Commissioning and running the GPSDO

Overview

Describes the behaviour using program version 2023-01-08. Some cosmetic changes may be seen from previous versions, these usually can be ignored.

The GPSDO has three modes:
- Startup
- A one time calibration run
- Normal operation

The calibration run is used to determine the actual sensitivity of the OCXO to changes of control voltage. It has to complete before normal operation can begin.

When calibration completes, the GPSDO reboots and starts normal operation. The user has various logging options, and can change some parameters.

Startup

The GPSDO runs some tests then waits for the GPS module to acquire a valid fix. When the module signals a valid fix, the unit enters either calibration or normal operation.

The progress of startup can be monitored by watching the status LED (always active) or via a terminal program attached to the serial/USB interface.

Normally, the status LED will start by flashing a binary pattern (explained below) indicating how many satellites are being monitored by the GPS module. Depending on the module, the received signal strength, if a warm or cold start this can continue up to 15 minutes.

Calibration

The first time the GPSDO is powered up, it enters calibration mode. This determines the sensitivity of the OCXO (the change of frequency for a given change of control voltage) and a nominal control voltage to use for subsequent starts. The calibration run takes more than an hour.

If the GPS receiver gained a fix in less than 15 minutes, it is recommended to turn the unit off for a few seconds then on again to restart it with a warmed up OCXO. The drift in a warming OCXO can upset the calibration algorithm causing it to loop endlessly.

The progress of the calibration run is indicated by the status LED, using a binary pattern (explained below) counting down from 16 to 1. The pattern is repeated every 4 seconds. For about half an hour, it will seem to be stuck on 16. This is because the CPU starts by trying control voltages at the limit of the range, then refines these until the OCXO is close to the correct frequency. It then alternates the frequency between 0.25Hz high and 0.25Hz low for more than an hour, measuring the change in voltage.

Once the calibration is complete, the PIC writes the configuration to non volatile memory and reboots. It will then enter run mode. If the calibration is interrupted, it starts from the beginning again.

If the correct logging mode is selected, the user can also see more information using the USB/serial connection.

Run mode

After calibration, or on any subsequent power up, the PIC enters run mode after startup. The LED flashes for every 1pps received. This should be once a second, but if the GPS receiver marks a 1pps as invalid, or a 1pps is missed, the LED does not flash.

- A long flash indicates the PIC is changing the control voltage.
- A double flash indicates the accuracy (as determined by the PIC) has not reached 1ppb. This is normal for the first few minutes.
- A single flash indicates the accuracy is 1ppb or better

It is recommended the GPSDO be allowed at least 15 minutes to warm up. From a cold start, it is not unusual to see the PIC reboot or reset frequently until the frequency is within pulling range, usually one or two minutes. Then it will double flash, with changes, as it tries to discipline the OCXO. The algorithm locks the OCXO to the 1pps as soon as it can, but the frequency changes to do so can be large. If all is well it should reach 1ppb within 15 minutes.

Ideally, the GPSDO is not switched off or moved. Its performance is measurably better after running for 24 hours.

If the correct logging mode is selected, the user can also see more information using the USB/serial connection.

The serial/USB User Interface

The GPSDO does not require any user input. However, there is more information available than can be indicated by a single LED. The interface is a 9600 baud serial port configured for 8 bit character with one stop bit.

The output can be viewed using a terminal emulator such as TeraTerm (recommended). The interface works with various terminal emulators however only TeraTerm has been tested for updating the firmware.

System Defaults

When the system is calibrated, values are written to non-volatile memory for use on subsequent starts. The values are:

- the sensitivity of the OCXO – displayed on startup, cannot be changed by user input
- The default control voltage on startup – a user may elect to update this if the GPSDO is to be used with no GPS module is attached. If set correctly the undisciplined OCXO will stabilise within 0.1Hz of 10MHz. See the V command below.
- The default logging at startup. Some users are interested only in the NMEA messages generated by the GPS module. The default after calibration is pass through – the GPSDO does not generate any logging messages, but passes all the data from the GPS module to the user interface. This can be overridden temporarily, or the default can be changed permanently.
- The maximum period between control voltage changes. The default is 512 seconds. This is a compromise between minimal frequency changes and the phase difference between the GPS signal and the generated signal. This also can be overridden temporarily, or the default can be changed permanently.

