Application Note
Rubidium Holdover for PTP Phase Synchronization Applications

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IEEE 1588 Precision Time Protocol (PTP) is widely adopted for providing frequency synchronization to wireless base station over Ethernet backhaul. Synchronization traceability comes from centrally located PTP grandmaster clocks. These clocks source PTP synchronization flows to the remote wireless base stations. Grandmaster clocks are protected from reference interruptions through the use of precision holdover oscillators such as embedded rubidium atomic clocks. This paper details how the Microsemi TimeProvider 4100 PTP Grandmaster Clock with a rubidium holdover oscillator can be configured to provide holdover protection for phase synchronization in wireless networks.

The TimeProvider 4100 PTP Grandmaster Clock is a Primary Reference Time Clock (PRTC) traceable clock designed to source PTP flows for frequency and phase synchronization. The system is generally locked to a GNSS input to assure 100 ns traceability to UTC, and can be protected with an internal rubidium holdover oscillator to hold tight phase synchronization in the event of a short term GNSS outage such as a GNSS antenna impairment of failure. The rubidium holdover oscillator can preserve phase accuracy to within 400 ns in a 24-hour period.

PTP Profiles for Phase Synchronization

The ITU has consented two PTP profiles for phase synchronization:

- ITU-T G.8275.1 PTP phase profile for full on-path support
- ITU-T G.8275.2 PTP phase profile for partial on-path support

Both profiles require phase traceability to a PRTC source with ±100 ns accuracy to UTC. PRTC traceability is generally assured by locking the grandmaster clock to a GNSS input. GNSS is widely deployed as a source of frequency and phase synchronization in communications networks, and the most common mode of interruption is impairment or failure of the external GNSS antenna input. The GNSS antenna is exposed to potential jamming events, and weather conditions such as lightning induced surge that can temporarily or permanently impair GNSS reception to the clock system. It is highly recommended that PTP clocks sourcing PTP phase synchronization be protected with rubidium holdover oscillators.

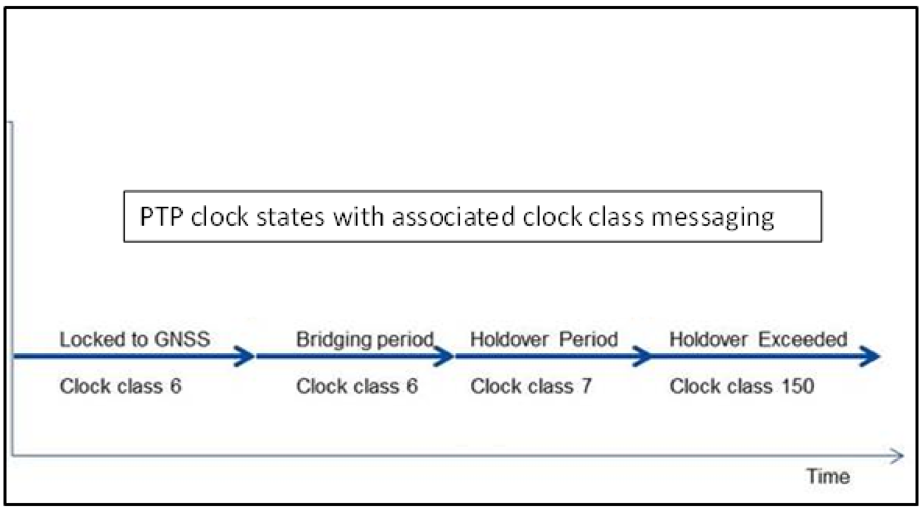
Configuring the TimeProvider 4100 Grandmaster Clock for Phase Holdover

PTP Grandmaster Clocks are required to signal their downstream PTP client clocks their states of operation through Clock Class messaging. Common operating states include GNSS locked, bridging, holdover, and holdover exceeded. Please refer to IEEE-1588 and relevant ITU standards for full detail on clock class messaging parameters.

The objective of this analysis is to provide customers with recommendations on how to configure the TimeProvider 4100 system with the rubidium option to provide a protection period for a given phase error (drift) range.

The TimeProvider 4100 supports a user-configurable bridging period, followed by a fixed 12-hour holdover period. Bridging is defined as the period between GNSS locked state, and formal entry into the 12-hour holdover period. Bridging time is user configurable from a minimum of 2 minutes to a maximum of 24 hours. The default setting for bridging is 15 minutes to allow the system to bridge through any momentary GNSS impairments without entering the holdover state with associated PTP clock class degradation from level 6 to level 7. At the end of the holdover period, the clock class will change to level 150 (holdover exceeded) as outlined in the following figure.

