

Lassen-SK8™

Embedded GPS Module

System Designer Reference Manual

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Preface

The Global Positioning System (GPS) is a satellite based navigation system operated and maintained by the U.S. Department of Defense. The GPS consists of a constellation of 24 satellites providing world-wide, 24 hour, three dimensional (3-D) coverage. Although originally conceived for military needs, GPS has a broad array of civilian applications including surveying, marine, land, aviation, and vehicle navigation. GPS is the most accurate technology available for vehicle navigation.

As a satellite based system, GPS is immune to the limitations of land based systems such as Loran. Loran navigation is limited in coverage and is encumbered by adverse weather. In addition, the accuracy of Loran navigation varies with geographic location and, even under ideal conditions, cannot compare with GPS. By computing the distance to GPS satellites orbiting the earth, a GPS receiver can calculate an accurate position. This process is called satellite ranging. A 2-D position calculation requires three satellite ranges. A 3-D position calculation, which includes altitude, requires four satellite ranges. GPS receivers can also provide precise time, speed, and course measurements which are beneficial for vehicle navigation.

Differential GPS (DGPS) is a sophisticated form of GPS navigation which provides even greater positioning accuracy. Differential GPS relies on error corrections transmitted from a GPS receiver placed at a known location. This receiver, called a reference station, calculates the error in the satellite range data and outputs corrections for use by other GPS receivers. These GPS receivers are designated as mobile units and can be dispersed as far as 100 Km from the base station. Differential GPS eliminates virtually all the measurement error in the satellite ranges and enables a highly accurate position calculation. The Lassen-SK8 is differential-ready for applications requiring DGPS accuracy.

Scope and Audience

Even if you have used other Global Positioning System (GPS) receivers, we recommend that you spend some time reading this manual. The following section provides you with a guide to this manual, as well as to other documentation included with this product.

Lassen-SK8 Manual Organization

All of the information required to integrate and operate the Lassen-SK8 is contained in this Manual. This manual contains the following chapters and appendices:

Chapter 1: Starter Kit

Chapter 2: Hardware Integration

Chapter 3: Software Interface

Chapter 4: Operation and Performance

Appendix A: Trimble Standard Interface Protocol

Appendix B: TSIP User's Guide

Appendix C: Trimble ASCII Interface Protocol (TAIP)

Appendix D: GPSSK User's Guide (TAIP)

Appendix E: NMEA 0183

Appendix F: Specifications and Mechanical Drawings

Glossary

The Lassen-SK8 is easy to integrate and simple to use. Before proceeding with Chapter 1, please review the information contained in this *Preface* for an overview of the Global Positioning System.

Technical Assistance

If you have problems and cannot find the information you need in this document, call the Trimble Technical Assistance Center (TAC). The phone numbers are:

+1-800-SOS-4TAC (North America)

+1-408-481-6940 (International)

+1-408-481-6020 (FAX)

You can call the Technical Assistance Center phones between 6 AM (0600) to 5:30 PM (1730) Pacific Standard Time. A support technician will take your call, help you determine the source of your problem, and provide you with any technical assistance you might need.

Email

You can send email to the Technical Assistance Center at any time. A support technician will respond to your email questions or comments. The email address is:

trimble_support@trimble.com.

Worldwide Web

Check the Trimble worldwide web site on the Internet (<http://www.trimble.com>) for the latest news on new products and releases.

Internet FTP Address

You can visit the Trimble Public FTP site at any time to access software patches, utilities, service bulletins, and FAQs. The FTP site address is:

`ftp.trimble.com/pub/sct/embedded/bin.`

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FaxBack is a completely automated fax response system for selecting documents and catalogs (lists of available documents) to be faxed back to a fax machine. Call from a tone-dialing phone and FaxBack guides you through the call by playing a pre-recorded voice message.

The FaxBack system is available 24 hours a day, seven days a week. You can order a variety of documents, including; data sheets, application notes, technical documentation, configuration guides, assembly drawings, and general information.

To call the FaxBack service, dial the following number and follow the instructions:

+1-408-481-7704

Reader Comment Form

A reader comment form is provided at the end of this guide. If this form is not available, comments and suggestions can be sent to:

Trimble Navigation Limited
645 North Mary Avenue
Post Office Box 3642, Sunnyvale, CA 94088-3642

All comments and suggestions become the property of Trimble Navigation Limited.

Document Conventions

<i>Italics</i>	Software menus, menu commands, dialog boxes and fields.
SMALL CAPITALS	DOS commands, directories, filenames, and filename extensions.
Courier	Represents what is printed on the computer screen.
Courier Bold	Information that to be typed in a software screen or window.
[Return] or [Ctrl] + [C]	Identifies a hardware function key or key combination that must be pressed on a computer keyboard.
Helvetica	Bold represents a software command button.

Notes, Tips, Cautions, and Warnings

Notes, tips, cautions, and warnings are used to emphasize important information.



Note – Notes give additional significant information about the subject to increase your knowledge, or guide your actions. A note can precede or follow the text it references.



Tip – Indicates a shortcut or other time or labor-saving hint that can help you make better use of the product.



Caution – Cautions alert you to situations that could cause hardware damage or software error. A caution precedes the text it references.



Warning – Warnings alert you to situations that could cause personal injury or unrecoverable data loss. A warning precedes the text it references.

1 Starter Kit

The Lassen-SK8, based on Sierra™ GPS technology, delivers an unmatched level of performance for embedded GPS applications. Sierra technology is Trimble's 8-channel GPS architecture based on two ASICs, the Scott RF ASIC and the Scorpion DSP.

The Scott RF ASIC features:

- Double down-conversion process
- Higher sensitivity
- Lowest power consumption

The double down-conversion process improves immunity to in-band jammers. The system provides a higher sensitivity which allows Lassen-SK8 to track weak satellites and improves position availability in environments with obscured coverage.

The Scorpion ASIC provides the following features in a single package:

- Integrates an 8-channel DSP with 4 correlators per channel
- 32-bit microprocessor
- Real-time clock
- DUART

The 8-channel, 32-correlator design provides extremely fast cold starts while delivering 2 meter DGPS performance. The high level of integration provides a small footprint (3.25" x 1.25" x 0.40") and contributes to the lowest power consumption (.75 watts) for a complete GPS receiver. The combination of small size and low power consumption allows Lassen-SK8 to be embedded in small battery operated devices and in devices where heat dissipation must be minimized.

The Starter Kit makes it simple to evaluate the Lassen-SK8 module's exceptional performance. The kit includes the following:

- Lassen-SK8 receiver installed inside an interface unit
- Magnetic mount antenna
- AC power adapter
- Serial interface cable
- GPS Tool Kit Software used to communicate with the GPS module

The interface unit is a sturdy metal enclosure containing an interface motherboard. The motherboard accepts 9 - 32 VDC power and provides regulated +5V and +3.6V BBU power to the Lassen-SK8 receiver module. The motherboard also provides two RS-232 connectors for quick and direct connection to a PC COM port. The Lassen-SK8 board can be removed from the motherboard for integration into the user's application (see Chapter 2, *Hardware Integration*).

1.1 Lassen-SK8 Overview

The Lassen-SK8 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 especially suited for embedded applications. The Lassen-SK8 features Trimble's latest signal processing code, a high-gain RF section for compatibility with standard 25 dB active gain GPS antennas, and a CMOS TTL level pulse-per-second (PPS) output for timing applications or as a general purpose synchronization signal

The Lassen-SK8 acquires a position fix with minimal delay after power cycling. The information necessary to help track satellites is stored in RAM using backup power for the following:

- Almanac
- Ephemeris
- Real-time clock
- Last position

User settings, including port parameters and receiver processing options, are stored in a non-volatile electrically erasable ROM (EEROM) that does not require backup power.

The Lassen-SK8 has two independently configurable serial I/O communication ports. Port 1 is a bi-directional control and data port utilizing the Trimble Standard Interface Protocol (TSIP) or Trimble ASCII interface protocol TAIP. Port 2 is a bi-directional port used to receive differential GPS (DGPS) corrections in industry standard RTCM SC-104 format and for output of industry standard ASCII NMEA sentences. The dual data I/O port characteristics and other options are user programmable and stored in non-volatile memory.



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

1.1.1 Interface Protocols

The Lassen-SK8 operates using either of three protocols — Trimble Standard Interface Protocol (TSIP), Trimble ASCII Interface Protocol (TAIP), and NMEA 0183 and are physically located at the following ports:

- Port 1 TSIP or TAIP
- Port 2 NMEA 0183

Port 1

TSIP is a powerful binary packet protocol that allows the system designer maximum configuration control over the GPS receiver for optimum performance in any number of applications. TSIP supports over 40 commands and their associated response packets for use in configuring the Lassen-SK8 receiver module to meet user requirements.

TAIP is designed for easy integration using programmable ASCII characters in the form of 2-character message types which provide position.

Port 2

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-SK8 receiver module supports most NMEA messages for GPS navigation. NMEA messages and output rates can be user selected as required. RTCM SC-104 is the GPS industry standard for differential correction data. The receive side of port 2 is configured to accept RTCM data.

1.1.2 Starter Kit Components

The Lassen-SK8 is available in a developer's Starter Kit or as individual boards. The Starter Kit includes all the components necessary to quickly test and integrate the module.

The Starter Kit components and the accessory part numbers are listed in Table 1-1 and Table 1-2.

Table 1-1. Lassen-SK8 Starter Kit

Starter Kit Part Reference	Part Number
Lassen-SK8 Starter Kit	29467-00
8-channel Lassen-SK8 receiver module (Socketed)	28479-99-D
SK8 Interface Unit	28832-10
Magnetic Mount GPS Antenna with Cable	28367-00
AC Power Adapter	29938
Power Cable	20260
Interface Cable DB9M/DB9F	19309-00
GPS Toolkit Disk	30643-01
System Designer Reference Manual	34149-01

Table 1-2. Lassen-SK8 Modules

Starter Kit Part Reference	Part Number
Standard Temperature Module	28835-10
Extended Temperature Module	28835-20

Table 1-3. Lassen SK-8 Optional Antennas

Antenna Reference	Part Number
Hard Mount GPS Antenna	28367-70
Rooftop Antenna Kit with 75 foot cable	23726-00



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

1.2 GPS Receiver Module

In the Starter Kit, the Lassen-SK8 is installed on an interface motherboard which is housed in a metal enclosure (see Figure 1-1). This packaging simplifies testing and evaluation of the module by providing an RS-232 serial interface which is compatible with most PC communication ports, and by providing a DC power supply which converts a 9 to 32 volts DC input to the regulated 5 volts required by the module. The DB9 connectors provide an easy connection to the PC's serial port using the interface cable provided in the kit. The metal enclosure protects the module and motherboard for testing outside of the laboratory environment.

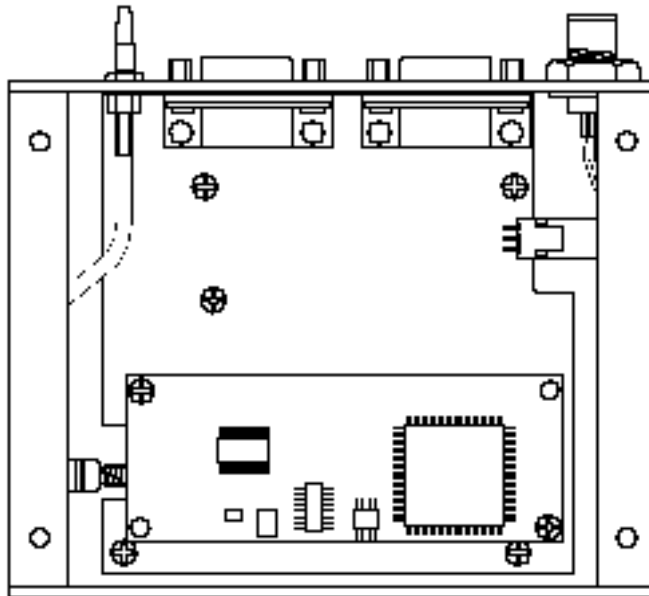


Figure 1-1. The Module Installed Inside the Interface Unit

The receiver module (see Figure 1-2) consists of a single 3.25" x 1.25" x 0.40" module. A standard SMB RF connector (J1) supports the GPS antenna connection. The center conductor supplies +5 VDC for the Low Noise Amplifier of the active antenna. An 8-pin, 0.1 inch header (J4) supports the serial interface (CMOS TTL level), the pulse-per-second (PPS) signal (CMOS TTL level), and the input power (+5 VDC). This module connects to the motherboard via the 8-pin header and is secured by two standoffs. An RF-interface cable connects the antenna port to an SMB connector on the enclosure panel.

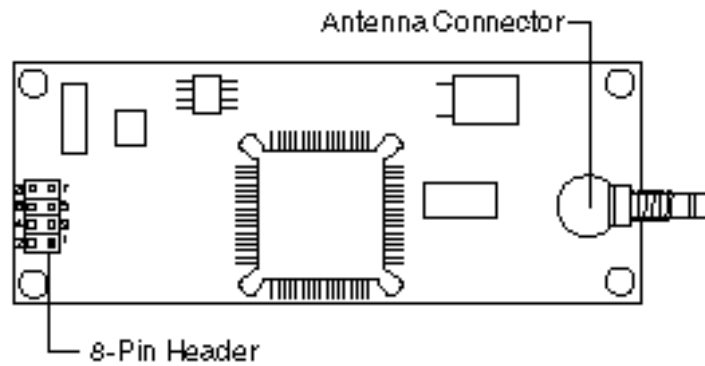


Figure 1-2. Receiver Module



Note – The receiver included in the Starter Kit contains a socket for the firmware ROM. This socketed board may be used to evaluate future releases of firmware. The standard OEM module is not equipped with a socket.

The interface motherboard includes a 9 to 32 VDC switching power supply which provides a regulated +5 VDC to the receiver. It also converts the TTL-level I/O to RS-232 for a direct interface to a computer. The motherboard provides an open-collector interface for the PPS and also includes a 3.6V lithium backup battery enabling lightning-fast hot starts. The Starter Kit includes an AC/DC converter for powering the module from an AC wall socket. The metal enclosure (see Figure 1-3) provides 2 interface port connectors, an antenna connector and a power connector. The mounting plate is secured to the metal enclosure with four screws. The eight pin header plugs into the corresponding 8-pin socket on the motherboard as shown in Figure 1-3.

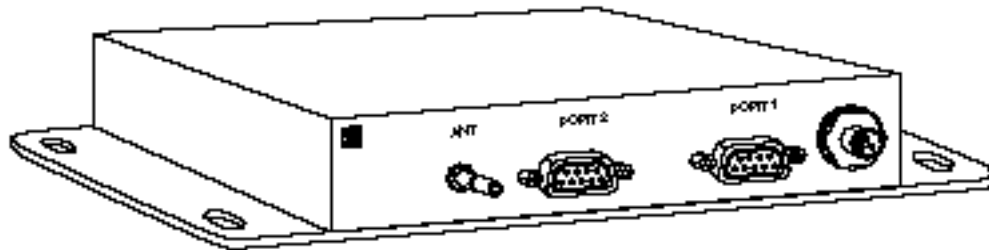


Figure 1-3. Starter Kit Interface Unit



Note – Due to the open-collector interface, the polarity of the PPS signal is inverted. The pulse is a 10µs negative-going pulse with the falling edge synchronized to UTC. When removed from the motherboard, the receiver provides a TTL level, positive-going pulse. In order to pull up the 1pps use a 10k pull up resistor as shown in the following illustration.

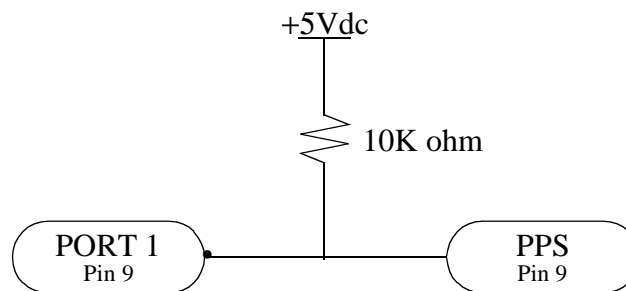


Figure 1-4. Open Collector PPS

The Starter Kit interface unit provides fifty percent of the duty cycle on the PPS line.

1.3 Antenna

The GPS antenna receives the GPS satellite signals and passes them to the receiver. Because the GPS signals are spread spectrum signals in the 1575 MHz range and do not penetrate conductive or opaque surfaces, the GPS antenna must be located outdoors with a clear view of the sky. The Lassen-SK8 requires an *active* antenna. The received GPS signals are very low power, approximately -140 dB, at the surface of the earth. Trimble's active antennas include a preamplifier that filters and amplifies the GPS signals before delivery to the receiver.

Trimble offers a variety of antennas for use with the Lassen-SK8. The compact magnetic mount GPS antenna and integral cable supplied with the Starter Kit is ideal for portable and mobile applications. A permanent, bulkhead mount antenna is also available. A compact, pole-mount rooftop antenna is available for fixed-site installations. Refer to Appendix F for mechanical outline drawings of the GPS antennas.

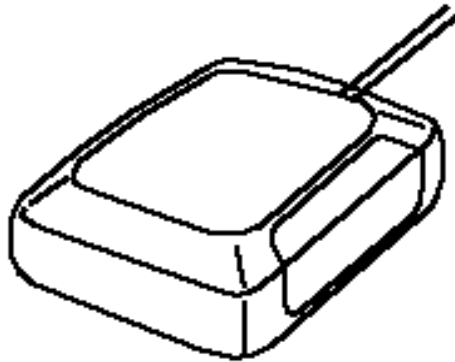


Figure 1-5. Magnetic Mount GPS Antenna

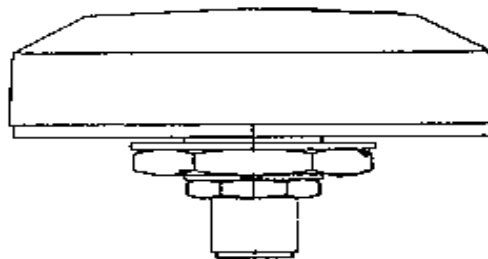


Figure 1-6. Hard Mount GPS Antenna

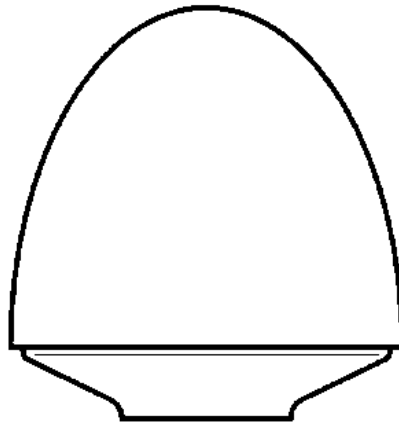


Figure 1-7. Bullet II GPS Antenna

1.4 Power

The receiver module is designed for embedded applications and requires a regulated +5.0 VDC input (+4.75 to +5.25 VDC). See *Power Requirements* in Chapter 4 for detailed specifications. In the Starter Kit, the motherboard includes a DC power regulator which converts a 9 to 32 VDC input to the regulated 5 VDC required by the module. Power can be applied to the Starter Kit module using one of two options: the DC power cable (see Figure 1-8) or the AC/DC power converter (see Figure 1-9).



Figure 1-8. DC Power Cable

The DC power cable is ideal for bench-top or automotive 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 unterminated 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 module and the antenna. The combined power consumption of the receiver module and the antenna is 200 milli-amps.



Note – The yellow wire is not used in the Starter Kit. Battery back-up 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 Starter Kit module. The AC/DC power converter converts 110 or 220 VAC to a regulated 12 VDC compatible with the Starter Kit module. 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.

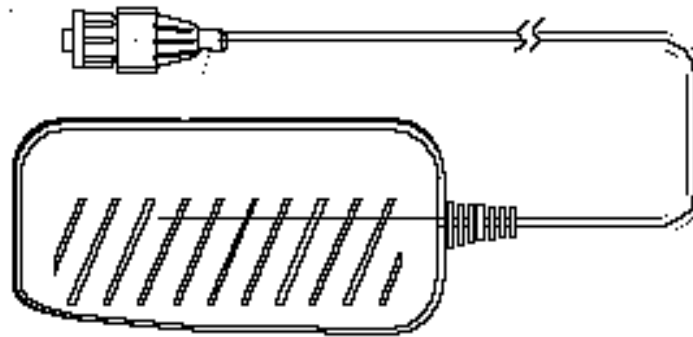


Figure 1-9. AC/DC Power Converter

1.5 Hardware Setup

The Lassen-SK8 supports TSIP, TAIP, and NMEA protocols. Port 1 is used for TSIP or TAIP I/O and port 2 is used to input RTCM corrections and output NMEA messages. Follow the steps below to setup the Starter Kit. Figure 1-10 illustrates the setup.

1. For TSIP or TAIP Protocols, connect one end of the 9-pin serial interface cable to Port 1 (or Port 2 to view NMEA data) of the receiver module. 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 pushing the antenna cable connector onto the SMB connector on the unit (to remove the antenna cable, simply pull the antenna connector off of the SMB connector). Place the antenna so that it has a clear view of the sky.
3. Using either the DC power cable or 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.

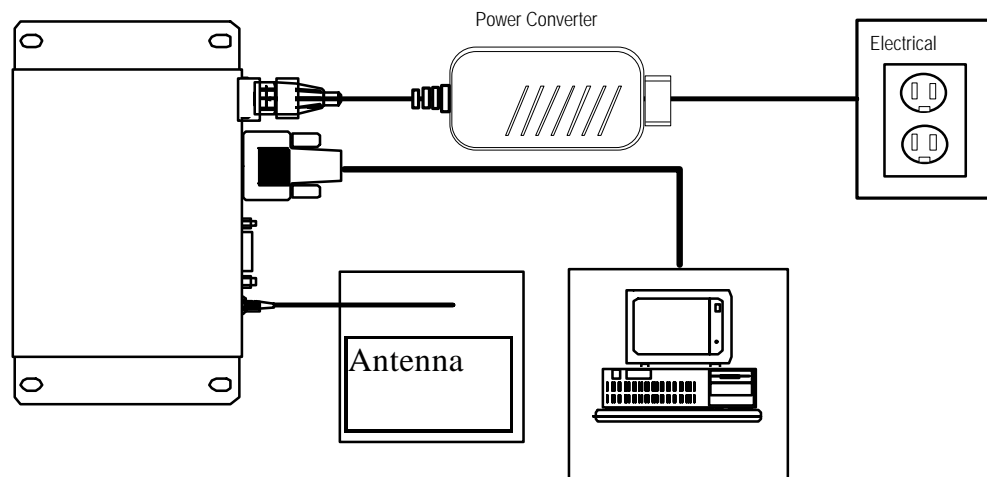


Figure 1-10. Interconnect Diagram

1.6 Running the TSIP Interface Program

The Starter Kit includes a disk containing TSIP interface programs which run on a PC-DOS platform. These programs aid system integrators in monitoring the receiver module's performance and in developing the software interface for the GPS module. The TSIP programs are described in detail in Appendix B, TSIP User's Guide.

1. Connect one end of the serial interface cable to Port 1 of the Starter Kit interface unit. Connect the other end of the cable to COM1 or COM 2 of your PC.
2. Turn on the DC power source or plug in the AC/DC converter.
3. Turn on the PC.
4. Insert the GPS Tool Kit disk in the disk drive.
5. Go to the directory where you wish to establish the GPS tool kit sub directory. In most cases, this will be the root directory on the C: drive.



Note – For detailed installation guidelines, read the install text file A:\README.TXT. The toolkit disk contains a self-extracting zip file that installs the program onto your DOS computer.

6. At the DOS prompt, type A:\INSTALL. The executable program creates a sub directory called TOOLKIT and installs the tool kit files.
7. Type the appropriate path name to execute the TSIPCHAT program (e.g. C:\TOOLKIT\TSIPCHAT). TSIPCHAT provides full access to the TSIP protocol. It converts binary TSIP packets into printable ASCII characters and vice versa. When TSIPCHAT is initiated, it configures the PC serial port to the default TSIP settings (9600 baud, 8-Odd-1).
8. After the TSIPCHAT title screen appears, press [?], and the primary TSIPCHAT screen shown in Figure 1-11 is displayed.
9. To test the connection, press [V]. This message requests the firmware version numbers from the GPS module. If connected and operating properly, the module should respond with a software version report within one second. This report will be displayed in the command window.

When a GPS antenna is connected to a receiver and has achieved a position fix, the transmitted position reports scroll through the report window (see Figure 1-11). These reports include position, velocity and other GPS information. A receiver health report is sent every few seconds, even when no satellites are being tracked.

```

:57 PM                                     tsipchat                                     5/13/96
troke Command List (Key Pkt-ID Description):
0x1E clear battery RAM ^A 0x2A altitude for 2-D $ 0x38 set/recv SV data
0x1F show S/W version I 0x2B input LLA pos < 0x3A show raw meas
0x21 show time o 0x2D show osc offset e 0x3B ephemeris info
0x21 sync PC to UTC T 0x2E set time from PC > 0x3C show track status
0x23 input XYZ pos u 0x2F show UTC info / 0x65 show DGPS info
0x24 show 2-D/3-D mode b 0x31 set acc ECEF pos ^H 0x70 pos flt operation
0x25 reset receiver B 0x32 set acc LLA pos q 0x7A NMEA output cntrl
0x26 receiver health 0 0x35 show I/O options = 0x8E extended cmds
0x27 show sig levels ^0 0x35 set I/O options r 0xBB receiver config
0x28 GPS sys message w 0x37 show last fix R 0xBC rcvr serial cfg
r Cmd; <Esc>=Exit; ^F=log TSIP; !,@=down,upload alm; ^I=COM Port
r Keystroke:
P, H, V, TDOP = 2.14, 1.15, 1.81, 1.21
mode is 2, auto diff, diff off
8F-20: 21:57:49.00 37:23.57696 N 122:2.19794 W -32.51
* 0.000 E 0.000 N 0.000 U - PP:Y I:3D-F
* 06(21Eh) 16( 99h) 09( BEh) 05( 8Bh) 24( E9h) 04( D8h)
: Auto 6 SV (3-D): 6 16 9 5 24 4
P, H, V, TDOP = 2.14, 1.15, 1.81, 1.21
mode is 2, auto diff, diff off
8F-20: 21:57:50.00 37:23.57695 N 122:2.19795 W -32.47
* 0.000 E 0.000 N 0.000 U - PP:Y I:3D-F
* 06(21Eh) 16( 99h) 09( BEh) 05( 8Bh) 24( E9h) 04( D8h)
    
```

Figure 1-11. TSIPCHAT Command Window and Report Window

The upper (shaded) portion of the screen is the command/response window and the lower portion of the screen is the automatic report window (auto window). The auto window displays a running account of the messages which are automatically output by the GPS module in the lower half of the screen. The most common reports are the position and velocity reports. Other automatic reports include receiver status and health information.

When the GPS module has completed a position fix and starts transmitting position reports, the position reports will begin scrolling in the auto window. An automatic receiver health report is sent every few seconds, even when no satellites are being tracked.

If the auto window is not displaying messages, then the GPS module may not be connected properly to the computer. To test the connection, press [V].

If the message, WAITING FOR REPLY appears continuously in the command window, then the GPS module is not communicating with the computer. If this occurs, re-check the interface cable connections and verify the serial port selection. If the communication failure still occurs after checking all connections and settings, please call the Trimble Technical Assistance Center (TAC) for assistance.

2 Hardware Integration

The integration of the Lassen-SK8 receiver module is discussed in two sections: Hardware Integration and Software Interface. This chapter, *Hardware Integration*, includes instructions for mounting the GPS module and physically connecting the module to the antenna, the host processor, and the power source. Chapter 3, *Software Interface*, provides guidelines for configuring the Lassen-SK8 receiver module to communicate with the host processor.

2.1 The Lassen-SK8 Receiver Module

In the Starter Kit, the Lassen-SK8 receiver module is installed on the interface motherboard to facilitate testing and evaluation. The receiver module can be detached from the motherboard for installation into a specific device.

The receiver module is connected to the motherboard at four points: the antenna connector, the interface connector, and two standoffs (see Figure 2-1). Follow the steps below to remove the receiver module from the motherboard.

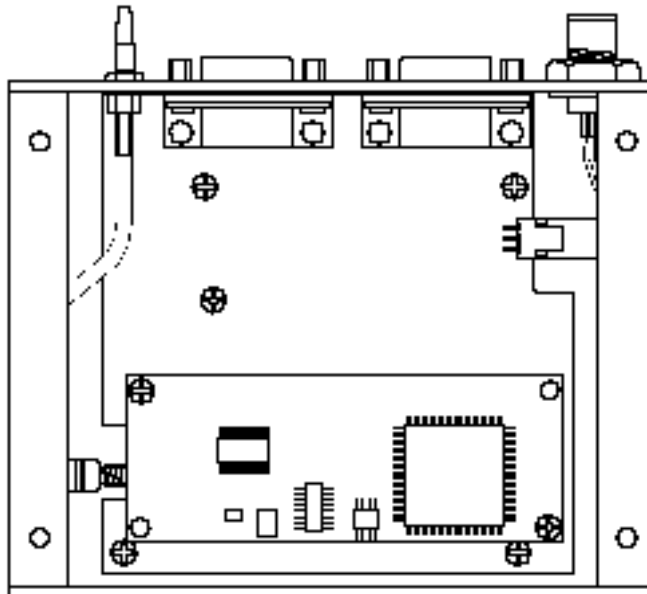


Figure 2-1. Motherboard Connection Points



Caution – Before disassembling the interface unit, disconnect the unit from any external power source and confirm that both you and your work surface are properly grounded for ESD protection. The interface unit motherboard contains a 3.6V lithium battery. Exercise caution when removing it from the Lassen-SK8 unit.

