

Mini-PCle GPS Disciplined Oscillator

From Jackson Labs Technologies, acquired by VIAVI Solutions

Mini-PCle LTE-Lite User Manual

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1 Introduction

1.1 Overview

The Mini-PCIe LTE-Lite GPSDO is a low-cost, highly-accurate Mini-PCIe compatible plug-in timing, frequency, position, and velocity reference module with internal GPS receiver and TCXO that is designed around the popular JLT LTE-Lite SMT module. The industry-standard Mini-PCIe form-factor and the metal shield surrounding the sensitive components on the board allows plugging the module into notebooks, laptops, desktops, embedded PC's, external Mini-PCIe to USB adaptors, and any Mini-PCIe compatible socket that supports USB functionality on the standard Mini-PCIe interface.

The Mini-PCIe module is intended to provide precise and stable timing and a very low Phase Noise and jitter frequency reference even in noisy environments with significant internal airflow such as can be expected inside notebook computers. The Mini-PCIe LTE-Lite is a true GPSDO rather than a Numerically Controlled Oscillator, using true precision analog disciplining of the high-end Crystal rather than digital phase-adjustments of a free running low-cost crystal, resulting in many orders of magnitude less jitter and Phase Noise. The Mini-PCIe module provides serial communications via the Mini-PCIe connector, a 1PPS CMOS output, a 20MHz CMOS output, and a LOCK-OK CMOS indicator all via industry standard U.FI miniature coax connectors. A GPS antenna signal is also connected to a U.FI coax connector, and provides +3.3V to the antennae amplifier.

The Mini-PCIe LTE-Lite GPSDO includes a high-performance GPS/QZSS receiver that can acquire and track up to 65 GPS signals down to a state of the art -165dBm , a 32bit processor, a low-noise 3V CMOS 10MHz, 19.2MHz, or 20MHz output (factory stuffed option), one 3.3V CMOS UTC-synchronized 1PPS output, one 1PPS interrupt on the DCD# line of the built-in USB serial port, NMEA status and Position-Velocity-and-Time (PVT) interface, precision voltage references, power filters, and DACs, as well as an industry-standard serial to USB converter connected via the standard Mini-PCIe module connector pins. It generates a low-noise 10/19.2/20MHz signal with typically better than $1\text{E}-09$ precision and accuracy (1ppb), better than typ. 135fs jitter (100Hz to 2MHz) and a 1PPS signal with typically better than $\pm 25\text{ns}$ stability when locked to UTC(GPS).

The Mini-PCIe LTE-Lite GPSDO provides status information on a CMOS/TTL output line that can directly drive LEDs, and has one serial output port for NMEA PVT and Oscillator status output. All configuration of the Mini-PCIe LTE-Lite GPSDO is done via pull-down TTL straps with built-in pull-up resistors, so no software configuration driver is needed on the users' system. The unit provides an industry-standard NMEA GPS serial output via the internal Mini-PCIe compatible connector that is enabled by default and provides Position/Velocity/Timing (PVT) information, and also provides a UTC-synchronized 1PPS signal on the USB serial port DCD# pin for NTP

applications. The Mini-PCIE LTE-Lite GPSDO also provides a NMEA-compatible proprietary status message on a secondary serial port that sends oscillator lock status as well as health status information to a users' system.

Please note that the Mini-PCIE industry specification allows two different interface formats on the Mini-PCIE connector: a PCIe serial connection, and a USB serial connection. The Mini-PCIE LTE-Lite module uses only the USB serial connection, and does not use the PCIe serial connection on the Mini-PCIE connector. Some third-party (chinese-made) adaptor boards are available that only support the PCIe connectivity and do not provide any USB connectivity, and these are thus not compatible to the Mini-PCIE industry standard and cannot be used with the Mini-PCIE LTE-Lite module unless they are modified to also provide a USB connectivity to the Mini-PCIE module.

