

GPS 16x TECHNICAL SPECIFICATIONS



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1 INTRODUCTION

1.1 CAUTION

The GPS system is operated by the government of the United States, which is solely responsible for its accuracy and maintenance. The GLONASS system is operated by the government of Russia, which is solely responsible for its accuracy and maintenance. Although the device is a precision electronic NAVigation AID (NAVAID), any NAVAID can be misused or misinterpreted, and therefore become unsafe. Use these products at your own risk. To reduce the risk, carefully review and understand all aspects of these Technical Specifications before using the device. When in actual use, carefully compare indications from the GPS to all available navigation sources including the information from other NAVAIDS, visual sightings, charts, etc. For safety, always resolve any discrepancies before continuing navigation.

1.2 FCC COMPLIANCE

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and may cause harmful interference to radio communications if not installed and used in accordance with the instructions. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This product does not contain any user-serviceable parts. Repairs should only be made by an authorized Garmin service center. Unauthorized repairs or modifications could result in permanent damage to the equipment, and void your warranty and your authority to operate this device under Part 15 regulations.

1.3 LIMITED WARRANTY

The Garmin standard limited warranty applies to this device. For more information, go to garmin.com/support/warranty.

1.4 OVERVIEW

The GPS 16x series products are complete GPS sensors including embedded receiver and antenna, designed for a broad spectrum of Original Equipment Manufacture (OEM) system applications. Based on the proven technology found in other Garmin GPS receivers, the GPS 16x tracks multiple satellites at a time while providing fast time-to-first-fix, one-second navigation updates, and low power consumption. This generation of GPS sensors includes the capability of FAA Wide Area Augmentation System (WAAS) differential GPS.

The GPS 16x design uses the latest technology and high-level circuit integration to achieve superior performance while minimizing space and power requirements. All critical components of the system including the RF/IF receiver hardware and the digital baseband are manufactured by Garmin to ensure the quality and capability of the GPS. The hardware capability combined with software intelligence makes the GPS 16x easy to integrate and use.

The GPS 16x series products are designed to withstand rugged operating conditions and are waterproof to IEC 60529 IPX7, immersion in 1 meter of water for 30 minutes. These complete GPS receivers require minimal additional components to be supplied by an OEM or system integrator. A minimum system must provide the GPS with a source of power and a clear view of the GPS satellites. The system may communicate with the GPS via an asynchronous serial communications port. Internal FLASH memory

allows the GPS to retain critical data such as satellite orbital parameters, last-known position, date, and time. End user interfaces such as keyboards and displays are the responsibility of the application designer.

1.5 FEATURES

- GPS receiver tracks and uses multiple satellites for fast, accurate positioning and velocity estimates.
- Differential DGPS capability using real-time WAAS or RTCM corrections yielding 3- to 5-meter position accuracy (see section [1.5 Technical Specifications](#)).
- Compact, rugged design ideal for applications with minimal space.
- May be remotely mounted in an out-of-the-way location.
- Factory configuration meets the needs of most systems that expect NMEA® 0183 data from a GPS receiver. Configuration commands are available to customize the NMEA 0183 output (see section [4.1 Received NMEA 0183 Sentences](#)).
- Highly accurate one-pulse-per-second (PPS) output for precise timing measurements. Pulse width is configurable in 20-millisecond increments from 20 ms to 980 ms with 1 μ s accuracy.
- Configurable for binary format data output on COM1 port.
- Flexible input voltage levels of 3.3 Vdc to 6.0 Vdc with over-voltage protection in the GPS 16xLVS, and 8.0 Vdc to 40 Vdc in the GPS 16xHVS.
- FLASH-based program with new software revisions available through website download.
- Non-volatile memory does not require battery backup.
- Waterproof design allows continuous exposure to the prevailing weather conditions at most locations.

1.6 TECHNICAL SPECIFICATIONS

Specifications are subject to change without notice.

1.6.1 Physical Characteristics

1.6.1.1 Size

3.58" (91.0 mm) diameter, 1.65" (42 mm) high

1.6.1.2 Weight

- GPS 16xLVS only: 6.0 oz (169 g)
- GPS 16xHVS only: 6.1 oz (174 g)
- GPS 16xLVS with 5-meter cable: 11.3 oz (320 g)
- GPS 16xHVS with 5-meter cable: 11.5 oz (325 g)
- GPS 16xLVS & 16xHVS cable alone: 5.3 oz (151 g)

1.6.1.3 Cable

GPS 16xLVS & 16xHVS: Black PVC-jacketed, 5-meter, foil-shielded, 8-conductor 28 AWG with RJ-45 termination

1.6.1.4 Color

GPS 16xLVS & 16xHVS: Black with white logos

1.6.1.5 Case Material

Polycarbonate thermoplastic that is waterproof to IEC 60529 IPX7 level (immersion in 1 meter of water for 30 minutes).

1.6.2 Electrical Characteristics

1.6.2.1 Input Voltage

- GPS 16xLVS: 3.3 Vdc to 6.0 Vdc regulated, <100 mV ripple
- GPS 16xHVS & 17HVS: 8.0 Vdc to 40 Vdc unregulated

1.6.2.2 Input Current

- GPS 16xHVS: 100 mA @ 8 Vdc
65 mA @ 12 Vdc
28 mA @ 40 Vdc
- GPS 16xLVS: 90 mA typical

1.6.2.3 Standby Current

<10 μ A for all GPS 16x models

1.6.2.4 GPS Receiver Sensitivity

-185 dBW minimum

1.6.3 Environmental Characteristics

- Operating Temperature: -30°C to +70°C (-22°F to +158°F)
- Storage Temperature: -40°C to +70°C (-40°F to +158°F)

1.6.4 GPS Performance

1.6.4.1 Receiver

WAAS enabled GPS receiver continuously tracks and uses multiple satellites to compute and update your position.

1.6.4.2 Acquisition Times

- Reacquisition: Less than 2 seconds
- Hot: Approx. 1 second (all data known)
- Warm: Approx. 38 seconds (initial position, time, and almanac known; ephemeris unknown)
- Cold: Approx. 45 seconds

1.6.4.3 Sentence Rate

1 second default; NMEA 0183 output interval configurable from 1 to 900 seconds in 1-second increments

1.6.4.4 Accuracy

- GPS Standard Positioning Service (SPS)
Position: <15 meters, 95% typical (100 meters with Selective Availability on)
Velocity: 0.1 knot RMS steady state
- DGPS (USCG/RTCM)
Position: 3–5 meters, 95% typical
Velocity: 0.1 knot RMS steady state
- DGPS (WAAS)
Position: <3 meters, 95% typical
Velocity: 0.1 knot RMS steady state
- PPS Time: ± 1 microsecond at rising edge of PPS pulse (subject to Selective Availability)
- Dynamics: 999 knots velocity (only limited at altitude greater than 60,000 feet), 3g dynamics

1.6.5 Interfaces

- True RS-232 output, asynchronous serial input compatible with RS-232 or TTL voltage levels, RS-232 polarity.
- User selectable baud rate: 4800, 9600, 19200, or 38400.

1.6.5.1 Port 1

- Configurable between NMEA 0183 Versions 2.00 (factory default) and 3.00
- ASCII output sentences GPALM, GPGGA, GPGLL, GPGSA, GPGSV, GPRMC, GPVTG (NMEA-approved sentences); PGRMB, PGRME, PGRMF, PGRMID, PGRMM, PGRMT, and PGRMV (Garmin proprietary sentences)
- NMEA 0183 Outputs (see section [4.2 Transmitted NMEA 0183 Sentences](#) for full protocol specifications)
 - Position, velocity, and time
 - Receiver and satellite status
 - Differential Reference Station ID and RTCM Data age
 - Geometry and error estimates
- NMEA 0183 Inputs (see section [4.1 Received NMEA 0183 Sentences](#) for full protocol specifications)
 - Initial position, date, and time (not required)
 - Earth datum and differential mode configuration command, PPS Enable, GPS satellite almanac
- Configurable for binary data output

1.6.5.2 Port 2

Real-time Differential Correction input (RTCM SC-104 message types 1, 2, 3, 7, and 9)

1.6.5.3 PPS

1 Hz pulse, programmable width, 1 μ s accuracy

1.6.5.4 Power Control

- Off: Open circuit
- On: Ground, or pull to low logic level <0.3 volts

2 GPS 16x WIRING AND PINOUTS

2.1 GPS 16x PINOUT

The GPS 16xLVS and GPS 16xHVS sensors utilize an 8-pin RJ-45 plug. The following is a functional description of each wire in the cable assembly.