User Commands

There are a number of user commands. Each one is a TAB key followed by an alphanumeric.

When the user presses the TAB key, logging is suspended and the prompt > appears. The user then has a few seconds to input the desired character. Due to programming constraints, a typed key or key pair (TAB, alphanumeric) may not result in an immediate response, there can be a delay of up to one second. However, the typing is captured so it is possible to type TAB then command without waiting for the prompt. Alphabetic commands are not case sensitive.

These commands do not interfere with the operation of the GPSDO.

T	Output the UTC date and time
S	Show some statistics
Z	Clear statistics
H	Show History. History is up to the last 24 voltage changes. Due to programming constraints, this is output one line a second
I	Shows the compilation date and the default maximum period

The next three commands make changes that are temporary but can be made permanent. See the W command below.

digit 0 to 4.	Changes what is logged to the serial connection: 0 – suppresses most messages 1 – allows most messages except the second by second output 2 – allows all messages 3 – NMEA pass through mode. Useful for redirecting output to a GPS monitoring program like VisualGPS. It is cancelled by putting in another log change command. 4 – debugging mode. Not useful for a user.
Digit 5 to 9	Alters the maximum time between control voltage adjustments of the OCXO. The default time is 512 seconds. This is 2^9. Entering a digit between 5 and 9 alters it to 2^{n+3}. For example, entering 5 alters the time to 256 seconds. The default is 6. The user may change this experimentally but the default provides satisfactory results under most circumstances.
V	Write the current control voltage as the startup voltage. Note the V command is not effective unless followed at some time by a W command. As the OCXO ages, the target control voltage can change from when calibration was performed. The change is not large and will not prevent achieving a lock from a cold start. Storing a more up to date value can be useful if the GPSDO is used a 10MHz source offline (without a GPS signal). Before using the V command, the user should ensure the value to be stored is an improvement on the previous value.

The following commands will result in a reboot.

R	Reboot
C	Calibrate. This is only useful if the OCXO or power supply is changed. Otherwise it is optional and may have no noticeable benefit. The logging will be reset to 3 and the maximum time for control voltage changes reset to 6 (512 seconds).
W	Writes the current logging (set by digits 0 to 4), maximum time between control voltage changes (set by digits 5 to 9), and a new default control voltage if this was saved by a previous V command. Until this command is

	used, any restart reverts to the previous values.
U	Request a firmware update. Full instruction for this are provided with the update. If this is accidentally entered, wait a minute and the firmware will reboot and resume normally. A power cycle will also cause a normal start, but it is preferable to wait for the one minute timeout to avoid removing power from the OCXO.

The status LED

The LED should give some indication of status at least once a minute when the unit is powered. If there is no indication, the LED may be faulty.

Binary

Some of the indications are given as binary numbers. The user usually has no reason to interpret these numbers, they are there for problem analysis. The numbers are presented as a sequence of 50ms flashes at half second intervals. A double flash (50ms on, 50ms off, 50ms on) is binary zero, a single flash is binary 1. If for instance the indication is of satellites in view (seen during the start phase), the sequence *flash/flash flash/flash* is interpreted as 101, which is the binary for decimal number 5.

There are two values that may be significant. During startup, if *flash flash* (zero) continues for many minutes it indicates there are no satellites in view. This could be due to antenna problems or very poor reception and may require investigation.

During calibration, the passes start with *flash/flash flash/flash flash/flash flash/flash flash/*, the binary value 10000, decimal 16. This should start counting down after about half an hour. If it doesn't, it may also be due to poor reception, faulty circuitry that does not allow the control voltage to swing through the full range, or an OCXO that is out of specification and cannot be controlled.