1. Remove the four screws which secure the bottom plate to the base of the metal enclosure. Set the bottom plate aside.
2. Remove the two screws securing the Lassen-SK8 module to the standoffs on the motherboard. These screws are located at opposite ends of the receiver module (see Figure 2-2)

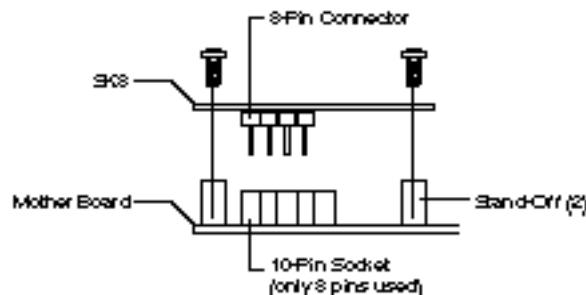


Figure 2-2. Removing the Receiver Module

3. Carefully pull the module straight off the motherboard to disengage the 8-pin header from the 10-pin socket on the motherboard (see Figure 2-2). Do not rotate or flex the module while disengaging the header, since this could damage the connector or the board components. Pull straight up, keeping the Lassen-SK8 parallel to the motherboard.
4. Disconnect the RF cable connecting the Lassen-SK8 module to the SMB connector on the enclosure. This connection was made by pushing the antenna cable connector onto the SMB connector on the receiver. To remove the antenna cable, grasp the cable connector and pull it straight off of the antenna connector. Do not twist the cable or attempt to pull it off at an angle, as this may damage the connector.
5. To reinstall the Lassen-SK8 board in the motherboard, follow steps 1 - 4 in reverse order.



Note – The Lassen-SK8 is designed for embedded applications. The digital I/O lines and power lines are not designed with additional ESD protection as a stand-alone module would be. Use standard CMOS ESD handling precautions when removing and installing the receiver module.

2.2 Interface Connector

The Lassen-SK8 power and data I/O functions are integrated into a single 8-pin header connector, J4. The J4 connector uses 0.025 inch pins on 0.10 inch spacing (refer to the mechanical outline drawing in Appendix F).

Table 2-1. I/O Connector Signals

Pin #	Function	Description
1	TXD 2	Port 2 transmit, CMOS/TTL
2	Prime Power	5VDC \pm 5%, 150 mA typical
3	TXD 1	Port 1 transmit, CMOS/TTL
4	Backup Power	+3.2VDC to +5.25VDC, 2uA typical
5	RXD 1	Port 1 receive, CMOS/TTL
6	1 PPS	Pulse-Per-Second, CMOS/TTL
7	RXD 2	Port 2 receive, CMOS/TTL
8	GND	Ground, Power and Signal

Pins 3 and 5 on J4 are also referred to as the primary serial port. Pins 1 and 7 are also referred to as the secondary serial port.

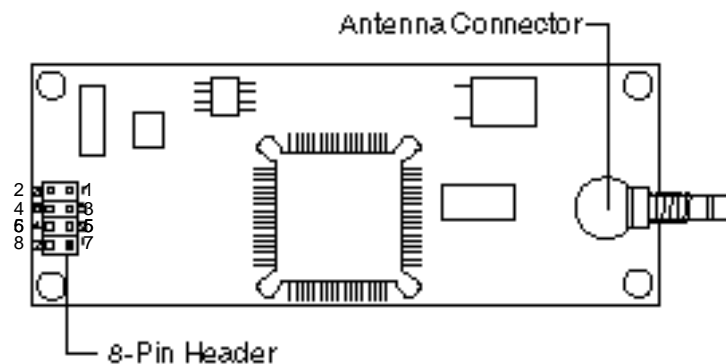


Figure 2-3. Interface Connector Pin Identification

2.3 Power Requirement

The Lassen-SK8 receiver module requires +5 volts DC \pm 5% at 150 mA, typically excluding the antenna. For power-on surge design considerations, the prime power should be able to source up to a maximum load of 200 mA. The on-board capacitance on prime power is 10 μ F. An important design consideration for power is the receiver module's internal clock frequency at 12.504 MHz \pm 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 2 of the I/O connector. Refer to Table 2-2 for the +5 VDC power specifications.

The Lassen-SK8 module 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, are stored in non-volatile EEROM 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 power-on time. A 3.6 volt lithium battery used for back-up power can last up to five years.



Note – 3.2V is the minimum allowable voltage. When the power output drops below 3.2V, the real-time clock may not operate over the specified full temperature range.

Table 2-2. Power Requirements

Signal	Voltage	Current	J4 Pin
VCC	+4.75 to +5.25	200 mA	2
Battery Backup	+3.2 to +5.25	0uA with prime power; 2uA @ 3.5V, 25°C without prime power	4
Ground	0	-	8

The Lassen-SK8 receiver module will maintain full performance specification when the prime power line is coupled with less than 100 mV of ripple noise, peak to peak from 1Hz to 1MHz.



Note – The Lassen-SK8 Starter Kit motherboard contains a 3.6V lithium battery.

2.4 Serial Interface

As an embedded design, the Lassen-SK8 receiver module provides direct CMOS compatible TTL level serial I/O. The RX and TX signals on the J4 I/O connector are driven directly by the DUART on the Lassen-SK8. Interfacing these signals directly to a DUART 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 J4 are TTL level. They are not inverted or driven to RS-232 levels.

2.5 Pulse Per Second

A ten microsecond wide, CMOS compatible TTL level pulse is available on pin 6 of the J4 I/O connector. This pulse is issued once per second with the rising edge of the pulse synchronized with UTC. The pulse will be shaped by the distributed impedance of the attached signal line and input circuit. The rising edge is typically less than 20 nSec. The falling edge should not be used.

The timing accuracy is ± 100 nanosecond (1σ) and is available only when valid position fixes are being reported. Repeatability checks of 10 sets of 100 one second samples taken over a period of 20 minutes showed an average variation of approximately 100 nanoseconds (not allowing for SA).

2.6 Mounting

The Lassen-SK8 provides four 0.125 inch mounting holes that will accept 3/16 inch round or hex standoffs with 3/8 inch height, and #4 or M3 mounting screws. Space constrained environments may require a different stand-off. Refer to the mechanical outline drawing in Appendix F for dimensions and clearances.

2.7 RF Shield

An optional RF shield is available for production versions of the standard temperature Lassen-SK8 module. The production versions of the Lassen-SK8 do not have a socketed EPROM. This RF shield protects the GPS module from interference with other electronics and also makes the module compliant with the CE emission specification. The RF shield is not compatible with the socketed board provided in the Starter Kit nor with the extended temperature board that has a TCXO oscillator.



Note – Many installations do not require the optional shield. The Lassen-SK8 is designed to be immune to most interference.

3 Software Interface

This chapter describes the Lassen-SK8 software interface, the start-up characteristics for the interface protocols, a description of the receiver operating modes, and a brief discussion of the interface protocols.

3.1 Start-up

ACE GPS 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 especially suited for embedded applications.

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. The receiver will automatically begin to search for and track GPS satellite signals at power-up.

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. Refer to Chapter 4 for additional information. The first time the receiver is powered-up, it is searching for satellites from a cold start (no almanac). While the receiver will begin to compute position solutions within the first two minutes, it actually takes the receiver about 15 minutes to download a complete almanac. This initialization process should not be interrupted. With a complete almanac and back-up power, the time to first fix can typically be shortened to less than 20 seconds. The receiver will respond to commands almost immediately after power-up.

3.2 Software Tool Kits

Trimble provides a Software Developers Tool Kit to support the TSIP and TAIP protocols. The Kit contains a user-friendly program to communicate with the receiver and includes sample C source code and reusable routines to aid in developing applications.

The following Appendices provide additional information:

- TSIP
 - Appendix A, Trimble Standard Interface Protocol
 - Appendix B, TSIP User's Guide
- TAIP
 - Appendix D, GPSSK User's Guide (TAIP)
 - Appendix E, NMEA 0183.

3.3 Communicating with the Lassen-SK8 Module

The Lassen-SK8 supports three I/O message protocols: TSIP, TAIP, and NMEA. The protocols are discussed at the end of this chapter, and are explained in detail in Appendices A through E.

Communication with the Lassen-SK8 module is through two CMOS compatible, TTL level serial ports. The port characteristics can be changed to accommodate your application requirements. Port parameters are stored in a non-volatile electrically erasable ROM (EEROM) that does not require backup power. Table 3-1 lists the default characteristics for each port.

Table 3-1. Default Serial Port Characteristics

Port	Input Protocol	Default Setup	Output Language	Default Setup
1	TAIP	Baud Rate: 4800 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control	TAIP	Baud Rate: 4800 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control
1	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
2	RTCM	Baud Rate: 4800 Data Bits: 8 Parity: None Stop Bits: 1 No Flow Control	NMEA	Baud Rate: 4800 Data Bits: 8 Parity: None Stop Bits: 1 No Flow Control

Any standard serial communications program, such as Windows Terminal or PROCOMM, can be used with the TAIP or NMEA interface protocol. TSIP is a binary protocol and outputs raw serial data onto the screen which cannot be read. Trimble encourages the use of the DOS compatible software tool kit provided for TSIP. The serial port drivers in the Trimble tool kit, TSIPCHAT, match the Lassen-SK8 serial port characteristics. The TSIPPRNT program converts binary data logged with the TSIPCHAT program into ASCII characters that may be printed and displayed.



Warning – When using the TSIP protocol to change port assignments or characteristics, confirm that your changes do not affect the ability to communicate with the receiver module.

3.4 Protocol Summary

The Lassen-SK8 receiver is shipped from the factory with the following configuration:

- TSIP
 - 9600 baud 8-odd-1 on Port 1
- NMEA out/RTCM in
 - 4800 baud 8-none-1 on Port 2

The receiver can easily be reconfigured for other combinations of language and port baud rate and parity. These settings are kept in BBRAM (Battery Backed Random Access Memory) and can be saved into non-volatile memory if desired. The commands include:

- TSIP command: 0xBC
- TAIP command: PT

Refer to Appendix A.3, Customizing Receiver Operations, for additional information on protocols.

If the receiver is not talking to application programs, the ports may be configured to an unknown setting. Use the following Toolkit program commands to return the receiver to the factory default setting:

- TSIP: SK8BREAK
- TAIP: SK8TAIP

3.4.1 TSIP Data Output

The Trimble Standard Interface Protocol (TSIP) is the native language for the Lassen-SK8. TSIP is a binary language, with a wide variety of commands and reports. TSIP reports can be output automatically, or they can be output as responses to queries. The format of the automatic reports can be easily configured. Refer to Appendix A.3, Customizing Receiver Operations and Appendix A.4, Automatic Position and Velocity Reports for further information. The receiver is shipped from the factory configured for single precision Latitude-Longitude-Altitude. Customized position and velocity formats can be created by using the information in Appendix A.3, Customizing Receiver Operations.

The TSIPCHAT program in the Lassen-SK8 Starter Kit permits using a computer keyboard to send the Request Packets to the GPS receiver. The responses to these requests are then displayed on a DOS computer screen in ASCII format. C source code routines for the TSIPCHAT program are also provided in the Starter Kit. C source can be used as a software design guide by programmers who need to communicate system integration information with the Lassen-SK8.

Configuring the ACE GPS receiver output protocol from TSIP to TAIP protocol.

TSIP command packet 0xBC can be configured in accordance with the following procedure:

1. Run TSIPCHAT -Cx (Where x = Host Computer COM Port).
2. Once TSIPCHAT is running:
 - a. Press [?]. The following will be displayed:

```
Keystroke Command List
```
3. Initiate the 0xBC Command Packet. Refer to Packet BC in the Appendix A, Trimble Standard Interface Protocol for further information.
 - a. Press [U]
 - b. Press the [SPACE{BAR] to cycle through the options. Enter the following:
 - c. Set (1)
 - d. Press [Enter]
4. Select the Port to be configured: Do the following:
 - a. Press the [SPACE{BAR] to cycle through the options
 - b. Select Port 1 (0)
 - c. Press [Enter]
5. Set the Receiver Port configuration Input Baud rate:
 - a. Press the [SPACE{BAR] to cycle through the options
 - b. Make a selection
 - c. Press [Enter]
6. Set the Receiver Port configuration Output Baud Rate:
 - a. Cycle through the options by pressing the [SPACE{BAR]
 - b. Select the Output Baud Rate
 - c. Press [Enter]
7. Set the Data Bits.
 - a. Select the appropriate Data Bits. TAIP is the default: TAIP =8.
 - b. Press [Enter]
8. Set Parity.
 - a. Select the appropriate Parity. TAIP is the default: TAIP =Odd.
 - b. Press[Enter]
9. Set Stop Bits.X
 - a. Select the appropriate Stop Bits. TAIP is the default: TAIP =8:
 - b. Press [Enter]

10. Set the Flow Control
 - a. Press the [SPACE{BAR] to cycle through the options
 - b. Select the appropriate Flow Control. TAIP is the default: TAIP =Off
 - c. Press[Enter]
11. Set Protocol In:
 - a. Press the [SPACE{BAR] to cycle through the options
 - b. Select TAIP (0)
 - c. Press [Enter]
12. Set Protocol Out:
 - a. Press the [SPACE{BAR] to cycle through the options
 - b. Select TAIP (0)
 - c. Press [Enter]
13. If satisfied with these selections:
 - a. Press [Y] — Saves the configuration
 - b. Press [N] — Aborts the configuration and displays the message: ABORTED

3.4.2 TAIP Data Output

The Trimble ASCII Interface Protocol (TAIP) is a Trimble-specified digital communication interface based on printable ASCII characters over a serial data link. TAIP interface provides the means to configure the Lassen-SK8 receiver to output various sentences in response to query or on a scheduled basis. TAIP messages may be scheduled for output at a user specified rate starting on a given epoch from top of the hour. For communication robustness, the protocol optionally supports checksums on all messages. It also provides the user with the option of tagging all messages with the unit's user specified identification number (ID). This greatly enhances the functional capability of the unit in a network environment. This protocol is described in Appendix C, Trimble ASCII Interface Protocol (TAIP).

The receiver can easily be configured to TAIP with the program SK8TAIP contained in the Toolkit. This program re-configures the Lassen-SK8 to Default TAIP settings: TAIP at 4800 8-none-1 on Port 1, RTCM in / silent out at 4800 8-none-1 on Port 2. The program stores these settings, along with all the other defaults, to non-volatile memory. The GPSSK program can now be used to control and re-configure the receiver.

Receiver configurations created in GPSSK can be stored in non-volatile memory using the RT command. As mentioned above, the receiver ports can also be set to TAIP through a TSIP port using TSIPCHAT and the TSIP command 0xBC.

Configuring the ACE GPS receiver output protocol from TAIP to TSIP protocol TAIP message PR

Configuring the receiver output from TAIP to TSIP will display binary data in now displayed on the screen.

1. Run GPSSK /x. Press [x] to select the Host Computer COM Port
2. When the GPS Main screen appears, press [ENTER]
3. Type the following message to set the receiver to TSIP.

```
>SPR;TAIP=FF;TSIP=TF;<
```

Where:

Table 3-2. TSIP Message Description

ELEMENT	DESCRIPTION
>	Beginning of command sentence
S	The Set Command
PR	The TAIP protocol message
TSIP	The desired protocol
FF	Port 1 off Port 2 off
TF	Port 1 in /out Port 2 off
I/O	Port 1 in Port 2 output
<	End of command sentence

4. Press [ENTER] to complete the change

Use TSIPCHAT to make additional changes.

3.4.3 NMEA 0183 Data Output

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. Although the Trimble Lassen-SK8 supports seven NMEA sentences that contain GPS information, the standard Lassen-SK8 only outputs the GGA and VTG data strings.



Note – Contact your Trimble sales representative if you need access to all or a subset of the other five NMEA sentences.

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-SK8, NMEA is an output only protocol. The NMEA protocol is described in detail in Appendix E, NMEA 0183.

The receiver is shipped from the factory with NMEA output on Port 2. Port 2 settings can be changed using TSIPCHAT and command 0xBC. TSIP command 0x7A changes the NMEA output sentences and output rates. The new settings are saved to BBRAM or they can be saved to non-volatile memory using TSIP command 0x8E-26.

3.5 Timing Applications

The Lassen-SK8 is an excellent source for accurate system timing. Examples of applications requiring accurate time are environmental data acquisition or synchronization of communications networks. The timing functions of the receiver are supported by the TSIP protocol. See Report Packet 41 in Appendix A for a description of the time function reports for TSIP.



Note – Note that GPS time differs from UTC (Universal Coordinated Time) by a variable integer number of seconds: $UTC = (GPS\ time) - (GPS\ UTC\ Offset)$

As of July 1997, the GPS UTC offset was 12 seconds. The offset increases by 1 second approximately every 18 months. System designers should plan to read the offset value as a part of the timing interface to obtain UTC. The GPS week number is in reference to a base week (Week #0), starting January 6, 1980.

The current GPUSC offset is contained within the almanac transmitted by the GPS system. The Lassen-SK8 must have a complete almanac before the offset data is valid.

3.5.1 Effect of GPS Week Number Roll-over (WNRO)

At 0000 hours Greenwich Mean Time (GMT) on 21/22 August 1999, the GPS Week Number will roll-over from 1023 to zero. Trimble receivers have numerous built-in protections to prevent this from being a catastrophic event. Systems may benefit however, from extra care with the first power-up after WNRO.



Note – GPS Week Numbers occupy a range from zero to 1023 such that the Week Number Roll Over (WNRO) occurs every 1024 weeks, or approximately every 19 years 8 months. August 1999 is the first roll-over for the GPS system since the beginning of GPS time on 06 January 1980.

The following two known issues for previous versions of receivers exist as a result of testing a representative sample of Trimble OEM receivers.

- An almanac recorded prior to WNRO is not correct after WNRO. This problem only exists when the receiver main power is OFF and battery back-up power is ON at the moment of WNRO. Once the receiver is cold started, a post-WNRO almanac is collected and the receivers behavior returns to normal.
- Day-month-year representations will be incorrect after WNRO when using specific TAIP and NMEA messages. Time and day information will not be effected however.

There is no impact for TSIP users on position or time information. The reported GPS week number will reset to zero however, and users that require this information may need to make a software modification to accommodate this change.

ACE GPS/Palisade Family Firmware Version 7.xx Software Modifications

The Lassen-SK8 receiver has been designed to handle WNRO and there are no problems with either dates or the first fix after WNRO through the year 2015.



Caution – Trimble OEM GPS receivers have reported the true GPS Week Number in TSIP messages 0x41 and 0x8F-20 as a number between 0 and 1023. The Lassen-SK8 however, outputs the Extended GPS Week Number as the absolute number of weeks since the beginning of GPS time or 06 January 1980. If the true GPS Week Number is desired, the system developer should ignore the extra MSBs of the Extended GPS Week Number and use only the 10 LSBs.

3.6 Differential GPS

The Lassen-SK8 module can use differential corrections to compute a Differential GPS position (DGPS). DGPS can provide position accuracy of 2 meters (1 sigma).

RTCM SC-104, the industry standard format for differential corrections, is available from most DGPS reference stations, Coast Guard beacon transmissions, and commercial DGPS subscription services. The Lassen-SK8 is fully compatible with RTCM SC-104 Version 2.1. The Lassen-SK8 is configured to accept RTCM SC-104 correction data over port 2 (J4, pin 7) at 4800 baud, 8 data bits, 1 stop bit and no parity. The DGPS operating mode is set to Automatic which means that the receiver will provide differential GPS solutions when valid correction data is available and will output standard GPS solutions when no valid correction data is available.

No setup is required to use RTCM SC-104 differential corrections, however, you may need to reconfigure the serial port characteristics (baud rate, data bits, stop bits and parity) to match the characteristics of your RTCM SC-104 data source using the TSIP packet BCh. See Appendix A for more information on this message. Table 3-1 summarizes the default characteristics for the Lassen-SK8 serial ports.

Alternatively, you may use Trimble's TSIP packets 60h and 61h to apply differential corrections through the Lassen-SK8 port 1 (J4, pin 5). These packets can be interleaved with the TSIP command stream. Packets 60h and 61h are useful in applications which require the use of a single communications channel between the Lassen-SK8 and the system. Note that using these messages requires you to reformat the RTCM SC-104 differential correction data into the 60h/61h message format. See Appendix A for more information on these messages.

4 Operation and Performance

This chapter describes the Lassen-SK8 satellite acquisition and tracking processes, performance characteristics and system architecture. This discussion assumes that you are familiar with the basic theory of the Global Positioning System. Before proceeding to the detailed discussion of the satellite acquisition and tracking process, please review the GPS satellite message description on the next page.

The Lassen-SK8 satellite acquisition and tracking algorithms can achieve a position solution without any initialization. The receiver automatically selects and tracks the best combination of satellites to compute position and velocity. As satellites move out of view, the Lassen-SK8 automatically acquires new satellites and includes them in the solution set as required.

4.1 GPS Satellite Message

Every GPS satellite transmits the Coarse/Acquisition (C/A) code and satellite data modulated onto the L1 carrier frequency (1575.42 MHz). The satellite data transmitted by each satellite includes a satellite almanac for the entire GPS system, its own satellite ephemeris and its own clock correction.

The satellite data is transmitted in 30-second frames. Each frame contains the clock correction and ephemeris for that specific satellite, and two pages of the 50-page GPS system almanac. The almanac is repeated every 12.5 minutes. The ephemeris is repeated every 30 seconds.

The system almanac contains information about each of the satellites in the constellation, ionospheric data, and special system messages. The GPS system almanac is updated weekly and is typically valid for months. The ephemeris contains detailed orbital information for a specific satellite. Ephemeris data changes hourly, but is valid for up to four hours. The GPS control segment updates the system almanac weekly and the ephemeris hourly through three ground-based control stations. During normal operation, the Lassen-SK8 module updates its ephemeris and almanac as needed.

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.

4.2 Satellite Acquisition and Time to First Fix

4.2.1 Cold-Start

The term “cold-start” describes the performance of a GPS receiver at power-on when no navigation data is available. “Cold” signifies that the receiver does not have a current almanac, satellite ephemeris, initial position, or time. The cold-start search algorithm applies to a Lassen-SK8 which has no memory of its previous session (i.e., is powered on without the memory backup circuit connected to a source of DC power). This is the “out of the box” condition of the GPS module as received from the factory.

In a cold-start condition the receiver automatically selects a set of eight satellites and dedicates an individual tracking channel to each satellite, to search the Doppler range frequency for each satellite in the set. If none of the eight selected satellites is acquired after a pre-determined period of time (time-out), the receiver will select a new search set of eight satellites and will repeat the process, until the first satellite is acquired. As satellites are acquired, the receiver automatically collects ephemeris and almanac data. The Lassen-SK8 uses the knowledge gained from acquiring a specific satellite to eliminate other satellites, those below the horizon, from the search set. This strategy speeds the acquisition of additional satellites required to achieve the first position fix.

The cold-start search sets are established to ensure that at least three satellites are acquired within the first two time-out periods. As soon as three satellites are found, the receiver will compute an initial position fix. The typical time to first fix is less than 2 minutes.

A complete system almanac is not required to achieve a first position fix. However, the availability and accuracy of the satellite ephemeris data and the availability of a GPS almanac can substantially shorten the time to first fix.



Note – When installed in the interface unit, the Lassen-SK8 receives back-up power from a lithium battery. This battery enables the Lassen-SK8 to always start from either a warm or hot start. To force a cold start, issue the 1E TSIP command ([Control] + [K]) in the TSIP chat program on the GPS toolkit diskette in the Starter Kit.

4.2.2 Warm Start

In a warm start condition, the receiver has been powered down for a period of 1-6 hours but has a current almanac and an initial position and time stored in memory.

When connected to an external backup battery and power is applied, the Lassen-SK8 retains the almanac, approximate position, and time to aid in satellite acquisition and reduce the time to first fix. When an external back-up battery is not used, the TSIP protocol allows the almanac, an initial position, and time to be uploaded to the receiver via the serial port, to initiate a warm start.

During a warm start, the Lassen-SK8 identifies the satellites which are expected to be in view, given the system almanac, the initial position and the approximate time. The receiver calculates the elevation and expected Doppler shift for each satellite in this expected set and directs the eight tracking channels in a parallel search for these satellites.

The warm start time to first fix, when the receiver has been powered down for more than 60 minutes (i.e. the ephemeris data is old) is usually less than 45 seconds.

4.2.3 Garage Search Strategy

During a warm start search, the Lassen-SK8 knows which satellites to search for, based on the system almanac, the initial position (last known position) and the current time. In some cases, the receiver may not be able to acquire the expected satellite signals (e.g. a vehicle parked in a garage or a vessel in a covered berth). Trimble's patented "garage search" strategy, also known as a split search, is designed for such situations.

If the receiver does not acquire the expected set of satellites within 5 minutes of power-on, some of the eight tracking channels will continue to search for the expected satellites (warm search) while the remaining channels are directed in a cold start search. This strategy minimizes the time to first fix in cases where the stored almanac, position and time are invalid. The stored information is flushed from memory, if the cold start search proves effective and the warm search fails.

4.2.4 Hot Start

A hot start strategy applies when the Lassen-SK8 has been powered down for less than 60 minutes, and the almanac, position, ephemeris, and time are valid. The hot start search strategy is similar to a warm start, but since the ephemeris data in memory is considered current and valid, the acquisition time is typically less than 20 seconds.

4.3 Satellite Mask Settings

Once the Lassen-SK8 has acquired and locked onto a set of satellites, which pass the mask criteria listed in this section, and has obtained a valid ephemeris for each satellite, it will output regular position, velocity and time reports according to the protocol selected.

The default satellite masks observed by the Lassen-SK8 are listed in Table 4-1. These masks serve as the screening criteria for satellites used in fix computations and ensure that position solutions meet a minimum level of accuracy. The Lassen-SK8 will only output position, course, speed and time when a satellite set can be acquired which meets all of the mask criteria. The satellite masks can be adjusted in GPS receivers accepting the TSIP protocol. (See the section titled *Key Setup Parameters*, located in Appendix A.)

Table 4-1. Default Satellite Mask Settings

Mask	Setting
Elevation	5°
SNR	2
PDOP	10
PDOP Switch	5

4.3.1 Elevation Mask

Satellites below a 5° elevation are not used in the position solution. Although low elevation satellites can contribute to a lower/better PDOP, the signals from low elevation satellites are poorer quality, since they suffer greater tropospheric and ionospheric distortion than the signals from higher elevation satellites. These signals travel further through the ionospheric and tropospheric layers.

In addition, low elevation satellites can contribute to frequent constellation switches, since the signals from these satellites are more easily obscured by buildings and terrain. Constellation switches can cause noticeable jumps in the position output. Since worldwide GPS satellite coverage is generally excellent, it is not usually necessary to use satellites below a 5° elevation to improve GPS coverage time. In some applications, like urban environments, a higher mask may be warranted to minimize the frequency of constellation switches and the impact of reflected signals.

4.3.2 SNR Mask

Although the Lassen-SK8 is capable of tracking signals with SNRs as low as 0, the default SNR mask is set to 3 to eliminate poor quality signals from the fix computation and minimize constellation switching. Low SNR values may result from:

- Low Elevation Satellites
- Partially Obscured Signals (e.g. Dense Foliage)
- Multi-Reflected Signals (Multi-Path)

The distortion of signals and the frequent constellation switches associated with low-elevation satellites were discussed above. In mobile applications, the attenuation of signals by foliage is typically a temporary condition. Since the Lassen-SK8 can maintain lock on signals with SNRs as low as 0, it offers excellent performance when traveling through heavy foliage.

Multi-reflected signals, also known as Multi-path, can degrade the position solution. Multi-path is most commonly found in urban environments with many tall buildings and a preponderance of mirrored glass, which is popular in modern architecture. Multi-reflected signals tend to be weak (low SNR value), since each reflection attenuates the signal. By setting the SNR mask to 2 or higher, the impact of multi-reflected signals is minimized.

4.3.3 PDOP Mask

Position Dilution of Precision (PDOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets which are tightly clustered or aligned in the sky will have a high PDOP and will contribute to a lower position accuracy. For most applications, a PDOP mask of 10 offers a satisfactory trade-off between accuracy and GPS coverage time. With world-wide GPS coverage now available, the PDOP mask can be lowered even further for many applications without sacrificing coverage. For differential GPS applications, PDOP related error can be the major contributor to position error. For differential GPS applications requiring the highest level of accuracy, the PDOP mask should be set to 7 or below.

4.3.4 PDOP Switch

The default positioning mode for the Lassen-SK8 is Automatic. In this mode, the receiver attempts to generate a 3-dimensional (3D) position solution, when four or more satellites meeting the mask criteria are visible. If such a satellite set cannot be found, the receiver will automatically switch to 2-dimensional (2D) mode. The PDOP switch establishes the trade-off between 3D positioning and PDOP. With the PDOP Switch set to 6, the receiver will compute a 2D position with a HDOP below 6 rather than a 3D position with a PDOP greater than 6, even when four or more satellites are visible.



Note – PDOP Switch is only used in Auto mode. If the PDOP Switch is greater than the PDOP Mask, it will stay in 3D mode.

4.4 Standard Operating Modes

The tracking mode controls the allocation of the receiver's tracking channels and the method used for computing position fixes. The output of GPS data is controlled by two operating modes:

- Fix Modes (2D, 3D, or Automatic)
- Differential GPS Mode (On, Off, or Auto)

Each of these operating modes is described below.

4.4.1 Fix Modes

The Lassen-SK8 offers three positioning modes: 2D Manual, 3D Manual, and Automatic 2D/3D. Automatic 2D/3D is the default mode for the Lassen-SK8. The positioning mode can be modified in receivers accepting TSIP commands. See Appendix A for more information on the TSIP protocol.

2D Manual

In 2D Manual mode, the Lassen-SK8 will only generate 2-dimensional (2D) position solutions (latitude and longitude only), regardless of the number of visible satellites. If the altitude is not entered, the receiver uses mean sea level as the default altitude. The greater the deviation between the actual and default altitudes, the greater the error in the 2D position. For TSIP applications, enter local altitude in MSL/HAE via TSIP packet 2AH (see Appendix A).



Note – 2D Manual mode is not recommended for differential GPS applications since any deviation in altitude will cause a significant error in the latitude and longitude. Only use the 2D Manual mode for flat land or marine applications where the elevation is known or constant. For DGPS applications, the 3D Manual mode is the recommended positioning mode for the highest level of accuracy.

