LN CSAC GPS Disciplined Oscillator

From Jackson Labs Technologies, acquired by VIAVI Solutions

LN CSAC GPSDO User Manual

Copyright © 2018, Jackson Labs Technologies, Inc.

1 Introduction

1.1 Overview

The LN CSAC GPSDO is based on the popular CSAC GPSDO and the FireFly-IIA GPSDO boards, combining both of these boards onto one single PCB. The LN CSAC GPSDO includes OCXO crystal circuitry to filter phase noise and significantly improve Allan Deviation (ADEV) performance of the CSAC oscillator. The LN CSAC GPSDO combines the very fast warmup and ultra high frequency accuracy of the standard JLT CSAC GPSDO with the very low phase noise and ultra high Allan Deviation (ADEV) performance of the JLT FireFly-IIA board onto one single fully integrated PCB.

The LN CSAC 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 on the CSAC oscillator to be operational, while out-performing many industry-standard Atomic Oscillators. The unit is available with a temperature range of -40° C to +85° C and greater than 100,000 hours MTBF.

To improve phase noise and ADEV performance over the standard CSAC GPSDO, the LN CSAC GPSDO uses an SC-cut single or double oven OCXO as a microprocessor-controlled 10MHz post-filter. The post filter is phase-locked to the raw CSAC oscillator output with a very long time constant (very small bandwidth, in the order of 0.01Hz or less). This assures that the phase noise, and ADEV performance below 100s of the CSAC oscillator is generated and defined by the SC-cut crystal, rather than the low-cost TCXO built into the CSAC oscillator itself. This allows for long-term Cesium stability, with excellent short term stability and phase noise, approaching up to 30dB in noise improvement at 1Hz to 10Hz offsets from the carrier. ADEV at 1s is improved by an order of magnitude or more with this setup.

The LN CSAC GPSDO provides an impressive frequency accuracy, long-term stability, and fast lock with low power consumption. By using a high-end SC-cut crystal oscillator filter, the Jackson Labs Technologies, Inc. LN CSAC GPSDO improves the phase noise and ADEV performance of the unit, and adds an isolated distribution amplifier with four output channels at 10MHz. The LN CSAC GPSDO provides LCD, RS-232 and USB serial links for command and control.

For long term Stratum-1 frequency accuracy and constant calibration the LN CSAC GPSDO includes an extremely high-performance GNSS receiver that can acquire and track up to 72 (50 for uBlox 6 GPS receiver) GNSS signals down to a state of the art –160dBm, a 32-bit processor that runs a Real

Time OS, a low-noise 10MHz distribution amplifier with four highly Isolated 10MHz Sine Wave outputs, one 5MHz CMOS output, one 1PPS UTC synchronized CMOS output, RS-232 and USB control interfaces, and a generic LCD interface. The LN CSAC GPSDO also includes a high-performance time-interval-counter that can measure the internally generated 1PPS signal from the GNSS 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. Software compensation measures residual aging, thermal, and g-sensitivity 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 two serial interfaces allow 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.

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 LN CSAC, the LN CSAC GPSDO 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 LN CSAC. To calibrate these errors out and achieve phase-lock to USNO UTC, the LN CSAC GPSDO uses a GNSS 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 GNSS 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 GNSS receiver is filtered by the CSAC, while the CSAC's long-term drift is removed by the GNSS receiver, resulting in both a very good short-term as well as USNO phase-locked long-term performance.

The 10MHz VCXO used in the CSAC oscillator exhibits phase noise and numerous spurs on the output of the CSAC. A microprocessor-controlled cleanup loop filter based on the JLT FireFly-IIA technology uses the 10MHz output of the CSAC VCXO, and steers a high-end SC-cut crystal oscillator with extremely low phase noise and ultra-high ADEV performance. This digital PLL loop has a time constant of more than 100s, and thus any phase noise and ADEV noise generated by the CSAC oscillator itself below 100s is filtered-out by the SC-cut post-filter. This allows close-in phase noise performance of -100dBc/Hz or better at 1Hz offset, a noise floor of -160dBc/Hz or better, and ADEV performance of 2E-012 from 0.1s to 10s on the highest-performance OCXO options. Three filtered 10MHz output are available, as well as one raw CSAC-generated 10MHz output is made available. The raw CSAC 10MHz output can be used for applications requiring the fasted frequency performance after power-on (120s lock after power-on to much better than 1ppb frequency accuracy) while the three filtered outputs take longer to stabilize as they are produced by an ovenized crystal

oscillator that takes longer to stabilize than the CSAC VCXO itself. A customer's application may use the raw 10MHz output initially after power-on to achieve the best frequency accuracy possible, then switch to the filtered 10MHz output once the ovenized crystal oscillator stabilizes to within customer-defined requirements. The FireFly-IIA software of the OCXO crystal post filter constantly measures the aging and temperature coefficients of the SC-cut crystal oscillator, and compensates for crystal aging and crystal tempco to improve ADEV performance within the loop bandwidth, and initial lock time after power on.

1.3 Dual Independent Microprocessor Controls

The LN CSAC GPSDO is conceptually a combination of the JLT CSAC GPSDO board, connected together with the FireFly-IIA Disciplined oscillator board onto one single PCB. The GPS receiver used on the FireFly-IIA board is removed, and replaced by the CSAC oscillator signal. Dual processors allow independent status query and control of loop parameters and setup functions of both the CSAC oscillator, and the on-board filter OCXO. Thus the LN CSAC board is really a combination of the CSAC GPSDO and the FireFly-IIA board both built into one single fully integrated PCB.

The FireFly-IIA part of the board is connected to the CSAC GPSDO side of the board with only three electrical connections:

1) Shared +12V Power supply

2) 10MHz from the CSAC drives the FireFly-IIA 1PPS reference input

3) LOCK_OK Status of the FireFly-IIA OCXO informs the LN CSAC GPSDO of OCXO status

The CSAC oscillator thus provides 10MHz to the FireFly-IIA circuitry on the PCB as a reference to discipline the internal OCXO to. This 10MHz is divided in an FPLD by 10E+06 to generate a local 1PPS signal, which is then fed into the FireFly-IIA time capture circuitry in lieu of the GPS receiver 1PPS signal. Thus the FireFly-IIA circuitry phase-locks the OCXO to the CSAC-generated 10MHz signal just as it would normally lock the OCXO to the GPS receiver generated USNO 10MHz reference.

The CSAC oscillator in turn is locked to the on-board GPS generated 1PPS signal, and is thus long-term phase-disciplined to the 10MHz USNO master reference oscillator. The result of this cascaded phase lock system is extremely good short- as well as long-term stability, and at the same time extremely good frequency accuracy and stability even in GPS-denied applications by using an internal Cesium Atomic reference.

The frequency accuracy, phase noise, ADEV, and warmup performance of the LN CSAC GPSDO is competitive to, and in many cases exceeds the performance of the highest performance commercial Cesium Frequency References available on the market today at price points, size, weight, and power consumption (SWAP) being typically an order of magnitude lower than these commercially available high-end Cesium Standards.

The FireFly-IIA side of the board provides a LOCK_OK signal (and corresponding Green LOCK OK LED) to the CSAC processor side, and the user may query the lock status of the OCXO through the CSAC-side serial port. The OCXO lock status is indicated in the CSAC Health status query as health item 0x1000 (see the description of the SYNC:HEAlth? status command). The unit will only indicate a fully locked and healthy status (SYNC:HEALTH == 0x0) if both the CSAC and the SC-cut OCXO are deemed locked by their respective control microprocessors.

Three serial control ports are available on the LN CSAC GPSDO: two CSAC GPSDO ports (RS-232 and USB) and one FireFly-IIA RS-232 control port. The FireFly-IIA control port is usually used to configure the OCXO loop bandwidth and warmup parameters, to download firmware into the FireFly-IIA microcontroller, and/or query the status of the OCXO phase locked loop inside the FireFly-IIA system. Most user applications will only use the CSAC GPSDO side serial interfaces as the LOCK OK status of the FireFly-IIA side of the board is available on the LN CSAC GPSDO microprocessor interface as well by using the sync:health? command.

1.4 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.

1.4.1 Use an approved Antenna Lightning Protector

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

1.4.2 Grounding

To avoid damaging the sensitive electronic components in the LN CSAC 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 GNSS antenna.

1.4.3 Power Connections

Make sure to connect the DC power to the device following the polarity indicated in Section 2.4 .

1.4.4 Environmental Conditions

This instrument is intended for indoor use. The use of a properly installed GNSS 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 LN CSAC GPSDO may be powered from an external 11.0V to 14.0V (12V nominal) DC source. Initial power consumption during OCXO warmup can approach 10W, while steady-state power consumption at +25C ambient is typically < 4.5W.

The internal USB port provides a convenient way to establish serial communications to the unit via a standard USB serial link, while the standard RS-232 interface allows serial communications for legacy SCPI and NMEA applications.

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?

2.2 Controlling the unit from a PC's USB port

1) Connect a 5V-compatible GNSS antenna to connector J4.

2) Connect a suitable 12V, 1A low-noise DC power supply to power connector J1.

3) Plug in a standard USB cable to USB connector U14. Plug the other end into a standard USB computer connector.

WARNING: PLEASE MAKE SURE NOT TO CONFUSE POWER CONNECTOR J1 AND LCD CONNECTOR J3 AS THESE TWO CONNECTORS ARE

MECHANICALLY IDENTICAL AND ARE THUS EASY TO CONFUSE. APPLYING POWER TO LCD CONNECTOR J3 WILL SEVERELY DAMAGE THE BOARD.

No software driver is typically required when operating under Windows XP/7/8 or later as Windows has the required USB driver already built-in. The board uses an industry-standard FTDI USB to serial controller, and drivers may be downloaded from the FTDI website if necessary. Once installed, the unit should simply show up as a new Serial Comm Port, and the operator may use Hyperterminal, TeraTerm, GPSCon, or any other serial control software to send commands and query status from the unit. The cost-free Jackson Labs GPSCon software package available on the JLT website support page (see Chapter 5 of this manual) is recommended for monitoring and controlling the unit. The Jackson Labs GPSCon program can be downloaded from the following website:

www.jackson-labs.com/index.php/support

The RS-232 serial port on connector J1 operates in parallel to the USB serial port, and commands can be sent and queried independently to and from both connectors. English language SCPI (GPIB) commands are available to switch the default serial output of the unit from the RS-232 serial port to the USB port and vice-versa, so user applications can use one of the two serial ports for NMEA pushed output sentences, and the other port for SCPI controll commands for example.

The unit will now lock to GPS (Red LED D6 is blinking when satellites are being received) and will indicate proper lock of both the CSAC oscillator AND the on-board OCXO when the Green LED D6 goes on. Once the green LED D6 is on, the unit will output 10MHz and 5MHz on the outputs with significantly better than 1ppb frequency accuracy.

The FireFly-IIA side of the board uses LED D26 to indicate status. The Red LED D26 will start blinking with a 1/2Hz heartbeat as soon as power is turned-on to indicate that the CSAC-generated 10MHz signal is properly being utilized to discipline the on-board OCXO to the CSAC. Once the OCXO is fully warmed-up and disciplined to the CSAC oscillator, LED D26 will start to light up Green while continuing to blink Red.

Please note that LED D6 will not light up green as long as the OCXO lock indicator LED D26 is not lit up. LED D6 indicates system status of both the CSAC oscillator and the OCXO, and both need to be locked and healthy to indicate properly on Green LED D6.

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

2.3 Phase Noise and ADEV Post Filter RS-232 serial port

The FireFly-IIA side of the LN CSAC GPSDO has its own independent RS-232 connector J6 which is typically only used for debugging and experimentation. The FireFly-IIA RS-232 serial port J6 may be used to query the health and status of the on-board OCXO and disciplining phase locked loop. It may also be used to set the loop control parameters of the FireFly-IIA OCXO section of the LN CSAC GPSDO. Please refer to the FireFly-IIA User Manual for a description of the command and control sentences available on connector J6, taking into account that the FireFly-IIA side of the board does not contain a GNSS receiver, and thus all FireFly-IIA GNSS receiver related commands are inactive on connector J6.

In a typical user application, the LN CSAC GPSDO control ports on connectors J1 and U14 are the only serial ports used, and the status of the FireFly-IIA side of the LN CSAC GPSDO board can be queried by using the sync:health? command on connectors J1 and U14.

2.4 Major connections

The major connections and features of the LN CSAC GPSDO PCB are shown in Figure 2.1.

Figure 2.1   Major connections and features of the LN CSAC GPSDO
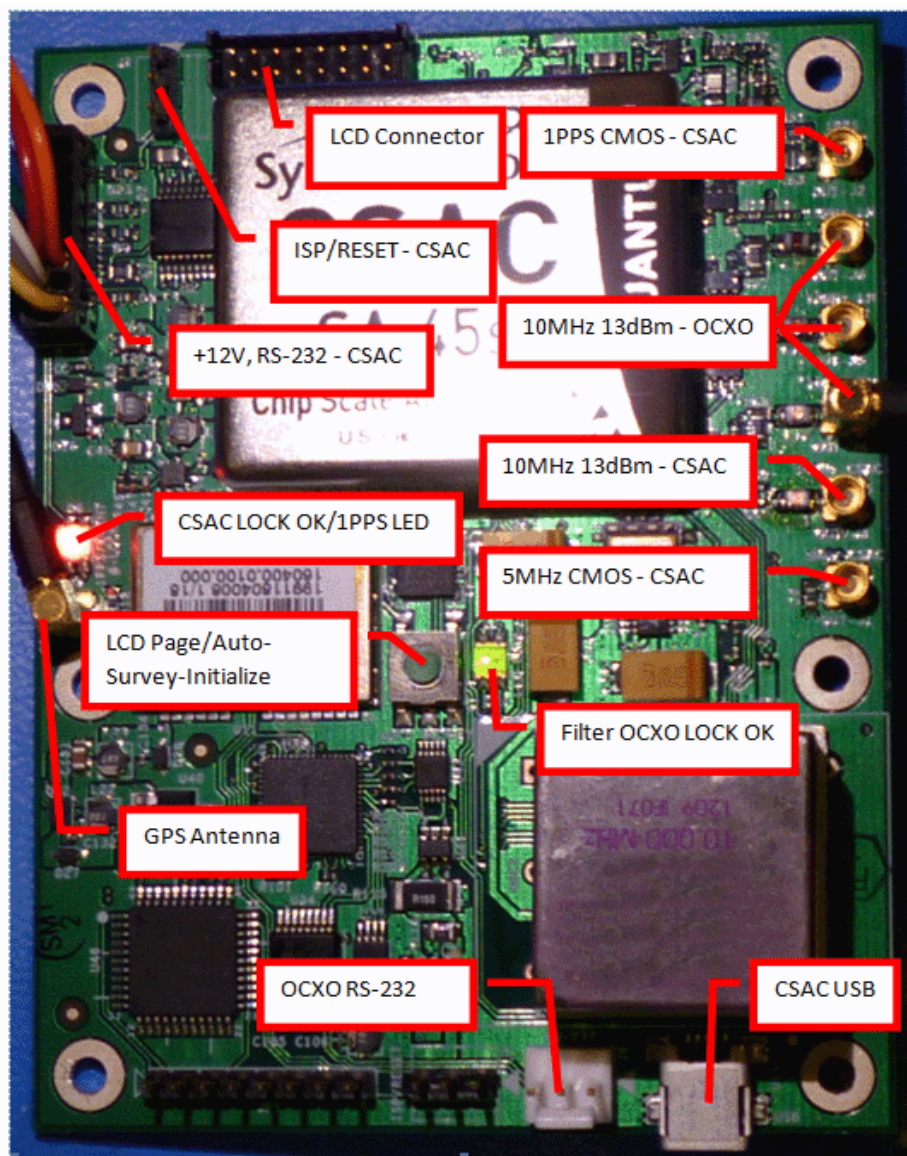
Table 2.1 shows the functions supported on connector J1.