Expected output

Under normal circumstances, the following patterns should be seen:

Startup – the GPSDO should be receiving data from the GPS module about the number of satellites in view. This is indicated in binary every 3 seconds. The value will start at zero but within 5 minutes should be over four (binary 100). The GPS module usually acquires 8 to 12 satellites before indicating it has a fix.

Calibration – the LED indicates a binary number each 4 seconds, starting from sixteen (binary 10000). The GPSDO spends up to half an hour refining the control voltages until the OCXO runs fast or slow by 0.25Hz. The voltage alternates each 256 seconds thereafter. After each 256 second period, the measured frequency must fall within limits to be accepted as a usable value. If accepted, the value indicated by the LED is decreased by 1. It is not unusual for a few values to be rejected, either due to poor signal or drift in a newly commissioned OCXO.

Run – the LED should give an indication every second. A long flash (more than 500ms) indicates either a restart (if the GPSDO cannot get the OCXO locked) or a change of control voltage. A restart will miss the next few seconds (no flash), a change is followed by a flash next second. If the flash is a double flash (50ms on, 100ms off, 50ms on) the output frequency may not be within specification (i.e. not within 1 part per billion). A single flash usually indicates within specification. A newly commissioned OCXO can take hours to be disciplined satisfactorily, so may alternate between double and single flashing.

Error indications

LED flashing rapidly – the microprocessor is running on its internal oscillator. Not receiving 10MHz from the OCXO. This is a fault and should be rectified.

No indication from the LED for over 10 seconds – Usually a fault condition. If the microprocessor is programmed and wired correctly, there should be some LED activity at least every 10 seconds. If it happens after startup and the GPSDO does not enter run/calibrate it indicates the 1pps signal is not received by the microprocessor. If this occurs during normal running, it could indicate the GPS has no good signal for an extended period.

LED flashes at about 10 second intervals – Not receiving NMEA input from the GPS receiver. Most GPS receivers output NMEA data at power on. A possible fault, but normal if the user is deliberately running the GPSDO with no GPS input.

Typical User Interface Output

By default, the GPSDO starts in logging mode 3 – output NMEA data. This suppresses almost all diagnostic output from the GPSDO. To switch from NMEA pass through to viewing all diagnostic data the user enters TAB 2, echoed on the display as >2

The following are actual logs with explanatory comments in italics.

