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The Saw Tooth Error Problem in GPS Receivers —

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The 1PPS (one pulse per second) output from a GPS receiver often comes with a "sawtooth error." This error is a consequence of the way most GPS receivers generate their 1PPS signal. The root of the sawtooth error is the disparity between the GPS receiver's internal clock, which is usually derived from a crystal oscillator, and the GPS time derived from the satellite signals. This difference in time is often communicated by the GPS receiver in terms of sawtooth correction values.

Eliminating or reducing the sawtooth error is critical, especially in precision timing applications. Here's how it can be addressed:

1. Direct Sawtooth Compensation:

- Some modern GPS receivers provide sawtooth correction values in their data outputs. These values give the magnitude and direction (advance or delay) of the sawtooth error.
- In systems that utilize both the 1PPS output and the data output from the GPS (like NMEA sentences), these correction values can be used to adjust the timing of the derived clock signal, effectively compensating for the sawtooth error.

2. Phase-Locked Loop (PLL) Smoothing:

- A PLL can be used to lock onto the 1PPS signal from the GPS receiver. By adjusting the PLL's loop bandwidth, the effect of sawtooth jitter can be reduced.
- A narrow loop bandwidth will suppress fast variations in the incoming 1PPS signal, smoothing out the jitter. However, it should be noted that narrowing the bandwidth too much can make the PLL slow to respond to genuine changes in the GPS timing.
- Pair the GPS receiver with a high precision OCXO. The GPS maintains long-term accuracy, while the OCXO provides short-term stability improvement.

3. Averaging Techniques:

- Averaging the timing over multiple 1PPS pulses can help in reducing the sawtooth error. This approach is beneficial when absolute real-time precision isn't as crucial, but the averaged timing accuracy over a short period is.

4. Use a High-Quality OCXO (Oven-Controlled Crystal Oscillator):

- Pair the GPS receiver with an OCXO. The GPS maintains long-term accuracy, while the OCXO provides short-term stability.
- The 1PPS signal is used to discipline the OCXO. By adjusting the control voltage of the OCXO over a longer period, the effects of sawtooth jitter can be minimized.

5. Utilizing Multi-GNSS Systems:

- Some systems use multiple GNSS (Global Navigation Satellite Systems) like GPS, GLONASS, Galileo, and BeiDou. By averaging or optimizing the 1PPS signals derived from different GNSS sources, the sawtooth error can be reduced.

6. Time-to-Digital Converters (TDC):

- Use a TDC to measure the exact time difference between the GPS 1PPS edge and a high-stability local oscillator's rising edge. This approach can give a very accurate measurement of the sawtooth error, which can then be corrected digitally.

7. Software Algorithms:

- Advanced algorithms can be used to predict and compensate for the sawtooth error. This might involve analyzing the pattern of errors over time and predicting future errors, then applying corrections accordingly.

In many high-precision applications, a combination of these techniques is used to ensure minimal error in the derived timing signals. The "best" technique or combination thereof often depends on the specific requirements of the application and the available hardware.