Lassen™ PT GPS Timing Receiver

System Designer Reference Manual

Part Number 50309-00
Revision A
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Trimble™

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Table of Contents

3 Software Interface

4 System Operation

A Trimble Standard Interface Protocol (TSIP)

B Lassen PT GPS Timing Receiver Monitor

C NMEA 0183

D Specifications and Mechanical Drawings

Glossary

About this Manual

This System Designer's Reference Manual describes how to integrate and operate the Lassen PT GPS timing receiver. The instructions in this manual assume that you know how to use the primary functions of Microsoft Windows.

***Note –** If you are not familiar with GPS, visit Trimble's website, www.trimble.com, for an interactive look at Trimble and GPS.*

Technical Assistance

If you cannot locate the information you need in this product documentation, contact the Trimble Technical Assistance Center at 800-767-4822.

CHAPTER

1

Starter Kit

- Product Overview
- Starter Kit
- Timing Receiver Performance
- Interface Protocols
- Ordering Starter Kit Components
- Starter Kit Interface Unit
- Power
- Hardware Setup
- Software Toolkit

Product Overview

The Lassen PT GPS receiver is a full featured, ultra low power timing receiver in a miniature form factor, suitable for a variety of embedded timing applications. The Lassen PT GPS receiver incorporates Trimble's FirstGPS™ architecture in the form of two ASICS: Colossus RF down converter and IO-TS-C33 baseband chip. The IO-TS-C33 integrates Trimble's IO digital signal processor with the Epson C33 RISC processor, real-time clock, UART, and 1Mbit memory. Together with the colossus RF ASIC, this implementation of FirstGPS technology makes possible one of the smallest (26 mm x 26 mm x 6mm) and lowest power (115mW) GPS timing modules available.

The Lassen PT GPS receiver outputs a 1 Pulse-Per-Second (PPS) timing signal accurate to UTC within 40 ns (1Σ), when using an over determined clock solution in a stationary mode.

Starter Kit

The Starter Kit makes it simple to evaluate the Lassen PT GPS receiver’s exceptional performance. The Starter Kit can be used as a platform for configuring the receiver module and as a platform for troubleshooting your design. The Starter Kit includes:

- Shielded Lassen PT GPS timing module mounted on an interface motherboard in a durable metal enclosure. The motherboard accepts 9 - 32 VDC power and provides regulated +3.3V power to the Lassen PT GPS receiver. The motherboard also contains:
  - 3.6V lithium battery that provides back-up power to the receiver.
  - Circuitry to convert the TTL output to RS-232, enabling the user to connect the RS-232 port in the Starter Kit to the PC COM port via an RS-232 cable connection.
- Bullet III Rooftop GPS Antenna (TNC).
- 75’ RG6 cable terminated with TNC connectors
- 9-pin RS-232 interface cable.
- AC/DC power supply adapter (input: 100-240VAC, output: 12 VDC).
- 5.1” RG178 interface cable (Hirose to bulkhead SMA) with attached TNC to SMA adapter.
- CD containing software tools used to communicate with the receiver, the System Designer Reference Manual, C-programming source routines to be used as a template for communicating with the receiver, and the Lassen PT Timing Receiver Monitor Program.

Removing the Lassen PT GPS Module

The Lassen PT GPS module is secured to the motherboard with double-sided adhesive tape allowing for easy removal and integration with the user's application. (The adhesive tape used by Trimble is 3M Scotch™, part number 4945).

Follow these steps to remove the module from the motherboard:

- Unplug the I/O cable and the RF cable from the module.
- Use a small flat-head screw driver to pry the Lassen PT GPS receiver module off the motherboard.

Warning – Once the Lassen PT GPS receiver module is removed from the motherboard, the double-sided tape loses some of it's adhesive quality. This adhesive tape may only be re-used for laboratory testing. When replacing the adhesive tape, use 3M Scotch™, part number 4945.

Timing Receiver Performance

The Lassen PT GPS receiver is a complete 8-channel parallel tracking GPS receiver designed to operate with the L1 frequency, Standard Position Service, Coarse Acquisition code. Using two highly integrated Trimble custom integrated circuits, the receiver is designed in a modular format, specially adapted for timing applications where small size and extremely low power consumption are required. The receiver features Trimble's latest signal processing code, a high-gain RF section for compatibility with standard active gain GPS antennas, and a CMOS TTL level pulse-per-second (PPS) output for timing applications or for synchronization.

The Lassen PT GPS receiver acquires a position fix with minimal delay after power cycling. The back-up battery is used to retain RAM memory and the Real Time clock (RTC) when main power is removed. The following is stored in battery backed memory:

- Almanac
- Ephemeris
- Last position

User settings such as port parameters and NMEA settings can be stored in the receiver’s non-volatile (Flash) memory. These settings are retained without application of main power or battery back-up power.

The Lassen PT GPS receiver has a single configurable serial I/O communication port.

Warning – When customizing port assignments or characteristics, confirm that your changes do not affect your ability to communicate with the receiver (see Chapter 3, Software Interface).

Interface Protocols

The Lassen PT GPS receiver operates using one of two protocols — Trimble Standard Interface Protocol (TSIP) or NMEA 0183. The factory default setting for the I/O port is TSIP bi-directional. Protocol selection and port characteristics are user configurable.

TSIP

TSIP is a powerful binary packet protocol that allows the system designer maximum configuration control over the GPS receiver for optimum performance in timing applications. TSIP supports multiple commands and their associated response packets for use in configuring the Lassen PT GPS receiver to meet user requirements.

NMEA

NMEA 0183 is an industry standard protocol common to marine applications. NMEA provides direct compatibility with other NMEA-capable devices such as chart plotters, radars, etc. The Lassen PT GPS receiver supports the ZDA NMEA message for GPS timing. Other NMEA messages and output rates can be user selected as required.

Ordering Starter Kit Components

The Lassen PT GPS receiver is available in a Starter Kit or as an individual module and associated antenna. The Starter Kit (49155-00) includes all the components necessary to quickly test and integrate the module:

- 5.1” receiver antenna transition cable (bulkhead SMA to Hirose H.FL) with attached SMA to TNC adapter
- AC/DC power supply adapter
- DC Power cable (3-wire)
- RS-232 interface cable DB9M/DB9F (pin to pin)
- 75’ rooftop antenna cable (TNC to TNC)
- CD-ROM containing software tools, the System Designer Reference Manual, and the Lassen PT Timing Receiver Monitor

Table 1.1 provides ordering information for the Lassen PT GPS module and the associated antennas and cables.

Table 1.1 Lassen PT GPS Timing Receiver Ordering Information

Products	Part Number
Lassen PT GPS timing receiver module	48843-00
Lassen PT GPS receiver Starter Kit	49155-00
Lassen PT GPS receiver antenna transition cable	49894-12
Bullet III 3.3 VDC rooftop Antenna (TNC)	48360-00
75’ Rooftop antenna cable (TNC to SMA)	49995-75

Note – *Part numbers are subject to change. Confirm part numbers with your Trimble representative when placing your order.*

Starter Kit Interface Unit

The Starter Kit interface unit consists of a Lassen PT GPS module attached to an interface motherboard, housed in a sturdy metal enclosure. This packaging simplifies testing and evaluation of the module by providing an RS-232 serial interface which is compatible with most PC communication ports. Power (9-32 VDC) is supplied through the power connector on the front of the interface unit. The motherboard features a switching power supply which converts this voltage input to the 3.3 volts required by the module. The DB9 connector allows for an easy connection to a PC serial port using the serial interface cable provided in the Starter Kit. The metal enclosure protects the module and the motherboard for testing outside of the laboratory environment.

The Lassen PT GPS receiver, installed in the Starter Kit interface unit, is a single module encased in a metal shield. The dimensions of the receiver in this enclosure are 26 mm H x 26 mm L x 6 mm H (1.02” W x 1.02” L x 0.24” H). A straight-in, panel-mount RF SMA connector supports the GPS antenna connection. The center conductor of the SMA connector also supplies +3.3 VDC for the Low Noise Amplifier of the active antenna. On the Lassen PT GPS module, an 8-pin (2x4), 0.09 inch header (J2) supports the serial interface (CMOS TTL level), the pulse-per-second (PPS) signal (CMOS TTL level), and the input power (+3.3 VDC). Figure 1.1 illustrates the module in the metal enclosure.

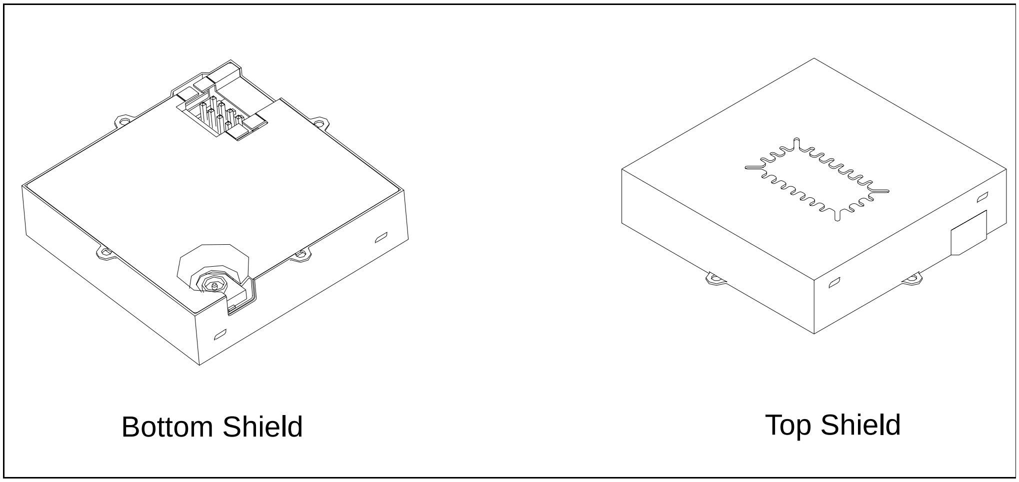


Figure 1.1 Lassen PT GPS Receiver Module

The interface motherboard includes a 9 to 32 VDC switching power supply which provides regulated +3.3 VDC power to the receiver, and contains circuitry which provides an RS-232 interface to a computer. A 3.6V lithium backup battery enables quick hot starts. The TTL level PPS is brought directly out to Pin 9 of the Port 2 DB9 connector on the front of the interface unit.

The Starter Kit includes an AC/DC converter for powering the module from an AC wall socket. The metal enclosure (see Figure 1.2.) provides 2 DB9 interface port connectors, an antenna connector, and a power connector. Port 1 on the metal enclosure is for serial I/O; port 2 is for PPS only.

The mounting plate is secured to the metal enclosure with four screws. The eight pin I/O header on the receiver module connects to a mating connector on a ribbon cable. The ribbon cable is attached to a mating I/O connector on the interface motherboard. Figure 1.2 illustrates the Starter Kit interface unit.

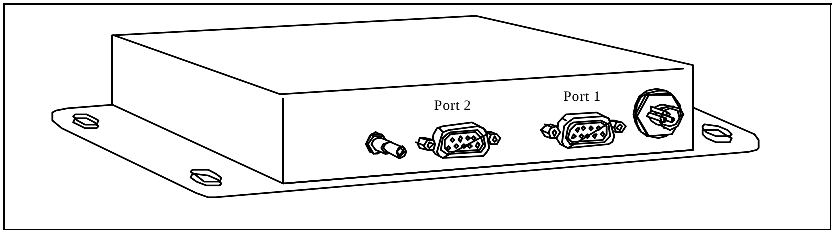


Figure 1.2 Starter Kit Interface Unit

Serial Port Interface

The Starter Kit interface unit is a DCE (Data Communication Equipment) device. To connect to a host computer, or DTE (Data Terminal Equipment) device, use a straight through cable. To connect a Differential Radio (DCE device) to the receiver (DCE Device) use a cross over cable or null modem cable.

Table 1.2 Port 1 Pinouts

Pin	Description
1	NC
2	TX
3	RX
4	NC
5	GND
6	NC
7	NC
8	NC
9	NC

Table 1.3 Port 2 Pinouts

Pin	Description
1	NC
2	NC
3	NC
4	NC
5	GND
6	NC
7	NC
8	NC
9	PPS Out

Pulse-Per-Second (PPS)

The Lassen PT GPS receiver provides a four microsecond wide, CMOS compatible TTL level Pulse-Per-Second (PPS). The PPS is a positive pulse available on pin 9 of the port 2 DB9 connector of the interface unit (see Table 1.3). The rising edge of the PPS pulse is synchronized with respect to UTC. The timing accuracy is within 40 nanoseconds (1Σ) to UTC in a static mode, after self-survey and with an overdetermined clock solution.

The rising edge of the pulse is typically less than 20 nanoseconds. The distributed impedance of the attached signal line and input circuit can affect the pulse shape and rise time. In it’s default setting, PPS can drive a load up to 5mA without damaging the module. The falling edge of the pulse should not be used. The PPS is not reported until the receiver acquires GPS time from the satellite and generates position fixes. The PPS is output immediately after self-survey is completed (approximately 30 minutes).

Power

The Lassen PT GPS receiver is designed for embedded applications and requires a regulated +3.3 VDC input (+3.0 to +3.6 VDC). The receiver provided in the Starter Kit is installed on a motherboard, providing a DC power regulator which converts a 9 to 32 VDC input to the regulated 3.3 VDC required by the receiver. Power can be applied to the interface unit using one of two options: the DC power cable (Figure 1.3), or the AC/DC power converter (Figure 1.4).

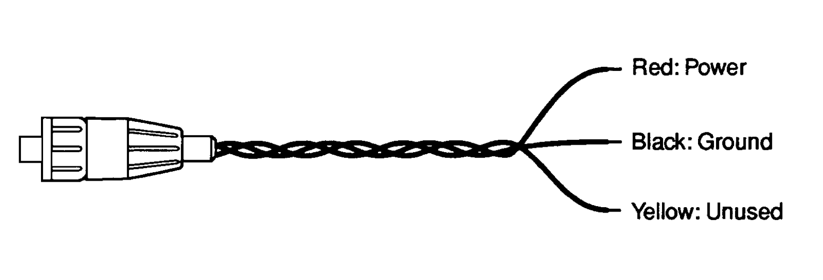


Figure 1.3 DC Power Cable

The DC power cable is ideal for bench-top testing environments. The power cable is terminated at one end with a 3-pin plastic connector which mates with the power connector on the metal enclosure. The un-terminated end of the cable provides easy connection to a DC power supply. Connect the red power lead to a source of DC positive +9 to +32 VDC, and connect the black power lead to ground. This connection supplies power to both the receiver and the antenna.

Note – *To ensure compliance with CE conducted emissions requirements when using the DC power cable, the Starter Kit interface unit must be bonded to a ground plane.*

Note – *The yellow wire of the DC power cable is not used. Battery back-up power is provided by a factory installed 3.6V lithium battery on the motherboard.*

The AC/DC power converter may be used as an alternate power source for the interface unit. The AC/DC power converter converts 110 or 220 VAC to a regulated 12 VDC compatible with the interface unit. The AC/DC power converter output cable is terminated with a 3-pin connector compatible with the power connector on the metal enclosure. The AC power cable is not provided in the kit, since this cable is country-specific. The input connector is a standard 3-prong connector used on many desktop PCs.

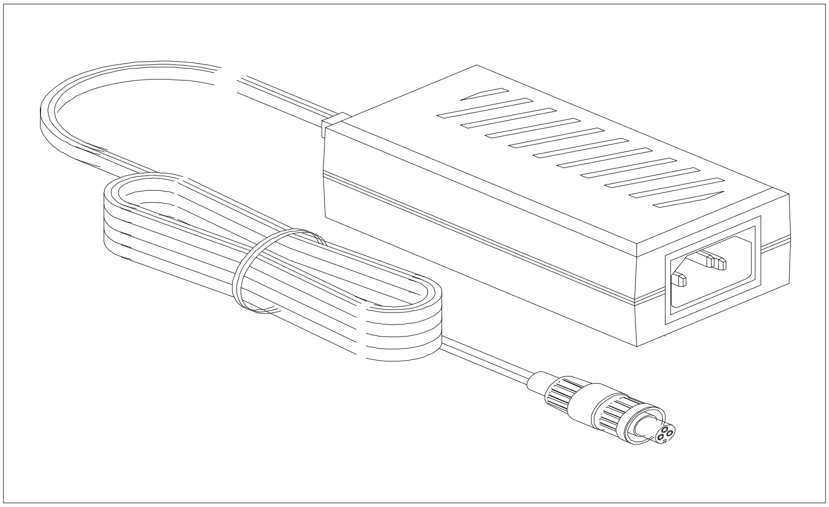


Figure 1.4 AC/DC Power Converter

Hardware Setup

The Lassen PT GPS receiver supports the TSIP and NMEA protocols. A single port supports both the input/output of TSIP messages and the output of NMEA messages. Follow the steps below to setup the Starter Kit interface unit. Figure 1.5 illustrates the setup.

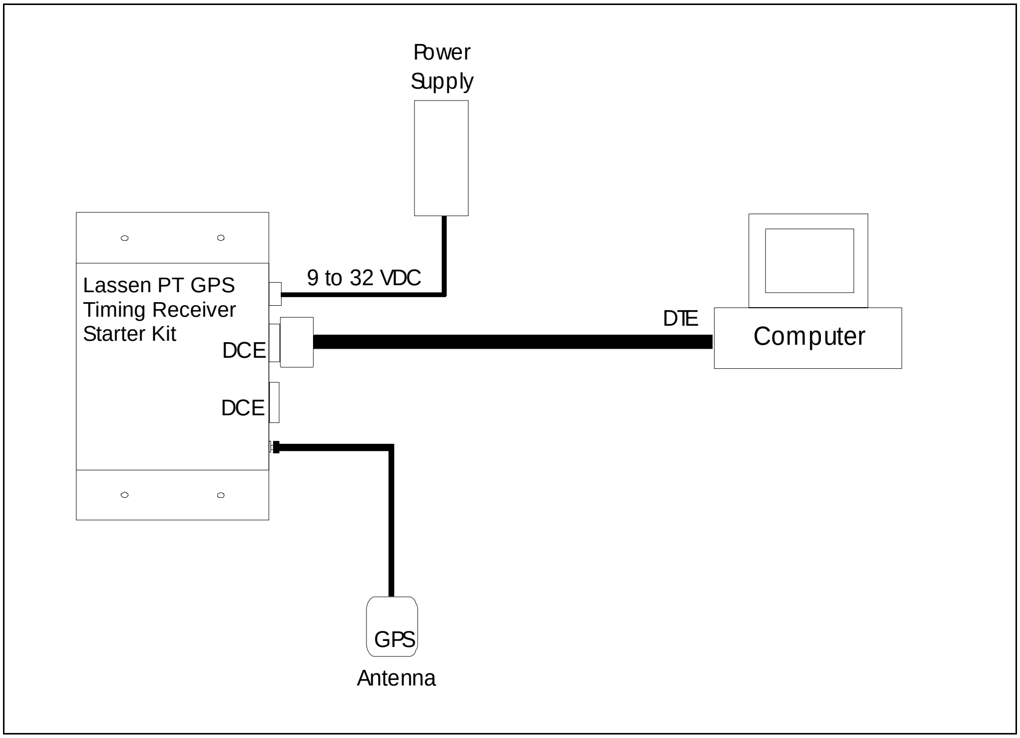


Figure 1.5 Starter Kit Interface Unit

1. When using the TSIP protocol, connect one end of the 9-pin serial interface cable to Port 1 of the interface unit. Connect the other end of the cable to COM1 or COM2 on a PC. A 9-pin-to-25-pin adapter may be required for the serial interface connection to a PC, if your PC has a 25-pin communication port.
2. Connect the antenna cable to the interface unit. This connection is made by attaching the antenna cable connector onto the SMA connector on the module. Place the antenna so that it has a clear view of the sky.
3. Using either the DC power cable or an AC/DC power converter, connect to the 3-pin power connector on the interface unit.
   - DC Power Cable — connect the terminated end of the power cable to the power connector on the interface unit. Connect the red lead to DC positive voltage (+9 to +32 VDC) and black power lead to DC ground. The yellow wire is not used. Switch on the DC power source.
   - AC/DC Power Converter — connect the output cable of the converter to the 3-pin power connector on the interface unit. Using the appropriate 3-prong AC power cable (not provided), connect the converter to an AC wall socket (110 VAC or 220 VAC). The AC power cable is not provided in the Starter Kit.

Software Toolkit

The CD provided in the Starter Kit contains the Lassen PT Monitor program used to monitor GPS performance and to assist system integrators in developing a software interface for the GPS module. This application are described in detail in Appendix B, *TSIP User's Guide*.

Lassen PT Monitor runs on the Windows 95/98/2000/XP platforms.

Following are quick start instructions for using the Lassen PT Monitor application to monitor the receiver's performance.

1. Connect one end of the serial interface cable to Port 1 of the interface unit. Connect the other end of the cable to the COM port of your PC.
2. Turn on the DC power source or plug in the AC/DC converter.
3. Insert the CD in the computer's CD-ROM drive.
4. The Lassen PT Monitor program may be run directly off the CD or it may be copied onto your computer's hard drive. To run the program off the CD, initiate the Lassen PT Monitor.exe file.
5. When the Lassen PT Monitor screen appears, the TX and RX indicators appear in the lower left corner of the status bar. A blinking TX indicates that the PC is transmitting commands to the receiver; a blinking RX indicates that the PC is receiving reports from the receiver. If either of these indicators stop blinking, there is no activity. The PC COM port settings appear in the lower right corner of this same status bar.
6. After a GPS antenna is connected to the receiver and the self survey has been completed, the receiver has achieved a position fix, the transmitted position reports, time, velocity, satellites tracked, and GPS receiver status appear on the screen. The receiver also sends a health report every few seconds, even if satellites are not being tracked.

***Note –** If the Lassen PT Monitor program displays a question mark (?) in a data field, the receiver has not reported a status for this field. If a (?) remains in the data field, the GPS module may not be communicating with the computer. Re-check the interface cable connections and verify the serial port selection and settings. If the communication failure continues after checking all connections and settings, please call the Trimble Technical Assistance Center (TAC) at 1 (800) 767-4822.*

CHAPTER

2

Hardware Integration

In this chapter:

- General Description
- Connectors
- Power Requirements
- Serial Interface
- Pulse-Per-Second (PPS)
- Mounting
- GPS Antenna

General Description

Trimble's new Lassen PT GPS timing receiver adds complete GPS functionality to mobile products, in a postage-stamp-sized footprint with ultra-low power consumption. Using Trimble's breakthrough FirstGPS™ architecture, the module delivers accurate timing solutions for use in all applications where precision timing is needed.

The Lassen PT GPS module is packaged in a tiny form factor (26 mm x 26 mm x 6 mm, including the metal shield). It typically requires only 100 mW of power (at 3.3 VDC). Total typical power usage, including the Trimble 3.3 VDC rooftop antenna, is 133 mW. The module includes flash memory for field upgrades and for storing the user configuration.