Table 2.1   Connector J1 pinout

Ref	NAME	Function	Specification
J1-1	ISP#	Enter ISP mode	GND pin 1 to activate
J1-2	RST_IN#	Reset the instrument	GND pin 2 to activate

Ref	NAME	Function	Specification
J1-5	LCD_KEY	Cycle through the LCD pages. Initiate Auto-Survey. Wired in paralell with switch S1.	GND momentarily to cycle LCD pages. GND for more than 8 seconds to initiate Auto-Survey.
J1-7	LOCK_OK_OUT	Indicates that no internal events are pending, the hardware is ok, and the CSAC is locked to GPS, and the OCXO is locked to the CSAC oscillator.	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	GPS_RS232	Raw NMEA output from GNSS receiver in RS-232 level format.	RS-232 level
J1-11	PPS_IN	External alternate 1PPS input.	TTL, 3.3V and 5V CMOS compatible.
J1-13	ALARM	Wired in paralell to the Red LED, blinks at 0.5Hz whenever a 1PPS pulse is received.	3.3V CMOS level can drive up to 5mA, series-terminated by 33 Ohms

2.4.1 Harness Pinning

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

Table 2.2   J1 pinout

PIN	NAME
1	ENTER_ISP#
2	RST_IN#
3	GND
4	GND
5	LCD_KEY
6	GND
7	LOCK_OUT_OK
8	RX RS-232
9	TX RS-232
10	GPS_RS232

PIN	NAME
11	PPS_IN
12	GND
13	ALARM
14	GND
15	+12V
16	+12V

Table 2.3 Miscellaneous connectors

Ref	Name	Function	Specification	Pinning
J2	ISP/RESET	ISP/RESET jumper	GND pin 1or 3 to activate	J2-1:ISP; J2-2:GND; J2-3:RST#
J4	Antenna	GNSS Antenna	5V Amplified Antenna, MMCX connector	Center:RF Input; Shield: GND
OUT_J1	5MHz OUT	5MHz output	5V CMOS	Center:RF output; Shield: GND
OUT_J2	1PPS OUT	1pps output	5V CMOS	Center:RF output; Shield: GND
OUT_J3-J6	10MHz OUT	10MHz output	Sine wave, +13dBm (+/3dBm) **N.B.: OUT-J3 is generated by the CSAC oscillator itself, while OUT-J4/J5/J6 are generated by the Noise-Filter SC-cut Crystal OCXO**	Center:RF output; Shield: GND
J6	OCXO RS-232	Serial Port of FireFly-IIA OCXO section of board	RS-232 levels	J6-1: TX, J6-2: GND, J6-3: RX
J7	OCXO ISP	ISP/LOCK OK of FireFly-IIA section of board	OCXO LOCK OK: 3.3V 5mA ISP: GND pin 2 to pin 1 to during power-on to put FireFly-IIA section of board into ISP mode	J7-1: GND, J7-2: ISP, J7-3: OCXO LOCK OK

2.4.2 Harness Connectors J1 and J3

The manufacturer for connectors J1 and J3 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 LN CSAC GPSDO PCB is:

Hirose DF11-16DP-2DSA01

2.4.3 Concurrent-GNSS Capabilities

LN CSAC GPSDO with firmware revision 0.74 and later and uBlox 8 GNSS receiver is capable of simultaneously receiving up to three concurrent GNSS systems at one time. Firmware revision 0.74 and later also supports the LN CSAC GPSDO with uBlox 6 GPS receiver. Concurrent GNSS operation aids performance by allowing reception of up to 72 GNSS satellites in challenged reception areas such as in urban canyons, under foliage, indoors, or close to the earth's poles, etc. Using multiple GNSS systems also increases robustness by not relying on a single GNSS system. Several of the systems operate at different carrier frequencies, so using multiple GNSS systems can increase immunity against jamming which often occurs at only one carrier frequency.

The multiple GNSS systems each have their own reference time and representation of UTC. For example, GPS uses the GPS time standard and provides a method to convert GPS time to UTC as defined by the US Naval Observatory (USNO). GLONASS, Galileo and BeiDou have similar reference times and UTC definitions. The LN CSAC GPSDO with multi-GNSS support automatically adjusts for offsets between the different GNSS time reference standards and synchronizes the 1PPS output to UTC (USNO) when GPS is being received. If GPS is not being received, the 1PPS output is synchronized to the best representation of UTC (USNO) available.

The selection of GNSS systems is made with the GPS:SYST:SEL command as detailed in Section 3.3.31 . Because these systems operate at different carrier frequencies with different bandwidths, it is necessary to use a GNSS antenna that is designed to receive all the required GNSS systems. Please note that the new and emerging Galileo system is now functional, and uses the same carrier frequency as GPS L1, albeit with a wider bandwidth. In our experience Galileo sats can be received with good C/No carrier to noise figures (>40dB) with standard legacy GPS antennae and distribution amplifiers/splitters. JLT thus recommends enabling at a minimum GPS, Galileo, and SBAS concurrently with the command: GPS:SYST:SEL GPS GAL SBAS, see also Section 3.3.31 . Using other GNSS systems such as Glonass will require an antenna system designed to support Glonass signals.

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds better support for legacy GPS receiver by switching the main talker ID to $GP for GGA, JLT GGA, RMC, and ZDA commands. This command allows the LN CSAC GPSDO to output NMEA sentences with navigation and PVT data for GPS only, see Section 3.3.32 for detailed operations and restrictions on talker ID mode.

The internal GNSS receiver can track up to three different GNSS systems and track up to 24 satellites concurrently, such as GPS, Galileo, Glonass, and SBAS at the same time. However only two different carrier frequencies may be received at any given time. So BeiDou and Glonass cannot be enabled concurrently when either GPS, Galileo, SBAS, or QZSS are simultaneously enabled as that would require tracking three different carrier frequencies.

Attempting to configure an invalid combination of GNSS systems or configure GNSS systems on LN CSAC GPSDO without uBlox 8 receiver with the GPS:SYST:SEL command will result in a Command Error response with no change to the configuration.

2.4.4 Connecting the GNSS Antenna

Connect the GNSS antenna to connector J4 using the BNC to MMCX cable adapter. Caution: use a Lightning Arrestor on your Antenna setup. Use an amplified GNSS antenna that is 5V compatible. The LN CSAC GPSDO GNSS (GPS for uBlox 6) receiver is a 72 (50 for uBlox 6 receiver) channel

high-sensitivity multi-GNSS receiver with very fast lock time. The unit can either be used in stationary applications using the automatic self-survey (Auto Survey with Position Hold) feature, or it can be used in mobile platforms. Using Position Hold mode improves timing and frequency accuracy especially in GPS-challenged antenna locations such as under foliage or with strong multipath signals.

The LN CSAC GPSDO 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. These navigation messages may either be sent to the RS-232 serial port or to the USB serial port.

The GNSS 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 LN CSAC 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 GNSS receiver allows operation with a phase stability error of typically less than +/-15 nanoseconds anywhere in the world.

2.4.5 Connecting an LCD Display

An optional, industry standard alphanumeric LCD display may be connected to the unit for displaying status information. LCD's with 16x2 characters are optimal, but 20x2 or 20x4 displays may also work. An example low-cost LCD display is available from www.mouser.com:

Newhaven Display PN: NHD-0216K1Z-NSW-BBW-L

The connector drives the LCD directly, and the 5V pin can also be used to drive the LCD's backlighting. Contrast of the LCD is adjusted via software command.

Figure 2.2 shows the mechanical connections. A schematic showing the connections from the LN CSAC GPSDO to the LCD panel is shown in Figure 2.3.

Figure 2.2   LCD display connection

Table 2.4   LCD connector J3 pinout

PIN	NAME
1	CONTRAST

PIN	NAME
2	+5V
3	GND
4	LCD_RS
5	For factory use only
6	LCD_RDWR
7	For factory use only
8	LCD_ENABLE
9	For factory use only
10	LCD_DATA4
11	For factory use only
12	LCD_DATA5
13	For factory use only
14	LCD_DATA6
15	For factory use only
16	LCD_DATA7

Figure 2.3   LCD display connections
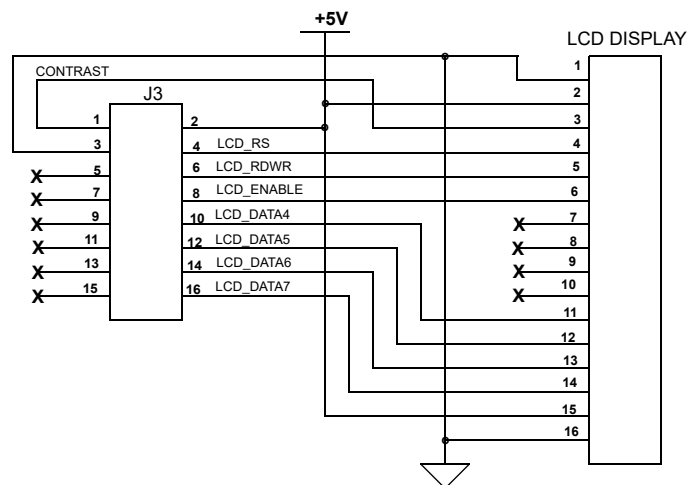
The Power and Ground symbols in Figure 2.3 are for reference only. 5V Power on connector J3 is available to drive the LCD display and its backlight only.

2.4.5.1 LCD Key

The LCD Key is activated by pressing S1 on the PCB (see Figure 2.1), or by grounding J1 pin 5. Momentarily activating the key cycles through the LCD display pages described in Section 2.4.5.2 . The LCD page can also be selected with the SYSTem:LCD:PAGE SCPI command. The last page displayed is remembered in NVRAM, and will be shown upon power up.

Activating the key for 8 seconds initiates the Auto-Survey and starting with firmware revision 0.71, switches the LCD to the Survey status display page. The Auto-Survey can also be initiated with the GPS:SURVey ONCE SCPI command.

2.4.5.2 LCD Display Pages

Following are the LCD display pages:

- **Time/Date**: (Figure 2.4) This page shows the time, date, number of tracked Satellites, and the lock status (PH = Position Hold mode)

Figure 2.4   Time/Date display page

- **GNSS Position**: (Figure 2.5) This page shows the GPS coordinates of the antenna position

Figure 2.5   GNSS position display page

- **GPS Height**: (Figure 2.6) This page shows the height in MSL of the GNSS antenna, as well as the operating mode (HOLD Position Hold mode)

Figure 2.6   GPS height display page

- **CSAC Steering**: (Figure 2.7) This page shows the internal ALARM indication of the CSAC oscillator itself. 0x0 indicates normal operation. Also shows the CSAC Oscillator steering offset required to maintain UTC lock, which is normalized to 1E-012 offsets. The CSAC steering offset is programmed into the CSAC oscillator NVRAM once every 24 hours, at which point the offset is set to "0" again. This allows the CSAC oscillator to power-on with the last internal offset stored in NVRAM, effectively storing the calibration parameter inside the CSAC oscillator once per day.

Figure 2.7   CSAC steering display page

- **CSAC Status**: (Figure 2.8) This page displays the following Cesium Vapor Cell status: Laser Current (LI), Cell Temperature (in ° C), and TCXO Steering Voltage (0V to 3.3V). The TCXO is locked to the Cesium Vapor Cell via a Phase Locked Loop, and generates the 10MHz output frequency.

Figure 2.8   CSAC status display page

- **TINT:** (Figure 2.9) TINT is the time interval offset between the internal CSAC oscillator phase, and UTC as generated by the GNSS receiver. It is displayed in nanoseconds. The PLL control loop will try to zero this offset over time as the unit follows UTC at NIST in Colorado via the Satellite transmissions. FEE indicates the Frequency Error Estimate, which is a unit-less number, and is estimated by comparing the UTC phase offset from 1000 seconds ago to the present phase offset. This is similar to the Allan Deviation number for a measurement interval of 1000 seconds. Smaller numbers are better, but numbers below 1E-012 are below the noise floor of the instrument. A number of 4E-012 for example can be loosely interpreted to be a phase drift of the 10MHz and 1PPS outputs of 4 picoseconds per second averaged over 1000 seconds as compared to the UTC master clock at NIST in Colorado.

Figure 2.9   TINT display page

- **Navigation**: (Figure 2.10) This page displays the following Navigation status: Course (in degrees), Speed (knots), operating mode, and altitude (feet).

Figure 2.10 Navigation display page

- **GPS/UTC Time**: (Figure 2.11) This page displays the following UTC/GPS Time information: UTC time (hh:mm:ss), GPS time (hh:mm:ss) and leapsecond offset (seconds).

Figure 2.11 GPS/UTC Time display page

- **Survey status**: (Figure 2.12) This page displays the status (NOT ACTIVE, ACTIVE or VALID), duration (seconds) and variance (mm^2) of the position survey.

Figure 2.12 Survey status display page

2.5 Loop parameter adjustment

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings for the CSAC to accommodate different mission scenarios (stationary versus mobile, steady state operation versus power cycling, etc.). These time constants determine the behavior of the unit during steady state operation, and when a frequency error is induced into the CSAC by adverse environmental effects such as tilt/shock of the unit, or due to thermal shocks. See Section 3.10.2 for details in configuring different loop time constant settings.

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. Table 2.5 shows the recommended loop time constants for LN CSAC GPSDO.

Table 2.5 Recommended Loop Settings

Usage	Normal Time Constant	Fast Time Constant
Loop Behavior	benign	aggressive
SERV:EFCS	0.6	2.0
SERV:PHASECO	1.2	10.0
SERV:EFCD	10	5

The commands to control the loop time constants are part of the SERVo? command. See also the SERVO Subsystem Section 3.10 .

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 0.6 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 5 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 LN CSAC GPSDO 1PPS signal and the UTC 1PPS signal as generated by the GNSS 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 2.13 when experiencing small externally stimulated frequency perturbations.

Figure 2.13 LN CSAC GPSDO phase compensation plot

2.6 Performance graphs

Figure 2.14 shows the typical Allan Deviation of the LN CSAC GPSDO with single oven OCXO in a thermally stable environment. Long-term GPS-locked ADEV performance approaches 1E-013 per day.

