor Pluggable (SFP) and four enhanced SFP (SFP+) for 10 GbE support, 100 Mbps Fast Ethernet and 1 GbE fanout
- Three choices of redundancy mechanisms (using two units):
  - Geographical fallover
  - Active/standby software redundancy
  - Active/active software redundancy
- Global Navigation Satellite System (GNSS) features:
  - Multi-constellation support: Global Positioning System (GPS), Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS), BeiDou Navigation Satellite System (BDS), Quasi-Zenith Satellite System (QZSS), Galileo and India's NavIC
  - Satellite-Based Augmentation System (SBAS) support
  - Multi-band L1/L2/E5B/L5 support
- Embedded BlueSky firewall technology for anti-jamming and anti-spoofing
- Synchronous Ethernet (SyncE) including enhanced ESMC and eEEC G.8262.1
- SSU function with jitter and wander input filtering
- Primary Reference Time Clock (PRTC) Class A (100 ns) and Class B (40 ns)
- Enhanced PRTC (ePRTC) ITU-T G.8272.1, 30 ns accuracy
- IPv6/IPv4 on all ports including management (OAM) with L3, L2, IPv4, and IPv6
- High performance: 2,000 PTP unicast at maximum profile rate of 128 PPS and NTP reflector (NTPr) 20,000 tps per port, for a total of 160,000 tps per unit and NTPd at 500 tps on three ports for a total of 1,500 tps per unit
- ITU-T G.8273.4 APTS with patented enhanced Automatic Asymmetry Compensation (AAC) over multiple network variations with multiple PTP client inputs and IEEE 1588-2019 majority vote mechanism
- Support for multiple IEEE 1588 v2 profiles per unit and per port
- Fully supports ITU-T profiles for frequency, time and phase synchronization: G.8265.1, G.8275.1, and G.8275.2 and L3, L2, IPv4, and IPv6
- 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
- Support for high-performance multi-domain boundary clock (operation mode) with class C (10 ns) and D (5 ns) accuracy
- TimePictra® synchronization management system support
- Support for inband management with PTP services
- Device management, PTP grandmaster, and PTP client on the same physical port to save cost

- Security via enhanced SSH and Terminal Access Controller Access-Control System (TACACS+), Remote Authentication Dial-In User Service (RADIUS), Authentication, Authorization and Accounting (AAA)
- IEEE 1588 2.1 2019 security support for prong C (architecture guidance) and prong D (monitoring and management)
- Monitoring and measurement capabilities for phase (PTP) and legacy ports

Benefits

- Flexibility to leverage legacy and new investments
- Mitigates impact of backhaul noise packet delay variation and asymmetry
- High-accuracy phase distribution over long-haul optical networks
- Preserves current Multiprotocol Label Switching (MPLS) network engineering

Applications

- 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

Oscillator Options

The standard TimeProvider 4100 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 grandmaster 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 following table for the OCXO, super OCXO and rubidium upgrades.

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 TP4100 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 TP4100 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 TimeProvider 4100 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.

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 oscillators consume less power, operate over a wide range of temperature operations 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.

Flexible Architecture

The TimeProvider 4100 series supports PTP, NTP and legacy frequency timing applications. The clock features four Building Integrated Timing Supply (BITS) ports (E1/T1), two 1 PPS/ ToD ports, two 1 PPS/10 MHz ports, one GNSS port and one craft port. Complementing its advanced feature set, the TimeProvider 4100 series offers optional expansion modules based on customer needs and deployment scenarios. Flexibility is of the utmost importance for enabling operators to select appropriate package, options and interfaces for their respective use cases and deployment models.

Optional Expansion Modules

The TimeProvider 4100 series provides the necessary flexibility to add internal expansion modules for various capabilities. The expansion module is an optional upgrade to the base unit.

E1/T1/CC/JCC Expansion Module

The E1/T1/CC/JCC internal module with 16 E1/T1/CC/JCC ports brings the unit to a total maximum of 20 E1/T1 ports (four in the base and 16 the in expansion module).

This expansion module includes 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 SSUs.

For needs beyond 40 E1/T1 ports, a TimeProvider 4100 grandmaster can be connected to an SSU or BITS system as a grandmaster reference with full Primary Reference Clock (PRC) traceability.