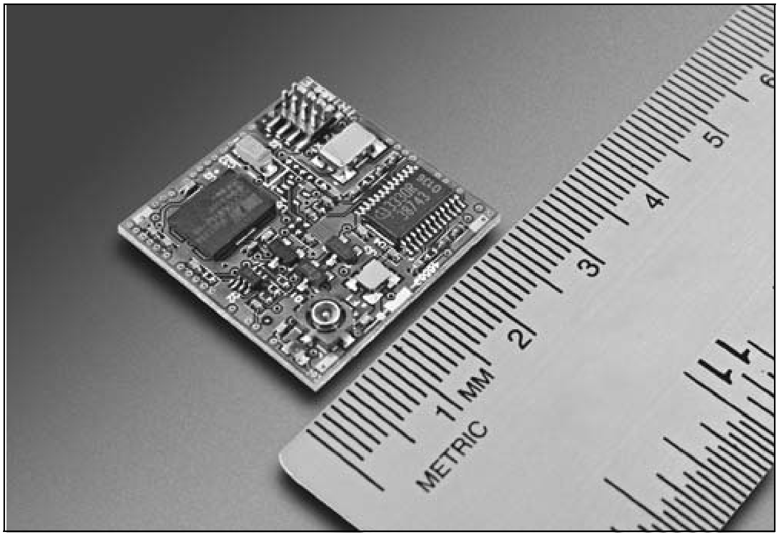


Figure 2.1 Lassen PT GPS Timing Receiver Board without Shield

Connectors

Digital IO/Power Connector

The Lassen PT GPS module uses a single 8-pin (2x4) male header connector for both power and data I/O. The power and I/O connector, J2, is a surface mount micro terminal strip. This connector uses 0.09 inch (2.286mm) high pins on 0.05 inch (1.27mm) spacing. The manufacturer of this connector is Samtec, part number ASP 69533-01.

Note – *See Appendix D for mechanical drawings and specifications.*

Mating Connectors

The customer must supply his own mating connector to the Lassen PT GPS receiver 8-pin (2x4) connector. There are two mating connectors available:

- Surface-Mount Mating Connector

  A recommended surface mount mating connector is Samtec's part number CLP-104-02.

  When a surface-mount mating connector is chosen, the RF connector must be attached to the Lassen PT GPS module prior to securing the module to the user's PCB. The mounting tabs on the edge of the shield may be used for securing the Lassen PT GPS module to the PCB when using the surface-mount mating scheme.

- Cable Strip Mating Connector

  A low profile, cable strip mating connector is the second I/O mating method. A recommended cable strip part is Samtec’s part number FFSD-04-?-XX part. The user will need to substitute the following letters and numbers into the part number when ordering this part where the '?' and 'XX' symbols occur: for the '?' symbol substitute the letter S for single end or D for double end; for the 'XX' symbol substitute the overall length in inches, ± 1/8 inch, with a 2 inch minimum. Since the signals are CMOS TTL level signals, Trimble does not recommend cable lengths of longer than six inches.

  If the cable strip I/O connector scheme is used, the connector side of the Lassen SQ module will be facing up and the mounting tabs will be on the top of the module away from PCB. The RF connector is easily accessible, using this interfacing methodology.

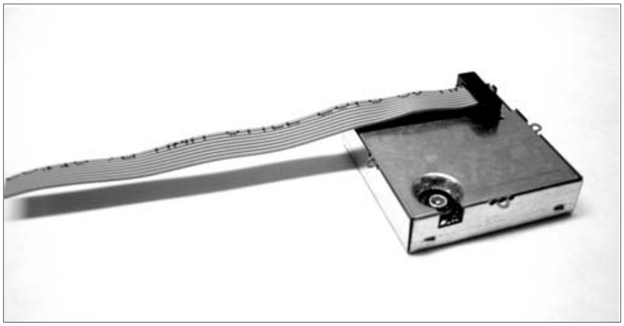


Figure 2.2 Cable Strip Mating Connector

RF Connector

The RF connector mounted on the Lassen SQ module is a Hirose connector, part number H.FL-R-SMT (10) 50 Ohm. The mating RF connector is Hirose H.FL-LP-XXX where XXX depends on the cable type.

Figure 2.3 Lassen PT GPS Module with Connectors

Possible cable manufactures include the following:

- 1.48 mm diameter (single shield) cable:
  - CO-6F/FH-SB manufactured by Hitachi Cable Ltd.
  - UL1979 manufactured by Junkosha Co., Ltd.
  - 0.8DS-PBE manufactured by Sumitomo Electric Industry Co., Ltd.
- 1.32 mm diameter cable (double shield):
- A12B0733 manufactured by Junkosha Co., Ltd.
- 1.47 mm diameter cable (single shield):
  - CXN2571 manufactured by W.L. Gore & Associated, Inc.

Trimble offers a 3.3 VDC rooftop antenna for use with the Lassen PT GPS receiver.

Digital IO/Power Connector Pinout

The digital IO/Power connector pinout information is listed in Table 2.1.

Table 2.1 J2 I/O Connector Signals

Pin number	Function	Description
1	TXD A	Serial Port A transmit, CMOS/TTL
2	GND	Ground, Power and Signal
3	RXD A	Serial Port A receive, CMOS/TTL
4	PPS	Pulse-Per-Second, CMOS/TTL
5	Reserve	No connect
6	Reserve	No connect
7	Prime Power (VCC)	+3.3 VDC to ± 0.3 VDC
8	Battery Backup Power	+2.5 VDC to + 3.6 VDC

Power Requirements

The Lassen PT GPS module requires +3.3 VDC ±0.3 VDC at 33 mA, typical excluding the antenna. The on-board capacitance is 10 µF. An important design consideration for power is the module's internal clock frequency at 12.504 MHz ± 3 KHz. Interference spurs on prime power in this narrow frequency band should be kept to less than 1mV.

The receiver does not require any special power up or down sequencing. The receiver power is supplied through pin 7 of the I/O connector. See Table 2.2 for the +3.3 VDC power specifications.

Warning – The Lassen PT GPS receiver is ready to accept TSIP commands approximately 2.1 seconds after power -up. If a command is sent to the receiver within this 2.1 second window, the receiver will ignore the command. The Lassen PT GPS receiver will not respond to commands sent within the 2.1 second window and will discard any associated command data.

Battery Back-up

The Lassen PT GPS receiver provides an input for battery back-up (BBU) power to keep the module's RAM memory alive and to power the real-time clock when the receiver's prime power is turned off. RAM memory is used to store the GPS almanac, ephemeris, and last position. User configuration data, including port parameters and receiver processing options can be stored in non-volatile Flash which does not require back-up power. By using battery back-up, time to first fix is reduced to 20 seconds (typical). Though not required, providing BBU power can reduce time to first fix. A 3.6 volt lithium battery used for back-up power can last up to five years.

Warning – If battery power is not present, the receiver's power can be turned off and then back on to force a system reset and a cold start. The receiver should be off for no less than 3 minutes to ensure that the RAM memory does not retain any old data due to the residual voltage from the power supply. Alternatively, you can enter the cold start command (TSIP Packet 0x1E) to force a system reset and a cold start. Cycle power and issue the cold start TSIP command immediately after switching the power back on.

***Note –** 2.5V is the minimum allowable battery back-up voltage. When the battery back-up power output drops below 2.5V, the real-time clock may not operate over the specified temperature range. This can also significantly extend the time to first fix.*

Table 2.2 Power Requirements

Signal	Voltage	Current	J2 Pin #
VCC	3.0 to 3.6	33mA	7
Battery Back-up	2.5 to 3.6	10.3µA (at 3.3 volts, +25°C)	8
Ground	0	--	2

Serial Interface

The Lassen PT GPS module provides direct CMOS compatible TTL level serial I/O. The RX and TX signals on the J2 I/O connector are driven directly by the UART on the Lassen PT GPS receiver. Interfacing these signals directly to a UART in your application circuitry provides direct serial communication without the complication of RS-232 or RS-422 line drivers.

Note – *The serial I/O signals on J2 are TTL level. They are not inverted or driven to RS-232 levels.*

Pulse-Per-Second (PPS)

The Lassen PT GPS timing receiver provides a four microsecond wide, CMOS compatible TTL level Pulse-Per-Second (PPS). The PPS is a positive pulse available on pin 4 of the power and I/O connector. The rising edge of the PPS pulse is synchronized with respect to UTC. The timing accuracy is within 40 nanoseconds (1Σ) to UTC valid position fixes are being reported.

The rising edge of the pulse is typically less than 40 nanoseconds. The distributed impedance of the attached signal line and input circuit can affect the pulse shape and rise time. The PPS can drive a load up to 5mA without damaging the module. The falling edge of the pulse should not be used.The PPS is output immediately after self survey is completed (approximately 30 minutes).

Mounting

The Lassen PT GPS PCB is encased in a metal enclosure. The enclosure acts as a protective case. There are four mounting solder tabs on the bottom of the enclosure. When the surface-mount mating connector is used, the mounting tabs may be used for securing the Lassen PT GPS module on the user’s PCB. When the cable strip I/O connector scheme is used, the connector side of the Lassen PT GPS module will be faced up and the mounting tabs will be on the top of the module away from PCB.

The Lassen PT GPS module can be attached to the integrator platform by many methodologies including solder, glue, double sided adhesive tape, and custom hold down mounts for the module's mounting tabs.

Note – *See Appendix D for mechanical drawings and specifications regarding the spacing of the mounting tabs and the dimensions of the enclosure.*

GPS Antenna

Trimble offers a 3.3 VDC rooftop antenna for use with the Lassen PT GPS receiver. The antenna receives the GPS satellite signals and passes them to the receiver. The GPS signals are spread spectrum signals in the 1575 MHz range and do not penetrate conductive or opaque surfaces. Therefore, the antenna must be located outdoors with a clear view of the sky. The Lassen PT GPS receiver requires an ***active*** antenna. The received GPS signals are very low power, approximately -130 dBm, at the surface of the earth. Trimble's active antenna includes a preamplifier that filters and amplifies the GPS signals before delivery to the receiver.

Figure 2.4 Bullet 3 Antenna

CHAPTER

3

Software Interface

In this chapter:

- Start-up
- Communicating with the Lassen PT GPS Module
- Port Protocol and Data Output Options

Start-up

The Lassen PT GPS timing module is a complete 8-channel parallel tracking GPS receiver designed to operate with the L1 frequency, standard position service, Coarse Acquisition code. When connected to an external GPS antenna, the receiver contains all the circuitry necessary to automatically acquire GPS satellite signals, track up to 8 GPS satellites, and compute location, speed, heading, and time. At power-up the receiver will begin a self-survey process. Upon completion (approximately 30 minutes), the receiver will provide an overdetermined timing solution.

The performance of a GPS receiver at power-on is determined largely by the availability and accuracy of the satellite ephemeris data and the availability of a GPS system almanac.

The first time the receiver is powered-up, it is searching for satellites from a cold start (no almanac, time, ephemeris, or stored position). While the receiver will begin to compute position solutions within the first two minutes, the receiver must continuously track satellites for approximately 15 minutes to download a complete almanac and ephemeris. This initialization process should not be interrupted. After initialization, the time is accurate with back-up power enabled, and the time to first fix can typically be shortened to less than 45 seconds. The receiver will respond to commands almost immediately after power-up (see Warning below).

Note – *See Chapter 4 for further detail on ephemeris data and the GPS almanac.*

Warning – The Lassen PT GPS receiver is ready to accept TSIP commands approximately 2.1 seconds after power -up. If a command is sent to the receiver within this 2.1 second window, the receiver will ignore the command. The Lassen PT GPS receiver will not respond to commands sent within the 2.1 second window and will discard any associated command data.

Communicating with the Lassen PT GPS Module

The Lassen PT GPS receiver supports two message protocols: TSIP and NMEA. Communication with the module is through a CMOS compatible, TTL level serial port. The port characteristics can be modified to accommodate your application requirements. Port parameters are stored in non-volatile memory (flash) which does not require backup power. Table 3.1. lists the default port characteristics.

Software Tools

The Software Tools provided on the Starter Kit CD-ROM includes a user friendly Windows application to facilitate communication with the receiver, via the Trimble Standard Interface Protocol (TSIP). Sample TSIP routines are provided in Appendix A.

Note – *The TSIP and NMEA protocols are discussed beginning on page 37 of this chapter, and in Appendix A, Appendix B, and Appendix C.*

Port Configuration

The Lassen PT GPS module has a single I/O port. Table 3.1 provides the default protocol and port configuration for the receiver, as delivered from the factory. TSIP IN/OUT is the default protocol.

Table 3.1 Default Protocol and Port Configuration

Input		Output	
Protocol	**Default Setup**	**Protocol**	**Default Setup**
TSIP	Baud Rate: 9600 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control	TSIP	Baud Rate: 9600 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control

The Lassen PT GPS receiver can also be configured to output NMEA messages. The industry standard port characteristics for NMEA are:

- Baud Rate: 4800
- Data Bits: 8
- Parity: None
- Stop Bits:1
- No Flow Control

Any standard serial communications program, such as Windows Hyper-Terminal or PROCOMM, can be used to view the NMEA output messages. TSIP is a binary protocol and outputs raw binary serial data that cannot be read when using Windows Terminal or PROCOMM. To view the output of the TSIP protocol in text format, use the TR_Monitor program (see the CD-ROM provided in the Starter Kit).

Warning – When using the TSIP protocol to change port assignments or settings, confirm that your changes do not affect the ability to communicate with the receiver (e.g., selecting the PC COM port settings that do not match the receiver’s, or changing the output protocol to TSIP while not using TSIPCHAT).

Port Protocol and Data Output Options

Protocol Configuration and Interface

The factory default protocol for the Lassen PT GPS receiver is the Trimble Standard Interface Protocol (TSIP), for both input and output. The serial port setting is 9600 baud 8-odd-1. The receiver protocol can be re-configured using TSIP command packet 0xBC, TR_Monitor, or a user written serial interface program. See Table 3.1 for protocol configuration options, and Appendix A for details on the 0xBC command packet.

TR_Monitor, a Windows-based GUI, provides a versatile graphical interface for monitoring TSIP data. This application allows the user to view complete receiver operations including data output, status and configuration. In this application, the entry of command packets is replaced by traditional point and click pull-down menus.

C source code example for TSIP commands are also provided in Appendix A. When used as software design templates, this source code can significantly speed-up code development.

The protocol settings and options are stored in battery-backed Random-Access-Memory (BBRAM). They can also be saved into the non-volatile memory (Flash), if desired, using command 0x8E-26. See to Appendix A for additional information on Flash storage for custom operation.

NMEA 0183 Protocol and Data Output Options

The National Marine Electronics Association (NMEA) protocol is an industry standard data protocol which was developed for the marine industry. Trimble has chosen to adhere stringently to the NMEA 0183 data specification as published by the NMEA. The Lassen PT GPS receiver also adheres to the NMEA 0183, Version 3.0 specification.

NMEA data is output in standard ASCII sentence formats. Message identifiers are used to signify what data is contained in each sentence. Data fields are separated by commas within the NMEA sentence. In the Lassen PT GPS receiver, NMEA is an output only protocol. The NMEA protocol is described in detail in Appendix C.

The receiver is shipped from the factory with the TSIP protocol configured on Port 1. The receiver can be reconfigured using TSIP command packet 0xBC, in conjunction with TSIPCHAT, SQ_Monitor, or a user written serial interface program.

The NMEA output messages selection and message output rate can be set using TSIP command packet 0x7A. The default setting is to output the ZDA message at a 1 second interval, when the receiver output protocol is configured to NMEA, using packet 0xBC.

If NMEA is to be permanent for the application, the protocol configuration (0xBC) and NMEA message output setting (0x7A) can be stored in the non-volatile memory (on-board flash) using TSIP command 0x8E-26.

CHAPTER

4

System Operation

In this chapter:In this chapter:

- Start-Up
- Automatic Operation
- Serial Data Communication
- Using the Lassen PT GPS in Mobile Applications
- Customizing Lassen PT GPS Operations
- System Architecture

This chapter describes the operating characteristics of the Lassen PT GPS timing receiver including start-up, satellite acquisition, operating modes, serial data communication, and the timing pulse. The Lassen PT GPS timing receiver acquires satellites and computes position and time solutions. It outputs data in the TSIP (or NMEA) protocol through its serial ports.

Start-Up

At power-up, the Lassen PT GPS automatically begins to acquire and track GPS satellite signals. It typically obtains its first fix in under two minutes.

During the satellite acquisition process, the Lassen PT GPS outputs periodic TSIP status messages on Port 1. These status messages confirm that the receiver is working.

Automatic Operation

When the Lassen PT GPS has acquired and locked onto a set of satellites that pass the mask criteria listed below, and has obtained a valid ephemeris for each satellite, it performs a self-survey. After a number of position fixes, lasting approximately 30 minutes, the self-survey is complete. At that time, the Lassen PT GPS automatically switches to a time-only mode and periodic outputs of navigation information cease.

Satellite Masks

The Lassen PT GPS continuously tracks and uses up to eight satellites in an overdetermined clock solution. The satellites must pass the mask criteria to be included in the solution.

Table 4.1 lists the default satellite masks used by the Lassen PT GPS. These masks serve as the screening criteria for satellites used in fix computations and ensure that solutions meet a minimum level of accuracy. The satellite masks can be adjusted using the TSIP protocol described in Appendix A.

Table 4.1 Default Satellite Mask Settings

Mask	Setting	Notes
Elevation	10°	SV elevation above horizon
SNR	4	Signal strength
DOP	8	Self-survey only

Elevation Mask

Satellites below 10° elevation are not used in the solution. Generally, signals from low-elevation satellites are of poorer quality than signals from higher elevation satellites. These signals travel farther through the ionospheric and tropospheric layers and undergo distortion due to these atmospheric conditions.

SNR Mask

Although the Lassen PT GPS is capable of tracking signals with SNRs as low as 2, the default SNR mask is set to 4 to eliminate poor quality signals from the fix computation. Low SNR values can result from:

- low-elevation satellites
- partially obscured signals (for example, dense foliage)
- multi-reflected signals (multipath)

Multi-reflected signals, also known as multipath, can degrade the position solution. Multipath is most commonly found in urban environments with many tall buildings and a preponderance of mirrored glass. Multi-reflected signals tend to be weak (low SNR value), since each reflection diminishes the signal. Setting the SNR mask to 4 or higher minimizes the impact of multi-reflected signals.

PDOP Mask

Position Dilution of Position (PDOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets that are tightly clustered or aligned in the sky have a high PDOP and contribute to a lower position accuracy. For most applications, a PDOP mask of 8 offers a satisfactory trade-off between accuracy and GPS coverage. With worldwide GPS coverage, the PDOP mask can be lowered even more for many applications without sacrificing coverage.

Note – *PDOP is only applicable during self-survey or whenever the receiver is performing position fixes.*

Tracking Modes

The Lassen PT GPS operates in one of two main fix modes:

- Self-Survey (Position fix mode)
- Overdetermined Clock mode

After establishing a reference position in Self-Survey mode, the Lassen PT GPS automatically switches to Overdetermined (OD) Clock mode.

Self-Survey Mode

At power-on, the Lassen PT GPS performs a self-survey by averaging 2000 position fixes. The number of position fixes until survey completion is configurable using the 8E-4B or 8E-A9 command.

The default mode during self-survey is 3-D manual, where the receiver must obtain a 3-D solution with a PDOP below both the PDOP mask and PDOP switch. The PDOP mask and switch criteria can be set and queried using a TSIP packet. If fewer than four conforming satellites are visible, the Lassen PT GPS receiver suspends data output.

The highest accuracy fix mode is 3-D manual, where altitude is always calculated along with the latitude, longitude, and time. Obtaining a position requires four satellites with a PDOP below the PDOP mask. Depending on how the PDOP mask is set, 3-D mode can be restrictive when the receiver is subjected to frequent obscuration or when the geometry is poor due to an incomplete constellation.

If only a 2-D solution is desired, or if the exact altitude is known, 2-D manual should be requested. In this case, the receiver uses either the last altitude obtained in a 3-D fix, or the altitude supplied by the user. Any error in the assumed altitude affects the accuracy of the latitude and longitude solution. Use packet BB to set the desired position fix mode.

Note – *Altitude and the fix mode are stored in non-volatile memory.*

Overdetermined Clock Mode

Overdetermined Clock Mode is used only in stationary timing applications. This is the default mode for the Lassen PT GPS receiver. After the receiver self-surveys its static reference position, it automatically switches to Overdetermined Clock Mode and determines the clock solution. The timing solution is qualified by a T-RAIM algorithm, which automatically detects and rejects faulty satellites from the solution.

In this mode, the Lassen PT GPS receiver does not navigate or update positions and velocities, but maintains the PPS output, solving only for the receiver clock error (bias) and error rate (bias rate).

PPS Output Options

The PPS (Pulse Per Second) output is the primary timing output generated by the Lassen SQ GPS receiver.

You can program the characteristics of the PPS output using TSIP packets. Packet 0x8E-4A allows you to enable or disable (turn it on or off), control the polarity, select the time base (GPS or UTC) and set the offset (control the cable delay compensation) of the PPS output. Packet 0x8E-4E allows you to set an accuracy criterion for the generation of the PPS signal based on the number of usable satellites. The accuracy of the PPS output depends to some degree on the number of satellites used in the solution that determine the placement of the PPS output. In some systems, it is preferable to have the PPS generated only when it meets the highest levels of accuracy and to leave it off if these accuracy levels are not met.

Note – *For a complete description of the packets described here, see Appendix A.*

Serial Data Communication

When the Lassen PT GPS receiver has acquired a set of satellites that conforms to the mask and mode settings and has collected a valid ephemeris for each satellite, it automatically commences periodic outputs of GPS data and generates a timing pulse (PPS).

The Lassen PT GPS receiver outputs TSIP super packets or NMEA messages. Use packet 8E-A5 to determine which timing super packet to output. These packets are described in Appendix A.

The factory default port setting is 9600 baud in/out, 8 data bits, odd parity, 1 stop bit. The serial port setting can be changed and stored in serial EEPROM using a TSIP command. This port can be configured to transmit timing packets, using packet 8E-A5 to determine which timing packet to output on this port.

GPS Timing

In many timing applications, such as time/frequency standards, site synchronization systems, and wireless voice and data networks, GPS receivers are used to steer a local reference oscillator. The steering algorithm combines the short-term stability of the oscillator with the long-term stability of the GPS PPS. An accurate GPS PPS allows the use of cost-effective crystal oscillators, which have less stability than expensive, high-quality oscillators, such as OCXO's (Oven Controlled Crystal Oscillator).

The GPS constellation consists of at least 24 orbiting satellites. Unlike most telecommunications satellites, GPS satellites are not geostationary, so satellites in view are constantly changing. Each GPS satellite contains four highly-stable atomic clocks, which are continuously monitored and corrected by the GPS control segment. Consequently, the GPS constellation can be considered a set of 24 orbiting "clocks" with worldwide 24-hour coverage.

A Trimble GPS receiver uses the signals from these GPS “clocks” to correct its own internal clock, which is not as stable or accurate as the GPS atomic clocks. A GPS receiver like the Lassen PT GPS receiver outputs a highly accurate timing pulse (PPS) generated by its internal clock, which is constantly corrected using the GPS clocks. In the case of the Lassen PT GPS receiver, this timing pulse is synchronized to UTC within 40 nanoseconds (1Σ) after survey is complete.

In addition to serving as highly-accurate stand-alone time sources, GPS receivers are used to synchronize distant clocks in communication or data networks. This is possible because all GPS satellites are corrected to a common master clock. Therefore, the relative clock error is the same, regardless of which satellites are used. For synchronization applications requiring a common clock, GPS is the ideal solution.

Position and time errors are related by the speed of light. This is why an accurate reference position is critical. A position error of 100 meters corresponds to a time error of approximately 333 ns.

The GPS receiver's clocking rate and software affect PPS accuracy. The Lassen PT GPS has a clocking rate of 3.126 MHz which enables a steering resolution of 320 ns (±160 ns). Using software algorithms like an overdetermined clock solution, the Lassen PT mitigates the effects of clock error to achieve a PPS accuracy within 40 ns (1Σ) to UTC after survey is complete.

Timing Operation

The Lassen PT GPS automatically outputs a PPS and time tag. With an accurate reference position, the receiver automatically switches to an overdetermined clock mode, activates its T-RAIM algorithm and outputs a precise PPS. Using a simple voting scheme based on pseudo-range residuals, the Lassen PT GPS integrity algorithm automatically removes the worst satellite with the highest residual from the solution set if that satellite’s residual is above a certain threshold.

