

# **HD CSAC Low Power GPSDO User Manual**

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# **HD CSAC Low Power User Manual**

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# 1 Introduction

## 1.1 Overview

The HD CSAC Low Power GPSDO is a game-changing, disruptive technology culminating from decades of research sponsored by the U.S. Government. It is a breakthrough technology that allows a Cesium Vapor Cell Atomic Reference Oscillator to be packaged in a unit several orders of magnitudes smaller than legacy products, with more than an order of magnitude in power reduction, and less than 2 minutes warm-up to be fully operational, while out-performing many industry-standard Atomic Oscillators. The HD CSAC Low Power GPSDO consumes as little as 450mW using a 5V power supply. The unit is available with a temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  and greater than 100,000 hours MTBF, and provides a socket for the CSAC Oscillator for easy upgrade or exchange of the CSAC Oscillator.

The HD CSAC Low Power GPSDO oscillator provides very high frequency accuracy, long-term stability, and fast lock with low power consumption. Through hardware and firmware support the Jackson Labs Technologies, Inc. HD CSAC Low Power GPSDO is based on the Jackson Labs Technologies, Inc. HD CSAC platform, but optimizes size, weight, and power (SWAP) by using new ultra-low-loss power supplies, a new processor architecture, and updated firmware. The HD CSAC Low Power GPSDO provides one RS-232 serial port and one TTL serial port for command and control, and operates from a +5V power supply. It includes one 3.3V CMOS and one LVDS 10MHz output, one LVDS 1PPS, and one 3.3V CMOS 1PPS output. It is function compatible to the FireFly-IIA board, and shares a similar IO connector while drastically reducing power consumption and improving performance. The HD CSAC Low Power GPSDO supports a mobile-mode GPS receiver with 50 channels and SBAS (WAAS/EGNOS/MSAS) support.

For long term Stratum-1 frequency accuracy and constant calibration the HD CSAC Low Power GPSDO includes an extremely high-performance GPS receiver that can acquire and track up to 50 GPS signals down to a state of the art  $-160\text{dBm}$ , a very low-power Cortex 32-bit processor that runs a Real Time OS, one 10MHz CMOS output, one 10MHz LVDS output, one 1PPS UTC synchronized LVDS and one CMOS 1PPS output, an RS-232 control interface, and one serial TTL port for simultaneous output of NMEA/SCPI data on the two serial ports. The HD CSAC Low Power GPSDO also includes a high-performance hardware time-interval-counter that can measure the internally generated 1PPS signal from the GPS receiver or an externally supplied 1PPS reference signal with a resolution of 20 picoseconds. The CSAC oscillator is phase-locked to either of these two 1PPS signals with better than 0.3ns average phase accuracy typically and uses a proprietary Jackson Labs Technologies, Inc. loop algorithm. Software compensation measures residual aging errors of the CSAC oscillator, and applies electronic compensation to reduce these residual errors.

This error compensation can improve performance especially in GPS-denied environments, and allows monitoring of the CSAC health and detection of performance abnormalities in the system.

Generic NMEA and SCPI (GPIB) commands on the serial interfaces allow for very fast integration into legacy applications, and by using the NMEA serial strings the unit can behave like a standard GPS receiver albeit with better than 1 meter horizontal accuracy typically, and full WAAS/EGNOS/MSAS SBAS support. The unit can be set up to stream NMEA or other data to either one of the serial interfaces, which leaves the other serial interface free to be used as a SCPI control or query command port.

## 1.2 Operating Principles

A Cesium Vapor Cell is excited from a VCEL Laser source. The VCSEL is modulated at 4.6 GHz to produce a complementary pair of sidebands separated by the cesium ground state hyperfine frequency of 9.2 GHz. As Cesium supply depletion is not a lifetime limiting factor in the HD CSAC, the HD CSAC Low Power implementation allows operational lifetimes that potentially exceed those of Cesium beam standards by far.

The Hyperfine transition frequency of the Cesium Vapor cell is affected by adverse environmental influences, and long-term frequency and phase errors are thus present in the HD CSAC Low Power GPSDO. To calibrate these errors out and achieve phase-lock to USNO UTC, the HD CSAC Low Power GPSDO uses a GPS receiver to generate a highly accurate, though unstable 1PPS signal, and this 1PPS signal is compared with a 1PPS signal generated by the CSAC 10MHz VCXO. The VCEL is digitally tuned to shift the frequency up or down slightly and very slowly to keep the CSAC 1PPS reference in phase-lock with the GPS generated 1PPS signal. This allows a very close tracking of the U.S. USNO UTC 1PPS signal to within tens of nanoseconds anywhere in the world, out-performing even the best free-running Atomic References in the long run. With this software PLL system the short-term instability of the GPS receiver is filtered by the HD CSAC Low Power GPSDO, while the CSAC's long-term drift is removed by the GPS receiver, resulting in both a very good short-term as well as USNO phase-locked long-term performance. The HD CSAC Low Power GPSDO uses a Jackson Labs Technologies, Inc. designed loop algorithm and capture hardware that far outperforms the Microsemi/Symmetricon CSAC internal factory loop algorithm and time-capture hardware, and at the same time provides better control of the loop parameters for fine-tuning to different application scenarios by the user.

## 1.3 General Safety Precautions

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design manufacture, and intended use of the instrument. Jackson Labs Technologies, Inc. assumes no liability for the customer's failure to comply with these requirements.

### 1.3.1 Use an approved Antenna Lightning Protector

The use of an approved, and properly grounded antenna lightning protector on the GPS antenna is required to prevent damage, injury or death in case of a lightning strike.



### **1.3.2 Grounding**

To avoid damaging the sensitive electronic components in the HD CSAC Low Power GPSDO always make sure to discharge any built-up electrostatic charge to a good ground source, such as power supply ground. This should be done before handling the circuit board or anything connected to it, i.e. the GPS antenna.

### **1.3.3 Power Connections**

Make sure to connect the DC power to the device following the polarity indicated in Section [2.3](#).

### **1.3.4 Environmental Conditions**

This instrument is intended for indoor use. The use of a properly installed GPS Antenna Lightning Protector is required. It is designed to operate at a maximum relative non-condensing humidity of 95% and at altitudes of up to 50,000 meters. Refer to the specifications tables for the dc and ac mains voltage requirements and ambient operating temperature range.



# 2 Quick-Start Instructions

## 2.1 Powering Up the Unit

The HD CSAC Low Power GPSDO is powered from an external 4.85V to 5.15V (5V nominal) 0.15A DC source. The typical steady-state power consumption of the unit is 112mA at 5V (0.56W) with GPS reception, and 0.45W with the GPS receiver in deep-sleep mode (CSAC holdover/flywheel mode).

Please note that the GPS receiver power supply is under user control. This allows the user to disable the GPS receiver for additional power savings when running in CSAC holdover (flywheel) mode without GPS. In order to disable the GPS receiver and its power supply as well as the GPS antenna 3.3V power output the unit will need to be set into external 1PPS locking mode with the following SCPI serial command:

```
SYNC:SOUR:MODE EXT
```

Sending this command once will turn off the units' GPS power supply, and put the unit into external 1PPS locking mode. The user does not need to supply an external 1PPS pulse and can leave the 1PPS input un-connected, but if supplied the unit will now lock to the external 1PPS reference on pin 11 of connector J1.

To turn the power supply for the GPS receiver and the GPS antenna back on please send the following command on one of the two serial interfaces:

```
SYNC:SOUR:MODE GPS
```

The GPS receiver will now be powered up again. The GPS receiver is powered-on by default when the unit is shipped from the factory.

These two commands are stored in NVRAM on the board, and the user thus only needs to send them once to the unit. Power consumption is reduced by about 100mW or more when the GPS receiver is turned-off, representing an almost 20% overall power savings when in CSAC holdover mode.

## 2.2 Operating the unit from the RS-232 port

- 1) Connect a 3.3V-compatible GPS antenna to connector J4.
- 2) Plug in a clean DC power source of +5V to the power pin 16 of connector J1.

**PLEASE NOTE THE POWER PINOUT OF THE LOW POWER HD CSAC UNIT HAS BEEN CHANGED FROM THE LEGACY 12V HD CSAC UNIT TO PREVENT DAMAGE TO THE BOARD WHEN INADVERTENTLY PLUGGING-IN A LEGACY 12V POWER SUPPLY INTO THE 5V HD CSAC LOW POWER GPSDO.**

Plug in the Ground connection to pins 14 and 15 of connector J1. RS-232 Serial TX and RX signals are available on pins 9 and 8 respectively of connector J1.

**DO NOT SUPPLY THE BOARD WITH A VOLTAGE OTHER THAN THE RATED 5V OPERATING VOLTAGE; USING A 12V POWER SUPPLY WILL SEVERELY DAMAGE THE BOARD AND VOID THE WARRANTY.**

Once serial communications have been established, the user can try sending, and experimenting with the following useful SCPI commands:

```
syst:stat?
gps?
sync?
diag?
meas?
csac?
help?
```

The third-party application GPSCon is recommended for monitoring and controlling the unit via the RS-232 serial port. This software is available at:

<http://www.realhamradio.com/gpscon-info.htm>

JLT also provides a freeware control program called Z38xx and this application program can be downloaded from the following website:

[www.jackson-labs.com/index.php/support](http://www.jackson-labs.com/index.php/support)

Z38xx provides real-time monitoring of the operation of the GPSDO, including status information, GPS satellite information, timing and control information, holdover prediction, reference Allan Variance and even a UTC clock with second accuracy. It also displays various logs, and stores all measurements on file for later analysis.

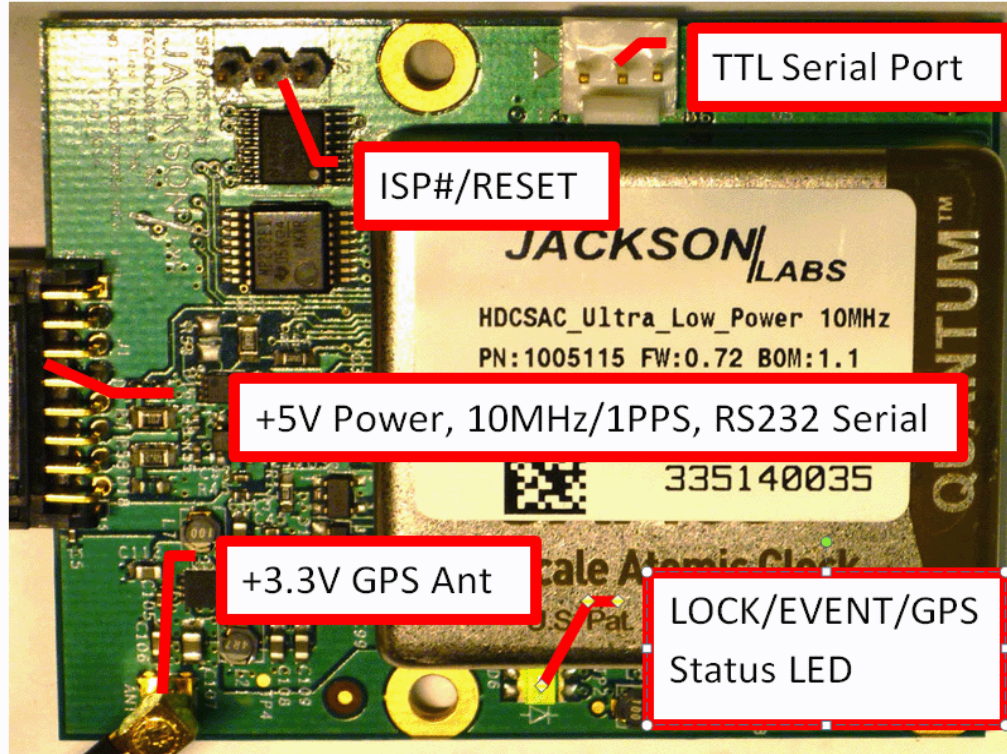
The unit will now lock to GPS (Red LED is blinking when satellites are being received) and will indicate proper lock when the Green LED goes on. Once the green LED is on, the unit will output 10MHz with significantly better than 1ppb frequency accuracy.

Please note that the GPS receiver establishes the internal antenna-gain right after power-on, so for proper operation the GPS antenna should always be connected prior to turning on the power supply.

## 2.3 Major connections

The major connections and features of the HD CSAC Low Power GPSDO PCB are shown in [Figure 2.1](#).

**Figure 2.1 Major connections and features of the HD CSAC Low Power GPSDO**



[Table 2.1](#) shows the functions supported on connector J1

**Table 2.1 Connector J1 pinout**

Ref	Name	Function	Specification
J1-1	+10MHz LVDS Output	10MHz differential output	+10MHz LVDS, +/-300mV, terminate to -10MHz LVDS through 100 Ohms resistor
J1-2	-10MHz LVDS Output	10MHz differential output	-10MHz LVDS, +/-300mV, terminate to +10MHz LVDS through 100 Ohms resistor
J1-4	-1PPS LVDS Output	1PPS differential output	-1PPS LVDS, +/-300mV, terminate to +1PPS LVDS through 100 Ohms resistor
J1-5	+1PPS LVDS Output	1PPS differential output	+1PPS LVDS, +/-300mV, terminate to -1PPS LVDS through 100 Ohms resistor

J1-7	LOCK_OK_OUT	Indicates that no internal events are pending, the hardware is ok, and the HD CSAC is locked to GPS.	3.3V CMOS output can drive up to 5mA, series-terminated by 33 Ohms
J1-8	RX_232	RS-232 receive data	RS-232 level
J1-9	TX_232	RS-232 transmit data	RS-232 level
J1-10	1PPS_CMOS	1PPS output in 3.3V CMOS level format. Do not terminate, use 1M or higher input impedance.	CMOS/TTL compatible 1PPS output, series-terminated by 50Ohms. <1ns rise and fall time. Do not end-terminate signal.
J1-11	PPS_IN	External alternate 1PPS input	TTL, 3.3V and 5V CMOS compatible
J1-13	10MHz Output	CMOS 10MHz output. Do not terminate, use 1M or higher input impedance.	3.3V CMOS level can drive up to 15mA, series-terminated by 50Ohms. <1ns rise and fall time. Keep wires shorter than 2 inches on this signal.