1.2 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.

1.2.1 Grounding

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

1.2.2 Antenna Lightning Protection

Always use a UL-certified, properly installed Antenna Lightning suppressor on the antenna cable when mounting the GPS antenna. Without proper Lightning Protection damage to equipment, injury, or death may result.

1.2.3 Power Connections

Make sure to connect the DC power to the device following the polarity indicated in Section 2.1 . Do not reverse the power pins as this will cause serious damage to the circuit board.

1.2.4 Environmental Conditions

This instrument is intended for indoor use. It is designed to operate at a maximum relative non-condensing humidity of 95% and at altitudes of up to 4000 meters. Refer to the specifications tables for the ac mains voltage requirements and ambient operating temperature range.

2 Usage Instructions

2.1 Connecting the Mini-PCIE LTE-Lite module

The Mini-PCIE LTE-Lite module is a plug-and-play product that only requires to be plugged into a computer with a compatible full-length Mini-PCIE socket, and a GPS antenna to be connected to start generating highly-accurate output frequency and 1PPS signals that are phase and frequency aligned to UTC (USNO) and thus allow NIST-tracability. Plugging-in the Mini-PCIE module into a computer will result in the Windows, Linux, and MAC OSs to automatically start to install the USB to serial adaptor driver.

PLEASE MAKE SURE TO FOLLOW THE MINI-PCIE EXTENSION MODULE PLUG-IN INSTRUCTIONS PROVIDED BY YOUR COMPUTER MANUFACTURER TO AVOID DAMAGE TO THE COMPUTER OR OTHER DEVICE WITH MINI-PCIE SOCKET, TO AVOID INJURY OR DEATH FROM ELECTRICAL SHOCK, AND TO AVOID DAMAGE TO THE MINI-PCIE LTE-LITE MODULE.

The Mini-PCIE module's serial interface is based on an industry-standard FTDI USB chipset, and updated drivers can be downloaded from the FTDI website if needed. The module will then appear as a standard serial (COM) port on the computer, and standard terminal programs or any program that can decode standard NMEA messages can be used to monitor the Mini-PCIE module. The Mini-PCIE module-internal software will auto-configure and auto-calibrate the unit without any user-interaction and the longer the unit runs the more accurate it will become. Please note that the Mini-PCIE LTE-Lite GPSDO only supports 3D mobile GPS mode, and does not support an Auto Survey function that is available in the JLT LTE-Lite SMT module.

When communicating to the unit through the USB cable, Windows Vista, Windows 7/8 and Linux will auto-recognize the unit as a USB serial COM adaptor, and automatically assign a serial port to the unit. Windows will automatically load the USB COM driver for the board, and may need to have access to the Internet to download the latest driver from the Microsoft update website. The user can verify the COM port that windows assigned to the unit under the Computer Management window (right click on computer and press the "MANAGE" button under Windows 7, or go to Control Panel/Computer Management). The unit should show up as a standard serial port adaptor under the "Ports (COM& LPT)" Icon. Please note the COM port number, as it is required for the initialization of application software.

The unit will start to search for satellites as soon as power is applied, and will start to lock the internal TCXO to UTC as soon as a GPS antenna is attached and more than 4 sats become visible. After 30 minutes or less the unit should stabilize the frequency, resulting in the "LOCK OK" output connector

to have a logic “high” of 3V on it. This LOCK OK output also drives the Mini-PCle status LEDs through the Mini-PCle connector, and the user should see the Mini-PCle status LEDs (if implemented) light up on their computer at this time. This LED and status output on the LOCK OK status coax connector will indicate the unit is fully synchronized to UTC, and generating a stable and accurate 20MHz/19.2MHz/10MHz output signal. The LOCK OK signal may go off momentarily from time to time as airflow touches the unit or sats come in and out of view - this is normal behavior.

