# Application Note: GPS Receiver Testing

# Leap Second Testing Made Easy

*The first leap second since late 2008 will be added to the official time scale on June 30, 2012. This will be the first mid-year leap second event in 16 years. No doubt most GPS receivers in current production have not experienced a leap second event and none would have experienced a mid-year leap second. For these reasons, it is strongly recommended to test the upcoming leap second event for all GPS receivers and systems to determine if algorithms and software successfully manages the leap second event and to uncover any detrimental effect of the leap second discontinuity.*

## Introduction

Spectracom's GPS constellation simulators, models GSG 54, 55, and 56 can easily simulate the leap second event of June 30, 2012. A typical test takes less than 35 minutes to set up and run. A sample leap second scenario is available for download. This application note provides background on the leap second event and describes leap second testing with the Spectracom simulator.

## What is a Leap Second?

Since the official definition of time is based on atomic standards, a leap second is inserted in the UTC time scale to keep it in step with the solar day much like a leap day is used to keep the calendar in step with the seasons. A leap second can be added or removed. It can occur at the end of the day on December 31 or June 30 and must be announced approximately 6 months in advance.

The sequence for adding a leap second to UTC compared to a normal day:

| Normal Day | Leap Second Event |
|---|---|
| 23:59:58 | 23:59:58 |
| 23:59:59 | 23:59:59 |
| 00:00:00 | 23:59:60 |
| 00:00:01 | 00:00:00 |

*Figure 1. Adding a leap second*

| | No future leap second (last leap on December 31, 2008) | Leap second coming on June 30, 2012 | Within +/- 6 hours of the leap second on UTC mid-night June 30, 2012 | After July 1 (no future leap second) |
|---|---|---|---|---|
| $WN_{LSF}$ | 488 | 670 | 670 | 670 |
| DN | 4 | 7 | 7 | 7 |
| $\Delta t_{LS}$ | 15 | 15 | 15 or 16 (depends if almanac updated and received) | |
| $\Delta t_{LSF}$ | 15 | 16 | 16 | 16 |
| UTC | GPS Time + $\Delta t_{LSF}$ | GPS Time + $\Delta t_{LS}$ | GPS Time + $\Delta t_{LS}$ + ($\Delta t_{LSF}$ - $\Delta t_{LS}$) | GPS Time + $\Delta t_{LSF}$ |

*Figure 2. Key leap second parameters in the UTC calculation*

## The Case Against Leap Seconds

There has been considerable discussion in the GPS and other precise timing communities that leap seconds are a nuisance at best, and can cause significant issues as more and more applications require precise timing data on a scale much better than a second. Google has recently posted their approach to managing leap seconds for their critical data center/server applications – they "smear" the leap second over a period of time (http://googleblog.blogspot.com/2011/09/time-technology-and-leaping-seconds.html). In fact, there is a discussion to eliminate leap seconds from the official time scale. This debate is likely to have added confusion in the GPS development community which in turn underscores the need for leap second testing to ensure proper performance of GPS devices.

## How GPS Manages Leap Seconds

The GPS (and other GNSS) system operates on the principal of synchronized precise time. Every satellite broadcasts "GPS Time" which was in sync with official UTC time at one point. GPS does not reconcile the discontinuity of a leap second in its time scale. It transmits GPS Time along with the number of leap seconds according to GPS Interface Specification IS-GPS-200E (latest June 2010). The responsibility to convert GPS time to UTC falls to the GPS receiver and supporting software.

The information about leap seconds is broadcast by the satellites as part of the almanac. The parameters that apply to the current and future leap second events are contained in subframe 4, page 18 of the navigation data message (see section 20.3.3.5.2.4 of the interface specification). The key parameters are as follows:

- $WN_{LSF}$ – Week number when the leap second becomes effective
- DN – Day number when the leap second becomes effective
- $\Delta t_{LS}$ – Current or past leap second value
- $\Delta t_{LSF}$ – Current or future leap second value

For correct management of the leap second event, the receiver must determine which value to use (either $\Delta t_{LS}$ or $\Delta t_{LSF}$, or both) for its UTC calculation.

For example:

1. If the leap second event is not in the past and if the present time is less than 6 hours before the leap second event, the receiver should use the value of $\Delta t_{LS}$.
2. If the present time is within a window of 6 hours before to 6 hours after the leap second event, the receiver is in a transition period where it looks at the difference between those 2 values and adds it to $\Delta t_{LS}$ (so if $\Delta t_{LS}$ is already updated in the almanac, zero is added, if not +1 is added).
3. If the present time is more than 6 hours past the leap second event the receiver will use the value for $\Delta t_{LSF}$.