Calibration output

Calibration logging starts in logging mode 2. The GPSDO has been running for about 30 minutes to allow the OCXO to warm up, then the GPSDO is rebooted

```
GPSDO Created 2023-01-08 <<< the date the program was created
Receiving serial data from GPS.
Satellites in view:
 12
GPS data is now valid.
Time Stamp: Date 080123 Time 022659 UTC.
No calibration data - starting calibration
 Ctrl 0.240001V Err=-12.937Hz over 8 secs. <<< testing at the control voltage limits
 Ctrl 3.760016V Err=15.219Hz over 8 secs.
 Ctrl 2.789657V Err=7.906Hz over 16 secs.  <<< the program changes the voltages
 Ctrl 1.027451V Err=-7.703Hz over 16 secs. <<< to get closer to 0.25Hz offset
 Ctrl 2.320443V Err=3.641Hz over 32 secs.
 Ctrl 1.449546V Err=-4.375Hz over 16 secs.
 Ctrl 1.680425V Err=-2.344Hz over 32 secs.
 Ctrl 2.118243V Err=1.750Hz over 64 secs.
 Ctrl 1.797401V Err=-1.270Hz over 64 secs.
 Ctrl 2.011988V Err=0.744Hz over 128 secs.
 Ctrl 1.852764V Err=-0.754Hz over 128 secs.
 Ctrl 1.879752V Err=-0.502Hz over 128 secs.
 Ctrl 1.959550V Err=0.247Hz over 256 secs.
 Ctrl 1.906594V Err=-0.249Hz over 256 secs.
Success!    <<< the values are close enough to 0.25Hz to be accepted for calculation

>t    <<< user input requesting a time stamp
Time Stamp: Date 080123 Time 024713 UTC. <<< about 20 minutes since starting

 Ctrl 1.959863V Err=0.246Hz over 256 secs.
Success!
 Ctrl 1.906489V Err=-0.255Hz over 256 secs.
Success!
 Ctrl 1.960279V Err=0.250Hz over 256 secs.
Success!
 Ctrl 1.907009V Err=-0.254Hz over 256 secs.
```

```
Success!
 Ctrl 1.960279V Err=0.247Hz over 256 secs.
Success!
 Ctrl 1.907424V Err=-0.250Hz over 256 secs.
Success!
 Ctrl 1.960591V Err=0.251Hz over 256 secs.
Success!
 Ctrl 1.907425V Err=-0.248Hz over 256 secs.
Success!
 Ctrl 1.960487V Err=0.249Hz over 256 secs.
Success!
 Ctrl 1.907216V Err=-0.254Hz over 256 secs.
Success!
 Ctrl 1.960590V Err=0.245Hz over 256 secs.
Success!
 Ctrl 1.907634V Err=-0.259Hz over 256 secs.
Success!
 Ctrl 1.961104V Err=0.241Hz over 256 secs.
Success!
 Ctrl 1.908574V Err=-0.253Hz over 256 secs. <<< not accepted for calculation
 Ctrl 1.962038V Err=0.251Hz over 256 secs.
Success!
 Ctrl 1.908885V Err=-0.250Hz over 256 secs.
Success!
 <<< system completes calibration, automatic reboot  with logging mode 3 >>>
GPSDO Created 2023-01-08
 Ctrl 1.934179V Sensitivity 0.1064 Volt/Hz
TH"#A###,035632.00,3254.99713,S,15144.88696,E,1,12,0.65,11.6,M,22.6,M,,*79
