A New High-Performance GPSDO

Based on the Lars Walenius design.

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Reference & Dividers   Buffers   TIC Circuit   Micro & Misc.

Introduction

Just what is a GPSDO? It's a **GPS D**isciplined **O**scillator. I guess that doesn't tell you very much! Essentially it is a reference oscillator you can use in your shack to know *exactly* where 10.000,000 MHz is. Because the reference is locked to GPS, it is inherently *Accurate* and *Traceable*. You can read more about GPSDOs, their uses, and how they work here:

> *A Beginner's Guide to GPS Disciplined Oscillators*, M. Greenman 2007.

More than 10 years ago, the author published a GPS Disciplined Reference (GPSDO) design based on a small Atmel processor, with code completely written in assembler. The Time Interval Counter (TIC), the part of the design which measures the reference and compares it with GPS, was completely realised inside the micro, so the component count of the design was very small. Much attention was paid to the analogue circuitry and the quality of OCXO used. While the design has been replicated many times around the world, and the results were really gratifying, the design proved difficult to optimise (due to code limitations), and in addition the code, which took six months to develop, was difficult to adapt, and a headache to maintain.

> ZL1BPU Simple GPSDO. The project has now been retired and is not supported.

So I thought it was time to develop a new design, and I resolved this time to use an Arduino processor, so the code would be easier to write, and much simpler to maintain. During research for the new GPSDO, I came across a recent design by the late Lars Walenius, which just about completely fitted the requirements, so rather than reinvent the idea, that is the direction I took.

> LARS GPSDO blog. 2007.

Unfortunately Lars died some years ago, and so there is no definitive web page or complete manual for his design beyond what he posted on his blog. I hope that this information will correct this lack of coherent information, and it will also offer some improvements which make the device more user- friendly. But don't treat this information as the sole source of the design - there is much to be learned from Lars' blog. All the credit for this design must go to Lars Walenius.

Time Interval Counter (TIC)

The central piece of circuitry in any GPSDO is the Time Interval Counter, or TIC. The purpose of this is to measure the current phase of the local reference (the oscillator to be disciplined) relative to a traceable reference, typically the 1PPS pulses from a high-quality GPS receiver.
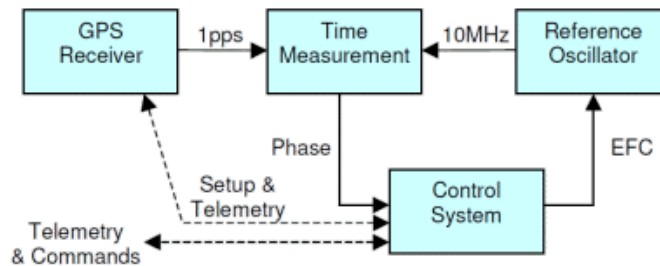
Block Diagram of a typical GPSDO.

In the original Simple GPSDO, the TIC was achieved using the internal timers, and had a resolution of only 100 ns. In the LARS design (as I will call it), a clever latch circuit is used. This idea was patented many years ago. In this design the reference phase is measured in hardware, using a latch, set by the the 1 PPS pulse rising edge, and cleared by the next reference edge, within one microsecond. The resulting pulse, 0 to 1 µs long, is integrated on a small capacitor and immediately read by the micro-controller. This method has a resolution of just 1 ns.
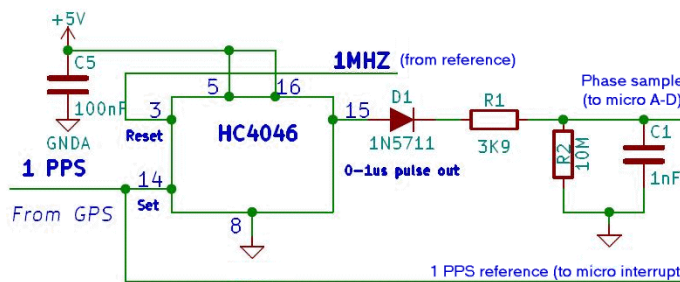
The LARS TIC (from original documentation)

The Lars Walenius Version

Since Lars is no longer with us, there's a risk that his original documentation may be lost. So I have preserved what there is of it here. There are four PDF documents, the original blog, and an interesting blog from another constructor. Read these

carefully. The PDFs contain all you need to know about setting up the GPSDO.

- Lars GPSDO Controller pp 1-7
- Lars GPSDO Controller pp 8-14
- Lars GPSDO Controller pp 15-18
- Lars GPSDO Controller pp 19-21

- The original Lars Walenius blog (while it still exists)
- Paul's Blog (has interesting performance results and useful ideas - even a circuit board).

The ZL1BPU Version

My version follows the LARS TIC circuity exactly, and the rest of the design is followed with some adaptation due to what parts were available. The prototype was built during Covid19 Level 3 Lock-Down, so there was no opportunity to purchase parts. By all means use the original LARS components if you can.

No changes have been made to the functionality of the code, but some significant additions have been made, which considerably improve the user-friendliness of the unit.

LCD Display
The original design used a computer link to monitor performance. This has been retained. But in order to allow monitoring of the ongoing performance of the unit, without the need of a computer connection, a serial LCD display was added. A serial (I^2C) display was necessary as not many spare pins were available on the micro, not enough for a parallel display, and by sheer coincidence the I^2C pins were free.

Having an LCD display allows the OCXO control voltage (the EFC) to be monitored continuously, along with the lock status, and of course this means that you don't need to have a computer connected all the time.

UTC Clock
Well, when you have a display available, and perfect GPS timing, why not display a clock? The clock is set manually, not by reading the NMEA data from the GPS receiver. This would have necessitated a far bigger micro (more code space) than the Arduino Nano selected. But setting the time is easy, as all you do is connect the NMEA output from the GPS receiver (via a socket on the back panel) to a GPS monitoring program on the PC for a few minutes while you set the clock.

I had to sacrifice the temperature measurement capability (which used the pins used by the clock setting switches), but if you later wish to add temperature measurement, you can always add an I^2C temperature chip.

The added GPSDO display.

Status Indication
There are four status indications: 'WARM', SEEK', 'LOCK' and 'HOLD". The number in the middle of the lower line is the accumulated TIC offset, and on the right the EFC control voltage (range 0 to 65535).

Minor Additions
I also added a 1 PPS LED on the panel to act as GPS fix indication (the LED does not flash if there is no fix), and three BNC sockets, for 10 MHz, 5 MHz and 1 MHz outputs. The back-lit LCD display serves as the power indicator.

The rear panel has sockets for 12 V power, battery backup (I included a simple charger), the three clock-setting buttons, a socket for 1 PPS output, the GPS receiver NMEA data output and antenna input, the USB connector, and a hole which allows access to the OCXO trim pot. The unit does not at present detect or report when it has lost AC power.

A front view of the working GPSDO.

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