Clock States and Associated Clock Class Messaging



Setting the Bridging Period

The TimeProvider 4100 allows the flexibility to set the bridging period to accommodate the behavior of the PTP client. PTP client designs fall into the following two cases:

- Case 1—Clients that switch on clock class transition from 6 to 7
- Case 2—Clients that switch on clock class transition from 7 to 150

The following table provides the recommended bridging time for PTP clients that switch from the PTP master on the transition from clock class 6 to any higher clock class. The table provides the recommended bridging time settings to hold all clients with this PTP grandmaster clock before signaling them through a clock class transition to switch to an alternate grandmaster or go to free run.

Recommended Bridging Time (Clock 6 to Higher Clock Class)

Case 1: Error Budget to Remain in Clock Class 6	Rb Bridging Time (user configurable)	Holdover Time (fixed at 12 hours)	Holdover Exceeded
Clock Class	**6**	**7**	**150**
250 ns for 16 hours	Set to 16 hours	16–28 hours	>28 hours
400 ns for 24 hours	Set to 24 hours	24–36 hours	>36 hours

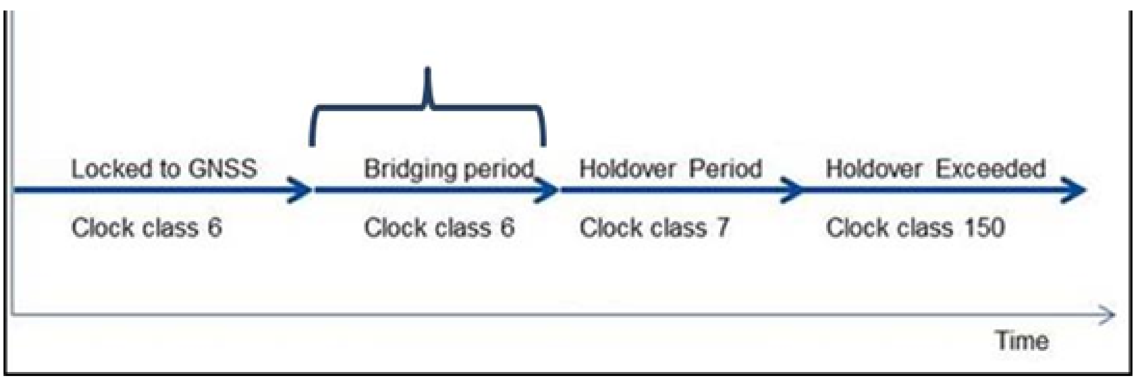
Protection time is the user set bridging time. For case 1, the client clock switching is triggered by the clock class transition from 6 to 7.

Note: Bridging time is configurable using the “tp4100> set bridge-time <value>” command. Bridging time can be set from 2 minutes (15-minute default) to 24 hours (maximum). After bridging time, the system enters the fixed 12-hour holdover period. After bridging time plus holdover time, the system enters the holdover exceeded state.

Note: This table provides typical performance after 30 days of continuous locked operation over a limited temperature range of ±5 °C during bridging and holdover time periods. It is only recommended to use rubidium for phase holdover protection.

The following figure shows the bridging period as the holdover protection time.

User-Configured Bridging Period



The following table provides the recommended bridging time for PTP clients that switch from the PTP master on the transition from clock class 7 to any higher clock class. These client designs will remain locked to PTP master clocks signaling either clock class 6 or 7. The table provides the recommended bridging time settings to hold all clients with this PTP grandmaster clock before signaling them through a clock class transition to the Holdover Exceeded state (clock class 150) to switch to an alternate grandmaster or go to free run.

Recommended Bridging Time (Clock 7 to Higher Clock Class)

Case 2: Error Budget to Remain in Clock Class 7	**Rb Bridging Time (user configurable)**	**Holdover Time (fixed at 12 hours)**	**Holdover Exceeded**
Clock Class	**6**	**7**	**150**
250 ns for 16 hours	Set to 4 hours	4–16 hours	>16 hours
400 ns for 24 hours	Set to 12 hours	12–24 hours	>24 hours
750 ns for 36 hours	Set to 24 hours	24–36 hours	>36 hours