Figure 2.14 Typical Allan Deviation of LN CSAC with single oven OCXO option

© 2018 Jackson Labs Technologies, Inc.
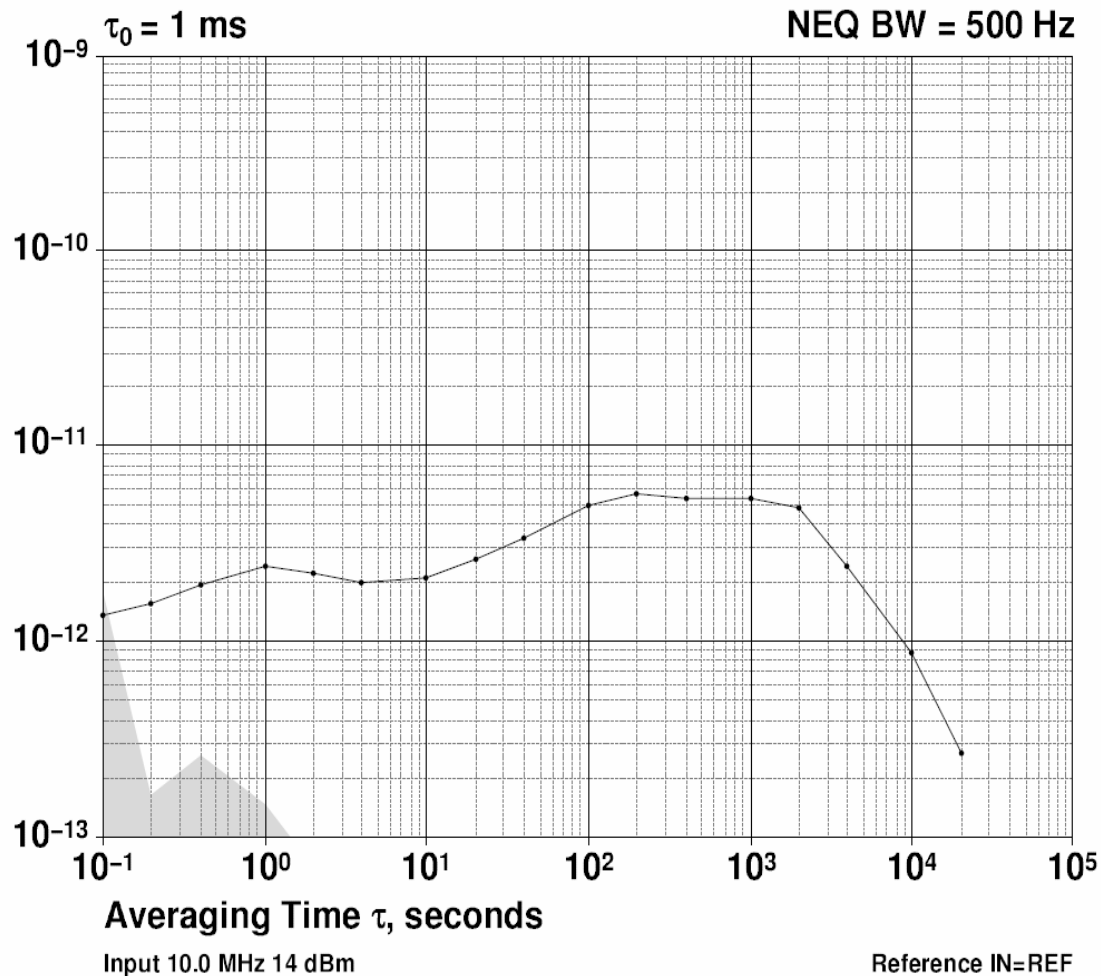
Figure 2.15 shows that the Allan Deviation of the free running CSAC unit bypassing the OCXO ADEV filter (GPS holdover, no GNSS antenna is attached) is quite good, approaching 5E-012 over 100,000 seconds in this typical plot. Notice the increased short term stability noise below 1000s averaging intervals as this 10MHz output bypasses the OCXO ADEV filter.

Figure 2.15 Allan Deviation of free running CSAC, measured at CSAC 10MHz output
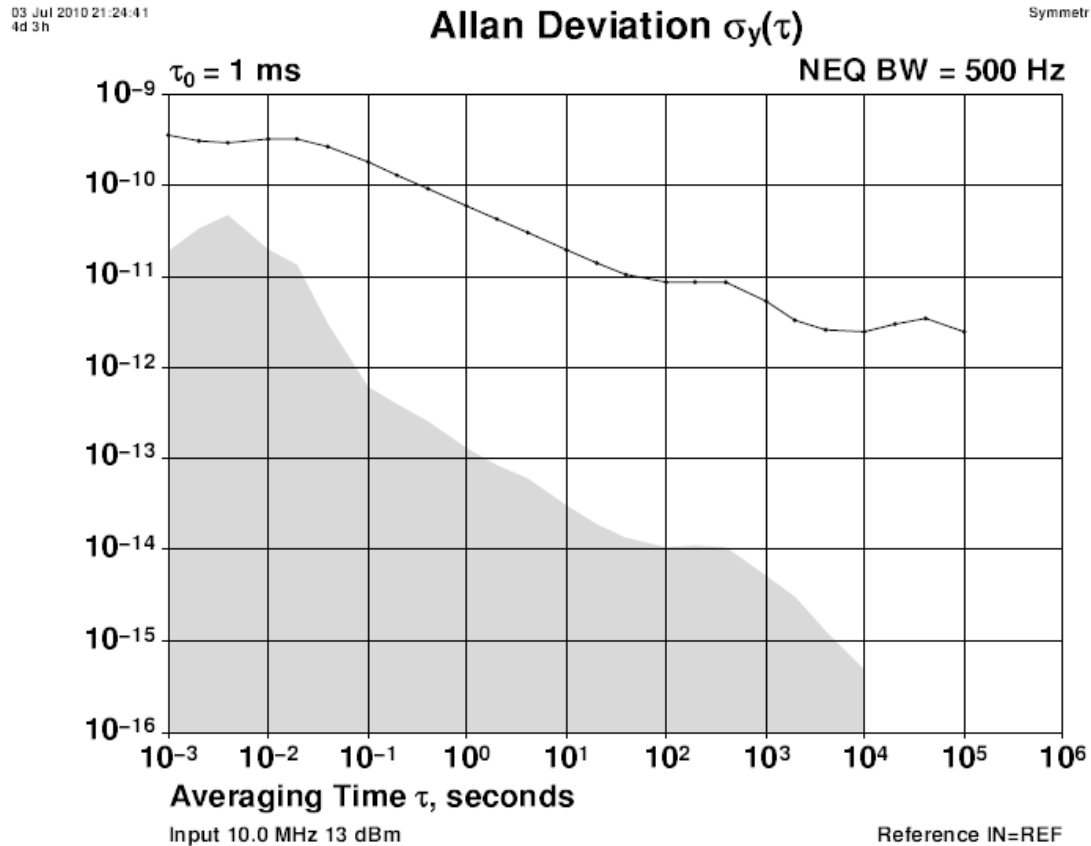
As shown in Figure 2.16, the Phase Noise of a typical LN CSAC GPSDO unit shows a noise floor of about -160Bc/Hz, with few spurs, most of which are 60Hz power supply related.

Figure 2.16 Typical Phase Noise of the LN CSAC GPSDO with DOCXO option

Trace	Notes	Input Freq	Sample Interval	dBc/Hz at 300 Hz	Duration	Acquired	Instrument
10Mhz (Unsaved)		10.000 MHz	0.010 s		2h 0m 0s	720000 pts	TimePod 5330A
10Mhz (Unsaved)		10.000 MHz	0.010 s	−156.8	3m 11s	19114 pts	TimePod 5330A
10Mhz (Unsaved)		10.000 MHz	0.010 s				TimePod 5330A
10Mhz (Unsaved)		10.000 MHz	0.010 s		1m 5s	6486 pts	TimePod 5330A
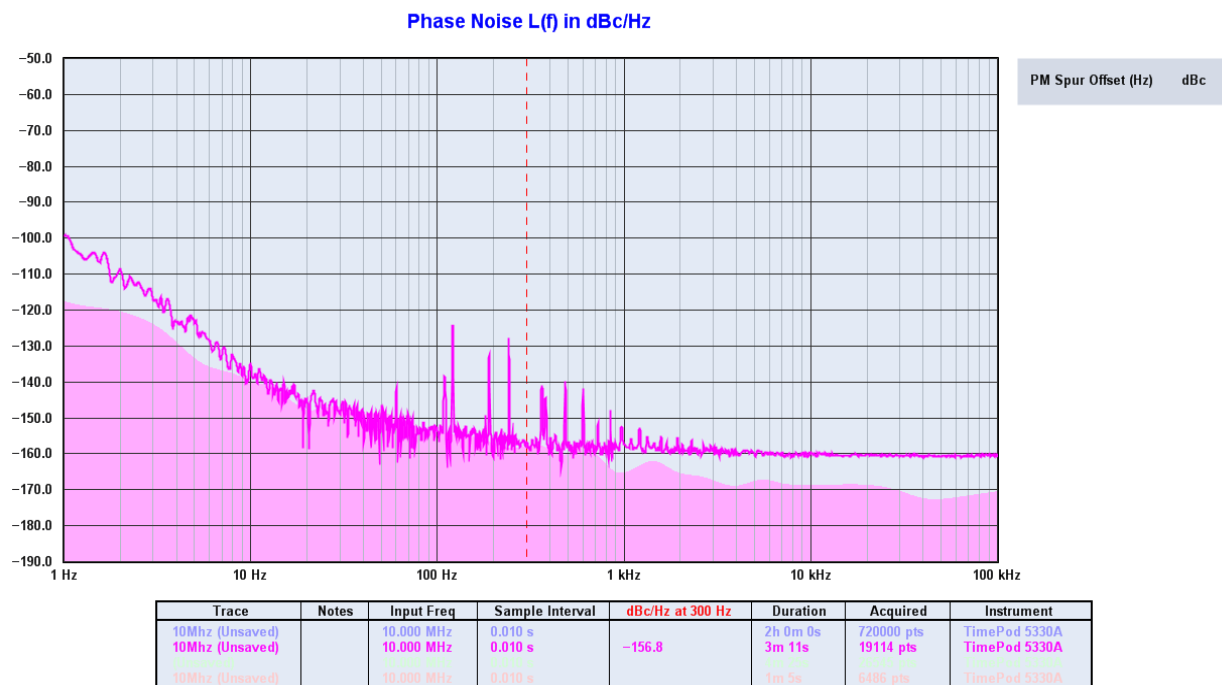
3 SCPI-Control Quick Start Instructions

3.1 Introduction

The LN CSAC GPSDO has three serial ports that can be used simultaneously for accessing the SCPI (**S**tandard **C**ommands for **P**rogrammable **I**nstrumentation) subsystem by using a host system terminal program such as TeraTerm or Hyperterminal. By default the terminal settings are 115200, 8N1, no flow-control.

Two of these serial ports (J1, U14) are connected to the CSAC GPSDO microprocessor, and the third RS-232 serial port (J6) is connected to the internal FireFly-IIA microprocessor.

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 LN CSAC GPSDO.

Additional information regarding the SCPI protocol syntax can be found on the following web site:

> http://www.ivifoundation.org/scpi/

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:

> **SYST:STAT?**
>
> **HELP?**
>
> **GPS?**
>
> **SYNC?**
>
> **DIAG?**

3.2 General SCPI Commands

The following command summary is valid for the CSAC GPSDO serial interfaces J1 and U15. The LN CSAC GPSDO board also contains a built-in FireFly-IIA microprocessor interface (J6) for

control of the OCXO disciplining process, please see the JLT <u>FireFly-IIA User Manual</u> for a review of the command syntax on the FireFly-IIA serial interface J6 as this is typically only used during the debugging and evaluation phase of the LN CSAC GPSDO.

3.2.1 *IDN?

This query outputs an identifying string. The response will show the following information:

> <model number>, <firmware revision>

3.2.2 HELP?

This query returns a list of the commands available for the LN CSAC GPSDO.

3.3 GPS Subsystem

Note: Please note that LN CSAC GPSDO 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 GNSS 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 <int> [0,255]
>
> GPS:GNGGA <int> [0,255]
>
> GPS:GGAGNSTat <int> [0,255]
>
> GPS:GNRMC <int> [0,255]
>
> GPS:GNZDA <int> [0,255]
>
> 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:SYSTem:SELect [GPS | SBAS | QZSS | GAL | BD ^ GLO]

GPS:NMEA:TALKid <GP | GN>

GPS:NMEA:SVNum <GP | GN>

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 commands allow the LN CSAC GPSDO to be used as an industry standard navigation GNSS receiver. The GGA, GSV, RMC, ZDA and PASHR 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 LN CSAC GPSDO RS-232 interface.

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

To indicate the GNSS systems enabled and available to generate the NMEA data, the LN CSAC GPSDO's NMEA output includes a two character talker ID before the GGA, GLL, RMC, GSA, GSV, and ZDA sentence headers. Table 3.1 shows the talker IDs for the supported GNSS systems. If more than one GNSS system is enabled and NMEA talker ID is set to GN, the talker ID of NMEA output

is GN except for the GSV sentence which outputs multiple sets of sentences for each talker ID. See Section 3.3.32 for details in NMEA talker ID mode configuration. Also, the GSV output uses a modified satellite numbering scheme as detailed in Table 3.1 to allow all different GNSS system satellites to be differentiated.

Please note that the position, direction, and speed data is delayed by one second from when the GNSS receiver internally reported these to the LN CSAC GPSDO 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 NMEA command settings 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 specifies the communication port where the NMEA messages will be sent.

3.3.5 GPS:PORT?

This query returns the port where the NMEA messages are sent.

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

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

This command instructs the LN CSAC GPSDO 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 CSAC warm-up phase.

This command has the following format:

GPS:GPGGA <int> [0,255]

The GPGGA string has the following data format:

$GPGGA,hhmmss.00,llll.llll,S/N,yyyyy.yyyy,W/E,f,ss,hh.h,aa.a,M,gg.g,M,,*[checksum]

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 <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

This command instructs the LN CSAC GPSDO 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 CSAC warm-up phase.

This command has the following format:

GPS:GGASTat <int> [0,255]

The GGASTat string has the following data format:

$GPGGA,hhmmss.00,llll.lllll,S/N,yyyyy.yyyy,W/E,l,ss,hh.h,aa.a,M,gg.g,M,,*[checksum]

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 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 <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

This command instructs the LN CSAC GPSDO 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 CSAC warm-up phase.

This command has the following format:

GPS:GPRMC   <int> [0,255]

The GPRMC string has the following data format:

$GPRMC,hhmmss.00,s,llll.lllll,S/N,yyyyy.yyyy,W/E,k.k,d.d,ddmmyy,,*[checksum]

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

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

This command instructs the LN CSAC GPSDO 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 CSAC warm-up phase.

This command has the following format:

GPS:GPZDA   <int> [0,255]

The GPZDA string has the following data format:

$GPZDA,hhmmss.00,dd,mm,yyyy,+00,00*[checksum]

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

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

GPS:GPGSV <int> [0,255]

LN CSAC GPSDO with firmware revision 0.74 and later and uBlox 8 GNSS receiver is capable of simultaneously receiving up to three concurrent GNSS systems and tracking up to 24 satellites at one time. When multiple GNSS systems are enabled in Section 3.3.31 and talker ID mode is configured to GN in Section 3.3.32 , multiple GSV sentences with different talker ID listed in Table 3.1 will be outputted.

For example, if GPS:SYST:SEL GPS SBAS GAL GLO command is sent and talker ID mode is GN, this command will have the following output format:

$GPGSV,x,x,ss,nn,ee,aaa,ss,...*[checksum]

$GLGSV,x,x,ss,nn,ee,aaa,ss,...*[checksum]

$GAGSV,x,x,ss,nnn,ee,aaa,ss,...*[checksum]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode to GP for GSV command where only $GPGSV (i.e., no $GLGSV, $GAGSV, or $GBGSV) string will be outputted for GPS, SBAS, and QZSS. See Section 3.3.33 for more details on merging satellite information for other GNSS systems in $GPGSV sentence.