1 GbE/10 GbE Expansion Module

The 1 GbE/10 GbE/100 Mbps expansion module provides 1 GbE or 100 Mbps fanout and 10 GbE support. The module features four SFP and four SFP+ ports to enable a combination of four 100 Mbps Fast Ethernet and four 1 GbE ports, or eight 1 GbE ports, or a combination of four 1 GbE ports and four 10 GbE ports. As networks evolve, 10 GbE has become more prevalent, so this internal fanout capability is critical to connect to newer network elements.

Optional External Legacy Expansions

The TimeProvider 4100 can connect to TimeProvider XT external extension shelves to easily migrate from traditional BITS/SSU deployments to a TimeProvider 4100-based modern architecture.

A typical recommended architecture would have two TimeProvider 4100 units in active/active redundancy mode, connected to multiple cascaded TimeProvider XT units to provide large scale E1/T1/CC/JCC output fan-out capabilities. Up to five TimeProvider XT extension shelves can be cascaded from TimeProvider 4100 pairs, thus allowing for up to 200 legacy signals ports. For further information please see the TimeProvider XT sell sheet, downloadable from the TimeProvider XT product web page.

Cascading of Units

The TimeProvider 4100 series is designed to enable cascading units for higher density applications and use cases. It can leverage a subtenancy architecture which allows a PTP client unit to subtend from a grandmaster using a ToD input/ output. The grandmaster, which we recommend be upgraded to use a rubidium atomic clock, is connected to GNSS constellations while the PTP client TimeProvider 4100 device can use a lower-cost oscillator without connectivity to GNSS. This architecture doubles the port count of the combined system. Units can crossconnect and can also connect to GPS, which enables a second reference when GNSS goes down.

Redundancy

Software redundancy enables a cost-effective redundancy architecture for flexibility, resiliency and investment protection. Both units need to be connected via a direct fiber and additional RJ45 cable connection and co-located at a maximum of 100 meters.

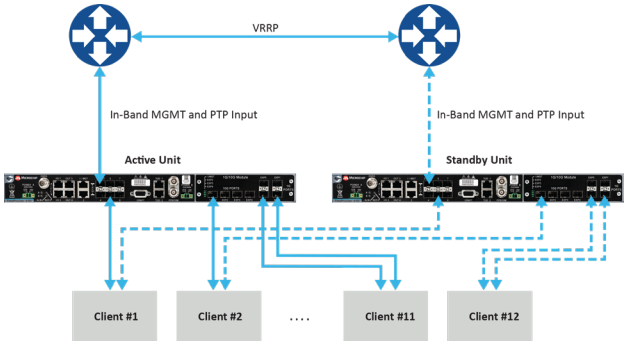
In this software redundancy schema, there are two possible mechanisms.

Active/Standby Mechanism

The Active/Standby model enables two units to 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, which can be a lower-grade device on the standby unit. License options need to be equivalent on both units. Active PTP client function and in-band management are supported on the active and the standby units.

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 grandmasters. This means the PTP client do not need to reset their internal clock state machine when connecting to a new grandmaster. Both redundant grandmaster units announce exactly the same 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 scheme (switch over 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 (except for G.8275.1) with recovery of the full list of connected PTP client. 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.

Resilient Solution

The TimeProvider 4100 series uses a passively cooled design with no fans, which minimizes the risks associated with rotation or moving parts. It also features passive heat sinks for thermal mitigation.

The TimeProvider 4100 series features layered protection and accepts three PTP inputs with 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.

The TimeProvider 4100 series supports up to three PTP client instances with majority vote mechanism (part of IEEE 1588 2.1 2019 prong C) to select the best input for APTS.

As an additional layer of protection, the TimeProvider 4100 series features optional oscillator upgrades for enhanced holdover performance.

It also provides dual Direct Current (DC) input for power redundancy and geographical network redundancy for failover.

Best-of-Breed Grandmaster Clock

The TimeProvider 4100 grandmaster is a best-in-class 1588 solution 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 cost-effective solution that can be easily adapted for a wide variety of use cases.

The TimeProvider 4100 series is an industry-leading grandmaster clock with a base model that offers multiple PTP profiles per unit, as well as dual master profile per port. It supports IEEE 1588 v2 frequency, time and phase profiles such as Telecom 2008, G.8265.1, G.8275.1 and G.8275.2.

The TimeProvider 4100 series SyncE supports enhanced Ethernet Synchronization Message Channel (ESMC) via extended Quality Level Threshold Limit Value (QL TLV) formats per ITU-T G.8264 Amendment 1 (03/2018) Clause 11.3.1.2. It also supports enhanced Synchronization Status Message (SSM) codes, cascaded enhanced Synchronous Ethernet Equipment Clocks (eEECs) (G.8262.1) add other extensions provided by the latest QL TLV format.