You may place the GPS antenna in a window, but it is recommended to place the GPS antenna with a full view of the sky for best performance. The antenna cable can be extended to 100m or more with high quality antenna cable (use quad shielded RG-6 75 Ohms cable, or high-quality 50 Ohms coax cable) without significant loss of signal quality.

WARNING: Make sure to use a proper, correctly installed, and certified Antenna Lightning Arrestor when placing the antenna outside as lightning strikes can cause damage, injury, or death to equipment and personnel.

Figure 2.1 Mini-PCle LTE-Lite Module



2.1.1 Airflow Warning

The Mini-PCle LTE-Lite module is sensitive to airflow. A metal shield is placed on top of the sensitive components such as the TCXO, references, and GPS receiver to mitigate airflow effects. For optimal performance the user should minimize the airflow the unit is exposed to by selecting a Mini-PCle socket away from fans and air-inlets if possible. The unit should optimally be operated in an airtight enclosure that uses conductive cooling rather than forced-air cooling. The Mini-PCle shield is quite effective in typical notebook computers, and testing has shown that most installations should result in adequate airflow shielding and TCXO stability performance.

2.1.2 USB Serial Port

The Mini-PCle LTE-Lite module has an internal RS-232 to USB serial port adaptor for the transmission of NMEA status sentences. The term “RS-232” and USB serial port are used interchangeably, as the RS-232 port is implemented and connected via the USB serial connection on

the Mini-PCIe edge connector built into the module. Windows and Linux have built-in support for this serial port functionality.

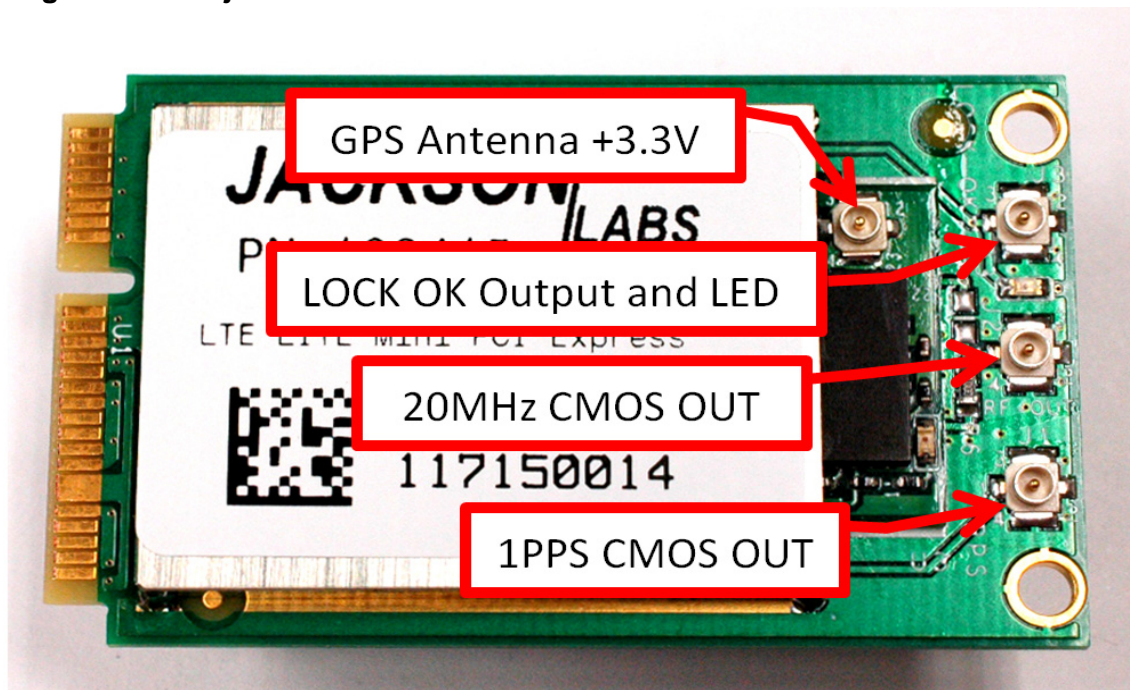
2.1.3 Major connections

The Mini-PCIe LTE-Lite module has a number of coax connectors and a status LED. These are driven by signals from the Mini-PCIe LTE-Lite module.

