CONNOR WINFIELD

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Optimizing Timing Performance of GPS Frequency Reference

Choose the right GPS timing solution is essential for 4G base station reliability and performance

Introduction

Choosing the right GPS timing solution is essential for 4G base station reliability and performance. The timing characteristics, GPS reliability with limited signal availability, and holdover characteristics during loss of GPS signals should all be considered. The Navsync CW25-TIM timing receiver has been optimized for timing applications with limited GPS signal conditions like indoor, window, or partially obscured views. This article discusses the software optimizations of the CW25-TIM for precise and reliable timing performance.

GPS Timing Solution

The CW25-TIM GPS receiver module is a small surface mount module with dimensions of only 25mm x 27mm x 3mm which incorporates an internal Numerically Controlled Oscillator (NCO) that creates an output frequency that is GPS software steered by the baseband processor of the CW25-TIM. The Self Survey mode allows the receiver to continuously calculate its geographic position for a period of 10 minutes (the NCO frequency is valid during this period but the phase error will fluctuate relative to the positional error).

After the 10 minute self survey period, the receiver will automatically calculate an average of the geographical position and fix this value in the receiver firmware, which allows the phase error of the NCO output frequency to be more accurately controlled.

More importantly, the receiver now no longer has to calculate a positional fix to update the NCO and this allows the receiver to maintain a highly accurate NCO output even down to one satellite being tracked. This feature means that the receiver would have to completely lose sight of all GPS satellites to stop the NCO being synchronised to GPS, which means that the CW25-TIM can be used as a highly reliable source of GPS synchronisation.

Figure 1 shows the performance of the CW25-TIM's NCO frequency output in terms of Maximum Time Interval Error (MTIE) which is an internationally recognised metric of any clock source. The definition of MTIE is the maximum error for all possible measurement intervals within the measurement period. The ETSI PRC mask shown represents the maximum acceptable MTIE for reliable telecommunications use.

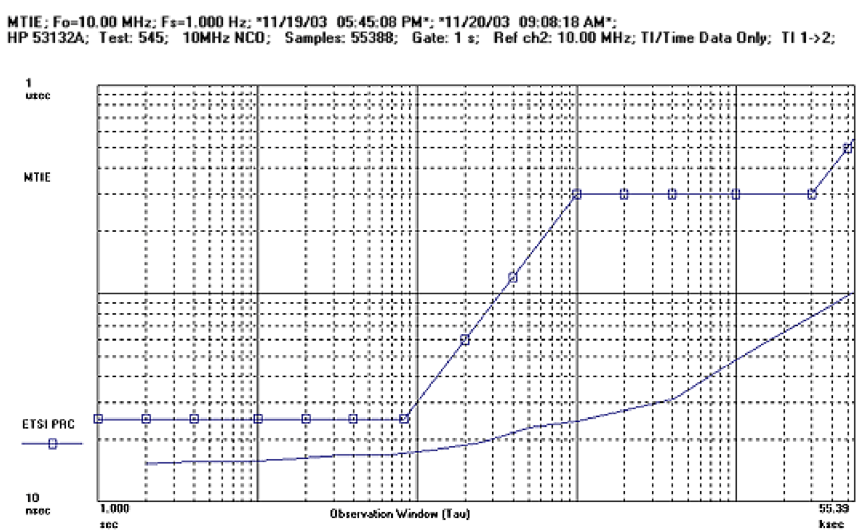

Figure 1: CW25-TIM MTIE Performance

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NCO Frequency Output Phase Control

Many GPS timing applications including WiMAX base stations require both one pulse per second and a phase synchronized frequency reference. The Navsync CW25-TIM high sensitivity GPS timing receiver offers precision GPS synchronized 1PPS and a Numerically Controlled Oscillator (NCO) frequency outputs, however the frequency output does not allow direct control of phase to maintain alignment with the 1PPS output. Because of this limitation, the CW25-TIM software includes an optional feedback loop to measure and control the NCO phase as shown in Figure 2.

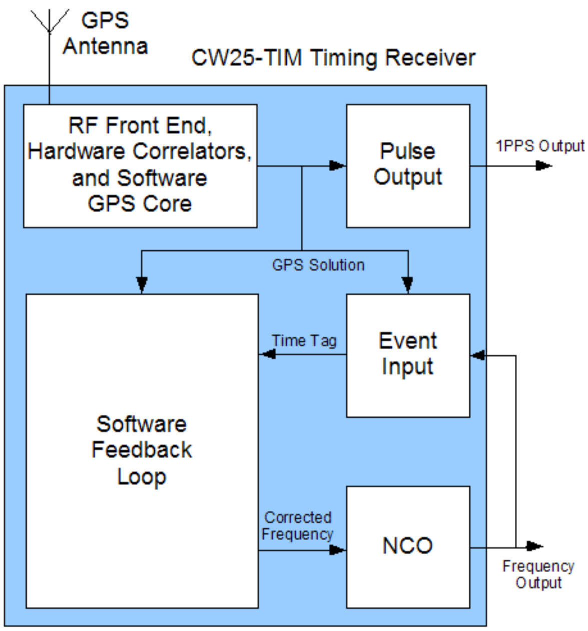

Figure 2: CW25-TIM Frequency Output Phase Control

Without NCO phase control, the GPS local clock drift solution directly determines the NCO output frequency. Over time, errors in setting the NCO frequency cause random walk of the NCO phase relative to the 1PPS. For applications requiring purely a frequency reference this random walk is acceptable, but for applications using the frequency output also as a time reference, the long term drift must be eliminated. To remove the long term drift and align the 1PPS and frequency output phase, the frequency output phase is measured using the CW25-TIM event input timer and through a feedback control loop. Small corrections are then applied to the NCO output frequency.