3D Manual

In 3D Manual mode, the Lassen-SK8 will only generate 3-dimensional (3D) position solutions (latitude, longitude, and altitude). A 3D solution requires at least four visible satellites which pass the mask criteria. If less than four conforming satellites are visible, the Lassen-SK8 will suspend position data outputs. 3D Manual mode is recommended for differential GPS applications requiring the highest level of accuracy.

2D/3D Automatic

The default operating mode for the Lassen-SK8 is 2D/3D Automatic. In this mode, the Lassen-SK8 attempts to generate a 3-dimensional (3D) position solution, if four or more satellites meeting the mask criteria are visible. If only three satellites are visible which meet the mask criteria, the Lassen-SK8 will automatically switch to 2-dimensional (2D) mode and will use the last calculated altitude, if available, or the default altitude in the position solution. In 2D/3D Automatic mode, the PDOP switch is active.

4.5 Differential GPS Operating Modes

The default mode for the Lassen-SK8 is DGPS Automatic. The Lassen-SK8 supports three DGPS Modes: On, Off, and Automatic, and the mode may be changed by issuing the appropriate TSIP command. See Appendix A for information on TSIP commands. The three DGPS operating modes are described below.

4.5.1 DGPS On

When DGPS On is selected, the Lassen-SK8 will only provide differential GPS solutions. If the source of correction data is interrupted or becomes invalid, the Lassen-SK8 will suspend all output of position, course and speed data. When a valid source of correction data is restored, the Lassen-SK8 will resume outputting corrected data.

4.5.2 DGPS Off

When DGPS Off is selected, the Lassen-SK8 will not provide differential GPS solutions, even if a valid source of correction data is supplied. In this mode, the receiver will only supply standard GPS data.

4.5.3 DGPS Automatic

DGPS Automatic is the default operating mode for the Lassen-SK8. In this mode, the Lassen-SK8 will provide differential GPS solutions when valid correction data is available. If a set of differentially correctable satellites cannot be found which meets the satellite mask settings, the receiver will transition to output standard GPS solutions. The Lassen-SK8 automatically switches between DGPS and standard GPS based on the availability of valid correction data.

4.5.4 Differential GPS Operation

The Lassen-SK8 is capable of accepting and decoding RTCM SC-104 data. RTCM SC-104 is an industry standard protocol for differential correction data. The Lassen-SK8 is configured to accept RTCM SC-104 correction data over Port 2 (J4, pin 7). Alternatively, you can use TSIP packets 60 and 61 or the TAIP and DD messages to input differential corrections through the primary serial port (J4, pin 5).

4.6 Position Accuracy

GPS position accuracy is degraded by atmospheric distortion, satellite and receiver clock errors, and Selective Availability (SA). Effective models for atmospheric distortion of satellite signals have been developed to minimize the impact of tropospheric and ionospheric effects. The impact of satellite clock errors is minimized by incorporating the clock corrections transmitted by each satellite used in the position solution. SA is the most significant contributor to position error and cannot be effectively combated except with differential GPS.

4.6.1 Selective Availability (SA)

The U.S. Department of Defense, through a program called Selective Availability, intentionally degrades GPS accuracy for civilian users. The SA program creates position errors by modifying the apparent position of each satellite and introducing random dither into each satellite's clock.

In extreme cases all sources of error (natural, PDOP, and SA) can combine to produce large position errors. The DOD's definition of accuracy under SA is 100 meters 2 dRMS (horizontal 2 dimensional, 95% of the time). In April 1996, the U.S. government approved plans for disabling SA.

4.6.2 Differential GPS (DGPS)

Differential GPS is an effective technique for overcoming the effects of SA and other sources of position error. DGPS relies on GPS error corrections transmitted by a reference station placed at a known location. The reference station compares its GPS position solution to its precisely surveyed position and calculates the error in each satellite's range measurement. The industry standard protocol for GPS correction data is RTCM SC-104.

The GPS corrections are broadcast to mobile GPS receivers in neighboring areas. The mobile receivers incorporate the GPS corrections in their position solution to achieve excellent accuracy. For marine applications, corrections are typically modulated on marine radio beacon broadcasts. For land-based applications, the correction data can be transmitted over FM sub-carrier, cellular telephone or dedicated UHF or VHF radio links.

DGPS can reduce position error to under 5 meters, 95% of the time under steady state conditions. The DGPS accuracy is highly dependent on the quality and age of the differential corrections and the proximity of the mobile receiver to the reference site.

4.7 Coordinate Systems

Once the Lassen-SK8 achieves its first fix, it is ready to commence output of position, velocity, and time information.

This information is output over serial communication channel in either the TSIP, TAIP, or NMEA protocol, as determined by the settings of the receiver. These protocols are defined in the following Appendices:

- TSIP - Appendix A
- TAIP - Appendix C
- NMEA - Appendix E

To change from one protocol to another, please see “Configuring your Receiver” in Appendix A.

4.7.1 TSIP Coordinate Systems

TSIP has the widest choice of coordinate systems. The output format is chosen by TSIP command 0x35. The output formats include the following:

- LLA position — Latitude, longitude, altitude (LLA) according to the WGS ellipsoid or one of over a hundred other datums. See Appendix A, Table A-86 for a list of available datums. Altitude can be chosen to be height above ellipsoid (HAE) or height above mean sea level (MSL).
- ENU velocity — ENU velocity is the velocity in East, North, and Up coordinates. These coordinates are easily converted to speed and heading.
- ECEF position and velocity — ECEF position and velocity is Earth-Centered, Earth-Fixed frame is a Cartesian coordinate frame with its center at the earth's center, the z-axis through the North Pole, and the x-axis through longitude 0 degrees, latitude 0 degrees. Velocity is reported relative to the same axes.
- UTM — Universal Transverse Mercator (UTM) is a mapping coordinate system used by many government agencies.

There are also two time coordinate systems:

- GPS time — GPS time is determined by an ensemble of atomic clocks operated by the Department of Defense (DOD).
- UTC time — UTC time is the world standard maintained by an ensemble of atomic clocks operated by government organizations around the world.

GPS time is steered relative to Universal Coordinated Time (UTC). GPS does not recognize leap seconds resulting in a situation where GPS time is currently 12 seconds ahead of UTC time. Time tags for most output messages can be in either UTC time or GPS time, as chosen by TSIP command 0x35.

4.7.2 NMEA 0183

The NMEA 0183 protocol only supports LLA format and UTC time. Velocity is always described as horizontal speed and heading; vertical speed is not output.

4.7.3 TAIP

The TAIP protocol only supports LLA position output. Timetags are GPS, except for the TM time mark message.

4.8 Performance Characteristics

4.8.1 Update Rate

The Lassen-SK8 computes and outputs position solutions once per second, on the second. NMEA outputs can be scheduled at a slower rate using TSIP command 7Ah. Refer to Appendix A.

4.8.2 Dynamic Limits

The dynamic operating limits for the Lassen-SK8 are listed below. These operating limits assume that the GPS module is correctly embedded and that the overall system is designed to operate under the same dynamic conditions.

Table 4-2. Lassen-SK8 Operating Limits

Operation	Limit
Acceleration	4 g (39.2 m/s ²)
Jerk	20 m/s ³
Speed	500 m/s
Altitude	18,000 m

4.8.3 Re-Acquisition

Re-acquisition time for a momentary signal blockages is typically under 2 seconds.

When a satellite signal is momentarily interrupted during normal operation, the receiver continues to search for the lost signal at the satellite's last known Doppler frequency. If the signal is available again within 15 seconds, the receiver will normally re-establish track within two seconds. If the lost signal is not re-acquired within 15 seconds, the receiver initiates a broader frequency search. The receiver will continue to search for the satellite until it falls below the elevation mask.

4.9 GPS Timing

In many timing applications, such as time/frequency standards, site synchronization systems and event measurement systems, GPS receivers are used to discipline local oscillators.

The GPS constellation consists of 24 orbiting satellites. Each GPS satellite contains a highly-stable atomic (Cesium) clock, which is 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.

GPS receivers use the signals from these GPS “clocks” to correct its internal clock, which is not as stable or accurate as the GPS atomic clocks. GPS receivers like the Lassen-SK8 output a highly accurate timing pulse (PPS) generated by its internal clock, which is constantly corrected using the GPS clocks. This timing pulse is synchronized to UTC within ± 500 ns.

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

GPS time accuracy is bounded by the same major source of error affecting position accuracy, Selective Availability. The position and time errors are related by the speed of light. Therefore, a position error of 100 meters corresponds to a time error of approximately 333 ns. The hardware and software implementation affects the GPS receiver's PPS accuracy level. The receiver's clocking rate determines the PPS steering resolution.

The Lassen-SK8 clocking rate is 3.126 MHz. This rate corresponds to a steering resolution of ± 160 ns. Software techniques such as over-determined clock algorithm can achieve PPS accuracy greater than Selective Availability because more satellites are used to give a higher timing accuracy.

4.9.1 Serial Time Output

Both the TSIP, TAIP, and NMEA protocols include time messages. Refer to Report Packet 41 in Appendix A or the ZDA descriptions in Appendix D for a description of the time reports for each protocol and the TAIP TM message.



Note – GPS time differs from UTC (Universal Coordinated Time) by a variable, integer number of seconds $UTC = (GPS \text{ time}) - (GPS / UTC \text{ offset})$.

As of June 1997, the GPS / UTC offset was 11 seconds. The offset has historically increased by 1 second about every 18 months. System designers should plan to read the offset value as a part of the timing interface to obtain UTC. The GPS week number is in reference to a base week (Week #0), starting January 6, 1980.

4.9.2 Timing Pulse Output (PPS)

A pulse-per-second (PPS), ten microsecond wide pulse is available on the Lassen-SK8 8-pin interface connector. The pulse is sent once per second and the rising edge of the pulse is synchronized with UTC. The pulse shape is affected by the distributed capacitance of the attached cabling and input circuit. The rising edge is typically less than 20 ns wide. The falling edge should never be used for timing applications.



Note – The PPS signal output by the Lassen-SK8 is a CMOS/TTL level signal. If this signal must be furnished to a remote location, the system designer should provide an RS-422 driver for the timing pulse.

When the Lassen-SK8 is installed on the interface motherboard (supplied in the Starter Kit), the PPS signal is connected to an open collector circuit and the polarity of the signal is inverted.

4.10 System Architecture

The Lassen-SK8 module (see Figure 4-1) 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 module receives the GPS satellite signals through the antenna feed line connector, amplifies the signals, and then 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.

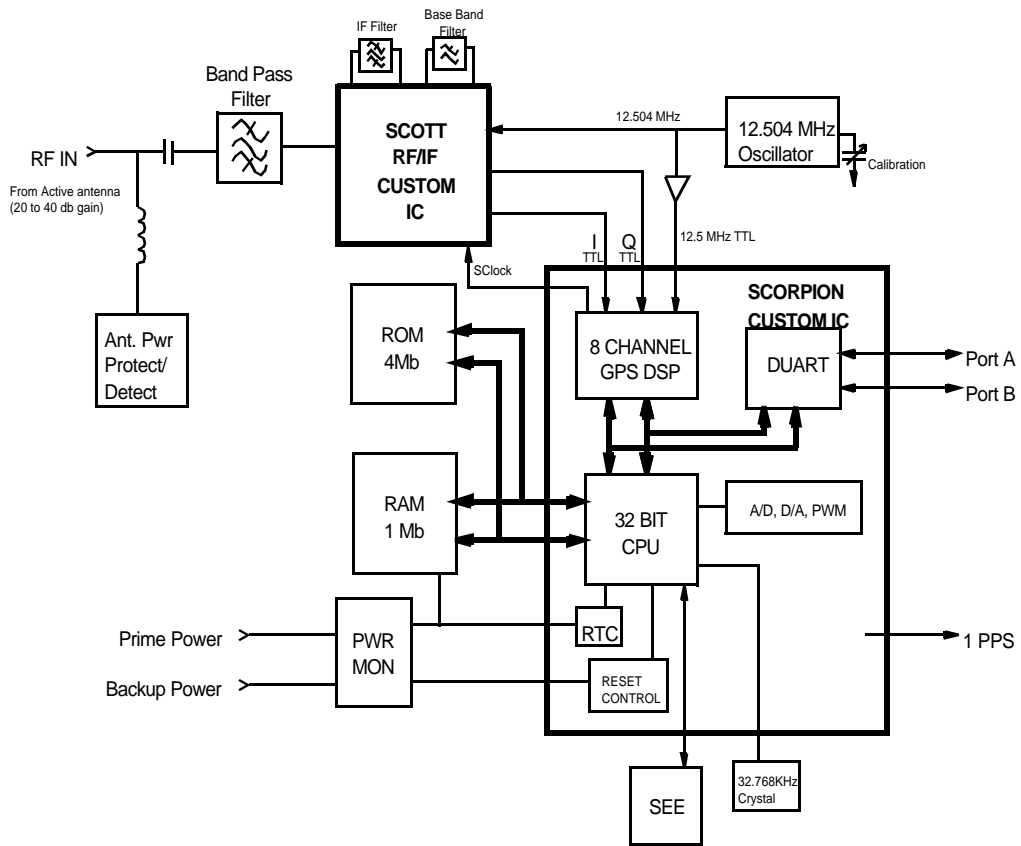


Figure 4-1. Lassen-SK8 Block Diagram

A Trimble Standard Interface Protocol

The Trimble Standard Interface Protocol (TSIP) provides the system designer with over 75 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 2 will help you determine which packets apply to your application. For those applications requiring customizing, see Page 3 for a detailed description of the key setup parameters. Application guidelines are provided for each TSIP Command Packet, beginning on Page 20.

A.1 Interface Scope

The Trimble Standard Interface Protocol is used in Trimble 6-channel and 8-channel 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-SK8 has two independently configurable serial I/O communication ports. Port1 is a bi-directional control and data port utilizing a Trimble Standard Interface Protocol (TSIP) or Trimble ASCII Interface Protocol (TAIP). Port 2 is a bi-directional port used to receive differential GPS (DGPS) corrections in the industry standard RTCM-104 format and for output of industry standard ASCII NMEA sentences. Port 1 can also be configured to TAIP I/O using the TSIP command. The dual data I/O port characteristics and other options are user programmable and stored in non-volatile 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. The GPSSK Utility, part of the GPS Tool Kit, is designed to exercise many of the TSIP messages.

A.2 Automatic Output Packets

The Lassen-SK8 receiver module is configured to automatically output the following packets. For minimal system implementations, these output packets provide all of the information required for operation including time, position, velocity, and receiver and satellite status and health. Position and velocity are reported using one or more of the packets listed below, depending on the selected I/O options. While there are other packets automatically output, the following packets provide the information most commonly used. No input packets are required.

Table A-1. Automatic Output Packets

Output Packet ID	Description	Reporting Interval
0x41	GPS time	5 seconds
0x42, 0x83, 0x4A, 0x84, 0x43, 0x56, 0x8F-17, 0x8F-18, 0x8F-20	position (choose packet with I/O options)	1 second
0x43, 0x56, 0x8F-20	velocity (choose packet with I/O options)	1 second
0x46	health of receiver	5 seconds
0x4B	machinecode/status (includes antenna fault detect)	5 seconds
0x6D	all-in-view satellite selection	1 second
0x82	DGPS position fix mode (only in DGPS mode)	1 second

Note – See page A-16 for a detailed description of the key receiver setup parameters.

A.3 Customizing Receiver Operations

To customize the Lassen-SK8 receiver output for your application:

1. Set up the receiver using TSIP commands until the receiver operation is as desired
2. Use command 0x8E-26 to store the settings in non-volatile memory

These settings will control receiver operation whenever the receiver is cold-started, or when battery back-up is lost. Table A-2 shows all of the commands that can be stored in SEEPROM.

A.3.1 TAIP Customizing

To customize the receiver for TAIP on either Port 1 or Port 2, use command 0x8E-40 which sets the TAIP default settings. Then use command 0xBC to change port baud settings and set the language to TAIP.

.If Port 1 is used, TSIP communication will stop so, use TAIP command RT, specifically:

```
>SRTSAVE_CONFIG<
```

to store to non-volatile memory instead of 0x8E-26 settings.

A.3.2 NMEA Customizing

To customize the NMEA output on Port 2, use the command 0x7A

A.3.3 Reconfiguring to Factory Default Settings

To reset the receiver configuration to factory default settings, use TSIP command 0x1E with data byte-F. This will negate all previous 0x8E-26 settings.



Caution – Whenever using command 0x8E-26 or 0x1E, wait two seconds before removing power. This allows the process of writing to non-volatile memory to be completed.



Warning – When changing port settings, record the new settings for future reference. These settings must be used whenever the receiver is powered up. If the port settings are lost, use theTPRESET program in the Toolkit disk to return the board to the factory default settings.

Table A-2. Customizing Receiver Operation I/Os

Input ID	Description	Output ID
0xBB	set/request query receiver configuration	BB
0xBC	set/request query port configuration	BC
0x35	set input/output options	55
0x70	enable/disable PV/altitude filters	70
0x7A	set NMEA schedule	7B
0x8E-15	set datums	8F-15
0x8E-19	enable UTM	8F-19
0x8E-20	enable superpacket	
0x8E-26	save settings	



Note – After setting wait 2 seconds.

A.4 Automatic Position and Velocity Reports

The receiver automatically outputs position and velocity reports at set intervals. Automatic report packets are controlled by Packet 35. Setting the control bits as indicated in the table below allows you to control which position and velocity packets are output.

Table A-3. Automatic Position and Velocity Reports Control Setting Bits

Packet ID	Description	Byte 0 Bit 0	Byte 0 Bit 1	Byte 0 Bit 4	Byte 0 Bit 5	Byte 1 Bit 0	Byte 1 Bit 1
0x42	single precision XYZ position	1		0			
0x83	double-precision XYZ position	1		1			
0x4A	single-precision LLA position		1	0			
0x84	double-precision LLA position		1	1			
0x43	velocity fix (XYZ, ECEF)					1	
0x56	velocity fix (ENU)						1
0x8F-17	Single Precision			0	1		
0x8F-18	Single Precision ELEF			0	1		
0x8F-20	LLA & ENU				1		

A.5 Warm Start Packets

If the receiver is connected to a back-up power source such as a lithium battery, the data required to cause a warm start is retained even when main power is turned off. Before power off, check the following automatic outputs to ensure a warm start will occur on the next power on cycle:

- The value of Packet 0x4B (byte 1, bit 3) is 0 which indicates that the almanac is complete and current.
- The position input (0x42,4A, 0x83, 0x84, 0x8F-17, 0x8F-18, 0x8F-20) are correct. See Table A-4.
- The time in Packet 41 is correct.
- Turning on main power will cause a warm start.

If however 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 (see Table A-5).

Table A-4. Warm Start Packet Commands

INPUT	Description
0x2B	initial position
0x2E	initial time
0x38-02	almanac (for each SV)
0x38-03	almanac health
0x38-04	ionosphere page
0x38-05	UTC correction

A.6 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 in the following order. After Packet 82 is output, the sequence is complete and the receiver is ready to accept commands.

Table A-5. Packet Power-up Output Messages

Output ID	Description	Notes
0x41	GPS time	This Packet is only output if GPS time is available.
0x45	software version	--
0x46	receiver health	--
0x4B	machine code/status	--
As chosen, see Table A-4	position/Velocity output	As chosen, see Table A-4.
82	DGPS position fix mode	--

A.7 Differential GPS Packets

For differential GPS applications you may need to implement the following TSIP control commands.

Table A-6. Differential GPS Packet TSIP Control Commands

Input ID	Description	Output ID
0xBC	Port configuration	0xBC
0x60	Differential GPS corrections (types 1 and 9)	--
0x61	Differential GPS corrections (type 2)	--
0xBB	Differential Auto or Manual operating mode. Maximum age that differential corrections will be used	0xBB
0x65	Differential correction data request	0x85

A.8 Timing Packets

If you are using the Lassen-SK8 as a timing system, you may need to implement the following TSIP control commands.

Table A-7. Timing Packet TSIP Control Commands

Input ID	Description	Output ID
0x21	get the current GPS time.	0x41
0xBB	setup static mode if desired.	0xBB
0x38-05	request UTC parameters.	0x58-05

A.9 Satellite Data Packets

The following packets contain a variety of GPS satellite data.

Table A-8. Satellite Date Packet Data I/O Descriptions

Input ID	Description	Output ID
0x27	request signal levels	0x47
0x28	request GPS system message	0x48
0x38	request/load satellite system data	0x58
0x39	set/request satellite disable or ignore health	0x59
0x3A/auto	request last raw measurement	0x5A
0x3C	request tracking status	0x5C
auto	Synchronized Measurement measurement packet	0x6F

A.10 Background Packets

The receiver automatically outputs a set of packets that the user may want to monitor for changes in receiver operations. These messages are output at the rates indicated in the table below.

Table A-9. Background Packet Output Messages

Output ID	Description	Notes
0x41	GPS time	If the receiver's GPS clock is set and the receiver is not outputting positions, time is output approximately every 5 seconds.
0x46, 0x4B	receiver health messages	Receiver health messages are output every 5 seconds.
0x6D	mode packets	Mode packets are output every second.

A.11 Backwards Incompatibility of Lassen-SK8 Packets with Previous TSIP Versions

Several new TSIP command packets have been made available with the release of the Lassen-SK8 receiver module, and some existing packets have been modified or are no longer supported. Table A-10 identifies the backwards compatibility of auto-output packets. Table A-11 identifies the backwards compatibility of the TSIP command packets. Unless otherwise noted, the commands and their corresponding output packets are still supported in the firmware.

Table A-10. Supported Auto-Output Packet Command Backward Compatibility

Old Packet	Control	New Packet	Control	Notes
0x40	auto	0x58-02	0x38-02	no longer auto
0x44	auto	0x6D	0x38-06	0x44 not supported
0x5A	auto	0x6F	auto	
0x5B	auto	0x58-06		no longer auto
0x5E	auto			0x5E not supported
0x8F-01, 0x8F-02	auto	0x8F-20	auto	0x01, 0x02 not supported

A.12 Recommended TSIP Packets

Table A-11. 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
	Packet output control	0x6E-01	0x6E-01
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
	Synchronized Measurement packet		0x6F
Receiver settings	query software version	0x1F	0x45
	set/query datum values	0x8E-15	0x8F-15
	query receiver ID & error status	0x26	0x4B, 0x46
	set/query satellite flags	0x39	0x59
	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
DGPS	query DGPS corrections	0x65	0x85
	query DGPS operating mode & status	0x62	0x82
	load DGPS Type 1 correction	0x60	
	load DGPS Type 2 correction	0x61	

Table A-11. Recommended TSIP Packet Data (Continued)

Function	Description	Input	Output
GPS system	query/load GPS system data	0x38	0x58
	GPS system message	0x28	0x48
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	

A.13 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 A-13.

Table A-12. 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
0x28	GPS system message	0x48
0x2A	altitude for 2-D mode	0x4A
0x2B	initial position (Lat, Lon, Alt)	--
0x2D	oscillator offset	0x4D
0x2E	set GPS time	0x4E
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
0x39	satellite disable	0x59
0x3A	last raw measurement	0x5A, see Note 2
0x3C	tracking status	0x5C, see Note 2
0x60	type 1 differential correction	--
0x61	set differential correction	--
0x62	request differential GPS position fix mode	0x82
0x65	differential correction status	0x85, see Note 2
0x6E	Synchronized Measurement output control	0x6E
0x70	filter configuration	0x70
0x7A	set/request NMEA output configuration	0x7B
0xBB	set receiver configuration	0xBB
0xBC	set port configuration	0xBB

Table A-12. User-Selected Command Packet Options (Continued)

Input ID	Packet Description	Output ID
0x8E-15	set/request current datum values	0x8F-15
0x8E-20	last fix with extra information (fixed point)	0x8F-20



Note 1. – Output is determined by Packet 0x35 settings. See Table A-5 to determine which messages are output at power-up.



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



Note 3. – Not all Packet 0x39 operations have a response. See Packet 0x39 description.

A.14 Report Packets Sent by the GPS Receiver to the User

The table below summarizes the packets output by the receiver. The table includes the output Packet ID, a short description of each packet, and the associated input packet. In some cases, the response packets depend on user-selected options. These selections are covered in the packet descriptions beginning on page A-23.

Table A-13. User-Selected Report Packet Options

Output ID	Packet Description	Input ID
0x41	GPS time	0x21, auto
0x42	single-precision XYZ position	0x25, 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
0x48	GPS system message	0x28
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
0x6E	Synchronized Measurement packet output control	
0x6F	Synchronized Measurement packet	Auto
0x56	velocity fix (ENU)	0x37, auto
0x57	information about last computed fix	0x37
0x58	GPS system data/acknowledge	0x38
0x59	sat enable/disable & health heed	0x39
0x5A	raw measurement data	0x3A
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
0x85	differential correction status	0x65
0x8F-20	last fix with extra information (fixed point)	auto, 0x37, 0x8E-20
0x8F-17	UTM	auto, 0x37

A.15 Key Setup Parameters or Packet BB

Selecting the correct operating parameters has significant impact on receiver performance. Packet 0xBB (set receiver configuration) controls the key setup parameters.

The default operating parameters allow the receiver to perform well in almost any environment. The user can optimize the receiver to a particular application if the vehicle dynamics and expected level of obscuration are understood. If the receiver is then taken out of this environment, the specifically tuned receiver may not operate as well as a receiver with the default options.

The table below lists suggested parameter selections as a function of obscuration and whether accuracy or fix density is important. In this table, NA indicates that the operating parameter is not applicable, DC (don't care) indicates that the user may choose the operating parameter.

Table A-14. Setup Parameters

Packet	Parameter	Accuracy	Fixes	Factory Default
0xBB	Fix mode	Man 3D	AUTO	AUTO
0xBB	Dynamics code	Land	Land	Land
0xBB	Elevation mask	10°	5°	5°
0xBB	Signal mask	6.0	4.0	2.0
0xBB	DOP mask	6.0	12.0	12.0
0xBB	DOP switch	NA	8.0	5.0
0xBB	DGPS correction age	10 Seconds	N/A	30 Seconds

The default values in Table A-15 allow the receiver to operate well under the most varied and demanding conditions. A user may choose to change the default parameters if the receiver is only required to perform in a specific or limited environment. The user should be warned that when the receiver is exposed to operating conditions which are different from the conditions described by the user setup, then the performance may be degraded.

Initially, the user must consider the environment in which the receiver is expected to operate. There is a trade-off between how frequently a position fix is output versus the absolute accuracy of the fix. The user must decide which takes priority and then make the appropriate selections. This becomes increasingly important when frequent satellite blockages are expected, as in downtown “urban canyon” environments and heavily foliated areas.

Following is a description of the key fields in Packet 0xBB.

A.15.1 Packet 0xBB - Set Fix Mode

Packet 0xBB is used to choose the appropriate position fix mode for your application: 2-D, 3-D or AUTO. The default mode is AUTO 2-D/3-D, where the receiver first attempts to obtain a 3-D solution with a PDOP below both the DOP mask and DOP switch. If this is not possible, then the receiver attempts to obtain a 2-D solution with a DOP less than the DOP mask. This mode supplies fairly continuous position fixes even when there is frequent obscuration. This mode is preferable for most land or air applications, where altitude changes are occurring and there is occasional obscuration.

The highest accuracy fix mode is 3-D manual, where altitude is always calculated along with the latitude, longitude, and time. However, this requires four satellites with a PDOP below the DOP mask set in Packet BB in order to obtain a position. Normally, this will provide the most accurate solution. Thus, if only 3-D solutions are desired, then the user should request 3-D manual mode. Depending on how the PDOP mask is set, this may be restrictive when the receiver is subjected to frequent obscuration, or when the geometry is poor due to an incomplete constellation.

Alternatively, if the user only wants a 2-D solution, then 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. However, any error in the assumed altitude will affect the accuracy of the latitude and longitude solution.

High accuracy users should avoid the 2-D mode and should expect fixes with accuracies which are at best as accurate as the supplied altitude. If a marine user enters sea-level as the altitude, then small errors in the horizontal solution will occur when the sea state is rough or there are high tidal variations. However, these errors may be smaller than the altitude errors induced by SA, so 2-D may be preferable for a marine user who does not want to observe "unusual" altitudes.

A.15.2 Dynamics Code

The feature 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 reverts to user entered altitude in 2-D auto. In AIR mode, the search and re-acquisition routines are optimized for high acceleration conditions.

A.15.3 Elevation Mask

This is the minimum elevation angle for satellites to be used in a solution output by the receiver. Satellites which are 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 SA 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 mask is set to five degrees and provides a reasonable trade-off of the benefits and drawbacks. High accuracy users may prefer a mask angle around ten degrees, where the ionosphere and troposphere begin to be more predictable

A.15.4 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. The factory default mask has been set to zero. High accuracy users may use a slightly higher mask of 6.0-8.0, since weaker measurements may be slightly noisier and are often caused by reflected signals which provide erroneous ranges.

One should also resist the temptation to set the elevation and SNR masks too low. The satellite geometry is sometimes improved considerably by selecting low elevation satellites. They 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 therefore 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.

A.15.5 DOP Mask and Switch

The DOP mask is the maximum DOP limit for any 2-D or 3-D position solution will be made. The DOP switch is the level at which the receiver stops attempting a 3-D solution, and tries for a 2-D solution when in automatic 2-D, 3-D mode. The switch level has no effect in either manual mode. Raising the DOP mask will generally increase the fix density during obscuration, but the fixes with the higher DOP will be less accurate (especially with SA present). Lowering the mask will improve the average accuracy at the risk of lowering the fix density.

A.15.6 Packet 0xBB - Set DGPS Mode

Packet 0xBB is used to set the differential GPS operating mode. The factory default mode is OFF. If differential corrections are available, the recommended mode is DGPS Auto. In this mode, the receiver computes differentially corrected positions whenever valid corrections are available. Otherwise, the receiver computes non-differentially corrected positions.

In manual DGPS mode, the receiver only computes solutions if corrections are available for the selected satellites. This is the most accurate mode but it is also the most selective, since the fix density is dependent on the availability of corrections. The applicability of corrections is determined by the maximum age which can be set using Packet 0xBB.