### 2.3.1 Harness Pinning

Table 2.2 is a table of the cable harness J1 pinout.

**Table 2.2 J1 pinout**

PIN	NAME
1	+10MHz LVDS
2	-10MHz LVDS
3	GND
4	-1PPS LVDS
5	+1PPS LVDS
6	GND
7	LOCK_OUT_OK
8	RX RS-232
9	TX RS-232
10	1PPS_CMOS
11	PPS_IN

12	GND
13	10MHz CMOS
14	GND
15	GND
16	+5V

**Table 2.3 Miscellaneous connectors**

Ref	Name	Function	Specification	Pinning
J2	ISP/RESET	ISP/RESET jumper	GND pin 1 or 3 to activate	J2-1:ISP; J2-2:GND; J2-3:RST#
J4	Antenna	GPS Antenna	3.3V Amplified Antenna, MMCX connector	Center:RF Input; Shield: GND
J5-1	RXD-TTL	TTL Serial Input into the board	3.3V or 5V CMOS or TTL level	J5-1 Input into HD CSAC board
J5-2	GND	serial port ground	GND	J5-2 GND
J5-3	TXD-TTL	TTL Serial Output from the board	3.3V CMOS output	J5-3 Output from HD CSAC board

## 2.3.2 Harness Connectors J1, and J5

The manufacturer for connector J1 is Hirose. A mating housing part number for this connector is available from Digikey, and crimp pins are also available from Digikey for different wire sizes:

<http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=H2025-ND>

The part number of the connectors soldered onto the HD CSAC Low Power PCB is:

Hirose PN: DF11-16DP-2DS52

The manufacturer for the TTL serial port connector J5 is Molex, and the connector J5 has Molex PN: 22-11-2032.

## 2.3.3 Connecting the GPS Antenna

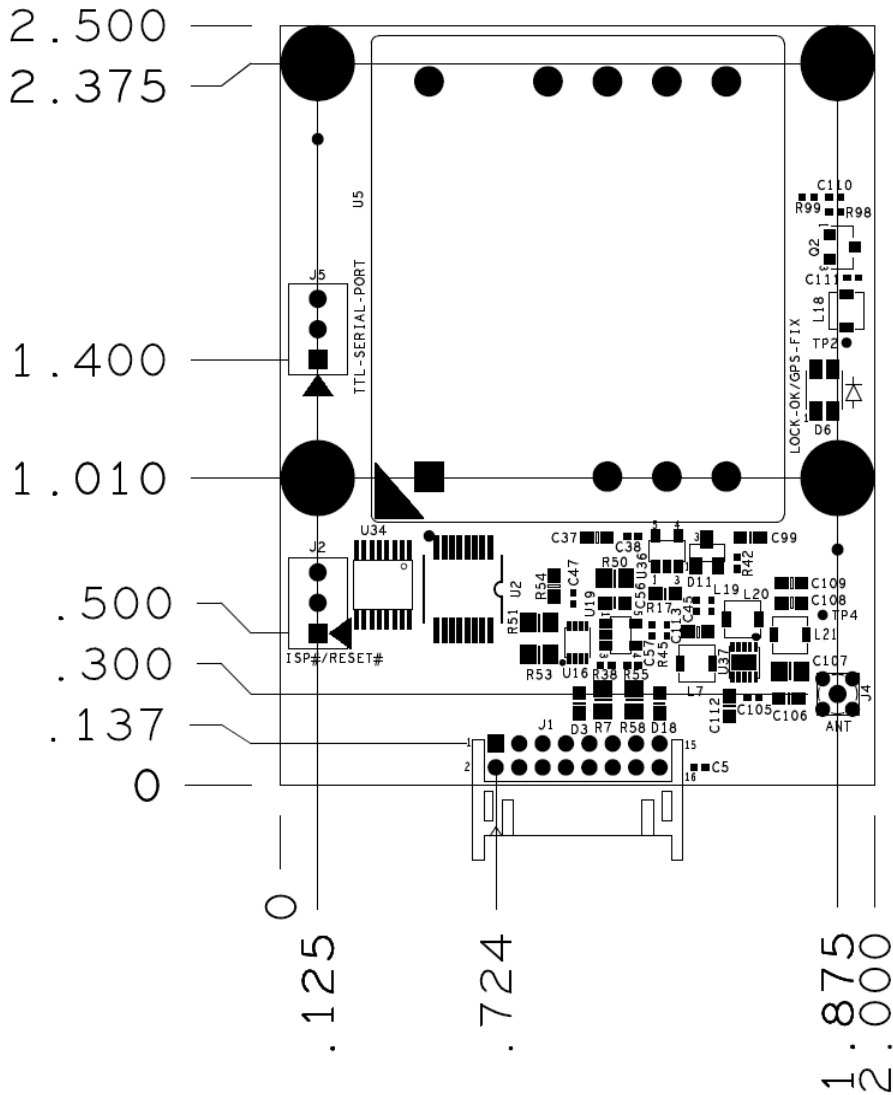
Connect the GPS antenna to connector J4 using the BNC to MMCX cable adapter. Caution: use a Lightning Arrestor on your Antenna setup. Use an amplified GPS antenna that is 3.3V LNA compatible. The HD CSAC Low Power GPS receiver is a 50 channel high-sensitivity GPS receiver with very fast lock time.

The HD CSAC Low Power is capable of generating standard navigation messages (see GPS:GPGGA, GPS:GPZDA, GPS:GPGSV, GPS:PASHR, and GPS:GPRMC serial commands) that are compatible with most GPS based navigation software.

The GPS receiver generates a 1PPS time signal that is phase synchronized to UTC. This 1PPS signal is used to frequency-lock the 10MHz Sine-Wave output of the HD CSAC Low Power GPSDO to UTC, thus disciplining the unit's Atomic Clock 10MHz frequency output to the US Naval master clock for very high frequency accuracy (typically better than 10 digits of frequency accuracy when locked to GPS). Using a high-performance Timing GPS receiver allows operation with a phase stability error of typically less than +/-15 nanoseconds anywhere in the world.

## 2.4 Mechanical Drawing

Figure 2.2 HD CSAC Low Power GPSDO Mechanical Drawing





## 2.5 Loop parameter adjustment

All loop parameters can be controlled via the serial ports.

Loop parameters are optimized for the Atomic Oscillator on the board, and changing the factory settings may cause the unit's performance to deteriorate.

The commands to control the loop parameters are part of the servo? command. See also the **SERVO Subsystem** section below.

The individual commands are:

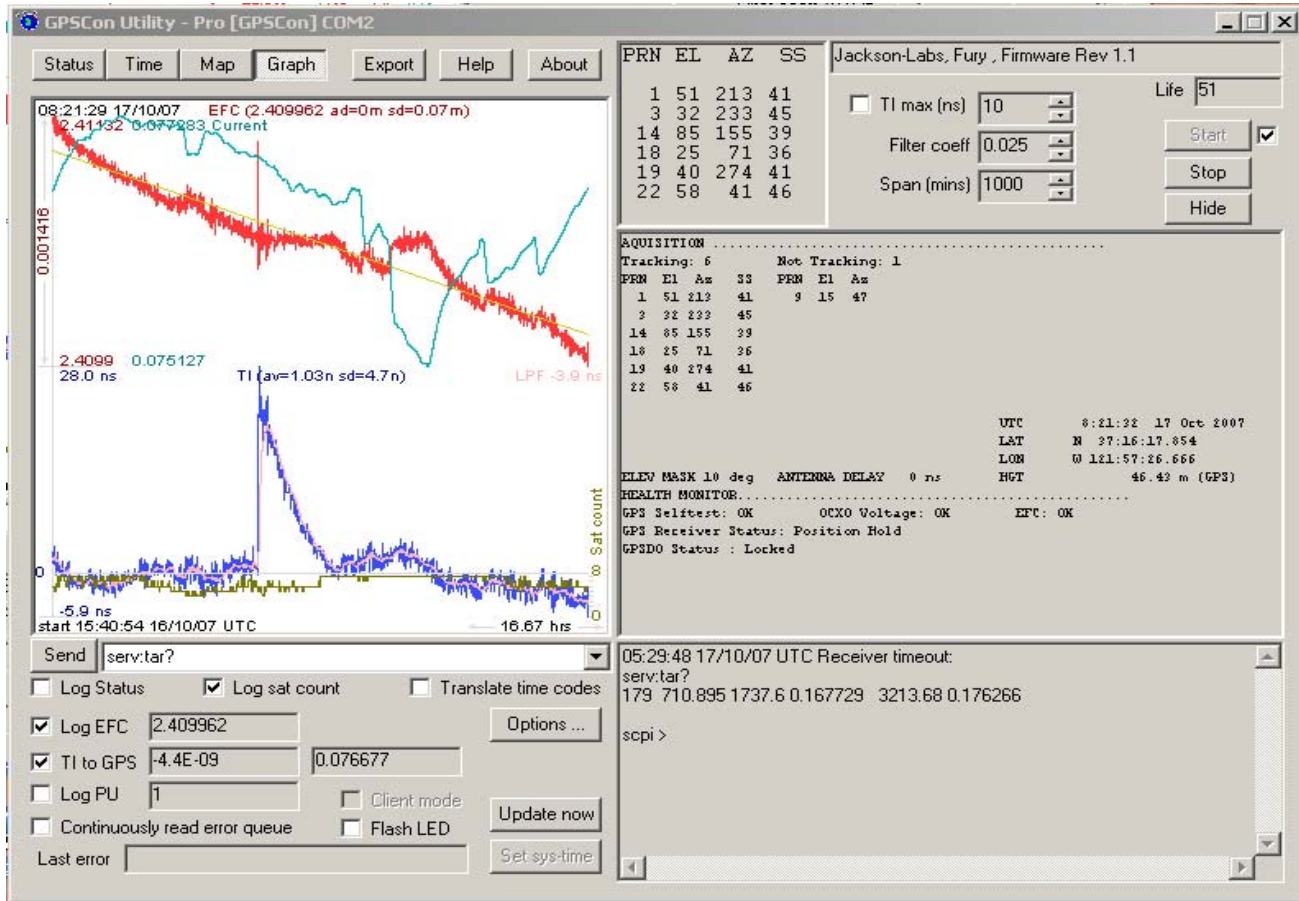
**EFC Scale:** this is the proportional gain of the PID loop. Higher values will give quicker convergence, and faster locking of the GPS time (lower loop time constant), lower values give less noise. Values between 0.7 and 6.0 are typical.

**EFC Damping:** overall IIR filter time constant. higher values increase loop time constant. Jackson Labs Technologies, Inc. typically uses values between 10 to 50. Setting this value too high may cause loop instability.

**Phase compensation:** this is the Integral part of the PID loop. This corrects phase offsets between the HD CSAC Low Power GPSDO 1PPS signal and the UTC 1PPS signal as generated by the GPS receiver. Set higher values for tighter phase-following at the expense of frequency stability. Typical values range from 1- 30. Setting this value too high may cause loop instability.

A well-compensated unit will show performance similar to the plot in [Figure 2.3](#) when experiencing small perturbations.

**Figure 2.3 HD CSAC Low Power phase compensation plot**



## 2.6 Performance graphs

Figure 2.4 shows the typical Allan Deviation of the HD CSAC Low Power unit when locked to GPS. ADEV performance approaches 1E-013 per day when locked to GPS. The plot shows that at averaging intervals of 1000 seconds and more the GPS disciplining algorithm starts to improve the performance of the CSAC oscillator.