The Lassen PT GPS receiver's default configuration provides optimal timing accuracy. The only item under user or host control that can affect the receiver's absolute PPS accuracy is the delay introduced by the interface cable. For long cable runs, this delay can be significant (1.25 ns per foot). TSIP packet 8Ex4A sets the cable delay parameter, which is stored in non-volatile memory. For the best absolute PPS accuracy, adjust the cable delay to match the installed cable length. The cable delay is about 1.25 nanoseconds per foot of cable. To compensate for the cable delay, use a negative offset to advance the PPS output.

Note – *GPS time differs from UTC (Universal Coordinated Time) by a small, sub-microsecond offset and an integer-second offset. The small offset is the steering offset between the GPS DoD clock ensemble and the UTC (NIST) clock ensemble. The large offset is the cumulative number of leap seconds since 1 January 1970, which, on 31 December 1998, was increased from 12 to 13 seconds. Historically, the offset increases by one second approximately every 18 months, usually just before midnight on 30 June or 31 December. System designers should note whether the output time is UTC or GPS time.*

Using the Lassen PT GPS in Mobile Applications

Although it is intended primarily for use in static applications, the Lassen PT GPS receiver can also be used in mobile applications. The factory default settings for the Lassen PT GPS assume that the antenna is going to be used in a static timing application. To use the Lassen PT GPS in mobile applications, you must disable the receiver's self-survey mechanism and ensure that a stored position does not exist in the nonvolatile EEPROM.

To prepare the Lassen PT GPS receiver for mobile applications, complete the following steps.

- Confirm that there is no stored position in the nonvolatile EEPROM by using command packet 8E-45 with data byte 1 set to 6 (accurate position segment.)

  This operation clears any stored position from the EEPROM.

- Disable the self-survey mechanism using command packet 8E-A9.

  If not disabled, the self-survey mechanism will automatically survey the antenna's position and then set the receiver to operate in a static, time-only mode.

- Set the desired position fix mode using command packet BB.

After these steps are completed, the Lassen PT GPS receiver is ready to operate properly in mobile applications. While operating in a mobile application, the receiver can continue to output a PPS pulse as well as timing packets.

Note – *The accuracy of the PPS output pulse will be degraded by a factor of about 3 when the unit is operated in a mobile application.*

Customizing Lassen PT GPS Operations

The Lassen PT GPS receiver provides a number of user configurable parameters that allow you to customize the operation of the unit. These parameters are stored in a non-volatile memory chip (EEPROM) to be retained during loss of power and through resets. At reset or power-up, the receiver configures itself based on the parameters stored in the EEPROM. You can change the values of these parameters to achieve the desired operations using a variety of TSIP packets. The Lassen PT GPS configures itself based on the new parameter immediately, but the new parameter value is not automatically saved to the EEPROM. You must direct the receiver to save the parameters to the EEPROM.

Parameters are grouped into sections of the EEPROM called segments. Each segment is identified with a number and contains a group of related parameters. To change the parameter values stored in EEPROM, send packet 0x8E-26 to direct the Lassen PT GPS to save the current parameter values in a specified segment in the EEPROM. You can also direct the receiver to set the parameter values to their factory default settings with packet 0x8E-45. When a segment is set to its factory defaults, the contents of the EEPROM segment are set and the Lassen PT GPS configures itself with the default settings.

In brief, to customize the Lassen PT GPS receiver operations for your application:

- Configure the receiver using TSIP command packets until the desired operation is achieved.
- Use TSIP packet 0x8E-26 to save the settings in non-volatile memory (EEPROM.)

The new settings will control receiver operations whenever it is reset or power cycled.

Table 4.1 through Table 4.8 list the user configurable parameters by segment number. Each table lists the parameter name, its factory default value, and the TSIP packet that sets or reads the parameter value (typically, one TSIP packet sets or reads several related parameters.)

Table 4.1 Receiver Configuration

Parameter	Factory default	Set	Request	Report
Operating dimension	4 (Full Position 3D)	BB	BB	BB
DGPS mode	3 (Auto DGPS/GPS)	BB	BB	BB
Dynamics code	1 (Land)	BB	BB	BB
Elevation mask	0.175 radians (10 degrees)	BB	BB	BB
Signal level mask	4.0 AMU	BB	BB	BB
PDOP mask	8.0	BB	BB	BB
PDOP switch	6.0	BB	BB	BB
Foliage mode	0 (never)	BB	BB	BB
DGPS age limit	30 seconds	BB	BB	BB
Have reference altitude flag	FALSE	2A	2A	4A
Reference altitude (meters)	0.0	2A	2A	4A

Table 4.2 OEM Configuration

Parameter	Factory Default	Set	Request	Report
Datum index	WGS 84 Ellipsoid	8E-14	8E-15	8F-15
Position	0x12	35	35	35
Velocity	0x02	35	35	35
Time	0x01	35	35	35
Auxiliary	0x02	35	35	35

Table 4.2 OEM Configuration (Continued)

Parameter	Factory Default	Set	Request	Report
Super packets output mask (byte 1)	0x32	8E-A5	8E-A5	8F-A5
Super packets output mask (byte 2)	0x21	8E-A5	8E-A5	8F-A5
Auto TSIP output mask	0xC0000900	8E-4D	8E-4D	8F-4D

Table 4.3 Port A and B Configuration

Parameter	Factory default	Set	Request	Report
Input baud rate	9600	BC	BC	BC
Output baud rate	9600	BC	BC	BC
Parity	Odd	BC	BC	BC
Data bits	8	BC	BC	BC
Stop bits	1	BC	BC	BC
Input protocol	TSIP	BC	BC	BC

Table 4.4 PPS Configuration

Parameter	Factory default	Set	Request	Report
PPS enabled switch	Enabled	8E-4A	8E-4A	8E-4A
PPS timebase	UTC	8E-4A	8E-4A	8E-4A
Polarity	TRUE	8E-4A	8E-4A	8E-4A
PPS offset	0.0 Seconds	8E-4A	8E-4A	8E-4A
PPS driver switch	3 (At least 1 SV)	8E-4E	8E-4E	8E-4E

Table 4.5 Position Information

Parameter	Factory default	Set	Request	Report
XYZ coordinates	Such that LLA coordinates are all zeros	31		
Have position flag	FALSE			

Table 4.6 Self-Survey Configuration

Parameter	Factory default	Set	Request	Report
Survey enable flag	TRUE	8E-A6	8E-A6	8F-A6
Survey length	2000	8E-A6	8E-A6	8F-A6
Survey save flag	FALSE	8E-A6	8E-A6	8F-A6
Survey operating dimension	Full Position 3D	0xBB	0xBB	0xBB

The survey operating dimension can be set to auto and 2D if segments are saved (8E-26) while a survey is in process. The receiver uses the dimension setting saved for the next survey. If a reference altitude has been entered and the receiver is set to 2D survey, the reference altitude is used. If a reference altitude has not been entered and the receiver is set to 2D survey, an altitude of 0 is used for 2D survey (not recommended).

Table 4.7 NMEA Configuration

Parameter	Factory default	Set	Request	Report
NMEA message mask	0x00000020 (ZDA)	7A	7A	7A
NMEA message rate	1	7A	7A	7A
NMEA options	0	7A	7A	7A

Table 4.8 UTC Information

Parameter	Factory default	Set	Request	Report
have_utc	FALSE			

System Architecture

The Lassen PT GPS timing receiver (see Figure 4.2) uses eight processing channels operating on the L1 frequency of 1575.42 MHz and using the coarse acquisition (C/A) code. The module uses custom integrated circuitry designed by Trimble to track the GPS satellite signals. These ICs also contain support circuitry to the navigation processor. An integrated 32-bit microprocessor is used for tracking, computing a position, and performing the I/O operations.

The Lassen PT GPS receives the amplified GPS satellite signals through the antenna feed line connector and passes them to the RF down converter. A highly stable crystal reference oscillator operating at 12.504 MHz is used by the down converter to produce the signals used by the 8-channel signal processor. The 8-channel signal processor tracks the GPS satellite signals and extracts the carrier code information as well as the navigation data at 50 bits per second.

Operation of the tracking channels is controlled by the navigation processor. The tracking channels are used to track the highest eight satellites above the horizon. The navigation processor will then use the optimum satellite combination to compute a position. The navigation processor also manages the ephemeris and almanac data for all of the satellites, and performs the data I/O.

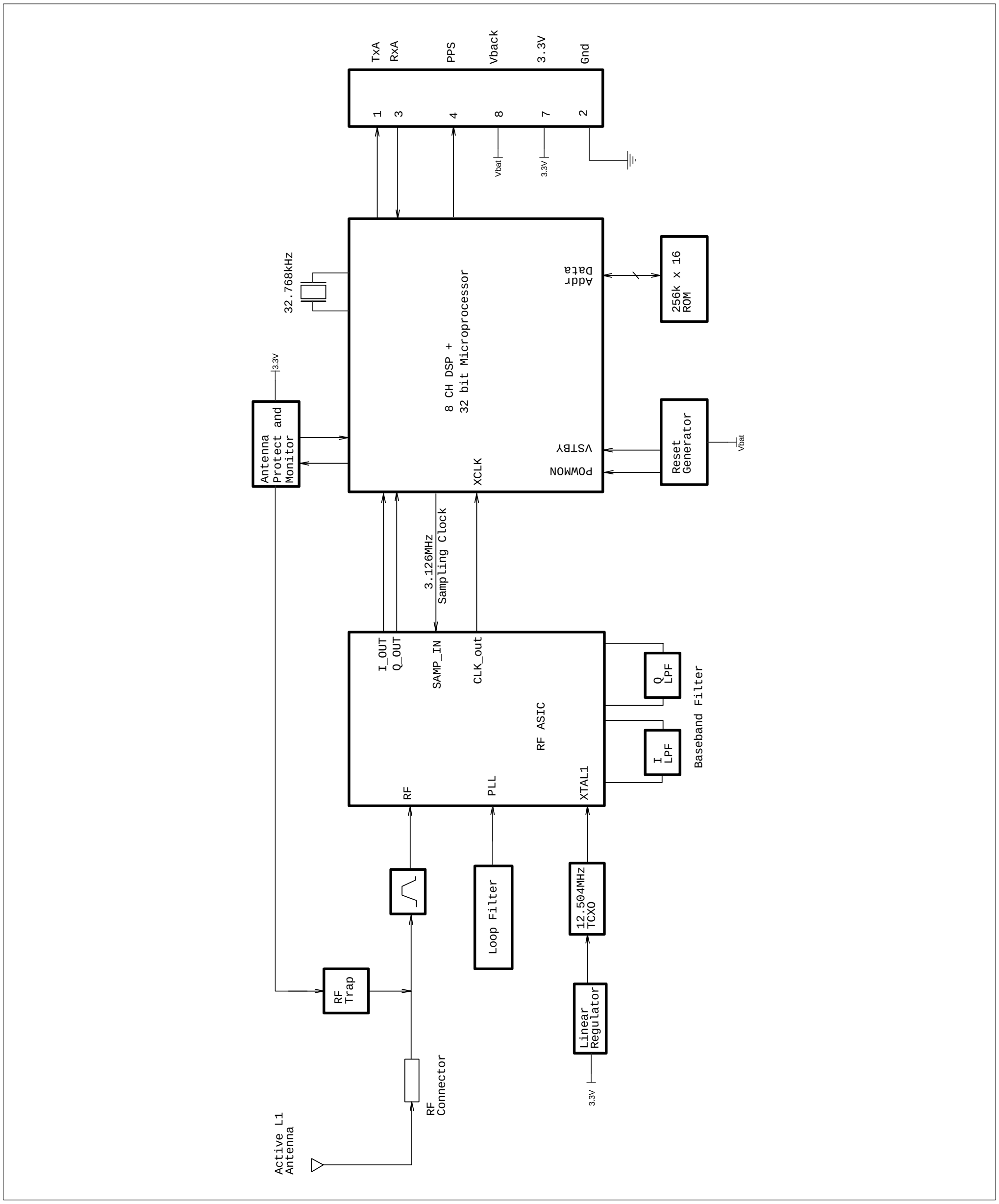


Figure 4.2 Lassen PT GPS Block Diagram

APPENDIX

A

Trimble Standard Interface Protocol (TSIP)

The Trimble Standard Interface Protocol (TSIP) provides the system designer with multiple commands that may be used to configure a GPS receiver for optimum performance in a variety of applications. TSIP enables the system designer to customize the configuration of a GPS module to meet the requirements of a specific application.

This appendix provides the information needed to make judicious use of the powerful features TSIP has to offer, to greatly enhance overall system performance, and to reduce the total development time. The reference tables beginning on page 62 will help you determine which packets apply to your application. Application guidelines are provided for each TSIP Command Packet, beginning on page 77.

Interface Scope

The Trimble Standard Interface Protocol is used extensively in Trimble receiver designs. The protocol was originally created for the Trimble Advanced Navigation Sensor (TANS) and is colloquially known as the TANS protocol even though the protocol applies to many other devices.

The Lassen PT GPS has one serial I/O communications port. This port is a bi-directional control and data port utilizing Trimble Standard Interface Protocol (TSIP). This port may also be used to receive TSIP commands and to output industry standard ASCII-based NMEA messages. The data I/O port characteristics and other options are user programmable and can be stored in non-volatile flash memory.

The TSIP protocol is based on the transmission of packets of information between the user equipment and the unit. Each packet includes an identification code (1 byte, representing 2 hexadecimal digits) that identifies the meaning and format of the data that follows. Each packet begins and ends with control characters.

This document describes in detail the format of the transmitted data, the packet identification codes, and all available information over the output channel to allow the user to choose the data required for his particular application. As will be discussed, the receiver transmits some of the information (position and velocity solutions, etc.) automatically when it is available, while other information is transmitted only on request. Additional packets may be defined for particular products and these will be covered in the specifications for those products as necessary.

The TSIPCHAT utility, part of the GPS Tool Kit, is designed to exercise many of the TSIP packets.

Packet Structure

TSIP packet structure is the same for both commands and reports. The packet format is:

```
<DLE> <id> <data string bytes> <DLE> <ETX>
```

Where:

- <DLE> is the byte 0x10
- <ETX> is the byte 0x03
- <id> is a packet identifier byte, which can have any value excepting <ETX> and <DLE>.

The bytes in the data string can have any value. To prevent confusion with the frame sequences <DLE> <ID> and <DLE> <ETX>, every <DLE> byte in the data string is preceded by an extra <DLE> byte ('stuffing'). These extra <DLE> bytes must be added ('stuffed') before sending a packet and removed after receiving the packet. Notice that a simple <DLE> <ETX> sequence does not necessarily signify the end of the packet, as these can be bytes in the middle of a data string. The end of a packet is <ETX> preceded by an odd number of <DLE> bytes.

Multiple-byte numbers (integer, float, and double) follow the ANSI/IEEE Std. 754 IEEE Standard for binary Floating-Point Arithmetic. They are sent most-significant byte first. This may involve switching the order of the bytes as they are normally stored in Intel based machines. Specifically:

- UINT8 = Byte: An 8 bit unsigned integer.
- UINT16 = Word: A 16 bit unsigned integer.
- INT16 = Integer: A 16 bit integer.
- INT32 = Long: A 32 bit integer.
- UINT32 = ULong: A 32 bit unsigned integer.
- Single — Float, or 4 byte REAL has a precision of 24 significant bits, roughly 6.5 digits.
- Double — 8 byte REAL has a precision of 52 significant bits. It is a little better than 15 digits.

Default Automatic Position and Velocity Reports

The Lassen PT GPS automatically outputs position and velocity reports at set intervals. Report intervals are controlled by packet 35.

Table A.1 Automatic Position and Velocity Reports

Output ID	Description
42	Single precision XYZ position
83	Double-precision XYZ position
4A	Single-precision LLA position
84	Double-precision LLA position
43	Velocity fix (XYZ ECEF)
54	See Note
56	Velocity fix (ENU)

Note – *When the receiver is in the Manual or Overdetermined Clock mode, it outputs packet 54 to provide the computed clock-only solution.*

Automatic Primary and Supplemental Timing Reports

Timing Packets 8F-AB and 8F-AC are automatically output at 1 Hz. These packets are part of the low-latency packet series AB/AC/AD/OB.

Initialization Packets to Speed Start-up

If you are not supplying the receiver with battery power when main power is off, you can still “warm-start” the receiver by sending the following commands after the receiver has completed its internal initialization and has sent Packet 82.

Table A.1 Initialization Packets

Input Byte	Description
0x2B	initial position
0x2E	initial time
0x38	almanac (for each SV)
0x38	almanac health
0x38	ionosphere page
0x38	UTC correction

Packets Output at Power-Up

The following table lists the messages output by the receiver at power-up. After completing its self-diagnostics, the receiver automatically outputs a series of packets which indicate the initial operating condition of the receiver. Messages are output as listed in the table below. After Packet 82 is output, the sequence is complete and the receiver is ready to accept commands.

Table A.2 Packet Power-up Output Messages

Output ID	Description	Notes
0x45	software version	--
0x46	receiver health	--
0x4B	machine code/status	--
As chosen, see Table A.1 default: 0 x 4A, 0 x 56	position/Velocity output	As chosen, see Table A.1.
0x41	GPS time	
82	DGPS position fix mode	--

Default Background Packets

The Lassen PT GPS automatically outputs a set of packets that you can monitor for changes in receiver operations, including receiver health, time, almanac pages, and ephemeris updates.

Table A.3 Background Packets

Output ID	Description	Notes
41	GPS time	If the receiver's GPS clock is set and the receiver is not outputting positions, time is output approximately every 16 seconds. Output approximately every 2.5 minutes if the receiver is doing position fixes.
46	Receiver health	Output approximately every 16 seconds, if the receiver is not doing fixes. Output approximately every 30 seconds if the receiver is doing position fixes. Whenever any bit in the health message changes, receiver health is automatically output.
6D	Mode packet	Output approximately every 30 seconds or when a constellation change occurs.

***Note –** The background packets listed in this table are automatically output. Background packets can be turned off.*

Satellite Data Packets

The following packets request data transmitted by the GPS satellites and satellite tracking information.

Table A.4 Satellite Data Packets

Input ID	Description	Output ID
20	Request almanac	40
27	Request signal levels	47
28	Request GPS system message	48
29	Request almanac health page	49
2F	Request UTC parameters	4F
38	Request/load satellite system data	58
39	Set/request satellite disable or ignore health	59
3A	Request last raw measurement	5A
3B	Request satellite ephemeris status	5B
3C	Request tracking status	5C

Low-Latency timing Packets

The Lassen PT GPS features a sequence of high-priority timing super packets, which are output within a bounded period of time after the PPS. The LLT packets offer an advanced data interface for applications requiring accurate data reports in a time constrained environment.

the first super packet will start transmission no later than 25 +/- 10 ms after the PPS transition.

The super packets which meet the LLTP criteria are in the table below. the packets are listed in order of output priority. Output of each packet can be turned on/off by using the mask in packet 8E-A5, but the output order cannot be changed.

The packets may also be requested (see the specific packet documentation for details).

Table A.5 Low-Latency Timing Packets

Packet ID	Description	Output ID
8F-AB	Primary Timing	8E-AB
8F-AC	Supplemental Timing	8E-AC

The receiver will output all other TSIP packets after the transmission of LLTP packet sequence is complete.

***Note –** Only the first packet will meet the LLTP specification. All other LLTP packets will be output immediately after the first LLTP packet completes.*

Recommended TSIP Packets

Table A.6 Recommended TSIP Packet Data

Function	Description	Input	Output
Protocol and port setup	set/query port configuration	0xBC	0xBC
	set/query NMEA configuration	0x7A	0x7B
	set/query I/O options (autoreport and format options)	0x35	0x55
Navigation	GPS time	0x21	0x41
	position & velocity (superpacket)	0x8E-20 or 0x37 or auto	0x8F-20
	double-precision LLA	0x37/auto	0x84
	double-precision XYZ	0x37/auto	0x83
	ENU velocity	0x37/auto	0x56
	XYZ velocity	0x37/auto	0x43
Satellite and tracking information	query receiver state (health)	0x26	0x46, 0x4B
	query current satellite selection	0x24	0x6D
	query signal levels	0x27	0x47
	query satellite information (azimuth, elevation, etc.)	0x3C	0x5C
Receiver settings	query software version	0x1F	0x45
	query receiver ID & error status	0x26	0x4B, 0x46
	set/query receiver configuration	0xBB	0xBB
	set altitude for 2D mode	0x2A	0x4A
	disable PV/altitude filters	0x70	0x70
	set/query positioning mode (2D v. 3D)	0xBB	0xBB
GPS System	query/load GPS system data	0x38	0x58

Table A.6 (Continued)Recommended TSIP Packet Data

Function	Description	Input	Output
Initialization	full reset (clear battery backup and/or non-volatile settings)	0x1E	
	soft reset	0x25	
	set GPS time	0x2E	0x4E
	set exact LLA	0x32	
	set approx. XYZ	0x23	
	set approx. LLA	0x2B	
	set exact XYZ	0x31	

Command Packets Sent to the Receiver

The table below summarizes the command packets sent to the receiver. The table includes the input Packet ID, a short description of each packet, and the associated response packet. In some cases, the response packets depend on user-selected options. These selections are covered in the packet descriptions beginning on page 77.

Table A.7 User-Selected Command Packet Options

Input ID	Packet Description	Output ID
0x1E	clear battery back-up/reset	See Note 1
0x1F	software version	0x45
0x21	current time	0x41
0x23	initial position (XYZ ECEF)	--
0x24	request receiver position fix mode	0x6D
0x25	soft reset & self-test	See Note 1
0x26	receiver health	0x46, 0x4B
0x27	signal levels	0x47
0x2A	altitude for 2-D mode	0x4A
0x2B	initial position (Lat, Lon, Alt)	--
0x2D	oscillator offset	0x4D
0x2E	set GPS time	0x4E
0x2F	UTC parameters request	0x4F
0x31	accurate initial position (XYZ Cartesian ECEF)	--
0x32	accurate initial position	--
0x35	I/O options	0x55
0x37	status and values of last position and velocity	0x57
0x38	load or request satellite system data	0x58
0x3C	tracking status	0x5C, see Note 2
0x70	filter configuration	0x70

Table A.7 User-Selected Command Packet Options (Continued)

Input ID	Packet Description	Output ID
0x7A	set/request NMEA output configuration	0x7B
0xBB	set receiver configuration	0xBB
0xBC	set port configuration	0xBC
0x8E-20	last fix with extra information (fixed point)	0x8F-20
0x8E-26	Store settings in Flash memory.	0x8F-26
8E-4A	set/request PPS characteristics	8F-4A
8E-4B	survey limit	8F-4B
8E-4D	packet output mask	8F-4D
8E-4E	set PPS output option	8F-4E
8E-A5	set or request packet broadcast mask	8F-A5
8E-A6	issue self-survey command	8F-A6
8E-AB	set/request primary timing packet	8F-AB
8E-AC	set/request supplemental timing packet	8F-AC

Note 1 – *Output is determined by packet 0 x 35. See Table A.2 to determine which messages are output at power-up.*

Note 2 – *No response sent if data is not available.*

Report Packets Sent by the Receiver to the User

The table below summarizes the packets output by the receiver. The response packets may depend on user-selected options.