$GPGSA,A,3,02,15,29,18,23,26,08,10,24,32,27,16,1.13,0.65,0.93*05
$GPGSV,4,1,13,02,21,073,36,08,05,217,28,10,57,257,36,13,01,146,*7B
$GPGSV,4,2,13,15,25,134,34,16,16,270,25,18,57,109,41,23,64,176,31*7A
$GPGSV,4,3,13,24,14,082,21,26,08,305,21,27,35,229,37,29,16,024,29*70
$GPGSV,4,4,13,32,28,347,21*43
   :
   :   <<< many minutes of NMEA data >>>
   :
$GPGSV,3,3,09,32,64,340,25*43
$GPGLL,3254.99627,S,15144.89083,E,051000.00,A,A*7C
$GPRMC,051001.00,A,3254.99628,S,15144.89080,E,0.078,,080123,,,A*6F
$GPVTG,,T,,M,0.078,N,0.144,K,A*2D
$GPGGA,051001.00,3254.99628,S,15144.89080,E,1,08,0.98,21.0,M,22.6,M,,*78
$GPGSA,A,3,18,23,08,10,24,22,32,27,,,,,2.14,0.98,1.90*0F
$GPGSV,3,1,09,08,28,235,19,10,61,184,38,16,00,300,,18,36,064,33*76
$GPGSV,3,2,09,22,29,333,22,23,43,132,42,24,20,114,31,27,48,271,15*72
$GPGSV,3,3,09,32,64,340,24*42
$GPGLL,3254.99628,S,15144.89080,E,051001.00,A,A*71
$GPRMC,051002.00,A,3254.99629,S,15144.89093,E,0.104,,080123,,,A*65
$GPVTG,,T,,M,0.104,N,0.192,K,A*2C
$GPGGA,0510
>2  <<< user requests a change to logging mode 2
 01 01 01 00 00 01 01 01 00 00 01 01
00320 01 00 00 01 01 01 00 00 01 01 00 00 00 01 01 00
00336 00 00 01 01 00 00 01 01 01 00 00 00 01 01 00 00
00352 00 01 01 00 00 00 01 01 00 00 01 01 01 00 00 00
00368 01 01 01 00 00 01 01 01 00 00 00 00 00 01 00 00
00384 00 00 01 00 00 00 00 01 00 00 00 00 00 01 00 00
00400 00 01 01 01 00 00 00 01 01 01 00 00 01 01 01 01
00416 01 01 01 01 01 01 01 01 01 01 02 01 01 01 01 01
00432 02 01 01 01 01 01 02 02 01 01 01 02 02 02 02 01
00448 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
00464 02 02 02 02 02 02 02 02 02 02 02 02 02 02 03 02
00480 02 02 02 02 02 02 02 02 02 02 02 03 02 02 02 02
```

```
00496 02 03 02 02 02 02 02 02 03 02 02 02 02 02 02 03
 Time 051326 UTC. Ctrl 1.934370 -0.016 ppb
00000 02 02 02 02 02 03 03 02 02
>h Time 035813 UTC. Ctrl 1.936934 2.589 ppb <<< user requests history
 Time 040018 UTC. Ctrl 1.935687 -1.172 ppb
 Time 040850 UTC. Ctrl 1.935619 -0.064 ppb
 Time 041722 UTC. Ctrl 1.935607 -0.012 ppb
 Time 042554 UTC. Ctrl 1.935624 0.016 ppb
 Time 042802 UTC. Ctrl 1.933571 -1.929 ppb
 Time 043046 UTC. Ctrl 1.934324 0.708 ppb
 Time 043918 UTC. Ctrl 1.934362 0.036 ppb
 Time 044750 UTC. Ctrl 1.934291 -0.067 ppb
 Time 045622 UTC. Ctrl 1.934282 -0.009 ppb
 Time 050454 UTC. Ctrl 1.934387 0.099 ppb
 Time 051326 UTC. Ctrl 1.934370 -0.016 ppb
 02 02 02 02 02 02 02 02 02 02
00032 02 02 02 02 02
```