Figure 2.4 Typical Allan Deviation of HD CSAC Low Power GPSDO locked to GPS

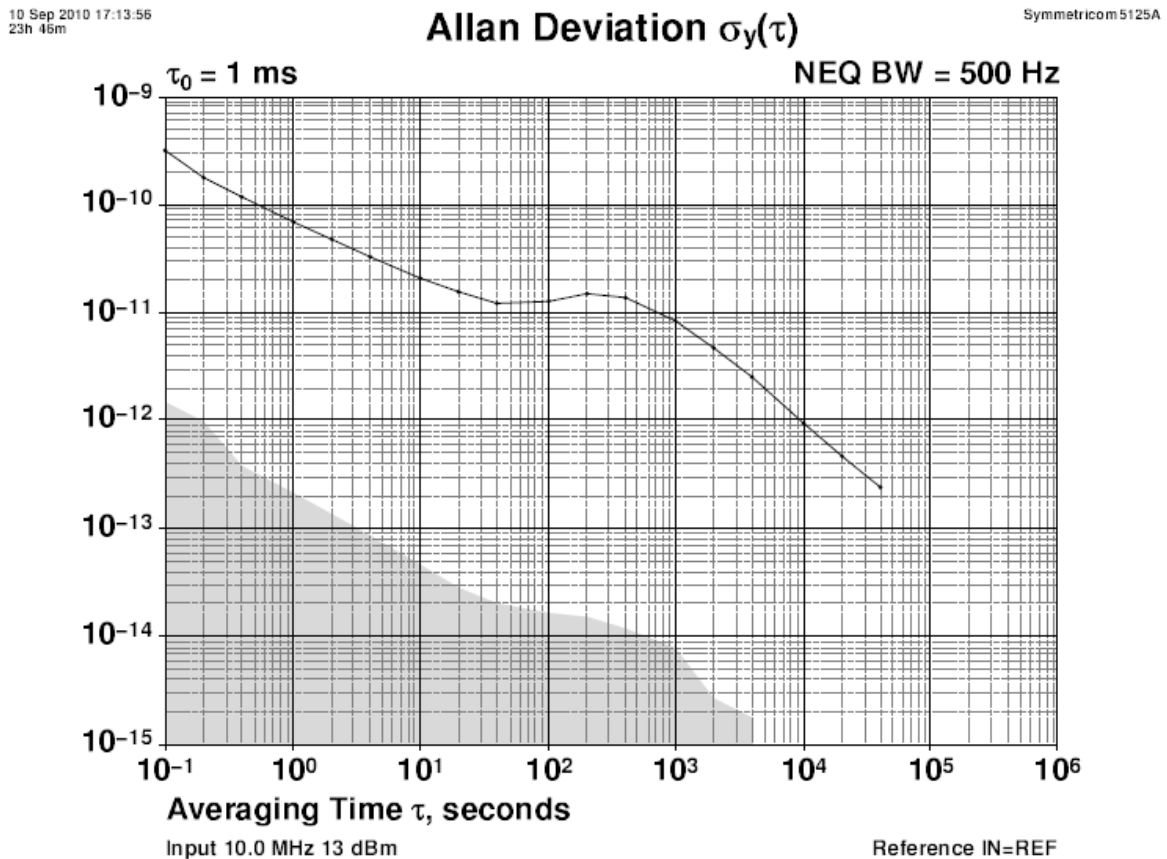
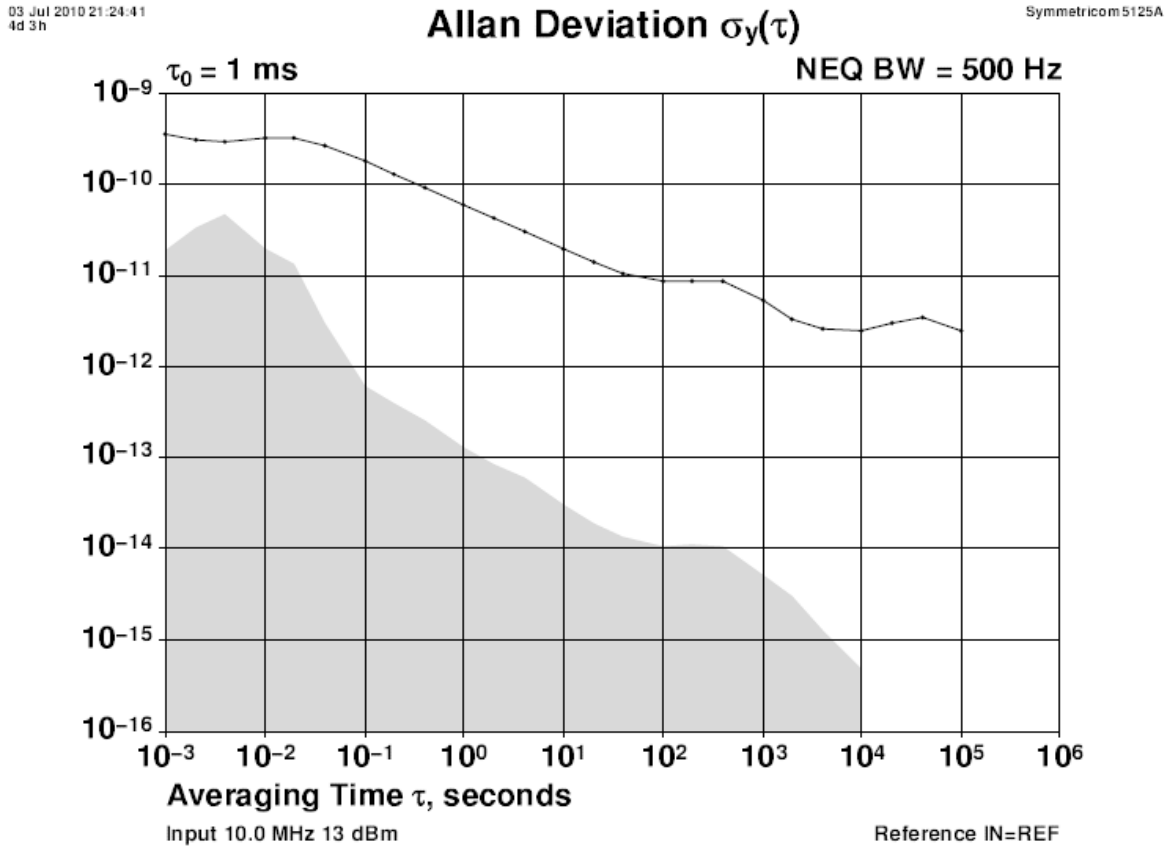


Figure 2.5 shows that the Allan Deviation of the free running unit (GPS holdover, no GPS antenna is attached) is quite good, approaching 5E-012 over 100,000 seconds in this typical plot.

Figure 2.5 Typical Allan Deviation of free running HD CSAC Low Power GPSDO



# 3 SCPI-Control Quick Start Instructions

## 3.1 Introduction

The HD CSAC Low Power GPSDO has two serial ports that can be used for accessing the SCPI (Standard Commands for Programmable Instrumentation) subsystem by using a host system terminal program such as TeraTerm or Hyperterminal. These ports operate simultaneously to each other, and can be set up to have pushed NMEA and other output sentences sent to either power, while the other port can be used for independent query and control commands. One port on connector J1 uses RS-232 levels, and the second port on connector J5 uses TTL levels only. By default the terminal settings are 115200, 8N1. The serial interface can send out standard NMEA messages, while simultaneously accepting SCPI commands from the user.

There are a number of commands that can be used as listed below. Most of these are identical or similar to Symmetricom 58503A commands. To get a listing of the available commands, send the HELP? query. This will return a list of all the available commands for the HD CSAC Low Power GPSDO.

Additional information regarding the SCPI protocol syntax can be found on the following web site:  
<http://www.scpiconsortium.org>

Please refer to the document SCPI-99.pdf for details regarding individual SCPI command definitions. A basic familiarity with the SCPI protocol is recommended when reading this chapter.

As a Quick-Start, the user may want to try sending the following commands to one of the serial interfaces:help?

**syst:stat?**

**help?**

**gps?**

**sync?**

**diag**

## 3.2 General SCPI Commands

### 3.2.1 \*IDN?

This query outputs an identifying string. The response will show the following information:  
 <company name>, <model number>, <serial number>, <firmware revision>

### 3.2.2 HELP?

This query returns a list of the commands available for the HD CSAC Low Power GPSDO.

## 3.3 GPS Subsystem

*Note: Please note that HD CSAC Low Power displays antenna height in MSL Meters rather than in GPS Meters on all commands that return antenna height [the legacy Fury GPSDO uses GPS height]. The NMEA position fixes are in the WGS84 coordinate system, while the X,Y, and Z velocity vectors are given in the ECEF coordinate system.*

The GPS subsystem regroups all the commands related to the control and status of the GPS receiver. The list of the commands supported is the following:

```

GPS:SATellite:TRACKing:COUNT?
GPS:SATellite:VISible:COUNT?
GPS:PORT <RS232 | USB>
GPS:PORT?
GPS:GPGGA <int> [0,255]
GPS:GGASTat <int> [0,255]
GPS:GPRMC <int> [0,255]
GPS:GPZDA<int> [0,255]
GPS:GPGSV<int> [0,255]
GPS:PASHR<int> [0,255]
GPS:XYZSPeed
GPS:DYNAMic:MODE <int> [0,7]
GPS:DYNAMic:MODE 8 (Automatic Dynamic Mode)
GPS:DYNAMic:MODE?
GPS:DYNAMic:STATe?
GPS:REFerence:ADELay <float> <s | ns > [-32767ns,32767ns]
GPS:REFerence:PULse:SAWtooth?
GPS:RESET ONCE
GPS:TMODE <ON | OFF | RSTSURV>
GPS:SURVey ONCE
GPS:SURVey:DURation <sec>

```

GPS:SURVey:VARiance <mm^2>  
 GPS:HOLD:POSition <cm, cm, cm>  
 GPS:SURVey:STATus?  
 GPS:INITial:DATE <yyyy,mm,dd>  
 GPS:INITial:TIME <hour,min,sec>  
 GPS:JAMlevel?  
 GPS:FWver?  
 GPS?

### 3.3.1 GPS:SATellite:TRAcking:COUnT?

This query returns the number of satellites being tracked.

### 3.3.2 GPS:SATellite:VISible:COUnT?

This query returns the number of satellites (PRN) that the almanac predicts should be visible, given date, time, and position.

### 3.3.3 NMEA Support

The following four commands allow the HD CSAC Low Power to be used as an industry standard navigation GPS receiver. The GPGGA, GPGSV, GPRMC, PASHR and GPZDA NMEA commands comprise all necessary information about the antenna position, height, velocity, direction, satellite info, fix info, time, date and other information that can be used by standard navigation applications via the HD CSAC Low Power RS-232 interface.

Once enabled, HD CSAC Low Power will send out information on the RS-232 transmit pin automatically every N seconds. All incoming RS-232 commands are still recognized by HD CSAC Low Power since the RS-232 interface transmit and receive lines are completely independent of one another.

Please note that the position, direction, and speed data is delayed by one second from when the GPS receiver internally reported these to the HD CSAC Low Power Microprocessor, so the position is valid for the 1PPS pulse previous to the last 1PPS pulse at the time the data is sent (one second delay). The time and date are properly output with correct UTC synchronization to the 1PPS pulse immediately prior to the data being sent.

Once set, the following two commands will be stored in NV memory, and generate output information even after power to the unit has been cycled.

### 3.3.4 GPS:PORT <RS232 | USB>

This command is not supported in the HD CSAC.

### 3.3.5 GPS:PORT?

This command is not supported in the HD CSAC.

### 3.3.6 GPS:GPGGA

This command instructs the HD CSAC Low Power to send the NMEA standard string \$GPGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute HD CSAC warm-up phase.

This command has the following format:

```
GPS:GPGGA <int> [0,255]
```

GPGGA shows height in MSL Meters, this is different from traditional GPS receivers that display height in GPS Meters. The difference between MSL and GPS height can be significant, 35m or more are common.

### 3.3.7 GPS:GGASTat

This command instructs the HD CSAC Low Power to send a modified version of the NMEA standard string \$GPGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute HD CSAC warm-up phase.

This command has the following format:

```
GPS:GGASTat <int> [0,255]
```

This command replaces the regular NMEA GGA validity flag with a decimal number indicating the lock-state of the unit. Please see section SERVO:TRACe for a detailed description of the lock state variable. The command allows capture of the position and other information available in the GGA command, as well as tracking the lock state and health of the unit's HD CSAC performance.

GGASTat shows height in MSL Meters, this is different from traditional GPS receivers that display height in GPS Meters. The difference between MSL and GPS height can be significant, 35m or more are common.

### 3.3.8 GPS:GPRMC

This command instructs the HD CSAC Low Power to send the NMEA standard string \$GPRMC every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute HD CSAC warm-up phase.

This command has the following format:

```
GPS:GPRMC <int> [0,255]
```

### 3.3.9 GPS:GPZDA

This command instructs the HD CSAC Low Power to send the NMEA standard string \$GPZDA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute HD CSAC warm-up phase.

This command has the following format:

```
GPS:GPZDA <int> [0,255]
```



### 3.3.10 GPS:GPGSV

This command instructs the HD CSAC Low Power to send the NMEA standard string \$GPGSV every N seconds, with N in the interval [0,255]. The command is disabled until the GPS receiver achieves a first fix.

```
GPS:GPGSV <int> [0,255]
```

### 3.3.11 GPS:PASHR

The PASHR command alongside the GPZDA command will give all relevant parameters such as time, date, position, velocity, direction, altitude, quality of fix, and more. As an example, the String has the following data format:

```
$PASHR,POS,0,7,202939.00,3716.28369,N,12157.43457,W,00087.40,????,070.01,000.31,-000.10,05.6,03.5,04.3,00.0,DD00*32
```

Please note that the length of the string is fixed at 115 characters plus the two binary 0x0d, 0x0a termination characters.

```
$PASHR,POS,0,aa,bbbbbb.00,cccc.ccccc,d,eeee.eeeee,f,ggggg.gg,hhhh,iii.ii,jjj.jj,kkkk.kk,ll.l,mm.m,nn.n,00.0,p.pp,*[checksum]
```

Where:

- aa: Number of Sats
- bbbbbb.00: Time of Day UTC
- cccc.ccccc,d: Latitude,S/N
- eeee.eeeee,f: Longitude,W/E
- ggggg.gg: Antenna Height in meters
- hhhh: Four fixed '?' symbols
- iii.ii: Course Over Ground
- jjj.jj: Speed in Knots
- kkkk.k: Vertical Velocity in meters/s
- ll.l: PDOP
- mm.m HDOP
- nn.n VDOP
- 00.0 Static number
- p.pp: Firmware version

This command instructs the HD CSAC Low Power to send the NMEA standard string \$PASHR every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute HD CSAC warm-up phase.

This command has the following format:

```
GPS:PASHR <int> [0,255]
```

### 3.3.12 GPS:XYZSPeed

This command is a 3D velocity vector output command. Enabling this command will output a 3 dimensional velocity vector indicating the unit’s speed in centimeters per second in the ECEF coordinate system.

X, Y, and Z speed are individually given, and are independent of each other. An accuracy estimate in centimeters per second is also given. The velocity data is time-stamped using the time-of-week with a resolution of milliseconds.

Additionally, the number of accrued Leapseconds is indicated in this message, which allows proper calculation of GPS time from UTC time as indicated by other messages, as well as proper handling of Leapsecond events.

Use the following format to generate the velocity vector every N seconds, with N in the interval [0,255]:

```
GPS:XYZSPeed <int> [0,255]
```

### 3.3.13 GPS:DYNAMic:MODE

This command allows the user to select the dynamic motion model being applied to the Kalman filters in the GPS receiver. This allows for larger amounts of filtering for lower velocity applications, effectively reducing noise and multipath interference. Applications with high acceleration can now be used with fast filter settings to allow for the most accurate GPS coordinates to be provided in high-dynamic applications such as Jet aircraft. Doppler tracking is enabled in all airborne modes, as Carrier Phase tracking is very difficult to achieve in high velocity applications. The GPS will perform Carrier Phase tracking for non-airborne modes.

