M48M TIMING ONCORE
GPS RECEIVER
User's Guide

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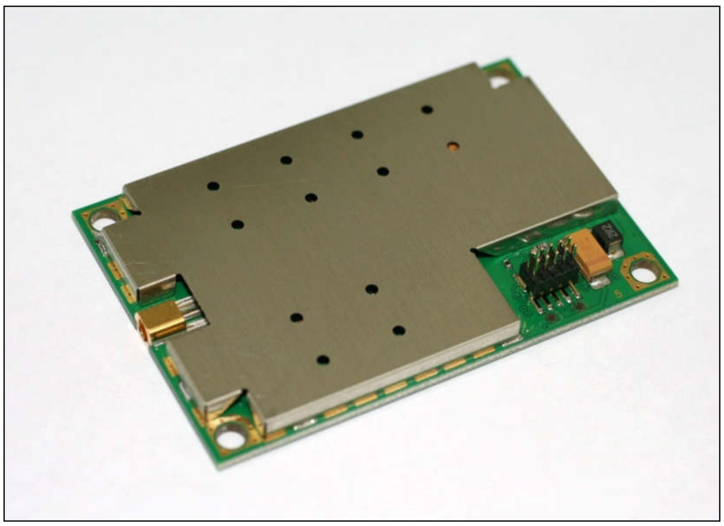
Revision A



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If you need help or have any questions regarding i-Lotus GPS products, contact your i-Lotus customer representative.

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Chapter 1 – INTRODUCTION

CHAPTER SUMMARY

Refer to this chapter for the following:

- An introduction to GPS and the M48M Oncore receivers
- A limited warranty for the receivers

OVERVIEW

The M48M is a high performance GPS timing receiver modules designed to be intelligent and compact . Armed with two fast acquisition channels complimenting the 32 tracking channels, each channel independently tracks both code and carrier for the superior performance required in today's GPS user environment. Specifically designed for embedded applications, the M48M, when combined with the active antennas, affords the engineer new freedom in bringing GPS technology to the most demanding Original Equipment Manufacturer (OEM) applications.
M48M receiver offerings include:

M48M Oncore Timing Receiver

The M48M Oncore Timing receiver is a highly optimized firmware making it one of the most capable timing receivers on the market. Standard features include precise, one-pulse-per-second (1PPS) outputs and features T-RAIM integrity monitoring algorithm.

Nonetheless, the main highlight of the M48M has an intelligent algorithm to overcome the issue of the GPS week rollover problem. The intelligent algorithm is able to decode the correct week number and dynamically align time correctly during each rollover.
Hence, it is able to decode the correct week number as long as possible in the GPS product life by aligning to the correct week number and be moved ahead along the years.

PRODUCT HIGHLIGHTS

Features present on M48M receivers include the following:

- 32-channel parallel receiver design
- Code plus carrier tracking (carrier-aided tracking)
- Position filtering
- Antenna current sense circuitry
- Operation from +2.85 to +3.15 Vdc regulated power
- 3V CMOS/TTL serial interface to host equipment
- Latitude, longitude, height, velocity, heading, time, and satellite status information transmitted at user determined rates (continuously or polled)
- Straight 10-pin power/data header for low-profile flat mounting against host circuit board. An optional right angle header is available for vertical PWA mounting.
- User selectable NMEA 0183 output

Additional features specific to the M48M positioning receiver include:

Additional features specific to the M48M timing receiver include:

- Precise 1PPS output <10 ns accuracy w/o sawtooth correction
- Automatic site survey
- Time RAIM (Time-Receiver Autonomous Integrity Monitoring) algorithm for checking timing solution integrity

APPLICATIONS

Considering that 24-hour, all weather, worldwide coverage is fundamental to GPS positioning and navigation, it is easy to envision a broad range of applications and a large community of GPS users. Applications include the following:

- Automobile Navigation
- Aircraft Navigation
- Land Navigation
- Marine Navigation
- Emergency Calling
- Theft Recovery
- Telematics
- Fleet Tracking
- Routing Systems
- Rail Management
- Asset Management
- Emergency Search and Rescue
- Utility Services
- Precise Time Measurement
- Frequency Stabilization
- Network Synchronization
- Surveying and Mapping
- Exploration

LIMITED WARRANTY ON I-LOTUS GPS PRODUCTS

What This Warranty Covers and For How Long,

i-Lotus Corporation Pte. Ltd. ("i-Lotus") warrants its Global Positioning System (GPS) Products ("Product") against defects on material and workmanship under normal use and service for a period of twelve (12) months from Product's in-service date, but in no event longer than eighteen (18) months from initial shipment of the Product.

i-Lotus, at its option, will at no charge either repair, exchange, or replace this Product during the warranty period provided it is returned in accordance with the terms of this warranty. Replaced parts or boards are warranted for the balance of the original applicable warranty period. All replaced parts or Product shall become the property of i-Lotus. Any repairs not covered by this warranty will be charged at the cost of replaced parts plus the i-Lotus hourly labor rate current at that time.

This express limited warranty is extended by i-Lotus to the original end user purchaser only and is not assignable or transferable to any other party. This is the complete warranty for Products manufactured by i-Lotus. i-Lotus does not warrant the installation, maintenance or service of the Product.

i-Lotus cannot be responsible in any way for any ancillary equipment not furnished by i-Lotus, which is attached to or used in connection with i-Lotus 's GPS Products, or for operation of the Product with any ancillary equipment and all such equipment is expressly excluded from this warranty.

The Global Positioning System is operated and supported by the U.S. Department of Defense and is made available for civilian use solely at its discretion. The Global Positioning System is subject to degradation of position, velocity, and time accuracies by the Department of Defense. I- does not warrant or control Global Positioning System availability or performance.
This warranty applies around the world.

What This Warranty Does Not Cover

(a) Defects or damage resulting from use of the Product in other than its normal and customary manner.
(b) Defects or damage from misuse, accident or neglect.
(c) Defects or damage from improper testing, operation, maintenance, installation, alteration, modification or adjustment.
(d) Defects or damage due to lightning or other electrical discharge.
(e) Product disassembled or repaired in such a manner as to adversely affect performance or prevent adequate inspection and testing to verify any warranty claim.
(f) Product which has had the serial number removed or made illegible.
(g) Freight costs to the repair depot.

How to Get Warranty Service

To receive warranty service, contact your Oncore reseller.

General Provisions

This warranty sets forth the full extent of i-Lotus's responsibility regarding the Product. Repair, replacement, or refund of the purchase price, at i-Lotus's option, is the exclusive remedy.

THIS WARRANTY IS GIVEN IN LIEU OF ALL OTHER EXPRESS WARRANTIES. IMPLIED WARRANTIES, INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE DURATION OF THIS LIMITED WARRANTY. IN NO EVENT SHALL I-LOTUS BE LIABLE FOR DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE PRODUCT, FOR ANY LOSS OF USE, LOSS OF TIME, INCONVENIENCE, COMMERCIAL LOSS, LOST PROFITS OR SAVINGS OR OTHER INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE INSTALLATION, USE, OR INABILITY TO USE SUCH PRODUCT, TO THE FULL EXTENT SUCH MAY BE DISCLAIMED BY LAW.

CHAPTER 2 - RECEIVER DESCRIPTIONS

CHAPTER SUMMARY

Refer to this chapter for the following:

- A simplified functional description of the operation of the M48M Oncore receiver
- Antenna power and gain requirements
- Physical size and electrical connections of the M48M Oncore receiver
- M48M Oncore receiver technical characteristics and operating features
- M48M installation precautions and mounting considerations
- Binary and NMEA interface protocol descriptions
- Operational details of the M48M Oncore receiver

OVERVIEW

The M48M Oncore receiver provides position, velocity, time, and satellite tracking status information via a serial port.

A simplified functional block diagram of the M48M receiver is shown below in Figure 2.1.

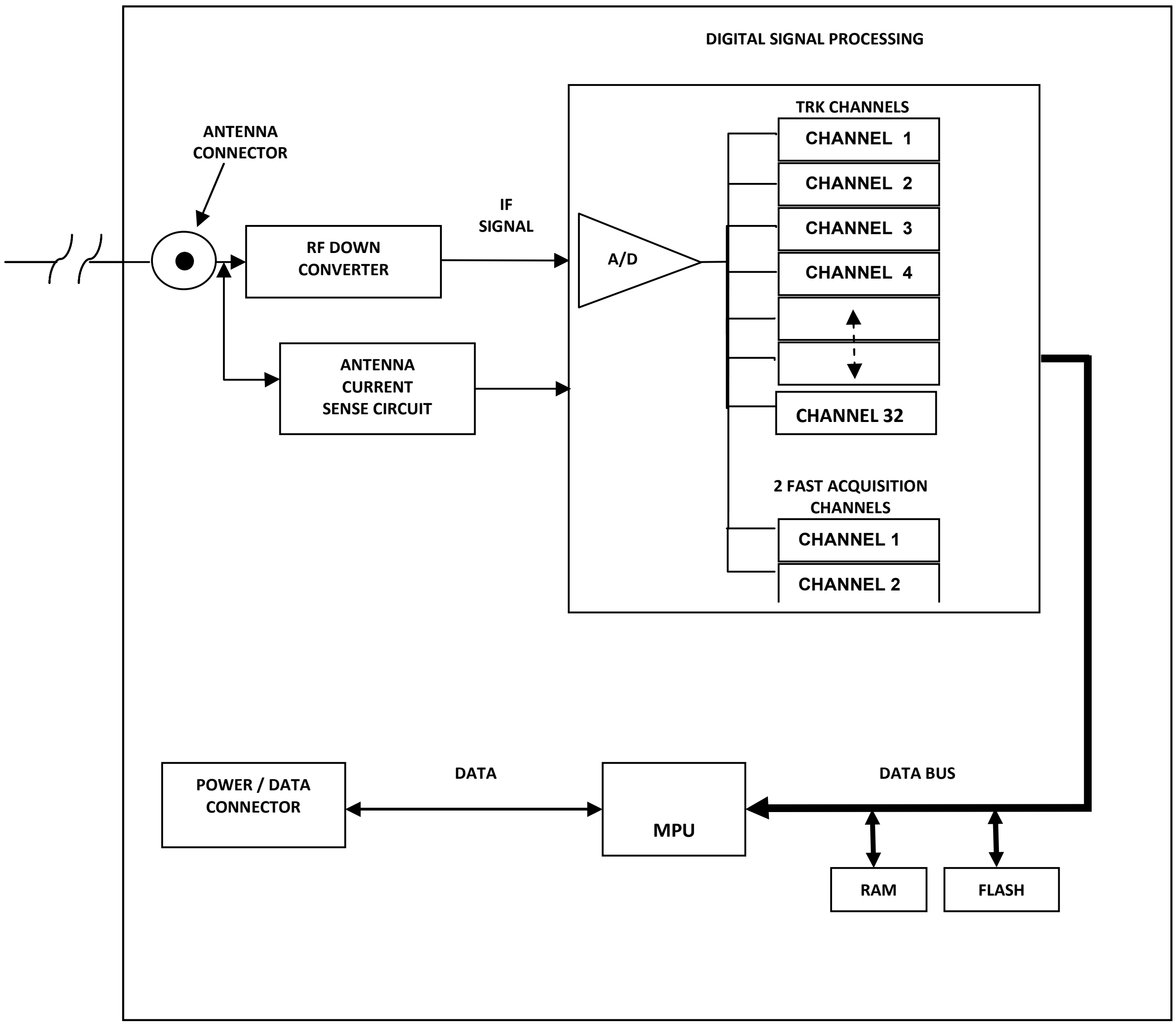

Figure 2.1: M48M Oncore Receiver Functional Block Diagram

The M48M Oncore receiver is capable of tracking thirty-two satellites simultaneously and is enhanced with two additional fast acquisition channels. The module receives the L1 GPS signal (1575.42 MHz) from the antenna and operates off the coarse/acquisition (C/A) code tracking. The code tracking is carrier aided. Time recovery capability is inherent in the architecture.

The L1 band signals transmitted from GPS satellites are typically collected, filtered, and amplified by micro-strip patch antennas such as the Type I or Type II. Signals from the antenna module are then routed to the RF signal processing section of the M48M via a single coaxial interconnecting cable. This interconnecting cable also provides bias power for the low-noise-amplifier (LNA) in the antenna. The M48M is capable of providing the antenna with 5V via J3 connector (pin 9 - antenna bias) with currents up to 80mA.

The RF signal processing section of the M48M printed circuit board (PCB) contains the required circuitry for down-converting the GPS signals received from the antenna module. The resulting intermediate frequency (IF) signal is then passed to the thirty-two channel code and carrier correlates section of the M48M where a single, high speed analog-to-digital (A/D) converter converts the IF signal to a digital sequence prior to channel separation. This digitized IF signal is then is split into thirty-two parallel channels for signal detection, code correlation, carrier tracking, and filtering.

The processed signals are synchronously routed to the position microprocessor (MPU) section. This section controls the receiver operating modes, decodes and processes satellite data, and the pseudo-range and delta range measurements used to compute position, velocity, and time.

