

2015 NIST Investigation of PMU Response to Leap Second

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Conclusions first:

- This presentation is short (10 minutes)
- 8 PMUs and 1 GPS receiver were tested
- 4 of the PMUs got their time via IRIG from the GPS receiver
- The other 4 use internal GPS receivers.
- All of the PMUs has issues and were not in compliance with IEEE C37.118.2 immediately following the leap second.
- The GPS receiver also had an issue immediately following the leap second.

What happened to the Receiver?

- The GPS receiver used in this investigation did not fully comply with IEEE-1344^{1,2} in two ways:
 - The BCD second and SBS count repeated 23:59:59 and did not progress to 23:59:60 before going to 00:00:00³.
 - The Leap Second Pending bit transitioned from 0 to 1 at 23:58:59, (one second early) and from 1 to 0 during the repeated 23:59:59, one second before the transition to 00:00:00 as specified.

1. IEEE-1344 is the common name for the extension to IRIG published in the PMU standard. The latest version of this is in Annex D of C37.118.1-2011.
2. Some technical changes happened between 1999, 2005, and 2011, use the 2011 standard!
3. Specified by IEEE-1344 but the IRIG standard is ambiguous on SBS behaviour.

What did the PMUs do?

Table 10: Summary of PMU response to leap second

PMU ID	1	2	3	4	5	6	7	8
Total period of time the SOC was not synchronized with UTC	17.000 s	47.000 s	4.000 s	0.150 s	1.933 s	4.000 s	2.000 s	3.000 s †
Pending bit was set at all	no	no	yes	yes	no	no	no	yes
Pending bit was set and cleared at the correct time	no	no	no	no	no	no	no	no
Occurred bit was set at all	no	no	yes	yes	no	no	no	yes
Occurred bit was set and cleared at the correct time	no	no	no	no	no	no	no	no
Number of seconds of TOD for which there were less the proper number of reports	1	1	many ††	1	1	1	1	1
Number of seconds of TOD for which there was more than the proper number of reports	1	1	1	1	1	1	1	1

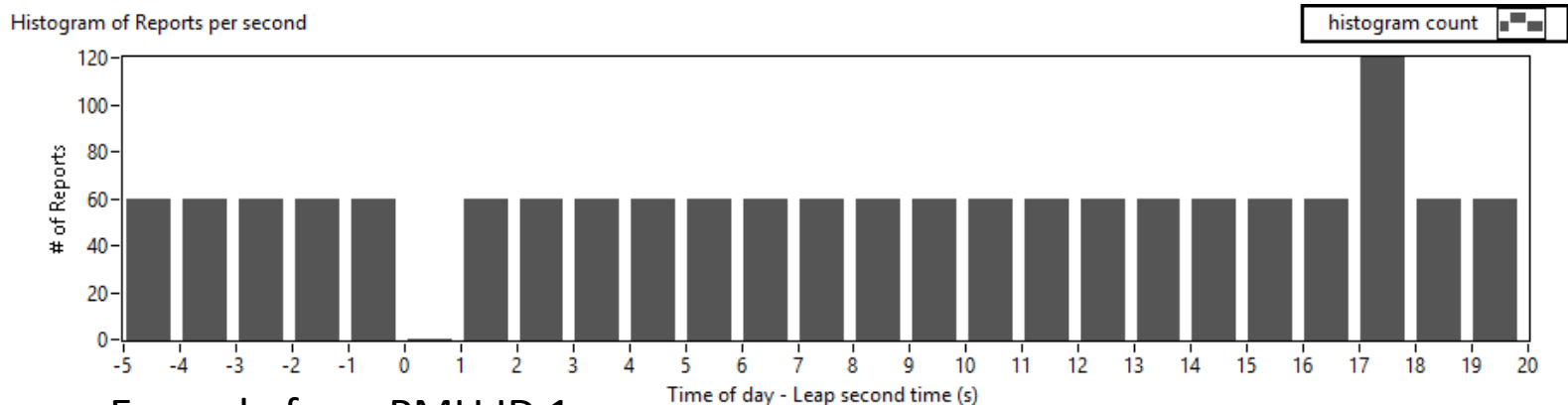
† PMU ID 8 was not synchronized with UTC for 1 second beginning 59 seconds before leap second and for 2 seconds immediately following leap second.

†† PMU ID 3 Beginning at the leap second and continuing at the time of writing, PMU ID 3 has sporadic periods where there are only 46 reports during a second. 14 reports are missing during these seconds.

Of the 4 PMUs using IRIG, only one of their behaviors could directly relate to the GPS receiver's incorrect behavior, the other 3 had issues as not directly attributable to the problem in the IRIG

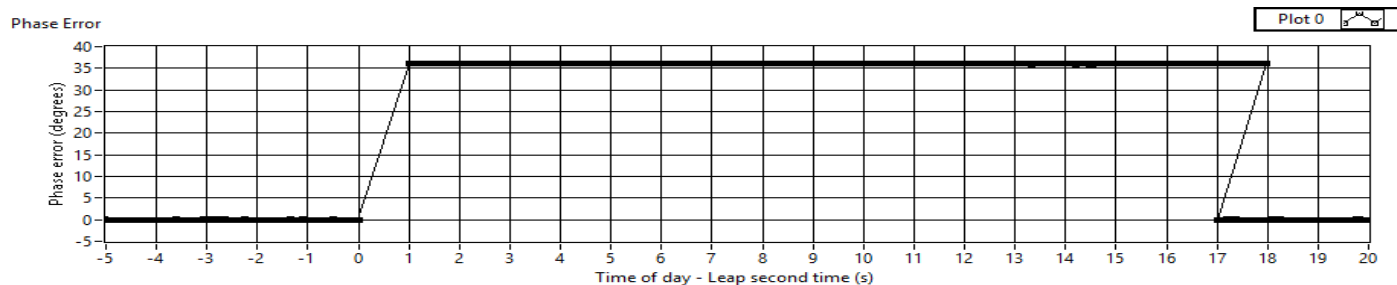
What happens when the time is not synchronized?

- “Missing” reports (the time never happened)
- “Duplicated” reports (reports that should have had a different time stamp)



What about the phase angles?

- for reports with incorrect time stamps, the phase angle “error” depends on the system frequency
 - At nominal frequency the phase angle is not changing.
 - So we ran the test at a constant 59.9Hz system frequency so you can see the phase angle “error”



Again, an example from PMI ID 1

- For 17 seconds, it appears like the phase has a 36 degree error (at 59.9Hz)
- Note that there are no reports for the second immediately following the leap second
- And there are two sets of reports for the second between 17 and 18 seconds after.

What should be done about this?

- IRIG standard is ambiguous about leap second responses so the ambiguities should either be clarified or vendors using IRIG will need to respond to every possible interpretation.
- All vendors need to test their devices for response to leap second.
 - This may mean expensive GPS simulation hardware will be needed for those devices with GPS receivers.
- Think hard about our critical infrastructure without testing of LS response.
- Read the NISTIR report and learn from the experiences of others.

Thank you

- Questions?

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