Premier Holdover Performance with Microsemi Rubidium Technology

With the emergence of a new generation of network-based time and frequency distribution based on precision timing protocol (PTP) comes a critical need to assure that the sources (such as grandmaster clocks) deliver the required performance in a real-world deployment. Stated another way, the PTP timing service is only as good as its source.

Holdover is the fundamental ability of a local clock to maintain the required performance levels during anticipated reference outage events that occur in real network deployment. For decades, the holdover requirements in telecom application were driven by frequency applications. However, maintaining frequency is much less demanding than maintaining time accuracy at the levels required in emerging standards.

With overall time delivery budgets now at the 1.1-microsecond level in current ITU standards and the reality that these budgets will only get tighter with time, the right holdover timekeeping budget that will support this evolution is critical. Although the exact timing of tighter requirements is not precisely known, it is fundamentally driven by applications ranging from Internet of Things (IoT) to smart cities that drive the need for exponentially more efficient use of the limited radio frequency (RF) spectrum resources and better time.

The next section presents the holdover performance of the Microsemi Miniature Laser-Driven Atomic Clock (MAC). This is the same novel technology based on coherent population trapping physics that drives our chip scale atomic clock (CSAC). The MAC is a high-performance systems version of the CSAC technology in applications where a modest increase in power and size can be supported. The MAC oscillator option is supported in all our system products that provide ITU specified primary reference timing clock (PRTC) capabilities.

The Nature of Clock Holdover

The holdover process is random by nature in a properly designed clock, as one would expect. A well-designed holdover prediction algorithm will eliminate predictable components. A good working example is a random walk—consider a blind-folded individual (who may have had too much to drink) who begins walking away from a flagpole in the middle of a field. Over time, the distance from the flag-pole would be observed as a random walk process. If we repeated the processing, say ten times, we would not expect the same answers. However, we would expect the general trend that the distance from the flagpole would increase with time (more precisely, the square root of time).

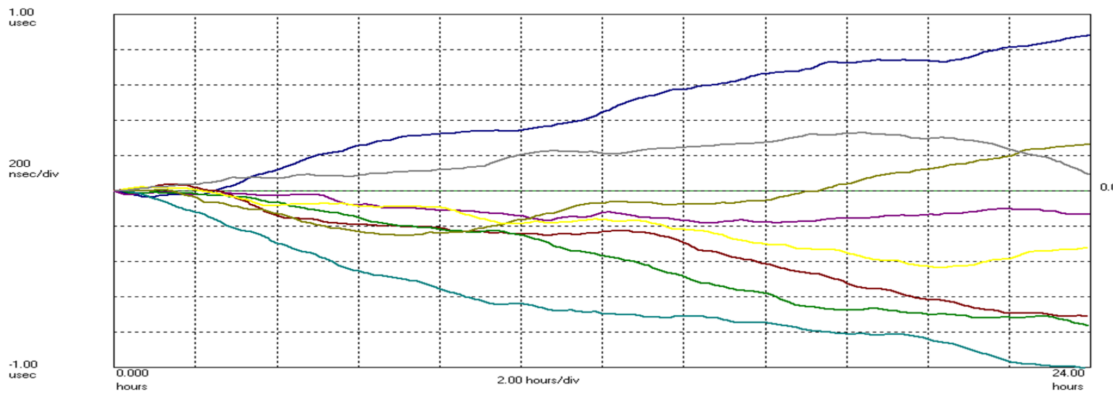
To illustrate this a bit further, consider the following simulation:

1. Using the Microsemi timing analysis tool, we investigated what 30 individual days of holdover would look like.
2. For the test we kept everything else at zero:
   - No initial clock estimation error
   - No significant temperature change
   - No other external perturbations
3. A simple mode of a precision oscillator with perfect drift estimation and 5×10^{-12} noise floor was assumed.

The following graph shows the Microsemi TimeMonitor Analyzer results of 8 of the 30 trials (30 graphs would be too busy). What we see is a random process where sometimes the clock drifts up and sometimes the clock drifts down over the 24-hour holdover interval.

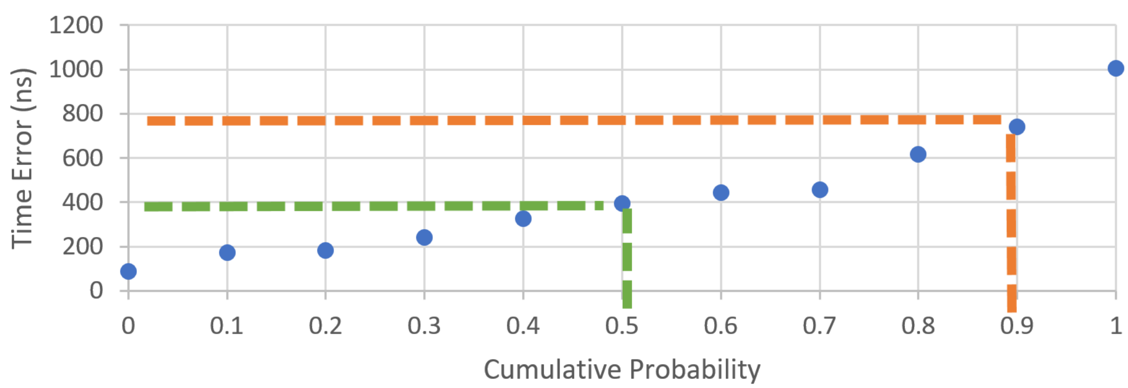
Note: Phase deviation in units of time; Fs= 1.000 Hz; Fo= 10.000000 MHz; 2017/10/30; 19:15:48

