Technical Bulletin #006: Holdover Experimental Summary

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Summary: Stable and accurate timing forms the foundation of many modern essential services. While Global Navigation Satellite Systems (GNSS) provide a cheap way to achieve extremely accurate timing, these systems are vulnerable to interference and complete outages, forcing systems that rely on them into a state of holdover. Testing and characterizing holdover performance is therefore essential for ensuring that these modern services do not go down when GNSS-based timing is unavailable.

Introduction

Accurate timing forms the foundation of many essential industries which ultimately provide critical services in the modern world. Commercial industries including power generation, telecommunications, and finance all rely on accurate and synchronized timekeeping [1]. Without accurate timekeeping, the services these industries and others provide would be seriously degraded if not interrupted entirely.

The main challenge when attempting to maintain accuracy in timekeeping sources, or clocks, is that any independent clock will experience some amount of drift over time when compared to a stable reference source. Clock drift is caused by several factors including ambient environmental changes, thermal noise, and the precision of the clocks themselves [2]. To correct this natural drift over time, the clock can be synchronized to a stable reference source through radio frequency (RF), internet protocol (IP), or by connecting directly to the source's reference output. In the United States, two of the most popular stable sources to synchronize to are the National Institute of Standards and Technology (NIST) WWVB radio station near Fort Collins, Colorado and the Global Positioning System (GPS). When these stable sources are active and able to be received, drifting clocks can synchronize their time to them. However, because these stable reference sources are transmitted as over-the-air signals to end users, it is possible for them to experience harmful interference from other signals. When enough interference occurs, the use of these stable sources by synchronized devices can become disrupted entirely.

When a stable reference source is no longer available for synchronization, the drifting clock is said to be in a state of holdover. Once a clock enters holdover, the amount of drift will continue to accumulate and has no upper bound as long as the state of holdover endures [3]. Despite this, the total drift can be minimal if the clock is extremely accurate. Extreme accuracy is the principle that the two stable sources referenced above, WWVB and GPS, rely on. Both sources derive their time from an ensemble of atomic clocks to increase accuracy [4]. Because these clocks are not themselves synchronized to a stable source, they too are in a state of holdover, yet because they are extremely accurate the total amount of drift that accumulates is miniscule. Unfortunately, these types of clocks are usually far too expensive and difficult to maintain for commercial industries to operate. While WWVB and GPS can operate in holdover for years at a time, most other clocks cannot operate in holdover for years at a time without accumulating an excessive and disruptive amount of drift. Because most commercial industries must instead rely on less accurate clocks when stable reference sources are unavailable, it is imperative that the holdover performance of these industry standard clocks be rigorously tested and characterized.

Experimental Design

When examining and identifying commercially available clocks as well as other supporting equipment, it is clear there are too many possible configurations to test with a single experiment. Therefore, to ensure that these various configurations are thoroughly tested and characterized, a series of three independent holdover experiments will be conducted, with each experiment utilizing a different configuration.

For this series of experiments, the main capability being tested and characterized is how well various combinations of oscillators perform as a reference to a clock in a state of holdover. Even though each experiment in the series will utilize a different combination of oscillators, the same clock will be used across all experiments. It is important to choose a clock that is easy to configure and integrate yet is also extremely accurate. The Oscilloquartz OSA 5422, a compact grandmaster clock, fulfills both criteria. The OSA 5422 is a Global Navigation Satellite System (GNSS) synchronized grandmaster clock and is available with an oven-controlled crystal oscillator (OCXO), a double oven-controlled crystal oscillator (DOCXO), or a rubidium oscillator. Regarding the total drift accumulated in the absence of a stable reference source, a DOCXO accrues less drift than an OCXO, and a rubidium oscillator accrues less drift than a DOCXO [5].

In addition to the onboard oscillator, the OSA 5422 also contains an enhanced primary reference time clock (ePRTC) multisource combiner. The combiner can combine “up to 5 different phase and frequency references” [5]. By combining multiple references with the existing GNSS connection, the OSA 5422 can create an accurate time source that is aligned with coordinated universal time (UTC) but can maintain strict timing requirements during GNSS outages [6]. The combiner will allow multiple different reference sources to be combined and tested throughout each experiment.

For each of the three experiments, a combination of DOCXO, rubidium, magnetic cesium, and optical cesium references will be used to steer the OSA 5422 once the clock is put into a state of holdover. The specific combinations that will be tested in each of the three experiments are enumerated in Table 1. Using the specified references, each experiment will last for a total duration of approximately 60 days, during which data will be collected and then analyzed following the completion of each experiment.

Table 1. Oscillator Combinations for Planned Holdover Experiments

References	Experiment 1	Experiment 2a	Experiment 2b	Experiment 3a	Experiment 3b
DOCXO	✓				
Rubidium		✓	✓	✓	✓
Magnetic Cesium	✓				✓
Optical Cesium		✓		✓	

The results of each experiment will then be presented in three subsequent bulletins which will be released following the completion of each experiment.

Conclusion

Ensuring stable and accurate holdover performance during the temporary absence of GNSS timing is imperative for the continued operation of many essential public and private services [1]. Therefore, the holdover performance of several different combinations of commercially available off the shelf references should be characterized over a period of many weeks during multiple experiments. The data and results from each experiment will then be analyzed and publicly released in three subsequent bulletins.

References

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