Frequency Stability Measurements Using a Tight Phase Lock Loop

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• Introduction

This article shows an example of using a tight PLL as a frequency measuring system [1]-[3]. HP 10811 ovenized crystal oscillators are used as both the locked oscillator and PLL reference, and the system thus measures the combined instability of two presumed identical and uncorrelated devices. A photograph and block diagram of the PLL module are shown in Figures 1 and 2 [4]. The power, reference input and control voltage output are at the rear. The system uses a 1st order PLL with a 10 millisecond time constant (suitable for frequency measurements at averaging times longer than that), and the OCVCXO control voltage output has an anti-aliasing low pass filter with a 160 Hz cutoff. A block diagram of the overall frequency measuring system is shown in Figure 3.

• Measurements

The data are obtained by recording the band-limited PLL control voltage at a 100 samples per second (s/s) rate for about 5 hours with a 12-bit Dataq DI-158UP data acquisition system (see Figure 4). The fractional frequency scale factor is 1.8×10^{-8} per volt with 1.1×10^{-12} resolution and is averaged by a factor of ten to $\tau = 0.1$ second for analysis. The resulting time-domain stability, corrected for one oscillator, is shown in Figure 5. The short-term noise for 0.1-100 seconds is flicker FM at about 2×10^{-12} which changes toward random walk FM and drift at longer averaging times with slight room temperature sensitivity. These results agree well with other measurements for this type of crystal oscillator [5].

Actually, the DI-158UP data acquisition system samples the data at its maximum sampling rate of 14,400 s/s and averages 144 such measurements to obtain each reading. That oversampling is desirable for two reasons. First, it means that the control voltage signal need be band-limited only by a low pass filter (LPF) having a cutoff frequency of 7.2 kHz or lower, which can be accomplished with a simple RC filter. The 10 kΩ and 0.1 µF RC LPF has a cutoff frequency of 160 Hz which supports a 100 s/s sampling rate while providing about 36 dB of attenuation at the Nyquist frequency (and the noise has a low frequency spectrum). Second, the averaging serves to produce an averaged rather than instantaneous frequency reading as required for stability analysis and equivalent to the voltage-to-frequency converter and counter used in the classic tight PLL measuring systems of References [1] and [2].

Figure 1. Photograph of HP 10811 PLL Module

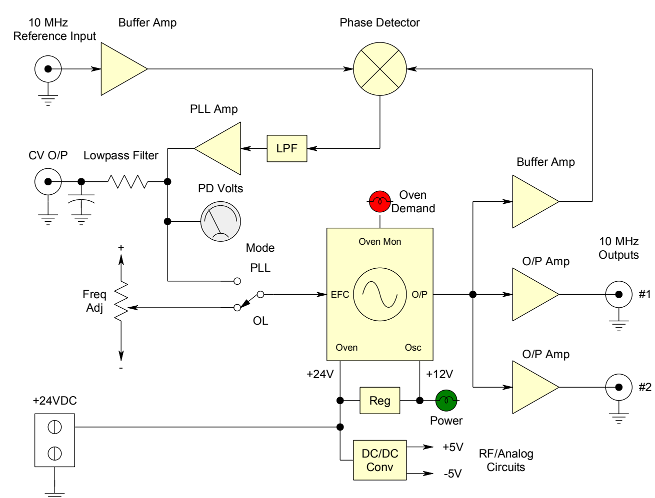

Figure 2. Block Diagram of PLL Module

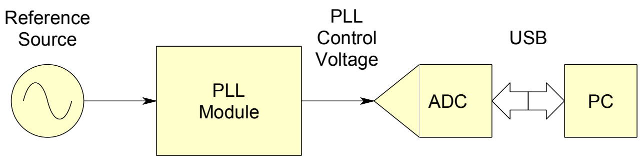

Figure 3. Block Diagram of Overall Frequency Measuring System

Figure 4. Photograph of Dataq DI-158UP USB Data Acquisition Module

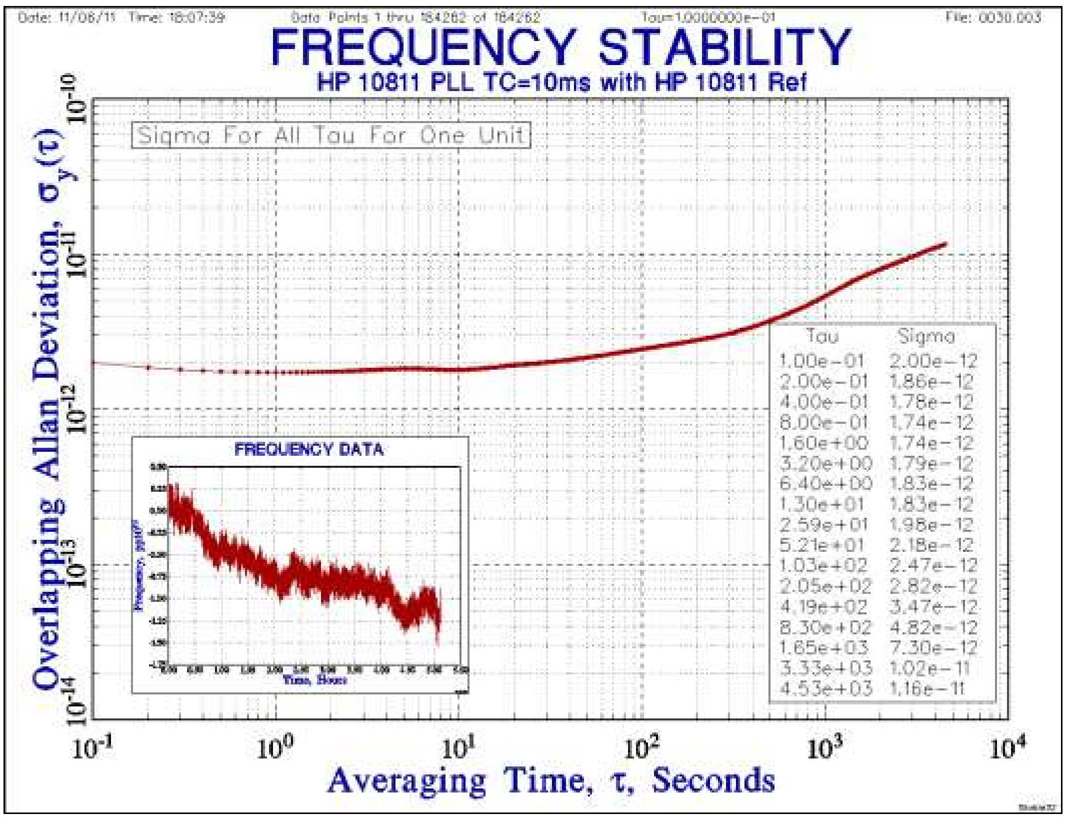

Figure 5. Stability Plot for a Single HP 10811Oscillator

• References

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3. J. Miles, "Time/Frequency Stability Measurements with the Tight PLL", June 2010.
4. W.J. Riley, "A 10 MHz OCVCXO and PLL Module", November 2011.
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