The command has the following syntax:

```
GPS:DYNAMic:MODE <int> [0,8]
```

Sending the following command to the HD CSAC Low Power will select a stationary GPS dynamic model for example:

```
gps:dynam:mode 1
```

The following table lists all available modes:

Value	Model	Application
0	Portable	Recommended as a default setting
1	Stationary	Used in stationary applications
2	Pedestrian	Used in man-pack, pedestrian settings
3	Automotive	Vehicular velocity applications

4	Sea	Used on Ships, where altitude is expected to be constant
5	Airborne <1g	Airborne applications with less than 1g acceleration
6	Airborne <2g	Airborne applications with less than 2g acceleration
7	Airborne <4g	Airborne applications with less than 4g acceleration
8	Automatic Mode	Select one of the above states (0 – 7) based on the actual velocity of the vehicle

The current dynamic state being applied to the GPS receiver can be queried with the command

GPS:DYNAMIC:STATE?

### 3.3.14 GPS:DYNAMIC:MODE 8 (Automatic Dynamic Mode)

Automatic Dynamic Mode allows the HD CSAC Low Power firmware to automatically configure the GPS receiver Kalman filter parameters based on actual mission velocities and motion profiles. The unit will try to set the GPS receiver to the optimal setting for any given velocity. The unit is able to set 7 different modes, as shown in section 3.3.13 .

The following table shows the Dynamic mode the unit will program into the GPS receiver when Automatic Mode is selected (Dynamic Mode 8).

Velocity Threshold	Selected Dynamic Model	Fallback to lower setting
0 – 2 knots	Stationary	none
>2 knots	Pedestrian	<1 knots
>10 knots	Automotive	<8 knots
>60 knots and >400 Feet/min climb/descent	Airborne 1g	<50 knots
>150 knots	Airborne 2g	<130 knots
>240 knots	Airborne 4g	<210 knots

In this Automatic mode, the unit will configure the GPS based on the actual vehicle-velocity:

Please note that in order to switch from the Automotive mode into the first Airborne (1g) mode, both a vehicle velocity greater than 60 knots as well as a climb/descent rate greater than 400 feet per minute are required. Alternatively, a vehicle velocity of greater than 100 Knots will also initiate a switch into airborne-1g mode.

Without an appropriate climb/descent, the unit will remain in Automotive mode.

The following command returns the setting of the GPS dynamic model:

GPS:DYNAMic:MODE?

The actual state chosen by the firmware for the GPS based on vehicle velocity can be obtained with the command:

GPS:DYNAMic:STATe?

A value between 0 and 7 is then returned depending on vehicle dynamics.

Settings will be applied immediately to the GPS receiver, and are stored in Non Volatile memory.

### 3.3.15 GPS:DYNAMic:STATe?

This query returns the actual state of the dynamic model, chosen by the firmware to be applied to the GPS receiver depending on vehicle velocity. It returns a value between 0 and 7, which correspond to one of the dynamic models defined in the Table in section 3.3.14 .

This state can be different from the user-selected Dynamic model mode for two reasons:

- if the dynamic mode is set to 8 (Automatic mode), the state will reflect the dynamic model being applied to the GPS receiver depending on actual vehicle dynamics

### 3.3.16 GPS:REFerence:ADELay <float> <s | ns > [-32767ns,32767ns]

The ADELay command allows bi-directional shifting of the 1PPS output in relation to the UTC 1PPS reference in one nanosecond steps. This allows antenna cable delay compensation, as well as retarding or advancing the 1PPS pulse arbitrarily. Typical antenna delays for a 30 foot antenna cable with 1.5ns per foot propagation delay would be compensated with the following command:

GPS:REF:ADEL 45ns

This command can be used to fine-tune different units to have co-incident 1PPS pulse outputs. Please note that during normal operation the 1PPS pulse may wander around the UTC 1PPS pulse while the unit is tracking the GPS signals. The present offset between the 1PPS output and the UTC 1PPS signal can be queried with the command SYNC:TINT? and this offset should be taken into account when calibrating two unit's 1PPS outputs to each other, since the lock algorithms will try to steer the HD CSAC for a 0.0ns offset to the UTC 1PPS time-pulse.

### 3.3.17 GPS:REFerence:PULse:SAWtooth?

This command returns the momentary sawtooth correction factor that the GPS receiver indicated.

### 3.3.18 GPS:RESET ONCE

Issues a reset to the internal GPS receiver. This can be helpful when changing the antenna for example, since the GPS receiver measures the antenna system's C/No right after reset, and adjusts its internal antenna amplifier gains accordingly. It takes approximately 1 minute for locking to commence after a GPS reset, as indicated by the red blinking LED.

### 3.3.19 GPS:TMODe <ON | OFF | RSTSURV>

This command is not supported in the HD CSAC.

### 3.3.20 GPS:SURVey ONCE

This command is not supported in the HD CSAC.

### 3.3.21 GPS:SURVey:DURation <sec>

This command is not supported in the HD CSAC.

### 3.3.22 GPS:SURVey:VARiance <mm<sup>2</sup>>

This command is not supported in the HD CSAC.

### 3.3.23 GPS:HOLD:POSition <cm, cm, cm>

This command is not supported in the HD CSAC.

### 3.3.24 GPS:SURVey:STATus?

This command is not supported in the HD CSAC.

### 3.3.25 GPS:INITial:DATE <yyyy,mm,dd>

Firmware revision 0.57 and later adds support for manually setting the time and date in the RTC in the event that no GPS signals are available. This command allows setting the internal RTC DATE manually when operating the unit in GPS denied environments. This command is compatible to the PTIME:OUT ON command described in section 3.5.5. to allow automatic time and date synchronization of two units to each other. The internal RTC is driven by the highly stable HD CSAC 10MHz signal, and thus has very high accuracy.

### 3.3.26 GPS:INITial:TIME <hour,min,sec>

Firmware revision 0.57 and later adds support for manually setting the time and date in the RTC in the event that no GPS signals are available. This command allows setting the internal RTC TIME manually when operating the unit in GPS denied environments. This command is compatible to the PTIME:OUT ON command described in section 3.5.5. to allow automatic time and date

synchronization of two units to each other. The internal RTC is driven by the highly stable HD CSAC 10MHz signal, and thus has very high accuracy.

### 3.3.27 GPS:JAMlevel?

Firmware revision 0.57 and later adds support for a GPS signal jamming-indicator. The GPS receiver will detect, and flag jamming interference with levels ranging from 0 (no jamming) to 255 (strong jamming). Any level exceeding 50 will cause a SYNC:HEALTH 0x800 event to be flagged, and the unit to disable the LOCK\_OUT\_OK signal on connector J1.

### 3.3.28 GPS:FWver?

This command returns the firmware version used inside the GPS receiver itself.

### 3.3.29 GPS?

This query displays the configuration, position, speed, height and other relevant data of the GPS receiver in one convenient location.

## 3.4 GYRO SUBSYSTEM

These commands are not supported in the HD CSAC.

```
GYRO:MODE <ON | OFF>
GYRO:TRACE <int> [0,255]
GYRO:PORT <RS232 | USB>
GYRO:PORT?
GYRO:CALibrate <float,float,float,float,float,float>
GYRO:CALibrate:COMPute
GYRO:CALibrate:RESET
GYRO:SENSitivity <float,float,float>
GYRO:GLOAD?
```

### 3.4.1 GYRO:MODE <ON | OFF>

This command is not supported in the HD CSAC.

### 3.4.2 GYRO:TRACE <int> [0,255]

This command is not supported in the HD CSAC.

### **3.4.3 GYRO:PORT <RS232 | USB>**

This command is not supported in the HD CSAC.

### **3.4.4 GYRO:PORT?**

This command is not supported in the HD CSAC.

### **3.4.5 GYRO:CAL <float,float,float,float,float,float>**

This command is not supported in the HD CSAC.

### **3.4.6 GYRO:CAL:COMPUTE**

This command is not supported in the HD CSAC.

### **3.4.7 GYRO:SENS and GPS:CAL:RESET**

This command is not supported in the HD CSAC.

### **3.4.8 GYRO:GLOAD?**

This command is not supported in the HD CSAC.

## **3.5 PTIME Subsystem**

The PTIME subsystem regroups all the commands related to the management of the time. The list of the commands supported is the following:

PTIME:DATE?

PTIME:TIME?

PTIME:TIME:STRing?

PTIME:TINterval?

PTIME:OUTput <on|off>

PTIME:LEAPsecond?

PTIME?

### 3.5.1 PTIME:DATE?

This query returns the current calendar date. The local calendar date is referenced to UTC time. The year, month, and day are returned.

### 3.5.2 PTIME:TIME?

This query returns the current 24-hour time. The local time is referenced to UTC time. The hour, minute, and second is returned.

### 3.5.3 PTIME:TIME:STRing?

This query returns the current 24-hour time suitable for display (for example, 13:24:56).

### 3.5.4 PTIME:TINTerval?

This query is equivalent to the command synchronization:TINTerval

### 3.5.5 PTIME:OUTput <ON | OFF>

Firmware revision 0.57 and later adds support for auto-initialization of time and date between to Jackson Labs Technologies, Inc. GPSDO units. This allows connecting two units together through the serial port with a null-modem cable, and having the master unit send time and date information to the slave unit. The slave unit's 1PPS reference input can also be driven by the master unit's 1PPS output signal, by setting the slave unit to external 1PPS sync mode using the sync:sour:mode ext command. This allows time-synchronization at the nanosecond level between two units which can be useful when operating in GPS denied environments.

Sending the command PTIM:OUT ON will cause the unit to automatically generate GPS:INIT:DATE and GPS:INIT:TIME sentences on the serial port once per second.

### 3.5.6 PTIME:LEAPsecond?

This command will return the internally applied leapsecond offset between GPS time and UTC time as stored in the EEPROM (GPS Almanac not received yet) or as indicated by the GPS receiver (GPS Almanac is available).

### 3.5.7 PTIME?

This query returns at once the result of the three following queries:

PTIME:DATE?

PTIME:TIME?

PTIME:TINTerval?

PTIME:OUTput?

PTIME:LEAPsecond?



## 3.6 SYNChronization Subsystem

This subsystem regroups the commands related to the synchronization of the HD CSAC Low Power with the GPS receiver. The list of the commands supported for this subsystem is the following:

```
SYNChronization:HOLDOver:DURATION?  
SYNChronization:HOLDOver:INITiate  
SYNChronization:HOLDOver:RECOvery:INITiate  
SYNChronization:SOURce:MODE <GPS | EXTERNAL | AUTO>  
SYNChronization:SOURce:STATE?  
SYNChronization:TINTerval?  
SYNChronization:IMMEDIATE  
SYNChronization:FEEstimate?  
SYNChronization:LOCKed?  
SYNChronization:OUTput:1PPS:RESET <ON | OFF>  
SYNChronization:OUTput:1PPs:RESET?  
SYNChronization:OUTput:FILTer <ON | OFF>  
SYNChronization:OUTput:FILTer?  
SYNChronization:HOLDOver:STATE?  
SYNChronization:TINTerval:THReshold [50,2000]  
SYNChronization?
```

### 3.6.1 SYNChronization:HOLDOver:DURATION?

This query returns the duration of the present or most recent period of operation in the holdover and holdover processes. This is the length of time the reference oscillator was not locked to GPS, and thus “coasting”. The time units are seconds. The first number in the response is the holdover duration. The duration units are seconds, and the resolution is 1 second. If the Receiver is in holdover, the response quantifies the current holdover duration. If the Receiver is not in holdover, the response quantifies the previous holdover. The second number in the response identifies the holdover state. A value of 0 indicates the Receiver is not in holdover; a value of 1 indicates the Receiver is in holdover.

### 3.6.2 SYNChronization:HOLDOver:INITiate

The SYNC:HOLD:INIT and SYNC:HOLD:REC:INIT commands allow the user to manually enter and exit the holdover state, even while GPS signals are still being properly received. This forced-holdover allows the unit to effectively disable GPS locking, while still keeping track of the state of the 1PPS output in relation to the UTC 1PPS signal as generated by the GPS receiver. When the unit is placed into forced-holdover with this command, the unit will indicate the time interval difference between the 1PPS output and the GPS UTC 1PPS signal by using the SYNC:TINT? command. This allows the user to see the HD CSAC drift when not locked to GPS for testing purposes, or to prevent the GPS receiver from being spoofed and affecting the HD CSAC frequency

accuracy. All other frequency-disciplining functions of the unit will behave as if the GPS antenna was disconnected from the unit while in this forced-holdover state.

### 3.6.3 SYNChronization:HOLDOVER:RECOVER:INITiate

This command will disable the forced holdover state (see the SYNC:HOLD:INIT command). The unit will resume normal GPS locking operation after this command has been sent.

### 3.6.4 SYNChronization:SOURce:MODE

The Source:Mode command allows an optional external 3.3V CMOS, 5V CMOS or TTL level 1PPS input to be connected to the HD CSAC Low Power GPSDO board on connector harness J1. This command also controls the power supply of the GPS receiver for additional power savings in holdover/flywheel mode.

The internal GPS receiver and the 3.3V GPS antenna power supply voltage are automatically disabled when setting the unit to EXTERNAL 1PPS Mode using the *sync:sour:mode ext* command. The GPS receiver and GPS antenna power supply are turned on again when the unit is set to GPS disciplining mode using the *sync:sour:mode gps* command. This allows for optimal power savings when the GPS receiver is not needed.

The unit can use this external 1PPS input instead of the internal, GPS-generated 1PPS. Switching to the external 1PPS is either done manually with the EXT command option, or automatically with the AUTO command option in case the GPS receiver goes into holdover mode for any reason. The command has the following format:

```
SYNChronization:SOURce:MODE <GPS | EXTERNAL | AUTO>
```

### 3.6.5 SYNChronization:SOURce:STATE?

This query shows the state of the external 1PPS synchronization option. The GPS receiver power supply is shut-off when in EXTERNAL disciplining mode.

### 3.6.6 SYNChronization:TINTerval?

This query returns the difference or timing shift between the HD CSAC Low Power 1PPS and the GPS 1PPS signals. The resolution is 1E-10 seconds.

### 3.6.7 SYNChronization:IMMEdiate

This command initiates a near-instantaneous alignment of the GPS 1PPS and Receiver output 1PPS. To be effective, this command has to be issued while not in holdover.