Cold start output

The logging mode was set previously to mode 2, this was written to non-volatile memory with the W command so it takes effect on subsequent starts.

```
GPSDO Created 2022-11-17 <<< the date the program was created
 Ctrl 1.927044V Sensitivity 0.1064 Volt/Hz
Receiving serial data from GPS.
Satellites in view:
 00 02 04 06 05 06 07 07 06 06 07 06 <<< GPS unit is acquiring satellites
 06 07 06 06 06 06 06 07 06 06 06 06
 07 07 06 07 06 07 07 07 07 07
GPS data is now valid.
Time Stamp: Date 080123 Time 013533 UTC.
[B410][01BC][019F][0182][0165][014B][0132][0119][0102][00ED][00D9][00C5][00B3]
[00A2][0092][0083] <<< the OCXO is nowhere near correct frequency
00000 76[00E6] <<< getting close, but cannot be captured
00000 63[00C1]00000 52[00A0]00000 43[0082]00000 36 68
 Time 013620 UTC. Ctrl 3.686080 1652.800 ppb <<< attempted lock
[0096] <<< lock failed
00000 14 36
 Time 013624 UTC. Ctrl 3.067591 1071.700 ppb <<< locked
00000 57 58 <<< this is the phase error in 25ns increments in hexadecimal
 <<< 57 hex is 87 decimal. Converting to 10MHz cycles the phase is 87/4 = 21.75 cycles
 Time 013626 UTC. Ctrl 3.388474 301.500 ppb
00000 4B 34
 Time 013628 UTC. Ctrl 2.911306 -448.400 ppb
00000 18 02
 Time 013630 UTC. Ctrl 2.296142 -578.000 ppb
00000 F0 E9 <<< the phase correction has overshot
 Time 013632 UTC. Ctrl 2.021812 -257.800 ppb
00000 E6 E9 <<< hex values 80 or greater are -ve
 Time 013634 UTC. Ctrl 2.030125 7.811 ppb
00000 ED EF
 Time 013636 UTC. Ctrl 2.030125 0.000 ppb
00000 F1 F1 F1 EF
 Time 013640 UTC. Ctrl 1.917068 -106.200 ppb
00000 ED ED
 Time 013642 UTC. Ctrl 1.853889 -59.400 ppb
00000 EF F1 F3 F6 F7 F9 FB FC FD FE FF 00 01 <<< almost stable
 Time 013655 UTC. Ctrl 1.885479 29.700 ppb
00000 02 02 01 01 01 00 00 00 00 00 00 00 FF 00 00 00
00016 00 00 01 01 02 01 02 03 03 04 05 06 06 07 08 08 <<< still not warmed up
 Time 013727 UTC. Ctrl 1.911169 24.100 ppb
00000 09 0A 0A 0A
```

```
 Time 013731 UTC. Ctrl 1.951902 38.300 ppb
00000 0A 09 08 06 05 03 02 01 00 FE
 Time 013741 UTC. Ctrl 1.912000 -37.500 ppb
00000 FD FD FD FE FE FE FF FF FF 00 00 01 01 02 03 03
00016 04 04 05 05 06 06 06 07
 Time 013805 UTC. Ctrl 1.931879 18.700 ppb
00000 08 08 08 08 07 07 07 07 07 07 07 06 06 06 06 06
00016 06 06 06 06 06 05 05 06 05 05 05 05 05 05 04 05
00032 05 04 04 04 04 04 04 04 04 03 04 03 03 04 03 04
00048 03 03 03 03 03 03 03 03 03 03 03 02 03 02 03 02
00064 02 02 02 02 02 02 02 02 02 02 02 02 02 01 02 01
00080 02 01 01 01 01 01 01 01 01 01 01 01 00 01 00 00
00096 01 00 00 00 00 00 00 00 FF
```
<<< about 5 minutes after the cold start >>>
```
 Time 013950 UTC. Ctrl 1.930268 -1.513 ppb
00000 00 00 FF 00 00 FF 00 00 FF 00 00 FF 00 00 FF 00
```
^^^ time since last control voltage change   ^^^ second by second phase error
```
00016 00 FF 00 00 00 00 00 00 00 00 00 00 FF 00 00 00
00032 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00048 00 00 00 00 00 00 00 00 01 00 00 00 00 01 01 00
00064 00 00 00 01 01 01 01 01 00 00 01 01 01 01 01 01
00080 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