The TimeProvider 4100 series is based on our newest platform and our latest-generation packet engine to provide the utmost flexibility to support multiple packet services in the box, to specify the service on each port (grandmaster, PTP client, probe, NTP), and to select management and PTP 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 PHY so they can deploy and scale their equipment without compromising on performance or features.

Primary Reference Time Clock

The TimeProvider 4100 series meets stringent precise time standards and complies with Primary Reference Time Clock (PRTC) Class A (100 ns) and 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 4100 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. The TimeProvider 4100 series supports GPS, GLONASS, BeiDou, Galileo, India's NavIC, QZSS and SBAS in its standard version. It is configured to support a single band by default.

The TimeProvider 4100 grandmaster also provides multi-band support with an enhanced GNSS receiver.

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 TP4100 unit displays bar charts with the respective satellite signal values for all constellations in parallel and for dual 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.

High Performance

The TimeProvider 4100 series can support 2,000 PTP client at maximum profile rate of 128 packet per second (PPS) with or without two-step clock. It also delivers high-performance NTP support with NTP hardware time stamping at of 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.

Operation Modes

The TimeProvider 4100 series can support multiple modes of operations:

- Gateway Clock mode
- Single Domain or Multi-Domain High-Performance Boundary Clock mode
- Enhanced PRTC mode
- SSU mode

Each operation mode is defined a very specific set of inputs that are used as reference signal reference. From an outputs perspective, all features of the grandmaster clock are available including the monitoring of external timing inputs.

Gateway Clock Mode

The TimeProvider 4100 grandmaster is a gateway clock, a class of synchronization product that accepts multiple inputs and generates a variety of outputs using a sophisticated mapping algorithm.

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

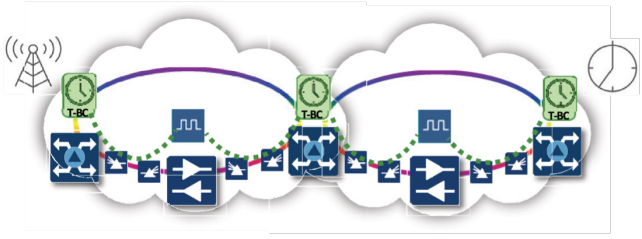
The TimeProvider 4100 series supports hybrid operation, which allows the frequency reference to come from only one frequency source (e.g. SyncE) and the time reference to come from another source (e.g., PTP).

The TimeProvider 4100 series supports these premium capabilities as well:

- Support for up to three PTP client 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 (on the main board as well as on the Ethernet expansion module)

High-Performance Boundary Clock Mode

An optional license can enable High-Performance Boundary Clock (HPBC) mode. This mode is used to enables 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 client with respective fiber length fields. Two different chromatic dispersion offset values can be calculated.

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 4100 series' ePRTC delivers a solution that 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 TimeProvider 4100 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 TP4100 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 4100 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 Time Cesium® 4400/4500 series, or with a high-performance atomic clock such as the 5071B.

Time Cesium 4x00 and CSIII products have one 10 MHz output and one 5 MHz output. The TP4100 grandmaster supports a 5 MHz or 10 MHz signal. 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 4100 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 as needed, rather than following the GNSS time regardless of its time scale 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 4100 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 4100 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 time scale will support the 14-day holdover standard requirement as well as 40-day holdover for the most recent 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 time period that the TP41000 ePRTC system is capable of maintaining with an accuracy of up to 10 ns to UTC without GNSS.

Our product experts and channel partners can assist you with deploying a TimeProvider 4100 grandmaster, including enabling the ePRTC mode and setting up the GNSS antenna and cabling.

Independence Between 10 MHz and 1 PPS Outputs

The local oscillator in any clock will need corrections to achieve the desired frequency and time services. In some applications, the same correction is applied to the 10 MHz

frequency outputs and the PPS time outputs. This means that the frequency service will have to be overcorrected to maintain coherence time with the 1 PPS output, even though this solution will add noise and possibly cause degradation from the time source,

The time scale in an ePRTC system requires both maximum stability and resiliency for its 10 MHz frequency services without introducing overcorrection to steer the time. The frequency outputs are optimized for frequency and the time outputs are optimized for time, so there is no need to make extra corrections.