### 3.6.8 SYNChronization:FEEstimate?

This query returns the Frequency Error Estimate, similar to the Allan Variance using a 1000s measurement interval and comparing the internal 1PPS to GPS 1PPS offset.

Values less than 1E-012 are below the noise floor, and are not significant.

### 3.6.9 SYNChronization:LOCKed?

This query returns the lock state (0=OFF, 1=ON) of the PLL controlling the HD CSAC.

### 3.6.10 SYNChronization:OUTput:1PPs:RESET <ON | OFF>

This command allows the generation of the 1PPS pulse upon power-on without an external GPS antenna being connected to the unit. By default the unit does not generate a 1PPS pulse until the GPS receiver has locked onto the Satellites. With the command SYNC:OUT:1PPS:RESET ON the unit can now be configured to generate an asynchronous 1PPS output after power-on even if a GPS antenna is not connected to the unit. Once the GPS receiver locks, the 1PPS pulse will align itself to UTC by stepping in 10 equally spaced steps toward UTC alignment. The default setting is OFF which means the 1PPS pulse is disabled until proper GPS lock is achieved.

### 3.6.11 SYNChronization:OUTput:1PPs:RESET?

This query returns the 1PPS output on reset setting.

### 3.6.12 SYNChronization:OUTput:FILTer <ON | OFF>

This command is not supported in the HD CSAC.

### 3.6.13 SYNChronization:OUTput:FILTer?

This command is not supported in the HD CSAC.

### 3.6.14 SYNChronization:HEAlth?

The SYNChronization:HEAlth? query returns a hexadecimal number indicating the system's health-status. Error flags are encoded in a binary fashion so that each flag occupies one single bit of the binary equivalent of the hexadecimal health-status flag.

The following system parameters are monitored and indicated through the health-status indicator. Individual parameters are 'ored' together which results in a single hexadecimal value encoding the following system status information:

If the phase offset to UTC is >250ns	HEALTH STATUS  = 0x4;
If the run-time is < 300 seconds	HEALTH STATUS  = 0x8;
If the GPS is in holdover > 60s	HEALTH STATUS  = 0x10;
If the Frequency Estimate is out of bounds	HEALTH STATUS  = 0x20;
If the short-term-drift (ADEV @ 100s) > 100ns	HEALTH STATUS  = 0x100;

For the first 3 minutes after a phase-reset: HEALTH STATUS |= 0x200;  
 If the HD CSAC Oscillator indicates an alarm HEALTH STATUS |= 0x400;  
 If the GPS receiver indicates a strong jamming signal HEALTH STATUS |= 0x800;  
 of >=50 (range is 0 to 255)

As an example, if the unit is in GPS holdover and the UTC phase offset is > 250ns then the following errors would be indicated:

- 1) UTC phase > 250ns: 0x4
- 2) GPS in holdover: 0x10

‘Oring’ these values together results in:

$$0x10 | 0x4 = 0x14$$

The unit would thus indicate: HEALTH STATUS: 0x14 and the Green LED as well as the LOCK\_OK output would go off, indicating an event is pending.

A health status of 0x0 indicates a properly locked, and warmed-up unit that is completely healthy.

### 3.6.15 SYNChronization:TINTerval:THReshold [50,2000]

This command selects the internal oscillator 1PPS phase-offset threshold as compared to UTC at which point the unit will initiate a counter-reset (jam-sync) aligning the HD CSAC generated 1PPS with the GPS generated UTC 1PPS phase. The CSAC 1PPS phase is allowed to drift up to this threshold before a jam-sync is initiated. The HD CSAC phase is slowly and continuously adjusted toward 0ns offset to UTC while the phase difference is less than the THReshold phase limit. The default setting is 220ns, allowing a drift of up to +/-220ns. Reaching this selected threshold will cause a jam-sync phase-normalization to be initiated, which will also cause an indication of the SYNC:HEALTH? Status of 0x200 to be indicated, and the Green LED to be turned-off for several minutes.

### 3.6.16 SYNChronization?

This query returns the results of these queries:

- SYNChronization:SOURce:MODE?
- SYNChronization:SOURce:STATE?
- SYNChronization:OUTput:1PPS:RESET?
- SYNChronization:LOCKed?
- SYNChronization:HOLDover:STATe?
- SYNChronization:HOLDover:DURation?
- SYNChronization:FEEstimate?

SYNChronization:TINterval?  
 SYNChronization:TINterval:THReshold  
 SYNChronization:OUTput:FILTer?  
 SYNChronization:HEAlth?

## 3.7 DIAGnostic Subsystem

This subsystem regroups the queries related to the diagnostic of the HD CSAC. The list of the commands supported for this subsystem is as follows:

DIAGnostic:ROSCillator:EFControl:RELative?  
 DIAGnostic:ROSCillator:EFControl:ABSolute?  
 DIAGnostic:LIFetime:COUNT?

### 3.7.1 DIAGnostic:ROSCillator:EFControl:RELative?

This query returns the Electronic Frequency Control (EFC) output value of the internal reference oscillator. It returns a percentage value between -100% to +100%.

### 3.7.2 DIAGnostic:ROSCillator:EFControl:ABSolute?

This query returns the Electronic Frequency Control (EFC) steering value of the HD CSAC oscillator in parts-per-trillion (1E-012).

### 3.7.3 DIAGnostic:LIFetime:COUNT?

This query returns the time since power on of the CSAC oscillator in hours.

### 3.7.4 DIAGnostic?

Sending the command diag? returns the following:

Relative oscillator setting  
 Absolute oscillator setting  
 Time since power-on in hours (lifetime)

An example of the syntax:

```
scpi > diag?
EFControl Relative: 0.025000%
EFControl Absolute: 5
Lifetime : +871
```

## 3.8 MEASURE Subsystem

The MEASURE subsystem regroups the queries related to parameters that are measured on-board the HD CSAC Low Power.

### 3.8.1 MEASure:TEMPerature?

Displays the PCB temperature around the CSAC oscillator.

### 3.8.2 MEASure:VOLTage?

Displays the CSAC TCXO steering voltage.

### 3.8.3 MEASure:CURRent?

Legacy SCPI command, instead of OCXO current this command displays the internal CSAC temperature.

### 3.8.4 MEASure:POWersupply?

Displays the power supply input voltage.

### 3.8.5 MEASure?

The MEASure? query returns the results of the following four queries:

MEASure:TEMPerature?

MEASure:VOLTage?

MEASure:CURRent?

MEASure:POWersupply?

## 3.9 SYSTEM Subsystem

This subsystem regroups the commands related to the general configuration of the HD CSAC Low Power. The list of the commands supported for this subsystem follows:

SYSTem:COMMunicate:SERial:ECHO <ON | OFF>

SYSTem:COMMunicate:SERial:PROmpt <ON | OFF>

SYSTem:COMMunicate:SERial:BAUD <9600 | 19200 | 38400 | 57600 | 115200>

SYSTem:FACToryreset ONCE

SYSTem:ID:SN?

SYSTem:ID:HWrev?

SYSTem:LCD:CONTRast [0,1.0]

SYSTem:LCD:CONTRast

SYSTem:LCD:PAGE [0,8]  
 SYSTem:LCD:PAGE?  
 SYSTem:COMMunicate:USB:BAUD <9600 | 19200 | 38400 | 57600 | 115200>  
 SYSTem:COMMunicate:USB:BAUD?  
 SYSTem:STATus?

### 3.9.1 SYSTem:COMMunicate:SERial:ECHO

This command enables/disables echo on RS-232. This command has the following format:

SYSTem:COMMunicate:SERial:ECHO <ON | OFF>

### 3.9.2 SYSTem:COMMunicate:SERial:PROmpt

This command enables/disables the prompt “scpi>” on the SCPI command lines. The prompt must be enabled when used with the software GPSCon. This command has the following format:

SYSTem:COMMunicate:SERial:PROmpt <ON | OFF>

### 3.9.3 SYSTem:COMMunicate:SERial:BAUD

This command sets the RS-232 serial speed. The serial configuration is always 8 bit, 1 stop bit, no parity, no HW flow control. Upon Factory reset, the speed is set at 115200 bauds. This command has the following format:

SYSTem:COMMunicate:SERial:BAUD <9600 | 19200 | 38400 | 57600 | 115200>

### 3.9.4 SYSTem:FACToryreset ONCE

This command applies the Factory Reset setting to the NVRAM. All aging, tempco, and user parameters are overwritten with factory default values.

### 3.9.5 SYSTem:ID:SN?

This query returns the serial number of the board

### 3.9.6 SYSTem:ID:HWrev?

This query return the Hardware version of the board

### 3.9.7 SYSTem:LCD:CONTRast [0,1.0]

This command is not supported in the HD CSAC.

### 3.9.8 SYSTem:LCD:CONTRast?

This command is not supported in the HD CSAC.

### 3.9.9 SYSTem:LCD:PAGE [0,8]

This command is not supported in the HD CSAC.

### 3.9.10 SYSTem:LCD:PAGE?

This command is not supported in the HD CSAC.

### 3.9.11 SYSTem:COMMunicate:USB:BAUD <9600 | 19200 | 38400 | 57600 | 115200>

This command is not supported in the HD CSAC.

### 3.9.12 SYSTem:COMMunicate:USB:BAUD?

This command is not supported in the HD CSAC.

### 3.9.13 SYSTem:STATus?

This query returns a full page of GPS status in ASCII format. The output is compatible with GPSCon.

## 3.10 SERVO Subsystem

This subsystem regroups all the commands related to the adjustment of the servo loop:

```

SERVo:DACGain <float> [0.1,10000]
SERVo: EFCScale <float>[0.0 , 500.0]
SERVo:EFCDamping <int>[2 , 4000]
SERVo:TEMPCompensation <float> [-4000.0, 4000.0]
SERVo:AGINGcompensation <float> [-10.0, 10.0]
SERVo:PHASECOrrrection <float> [-500.0, 500.0]
SERVo:1PPSoffset <int> ns
SERVo:TRACe <int > [0,255]
SERVo?

```

### 3.10.1 SERVo:DACGain

This command is used for factory setup.



### 3.10.2 SERVo:EFCScale

Controls the Proportional part of the PID loop. Typical values are 0.7 to 6.0. Larger values increase the loop control at the expense of increased noise while locked. Setting this value too high can cause loop instabilities.

This command has the following format:

```
SERVo: EFCScale <float>[0.0 , 500.0]
```

### 3.10.3 SERVo:EFCDamping

Sets the Low Pass filter effectiveness of the DAC. Values from 2.0 to 50 are typically used. Larger values result in less noise at the expense of phase delay. This command has the following format:

```
SERVo:EFCDamping <int>[2 , 4000]
```

### 3.10.4 SERVo:TEMPCompensation

This parameter is a coefficient that reflects the correlation between the temperature of the HD CSAC versus the required frequency steering. Monitoring the tempco and aging parameters provides a mechanism to track the health of the HD CSAC oscillator. Excessively high values that appear from one day to the next could be an indicator of failure on the board. This coefficient is automatically computed and adjusted over time by the Jackson Labs Technologies, Inc. firmware. This command has the following format:

```
SERVo:TEMPCompensation <float> [-4000.0, 4000.0]
```

### 3.10.5 SERVo:AGINGcompensation

This parameter is a coefficient that represents the drift of the EFC needed to compensate the natural drift in frequency of the HD CSAC due to aging. This coefficient is automatically computed and adjusted over time by the Jackson Labs Technologies, Inc. firmware. This command has the following format:

```
SERVo:AGINGcompensation <float> [-10.0, 10.0]
```

### 3.10.6 SERVo:PHASECOrrrection

This parameter sets the Integral part of the PID loop. Loop instability will result if the parameter is set too high. Typical values are 10.0 to 30.0. This command has the following format:

```
SERVo:PHASECOrrrection <float> [-500.0, 500.0]
```

### 3.10.7 SERVo:1PPSoffset

This command sets the HD CSAC Low Power 1PPS signal's offset to UTC in 100ns steps.

Using the SERV:1PPS command results in immediate phase change of the 1PPS output signal.

This command has the following format:

```
SERVo:1PPSoffset <int> ns
```

### 3.10.8 SERVo:TRACe

This command sets the period in seconds for the debug trace. Debug trace data can be used with Ulrich Bangert’s “Plotter” utility to show UTC tracking versus time etc.

This command has the following format:

```
SERV0:TRACe <int> [0,255]
```

An example output is described here:

**08-07-31 373815 60685 -32.08 -2.22E-11 14 10 6 0x54**

[date][1PPS Count][Fine DAC][UTC offset ns][Frequency Error Estimate][Sats Visible][Sats Tracked][Lock State][Health Status]

Please see the **SYNChronization:HEALTH?** command for detailed information on how to decode the health status indicator values. The Lock State variable indicates one of the following states:

Value	State
0	HD CSAC warmup
1	Holdover
2	Locking (HD CSAC training)
4	[Value not defined]
5	Holdover, but still phase locked (stays in this state for about 100s after GPS lock is lost)
6	Locked, and GPS active

### 3.10.9 SERVo?

This command returns the result of the following queries:

- SERV0:DACGain?
- SERV0:EFCScale?
- SERV0:EFCDamping?
- SERV0:TEMPCompensation?
- SERV0:AGINGcompensation?
- SERV0:PHASECOrrrection?
- SERV0:1PPSoffset?
- SERV0:TRACE : 0

## 3.11 CSAC Subsystem

The following commands are used to query the microcontroller built into the HD CSAC oscillator itself.

### 3.11.1 CSAC:RS232?

This query returns the state (OK or FAIL) of the serial communication between the main CPU and the HD CSAC internal microcontroller. When the state is FAIL, there is a communication breakdown, and the unit should be power cycled to clear the communication error.

### 3.11.2 CSAC:STeer?

This query returns the current Frequency Adjustment in units of parts-per-trillion (1E-012).