RJ-45 Pin #	Wire Color	Signal Name	Description
1	Red	POWER	<p>GPS 16xLVS: Regulated +3.3 to +6 Vdc. Typical operating current is 80 mA. An internal 6.67 Vdc transient zener diode and a positive temperature coefficient resistor protect from transients and over-voltages. With voltages greater than 6.8 Vdc the zener will draw several amps of current through the resistor, causing it to heat rapidly and eventually power the unit off, unless an external fuse blows first. When proper supply voltages are returned, the resistor will cool and allow the GPS 16xLVS to operate.</p> <p>GPS 16xHVS: Vin can be an unregulated 8.0 Vdc to 40 Vdc, optimized for 12 Vdc. Typical operating power is 780 mW. This voltage drives a switching regulator with a nominal 5.0 Vdc output, which powers an internal linear regulator, producing the system Vcc.</p>
2	Black	GROUND	Power and Signal Ground
3	Yellow	REMOTE POWER ON/OFF	External Power Control Input. Active (ON) if less than 0.3 Vdc. Inactive (OFF) if open-circuit. Pulling this pin to ground enables the unit; leaving the pin open-circuited powers the internal regulators off and drops the supply current to less than 1 mA. This input is intended to be driven by an open-collector output.
4	Blue	PORT 1 DATA IN	First Serial Asynchronous Input. RS-232 compatible with maximum input voltage range $-25 < Vdc < 25$. This input may also be directly connected to standard 3 to 5 Vdc CMOS logic. The low signal voltage requirement is $<0.6 V$, and the high signal voltage requirement is $>2.4 Vdc$. Input impedance is between 3.0 and 7.0 k Ω . This input may be used to receive serial initialization/ configuration data as specified in section 4.1 Received NMEs 0183 Sentences .
5	White	PORT 1 DATA OUT	First Serial Asynchronous Output. This RS-232 compatible output normally provides serial data which is formatted per <i>NMEA 0183, Version 3.0</i> . The NMEA 0183 baud rate is switchable in the range of 4800 to 38400 baud. The default baud rate is 4800.
6	Gray	PPS	One-Pulse-Per-Second Output. Typical voltage rise and fall times are 300 ns. Impedance is 150 Ω . Open circuit output voltage is low = 0 Vdc and high = Vin in the GPS 16xLVS, and low = 0 Vdc and high = 5.0 Vdc in the GPS 16xHVS and GPS 17HVS. The default format is a 100 ms wide active-high pulse at a 1 Hz rate; the pulse width is configurable in 20 ms increments. Rising edge is synchronized to the start of each GPS second. This output provides between 800 mVp-p to 1.7 Vp-p for GPS 16xLVS and 1.4 Vp-p for the GPS 16xHVS and 17HVS into a 50 Ω load. The pulse time measured at the 50% voltage point will be about 50 ns earlier with a 50 Ω load than with no load.
7	Green	PORT 2 DATA IN	Second Serial Asynchronous Input, electrically identical to PORT 1 DATA IN. This input may be used to receive serial differential GPS data formatted per <i>RTCM SC-104 Recommended Standards For Differential Navstar GPS Service, Version 2.2</i> (see section 4.5 Received RTCM Data for details).
8	Violet	PORT 2 DATA OUT	Second Serial Asynchronous Output, electrically identical to PORT 1 DATA OUT. Reserved for future use.