Table A.8 User-Selected Report Packet Options

Output ID	Packet Description	Input ID
0x41	GPS time	0x21, auto
0x42	single-precision XYZ position	0x37, auto
0x43	velocity fix (XYZ ECEF)	0x37, auto
0x45	software version information	0x1F, power-up
0x46	health of Receiver	0x26, auto, power-up
0x47	signal level for all satellites	0x27
0x4A	single-precision LLA position	0x37, auto
0x4B	machine code/status	0x26, auto, power-up
0x4D	oscillator offset	0x2D
0x4E	response to set GPS time	0x2E
0x55	I/O options	0x35
0x56	velocity fix (ENU)	0x37, auto
0x57	information about last computed fix	0x37
0x58	GPS system data/acknowledge	0x38
0x5C	satellite tracking status	0x3C
0x6D	all-in-view satellite selection	0x24, auto
0x82	differential position fix mode	0x62, auto
0x83	double-precision XYZ	auto, 0x37
0x84	double-precision LLA	auto, 0x37
0x8F-20	last fix with extra information (fixed point)	auto, 0x37, 0x8E-20
0xBB	GPS navigation configuration	0xBB
0xBC	Receiver port configuration	0xBC
8F-4A	PPS characteristics	8E-4A

Table A.8 User-Selected Report Packet Options (Continued)

8F-4B	survey limit	8E-4B
8F-4D	automatic packet output	8E-4D
8F-4E	PPS output option	8E-4E
8F-A5	packet broadcast mask	8E-A5
8F-A6	response to self-survey command	8E-A6
8F-AB	set/request primary timing packet	8E-AB
8F-AC	set/request supplemental timing packet	8E-AC

Set Primary Receiver Configuration Packet 0xBB

TSIP command packet BB contains the primary receiver configuration parameters.

The Lassen PT GPS stores three independent sets of configuration parameters. These are designated as the “Mobile”, “Survey” and “Timing” configurations. The active configuration is determined by the survey state:

Table A.9 Survey State Configurations

Survey State	Active Configuration
Survey Disabled	Mobile
Survey Active	Survey
Survey Complete	Timing

When the survey state changes, the receiver automatically switches to the new configuration. Only the active configuration can be programmed.

To program configurations, switch the active configuration by changing to the appropriate survey state using packets 8E-A6 and 8E-A9, update the configuration (BB), and save settings (8E-26).

There are restrictions to the dynamics code and operating dimension settings, which take effect when survey is enabled, ensuring that the receiver performs a valid survey and enters a timing mode afterwards. The following table shows the valid settings for each configuration.

Table A.10 Survey State Configurations

Survey State	Active Configuration	Dynamics Code	Operating Dimension
Survey Disabled	Mobile	any	any
Survey Active	Survey	Land/Sea/Air	2D or 3D or Auto
Survey Complete	Timing	Stationary	1SV or Over-determined

Send packet BB with subcode 0 as the only data byte, to query for the primary receiver configuration. The receiver responds with report packet BB. When sending this packet, enter 0xFF or –1.0 to leave any parameter unchanged.

Dynamics Code

The default is LAND mode, where the receiver assumes a moderate dynamic environment. In this case, the satellite search and re-acquisition routines are optimized for vehicle-type environments. In SEA mode, the search and re-acquisition routines assume a low acceleration environment and the receiver reverts to the user-entered altitude in 2-D auto. In AIR mode, the search and re-acquisition routines are optimized for high acceleration conditions.

Elevation Mask

This is the minimum elevation angle for satellites to be used in a solution output by the receiver. Satellites near the horizon are typically more difficult to track due to signal attenuation, and are also generally less accurate due to higher variability in the ionospheric and tropospheric corruption of the signal. When there are no obstructions, the receiver can generally track a satellite down to near the horizon. However, when this mask is set too low, the receiver may experience frequent constellation switching due to low elevation satellites being obscured.

Frequent constellation switching is undesirable because position jumps may be experienced when Selective Availability is present and DGPS is not available to remove these effects. The benefit of a low elevation mask is that more satellites are available for use in a solution and a better PDOP may be yielded. The current default mask is set to 0.1745 radians (10°) and provides a reasonable trade-off between the benefits and drawbacks.

Signal Level Mask

This mask defines the minimum signal strength for a satellite used in a solution. There is some internal hysteresis on this threshold, which allows brief excursions below the threshold if lock is maintained and the signal was previously above the mask. This mask should be lowered only with caution since it is also used to minimize the effects of jammers and reflected signals on the receiver. Users who require high accuracy can use a slightly higher mask of 6.0-8.0, since weaker measurements may be noisier and are often caused by reflected signals, which provide erroneous ranges.

Make sure the elevation and SNR masks are not set too low. The satellite geometry is sometimes improved considerably by selecting low-elevation satellites. These satellites are, however, subject to significant signal degradation by the greater ionospheric and tropospheric attenuation that occurs. They are also subject to more obscuration by the passing scenery when the receiver is in a moving vehicle. The code phase data from those satellites is more difficult to decode and therefore has more noise.

Note – *A level of hysteresis in the signal level mask is allowed in the core operating software. The hysteresis allows the receiver to continue using satellite signals which fall slightly below the mask and prevents the receiver from incorporating a new signal until the signal level slightly exceeds the mask. This feature minimizes constellation changes caused by temporary fluctuations in signal levels.*

Packet Descriptions

Command Packet 0x1E - Clear Battery Backup, then Reset

This packet commands the GPS receiver to clear all battery back-up data and to perform a software reset. This packet contains one data byte.

Table A.11 Command Packet 0x1E Format

Byte	Item	Type	Value	Definition
0	Reset mode	Unit 8	0x4B 0x46	Cold start: Erase BBRAM and restart Factory reset: Erase BBRAM and Flash and restart

Warning – All almanac, ephemeris, current position, mode, and communication port setup information is lost when executing the “Factory Reset” command. In normal use this packet should not be sent.

Warning – It is very helpful to keep a fresh copy of the current almanac, which is stored in the file GPSALM.DAT collected by the TSIPCHAT command “!”. This allows near-instantaneous recuperation by the receiver in case of power loss or clearing of battery-backed memory by using the TSIPCHAT command “@” to load it back into the receiver memory.

Command Packet 0x1F - Request Software Versions

This packet requests information about the version of software running in the Navigation and Signal Processors. This packet contains no data. The GPS receiver returns Packet 0x45.

Command Packet 0x21 - Request Current Time

This packet requests current GPS time. This packet contains no data. The GPS receiver returns Packet 0x41.

Command Packet 0x23 - Initial Position (XYZ Cartesian ECEF)

This packet provides the GPS receiver with an approximate initial position in XYZ coordinates. This packet is useful if the user has moved more than about 1,000 miles since the previous fix. (Note that the GPS receiver can initialize itself without any data from the user; this packet merely reduces the time required for initialization.) **This packet is ignored if the receiver is already calculating positions.** The data format is shown below.

Note – *To initialize using the Latitude-Longitude-Altitude representation, use Command Packet 0x2B.*

Table A.12 Command Packet 0x23 Data Format

Byte	Item	Type	Units
0-3	X	Single	Meters
4-7	Y	Single	Meters
8-11	Z	Single	Meters

Command Packet 0x24 - Request GPS Receiver Position Fix Mode

This packet requests current position fix mode of the GPS receiver. This packet contains no data. The GPS receiver returns Packet 0x6D.

Command Packet 0x25 - Initiate Soft Reset & Self Test

This packet commands the GPS receiver to perform a software reset. This is equivalent to cycling the power. The GPS receiver performs a self-test as part of the reset operation. This packet contains no data. Following completion of the reset, the receiver will output the start-up messages (see Table A.2). The GPS receiver sends Packet 0x45 only on power-up and reset (or on request); thus if Packet 0x45 appears unrequested, then either the GPS receiver power was cycled or the GPS receiver was reset.

Command Packet 0x26 - Request Health

This packet requests health and status information from the GPS receiver. This packet contains no data. The GPS receiver returns Packet 0x46 and 0x4B.

Command Packet 0x27 - Request Signal Levels

This packet requests signal levels for all satellites currently being tracked. This packet contains no data. The GPS receiver returns Packet 0x47.

Command Packet 0x2A - Altitude for 2-D Mode

Reference Altitude is the altitude used for manual 2-D positions if the altitude flag is set. Altitude is in units of HAE WGS-84 or MSL depending on the selected I/O options for the position (see page 85). The Altitude Flag determines whether or not the Reference Altitude will be used. If set, it will be used. If cleared, altitude hold (last 3-D altitude) is used.

Note – *With no data byte, this packet requests the current values of these altitude parameters. In this case, the GPS receiver returns Packet 4A.*

This packet sets or requests the altitude parameters used for the Manual 2-D mode: Reference Altitude and Altitude Flag. Packet 0x4A (9 byte format) is returned.

Table A.13 Packet 0x2A Set Reference Altitude Description

Byte	**Item**	**Type**	**Definition**
0-3	Altitude	Single	Reference altitude for 2-D

Table A.14 Packet 0x2A Clear Reference Altitude Description

Byte	Item	Type	Value	Definition
0	Altitude Flag	UINT8	0 x FF	Clear Altitude flag

Note – *With no data bytes, this packet requests the current values of these altitude parameters. In this case, the GPS receiver returns Packet 4A (9 byte format).*

Command Packet 0x2B - Initial Position (Latitude, Longitude, Altitude)

This packet provides the GPS receiver with an approximate initial position in latitude and longitude coordinates (WGS-84). This packet is useful if the user has moved more than about 1,000 miles since the previous fix. (Note that the GPS receiver can initialize itself without any data from the user; this packet merely reduces the time required for initialization.) **This packet is ignored if the receiver is already calculating positions**. The data format is shown in the table below.

Table A.15 Command Packet 0x2B Data Format

Byte	Item	Type	Units
0-3	Latitude	Single	Radians, north
4-7	Longitude	Single	Radians, east
8-11	Altitude	Single	Meters

Note – *To initialize with ECEF position, use Command Packet 0x23.*

Command Packet 0x2D - Request Oscillator Offset

This packet requests the calculated offset of the GPS receiver master oscillator. This packet contains no data. The GPS receiver returns Packet 0x4D. This packet is used mainly for service. The permissible oscillator offset varies with the particular GPS receiver unit.

Command Packet 0x2E - Set GPS Time

This packet provides the approximate GPS time of week and the week number to the GPS receiver. The GPS receiver returns Packet 0x4E. The data format is shown below. The GPS week number reference is Week # 0 starting January 6, 1980. The seconds count begins at the midnight which begins each Sunday morning. This packet is usually not required when the battery back-up voltage is applied as the internal clock keeps time to sufficient accuracy. **This packet is ignored if the receiver has already calculated the time from tracking a GPS satellite**.

Note – *See report Packet 41 for information on the Extended GPS week number.*

Table A.16 Command Packet 0x2E Data Formats

Byte	Item	Type	Units
0-3	GPS time of week	Single	Seconds
4-5	Extended GPS week number	INT16	Weeks

Command Packet 0x31 - Accurate Initial Position (XYZ Cartesian ECEF)

This packet is identical in content to Packet 0x23. This packet provides an initial position to the GPS receiver in XYZ coordinates. However, the GPS receiver assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available. For acquisition aiding, the position provided by the user to the GPS receiver in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.

Table A.17 Command Packet 0x31 Data Format

Byte	Item	Type	Units
0-3	X-axis	Single	Meters
4-7	Y-axis	Single	Meters
8-11	Z-axis	Single	Meters

Command Packet 0x32 - Accurate Initial Position, (Latitude, Longitude, Altitude)

This packet is identical in content to Packet 0x2B. This packet provides the GPS receiver with an accurate initial position in latitude, longitude, and altitude coordinates. However, the GPS receiver assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available. For acquisition aiding, the position provided by the user to the GPS receiver in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.

Table A.18 Command Packet 0x32 Data Format

Byte	Item	Type	Units
0-3	Latitude	Single	Radians, North
4-7	Longitude	Single	Radians, East
8-11	Altitude	Single	Meters

Command Packet 0x35 - Set/Request I/O Options

Packet 35 is used to control the format and timing of the position and velocity output. This packet requests the current I/O options and allows the I/O options to be set as desired. To request the option settings without making any changes, send the packet with no data bytes. To change the option settings, include four data bytes with the values. The I/O options, their default settings, and the byte values for all possible configurations are shown below.

The Set/Request I/O options are stored in battery-backed memory. To store them in non-volatile RAM (Flash) use the 0x8E-26 command. The GPS receiver returns Packet 0x55. See Table A.2 for information on saving the settings to non-volatile memory. These abbreviations apply to the following table: ALT (Altitude), ECEF (Earth-centered, Earth-fixed), XYZ (Cartesian coordinates), LLA (latitude, longitude, altitude), HAE (height above ellipsoid), WGS-84 (Earth model (ellipsoid)), MSL geoid (mean sea level), and UTC (coordinated universal time).

Table A.19 Command Packets 0x35 and 0x55 Data Descriptions

Byte	Bit	Item	Type	Value	Definition	Associated Packets
Position						
0	0 (LSB)	XYZ ECEF	Bit	0 1	XYZ ECEF output off XYZ ECEF output on	0x42 (single) 0x83 (double)
	1	LLA Output	Bit	0 1	LLA output off LLA output on	0x4A (single) 0x84 (double)
	2	LLA ALT Output	Bit	0 1	HAE (Note 1) MSL geoid	0x4A / 0x84 0x8F-17 0x8F-18
	3	ALT input	Bit	0 1	HAE (Note 1) MSL geoid.	0x2A
	4	Precision-of-position output	Bit	0 1	Send single-precision packet. Send double-precision packet.	0x42, 0x4A 0x83, 0x84
	5	Super Packet Output	Bit	0 1	Output no Super Packets. Output all enabled Super Packets.	0x8F-20 (Note 2)
	6-7	Reserved				
Velocity						
1	0	XYZ ECEF	Bit	0 1	XYZ ECEF output off XYZ ECEF output on	0x43
	1	ENU output	Bit	0 1	ENU output off ENU output on	0x56
	2-7	Reserved				

Table A.19 Command Packets 0x35 and 0x55 Data Descriptions (Continued)

Byte	Bit	Item	Type	Value	Definition	Associated Packets
Timing						
2	0	Time Type	Bit	0 1	GPS time UTC	0x42, 0x43, 0x4A, 0x83, 0x84, 0x56
	1	Fix computation time	Bit	0 1	ASAP Next integer second	N/A
	2	Fix output time	Bit	0 1	When computed Only on request	37
	3	Synchronized measurements	Bit	0 1	Off On	N/A
	4	Minimize projection	Bit	0 1	Off On	N/A
	5-7	Unused				
Auxiliary/Pseudo Range Measurements						
3	0	Raw measuring	Bit	0 1	Raw measurements off Raw measurements on	0x5A
	1	Raw / Filtered	Bit	0 1	Raw PR's in 5A Filtered PR's in 5A	0x5A (Note 3)
	2	Reserved				
	3	Output dB Hz instead of AMU	Bit	0 1	Output dB Hz Output AMU's	0x5A, 0x5C, 0x47
	4-7	Reserved				

Note 1– *In the current version of the Lassen PT GPS, the output HAE altitude is always in the WGS-84 datum. The input HAE altitude is always in the WGS-84 datum.*

Note 2– *Packet 8E must be used to specify which superpacket is to be output.*

Note 3 – *Automatic output of 0x5A messages is supported in the Lassen PT GPS for backwards compatibility with older TSIP applications.*

Bytes 0-1

Bytes 0 and 1 control the message output format.

Byte 2

Byte 2 contains the five time parameters described below:

- Time Type - This bit defines whether the time tags associated with a position fix are in GPS time or UTC time. The default is UTC time.
- Fix Computation Time - This bit controls the time and frequency of position fixes. The default is ASAP.

  Alternatively, in the integer second mode, the most recent measurements are projected to next integer second, and the solution is then valid at this time. The benefit of this mode is the standard fix time and a 1 Hz output rate. The drawbacks are that some measurement projection is performed and that the fix may be slightly older than with the default option. This mode also conforms to the output rate of NMEA.
- Output Time - This bit defines whether fixes are automatically output when computed or only sent in response to a packet 37 request. The default is automatic output.
- Synchronized Measurements - This bit controls whether all satellite range measurements are required to have the same time tag. The default is OFF. Slightly older measurements are tolerated (on the order of 3-5 seconds) to provide solutions when obscurations make it impossible to obtain exactly concurrent measurements from each satellite.

When this bit is ON, all measurements are required to have the same time tag. This mode is used only when the user application requires all satellite measurements to be identical to the position time tag. If a satellite that is in the selected set for the solution is lost, then no fix will be made until a new selection is made.

The synchronized measurement mode combined with the minimized projection timing mode (see next paragraph) allows absolutely no measurement projection. However, obscurations may reduce the fix density when there are limited satellites. Use this mode cautiously.

- Minimized Projection - This bit controls the time of the position fix relative to the time of the satellite range measurements. The default mode is OFF. In this mode, the time of solution is the time at which the GPS position fix is computed. Thus, all measurements are projected by an interval which is roughly the amount of time it takes to compute the solution. This approach minimizes the latency between the time tag of the computed solution and the solution output. The drawback is that the measurement projection (which is only about 100 ms) may induce some error during high accelerations.

  Alternatively, when minimized projection is ON, the time of the solution is the time of the most recent measurements. Thus, if all measurements are taken at exactly the same time, there is no measurement projection. If a selected satellite's measurement time lags the most recent measurement, then it is projected to this time. The difference is that the fix will have more latency than a fix provided with the above timing option. This is the best choice for users performing non real-time error analysis, or non real-time DGPS solution-space corrections. This is also the preferable mode for users integrating GPS with other sensors, where communication lags are the dominant latencies, and thus the time lag between the applicability and availability of the fix is small.

Byte 3

Byte 3, the auxiliary byte, controls the output of additional fix data. It contains two control bits:

- Bit 0 controls the output of raw measurements (Packet 5A).
- Bit 1 controls whether the raw measurements output in packet 5A are doppler smoothed.

Command Packet 0x37 - Request Status and Values of Last Position and Velocity

This packet requests information regarding the last position fix and is only used when the receiver is not automatically outputting positions. The GPS receiver returns Report Packet 0x57 followed by the position/velocity packets specified in Command Packet 0x35.

Command Packet 0x38 - Request/Load Satellite System Data

This packet requests current satellite data (almanac, ephemeris, etc.) or permits loading initialization data from an external source (for example, by extracting initialization data from an operating GPS receiver unit via a data logger or computer and then using that data to initialize a second GPS receiver unit). The GPS receiver returns Packet 0x58. (Note that the GPS receiver can initialize itself without any data from the user; it merely requires more time.)

To request data without loading data, use only bytes 0 through 2; to load data, use all bytes. Before loading data, observe the caution notice below. The data formats are located in Report Packet 0x58.

Table A.20 Command Packet 0x38 Data Formats

Byte	Item	Type	Value	Definition
0	Operation	UINT8	1 2	Request data from Lassen PT GPS receiver; Load data into Lassen PT GPS receiver
1	Type of data	UINT8	2 3 4 5 6	Almanac Health page, T_oa, WN_oa Ionosphere UTC Ephemeris
2	Sat PRN#	UINT8	0 1 - 32	Data that is not satellite - ID specific Satellite PRN number
3	Length (n)	UINT8		Number of bytes of data to be loaded
4 to n+3	Data	UINT8		Satellite data

Warning – Proper structure of satellite data is critical to Lassen PT GPS receiver operation. Requesting data is not hazardous; Loading data improperly is hazardous. Use this packet only with extreme caution. The data should not be modified in any way. It should only be retrieved and stored for later download. The ephemeris data cannot be loaded into the receiver.

Command Packet 0x3C - Request Current Satellite Tracking Status

This packet requests the current satellite tracking status. The GPS receiver returns Packet 0x5C if data is available.

Table A.21 Command Packet 0x3C Data Format

Byte	Item	Type	Value	Definition
0	Satellite #	UINT8	0 1 - 32	All satellites in the current tracking set desired satellite

Report Packet 0x41 - GPS Time

This packet provides the current GPS time of week and the week number. The GPS receiver sends this packet in response to Packet 0x21 and during an automatic packets update cycle. Update cycles occur approximately every 5 seconds. The data format is shown below.

Table A.22 Report Packet 0x41 Data Formats

Byte	Item	Type	Units
0-3	GPS time of week	Single	seconds
4-5	Extended GPS week number	INT16	weeks
6-9	GPS UTC offset	Single	seconds

***Note –** UTC time lags behind GPS time by an integer number of seconds; UTC = (GPS time) - (GPS UTC offset).*

Warning – GPS week number runs from 0 to 1023 and then cycles back to week #0. week # 0 began January 6, 1980. The first cycle back to week #0 was on August 22, 1999. The extended GPS week number however, does not cycle back to 0. For example: the week # for August 22, 1999 = 1024; the Week # for April 1, 2002 = 1160.

The seconds count begins with "0" each Sunday morning at midnight GPS time. A negative indicated time-of-week indicates that time is not yet known; in that case, the packet is sent only on request. The following table shows the relationship between the information in Packet 0x41, and the Packet 0x46 status code.

Table A.23 Packets 0x41 and 0x46 Status Code Relationships

Approximate Time Accuracy	Time Source	Sign (TOW)	Packet 46 Status Code
none	no time at all	-	0x01
unknown	approximate time from real-time clock or Packet 2E	+	0x01
20-50 msec + clock drift	time from satellite	+	0x02 - 0x0C
full accuracy	time from GPS solution	+	0x00

***Note –** Before using the GPS time from Packet 0x41, verify that the Packet 0x46 status code is 00 ("Doing position fixes"). This will ensure the most accurate GPS time.*

Report Packet 0x42 - Single-Precision Position Fix, XYZ ECEF

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O “position” option is set to XYZ ECEF (byte 0: bit 0, Packet 0x35)and the I/O Precision-of-Position Output (byte 0: bit 4, Packet 0x35) is set to single-precision, then the GPS receiver sends this packet each time a fix is computed. The data format is shown below.

Table A.24 Report Packet 0x42 Data Formats

Byte	Item	Type	Units
0-3	X	Single	meters
4-7	Y	Single	meters
8-11	Z	Single	meters
12-15	Time-of-fix	Single	seconds

The time-of-fix is in GPS time or UTC as selected by the I/O “timing” option. Packet 83 provides a double-precision version of this information.

Report Packet 0x43 - Velocity Fix, XYZ ECEF

This packet provides current GPS velocity fix in XYZ ECEF coordinates. If the I/O velocity option is set to XYZ ECEF (byte 1, bit 0, Packet 0x35), then the GPS receiver sends this packet each time a fix is computed. The data format is shown below.

Table A.25 Report Packet 0x43 Data Formats

Byte	Item	Type	Units
0-3	X velocity	Single	meters/second
4-7	Y velocity	Single	meters/second
8-11	Z velocity	Single	meters/second
12-15	bias rate	Single	meters/second
16-19	time-of-fix	Single	seconds

The time-of-fix is in GPS time or UTC as selected by the I/O “timing” option (byte 2, bit 0, Packet 0x35).

Report Packet 0x45 - Software Version Information

This packet provides information about the version of software in the Navigation and Signal Processors. The GPS receiver sends this packet after power-on and in response to Packet 0x1F.

Table A.26 Report Packet 0x45 Data Formats

Byte	Item	Type
0	Major version number	UINT8
1	Minor version number	UINT8
2	Month	UINT8
3	Day	UINT8
4	Year number minus 1900	UINT8
5	Major revision number	UINT8
6	Minor revision number	UINT8
7	Month	UINT8
8	Day	UINT8
9	Year number minus 2000	UINT8

The first 5 bytes refer to the Navigation Processor and the second 5 bytes refer to the Signal Processor.

Report Packet 0x46 - Health of Receiver

This packet provides information about the satellite tracking status and the operational health of the receiver. The receiver sends this packet after power-on or software-initiated resets, in response to Packet 0x26 and, every five seconds. Packet 0x4B is always sent along with this packet.