Table 3.1 PRN numbering scheme for GNSS systems

GNSS Type	SV Range	GPGSV PRN vehicle numbering	Talker ID
GPS	G1-G32	1-32	GP
SBAS	S120-S158	33-64,152-158	GP
Galileo	E1-E36	301-336	GA
BeiDou	B1-B37	401-437	GB
IMES	I1-I10	173-182	GP
QZSS	Q1-Q5	193-197	GP
GLONASS	R1-R32, R?	65-96,0	GL

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

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,eeeee.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 LN CSAC GPSDO 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 CSAC warm-up phase.

This command has the following format:

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

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

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:GNGGA <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

Similar to the GPS:GPGGA command. This command instructs the LN CSAC GPSDO to send the NMEA standard string $GNGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute CSAC warm-up phase.

This command has the following format:

GPS:GNGGA <int> [0,255]

The GNGGA string has the following data format:

$GNGGA,hhmmss.00,llll.lllll,S/N,yyyyy.yyyy,W/E,f,ss,hh.h,aa.a,M,gg.g,M,,*[checksum]

GNGGA 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.

3.3.14 GPS:GGAGNSTat <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

Similar to the GPS:GGASTat command.This command instructs the LN CSAC GPSDO to send a modified version of the NMEA standard string $GNGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 2 minute CSAC warm-up phase.

This command has the following format:

GPS:GGAGNSTat <int> [0,255]

The GGAGNSTat string has the following data format:

$GNGGA,hhmmss.00,llll.lllll,S/N,yyyyy.yyyy,W/E,l,ss,hh.h,aa.a,M,gg.g,M,,*[checksum]

This command replaces the regular NMEA GGA validity flag with a decimal number indicating the lock-state of the unit. Please see Section 3.10.12 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 CSAC performance.

GGAGNSTat 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.

3.3.15 GPS:GNRMC <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

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

This command has the following format:

GPS:GNRMC <int> [0,255]

The GNRMC string has the following data format:

$GNRMC,hhmmss.00,s,llll.llll,S/N,yyyyy.yyyy,W/E,k.k,d.d,ddmmyy,,*[checksum]

3.3.16 GPS:GNZDA <int> [0,255]

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

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

This command has the following format:

GPS:GNZDA <int> [0,255]

The GNZDA string has the following data format:

$GNZDA,hhmmss.00,dd,mm,yyyy,+00,00*[checksum]

3.3.17 GPS:DYNAMic:MODE <int> [0,7]

This command allows the user to select the dynamic motion model being applied to the Kalman filters in the GNSS 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 GNSS receiver 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 LN CSAC GPSDO will select a stationary GNSS dynamic model for example:

GPS:DYNAM:MODE 1

The following table lists all available modes:

Table 3.2 Supported Dynamic GNSS Operating 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 LN CSAC GPSDO uses a GNSS receiver that is capable of running in a stationary mode with Position Auto Survey called Position Hold Mode. This mode increases timing stability by storing the position into memory, and solving the GNSS signal only for time as the position is not expected to change. Two modes can be selected for Auto Survey operation (see Section 3.3.23 for a description of the GPS:TMODE command):

   1) Manually setting Timing Mode to ON with a hard-coded position in NV memory

   2) Enabling Auto Survey to start automatically after power-on by setting Timing Mode to RSTSURV

If either one of the above two GPS:TMODE Auto Survey/Position Hold modes is selected, the GPS:DYNAMic:MODE command is disabled internally and its setting is ignored as the unit does not expect any motion on the antenna. In this case, the dynamic state as programmed into the GNSS receiver is set to STATIONARY independent of the user selection for GPS:DYNAMic:MODE.

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

GPS:DYNAMic:STATE?

Please note that this command syntax has changed from previous products such as the FireFly-IIA GPSDO units which did not support Position Hold Auto Survey modes.

3.3.18 GPS:DYNAMic:MODE 8 (Automatic Dynamic Mode)

Automatic Dynamic Mode allows the LN CSAC GPSDO firmware to automatically configure the GNSS receiver Kalman filter parameters based on actual mission velocities and motion profiles. The unit will try to set the GNSS receiver to the optimal setting for any given velocity. The unit is able to set 7 different modes, as shown in Section 3.3.17 .

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

Table 3.3   Auto Dynamic Mode Switching Rules

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 GNSS receiver 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 GNSS dynamic model:

> GPS:DYNAMic:MODE?

The actual state chosen by the firmware for the GNSS receiver 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.

The dynamic state is always set to STATIONARY if one of the Position Hold Auto Survey stationary modes is selected using the command GPS:TMODE, as the Position Hold mode setting overrides any dynamic state user setting.

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

3.3.19 GPS:DYNAMic:STATe?

This query returns the actual state of the dynamic model, chosen by the firmware to be applied to the GNSS receiver depending on vehicle velocity. It returns a value between 0 and 7, which correspond to one of the dynamic models defined in Table 3.3.

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 GNSS receiver depending on actual vehicle dynamics
- if the GNSS Timing Mode is set to ON or to RSTSURV, the dynamic state will always be set to 1 (Stationary)

3.3.20 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 GNSS 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 CSAC for a 0.0ns offset to the UTC 1PPS time-pulse.

3.3.21 GPS:REFerence:PULse:SAWtooth?

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

3.3.22 GPS:RESET ONCE

Issues a reset to the internal GNSS receiver. This can be helpful when changing the antenna for example, since the GNSS 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.

3.3.23 GPS:TMODe <ON | OFF | RSTSURV>

This command selects the Timing Mode of the GNSS receiver.

If the Timing Mode is OFF, the receiver will act as a regular GNSS receiver. This mode has to be chosen if the unit is mobile.

If the Timing Mode in ON, the timing features of the GNSS receiver are enabled. At power-up, the Hold position stored in NV memory will be sent to the GNSS receiver and will be used as the reference. In order to use this mode, the receiver position must be known as exactly as possible. Errors in the Hold position will translate into time errors depending on the satellite constellation.

The Hold position can be set manually by the user or can be the result of a Survey executed by the GNSS receiver.

If the Timing Mode is RSTSURV, the GNSS receiver will start a Survey every time the unit is powered-on and following the Survey, the GNSS receiver will run with the timing features enabled.

3.3.24 GPS:SURVey ONCE

This command starts a Survey. At the end of the Survey, the calculated Hold position will be stored in NV memory. The Survey parameters can be set with the command **GPS:SURVey:DURation** and **GPS:SURVey:VARiance**

3.3.25 GPS:SURVey:DURation <sec>

This command sets the Survey minimal duration.

3.3.26 GPS:SURVey:VARiance <mm^2>

This command specifies the minimum variance of the average position computed during the Survey. This minimum value is used as a threshold under which the GNSS receiver can stop the Survey. The GNSS receiver will stop the Survey when the minimal duration has been reached and the variance of the average position is under the specified minimum variance.

3.3.27 GPS:HOLD:POSition <cm, cm, cm>

This command allows the user to specify manually the exact position of the antenna. This command will overwrite the Hold position in NV memory. Subsequent Survey will overwrite also the Hold position. The Hold position is stored in ECEF coordinates

3.3.28 GPS:SURVey:STATus?

This query displays the current status of the survey. The status of the survey is in one of the 3 states:

ACTIVE : a survey is in progress

VALID : a survey has been achieved successfully and the GNSS receiver is now using this Hold position as reference.

INVALID : no survey are in progress or have been achieved since the last power cycle.

When in ACTIVE or VALID state, this query will also display the duration, the Hold position in ECEF coordinates and the position variance .

3.3.29 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 GNSS 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 CSAC 10MHz signal, and thus has very high accuracy.

3.3.30 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 GNSS 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 CSAC 10MHz signal, and thus has very high accuracy.

3.3.31 GPS:SYSTem:SELect [GPS | SBAS | QZSS | GAL | BD ^ GLO]

LN CSAC GPSDO with firmware revision 0.74 and later and uBlox 8 GNSS receiver is capable of simultaneously receiving up to three concurrent GNSS systems at one time. Firmware revision 0.74 and later also supports the LN CSAC GPSDO with uBlox 6 GPS receiver. This command selects the GNSS systems that are enabled in the GNSS receiver and are used to generate the timing and positioning information for the NMEA data, and to generate the 1PPS reference for the GPSDO. The command is followed by a list of the shortened names of the GNSS systems to enable. The shortened names of supported GNSS system include GPS, SBAS, QZSS, BD (BeiDou), GAL (Galileo) and GLO (GLONASS). Please see Section 2.4.3 for restrictions on the concurrent GNSS systems that can be enabled. Configuration with invalid combinations of GNSS systems or LN CSAC GPSDO without uBlox 8 receiver will result in a Command Error response and no change to the configuration.

The following example command will enable GPS, SBAS, Galileo and GLONASS all concurrently:

> GPS:SYST:SEL GPS SBAS GAL GLO

The following command will query the currently enabled GNSS systems:

> GPS:SYST:SEL?

The LN CSAC GPSDO with uBlox 8 receiver will respond to the query with the list of enabled GNSS systems such as:

> GPS SBAS GAL GLO

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands. See Section 3.3.32 for detailed operations and restrictions on talker ID mode.

3.3.32 GPS:NMEA:TALKid <GP | GN>

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode between GP and GN for GGA, JLT GGA, RMC, and ZDA commands.

This command has the following format and changed setting will be applied immediately to the CSAC GPSDO, and is stored in NV memory:

> GPS:NMEA:TALKid <GP | GN>

The following command returns the NMEA talker ID mode stored in NV memory:

> GPS:NMEA:TALKid?

Sending command with invalid parameter or LN CSAC GPSDO without uBlox 8 receiver will result in a Command Error response and no change to the configuration.

Several rules are applied when switching between GN and GP talker ID mode:

• The $GNxxx NMEA string is equivalent to corresponding $GPxxx NMEA string except for the main talker ID $GN at the header.

• Sending GPS:NMEA:TALK GP command or any of the GPxxx commands will change the talker ID mode to GP for all GGA, JLT GGA, RMC, and ZDA commands with any combination of GNSS systems enabled in Section 3.3.31 .

- If talker ID mode is GN and only one GNSS system is enabled (i.e., GPS|SBAS|QZSS only, or Galileo only, or GLONASS only, or BeiDou only), the corresponding GNSS-specific talker ID listed in Table 3.1 will be used.
- Sending GPS:NMEA:TALK GN command or any of the GNxxx commands will change the talker ID mode to GN for all GGA, JLT GGA, RMC, and ZDA commands when more than one GNSS system is enabled.
- If talker ID mode is GP, the GSV command will only contain the satellite information for GPS, SBAS, and QZSS only, if available. To include satellite info from other GNSS systems in $GPGSV string, GPS:NMEA:SVNum GN command discussed in Section 3.3.33 can be used.

The GPS:NMEA:TALK GP and GPxxx commands are useful for environment with poor GPS reception with multiple concurrent GNSS systems enabled to output valid navigation and PVT data for GPS system. Please see Section 2.4.3 for details of merits in concurrent GNSS systems.

For example, the following commands can be used for enabling GPS, SBAS and Galileo at the same time but outputting GGA and RMC sentences every one second with talker ID $GP at the header:

> GPS:SYST:SEL GPS SBAS GAL
>
> GPS:GPGGA 1
>
> GPS:GPRMC 1

3.3.33 GPS:NMEA:SVNum <GP | GN>

LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 GNSS receiver adds support for switching the talker ID mode to GP for GSV command where only $GPGSV (i.e., no $GLGSV, $GAGSV, or $GBGSV) string will be outputted for GPS, SBAS, and QZSS.

This command allows the LN CSAC GPSDO to include all available satellite information for GPS, SBAS, QZSS, Galileo, GLONASS, and BeiDou in $GPGSV string when the talker ID mode is set to GP in Section 3.3.32 . The default mode for this command is GP which excludes satellite information for GNSS systems other than GPS, SBAS, and QZSS.

This command is effective only when the talker ID mode is GP meaning that GSV command will have GNSS-specific talker ID listed in Table 3.1 for each GNSS system enabled if talker ID mode is GN.

This command has the following format:

> GPS:NMEA:SVNum <GP | GN>

If talker ID mode is GP, sending GPS:NMEA:SVN GN command will include all satellites in view in multiple $GPGSV sentences for up to 24 satellites.

3.3.34 GPS:JAMlevel?

Firmware revision 0.57 and later adds support for a GNSS signal jamming-indicator. The GNSS 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.

3.3.35 GPS:FWver?

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

3.3.36 GPS?

This query displays the selected GNSS systems and NMEA talker ID for LN CSAC GPSDO with firmware revision 0.75 and later and uBlox 8 receiver, configuration, position, speed, height and other relevant data of the GNSS receiver in one convenient location.

3.4 GYRO SUBSYSTEM

The following Gyro commands are supported:

> 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?
>
> GYRO?

3.4.1 GYRO:MODE <ON | OFF>

Enables or disables electronic compensation. This feature must be calibrated at the factory before it can be used.

The following command returns the status of compensation setting:

> GYRO:MODE?

3.4.2 GYRO:TRAce <int> [0,255]

This command sets up the output period of the Accelerometer data (in g's per axis, and in tilt in Degrees per axis). The fastest period is 50ms (20 outputs per second) achieved when setting the command to GYRO:TRAce 1. The resolution of this command is 1/20 of a second. Setting the command to 0 disables the Accelerometer output.

This command has the following format:

> GYRO:TRAce <int> [0,255]

The following command returns the setting of the period:

> GYRO:TRAce?

The output of the system is in six floating point numbers: the acceleration on the X, Y, and Z axis in g's, and the Tilt of the X, Y, and Z axis in Degrees (-90 to +90).

Please note that the Accelerometer has its best resolution and accuracy when the earth's gravitational acceleration is perpendicular to the axis to be measured. Thus the sensors accuracy and resolution will be best when the tilt of any axis is around 0 Degrees. The worst performance (with an accuracy of only ~ +/-5 Degrees) is when any of the axis are at their +/- 90 Degree angles, this is due to the fact that a SIN(g-load) calculation is done to generate the output normalized to Degrees, and the vector is thus least sensitive at +/- 90 Degree angles.

Acceleration can be measured with up to +/-3g range on all three axis. Please note that since the tilt angle is calculated from the acceleration vectors (using gravity) that the tilt angles will actually exceed +/-90 Degrees when acceleration greater than 1g is applied.

3.4.3 GYRO:PORT   <RS232 | USB>

This commands specifies the communication port where the GYRO traces will be sent.

3.4.4 GYRO:PORT?

This query returns the port where the GYRO traces are sent.

3.4.5 GYRO:CALibrate <float,float,float,float,float,float>

This command is used to manually calibrate the gain and offset of the Accelerometer output. Both offset and gain need to be calibrated on the unit to properly format the output of the three axis tilt to be -90 Degrees to +90 Degrees, and the 0 Degree reference.

By default, the unit is shipped with a normalized output of 0 Degrees Offset, and a gain of 1.0, and the user will need to calibrate their unit in their system.

This command has the following format:

> GYRO:CALibrate <float>, <float>, <float>, <float>, <float>, <float>

Calibration is accomplished by slowly tilting the unit on all six axis and measuring the maximum and minimum tilt indications in all six axis, and writing these down on a piece of paper to calculate the calibration values. See also the GYRO:CALibrate:COMPute command for a semi-automated calibration method.

Example: if the result for say the X axis is -87 Degrees to +93 Degrees, then we need to remove an offset of +3 Degrees from the X axis while the gain of the X axis is properly set. We would thus send the following calibration command to the unit:

> GYRO:CAL -3, 0, 0, 1, 1, 1

This will remove a 3 Degree offset from the X Axis, and keep the Y and Z axis without offset or gain adjustments.