Initial "Cold Start"

In the first power up of the receiver, none of the setup information is available to the receiver. The receiver will perform a “Cold Start”, where position, time, and almanac information are not available. Hence, the Time To First Fix (TTFF) will be somewhat longer than if the information had been available.

The main thing the system designer must keep in mind is that a receiver coming up in a Cold Start scenario is defaulted to Moto Binary protocol, and NO MESSAGES are ACTIVE. The receiver is running through its normal housekeeping routines, developing new fix data, etc., but it will not send any of this data out of the serial port until it is requested.

If the receiver is being used as part of a larger system where the user has access to the receiver’s serial port through application software such as SiRFOncore, the user can simply use the software to reinitialize the receiver into the desired mode.

Embedded developers have to be careful since they typically do not have direct access to the receiver's serial port. In this case the best thing to do is to ASSUME that the receiver will always wake up in a defaulted condition and include code in the application software to initialize the receiver every time power is cycled. This code may be as simple as merely directing the receiver to output a standard Binary Position/Status/Data message (@@Ha for instance), or may possibly involve uploading a stored almanac, switching the receiver over to NMEA mode and initializing the desired NMEA strings. No matter, the effect is still the same: if the receiver wakes up with all setup information intact, there's no harm done, the initialization commands merely reinforce the configuration data already present in memory. If the receiver powers up in the defaulted mode the initialization code ensures that the receiver operates in the manner intended.

Built-in SMARTSAVE Memory Backup

Built-in smartsave backup feature enables the system setup information to be automatically saved into the flash memory after its initial "Cold Start". The smartsave feature is useful for increasing the speed of satellite acquisition and fix determination when the receiver is powered up after a period of inactivity.

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Antenna Drive and Protection Circuitry

The M48M is capable of detecting the presence of an antenna. The receiver utilizes an antenna sense circuit that can detect under current (open condition), over current (shorted or exceeding maximum receiver limits), or a valid antenna connection. The M48M is designed to provide up to 80 mA of current via the antenna power supply circuit. The circuit contains short protection and a means for detecting over current and open circuit conditions of the connection between it and the antenna. This allows the user a degree of confidence that the antenna is connected properly and is drawing current. This feature can eliminate hours of troubleshooting, especially in a new installation.

The antenna power supply circuit consists of a current sense resistor, a pass transistor, and Analog to digital Converter (ADC) inside the microprocessor. The ADC measures the voltage developed across the current sense resistor with defined thresholds. If the antenna is drawing 10 mA or more, the software understands that an antenna is attached. If the signal is absent, indicating an under-current condition, an alarm bit is set to alert the user. Having this alarm bit high does not prevent the receiver from operating, and may in fact be high all the time when utilizing an antenna with low current draw, or when supplying the antenna with power through an external source using a bias-T.

The over current detection circuit operates in a similar manner. When the voltage drop across the current sense resistor is equal to the over current threshold (set at about 80 mA at room) the software understands some fault in the antenna. As with the undercurrent sensor, the software will trigger an alarm bit that indicates the over-current condition.

The antenna detection command provides the user with following options.

1. Switch off the Antenna detection Algorithm.
2. Switch on the Antenna detection Algorithm and activate protection mechanism.
3. Switch on the Antenna detection Algorithm and deactivate the protection mechanism.

The antenna sense circuit was designed to operate with the Antenna Type I and Antenna Type II GPS antennas, therefore non-quantified antennas may exceed the threshold limits as listed below:

Normal operation @25^{o}C	:	greater than 10mA and less than or equal to 80mA
Under current detect @ 25^{o}C	:	less than 10 mA
Over current detect @ 25^{o}C	:	greater than 80 mA

***NOTE*:** *An external power source such as a bias-T must be used if the antenna circuit power requirement exceeds the upper limit.*

The antenna status information is output in the following I/O messages:

- @@Ha(12 Channel Position/Status/Data Message)
- @@Hb (12 Channel Short Position Message)

***NOTE**: Detection of an under current situation will not prevent the M48M from operating. The module will continue to operate normally, but will raise the error flag in the two messages, indicating a possible antenna problem.*

A chart of the typical output voltage vs. the load current is shown below in figure 2.2. Note that there is some drop to the output voltage as higher currents are drawn due to IR losses across the current sense resistor and pass transistor. The system engineer should consider this drop if the coax run to the antenna is going to be long, and/or the gain of the antenna being used is adversely affected by lowered input voltage. Note that the M48M can accept 5V on the antenna bias pin (Pin 9.)

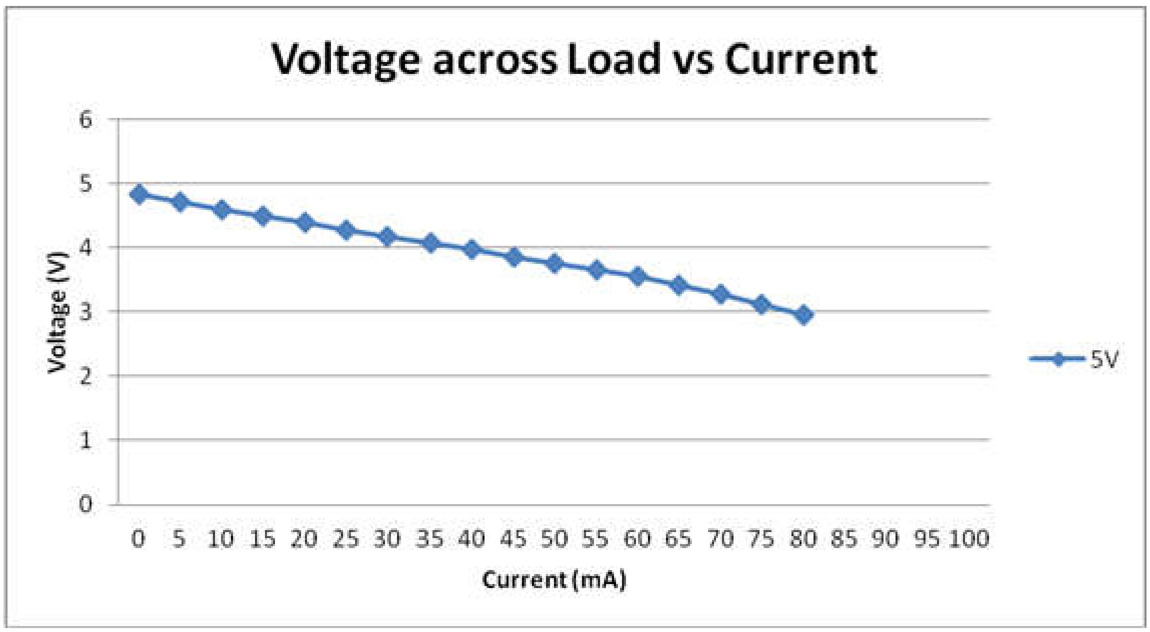

Figure 2.2 antenna drive circuit performance

Active Antenna Configuration

The recommended external gain (antenna gain minus cable and connector losses) for the M48M is 10 to 50 dB. A typical antenna system might have an active antenna such as the Antenna Type I with 29 dB of gain and five meters of cable with 5 dB of loss. The net external gain would then be 24 dB, which is well within the acceptable range. While the receiver may track satellites with gain values outside of the recommended limits, performance may suffer and the receiver may be more susceptible to noise and jamming from other RF sources. For more information on antennas, refer to Chapter 4.

M48M Receiver Electrical Connections

The M48M receivers receive electrical power and receive/transmit I/O signals through a 10-pin power/data connector (J3) mounted on the receiver. Figure 3.3 below illustrates the positions of both the 10-pin header and the MMCX antenna connector (J1).

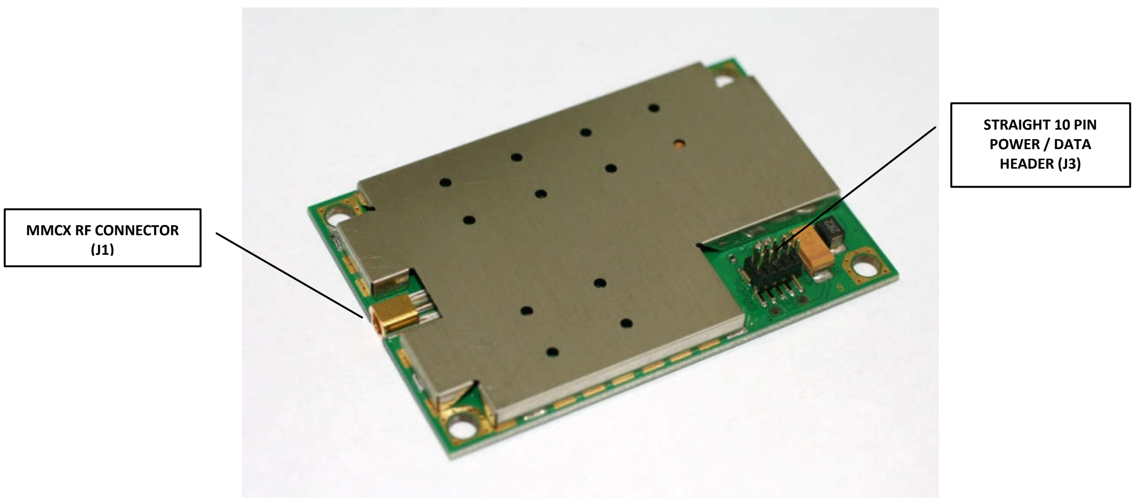

Figure 2.3: M48M Oncore Receiver

The following table lists the assigned signal connections of the M48M receiver's power and data connector (J3).

Table 2.1: M48M Power/Data Connector (J3) Pin Assignments

Pin #	Signal Name	Description
1	TxD1	Transmit Data (3V logic)
2	RxD1	Receive Commands (3V logic)
3	+3V PWR	Regulated 3Vdc Input
4	1PPS	1 pulse-per-second output
5	Ground	Signal and Power common
6	Battery	Optional External Backup
7	Reserved	Not currently used
8	RTCM In	RTCM correction input
9	Antenna Bias	3V-5V antenna bias input
10	Reserved	Not currently used

M48M Nominal Voltage and Current Ranges

Main Power

Voltage: 2.85V to 3.15V regulated, 50 mV peak-to-peak ripple

Current: 96 mA maximum (without antenna)

M48M ONCORE RECEIVER

PRINTED CIRCUIT BOARD MECHANICAL DRAWINGS

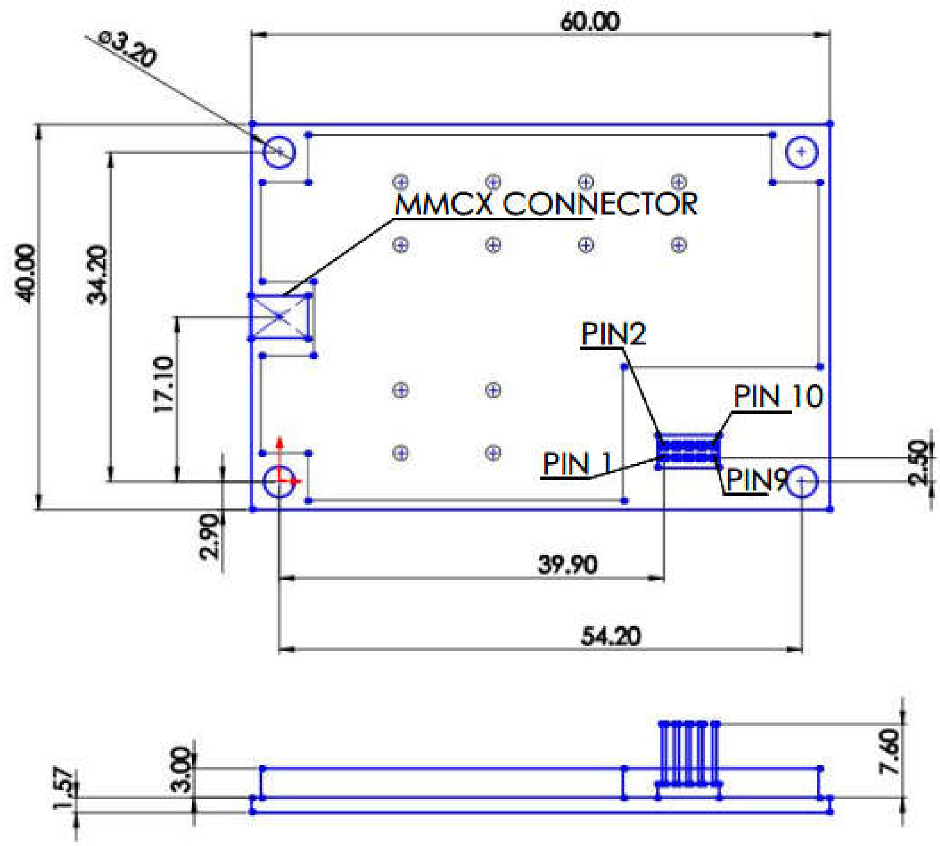

Figure 2.4: M48M Oncore Printed Circuit Board Layout with Straight, 0.050" [1.27mm] Pitch, 10 Pin Data Header