Table 1: GPS 16x Wire Pinout

2.2 GPS 16x WIRING DIAGRAMS

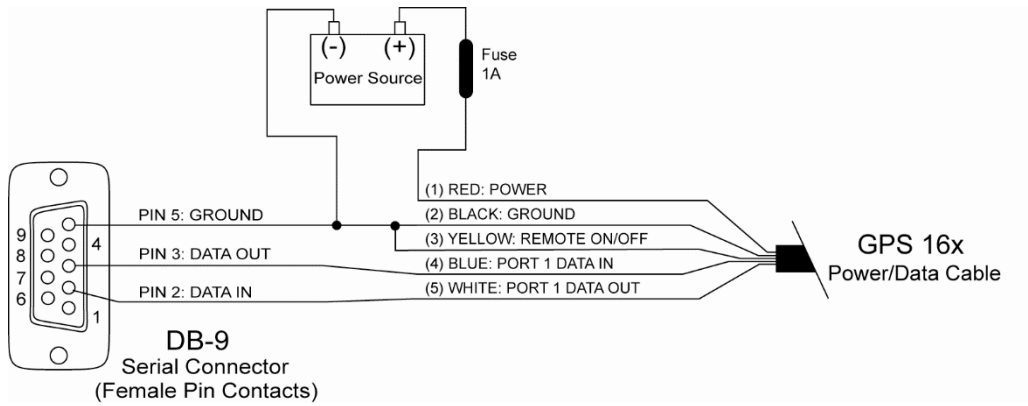


Figure 1: Computer Serial Port Interconnection

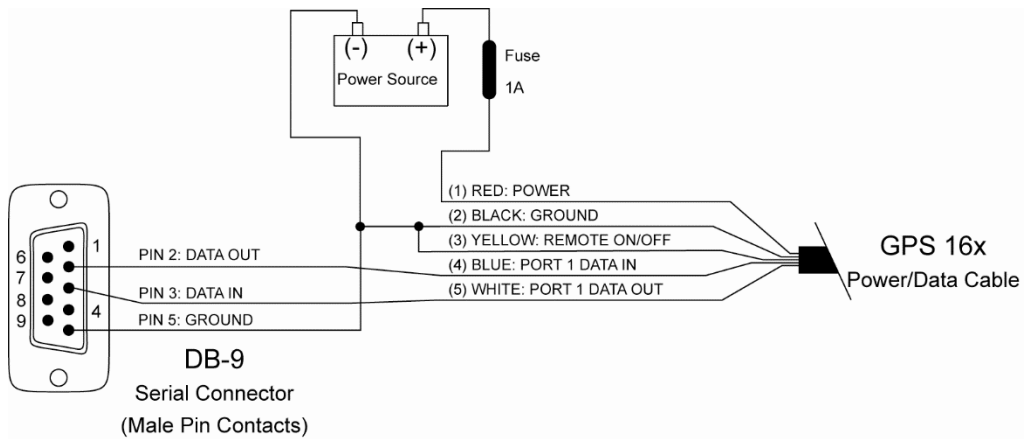


Figure 2: PDA Serial Port Interconnection

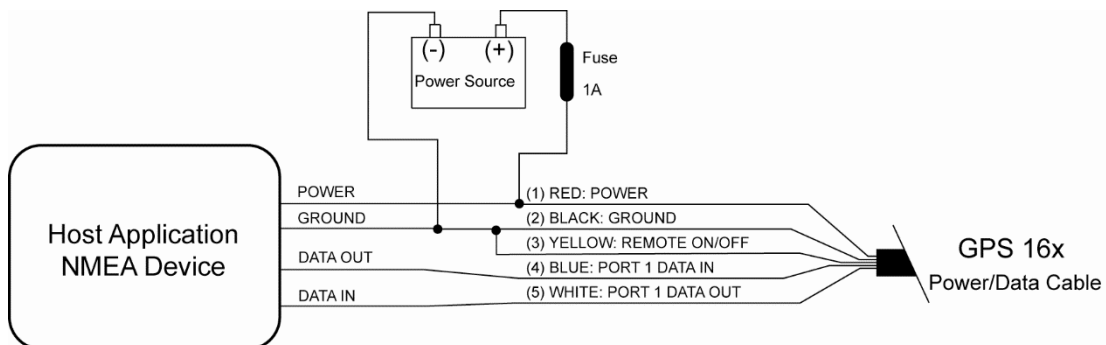


Figure 3: Basic NMEA Device Interconnection

3 MECHANICAL CHARACTERISTICS & MOUNTING

3.1 GPS 16x FLUSH MOUNT

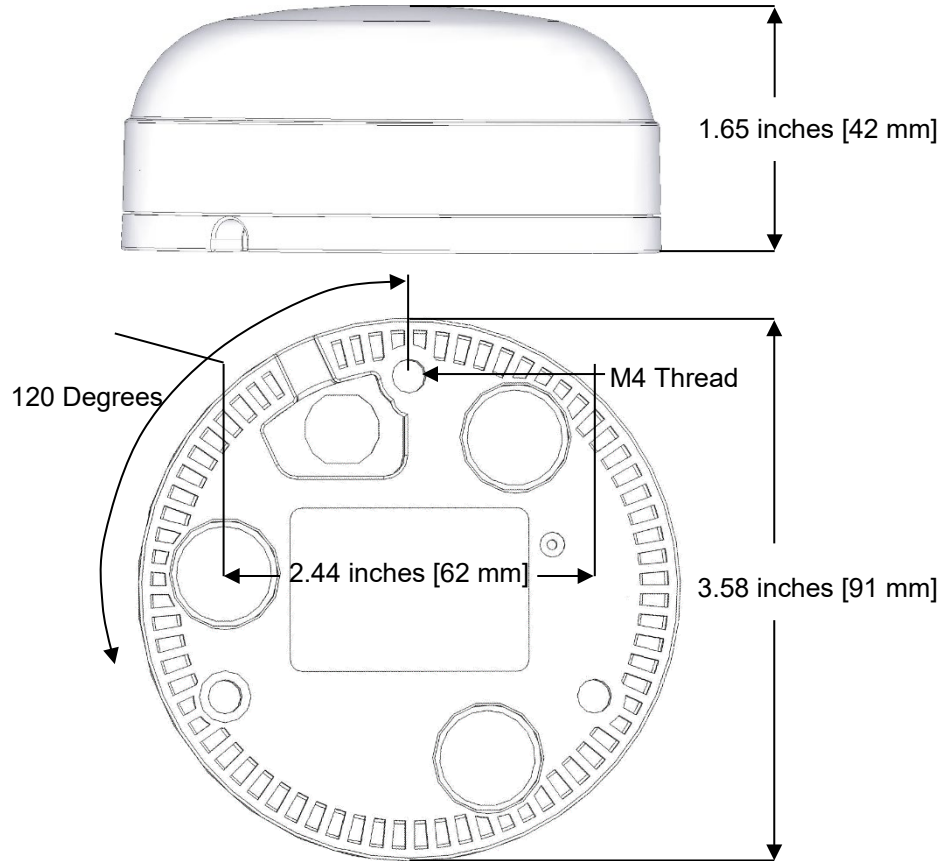


Figure 4: GPS 16x Flush Mount Dimensions

3.2 GPS 16x OPTIONAL MAGNETIC MOUNT

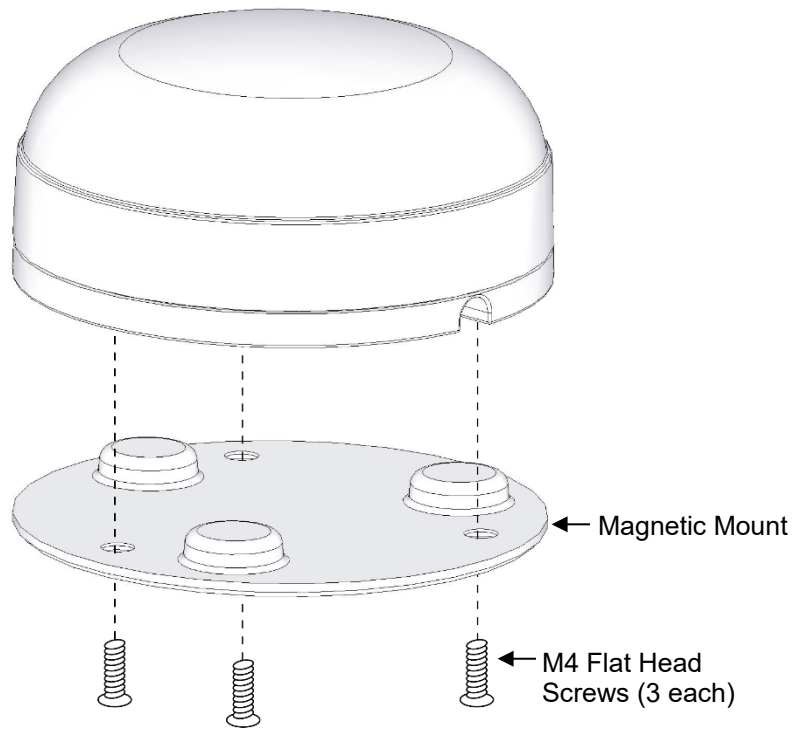


Figure 5: Optional GPS 16x Magnetic Mount

4 SOFTWARE INTERFACE

The GPS 16x series products interface protocol design on COM1 is based on the National Marine Electronics Association's NMEA 0183 ASCII interface specification. The COM2 port can receive differential GPS (DGPS) correction data using the Radio Technical Commission for Maritime Services' RTCM SC-104 standard. These standards are fully defined in *NMEA 0183, Version 3.0* (copies may be obtained from NMEA, www.nmea.org) and *RTCM Recommended Standards For Differential Navstar GPS Service, Version 2.2, RTCM Special Committee No. 104* (copies may be obtained from RTCM, www.rtcn.org).

The GPS 16x series products interface protocol, in addition to transmitting navigation information as defined by NMEA 0183, transmits additional information using the convention of Garmin proprietary sentences.

Binary information can alternatively be output on the COM1 port; see [Appendix B: Garmin Binary Output Format](#) for details.

The following sections describe the NMEA 0183 data format of each sentence transmitted and received by the GPS 16x series products. The baud rate selection, one-pulse-per-second output interfaces and RTCM differential GPS input are also described.

4.1 RECEIVED NMEA 0183 SENTENCES

The following paragraphs define the sentences that can be received on the GPS sensors' COM1 port. Null fields in the configuration sentence indicate no change in the particular configuration parameter. All sentences received by the GPS sensor must be terminated with <CR><LF>, the ASCII characters for carriage return (0D hexadecimal) and line feed (0A hexadecimal). The checksum *hh is used for parity checking data and is not required, but is recommended for use in environments containing high electromagnetic noise. It is generally not required in normal PC environments. When used, the parity bytes (hh) are the ASCII representation of the exclusive-or (XOR) sum of all the characters between the "\$" and "*" characters, non-inclusive. The hex representation must be a capital letter, such as 3D instead of 3d. Sentences may be truncated by <CR><LF> after any data field and valid fields up to that point will be acted on by the sensor.

4.1.1 Almanac Information (ALM)

The \$GPALM sentence can be used to initialize the GPS sensor's stored almanac information in the unlikely event of non-volatile memory loss or after storing longer than six months without tracking GPS satellites.

\$GPALM,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>,<13>,<14>,<15>*hh<CR><LF>

<1>	Total number of ALM sentences to be transmitted by the GPS sensor during almanac download. This field can be null or any number when sending almanac to the GPS sensor.
<2>	Number of current ALM sentence. This field can be null or any number when sending almanac to the GPS sensor.
<3>	Satellite PRN number, 01 to 32
<4>	GPS week number
<5>	SV health, bits 17-24 of each almanac page
<6>	Eccentricity
<7>	Almanac reference time
<8>	Inclination angle
<9>	Rate of right ascension
<10>	Root of semi major axis
<11>	Omega, argument of perigee
<12>	Longitude of ascension node
<13>	Mean anomaly
<14>	af0 clock parameter
<15>	af1 clock parameter

4.1.2 Sensor Initialization Information (PGRMI)

The \$PGRMI sentence provides information used to initialize the GPS sensor's set position and time used for satellite acquisition. Receipt of this sentence by the GPS sensor causes the software to restart the satellite acquisition process. If there are no errors in the sentence, it will be echoed upon receipt. If an error is detected, the echoed PGRMI sentence will contain the current default values. Current PGRMI defaults (with the exception of the Receiver Command, which is a command rather than a mode) can also be obtained by sending \$PGRMIE to the GPS sensor.

\$PGRMI,<1>,<2>,<3>,<4>,<5>,<6>,<7>*hh<CR><LF>

<1>	Latitude, ddmm.mmm format (leading zeros must be transmitted)
<2>	Latitude hemisphere, N or S
<3>	Longitude, dddmm.mmm format (leading zeros must be transmitted)
<4>	Longitude hemisphere, E or W
<5>	Current UTC date, ddmmyy format
<6>	Current UTC time, hhmmss format
<7>	Receiver Command, A = Cold Start, R = Unit Reset

4.1.3 Sensor Configuration Information (PGRMC)

The \$PGRMC sentence provides information used to configure the GPS sensor's operation. Configuration parameters are stored in non-volatile memory and retained between power cycles. The GPS sensor will echo this sentence upon its receipt if no errors are detected. If an error is detected, the echoed PGRMC sentence will contain the current default values. Current default values can also be obtained by sending \$PGRMCE to the GPS sensor.

\$PGRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>,<13>,<14>*hh<CR><LF>

<1>	Fix mode, A = Automatic, 3 = 3D exclusively
<2>	Altitude above/below mean sea level, -1500.0 to 18000.0 meters
<3>	Earth datum index. If the user datum index (96) is specified, fields <4> through <8> must contain valid values. Otherwise, fields <4> through <8> must be null. Refer to Appendix A: Earth Datums for a list of earth datums and the corresponding earth datum index.
<4>	User earth datum semi-major axis, 6360000.000 to 6380000.000 meters (.001 meters resolution)
<5>	User earth datum inverse flattening factor, 285.0 to 310.0 (10 ⁻⁹ resolution)
<6>	User earth datum delta x earth centered coordinate, -5000.0 to 5000.0 meters (1 meter resolution)
<7>	User earth datum delta y earth centered coordinate, -5000.0 to 5000.0 meters (1 meter resolution)
<8>	User earth datum delta z earth centered coordinate, -5000.0 to 5000.0 meters (1 meter resolution)
<9>	Differential mode, A = Automatic (output DGPS data when available, non-DGPS otherwise), D = Differential exclusively (output only differential fixes)
<10>	NMEA 0183 Baud rate, 3 = 4800, 4 = 9600, 5 = 19200, 8 = 38400
<11>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<12>	PPS mode, 1 = Off, 2 = On
<13>	PPS pulse length, 0 though 48 = (n+1)*20 ms. Example: n = 4 corresponds to a 100 ms wide pulse
<14>	Dead reckoning valid time 1 to 30 (sec)

All configuration changes take affect after receipt of a valid value except baud rate and PPS mode. Baud rate and PPS mode changes take effect on the next power cycle or an external reset event.

4.1.4 Additional Sensor Configuration Information (PGRMC1)

The \$PGRMC1 sentence provides additional information used to configure the GPS sensor operation. Configuration parameters are stored in non-volatile memory and retained between power cycles. The GPS sensor will echo this sentence upon its receipt if no errors are detected. If an error is detected, the echoed PGRMC1 sentence will contain the current default values. Current default values can also be obtained by sending \$PGRMC1E to the GPS sensor.

\$PGRMC1,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>,<13>,<14>,<15>*hh<CR><LF>

<1>	NMEA 0183 output time 1-900 (sec)
<2>	Binary Output Data, 1 = Off, 2 = On.
<3>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<4>	DGPS beacon frequency: 0.0, 283.5–325.0 kHz in 0.5 kHz steps
<5>	DGPS beacon bit rate: 0, 25, 50, 100, or 200 bps
<6>	DGPS beacon scanning, 1 = Off, 2 = On
<7>	NMEA 0183 version 2.30 mode indicator, 1 = Off, 2 = On
<8>	DGPS mode, W = WAAS Only, N = None (DGPS disabled)
<9>	Power Save Mode, P = Power Save mode, N = Normal
<10>	No Effect (Adaptive Transmission Enabled, 1 = Off, 2 = On)
<11>	No Effect (Auto Power Off, 1 = Off, 2 = On)
<12>	No Effect (Power On with External Charger, 1 = Off, 2 = On)
<13>	PPS Auto Off Mode, 1 = Off, 2 = On
<14>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<15>	Low Velocity Threshold, 1 = Off, 2 = On

Configuration changes take effect immediately, with the exception of Binary Output Data and PPS Auto Off Mode, which take effect on the next power cycle or a reset event. A reset can be commanded by sending the sentence "\$PGRMI,,,,,,R" (see section 4.1.2 [Sensor Initialization Information \(PGRMI\)](#)). If the GPS sensor is in the Binary data mode, it is necessary to send the following eight-byte data stream to temporarily change the data format to NMEA 0183. Then follow by sending a PGRMC1 sentence that turns off the Binary Output Data format:

10 0A 02 26 00 CE 10 03 (Hexadecimal)

4.1.5 Output Sentence Enable/Disable (PGRMO)

The \$PGRMO sentence provides the ability to enable and disable specific output sentences. The following sentences are enabled at the factory: GPGLA, GPGLSA, GPGLSV, GPRMC, and PGRMT. This sentence is not intended for turning on and off sentences as a means of polling while the receiver is in use; instead, it is intended to allow systems integrators to initialize the GPS receiver so it produces only the sentences required by the target application.