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.

Monitoring

The TimePictra software suite offers intuitive feedback for ease of use. The Microchip-branded webGUI that is available on the TimeProvider 4100 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

The TimeProvider 4100 series features Time Error calculation for monitoring PTP traffic as well as 1 PPS monitoring.

Monitoring also supports legacy signals including E1/T1/CC/JCC, SyncE and 10 MHz signals. Frequency Time Interval Error (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 client. SyncE signal monitoring uses the same physical port as PTP monitoring. PTP monitoring is supported on 1 GbE/10 GbE/ 100 Mbps expansion module ports, as well as NTPr.

TDEV Support

The TimeProvider 4100 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 TimeProvider 4100 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 RJ-45 or as an SFP or 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 preserved. Support for NTP client and local time assures time alignment for system logs.

A communication system between the grandmaster and the TimePictra software 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.

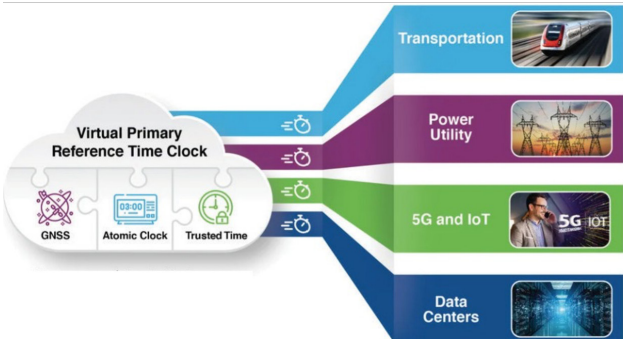
Virtual PRTC (vPRTC) Architecture

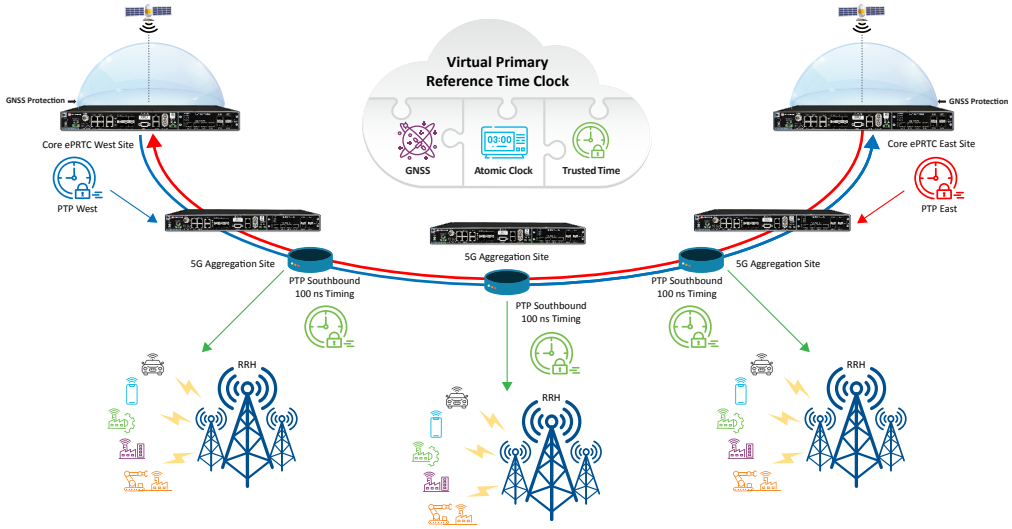
This architecture prescribes:

- Leveraging the existing optical network to avoid using expensive dark fiber
- Supporting Optical Timing Channel (OTC) using dedicated lambda to transport time in the most rapid way to provide the utmost resiliency
- Supporting Optical Supervisory Channel (OSC) which allows timing traffic to share the same channel as management traffic as an alternative to OTC deployment
- A redundant source of time based on 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 OTC for highest accuracy.