M48M TIMING RECEIVER TECHNICAL CHARACTERISTICS

Table 2.2 Oncore Technical Characteristics – M48M Timing Model

General Characteristics	Receiver Architecture	32 parallel channel L1 1575.42 MHz C/A code (1.023 MHz chip rate) Code plus carrier tracking (carrier aided tracking)
	Tracking Capability	32 simultaneous satellite vehicles
Performance Characteristics	Dynamics	Velocity: 1000 knots (515 m/s) > 1000 knots (515 m/s); at altitudes < 60,000 ft. (18000m) Acceleration: 4g Jerk: 5 m/s^3
	Acquisition Time (Time To First Fix, TTFF) (Tested at –40ºC to +85ºC)	< 01 s typical TTFF-hot (with current almanac, position, time and ephemeris) < 30 s typical TTFF-warm (with current almanac, position, time) < 33 s typical TTFF-cold (No stored information) < 1.0 s internal reacquisition (typical)
	Timing Accuracy 1 Pulse Per Second (PPS)	Performance not using clock granularity message: < 10 ns, 1-sigma < 30 ns, 6-sigma
	Datum	WGS-84 default One user definable datum
Antenna	Antenna Requirements	Active antenna module powered by receiver module (80mA max) 10dB to 50dB external antenna gain measured at receiver input 5 Vdc antenna power provided via header connector
Serial Communication	Output Messages	Latitude, longitude, height, velocity, heading, time Binary protocol at 9600 baud NMEA 0183 (GGA, GLL, GSA, GSV, RMC, VTG, ZDA) Software selectable output rate (continuous or poll) TTL interface (0 to 3 V)
Electrical Characteristics	Power Requirements	2.8 Vdc to 3.3 Vdc; 50 mVp-p ripple (max)
	Power Consumption	288 mW @ 3 V without antenna
Physical Characteristics	Dimensions	40.0 x 60.0 x 9.8 mm
	Weight	Receiver 14.2 g
	Connectors	Data/power: 10 pin (2x5) unshrouded header on 0.050 in. centers (straight configuration) RF: right angle MMCX
	Antenna to Receiver Interconnection	Single coaxial cable (with power on center conductor to support active antenna) Antenna sense circuit
Environmental Characteristics	Operating Temperature	-40ºC to +85ºC
	Storage Temperature	-40ºC to +85ºC
	Humidity	95% over dry bulb range of +38ºC to +85ºC
	Altitude	18,000 m (60,000 ft.) maximum > 18,000 m (60,000 ft.) for velocities < 515 m/s (1000 knots)
Miscellaneous	Standard Features	Position hold with automatic site survey Clock granularity error message T-RAIM (Timing Receiver Autonomous Integrity Monitoring)

RF Jamming Immunity

Many precise timing GPS installations require locating the GPS antenna at close range to other systems. Some of these transmitters may randomly cause the GPS receiver to lose lock on tracked satellites. This can be very disconcerting to the timing user since the system must rely on clock coasting until the satellite signals are reacquired. Long coasting times require more expensive oscillators for the timing electronics in order to meet system specifications for holdover capability.

Experience has shown that receiver selectivity, or the ability to select only the GPS band of information and reject all other signals, is an important feature for GPS receivers, especially in cases such as those often encountered in timing applications.

Adaptive Tracking Loops (M48M Timing Receiver Only)

The jamming immunity of the M48M Oncore timing receiver is done by an innovative software technique to further improve the immunity. The technique takes advantage of the fact that for precise timing applications, the receiver is not moving. In mobile GPS applications, the receiver must be able to track satellites under varying dynamics. Vehicle acceleration causes an apparent frequency shift in the received signal due to Doppler shift. In order to track signals through acceleration, the tracking loops are wide enough to accommodate the maximum expected vehicle acceleration and velocity. When the receiver is stationary, the tracking loops do not need to be as wide in order to track the satellites. In the M48M timing receiver firmware, the satellite tracking loops are narrowed once the receiver has acquired the satellites and reached a steady state condition. This adaptive approach allows the tracking loops to be narrowed for maximum interference rejection while not unduly compromising the rapid startup and acquisition characteristics of the receiver.

Test results have demonstrated that this approach is effective at providing an additional 10 dB of jamming immunity to both in-band and out-of-band signals. The combined results of the additional filtering and the adaptive tracking loops in the M48M Oncore combine to provide the user with a receiver/antenna system effective at improving RF jamming immunity, thus making installation in timing applications more flexible and robust. The status of the tracking loops (wide-band or narrow-band) are indicated by status bits in the @@Ha and @@Hb messages

Time RAIM Algorithm

Time **R**eceiver **A**utonomous **I**ntegrity **M**onitoring (T-RAIM) is an algorithm in Oncore timing receivers (including the M48M) that uses redundant satellite measurements to confirm the integrity of the timing solution. The T-RAIM approach is borrowed from the aviation community where integrity monitoring is safety critical.

In most surveying systems and instruments, there are more measurements taken than are required to compute the solution. The excess measurements are redundant. A system can use redundant measurements in an averaging scheme to compute a blended solution that is more robust and accurate than using only the minimum number of measurements required. Once a solution is computed, the measurements can be inspected for blunders. This is the essence of T-RAIM.

In order to perform precise timing, the GPS receiver position is determined and then the receiver is put into Position-Hold mode where the receiver no longer solves for position. With the position known, time is the only remaining unknown. When in this mode, the GPS receiver only requires one satellite to accurately determine time. If multiple satellites are tracked, then the time solution is based on an average of the satellite measurements. When the average solution is computed, it is compared to each individual satellite measurement to screen for blunders. A residual is computed for each satellite by differencing the solution average and the measurement. If there is a bad measurement in the set, then the average will be skewed and one of the measurements will have a large residual. If the magnitude of the residuals exceeds the expected limit, then an alarm condition exists and the individual residuals are checked. The magnitude of each residual is compared with the size of the expected measurement error. If the residual does not fall within a defined confidence level of the measurement accuracy, then it is flagged as a blunder. Once a blunder is identified, then it is removed from the solution and the solution is recomputed and checked again for integrity.
A simple analogy can be used to demonstrate the concept of blunder detection and removal: a table is measured eight times using a tape measure. The measurements are recorded in a notebook, but one of the measurements is recorded incorrectly. The tape measure has 2 mm divisions, so the one-sigma (1σ) reading error is about 1 mm. This implies that 95% of the measurements should be within 2 mm of truth. The measurements and residuals are recorded in the table on the following page. From the residual list, it is clear that trial six was a blunder. With the blunder removed, the average and residuals are recomputed. This time, the residuals fall within the expected measurement accuracy. This is shown in Table 2.3 below.

Table 2.3: Blunder Detection Example

Trial	Measurement (m)	Residual (mm)	Status	New Residual (mm)
1	9.998	14.5	OK	2
2	10.001	11.5	OK	-1
3	9.999	13.5	OK	1
4	10.000	12.5	OK	0
5	10.002	10.5	OK	-2
6	10.100	-87.5	removed	
7	9.999	13.5	OK	1
8	10.001	11.5	OK	-2
Ave	**10.0125**		10.000	

Automatic Site Survey (M48M Timing Receiver Only)

The Automatic Site Survey mode simplifies system installation for static timing applications. This automatic position determination algorithm is user initiated and can be deactivated at any time.

The default Automatic Site Survey averages a total of 10,000 (slightly over 2 1/2 hours) valid 2D and 3D position fixes. If the averaging process is interrupted, the averaging resumes where it left off when tracking resumes. During averaging, bit 4 of the receiver status words in the Position/Status/Data Messages (@@Ha and @@Hb) is set. Once the position is surveyed, the M48M timing receiver automatically enters the Position-Hold Mode. At this point, the auto survey flag is cleared and the normal position-hold flag is set in the receiver status byte of the @@Ha and @@Hb messages.

However, should the user requires a smaller sample size for a quicker but not so accurate result, there is an option to allow user to select a 3,000 or a 5,000 site survey sample sizes.

Once the antenna site has been surveyed in the default mode manner, the user can expect a 2D position error of less than 10 meters with 95% confidence, and a 3D error of less than 20 meters with 95% confidence.

Throughout the survey time the T-RAIM algorithm (if enabled) is active and is capable of detecting satellite anomalies, however isolation and removal of the bad measurement is not possible. Once the survey is completed, the T-RAIM algorithm is capable of error detection, isolation, and removal.

Status of the Automatic Site Survey and Position-Hold Modes is retained in memory when the receiver is powered down.

Mean Time Between Failure (MTBF)

The MTBF for the M48M Oncore family of GPS receivers has been computed using the methods, formulas, and database of MIL-HDBK-217 to be approximately 750,000 hours (>85 years) at 40ºC. The value has been computed assuming a static application in a benign environment at the given temperature. This reliability prediction only provides a broad estimate of the expected random failure rates of the electrical components during the useful life of the product, and is not to be used as absolute indications of true field failure rates

Receiver Module Installation

Your receiver has been carefully inspected and packaged to ensure optimum performance. As with any piece of electronic equipment, proper installation is essential before you can use the equipment. When mounting the M48M receiver board into your housing system, special precautions need to be considered. Before you install the receiver, please review the following:

Electrostatic Precautions

The Oncore Receiver printed circuit boards (PCBs) contain parts and assemblies sensitive to damage by electrostatic discharge (ESD). Use ESD precautionary procedures when handling the PCB. Grounding wristbands and anti-static bags are considered standard equipment in protecting against ESD damage.

Electromagnetic Considerations

The Oncore receiver PC boards contain a very sensitive RF receiver; therefore you must observe certain precautions to prevent possible interference from the host system. Because the electromagnetic environment will vary for each OEM application, it is not possible to define exact guidelines to assure electromagnetic compatibility. The frequency of GPS is 1.575 GHz. Frequencies or harmonics close to the GPS frequency may interfere with the operation of the receiver, desensitizing the performance. Symptoms include lower signal to noise values, longer TTFFs and the inability to acquire and track signals. In cases where RF interference is suspected, common remedies are to provide the receiver with additional RF shielding and/or moving the antenna away from the source of the interference.

RF Shielding

The RF circuitry sections on the M48M are surrounded with an RF shield to provide some protection against potential interference from external sources. When a design calls for the M48M to be near or around RF sources such as radios, switching power supplies, microprocessor clocks, etc., it is recommended that the M48M be tested in the target environment to identify potential interference issues prior to final design. In worst-case situations, the M48M PCB may require an additional metal shield to eliminate electromagnetic compatibility (EMC) problems.

Thermal Considerations

The receiver operating temperature range is -40°C to +85°C, and the storage temperature range is -40°C to +85°C. Before installation, you should perform a thermal analysis of the housing environment to ensure that temperatures do not exceed +85°C when operating or stored. This is particularly important if air circulation in the installation site is poor, other electronics are installed in the enclosure with the M48M, or the M48M is enclosed within a shielded container due to electromagnetic interference (EMI) requirements.

Grounding Considerations

The ground plane of the receiver is connected to the four mounting holes. For best performance, it is recommended that the mounting standoffs in the application be grounded. The receiver will still function properly if it is not grounded via the mounting holes, but the shielding may be less effective.

PCB Mounting Hardware

The M48M Oncore PCB is normally mounted on round or hex female threaded metal standoffs and retained with metal English or metric screws. Mounting standoffs are available in a wide variety of materials with English or metric threads. Several sources are listed in Table 3.5. Key points in selecting the four screws and standoffs that will mechanically hold and secure the M48M to the application PCB are the screw sizes, screw head designs, and the diameter and length of the standoffs.
The four holes in the M48M PCB are designed to accommodate 4-40 (English) or 2.5 or 3mm (metric) mounting screws. It is recommended that these screws have Philips, Torx, or other head designs that retain the installation tool in order to avoid component damage that may occur if the tool slips out of the screw head. Recommended torque to assemble the M48M PCB to the standoffs is 6 in-lb, with a maximum of 7 and minimum of 5 in-lb. While somewhat higher torques can be tolerated, use of extremely high torques can possibly crack internal clads in the four-layer M48M PCB. Washers are not required or recommended.

Standoffs should have a maximum outside diameter (OD) of .187" (4.5mm). Note that these are standard sizes and should be easy to procure from a number of sources. Use of larger diameter standoffs can result in damage to small surface mount components mounted in close proximity to the mounting holes. If standoffs of the recommended diameters are not available, the next larger available diameter may possibly be used, but fit should be carefully verified before committing to large-scale production.

Obviously the height of the standoffs will be determined by the components that are populated on the application PCB, especially the height of the 10-pin receptacle. See Figures 3.4, which are outline drawings of the M48M receiver. The drawings describe the overall placement and height of large components and connectors populated on both sides of the M48M PCB.

System Integration

The M48M receiver is an intelligent GPS sensor intended to be used as a component in a precision positioning, navigation, or timing system. The M48M is capable of providing autonomous position, velocity, and time information over a standard serial port. The minimum usable system combines the M48M receiver, antenna, and an intelligent system controller device.