The AUTO mode avoids the fix density problem but opens the possibility of going in and out of DGPS mode, potentially resulting in position and velocity jumps. In differential OFF mode, the receiver will not use corrections even if they are valid. If accuracy is critical, use MANUAL DGPS mode. If fix density is critical, AUTO DGPS is the recommended mode.

A.16 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:

- INTEGER — A 16 bit unsigned number sent in two's complement format.
- 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.

A.17 Packet Descriptions

A.17.1 Command Packet 0x1D

This packet commands the GPS receiver to set or clear the oscillator offset in battery-backed memory. This is normally used for servicing the unit.

To clear the oscillator offset, one data byte is sent: the ASCII letter 'C' = 0x43.

To set the oscillator offset, four data bytes are sent: the oscillator offset in Hertz as a Single real value.

A.17.2 Command Packet 0x1E

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.



Caution – All almanac, ephemeris, current position, mode, and communication port setup information is lost by the execution of this command. In normal use this packet should not be sent. 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.

Table A-15. Command Packet 0x1E Format

Byte	Item	Type	Value	Meaning
0	Reset Mode	BYTE	0x46 ASCII “F”	Erase BBRAM, reset nonvolatile memory to factory default, and restart
			0x4B	Erase BBRAM and Reset

A.17.3 Command Packet 0x1F

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.

A.17.4 Command Packet 0x21

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

A.17.5 Command Packet 0x23

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 a 1,000 miles after 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.

To initialize with latitude-longitude-altitude, use Command Packet 0x2B.

Table A-16 Command Packet 0x23 Data Format

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

A.17.6 Command Packet 0x24

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

A.17.7 Command Packet 0x25

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-5). 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.

A.17.8 Command Packet 0x26

This packet requests health and status information from the GPS receiver. This packet contains no data. The GPS receiver returns packet 0x 46 and 0x4B.

A.17.9 Command Packet 0x27

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

A.17.10 Command Packet 0x28

This packet requests the most recent GPS system ASCII message sent with the navigation data by each satellite. This packet contains no data. The GPS receiver returns Packet 0x48.

A.17.11 Command Packet 0x2A



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

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. 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 bytes, this packet requests the current values of these altitude parameters. In this case, the GPS receiver returns Packet 4A.

Table A-17. Packet 0x2A Set Altitude Only Description

Byte	Item	Type	Meaning
0-3	Altitude	SINGLE	Reference altitude for 2-D



Note – Sets the Altitude Flag.

Table A-18. Reset Altitude Flag Description

Byte	Item	Type	Value	Meaning
0	Altitude Flag	BYTE	0 x 00	Clear Altitude flag

A.17.12 Command Packet 0x2B

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 1,000 miles after 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. To initialize with ELEF position, use Command Packet 0x23. The data format is shown in Table A-19:

Table A-19. Command Packet 0x23 Data Format

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

A.17.13 Command Packet 0x2D

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.

A.17.14 Command Packet 0x2E

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 A.17.22, Report Packet 41 for information on the Extended GPS week number.

Table A-20. Command Packet 0x2E Data Formats

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

A.17.15 Command Packet 0x31

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 and in time transfer (one-satellite mode) applications. 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.

A.17.16 Command Packet 0x32

This packet is identical in content to Packet 0x2B. This packet provides the GPS receiver with an approximate 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 and in time transfer (one-satellite mode) applications. 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.

A.17.17 Command Packet 0x35

This packet requests the current I/O option states and optionally allows the I/O option states to be set as desired.

To request the option states without changing them, the user sends the packet with no data bytes included. To change any option states, the user includes 4 data bytes with the values. The I/O options, their default states, and the byte values for all possible states are shown below. These option states are held in battery-backed memory and can be set into non-volatile RAM (EEPROM) with the 0x8E-26 command. The GPS receiver returns Packet 0x55. See A.3 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-21. Command Packets 0x35 and 0x55 Data Descriptions

Byte	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
0	position	0 (LSB)	1	XYZ ECEF Output 0: off 1: on	0x42 or 0x83
		1	0	LLA Output 0: off 1: on	0x4A or 0x84
		2	0	LLA ALT Output 0: HAE (datum) 1: MSL geoid	0x4A or 0x84 0x8F-17 0x8F-18
		3	0	ALT input 0: HAE (datum) 1: MSL geoid	0x2A
		4	0	Precision-of-position output 0: Send single-precision packet 1: Send double- precision packet	0x42/4A/8F- 17 0x83/84/8F- 18
0	position	5	0	0: output no Super Packets 1: output all enabled Super Packets	0x8F-17, 0x8F-18 0x8F-20
		6-7	0	not used	
1	velocity	0	1	XYZ ECEF Output 0: off 1: on	0x43
		1	0	ENU Output 0: off 1: on	0x56
		2-7	0	not used	

Table A-21. Command Packets 0x35 and 0x55 Data Descriptions (Continued)

Byte	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
2	timing	0	0	time type 0: GPS time 1: UTC	0x42, 0x43, 0x4A, 0x83, 0x84, 0x56, 0x8F-17, 0x8F-18
		1	0	reserved	
		2	0	reserved	
		3	0	reserved	
		4	0	reserved	
		5-7	0	not used	
3	Auxiliary PR meas.	0	0: off		0x5A
		1	0: raw	0: raw Pr's in 5A 1: filtered PR's in 5A	0x5A
		2	reserved		
		3	0: off 1: on	output dBHz instead of AMU	0x5A, 0x5C, 0x47, 0x6F
		4-7	reserved		



Note – Automatic output of 5 A messages is supported in the Lassen-SK8 for backwards compatibility with older TSIP applications.



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

A.17.18 Command Packet 0x37

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 the position/velocity auto packets specified in the 0x35 message as well as message 0x57.

A.17.19 Command Packet 0x38

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 0 x 5B.

Table A-22. Command Packet 0x38 Data Formats

Byte	Item	Type	Value	Meaning
0	Operation	Byte	1 2	Request data from SVeeSix; Load data into SVeeSix
1	Type of data	Byte	1 2 3 4 5 6	not used Almanac Health page, T_oa, WN_oa Ionosphere UTC Ephemeris; request only
2	Sat PRN#	Byte	0 1 - 32	data that is not satellite - ID specific satellite PRN number
3	length (n)	Byte		number of bytes of data to be loaded
4 to n+3	data		n Bytes	



Caution – Proper structure of satellite data is critical to SVeeSix 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 reload.



Note – Ephemeris can not be loaded into the receiver in Version 7.52.

A.17.20 Command Packet 0x39

Normally the GPS receiver selects only healthy satellites (based on transmitted values in the ephemeris and almanac) which satisfy all mask values, for use in the position solution. This packet allows you to override the internal logic and force the receiver to either unconditionally disable a particular satellite or to ignore a bad health flag. The GPS receiver returns Packet 0x59 for operation modes 3 and 6 only.

It should be noted that when viewing the satellite disables list, the satellites are not numbered but are in numerical order. The disabled satellites are signified by a “1” and enabled satellites are signified by a “0”.

Table A-23. Command Packet 0x39 Data Formats

Byte	Item	Type	Value	Meaning
0	Operation	Byte	1	Enable for selection (default)
			2	Disable for selection
			3	Request enable - or - disable status of all 32 satellites
			4	Heed health on satellite (default)
			5	Ignore health on satellite
			6	Request heed - or - ignore health on all 32 satellites
1	Satellite #	Byte	0	all 32 satellites
			1 - 32	any one satellite PRN number

This information is not held in battery-backed memory. At power-on and after a reset the default values are set for all satellites.



Caution – Ignoring satellite health flags can cause the GPS receiver software to lock up. An unhealthy satellite may contain defective data. Use extreme caution when ignoring satellite health flags.

A.17.21 Command Packet 0x3C

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

Table A-24. Command Packet 0x3C Data Format

Byte	Item	Type	Value	Meaning
0	Satellite #	Byte	0	All satellites in the current tracking set
			1 - 32	Desired satellite

A.17.22 Report Packet 0x41

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 update cycle. Update cycles occur approximately every 5 seconds. The data format is shown below.

Table A-25. Report Packet 0x41 Data Formats

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



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



Caution – GPS week numbers run from 0 to 1023 and then cycles back to week #0. Week # 0 began January 6, 1980. There will be another week #0 beginning August 22, 1999. The extended GPS week number however, does not cycle back to 0. For example, August 22, 1999 starts week number 1024.

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-26. 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	+	not 0x01
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.

A.17.23 Report Packet 0x42

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 output” 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-27. 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.

A.17.24 Report Packet 0x43

This packet provides current GPS velocity fix in XYZ ECEF coordinates. If the I/O “velocity” option is set to “XYZ ECEF”, then the GPS receiver sends this packet each time a fix is computed. The data format is shown below.

Table A-28. Report Packet 0x43 Data Formats

Byte	Item	Type	Value
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.

A.17.25 Report Packet 0x45

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-29. Report Packet 0x45 Data Formats

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

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

A.17.26 Report Packet 0x46

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, during an update cycle. Packet 0x4B is always sent with this packet.

Table A-30. Report Packet 0x46 Data Formats

Byte	Item	Type	Value	Meaning
0	Status Code	BYTE	0 h	Doing position fixes
			01 h	Don't have GPS time yet
			02 h	need initialization
			03 h	PDOP is too high
			08 h	No usable satellites
			09 h	Only 1 usable satellite
			0A h	Only 2 usable satellites
			0B h	Only 3 usable satellites
			0C h	The chosen satellite is unusable
			1	Status codes

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

Table A-31. Report Packet 0x46 Bit Positions and Descriptions

Status Code Bit Position	Meaning if bit value = 1
0 (LSB)	No battery back-up at start-up (note 1)
1	not used
2	not used
3	not used
4	Antenna feed line fault (open or short)
5	not used
6	not used
7 (MSB)	not used



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

A.17.27 Report Packet 0x47

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-32. Report Packet 0x47 Data Formats

Byte	Item	Type
0	Count	BYTE
1	Satellite number 1	BYTE
2- 5	Signal level 1	SINGLE
6	Satellite number 2	BYTE
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. The signal level provided in this packet is a linear measure of the signal strength after correlation or de-spreading. Units, either AMU or dBHz, are controlled by Packet 0x35.

A.17.28 Report Packet 0x48

This packet provides the most recent 22-byte ASCII message broadcast in the GPS satellite navigation message. The receiver sends this packet in response to Packet 0x28.

The message effectively is a bulletin board from the Air Force to GPS users. The format is free-form ASCII and is often enabled or encrypted. The message may be blank.

A.17.29 Report Packet 0x4A

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, then the receiver sends this packet each time a fix is computed.

A.17.30 Main 0x4A Report Packet Type

The data format is shown below:

Table A-33. 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 UTZ)

The LLA conversion is done according to the datum selected using Packet 0x8E-15. The default 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



Caution – 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.

A.17.31 Second 0x4A Packet Type

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 for the position.

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-34. Reference Altitude

Byte	Item	Type	Units
0-3	Reference Altitude	SINGLE	Meters
4-7	Reserved	SINGLE	
8	Altitude flag	BYTE	

A.17.32 Report Packet 0x4B

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-35. Report Packet 0x4B Data Formats

Byte	Item	Type/Value	Status/Meaning
0	Machine ID	BYTE	6-channel receiver
1	Status 1	BYTE	see Table A-36
2	Status 2	BYTE	Bit 0 = Super packets supported

The status codes are encoded into individual bits within the bytes. The bit positions and their meanings are shown in Table A-36.

Table A-36. Report Packet 0x4B Bit Positions and Descriptions

Status 1 Bit Position	Meaning if bit value = 1
0 (LSB)	not used
1	not used
2	not used
3	The almanac stored in the receiver, is not complete and current
4-7	not used

A.17.33 Report Packet 0x4D

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

A.17.34 Report Packet 0x4E

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-37. 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.

A.17.35 Report Packet 0x55

This packet requests the current I/O option states and optionally allows the I/O option states to be set as desired.

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-38. Command Packets 0x55 and 0x35 Data Descriptions

Byte	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
0	position	0 (LSB)	1	XYZ ECEF Output 0: off 1: on	0x42 or 0x83
		1	0	LLA Output 0: off 1: on	0x4A or 0x84
		2	0	LLA ALT Output 0: HAE (datum) 1: MSL geoid	0x4A or 0x84 0x8F-17 0x8F-18
		3	0	ALT input 0: HAE (datum) 1: MSL geoid	0x2A
		4	0	Precision-of-position output 0: Send single-precision packet 1: Send double-precision packet	0x42/4A/8F-17 0x83/84/8F-18
0	position	5	0	0: output no Super Packets 1: output all enabled Super Packets	0x8F-17, 0x8F-18 0x8F-20
		6-7	0	not used	
1	velocity	0	1	XYZ ECEF Output 0: off 1: on	0x43
		1	0	ENU Output 0: off 1: on	0x56
		2-7	0	not used	

Table A-38. Command Packets 0x55 and 0x35 Data Descriptions (Continued)

Byte	Parameter Name	Bit Position	Default Bit Value	Option	Associated Packet
2	timing	0	0	time type 0: GPS time 1: UTC	0x42, 0x43, 0x4A, 0x83, 0x84, 0x56, 0x8F-17, 0x8F-18
		1	0	reserved	
		2	0	reserved	
		3	0	reserved	
		4	0	reserved	
		5-7	0	not used	
3	Auxiliary PR meas.	0	0: off		0x5A
		1	0: raw	0: raw PR's in 5A 1: filtered PR's in 5A	0x5A
		2	reserved		
		3	0: off 1: on	output dBHz instead of AMU	0x5A, 0x5C, 0x47, 0x6F
		4-7	reserved		



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



Note – Automatic output of 5 A messages is supported in the Lassen-SK8 for backwards compatibility with older TSIP applications.

A.17.36 Report Packet 0x56

If East-North-Up (ENU) coordinates have been selected for the I/O “velocity” option, 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-39. 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.

A.17.37 Report Packet 0x57

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-40. Report Packet 0x57 Data Formats

Byte	Item	Type/Units	Byte 0 Value/Velocity
0	Source of information	BYTE/ - - -	00/none 01/regular fix
1	Mfg. diagnostic	BYTE/ - - -	
2-5	Time of last fix	SINGLE/seconds, GPS time	
6-7	Week of last fix	INTEGER/weeks, GPS time	

A.17.38 Report Packet 0x58

This packet provides GPS data (almanac, ephemeris, etc.). The receiver sends this packet under the following conditions:

- On request
- In response to Packet 0x38 (acknowledges the loading of data)

The data format is shown below.

Table A-41. Report Packet 0x58 Data Formats

Byte	Item	Type	Value	Meaning
0	Operation	BYTE	0 1 2	Data type cannot be loaded Acknowledge Data Out
1	Type of data	BYTE	2 3 4 5 6	Almanac Health page, T_oa, IONO UTC Ephemeris
2	Sat PRN #	BYTE	0 1 to 32	Data that is not satellite ID-specific Satellite PRN number
3	length (n)	BYTE		Number of bytes of data to be loaded
4 to n+3	data	n BYTES		

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

Table A-42. Report Packet 0x58 Almanac Data

Byte	Item	Type	Meaning/FCD 200 Sec. No.
4	t_oa_raw	BYTE	Sec 20.3.3.5.1.2
5	SV_HEALTH	BYTE	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
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	INTEGER	Sec 20.3.3.5.1.2
68-69	wn_oa	INTEGER	Sec 20.3.3.5.1.2



Note – All angles are in radians.



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

Table A-43. Report Packet 0x58 Almanac Health Data

Byte	Item	Type	Meaning/IDC 200 Sec.
4	week # for health	BYTE	Sec 20.3.3.5.1.3
5-36	SV_health	BYTE	Sec 20.3.3.5.1.3
37	t_oa for health	BYTE	Sec 20.3.3.5.1.3
38	current t_oa	BYTE	units = seconds/2048
39-40	current week #	INTEGER	

Table A-44. Report Packet 0x58 Ionosphere Data

Byte	Item	Type	Meaning/ICD 200 Sec
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-45. Report Packet 0x58 UTC Data

Byte	Item	Type	Meaning/ICD 200 Sec.
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-46. Report Packet 0x58 Ephemeris Data

Byte	Item	Type	Meaning/ICD 200 Sec.
4	sv_number	BYTE	SV PRN number
5-8	t_ephem	SINGLE	time of collection
9-10	weeknum	INTEGER	Sec 20.3.3.3, Table 20-I
11	codeL2	BYTE	Sec 20.3.3.3, Table 20-I
12	L2Pdata	BYTE	Sec 20.3.3.3, Table 20-I
13	SVacc_raw	BYTE	Sec 20.3.3.3, Table 20-I
14	SV_health	BYTE	Sec 20.3.3.3, Table 20-I
15-16	IODC	INTEGER	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

Table A-46. Report Packet 0x58 Ephemeris Data (Continued)

Byte	Item	Type	Meaning/ICD 200 Sec.
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	BYTE	Sec 20.3.3.4
42	fit_interval	BYTE	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
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	$= (\text{sqrt_A})^2$
139-146	n	DOUBLE	derived from delta_n
147-154	r1me2	DOUBLE	$= \text{sqrt}(1.0 - e^2)$
155-162	OMEGA_n	DOUBLE	derived from OMEGA_0, OMEGADOT
163-170	ODOT_n	DOUBLE	derived from OMEGADOT



Note – All angles are in radians.



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

A.17.39 Report Packet 0x59

Normally the GPS receiver selects only healthy satellites (based on transmitted values in the ephemeris and almanac) which satisfy all mask values, for use in the position solution. This packet allows you to override the internal logic and force the receiver to either unconditionally disable a particular satellite or to ignore a bad health flag. The GPS receiver returns Packet 0x59 for operation modes 3 and 6 only. The data format is shown below.

Table A-47. Report Packet 0x59 Data Formats

Byte	Item	Type	Value	Meaning
0	Operation	BYTE	3	The remaining bytes tell whether receiver is allowed to select each satellite.
			6	The remaining bytes tell whether the receiver heeds or ignores each satellite's health as a criterion for selection.
1 to 32	Satellite #	32 BYTES (1 byte per satellite)		(Depends on byte 0 value.)
			0	Enable satellite selection or heed satellite's health. Default value.
			1	Disable satellite selection or ignore satellite's health.

This information is not held in battery-backed memory. At power-on and after a reset, the default values are set for all satellites.

A.17.40 Report Packet 0x5A

This packet provides raw GPS measurement data. If the I/O “auxiliary” option has been selected, the receiver sends this data automatically as measurements are taken. The data format is shown below.

Note – A new Report Packet, 0x 6F has full pseudo-ranges and integrated doppler.

Table A-48. Report Packet 0x5A Data Formats

Byte	Item	Type	Units
0	Satellite PRN Number	BYTE	-----
1	Sample Length	SINGLE	msec
5	Signal Level	SINGLE	AMU or dBHz
9	Code phase	SINGLE	1/16th chip
13	Doppler	SINGLE	Hertz
17	Time of Measurement	DOUBLE	sec

Application Note – Packet 0x5A provides the raw satellite signal measurement information used in computing a fix.

Satellite PRN (Byte 0) is a unique identification number for each of the 32 GPS satellites.

Sample length (Byte 1) is the number of milliseconds over which the measurement was averaged. Thus if the sample length is 428, then the receiver tracked the satellite and collected the measurement over a 428 millisecond period. The receiver uses a 500 millisecond dwell time per satellite, however, if the channel is sequencing on several satellites, the sample length will be closer to 400 milliseconds due to re-acquisition and loop setting times.

The codephase (Byte 9) value is the average delay over the sample interval of the received C/A code and is measured with respect to the receiver's millisecond timing reference. Thus, it includes all receiver, satellite, and propagation biases and errors. It is expressed in 1/16th of a C/A code chip.

The doppler (Byte 13) value is apparent carrier frequency offset averaged over the sample interval. It is measured with respect to the nominal GPS L1 frequency of 1575.42 MHz, referenced to the receiver's internal oscillator. Thus, it includes all receiver and satellite clock frequency errors. It is expressed in Hertz at the L1 carrier.

The time of measurement (Byte 17) is the center of the sample interval adjusted by adding the receiver supplied codephase (modulo mS) to a user determined integer number of mS between user and satellite.

The receiver codephase resolution is 1/16th of a C/A code chip, this corresponds to:

$$\begin{aligned} 1/16 * \text{C/A code chip} &\approx 977.517\text{ns}/16 &\approx 61.0948 \text{ ns} \\ &\approx 61.0948 * \text{speed of light, m/s} \\ &\approx 18.3158 \text{ meter} \end{aligned}$$

The integer millisecond portion of the pseudo-range must then be derived by utilizing the approximate user and satellite positions. Rough user position (within a few hundred kilometers) must be known; the satellite position can be found in its almanac / ephemeris data.

Each mS integer corresponds to:

$$\begin{aligned} \text{C/A code epoch} * \text{speed of light} &= 1 \text{ ms} * \text{speed of light, m/s} \\ &\approx 300\text{km (approx.)} \\ &\approx 299.792458 \text{ km (precise)} \end{aligned}$$

The satellite time-of-transmission for a measurement can be reconstructed using the code phase, the time of measurement, and the user-determined integer number of milliseconds.



Note – The receiver occasionally adjusts its clock to maintain time accuracy within 1 msec. At this time, all pseudorange values for all satellites are adjusted upward or downward by one millisecond. Message 0x6F shows this clearly; it is hidden in 0x5A.

A.17.41 Report Packet 0x5C

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 in Table A-49.

Table A-49. Report Packet 0x5C Data Formats

Byte/Item	Type/Units	Value/Meaning
Byte 0 - Satellite PRN number	BYTE/number 1 - 32	
Byte 1 - Channel code	BYTE	Bit 4-6, channel number, 0-7
		Bit position within byte 1 7(MSB) 3 (channel number beginning with 0)
Byte 2/Acquisition flag	BYTE	Byte 2 value: 0 never acquired 1 acquired 2 re-opened search
Byte 3/Ephemeris flag	BYTE	Byte 3 value: 0 flag not set good ephemeris for this satellite (<4 hours old, good health)
Byte 4 - 7/Signal level	SINGLE	same as in Packet 0x47
Byte 8 - 11/GPS time of last measurement	SINGLE/seconds	Byte 8 - 11 value: <0 no measurements have been taken
Byte 12 - 15/Elevation	SINGLE/radians	Approximate elevation of this satellite above the horizon. Updated about every 15 seconds. Used for searching and computing measurement correction factors.
Byte 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.
Byte 20/old measurement flag	BYTE	Byte 20 value: 0 flag not set >0 the last measurement is too old to use for a fix computation.
Byte 21/Integer msec flag	BYTE	Byte 21 value: Don't have good knowledge of integer millisecond range to this satellite 1 msec from sub-frame data collection 2 verified by a bit crossing time 3 verified by a successful position fix 4 suspected msec error

Table A-49. Report Packet 0x5C Data Formats (Continued)

Byte/Item	Type/Units	Value/Meaning
Byte 22/bad data flag	BYTE	Byte 22 value: 0 flag not set 1 bad parity 2 bad ephemeris health
Byte 23/Data collection flag	BYTE	Byte 23 value: 0 flag not set >0 The receiver currently is trying to collect data from this satellite.

A.17.42 Command Packet 0x60 -Type 1 Differential GPS Corrections

This packet provides the SVeeSix with differential corrections from RTCM SC-104 record types 1 and 9, in the TSIP format. There is no response to this packet. The units and scale factors are as defined by RTCM-104 version 1. If byte 3 bit 7 is set, the unit and scale factors are defined by RTCM SC-104 version 2. If bit 6 is set, the corrections are as in RTCM Type 9 records. The format for this packet is shown in Table A-50:

Table A-50. Report Packet 0x60 Data Formats

Byte	Bit	Item	Type	Units
0 - 1	All	Modified z-count	WORD	.6 SEC
2	All	Station health	BYTE	
3	7	not used	BIT	
	6	Type 9 flag	BIT	0 = type 1 1 = type 9
	0 - 5	Number of SVs in packet	BITS	

The next 5 bytes are repeated as a group for each satellite. The SV PRN and scale factor contains the SV PRN in the lower 5 bits, and the scale factor in the upper 3 bits. Range corrections are scaled by 0.02 meters times 2 raised to the scale factor power. Range-rate corrections are scaled by 0.002 meters per second times 2 raised to the scale factor power. The format is shown in Table A-51.

Table A-51. Report Packet 0x60 Data Formats for Health and Power

Byte	Item	Type	Units
4+ (N*5)	SV PRN scale factor	BYTE	
5+ (N*5)	Range correction	WORD	RTCM-104
7+ (N*5)	Range-rate correction	BYTE	RTCM-104
8+ (N*5)	IODE	BYTE	

A.17.43 Command Packet 0x61 -Set Differential GPS Corrections

This TSIP packet provides the delta differential corrections from RTCM-104 record type 2. There is no response to this packet. Scale factors are version 1 unless the version 2 flag is set. The format for this packet is shown in Table A-52.

Table A-52. Command Packet 0x61 Data Formats

Byte	Item	Type	Units
0 - 1	Modified Z-count	WORD	.6 SEC
2 (set MSB for version 2)	Bit 7 = 1 Bit 0-6 = number of SVs	BYTE	
The next 3 bytes are repeated as a group for each satellite:			
3+ (N*3)	SV PRN & scale factor	BYTE	
4+ (N*3)	Delta range correction	WORD	RTCM-104

The units and scale factors are as defined by Packet 0x60. Delta range correction rates are not entered.

A.17.44 Command Packet 0x62

This packet requests the differential position fix mode of the GPS receiver. A single data byte is sent.

To request Report Packet 0x82, the data byte is set to contain any value between 0x5 and 0xFF.

A.17.45 Command Packet 0x65

This packet requests the status of differential corrections for a specific satellite or for all satellites for which data is available. This packet contains only one byte specifying the PRN number of the desired satellite or zero to request all available. The response is a Packet 0x85 for each satellite if data is available. If the receiver has no valid data for any satellite, no reply will be sent.

A.17.46 Report Packet 0x6D

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 when the receiver is doing an overdetermined fix or every 5 seconds. The data format is shown in Table A-53.

Table A-53. Report Packet 0x6D Data Formats

Report 6D Byte	Item	Type	Meaning																		
0	overdetermined mode	BYTE	<table border="1"> <thead> <tr> <th>BIT</th> <th>Value</th> <th>Meaning</th> </tr> </thead> <tbody> <tr> <td>0-2</td> <td>3</td> <td>2D</td> </tr> <tr> <td></td> <td>4</td> <td>3D</td> </tr> <tr> <td>3</td> <td>0</td> <td>Auto</td> </tr> <tr> <td></td> <td>1</td> <td>Manual</td> </tr> <tr> <td>4-7</td> <td>--</td> <td>nsvs</td> </tr> </tbody> </table>	BIT	Value	Meaning	0-2	3	2D		4	3D	3	0	Auto		1	Manual	4-7	--	nsvs
BIT	Value	Meaning																			
0-2	3	2D																			
	4	3D																			
3	0	Auto																			
	1	Manual																			
4-7	--	nsvs																			
1-4	PDOP	SINGLE	PDOP																		
5-8	HDOP	SINGLE	HDOP																		
9-12	VDOP	SINGLE	VDOP																		
13-16	TDOP	SINGLE	TDOP																		
(16+nsvs)	SV PRN	BYTE																			

A.17.47 Command Packet 0x6E — Set or Request Synchronized Measurement Parameters

Packet 6E sets or requests the Synchronized Measurement parameters. The synchronized measurement parameters are sent by the GPS receiver in Packet 0x6F

Enable / Disable Synchronized Measurements

Controls whether synchronized measurements will be output at the output interval



Note – Synchronized Measurement outputs will only be available after the GPS receiver has made a position fix once the receiver is turned on or reset by Command Packet 0x25. This ensures that information within the Synchronized Measurement packet will be valid.

Output Level

The period of the Synchronized Measurement outputs is synchronized to the GPS time of the week. For example, outputs occur when the GPS time of week equals $(INT * N)$, where INT is the selected output interval and N is an integer.

Two forms of this packet are shown in Table A-54 and Table A-55. The response for both forms of this packet is Packet 0x6E, Synchronized Measurement Parameters.

Table A-54. Set Synchronized Measurement Parameters

Byte #	Item	Type	Value	Meaning
0	Subcode	BYTE	1	Synchronized measurement Parameters
1	Enable	BYTE	0	Disable outputs
			1	Enable Outputs
2	Output Interval	BYTE	1-255	Output interval in seconds, synchronized to the GPS time of week

Table A-55. Request Synchronized Measurement Parameters

Byte #	Item	Type	Value	Meaning
0	Subcode	BYTE	1	Synchronized measurement Parameters

A.17.48 Report Packet 0x6E — Synchronized Measurements

Report Packet 0x6E reports the setting of Synchronized Measurement parameters. The values are shown in Table A-56. See Command Packet 0x6E for more information.

Table A-56. Set Synchronized Measurement Parameters

Byte #	Item	Type	Value	Meaning
0	Subcode	BYTE	1	Synchronized Measurement Parameters
1	Enable	BYTE	0	Outputs are disabled
			1	Outputs are enabled
2	Output Interval	BYTE	1-255	Output interval in seconds, synchronized to the GPS time of week

A.17.49 Report Packet 0x6F, Subcode 1

Table A-57 Synchronized Measurements Report

Byte #	Item	Type	Value	Meaning
0	Subcode	BYTE	1	Synchronized Measurements
<i>Begin Preamble</i>				
1	Preamble	BYTE	2	Begin preamble
2-3	Length	INTEGER		Number of bytes: preamble to postamble inclusive
4-11	Receive Time	DOUBLE	<i>msecs</i>	Time of GPS week
12-19	Clock Offset	DOUBLE	<i>msecs</i>	Receiver clock offset
20	# of SVs	BYTE		Number of satellites
<i>Begin Packet Data (bytes = number of SVs times 27 bytes per SV)</i>				
21,48,...	SV PRN	BYTE	1-32	Pseudorandom number of satellite
22, 49,...	FLAGS1	BYTE	Table 0-2	Flag values show Synchronized Measurement status of satellite
23, 50,...	FLAGS2	BYTE	0	Reserved (set to zero)
24, 51,...	Elevation Angle	BYTE	<i>degrees</i>	Satellite elevation angle
25-26, 52-53,...	Azimuth	INTEGER	<i>degrees</i>	Satellite azimuth
27, 54,...	SNR	BYTE	<i>AMUs/4</i>	Number of AMUs times four

Table A-57 Synchronized Measurements Report (Continued)

Byte #	Item	Type	Value	Meaning
28–35, 55–62,...	Pseudorange	DOUBLE	<i>meters</i>	Full L1 C/A Pseudorange, filtered
36–43, 63–70,...	Carrier Phase	DOUBLE	<i>cycles</i>	L1 band Continuous Phase (truncated to integer value)
44–47, 71–74,...	Doppler	SINGLE	<i>hertz</i>	L1 band Doppler
<i>End of the packet data</i>				
21+27n 22+27n	Checksum	INTEGER	—	Sum of bytes before checksum starting with preamble
23+27n	Postamble	BYTE	3	



Note – The sign convention provides for a carrier-phase decrease when the pseudorange increases and the doppler is negative.