The major connections and features of the Mini-PCIe LTE-Lite module are shown in **Figure 2.2**. Using any of the signal outputs on the U.FL connectors is optional as the unit provides Position, Velocity, and Timing (PVT) information via the USB serial interface as well as accurate 1PPS timing on the DCD# interrupt of the USB port. For proper PVT information to be generated a GPS antenna must be connected to the U.FI GPS Antenna port coax connector. This antenna feed can be removed after the unit has disciplined its internal TCXO, and the module will continue to generate timing information (time/date/1PPS signals) generated by the internal highly-stable TCXO.

All outputs are 3V CMOS compatible, and the 20MHz RF and 1PPS outputs should be connected to 50 Ohms coax cables with open ended (1K Ohms or higher) termination at the end of the coax cable. The 1PPS rising-edge is aligned to UTC(GPS) to within better than 100ns accuracy typically, and phase-locked to the 20MHz output. The 1PPS output is generated by the internal TCXO, and thus free of any sawtooth type noise. The LOCK OK output is capable of driving an LED with up to 5mA output current. The GPS antenna connector can drive 3.3V with up to 60mA onto the antenna-internal amplifier.

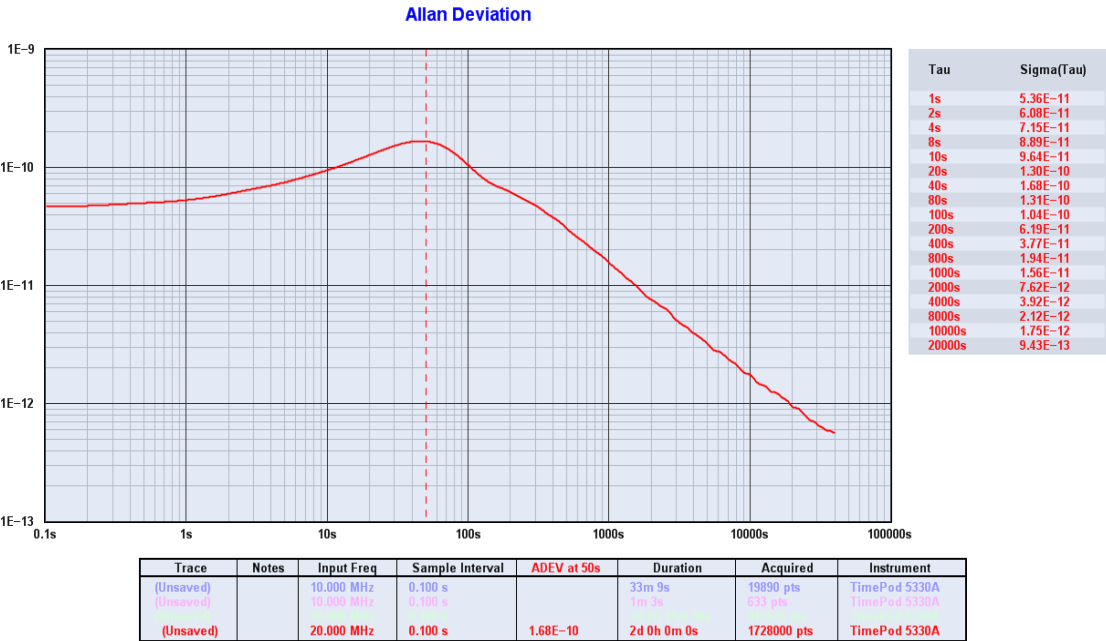
Figure 2.2 Major connections of the Mini-PCIe LTE-Lite module