\$PGRMO,<1>,<2>*hh<CR><LF>

<1>	Target sentence description (e.g., PGRMT, GPGLSV, etc.)
<2>	Target sentence mode, where: 0 = disable specified sentence 1 = enable specified sentence 2 = disable all output sentences 3 = enable all output sentences (except GPALM) 4 = restore factory default output sentences

The following notes apply to the PGRMO input sentence:

If the target sentence mode is "2" (disable all), "3" (enable all), or "4" (restore defaults), the target sentence description is not checked for validity. In this case, an empty field is allowed (e.g., \$PGRMO,,3), or the mode field may contain from 1 to 5 characters.

If the target sentence mode is "0" (disable) or "1" (enable), the target sentence description field must be an identifier for one of the sentences that can be output by the GPS sensor.

If either the target sentence mode field or the target sentence description field is not valid, the PGRMO sentence will have no effect.

\$PGRMO,GPALM,1 will cause the GPS sensor to transmit all stored almanac information. All other NMEA 0183 sentence transmission will be suspended temporarily.

\$PGRMO,,G will cause the COM port to change to Garmin Data Transfer format for the duration of the power cycle. You must enable Garmin Data Transfer format to update the GPS 16x series products.

4.2 TRANSMITTED NMEA 0183 SENTENCES

The subsequent paragraphs define the sentences that can be transmitted on COM1 by the GPS sensor.

4.2.1 Sentence Transmission Rate

Sentences are transmitted with respect to the user selected baud rate.

The GPS sensor will transmit each sentence (except where noted in particular transmitted sentence descriptions) at a periodic rate based on the user selected baud rate and user selected output sentences. The GPS sensor will transmit the selected sentences contiguously. The length of the transmission can be determined by the following equation and Tables 2 and 3:

$$\text{length of transmission} = \frac{\text{total characters to be transmitted}}{\text{characters transmitted per second}}$$

Sentence	Output by Default?	Maximum Characters
GPRMC	<input type="checkbox"/>	74
GPGGA	<input type="checkbox"/>	82
GPGSA	<input type="checkbox"/>	66
GPGSV	<input type="checkbox"/>	70
PGRME		35
GPGLL		44
GPVTG		42
PGRMV		32
PGRMF		82
PGRMB		40
PGRMID		82
PGRMM		32
PGRMT	<input type="checkbox"/>	50

Table 2: NMEA 0183 Output Sentence Order and Size

Baud	Characters per Second
4800	480
9600	960
19200	1920
38400	3840

Table 3: Characters per Second for Available Baud Rates

The maximum number of fields allowed in a single sentence is 82 characters including delimiters. Values in the table include the sentence start delimiter character "\$" and the termination delimiter <CR><LF>. The factory set defaults will result in a once-per-second transmission at the NMEA 0183 specification transmission rate of 4800 baud.

Regardless of the selected baud rate, the information transmitted by the GPS sensor is referenced to the one-pulse-per-second output pulse immediately preceding the GPRMC sentence, or whichever sentence is output first in the burst (see Table 2 above).

4.2.2 Transmitted Time

The GPS sensor outputs Coordinated Universal Time (UTC) date and time of day in the transmitted sentences. Before the initial position fix, the on-board clock provides the date and time of day. After the initial position fix, the date and time of day are calculated using GPS satellite information and are synchronized with the one-pulse-per-second output.

The GPS sensor uses information obtained from the GPS satellites to add or delete UTC leap seconds and correct the transmitted date and time of day. The transmitted date and time of day for leap second correction follow the guidelines in *National Institute of Standards and Technology Special Publication 432 (Revised 1990)*. This document is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, U.S.A.

When a positive leap second is required, one second is inserted at the beginning of the first hour (0h 0m 0s) of the day that the positive leap is occurring. The minute containing the leap second is 61 seconds long. The GPS sensor would have transmitted this information for the leap second added December 31, 1998 as follows:

```
$GPRMC,235959,A,3851.3651,N,09447.9382,W,000.0,221.9,071103,003.3,E*69
```

```
$GPRMC,000000,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*67
```

```
$GPRMC,000000,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*67
```

```
$GPRMC,000001,A,3851.3651,N,09447.9382,W,000.0,221.9,081103,003.3,E*66
```

If a negative leap second should be required, one second will be deleted at the end of some UTC month. The minute containing the leap second will be only 59 seconds long. In this case, the GPS sensor will not transmit the time of day 0h 0m 0s (the “zero” second) for the day from which the leap second is removed.

```
$GPRMC,235959,A,3851.3650,N,09447.9373,W,000.0,000.0,111103,003.3,E*69
```

```
$GPRMC,000001,A,3851.3650,N,09447.9373,W,000.0,000.0,121103,003.3,E*6A
```

```
$GPRMC,000002,A,3851.3650,N,09447.9373,W,000.0,000.0,121103,003.3,E*69
```

4.2.3 Global Positioning System Almanac Data (ALM)

Almanac sentences are not normally transmitted. Almanac transmission can be initiated by sending the GPS sensor a \$PGRMO,GPALM,1 command. Upon receipt of this command, the GPS sensor will transmit available almanac information on GPALM sentences. During the transmission of almanac sentences, other NMEA 0183 data output will be suspended temporarily.

```
$GPALM,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>,<13>,<14>,<15>*hh<CR><LF>
```

<field information> can be found in section [4.1.1 Almanac Information \(ALM\)](#).

4.2.4 Global Positioning System Fix Data (GGA)

```
$GPGGA,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,M,<10>,M,<11>,<12>*hh<CR><LF>
```

<1>	UTC time of position fix, hhmmss format
<2>	Latitude, ddmm.mmmm format (leading zeros will be transmitted)
<3>	Latitude hemisphere, N or S
<4>	Longitude, dddmm.mmmm format (leading zeros will be transmitted)
<5>	Longitude hemisphere, E or W
<6>	GPS quality indication, 0 = Fix not available, 1 = Non-differential GPS fix available, 2 = Differential GPS (DGPS) fix available, 6 = Estimated
<7>	Number of satellites in use, 00 to 12 (leading zeros will be transmitted)
<8>	Horizontal dilution of precision, 0.5 to 99.9
<9>	Antenna height above/below mean sea level, -9999.9 to 99999.9 meters
<10>	Geoidal height, -999.9 to 9999.9 meters
<11>	Differential GPS (RTCM SC-104) data age, number of seconds since last valid RTCM transmission (null if not an RTCM DGPS fix)
<12>	Differential Reference Station ID, 0000 to 1023 (leading zeros will be transmitted, null if not an RTCM DGPS fix)

4.2.5 GPS DOP and Active Satellites (GSA)

\$GPGSA,<1>,<2>,<3>,<3>,<3>,<3>,<3>,<3>,<3>,<3>,<3>,<3>,<3>,<4>,<5>,<6>*hh<CR><LF>

<1>	Mode, M = Manual, A = Automatic
<2>	Fix type, 1 = Not available, 2 = 2D, 3 = 3D
<3>	PRN number, 01 to 32, of satellite used in solution, up to 12 transmitted (leading zeros will be transmitted)
<4>	Position dilution of precision, 0.5 to 99.9
<5>	Horizontal dilution of precision, 0.5 to 99.9
<6>	Vertical dilution of precision, 0.5 to 99.9

4.2.6 GPS Satellites in View (GSV)

\$GPGSV,<1>,<2>,<3>,<4>,<5>,<6>,<7>,...<4>,<5>,<6>,<7>*hh<CR><LF>

<1>	Total number of GSV sentences to be transmitted
<2>	Number of current GSV sentence
<3>	Total number of satellites in view, 00 to 12 (leading zeros will be transmitted)
<4>	Satellite PRN number, 01 to 32 (leading zeros will be transmitted)
<5>	Satellite elevation, 00 to 90 degrees (leading zeros will be transmitted)
<6>	Satellite azimuth, 000 to 359 degrees, true (leading zeros will be transmitted)
<7>	Signal to noise ratio (C/No) 00 to 99 dB (leading zeros will be transmitted)

Note: Items <4>,<5>,<6>, and <7> repeat for each satellite in view to a maximum of four (4) satellites per sentence. Additional satellites in view information must be sent in subsequent bursts of NMEA 0183 data. These fields will be null if unused.