Table A-58 FLAGS1 Bit Assignments

Bit	Meaning
0 (LSB)	Reserved (set to zero)
1	L1 Carrier-phase Cycle Slip 0: No 1: Yes
2	Reserved (set to zero)
3	Reserved (set to zero)
4	Valid L1 Carrier-phase: 0: No 1: Yes
5	Reserved (set to zero)
6	Reserved (set to zero)
7 (MSB)	New Position Calculated: 0: No 1: Yes

A.17.50 Command Packet 0x70

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 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 PV 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, Command 0x70 is sent with no databytes. To input new settings, Command 0x70 is sent with four data bytes, as shown in Table A-59. Also see A.3 for information on saving the settings to non-volatile memory.

Table A-59. Command and Report Packet 0x70 Field Descriptions

Byte/Item	Item	Type	Bit Number
0	PV Filter	BYTE	0 - Off 1 - On
1	Static Filter	BYTE	0 - Off 1 - On
2	Altitude Filter	BYTE	0 - Off 1 - On
3	Reserved	BYTE	

A.17.51 Report 0x70

This report is sent as a response to Command 0x70 as either a query or a set. It contains four bytes, as shown in Table A-59.

A.17.52 Command Packet 0x7A

The NMEA message mask is a 32-bit vector which 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” seconds.

Hex values are “OR”ed together to produce the desired combined output mask. For example, a mask value of 0x00000005 would mean GGA and VTG messages are enabled for output (the default mask), and a mask value of 0x00000013F would mean all of the messages are enabled for output. The Hex values used to request the NMEA interval and message mask are listed below.

GGA: 0x00000001
 GLL: 0x00000002
 VTG: 0x00000004
 GSV: 0x00000008
 GSA: 0x00000010
 ZDA: 0x00000020
 RMC: 0x00000100

See A.3 for information on saving the settings to non-volatile memory.

Table A-60. Command Packet 0x7A Data Formats

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0	

To set the NMEA interval and message mask:

Table A-61. Command Packet 0x7A Data Formats for Setting NMEA Interval and Message Mask

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0	
1	Interval	BYTE		The time in seconds between NMEA messages (position fix rate if 0)
2-5	Output mask	UNSIGNED LONG INT		The NMEA bit-mask for outputting messages

A.17.53 Report Packet 0x7B

Report Packet 0x7B has one form. See Command Packet 0x7A for more information about the data formats.

To set the NMEA interval and message mask, use the values shown in Table A-62.

Table A-62. Report Packet 0x7B Message Mask Settings

Byte	Item	Type	Value	Meaning
0	Subcode	BYTE	0	
1	Interval	BYTE		The time in seconds between NMEA messages
2-5	Output mask	UNSIGNED LONG INT		The NMEA bit-mask for outputting messages

A.17.54 Report Packet 0x82

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/GPD (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 Manual GPS (Differential off) — The receiver does position solutions without differential corrections, even if the differential corrections are available.
- Mode 1 Manual GPD (Differential on) — The receiver only does position solutions if valid differential correction data are available.
- Mode 2 Auto GPS (Differential currently off) — 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 Auto GPD (Differential currently on) — The receiver is receiving differential correction data for all satellites in a constellation which meets all other masks, and is doing differential position solutions.

A.17.55 Report Packet 0x83

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 double position option is selected, the receiver sends this packet each time a fix is computed. The data format is shown in Table A-63.

Table A-63. 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.

A.17.56 Report Packet 0x84

This packet provides current GPS position fix in LLA coordinates. If the I/O “position” option is set to “LLA” and the double position option is selected, the receiver sends this packet each time a fix is computed. The data format is shown in Table A-64.

Table A-64. 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.



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

A.17.57 Report Packet 0x85

This packet provides the status of differential corrections for a specific satellite. It is sent in response to Packet 0x65. The format of this packet is shown in Table A-65.

Table A-65. Report Packet 0x85 Data Formats

Report 85 Byte	Item	Type	Units
0	Satellite PRN number	BYTE	
1	Summary status code	BYTE	
2	Station health	BYTE	
3	Satellite health (UDRE)	BYTE	
4	IODE 1	BYTE	
5	IODE 2	BYTE	
6	Z-count as Time-of-Week	SINGLE	seconds
10	Range correction	SINGLE	meters
14	Range-rate correction	SINGLE	m/sec
18	Delta range correction	SINGLE	meters

The summary status code is encoded in Table A-66.

Table A-66. Report Packet 0x85 Summary Status Code Encoding

0	good correction data
1	good delta correction data
2	station health bad (5 or 7)
3	data too old (60 seconds)
4	UDRE too high (>4)
5	IODE mismatch with ephemeris
6	satellite not in current Type1 message

A.17.58 Packets 0x8E and 0x8F

Refer to Section A.18 for information on Packets 0x8E and 0x8F.

A.17.59 Command Packet 0xBB

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

Table A-67. Command Packet 0xBB Query Mode Data Format

Byte #	Item	Type	Value	Meaning	Default
0	Subcode	BYTE	0 x 03	Query mode	

TSIP Packet 0xBB is used to set GPS Processing options. The table below lists the individual fields within the 0xBB Packet. See A.3 for information on saving the settings to non-volatile memory.

Table A-68. Command and Report Packet 0xBB Field Descriptions

Byte #	Item	Type	Value	Meaning	Default
0	Subcode	BYTE	0x03		0x03
1	Operating Dimension	BYTE	0 3 4	Automatic (2D/3D) Horizontal (2D) Full Position (3D)	Automatic
2	DGPS Mode	BYTE	0 1 2 or 3	DGPS off DGPS only DGPS auto	DGPS auto
3	Dynamics Code	BYTE	4	Land Sea Air Stationary	Land
4-14	Reserved			Not used	
15-18	Elevation Mask	SINGLE	0.0 - 1.75	Lowest satellite elevation for fixes (radians)	0.0873 (5)
19-22	AMU Mask	SINGLE		Minimum signal level for fixes	2.0
23-26	DOP Mask	SINGLE		Maximum DOP for fixes	12.0
27-30	DOP Switch	SINGLE		Selects 2D/3D mode	5.0
31-34	Reserved			Not used	
35	DGPS Age Limit	BYTE		Maximum time to use a DGPS correction (seconds)	30
36-39	Reserved	BYTE	0	Not used	

A.17.60 Report Packet 0xBB

TSIP Packet 0xBB is used to report the GPS Processing options. See Table A-68.

A.17.61 Command Packet 0xBC

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 A.3 for information on saving the settings to non-volatile memory.

Table A-69. Command Packet 0xBC Port Characteristics Query Field Descriptions

Byte #	Item	Type	Value	Meaning
0	Port Number	BYTE	0 1 FF	Port 1 Port 2 Current port

TSIP Packet 0xBC is used to set the communication parameters on Port 1 and Port 2. The table below lists the individual fields within the Packet 0xBC.

Table A-70. Command Packet 0xBC Field Descriptions

Byte #	Item	Type	Value	Meaning
0	Port to Change	BYTE	0 1 0xFF	Port 1 Port 2 Current port
1	Input Baud Rate	BYTE	0 1 2 3 4 5 6 7 8 9	None 110 baud 300 baud 600 baud 1200 baud 2400 baud 4800 baud 9600 baud 19200 baud 38400 baud
2	Output Baud Rate	BYTE	As above	As above
3	# Data Bits	BYTE	2 3	7 bits 8 bits
4	Parity	BYTE	0 1 2	None Odd Even
5	# Stop Bits	BYTE	0	1 bit 2 bits

Table A-70. Command Packet 0xBC Field Descriptions (Continued)

Byte #	Item	Type	Value	Meaning
6	Flow Control	BYTE	0-F	OR of bits: 0 = none, 1 = RTS CTS 2 = transmit Xon Xoff 4 = transmit Xany 8 = receive Xon Xoff.
7	Input Protocols	BYTE	0-1F	OR of bits: 0 = none 1 = TAIP 2 = TSIP 8 = RTCM
8	Output Protocols	BYTE	0-1F	0 = none 1 = TAIP 2 = TSIP 4 = NMEA
9	Reserved	BYTE	0	None

A.17.62 Report Packet 0xBC

TSIP Packet BC is used to request the communication parameters on Port 1 and Port 2. The table below lists the individual fields within Packet 0xBC.

Table A-71. Report Packet 0xBC Field Descriptions

Byte #	Item	Type	Value	Meaning
0	Port to Change	BYTE	0 1	Port 1 Port 2
1	Input Baud Rate	BYTE	0 1 2 3 4 5 6 7 8 9	None 110 baud 300 baud 600 baud 1200 baud 2400 baud 4800 baud 9600 baud 19200 baud 38400 baud
2	Output Baud Rate	BYTE	As above	As above
3	# Data Bits	BYTE	2 3	7 bits 8 bits
4	Parity	BYTE	0 1 2	None Odd Even

Table A-71. Report Packet 0xBC Field Descriptions (Continued)

Byte #	Item	Type	Value	Meaning
5	# Stop Bits	BYTE	0 2	1 bits for 6-8 data bits 2 bits
6	Flow Control	BYTE	0-F	OR of bits: 0 = none, 1 = RTS CTS 2 = transmit Xon Xoff 4 = transmit Xany 8 = receive Xon Xoff.
7	Input Protocols	BYTE	0-1F	OR of bits: 0 = none 1 = TAIP 2 = TSIP 8 = RTCM
8	Output Protocols	BYTE	0-1F	0 = none 1 = TAIP 2 = TSIP 4 = NMEA
9	Reserved	BYTE	0	None

A.18 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.

A.18.1 Command Packet 0x8E-15 - Set/Request Datum (not supported with Firmware 7.52)

This packet allows the user to change the default datum from WGS-84 to one of 180 selected datums or a user-entered custom datum. (However version 7.52 firmware will only support WGS-84 datum.) The datum is a set of 6 parameters which describe an ellipsoid to convert the GPS receiver's internal coordinate system of XYZ ECEF into Latitude, Longitude and Altitude (LLA). This will affect all calculations of LLA in packets 0x4A and 0x84.

The user may wish to change the datum to match coordinates with some other system (usually a map). Most maps are marked with the datum used and in the US the most popular datum for maps is NAD-27. The user may also wish to use a datum which is more optimized for the local shape of the earth in that area. However, these optimized datum are truly "local" and will provide very different results when used outside of the area for which they were intended. WGS-84 is an excellent general ellipsoid valid around the world. See A.3 for information on saving the settings to non-volatile memory.



Note – Version 7.52 firmware supports only WGS-84 datum.

To request the current datum setting, the command packet contains only one data byte as shown in Table A-73. Report Packet 0x8F-15 is returned.

Table A-72. Command Packet 0x8E-15 Field Descriptions

Byte	Type	Value
0	Superpacket ID	0 x 15

To change to one of the internally held datum the packet must contain exactly 2 bytes representing the integer value of the index of the datum desired:

Table A-73. Command Packet 0x8E-15 Datum Index Field Descriptions

Byte	Type	Value
0	Superpacket ID	0 x 15
1-2	INTEGER	Datum index



Note – To request the current datum, send Packet 8E-15 with no data bytes.

Alternatively, the unit will accept a 42 byte input packet containing 6 double precision floating point value representing the ellipse. The first 3 are DX, DY and DZ which represent an offset in meters from the ECEF origin for the ellipse. The fourth parameter is the semi-major axis of the ellipse (called the a-axis) and is also in meters. The fifth parameter is the eccentricity squared of the ellipse and is dimensionless.



Caution – The GPS receiver does not perform an integrity check on the datum values. If unusual inputs are used, the output will be equally unusual.

Table A-74. Command Packet 0x8E-15 Eccentricity of the Ellipse Parameter Field Descriptions

Byte	Type	Value	Units
0	Superpacket ID	0 x 15	
1-8	DOUBLE	DX	m
9-16	DOUBLE	DY	m
17-24	DOUBLE	DZ	m

Table A-74. Command Packet 0x8E-15 Eccentricity of the Ellipse Parameter Field Descriptions

25-32	DOUBLE	A-axis	m
33-40	DOUBLE	Eccentricity Squared	none



Note – Eccentricity Squared is related to flattening by the following equation:

$$e^2 = 2p - p^2$$

A.18.2 Command Packet 0x8E-19

This packet allows the user to enable or disable the position report in UTM (Universal Transverse Mercator) format. If bit 4, byte 0 of Command Packet 0x35 is set to double precision, the 0x8F-18 packets will be enabled. If the bit set to single precision, the 0x8F-17 packets will be enabled. See A.3 for information on saving the settings to non-volatile memory.

Table A-75. Command Packet 0x8E-19 Field Description

Byte	Description	Type	Value
0	Subcode	Byte	0x19
1	UTM Status	Char	E = Enable (0x45)

A.18.3 Command Packet 0x8E-20

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 Table A-76. 0x37 can also be used for requesting 0x8F-20 if the 0x8F-20 is scheduled for auto output. See A.3 for information on saving the settings to non-volatile memory.

Table A-76. Command Packet 0x8E-20 Field Descriptions

Byte	Item	Type	Meaning
0	Sub-packet id	BYTE	Id for this sub-packet (always 0x20)
1	Mark for Auto-report (cf. bit 5 of Packet 35)	BYTE	0 = do not auto-report 1 = mark for auto-report



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

A.18.4 Command Packet 0x8E-26

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

Table A-77. Command Packet 0x8E-26 Definitions

Byte #	Item	Type	Value	Meaning
0	Subcode	BYTE	0x26	Save Settings

A.18.5 Report Packet 0x8F-15 - Current Datum Values (not supported with Firmware 7.52)

This packet contains 43 data bytes with the values for the datum currently in use and is sent in response to Packet 0x8E-15. (However, version 7.52 firmware will only support WGS-84 datum.) If a built in datum is being used both the datum index and the 5 double precision values for that index will be returned. If the receiver is operating on a custom user entered datum the datum index will be set to -1 and the 5 values will be displayed. These 5 values describe an ellipsoid to convert ECEF XYZ coordinate system into LLA.

Table A-78. Report Packet 0x8F-15 Field Descriptions for Converting Ellipsoid ECEF XYZ to Coordinate System LLA

Byte	Type	Value
0	BYTE	Id for this sub-packet (always 0x15)
1-2	INTEGER	Datum Index (-1 for custom)
3-10	DOUBLE	DX
11-18	DOUBLE	DY
19-26	DOUBLE	DZ
27-34	DOUBLE	A-axis
35-42	DOUBLE	Eccentricity Squared



Note – A complete list of datums is provided at the end of this appendix. Eccentricity Squared is related to flattening by the following equation:

$$e^2 = 2p - p^2$$

A.18.6 Report Packet 0x8F-17

This packet reports position in single precision UTM (Universal Transverse Mercator) format. The UTM coordinate system is typically used for U.S. and international topographical maps.

The UTM coordinate system lays out a world-wide grid consisting of the following:

- 60 North/South zones in 6° increments extending eastward from the International Date Line
- 10 East/West zones divided in 8° increments extending above and below the Equator.

Coordinates within these boundaries cover all surface locations from 80° South to 84° North and encircle the earth. Locations are indicated by offset from the equator and in the zones east of the International Date Line. These offsets are known as Northing and Easting and are expressed in meters. UTM is not usable in polar regions.

Table A-79. Report Packet 0x8F-17 Field Descriptions

Byte	Description	Type	Value
0	Subcode	Byte	0x17
1	Gridzone Designation	Char	
2-3	Gridzone	Integer	
4-7	Northing	Single	Meters
8-11	Easting	Single	Meters
12-15	Altitude	Single	Meters
16-19	Clock Bias	Single	Meters
20-23	Time of Fix	Single	Seconds

A.18.7 Report Packet 0x8F-18

This packet reports position in double precision UTM (Universal Transverse Mercator) format. The UTM coordinate system is typically used for U.S. and international topographical maps.

The UTM coordinate system lays out a world-wide grid consisting of the following:

- 60 North/South zones in 6° increments extending eastward from the International Date Line
- 10 East/West zones divided in 8° increments extending above and below the Equator.

Coordinates within these boundaries cover all surface locations from 80° South to 84° North and encircle the earth. Locations are indicated by offset from the equator and in the zones east of the International Date Line. These offsets are known as Northing and Easting and are expressed in meters. UTM is not usable in polar regions.

Table A-80. Report Packet 8F-18 Field Descriptions

Byte	Description	Type	Value
0	Subcode	Byte	0x18
1	Gridzone Designation	Char	
2-3	Gridzone	Integer	
4-11	Northing	Double	Meters
12-19	Easting	Double	Meters
20-27	Altitude	Double	Meters
28-35	Clock Bias	Double	Meters
36-39	Time of Fix	Single	Seconds

A.18.8 Report Packet 0x8F-19

This packet reports whether the UTM output packets is enabled. If bit 4 byte 0 in packet 0x35 /0x55 is single precision, 0x17 will be output.

Table A-81. Command Packet 0x8F-19 Field Descriptions

Byte	Description	Type	Value
0	Subcode	Byte	0x19
1	UTM Status	Char	E = Enable D = Disable

A.18.9 Report Packet 0x8F-20

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-82. Report Packet 0x8F-20 Data formats

Byte/Item	Type	Meaning
0	Sub-packet id / BYTE	Id for this sub-packet (always 0x20)
1	KeyByte / BYTE	Reserved for Trimble DGPS Post-processing.
2-3	east velocity / INTEGER	units 0.005 m/s or 0.020 m/s (see Byte 24). Overflow = 0x8000
4-5	north velocity / INTEGER	units 0.005 m/s or 0.020 m/s (see Byte 24). Overflow = 0x8000

Table A-82. Report Packet 0x8F-20 Data formats (Continued)

6-7	up velocity / INTEGER	units 0.005 m/s or 0.020 m/s (see Byte 24). Overflow = 0x8000
Byte/Item	Type	Meaning
8-11	Time Of Week / UNSIGNED LONG INTEGER	GPS Time in milliseconds
12-15	Latitude / LONG INTEGER	WGS-84 latitude, units = 2^{-31} semicircle. Range = -2^{30} to 2^{30} .
16-19	Longitude / UNSIGNED LONG INTEGER	WGS-84 longitude east of meridian, units = 2^{-31} semicircle. Range = 0 to 2^{32} .
20-23	Altitude / LONG INTEGER	Altitude above WGS-84 ellipsoid, mm.
24	Velocity Scaling	When bit 0 is set to 1 velocities in bytes 2 through 7 have been scaled by 4
25	Reserved	
26	Datum	Datum index + 1 0=unknown
27	Fix Type / BYTE	Type of fix. This is a set of bit flags. 0 (LSB) 0: Fix was available 1: No fix available 1 0: Fix is autonomous 1: Fix was corrected with RTCM 2 0: 3D fix 1: 2D fix 3 0: 2D fix used last-calculated altitude 1: 2D fix used entered altitude 4 0: unfiltered 1: position or altitude filter on 5-7 not used (always 0)
28	NumSVs / BYTE	Number of satellites used for fix. Will be zero if no fix was available.
29	UTC Offset / BYTE	Number of leap seconds between UTC time and GPS time.
30-31	Week / INTEGER	GPS time of fix, weeks.

Table A-82. Report Packet 0x8F-20 Data formats (Continued)

Byte/Item	Type	Meaning
32-47	FIX SVs	Repeated groups of 2 bytes, one for each satellite. There will always be 8 of these groups. The bytes are 0 if group N/A. The following table describes the contents of each group.
48-56	Iono Params / 8 CHARS	The broadcast ionospheric parameters.

Table A-83. Report Packet 0x8F-20 Fix SVs field 32-47

Byte/Item	Type	Bit Number	Meaning
32	BYTE	0-5 6-7	PRN (IODC - IODE)/256
33	BYTE	0-7	IODE

A.18.10 Report Packet 0x8F-26

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

Table A-84. Report Packet 0x8F-26 Field Descriptions

Byte/Item	Item	Type	Bit Number	Meaning
0	Subcode	BYTE	0x26	Save Settings
1-4	Status	U32		Reserved

A.19 Datums

Datum selections are not available for version 7.52 firmware.

Table A-85. Datums

Index	DX	DY	DZ	A-axis	Eccentricity	Description
0	0	0	0	6378137.000	0.00669437999014	/*WGS-84*/
1	-128	481	664	6377397.155	0.00667437311265	/*Tokyo from old J6 values*/
2	-8	160	176	6378206.400	0.00676865799761	/*NAD-27*/
3	-9	151	185	6378206.400	0.00676865799761	/*Alaska/Canada*/
4	-87	-98	-121	6378388.000	0.00672267002233	/*European*/
5	-133	-48	148	6378160.000	0.00669454185459	/*Australian*/
6	0	0	4	6378135.000	0.00669431777827	/*WGS-72*/
7	0	0	0	6378137.000	0.00669438002290	/*NAD-83*/
8	0	0	0	6378137.000	0.00669437999014	/*NAD-02*/
9	0	0	0	6378137.000	0.00669437999014	/*Mexican*/
10	0	0	0	6378137.000	0.00669437999014	/*Hawaiian*/
11	0	0	0	6378137.000	0.00669437999014	/*Astronomic*/
12	0	0	0	6378137.000	0.00669437999014	/*U S Navy*/
13	-87	-98	-121	6378388.000	0.00672267002233	/*European*/
14	-134	-48	149	6378160.000	0.00669454185459	/*Australian 1984*/
15	-166	-15	204	6378249.145	0.00680351128285	/*Adindan-Mean*/
16	-165	-11	206	6378249.145	0.00680351128285	/*Adindan-Ethiopia*/
17	-123	-20	220	6378249.145	0.00680351128285	/*Adindan-Mali*/
18	-128	-18	224	6378249.145	0.00680351128285	/*Adindan-Senegal*/
19	-161	-14	205	6378249.145	0.00680351128285	/*Adindan-Sudan*/
20	-43	-163	45	6378245.000	0.00669342162297	/*Afgooye-Somalia*/
21	-150	-250	-1	6378388.000	0.00672267002233	/*Ain El Abd-Bahrain*/
22	-491	-22	435	6378160.000	0.00669454185459	/*Anna 1 Astro 1965*/
23	-143	-90	-294	6378249.145	0.00680351128285	/*Arc 1950-Mean*/
24	-138	-105	-289	6378249.145	0.00680351128285	/*Arc 1950-Botswana*/
25	-125	-108	-295	6378249.145	0.00680351128285	/*Arc 1950-Lesotho*/
26	-161	-73	-317	6378249.145	0.00680351128285	/*Arc 1950-Malawi*/
27	-134	-105	-295	6378249.145	0.00680351128285	/*Arc 1950-Swaziland*/
28	-169	-19	-278	6378249.145	0.00680351128285	/*Arc 1950-Zaire*/
29	-147	-74	-283	6378249.145	0.00680351128285	/*Arc 1950-Zambia*/
30	-142	-96	-293	6378249.145	0.00680351128285	/*Arc 1950-Zimbabwe*/
31	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960-Mean*/
32	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960-Kenya*/
33	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960-Tanzania*/

Table A-85. Datums (Continued)

Index	DX	DY	DZ	A-axis	Eccentricity	Description
34	-205	107	53	6378388.000	0.00672267002233	/*Ascension Isl 1958*/
35	145	75	272	6378388.000	0.00672267002233	/*Astro Beacon E 1945*/
36	114	-116	-333	6378388.000	0.00672267002233	/*Astro B4 Sorol Atoll*/
37	-320	550	-494	6378388.000	0.00672267002233	/*Astro Dos 71/4*/
38	124	-234	-25	6378388.000	0.00672267002233	/*Astro Station 1952*/
39	-133	-48	148	6378160.000	0.00669454185459	/*Australian Geo 1966*/
40	-127	-769	472	6378388.000	0.00672267002233	/*Bellevue (IGN)*/
41	-73	213	296	6378206.400	0.00676865799761	/*Bermuda 1957*/
42	307	304	-318	6378388.000	0.00672267002233	/*Bogota Observatory*/
43	-148	136	90	6378388.000	0.00672267002233	/*Compo Inchauspe*/
44	298	-304	-375	6378388.000	0.00672267002233	/*Canton Island 1966*/
45	-136	-108	-292	6378249.145	0.00680351128285	/*Cape*/
46	-2	151	181	6378206.400	0.00676865799761	/*Cape Canaveral mean*/
47	-263	6	431	6378249.145	0.00680351128285	/*Carthage*/
48	175	-38	113	6378388.000	0.00672267002233	/*Chatham 1971*/
49	-134	229	-29	6378388.000	0.00672267002233	/*Chua Astro*/
50	-206	172	-6	6378388.000	0.00672267002233	/*Corrego Alegre */
51	-377	681	-50	6377397.155	0.00667437223180	/*Djakarta (Batavia)*/
52	230	-199	-752	6378388.000	0.00672267002233	/*DOS 1968*/
53	211	147	111	6378388.000	0.00672267002233	/*Easter Island 1967*/
54	-87	-98	-121	6378388.000	0.00672267002233	/*Euro 1950-Mean*/
55	-104	-101	-140	6378388.000	0.00672267002233	/*Euro 1950-Cyprus*/
56	-130	-117	-151	6378388.000	0.00672267002233	/*Euro 1950-Egypt*/
57	-86	-96	-120	6378388.000	0.00672267002233	/*Euro 1950-Eng/Scot*/
58	-86	-96	-120	6378388.000	0.00672267002233	/*Euro 1950-Eng/Ire*/
59	-84	-95	-130	6378388.000	0.00672267002233	/*Euro 1950-Greece*/
60	-117	-132	-164	6378388.000	0.00672267002233	/*Euro 1950-Iran*/
61	-97	-103	-120	6378388.000	0.00672267002233	/*Euro 1950-Sardinia*/
62	-97	-88	-135	6378388.000	0.00672267002233	/*Euro 1950-Sicily*/
63	-87	-95	-120	6378388.000	0.00672267002233	/*Euro 1950-Norway*/
64	-84	-107	-120	6378388.000	0.00672267002233	/*Euro 1950-Port/Spain*/
65	-86	-98	-119	6378388.000	0.00672267002233	/*European 1979*/
66	-133	-321	50	6378388.000	0.00672267002233	/*Gandajika Base*/
67	84	-22	209	6378388.000	0.00672267002233	/*Geodetic Datum 1949*/
68	-100	-248	259	6378206.400	0.00676865799761	/*Guam 1963*/
69	252	-209	-751	6378388.000	0.00672267002233	/*GUX 1 Astro*/
70	-73	46	-86	6378388.000	0.00672267002233	/*Hjorsey 1955*/

Table A-85. Datums (Continued)

Index	DX	DY	DZ	A-axis	Eccentricity	Description
71	-156	-271	-189	6378388.000	0.00672267002233	/*Hong Kong 1963*/
72	209	818	290	6377276.345	0.00663784663020	/*Indian-Thai/Viet*/
73	295	736	257	6377301.243	0.00663784663020	/*Indian-India/Nepal*/
74	506	-122	611	6377340.189	0.00667053999999	/*Ireland 1965*/
75	208	-435	-229	6378388.000	0.00672267002233	/*ISTS O73 Astro 1969*/
76	89	-79	-202	6378388.000	0.00672267002233	/*Johnston Island 1961*/
77	-97	787	86	6377276.345	0.00663784663020	/*Kandawala*/
78	145	-187	103	6378388.000	0.00672267002233	/*Kerguelen Island*/
79	-11	851	5	6377304.063	0.00663784663020	/*Kertau 1948 */
80	94	-948	-1262	6378388.000	0.00672267002233	/*La Reunion*/
81	42	124	147	6378206.400	0.00676865799761	/*L.C. 5 Astro*/
82	-90	40	88	6378249.145	0.00680351128285	/*Liberia 1964*/
83	-133	-77	-51	6378206.400	0.00676865799761	/*Luzon-Phillippines*/
84	-133	-79	-72	6378206.400	0.00676865799761	/*Luzon-Mindanao*/
85	41	-220	-134	6378249.145	0.00680351128285	/*Mahe 1971*/
86	-289	-124	60	6378388.000	0.00672267002233	/*Marco Astro*/
87	639	405	60	6377397.155	0.00667437223180	/*Massawa*/
88	31	146	47	6378249.145	0.00680351128285	/*Merchich*/
89	912	-58	1227	6378388.000	0.00672267002233	/*Midway Astro 1961*/
90	-92	-93	122	6378249.145	0.00680351128285	/*Minna*/
91	-247	-148	369	6378249.145	0.00680351128285	/*Nahrwan-Masirah*/
92	-249	-156	381	6378249.145	0.00680351128285	/*Nahrwan-UAE*/
93	-243	-192	477	6378249.145	0.00680351128285	/*Nahrwan-Saudia*/
94	616	97	-251	6377483.865	0.00667437223180	/*Namibia*/
95	-10	375	165	6378388.000	0.00672267002233	/*Naparima
96	-8	159	175	6378206.400	0.00676865799761	/*NAD 27-Western US*/
97	-9	161	179	6378206.400	0.00676865799761	/*NAD 27-Eastern US*/
98	-5	135	172	6378206.400	0.00676865799761	/*NAD 27-Alaska*/
99	-4	154	178	6378206.400	0.00676865799761	/*NAD 27-Bahamas*/
100	1	140	165	6378206.4	0.00676865799761	/*NAD 27-San Salvador*/
101	-10	158	187	6378206.4	0.00676865799761	/*NAD 27-Canada*/
102	-7	162	188	6378206.4	0.00676865799761	/*NAD 27-Alberta/BC*/
103	-22	160	190	6378206.4	0.00676865799761	/*NAD 27-East Canada*/
104	-9	157	184	6378206.4	0.00676865799761	/*NAD 27-Manitoba/Ont*/
105	4	159	188	6378206.4	0.00676865799761	/*NAD 27-NW Ter/Sask*/
106	-7	139	181	6378206.4	0.00676865799761	/*NAD 27-Yukon*/
107	0	125	201	6378206.4	0.00676865799761	/*NAD 27-Canal Zone*/