2.1.4 Typical Phase Noise and ADEV Plots

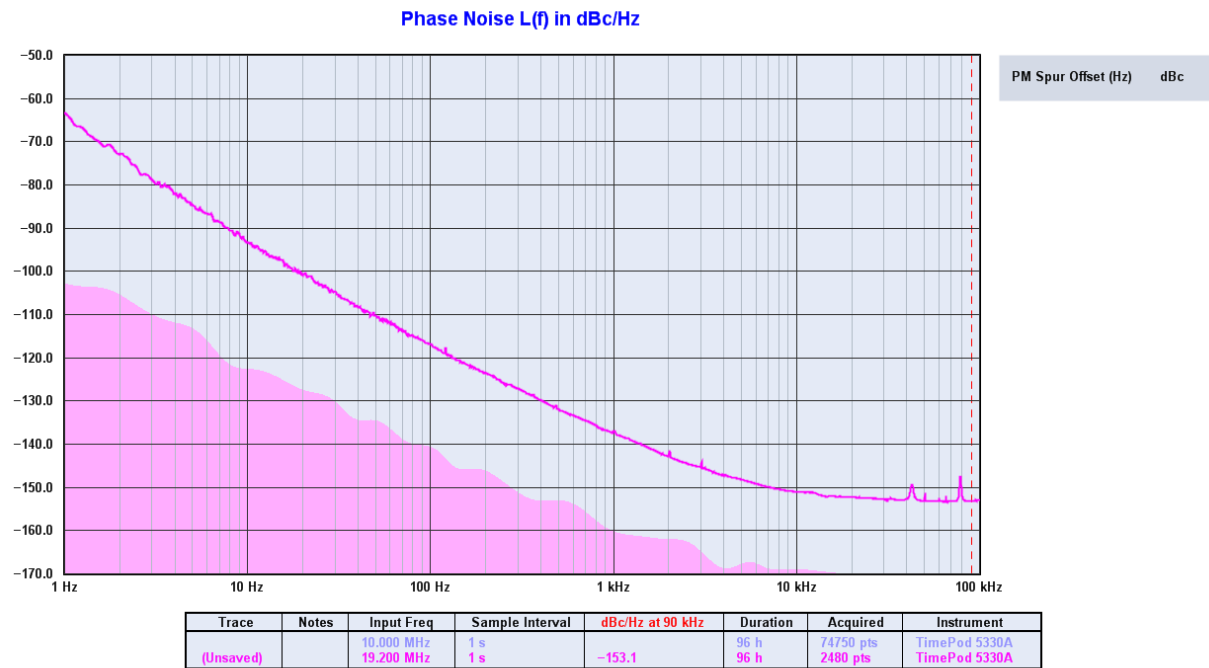
The following plot shows a typical ADEV plot for the Mini-PCIE LTE-Lite module. The unit had been operating for 5+ days, has not been moved or vibrated in any way, and was completely shielded from airflow by placing the unit into an airtight enclosure.