Interface Protocols

The M48M Timing Oncore receiver has one serial data ports. The first port provides the main control and data path between the M48M and the system controller.

Table 2.4: M48M Oncore Interface Protocols

Format	Binary	NMEA 0183
Type	Binary	ASCII
Direction	In/Out	In/Out
Port	1	1
Baud Rate	9600	4800
Parity	None	None
Data Bits	8	8
Start/Stop bits	1/1	1/1

Serial Input/Output

The serial interface pins, RxD and TxD, are the main signals available for user connection. A ground connection is also required to complete the serial interface. The M48M's serial port operates under interrupt control. Incoming commands and data are stored in a buffer that is serviced once a second by the receiver's operating program. There is no additional protection or signal conditioning besides the protection designed into the microprocessor since the RxD and TxD pins are connected to the microprocessor directly. TxD and RxD are standard inverted serial signals with 3V voltage swings.

Note: THE M48M SERIAL PORTS ARE NOT 5V LOGIC COMPLIANT

For input signals, minimum input high voltage is 2V and the maximum input high voltage is 3V. Minimum input low voltage is 0 V and the maximum input low voltage is 0.8 V. For output signals, minimum output high voltage is 2.4 V and the maximum output low voltage is 0.5 V. This interface is not a conventional RS-232 interface that can be connected directly to a PC serial port, an RS-232 driver/receiver is required to make this connection. The driver/receiver provides a voltage shift from the 3V outputs to a positive and negative voltage (typically +/- 8V), and also has an inversion process in it.

Binary Format

NOTE:
In the following discussion and in ensuing areas of the manual concerned with communications protocols, data characters without any prefixes will be interpreted as decimal data, data beginning with '0x' will be interpreted as hex data, and data beginning with a lower case 'b' will be interpreted as binary data.

The native binary data messages used by all Oncore receivers (including the M48M) consist of a variable number of binary characters (hex bytes). For ease of use, many Oncore users commonly refer to these binary sequences by their ASCII equivalents. For instance, all binary messages begin with the hex characters '0x40 0x40', which most users convert to the ASCII equivalents: '@@'.

- The first two characters after the '@@' header comprise the Message ID and identify the particular structure and format of the remaining data.

- This message data can vary from one byte to over 150 bytes, depending on the message being transmitted or received.

- Immediately following the message data is a single byte checksum which is the Exclusive-Or (XOR) of all bytes after the '@@' and before the checksum).

- The message is terminated with the Carriage Return/Line Feed pair: '0x0D 0x0A'.

Summarizing, every binary message has the following components:

Message Start:
@@ - (two hex 0x40's) denote the start of binary message.

Message ID:
(A.Z(a..z, A..Z) - Two ASCII characters - the first an ASCII upper-case letter, followed by an ASCII lowercase or upper case letter. These two characters together identify the message type and imply the correct message length and format.

Binary Data Sequence:
A variable number of bytes of binary data dependent on the command type.

Checksum:
The Exclusive-Or of all bytes after the '@@', and prior to the checksum.

Message Terminator:
'0x0D 0x0A' - Carriage Return/Line Feed pair denoting the end of the binary message.

Almost all receiver input commands have a corresponding response message so that you can determine whether the input command(s) have been accepted or rejected by the receiver. The message format descriptions in Chapter 4 detail the input command and response message formats. Information contained in the data fields is normally numeric. The interface design assumes that the operator display is under the control of an external system data processor and that display and message formatting code reside in its memory. This approach gives you complete control of the display format and language.

All M48M receivers read command strings in the input buffer once per second. If a full command has been received, the receiver operates on that command and performs the indicated function. Input character string checks are performed on the input commands. A binary message is considered to be valid if it began with the '@@' characters, the message is the correct length for its type, the checksum validates, and the command is terminated with a CR/LF pair. Improperly formatted messages are discarded.

You must take care in correctly formatting the input command. Pay particular attention to the number of parameters and their valid ranges. An invalid message could be interpreted as a valid unintended message. A beginning '@@', a valid checksum, a terminating carriage return/line feed, the correct message length and valid parameter ranges are the only indicators of a valid input command to the receiver. For multi-parameter input commands, the receiver will reject the <u>entire</u> command if one of the input parameters is out of range. Once the input command is detected, the receiver validates the message by checking the checksum byte in the message. Input and output data fields contain binary data that can be interpreted as scaled floating point or integer data. The field width and appropriate scale factors for each parameter are described in the individual I/O message format descriptions. Polarity of floating point data (positive or negative) is described via the two's complement presentation.

Input command messages can be stacked into the receiver input buffer up to the depth of the message buffer (1200 characters long). The receiver will operate on all full messages received during the previous one second interval and will process them in the order they are received. Previously scheduled messages may be output before the responses to the new input commands.

Almost all input commands have a corresponding output response message. Input commands may be of the type that changes configuration parameters of the receiver. Examples of these input command types include commands to change the initial position, receiver internal time and date, satellite almanac, etc. These input commands, when received and validated by the receiver, change the indicated parameter and result in a response message to show the new value of the parameter that was changed. If the new value shows no change, then the input command was either formatted improperly, or one of the input parameters was out of its valid range.

NOTE: *Every change-parameter type input command (except for the @@Ci message) has a corresponding response message showing the configuration parameter change. To request the current status of any current receiver parameter, simply enter an input command with at least one parameter out of the normal range. The response to properly formatted commands with out-of-range parameters is to output the original unchanged value of the parameter in the response message.*

Input commands may also be of the type that enable or disable the output of data or status messages. These output status messages include those that the external controller will use for measuring position, velocity, and time. Status messages are output at the selected update rate (typically, once per second) for those messages that contain position, velocity, or time, or can be commanded to output the data one time upon request. The rate at which the data is output in the continuous output mode is dependent on the update rate requested by the user. Table 2.5 below shows the rates at which the data messages are output for each type of message, depending on the setting of the continuous/polled option that is part of the input command.

Table 2.5: Binary Mode Data Message Output Rates

OUTPUT MESSAGE TYPE	MESSAGE ID	CONTINUOUS (m=1..255)	POLLED (m=0)
12 Channel Position/Status/Data	@@Ha	At user selected update rate	When requested
ASCII Position Message	@@Eq	At user selected update rate	When requested
12 Channel T-RAIM Status**	@@Hn	At user selected update rate	When requested
Visible Satellite Status	@@Bb	When visibility status changes	When requested
UTC Offset Status	@@Bo	When UTC offset available or when it changes	When requested
Leap Second Status	@@Gj		When requested

**M48M timing receiver only

In cases where more than one output message is scheduled during the same one second interval, the receiver will output all scheduled messages but will attempt to limit the total number of bytes transmitted each second to 800 bytes. For the case of multiple output messages, if the next message to be sent fits around the 800 byte length goal, then the message will be output. For example, if messages totaling 758 bytes are scheduled to be sent, and the user requests another 58 byte message, then 816 bytes will actually be sent. If the user requests yet another 86 byte message, then its output will be left pending and will be scheduled when the total number of output bytes allows.

Exclusive-Or (XOR) Checksum Creation

In the binary mode a checksum must be included with every command to the receiver. Conversely, all messages from the receiver include a checksum that may be used to verify the contents of the message.

An example message is used to illustrate the procedure.

Command name: 32 Channel Position/Status/Data Output Message

Command in Binary format: @ @ H a m C < C R > < L F >

In this message, ‘m’ indicates the response message rate (i.e. 1 = once per second, 2 = once every two seconds, etc.), and ‘C’ is the checksum. In calculating the checksum, only the ‘H', 'a', and 'm’ characters are used. The Exclusive-Or (XOR) operation yields a one if only one of the bits is a one. Setting ‘m’ to ‘1’ (or 0x01 in hex), we have the following:

Character	Hexadecimal	Binary
H	0x48	01001000
a	0x61	01100001
XOR of 0x48 and 0x61:	0x29	00101001
m	0x01	00000001
XOR of 0x29 and 0x01:	0x28	00101000

The final checksum would then be '0x28' in hexadecimal. The complete command would then be as follows:

Message format @ @ H a m C <CR> <LF>

Hexadecimal: 0x40 0x40 0x48 0x61 0x01 0x28 0x0D 0x0A

ASCII: @ @ H a ^A % ^M ^J

To enter this command using the SiRF Oncore software, one would open the <Msg> window and type: @@Ha01<Enter> on the command line.

Note: *Within the SiRF Oncore software, characters beyond the fourth character are treated as hexadecimal numbers, the checksum is computed automatically, and the <CR><LF> pair is automatically appended to the command.*

The receiver will now output the standard 32 Channel Position/Status/Data message once every second.

Milliarcsecond to Degree Conversion

The primary output message of M48M receiver in binary mode is the 32 Channel Position/Status/Data Message (@@Ha). In this message, the latitude and longitude are reported in milliarcseconds, (or mas). An example of converting mas to degrees is illustrated below.

One degree of latitude or longitude has 60 arcminutes, or 3600 arcseconds, or 3,600,000 milliarcseconds. To convert the positive or negative milliarcseconds to conventional degrees, minutes, and seconds follow this procedure:

1. Divide the mas value by 3,600,000

   The integer portion of the quotient constitute the whole degrees

2. Multiply the remaining decimal fraction of the quotient by 60

   The integer portion of the product constitute the whole minutes

3. Multiply the remaining decimal fraction of the product by 60

   The integer portion of the product constitute the whole seconds

4. The remaining decimal fraction of the product constitute the decimal seconds

CONVERSION EXAMPLE: Michigan Avenue, Chicago, IL:

Latitude = 150748869 mas Longitude=-315445441 mas

1. Latitude: 150748869 mas / 3600000 = 41.87468583
   Longitude: -315445441 mas / 3600000 = -87.62373361

   Whole Degrees of Latitude = 41, Whole degrees of Longitude = -87

2. Latitude: 0.87468583 * 60 = 52.48114980
   Longitude -0.62373361 * 60 = 37.42401660

   Whole Minutes of Latitude = 52, Whole Minutes of Longitude = 37

3. Latitude: 0.48114980 * 60 = 28.86898800
   Longitude: -0.42401660 * 60 = 25.44099600

   Whole Seconds of Latitude = 28, Whole Seconds of Longitude = 25

4. Decimal seconds of latitude, = 0.868988,
   Decimal seconds of longitude = 0.440996

The decimal seconds of both latitude and longitude are then truncated to 3 decimal places, giving a final result of:

Latitude = 41º 52'28.869" Longitude = -87º 37'25.441"

NMEA Protocol Support

The M48M Positioning Receiver firmware supports the NMEA 0183 format for GPS data output. Output of data in the NMEA-0183 standard format allows a direct interface via the serial port to electronic navigation instruments that support the specific output messages. NMEA formatted messages may also be used with most commercially available mapping and tracking programs. The following NMEA output messages are supported as per the NMEA-0183 Specification Revision 2.0.1:

Message	Description
GPGGA	GPS Fix Data
GPGLL	Geographic Position Latitude/Longitude
GPGSA	GPS DOP and Active Satellites
GPGSV	GPS Satellites in View
GPRMC	Recommended Minimum Specific GPS/Transit Data
GPVTG	Track Made Good and Ground Speed
GPZDA	Time and Date

You can enable or disable each message output independently and control the update rate at which the information is output. The seven NMEA messages may be individually programmed to be sent out continuously at any rate from once-per-second to once-every-9999 seconds, or may be requested as individually polled responses.

The M48M receiver retains the output settings when powered off and reconfigures itself to the same state when powered up again. For a receiver to be used for the first time (factory default), it will start up in the default state ie. Binary format at 9600 baud with all messages in the polled configuration.

NMEA Commands to the Receiver

All NMEA commands are formatted in sentences that begin with the ASCII '$' character and end with ASCII <CR><LF>. A five character sequence (PMOTG) occurs after the ASCII $, identifying the command as a **P**roprietary **MOT**orola **G**PS command. A five character address occurs after the $PMOTG. The first two characters are the talker ID (which is GP for GPS equipment), and the last three characters are the sentence formatter (or message ID) from the list above. The next four characters designate the update rate being requested. The command is then terminated with an optional checksum and the normal Carriage Return/Line Feed characters. Several examples are shown below. Note that unlike Binary messages, NMEA messages are not fixed length. Field widths within the message can vary depending on the contained data, and are delimited by the ASCII comma character.

As noted above, checksums are supported in NMEA protocol, but are not required as they are in the binary protocol. The checksum is calculated by XORing the 8 data bits of each character in the sentence between, but not including, the $ and the optional (*) or checksum (CS). The high and low nibbles of the checksum byte are sent as ASCII characters.