4.2.7 Recommended Minimum Specific GPS/TRANSIT Data (RMC)

\$GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>*hh<CR><LF>

<1>	UTC time of position fix, hhmmss format
<2>	Status, A = Valid position, V = NAV receiver warning
<3>	Latitude, ddmm.mmmm format (leading zeros will be transmitted)
<4>	Latitude hemisphere, N or S
<5>	Longitude, dddmm.mmmm format (leading zeros will be transmitted)
<6>	Longitude hemisphere, E or W
<7>	Speed over ground, 000.0 to 999.9 knots (leading zeros will be transmitted)
<8>	Course over ground, 000.0 to 359.9 degrees, true (leading zeros will be transmitted)
<9>	UTC date of position fix, ddmmyy format
<10>	Magnetic variation, 000.0 to 180.0 degrees (leading zeros will be transmitted)
<11>	Magnetic variation direction, E or W (westerly variation adds to true course)
<12>	Mode indicator (only output if NMEA 0183 version 2.30 active), A = Autonomous, D = Differential, E = Estimated, N = Data not valid

4.2.8 Track Made Good and Ground Speed (VTG)

\$GPVTG,<1>,T,<2>,M,<3>,N,<4>,K,<5>*hh<CR><LF>

<1>	True course over ground, 000 to 359.9 degrees (leading zeros will be transmitted)
<2>	Magnetic course over ground, 000 to 359.9 degrees (leading zeros will be transmitted)
<3>	Speed over ground, 000.0 to 999.9 knots (leading zeros will be transmitted)
<4>	Speed over ground, 0000.0 to 1851.8 kilometers per hour (leading zeros will be transmitted)
<5>	Mode indicator (only output if NMEA 0183 version 2.30 active), A = Autonomous, D = Differential, E = Estimated, N = Data not valid

4.2.9 Geographic Position (GLL)

\$GPGLL,<1>,<2>,<3>,<4>,<5>,<6>,<7>*hh<CR><LF>

<1>	Latitude, ddmm.mmmm format (leading zeros will be transmitted)
<2>	Latitude hemisphere, N or S
<3>	Longitude, dddmm.mmmm format (leading zeros will be transmitted)
<4>	Longitude hemisphere, E or W
<5>	UTC time of position fix, hhmmss format
<6>	Status, A = Valid position, V = NAV receiver warning
<7>	Mode indicator (only output if NMEA 0183 version 2.30 active), A = Autonomous, D = Differential, E = Estimated, N = Data not valid

4.2.10 Estimated Error Information (PGRME)

\$PGRME,<1>,M,<2>,M,<3>,M*hh<CR><LF>

<1>	Estimated horizontal position error (HPE), 0.0 to 999.9 meters
<2>	Estimated vertical position error (VPE), 0.0 to 999.9 meters
<3>	Estimated position error (EPE), 0.0 to 999.9 meters

4.2.11 GPS Fix Data Sentence (PGRMF)

\$PGRMF,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>,<13>,<14>,<15>*hh<CR><LF>

<1>	GPS week number (0 to 1023)
<2>	GPS seconds (0 to 604799)
<3>	UTC date of position fix, ddmmyy format
<4>	UTC time of position fix, hhmmss format
<5>	GPS leap second count
<6>	Latitude, ddmm.mmmm format (leading zeros will be transmitted)
<7>	Latitude hemisphere, N or S
<8>	Longitude, dddmm.mmmm format (leading zeros will be transmitted)
<9>	Longitude hemisphere, E or W
<10>	Mode, M = Manual, A = Automatic
<11>	Fix type, 0 = no fix, 1 = 2D fix, 2 = 3D fix
<12>	Speed over ground, 0 to 1851 kilometers/hour
<13>	Course over ground, 0 to 359 degrees, true
<14>	Position dilution of precision, 0 to 9 (rounded to nearest integer value)
<15>	Time dilution of precision, 0 to 9 (rounded to nearest integer value)

4.2.12 Programmable Device ID (PGRMID)

The Garmin Proprietary sentence \$PGRMID gives the device owner the flexibility of naming each sensor device with a custom text value.

\$PGRMID,<1>,<2>,<3>*hh<CR><LF>

<1>	ID Configuration Command, S = Set ID, C = Clear ID, E = Echo ID
<2>	User Defined ID (Maximum number of characters = 58)
<3>	Garmin Unit ID (Predefined and unique to each device)

4.2.13 Map Datum (PGRMM)

The Garmin Proprietary sentence \$PGRMM gives the name of the map datum currently in use by the GPS sensor. This information is used by the Garmin MapSource real-time plotting application.

\$PGRMM,<1>*hh<CR><LF>

<1>	Name of map datum currently in use (variable length field, for example., "WGS 84")
-----	--

4.2.14 Sensor Status Information (PGRMT)

The Garmin Proprietary sentence \$PGRMT gives information concerning the status of the GPS sensor. This sentence is transmitted once per minute regardless of the selected baud rate.

\$PGRMT,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>

<1>	Product, model and software version (variable length field, e.g., "GPS 16xHVS VER 2.05")
<2>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<3>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<4>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<5>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<6>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<7>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<8>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<9>	No Effect (This field is not used on this model and is included only for backwards compatibility)

4.2.15 3D Velocity Information (PGRMV)

\$PGRMV,<1>,<2>,<3>*hh<CR><LF>

<1>	True east velocity, -514.4 to 514.4 meters/second
<2>	True north velocity, -514.4 to 514.4 meters/second
<3>	Up velocity, -999.9 to 999.9 meters/second

4.2.16 DGPS Beacon Information (PGRMB)

Note: PGRMB is not supported at this time.

\$PGRMB,<1>,<2>,<3>,<4>,<5>,K,<6>,<7>*hh<CR><LF>

<1>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<2>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<3>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<4>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<5>	Distance to beacon reference station in kilometers
<6>	No Effect (This field is not used on this model and is included only for backwards compatibility)
<7>	DGPS fix source (R = RTCM, W = WAAS, N = Non-DGPS Fix)
<8>	DGPS mode, A = Automatic, W = WAAS Only, R = RTCM Only, N = None (DGPS disabled)

4.3 BAUD RATE SELECTION

Baud rate selection can be performed by sending the appropriate configuration sentence to the GPS sensor as described in the \$PGRMC section [4.1.3 Sensor Configuration Information \(PGRMC\)](#), field <10>.

4.4 ONE-PULSE-PER-SECOND (PPS) OUTPUT

The highly accurate one-pulse-per-second (PPS) output is provided for applications requiring precise timing measurements. The signal is generated after the initial position fix has been calculated and continues until the unit is powered down. The rising edge of the signal is synchronized to the start of each GPS second. Regardless of the selected baud rate, the information transmitted by the GPS sensor is referenced to the pulse immediately preceding the NMEA 0183 RMC sentence.

The accuracy of the one-pulse-per-second output is maintained only while the GPS sensor can compute a valid position fix. To obtain the most accurate results, the one-pulse-per-second output should be calibrated against a local time reference to compensate for cable and internal receiver delays and the local time bias.

The default pulse width is 100 ms, however; it may be programmed in 20 ms increments between 20 ms and 980 ms as described in \$PGRMC section [4.1.3 Sensor Configuration Information \(PGRMC\)](#), field <13>.

4.5 RECEIVED RTCM DATA

Position accuracy of less than 5 meters can be achieved with the GPS 16x series products by using Differential GPS (DGPS) real-time pseudo-range correction data in RTCM SC-104 format, with message types 1, 2, 3, 7, and 9. These corrections can be received by the GPS 16x series products on COM2. The RTCM data must be received at the same baud rate as the COM1 port. For details on the SC-104 format, refer to RTCM Paper 134-89/SC 104-68 by the Radio Technical Commission for Maritime Services.

APPENDIX A: EARTH DATUMS

The following is a list of the Garmin Earth datum indices and the corresponding earth datum name (including the area of application):

- 0 ADINDAN - Ethiopia, Mali, Senegal, Sudan
- 1 AFGOOYE - Somalia
- 2 AIN EL ABD 1970 - Bahrain Island, Saudi Arabia
- 3 ANNA 1 ASTRO 1965 - Cocos Island
- 4 ARC 1950 - Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, Zimbabwe
- 5 ARC 1960 - Kenya, Tanzania
- 6 ASCENSION ISLAND 1958 - Ascension Island
- 7 ASTRO BEACON E - Iwo Jima Island
- 8 AUSTRALIAN GEODETIC 1966 - Australia, Tasmania Island
- 9 AUSTRALIAN GEODETIC 1984 - Australia, Tasmania Island
- 10 ASTRO DOS 71/4 - St. Helena Island
- 11 ASTRONOMIC STATION 1952 - Marcus Island
- 12 ASTRO B4 SOROL ATOLL - Tern Island
- 13 BELLEVUE (IGN) - Efate and Erromango Islands
- 14 BERMUDA 1957 - Bermuda Islands
- 15 BOGOTA OBSERVATORY - Colombia
- 16 CAMPO INCHAUSPE - Argentina
- 17 CANTON ASTRO 1966 - Phoenix Islands
- 18 CAPE CANAVERAL - Florida, Bahama Islands
- 19 CAPE - South Africa
- 20 CARTHAGE - Tunisia
- 21 CHATHAM 1971 - Chatham Island (New Zealand)
- 22 CHUA ASTRO - Paraguay
- 23 CORREGO ALEGRE - Brazil
- 24 DJAKARTA (BATAVIA) - Sumatra Island (Indonesia)
- 25 DOS 1968 - Gizo Island (New Georgia Islands)
- 26 EASTER ISLAND 1967 - Easter Island
- 27 EUROPEAN 1950 - Austria, Belgium, Denmark, Finland, France, Germany, Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland
- 28 EUROPEAN 1979 - Austria, Finland, Netherlands, Norway, Spain, Sweden, Switzerland
- 29 FINLAND HAYFORD 1910 - Finland
- 30 GANDAJIKA BASE - Republic of Maldives
- 31 GEODETIC DATUM 1949 - New Zealand
- 32 ORDNANCE SURVEY OF GREAT BRITAIN 1936 - England, Isle of Man, Scotland, Shetland Islands, Wales
- 33 GUAM 1963 - Guam Island
- 34 GUX 1 ASTRO - Guadalcanal Island
- 35 HJORSEY 1955 - Iceland
- 36 HONG KONG 1963 - Hong Kong