Figure 2.3 Typical ADEV plot of 20MHz Mini-PCIE LTE-Lite module



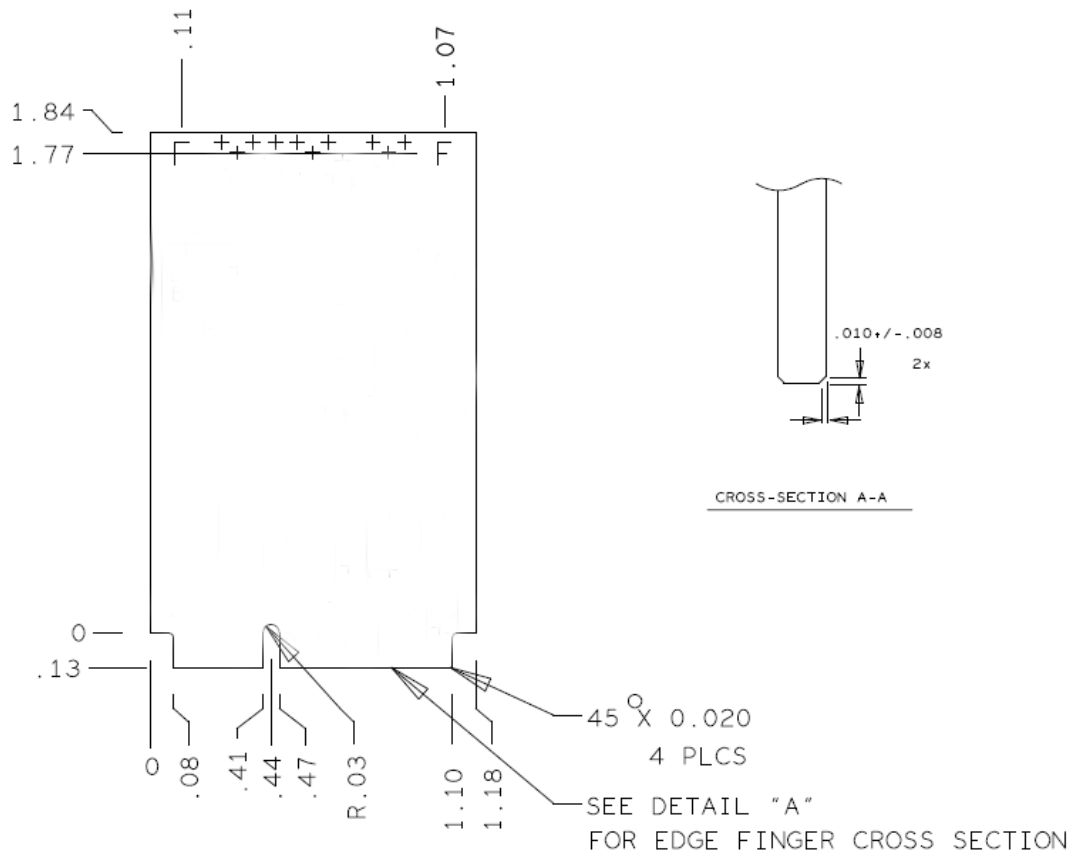
The following plot shows a typical Phase Noise plot of the TCXO buffered RF output for the Mini-PCIE LTE-Lite module. The unit had been operating for 1 day, and was completely shielded from airflow by placing the unit into an airtight enclosure.

Figure 2.4 Typical Phase Noise plot of 19.2MHz Mini-PCle LTE-Lite module



2.1.5 Mini-PCle LTE-Lite Module Mechanical Dimensions

Figure 2.5 Mechanical dimensions



2.2 Connecting a GPS Antenna

Connect the GPS antenna to the U.FI type coax connector shown in [Figure 2.1](#). Please note that this is the coax connector closest to the small metal shield, and soldered directly to the LTE-Lite SMT module. Please make sure to connect the GPS antenna prior to connecting power to the unit.

Caution: use a Lightning Arrestor on your Antenna setup.

The unit will provide +3.3V DC to the external antenna with up to 60mA of current. The Mini-PCle LTE-Lite module GPS receiver includes a 65 channel high-sensitivity GPS receiver with very fast lock time that supports QZSS/WAAS/EGNOS/MSAS Satellite Based Augmentation Systems (SBAS).

The Mini-PCle LTE-Lite module is capable of generating a number of standard navigation messages that are compatible with most GPS based navigation software and are sent to the USB port. The GPS receiver generates a 1PPS time signal that is phase synchronized to UTC. This 1PPS signal is used to frequency-lock the TCXO output of the unit to UTC, thus disciplining the unit's 20MHz/19.2MHz/10MHz frequency output to the US Naval master clock for very high frequency

accuracy (typically better than 1ppb of frequency accuracy when locked to GPS). Over the long term, the Mini-PCIe LTE-Lite module will out-perform free-running Cesium Atomic Frequency Standards.