Note – *If receiver status changes between five second outputs, no notification is given until the next cycle.*

Table A.27 Report Packet 0x46 Data Formats

Byte	Bit	Item	Type	Value	Definition
0		Status code	UINT8	0x00 0x01 0x02 0x03 0x08 0x09 0x0A 0x0B 0x0C	Doing position fixes Don't have GPS time yet Need initialization (0=normal, 1=shutdown due to RF initialization timeout) PDOP is too high No usable satellites Only 1 usable satellite Only 2 usable satellites Only 3 usable satellites The chosen satellite is unusable
1	0	Battery backup	Bit	0 1	OK BBRAM was not available at start-up
1	4	Antenna feedline fault		0 1	OK short

The error codes in Byte 1 of Packet 0x46 are encoded into individual bits within the byte. The bit positions are their meanings are shown below.

Note – *After status is detected, its bit remains set until the receiver is reset.*

Report Packet 0x47 - Signal Levels for all Satellites

This packet provides received signal levels for all satellites currently being tracked or on which tracking is being attempted (i.e., above the elevation mask and healthy according to the almanac). The receiver sends this packet only in response to Packet 0x27. The data format is shown below.

Table A.28 Report Packet 0x47 Data Formats

Byte	Item	Type
0	Count	UINT8
1	Satellite number 1	UINT8
2- 5	Signal level 1	Single
6	Satellite number 2	UINT8
7-10	Signal level 2	Single
(etc.)	(etc.)	(etc.)

Up to 8 satellite number/signal level pairs may be sent, indicated by the count field. Signal level is normally positive. If it is zero then that satellite has not yet been acquired. If it is negative then that satellite is not currently in lock. The absolute value of signal level field is the last known signal level of that satellite.

Note – *The signal level provided in this packet is a linear measurement of the signal strength after correlation or de-spreading. Units, either AMU or dBHz, are controlled by Packet 0x35.*

Report Packet 0x4A - 20 Byte Format

This packet provides current GPS position fix in LLA (latitude, longitude, and altitude) coordinates. If the I/O Position option is set to LLA and the I/O Precision-of-Position Output is set to single-precision (all controlled by Packet 35), then the receiver sends this packet each time a fix is computed. Command Packet 35 controls position output (XYZ or LLA) and (single or double) output precision. The data format is shown in below.

Table A.29 Report Packet 0x4A Data Formats

Byte	Item	Type	Units
0-3	Latitude	Single	radians; + for north, - for south
4-7	Longitude	Single	radians; + for east, - for west
8-11	Altitude	Single	meters (HAE or MSL)
2-15	Clock Bias	Single	meters
6-19	Time-of-Fix	Single	seconds (GPS or UTC)

The default altitude conversion is WGS-84. Altitude is referred to the datum ellipsoid or the MSL Geoid, depending on which I/O “LLA altitude” option is selected. The time-of-fix is in GPS time or UTC, depending on which I/O “timing” option is selected. This packet also is sent at start-up with a negative time-of-fix to report the current known position. Packet 0x84 provides a double-precision version of this information.

Warning – When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.

Report Packet 0x4A - 9 Byte Format

Report Packet 0x4A is also sent in response to the setting or requesting of the Reference Altitude Parameters using Command Packet 0x2A. These parameters can be used in the Manual 2-D mode.

Reference Altitude

The altitude used for manual 2-D positions if the altitude flag is set. Altitude is in units of HAE WGS-84 or MSL depending on the selected I/O options set for positioning with Command Packet 35.

Altitude Flag

A flag that determines whether or not the Reference Altitude will be used. If set, it will be used. If cleared, altitude hold (last 3-D altitude) will be used. The data format is shown in the following table.

Table A.30 Reference Altitude

Byte	Item	Type	Units
0-3	Reference Altitude	Single	Meters
4-7	Reserved		
8	Altitude flag	UINT8	

Report Packet 0x4B - Machine/Code ID and Additional Status

The receiver transmits this packet in response to packets 0x25 and 0x26 and following a change in state. In conjunction with Packet 0x46, “health of receiver,” this packet identifies the receiver and may present status messages. The machine ID can be used by equipment communicating with the receiver to determine the type of receiver to which the equipment is connected. Then the interpretation and use of packets can be adjusted accordingly.

Table A.31 Report Packet 0x4B Data Formats

Byte	Item	Type/	Definition
0	Machine ID	UINT8	Receiver dependent
1	Status 1	UINT8	See Table A.32
2	Status 2	UINT8	Bit 0 = Super packets supported

The status codes are encoded into individual bits within the bytes. The bit positions and their meanings are listed in the table below.

Table A.32 Report Packet 0x4B Bit Positions and Descriptions

Status 1 Bit Positions	Meaning if bit value = 1
0 (LSB)	Not used
1	Real-time Clock was not available at power-up.
2	Not used
3	The almanac stored in the receiver is not complete and current.
4-7	Not used

Report Packet 0x4D - Oscillator Offset

This packet provides the current value of the receiver master oscillator offset in Hertz at carrier. This packet contains one single precision number. The receiver sends this packet in response to Packet 0x2D. The permissible offset varies with the receiver unit.

Report Packet 0x4E - Response to Set GPS Time

Indicates whether the receiver accepted the time given in a Set GPS time packet. the receiver sends this packet in response to Packet 0x2E. This packet contains one byte.

Table A.33 Report Packet 0x4E Data Formats

Value	Meaning
ASCII “Y”	The receiver accepts the time entered via Packet 2E. The receiver has not yet received the time from a satellite.
ASCII “N”	The receiver does not accept the time entered via Packet 2E. The receiver has received the time from a satellite and uses that time. The receiver disregards the time in Packet 0x 2E.

Report Packet 0x4F - UTC Parameters Report

This packet is sent in response to command packet 2F and contains 26 bytes. It reports the UTC information broadcast by the GPS system. For details on the meanings of the following parameters, consult ICD-200, Sections 20.3.3.5.2.4, 20.3.3.5.1.8, and Table 20-IX. On the simplest level, to get UTC time from GPS time, subtract ΔT_{LS} seconds. The other information contained in this packet indicates when the next leap second is scheduled to occur.

Table A.34 Report UTC Parameters

Byte	Value	Type
0-7	A0	DOUBLE
8-11	A1	SINGLE
12-13	ΔT_{LS}	INTEGER
14-17	T_{OT}	SINGLE
18-19	WN_T	INTEGER
20-21	WN_{LSF}	INTEGER
22-23	DN	INTEGER
24-25	ΔT_{LSF}	INTEGER

Report Packet 0x54 - Bias and Bias Rate Report

The receiver sends this packet to provide the computed clock-only solution when the receiver is in the manual or automatic Overdetermined Clock mode or Time Only (1-SV) mode.

Table A.35 Report Packet 54

Byte	Item	Type	Units
0-3	Bias	SINGLE	meters
4-7	Bias rate	SINGLE	meters/second
8-11	Time of fix	SINGLE	seconds

The bias is the offset of the receiver internal time clock from GPS time. Bias is expressed as meters of apparent range from the satellites. It is used to correct the one PPS output. Bias rate is the frequency error of the receiver internal oscillator. It is expressed as apparent range rate. Time-of-fix is in GPS or UTC time as selected by the I/O “timing” option in packet 0x35.

Warning – For accurate interpretation of the propagation delay, the precise constant for the speed of light must be used. The ICD-200 value for the speed of light is 299,792,458 meters per second.

Report Packet 0x55 - I/O Options

These abbreviations apply to the following table: ALT (Altitude), ECEF (Earth-centered, Earth-fixed), XYZ (Cartesian coordinates), LLA (latitude, longitude, altitude), HAE (height above ellipsoid), WGS-84 (Earth model (ellipsoid)), MSL geoid (Earth (mean sea level) mode), and UTC (coordinated universal time).

Table A.36 Command Packets 0x55 and 0x35 Data Descriptions

Byte	Bit	Item	Type	Value	Definition
Position					
0	0	XYZ ECEF	Bit	0 1	XYZ ECEF output off XYZ ECEF output on
0	1	LLA Output	Bit	0 1	LLA output off LLA output on
0	2	LLA ALT Output	Bit	0 1	HAE (WGS-84 datum) MSL geoid
0	3	ALT input	Bit	0 1	HAE (WGS-84 datum). MSL geoid
0	4	Precision-of-position output	Bit	0 1	Send single-precision packet. Send double-precision packet.

Table A.36 Command Packets 0x55 and 0x35 Data Descriptions (Continued)

Byte	Bit	Item	Type	Value	Definition
0	5	Super Packet Output	Bit	0 1	Output no Super Packets. Output all enabled Super Packets.
0	6-7	Reserved			
Velocity					
1	0	XYZ ECEF	Bit	0 1	XYZ ECEF output off XYZ ECEF output on
1	1	ENU output	Bit	0 1	ENU output off ENU output on
1	2-7	Reserved			
Timing					
2	0	Time Type	Bit	0 1	GPS time UTC
2	1-7	Reserved			
Auxiliary / Range Measurements					
3	0	Raw measuring	Bit	0 1	Raw measurements off Raw measurements on
3	1	Raw / Filtered	Bit	0 1	Raw PR’s in 0x5A Filtered PR’s in 0x5A
3	2	Reserved			
3	3	Output dB Hz instead of AMU	Bit	0 1	Output dB Hz Output AMU’s
3	4-7	Reserved			

Note 1 – *See the associated superpacket output, described later in this appendix. Packet 8E must be used to specify which superpacket is to be output.*

Note 2 – *Automatic output of 0x5A raw measurement messages is supported in the Lassen PT GPS receiver for backwards compatibility with older TSIP applications.*

Report Packet 0x56 - Velocity Fix, East-North-Up (ENU)

If East-North-Up (ENU) coordinates have been selected for the I/O "velocity" option (see Packet 0x35), the receiver sends this packet under the following conditions:

- Each time that a fix is computed
- In response to Packet 0x37 (last known fix)

The data format is shown below.

Table A.37 Report Packet 0x56 Data Formats

Byte	Item	Type	Units
0-3	East Velocity	Single	m/s; + for east, - for west
4-7	North Velocity	Single	m/s; + for north, - for south
8-11	Up Velocity	Single	m/s; + for up, - for down
12-15	Clock Bias Rate	Single	m/s
16-19	Time-of-Fix	Single	seconds (GPS or UTC)

The time-of-fix is in GPS or UTC time as selected by the I/O "timing" option.

Report Packet 0x57 - Information About Last Computed Fix

This packet provides information concerning the time and origin of the previous position fix. The receiver sends this packet, among others, in response to Packet 0x37. The data format is shown below.

Table A.38 Report Packet 0x57 Data Formats

Byte	Item	Type	Units	Byte 0 Value/Velocity
0	Source of information	UINT8	--	00 temporary no fix 01 good current fix
1	Mfg. diagnostic	UINT8	--	
2-5	Time of last fix	Single	seconds, GPS time	
6-7	Week of last fix	INT16	weeks, GPS time	

Report Packet 0x58 - Satellite System Data/Acknowledge from Receiver

This packet provides GPS data (almanac, ephemeris, etc.). The receiver sends this packet in response to Packet 0x38 (acknowledges the loading of data). The data format is shown below.

Table A.39 Report Packet 0x58 Data Formats

Byte	Item	Type	Value	Definition
0	Operation	UINT8	1 2	Request data from receiver; Load data into receiver
1	Type of data	UINT8	2 3 4 5 6	Almanac Health page, T_oa, WN_oa Ionosphere UTC Ephemeris
2	Sat PRN#	UINT8	0 1 - 32	Data that is not satellite - ID specific satellite PRN number
3	Length (n)	UINT8		Number of bytes of data to be loaded
4 to n+3	Data			

Note – *If data is not available, byte 3 is set to 0 and "no" data is sent.*

The binary almanac, health page, and UTC data streams are similar to Report Packets 0x40, 0x49, and 0x4F respectively, but these reports are preferred. To get ionosphere or ephemeris, this report must be used.

Note – *Ephemeris cannot be loaded into Lassen PT GPS receiver.*

Table A.40 Report Packet 0x58 Almanac Data

Byte	Item	Type	Definition / ICD-GPS-200
4	t_oa_raw	UINT8	Sec 20.3.3.5.1.2
5	SV_HEALTH	UINT8	Sec 20.3.3.5.1.2
6-9	e	Single	Sec 20.3.3.5.1.2
10-13	t_oa	Single	Sec 20.3.3.5.1.2

Table A.40 Report Packet 0x58 Almanac Data

14-17	i_o	Single	Sec 20.3.3.5.1.2
18-21	OMEGADOT	Single	Sec 20.3.3.5.1.2
22-25	sqrt_A	Single	Sec 20.3.3.5.1.2
26-29	OMEGA_0	Single	Sec 20.3.3.5.1.2
30-33	omega	Single	Sec 20.3.3.5.1.2
34-37	M_0	Single	Sec 20.3.3.5.1.2
38-41	a_f0	Single	Sec 20.3.3.5.1.2
42-45	a_f1	Single	Sec 20.3.3.5.1.2
46-49	Axis	Single	Sec 20.3.3.5.1.2
50-53	n	Single	Sec 20.3.3.5.1.2
54-57	OMEGA_n	Single	Sec 20.3.3.5.1.2
58-61	ODOT_n	Single	Sec 20.3.3.5.1.2
62-65	t_zc	Single	Sec 20.3.3.5.1.2. see Note 2.
66-67	weeknum	INT16	Sec 20.3.3.5.1.2
68-69	wn_oa	INT16	Sec 20.3.3.5.1.2

Note 1 – *All angles are in radians.*

Note 2 – *If data is not available, t_zc is set to -1.0.*

Table A.41 Report Packet 0x58 Almanac Health Data

Byte	Item	Type	Definition/ ICD-GPS-200
4	week # for health	UINT8	Sec 20.3.3.5.1.3
5-36	SV_health	UINT8	Sec 20.3.3.5.1.3
37	t_oa for health	UINT8	Sec 20.3.3.5.1.3
38	current t_oa	UINT8	units = seconds/2048
39-40	current week #	INT16	

Table A.42

Byte	Item	Type	Definition / IDC-GPS-200
4-11	---	---	not used
12-15	alpha_0	Single	Sec 20.3.3.5.1.9
16-19	alpha_1	Single	Sec 20.3.3.5.1.9
20-23	alpha_2	Single	Sec 20.3.3.5.1.9
24-27	alpha_3	Single	Sec 20.3.3.5.1.9
28-31	beta_0	Single	Sec 20.3.3.5.1.9
32-35	beta_1	Single	Sec 20.3.3.5.1.9
36-39	beta_2	Single	Sec 20.3.3.5.1.9
40-43	beta_3	Single	Sec 20.3.3.5.1.9

Table A.43

Byte	Item	Type	Definition / IDC-GPS-200
4-16	---	---	not used
17-24	A_0	Double	Sec 20.3.3.5.1.8
25-28	A_1	Single	Sec 20.3.3.5.1.8
29-30	delta_t_LS	Integer	Sec 20.3.3.5.1.8
31-34	t_ot	Single	Sec 20.3.3.5.1.8
35-36	WN t	Integer	Sec 20.3.3.5.1.8
37-38	WN_LSF	Integer	Sec 20.3.3.5.1.8
39-40	DN	Integer	Sec 20.3.3.5.1.8
41-42	delta_t_LSF	Integer	Sec 20.3.3.5.1.8

Table A.44

Byte	Item	Type	Definition / IDC -GPS-200
4	sv_number	UINT8	SV PRN number
5-8	t_ephem	Single	time of collection
9-10	weeknum	INT16	Sec 20.3.3.3, Table 20-I

Table A.44 (Continued)

Byte	Item	Type	Definition / IDC -GPS-200
11	codeL2	UINT8	Sec 20.3.3.3, Table 20-I
12	L2Pdata	UINT8	Sec 20.3.3.3, Table 20-I
13	SVacc_raw	UINT8	Sec 20.3.3.3, Table 20-I
14	SV_health	UINT8	Sec 20.3.3.3, Table 20-I
15-16	IODC	INT16	Sec 20.3.3.3, Table 20-I
17-20	T_GD	Single	Sec 20.3.3.3, Table 20-I
21-24	t_oc	Single	Sec 20.3.3.3, Table 20-I
25-28	a_f2	Single	Sec 20.3.3.3, Table 20-I
29-32	a_f1	Single	Sec 20.3.3.3, Table 20-I
33-36	a_f0	Single	Sec 20.3.3.3, Table 20-I
37-40	SVacc	Single	Sec 20.3.3.3, Table 20-I
41	IODE	UINT8	Sec 20.3.3.4
42	fit_interval	UINT8	Sec 20.3.3.4
43-46	C_rs	Single	Sec 20.3.3.4
47-50	delta_n	Single	Sec 20.3.3.4
51-58	M_0	Double	Sec 20.3.3.4
59-62	C_uc	Single	Sec 20.3.3.4, radians
63-70	e	Double	Sec 20.3.3.4
71-74	C_us	Single	Sec 20.3.3.4, radians
75-82	sqrt_A	Double	Sec 20.3.3.4
83-86	t_oe	Single	Sec 20.3.3.4
87-90	C_ic	Single	Sec 20.3.3.4, radians
91-98	OMEGA_0	Double	Sec 20.3.3.4
99-102	C_is	Single	Sec 20.3.3.4, radians
103-110	i_0	Double	Sec 20.3.3.4
111-114	C_rc	Single	Sec 20.3.3.4

Table A.44 (Continued)

Byte	Item	Type	Definition / IDC -GPS-200
115-122	omega	Double	Sec 20.3.3.4
123-126	OMEGADOT	Single	Sec 20.3.3.4
127-130	IDOT	Single	Sec 20.3.3.4
131-138	Axis	Double	= $(sqrt\_A)^2$
139-146	n	Double	derived from delta_n
147-154	r1me2	Double	= $sqrt(1.0\text{-}e^2)$
155-162	OMEGA_n	Double	derived from OMEGA_0, OMEGADOT
163-170	ODOT_n	Double	derived from OMEGADOT

***Note –** All angles are in radians.*

Report Packet 0x5C - Satellite Tracking Status

This packet provides tracking status data for a specified satellite. Some of the information is very implementation-dependent and is provided mainly for diagnostic purposes. The receiver sends this packet in response to Packet 0x3C. The data format is shown below.

Table A.45 Report Packet 0x5C Data Formats

Byte	Bit	Item	Type	Value	Definition
0		Satellite PRN number	UINT8	number 1 - 32	
1	0-2	Reserved			
1	3-5	Channel	Bits	0-7	
1	6-7	Reserved			
2		Acquisition flag	UINT8	0 1 2	Never acquired Acquired Re-opened search

Table A.45 Report Packet 0x5C Data Formats (Continued)

Byte	Bit	Item	Type	Value	Definition
3		Ephemeris flag	UINT8	0 1	Flag not set Good ephemeris for this satellite (<4 hours old, good health)
4-7		Signal level	Single	Same as in Packet 0x47	
8-11		GPS time of last measurem ent	Single	<0 >0	No measurements have been taken. Center of the last measurement taken from this satellite.
12-15		Elevation	Singles	radians	Approximate elevation of this satellite above the horizon. Updated about every 15 sec.s. Used for searching and computing measurement correction factors.
16-19		Azimuth	Single	radians	Approximate azimuth from true north to this satellite. Updated typically about every 3 to 5 minutes. Used for computing measurement correction factors.
20-23		Reserved			

Report Packet 0x6D - All-In-View Satellite Selection

This packet provides a list of satellites used for position fixes by the GPS receiver. The packet also provides the PDOP, HDOP, and VDOP of that set and provides the current mode (automatic or manual, 3-D or 2-D). This packet has variable length equal to 16+nSVs where “nSVs” is the number of satellites used in the solution.

The GPS receiver sends this packet in response to Packet 0x24 or whenever a new satellite selection is attempted. The GPS receiver attempts a new selection every 30 seconds and whenever satellite availability and tracking status change. The data format is shown below.

Table A.46 Report Packet 0x6D Data Formats

Byte	Bit	Item	Type	Value	Definition
0	0-2	Dimension	UINT8	0 1 2 3 4 5 6	Auto Time only (1-SV) 2D clock hold 2D 3D Overdetermined clock DGPS reference
0	3			0 1	Auto Manual
0	4-7			-	nSVs
1-4		PDOP	Single		PDOP
5-8		HDOP	Single		HDOP
9-12		VDOP	Single		VDOP
13-16		TDOP	Single		TDOP
(16+nSVvs)		SV PRN	UINT8		

***Note –** The Lassen PT GPS receiver sends this packet automatically after a position fix or every second if no position fix occurs.*

Command Packet 0x70 - Filter Control

Trimble OEM receivers have a number of filters. Command 0x70 provides control for these filters. It returns Report 0x70. There are three filters associated with 0x70:

- Position-Velocity (PV) Filter
- Static Filter
- Altitude Filter

The Position-Velocity (PV) Filter is the main filter and is used to “soften” the effect of constellation switches on position fixes. The filter has virtually no effect on velocity output and there is no lag due to vehicle dynamics. There may be a small increase in accuracy however.

A feature of the PV filter is the “Static Filter” which engages when the receiver is moving very slowly. This feature improves accuracy in the urban environment. The static filter should be turned off for the following applications:

- Slow-moving environments such as walking or drifting with the current
- When rooftop testing of receivers for moving applications

The altitude filter is a simple averaging filter with a time constant of a few seconds. It should be left on in marine and land applications.

To query for the current settings, use Command Packet 0x70 with no databytes. To input new settings, Command Packet 0x70 is sent with four data bytes.

Table A.47 Command Packet 70 Data Formats

Byte	Item	Type	Value	Definition
0	Position Velocity Filter	UINT8	0 1	Off On
1	Static Filter	UINT8	0 1	Off On
2	Altitude Filter	UINT8	0 1	Off On
3	Reserved			

Report Packet 0x70

This report is sent as a response to Command Packet 0x70 as either a query or a set. It contains four bytes, as shown in Table A.49.

Command Packet 0x7A

The NMEA message determines whether or not a given NMEA message will be output. If the bit for a message is set, the message will be sent every "interval" second. Use the values shown below to determine the NMEA interval and message mask. While fixes are being generated, the output order is: ZDA, GGA, GLL, VTG, GSA, GSV, RMC.

Table A.48 Command Packet 0x7A and Report Packet 0x7B Data Formats

Byte	Bit	Item	Type	Value	Definition
0		Subcode	UINT8	0	
1		Interval	UINT8	1-255	Fix interval in seconds
2		Reserved			
3		Reserved			
4	0	RMC	Bit	0 1	Off On
4	1-7	Reserved			
5	0	GGA	Bit	0 1	Off On
5	1	GLL	Bit	0 1	Off On
5	2	VTG	Bit	0 1	Off On
5	3	GSV	Bit	0 1	Off On
5	4	GSA	Bit	0 1	Off On
5	5	ZDA	Bit	0 1	Off On
5	6-7	Reserved			

Report Packet 0x7B

This packet provides the NMEA settings and interval.

Report Packet 0x82 - Differential Position Fix Mode

This packet provides the differential position fix mode of the receiver. This packet contains only one data byte to specify the mode. The packet is sent in response to Packet 0x62 and whenever a satellite selection is made and the mode is Auto GPS / DGPS (modes 2 and 3). The receiver switches automatically between modes 2 and 3 based on the availability of differential corrections for a constellation which meets all other masks. If such a constellation is not available, then the receiver stays in its current automatic mode (2 or 3), and does not do position solutions.

Valid modes are:

Mode 0	Differential off (Manual GPS) — The receiver does position solutions without differential corrections, even if the differential corrections are available.
Mode 1	Differential on (Manual DGPS) — The receiver only does position solutions if valid differential correction data are available.
Mode 2	Differential currently off (Auto DGPS) — The receiver is not receiving differential correction data for all satellites in constellation which meets all other masks, and is doing non-differential position solutions.
Mode 3	Differential currently on (Auto DGPS) — The receiver is receiving differential correction data for all satellites in a constellation which meets all other masks, and is doing differential position solutions.