After the Offset is removed, we may have to adjust the gain of the axis sensor. For example if the range of the X Axis output is -82 Degrees to +78 Degrees then the axis has both an offset of 2 degrees, and a gain error of 90/80 Degrees (a factor of 1.125).

Thus we need to add 2 Degrees offset, and a gain of 1.125. The calibration command would thus look as follows:

GYRO:CAL 2, 0, 0, 1.125, 1, 1

All three axis need to be calibrated simultaneously as shown above for the X Axis.

The following command returns the setting of the calibration factors of the accelerometer system:

GYRO:CALibrate?

Due to the nature of the accelerometer chip, the Z axis will have the largest error and lowest sensitivity of all three axis. The X, and Y axis will have the best resolution and highest sensitivity when the unit is sitting level (horizontally).

3.4.6 GYRO:CALibrate:COMPute

This command can be used to automatically compute the offset and gain compensation of the accelerometer output for units that are not factory-calibrated. The goal is to have the unit indicate a range of +/- 1.0g on all three axis when slowly rotated through the axis, as well as 0.0g for any axis that is perpendicular to the earth's gravity.

The user must establish the minimum and maximum g-loads that are displayed on all three axis by slowly tilting the unit over 180 Degrees on all three axis. These values are written down on a piece of paper, and the system calculates the required gain and offset parameters to scale the accelerometer output to +/- 1g peak-to-peak scale, and 0g indication based on entering these values. The GYRO:CAL:COMPute command will query the user for the maximum and minimum indicated g-loads. The GYRO:TRACE 10 command can be used to help establish the g-indications on the three different axis to aid in this calibration.

3.4.7 GYRO:CALibrate:RESET

Used for factory calibration of Gyro subsystem.

3.4.8 GYRO:SENSitivity <float,float,float>

Used for factory calibration of Gyro subsystem.

3.4.9 GYRO:GLOAD?

This command will return the present acceleration on the X, Y, and Z axis.

3.4.10 GYRO?

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

GYRO:MODE?
GYRO:TRAce?
GYRO:CALibrate?
GYRO:SENSitivity?
GYRO:GLOAD?

GYRO:PORT?

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:LEAPsecond:PENDing?

PTIMe:LEAPsecond:ACCumulated?

PTIMe:LEAPsecond:DATE?

PTIMe:LEAPsecond:DURation?

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.

The following command returns the PTIME output setting stored in NV memory:

PTIMe:OUTput?

Sending the command PTIM:OUT ON will cause the unit to automatically generate GPS:INIT:DATE and GPS:INIT:TIME sentences described in Section 3.3.29 and Section 3.3.30 on the serial port once per second.

3.5.6 PTIMe:LEAPsecond?

This command returns the results of the four following queries:

PTIMe:LEAPsecond:PENDing?

PTIMe:LEAPsecond:ACCumulated?

PTIMe:LEAPsecond:DATE?

PTIMe:LEAPsecond:DURation?

An example of a pending leapsecond event follows:

LEAPSECOND PENDING: 1

LEAPSECOND ACCUMULATED: 16

LEAPSECOND DATE: 2015,6,30

LEAPSECOND DURATION: 61

Please note that the unit stores pending leapsecond events in NV memory, and applies them correctly even if the antenna is removed prior to the leapsecond as long as the pending information has been received and stored in NV memory, and the unit has a properly set RTC time and date. This feature sets JLT units apart from competitive products that only apply a leapsecond correctly if the GNSS antenna is connected to the unit during the actual leapsecond event, and may thus miss the leapsecond event entirely.

3.5.7 PTIMe:LEAPsecond:PENDing?

This command returns 1 if the GPS Almanac data contains a future pending leap second data and 0 if no future leap second is pending or Almanac data is not available. The GNSS receiver must have the GPS system enabled for the GPS Almanac to be available.

3.5.8 PTIMe:LEAPsecond:ACCumulated?

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 GNSS receiver (GPS Almanac is available).

3.5.9 PTIMe:LEAPsecond:DATE?

This command returns the date of the pending leap second, if any.

3.5.10 PTIMe:LEAPsecond:DURation?

This command returns the duration of the last minute of the day during a leap second event. The returned value is 59, 60 or 61 if GPS Almanac data is available, and 0 otherwise. A response of 60 indicates that no leap second is pending.

3.5.11 PTIMe?

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

> PTIMe:DATE?
>
> PTIMe:TIME?
>
> PTIMe:TINTerval?
>
> PTIMe:OUTput?
>
> PTIMe:LEAPsecond:ACCumulated?

3.6 SYNChronization Subsystem

This subsystem regroups the commands related to the synchronization of the LN CSAC GPSDO with the GNSS receiver. The list of the commands supported for this subsystem is the following:

> SYNChronization:HOLDover:DURation?
>
> SYNChronization:HOLDover:STATe?
>
> 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:1PPS:WIDTH <int> <ms | us > [200us,600ms]
>
> SYNChronization:OUTput:FILTer <ON | OFF>
>
> SYNChronization:OUTput:FILTer?
>
> SYNChronization:HEAlth?
>
> SYNChronization:TINTerval:THReshold <int> [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 GNSS receiver 1PPS, 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:STATe?

This query returns the current holdover state with possible responses being NONE, MANUAL, or ON. NONE indicates the holdover state is off. MANUAL indicates the holdover is manually enabled with the SYNChronization:HOLDover:INITiate command. ON indicates that holdover is enabled due to lack of external GNSS receiver 1PPS or valid GNSS fix.

3.6.3 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 GNSS 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 CSAC drift when not locked to GPS for testing purposes, or to prevent the GNSS receiver from being spoofed and affecting the CSAC frequency accuracy. All other frequency-disciplining functions of the unit will behave as if the GNSS antenna was disconnected from the unit while in this forced-holdover state.

3.6.4 SYNChronization:HOLDover:RECovery: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.

3.6.5 SYNChronization:SOURce:MODE <GPS | EXTernal | AUTO>

The Source:Mode command allows an optional external 3.3V CMOS, 5V CMOS or TTL level 1PPS input to be connected to the LN CSAC GPSDO board on connector harness J1. 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 GNSS receiver goes into holdover mode for any reason. The command has the following format:

SYNChronization:SOURce:MODE <GPS | EXTernal | AUTO>

The following command returns the current mode setting stored in NV memory:

SYNChronization:SOURce:MODE?

3.6.6 SYNChronization:SOURce:STATe?

This command returns the state of the SYNC:SOUR:MODE command, and may return GPS or EXT.

3.6.7 SYNChronization:TINTerval?

This query returns the difference or timing shift between the LN CSAC GPSDO 1PPS and the GNSS 1PPS signals. The resolution is 1E-10 seconds.

3.6.8 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.

3.6.9 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 GNSS 1PPS offset.

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

3.6.10 SYNChronization:LOCKed?

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

3.6.11 SYNChronization:OUTput:1PPS:RESET <ON | OFF>

This command allows the generation of the 1PPS pulse upon power-on without an external GNSS antenna being connected to the unit. By default the unit does not generate a 1PPS pulse until the GNSS 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 GNSS antenna is not connected to the unit. Once the GNSS 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 GNSS lock is achieved**.

3.6.12 SYNChronization:OUTput:1PPS:RESET?

This query returns the 1PPS output on reset setting.

3.6.13 SYNChronization:OUTput:1PPS:WIDTH <int> <ms | us > [200us,600ms]

LN CSAC GPSDO with Firmware revision 0.75 and later adds support for changing the pulse width of CSAC 1PPS output signal. By default the unit generate an asynchronous or UTC-aligned 1PPS pulse with pulse width of 600 ms. With the command SYNC:OUT:1PPS:WIDTH 200ms the unit can now configure the 1PPS pulse width to 200ms or any integer value between 200 us and 600 ms.

This command has the following format:

SYNChronization:OUTput:1PPS:WIDTH <int> <ms | us > [200us,600ms]

The following command returns the current pulse width setting stored in NV memory:

SYNChronization:OUTput:1PPS:WIDTH?

The unit of parameter for this command can be either us or ms. For example, command SYNC:OUT:1PPS:WIDTH 200000us and command SYNC:OUT:1PPS:WIDTH 200ms will both configure the pulse width to 200ms.

If the 1PPS output signal is already available before sending this command, a 1PPS pulse with the specified pulse width will be generated on the next second and every second thereafter.

3.6.14 SYNChronization:OUTput:FILTer <ON | OFF>

This command enables/disables the Phase Noise filter.

3.6.15 SYNChronization:OUTput:FILTer?

This query returns the Phase Noise filter setting.

3.6.16 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 < 200 seconds	HEALTH STATUS |= 0x8;
If the GNSS receiver 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 CSAC Oscillator indicates an alarm	HEALTH STATUS |= 0x400;
If the GNSS receiver indicates a strong jamming signal of >=50 (range is 0 to 255) and is in holdover	HEALTH STATUS |= 0x800;

As an example, if the unit is in GNSS receiver holdover (see Section 3.6.2 for possible cause of holdover state) and the UTC phase offset is > 250ns then the following errors would be indicated:

  1) UTC phase > 250ns: 0x4

  2) GNSS receiver 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.

3.6.17 SYNChronization:TINTerval:THReshold <int> [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 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 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.

3.6.18 SYNChronization?

This query returns the results of the following queries:

        SYNChronization:SOURce:MODE?

        SYNChronization:SOURce:STATe?

        SYNChronization:OUTput:1PPS:RESET?

        SYNChronization:OUTput:1PPS:WIDTH?

        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 LN CSAC GPSDO.The list of the commands supported for this subsystem is the following:

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 -100.00% to +100.00%.

3.7.2 DIAGnostic:ROSCillator:EFControl:ABSolute?

This query returns the Electronic Frequency Control (EFC) steering value of the 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 result of the three following queries:

DIAGnostic:ROSCillator:EFControl:RELative? : Relative oscillator setting

DIAGnostic:ROSCillator:EFControl:ABSolute? : Absolute oscillator setting

DIAGnostic:LIFetime:COUNt? : 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 on the LN CSAC GPSDO. The list of the commands supported for this subsystem is the following:

MEASure:TEMPerature?

MEASure:VOLTage?

MEASure:CURRent?

MEASure:POWersupply?

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 LN CSAC GPSDO. 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 <ON | OFF>

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 <ON | OFF>

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

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

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

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 NV memory. 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 sets the contrast of the LCD.

3.9.8 SYSTem:LCD:CONTrast?

This query returns the current contrast of the LCD.

3.9.9 SYSTem:LCD:PAGE [0,8]

This command displays the requested page on the LCD. Starting with firmware version 0.71, nine different pages are supported as described in Section 2.4.5.2 . Table 3.4 lists the LCD page numbers and corresponding names.

Table 3.4   Supported Displays on LCD Pages

Value	LCD Page
0	Time/Date
1	GPS Position
2	GPS Height
3	CSAC Steering
4	CSAC Status
5	TINT
6	Navigation
7	GPS/UTC Time
8	Survey Status

3.9.10 SYSTem:LCD:PAGE?

This query returns the current page of the LCD.

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

This command sets the speed of the serial USB port.

3.9.12 SYSTem:COMMunicate:USB:BAUD?

This query returns the speed of the serial USB port.

3.9.13 SYSTem:STATus?

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

3.10 SERVO Subsystem

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

SERVo:LOOP <ON | OFF>

SERVo:MODE <OFF | NORMal | FAST | AUTO>

SERVo:STATe?

SERVo:DACGain <float> [0.001, 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:PHASECOrrection <float> [-500.0, 500.0]

SERVo:1PPSoffset <int> ns [-5000000, 5000000]

SERVo:TRACe:PORT <RS232 | USB>

SERVo:TRACe <int > [0,255]

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

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

SERVo:PHASECOrrection:FAST <float> [-500.0, 500.0]

SERVo?

3.10.1 SERVo:LOOP <ON | OFF>

This command enables or disables the servo loop for the selected servo loop. With the loop disabled, no changes are made to the oscillator frequency control. Normally the servo loop is left enabled.

The following command returns the current loop setting where 1 means enabled:

SERVo:LOOP?

3.10.2 SERVo:MODE <OFF | NORMal | FAST | AUTO>

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. This command allows auto-setting of all of the servo loop time constants to factory-default values as described in Section 2.5 with one single command entry.

This command is useful in setting the filter loop time constants for different mission profiles to accommodate different usage scenarios of the LN CSAC GPSDO. The loop time constant of the CSAC can be chosen with these settings.

The AUTO mode lets the firmware determine by itself which loop time constant is used, thus optimizing the units' performance dynamically depending on the environmental effects on the CSAC. The AUTO setting will quickly react to phase perturbations and will try to set NORMal settings (long time constant) whenever the unit is in stable conditions to minimize residual noise, and to improve the ADEV performance of the filtered output as much as possible for a particular environment. NORMal settings are useful in stationary applications, whereas FAST settings are preferred for mobile applications such as in vehicles, man-packs, or aircraft.

The following command returns the current mode setting:

SERVo:MODE?

If SERVo:MODE OFF is sent or in factory-default settings, the SERVo:MODE? query will result in a Command Error response. By default, the servo mode is disabled and NORMal settings are used.

3.10.3 SERVo:STATe?

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings.

This query responds with the current loop parameter settings, NORMAL or FAST. When the SERVo:MODE command is configured to AUTO, the SERVo:STATe? query responds with the automatically selected loop parameter setting, NORMAL or FAST. If the servo mode is currently in OFF setting, the SERVo:STATe? query will result in a Command Error response.

3.10.4 SERVo:DACGain <float> [0.001, 10000]

This command is used for factory setup.

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

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is FAST will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is NORMAL or SERVo:MODE is OFF.

Controls the Proportional part of the PID loop. Typical values are 0.6 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]

The following command returns the current value for NORMAL EFC scale setting:

SERVo:EFCScale?

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

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is FAST will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is NORMAL or SERVo:MODE is OFF.

Sets the Low Pass filter effectiveness of the DAC. Values from 5 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]

The following command returns the current value for NORMAL EFC damping setting:

SERVo:EFCDamping?

3.10.7 SERVo:TEMPCOmpensation <float> [-4000.0, 4000.0]

This parameter is a coefficient that reflects the correlation between the temperature of the CSAC versus the required frequency steering. Monitoring the tempco and aging parameters provides a mechanism to track the health of the CSAC oscillator. Excessively high values that appear from one day to the next could be an indicator of failure on the board.

The CSAC has its own temperature compensation algorithm that is not compatible with internal temperature compensation algorithm in LN CSAC GPSDO firmware. By default automatic temperature compensation is disabled for LN CSAC GPSDO and default value is set to 0 which is equivalent to no additional temperature compensation is applied.

Assigning a non-zero value to this parameter may result in frequency instability, and assigned value will be stored in NV memory and remain unchanged. This command has the following format:

SERVo:TEMPCOmpensation <float> [-4000.0, 4000.0]

The following command returns the current value of the temperature compensation:

SERVo:TEMPCOmpensation?

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

This parameter is a coefficient that represents the drift of the EFC needed to compensate the natural drift in frequency of the 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]

The following command returns the current computed or manually configured value of the aging compensation:

SERVo:AGINGcompensation?

3.10.9 SERVo:PHASECOrrection <float> [-500.0, 500.0]

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is FAST will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is NORMAL or SERVo:MODE is OFF.

This parameter sets the Integral part of the PID loop. Loop instability will result if the parameter is set too high. Typical values are 1.0 to 30.0. This command has the following format:

SERVo:PHASECOrrection <float> [-500.0, 500.0]

The following command returns the current value for NORMAL Phase correction setting:

SERVo:PHASECOrrection?