Table A-85. Datums (Continued)

Index	DX	DY	DZ	A-axis	Eccentricity	Description
108	-3	143	183	6378206.4	0.00676865799761	/*NAD 27-Caribbean*/
109	0	125	194	6378206.4	0.00676865799761	/*NAD 27-Central Amer*/
110	-9	152	178	6378206.4	0.00676865799761	/*NAD 27-Cuba*/
111	11	114	195	6378206.4	0.00676865799761	/*NAD 27-Greenland*/
112	-12	130	190	6378206.4	0.00676865799761	/*NAD 27-Mexico*/
113	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Alaska*/
114	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Canada*/
115	0	0	0	6378137.0	0.00669438002290	/*NAD 83-CONUS*/
116	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Mex/Cent Am*/
117	-425	-169	81	6378388.0	0.00672267002233	/*Observatorio 1966*/
118	-130	110	-13	6378200.0	0.00669342162297	/*Old Egyptian 1907*/
119	61	-285	-181	6378206.4	0.00676865799761	/*Old Hawaiian-mean*/
120	89	-279	-183	6378206.4	0.00676865799761	/*Old Hawaiian-Hawaii*/
121	45	-290	-172	6378206.4	0.00676865799761	/*Old Hawaiian
122	65	-290	-190	6378206.4	0.00676865799761	/*Old Hawaiian
123	58	-283	-182	6378206.4	0.00676865799761	/*Old Hawaiian
124	-346	-1	224	6378249.15	0.00680351128285	/*Oman*/
125	375	-111	431	6377563.4	0.00667053999999	/*Ord Sur Brit '36-Mean*/
126	375	-111	431	6377563.4	0.00667053999999	/*OSB-England*/
127	375	-111	431	6377563.4	0.00667053999999	/*OSB-Isle of Man*/
128	375	-111	431	6377563.4	0.00667053999999	/*OSB-Scotland/ Shetland*/
129	375	-111	431	6377563.4	0.00667053999999	/*OSB-Wales*/
130	-307	-92	127	6378388.0	0.00672267002233	/*Pico De Las Nieves*/
131	-185	165	42	6378388.0	0.00672267002233	/*Pitcairn Astro 1967*/
132	16	196	93	6378388.0	0.00672267002233	/*Prov So Chilean 1963*/
133	-288	175	-376	6378388.0	0.00672267002233	/*Prov S.American 1956- Mean*/
134	-270	188	-388	6378388.0	0.00672267002233	/*Prov S.American 1956- Bolivia*/
135	-270	183	-390	6378388.0	0.00672267002233	/*Prov S.American 1956-N Chile*/
136	-305	243	-442	6378388.0	0.00672267002233	/*Prov S.American 1956-S Chile*/
137	-282	169	-371	6378388.0	0.00672267002233	/*Prov S.American 1956- Colom*/
138	-278	171	-367	6378388.0	0.00672267002233	/*Prov S.American 1956- Ecuador*/

Table A-85. Datums (Continued)

Index	DX	DY	DZ	A-axis	Eccentricity	Description
139	-298	159	-369	6378388.0	0.00672267002233	/*Prov S.American 1956-Guyana*/
140	-279	175	-379	6378388.0	0.00672267002233	/*Prov S.American 1956-Peru*/
141	-295	173	-371	6378388.0	0.00672267002233	/*Prov S.American 1956-Venez*/
142	11	72	-101	6378206.4	0.00676865799761	/*Puerto Rico*/
143	-128	-283	22	6378388.0	0.00672267002233	/*Quatar National*/
144	164	138	-189	6378388.0	0.00672267002233	/*Qornoq*/
145	-225	-65	9	6378388.0	0.00672267002233	/*Rome 1940*/
146	-203	141	53	6378388.0	0.00672267002233	/*Santa Braz*/
147	170	42	84	6378388.0	0.00672267002233	/*Santo (DOS)*/
148	-355	21	72	6378388.0	0.00672267002233	/*Sapper Hill 1943*/
149	-57	1	-41	6378160.0	0.00669454185459	/*S. American 1969-Mean*/
150	-62	-1	-37	6378160.0	0.00669454185459	/*S. American 1969-Argentina*/
151	-61	2	-48	6378160.0	0.00669454185459	/*S. American 1969-Bolivia*/
152	-60	-2	-41	6378160.0	0.00669454185459	/*S. American 1969-Brazil*/
153	-75	-1	-44	6378160.0	0.00669454185459	/*S. American 1969-Chile*/
154	-44	6	-36	6378160.0	0.00669454185459	/*S. American 1969-Colombia*/
155	-48	3	-44	6378160.0	0.00669454185459	/*S. American 1969-Ecuador*/
156	-53	3	-47	6378160.0	0.00669454185459	/*S. American 1969-Guyana*/
157	-61	2	-33	6378160.0	0.00669454185459	/*S. American 1969-Paraguay*/
158	-58	0	-44	6378160.0	0.00669454185459	/*S. American 1969-Peru*/
159	-45	12	-33	6378160.0	0.00669454185459	/*S. American 1969-Trin/Tob*/
160	-45	8	-33	6378160.0	0.00669454185459	/*S. American 1969-Venezuela*/
161	7	-10	-26	6378155.0	0.00669342162297	/*South Asia*/
162	-499	-249	314	6378388.0	0.00672267002233	/*Southeast Base*/
163	-104	167	-38	6378388.0	0.00672267002233	/*Southwest Base*/
164	-689	691	-46	6377276.345	0.00663784663020	/*Timbalai 1948 */
165	-148	507	685	6377397.16	0.00667437223180	/*Tokyo-Mean*/
166	-146	507	687	6377397.16	0.00667437223180	/*Tokyo-Korea*/
167	-158	507	676	6377397.16	0.00667437223180	/*Tokyo-Okinawa*/

Table A-85. Datums (Continued)

Index	DX	DY	DZ	A-axis	Eccentricity	Description
168	-632	438	-609	6378388.0	0.00672267002233	/*Tristan Astro 1968*/
169	51	391	-36	6378249.15	0.00680351128285	/*Viti Levu 1916*/
170	102	52	-38	6378270.0	0.00672267002233	/*Wake-Eniwetok */
171	-265	120	-358	6378388.0	0.00672267002233	/*Zanderij */
172	-384	664	-48	6377397.16	0.00667437223180	/*Bukit Rimpah*/
173	-104	-129	239	6378388.0	0.00672267002233	/*Camp Area Astro*/
174	-403	684	41	6377397.16	0.00667437223180	/*Gunung Segara*/
175	-333	-222	114	6378388.0	0.00672267002233	/*Herat North*/
176	-637	-549	-203	6378388.0	0.00672267002233	/*Hu-Tzu-Shan*/
177	-189	-242	-9	6378388.0	0.00672267002233	/*Tananarive Observ. 1925*/
178	-155	171	37	6378388.0	0.00672267002233	/*Yacare*/
179	- 146.4	507.9	681.5	6377397.155	0.00667437223180	/*Tokyo GSI coords */

A.20 Reference Documents

Unless otherwise indicated the issue of each document which was in effect on 1 May 1987 is the issue to be used.

- SS-GPS-300B*** System Specification for the NAVSTAR Global Positioning System
- ICD-GPS-200*** NAVSTAR GPS Space Segment/Navigation User Interfaces
- P/N 17035*** Trimble Advanced Navigation Sensor Specification and User's Manual Rev. A October 1990
- RTCM (SC-104)*** RTCM Recommended Standards For Differential NAVSTAR GPS Service Version 2.0. RTCM Special Committee No. 104. Published by the Radio Technical Commission For Maritime Services Washington D.C. January 1 1990.
- GPS - A Guide to the Next Utility***
Trimble 1990 - an introduction in non-mathematical terms to the GPS system.

Proceedings - Institute of Navigation Washington DC

A series of 3 abstracts published between 1980 & 1986 of papers from the Journal of the Institute of Navigation. Essential source material for any system designer.

B TSIP User's Guide

The OEM GPS Tool Kit program disk includes several TSIP interface programs designed to help developer's evaluate and integrate the GPS module and create GPS and differential GPS applications. These programs run on a PC-DOS platform. They are intended as a base upon which to build application specific software, so the source code in ANSI C is included for many of these programs. The OEM GPS Tool Kit program disk includes the following programs:

- TSIPCHAT.EXE: reads TSIP reports and prints them to the screen. It also allows the user to exercise TSIP commands, by translating keystroke codes into TSIP commands which are output over the serial port. When data input is required, TSIPCHAT prompts the user for the information. TSIPCHAT can also log TSIP reports in binary format, and can set time on a PC based on time information from the GPS module. Source code is provided.
- TSIPPRNT.EXE: interprets a binary TSIP data stream, such as logged by TSIPCHAT, and prints it to a file. Source code is provided.
- RTCM_MON.EXE: monitors a serial port carrying RTCM differential corrections, translates the messages and prints them to the screen.
- TCHAT.EXE: provides a good working basis for GPS development. Source code is provided. The program is Microsoft Visual C and Borland C compatible.

This appendix provides explicit instructions for each of the programs contained in the OEM GPS Tool Kit, and guidelines for using the source code as template for integrated systems applications.



Note – The GPS Tool Kit diskette contains a self-extracting ZIP file that installs a complete developer's environment within the hard disk directory you select. Installation instructions are provided in the READ.ME file on the diskette and in Chapter 1 of this manual.

TSIPCHAT

TSIPCHAT is a program that provides full visibility into the TSIP interface. Source code is provided. The source code (dual windows) requires a BORLAND C compiler.

Starting TSIPCHAT

To start the program, type TSIPCHAT-C1 or TSIPCHAT-C2 for COM1 or COM2. the command line is: TSIPCHAT-Cx where 'x' is 1 for PC serial port COM1 or 2 for COM2. This choice can be changed while TSIPCHAT is running using the [CTRL] + [I] command.

As TSIPCHAT starts, it displays a list of commands in the upper half of the console screen (command window) and a running account of automatic (unrequested) reports in the bottom half of the screen (auto window). It also sets the serial port to the default settings of 9600 baud, 8-Odd-1.

If the receiver is alive and outputting positions, position reports scroll immediately in the auto window. If the auto window is empty, type 'v' to test if the receiver is connected properly to the computer. If the serial port is properly connected, the receiver responds within a second with the receiver software version numbers; otherwise "waiting for reply" remains on the screen.

Report Packets

When a TSIP report packet is issued by the receiver, it is received by TSIPCHAT, translated into a printable form and put on the screen. If the report packet has been specifically requested by a command, it is put in the command (upper) window; otherwise, it is reported in the auto (lower) window.

The common automatic reports are the navigation reports: position, velocity, and health data. The [CTRL] + [O] command can change the content of these auto-reports or turn them on and off. Other automatic reports include almanac, ephemeris status, and almanac health page when decoded; and receiver health, machine code status, and satellite selection at regular intervals.

Command Packets

TSIPCHAT uses keystroke codes to send TSIP Packet packets to the receiver. For instance, the keystroke [v] sends the TSIP Packet 0x1F, requesting a TSIP Report Packet 0x45 listing the software versions. A complete list of keystrokes and their associated TSIP commands can be called up by pressing the [?] key.

Many TSIP command packets require user-provided data or parameters. For instance, a request for a satellite almanac report packet requires the satellite identifier (SV PRN). In such cases, TSIPCHAT will prompt the user for inputs. For any of the following three type of prompts, pressing the [CTRL] + [Z] keys or [ESCAPE] key aborts the whole command:

1. prompt for number: to enter a numerical value, type the value and hit [ENTER]. If no value is typed, the value entered will be 0.
2. prompt for selection: to select from a number of choices, cycle through the choices with the [SPACE{BAR] and select with [ENTER]. An index 0 - 9 associated with the choice is shown in parentheses; this index can be typed in for direct access of the choice.
3. prompt for confirmation: to confirm when asked, type [y] or [y]'. Any other keystroke will be 'negative', including just the [ENTER] key.

TSerial Port Control

To control the serial port settings on the data channel, Channel A of the Lassen-SK8, use the TSIP 0 x BB command.

To control the serial port settings on the computer, use the keystroke [CTRL] + [I] keys. This keystroke does not generate a TSIP packet, it prompts for the parameters for the buffered serial port. On start-up, the program automatically sets the port parameters to 9600 baud, 8-odd-1. If the port parameters are changed from the default during the execution of TSIPCHAT, upon exit the program asks if the serial port is to be reset to the default.

File Storage

TSIPCHAT provides for file storage of a native binary TSIP stream. The native binary stream records the data coming off the serial port into a file. To turn data collection on and off, use the keystroke [CTRL] + [F]'. The user has the option to append to a previously existing file. All report packet bytes are recorded into the file, whether translatable into packets or not. The exception is that using [ESCAPE] to terminate the program exits gracefully, i.e. not record the partially-received packet at the end of the file. Using the plus (+) character does not terminate gracefully and records all bytes at the end. The recorded binary data stream is translated into an ASCII file with the program TSIPPRNT.

**Quick-Start Almanac
Get and Load**

A stored almanac can allow the receiver to be “warm-started”, reducing time to first fix. If the receiver is started 'cold', with no almanac data in memory, it performs a search for satellites in the sky, which can take a few minutes. If the receiver has a recent almanac of satellite orbits, fixes begin within a minute. The receiver responds most quickly if loaded with time, frequency offset, last position, and a recent almanac. There is a command sequence for getting an almanac from the receiver and storing in a file named GPSALM.DAT, and a reverse command sequence for reading a file named GPSALM.DAT on the computer and loading it into the receiver. These command sequences use the Packet 0x38 and the Report Packet 0x58.

Use the exclamation point (!) for the get-and-store sequence, and the at symbol (@) for the read-and-load sequence'. It is useful to record a fresh almanac every few days. A new almanac is available after the receiver has been operating continuously for about fifteen minutes. Check the health message to see that “Almanac not complete and current” is no longer reported before recording the almanac.

**Setting PC Time from
the Receiver**

TSIPCHAT includes the capability to set the PC clock to UTC time from the GPS satellite signal. (GPS time differs from UTC time by leap seconds.) The keystroke 'z' requests a time set Packet 0x21, Report Packet 0x41). The first time the request is made during execution of the program, the user is prompted for the local time zone offset. The user time zone offset is '0' for UTC/GMT; -5 for EST, -4 for EDT; -8 for PST, -7 for PDT; and positive numbers if ahead of (east of) GMT. Allowable range is 13 hours, plus or minus. The accuracy of this software method is approximately ± 0.5 seconds.

Exiting TSIPCHAT

To exit the program, hit the [EXCAPE] key.

TSIPPRNT

TSIPPRNT translates TSIP report packet byte streams into readable reports. It uses the same report interface routines as TSIPCHAT, but uses 'printf' rather than 'cprintf' so that output can be redirected to a file.

The command line for console output is:

```
TSIPPRNT tsip_filename
```

where *tsip_filename* is the name of a stream of TSIP report packets collected directly from the receiver output port or from TSIPCHAT. The command line for re-directing output to a file is:

```
TSIPPRNT tsip_filename > ascii_filename
```

Full source code is provided. TSIPPRNT is created by compiling under any C compiler with the macro FILE_INPUT defined (BORLAND and PORT_INPUT *not* defined) and with the include file TSIPINCL.H. The following routines must be compiled:

TSIPPRNT.C (main)

TSIP_RPT.C

TSIP_IFC.C

TSIPPRNT code can be easily modified by the user to supply any ASCII output file format that is required by adjusting the report interpreter routines in TSIP_RPT.C, provided the necessary information is contained in the binary input file. Software flow follows that of TSIPCHAT, except with no user-interactive and command features.

RTCM_MON

RTCM_MON translates RTCM SC-104 Version 2.0 (Differential GPS correction) byte streams off a serial port. It is designed to be configured to the same port parameters as the TSIP receiver. RTCM streams can best be tested by using the TSIP receiver itself as a decoder, using TSIPCHAT and the '/' command (Packet 0x65) which returns Packet 0x85 listing all differential RTCM messages decoded. RTCM_MON is provided in case the user prefers to use a direct connection to a computer serial port to decode an RTCM stream.

The RTCM_MON command line has no arguments. When listening to the serial port, characters will be printed on the screen. RTCM 6-of-8 bytes are identified by the first two bits (binary 01?????) and all other bytes are reported as non-RTCM bytes. Once the program locks onto the RTCM preamble and framing, it begins to report differential correction messages for each of the satellites.

To exit the program, press [ESCAPE].

Bit-Slipping

Even though the RTCM bytes are 6 bits of data and fit neatly into a 8-bit byte once the lead bits '01' are attached, some reference receivers do not align the RTCM data onto 8-bit boundaries for the serial link ("bit-slipping"). RTCM_MON automatically searches for bit-slipping.

Serial Port Parameters The default at start-up is 9600 baud, 8-odd-1. The serial port parameters on the computer can be adjusted by typing '^I'. The program will prompt for new serial port parameters.

TCHAT TCHAT is a simplified version of TSIPCHAT. TCHAT.C provides a good basis for GPS software development.

The command line syntax is:

```
TCHAT -c[port number] -f<optional file name>
```

where <optional file name> is the name where bytes received directly from the receiver will be collected.

Full source code is provided. Unlike TSIPCHAT TCHAT can be compiled under both Microsoft and Borland Compilers. It uses the same source code modules as TSIPCHAT. The following modules comprise TCHAT:

```
TCHAT.C (main)
TSIP_RPT.C
TSIP_IFC.C
SERIAL.C
```

Software flow follows the same as TSIPCHAT, except that the display and user interface has been greatly simplified. It is recommended that software developer's become familiar with TCHAT before studying the source code to TSIPCHAT.

C Trimble ASCII Interface Protocol (TAIP)

Trimble ASCII Interface Protocol (TAIP) is a Trimble-specified digital communication interface based on printable ASCII characters over a serial data link. TAIP was designed specifically for vehicle tracking applications but has become common in a number of other applications because of its ease of use. TAIP supports both scheduled and polled responses.

TAIP messages may be scheduled for output at a user specified rate starting on a given epoch from top of the hour. For communication robustness, the protocol optionally supports checksums on all messages. It also provides the user with the option of tagging all messages with the unit's user specified identification number (ID). This greatly enhances the functional capability of the unit in a network environment.

Additionally, given the printable ASCII format of all communication, TAIP is ideal for use with mobile data terminals, seven bit modems and portable computers. Although, sensors incorporating this protocol are shipped from the factory with a specific serial port setting, the port characteristics are fully programmable through TAIP messages.

This appendix is designed for easy reference to TAIP message formats and describes all the TAIP messages defined at the time of printing. Some of the defined TAIP messages are not supported by the Lassen-SK8 receiver. The Lassen-SK8 supports the following TAIP messages:

Lassen-SK8 supported TAIP messages include:

AL Altitude/Up Velocity	PR Protocol
AM Alarm	PT Port Characteristic
AP Auxiliary Port Characteristic	PV Position/Velocity Solution
CP Compact Position Solution	RM Reporting Mode
DC Differential Corrections	RT Reset Mode
DD Delta Differential Corrections	ST Status
ID Identification Number	TM Time/Date
IP Initial Position	VR Version Number
LN Long Navigation Message	

C.1 Message Format

All TAIP communication uses printable, uppercase ASCII characters. The interface provides the means to configure the unit to output various sentences in response to queries or on a scheduled basis. Each sentence has the following general format:

$$ABB\{C\}[\ ;ID=DDDD][\ ;*FF]<$$

where:

Table C-1. Message Formats

>	Start of new message
A	Message qualifier
BB	a two character message identifier
C	data string
DDDD	Optional 4 character vehicle ID
FF	Optional 2 character checksum
<	delimiting character
{x}	signifies that x can occur any number of times.
[x]	signifies that x may optionally occur once.

C.1.1 Start of a New Message

The > character (ASCII code 62 decimal) is used to specify the start of a new sentence.

C.1.2 Message Qualifier

A one character message qualifier is used to describe the action to be taken on the message. The following table lists the valid qualifiers.

Table C-2 Message Format Qualifiers

Qualifier	Action
Q	Query for a single sentence (sent to GPS sensor).
R	Response to a query or a scheduled report (from the sensor)
F	Schedule reporting frequency interval in seconds
S	Set command to download time to the GPS receiver
D	Specify a minimum distance traveled and a minimum and maximum time interval for the next report

Details on the use of message qualifiers are given in the last section of this appendix, *Communication Using TAIP*.



Note – All TAIP message characters must be in uppercase.

C.1.3 Message Identifier

A unique two character message identifier consisting of alphabetical characters is used to identify type messages. For example: PR for Protocol or VR for Version Number.

C.1.4 Data String

The format and length of a data string is dictated by the message qualifier and the message identifier. The data string may contain any printable ASCII character with the exception of the >, <, and ; characters. Detailed descriptions of each message format are provided in the specific message sections of this Appendix. Most messages are length sensitive and unless otherwise specified, field separators, including spaces are not used.

C.1.5 Vehicle ID

A vehicle identification(ID) may optionally be used in all the communications with the sensor. Each sensor in the fleet may be assigned a four character alpha-numeric ID and be forced to output that ID in all messages. The default is: ID set to 0000 and the ID Flag set to F (false).

The sensor will check all incoming messages for ID. If no ID is specified, the sensor will accept the message. If the ID is included in messages but does not compare with the ID previously set, the message will be ignored. This applies even when the ID Flag is turned off.

C.1.6 Checksum

The checksum field provides for an optional two digit hex checksum value, which is computed as XOR of *all characters* from the beginning of the sentence up to and including the * character. If provided, the checksum is always the last element of the sentence before the message delimiter. The default mode of operation is to include checksum in sentences. The use of checksums can help in instances where the communication channel is noisy.

Example:

The following message to set the vehicle ID flag on includes checksum.

```
>SRM; ID_FLAG=T; *6F<
```

The checksum (6F) was generated by XOR'ing the ASCII codes for > and S then XOR'ing that result with the ASCII code for R and so forth, up to and including the * character.

C.1.7 Message Delimiter

The < character signifies end of a sentence and is used as the message delimiter.

C.2 Sample PV Message

The Position/Velocity Solution (PV) message is one of the more commonly used TAIP messages and most sensors using TAIP are set by default to output the PV message once every 5 seconds.

The following analysis of a typical PV message is provided to further explain the TAIP message protocol.

```
>RPV15714+3739438-1220384601512612;ID=1234;*7F<
```

Table C-3. Time and Distance Reporting Message Format Qualifiers

ID	Meaning
>	Start of Message Delimiter
R	Response Qualifier
PV	PV message Identifier
15714	GPS Time of Day
+3739438	Latitude
-12203846	Longitude
015	Speed
126	Heading
1	Source of Data
2	Age of Data
;ID=1234	Vehicle ID
*7F	Checksum
<	End of Message Delimiter



Note – Refer to the discussion of the PV message data string for more detail on how this message is interpreted.

C.3 Time and Distance Reporting

The “D message qualifier allows you to specify a minimum distance traveled as well as a minimum and maximum time interval for the next report. Units that are stationed at a fixed location can be programmed to report only when the unit moves “off station or after a certain elapsed time since last report, but no more often than the specified minimum time interval.

The message format used with the D qualifier is shown below:

```
>DAABBBBCCCCEEEEFFFF [ ; ID=GGGG ] [ ; *HH ] <
```

Table C-4. Time and Distance Reporting Message Format Qualifiers

ID	Meaning
>	start of message delimiter
D	the Distance message qualifier
AA	message to report (i.e. PV means Position Velocity message)
BBBB	minimum time (seconds) interval between reports ($T_{interval}$)
CCCC	report epoch (number of seconds from top of the hour)
EEEE	delta distance (meters) from last reported distance
FFFF	maximum time (seconds) interval between reports (T_{max})
GGGG	optional vehicle identification number (user selected)
HH	optional checksum
<	End of message delimiter



Note – If BBBB = 0, then the message output is disabled. If FFFF = 0, maximum time feature is disabled (the unit will only report if current position is greater than or equal to the delta distance specified in EEEE).

Example:

When the message: >DPV0030000505000900;ID=0105< is sent to the GPS receiver, it specifies that vehicle number 105 ($GGGG = 0105$) is to report the Position Velocity message ($AA = PV$) whenever its current position differs from the previously reported position by at least 500 meters ($EEEE = 0500$), but no more often than every 30 seconds ($BBBB = 0030$) or less often than every 15 minutes ($FFFF = 0900$ seconds). The minimum and maximum time-out reports are to be issued with a 5 second offset ($CCCC = 0005$) from the top of the hour. The optional checksum was not used in this example. The square brackets, [...], shown in the format description above are used to indicate optional data. The brackets themselves are never included in the actual TAIP message string.

The D message qualifier was designed by Trimble for use by Ambulance Companies to limit communication traffic between mobile units and the base when the ambulances are stationary on-station. When the ambulance has reached its stationary dispatch site, the operator signals the base by voice or by pushing a button on a Mobile Data Terminal (MDT) signifying that the unit is now on station. Once this communication is made, the base operator issues a D qualifier and message so that the ambulance will only report either when it moves off-station or at specific reporting intervals.

C.4 Latitude and Longitude Conversion

The TAIP protocol reports latitude as positive north decimal degrees and longitude as positive east decimal degrees, using the WGS-84 datum. For your application, you may wish to convert to degrees, minutes and seconds. The following example illustrates the conversion of decimal degrees to degrees, minutes and seconds.

Example:

Given latitude and longitude in decimal degrees,

Latitude:	+37.39438 degrees
Longitude:	-122.03846 degrees

Convert latitude by multiplying the decimal fraction of degrees by 60 to convert to minutes

$$0.39438 \times 60 = 23.6628 \text{ minutes}$$

Retain the integer (23) portion as the minutes then multiply the decimal fraction by 60 to convert to seconds,

$$0.6628 \times 60 = 39.768 \text{ seconds}$$

Since the sign of the latitude in this example is positive the result is:

$$\text{Latitude: N } 37^{\circ} 23' 39.77''$$

The longitude is converted in the same fashion:

$$\text{Longitude: W } 122^{\circ} 02' 18.46''$$

Note – At the earth's equator, one degree of latitude and longitude represents 68.7 miles; therefore, 0.00001 degrees represents approximately 3.6 feet or 1.1 meters. Each second represents approximately 100.76 ft. (30.7 m).

C.5 Message Data Strings

The following table lists all the TAIP messages currently defined and comments regarding their application:

Table C-5. Message Data String Descriptions

Identifier	Message Name
AL	Altitude/Vertical Velocity
AP	Auxiliary Port Characteristic
CP	Compact Position Solution
DC	Differential Corrections
DD	Delta Differential Corrections
ID	Vehicle ID
IP	Initial Position
LN	Long Navigation Message
PR	Protocol
PT	Port Characteristic
PV	Position/Velocity Solution
RM	Reporting Mode
RT	Reset
ST	Status
TM	Time/Date
VR	Version Number

The data string format of each message is described in the following pages.



Note – The Trimble GPS sensor may not support all the message types. Please refer to page 1 of this appendix for a list of the messages your sensor supports.



Note – All TAIP message characters must be in uppercase.

C.6 AL Altitude/Up Velocity

Data String Format:

AAAAABBBBBBCCCCDE

Table C-6. Altitude/Up Velocity Data String Descriptions

Item	# of Char	UNITS	Format	Value
GPS Time of day	5	Sec	AAAAA	
Altitude	6	Meter	BBBBBB	
Vertical Velocity	4	MPH	CCCC	
Source	1	n/a	D	0 = 2D GPS
				1 = 3D GPS
				2 = 2D DGPS
				3 = 3D DGPS
				6 = DR
				8 = Degraded DR
				9 = Unknown
Age of Data Indicator	1	n/a	E	2 = Fresh, <10 seconds
				1 = Old, >10 seconds
				0 = Not available
Total	17			

Altitude is above mean sea level in WGS-84. The GPS time of day is the time of fix rounded to the nearest second. This message contains data obtained from the last 3 dimensional fix and may not be current.



Note – The data in this message is to be considered invalid and should not be used, if the Age of Data Indicator is equal to 0 (signifying data not available).

C.7 AM Alarm

Lassen-SK8 does not support this TAIP message.

C.8 AP Auxiliary Port Characteristic

Data String Format:

AAAA, B, C, D, E, F

Table C-7. Auxiliary Port Characteristics Data String Descriptions

Item	# of Char	UNITS	Format	(Value)
Baud Rate	4	n/a	AAAA	9600, 4800, 2400, 1200, or 0300
# of data bits	1	n/a	B	7 or 8
# of stop bits	1	n/a	C	1 or 2
Parity	1	n/a	D	N = None
				O = Odd
				E = Even
Auxiliary Port Number	1	n/a	E	1
Reserved	1	n/a	F	0
Total	9	including commas		

This message defines the characteristics for the auxiliary port. The auxiliary port must be the RTCM input port on differential ready sensors.

The default settings of the auxiliary port are 4800 baud, 8 data bits, parity none, and 1 stop bit.

Example:

The following command will set the auxiliary port characteristics to 2400 baud, 8 data bits, 1 stop bit and no parity.

```
>SAP2400,8,1,N,1,0<
```



Note – See the inclusion of 0 in the reserved field



Note – The AP command applies only to receivers with dual serial ports.



Note – The AP command requires commas between data fields.

