10 MHz Simple GPSDO

by

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1. Description

The *Navman* TU30-D140-221 Jupiter GPS engine has a high accuracy 10 kHz output synchronised to UTC. A 10 MHz *ISOTEMP* OCXO 134-10 is divided down to 10 kHz and phase locked to this GPS signal. The 2nd order loop has an $\omega_0 = 2\pi\ 0.007$ Hz and damping δ=0.7

If required, the GPS receiver can be controlled via an RS-232 port, and a 1PPS (one pulse per second) signal is available on DCD; this can be used by a computer to keep precise UTC time to a few tens of ns.

2. Operation

Connect 12 Volt DC power and a GPS antenna. The GPS engine will acquire satellites and be locked to UTC within 2 minutes. The indication of this is when the 1PPS LED flashes exactly in time with MSF, DCF, WWV etc radio one-second time marks. After 7 minutes, the oven will be up to temperature, and after 10 minutes the 10 MHz PLL will be in lock.

One can now use the GPSDO; but the OCXO is still stabilising. The mean frequency will be accurate to better than 10^{-10} after an hour, and improving to $\sim10^{-12}$ after 24 hours. Summary:

Mins	State & Mean Frequency	Mins	State & Mean Frequency	
2	GPS locked to satellites	30	Error	< 2x10e-10
7	Oven up to temperature	45	..	< 1x10e-10
10	PLL in lock	> 60	..	< 5x10e-11
15	Error < 1x10e-9			

3. Connectors

Power

The GPSDO requires a 11 to 15 Volt, 1 Amp DC stabilised power supply connected to the terminal block; the positive terminal is closest to the lid and marked "+". A series diode protects the 0082-004 PCB (but not the OCXO). Start up current is 1 amp, reducing to 400ma when the OCXO oven is up to temperature. The oven makes the GPSDO feel rather warm, so ensure sensible ventilation.

GPS Antenna

The MCX socket is for the GPS antenna. It is 'live', with a +5V DC signal to supply an active antenna. The supply is NOT protected against short circuit. If you use a passive antenna, you MUST remove this 5V feed: open the GPSDO, identify the PINK wire and disconnect it from the red terminal on the 0082-00x interface PCB. Alternatively, release the pink wire from the GPS 20-way connector. Ensure the loose end cannot touch live parts.

RS-232

The DE9 female socket is wired as a DCE (i.e. modem). The services are:

Pin	Name	Signal
1	DCD	25.6 ms 1PPS synchronised to UTC on leading (negative) edge
2	RXD	Serial o/p data to computer
3	TXD	Serial i/p data from computer
5	COM	Common return (0v)

The other pins are not connected. The serial port driver IC is a MAX233CPP (or equivalent) and it is socketed for easy replacement.

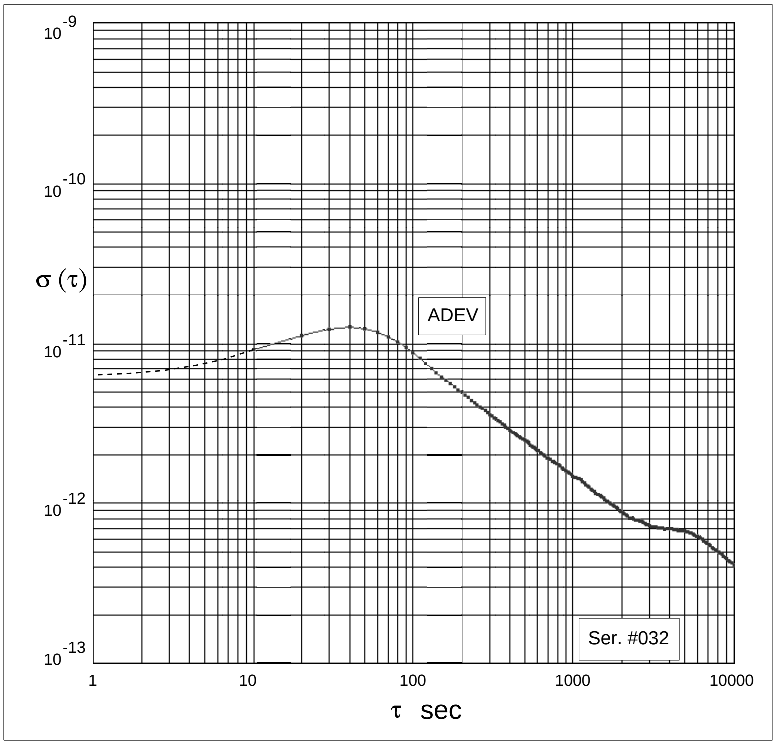
The default serial data communication protocol is *NMEA-0183* , ASCII plaintext at 4800 baud, format 8N1. This can be displayed on a computer using a 'dumb terminal' program. *Rockwell/Navman* binary protocol can be selected temporarily by external software command, or permanently by removing the connection to GPS 20-way connector pin 7.