- 37 INDIAN - Bangladesh, India, Nepal
- 38 INDIAN - Thailand, Vietnam
- 39 IRELAND 1965 - Ireland
- 40 ISTS O73 ASTRO 1969 - Diego Garcia
- 41 JOHNSTON ISLAND 1961 - Johnston Island
- 42 KANDAWALA - Sri Lanka
- 43 KERGUELEN ISLAND - Kerguelen Island
- 44 KERTAU 1948 - West Malaysia, Singapore
- 45 L.C. 5 ASTRO - Cayman Brac Island
- 46 LIBERIA 1964 - Liberia
- 47 LUZON - Mindanao Island
- 48 LUZON - Phillippines (excluding Mindanao Island)
- 49 MAHE 1971 - Mahe Island
- 50 MARCO ASTRO - Salvage Islands
- 51 MASSAWA - Eritrea (Ethiopia)
- 52 MERCHICH - Morocco
- 53 MIDWAY ASTRO 1961 - Midway Island
- 54 MINNA - Nigeria
- 55 NORTH AMERICAN 1927 - Alaska
- 56 NORTH AMERICAN 1927 - Bahamas (excluding San Salvador Island)
- 57 NORTH AMERICAN 1927 - Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua)
- 58 NORTH AMERICAN 1927 - Canal Zone
- 59 NORTH AMERICAN 1927 - Canada (including Newfoundland Island)
- 60 NORTH AMERICAN 1927 - Caribbean (Barbados, Caicos Islands, Cuba, Dominican Republic, Grand Cayman, Jamaica, Leeward Islands, Turks Islands)
- 61 NORTH AMERICAN 1927 - Mean Value (CONUS)
- 62 NORTH AMERICAN 1927 - Cuba
- 63 NORTH AMERICAN 1927 - Greenland (Hayes Peninsula)
- 64 NORTH AMERICAN 1927 - Mexico
- 65 NORTH AMERICAN 1927 - San Salvador Island
- 66 NORTH AMERICAN 1983 - Alaska, Canada, Central America, CONUS, Mexico
- 67 NAPARIMA, BWI - Trinidad and Tobago
- 68 NAHRWAN - Masirah Island (Oman)
- 69 NAHRWAN - Saudi Arabia
- 70 NAHRWAN - United Arab Emirates
- 71 OBSERVATORIO 1966 - Corvo and Flores Islands (Azores)
- 72 OLD EGYPTIAN - Egypt
- 73 OLD HAWAIIAN - Mean Value
- 74 OMAN - Oman
- 75 PICO DE LAS NIEVES - Canary Islands
- 76 PITCAIRN ASTRO 1967 - Pitcairn Island

- 77 PUERTO RICO - Puerto Rico, Virgin Islands
- 78 QATAR NATIONAL - Qatar
- 79 QORNOQ - South Greenland
- 80 REUNION - Mascarene Island
- 81 ROME 1940 - Sardinia Island
- 82 RT 90 - Sweden
- 83 PROVISIONAL SOUTH AMERICAN 1956 - Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela
- 84 SOUTH AMERICAN 1969 - Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Venezuela, Trinidad and Tobago
- 85 SOUTH ASIA - Singapore
- 86 PROVISIONAL SOUTH CHILEAN 1963 - South Chile
- 87 SANTO (DOS) - Espirito Santo Island
- 88 SAO BRAZ - Sao Miguel, Santa Maria Islands (Azores)
- 89 SAPPER HILL 1943 - East Falkland Island
- 90 SCHWARZECK - Namibia
- 91 SOUTHEAST BASE - Porto Santo and Madeira Islands
- 92 SOUTHWEST BASE - Faial, Graciosa, Pico, Sao Jorge, and Terceira Islands (Azores)
- 93 TIMBALAI 1948 - Brunei and East Malaysia (Sarawak and Sabah)
- 94 TOKYO - Japan, Korea, Okinawa
- 95 TRISTAN ASTRO 1968 - Tristan da Cunha
- 96 User defined earth datum
- 97 VITI LEVU 1916 - Viti Levu Island (Fiji Islands)
- 98 WAKE-ENIWETOK 1960 - Marshall Islands
- 99 WORLD GEODETIC SYSTEM 1972
- 100 WORLD GEODETIC SYSTEM 1984
- 101 ZANDERIJ - Surinam
- 102 CH-1903 - Switzerland
- 103 Hu - Tzu - Shan
- 104 Indonesia 74
- 105 Austria
- 106 Potsdam
- 107 Taiwan - modified Hu-Tzu-Shan
- 108 GDA - Geocentric Datum of Australia
- 109 Dutch

APPENDIX B: GARMIN BINARY OUTPUT FORMAT

Note: The following applies to all software versions of GPS 16xLVS and GPS 16xHVS.

Two records are transmitted once per second by the GPS 16x series products. One record contains primarily post-process information, such as position and velocity information. The second record contains receiver measurement information. The records are sent at a default baud rate of 9600 baud, 8 data bits, and no parity.

Records begin with a delimiter byte (10 hex). The second byte identifies the record type (33 hex for a position record, 34 hex for a receiver measurement). The third byte indicates the size of the data. The fourth byte is the first byte of data. The data is then followed by a checksum byte, a delimiter byte (10 hex), and an end-of-transmission character (03 hex).

Note: If RTCM-104 differential data is sent to the GPS sensor, the board will reset the Garmin Binary Output Data baud rate to the same baud rate used for RTCM-104 data. If the differential inputs are used on the GPS sensor, the RTCM-104 data must be sent to the GPS sensor at 9600 baud (preferred) or 4800 baud. RTCM-104 baud rates less than 4800 baud are not supported by the GPS sensors as it would limit bus bandwidth past the point where a once-per-second Garmin binary output data rate could be maintained.

Position Record

- 0x10 (DLE is first byte)
- 0x33 (Position record identifier)
- 0x40 (Size of data)
- cpo_pvt_data (See description below)
- one-byte checksum (The addition of bytes between the delimiters should equal 0)
- 0x10 (DLE)
- 0x03 (ETX is last byte)

```
typedef struct
{
    float    alt;
    float    epe;
    float    eph;
    float    epv;
    int      fix;
    double   gps_tow;
    double   lat;
    double   lon;
    float    lon_vel;
    float    lat_vel;
    float    alt_vel;
    float    msl_hght;
    int      leap_sec;
    long     grmn_days;
} cpo_pvt_data;
```

```

alt      Ellipsoid altitude (meters)
epe      Estimated position error (meters)
eph      Position error, horizontal (meters)
epv      Position error, vertical (meters)
fix      0 = no fix; 1 = no fix; 2 = 2D; 3 = 3D; 4 = 2D differential; 5 = 3D differential;
        6 and greater = not defined
gps_tow  GPS time of week (sec)
lat      Latitude (radians)
lon      Longitude (radians)
lon_vel  Longitude velocity (meters/second)
lat_vel  Latitude velocity (meters/second)
alt_vel  Altitude velocity (meters/ second)
msl_hght height (mean sea level) (meters)
leap_sec UTC leap seconds
grmn_days Garmin days (days since December 31, 1989)

```

Satellite Data Record

The satellite data has a record ID of 0x72 with 84 (0x54) data bytes. The data bytes contain data for 12 satellites as described below.

```

typedef      struct
{
    uint8      svid; //space vehicle identification (1-32 and 33-64 for WAAS)
    uint16     snr;   //signal-to-noise ratio
    uint8      elev; //satellite elevation in degrees
    uint16     azmth; //satellite azimuth in degrees
    uint8      status; //status bit-field
} cpo_sat_data;

```

The status bit field represents a set of booleans described below:

Bit	Meaning when bit is one (1)
0	The unit has ephemeris data for the specified satellite.
1	The unit has a differential correction for the specified satellite.
2	The unit is using this satellite in the solution.

This pattern is repeated for 12 satellites for a total of 12 X 7 bytes = 84 (0x54) bytes.

The RS-232 Packet for the Satellite Record looks like:

- 0x10 (DLE is first byte)
- 0x72 (Record ID – single byte)
- 0x54 (Number of data bytes – single byte)
- 12 cpo_sat_data records
- 0x## (2's complement of the arithmetic sum of the bytes between the delimiters)
- 0x10 (DLE)
- 0x03 (ETX is last byte)

The USB Packet for the Satellite Record looks like:

- 0x72 (Record ID – single byte)
- 0x54 (Number of data bytes – single byte)
- 12 cpo_sat_data records

Sample C Code

DLE and ETX bytes:

Sample C code to receive the two records should filter DLE and ETX bytes as described below:

```
typedef enum
{
    DAT,
    DLE,
    ETX
} rx_state_type;

/* Declare and initialize static variables */
static char    in_que[ 256 ];
static int     in_que_ptr = 0;
static rx_state_type rx_state = DAT;

.
.
.

void add_to_que( char data )
{
#define DLE_BYTE 0x10
#define ETX_BYTE 0x03

if ( rx_state == DAT )
{
    if ( data == DLE_BYTE )
    {
        rx_state = DLE;
    }
    else
    {
        in_que[ in_que_ptr++ ] = data;
    }
}
else if ( rx_state == DLE )
{
    if ( data == ETX_BYTE )
    {
        rx_state = ETX;
    }
    else
    {
        rx_state = DAT;
        in_que[ in_que_ptr++ ] = data;
    }
}
else if ( rx_state == ETX )
{
    if ( data == DLE_BYTE )
    {
        rx_state = DLE;
    }
}

if ( in_que_ptr > 255 )
{
    in_que_ptr = 0;
}
}
```

APPENDIX C: EPHEMERIS DATA DOWNLOAD (PROGRAMMING EXAMPLE)

Synopsis

This section describes, using an example, how to download ephemeris information from a Garmin 15, 16, 17 or 18 family GPS unit with the exception of the GPS 15-W and the GPS 15-F.