NMEA Command Examples

1. Assume the user desires a single (polled) **RMC** message. The required command string (without the optional checksum) is:

   $PMOTG,RMC,0000,<CR><LF>

2.
3. Assuming that the user now desires the **RMC** message to be sent once each second, the command string would change to:

   $PMOTG,RMC,0001,<CR><LF>

NMEA Response Examples

The response to the command in Example 1 above would be:

$GPRMC,hhmmss.ss,a,ddmm.mmmm,n,ddmm.mmmm,w,z.z,y.y,d.d,v*CC<CR><LF>

where:

- '$GPRMC' is the message header
- 'hhmmss.ss' is the UTC time of the position fix in hours, minutes, and seconds
- 'a' is the current position fix status with 'A' designating a valid position, and 'V' indicating an invalid position
- 'ddmm.mmmm' is the current latitude in degrees and minutes
- 'n' is the direction of the latitude with 'N' indicating North and 'S' indicating South
- 'dddmm.mmmm' is the current longitude in degrees and minutes
- 'w' is the direction of the longitude with 'W' indicating West and 'E' indicating East
- 'z.z is the current ground-speed in knots
- 'y.y' is the current direction, referenced to true North
- 'ddmmyy' is the UTC date of the position fix
- 'd.d' is the magnetic variation in degrees (always 0.0 with M48M)
- 'v' is the direction of the variation (always nulled with M48M)
- 'CC' is the checksum

Note that unlike the binary messages, NMEA messages can vary in length. If any value has not been determined yet the data position will be nulled. For example, if you request the RMC message before the receiver has tracked any satellites and developed a position solution, the response will look like this:

$GPRMC,,V,,,,,,,,,*CC<CR><LF>

For the case where more than one output message is scheduled during the same one second interval, the receiver will output all scheduled messages but will attempt to limit the number of bytes transmitted each second to 400 bytes. For the case of multiple output messages, if the next message to be sent fits into the 400 byte length goal, then the message will be output. For example, if messages totaling 334 bytes are scheduled to be sent, and the user requests another 80 byte message, then 414 bytes will actually be sent. If the user requests yet another 70 byte message, then its output will not be generated. The order for priority of transmitting messages is simply alphabetical. The NMEA messages are input and output on the primary serial port just as in binary mode. For details, see Chapter 4 of this document.

Input/Output Processing Time

User commands sent to the M48M are placed in an input buffer that is serviced once per second. When powered on and available satellites are tracked, the current receiver position is available. If insufficient satellite signals are received to develop a current fix, the last known position is output. The message response time will be the time from the transmission of the first byte of input data to the transmission of the last byte of output data. The command processing time will be skewed since the time will be dependent on when the input message buffer is processed. For best case processing, the input command would have to arrive just before the input buffer data is processed, and the output response would have to be the first (or only) receiver output. For worst case processing, the input command would have to arrive just after the input buffer data had been processed, and the output response would have to be the last receiver output.

Assuming 1 ms per transmission of a data byte, assuming 50 ms command processing, and assuming a uniform distribution for time of input command data entry, the best case, typical case, and worst case scenarios are shown below.

Best Case **UTC Time Correction** command (@@Aw):

BC time = shortest command input + command processing + shortest command output

= 10 ms +50 ms +10 ms
= 70 ms

Typical Case **UTC Time Correction** command:

TC time = input anywhere across one second period + command processing + output anywhere across one second period following command processing

= 0.5s+0.05s+0.475s
= 1.025 s

Worst Case **UTC Time Correction** command:

WC time = input beginning of one second period + output end of one second period

= 1 s+1 s
= 2 s

DATA LATENCY

The receiver can output position, velocity, and time data on the serial port at a maximum rate of once each second. The start of the output data is timed to closely correspond with the receiver measurement epoch. The measurement epoch is the point in time at which the receiver makes satellite range measurements for the purpose of computing position. The first byte of serial data in the position message is output between 0 and 50ms after the most recent receiver measurement epoch. Refer to Figure 3.7 for the discussions that follow.

Let T_k be the most recent measurement epoch. The receiver takes about one second to compute data from the satellite range measurements. Consequently, the data that is output 0 to 50 ms after T_k represents the best estimate of the position, velocity, and time based on the measurements taken one second in the past, at time T_{k-1}. Position data (latitude, longitude, and height) is computed from the most recent measurement epoch data, and is output immediately after the next measurement epoch, which is 1.0 to 1.05 seconds after the original measurements were taken.

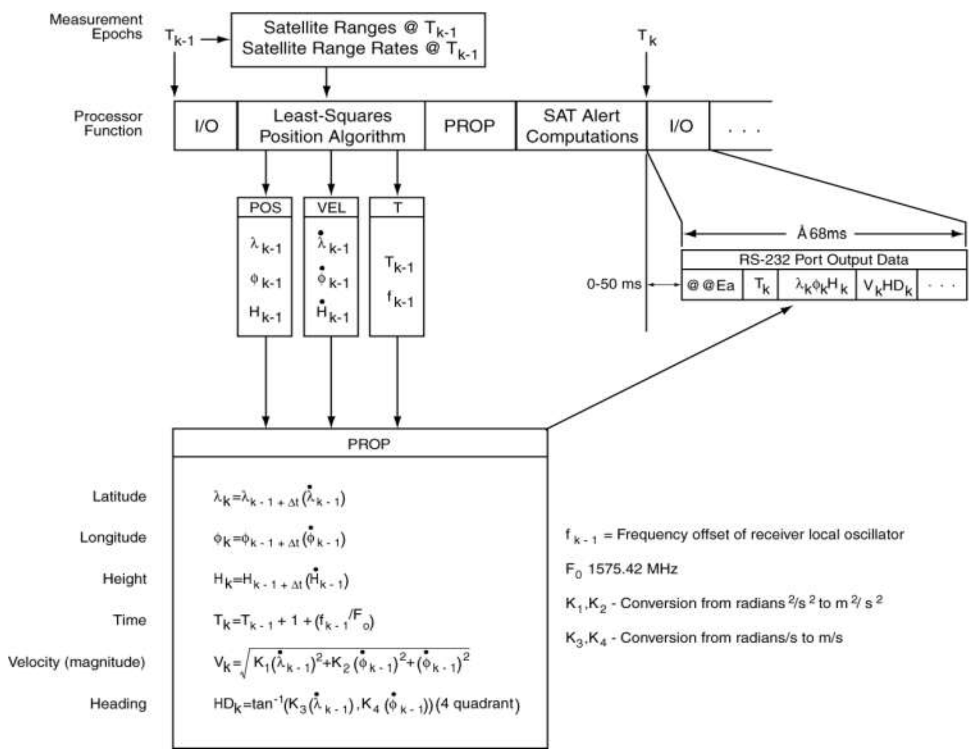

Figure 2.5: Position/Status/Data Output Message Latency

To compensate for the one second computational pipeline delay, a one second propagated position is computed that corresponds to T_k based on the position and velocity data computed from measurements taken at time T_{k-1}. In this way, the position data output on epoch T_k will most closely correspond with the receiver true position when the data is output on the serial port. Of course, there can be a position error due to the propagation process if the receiver is undergoing acceleration. The error can be as large as 4.5 m for every G of acceleration. There is no significant error under stationary or constant velocity conditions.

Position Data Latency

The position data output in the current data packet (i.e., at time T_k) is the result of a Least Squares Estimation (LSE) algorithm using satellite pseudorange measurements taken at time T_{k-1}. The resulting LSE position corresponding to time T_{k-1} is then propagated one second forward by the velocity vector (the result of an LSE fit using satellite pseudorange rate measurements taken at T_{k-1}). The resulting propagated position is output at the T_k epoch.

Velocity Data Latency

The velocity data output in the current data packet (i.e., at time T_k) is the result of an LSE fit using satellite pseudorange rate measurements taken at time T_{k-1}. The pseudorange rate measurements are derived from the difference in integrated carrier frequency data sampled at measurement epochs T_{k-1} and (Tk_{-1} - 200 ms). In effect, the resulting velocity data represents the average velocity of the receiver halfway between T_{k-1} and (T_{k-1} -200 ms).

Time Data Latency

The time data output in the current data packet (i.e., at time T_k) is the result of an LSE fit using satellite pseudorange measurements taken at time T_{k-1}. The time estimate at T_{k-1} is then propagated by one second plus the computed receiver clock bias rate at time $T_{k-1,}$ before being output at time T_k. The resulting time data is the best estimate of local time corresponding to the T_k measurement epoch based on data available at T_{k-1}.

ONE PULSE PER SECOND (1PPS) TIMING

Measurement Epoch Timing

The M48M receiver timing is established relative to an internal, asynchronous, 1 kHz clock derived from the local oscillator. The receiver counts the 1 kHz clock cycles, and uses each successive 1000 clock cycles to define the time when the measurement epoch is to take place. The measurement epoch is the point at which the receiver captures the pseudorange and pseudorange rate measurements for computing position, velocity, and time.

When the receiver starts, it defines the first clock cycle as the measurement epoch. Every 1000 clock cycles from that point define the next measurement epoch. Each measurement epoch is

about one second later than the previous measurement epoch, where any difference from 1.000000000 seconds is the result of the receiver local oscillator intentional offset (about +60 μs/s) and the oscillator's inherent instability (+/-30 ppm over specified temperature range).

When the M48M processor computes receiver local time, this time corresponds to the time of the last receiver measurement epoch. The Oncore process precisely determines this time to an accuracy of approximately 20 to 300 ns depending on satellite geometry and the effects of Selective Availability (if Selective Availability were to ever be reactivated by the DoD.)

The computed time is relative to UTC or GPS time depending on the time type as specified by the user using the Time Mode command (@@Aw). The Oncore system timing is designed to slip time when necessary in discrete one millisecond intervals so that the receiver local time corresponds closely to the measurement epoch offset. The Oncore observes the error between actual receiver local time and the desired measurement epoch offset and then slips the appropriate integer milliseconds to place the measurement epoch to the correct integer millisecond. When a time skew occurs (such as after initial acquisition or to keep time within limits due to local oscillator drift), the receiver lengthens or shortens the next processing period in discrete one millisecond steps.

The rising edge of the 1PPS signal is the time reference. The falling edge will occur approximately 200 ms (+/-1 ms) after the rising edge. The falling edge should not be used for accurate time keeping.

Output Data Timing Relative To Measurement Epoch

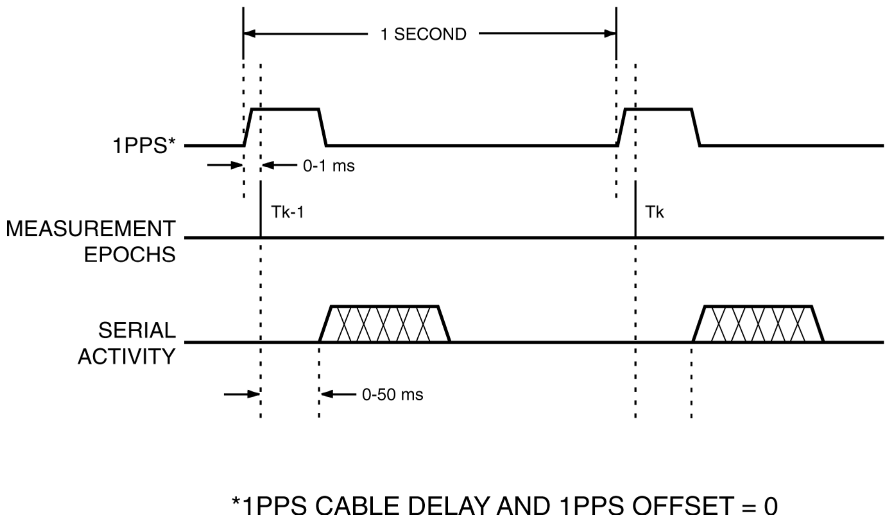

Figure 2.6: Output Signal Timing

The 32 Channel Position/Status/Data Messages (@@Ha and @@Hb), the T-RAIM Setup and Status Message (@@Hn), and the Time Message (@@Gb) are the only output messages containing time information. If enabled, these messages will be output from the receiver shortly after a measurement epoch. Generally, the first data byte in the first message will be output between 0 to 50 ms after a measurement epoch. For the Position/Status/Data Message, the time output in the message reflects the best estimate of the most recent measurement epoch. A simple timing diagram is shown in figure 2.6.

1PPS Cable Delay Correction and 1PPS Offset

Users can compensate for antenna cable length with the 1PPS Cable Delay Command (@@Az).
The 1PPS can also be positioned anywhere in the one second window using the 1PPS Offset command (@@Ay). The rising edge of the 1PPS is placed so that it corresponds to the time indicated by the following equation:

1PPS rising edge time = top of second -1PPS cable delay + 1PPS offset

Consider the following example:

True Top of second =	10.000000000 s
1PPS cable delay correction =	0.000654321 s
1PPS offset =	0.100000000 s
1PPS rising edge time =	10.099345679 s

The rising edge of the 1PPS signal is adjusted so that it occurs corresponding to the fractional part of time equal to the total above. The fractional part of time is measured relative to UTC or GPS time depending on the setting of the Time Mode.

OPERATIONAL CONSIDERATIONS

When powered on, the M48M Oncore Receiver automatically acquires and tracks satellites; measures the pseudorange and phase data from each of up to thirty-two satellites; decodes and collects satellite broadcast data; computes the receiver's position, velocity, and time; and outputs the results according to the current I/O configuration selected by the user.