Note – *The Lassen PT GPS receiver sends this packet automatically after every position fix except when in Mode 0.*

Report Packet 0x83 - Double-Precision XYZ Position Fix and Bias Information

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O Position option is set to XYZ ECEF and the I/O Precision of Position option is set to Double (see Packet 0x35), the receiver sends this packet each time a fix is computed. The data format is shown below.

Table A.49 Report Packet 0x83 Data Formats

Byte	Item	Type	Units
0-7	X	Double	meters
8-15	Y	Double	meters
16-23	Z	Double	meters
24-31	clock bias	Double	meters
32-35	time-of-fix	Single	seconds

The time-of-fix is in GPS time or UTC, as selected by the I/O “timing” option.

Packet 42 provides a single-precision version of this information.

Report Packet 0x84 - Double-Precision LLA Position Fix and Bias Information

This packet provides current GPS position fix in LLA coordinates. If the I/O Position option is set to LLA and the Precision of Position option is set to Double (see Packet 0x35), the receiver sends this packet each time a fix is computed. The data format is shown below.

Table A.50 Report Packet 0x84 Data Formats

Byte	Item	Type	Units
0-7	latitude	Double	radians; + for north, - for south
8-15	longitude	Double	radians; + for east, - for west
16-23	altitude	Double	meters
24-31	clock bias	Double	meters
32-35	time-of-fix	Single	seconds

The time-of-fix is in GPS time or UTC, as selected by the I/O "timing" option.

Warning – When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p (PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.

Packets 0x8E and 0x8F - Superpacket

See page 126 for information on Packets 0x8E and 0x8F.

Command Packet 0xBB - Navigation Configuration

In query mode, Packet 0xBB is sent with a single data byte and returns Report Packet 0xBB.

***Note –** This Command Packet replaces Packets 0x2C, 0x62, 0x75, and 0x77.*

Table A.51 Command Packet 0xBB Query Mode Data Format

Byte #	Item	Type	Value	Definition	Default
0	Subcode	UINT8	0x00	Query mode	

TSIP Packet 0xBB is used to set GPS Processing options. The table below lists the individual fields within the 0xBB Packet. See Table A.2 for information on saving the settings to non-volatile memory.

Table A.52 Command and Report Packet 0xBB Field Descriptions

Byte #	Item	Type	Value	Definition	Default
0	Subcode	UINT8	0x00	Query mode	0x03
1	Operating Dimension	UINT8	0 3 4	Automatic (2D/3D) Horizontal (2D) Full Position (3D)	Automatic
2	DGPS Mode	UINT8	0 1 2 or 3	DGPS off DGPS only DGPS auto	DGPS auto
3	Dynamics Code	UINT8	1 2 3 4	Land Sea Air Stationary	Land
4	Solution Mode	BYTE	1	Overdetermined fix	Overdetermined fix
5-8	Elevation Mask	Single	0.0 - 1.57 (radian)	Lowest satellite elevation for fixes	0.0873 (5^{o})
9-12	AMU Mask	Single	0-25 (AMU)	Minimum signal level for fixes	2.0

Table A.52 Command and Report Packet 0xBB Field Descriptions (Continued)

Byte #	Item	Type	Value	Definition	Default
13-16	DOP Mask	Single	0.2-100	Maximum DOP for fixes	8.0
17-20	DOP Switch	Single	0.2-100	Selects 2D/3D mode	6.0
21	DGPS Age Limit	UINT8	2-90 (seconds)	Maximum time to use a DGPS correction (seconds)	30
22-39	Reserved				

Command Packet 0xBC - Protocol Configuration

TSIP Packet 0xBC is used to query the port characteristics. In query mode, Packet 0xBC is sent with a single data byte and returns Report Packet 0xBC. (See Table A.2 for information on saving the settings to non-volatile memory.)

TSIP Packet 0xBC is used to set the communication parameters on Port 1. The table below lists the individual fields within the Packet 0xBC and provides query field descriptions.

The BC command settings are retained in battery-backed RAM.

Table A.53 Command Packet 0xBC Port Characteristics

Byte	Bit	Item	Type	Value	Definition
0		Port to Set	UINT8	0 1 0xFF	Port 1 Port 2 Current port
1		Input Baud Rate	UINT8	2 3 4 5 6 7 8 9	reserved reserved reserved reserved 4800 baud 9600 baud 19200 baud 38400 baud
2		Output Baud Rate	UINT8	As above	As above (Note 1)
3		# Data Bits	UINT8	2 3	7 bits 8 bits
4		Parity	UINT8	0 1 2	None Odd Even
5		# Stop Bits	UINT8	0 1	1 bit 2 bits
6		Flow Control	UINT8	0	0 = none
7	0	Reserved			
	1	TSIP input	Bit	0 1	off on
	2	Reserved			
	3	Reserved			
	4-7	Reserved			

Table A.53 Command Packet 0xBC Port Characteristics (Continued)

Byte	Bit	Item	Type	Value	Definition
8	0	Reserved			
	1	TSIP output	Bit	0 1	off on
	2	NMEA output	Bit	0 1	off on
	3-7	Reserved			
9		Reserved			

Note 1 – *The Lassen PT GPS receiver requires that the input and output baud rates be identical.*

Warning – TSIP input or output must have 8 databits (byte 3).

TSIP Superpackets

Several packets have been added to the core TSIP protocol to provide additional capability for OEM receivers. In OEM Packets 0x8E and their 0x8F responses, the first data byte is a sub-code which indicates the superpacket type. For example, in Packet 0x8E-15, 15 is the sub-code that indicates the superpacket type. Therefore the ID code for OEM packets is 2 bytes long followed by the data.

Command Packet 0x8E-20 - Request Last Fix with Extra Information

This packet requests Packet 0x8F-20 or marks it for automatic output. If only the first byte (20) is sent, an 0x8F-20 report containing the last available fix will be sent immediately. If two bytes are sent, the packet is marked/unmarked for auto report according to the value of the second byte as shown in below. 0x37 can also be used for requesting 0x8F-20 if the 0x8F-20 is scheduled for auto output.

Table A.54 Command Packet 0x8E-20 Field Descriptions

Byte	Item	Type	Definition
0	Sub-packet id	UINT8	0x20
1	Mark for Auto-report (See Packet 35 byte 0 bit 5)	UINT8	0 = do not auto-report 1 = mark for auto-report

Note – *Auto-report requires that superpacket output is enabled. Refer to Command Packet 35.*

Report Packet 0x8F-20 - Last Fix with Extra Information (binary fixed point)

This packet provides complete information about the current position velocity fix in a compact, fixed-length 56-byte packet. The fields are fixed-point with precision matched to the receiver accuracy. It can be used for automatic position/velocity reports. The latest fix can also be requested by 0x8E-20 or 0x37 commands.The data format is shown below.

Table A.55 Report Packet 0x8F-20 Data Formats

Byte	Bit	Item	Type	Value	Definition
0		Sub-packet id	UINT8		Id for this sub-packet (always 0x20)
1		KeyByte	UINT8		Reserved
2-3		east velocity	INT16		0.005 m/s or 0.020 m/s See Note 1.
4-5		north velocity	INT16		0.005 m/s or 0.020 m/s See Note 1.
6-7		up velocity	INT16		0.005 m/s or 0.020 m/s See Note 1.
8-11		Time Of Week	UINT32		GPS Time in milliseconds
12-15		Latitude	INT32	-2^{30} to 2^{30}	WGS-84 latitude, 2^{-31} semicircle (-90° - 90°)
16-19		Longitude	UINT32	0 to 2^{32}	WGS-84 latitude, 2^{-31} semicircle (0° - 360°)
20-23		Altitude	UINT32		Altitude above WGS-84 ellipsoid, mm.
24	0	Velocity Scaling		0 1	0.005 m/s^2 0.020 m/s^2
	1-7	Reserved			
25		Reserved			
26		Datum			Datum index + 1 0=unknown

Table A.55 Report Packet 0x8F-20 Data Formats (Continued)

Byte	Bit	Item	Type	Value	Definition
27	0	Fix Available	Bit	0 1	Yes No
	1	DGPS Corrected	Bit	0 1	No Yes
	2	Fix Dimension	Bit	0 1	3D 2D
	3	Alt Hold	Bit	0 1	Last 3D Altitude User-entered altitude
	4	Filtered	Bit	0 1	Unfiltered Filtered
	5-7	Reserved			
28		NumSVs	UINT8		Number of satellites used for fix. Will be zero if no fix was available.
29		UTC Offset	UINT8		Number of leap seconds between UTC time and GPS time.
30-31		Week	INT16		GPS time of fix, weeks.
32	0-5	PRN 1	UINT8	1-32	PRN of first satellite
	6-7	Reserved			
33		IODE 1	UINT8		IODE of first satellite
34	0-5	PRN 2	UINT8	1-32	PRN of second satellite
	6-7	Reserved			
35		IODE 2	UINT8		IODE of second satellite
36	0-5	PRN 3	UINT8	1-32	PRN of third satellite
	6-7	Reserved			
37		IODE 3	UINT8		IODE of third satellite
38	0-5	PRN 4	UINT8	1-32	PRN of fourth satellite
	6-7	Reserved			

Table A.55 Report Packet 0x8F-20 Data Formats (Continued)

Byte	Bit	Item	Type	Value	Definition
39		IODE 4	UINT8		IODE of fourth satellite
40	0-5	PRN 5	UINT8	1-32	PRN of fifth satellite
	6-7	Reserved			
41		IODE 5	UINT8		IODE of fifth satellite
42	0-5	PRN 6	UINT8	1-32	PRN of sixth satellite
	6-7	Reserved			
43		IODE 6	UINT8		IODE of sixth satellite
44	0-5	PRN 7	UINT8	1-32	PRN of seventh satellite
	6-7	Reserved			
45		IODE 7	UINT8		IODE of seventh satellite
46	0-5	PRN 8	UINT8	1-32	PRN of eighth satellite
	6-7	Reserved			
47		IODE 8	UINT8		IODE of eighth satellite
48-55		Ionospheric Parameters			

***Note –** Velocity scale controlled by byte 24, bit 1. Overflow = 0x8000.*

Command Packet 0x8E-26 - Non-Volatile Memory Storage

The 0x8E-26 command is issued with no data to cause the current settings to be saved to non-volatile memory. The 0x8F-26 report is generated after the values have been saved. (See Chapter 3 for information on the settings that can be saved to non-volatile memory.)

Table A.56 Command Packet 0x8E-26 Definitions

Byte #	Item	Type	Value	Definition
0	Subcode	UINT8	0x26	Save Settings

Report Packet 0x8F-26 - Non-Volatile Memory Status

This report will be issued after an 0x8E-26 command.

Table A.57 Report Packet 0x8F-26 Field Descriptions

Byte/	Item	Type	Value	Definition
0	Subcode	UINT8	0x26	Save Settings
1-4	Reserved			

Command Packet 8E-4A - Set/Request PPS Characteristics

Using this packet, you can query and control the receiver's PPS characteristics. The receiver responds to a query or control command with packet 8F-4A. The packet contains 16 bytes in the following order:.

Table A.58 Command Packet 0x8E-4A Field Descriptions

Byte/	Item	Type	Meaning
0	Sub-packet ID	Byte	Always 0x4A
1	PPS Driver Switch	Byte	0 = off 1 = on (default)
2	Time Base	Byte	0: GPS 1: UTC (default)
3	Reserved		
4-11	PPS Offset or Cable Delay	Double	seconds (default = 0.0)
12-15	Reserved		

To request 8F-4A, send a two-byte 8E-4A packet without any parameters. To update parameters, send the entire 16-byte message.

The default setting for byte 3 is positive. Bytes 4 to 11 define the PPS cable delay offset. These bytes allow the application to adjust the cable delay offset for longer or shorter cable lengths. Use a cable delay of ± 1.25 ns/foot to adjust PPS offset for cable lengths. A negative value should be used to advance the PPS. Lassen PT GPS estimates the bias uncertainty as part of a PPS validity monitor. If the bias uncertainty exceeds the threshold, then Lassen PT GPS disables the PPS output. The default bias uncertainty threshold is 300 meters, but this parameter may be programmed by the application. Lassen PT GPS limits the threshold to $3x10^8$ meters. Each time the application adjusts the packet 8E-4A settings, the new settings are stored in nonvolatile memory.

Report Packet 8F-4A - PPS Characteristics

This packet reports Lassen PT GPS PPS characteristics. This packet is sent in response to a query or control command with packet 8E-4A. The packet contains 16 bytes in the following order:.

Table A.59 Command Packet 0x8F-4A

Byte/	Item	Type	Meaning
0	Sub-packet ID	Byte	Always 0x4A
1	PPS Driver Switch	Byte	0 = off 1 = on
2	PPS Time Base	Byte	0: GPS 1: UTC (default)
3	Reserved		
4-11	PPS Offset or Cable Delay	Double	seconds (default = 0.0)
12-15	Reserved		

Command Packet 8E-4E - Set PPS Output Option

This command packet sets the PPS driver switch to one of the values listed in Table A.2. The receiver returns packet 8F-4E. The current driver switch value can be requested by sending this packet with no data bytes except the subcode byte.

Driver switch values 3 and 4 only make sense in Overdetermined Timing mode. In any position fix mode the effective choices are always on or during fixes which you get if you set the driver switch to 3 or 4.

Table A.60 Command Packet 0x8E-4E

Byte #	Item	Type	Value	Definition
0	Subcode	Byte	0x26	Always 0x4E
1	PPS Driver Switch	Byte	2 3 4	PPS is always output PPS is output when at least one satellite is tracking PPS is output when at least three satellites are tracking

Report Packet 0x8F-4E

This report packet is output after the command packet 8E-4E has been executed. See the corresponding command packet for information about the data formats.

Command Packet 8E-A5 - Set or Request Packet Broadcast Mask

Use command packet 8E-A5 to set the packet broadcast masks or to request the current mask settings, see Table.3. The Lassen PT GPS replies to requests with response packet 8F-A5. The broadcast mask is bitwise encoded to allow the user to turn on and off the automatic output (broadcast) of certain packets. For those broadcast packets that have multiple formats, the Lassen PT GPS will broadcast only one of the formats. If more than one of the formats is masked on for broadcast, then the format with the greatest precision of content are sent and the rest are not. The coding for each bit in the mask follows:

0: Turn off automatic output (broadcast) of this packet
1: Turn on automatic output (broadcast) of this packet

Table A.61 Command Packet 8E-A5

Byte	Bit	Item	Type	Default	Meaning
0		Subcode	Byte field	0xA5	Subcode
1-2	5		Bit field	0	Enable auto TSIP outputs (default set to Quite TSIP mode)
	6	0x8F-AB		1	0X8F-AB, primary timing information on all TSIP output ports
	7	0x8F-AC		1	0x8F-AC, supplemental timing information on all TSIP port
3-4	0-15		Bit field		Reserved (always 0)

Report Packet 8F-A5

This report packet is output after the command packet 8E-A5 has been executed and is identical in structure to packet 8E-A5. See the corresponding command packet for information about the data formats.

Command Packet 8E-A6 - Issue Self-Survey Command

This command packet, see Table A.4, starts a self-survey. The Lassen PT GPS responds with report packet 8F-A6. This command has no effect when survey is disabled.

Table A.62 Command Packet 8E-A6

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0xA6	
1	Self-survey command	BYTE	0 1	Restart self-survey Clear, stored position

Report Packet 8F-A6

This report packet is output after the command packet 8E-A6 has been executed and is identical in structure to packet 8E-A6. See the corresponding command packet for information about the data formats.

Command Packet 8E-A9 - Set Self-Survey Parameters

Use command packet 8E-A9 to set the self-survey parameters or to request the current settings, see Table A.63. The receiver replies with response packet 8F-A9.

Data Fields:

Self-Survey Enable: Use this field to enabled or disabled the self-survey mechanism.

0: Disable the self-survey mechanism

1: Enable the self-survey mechanism

Position Save Flag: Use this field to tell the self-survey mechanism to automatically save (or to not save) the self-surveyed position at the end of the self-survey procedure.

0: Do not automatically save the surveyed position when the self-survey is complete

1: Automatically save the surveyed position when the self-survey is complete.

Self-Survey Length: Use this field to specify the number of position fixes that are to be averaged together to form the self-surveyed position used for clock-only fixes.

Limits: 1 to (2^{31} - 1) fixes.

Note – *After disabling the self-survey, the survey in progress can be stopped by issuing a restart self-survey command (0x8E-A6).*

Table A.63 Command Packet 8E-A9 Data Format <<segment 7>>

Byte	Item	Type	Value	Description
0	Subcode	Byte	0xA9	
1	Self-Survey Enable	Byte	0 1	Disabled Enabled (factory default)
2	Position Save Flag	Byte	0 1	Don’t save position (factory default) Save self-surveyed position
3-6	Self-Survey Length	Double	see above	Number of fixes (factory default = 2000)
7-10	Reserved			

Report Packet 0x8F-A9

This report packet is output after the command packet 8E-A9 has been executed and is identical in structure to packet 8E-A9. See the corresponding command packet for information about the data formats.

Command Packet 8E-AB - Request Primary Timing Packet

This command packet, see Table A.64, can be used to request the primary timing packet 8F-AB. To receive report packet 8F-AB once per second use command 8E-A5 to enable the automatic output.

The Request Type item determines how the receiver replies to this command.

- Request Type 0: The most current primary timing values will be sent in report packet 8F-AB immediately.
- Request Type 1: The response is not sent immediately. Instead report packet 8F-AB is sent within 25ms after the next PPS output. This is the same time that the packet would be automatically sent if enabled.
- Request Type 2: Same as type 1 except that both report packets 8F-AB and 0x8F-AC are sent after the next PPS output.

Table A.64 Command Packet 8E-AB

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0xAB	
1	Request type	BYTE	0 1 2	Send 0x8F-AB immediately Send 0x8F-AB on-time next second Send 0x8F-AB and 0x8F-AC on-time next second

Report Packet 8F-AB

This automatic report packet, see Table A.65, provides time information once per second if enabled with command packet 8E-A5. GPS week number, GPS time-of-week (TOW), UTC integer offset, time flags, date and time-of-day (TOD) information is provided. This packet can be requested with packet 8E-AB. This packet begins transmission within 30 ms after the PPS pulse to which it refers.

Data Fields:

Time of Week: This field represents the number of seconds since Sunday at 00:00:00 GPS time for the current GPS week. Time of week is often abbreviated as TOW.

Week Number: This field represents the current GPS week number. GPS week number 0 started on January 6, 1980. Unfortunately, the GPS system has allotted only 10-bits of information to carry the GPS week number and therefore it rolls-over to 0 in just 1024 weeks (19.6 years), and there is no mechanism built into GPS to tell the user to which 1024 week epoch the week number refers. The first week number roll-over occurred as August 21, 1999 (GPS) transitioned to August 22, 1999 (GPS). The Lassen PT GPS adjusts for this week rollover by adding 1024 to any week number reported by GPS that is less than week number 1023, which began on December 14, 1997. With this technique, the Lassen PT GPS will provide an accurate translation of GPS week number and TOW to time and date until July 30, 2017.

UTC Offset: This field represents the current integer leap second offset between GPS and UTC according to the relationship: Time (UTC) = Time (GPS) - UTC Offset. The UTC offset information is reported to Lassen PT GPS by the GPS system and can take up to 12.5 minutes to obtain. Before the Lassen PT GPS has received UTC information from the GPS system, it is only capable of representing time in the GPS time scale, and the UTC offset will be shown as 0.

Timing Flags: This field is bitwise encoded to provide information about the timing outputs. Unused bits should be ignored.

Bit 0: When 0, the date and time fields broadcast in packet 0x8F-AB are in the GPS time scale. When 1, these fields are in the UTC time scale and are adjusted for leap seconds.

Bit 2: When 0, time has been set from GPS. When 1, time has not yet been set from GPS.

Bit 3: When 0, UTC offset information has been received. When 1, UTC offset information is not yet known.

Time of Day: The time of day is sent in hours-minutes-seconds format and varies from 00:00:00 to 23:59:59, except when time is in UTC and a leap second insertion occurs. In this case the time will transition from 23:59:59 to 23:59:60 to 00:00:00.

Date: The date is sent in day-month-year format.

Table A.65 Report Packet 0x8F-AB

Byte	Bit	Item	Type	Value	Meaning
0		Subcode	BYTE		0xAB
1-4		Time of week	ULONG		GPS seconds of week
5-6		Week Number	UINTEGER		GPS Week Number (see above)
7-8		UTC Offset	INTEGER		UTC Offset (seconds)
9	0	Timing Flag	Bit Field	0 1	GPS time UTC time
	1			0 1	Reserved Reserved
	2			0 1	Time is set Time is not set
	3			0 1	Have UTC info No UTC info
10		Seconds	BYTE	0-59	(60 for UTC leap second event)
11		Minutes	BYTE	0-59	Minutes of Hour
12		Hours	BYTE	0-23	Hour of Day
13		Day of Month	BYTE	1-31	Day of Month
14		Month	BYTE	1-12	Month of Year
15-16		Year	UINTEGER		Four digits of Year (e.g. 1999)

Command Packet 8E-AC - Request Supplemental Timing Packet

This command packet, see Table A.66, can be used to request the supplemental timing packet 8F-AC. To receive report packet 8F-AC once per second use command 8E-A5 to enable the automatic output.

The Request Type item determines how the receiver will reply to this command.

- Request Type 0: The most current supplemental timing values will be sent in report packet 8F-AC immediately.
- Request Type 1: The response is not sent immediately. Instead report packet 8F-AC is sent within 300ms after the next PPS output. This is the same time that the packet would be automatically sent if enabled.
- Request Type 2: Same as type 1 except that both report packets 8F-AB and 8F-AC are sent after the next PPS output.

Table A.66 Command Packet 8E-AC

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0xAC	
1	Request type	BYTE	0 1 2	Send 0x8F-AC immediately Send 0x8F-AC on-time next second Send 0x8F-AB and 0x8F-AC on-time next second

Report Packet 8F-8C - Supplemental Timing Packet

This report packet provides supplemental timing information once per second if enabled with command packet 8E-A5. Information regarding position, unit status and health, and the operational state of the unit is provided. This packet can be requested with command packet 8E-AC. When enabled, this packet is transmitted once per second shortly after report packet 8F-AB.

The position sent in report packet 8F-AC depends on the Receiver Operating Mode and on self-survey activity. When a self-survey is in progress, the position sent is the running average of all of the position fixes collected so far. When the self-survey ends or whenever the receiver is using a time-only operating mode, then the position sent is the position the receiver is using to perform time-only fixes. When the self-survey is disabled or otherwise inactive and the receiver is using a position fix operating mode, then the position sent is the position fix computed on the last second.

Data Fields

Receiver Mode: This field shows the fix mode that the GPS receiver is currently configured for. The Lassen PT GPS receiver spends most of its time in the Overdetermined Clock mode where it uses all available satellites to perform the best time-only fix possible. See packet 0xBB for a description of all available receiver modes.

Self-Survey Progress: When a self-survey procedure is in progress, this field shows the progress of the survey as a percentage of fixes collected so far. The self-survey will be complete when the self-survey progress reaches 100 percent.

Minor Alarms: This field is bitwise encoded with several minor alarm indicators. A minor alarm indicates a condition that the user should be alerted to, but does not indicate an immediate (or necessarily any) impairment of functionality. For each bit, a value of 0 means that the condition is not indicated. Bits not described below should be ignored.