Garmin Binary Format Review

To download the ephemeris data, you must first command the unit to output information in Garmin Binary Format (Garmin mode) instead of the default NMEA output format. To put the unit in Garmin mode, connect to the unit using a terminal program and send the following NMEA sentence:

```
$PGRMO,,G*hh<CR><LF>
```

The checksum *hh is used for parity checking data and generally is not required in normal PC environments, but is recommended for use in environments containing high electromagnetic noise. When used, the parity bytes (hh) are the ASCII representation of the exclusive-or (XOR) sum of all the characters between the "\$" and "*" characters, non-inclusive. Sentences may be truncated by <CR><LF> after any data field and valid fields up to that point will be acted on by the GPS sensor. See section [4 Software Interface](#). The unit will stay in Garmin mode until the next power cycle.

Now that unit is in Garmin binary format, transmitted and received packets are structured as follows:

Byte Description	Name	Notes
Packet Delimiter	DLE	0x10
Packet ID (type)	ID	Packet type
Data Size	SIZE	Number of bytes in data portion(not including escaped DLEs. See below)
Data bytes	DATA	Not to exceed 256 bytes
.	.	.
.	.	.
.	.	.
Checksum	CHKSUM	2's complement of the arithmetic sum of all the bytes from the Packet ID byte to the last DATA byte(inclusive) not counting escaped DLEs. See below
Packet Delimiter	DLE	0x10
End of Packet	ETX	0x03

The DLE (0x10) is a delimiter byte used in conjunction with the ETX byte to determine beginning and ending of a packet. However, a 0x10 could appear in the data itself; if this occurs, the byte is escaped with another DLE byte (sometimes referred to as DLE stuffing). In other words, if a DLE occurs in the data, another DLE is transmitted immediately after to indicate that it is a data byte and it is not being used as a delimiter. Note that the size byte of the packet does not count the second DLE byte in an escaped DLE pair in the data field. Since a DLE that is a part of the data will have a second DLE to escape it, a single DLE followed by an ETX byte means that the end of a packet has been reached.

In order to interpret these packets properly, one must remove the escaped DLE bytes. This can be achieved using an algorithm similar to the Sample C Code fragment on the previous page.

Ephemeris Download Procedure

The following is the sequence of events that occurs when downloading ephemeris.

Send a packet containing the command that requests ephemeris data (IOP_DOWN_LOAD_EPH). The packet should look like this:

TX Packet: Ephemeris Data Request

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Command Data ID	IOP_CMND_DATA	0x0A
Number of bytes in data	SIZE	0x02
Request to D/L ephemeris	IOP_DOWN_LOAD_EPH	0x5D
Pad to 2 bytes	DATA	0x00
Checksum calculation	CHKSUM	0x97*
Delimiter	DLE	0x10
End	ETX	0x03

* From now on, checksum calculation will not be shown for every packet example

The unit will return an acknowledgement packet that will look like this:

RX Packet: Acknowledgement

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Acknowledgement ID	IOP_ACK_BYTE	0x06
Number of bytes in data	SIZE	0x02
Request to D/L ephemeris	IOP_CMND_DATA	0x0A
Pad	DATA	0x00
Checksum calculation	CHKSUM	----
Delimiter	DLE	0x10
End of packet	ETX	0x03

Then, the unit will immediately send a packet communicating how many data packets to expect for the ephemeris download (a maximum of twelve):

RX Packet: Number of Data Packets to Expect

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Record ID	IOP_RECORDS	0x1B
Number of bytes in data	SIZE	0x02
Number of records	NUM_SV	0x0C
Pad	DATA	0x00
Checksum calculation	CHKSUM	----
Delimiter	DLE	0x10
End of packet	ETX	0x03

This packet requires acknowledgement, as shown below (note that the data field contains the IOP_RECORDS ID to indicate the acknowledgement of the IOP_RECORDS packet):

TX Packet: Acknowledgement

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Record ID	IOP_ACK_BYTE	0x06
Number of bytes in data	SIZE	0x02
Pad	DATA	0x00
ID of packet being ACK'd	IOP_RECORDS	0x1B
Checksum calculation	CHKSUM	----
Delimiter	DLE	0x10
End of packet	ETX	0x03

Next, the unit will send the specified number of packets containing the ephemeris information. An example packet is shown below. Each packet should be acknowledged as before (be sure to modify the ACK packet to indicate what type of packet being acknowledged. For ephemeris data, the ID is 0x35).

RX Packet: Ephemeris Data

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Ephemeris data ID	IOP_SPC_EPH_DATA	0x35
Number of bytes in data	SIZE	0x78
Ephemeris data	DATA	----
.	.	.
.	.	.
.	.	.
Checksum calculation	CHKSUM	----
Delimiter	DLE	0x10
End of packet	ETX	0x03

The data portion of each packet can then be parsed into an instance of the following structure. Each of these structures represents data from a single satellite.

```
typedef struct          /* ephemeris data record for SPC          */
{
  sint16  wn;          /* week number (weeks)          */
  float   toc;         /* reference time of clock parameters (s)          */
  float   toe;         /* reference time of ephemeris parameters (s)          */
  float   af0;         /* clock correction coefficient - group delay (s)          */
  float   af1;         /* clock correction coefficient (s/s)          */
  float   af2;         /* clock correction coefficient (s/s/s)          */
  float   ura;         /* user range accuracy (m)          */
  double  e;           /* eccentricity (-)          */
  double  sqrta;       /* square root of semi-major axis (a) (m**1/2)          */
  double  dn;          /* mean motion correction (r/s)          */
  double  m0;          /* mean anomaly at reference time (r)          */
  double  w;           /* argument of perigee (r)          */
  double  omg0;        /* right ascension (r)          */
  double  i0;          /* inclination angle at reference time (r)          */
  float   odot;        /* rate of right ascension (r/s)          */
  float   idot;        /* rate of inclination angle (r/s)          */
  float   cus;         /* argument of latitude correction, sine (r)          */
  float   cuc;         /* argument of latitude correction, cosine (r)          */
  float   cis;         /* inclination correction, sine (r)          */
  float   cic;         /* inclination correction, cosine (r)          */
  float   crs;         /* radius correction, sine (m)          */
  float   crc;         /* radius correction, cosine (m)          */
  unsigned char iod; /* issue of data          */
} SDM_spc_eph_type;
```

An example function to do the parsing is shown below. Note that the double data types are converted by the function `cnvt_ieee_double()`. This function merely swaps the upper and lower words of the double. This is necessary on GPS 15, 16, 17 series sensors due to a compatibility issue with the IEEE floating point standard): In this example, the array `m_TempArray` contains the data portion of the ephemeris packet (with DLE stuffing removed).

```

/*****
*
*   PROCEDURE NAME:
*   copyData - ephemeris data unpacker
*
*   DESCRIPTION:
*   unpacks data from ephemeris packet DATA field after extraneous DLEs
*   have been removed. Note that sint16 refers to a signed 16-bit
*   integer type.
*
*****/
void GPM_ephList::copyData      /* ephemeris data unpacker          */
(
    GPM_ephData* pTemp          /* pointer to ephemeris data array */
)
{
    pTemp->EphStruct.wn = *(sint16*)&m_TempArray[IDX_EPH_WN];
    pTemp->EphStruct.toc = *(float*)&m_TempArray[IDX_EPH_TOC];
    pTemp->EphStruct.toe = *(float*)&m_TempArray[IDX_EPH_TOE];
    pTemp->EphStruct.af0 = *(float*)&m_TempArray[IDX_EPH_AF0];
    pTemp->EphStruct.af1 = *(float*)&m_TempArray[IDX_EPH_AF1];
    pTemp->EphStruct.af2 = *(float*)&m_TempArray[IDX_EPH_AF2];
    pTemp->EphStruct.ura = *(float*)&m_TempArray[IDX_EPH_URA];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_E]);
    pTemp->EphStruct.e = *(double*)&m_TempArray[IDX_EPH_E];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_SQRTA]);
    pTemp->EphStruct.sqrta = *(double*)&m_TempArray[IDX_EPH_SQRTA];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_DN]);
    pTemp->EphStruct.dn = *(double*)&m_TempArray[IDX_EPH_DN];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_M0]);
    pTemp->EphStruct.m0 = *(double*)&m_TempArray[IDX_EPH_M0];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_W]);
    pTemp->EphStruct.w = *(double*)&m_TempArray[IDX_EPH_W];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_OMG0]);
    pTemp->EphStruct.omg0 = *(double*)&m_TempArray[IDX_EPH_OMG0];

    cnvt_ieee_double((long *)&m_TempArray[IDX_EPH_I0]);
    pTemp->EphStruct.i0 = *(double*)&m_TempArray[IDX_EPH_I0];

    pTemp->EphStruct.odot = *(float*)&m_TempArray[IDX_EPH_ODOT];
    pTemp->EphStruct.idot = *(float*)&m_TempArray[IDX_EPH_IDOT];
    pTemp->EphStruct.cus = *(float*)&m_TempArray[IDX_EPH_CUS];
    pTemp->EphStruct.cuc = *(float*)&m_TempArray[IDX_EPH_CUC];
    pTemp->EphStruct.cis = *(float*)&m_TempArray[IDX_EPH_CIS];
    pTemp->EphStruct.cic = *(float*)&m_TempArray[IDX_EPH_CIC];
    pTemp->EphStruct.crs = *(float*)&m_TempArray[IDX_EPH_CRS];
    pTemp->EphStruct.crc = *(float*)&m_TempArray[IDX_EPH_CRC];
    pTemp->EphStruct.i0d = *(unsigned char*)&m_TempArray[IDX_EPH_I0D];

    return;
} /* copyData */