Overlay Graph (8 of 30 Individual Day Holdover Runs)



To better understand what is really achievable, we can look at the data from a cumulative distribution perspective, as seen in the next graph. This graph shows the probability that the 24-hour holdover time error is less than certain threshold. Now, with cumulative distribution graphs, we can see that we meet better than 750 nanoseconds of time error 90% of the time. By using a high probability of success (for example, 90%) we can have better confidence that 9 out of 10 times we can achieve the specified level. On the other hand, we can also see that we meet a better threshold (400 nanoseconds), but only 50% of the time. Be careful with descriptions such as "the holdover error is approximate", as perhaps your definition of approximate is not the same as the vendor.

24-Hour Time-Keeping Error (30 Days, Same Oscillator)



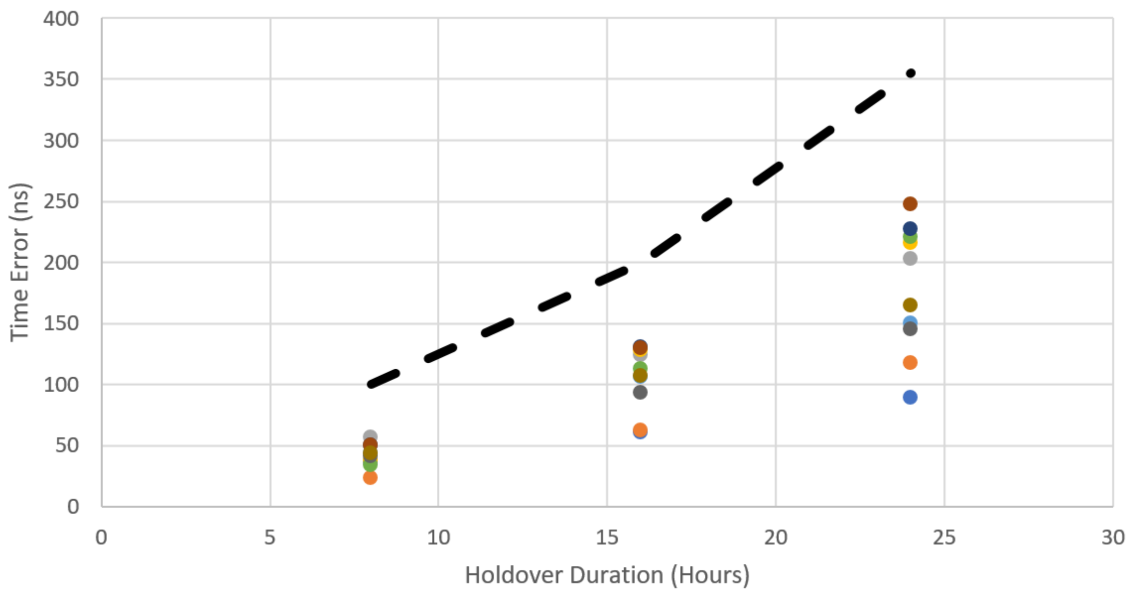
MAC Holdover Performance

To avoid the pitfalls of discussing "approximate holdover performance", it is necessary to instrument a statistically significant test. This test is defined with sensible rigor:

- Instead of 1 oscillator tested as "typical", ten oscillators are included in the study.
- The oscillators are evaluated within an overall system included the actual servo system algorithm and GNSS noise for expected antenna installation.
- Each test includes a 7-day tracking period (much less than the 30-day periods quoted by other vendors) but sufficient to learn the behavior of the oscillator.

The following graph shows the holdover performance as a function of holdover duration for each of the ten trials. Three holdover durations (8 hours, 16 hours, and 24 hours) were processed in detail. Also plotted with the dashed black line is the timekeeping performance of the current generation MAC for comparison. As can be seen, the user can have a confidence in the real-world compliance of a MAC-based system to our holdover specification. For example, while we specify 400-nanosecond holdover time compliance over 24 hours, in fact the average time error (or typical) is 178 nanoseconds in this study.

Holdover Timekeeping Error Microsemi Miniature Laser-Driven Atomic Clock (MAC Rubidium)



Conclusion

Given that timing service performance is only as good as its source, it is important to select the right sources in the next generation networks. This study shows the benefit of leveraging the premier holdover performance of the Microsemi Miniature Laser Driven Atomic Clock (MAC). Unlike non-atomic clock technology that is being pushed to the limits to keep up with the increasing need for precise timekeeping, the applicability of this new laser-based atomic clock technology is shown. A well-designed time service architecture should be built on the foundation of atomic clock based systems sourcing the distribution.

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