C.9 CP Compact Position Solution

Data String Format:

AAAAABBBCCCCDDDEEEFFG

Table C-8. Compact Position Solutions Data String Descriptions

Item	# of Char	UNITS	Format	(Value)
GPS Time of day	5	Sec	AAAAA	
Latitude	7	Deg	BBBCCCC	
Longitude	8	Deg	DDDEEEEE	
Source	1	n/a	F	0 = 2D GPS
				1 = 3D GPS
				2 = 2D DGPS
				3 = 3D DGPS
				6 = DR
				8 = Degraded DR
				9 = Unknown
Age of Data Indicator	1	n/a	G	2 = Fresh, <10 sec
				1 = Old, >10 sec
				0 = Not available
Total	22			

Position is in latitude (positive north) and longitude (positive east) WGS-84. The GPS time of day is the time of fix rounded to the nearest second.



Note – The data in this message is to be considered invalid and should not be used, if the Age of Data Indicator is equal to 0 (signifying data not available).DC Differential Corrections

This message provides the sensor with differential corrections from RTCM-104 record types 1 and 9. The values are numerical values written out in hex format, thus for each byte of data there is a two digit hex number.

The format of the data string is as follows:

AAAABBCC{DDEEEFFGG}

Table C-9. RTCM-104 Record Types 1 and 9 Data String Descriptions

Item	# of Char	Type	UNITS	Format
Modified Z-count	4	WORD	.6 sec	AAAA
Station health	2	BYTE	n/a	BB
Number of SVs	2	BYTE	n/a	CC
The next 5 bytes (10 characters) are repeated for each SV				
SV PRN & health				
(UDRE)	2	BYTE	n/a	DD
Range Correction	4	WORD	RTCM-104	EEEE
Range-rate correction	2	BYTE	RTCM-104	FF
IODE	2	BYTE	n/a	GG

The units and scale factors are as defined by RTCM-104 version 1. The SV PRN and health contains the SV PRN in the lower 5 bits and the health/UDRE/scale factor in the upper 3 bits. Range corrections are scaled by 0.02 meters times 2 raised to the health power. Range-rate corrections are scaled by 0.002 meters per second times 2 raised to the health power.



Note – The DC and DD TAIP messages described herein apply only to differential ready sensors and are provided to enclose differential corrections within the TAIP format.

Use of DC and DD messages to input corrections requires only one communications channel. Use of the auxiliary port to input RTCM-104 corrections assumes a separate communications channel is available for broadcast and receipt of differential corrections.

The TAIP software toolkit, GPSSK, does not support DC and DD messages.

C.10 DC Differential Corrections

The DC message provides the sensor with differential corrections from type-1 and type-9 RTCM-104 records. The numerical are written out in hex format producing a two digit hex number for each data byte.

Data String Format:

```
AAAABBCC{DDEEEFFGG}
```

Table C-10. Delta Differential Corrections Data String Descriptions

Item	# of Char	Type	UNITS	Format
Modified Z-count	4	WORD	.6 sec	AAAA
Station health	2	BYTE	N/A	BB
Number of SVs	2	BYTE	N/A	CC
The next five bytes (10 characters) are repeated for each SV.				
SV PRN & scale factor	2	BYTE	n/a	DD
Range correction	4	WORD	RTCM-104	EEEE
Range-rate correction	2	BYTE	RTCM-104	FF
IODE	2	BYTE	n/a	GG

Units and scale factors are defined by RTCM-104, version 2. The SV PRN and scale factor contains the SV PRN in the lower 5 bits and the scale factor in the higher 3 bits. The scale factor has only three acceptable values:

- 0 - Use with low scale factor
- 4 - Use with high scale factor
- 7 - Do not use

Range corrections are scaled by 0.02 meters for low scale factor and 0.32 m/sec for high scale factor.



Note – DC and DD TAIP messages are used to enclose differential corrections within the TAIP format.



Note – DC and DD messages used to input corrections require only one communications channel. When the auxiliary port is used to input RTCM 104 corrections, it assumes a separate communications channel is available for broadcast and receipt of differential corrections.



Note – The TAIP Software Toolkit does not support DC and DD messages.

C.11 DD Delta Differential Corrections

This message provides the sensor with delta differential corrections from RTCM-104 record type 2. The values are numerical values written out in hex format, thus for each byte of data there is a two digit hex number.

The format of the data string is as follows:

AAAABB{CCDDDD}

Table C-11. Delta Differential Corrections Data String Descriptions

Item	# of Char	Type	UNITS	Format
Modified Z-count	4	WORD	.6 sec	AAAA
Number of SVs	2	BYTE	n/a	BB
The next 3 bytes (6 characters) are repeated for each SV				
SV PRN	2	BYTE	n/a	CC
Delta Range Correction	4	WORD	RTCM-104	DDDD



Note – The units and scale factors are as defined by RTCM-104 version 1. The health/UDRE/scale factor given for the specific SV in the most recent message DC is used. Delta range corrections are scaled by 0.02 meters times 2 raised to the health power.

The DC and DD TAIP messages described herein apply only to differential ready sensors and are provided to enclose differential corrections within the TAIP format.

Use of DC and DD messages to input corrections requires only one communications channel. Use of the auxiliary port to input RTCM-104 corrections assumes a separate communications channel is available for broadcast and receipt of differential corrections.

Note – The TAIP software toolkit, GPSSK, does not support DC and DD messages.

C.12 ID Identification Number

Data String Format:

AAAA

Table C-12. Identification Number Data String Descriptions

Item	# of Char	UNITS	Format
Vehicle ID	4	n/a	AAAA
Total	4		

This message is used to report or set the vehicle's (or sensor's) unique, four character, alpha-numeric, user assigned ID. The default at cold start is 0000.

Example:

The following message will set the vehicle ID to 101.

```
>SID0101<
```

The following is simply a response to a query for vehicle ID.

```
>RID0101<
```



Note – The sensor will always check incoming messages for ID and compare with the vehicle ID set in the sensor's memory. If no ID is included in the message, the sensor will assume a match and accept the message. If the message sent to the sensor does contain a vehicle ID but that ID does not match the ID previously set in the sensor, the message will be ignored. This process is followed even when the ID_Flag is turned off (refer to the message RM).

C.13 IP Initial Position

Data String Format:

AAABBBBCCCC

Table C-13. Initial Position Data String Descriptions

Item	# of Char	UNITS	Format
Initial Latitude	3	Deg	AAA
Initial Longitude	4	Deg	BBBB
Initial Altitude	5	10 Meters	CCCCC
Total	12		

This is a very coarse initial position that the user can provide to aid the sensor in obtaining its first fix. This is specially useful with sensors that do not have non-volatile (Battery Backed-up) memory. In such cases, every time the unit is powered up, it goes through a complete cold-start and it has absolutely no knowledge of where it is. Providing this message improves performance by decreasing the time to first fix and enhances the accuracy of the initial two dimensional navigation solutions by providing a reference altitude. In case of units with non-volatile memory, sending this message is only helpful if the unit has moved more than 1,000 miles since its previous fix. In either case, the sensor can initialize itself appropriately without any data from the user; It merely requires more time.



Note – For all the above values, the first character specifies the sign (+/-).

Example:

The following message will set the initial position to 37⁰ North, 122⁰ West, altitude 10 meters.

```
>SIP+37-122+0001<
```

C.14 LN Long Navigation Message

Data String Format:

AAAAABBBCCDDDDDDDEEEEEFFFFFFFGGGGGGHHII IJK
 KKKLMMMNOOPPQQPPQQ . . . PPQQRRRRRRRRRRRST

Table C-14. Long Navigation Message Data String Descriptions

Item	# of Char	UNITS	Format	Value
GPS Time of day	8	Sec	AAAAA.BBB	
Latitude	10	Deg	CCC.DDDDDDD	
Longitude	11	Deg	EEEE.FFFFFFF	
Altitude above MSL	9	Ft	GGGGGGG.HH	
Horizontal Speed	4	MPH	III.J	
Vertical Speed	5	MPH	KKKK.L	
Heading	4	Deg	MMM.N	
Number of SVs used	2	n/a	OO	
SV Id (See note)	2	n/a	PP	
IODE (See note)	2	n/a	QQ	
Reserved	10	n/a	RRRRRRRRRR	
Source	1	n/a	S	0 = 2D GPS
				1 = 3D GPS
				2 = 2D DGPS
				3 = 3D DGPS
				6 = DR
				8 = Degraded DR
				9 = Unknown
Age of Data Indicator	1	n/a	T	2 = Fresh, <10 sec
				1 = Old, >10 sec
				0 = Not available
Total	65	Plus the number of SV's used times 4		



Note – At least 2 satellites are required to get the LN Message.

Position is in latitude (positive north) and longitude (positive east) WGS-84. Heading is in degrees from True North increasing eastwardly. The GPS time of day is the time of fix rounded to the nearest second.



Note – The data in this message is to be considered invalid and should not be used, if the Age of Data Indicator is equal to 0 (signifying data not available).

C.15 PR Protocol

The protocol message (PR) is the method used to control which I/O protocols are active on each of the two Lassen-SK8 ports. Each protocol can be set to:

- Off
- Input Only
- Output Only
- Both Input and Output

The PR data string format is:

```
[ ;TAIP=xy ] [ ;TSIP=xy ] [ ;NMEA=xy ] [ ;RTCM=xy ]
```

Table C-15. PR Data String Descriptions

Item	# of Char	UNITS	Format	(Value)
Port 1	Protocol 1	n/a	x	T = Both in and out I = Input only O = Output only F = Off N = Not Available
Port 2	Protocol 1	n/a	y	

There are two restrictions to setting protocols.

- RTCM is input only
- TAIP cannot be running on both ports at the same time



Note – If a protocol is not implemented within the application, x and/or y will have the value N, and any set message for that protocol is ignored.

It is possible to turn off all input processing on a port. If this is done, neither TAIP nor TSIP can be used to change the active protocols. The break sequence must be used.

If you do not use battery back-up, all port characteristics will reset to the default after power is removed.

C.16 PT Port Characteristic

Data String Format:

AAAA, B, C, D

Table C-16. Port Characteristic Data String Descriptions

Item	# of Char	UNITS	Format	(Value)
Baud Rate	4	n/a	AAAA	(9600, 4800, 2400, 1200, or 0300)
# of data bits	1	n/a	B	(7 or 8)
# of stop bits	1	n/a	C	(1 or 2)
Parity	1	n/a	D	(N = None)
				(O = Odd)
				(E = Even)
Total	10	including commas		

This message defines the characteristics for the primary TAIP port.

Most TAIP using sensors use the following default port characteristics (consult the *Installation and Operator's Manual*):

- 4800 baud
- 8 data bits
- 1 stop bit
- No parity



Note – The characteristics set by this message will be stored in the sensor's memory. The Lassen-SK8 family of sensors do not include an internal battery but provide a battery back-up input line that may be used to retain memory when main power is removed.



Note – If you do not use battery back-up, all port characteristics will reset to the default after power is removed.



Note – The PT command uses commas between data fields.

C.17 PV Position/Velocity Solution

Data String Format:

AAAAABBBCCCCDDDEEEEEFFFGGGHI

Table C-17. Position/Velocity Solution Data String Descriptions

Item	# of Char	UNITS	Format	Value
GPS Time of day	5	Sec	AAAAA	
Latitude	8	Deg	BBB.CCC CC	
Longitude	9	Deg	DDDD.E EEEE	
Speed	3	MPH	FFF	
Heading	3	Deg	GGG	
Source	1	n/a	H	0 = 2D GPS
				1 = 3D GPS
				2 = 2D DGPS
				3 = 3D DGPS
				6 = DR
				8 = Degraded DR
Age of Data Indicator	1	n/a	I	2 = Fresh, <10 sec
				1 = Old, >10 sec
				0 = Not available
Total	30			

Position is in latitude (positive north) and longitude (positive east) WGS-84. Heading is in degrees from True North increasing eastwardly. The GPS time of day is the time of fix rounded to the nearest second.



Note – The data in this message is to be considered invalid and should not be used, if the Age of Data Indicator is equal to 0 (signifying data not available).

C.18 RM Reporting Mode

Data String Format:

```
[ ;ID_FLAG=A ] [ ;CS_FLAG=B ] [ ;EC_FLAG=C ] [ ;FR_FLAG=D ]
[ ;CR_FLAG=E ]
```

Table C-18. IReporting Mode Data String Descriptions

Item	# of Char	UNITS	Format	Value
ID Flag	1	n/a	A	T = True F = False
CS Flag	1	n/a	B	T = True F = False
EC Flag	1	n/a	C	T = True F = False
FR Flag	1	n/a	D	T = True F = False
CR Flag	1	n/a	E	T = True F = False

ID Flag determines whether the unit is to include the vehicles ID with each report.

CS Flag determines whether the unit is to include a checksum as part of each message.

EC Flag, when set, will cause the unit to echo back all complete and properly formatted set commands, except for DC and DD, with a “Response qualifier. This provides an easy way to verify that the unit did in fact receive the intended data.

FR Flag indicates whether the unit is to report messages automatically per their individually scheduled frequency. When set to false, the unit will only respond when queried for a specific message.

CR Flag, when set to True, will cause the sensor to append a carriage return and line feed [CR] [LF] to the end of each message output. This is useful when viewing the unencoded sensor responses on a terminal or a PC.

The default value at start-up for ID flag and the CR flag is false; the default for CS, EC and FR flags is true.

Example:

The following command will turn checksums off and carriage return on:

```
>SRM;CS_FLAG=F;CR_FLAG=T<
```



Note – Note the use of semicolon before the flag name.

C.19 RT Reset Mode

Data String Format:

Any one of the following data strings can be set. Upper case characters are required.

[]
 [COLD]
 [FACTORY]
 [SAVE_CONFIG]

Table C-19. Reset Mode Data String Descriptions

Item	# of Char	Description
[]	0	Warm start
[COLD]	4	Cold start
[FACTORY]	7	Factory Reset
[SAVE_CONFIG]	15	Save serial EEPROM user values

The only valid qualifier is SET.

The SAVE_CONFIG data string is the only method of saving the TAIP protocol definition to Serial EEPROM.

The following command will save the protocol and port definitions to Serial EEPROM:

```
>SRTSAVE_CONFIG<
```

C.20 ST Status

Data String Format:

AABCDDEFGG



Note – This message provides information about the satellite tracking status and the operational health of the sensor. This information is contained in five status bytes which are output as five 2 digit hexadecimal values. The data format and the meanings of the hex characters are given in the following tables.

Table C-20. Data String Hex Characters

Item	# of Char	UNITS	Format	
Tracking Status Code	2	n/a	AA	(see table below)
Status Codes - Nibble 1	1	n/a	B	(see table below)
Status Codes - Nibble 2	1	n/a	C	(see table below)
Machine ID	2	n/a	DD	
Status Codes - Nibble 3	1	n/a	E	not currently used
Status Codes - Nibble 4	1	n/a	F	see table below
reserved	2	n/a	GG	not currently used

Table C-21. Tracking Status Code

Value	AA Meaning
00	Doing position fixes
01	Don't have GPS time yet
02	Not used
03	PDOP is too high
08	No usable satellites
09	Only 1 usable satellite
0A	Only 2 usable satellites
0B	Only 3 usable satellites
0C	6-Ch units only: the chosen satellite is unusable.



Note – In the tables below, an X in a column means that fault is being reported.

Table C-22. Error Codes: Nibble 1

Value of B	Definition		Notes
	Antenna Feedline fault Open or Short. See note	Excessive reference frequency error	
0			No problems Reported
1		X	
2	X		
3	X	X	

Table C-23. Error codes: Nibble 2

Value of C	Definition			
	Battery back-up Failed See note	Signal processor Error. See note	Alignment Error, Channel or Chip 1. See note	Alignment Error, Channel or Chip 2. See note
0	No problems reported			
1				X
2			X	
3			X	X
4		X		
5		X		X
6		X	X	
7		X	X	X
8	X			
9	X			X
A	X		X	
B	X		X	X
C	X	X		
D	X	X		X
E	X	X	X	
F	X	X	X	X

Table C-24. Error Codes – Nibble 4

Value of F	Definition			
	Synthesizer Fault	Battery Powered Timer/Clock Fault	A-to-D Converter Fault	Stored Almanac is not Complete or Current
0	No problems reported			
1				X
2			X	
3			X	X
4		X		
5		X		X
6		X	X	
7		X	X	X
8	X			
9	X			X
A	X		X	
B	X		X	X
C	X	X		
D	X	X		X
E	X	X	X	
F	X	X	X	X



Note – After this error is detected, its bit remains set until the sensor is reset.



Note – This bit is 1 if the last computed reference frequency error indicated that the reference oscillator is out of tolerance.

C.21 TM Time/Date

Data String Format:

AABBCCDDDEEFFGGGGHHIJKLLLLL

Table C-25. TM Time/Data Data String Descriptions

Item	# of Char	UNITS	Format	(Value)
Hours	2	Hour	AA	
Minutes	2	Min	BB	
Seconds	5	Sec	CC.DDD	
Date; Day	2	Day	EE	
Date; Month	2	Month	FF	
Date; Year	4	Year	GGGG	
GPS/UTC Time Offset	2	Sec	HH	
Current Fix Source	1	n/a	I	0 = 2D GPS
				1 = 3D GPS
				2 = 2D DGPS
				3 = 3D DGPS
				6 = DR
				8 = Degraded DR
				9 = Unknown
Number of Usable SVs	2	n/a	JJ	
GPS/UTC Offset Flag	1	n/a	K	(1 = Valid)
				(0 = Invalid)
Reserved	5	n/a	LLLLL	
Total	28			

This message outputs the time and date as computed by the GPS sensor. The time is most accurate when the unit is doing fixes. It is less accurate but still usable when the unit is not doing fixes but the Number of Usable SVs is one or more.



Note – GPS/UTC Time Offset is the difference between GPS and UTC time standards in seconds. The UTC time of Day is only valid if the GPS/UTC Offset Valid Flag is indicating valid.

The TM message is supported under the Set qualifier which allows you to download time to a GPS receiver that does not have a real-time clock.

The format for using the S qualifier with the TM message is:

>STMAABBCCDDDEEFFFGGGGGGGGGGG<

Where:

>	Start of message delimiter
S	Set message qualifier
TM	Time message identifier
AA	Hours, UTC time of day
BB	Minutes, UTC time of day
CCCC	Seconds, UTC time of day to three decimal places
DD	Day
EE	Month
FFFF	Year
GGGGGGGGGG	Reserved (fill with zeros)
<	End of message delimiter

Fields AA through GGGG must be downloaded but the remaining fields may be filled with zeros (0) to create a total data stream of 28 characters. For warm-start performance, downloaded time must only be accurate to ± 5 minutes so the entire field may be filled with zeros. However if you wish to specify seconds, use a format such as 08150 to represent 8.15 seconds. The reserved field, GGGGGGGGGG, should be filled with zeros.

Example:

When the >STM1925000002806199400000000000< message is sent to the GPS receiver, it specifies that the receiver should set its internal time to 19:25 (7:25 PM) UTC, 28 June 1994. The time downloaded to the receiver should be accurate to ± 5 minutes (use UTC, not local time) for optimum warm start or hot start acquisition.

C.22 VR Version Number

Data String Format:

XXXXXXXX;VERSION A.AA(BB/BB/BB); CORE VERSION C.CC (DD/DD/DD); E

Table C-26. Version Number Data String Descriptions

Item	# of Char	UNITS	Format
Product Name	n/a	n/a	n/a
Major Version number	4	n/a	A.AA
Major Release Date	8	n/a	BB/BB/BB

C.23 Communication Using TAIP

Communication with the unit takes place in four different ways. Message qualifiers are used to differentiate between these.

C.23.1 Query for Single Sentence

The query(Q) message qualifier is used to query the GPS sensor to respond immediately with a specific message. The format is:

```
>QAA[ ; ID=BBBB ] [ ; *CC ] <
```

where AA is the requested message identifier. Messages supported by this qualifier are AL, AM, AP, CP, ID, IP, LN, PT, PV, RM, ST, TM, VR, and X1.

Scheduled reporting frequency interval

The scheduled reporting frequency interval(F) message qualifier is used to tell the unit how often and when to report a specific message. The format is:

```
>FAABBBBCCCC [ ; ID=DDDD ] [ ; *FF ] <
```

where sending this sentence tells the unit to report message specified by the two digit identifier AA at the time interval of BBBB seconds with time epoch at CCCC seconds from top of the hour. Specifying time interval of 0000 stops scheduled reporting of the message. The default is 0000 time interval for all messages except PV. The output frequency for PV at cold-start is set at once every five seconds, zero seconds from top of the hour. Messages supported by this qualifier are AL, AM, AP, CP, ID, IP, LN, PT, PV, RM, ST, TM, VR, and X1.



Note – The data specified by this qualifier is the timing of the message output and may be different from the time tag of the data in the message.

C.23.2 The Response to Query or Scheduled Report

The response(R) qualifier carry various types of data between the unit and the user equipment. The format is:

```
>RAA[ {B} ] [ ; ID=CCCC ] [ ; *DD ] <
```

where AA is the two character message identifier and {B} specifies the data string within the message. For the format of {B}, please refer to the message definitions in the previous section. Messages supported by the response qualifier are AL, AM, AP, CP, ID, IP, LN, PT, PV, RM, ST, TM, VR, and X1.

C.23.3 The Set Qualifier

The set (S) qualifier enables the user equipment to initialize/set-up various types of data in the GPS unit. The format is:

```
>SAA[ {B} ] [ ; ID=CCCC ] [ ; *DD ] <
```

where AA is the two character message identifier and {B} specifies the data string within the message. For the format of {B}, please refer to the message definitions in the previous section. Note that all the messages have very specific formats and are length dependent. Messages normally supported by the set qualifier are AL, AP, CP, DC, DD, ID, IP, LN, PT, PV, RM and TM (the Placer GPS/DR does not support the set qualifier for the AP message).

The set qualifier may be used with the AL, CP, LN, or PV message to set more precise initial position data into the GPS sensor than can be set with the IP message.

C.23.4 Sample Communication Session

The following is a sample communication session to illustrate how message qualifiers are used. Query the sensor for version number for the TAIP firmware:

```
>QVR<
```

The sensor responds with a message in the following form:

```
>RVR OEM SK8 OEM STTP APP; VERSION 7.52 (05/23/97); *38<
```



Note – The sensor identified its product name, firmware version number, core signal processing version number, and release dates, then included the checksum for the message (the default for the CS Flag is TRUE). Also notice that the sensor did respond to our query even though we did not send a checksum.

Query the sensor for its ID number:

```
>QID<
```

The sensor will respond (assuming factory default settings):

```
>RID0000; *70<
```

Set the ID to match the number for a vehicle in your fleet and then tell the sensor to include the Vehicle ID in its responses:

```
>SID1234<
```

```
>SRM; ID_FLAG=T<
```

Most Placer family sensors are set by default to report the PV message once every 5 seconds. To schedule the PV message from vehicle 1234 to respond once every 10 seconds, starting at 5 seconds after the top of the hour, use the following command:

```
>FPV00100005;ID=1234<
```

The sensor will check the ID included in the message for a match with its own and then reschedule the PV message. At the next scheduled time, the sensor will respond with:

```
>RPV15714+3739438-1220384601512612;ID=1234;*7F<
```



Note – The time given in the message is the time of the last GPS fix (04:21:54 GPS), not necessarily the time of the message response. If the time of last fix is 10 or more seconds old, the age flag will be set to 1.

D GPSSK User's Guide (TAIP)

The TAIP Tool Kit, known as GPSSK is a software package available from Trimble Navigation to assist users of the Trimble ASCII Interface Protocol (TAIP). GPSSK supports all Trimble sensors that use TAIP.

GPSSK can be used to setup, diagnose, and monitor your sensor and provides the following capabilities:

- Program the GPS sensor for automatic message reporting and verify the success of the programming.
- Quickly program Vehicle ID numbers into a fleet of sensors.
- Log the GPSSK session with the GPS sensor to disk and replay the data.
- On-screen plotting of GPS positions from the sensor.
- Poll for and view combinations of TAIP messages.
- Set different polling intervals for each message type.
- Conduct an interactive terminal session with the GPS sensor.



Note – The information about GPSSK in this document is presented as a general overview. The GPSSK distribution diskette includes a READ.ME file that details the most current information about GPSSK functions and on loading and using GPSSK.

The GPSSK program does not support the TAIP messages DC and DD. These messages are used to input differential corrections to the receiver and are defined as special TAIP format versions of RTCM SC-104 Type 1 and Type 2 messages.

The GPSSK program requires well over 500K RAM. It may not run in a DOS window, and may require removal of TSRs.

D.1 The GPSSK Files

GPSSK is included on the on 3.5 inch DOS formatted GPS Toolkit diskette. The diskette contains the following GPSSK related files:

- GPSSK.EXE The executable GPSSK program
- GPSSK.HLP The on-line, context-sensitive help file
- READ.ME Current information about GPSSK
- TAIP.C Sample source code for encoding and decoding TAIP

D.2 TAIP.C Source File

The sample source code for encoding and decoding TAIP messages is provided as a guide for the system integrator who is developing a communications controller that handles TAIP. There is no warranty of any kind on this software. Use it at your own risk.

The distribution diskette is not copy protected. Before using GPSSK or installing on your hard disk, make a working copy and put the original diskette in a safe place. During normal use, GPSSK will save configuration information to the diskette or current directory. Storing the original diskette away will allow you to restore the original configuration should you encounter problems.

Copy the files GPSSK.EXE and GPSSK.HLP to a hard disk directory.

D.3 GPSSK Start-up

At the DOS prompt in the directory containing GPSSK, enter the command:

```
GPSSK
```

When the program is finished loading into memory, the GPSSK title page will be displayed. The program will then wait for 10 seconds to begin normal execution; you may bypass the 10 second wait by pressing any key after the title page is displayed.

The function key menu will be displayed on the bottom of the screen. GPSSK is structured as a hierarchy of menus. The function keys control access to the menus.

To terminate GPSSK, simply back out of the menu structure by pressing [F9] until GPSSK prompts you to confirm your desire to exit the program.

At start-up, GPSSK will attempt to initialize itself by querying the sensor for some basic information. If you wish to abort the sensor initialization process and use GPSSK to replay stored data, enter [Ctrl] + [X] (hold down the control key and press x). If initialization has been aborted, you must restart GPSSK when you wish to communicate with the sensor.

D.4 On-line Help

Once GPSSK is running, on-line help is available to assist in performing all the GPSSK operations. Help is context sensitive and will display information regarding the current display or menu. A brief overview of GPSSK is available in the main menu's help screen.

There are several command line options available. For help with command line options, run GPSSK with the /HELP argument:

```
GPSSK /HELP
```

The help available on the GPSSK main menu will explain menu operation and the menu hierarchy.

D.5 Connecting the GPS Sensor

Consult the *Installation and Operator's Manual* for information on installation, power requirements and cables specific to your Placer family sensor.

Connect the serial port of the sensor to the computer's COM1 or COM2 port. The default serial port settings for GPSSK are:

- 4800 baud
- 8 data bits
- 1 stop bit
- no parity

These default settings match the default settings for most Placer family sensors. Consult the *Installation and Operator's Manual* for the actual default settings and type of serial port on your sensor.

If the sensor is connected to COM2, start GPSSK by entering the command:

```
GPSSK /2
```



Note – A null modem may be required when connecting the sensor to a personal computer. The serial port on your computer is a DTE port (data terminal equipment) designed to connect to a DCE port (data communications equipment). If your sensor's serial port is DTE, you must use a null modem adapter.

E NMEA 0183

NMEA 0183 is an interface protocol created by the National Marine Electronics Association. The latest release of NMEA 0183 is Version 2.1 (October 15, 1995). This protocol was originally established to allow marine navigation equipment to share information. NMEA 0183 is a simple, yet comprehensive ASCII protocol which defines both the communication interface and the data format. Since it is a well established industry standard, NMEA 0183 has also gained popularity for use in applications other than marine electronics.

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-SK8 receiver is available with firmware that supports a subset of the NMEA 0183 messages: GGA and VTG. For a nominal fee, Trimble can offer custom firmware with a different selection of messages to meet your application requirements.

This appendix provides a brief overview of the NMEA protocol and describes both the standard and optional messages offered by the Lassen-SK8.

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

E.1 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 characteristics of the NMEA 0183 data transmissions.

Table E-1. NMEA 0183 Characteristics

Signal Characteristic	NMEA Standard
Baud Rate	4800
Data Bits	8 (d7=0)
Parity	None (Disabled)
Stop Bits	1

E.2 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-SK8. 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.

E.3 NMEA 0183 Message Options

The Lassen-SK8 outputs two messages: GGA (NMEA Version 2.1) and VTG. These messages are output at a 1 second interval with the “GP” talker ID and checksums.



Note – The user can configure a custom mix of the messages listed in table C-2. See TSIP command packet BB in Appendix A for details on configuring NMEA output.

Table E-2. Lassen-SK8 NMEA Messages

Setting	Message	Description
Default	GGA	GPS Fix Data (NMEA Version 2.1)
	GLL	Geographic Position - Latitude/Longitude
	GSA	GPS DOP and Active Satellites
	GSV	GPS Satellites in View
	RMC	Recommended Minimum Specific GPS/Transit Data
Default	VTG	Track Made Good and Ground Speed
	ZDA	Time & Date

The format for each message in table C-2 is described in more detail in the next section.

E.4 NMEA 0183 Message Formats

E.4.1 GGA - GPS Fix Data

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

Table E-3. 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)

Note – The GGA message provides 3 decimal points of precision in non-differential mode and 4 decimal points of accuracy differential mode.

E.4.2 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.

```
GLL, llll.lll, a, yyyyy.yyy, a, hhmmss.s, A
```

Table E-4. 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

E.4.3 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.

```
GSA, a, x, xx, xx, xx, xx, xx, xx, xx, xx, xx, xx, xx, x.x, x.x, x.x
```

Table E-5. 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)

E.4.4 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.

```
GSV , x , x , xx , xx , xx , xxx , xx , xx , xx , xxx , xx , xx , xx , xxx , xx , xx , xx
, xxx , xx
```

Table E-6. 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

E.4.5 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.

```
RMC,hhmmss.s,A,llll.lll,a,yyyyy.yyy,a,x.x,x.x,xxxxxx,x.
x,a*hh
```

Table E-7. 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	Checksum (Mandatory for RMC)

E.4.6 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).

```
VTG,x.x,T,x.x,M,x.x,N,x.x,K
```

Table E-8. 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.