Time to First Fix (TTFF)

TTFF is a function of position uncertainty, time uncertainty, almanac age, and ephemeris age as shown in the table below. The information shown below in Table 2.8 assumes that the antenna has full view of the sky when turned on.

Table 2.6: Typical M48M TTFF Information

Power-up State	**Age**		**TTFF M48M Timing**
	ALMANAC	EPHEMERIS	
Hot	1 month	< 4 hrs	< 1s
Warm	1 month	Unavailable	< 30s
Cold (default)	Unavailable	Unavailable	< 33s

N/A - Not applicable. Knowledge of this parameter has no effect on TTFF in this configuration.

First Time On

When the M48M receiver powers up for the first time after factory shipment, the initial date and time will be incorrect. This will force the receiver into a cold power-up state (cold start), and it will begin to search the sky for all available satellites. After one satellite has been acquired, the date and time will automatically be set using data downloaded from the satellite. When three or more satellites are tracked, automatic position computation is initiated. At power down, the M48M receiver remembers its current configuration.

Initialization

When powered up, the M48M acquisition and tracking algorithms will automatically start acquiring satellites and will compute position when it acquires at least three. For each of the user controlled outputs, the receiver remembers the previously requested message formats (continuous or polled) and the update rate. If no messages were active the last time the receiver was used, it waits for an input command before it outputs any other data, even though it may have acquired satellites and is computing position fixes internally.

The M48M does not need to be initialized to its approximate position to acquire satellites and compute position, nor does it require a current satellite almanac. However, the TTFF will be considerably shorter if you help the receiver locate satellites by providing it with the current date and approximate time, approximate local position and a current satellite almanac. This will allow the receiver to perform a "Warm Start" vs. a "Cold Start". The M48M retrieves its last known position coordinates when main power is reapplied, and uses this information in the satellite acquisition algorithm. In addition, the receiver retains the almanac and last used satellite ephemeris. If you move the receiver a great distance before using it again, it will find and acquire satellites, but the TTFF may be longer than normal because the receiver will start looking for the satellites that are actually visible at the last known coordinates. You can initialize the new approximate position coordinates for faster TTFF if desired.

Shut Down

It is recommended that the receiver not be shut down within 35s of computing an initial 2D or 3D position fix. This allows time for a full set of ephemeredes to be downloaded to memory, which may shorten the next startup time.

Received Carrier to Noise Density Ratio (C/No)

The Position/Status/Data Message output C/No for each receiver channel, which can be used to determine the relative signal levels of received satellite signals (refer to Figure 2.7 below). C/No is the received carrier to noise density ratio. The units are dB-Hz, where No is the noise density ratio received in a 1 Hz bandwidth. The C/No may be converted into received signal strength using the plot in Figure 2.7.The satellite signal strength is measured at the antenna input. Typical "good" C/No numbers reported by an with a properly installed antenna system are between 40 and 55 dB-Hz.

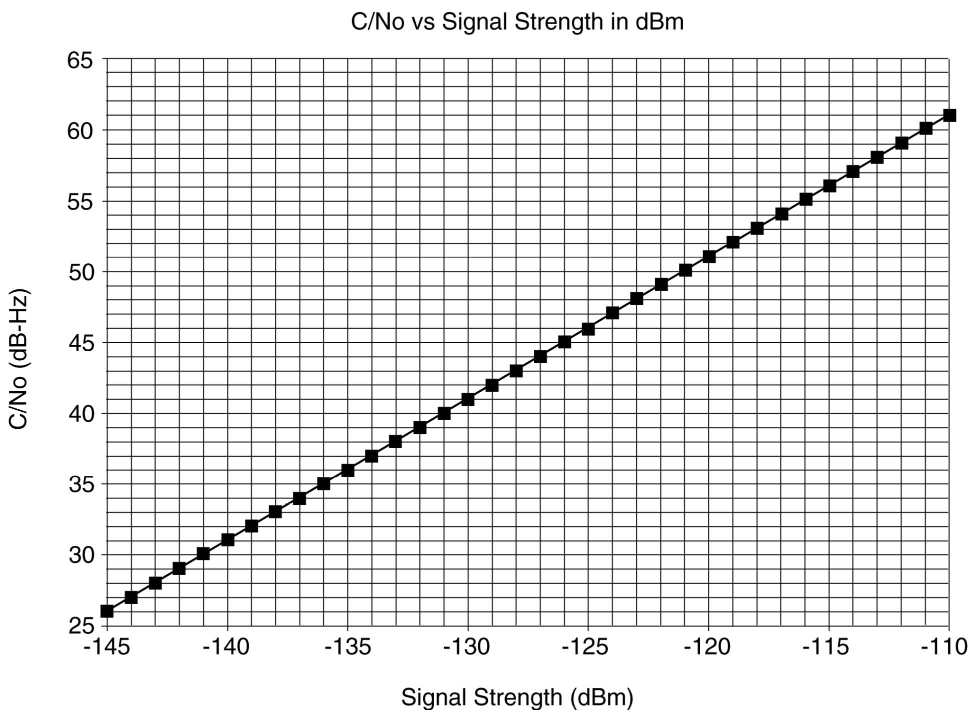

Figure 2.7: Approximate Signal Strength vs. Reported C/No

SETTING UP RECEIVERS FOR TIMING APPLICATIONS

M48M as a Precision Timing Receiver

As supplied, the M48M Timing Receiver default operating parameters are already set up for optimal operation. There is no need to set the Mask Angle to 10 degrees as this is the default condition for this receiver.

- Enter the Position-Hold-Position using the @@As command. The coordinates can either be determined by a professional site survey or you can use the Auto-Survey function of the M48M timing receiver. Invoking this function (mode 3 of the @@Gd command) will automatically average 10,000 position fixes and then force the receiver into Position-Hold.

- Set the timing parameters using the @@Gf, @@Ge, and @@Hn messages

@@Gf – This message is used to set the T-RAIM alarm limit. The receiver defaults time is 1000ns, but the user may select any value between 300 and 1,000,000ns using this command. Typical values are between 500 and 1000ns.

@@Ge – This message is used to turn the T-RAIM function on and off. The receiver must be in Position-Hold mode in order to get full functionality from the T-RAIM algorithm. If the receiver is left in positioning mode the T-RAIM can only detect a bad satellite, it cannot remove it from the time solution.

@@Hn – The @@Hn T-RAIM Status Message is normally set up to send status strings once a second so that the user's external software can be immediately alerted to any alarm conditions.

Chapter 3 – Antenna Descriptions

CHAPTER SUMMARY

Refer to this chapter for the following:

- Product descriptions for the antenna for M48M Timing
- Installation precautions and setup
- Electrical Parameters
- Mechanical Dimensions

Antenna Type I

Antenna Description

The antenna is designed to operate with the successful family of Oncore GPS receivers, as well as many GPS receivers from other manufacturers. The 3V version of the GPS Antenna is specifically designed to operate with M48M Oncore receivers. The antenna is a general purpose GPS active antenna designed to meet the stringent environmental and performance needs of the automotive market place.

The antenna design reflects high standard for performance when operating in foliage/urban canyon environments and in the presence of electromagnetic interference. The small footprint, low profile package and the shielded LNA (low noise amplifier) offer significantly enhanced performance while operating in a variety of GPS environments. Furthermore, magnetic and blind hole direct mounting options make the antenna suitable for a number of different installation configurations.

Table 3.1 Active Antenna Technical Characteristics

GENERAL CHARACTERISTICS	Antenna Description	Passive dielectric patch antenna Top and bottom radome plastic housing assembly Active low noise amplifier/filter –PWB assembly RF cable with connector assembly
	Operating Frequency	L1 (1575.42 MHz, +/- 1.02 MHz)
PERFORMANCE CHARACTERISTICS	Input Impedance	50 Ohm
	VSWR	1.5 (typical) @ 1575.42 MHz (2.5 max)
	Bandwidth	10 to 45 MHz (± 3dB points)
	Polarization	Right hand circular
	Azimuth Coverage	360°
	Elevation Coverage	0° to 90°
	Gain Characteristics of Antenna Element	+2.0 dBic minimum at zenith -10 dBic minimum at 0° elevation
	Filtering	-30dB @ 1675 MHz (typical) -30dB @ 1475 MHz (typical)
	Antenna Gain	3 Vdc version 24dB (typical, including 5 dB cable loss)
	Noise Figure	<1.8dB (typical), 2.2dB (max)
	Dynamics	Vibration: 7.7 G's (Military Standard 810E) Shock: 100 G's (Military Standard 810E)
ELECTRICAL CHARACTERISTICS	Power Requirements	3 V ± 0.2 Vdc for GC3LPxxxxx models
	Current Consumption	16mA (typical), 20mA (max)
PHYSICAL CHARACTERISTICS	Dimensions	38 x 34 x 13.2 mm ± 0.5 mm
	Weight	< 89 grams (including 5m cable and connector)
	Mounting Methods	Magnetic and Blind holes (2) Taplite screw size of 2.6 x 5 mm (1 mm thick base plate)
	Radome color	Black
	Cable Connectors	MMCX r/a plug – Standard for 3 Vdc antenna
	Antenna to receiver Interconnection	Single shield RG-316 type coaxial cable 5 meters (25 ft.) long (See connectors above)
ENVIRONMENTAL CHARACTERISTICS	Operating Temperature	-40ºC to +100ºC
	Storage Temperature	-40ºC to +100ºC
	Thermal Testing	Cycled 600 hours at –40°C and +100°C
	UV Radiation	Sunshine Carbon Arc System – JIS D0205
	Salt Spray Test	320 hours, Spray 5% NaCl solvent at +35°C
	Immersion Test	60 minutes at 1 meter
MISCELLANEOUS	Optional Features	Special order model: Substrate (w/o radome and base) version with cable and connector
NOTE	All values above are referenced to 25°C unless indicated otherwise	

Antenna Gain Pattern

The sensitivity of an antenna as a function of elevation angle is represented by the gain pattern. Some directions are much more appropriate for signal reception than others, so the gain characteristics of an antenna play a significant role in the antenna's overall performance. A cross-sectional view of the antenna gain pattern along a fixed azimuth (in a vertical cut) is displayed in the following figure. The gain pattern clearly indicates that the antenna is designed for full, upper hemispherical coverage, with the gain diminishing at low elevations. This cross-section is representative of any vertical cross section over a full 360 degree azimuth range and thus, the 3 dimensional gain pattern is a symmetric spheroidal surface. It is important to note that this gain pattern varies in elevation angle, but not in horizontal azimuth. This design is well-suited for many GPS applications, accommodating full sky coverage above the local horizon and minimizing ground reflected multipath effects.

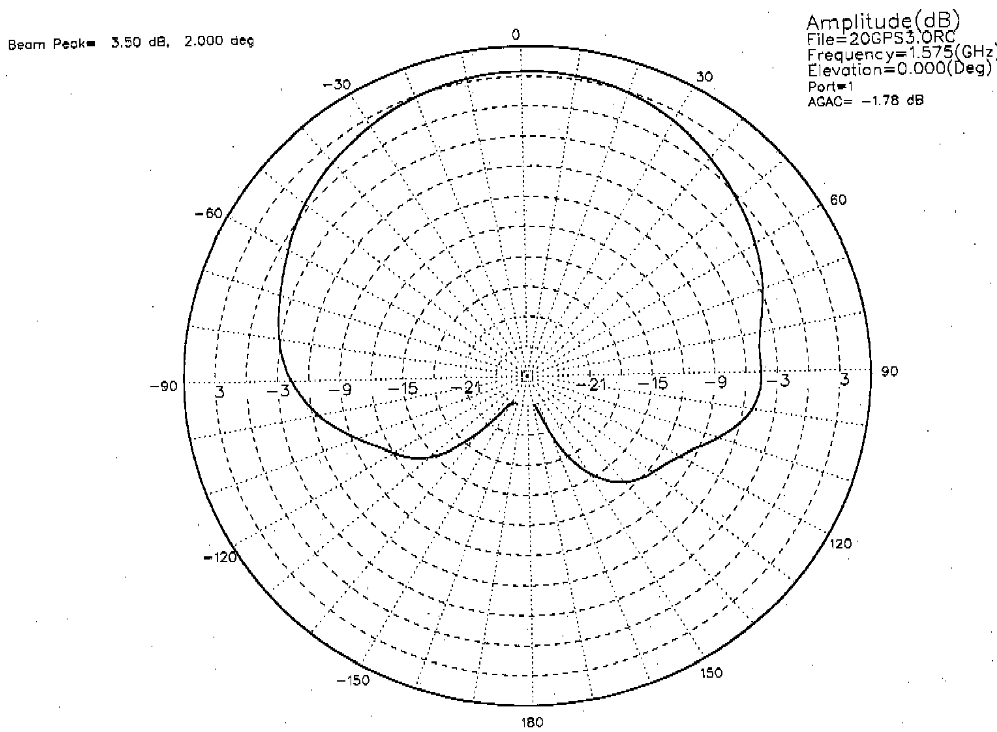

Figure 3.1: Typical Antenna Gain Pattern

Mechanical Dimensions
All dimensions are in mm and are for reference purposes only.