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## Testing Leap Seconds with the GSG-5 Series GPS Simulator

It's easy. "Leap second" is an easily edited scenario parameter from all the user interfaces (front panel, web browser UI, GSG StudioView software). A value of 1 adds an offset of 1 between $\Delta t_{LSF}$ and $\Delta t_{LS}$ (this value can also be signed to indicate a negative leap second) and the week and day numbers are configured to indicate the leap second at the next possible leap second event (either June 30 or December 31). For example, if the leap second parameter is non-zero, then the simulation will indicate the leap second event occurs on June 30 at any time in the first half of the year and at December 31 for any time in the second half of the year.

A scenario file is available for download with the parameters in figure 3 below.

This scenario starts 30 minutes before midnight on June 30, 2012 (this is not exactly UTC, it is close because it is GPS Time, after all, we are just like GPS!). It runs for an hour with a leap second event at UTC midnight.

In a successful test, we expect the receiver receives the information about the current number of leap seconds, the future leap seconds, and the week number of the next occurrence about 10 minutes after scenario start.

The receiver reports the leap second on time and the current number of leap seconds as shown by the receiver updates from 15 to 16. At this time the almanac for the leap second values has not updated, it still reports the last received almanac information.

Sometime between 9-10 minutes after the leap second has occurred, the receiver receives the updated almanac information and the leap second values are now the same.

## Conclusion

The management of a leap second event should be tested in critical GPS applications. The only way to test leap seconds is through simulation. The alternative is to "hope and pray" when living through an actual leap second event in which case it is too late to fix something the has gone wrong. Spectracom's GSG series of GPS simulators lives up to its promise of delivering easy and thorough testing tools. The company is especially suited for testing timing function due to its heritage with precision timing systems. Please contact us for more information.

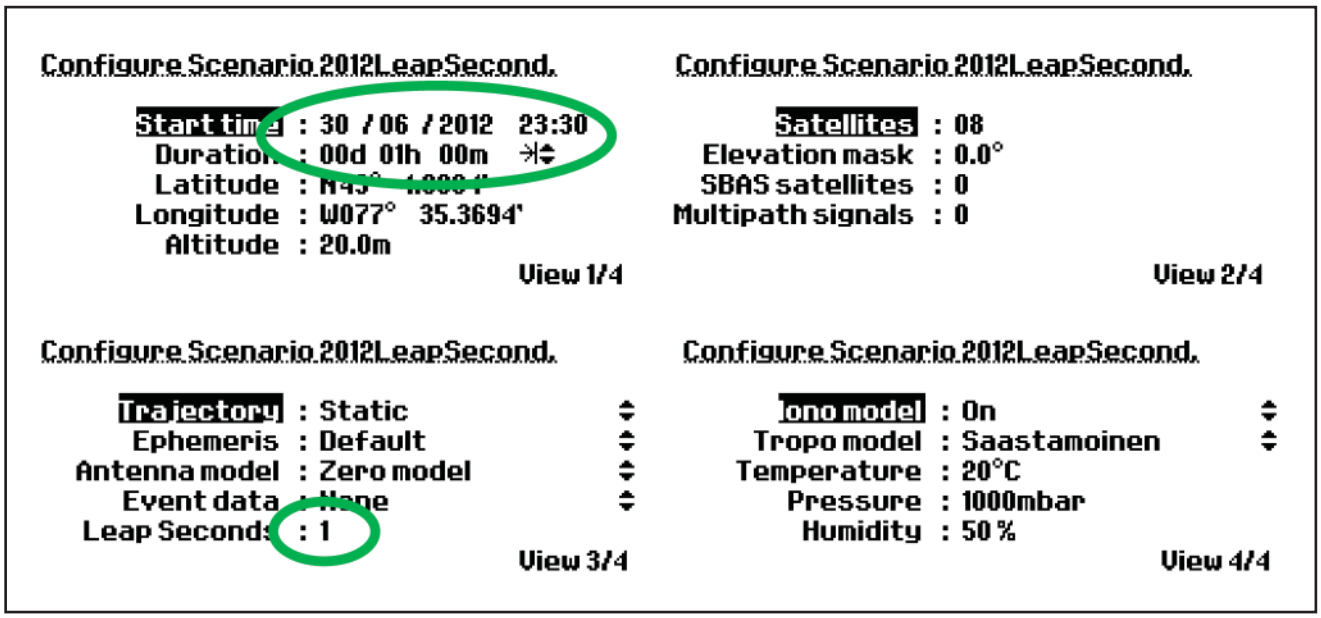


*Figure 3. Configuration scenario parameters*



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