E.4.7 ZDA - Time & Date

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

ZDA, hhmms . s , xx , xx , xxxx , xx , xx

Table E-9. ZDA - Time & Date Message Parameters

Field #	Description
1	UTC
2	Day (01 to 31)
3	Month (01 to 12)
4	Year
5	Local Zone Description Hours (± 13 hours). Local zone description is the number of whole hours added to local time to obtain UTC. The zone description is always negative for eastern longitudes.
6	Local Zone Description Minutes. Local zone description minutes using the same sign convention as local zone hours.



Note – Fields #5 and #6 are null fields in the Lassen-SK8 output. A GPS receiver cannot independently identify the local time zone offsets.

F Specifications and Mechanical Drawings

The Lassen-SK8 module is designed for embedded industrial computing or control, mobile computing or data collection, precision timing, and vehicle tracking applications. This appendix includes the system specifications and mechanical drawings for the Lassen-SK8 receiver module and the miniature magnetic mount GPS antenna.

F.1 GPS Receiver

F.1.1 General

- L1 frequency (1575.42 MHz), C/A code (Standard Positioning Service), 8-channel, continuous tracking receiver, 32 correlator

F.1.2 Accuracy

- Position 25 meters CEP (50%) without SA (Selective Availability)
- Velocity 0.1 m/sec. (1 Sigma) steady state conditions (without SA)
- Time UTC to nearest microsecond with 1 pulse per second available

F.1.3 DGPS Accuracy

- Position 2 meters CEP (50%) without SA (Selective Availability)
- Velocity 0.05 m/sec. (1 Sigma) steady state conditions (without SA)
- Time ± 500 nanosecond (nominal)

F.1.4 Datum

- WGS-84 (standard DMA datum set)

F.1.5 Acquisition Rate

- Cold Start <3 minutes (90%)
- Warm Start <45 seconds (90%)
- Hot Start <12 seconds (90%)

F.1.6 Dynamics

- Altitude -1000 m to +18,000 m
- Velocity 515 m/sec. (maximum)
- Acceleration 4g (39.2 m/sec.²)
- Jerk 20 m/sec.³

F.2 Environmental Characteristics

F.2.1 Temperature

- Receiver board: Operating, -10^oC to + 60^oC (standard)
Storage, -40^oC to +85^oC (optional)
-55^oC to +100^oC
- GPS Antenna: Operating, -40^oC to +85^oC

F.2.2 Vibration

- 0.008g²/Hz 5Hz–20 Hz
- 0.05g²/Hz 20Hz–100Hz
- -3dB/octave 100Hz–900Hz
- Specifications comply with SAE J1211 requirements

F.2.3 Altitude

- -400 to +18,000 meters MSL

F.2.4 Humidity

- 95% R.H. non-condensing @ +60^oC

F.3 Physical Characteristics

F.3.1 Size

- Receiver board: 82.6 mm x 1.30 mm x 10.2 mm (3.25" x 1.25" x 0.40")
- Antenna: 47 mm x 40 mm x 13.3 mm (1.85" x 1.58" x 0.52")

F.3.2 Weight

- Receiver board: 19.6 g (0.7 oz) without optional shield
- Receiver board: 36.4 g (1.3 oz) with optional shield

F.3.3 Power

- Prime Power: +5 volts DC ($\pm 5\%$); 150 ma (.75 watts typical) without antenna
- Prime Power: +5 volts DC ($\pm 5\%$); 175 ma (.875 watts typical) with antenna
P/N 28367-00
- RAM Backup: optional +3.2 - +5.25 volts DC input via 8-pin header J3; 1 micro amp

F.4 Input/Output

F.4.1 Interface

- Two TTL level, bi-directional, serial I/O ports on J3 8-pin header

F.4.2 Protocols Available

- Trimble Standard Interface Protocol (TSIP); binary data I/O provides maximum bi-directional control over all GPS board functions. Sample C source code interface routines are available.
- NMEA 0183: Industry standard ASCII protocol for marine electronics applications. Supports NMEA sentences GGA, VTG, GLL, ZDA, and GSV, GSS, RMC.



Note – GGA and VTG are factory default messages.

F.5 Pulse Per Second

F.5.1 Timing

- Rising edge of pulse synchronized to UTC within 100 ns, nominal

F.5.2 Pulse Width

- 10 microsecond wide pulse; rising edge is 20 nanoseconds or less, depending upon distributed capacitance in cable

F.5.3 Output

- TTL level signal

F.6 RF Interference

F.6.1 Jamming

- Resistant to broadband noise jamming where jamming-to-signal power ratio is 20 dB or less, measured at the antenna/preamplifier interface when input signal is at -160 dBW

F.6.2 Burnout

- Protected from damage by RF signals at frequencies 100 MHz or more from the L1 frequency (1575.42 MHz) with received power up to one watt at the antenna

F.7 Lassen-SK8 Crystal Specifications

F.7.1 Electrical

- Operating Frequency: 16.368MHz
- Crystal Frequency: 16.368MHz, Fundamental Mode
- Load Capacitance, C_L : 32.8pF \pm 0.5pF
- Tolerance:

Calibration	\pm 10 ppm max @ 25°C
Stability	\pm 05 ppm max @ -20°C to +70°C
	\pm 10 ppm max @ -40°C to +85°C
Aging:	\pm 01 ppm max first year
	\pm 05 max for 10 years
- Motional:

Capacitance
Inductance
Resistance
- Drive Level: 0,100 mW Method of measurement: IEC Standard 444
Transmission line method.
- Short Term Frequency-to-Temperature stability: 0.07 ppm/°C (Proposed Specification)

F.7.2 Environmental

- Temperature:

Operational	-40°C to +85°C
Storage	-55°C to +105°C
- SMD Device Reflow \pm 0.5 ppm max change after 240°C for 20 seconds
- Shock: \pm 0.5 ppm max change after 5000G 6 msec, .5 sine
- G Sensitivity: \pm 0.100 5 ppm max per G
- Vibration:

\pm 0.5 ppm max change — 0.008g ² /Hz to 20Hz
\pm 0.5 ppm max change — 0.05g ² /Hz to 100Hz
-3 dB/octave — 100Hz to 900 Hz

F.7.3 Mechanical

- Enclosure: HC-45/U-SMD — Lead length 12.7 mm
- Enclosure Style: Resistance weld
- Electrodes: Gold
- Markings on Top: 5-digit Crystal Frequency
Manufacturer Name or Logo
Date Code or Lot Number

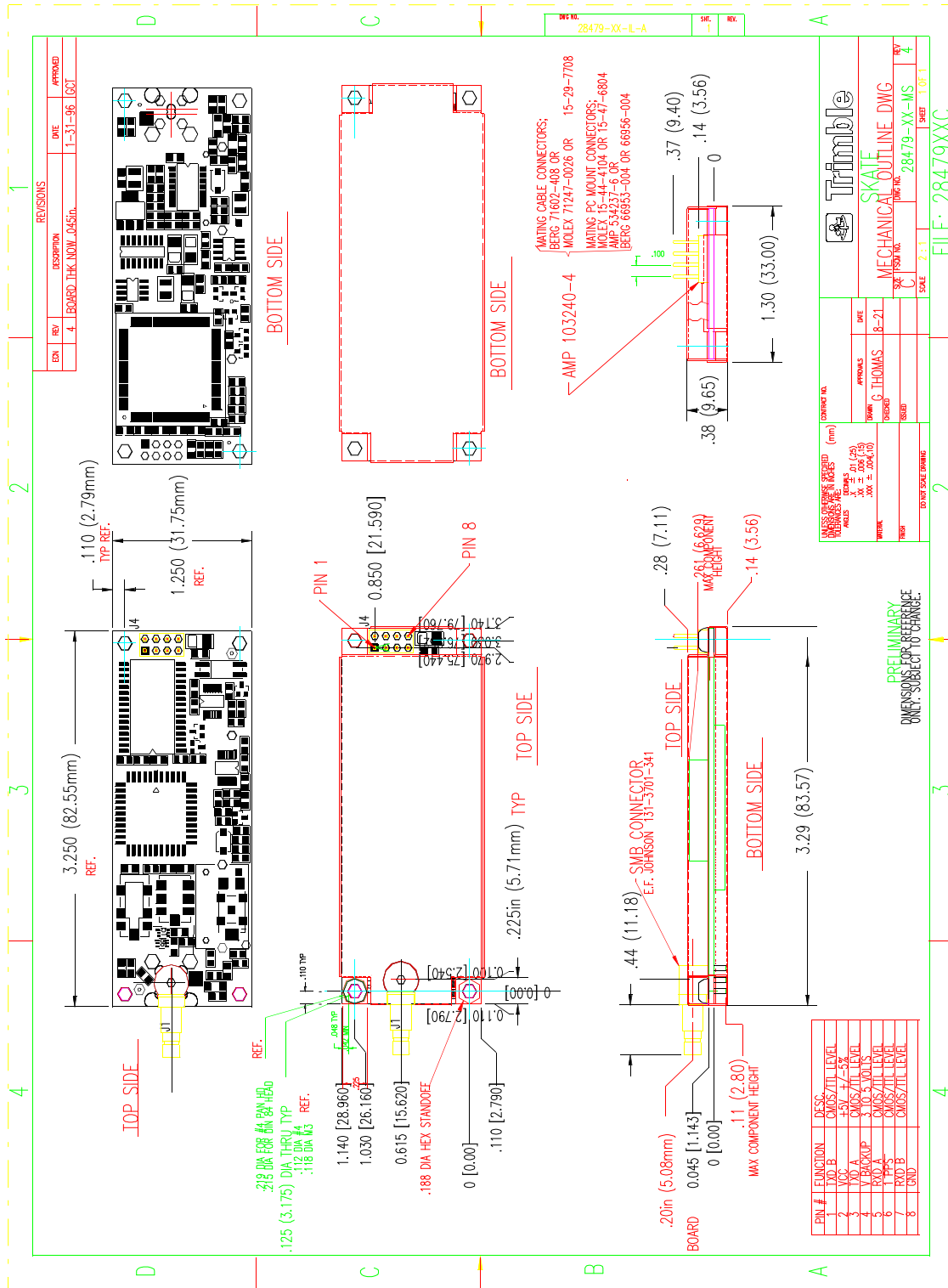
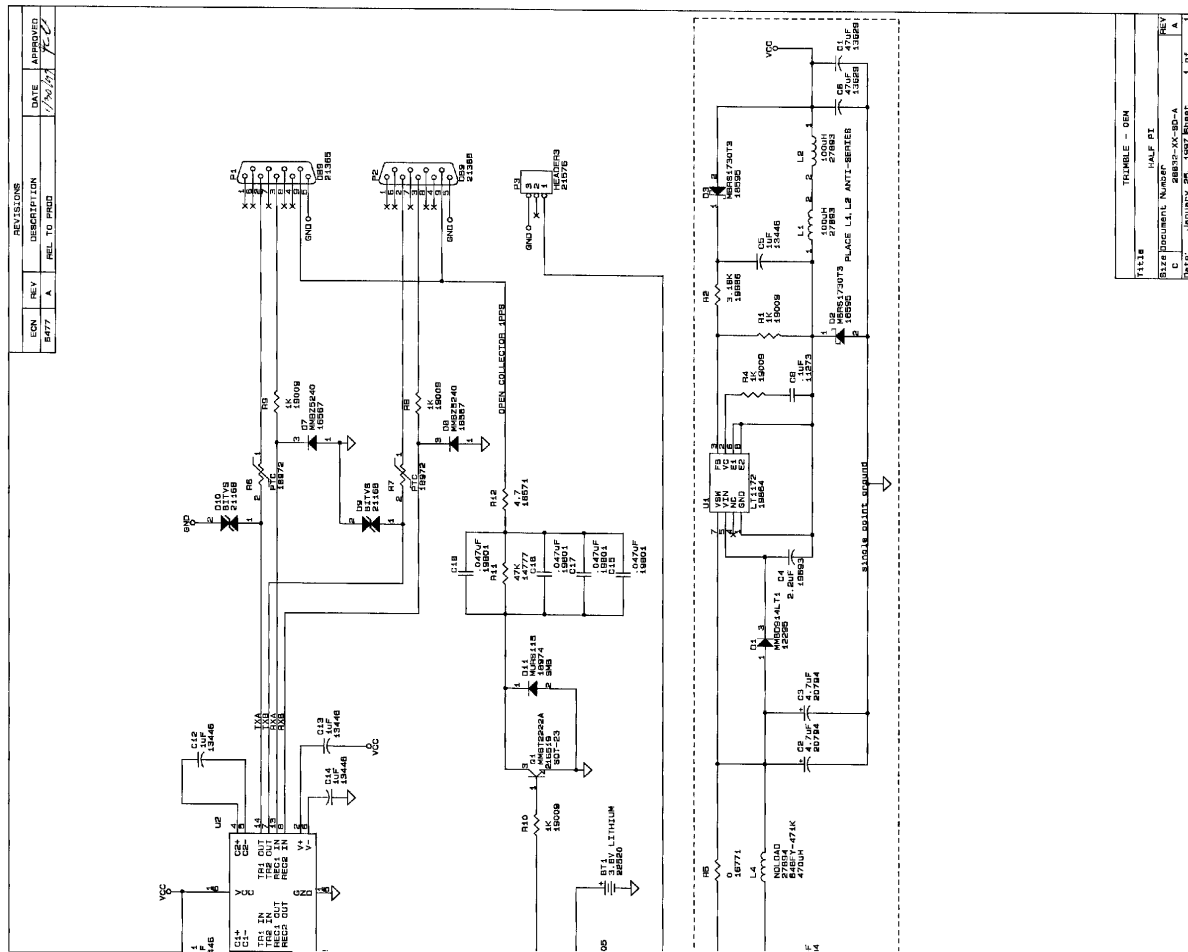


Figure F-1. Lassen-SK8 Mechanical Drawing - Circuit Board



REVISIONS		DATE	APPROVED
CON	REV		
E477	A	1/20/07	JC
DESCRIPTION			
REL TO PWD			

THUMBLE - 02M
HALF PT
SIZE DOCUMENT NUMBER
C
REV
A
DATE
1/20/07

Figure F-2

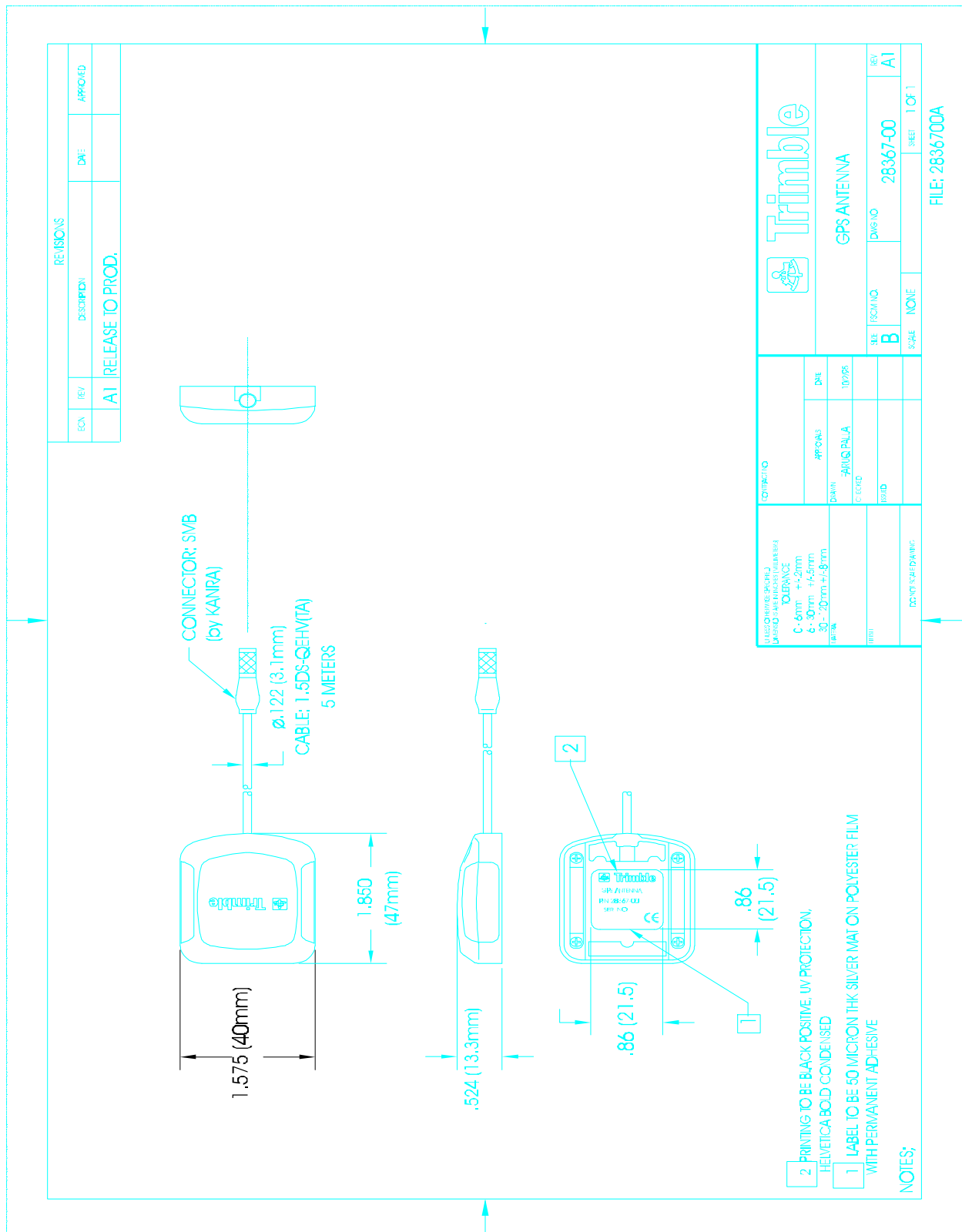


Figure F-3. GPS Miniture Antenna'

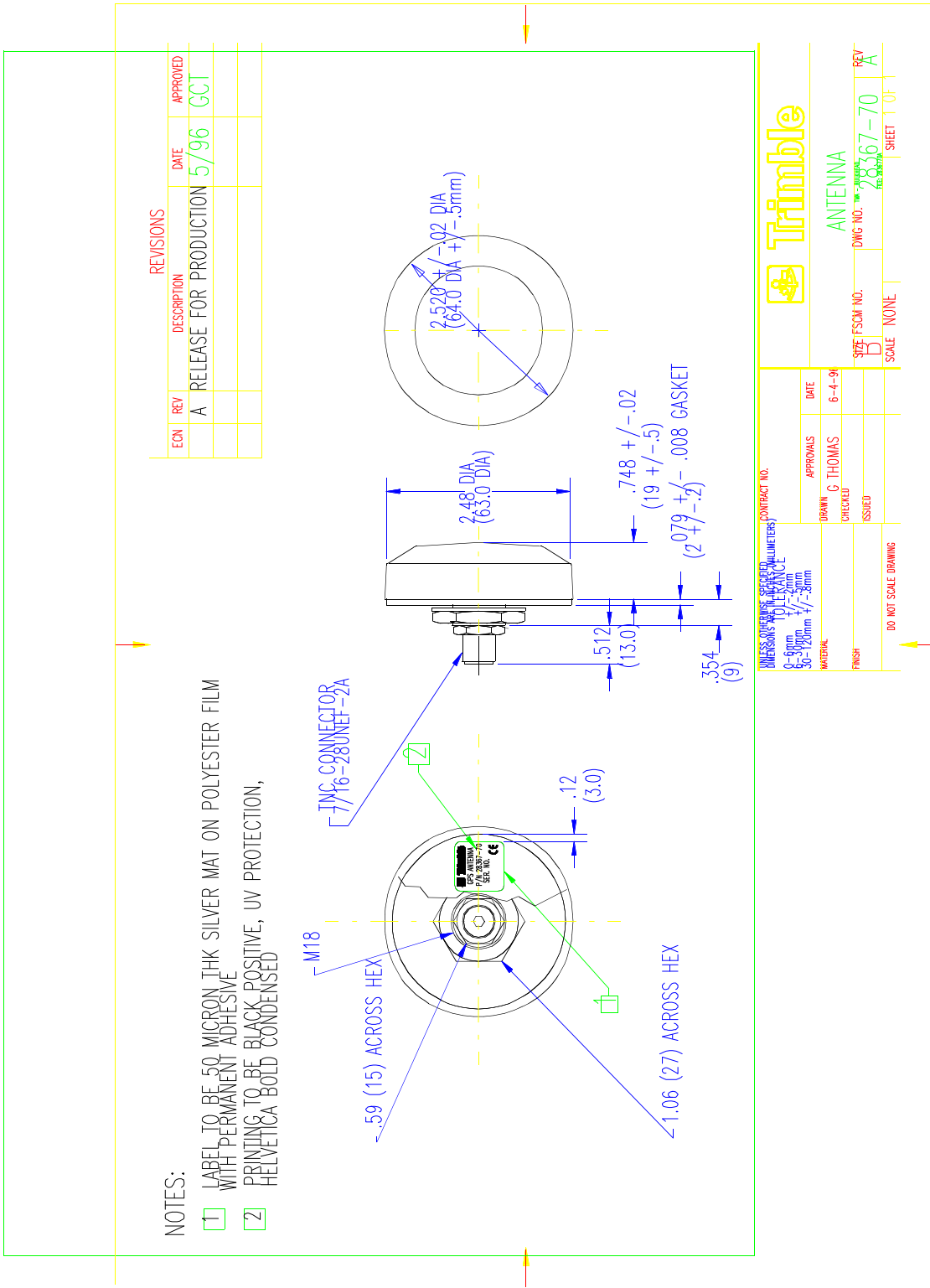


Figure F-4. Bulkhead Antenna

Glossary

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

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
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 from 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.
3-D GPS mode	A procedure of determining a 3-D position using signals received from the best (or only) four available GPS satellites. 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, azimuth angle, and estimated Doppler of the satellites. Each satellite 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 require 7 bits of data to send, but are often sent 8 bits at a time with the extra bit being a zero.
asynchronous communication	A method of sending data in which the bits can be sent at 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 time can elapse before the next character is sent. \
auto GPS mode	A procedure of automatically determining either a 2-D or 3-D 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 of the available satellites, and the defined PDOP switch value. (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.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
bandwidth	The range of frequencies occupied by a signal. Also, the information carrying capability of a communication channel or line.
baud	A measure of the speed of data transmission. Baud and bit rate are the same for direct equipment interconnections (e.g., 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 communication 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, and represents one character.
C/A code	The Coarse/Acquisition code. This is the civilian code made available by the Department of Defense. It is subject to selective availability (SA). Users can reduce the effects of SA by using differential GPS.
carrier	The radio signal on which information is carried. The carrier can be sensed to determine the presence of a signal.
channel	Either a single frequency or a pair of radio frequencies used 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 of 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 that comprise a subsystem or system.
data bits	The bits in a byte of data which carry the actual information.
datum	Refers to a mathematical model of the earth. Many local datums model the earth for a small region: e.g., Tokyo datum, 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 that connects to DTE using an RS-232 or CCITT V.24 standard interface.
default setting	A preset or initial value that is assumed to be the preferred or appropriate selection for most situations. The Placer GPS sensor is shipped with factory default configuration settings; the settings were determined by Trimble Navigation.
DGPS	see <i>differential GPS</i>

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
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.
differential GPS	A procedure of correcting GPS solutions to achieve improved 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 collected 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 of GPS phase measurements is to take differences between receivers (single difference), then between satellites (double 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 <i>differential GPS</i>
dilution of precision	A description of the purely geometrical contribution to the uncertainty in a position fix, given by the expression $DOP = \sqrt{\text{TRACE}(A^{-1})}$ where A^{-1} is the design matrix for the 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 <i>dilution of precision</i> .
Doppler aiding	The use of Doppler carrier-phase measurements to smooth code-phase position measurements.
Doppler shift	The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and 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 of the spin axis.
elevation angle	The angle between the line of sight vector and the horizontal plane.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
elevation mask angle	A measure of the minimum elevation angle, above the horizon, above which a GPS satellite must be located before the signals from the satellite will be used to compute a GPS location solution. Satellites below the elevation angle are considered unusable. The elevation mask angle is used to prevent the GPS receiver from computing position solutions using satellites which are likely to be obscured by buildings or mountains.
ellipsoid	In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis. It is often used interchangeably with spheroid. Two quantities define an ellipsoid; these are usually given as the length of the semimajor axis, a , and the flattening, $f = (a - b)/a$, where b is 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 position of the satellite. This information is broadcast by the satellites.
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.
frequency	The number of vibrations per second of an audio or radio signal. Measured in hertz (Hz), kilohertz (kHz), or megahertz (MHz). GPS frequencies are: L1 = 1575.42 MHz L2 = 1227.60 MHz
GDOP	Geometric Dilution of Precision. GDOP describes how much an uncertainty in pseudo-range and time affects the uncertainty in a position solution. GDOP depends on where 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 the geoid. It is defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surface established as the origin of datum. This relationship can be defined by six quantities, generally (but not necessarily) the geodetic latitude, longitude, and the height of the origin, the two components of the deflection of the vertical at the origin, 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 is 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.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
GPD	GPS with differential corrections applied.
GPS	Global Positioning System. A constellation of 24 radio navigation (not communication) satellites which transmit signals used (by GPS receivers) to determine precise location (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 signals.
GPS processor	An electronic device that interprets the GPS radio navigation 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 not 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 contains time synchronization information for the transfer from C/A to P-code.
interface cable	The interface cable allows data to flow between the Placer RPU and the communication equipment. One end of the cable has a single 37-pin connector; the other end of this cable has an RS-232 connector and a set of fused red and black power leads.
interference	Refers to the unwanted occurrences on communication channels that are a result of natural or man-made noises and signals, not properly a part of the signals being transmitted or received.
integrated Doppler	A measurement of Doppler shift frequency or phase over time.
IODE	Issue Of Data, Ephemeris. Part of the navigation data. It is 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 the same frequency
Kalman filter	A numerical method used to track a time-varying signal in the presence of noise. If the signal can be characterized by some number of parameters that vary slowly with time, then 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 <i>satellite masks</i> .

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
maximum PDOP	A measure of the maximum Position Dilution of Precision (PDOP) that is acceptable in order for the GPS processor to determine a location solution (see PDOP).
NAVSTAR	The name given to the GPS satellites, built by Rockwell International, which is an acronym formed from NAVigation System with Time And Ranging.
NMEA	National Marine Electronics Association. An association that defines marine electronic interface standards for the purpose of serving the public interest.
NMEA 0183 message	NMEA 0183 is a standard for interfacing marine electronics navigational devices. The standard specifies the message format used to communicate with marine devices/components.
packet	An “envelope” for data, which contains addresses and error 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 number of items in a set (e.g., bits in a byte).
PDOP	Position Dilution of Precision. PDOP is a unitless figure of 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 GPS modes. The PDOP constellation switch is only active when the GPS mode of operation is set to Auto.
PRN	Pseudo-random noise. Each GPS satellite generates its own distinctive PRN code, which is modulated onto each carrier. 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 control 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 speed of light by the apparent transit time of the signal from the GPS satellite. Pseudo-range differs from actual range because 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.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
range	A term used to refer to the distance radio signals can travel before they must be received or repeated due to loss of signal strength, the curvature of the earth and the noise introduced because of moisture in the air surrounding the earth's surface.
range rate	The rate of change of range between the satellite and receiver. The range to a satellite changes due to satellite and observer motions. Range rate is determined by measuring the Doppler shift of the satellite beacon carrier.
read-only memory	Memory whose contents can be read, but not changed. Information is placed into ROM only once. The contents of ROM are not erased when the system unit's power is turned off.
real time clock	An electronic clock, usually battery powered, that keeps current time. Used by a GPS receiver during a warm or hot start to determine where to search for GPS satellite signals.
relative positioning	The process of determining the vector distance between two points and the coordinates of one spot relative to another. This technique yields GPS positions with greater precision 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 the 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 GPS services. "RTCM Recommended Standards For Differential GPS Service," prepared by RTCM Special Committee No. 104 (RTCM SC-104), defines a communication protocol for sending GPS differential corrections from a differential reference station to remote GPS receivers.
satellite masks	As satellites approach the horizon, their signals can become weak and distorted, preventing the receiver from gathering accurate data. Satellite masks enable you to establish criteria for using satellite data in a position solution. There are three types of satellite masks: Elevation, SNR, and PDOP.
SA	Selective Availability. This is the name of the policy and the implementation scheme by which unauthorized users of GPS 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 that 50% of the position estimates will fall within the surface of the sphere.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
serial communication	A system of sending bits of data on a single channel one after the other, rather than simultaneously.
serial port	A port in which each bit of information is brought in/out on a 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 are considered unusable.
signal to noise ratio	A measure of the relative power levels of a communication signal and noise on a data line. SNR is expressed in decibels (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 the L-band signal with a PRN code in order to spread the signal 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 provide some resistance to noise and multipath.
SPS	Standard Positioning Service. Refers to the GPS as available to the authorized user.
start bit	In asynchronous transmission, the start bit is appended to the 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 the end of each character. It sets the receiving hardware to a condition where it looks for the start bit of a new character.
SV	Space Vehicle (GPS satellite).
synchronous communication	A method of sending digital data in which the bits come at 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 uppercase 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 receiver operational status. Also see <i>TSIP</i>
TNL 4000RL	Trimble Navigation, Ltd. Reference Locator (4000RL). Product name for the Differential GPS Reference Station.

2-D	Two Dimensional. A 2-D position is defined as latitude and longitude. Altitude is assumed to be fixed.
TSIP	Trimble Standard Interface Protocol. A binary/hex packet bi-directional protocol, also known as the TANS protocol. Used by a large number of Trimble sensors. TSIP is the subset of TANS which is recognized by all Trimble sensors except the 4000 series. The TSIP protocol is defined in full in Appendix A.
URA	Satellite user range accuracy. The URA is sent by the satellite and is computed by the GPS operators. It is a statistical indicator 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: UTC - EST = 5 hours).

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