Improving the Performance of Low Cost GPS Timing Receivers

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Over the past decade, we have been very successful in synchronizing atomic clocks at remote locations using Motorola's timing receivers (PVT-6, ONCORE VP/UT+, M12+); one such application is Very Long Baseline Interferometry (VLBI) which uses Hydrogen Masers at multiple radio astronomy facilities in isolated locations chosen for scientific and RFI reasons. VLBI requires clock "smoothness" at levels ~1:10^{14} over one day and epoch timing that can be trusted at levels < 100 nsec. We have found that the 1PPS ticks from a low-cost single-frequency GPS receiver (operating in position-fixed mode) easily meet these requirements when measurements are averaged over several minutes [1]. We have also calibrated the "DC" offsets of the most recent M12+ receivers in order to improve the accuracy of the timing epoch [2].

The architecture of the Motorola receivers makes the 1PPS outputs occur at edges of an internal timing clock. For the PVT-6/ONCORE receivers, the clock is at 9.54 MHz and the resultant 1PPS output shows a sawtooth "dither" with a peak-to-peak amplitude of $(9.54\ \text{MHz})^{-1}$=104 nsec. The clock in the newer M12+ receivers is ~40 MHz, giving rise to a ~25 nsec peak-to-peak sawtooth. Many tests have shown that, over a long measurement interval, the dither is a zero-mean noise-like source. A one-byte binary message sent by these receivers reports on the sawtooth error that will apply to the *next* pulse; this correction can be applied to time-interval counter readings to improve the measurement precision.

However, the epoch any arbitrary 1PPS signal cannot be trusted because of the sawtooth "dither". Also, if the 1PPS signal is being used to discipline a crystal oscillator by averaging over times < 1 minute, the sawtooth will occasionally drift through a zero-beat; at such times, statistical averaging fails and the crystal is pulled off frequency.

In this paper we describe a simple circuit using a microprocessor and a programmable delay line that removes the "next pulse" sawtooth error at levels of 1-2 nsec. This circuit is incorporated in the second generation CNS Clock II [3].

Since Motorola has discontinued the M12+ timing receiver, we will briefly discuss the performance of its replacement, the iLotus M12M [4].

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[1] See "*Timing for VLBI(2005)*" and "*Low-cost, High Accuracy GPS Timing(2000)*", available at http://gpstime.com/.

[2] See "*Critical Evaluation of the Motorola M12+ GPS Timing Receiver vs. the Master Clock at the United States Naval Observatory, Washington DC*", available at http://gpstime.com/.

[3] See http://www.cnssys.com/ for further information.

[4] See http://www.synergy-gps.com/content/view/20/31/ for more information.