### 3.11.3 CSAC:STATus?

This query returns the status value in [0,9] as shown below:

Alarm	Definition
0	Locked
1	Microwave Frequency Steering
2	Microwave Frequency Stabilization
3	Microwave Frequency Acquisition
4	Laser Power Acquisition
5	Laser Current Acquisition
6	Microwave Power Acquisition
7	Heater equilibration
8	Initial warm-up
9	Asleep (ULP mode only)

### 3.11.4 CSAC:ALarm?

This query returns the Alarm value as shown below:

Alarm	Definition
0x0001	Signal Contrast Low
0x0002	Synthesizer tuning at limit
0x0010	DC Light level Low
0x0020	DC Light level High
0x0040	Heater Power Low
0x0080	Heater Power High
0x0100	uW Power control Low
0x0200	uW Power control High

<b>Alarm</b>	<b>Definition</b>
0x0400	TCXO control voltage Low
0x0800	TCXO control voltage High
0x1000	Laser current Low
0x2000	Laser current High
0x4000	Stack overflow (firmware error)

### 3.11.5 CSAC:MODE?

This query returns the HD CSAC mode as shown below:

0x0001	Analog tuning enable
0x0002	Reserved
0x0004	Reserved
0x0008	1 PPS auto-sync enable
0x0010	Discipline enable
0x0020	Ultra-low power mode enable
0x0040	Reserved
0x0080	Reserved

### 3.11.6 CSAC:CONTrast?

This query returns the indication of signal level typically ~4000 when locked, and ~0 when unlocked.

### 3.11.7 CSAC:LASer?

This query returns the current (in mA) driving the laser.

### 3.11.8 CSAC:TCXO?

This query returns the TCXO Tuning Voltage, 0-2.5 VDC tuning range ~ +/- 10 ppm

### 3.11.9 CSAC:SIGnal?

This query returns the indication of signal level.

### 3.11.10 CSAC:HEATpackage?

This query returns the Physics package heater power typically 15mW under NOC.

### **3.11.11 CSAC:TEMP?**

This query returns the Temperature measured by the HD CSAC unit in °C, absolute accuracy is +/- 2°C.

### **3.11.12 CSAC:FWrev?**

This query returns the Firmware version of the HD CSAC unit.

### **3.11.13 CSAC:SN?**

This query returns the Serial Number of the HD CSAC in the form YYMMCSNNNNN where YYMM is the year and month of production and NNNNN is the serialized unit of that month.

### **3.11.14 CSAC:LIFETIME?**

This query returns the accumulated number of hours that the HD CSAC has been powered on since the last factory reset of the HD CSAC Low Power board. The value is stored in the external NVRAM and updated every hour when the HD CSAC is powered on.

### **3.11.15 CSAC:STeer:LATch ONCE**

This command stores the momentary steering offset into the HD CSAC internal NVRAM. This is done automatically by the firmware once every 24 hours, so as not to damage the HD CSAC NVRAM which has a limited number of write cycles. The user may force this value to be stored into the HD CSAC by issuing the HD CSAC:STeer:LATch ONCE command

### **3.11.16 CSAC?**

This query displays all the HD CSAC queries defined above.



# 4 Firmware Upgrade Instructions

## 4.1 Introduction

The following is a short tutorial on how to upgrade the HD CSAC Low Power GPSDO firmware. Please follow the instructions in order to prevent corrupting the HD CSAC Low Power GPSDO Flash, which may require reflashing at the factory.

With some practice, the entire Flash upgrade can be done in less than one minute, even though the following seems like a fairly long list of instructions.

## 4.2 ISP Flash Loader Utility Installation

Jackson Labs Technologies, Inc. recommends using the Flash Magic utility to upgrade the contents of Flash memory on the HD CSAC Low Power. It is available for download on the Flash Magic website:

<http://www.flashmagictool.com/>

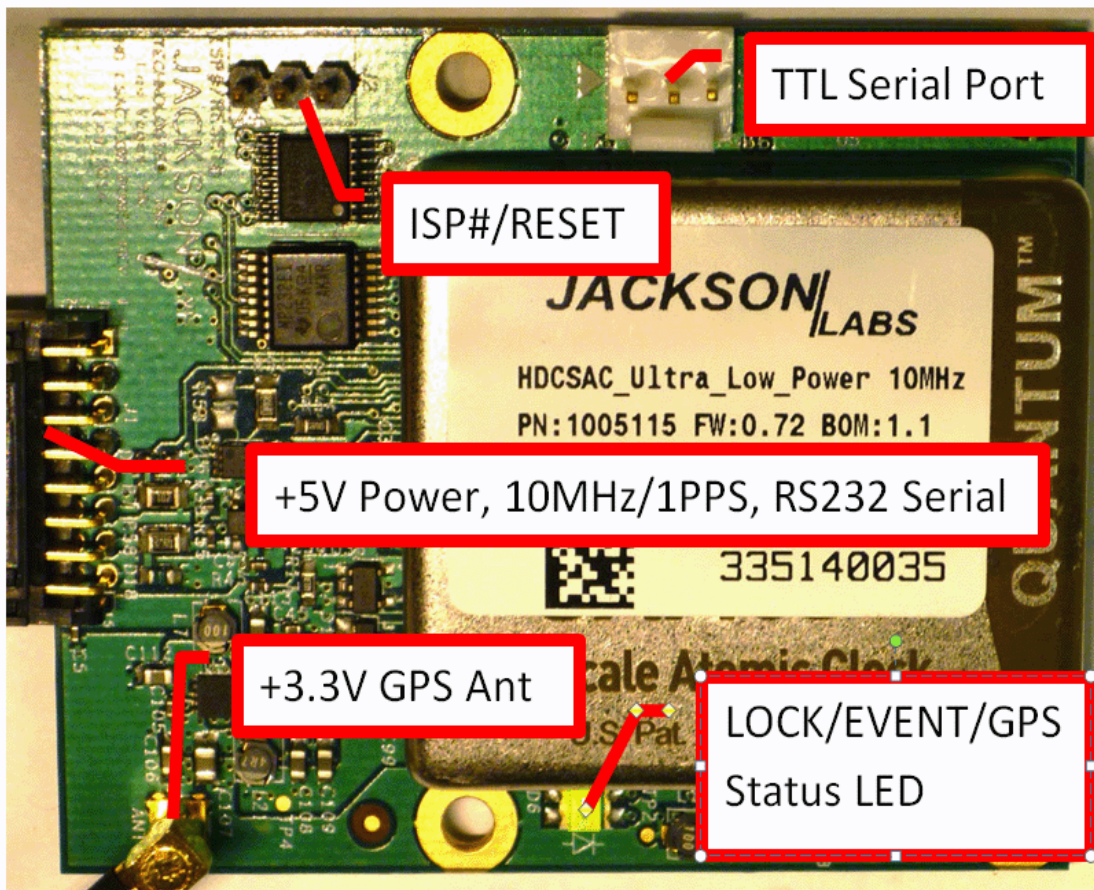
Follow the directions given on the website for installing the utility on your computer.

*Note: The Philips LPC2000 utility that is used on other Jackson Labs Technologies, Inc. products will not support the newer LPC1768 low-power Cortex processor used on the HD CSAC Low Power GPSDO.*

## 4.3 Putting the PCB into In-Circuit Programming (ISP) mode

Momentarily short-out pins 1 and 2 of header J2 using a jumper or other conductive material during power-on (See [Figure 4.1](#)). Both LED's should remain off, indicating the unit is properly placed into ISP mode. If the LED's light up after power-on, the unit is not in ISP mode.

**Figure 4.1 Location of header J2**



## 4.4 Downloading the Firmware

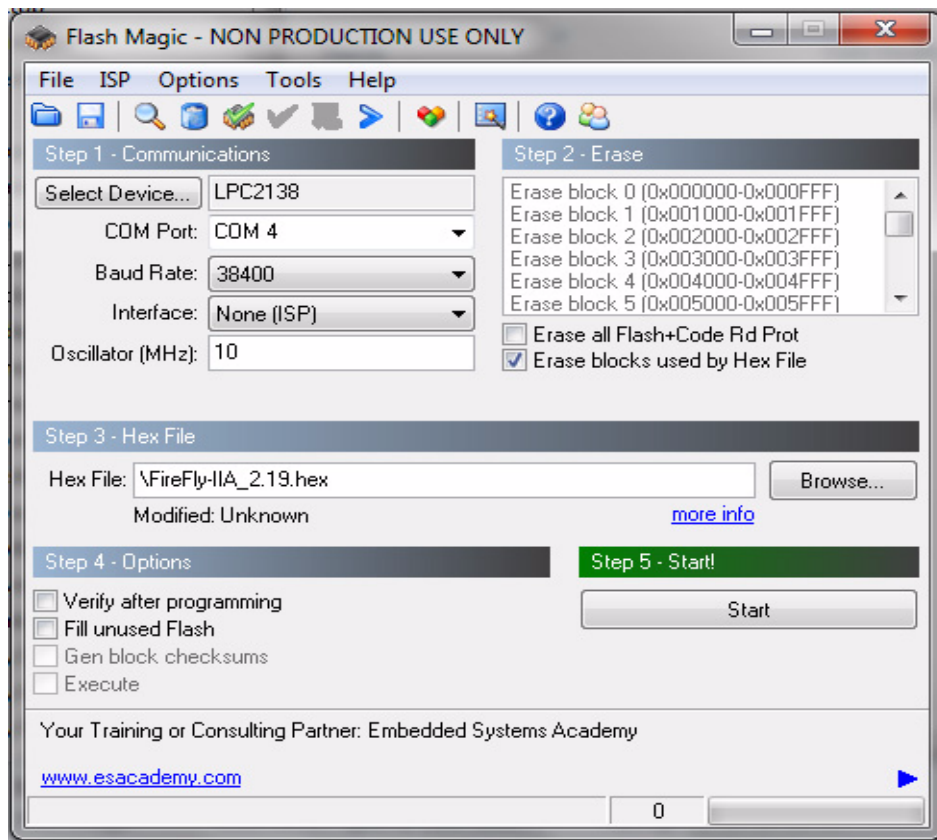
Download the latest version of HD CSAC Low Power GPSDO firmware from the Jackson Labs Technologies, Inc. support website and store it in a place that will be remembered. The firmware executable file for the HD CSAC Low Power GPSDO and the HD CSAC boards are NOT identical because the two boards use different processors. The file is in .hex format. The unit needs to be connected to the computer’s RS-232 serial port prior to firmware download. Connect a DB-9 serial connector to the HD CSAC Low Power GPSDO as indicated in Section 2.3 .

### 4.4.1 Using the Flash Magic Flash Programming Utility

A) Open the Flash Magic utility. Set the COM port in the Flash Magic application as needed on your PC. Set “Interface” to “None (ISP)”.

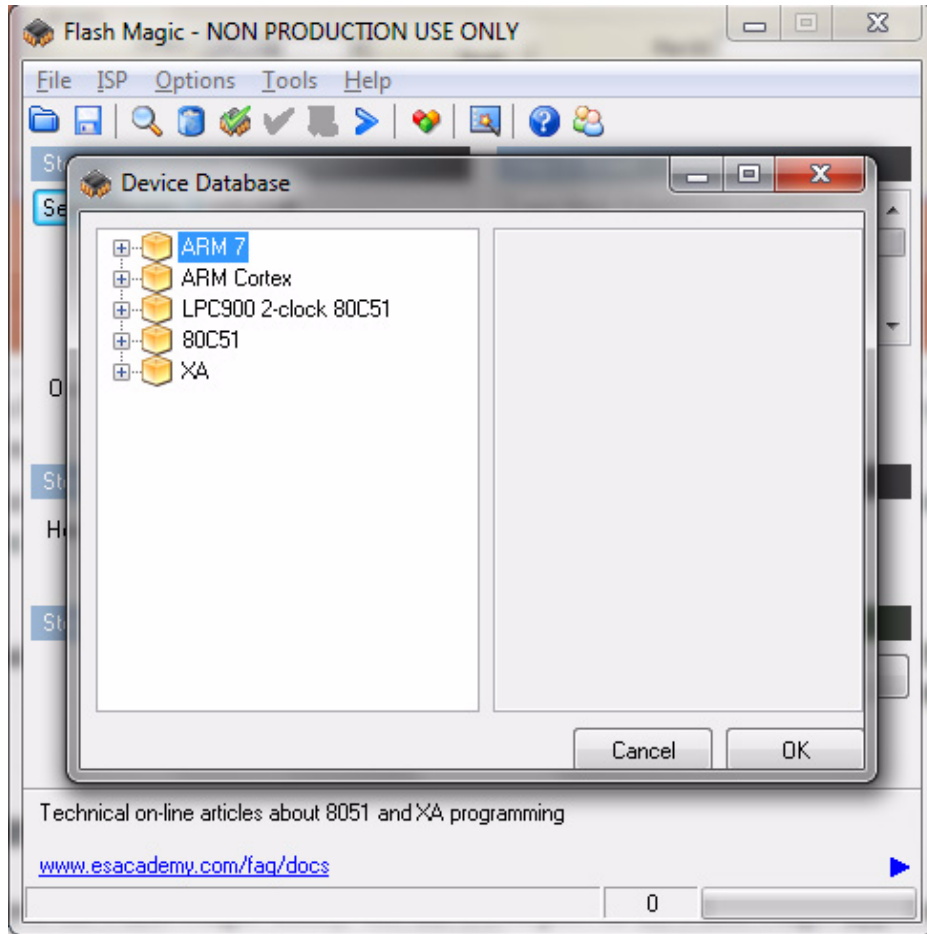


Figure 4.2 Flash Magic programming utility

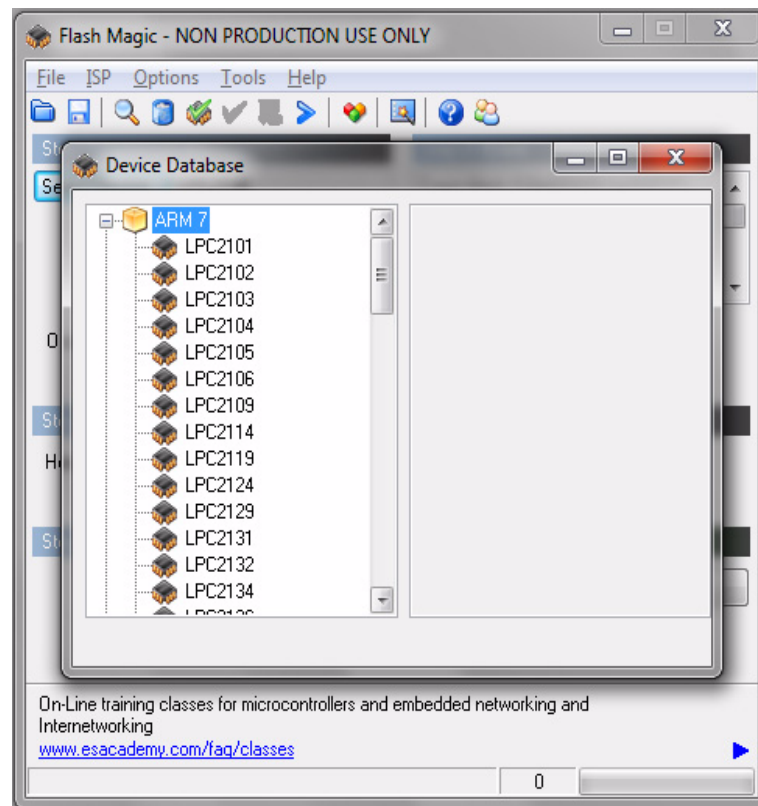


B) Press the “Select Device” button and the window shown in **Figure 4.3** will appear:

**Figure 4.3 Device selection window**



C) Expand the ARM CORTEX folder and select the appropriate processor, **in this case the LPC1768.**

**Figure 4.4 Expanded device selection window**

D) Select the Baud Rate of the Flash Magic utility to be 230.4KB or slower.