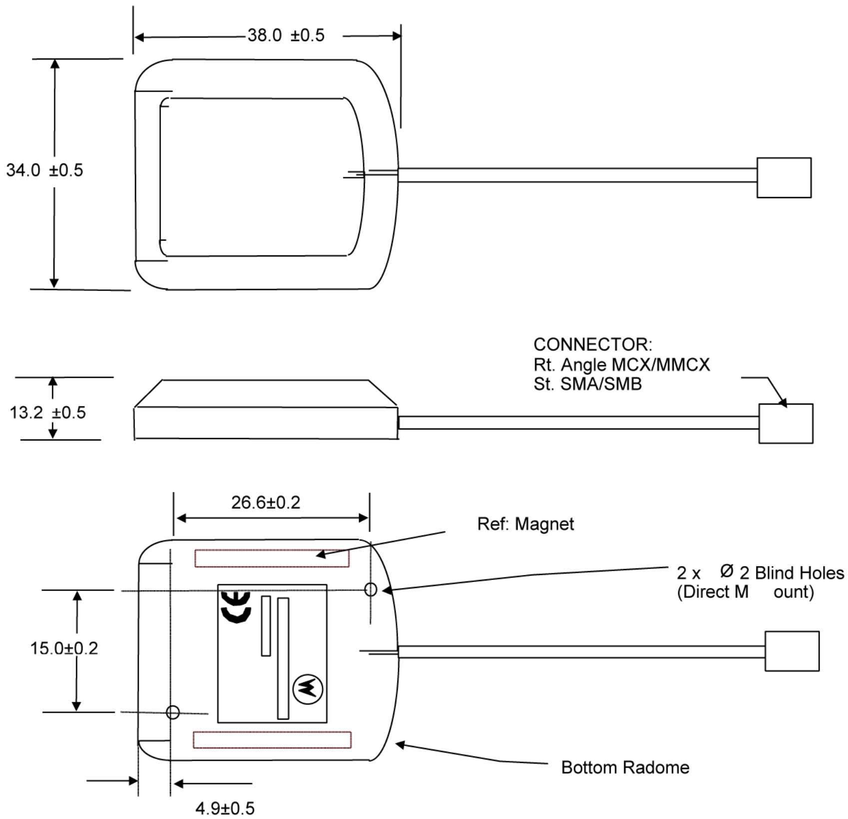

Figure 3.2: Magnet/Direct Mount Configuration

Mechanical Dimensions (Continued)
All dimensions are in mm and are for reference purposes only.

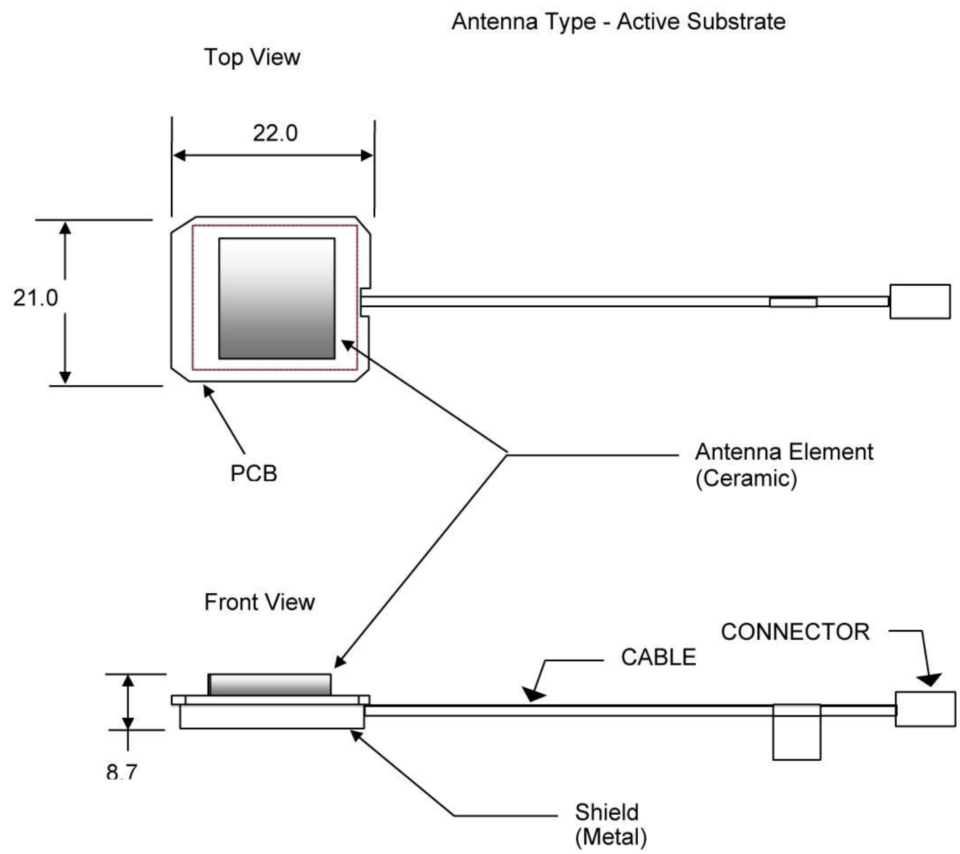

Figure 3.3: Antenna Substrate Configuration

RF Connectors/Cables Information

Shikoku 1.5DS-QEHV coaxial cable is used in the antenna assemblies. This cable is very similar to RG-316. Figure 4.5 shows simplified views of the cable construction while Table 4.8 details the electrical and mechanical characteristics.

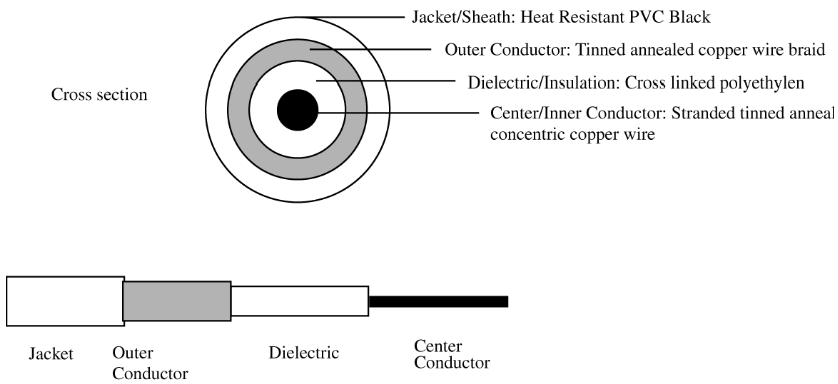

Figure 3.4: Antenna Cable Construction

Table 3.2 Characteristics of coaxial cable

Item	Specification
Center Conductor	Tinned Annealed Copper Wire, 0.54mm diameter (7strands of 0.18 mm)
Maximum inner conductor resistance (20°C)	120 ohms/km
Dielectric/Insulation	Cross linked polyethylene, thickness 0.53mm
Outer Conductor	Tinned annealed copper wire braid, outside diameter - 1.6mm
Jacket Sheath	Material Thickness 0.5mm. Finished Diameter of 3.1 +/- 0.20mm
Approximate weight of cable	15 kg/km
Minimum bend radius	31mm
Test voltage	1000V/min
Minimum insulation resistance	1000 Meg-ohm/km
Characteristic Impedance	50 +/- 2 ohms
Operating Temperature Range	-40 to +105 ºC
Standard Attenuation	0.91 dB/m at 900 MHz 1.26 dB/m at 1500 MHz 1.32 dB/m at 1600 MHz 1.50 dB/m at 1900 MHz 1.54 dB/m at 2000 MHz

Antenna Placement

When mounting the antenna module, it is important to remember that GPS positioning performance will be optimal when the antenna patch plane is level with the local geographic horizon, and the antenna has full view of the sky ensuring direct line-of-sight to all visible satellites over head.

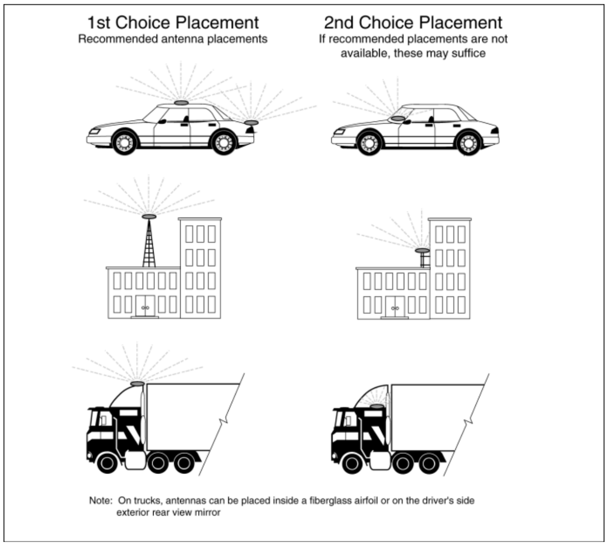

Figure 3.5: Proper Antenna Placement

Antenna System RF Parameter Considerations

Both the gain and the noise of the overall system affect the performance of the A/D converter in the Oncore GPS receiver. The illustration below illustrates typical values for the M48M receiver when used with the antenna and the standard length of 5 meters of cable. The thresholds and ranges listed should be considered to have a tolerance of 2 to 3 dB. Figure 4.7 below details a typical configuration.

System Constraints:

- The gain in decibels is cumulative through all stages (i.e. G = G1+ G2 + G3 ..). The optimal gain of the antenna, cabling and any in-line amplifiers and splitters for the receiver is between 18 and 36 dB. The may operate outside of the optimal gain range but performance will degrade. Therefore, we do not recommend operating outside of the optimal gain range as indicated above. For the system illustrated below, the external gain is approximately 24 dB in front of the receiver.

- System noise (F) is not to exceed 4dB. The cascaded system noise figure formula is:

$$f = f1 + \frac{f2-1}{g1} + \frac{f3-1}{g1 \times g2}\text{.........,}$$ (=1.9dB for the system shown below)

.

where f_1 is the noise figure for stage one and g_1 is the gain for stage one. Note that all of the values used in this equation are absolute. The resulting number must be converted back to decibels in order ascertain if it is less than 4dB and to compare it with other antenna systems configurations.

Recall the formula for converting absolute values to decibels, and decibels to absolute values: $10\log f = f(\text{dB})$.

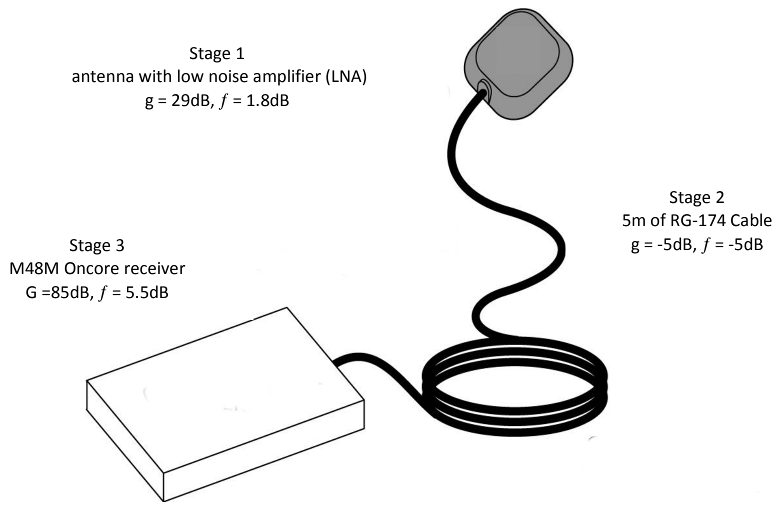

Figure 3.6: Typical System Gain/Noise Figure Calculations

Antenna Type II

Antenna Description

The antenna is intended for use in GPS timing applications and is designed for use with Oncore receivers as well as many GPS receivers from other manufacturers. GPS signals are received by the antenna, amplified within the antenna assembly, and then relayed via cable to the receiver module for processing. The conical radome housing is manufactured from an Ultra Violet (UV) resistant material. A tubular mounting nut specially designed for ease of weatherproofing, assures superior performance while operating in the world's most challenging weather environments.