00096 01 01 02 02 02 02 02 02 02 02 02 02 02 02 02 02
00112 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
00128 03 03 03 03 03 03 03 03 02 02 02 03 03 03 03 03
00144 03 03 03 03 03 03 03 03 03 03 03 03 03 04 04 04
00160 04 03 03 03 03 04 04 04 04 04 04 03 03 04 04 04
00176 04 04 04 03 03 04 04 04 04 04 04 04 04 04 04 04
 Time 014302 UTC. Ctrl 1.931701 1.346 ppb
00000 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 03
00016 04 04 04 03 04 04 04 04 04 04 04 04 04 04 04 04
00032 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 03
00048 04 04 04 04 04 04 03 04 04 04 04 04 04 04 04 04
00064 03 04 04 04 04 04 04 04 04 04 04 04 05 04 04 05
00080 04 04 05 04 04 05 04 05 05 04 05 05 05 05 05 05
00096 05 04 05 05 05 05 04 05 05 05 05 05 05 05 05 05
00112 05 05 05 05 05 06 05 05 05 05 06 05 05 06 05 06
 Time 014510 UTC. Ctrl 1.933434 1.628 ppb
00000 05 06 05 05 05 05 06 05 06 05 05 05 05 05 05 04
00016 05 04 05 04 05 05 04 05 04 05 04 05 04 04 04 04
00032 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 03
00048 04 03 04 03 04 03 04 03 04 03 04 03 03 03 03 03
00064 03 03 03 03 03 03 03 03 02 03 02 03 02 03 02 03
00080 02 03 02 03 02 02 02 02 02 02 02 02 02 02 02 02
00096 02 02 02 02 02 01 01 01 01 02 01 01 01 01 01 01
00112 01 01 01 01 01 01 01 01 00 01 00 01 00 00 00 00
00128 01 00 00 00 00 00 00 00 00 FF
 Time 014728 UTC. Ctrl 1.932421 -0.952 ppb
00000 00 00 00 00 00 00 FF 00 FF 00 FF 00 00 FF 00 FF
00016 00 FF 00 FF FF FF FF FF FF 00 FF 00 FF FF FF FF
00032 FF FF 00 FF FF FF FF FF FF FF FF FF FF FF FF FF
00048 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00064 FF FF FF FF FF FF FF FF FF FF FF FF FF FF 00 FF
00080 FF FF FF 00 FF FF 00 FF 00 FF FF 00 FF 00 FF FF
00096 00 FF FF FF FF 00 FF FF FF FF FF FF FF FF FF FF
00112 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00128 FF FF 00 FF FF FF FF FF FF FF FF FF FF FF FF FF
00144 00 FF FF FF FF FF FF FF FF FF FF FF FF FF 00 FF
```
<<< about 15 minutes after starting. The GPSDO is running within specification >>>
```
00160 FF 00 FF FF 00 FF FF 00 00 FF 00 00 FF 00 00 FF
00176 00 FF FF 00 FF FF 00 FF 00 00 FF 00 00 FF FF 00
00192 FF FF 00 FF FF 00 FF FF 00 FF FF 00 00 FF 00 00
```

```
00208 FF 00 00 FF 00 00 FF 00 00 FF 00 00 FF 00 00 FF
00224 FF 00 FF FF 00 00 FF 00 00 FF 00 00 FF 00 00 00
00240 00 00 00 FF 00 00 00 00 00 00 FF 00 00 00 00 00
00256 00 00 00 00 00 00 00 00 00 00 00 00 01 00
>i     <<< user inquiry.
GPSDO Created 2022-11-17 Max. period: 512 secs.
00272 00 00 00 01 00 00 00 00 00 00 00 00 00 01 00 00
00288 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00
00304 00 01 01 00 00 01 01 00 01 01 00 00 01 01 00 01
00320 01 01 00 01 01 00 01 01 01 01 01 01 00 01 01 01
00336 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
00352 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 02
00368 01 01 01 02 01 01 01 02 02 01 01 02 02 01 01 01
00384 02 02 01 02 02 02 01 02 02 02 01 02 02 02 01 02
00400 02 02 01 02 02 02 01 02 02 02 01 02 02 02 02 02
00416 02 02 02 02 02 02 02 02 02 02 02 03 02 02 02 03
00432 03 02 02 03 03 02 02 03 03 02 03 03 03 02 03 03