Rockwell/Navman Serial Data I/O specifications are at `http://www.gpskit.nl/downloads-en.htm`

10 MHz
A 10 MHz, 4.8V pk-pk square-wave (source 50 Ω) is available on the BNC socket. It can drive a 50 Ω load with amplitude 2.4V pk-pk, delivering 14 dBm at 10 MHz. Harmonics are easily detectable at 1250 MHz.

LED
A red LED flashes with the 1PPS signal and the start of the pulse signifies the UTC second. It is essentially a "heartbeat" signal.

4. Performance
This is a *simple*, lo-cost GPSDO and its short term performance is dominated by the oscillator used. Its primary purpose is driving frequency counters and generating frequency markers and it is reasonably well suited to frequency synthesis. Long term accuracy (days) tends to that of the GPS system itself. In general terms, the second-to-second frequency accuracy is of order $5x10^{-11}$. A histogram of mean frequency error taken over a 10s period shows the deviation exceeding $\pm 5x10^{-11}$ (0.0005 Hz) approximately1% of the time.



Allan Deviation Plot for 'simple' GPSDO with IsoTemp OCXO134-10. PLL filter bandwidth 0.007 Hz. Frequency deviations measured at 10 MHz relative to Rubidium standard using an HP53131A frequency counter.

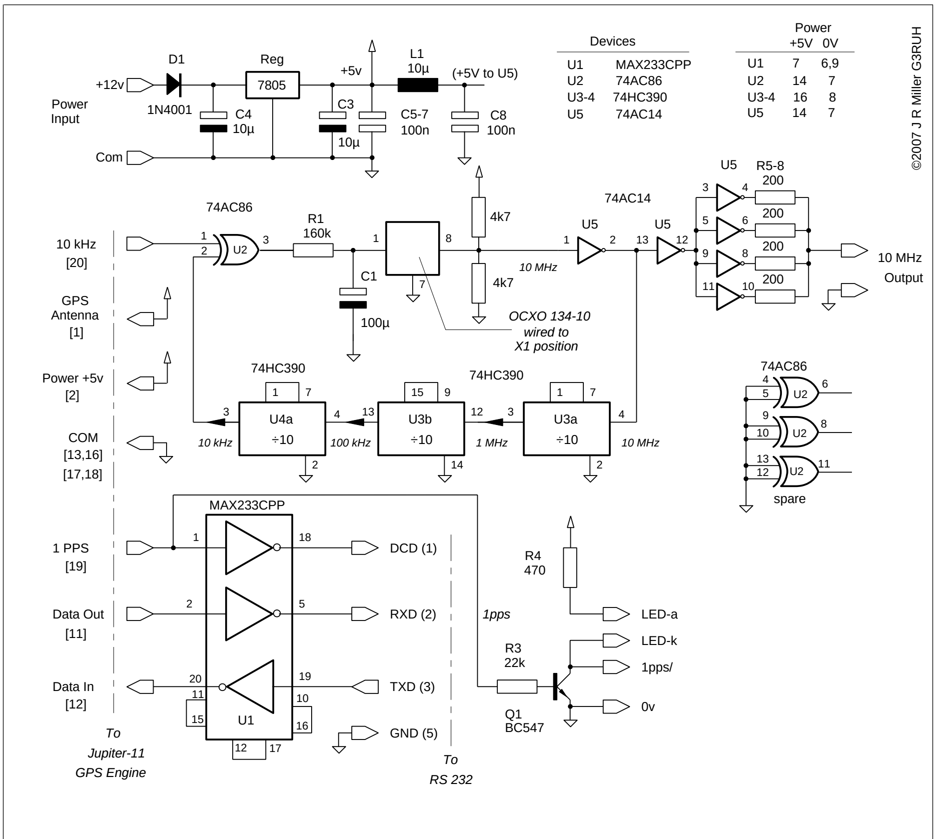
Allan deviation σ(τ) shows the RMS frequency change you can expect over a τ second interval.

Whilst the short term jitter (second-to-second) of the GPS 10 kHz source signal is about 7ns RMS, its effect is greatly diminished by the PLL loop filter. This means that the GPSDO *short term* stability is defined by the OCXO.

The longer term GPS 10 kHz source signal has very slow navigation solution phase wander of order tens of ns and this sets the longer term GPSDO stability (τ = thousands of seconds).