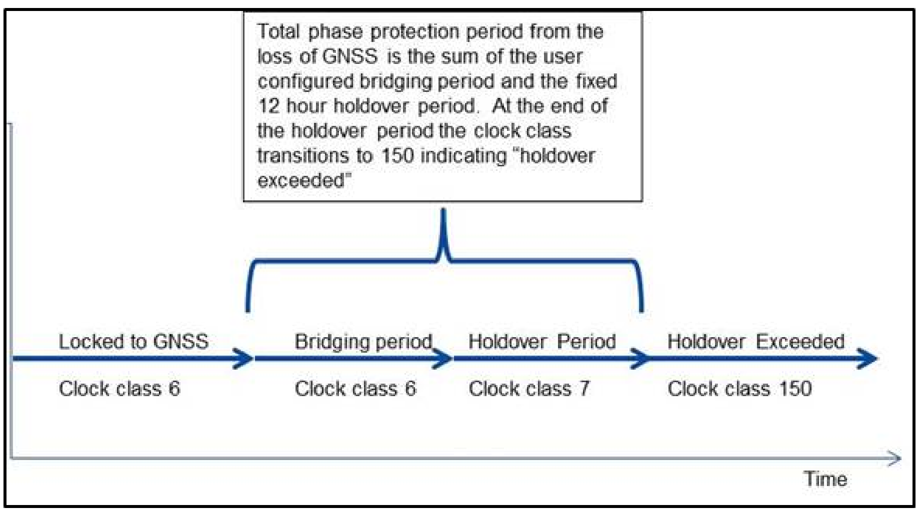
Protection period is the sum of user-set bridging time and the fixed 12-hour holdover period. For case 2, the client clock switching is triggered by the clock class transition from 7 to 150.

Note: Bridging time is configurable using the “tp4100> set bridge-time <value>” command. Bridging time can be set from 2 minutes (15-minute default) to 24 hours (maximum). After bridging time, the system enters the fixed 12-hour holdover period. After bridging time plus holdover time, the system enters the holdover exceeded state.

Note: This table provides typical performance after 30 days of continuous locked operation over a limited temperature range of ±5 °C during bridging and holdover time periods. It is only recommended to use rubidium for phase holdover protection.

As shown in the following figure, the holdover protection period is the sum of the bridging period and the fixed 12-hour holdover period.

Protection Period

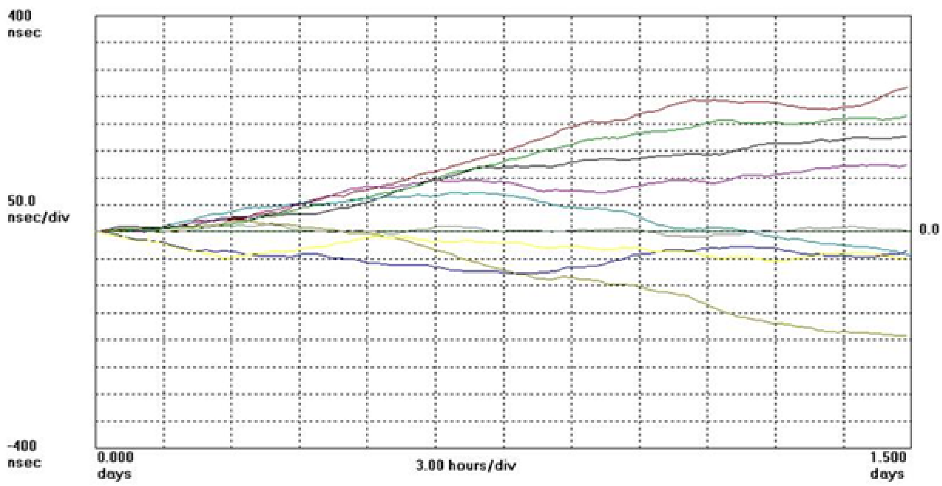


The protection period is the sum of bridging time and holdover time for case 2 client clocks.

Microsemi Rubidium Miniature Atomic Clock Performance

The following analysis shows the typical performance for the Rubidium oscillator used in the TimeProvider 4100 as a reference.

Typical Rubidium Oscillator Performance



The TimeProvider 4100 has an option for a state-of-the-art laser-driven rubidium oscillator based on cold population trapping. The graph shows the accumulate time offset for 8 simulated rubidium units based on our specification for the noise model limits. It can be seen that the behavior is not strictly monotonic, as the time error is the integration of the underlying frequency noise from the rubidium atomic clock. This result demonstrates that typical performance can maintain phase offset within ±300 ns in 36 hours.

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