The CW25-TIM GPS engine provides a solution for GPS time and local clock drift once per second, within 32 ms after the top of the second. To coordinate timing between the GPS solution and the 1PPS and event input hardware, the CW25-TIM baseband processor is synchronized every 16 ms by a pulse generated by the RF front end. This pulse also drives an interrupt in the software to increment a TTick counter. The 1PPS and event input hardware counters are reset by this 16 ms pulse and are driven by the same 200 MHz clock resulting in a 5 ns event input and 1PPS output resolution.

The CW25-TIM uses the event hardware and the GPS solution to provide a time tag for the rising edge of one cycle of the NCO frequency output. The event hardware is disabled during most of the one second solution update interval, but is enabled one TTick (16 ms) before the the GPS solution is updated, so that the NCO phase measurement will be close in time to the top of the second (rising edge of the 1PPS). The NCO frequency output phase error is calculated by removing an integer number of cycles from the fractional part of the time tag.

Because of the uncertainty in the number of whole cycles to be removed, the frequency output must be sufficiently low so that the period is much less than the accuracy of the GPS solution. Typically 2.5 MHz has been used since the period, 400 ns, is much greater than the CW25's 30 ns RMS timing accuracy. This limitation is an artifact of time tagging the event measurements and is not a hardware limitation since the period of a 10 MHz output, 100 ns, is much less than the 5 ns hardware resolution. An alternate implementation not based on the GPS time tag for phase measurements is possible to remove this limitation.

The software feedback loop consists of a discrete time Proportional-Integral (PI) controller which behaves as a low pass filter with a 2 milliHertz bandwidth. This filter produces a small change in frequency that is added to the frequency from the local clock drift solution to set the NCO output frequency. When a GPS fix is initially obtained, the relative phase of the 1PPS and frequency output is random so that the error is up to one half cycle of the frequency output. To reduce the intial phase lock time, a faster controller is used to decrease the settling time. After the phase error settles, the RMS phase error between the rising edges of the 1PPS and the NCO frequency output is less than 10 ns. This performance is maintained during holdover and recovery from holdover so that the disturbances from a holdover event are minimized.

Holdover

During periods of GPS signal loss the receiver enters a holdover mode and bases the timing outputs on the last known solution time and clock drift solution. With a loss of GPS lock the receiver will continue to calculate its best estimate for GPS time and local clock drift based on any available GPS measurements. However, these estimates can vary significantly from the last known good values and are not reliable for holdover operation. By storing the last known good time and clock drift solutions, the stability of the 1PPS and event outputs becomes dependent upon the stability of the local oscillator. For strict holdover requirements the CW25-TIM's internal Temperature Controlled Oscillator (TCXO) can be replaced with an external Oven Controlled Oscillator (OCXO) with the required stability. Upon recovery from holdover, the 1PPS and phase synchronized NCO frequency output return to the GPS corrected phase at user-configurable rate.

Complete Timing Solutions

Navsync's parent company, Connor-Winfield, Inc., has combined the timing performance and reliability of the Navsync CW25-TIM with nearly 45 years of timing experience to create complete GPS timing solutions. Figure 3 shows a block diagram of the FR125 GPS Frequency Reference that includes an OCXO for holdover stability and Phase Lock Loop (PLL) with Voltage Controlled OCXO (VCOCXO) for low phase noise performance.

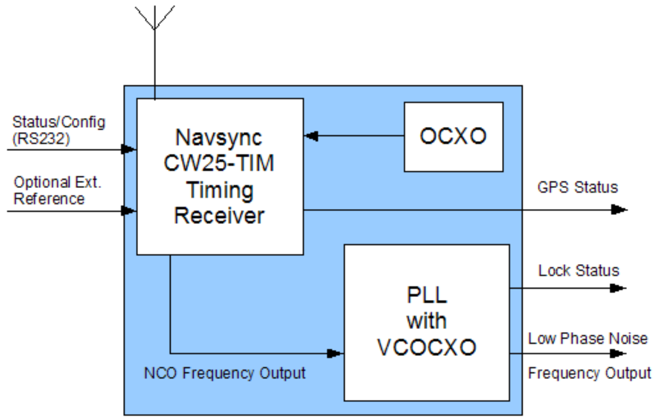

Figure 3: FR125 GPS Frequency Reference

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Links

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