A data sheet for the *IsoTemp* OCXO 134-10 oscillator can be downloaded from the manufacturer at:
`http://www.isotemp.com/ocxo134.htm`

Interface/PLL PCB Schematic
The 10 MHz oscillator drives a 3 stage decade divider and the 10 kHz signal that results is compared in phase with a 10 kHz signal from the GPS receiver using an EXOR gate U2 pins 1/2/3. The average voltage at U2 pin 3 is available at the output of the low-pass filter R1/C1, and this is used to adjust the OCXO



GPS Interface & PLL [Part # 0082-004]

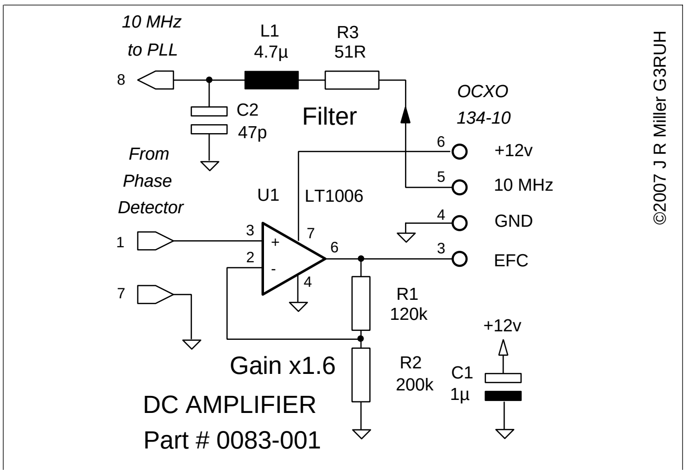
frequency to keep both 10 kHz signals locked in phase, and thus the 10 MHz locked to the GPS satellite constellation clocks.

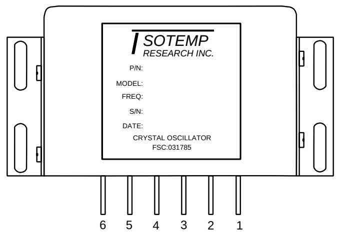
Note that the 7805 regulator is mounted off the PCB because it needs a heatsink.

DC Amplifier

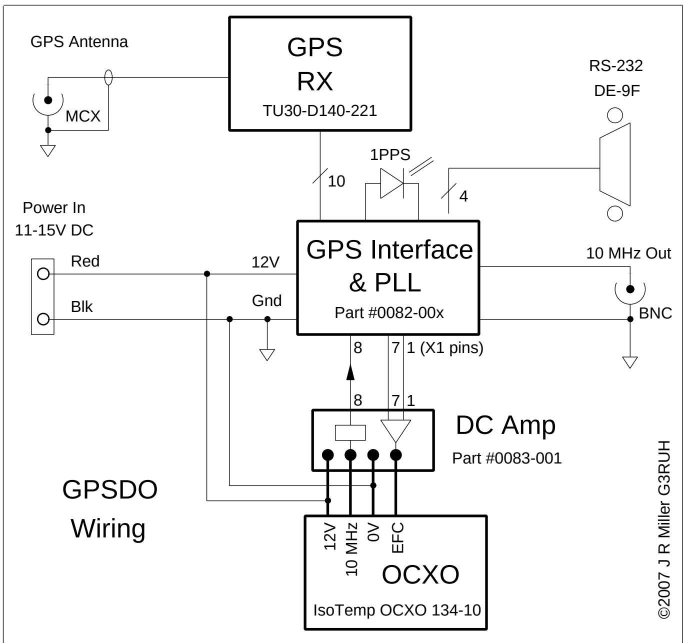
This small circuit PCB is mounted on the OCXO pins. It has two functions:

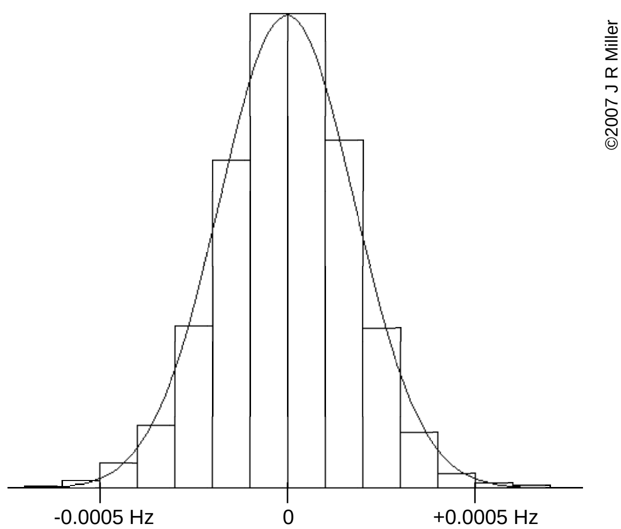
(1) amplify the 0-5V range of the phase detector up to the 0-8V range needed at the oscillator EFC input; (2) a resonant circuit magnifies the OCXO 10 MHz output by about x2.5 to drive the PLL input with a 5V pk-pk signal to reduce zero-crossing noise.





PIN CONNECTIONS	
PIN	FUNCTION
1	OVEN MONITOR
2	REFERENCE VOLTAGE
3	VCO INPUT
4	0 VOLTS
5	R.F. OUTPUT
6	+ VDC





Frequency deviation from 10 MHz
Measurements averaged over 10s
(Typical distribution)