```


Each data member of the ephemeris data structure is indexed into the data array of the ephemeris packet and cast as the appropriate data type. The indices are as follows (note that they correlate to the data members of the structure respectively):

```
#define IDX_EPH_WN          0
#define IDX_EPH_TOC        4
#define IDX_EPH_TOE        8
#define IDX_EPH_AF0        12
#define IDX_EPH_AF1        16
#define IDX_EPH_AF2        20
#define IDX_EPH_URA        24
#define IDX_EPH_E           28
#define IDX_EPH_SQRTA       36
#define IDX_EPH_DN          44
#define IDX_EPH_M0          52
#define IDX_EPH_W           60
#define IDX_EPH_OMG0        68
#define IDX_EPH_I0          76
#define IDX_EPH_ODOT        84
#define IDX_EPH_IDOT        88
#define IDX_EPH_CUS         92
#define IDX_EPH_CUC         96
#define IDX_EPH_CIS        100
#define IDX_EPH_CIC        104
#define IDX_EPH_CRS        108
#define IDX_EPH_CRC        112
#define IDX_EPH_IOD        116
```

The last packet will be a “download complete” packet that will look like this:

TX Packet: Download Complete

Byte Description	Name	HEX Value
Delimiter	DLE	0x10
Download Complete ID	IOP_DL_CMPLT	0x0c
Number of bytes in data	SIZE	0x02
Ephemeris Download ID	IOP_DOWN_LOAD_EPH	0x5D
Pad	DATA	0x00
Checksum calculation	CHKSUM	----
Delimiter	DLE	0x10
End of packet	ETX	0x03

After properly acknowledging this packet (ACK the IOP_DL_CMPLT ID), the ephemeris download is complete.

APPENDIX D: SENSOR CONFIGURATION SOFTWARE

The Garmin Sensor Configuration Software (SNSRXCFG.exe) configures the GPS sensors based on user-selected parameters. Some application features include the ability to download GPS sensor configuration, maintain different configurations in files, and perform GPS sensor configurations quickly with the use of one function key.

This section provides a brief overview of the Sensor Configuration Software. Refer to this section when using the software to configure your Garmin sensor.

Downloading the Sensor Configuration Software

The SNSRXCFG software is available from the Garmin website. To download the software, go to https://www8.garmin.com/support/download_details.jsp?id=4053, and click **Download**.


Selecting a Model

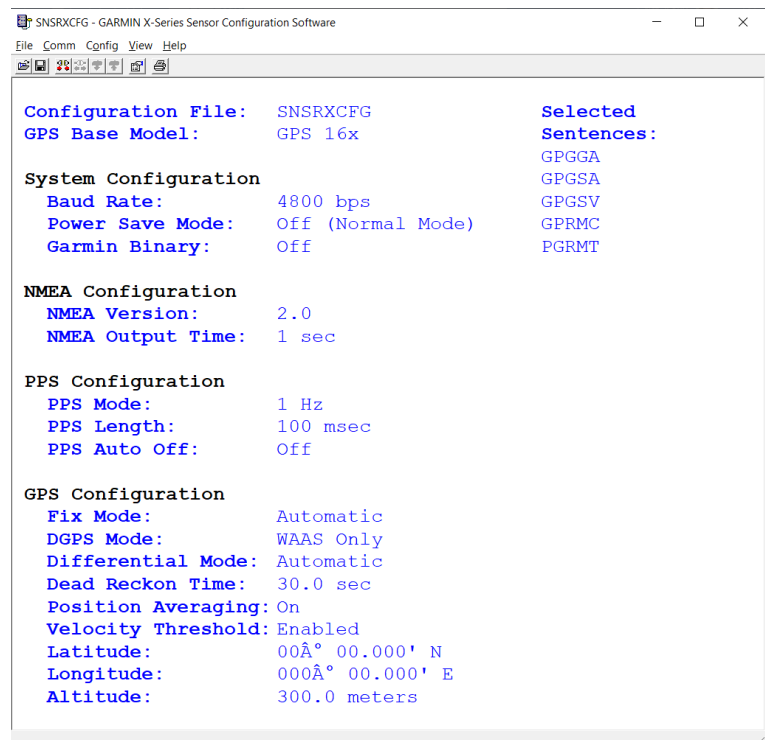
1. Double-click **SNSRXCFG.exe**.
2. Select the radio button next to the type of Garmin sensor you are configuring.
3. Select **OK**.

Connecting to the Sensor

After selecting the type of sensor, the following window opens. This is the main window for the program.

To configure your sensor, you must first connect to the sensor.

1. Select **Config > Switch to NMEA Mode** (or press the F10 key).
2. Select **Comm > Setup** to open the Comm Setup window.
3. Select the serial port to which the sensor is connected: select **Auto** to have the program automatically determine the baud rate, or select **Manual** to manually select the baud rate.
4. Click **OK**.
5. Click the **Connect** icon , or select **Comm > Connect**.
6. To view the current programming of the sensor, select **Config > Get Configuration from GPS** (or press the F8 key). The current programming of the sensor appears as shown in the example to the right.



Menus

File Menu

The File Menu allows you to open, save, and print sensor configurations. The items in the File Menu work like most Windows-based programs.

Comm Menu

The Comm (Communication) Menu allows you to set the port number and baud rate, as well as connect to the sensor and disconnect from the sensor.

Setup: Opens the Comm Setup window. Select the serial port to which the sensor is connected from the drop-down list. Select **Auto** (the program determines the baud rate on its own) or **Manual** (you enter the baud rate) for the baud rate entry.

Connect: Select **Connect** to connect to the sensor in order to change or view the configuration.

Disconnect: Select **Disconnect** to disconnect from the sensor.

Config Menu

The Config (Configuration) Menu allows you to configure the sensor as it is connected.

Sensor Configuration (F6): Opens the Sensor Configuration window, shown to the right. Many of the fields in this window should not be changed. Refer to the beginning of this manual for information on many of these fields. This window is used to enter a new latitude, longitude, and altitude for the sensor. This is especially helpful when you are programming the sensor for use in a particular geographic location.

Click **Reset Unit** to perform a reset on the unit, much like cycling the power.

Resetting the non-volatile memory (**Reset NonVol**) clears all of the data from the non-volatile memory.

NMEA Sentence Selections (F7): Displays the NMEA Sentence Selections window. If the sentence is enabled, a check mark appears in the box to the left of the sentence name. Click the box to enable or disable to the sentence.

Get Configuration From GPS (F8): Retrieves the current programming from the sensor. The programming is then displayed in the Main Interface window.

Send Configuration To GPS (F9): Sends your updated configuration programming to the sensor.

Switch to NMEA Mode (F10): Switches the unit to NMEA Mode. The sensor must be in NMEA Mode when connected to this software.

Switch to Garmin Mode (F11): Switches the unit to Garmin Mode.

The screenshot shows the 'Sensor Configuration' dialog box with the following sections and settings:

- System Configuration:** Baud Rate: 4800; Power Save Mode: ; Garmin Binary Output: . Note: Selecting "Garmin Binary Output" will disable NMEA output. The device will instead output data in Garmin Binary format.
- NMEA Configuration:** NMEA: 2.0; NMEA Output Time: 1; Talker ID: GP.
- Pulse-Per-Second (PPS) Configuration:** Enable Pulse Per Second: ; PPS Auto Off Mode: ; PPS Length: 100.
- GPS Configuration:** Fix Mode: Automatic; DGPS Mode: WAAS Only; Diff Mode: Automatic; Low Velocity Threshold: Enable; Dead Reckon Valid Time: 30 sec; Position Averaging: ; Earth Datum: WGS 84; Latitude: 0° 0' 0" N; Longitude: 0° 0' 0" E; Altitude: 300 meter; Update Rate: 1; Dynamics Mode: LOW; DA: 6378137; DF: 298.257223563; DX: 0; DY: 0; DZ: 0; GNSS Source: GPS, GLONASS, BDS, GALILEO.
- Configuration Profile:** Accessory-ON resistor: Installed, NOT Installed.
- Output Mode:** GPS17x compatible.
- Device ID:** (Empty text field)
- Commands:** Reset Unit, Reset NonVol, Set Autolocate, Test Mode.
- Buttons:** OK, Cancel.

Update Software (F12): After you have downloaded a new software version for the sensor, you can update the sensor with the new software. Select **Update Software** and then select the file using the Open dialog box. You must locate both the .rgn file and the updater.exe file.

View Menu

The View Menu allows you to view the NMEA sentences transmitted by the sensor. You can also customize how the program looks by showing and hiding the Toolbar and Status Bar.

Help Menu

The Help Menu displays the software version and copyright information.