E) Set the Oscillator (MHz) to "10".

F) Check the box marked "Erase blocks used by Hex File".

**Warning:** Make sure NOT(!) to check the box marked "Erase all Flash+Code Rd Prot" under any circumstances, this may erase factory calibration data, and the unit will not operate and will have to be returned to the factory. Checking this box on the ISP utility will thus void the warranty.

G) Under "Step 3 - Hex File" browse for the hex file that you downloaded in step 4.4 .

H) Go to Step 5 and press "Start". You will observe the firmware being downloaded to the HD CSAC Low Power.

## 4.5 Verifying Firmware Update

Remove the jumper from header J2, and power cycle the unit. Both LED's should blink.

During power on, the unit sends an ID string out of the serial port at 115200 Baud by default. The firmware version can also be queried by sending the \*IDN? command. Verify that the firmware version is the version that was downloaded.



# 5 GPSCon Utility

## 5.1 Description

GPSCon is a program for the monitoring and control of a variety of GPS time and frequency standard receivers. It communicates with the receiver using the SCPI command set. This utility can be obtained directly from Real Ham Radio.com at the following URL:

<http://www.realhamradio.com/gpscon-buy-now.htm>

*Important note: On newer, faster computers running Windows 7, GPSCon may not acquire data correctly. Try running GPSCon in Windows XP compatibility mode, and as an administrator. If you encounter problems, it is recommended that you install GPSCon on a slower computer using Windows XP.*

## 5.2 Z38xx Utility

If the GPSCon utility is not available, you may use the Z38xx utility. The Z38XX utility is a PC monitor program for GPS Disciplined References (GPSR) which communicate using the SCPI (Standard Commands for Programmable Instrumentation) Protocol. It is available on the Jackson Labs Technologies, Inc. website under the “Support” tab:

[http://www.jackson-labs.com/assets/uploads/main/Z38XX\\_download.zip](http://www.jackson-labs.com/assets/uploads/main/Z38XX_download.zip)

The program provides real-time monitoring of the operation of the GPSR, including status information, GPS satellite information, timing and control information, holdover prediction, reference Allan Variance and even a UTC clock with second accuracy. It also displays various logs, and stores all measurements on file for later analysis.

## 5.3 GPSCon Installation

Follow the directions that come with GPSCon for installing the utility on your computer.

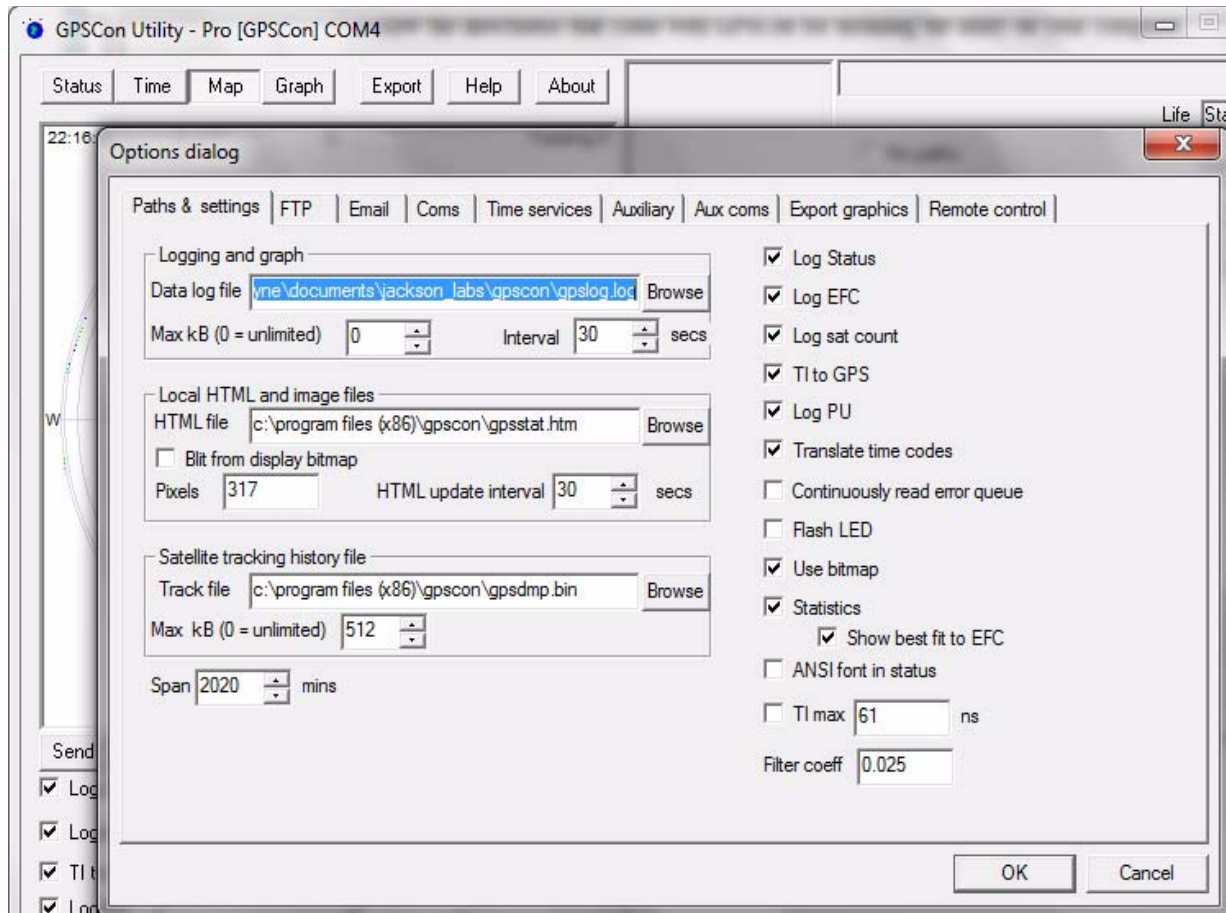
## 5.4 Using GPSCon

The GPSCon utility has a help file that should be consulted in order to get the full functionality of this utility. Only a few of the features and commands are mentioned in this chapter for convenience.

## 5.4.1 Setting the options

To set up the options for your GPSCon session, press the “Options” button below the display area. The window shown in [Figure 5.1](#) will appear. You can select from the tabs which options you wish to set.

**Figure 5.1 Options window**



### 5.4.1.1 Communication Parameters

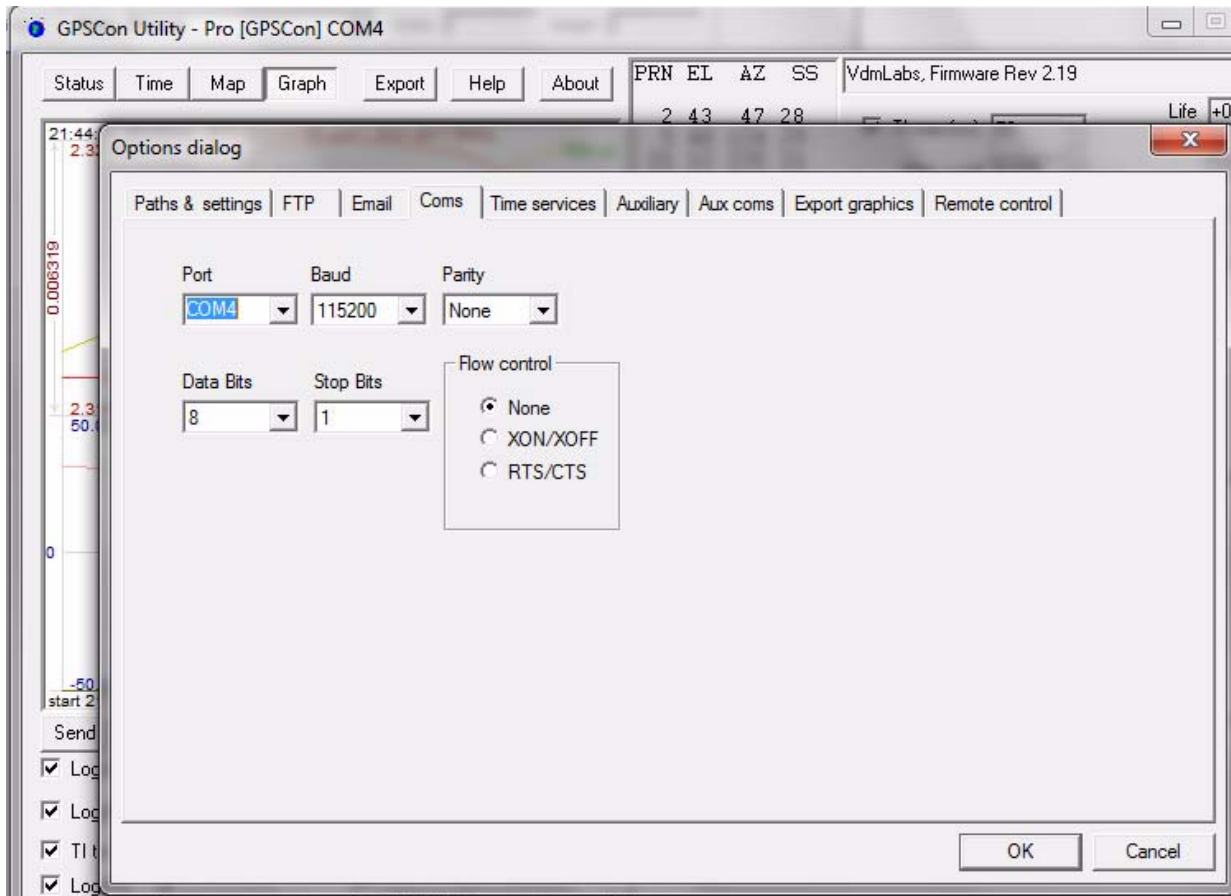
Before you can use GPSCon you must set the communication parameters for your system. Open the dialog box by pressing the “Options” button. Then select the “Coms” tab. You will see the window shown in [Figure 5.2](#). Select the correct COM port for your computer and set the baud rate to 115200, parity to None, Data Bits to 8 and Stop Bits to 1. Set Flow Control to “None”. Once you have configured the communication parameters, press the “OK” button to close the window.

### 5.4.1.2 Auxiliary parameters

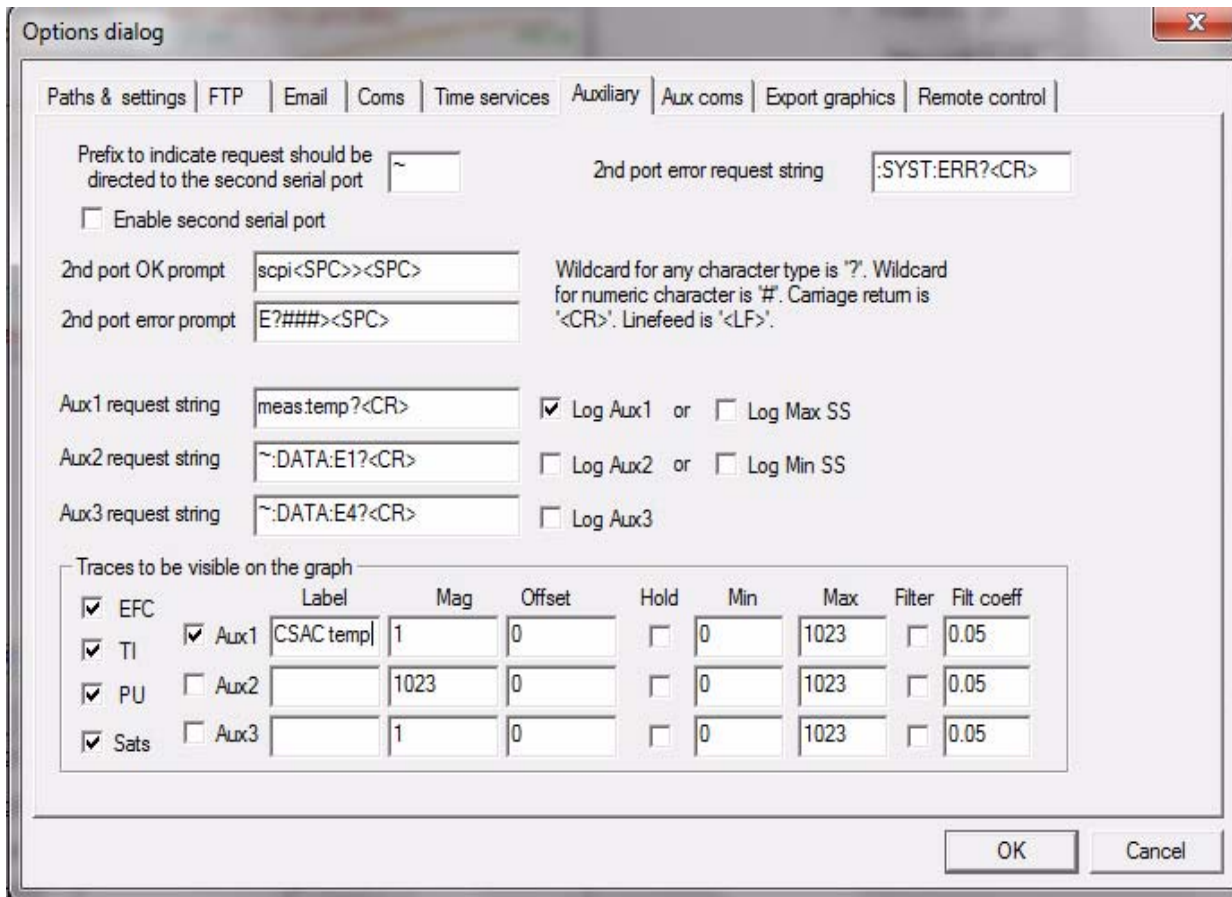
After pressing the “Options” button, you can select “Auxiliary” and set other options or measurements. See [Figure 5.3](#) for an example of an auxiliary measurement. You will notice that the “Aux 1 request string” has been set to `meas : temp?<CR>` and the “Log Aux1” box is checked. In

the area below labeled “Traces to be visible on the graph”, the box “Aux 1” is checked and the label “HD CSAC temp” has been added.