2.3 USB serial connection (via the Mini-PCIe connector pins)

- The unit outputs strings to the USB Serial port at 38400 baud, 8N1.
- The unit cannot receive serial data and ignores serial data sent to it.
- The unit supplies a 1PPS signal to the DCD# pin of the USB port which can be used to synchronize programs such as NTP or GPSD.
- Plug the Mini-PCIe LTE-Lite module into your computers' Mini-PCIe socket. The computer should automatically install the driver, or prompt you to download the FTDI USB/serial driver. This will attach the Mini-PCIe module to your PC's Hyperterminal, TeraTerm, or a NMEA compatible program such as the uBlox u-center application. Please initialize your PC application software to the proper COM port (automatically assigned by Windows) and configure the application software for 38400 Baud, 8 bits, no parity, 1 stop bit, and no flow control where applicable.

2.3.1 JLT Proprietary STATUS Output Sentence

The Mini-PCIe LTE-Lite module will send a JLT proprietary NMEA-style oscillator status and health output string to the USB port. The string has the following exemplary format:

```
$PJLTS,0.33,-31.15,189,2,1.6970169,56.5672,1.6E-8,0,7,0x228*44
```

```
$PJLTS,-1.35,-31.15,190,2,1.6970190,56.5672,1.6E-8,0,7,0x228*60
```

The fields of this status string are encoded as follows:

```
$PJLTS,-1.35,-31.15,190,2,1.6970190,56.5672,1.6E-8,0,7,0x228*60
```

[\$JLT Proprietary Status String ID],[filtered UTC offset in ns], [raw UTC offset in ns], [number of captured 1PPS pulses], [lock status], [EFC voltage], [EFC percentage (0% to 100%)], [estimated frequency accuracy (similar to 100s ADEV)], [seconds in holdover], [number of Sats tracked (<=12)], [health status]*[NMEA compatible checksum]

N.B: Please note that from time to time this serial port will have short binary messages on it which are routed to the internal GPS receiver. It is thus recommended that any parser using the output from this serial port only parses sentences beginning with a valid '\$' character, and that a parser also checks the NMEA checksum at the end of the sentence, and discards any messages or data that does not have valid NMEA format without any adverse effects to the parser itself in case binary messages (essentially random noise) are present on this serial port.

2.3.1.1 Lock Status Definition

Lock Status definitions:

Value	State
0	TCXO warmup

1	Holdover
2	Locking (TCXO 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, no pending events, and GPS is active

The third binary bit in the status parameter is encoded in the same status as the LOCK-OK LED and signal on the U.FI coax connector.

2.3.1.2 Health Status Definition

The proprietary JLT NMEA-like status sentence contains a hexadecimal status word that shows system health, and oscillator status. Encoding is done by each bit indicating a specific parameter, and thus all bits are orthogonal to each other and can be easily decoded.

The definition of the health parameter is as follows:

If the TCXO coarse-DAC is maxed-out at 255	HEALTH STATUS = 0x1
If the TCXO coarse-DAC is mined-out at 0	HEALTH STATUS = 0x2
If the phase offset to UTC is >250ns	HEALTH STATUS = 0x4
If the run-time is < 300 seconds	HEALTH STATUS = 0x8
If the GPS is in holdover > 60s	HEALTH STATUS = 0x10
If the Frequency Estimate is out of bounds	HEALTH STATUS = 0x20
If the TCXO voltage is too high	HEALTH STATUS = 0x40
If the TCXO voltage is too low	HEALTH STATUS = 0x80
For the first 2 minutes after a phase-reset, or a coarse-DAC change	HEALTH STATUS = 0x200

3 Certification and Warranty

3.1 Certification

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

3.1.1 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.

3.1.2 Limitation of Warranty

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