00448 03 03 03 03 03 03 03 03 03 03 03 03 03 03 03 03
00464 03 03 03 04 03 03 03 04 03 03 03 04 03 03 03 04
00480 04 03 03 04 04 04 03 04 04 04 04 04 04 04 04 04
00496 04 04 04 04 04 04 04 04 04 04 04 04 04 05 05 04
 Time 015600 UTC. Ctrl 1.933254 0.783 ppb
00000 04 04 05 05 04 04 04 05 04 04 04 04 05 05 04 04
00016 04 05 05 04 04 04 05 04 04 04 04 05 04 04 04 04
00032 04 04 04 04 04 04 04 04 04 04 04 04 04 04 03 04
00048 04 04 04 04 03 04 04 04 04 03 03 04 04 04 03 03
00064 04 04 04 04 03 03 04 04 04 03 03 04 04 04 03 03
00080 03 04 04 04 03 03 04 04 04 03 03 04 04 04 03 03
00096 03 04 04 04 03 03 04 04 04 03 03 04 04 04 03 03
00112 04 04 04 03 03 04 04 04 04 03 03 04 04 04 03 03
00128 04 04 04 04 03 03 04 04 04 03 03 04 04 04 04 03
00144 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04
00160 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04
00176 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04
 Time 015912 UTC. Ctrl 1.933959 0.663 ppb
00000 03 03 04 04 03 03 03 03 03 04 03 03 03 03 03 03
00016 03 03 03 03 03 03 03 03 03 03 02 03 03 03 03 03
00032 03 02 02 03 03 03 03 02 02 02 03 03 03 02 02 02
00048 02 02 03 03 02 02 02 02 02 02 02 02 02 02 02 02
00064 02 02 02 02 02 02 02 01 01 01 02 02 02 01 01 01
00080 01 01 02 01 01 01 01 01 01 01 01 01 01 01 01 01
00096 00 01 01 01 01 01 01 00 00 01 01 01 01 00 00 00
00112 00 01 01 01 00 00 00 00 01 01 01 00 00 00 00 01
00128 01 00 00 00 00 00 00 00 00 00 00 00 FF
 Time 020133 UTC. Ctrl 1.933154 -0.757 ppb
00000 FF FF 00 00 00 FF FF FF FF FF 00 00 FF FF FF FF
00016 FF 00 00 FF FF FF FF FF FF FF FF FF FF FF FF FF
00032 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00048 FF FF FF FF FF FF FF FF FF FF 00 FF FF FF FF FF
00064 FF 00 00 00 FF FF FF 00 00 00 00 00 FF FF FF 00
00080 00 00 00 00 FF FF FF 00 00 00 00 00 FF FF FF 00
00096 00 00 00 00 00 FF 00 00 00 00 00 00 00 00 00 00
00112 00 00 00 00 00 00 01 00 00 00 00 00 00 01 01 00

>0  <<< user suppresses all diagnostic output, then makes several inquiries.

>t
Time Stamp: Date 080123 Time 020350 UTC.


>h Time 013620 UTC. Ctrl 3.686080 1652.800 ppb
 Time 013624 UTC. Ctrl 3.067591 1071.700 ppb
```

```
Time 013626 UTC. Ctrl 3.388474 301.500 ppb
Time 013628 UTC. Ctrl 2.911306 -448.400 ppb
Time 013630 UTC. Ctrl 2.296142 -578.000 ppb
Time 013632 UTC. Ctrl 2.021812 -257.800 ppb
Time 013634 UTC. Ctrl 2.030125 7.811 ppb
Time 013636 UTC. Ctrl 2.030125 0.000 ppb
Time 013640 UTC. Ctrl 1.917068 -106.200 ppb
Time 013642 UTC. Ctrl 1.853889 -59.400 ppb
Time 013655 UTC. Ctrl 1.885479 29.700 ppb
Time 013727 UTC. Ctrl 1.911169 24.100 ppb
Time 013731 UTC. Ctrl 1.951902 38.300 ppb
Time 013741 UTC. Ctrl 1.912000 -37.500 ppb
Time 013805 UTC. Ctrl 1.931879 18.700 ppb
Time 013950 UTC. Ctrl 1.930268 -1.513 ppb
Time 014302 UTC. Ctrl 1.931701 1.346 ppb
Time 014510 UTC. Ctrl 1.933434 1.628 ppb
Time 014728 UTC. Ctrl 1.932421 -0.952 ppb
Time 015600 UTC. Ctrl 1.933254 0.783 ppb
Time 015912 UTC. Ctrl 1.933959 0.663 ppb
Time 020133 UTC. Ctrl 1.933154 -0.757 ppb

>s
Up 1682 secs. Lost Fix:0 No 1ppS:0 Rejected:0
```