3.10.10 SERVo:1PPSoffset <int> ns [-5000000, 5000000]

This command sets the LN CSAC GPSDO 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 [-5000000, 5000000]

The following command returns the current value of the 1PPS offset setting:

SERVo:1PPSoffset?

3.10.11 SERVo:TRACe:PORT <RS232 | USB>

This command selects the serial port for trace debug output. This command has the following format:

SERVo:TRACe:PORT <RS232 | USB>

The following command returns the current trace port setting:

SERVo:TRACe:PORT?

3.10.12 SERVo:TRACe <int > [0,255]

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:

SERVo:TRACe <int > [0,255]

The following command returns the current value of the trace period:

SERVo:TRACe?

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 states in Table 3.5.

Table 3.5 Lock State Indications

Value	State
0	CSAC warmup
1	Holdover
2	Locking (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

3.10.13 SERVo:EFCScale:FAST <float> [0.0, 500.0]

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is NORMAL will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is FAST and SERVo:MODE is not OFF.

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:FAST <float> [0.0, 500.0]

The following command returns the current value for FAST EFC scale setting:

      SERVo:EFCScale:FAST?

3.10.14 SERVo:EFCDamping:FAST <int> [2, 4000]

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is NORMAL will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is FAST and SERVo:MODE is not OFF.

Sets the Low Pass filter effectiveness of the DAC. Values from 5 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:FAST <int> [2, 4000]

The following command returns the current value for FAST EFC damping setting:

      SERVo:EFCDamping:FAST?

3.10.15 SERVo:PHASECOrrection:FAST <float> [-500.0, 500.0]

LN CSAC GPSDO with firmware revision 0.74 and later adds support for two different phase loop time constant settings. See Section 2.5 for details of recommended loop time constant settings. Changing this parameter while response of SERVo:STATe? command is NORMAL will NOT change current operation of the servo loop. This command will be effective only when SERVo:STATe is FAST and SERVo:MODE is not OFF.

This parameter sets the Integral part of the PID loop. Loop instability will result if the parameter is set too high. Typical values are 1.0 to 30.0. This command has the following format:

      SERVo:PHASECOrrection:FAST <float> [-500.0, 500.0]

The following command returns the current value for FAST Phase correction setting:

      SERVo:PHASECOrrection:FAST?

3.10.16 SERVo?

This command returns the result of the following queries:

SERVo:LOOP?

SERVo:MODE? (if SERVo:MODE is not OFF)

SERVo:STATe? (if SERVo:MODE is not OFF)

SERVo:DACGain?

SERVo:EFCScale?

SERVo:EFCScale:FAST? (if SERVo:MODE is not OFF)

SERVo:PHASECOrrection?

SERVo:PHASECOrrection:FAST? (if SERVo:MODE is not OFF)

SERVo:EFCDamping?

SERVo:EFCDamping:FAST? (if SERVo:MODE is not OFF)

SERVo:TEMPCOmpensation?

SERVo:AGINGcompensation?

SERVo:1PPSoffset?

SERVo:TRACe:PORT?

SERVo:TRACe?

3.11 CSAC Subsystem

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

CSAC:TYPE?

CSAC:LOCKed?

CSAC:RS232?

CSAC:STeer?

CSAC:STATus?

CSAC:ALarm?

CSAC:MODE?

CSAC:CONTrast?

CSAC:LASer?

CSAC:TCXO?

CSAC:SIGnal?

CSAC:HEATpackage?

CSAC:TEMPerature?

CSAC:FWrev?

CSAC:SN?

CSAC:LIFEtime?

CSAC:STeer:LATch ONCE

CSAC:POWer <ON | OFF>

CSAC?

3.11.1 CSAC:RS232?

This query returns the state (OK or FAIL) of the serial communication between the main CPU and the 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 in Table 3.6.

Table 3.6   CSAC Status Definitions

Status	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 in Table 3.7.

Table 3.7   CSAC Alarm Definitions

Alarm	Definition
0x0001	Signal Contrast Low

Alarm	Definition
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
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 CSAC mode as shown in Table 3.8.

Table 3.8   CSAC Mode Definitions

Mode	Definition
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:TEMPerature?

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

3.11.12 CSAC:FWrev?

This query returns the Firmware version of the CSAC unit.

3.11.13 CSAC:SN?

This query returns the Serial Number of the 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 CSAC has been powered on since the last factory reset of the LN CSAC GPSDO board. The value is stored in the external NV memory and updated every hour when the CSAC is powered on.

3.11.15 CSAC:STeer:LATch ONCE

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

3.11.16 CSAC:TYPE?

LN CSAC GPSDO with firmware revision 0.75 and later adds support for querying the model of CSAC on the LN CSAC GPSDO board.

3.11.17 CSAC:LOCKed?

LN CSAC GPSDO with firmware revision 0.75 and later adds support for querying the lock status of the CSAC. A value of 1 is returned if the CSAC is in atomic lock.

3.11.18 CSAC:POWer <ON | OFF>

LN CSAC GPSDO with firmware revision 0.74 and later adds support for sending the CSAC into Ultra-Low Power (ULP) mode. By default the normal power mode is ON and sending CSAC:POWer OFF command will put the CSAC in ULP mode.

The CSAC may loses atomic lock while in ULP mode. JLT thus recommends keeping the CSAC:POWer ON setting for normal operation and optimal performance on LN CSAC GPSDO.

This command has the following format:

      CSAC:POWer <ON | OFF>

The following command returns the current power setting where ON means normal power mode:

      CSAC:POWer?

3.11.19 CSAC?

This command returns the result of the following queries:

      CSAC:TYPE?
      CSAC:LOCKed?
      CSAC:RS232?
      CSAC:STeer?
      CSAC:STATus?
      CSAC:ALarm?
      CSAC:MODE?
      CSAC:CONTrast?
      CSAC:LASer?
      CSAC:TCXO?
      CSAC:SIGnal?
      CSAC:HEATpackage?
      CSAC:TEMPerature?
      CSAC:SN?
      CSAC:FWrev?
      CSAC:LIFEtime?

CSAC:POWer?

4 Firmware Upgrade Instructions

4.1 Introduction

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

It is not expected that the built-in FireFly-IIA microcontroller of the LN CSAC GPSDO requires any future firmware updates, so the procedure to do firmware upgrades to that microcontroller will be published seperately if the need arises.

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 LN CSAC GPSDO. 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 LPC2368 processor used on the LN CSAC 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

Short out pins 1 and 2 of J2 prior to power on.

4.4 Downloading the Firmware

Download the latest version of LN CSAC GPSDO firmware from the Jackson Labs Technologies, Inc. support website and store it in a place that will be remembered. 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 LN CSAC GPSDO as indicated in Section 2.4 . Please note that the unit can only be upgraded through the RS-232 port, not through the USB serial port.

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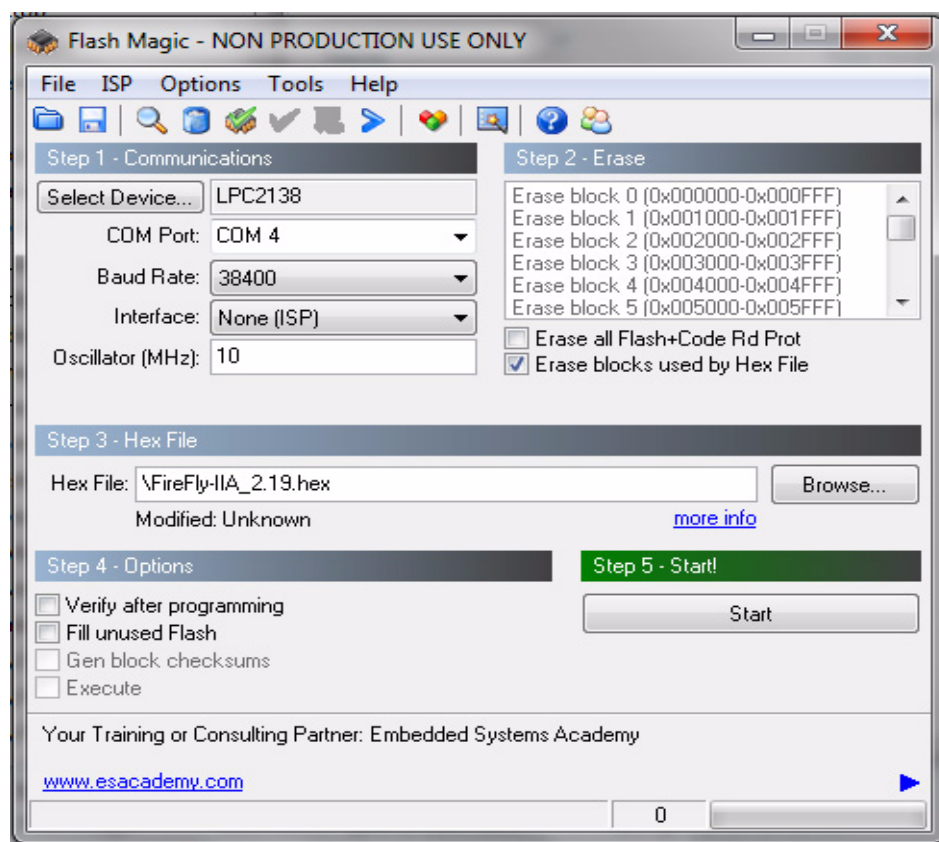
B) Press the "Select Device" button and the window shown in Figure 4.3 will appear:

Figure 4.3   Device selection window
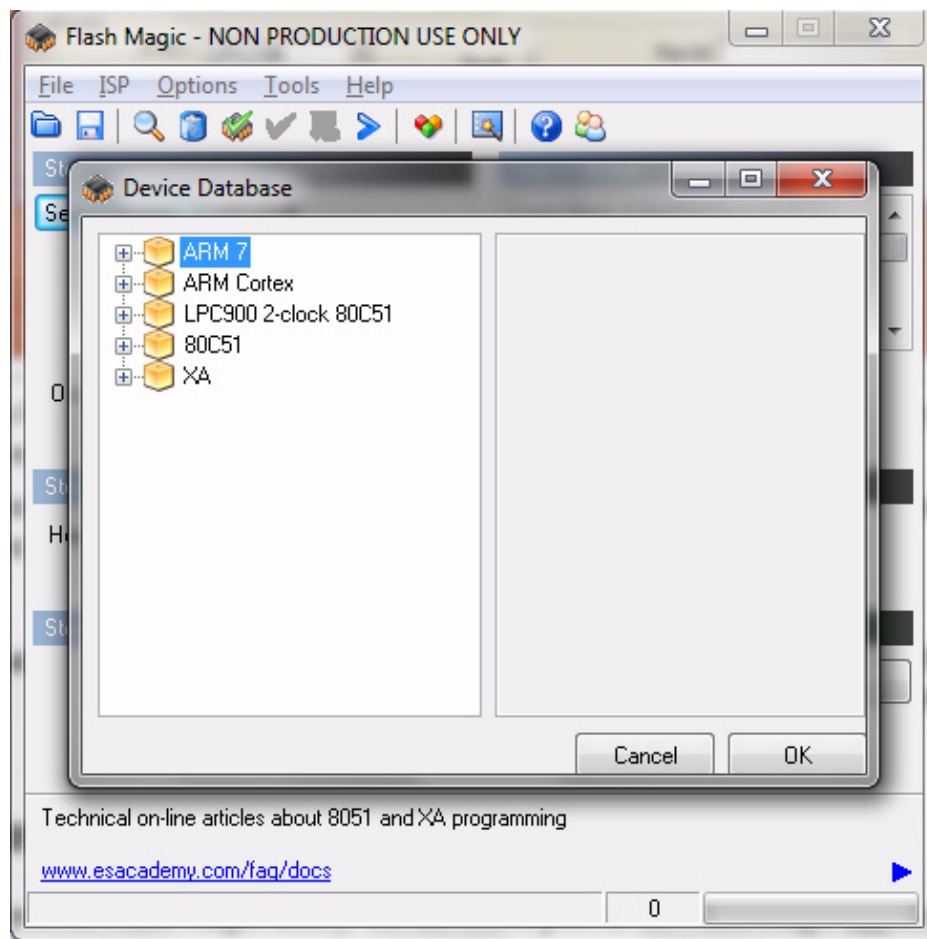
C) Expand the ARM7 folder and select the appropriate processor, in this case the LPC2368.

Figure 4.4   Expanded device selection window
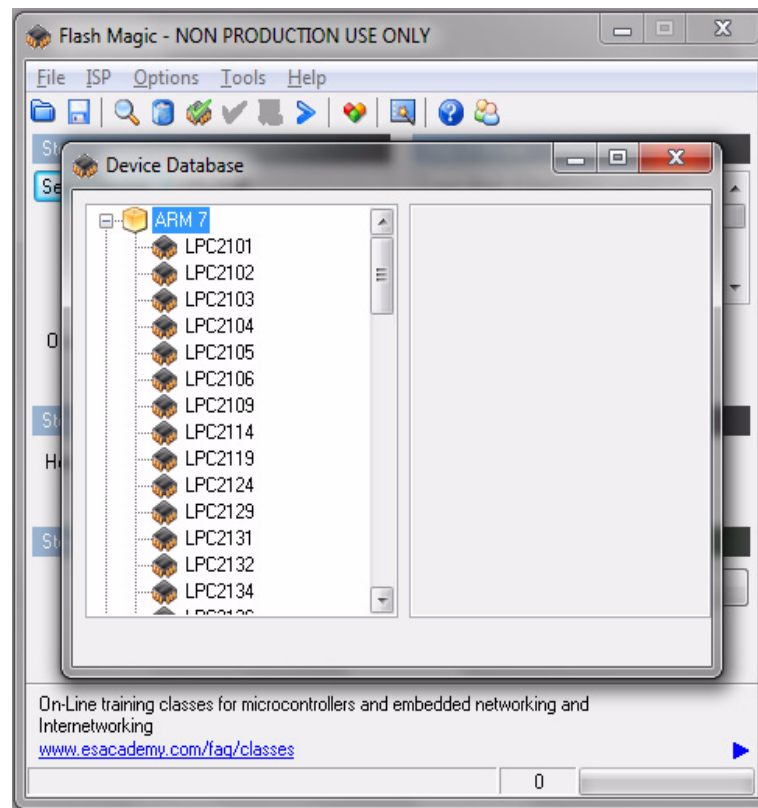
D) Select the Baud Rate of the Flash Magic utility to be 230.4KB or slower.

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 LN CSAC GPSDO.

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 - Jackson Labs Edition is a program for the monitoring and control of a Jackson Labs Technologies, Inc. GPSDO, Simulator and receiver products. It communicates with the receiver using the SCPI command set. This free version of the GPSCon utility is compatible only with Jackson Labs products is available for download from the support section of the Jackson Labs website:

http://www.jackson-labs.com/index.php/support

5.2 Installation

Extract the contents of the ZIP file downloaded from the Jackson Lab's website and execute the MSI installer. Follow the on-screen instructions to complete the installation of GPSCon.

5.3 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 appendix for convenience.