Bit 1	Antenna Open
Bit 2	Antenna Short
Bit 3	When 1, indicates that no satellites are yet usable. In order for a satellite to be usable, it must be tracked long enough to obtain ephemeris and health data.
Bit 5	When 1, indicates that a self-survey procedure is in progress.
Bit 6	When 1, indicates that there is no accurate position stored in EEPROM.
Bit 7	When 1, indicates that the GPS system has alerted the GPS that a leap second transition is pending.
Bit 8	When 1, indicates that the GPS is operating in one of its test modes.
Bit 9	When 1, indicates that the accuracy of the position being used for a time-only fix is questionable. While operating in the Overdetermined Clock mode (which is most of the time) with at least 2 satellites available, the receiver can detect position inaccuracies as small as 1/2 to 1 mile. If this bit is set, it is likely that the receiver is using a stored position but has been moved to a new site. The stored position should be cleared (packet 0x8E-45) and a new position should be established either by user input (packet 0x31 or 0x32) or by self-survey (packet 0x8E-A6).
Bit 10	When 1, indicates that one or more EEPROM segments where found to be corrupt at reset and had to be set to their factory default settings. Use packet 0x3F-11 to retrieve details about which segments where corrupt and to clear this bit. The GPS will send packet 0x5F-11 with the segment status. Only bits 2-12 of the segment status are used to set this alarm bit.
Bit 11	When 1, indicates that the almanac is not current or complete.

GPS Decoding Status: This field indicates the decoding status of the GPS receiver.

Local Clock Offset: This field carries the offset of the local clock relative to UTC or GPS as reported by the GPS receiver in nanoseconds. Positive values indicate that the Lassen PT GPS local clock is late relative to GPS or UTC. Also known as bias.

Oscillator Offset: This field carries the frequency offset of the local clock relative to UTC or GPS as reported by the GPS receiver in ppb (parts-per-billion). Positive values indicate that the Lassen PT GPS local clock is running slow relative to GPS or UTC. Also known as bias rate.

Latitude: This field carries the latitude of the position being shown. The units are in radians and vary from $-\pi/2$ to $+\pi/2$. Negative values represent southern latitudes. Positive values represent northern latitudes.

Longitude: This field carries the longitude of the position being shown. The units are in radians and vary from $-\pi$ to $+\pi$. Negative values represent western longitudes. Positive values represent eastern longitudes.

Altitude: This field carries the altitude of the position being shown. The units are in meters according to the current datum.

PPS Output Status: This field identifies the status of the PPS output.

The table below identifies the fields associated with packet 8F-AC.

Table A.67 Report Packet 8F-AC

Byte	Bit	Item	Type	Value	Meaning
0		Subcode	BYTE	0xAC	
1		Receiver Mode	BYTE	0 1 3 4 5 6 7	Automatic (2D/3D) Single Satellite (Time) Horizontal (2D) Full Position (3D) DGPS Reference Clock Hold (2D) Overdetermined Clock
2		Reserved			
3		Self-Survey Progress	BYTE	0-100	Percent completed
4-7		Reserved			
8-9		Reserved			
10-11		Minor Alarms	UINTEGER	Bit field	Bit 1: Reserved Bit 2: Antenna Shorted Bit 3: Not tracking satellites Bit 5: Survey-in progress Bit 6: No stored position Bit 7: Leap second pending Bit 8: In test mode Bit 10: EEPROM segments status Bit 11: Almanac status
12		GPS Decoding Status	BYTE	0 1 3 8 9 0x0A 0x0B 0x0C 0x10	Doing fixes Do not have GPS time PDOP is too high No usable satellites Only 1 usable satellite Only 2 usable satellites Only 3 usable satellites The chosen satellite is unusable TRAIM rejected the fix
13		Reserved			

Table A.67 Report Packet 8F-AC (Continued)

Byte	Bit	Item	Type	Value	Meaning
14		Reserved			
15		Reserved			
16-19		Bias	SINGLE		Estimate of UTC/GPS offset (ns) of local clock
20-23		Bias Rate	SINGLE		Estimate of UTC/GPS offset (ppb) of local clock
24-27		Reserved			
28-31		Reserved			
32-35		Reserved			
36-43		Latitude	DOUBLE		Radians
44-51		Longitude	DOUBLE		Radians
52-59		Altitude	DOUBLE		Meters
60-63		Reserved			
64		PPS output status	UINT8		0: PPS Not Generated 1: PPS Was Generated
65-67		Reserved			

Sample TSIP Routines

The following sections give sample routines that use command packet 0x1F and report packet 0×45 for getting software version information from the Lassen PT GPS via COM1. Source code for a working TSIP monitor program is available at ***www.trimble.com/support/files***.

Sending out TSIP command packet 0x1F

In general, all TSIP packets use the structure TSIPPKT:

```
#define MAX_RPTBUF  256

typedef struct {
        short
        cnt;                       /* size of buf */
        unsigned char
        status,                    /* TSIP packet format
                                   and parse status */
        code,                      /* TSIP id code */
        buf[MAX_RPTBUF];           /* command or report
                                   string */
} TSIPPKT;
```

Communication with the Lassen PT GPS is accomplished through command routines and report routines. Each command routine use *send_cmd()* which supplies the DLE stuffing to the command string and sends the command to the serial port using the primitive function *sendb()*.

All TSIP packet formats take the form *<DLE><ID><Data String Bytes><DLE><ETX>*, where *<DLE>* and *<ETX>* are reserved frame characters with values 0x10 and 0x03, respectively, and *<ID>* is the packet identifier. The following routines perform DLE stuffing on a command packet and send it to the Lassen PT GPS.

```
#define DLE  0x10
#define ETX  0x03

#define PORT 1

/* Send a byte to Port 1 */
short sendb(unsigned char db)
{
   /* put_char outputs a character to the serial port; it
  * returns 0 for success and 1 for failure.
   */
   return(put_char(PORT, db));
}

/* Format a command for sending to a TSIP receiver */
void send_cmd(TSIPPKT *cmd)
{
short i;

        sendb(DLE);
        sendb(cmd->code);
        for (i = 0; i < cmd->cnt; i++) {
             if (cmd->buf[i] == DLE)
                sendb(DLE);

             sendb(cmd->buf[i]);
                                 }

        sendb(DLE);
        sendb(ETX);
}
```

To issue command packet 0x41 to request software version from the Lassen PT GPS use the following routine.

```
/* Request software version */
void cmd_0x1F(void)
{
TSIPPKT cmd;

        cmd.cnt = 0;
        cmd.code = 0x1F;
        send_cmd(&cmd);
}
```

Handling incoming TSIP packet 0x45

Report routines handle incoming receiver packets. They call the routine *end_of_rptpkt()* which accumulates from the serial buffer, unstuffs these bytes, and checks whether the end-of-packet sequence *<DLE><EXT>* has been received.

```
#define FALSE          0
#define TRUE           !FALSE
#define INCOMPLETE     0
#define HAVE_DLE       1
#define COMPLETE       2
#define MAXEND_RPTBUF 256

/* Read bytes until serial buffer is empty or a complete
                                  report has
* been received; end of report is signified by DLE ETX.
*/
short end_of_rptpkt(TSIPPKT *rpt)
{
short this_byte;
```

```
        for (;;) {
                this_byte = getb();
                if (this_byte == -1) {
                      return(FALSE);
        }

if (rpt->status == HAVE_DLE) {
        switch (this_byte) {
        case DLE: /* DLE-stuffed, so it’s a data byte */
        break;

        case ETX: /* End of message. */
                rpt->status = COMPLETE;
                return(TRUE);
        default: /* If previous message has ended, this is
        new ID code. */
                reset_rptbuf(rpt); /* if not, this is an
                                  error. */
                rpt->code = this_byte;
                return(FALSE);
        }
}
        else if (this_byte == DLE) {
           /* DLE byte without previous DLE stuffing…must
                                  be stuffing. */
           rpt->status = HAVE_DLE;
           continue;
           }

/* normal byte; add to report */
rpt->status = INCOMPLETE;
rpt->buf[rpt->cnt] = this_byte;
rpt->cnt++;
if (rpt->cnt > MAX_RPTBUF) {
```

```
                reset_rptbuf (rpt);
                return(FALSE);
                }
          }
      }

      /* Prepare for receipt of new report */
      void reset_rptbuf (TSIPPKT *rpt)
      {
                rpt->cnt = 0;
                rpt->code = ETX;
                rpt->status = INCOMPLETE;
}
```

APPENDIX

B

Lassen PT GPS Timing Receiver Monitor

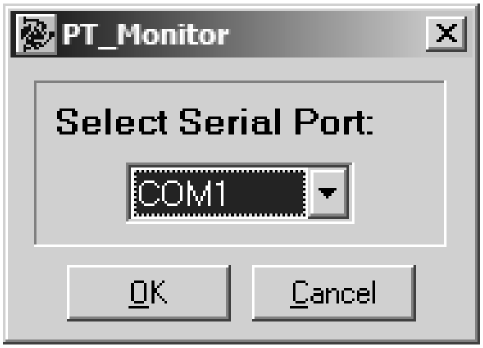
In this appendix:

- Start-Up
- Main Screen

The Timing Receiver Monitor program disk is included with the Product Starter Kit. The latest version of the program is also available on the Trimble website: www.trimble.com/products/timing

Start-Up

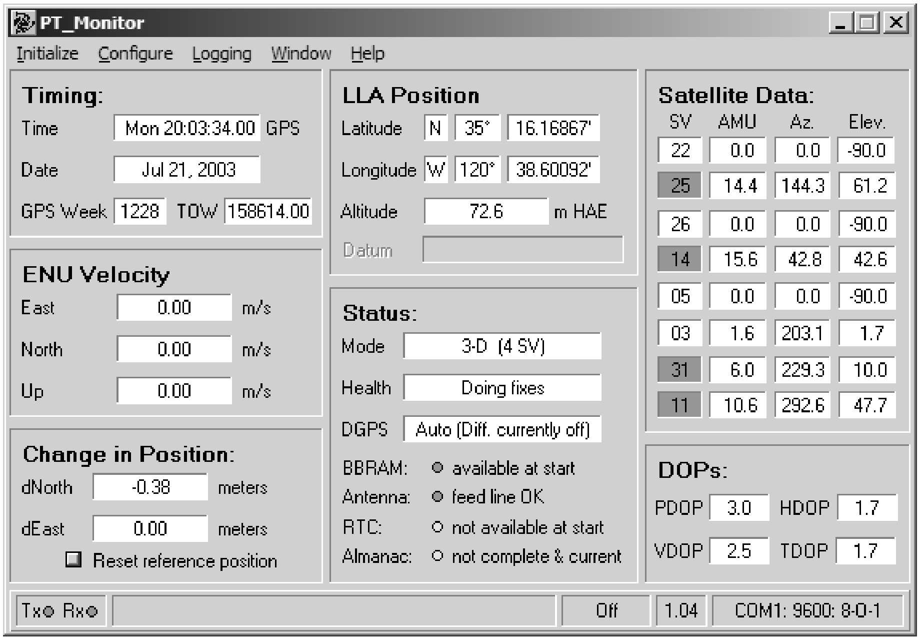
The *Serial Port Selection* screen shown below appears at the start of the program:



This screen lets you choose which PC serial port the Lassen PT GPS is connected to. If the desired port is not available in the selection box, you can start the program using the parameter –c*, with * being the number of the serial port you want to select.

Main Screen

The main screen for the Timing Receiver Monitor is shown below:



The main screen displays time, position, SV selection and data, receiver status, and timing outputs. The status bar displays Tx and Rx activity, program hints, firmware version number, and serial port settings. The menu provides other options for sending data to and requesting data from the receiver.

For additional program information and help, see the Help menu.

APPENDIX

C

NMEA 0183

This appendix provides a brief overview of the NMEA 0183 protocol, and describes both the standard and optional messages offered by the Lassen PT GPS receiver.

NMEA 0183 is a simple, yet comprehensive ASCII protocol which defines both the communication interface and the data format. The NMEA 0183 protocol was originally established to allow marine navigation equipment to share information. Since it is a well established industry standard, NMEA 0183 has also gained popularity for use in applications other than marine electronics. The latest release of NMEA 0183 is Version 3.0 (July 1, 2000). Trimble Navigation supports both version 2.1 and version 3.0. The primary change in release 3.0 is the addition of the mode indicators in the GLL, RMC, and VTG messages.

For those applications requiring output only from the GPS receiver, NMEA 0183 is a popular choice since, in many cases, an NMEA 0183 software application code already exists. The Lassen PT GPS receiver is available with firmware that supports a subset of the NMEA 0183 messages: GGA, GLL, GSA, GSV, RMC, VTC, and ZDA. For a nominal fee, Trimble can offer custom firmware with a different selection of messages to meet your application requirements.

For a complete copy of the NMEA 0183 standard, contact:

NMEA National Office
PO Box 3435
New Bern, NC 28564-3435
U.S.A.
Telephone: +1-919-638-2626
Fax: +1-919-638-4885

The NMEA 0183 Communication Interface

NMEA 0183 allows a single source (talker) to transmit serial data over a single twisted wire pair to one or more receivers (listeners). The table below lists the standard characteristics of the NMEA 0183 data transmissions.

Table C.1 NMEA 0183 Standard Characteristics

Signal Characteristic	NMEA Standard
Baud Rate	4800
Data Bits	8
Parity	None (Disabled)
Stop Bits	1

NMEA 0183 Message Format

The NMEA 0183 protocol covers a broad array of navigation data. This broad array of information is separated into discrete messages which convey a specific set of information. The entire protocol encompasses over 50 messages, but only a sub-set of these messages apply to a GPS receiver like the Lassen PT GPS receiver. The NMEA message structure is described below.

```
$IDMSG,D1,D2,D3,D4,.......,Dn*CS[CR][LF]
```

"$"	The "$" signifies the start of a message.
ID	The talker identification is a two letter mnemonic which describes the source of the navigation information. The GP identification signifies a GPS source.
MSG	The message identification is a three letter mnemonic which describes the message content and the number and order of the data fields.
","	Commas serve as delimiters for the data fields.
Dn	Each message contains multiple data fields (Dn) which are delimited by commas.
"*"	The asterisk serves as a checksum delimiter.
CS	The checksum field contains two ASCII characters which indicate the hexadecimal value of the checksum.
[CR][LF]	The carriage return [CR] and line feed [LF] combination terminate the message.

NMEA 0183 messages vary in length, but each message is limited to 79 characters or less. This length limitation excludes the "$" and the [CR][LF]. The data field block, including delimiters, is limited to 74 characters or less.

Field Definitions

Many of the NMEA date fields are of variable length, and the user should always use the comma delineators to parse the NMEA message date field. Table C.2 specifies the definitions of all field types in the NMEA messages supported by Trimble.

Table C.2 Field Type Summary

Type	Symbol	Definition
Status	A	Single character field: A=Yes, data valid, warning flag clear V=No, data invalid, warning flag set
Special Format Fields		
Latitude	llll.lll	Fixed/variable length field: Degreesminutes.decimal-2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Longitude	yyyyy.yyy	Fixed/Variable length field: Degreesminutes.decimal-3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Time	hhmmss.ss	Fixed/Variable length field: hoursminutesseconds.decimal-2 fixed digits of minutes, 2 fixed digits of seconds and a variable number of digits for decimal-fraction of seconds. Leading zeros always included for hours, minutes, and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.

Table C.2 Field Type Summary (Continued)

Type	**Symbol**	**Definition**
Defined		Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in this standard by the presence of one or more valid characters. Excluded from the list of allowable characters are the following that are used to indicated field types within this standard: "A", "a", "c", "hh", "hhmmss.ss", "llll.ll", "x", "yyyyy.yy"
Numeric Value Fields		
Variable	x.x	Variable length integer or floating numeric field. Optional leading and trailing zeros. The decimal point and associated decimal-fraction are optional if full resolution is not required (example: 73.10=73.1=073.1=73).
Fixed HEX	hh	Fixed length HEX numbers only, MSB on the left
Information Fields		
Fixed Alpha	aa	Fixed length field of upper-case or lower-case alpha characters
Fixed number	xx	Fixed length field of numeric characters

Note – *Spaces are only be used in variable text fields.*

Note 2 – *Units of measure fields are appropriate characters from the Symbol column (see Table C.2), unless a specified unit of measure is indicated.*

Note 3 – *Fixed length field definitions show the actual number of characters. For example, a field defined to have a fixed length of 5 HEX characters is represented as hhhhh between delimiters in a sentence definition.*

NMEA 0183 Message Options

The Lassen PT GPS receiver can output any or all of the messages listed in Table C.3. In its default configuration (as shipped from the factory), the Lassen PT GPS receiver outputs two messages: GGA and VTG. These messages are output at a 1 second interval with the "GP" talker ID and checksums. These messages are output at all times during operation, with or without a fix. If a different set of messages ha been selected (using Packet 0x7A), and this setting has been stored in Flash memory (using Packet 0x8E-26), the default messages are permanently replaced until the receiver is returned to the factory default settings.

***Note –** The user can configure a custom mix of the messages listed in Table C.3. See Chapter 3, and TSIP command packets 0xBC, 0x7A, and 8E-26 in Appendix A for details on configuring NMEA output.*

Warning – If too many messages are specified for output, you may need to increase the unit's baud rate.

Table C.3 Lassen SQ GPS Receiver NMEA Messages

	Message	Description
Default Output	GGA	GPS fix data
	GLL	Geographic position - Latitude/Longitude
	GSA	GPS DOP and active satellites
	GSV	GPS satellites in view
	RMC	Recommended minimum specific GPS/Transit data
Default Output	VTG	Track made good and ground speed
	ZDA	Time & Date

The format for each message in Table C.3 is described in more detail in the next section.

NMEA 0183 Message Formats

GGA - GPS Fix Data

The GGA message includes time, position and fix related data for the GPS receiver.

```
$GPGGA,hhmmss.ss,llll.lll,a,nnnnn.nnn,b,t,uu,
v.v,w.w,M,x.x,M,y.y,zzzz*hh <CR><LF>
```

Table C.4 GGA - GPS Fix Data Message Parameters

Field #	Description
1	UTC of Position
2,3	Latitude, N (North) or S (South)
4,5	Longitude, E (East) or W (West)
6	GPS Quality Indicator: 0 = No GPS, 1 = GPS, 2 = DGPS
7	Number of Satellites in Use
8	Horizontal Dilution of Precision (HDOP)
9, 10	Antenna Altitude in Meters, M = Meters
11, 12	Geoidal Separation in Meters, M=Meters. Geoidal separation is the difference between the WGS-84 earth ellipsoid and mean-sea-level.
13	Age of Differential GPS Data. Time in seconds since the last Type 1 or 9 Update
14	Differential Reference Station ID (0000 to 1023)
hh	Checksum

GLL - Geographic Position - Latitude/Longitude

The GLL message contains the latitude and longitude of the present vessel position, the time of the position fix and the status.

```
$GPGLL,llll.lll,a,yyyyy.yyy,a,hhmmss.ss,A,i*hh<CR>
<LF>
```

Table C.5 GLL - Geographic Position - Latitude / Longitude Message Parameters

Field #	Description
1,2	Latitude, N (North) or S (South)
3,4	Longitude, E (East) or W (West)
5	UTC of position
6	Status: A = Valid, V= Invalid
7	Mode Indicator A=Autonomous Mode D=Differential Mode E=Estimated (dead reckoning) Mode M=Manual Input Mode S=Simulated Mode N-Data Not Valid
hh	Checksum

GSA - GPS DOP and Active Satellites

The GSA messages indicates the GPS receiver's operating mode and lists the satellites used for navigation and the DOP values of the position solution.

```
$GPGSA,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,
xx,x.x,x.x,x.x*hh<CR><LF>
```

Table C.6 GSA - GPS DOP and Active Satellites Message Parameters

Field #	Description
1	Mode: M = Manual, A = Automatic. In manual mode, the receiver is forced to operate in either 2D or 3D mode. In automatic mode, the receiver is allowed to switch between 2D and 3D modes subject to the PDOP and satellite masks.
2	Current Mode: 1 = fix not available, 2 = 2D, 3 = 3D
3 to 14	PRN numbers of the satellites used in the position solution. When less than 12 satellites are used, the unused fields are null
15	Position dilution of precision (PDOP)
16	Horizontal dilution of precision (HDOP)
17	Vertical dilution of precision (VDOP)
hh	Checksum

GSV - GPS Satellites in View

The GSV message identifies the GPS satellites in view, including their PRN number, elevation, azimuth and SNR value. Each message contains data for four satellites. Second and third messages are sent when more than 4 satellites are in view. Fields #1 and #2 indicate the total number of messages being sent and the number of each message respectively.

```
$GPGSV,x,x,xx,xx,xx,xxx,xx,xx,xx,xxx,xx,xx,xx,
xxx,xx,xx,xx,xxx,xx*hh<CR><LF>
```

Table C.7 GSV - GPS Satellites in View Message Parameters

Field #	Description
1	Total number of GSV messages
2	Message number: 1 to 3
3	Total number of satellites in view
4	Satellite PRN number
5	Satellite elevation in degrees (90° Maximum)
6	Satellite azimuth in degrees true (000 to 359)
7	Satellite SNR (C/No), null when not tracking
8,9,10,11	PRN, elevation, azimuth and SNR for second satellite
12,13,14,15	PRN, elevation, azimuth and SNR for third satellite
16,17,18,19	PRN, elevation, azimuth and SNR for fourth satellite
hh	Checksum

RMC - Recommended Minimum Specific GPS/Transit Data

The RMC message contains the time, date, position, course, and speed data provided by the GPS navigation receiver. A checksum is mandatory for this message and the transmission interval may not exceed 2 seconds. All data fields must be provided unless the data is temporarily unavailable. Null fields may be used when data is temporarily unavailable.

```
$GPRMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,
x.x,x.x,xxxxxx,x.x,a,i*hh<CR><LF>
```

Table C.8 RMC - Recommended Minimum Specific GPS / Transit Data Message Parameters

Field #	Description
1	UTC of Position Fix.
2	Status: A = Valid, V = navigation receiver warning
3,4	Latitude, N (North) or S (South).
5,6	Longitude, E (East) or W (West).
7	Speed over the ground (SOG) in knots
8	Track made good in degrees true.
9	Date: dd/mm/yy
10,11	Magnetic variation in degrees, E = East / W= West
12	Position System Mode Indicator; A=Autonomous, D=Differential, E=Estimated (Dead Reckoning), M=Manual Input, S=Simulation Mode, N=Data Not Valid
hh	Checksum (Mandatory for RMC)

VTG - Track Made Good and Ground Speed

The VTG message conveys the actual track made good (COG) and the speed relative to the ground (SOG).

```
$GPVTG,x.x,T,x.x,M,x.x,N,x.x,K,i*hh<CR><LF>
```

Table C.9 VTG - Track Made Good and Ground Speed Message Parameters

Field #	Description
1	Track made good in degrees true.
2	Track made good in degrees magnetic.
3,4	Speed over the ground (SOG) in knots.
5,6	Speed over the ground (SOG) in kilometer per hour.
7	Mode Indicator: A=Autonomous Mode, D=Differential Mode, E=Estimated (dead reckoning) Mode, M=Manual Input Mode, S=Simulated Mode, N-Data Not Valid
hh	Checksum

ZDA - Time & Date

The ZDA message contains UTC, the day, the month, the year and the local time zone.

```
$GPZDA,hhmmss.ss,xx,xx,xxxx,,*hh<CR><LF>
```

Table C.10 ZDA - Time & Date Message Parameters

Field #	Description
1	UTC
2	Day (01 to 31)
3	Month (01 to 12)
4	Year
5	unused
6	unused
hh	Checksum

Note – *Fields #5 and #6 are null fields in the Lassen PT GPS receiver output. A GPS receiver cannot independently identify the local time zone offsets.*

Warning – If UTC offset is not available, time output will be in GPS time until the UTC offset value is collected from the GPS satellites. When the offset becomes available, the time will jump to UTC time.