Specifications

Mechanical

- Size: 1 RU
- Height: 1.73 in. (44 mm)
- Width: 17.24 in. (438 mm)
- Depth: 9.30 in. (237 mm)
- Depth with connectors on faceplate: 10.07 in. (256 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 and 23-inch options with rack adapter sold separately
- Weight: 8 pounds (10 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: 28 Watts (max), 20 Watts (typical)
- Rubidium model with DC supply: 35 Watts (max), 28 Watts (typical)

Oscillator

- Oscillator options: OCXO, super OCXO and rubidium
- Compliant with ITU-T G.812 holdover with pull-in/hold-in range quality metrics

GNSS

- Multi-constellations: GPS, GLONASS, BeiDou, QZSS, NavIC/IRNSS and Galileo
- SBAS support
- Multi-band support
  - GPS L1/L2C
  - Galileo E1/E5b
  - Glonass L1/L2
  - BeiDou B1I/B2I
  - QZSS L1/L2C
  - NavIC L1/L5
- 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 G-BTCA 1.0 (Global Best grandmaster Clock Algorithm)

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, PTP 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 including 10 GbE expansion
- Configuration of PTP client load percentage threshold for the entire system with alarm when exceeds
- NTPr v4 and v6 and NTPd with MD5 security
- NTP client mode for setting log files – NTPv4&v3 (RFC5905)
- Up to 10 HMAC keys – MD5, SHA224, SHA256, SHA512, RC4
- Status in CLI and TimePictra software suite – three NTP servers (configurable)
- 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, ETH3 or EXP1 ports
- MGT port: ETH1, ETH3 and EXP1 are capable of management only as well as PTP client, PTP grandmaster, NTPr and PTP monitoring (probe function)
- Ports ETH2 and ETH4-8 and EXP1–8 can operate as packet engine services (PTP GM, NTP, PTP probe) module
- 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
- Three redundancy mechanisms are supported: geographical redundancy through network topology and failover, active/standby dual unit software redundancy and active/active dual unit software redundancy

ePRTC

- ePRTC ITU-T G.8272.1 30 ns accuracy with support for both 10 MHz or 5 MHz input from cesium clock
- Enhanced holdover from 14 days to 40 days to meet upcoming ITU-T G.8272.1 standard revision
- 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
- Support for combination 1 PPS and NTP as time reference to leverage national official time as input
- 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 to external grandmaster such as 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 40 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 PTP client count of 64 PTP clients and software upgrade options through licensing to 128, 256, 512, 790, 1000 and 2000 PTP client at 128 packets per second
- NTP license
- HPBC 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

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
- 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 servers)
- 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 4100 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)
- KexAlgorithms curve25519-sha256@libsshorg, diffie-hellman-group-exchange-sha256
- Ciphers chacha20-poly1305@openssh.com, aes256- gcm@ openssh.com, aes128-gcm@openssh.com, aes256-ctr, aes192-ctr, aes128-ctr
- MACs hmac-sha2-512-etm@openssh.com, hmac-sha2-256-etm@openssh.com, hmac-sha2-512, hmac-sha2-256/ etc/ssh/moduli

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 switch over: < 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 grandmasters, 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 performance exceeds class D (15 ns accuracy for a chain of 15 boundary clocks) with an average 1 ns boundary clock accuracy

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/CC/JCC measurement (two channels)
- Frequency TIE and MTIE
- 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 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 Gigabit Ethernet ports – shielded RJ45, 100/1000 BASE-T Ethernet
- Six Gigabit Ethernet SFP cages – ports support either:
  - SFP (optical), 1000BASE-X
  - SFP (electrical), 1000BASE-T
- Optional expansion module: four SFP and four SFP+ for 10 GbE support and 1 GbE or 100 Mbps optical fan out
- Four E1/T1: two input/output ports and two output ports over balanced RJ48c connectors, 120Ω/100Ω impedance
- Optional expansion module: 16 E1/T1/CC/JCC 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)
- 1 PPS user-configurable pulse width two 10 MHz/1 PPS input/output ports over single-ended BNC connectors, 50Ω impedance
- Support for TimeProvider XT external Extension Shelf with 40 outputs E1/T1/CC/JCC, plug-in modules with connectors RJ-48, BNC, Wire Wrap, SCSI, and IDE
- Two ToD/1 PPS input/output 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 ACMA
- KC Korea EMC

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 9835
- EU EMC Directive 2014/30/EU
  - EN55032
- Radio Equipment Directive (RED) 2014/53/EU
  - EN 301 489-1
  - EN 301 489-19
  - EN 303 413
- EN 300 386
- Deutsche Telekom EMC Specification 1TR9

Immunity Compliance

- KS C 9835 (Criteria A)
- British Telecom GS7
- EU EMC Directive 2014/30/EU
  - EN55035

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

*When following deployment guidelines as specified in the user manual

TimeProvider 4100 Server Physical Outline