5.3.1 Setting the options

To set up the options for your GPSCon session, press the ⚒ wrench icon under the menu bar, or select Settings / Options on the menu. 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
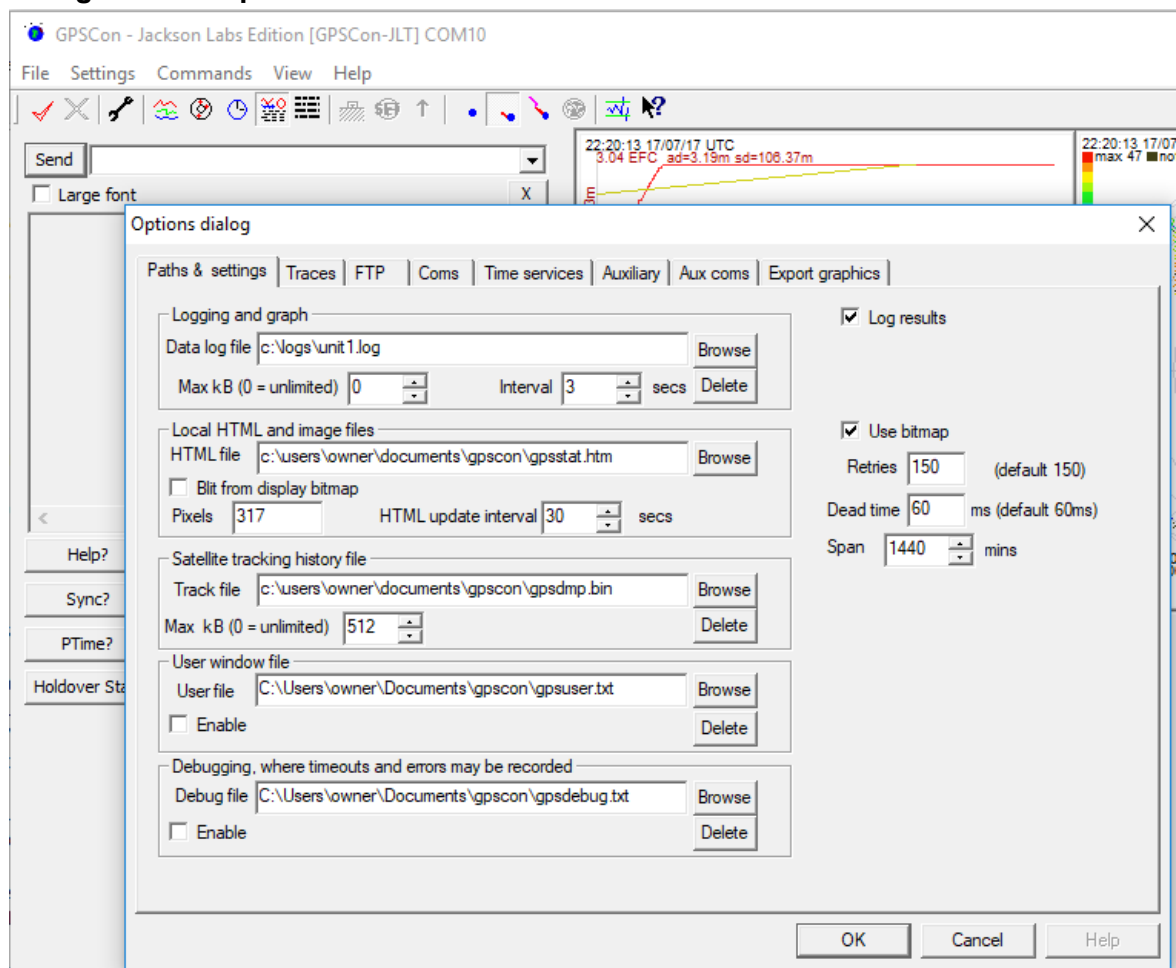
5.3.1.1 Communication Parameters

Before you can use GPSCon you must set the communication parameters for your system. Open the dialog box by pressing the ✦ wrench icon. Then select the "Coms" tab. You will see the window shown in Figure 5.2. Available COM ports for your particular computer are indicated with a "*" symbol next to the COM port number in the drop-down menu. You can only select COM ports with this adjacent symbol. Select the correct COM port for your computer's serial port connection 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.

5.3.1.2 Auxiliary Parameters

After pressing the ✦ wrench icon, you can select the "Auxiliary" tab to configure auxiliary measurements. See Figure 5.3 for an example of an auxiliary measurement. You will notice that the "Aux1" request string has been set to `meas:current?<CR>` and the "Trace to go to" is set to trace position 6. See "Trace position" diagram for the arrangement of the trace positions in the trace

window. In this example the data obtained from the meas:current? query will be plotted in trace position 6.
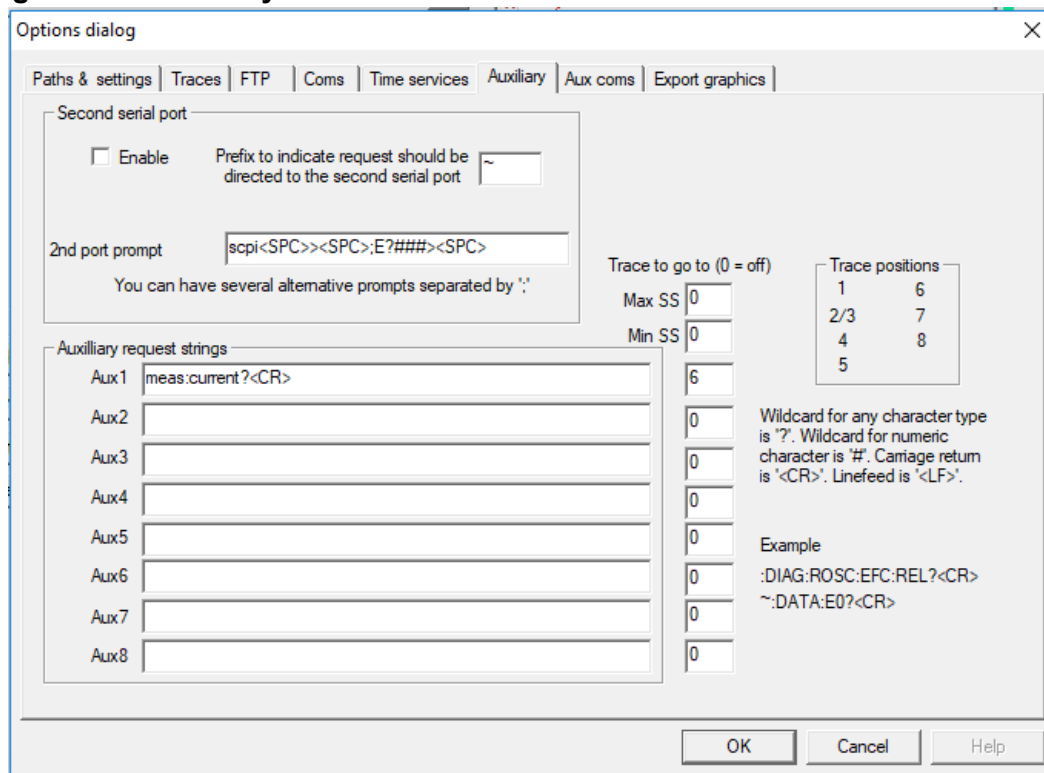
5.3.1.3 Traces Parameters

After pressing the ⚒ wrench icon, you can select the "Traces" tab and configure the trace labels and vertical plot ranges. See Figure 5.4 for an example of an auxiliary measurement. The labels and parameters are completed by default for traces 1 through 5. Any of the eight traces can be replaced by auxiliary traces as described in Section 5.3.1.2 . Press the "Help" button for a full description of each option in the Traces tab.

Figure 5.2   Setting the communications parameters
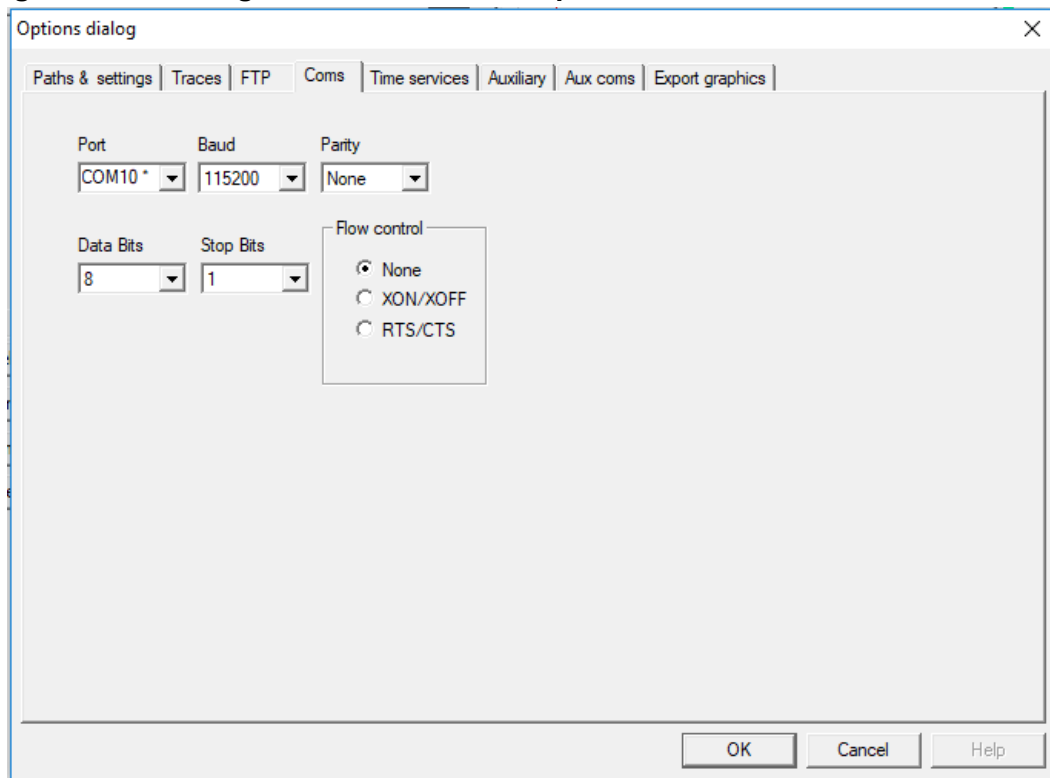
Figure 5.3   Auxiliary Parameters window

Figure 5.4   Traces Parameters window

5.3.2 Sending manual commands to the receiver

You can send SCPI commands manually by using the drop-down box in the upper left of the main window as shown in Figure 5.5. Care must be taken when sending these commands so be sure that the command that you select is supported by the LN CSAC GPSDO. Once you've selected the command you can press "Send" to send it to the LN CSAC GPSDO. You can also send common commands by clicking on the buttons below the message window. You can hover over the buttons to see the exact command that is sent.

Figure 5.5   Sending manual commands
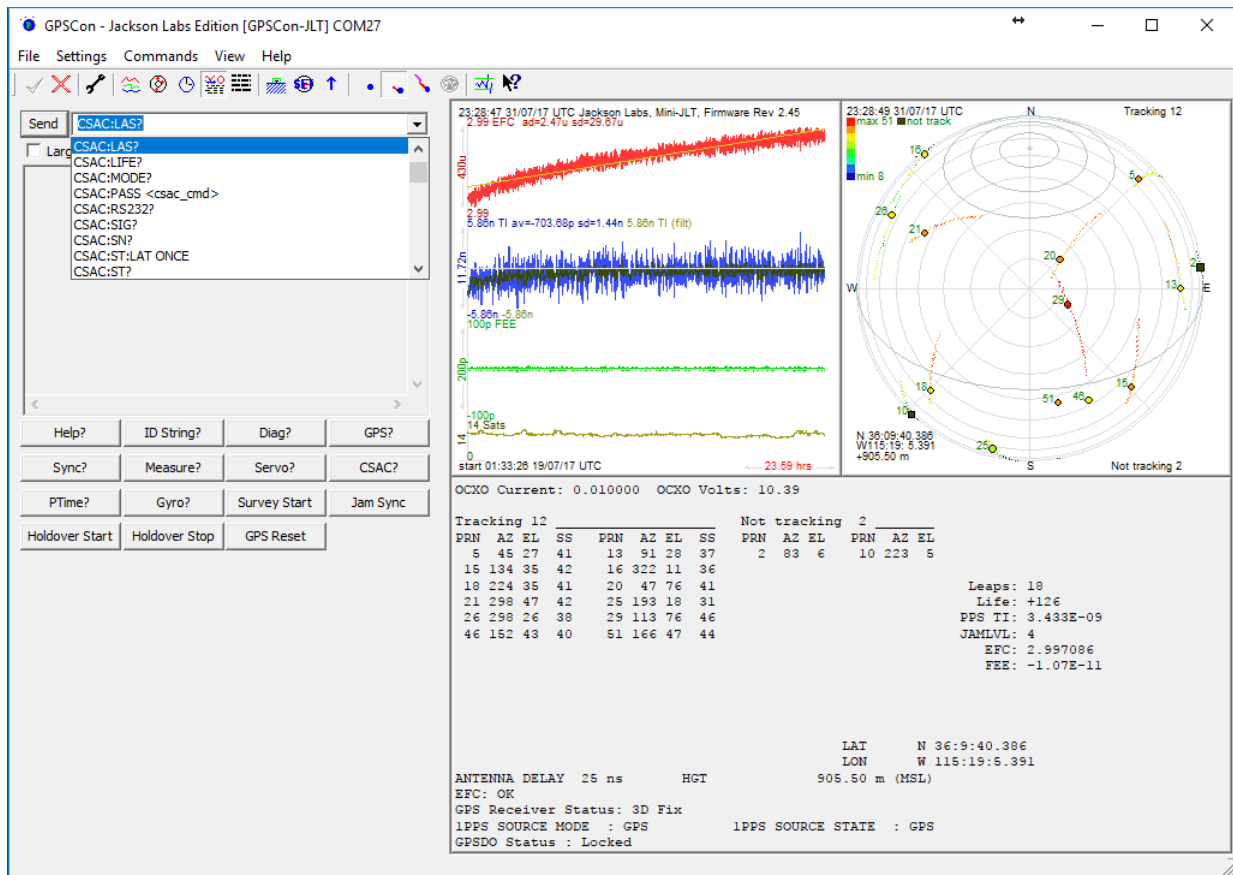
5.3.3 Using the Mouse in the Graph Window

Refer to Figure 5.6 for the following description. The default view in GPSCon is "All" which you can select with the View/All menu option. To see a larger view of the graph, select the View/Graph menu option.

In the graph window the horizontal range of the graph can be set using he mouse. Set the start time by left clicking on the desired start point. If you wish, the stop time may also be set by right clicking the desired stop point. The set start and stop times can be removed by left double-clicking anywhere on the graph.

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."

When you have locked the start and stop time using the mouse, you can scroll left or right through the data. To scroll to a later time, use Shift + Left click. To scroll to an earlier time, use Shift + Right click.