Note – *GPS time can be used as a timetag for the 1PPS. The ZDA message comes out 100-500 msec after the PPS.*

Exception Behavior

When no position fix is available, some of the data fields in the NMEA messages will be blank. A blank field has no characters between the commas. There are three general cases when no fix is available: at power-up without BBRAM (cold start); at power-up with BBRAM (warm start); and when the GPS signal is temporarily blocked. These three cases have different NMEA output behavior in the Lassen PT GPS receiver. This section describes the behavior for the current product. The specification for this behavior may change in future products.

Power-up with No BBRAM

In this case, no previous fix is available in battery-backed memory. If the output message list and output rate has been customized (using TSIP command packet 0x7A) and stored in Flash memory, then at power-up the receiver will output the messages according to the customized setting. Otherwise, GGA messages are output every second. Before fixes are available, the message fields will be empty.

Power-up with BBRAM

In this case, a previous fix is available in battery-backed memory at power-up. If the output message list and output rate has been customized (using TSIP command packet 0x7A) and stored in Flash memory, then at power-up the receiver will output the messages according to the customized setting. Otherwise, GGA messages are output every second. Before fixes are available, the message fields will be empty except for the Time field, assuming the back-up battery power is present so that time can be tracked continuously by the RTC (Real Time Clock).

Interruption of GPS Signal

If the GPS signal is interrupted temporarily, the NMEA will continue to be output according to the user-specified message list and output rate. Position and velocity fields will be blank until the next fix, but most other fields will be filled.

APPENDIX

D

Specifications and Mechanical Drawings

The Lassen PT GPS receiver is designed fora variety of embedded timing applications. This appendix includes the system specifications and mechanical drawings for the Lassen PT GPS receiver and the available GPS antenna.

Lassen PT GPS Timing Receiver Specifications

Performance

General	L1 frequency (1575.42 MHz), C/A code (Standard Positioning Service), 8-channel, continuous tracking receiver, 32 correlators
Update Rate	TSIP @ 1 Hz; NMEA @ 1 Hz
Accuracy	Horizontal: <6 meters (50%), <9 meters (90%) Altitude: <11 meters (50%), <18 meters (90%) Velocity: 0.06 m/sec. PPS: within 20 ns to UTC (1 Sigma)
Acquisition	Reacquisition: <2 sec. (90%) Hot Start: <14 sec. (50%), <18 sec. (90%) Warm Start: <38 sec. (50%), <45 sec. (90%) Cold Start: <90 sec. (50%), <170 sec. (90%) Cold start requires no initialization. Warm start implies last position, time and almanac are saved by backup power. Hot start implies ephemeris also saved.
Dynamics	Acceleration: 4g (39.2 m/sec2) Motional jerk: 20 m/sec3
Operational	Altitude <18000m or velocity <515m/s (COCOM Limit) Either limit may be exceeded but not both

Interface

Connectors	I/O: 8-pin (2x4) male header, micro terminal strip ASP 69553.01 RF: Low-profile coaxial connector H.FL-R-SMT (10), 50 Ohm
Serial Port	1 serial port (transmit/receive)
PPS	3.3 V CMOS-compatible, TTL-level pulse Once per second with the rising edge of the pulse synchronized with UTC
Protocols	TSIP @ 9600 baud, 8 bits NMEA 0183 v3.0, selectable baud rate, 8 bits
NMEA	ZDA, GGA, GGL, GSA, GSV, RMC, VTG Optional output messages configured using TSIP command packets; selection stored in flash memory

Electrical

Prime Power	+3.0 VDC to +3.6 VDC (3.3 V typ.)
Consumption	GPS board only: 133.3 mW@3.3 Vdc
Backup Power	+2.5 VDC to +3.6 VDC
Ripple Noise	Max 60 mV, peak-to-peak from 1 Hz to 1 MHz
Antenna	Chort-circuit detection and protection

Environmental

Operating Temp.	-40°C to +85°C	
Storage Temp.	-55°C to +105°C	
Vibration	0.008 g2/Hz	5 Hz to 20 Hz
	0.05 g2/Hz	20 Hz to 100 Hz
	-3Db/OCTAVE	100 Hz to 900 Hz
Humidity	5% to 95% R.H. non-condensing @ +60°C	
Altitude	-400 to 18000 m max	

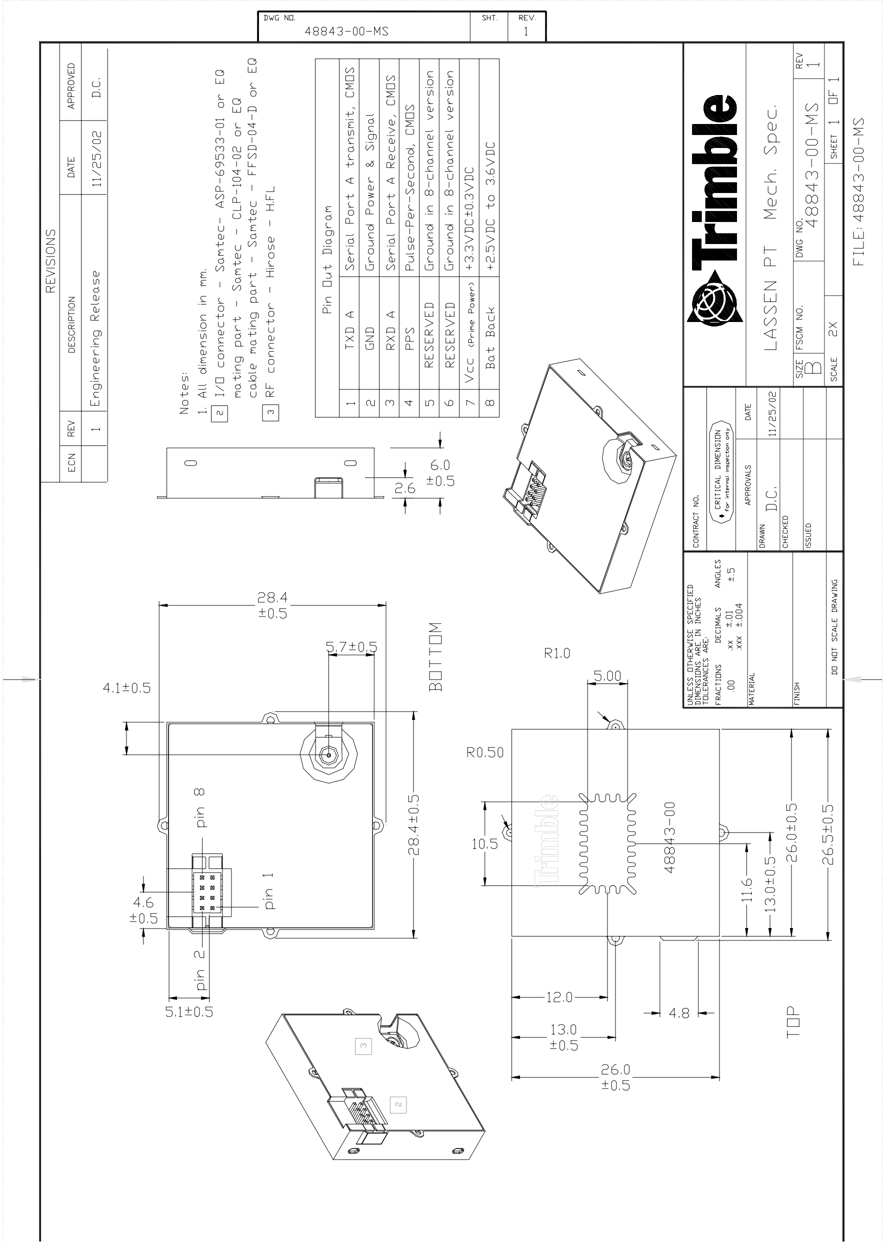
Physical

Enclosure	Metal enclosure with solder mounting tabs
Outside Dim.	26 mm W x 26 mm L x 6.4 mm H (1.02" x 1.02" x 0.25")
Weight	Approximately 5.7 grams (0.2 ounces) including the shield

Accessories

Rooftop Antenna	Bullet III TNC (F) 3.3 Vdc with 30dBi gain
Cable	75 feet of RG6 with TNC (M) connectors
Transition Cable	RF transition cable for connecting the RF module with external cable (Hirose to bulkhead SMA). Cable length: 10 inches

Figure D.1 Lassen PT GPS Timing Receiver



Glossary

This section defines technical terms and abbreviations used in this manual. It includes terms from the field of GPS technology.

2-D GPS mode A procedure of determining a 2-D position using signals received from the best (or only) three available GPS satellites. Altitude is assumed to be known and constant. A 2-D position solution will only be determined if signals fro three or more satellites are available.

2 dRMS Twice the distance root mean squared. The error distance within which 95% of the position solutions will fall.

3-D Three Dimensional. A 3-D position is defined as latitude, longitude, and altitude.

2-D Two Dimensional. A 2-D position is defined as latitude, longitude, and altitude.

3-D GPS mode A procedure of determining a 3-D position using signals received from the best (or only) four available GPS satellit A 3-D position solution will only be determined if signals from four or more satellites are available.

almanac A reduced-precision subset of the ephemeris parameters. Used by the receiver to compute the elevation angle, azimu angle, and estimated Doppler of the satellites. Each satelli broadcasts the almanac for all the satellites in the system.

ASCII American Standard Code for Information Interchange. A standard set of 128 characters, symbols and control codes used for computer communications. ASCII characters requ 7 bits of data to send, but are often sent 8 bits at a time wi the extra bit being a zero.

communication random times. Data transmission is not synchronized to a clock. With asynchronous transmission, each character is transmitted one at a time with a “start” bit at the beginning and one or more “stop” bits at the end. Any amount of tim can elapse before the next character is sent. \

auto GPS mode A procedure of automatically determining either a 2-D or 3 position using signals received from GPS satellites. The solution automatically transitions between 2-D and 3-D depending on the number of satellites available, the PDOP the available satellites, and the defined PDOP switch valu (See PDOP and PDOP constellation switch).

azimuth angle The angle of the line-of-site vector, projected on the horizontal plane, measured clockwise from true North.

bandwidth The range of frequencies occupied by a signal. Also, the information carrying capability of a communication chanr or line.

baud A measure of the speed of data transmission. Baud and bit rate are the same for direct equipment interconnections (e. via RS-232). Baud and bit rate are not the same for modulated data links, whether wire or radio.

bit Binary digit. The smallest unit of information into which digital data can be subdivided and which a computer can hold. Each bit has only two values (e.g., on/off, one/zero, true/false).

bit rate The rate at which bits are transmitted over a communicati path. Normally expressed in bits per second (bps).

byte A set of contiguous bits that make up a discrete item of information. A byte usually consists of a series of 8 bits, a represents one character.

C/A code The Coarse/Acquisition code. This is the civilian code ma available by the Department of Defense. It is subject to selective availability (SA). Users can reduce the effects of S by using differential GPS.

can be sensed to determine the presence of a signal.

channel Either a single frequency or a pair of radio frequencies use as a communication path.

chip The length of time to transmit either a zero or a one in a binary pulse code.

chip rate Number of chips per second (e.g., C/A code = 1.023 MHz

configuration A set of conditions or parameters that define the structure an item. A configuration defines the GPS processing and characteristics of the RS-232 interface ports. The term configuration can also define the hardware components th comprise a subsystem or system.

data bits The bits in a byte of data which carry the actual informati

datum Refers to a mathematical model of the earth. Many local datums model the earth for a small region: e.g., Tokyo datu Alaska, NAD-27 (North America). Others, WGS-84, for example, model the whole earth.

DCE Data Communications Equipment. The equipment that provides the functions required to establish, maintain, and terminate a communication connection. Any equipment th connects to DTE using an RS-232 or CCITT V.24 standar interface.

default setting A preset or initial value that is assumed to be the preferred appropriate selection for most situations. The Lassen SK I GPS sensor is shipped with factory default configuration settings; the settings were determined by Trimble Navigati

DGPS see *differential GPS*

DGPS reference station A device that tracks all GPS satellites in view, periodically performs inter-channel calibrations, and calculates and transmits differential corrections.

differential capable A term used to describe a GPS receiver that is capable of receiving and applying differential GPS corrections.

position accuracy. Differential GPS provides 2 to 5 meter position accuracy. Differential accuracy is obtained by applying corrections determined by the stationary Differential GPS Reference Station to the GPS data collect by the RPU unit on-board the vehicle.

differential processing GPS measurements can be differenced between receivers, satellites, and epochs. Although many combinations are possible, the present convention for differential processing GPS phase measurements is to take differences between receivers (single difference), then between satellites (doub difference), then between measurement epochs (triple difference).

differential relative positioning Determination of relative coordinates of two or more receivers which are simultaneously tracking the same satellites. Static differential GPS involves determining baseline vectors between pairs of receivers. Also see *differential GPS*

dilution of precision A description of the purely geometrical contribution to the uncertainty in a position fix, given by the expression DOP SQRT TRACE (AA) where AA is the design matrix for th instantaneous position solution (dependent on satellite-receiver geometry). The DOP factor depends on the parameters of the position-fix solution. Standard terms for the GPS application are:

GDOP: Geometric (three position coordinates plus clock offset in the solution)

PDOP: Position (three coordinates)

HDOP: Horizontal (two horizontal coordinates)

VDOP: Vertical (height only)

TDOP: Time (clock offset only)

DOP see *dilution of precision*.

Doppler aiding The use of Doppler carrier-phase measurements to smooth code-phase position measurements.

the rate of change of the range between the transmitter anc receiver.

earth-centered earth-fixed Cartesian coordinate system where the X direction is the intersection of the prime meridian (Greenwich) with the equator. The vectors rotate with the earth. Z is the direction the spin axis.

elevation angle The angle between the line of sight vector and the horizon plane.

elevation mask angle A measure of the minimum elevation angle, above the horizon, above which a GPS satellite must be located befc the signals from the satellite will be used to compute a GP location solution. Satellites below the elevation angle are considered unusable. The elevation mask angle is used to prevent the GPS receiver from computing position solutio using satellites which are likely to be obscured by building or mountains.

ellipsoid In geodesy, unless otherwise specified, a mathematical figu formed by revolving an ellipse about its minor axis. It is oft used interchangeably with spheroid. Two quantities define ellipsoid; these are usually given as the length of the semimajor axis, a, and the flattening, f = (a - b)/a, where b the length of the semiminor axis.

ephemeris A set of parameters that describe the satellite orbit very accurately. It is used by the receiver to compute the positic of the satellite. This information is broadcast by the satelli

epoch Measurement interval or data frequency, as in making observations every 15 seconds. Loading data using 30-second epochs means loading every other measurement.

firmware A set of software computer/processor instructions that are permanently or semi-permanently resident in read-only memory.

signal. Measured in hertz (Hz), kilohertz (kHz), or megahe (MHz).

GPS frequencies are: L1 = 1575.42 MHz

L2 = 1227.60 MHz

GDOP Geometric Dilution of Precision. GDOP describes how mu an uncertainty in pseudo-range and time affects the uncertainty in a position solution. GDOP depends on whe the satellites are relative to the GPS receiver and on GPS clock offsets.

geodetic datum A mathematical model designed to best fit part or all of th geoid. It is defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surfa established as the origin of datum. This relationship can b defined by six quantities, generally (but not necessarily) tl geodetic latitude, longitude, and the height of the origin, tl two components of the deflection of the vertical at the orig and the geodetic azimuth of a line from the origin to some other point. The GPS uses WGS-84.

geoid The actual physical shape of the earth which is hard to describe mathematically because of the local surface irregularities and sea-land variations. In geodetic terms it i the particular equipotential surface which coincides with mean sea level, and which may be imagined to extend through the continents. This surface is everywhere perpendicular to the force of gravity.

GPD GPS with differential corrections applied.

navigation (not communication) satellites which transmit signals used (by GPS receivers) to determine precise locati (position, velocity, and time) solutions. GPS signals are available world-wide, 24 hours a day, in all weather conditions. This system also includes 5 monitor ground stations, 1 master control ground station, and 3 upload ground stations.

GPS antenna An antenna designed to receive GPS radio navigation signa

GPS processor An electronic device that interprets the GPS radio navigati signals (received by a GPS antenna) and determines a location solution. The GPS processor may also be able to apply (and determine) differential GPS corrections.

GPS receiver The combination of a GPS antenna and a GPS processor.

GPS time The length of the second is fixed and is determined by primary atomic frequency standards. Leap-seconds are no used, as they are in UTC. Therefore, GPS time and UTC differ by a variable whole number of seconds.

HDOP Horizontal Dilution of Precision.

HOW Handover word. The word in the GPS message that contai time synchronization information for the transfer from C/A P-code.

interface cable (serial) The interface cable allows data to flow between the Lasse SK II GPS and the communication equipment. One end of the cable has a 9-pin female RS-232 connector and the oth end of this cable has a 9-pin male RS-232 connectors.

interference Refers to the unwanted occurrences on communication channels that are a result of natural or man-made noises an signals, not properly a part of the signals being transmitted received.

integrated Doppler A measurement of Doppler shift frequency or phase over time.

the issue number of the ephemeris information. A new ephemeris is available usually on the hour. Especially important for Differential GPS operation that the IODE change is tracked at both the reference station and mobile stations.

jamming — Interference (in either transmitting or receiving signals) caused by other radio signals at exactly or approximately t same frequency

Kalman filter — A numerical method used to track a time-varying signal ir the presence of noise. If the signal can be characterized by some number of parameters that vary slowly with time, th Kalman filtering can be used to tell how incoming raw measurements should be processed to best estimate those parameters as a function of time.

masks — See *satellite masks*.

maximum PDOP — A measure of the maximum Position Dilution of Precision (PDOP) that is acceptable in order for the GPS processor t determine a location solution (see PDOP).

NAVSTAR — The name given to the GPS satellites, built by Rockwell International, which is an acronym formed from NAVigati System with Time And Ranging.

NMEA — National Marine Electronics Association. An association tl defines marine electronic interface standards for the purpc of serving the public interest.

NMEA 0183 message — NMEA 0183 is a standard for interfacing marine electroni navigational devices. The standard specifies the message format used to communicate with marine devices/components.

packet — An "envelope" for data, which contains addresses and errc checking information as well as the data itself.

parity — A scheme for detecting certain errors in data transmission. Parity defines the condition (i.e., even or odd) of the numb of items in a set (e.g., bits in a byte).

merit that describes how an uncertainty in pseudo-range affects position solutions.

PDOP constellation switch
A value, based on PDOP, that defines when the GPS receiver/processor should switch between 2-D and 3-D GI modes. The PDOP constellation switch is only active whe the GPS mode of operation is set to Auto.

PRN
Pseudo-random noise. Each GPS satellite generates its ow distinctive PRN code, which is modulated onto each carri The PRN code serves as identification of the satellite, as a timing signal, and as a subcarrier for the navigation data.

protocol
A formal set of rules that describe a method of communication. The protocol governs the format and cont of inputs and outputs.

pseudo-range
A measure of the range from the GPS antenna to a GPS satellite. Pseudo-range is obtained by multiplying the spee of light by the apparent transit time of the signal from the GPS satellite. Pseudo-range differs from actual range becau the satellite and user clocks are offset from GPS time and because of propagation delays and other errors.

RAM
Random-Access Memory.

random-access memory
Memory in which information can be referred to in an arbitrary or random order. The contents of RAM are lost when the System Unit is turned off.

range
A term used to refer to the distance radio signals can trave before they must be received or repeated due to loss of sig strength, the curvature of the earth and the noise introduce because of moisture in the air surrounding the earth's surfa

range rate
The rate of change of range between the satellite and receiver. The range to a satellite changes due to satellite a observer motions. Range rate is determined by measuring t Doppler shift of the satellite beacon carrier.

Information is placed into ROM only once. The contents c ROM are not erased when the system unit's power is turne off.

real time clock An electronic clock, usually battery powered, that keeps current time. Used by a GPS receiver during a warm or hc start to determine where to search for GPS satellite signals

relative positioning The process of determining the vector distance between tv points and the coordinates of one spot relative to another. This technique yields GPS positions with greater precisior than a single point positioning mode can.

rise/set time Refers to the period during which a satellite is visible; i.e., has an elevation angle that is above the elevation mask. A satellite is said to "rise" when its elevation angle exceeds t mask and "set" when the elevation drops below the mask.

ROM Read-Only Memory.

RS-232 A communication standard for digital data. Specifies a number of signal and control lines. RS-232 is often associated with a 25 pin connector called a DB-25.

RTCM Radio Technical Commission for Maritime Services. Commission that recommends standards for differential G services. "RTCM Recommended Standards For Differenti GPS Service," prepared by RTCM Special Committee No 104 (RTCM SC-104), defines a communication protocol f sending GPS differential corrections from a differential reference station to remote GPS receivers.

satellite masks As satellites approach the horizon, their signals can becon weak and distorted, preventing the receiver from gatherin accurate data. Satellite masks enable you to establish crite for using satellite data in a position solution. There are thr types of satellite masks: Elevation, SNR, and PDOP.

implementation scheme by which unauthorized users of G will have their accuracy limited to 100 meters 2D RMS horizontal and 156 meters 2D RMS vertical.

SEP Spherical Error Probability. The radius of a sphere such th 50% of the position estimates will fall within the surface c the sphere.

serial communication A system of sending bits of data on a single channel one af the other, rather than simultaneously.

serial port A port in which each bit of information is brought in/out o single channel. Serial ports are designed for devices that receive data one bit at a time.

signal to noise level GPS signals with SNRs that do not meet the mask criteria a considered unusable.

signal to noise ratio A measure of the relative power levels of a communicatio signal and noise on a data line. SNR is expressed in decibe (dB).

SNR Signal to Noise Ratio.

spread spectrum The received GPS signal is a wide bandwidth, low-power signal (-160dBW). This property results from modulating t L-band signal with a PRN code in order to spread the sign energy over a bandwidth which is much greater than the signal information bandwidth. This is done to provide the ability to receive all satellites unambiguously and to provi some resistance to noise and multipath.

SPS Standard Positioning Service. Refers to the GPS as availal to the authorized user.

start bit In asynchronous transmission, the start bit is appended to t beginning of a character so that the bit sync and character sync can occur at the receiver equipment.

stop bit In asynchronous transmission, the stop bit is appended to t end of each character. It sets the receiving hardware to a condition where it looks for the start bit of a new characte

synchronous communication A method of sending digital data in which the bits come a fixed, rather than random, times and are synchronized to a clock.

TAIP Trimble ASCII Interface Protocol. Designed originally for vehicle tracking applications, TAIP uses printable upperca ASCII characters in 16 message types for easy integration with mobile data modems, terminals, and personal computers. The TAIP protocol is defined in full in Appendix C.

TANS Trimble Advanced Navigation Sensor. Also refers to a Trimble-specified interface protocol for digital packet communication to/from the GPS receiver. Data output includes time-tagged position and velocity, satellite status, dilution of precision factors and diagnostics of GPS receiv operational status.

Also see *TSIP*

TNL 4000RL Trimble Navigation, Ltd. Reference Locator (4000RL). Product name for the Differential GPS Reference Station.

TSIP Trimble Standard Interface Protocol. A binary/hex packet directional protocol, also known as the TANS protocol. Us by a large number of Trimble sensors. TSIP is the subset c TANS which is recognized by all Trimble sensors except t 4000 series. The TSIP protocol is defined in full in Appendix A.

and is computed by the GPS operators. It is a statistical indicatory of the contribution of the apparent clock and ephemeris prediction accuracies to the ranging accuracies obtainable with a specific satellite based on historical data

UTC Universal Time Coordinated. Uniform atomic time system/standard that is maintained by the US Naval Observatory. UTC defines the local solar mean time at the Greenwich Meridian.

UTC offset The difference between local time and UTC (Example: U - EST = 5 hours).