**Figure 5.2 Setting the communications parameters**



**Figure 5.3 Auxiliary parameters window**



### 5.4.1.3 Other options

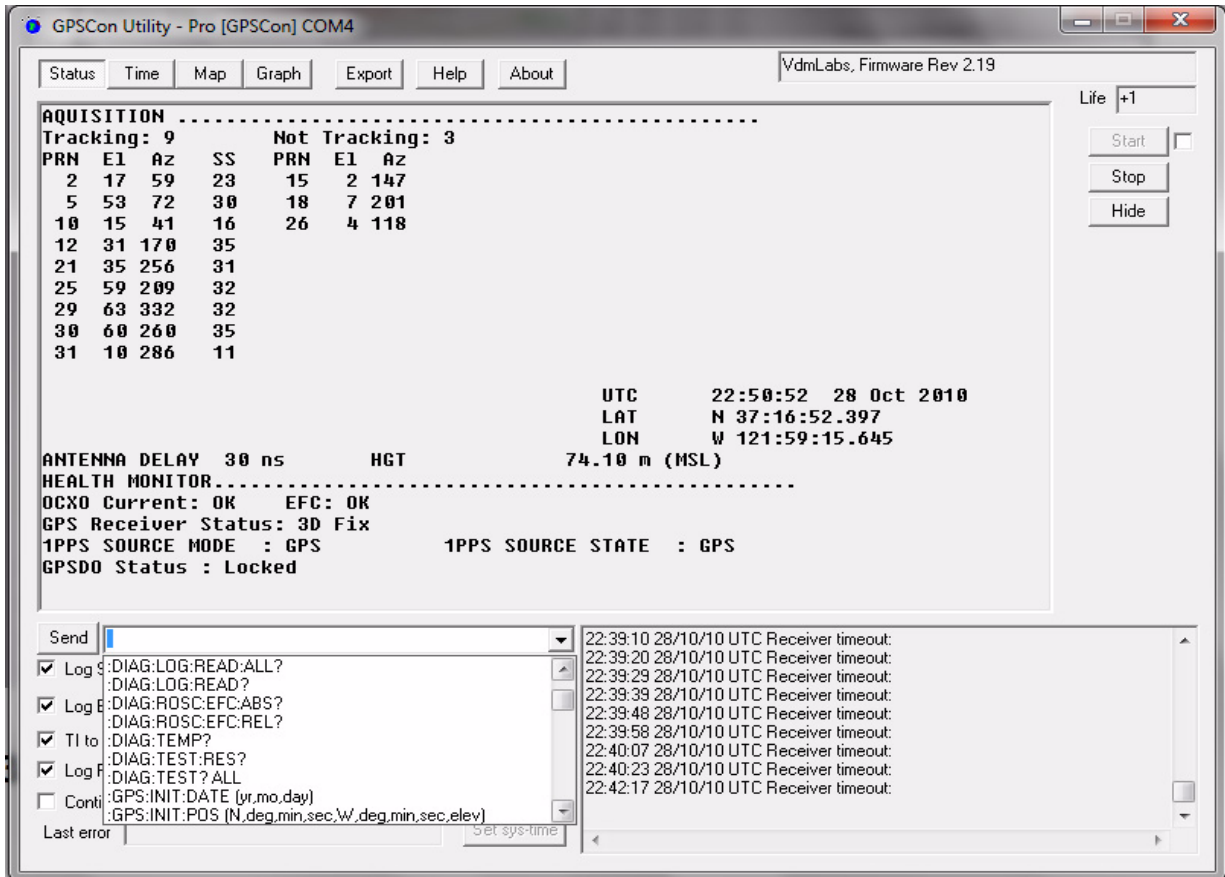
The other tabs in the options window can be selected and you can set whatever options you need, such as paths for logging or exporting graphics.



### 5.4.2 Sending manual commands to the receiver

You can send SCPI commands manually by using the drop-down box under the display window as shown in [Figure 5.4](#). Care must be taken when sending these commands so be sure that the command that you select is supported by the HD CSAC Low Power. Once you've selected the command, you can press "Send" to send it to the HD CSAC Low Power.

**Figure 5.4 Sending manual commands**



### 5.4.3 Use of the mouse in graph mode

Refer to [Figure 5.5](#) for the following description. In graph mode the span of the graph may be set using the span setting. Alternatively, the start and or stop time of the graph may be locked using the mouse. Set the start time by left clicking on the desired start point. If you wish, the stop time may also be locked by right clicking the desired stop point. This can all be unlocked by left double-clicking anywhere on the graph. Double-click always causes all of the selected span data to be displayed. At the next update cycle, the selected span, if not set to zero, will be enforced. However, the left click, and if chosen the right click, always overrides the span setting.

To display all of the data in the file without manually setting the span to zero, you should right double-click in the graph. This has the effect of setting the start time to zero, the stop time to infinity, and asserting the mouse override condition. To release, left double-click.

Since this is harder to describe than to actually do, here is a paraphrase of the above:

"To zoom in: The mouse is used to set the left extent and the right extent of the portion of the curve that the user wants to fill the screen. Click once with the left mouse button on the point that marks the left side of what you want to be the magnified curve. Immediately that point becomes the left end of the curve. Then similarly click the right mouse button on the curve at the time you wish to be the right most portion of the magnified curve and it immediately becomes the end point on the right side. And, finally to return to the zoomed out ("fit to window") view, left double-click on the curve."

Remember, in order to see all the data in the log file, you must either set the span control to zero, or right double-click in the graph.

When you have locked the start and stop time using the mouse, you can scroll left or right through the data without changing the span. To scroll to a later time, use Shift + Left click. To scroll to an earlier time, use Shift + Right click. Double left click to release everything.

The time span indication at the lower right of the graph will turn red to signify that mouse override is in effect.

**Figure 5.5 Graph display**

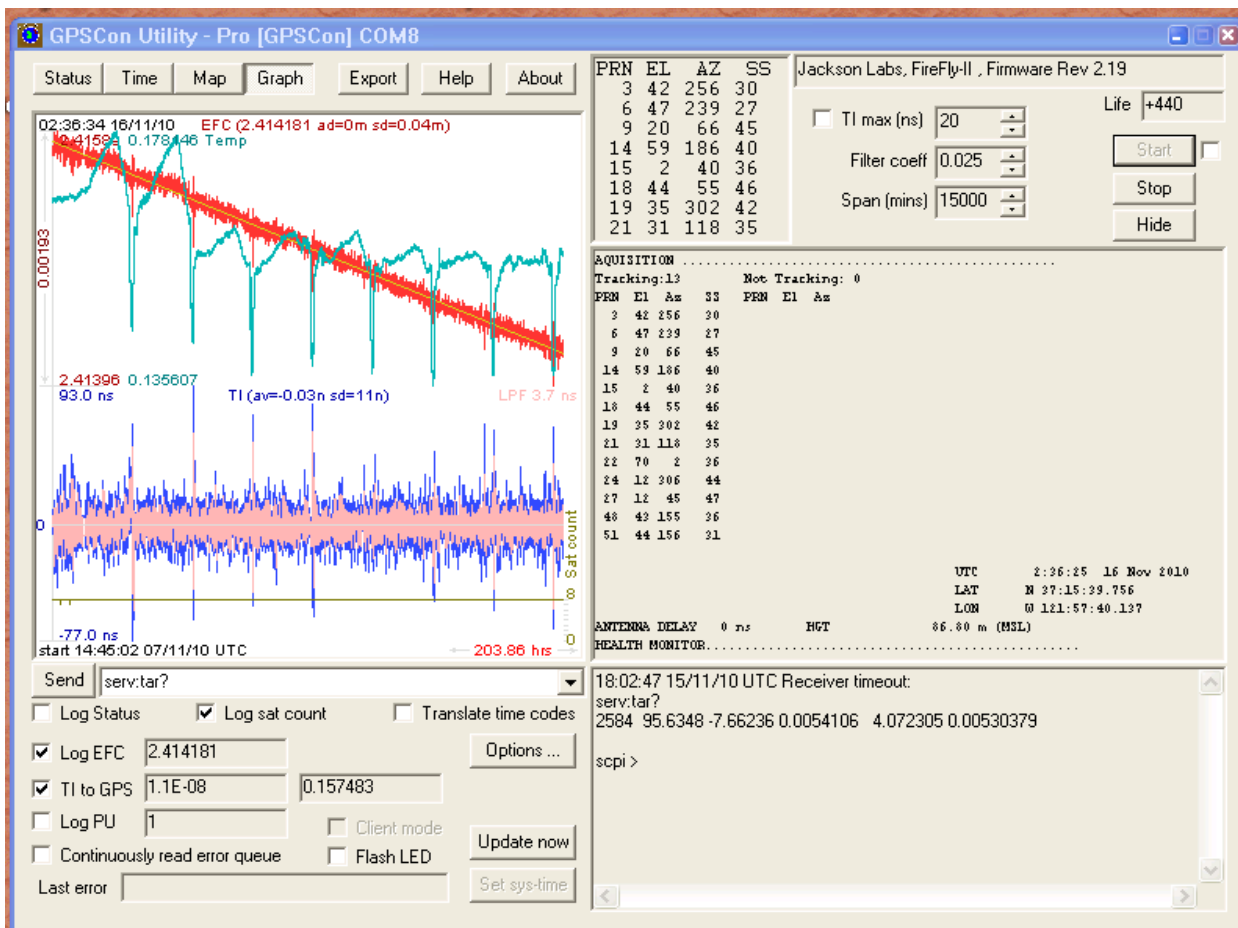


Figure 5.6 Expanded Graph Display



### 5.4.4 Exporting the graphics

The settings which control the mode of the Export function are contained in the Options dialog.

Export allows you to create an image file of either the graph or the satellite map. You select which you want using the radio buttons. If you select 'Graph', you have the option to export only that which is currently visible, or to export the graph which is a plot of the entire logfile contents. Use the checkbox "All" to make this choice.

You may nominate a size in X and Y. The file format may be .BMP, .JPG, .GIF, or .PNG. Your settings will be stored and will be the default next time you open this dialog.

If you choose to export the graph, you might want to override the TI max setting in force on the screen display. You may do this by entering a non-zero value into the 'Override TI' control. A value of zero causes the export to take the same setting if any as the screen display.

The export may be done automatically on a timed basis. Simply enter a non-zero value in seconds to choose an export time interval. To manually export in accordance with the settings, press the 'Export' button.



# 6 Certification and Warranty

## 6.1 Certification

Jackson Labs Technologies, Inc. certifies that this product met its published specifications at time of shipment.

### 6.1.1 Warranty

This Jackson Labs Technologies, Inc. hardware product is warranted against defects in material and workmanship for a period of 1 (one) year from date of delivery. During the warranty period Jackson Labs Technologies, Inc. will, at its discretion, either repair or replace products that prove to be defective. Jackson Labs Technologies, Inc. does not warrant that the operation for the software, firmware, or hardware shall be uninterrupted or error free even if the product is operated within its specifications.

For warranty service, this product must be returned to Jackson Labs Technologies, Inc. or a service facility designated by Jackson Labs Technologies, Inc. Customer shall prepay shipping charges (and shall pay all duties and taxes) for products returned to Jackson Labs Technologies, Inc. for warranty service. Except for products returned to Customer from another country, Jackson Labs Technologies, Inc. shall pay for return of products to Customer. If Jackson Labs Technologies, Inc. is unable, within a reasonable time, to repair or replace any product to condition as warranted, the Customer shall be entitled to a refund of the purchase price upon return of the product to Jackson Labs Technologies, Inc.

### 6.1.2 Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Customer, Customer-supplied software or interfacing, unauthorized modification or misuse, opening of the instruments enclosure or removal of the instruments panels, operation outside of the environmental or electrical specifications for the product, or improper site preparation and maintenance. **JACKSON LABS TECHNOLOGIES, INC. SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR**

**PURPOSE.** No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted by this document. Jackson Labs Technologies, Inc. products are not intended for use in medical, life saving, or life sustaining applications.

### **6.1.3 Exclusive Remedies**

**THE REMEDIES PROVIDED HEREIN ARE THE CUSTOMER'S SOLE AND EXCLUSIVE REMEDIES. JACKSON LABS TECHNOLOGIES, INC. SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.**