Figure 5.6   Graph display

© 2018 Jackson Labs Technologies, Inc.
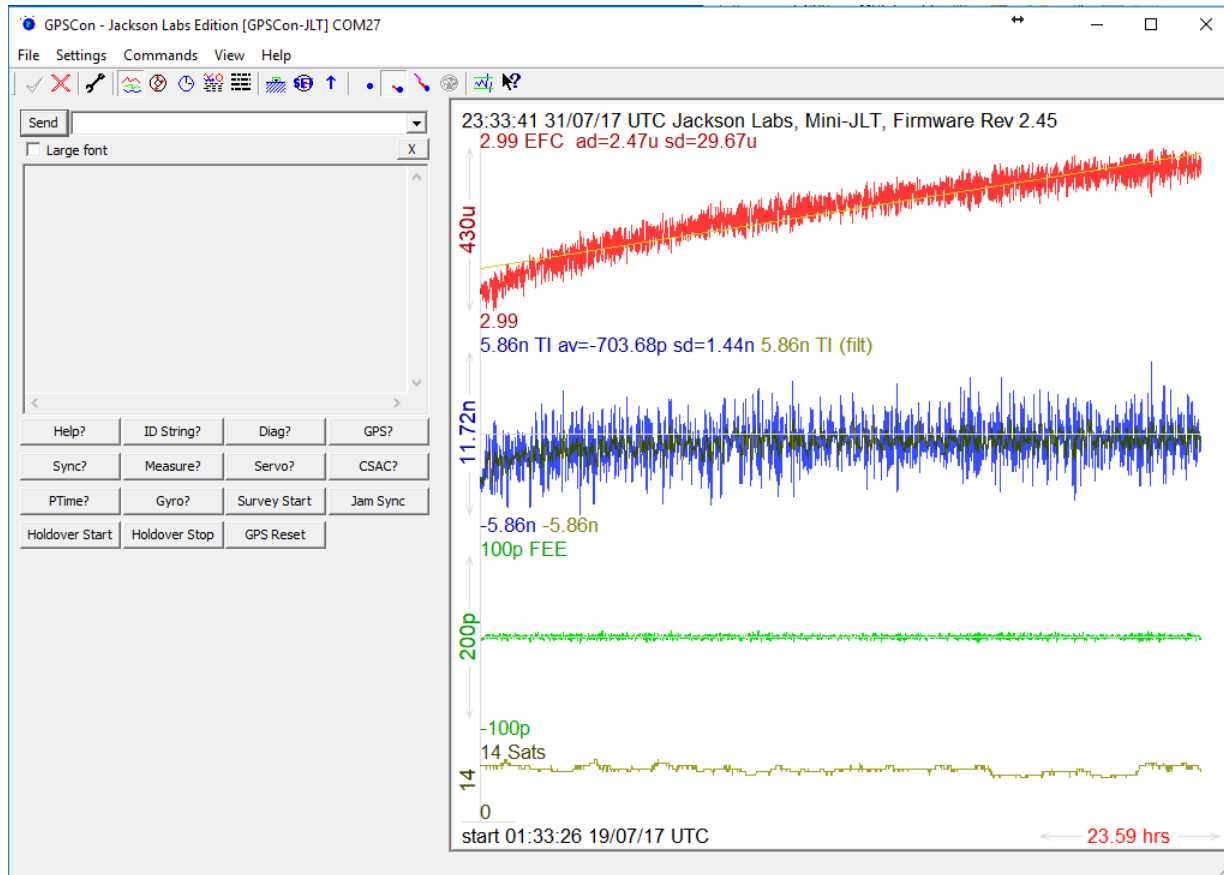
**Figure 5.7   Expanded Graph Display**
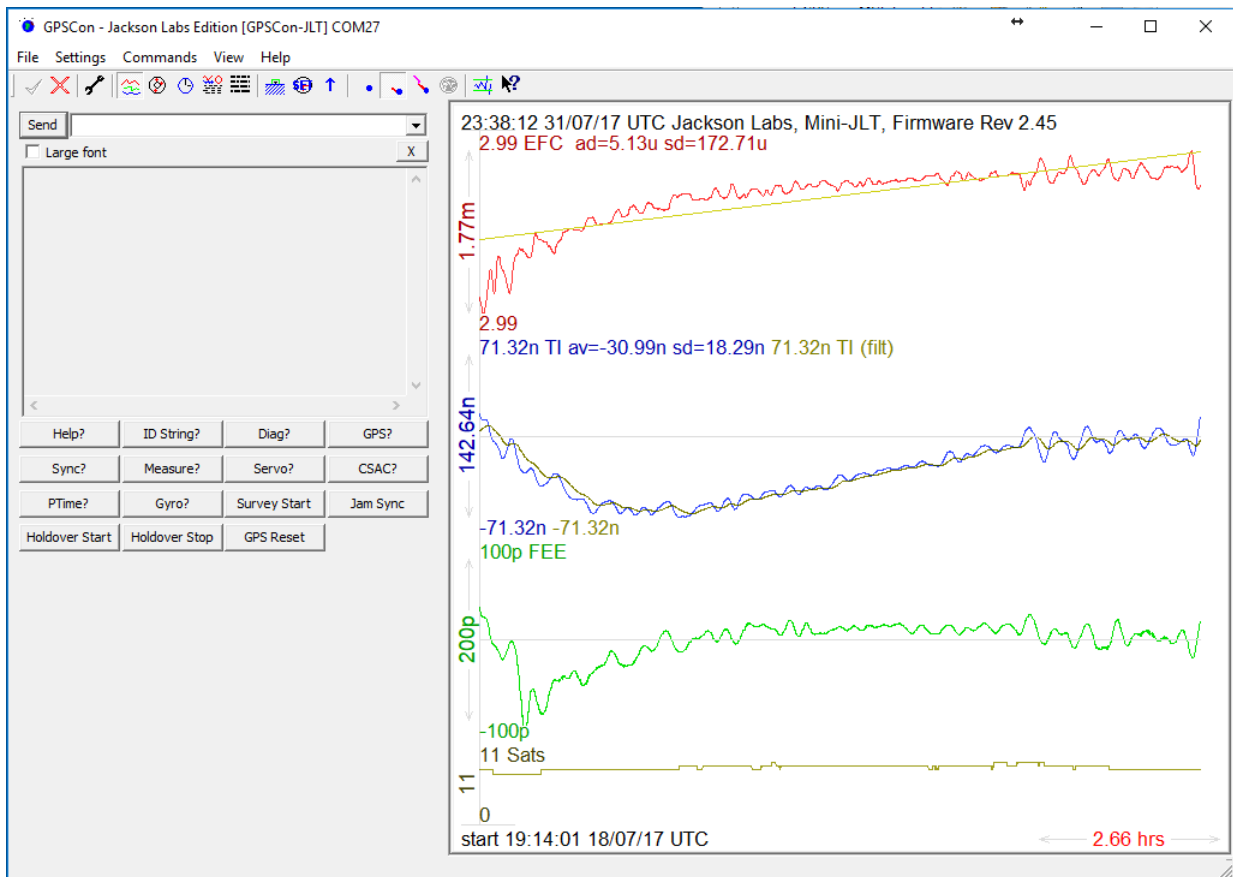
5.3.4 Exporting the graphics

The settings which control the export function are contained in the "Export graphics" tab in the Options dialog.

Export allows you to create an image file of the graph and/or the satellite trails map. You can select which you want by specifying a file for the Graph path and/or Map path. If you export the 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 "Export all graph data" to make this choice.

You may select a size of the exported images 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.

Figure 5.8   Captured Data Example
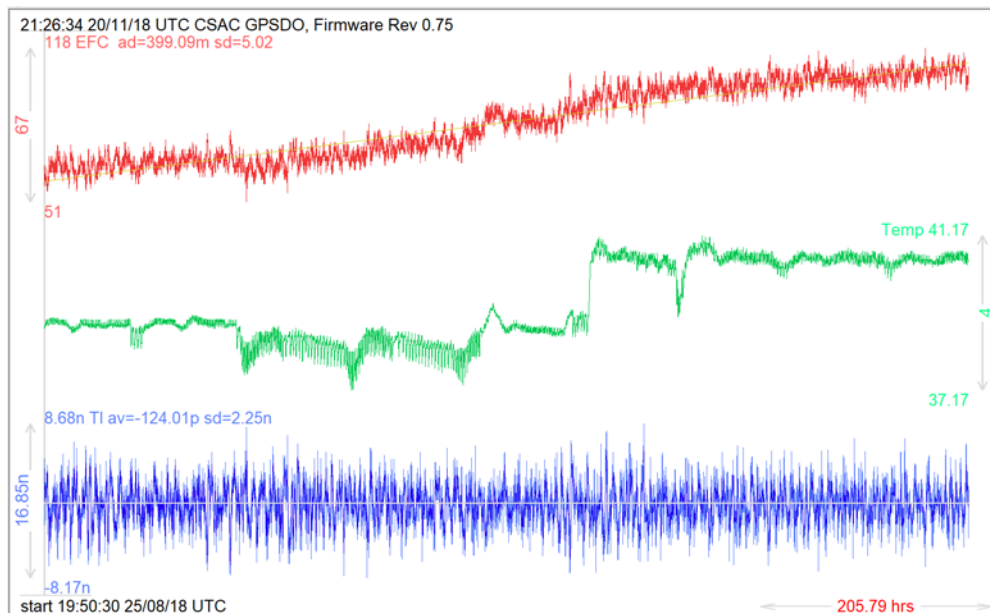
Figure 5.9   Zoomed Captured Data Example
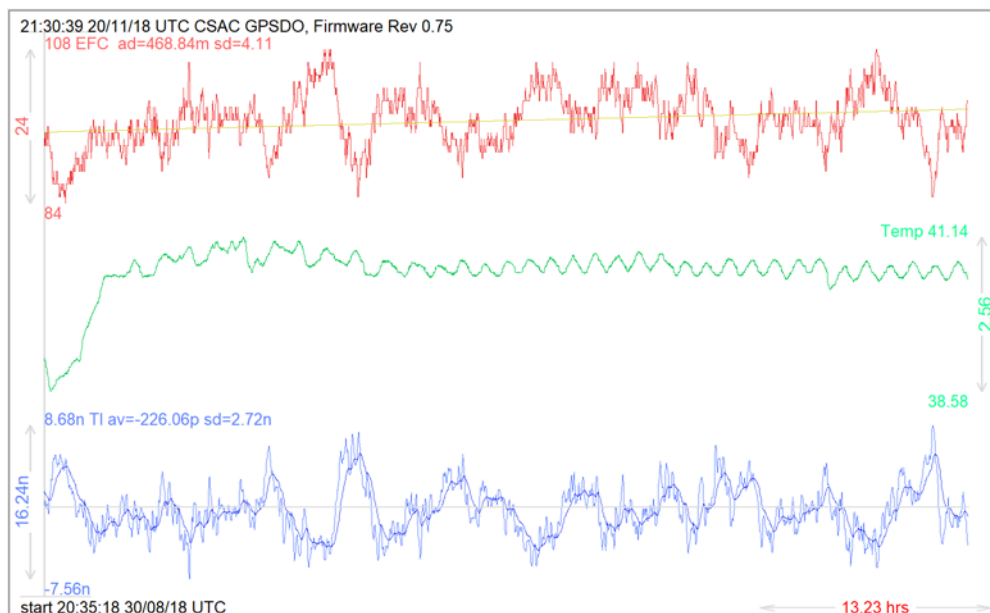
5.4 Interpreting the Data

Figure 5.8 shows the data acquired by the LN CSAC GPSDO unit over a period of more than 200 hours The red trace is EFC (CSAC frequency steering value). The crystal is aging (becoming faster in frequency over time). This requires the steering value to be increased to maintain precisely 10.0MHz. A drift of 67 parts-per-trillion (1E-012) is visible over 200 hours. On the left side of the

screen the EFC range over this 200 hour plot is displayed vertically as 6.7E-011. This means the drift of the EFC value due to aging is ~2.9E-09 per year.

This is the same as 0.008ppb drift due to aging per day.This crystal aging is fully compensated by the firmware with and without GNSS reception of course.

The board temperature is shown in tortoise. We can see it ranges from 37.17°C to 41.17°C. The CSAC senses the temperature change and actively compensate for the change.

In Figure 5.9, which is a zoom of Figure 5.8, we can see the phase offset error of the CSAC to the UTC GNSS reference. We can see the maximum drift is -8.17ns to +8.68ns. The average is (TI av=-0.12ns). The standard deviation over the 200 hour plot is sd=2.25ns. This means the average error of the 10MHz phase of this unit over 200 hours is only +/-2.25ns rms. Or, in other words the average jitter (wander) over 200 hours of operation is:

$$2.25\text{ns} / 200 \text{ Hrs} / 3600 = 3.13\text{E-015}$$

The unit disciplines its internal 10MHz reference to within less than +/-9ns peak to peak of UTC at all times, which is less than one complete clock cycle at 10MHz.

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.

7 Revision History

7.1 Revision Table

Revision history of the LN CSAC GPSDO User Manual is listed in Table 7.1.

Table 7.1 Revision History

Document ID	Release Date	ECN	Firmware Version
LN CSAC GPSDO User Manual v1.2	12 December, 2018	80200573 & 80200568 & 80200525	0.75
Modifications	Updated Section 2.2 Controlling the unit from a PC's USB port Added Section 2.4.3 Concurrent-GNSS Capabilities Updated Section 2.5 Loop parameter adjustment Updated Section 3.3.3 NMEA Support Updated Section 3.3.6 - Section 3.3.10 GPS:GPxxx commands Added Section 3.3.13 - Section 3.3.16 GPS:GNxxx commands Added Section 3.3.31 GPS:SYSTem:SELect [GPS | SBAS | QZSS | GAL | BD ^ GLO] Added Section 3.3.32 GPS:NMEA:TALKid <GP | GN> Added Section 3.3.33 GPS:NMEA:SVNum <GP | GN> Updated Section 3.4.5 GYRO:CALibrate <float,float,float,float,float,float> Updated Section 3.5.6 PTIMe:LEAPsecond? Added Section 3.5.7 PTIMe:LEAPsecond:PENDing? Added Section 3.5.8 PTIMe:LEAPsecond:ACCumulated? Added Section 3.5.9 PTIMe:LEAPsecond:DATE? Added Section 3.5.10 PTIMe:LEAPsecond:DURation? Added Section 3.6.2 SYNChronization:HOLDover:STATe? Added Section 3.6.13 SYNChronization:OUTput:1PPS:WIDTH <int> <ms | us > [200us,600ms] Added Section 3.10.1 SERVo:LOOP <ON | OFF> Added Section 3.10.2 SERVo:MODE <OFF | NORMal | FAST | AUTO> Added Section 3.10.3 SERVo:STATe? Updated Section 3.10.5 & Section 3.10.6 & Section 3.10.9 SERVO loop time constant (TC) Updated Section 3.10.7 SERVo:TEMPCOmpensation <float> [-4000.0, 4000.0] Added Section 3.10.11 SERVo:TRACe:PORT <RS232 | USB> Added Section 3.10.13 & Section 3.10.14 & Section 3.10.15 SERVO FAST loop TC Added Section 3.11.16 CSAC:TYPE? Added Section 3.11.17 CSAC:LOCKed? Added Section 3.11.18 CSAC:POWer <ON | OFF>

Document ID	Release Date	ECN	Firmware Version
LN CSAC GPSDO User Manual v1.2	12 December, 2018	80200573 & 80200568 & 80200525	0.75
Modifications Cont.	Updated Chapter 5 GPSCon Utility Removed Section 5.2 Z38xx Utility Added Section 5.3.1.3 Traces Parameters Added Section 5.4 Interpreting the Data Added Chapter 7 Revision History		
LN CSAC GPSDO User Manual v1.1	18 March, 2014	100-001-000126 & 100-001-000125 & 100-001-000124	0.71
Modifications	Added Section 1.4.1 Use an approved Antenna Lightning Protector Updated Section 2.2 Controlling the unit from a PC's USB port Added Section 2.4.4.1 LCD Key Updated Section 2.4.4.2 LCD Display Pages Removed 3.3.23 GPS:SURVey:STATus:DURation? Added Section 3.7.3 DIAGnostic:LIFetime:COUNt? Updated Section 3.9.9 SYSTem:LCD:PAGE [0,8]		
LN CSAC GPSDO User Manual v1.0	15 November, 2012	100-001-000121	0.66
Modifications	Initial release		