Table 3.3 Antenna Technical Characteristics

GENERAL CHARACTERISTICS	Antenna Description	Molded UV- resistant plastic conical radome Aluminum die cast bottom housing Electrically shielded low noise amplifier assembly Operating Frequency L1 (1575.42 MHz, +/- 2 MHz)
PERFORMANCE CHARACTERISTICS	Input Impedance	50 Ohms
	VSWR	1.5 (typical) @ 1575.42 MHz
	Bandwidth	25 MHz (typical) +/- 3dB points)
	Filtering	40dB at +/- 50MHz from L1
	Polarization	Right hand circular
	Azimuth Coverage	360°
	Elevation Coverage	0° to 90°
	Patch Element Gain Characteristics	+2.0 dBic minimum at zenith, -10 dBic minimum at 0° elevation
	LNA Gain	25dB (typical)
	Noise Figure	< 1.5dB (typical)
	Dynamics	Vibration: SAE J1455
ELECTRICAL CHARACTERISTICS	Input Voltage Range	5 +/- 0.25 Vdc
	Current Requirements	26 mA @ 5 Vdc (typical)
PHYSICAL CHARACTERISTICS	Dimensions	102.0 diameter x 82.0 height (mm)
	Weight	312 grams
	Mount	Center mount (M28 nut)
	Connector	N jack
ENVIRONMENTAL CHARACTERISTICS	Operating Temperature	-40ºC to +85ºC
	Storage Temperature	-40ºC to +85ºC
	Humidity	85% non-condensing @ +30ºC to +60ºC
	UV Radiation Test	JIS D0202 (Sunshine Carbon Arc System)
	Salt Spray Test	Spray 5% NaCl solvent at +35°C
	Immersion Test	1 meter (with connector sealed)
	Transient Voltage Test	+/- 12 kV
MISCELLANEOUS	Optional Features	Post Mount Bracket, P/N (MNT62312B1)
NOTE	All performance measurements are typical and referenced to 25°C unless indicated otherwise	

Antenna Gain Pattern

The sensitivity of an antenna as a function of elevation angle is represented by the gain pattern. Some directions are much more appropriate for signal reception than others, so the gain characteristics of an antenna play a significant role in the antenna's overall performance.

A cross-sectional view of the antenna gain pattern for the antenna along a fixed azimuth (in a vertical cut) is displayed in the following figure. The gain pattern clearly indicates that the antenna is designed for full, upper hemispherical coverage, with the gain diminishing at low elevations. This cross-section is representative of any vertical cross section over a 0 to 360 degree azimuth range and thus, the 3 dimensional gain pattern is a symmetric spheroidal surface. It is important to note that this gain pattern varies in elevation angle, but not in horizontal azimuth. This design is well suited for many GPS applications, accommodating full sky coverage above the local horizon and minimizing ground reflected multipath effects.

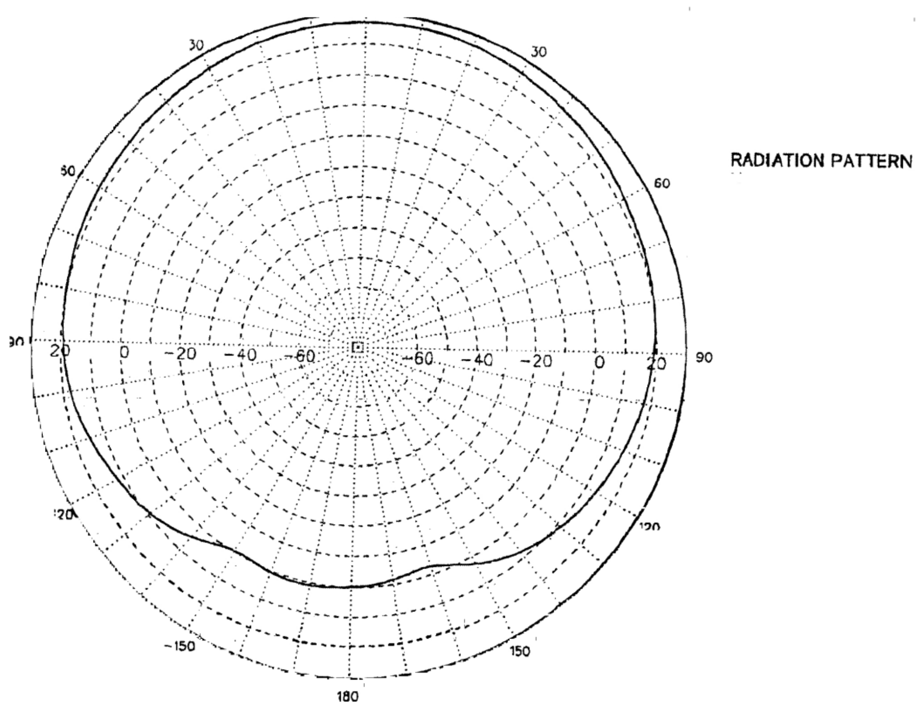

Figure 3.7: Typical Antenna Gain Pattern

Installation Precautions

The following precautions should be taken into consideration to avoid the introduction of hazards and adversely affecting performance when installing the GPS Antenna.

- Mounting bracket must be grounded in accordance with the National Electric Code Section 810-21.
- Avoid contact with power lines; serious injury could result.
- Avoid making the antenna the highest point on the roof.
- Locate the antenna such that there is a 360° view of the sky.
- Do NOT place any obstructions over or around the antenna.
- For optimal performance, do NOT place the antenna inside a building.
- To prevent ESD damage to the antenna, do NOT touch the center pin on the
- antenna connector.
- Use only a 50 ohm transmission line when connecting to the antenna.
- Do NOT apply more than 5 VDC to the center pin of the antenna.
- If more than one receiver is fed by a single antenna, ensure that the receivers are isolated by a high isolation RF splitter. Low isolation passive splitters can cause sub-optimal performance.

Antenna Mounting

The antenna is installed with a center-mounting scheme. It uses an industry standard 'N' connector that is incorporated with the post mount bracket. The minimum torque to assemble the antenna and custom hex nut on the post mount bracket is 70 kg-cm (61 in-lb); do not exceed 100 kg-cm (86.8 inch-lb). It is recommended that an adjustable wrench with a minimum opening of 1½ inches be used for this assembly. For optimal performance, ensure that the base of the antenna is positioned as close as possible to the top of the mounting pole. Select a mounting location with a clear view of the sky (360°) and use extreme caution when mounting near high voltage power lines.

It is recommended that the mounting bracket, designed specifically for the antenna, be used when installing the antenna. It can be used to install the antenna to a nominal 1 inch schedule 40 size pipe (approximately 1.6" OD). The four units included in the mounting assembly are the U-bolt, post mount bracket, lock washer and hex nut as illustrated in the following figure.

Antenna in Extreme Weather and Environmental Conditions

To provide additional protection against extreme weather and environmental conditions, a length of plastic tubing covering the N connector on the bottom of the antenna is recommended to keep driven rain from directly impinging on the connector mating area. This tubing should be secured to the mounting nut of the antenna assembly and should extend several inches past the mating N connectors. A product similar to Armstrong's Armaflex Pipe Insulation Tubing products is recommended. More information on this product can be found at www.armaflex.com. Use a weather resistant cable tie or clamp to secure the tubing material to the mounting nut.

Antenna Cable and Connector Requirements

The antenna module consumes five-volt power diplexed from the interconnecting coaxial cable. A 50 ohm coaxial cable is recommended for proper connection of the antenna module to the receiver module. Note that for GPS receivers such as the , signal attenuation along the cable should not exceed 8 dB at a frequency of 1575.42 MHz (the GPS L1 frequency). For RG-58 cables, the maximum cable length is restricted to approximately 12m to satisfy this 8 dB requirement.

For long cable runs, cables specifically designed for use at microwave frequencies are recommended. These cables are typically constructed with a low-loss foam dielectric between the center conductor and the outer shield.

The antenna uses an industry standard female N connector. Weatherproof mating N-connectors are required to ensure a water resistant seal. Some suggested cable connector vendors are:

- AMP
- Amphenol
- Huber + Suhner

Chapter 4 - I/O COMMANDS

CHAPTER SUMMARY

Refer to this chapter for the following:

- The I/O commands supported by the M48M Oncore receiver
- Detailed command descriptions

OVERVIEW

The Binary commands can be used to initialize, configure, control and monitor the M48M receivers. The binary commands are supported on the primary communications port at 9600 baud. Immediately following this page are listings of the input commands in alphabetical order. Command and response structures are detailed on subsequent pages.

The input and output data fields following the message headers contain binary data that can be interpreted as scaled floating point or integer data. The field width and appropriate scale factors for each parameter are described in the individual I/O message format descriptions. Polarity of floating point data is described via two's complement presentation.

Input commands may also be of the type query current parameter status, or enable and disable the output of data or status messages. These output status messages include those that the external controller will use for obtaining position, velocity, time, and status data.

Some care must be exercised in interpreting the command arguments. On the following pages it sometimes makes sense to display the command arguments as ASCII characters, while in others the hex representation may be a little clearer. As mentioned previously, the receiver doesn’t really care which method is used to generate the messages sent to the receiver so long as the binary strings sent to the receiver meet the specifications. Where possible, complete hex command strings have been included as examples of what the complete command strings look like. Once a basic understanding of the message protocols is developed by the user, things will become much clearer.

Also included in this chapter are message structures for the seven NMEA messages supported by the M48M positioning receiver (The NMEA protocol is not supported by the M48M timing receiver.

The SiRF Oncore mnemonics shown in the following table are only to be used with the ‘Extra Message’ window in SiRF Oncore. Each mnemonic causes SiRF Oncore to run a macro that sends a properly formatted string to the along with the checksum, carriage return, and line feed. See the SiRF Oncore help files for further explanation in the use of these commands.

I/O COMMAND LIST INDEX BY BINARY COMMAND

Table 5.1: Input Commands Listed by Binary Command Header

Binary Command	Function	Description	M48M Timing	Page #
@@Ag	Satellite	Satellite Mask Angle	√	60
@@Ao	Setup	Datum ID Codes	√	62
@@Ap	Setup	User Defined Datum	√	64
@@Aq	Setup	Ionospheric Correction Select	√	67
@@AQ	Position	Position Filter Select	√	69
@@As	Timing	Position-Hold Parameters	√	71
@@Aw	Time	UTC Correction Select	√	73
@@Ay	Time	1PPS Offset	√	75
@@Az	Time	1PPS Cable Delay	√	77
@@Bb	Satellite	Satellite Visibility Message	√	79
@@Bd	Almanac	Almanac Status Message	√	81
@@Bj	Setup	Leap Second Status	√	83
@@Bo	Time	UTC Offset Output Message	√	85
@@Bp	Receiver	Request UTC/Ionospheric Data	√	87
@@Cf	Receiver	Set to Defaults	√	90
@@Ci	NMEA	Switch I/O to NMEA Protocol	√	92
@@Cj	Receiver	Receiver ID	√	94
@@Co	Receiver	UTC/Ionospheric Data Input	√	96
@@Eq	Position	ASCII Position Message	√	99
@@Ga	Position	Combined Position Message	√	102
@@Gb	Time	Combined Time Message	√	104
@@Gc	1PPS	1PPS Control Message	√	107
@@Gd	Position	Position Mode Control Message	√	109
@@Ge	Time	T-RAIM Select Message	√	111
@@Gf	Time	T-RAIM Alarm Message	√	113
@@Gj	Time	Leap Second Pending	√	115
@@Ha	Position	12 Channel Position/Status/Data	√	117
@@Hb	Position	12 Channel Short Position Message	√	122
@@Hn	Time	12 Channel T-RAIM Status Message	√	125

Table 5.1: Input Commands Listed by Binary Command Header (continued)

Binary Command	Function	Description	M48M Timing	Page #
GPGGA	NMEA	GPS Fix Data	√	127
GPGLL	NMEA	Geographic Latitude/Longitude	√	130
GPGSA	NMEA	GPS DOP and Active Satellites	√	132
GPGSV	NMEA	GPS Satellites in View	√	134
GPRMC	NMEA	Recommended Minimum Data	√	136
GPVTG	NMEA	Track Made Good and Speed	√	138
GPZDA	NMEA	Time and Date	√	140
FOR	NMEA	Switch to Binary	√	142

SATELLITE MASK ANGLE COMMAND (@@Ag)

Applicability: M48M Positioning and Timing receivers

The receiver will attempt to track satellites for which the elevation angle is greater than the satellite mask angle. This parameter allows the user to control the elevation angle that was used for this decision. Typical values are between 5 and 10 degrees. Depending on the antenna used, the receiver is capable of tracking satellites down to the horizon, but range and therefore time errors will increase due to atmospheric distortion of the signals from the low satellites.

Range: 0 to 45 degrees

Default values:
M48M Timing Receiver: 10 degrees

SATELLITE MASK ANGLE (@@Ag)

Binary Format

Query current **Satellite Mask Angle:**

@@AgxC<CR><LF>
where: x = 1 ‘0xFF’ hex byte
0xD9= checksum
Message length: 8 bytes

Complete hex string to query the current **Satellite Mask Angle**:

0x40 40 41 67 FF D9 0D 0A

Change current **Satellite Mask Angle:**

@@AgdC<CR><LF>
where: d = degrees — 0..45 degrees (0x00 – 0x2D), if value input is greater than 45 degrees, the mask angle will be capped at 45 degrees
C = checksum
Message length: 8 bytes

Response to either command:

@@AgdC<CR><LF>
where: d = degrees — 0..45 degrees (0x00 – 0x2D)
C = checksum
Message length: 8 bytes

DATUM SELECT COMMAND (@@Ao)

Applicability: M48M and M48M Timing receivers

The M48M has one predefined datum (WGS-84) stored in non-volatile memory, and one user definable datum. Datums are referenced by an ID number. The predefined datum is number 49, and the user definable datum is number 50.

The user instructs the receiver which datum to use by sending the Datum Select command. The user can instruct the GPS receiver to use the user definable datum by sending a Datum Select command with the ID option set to 50.

> *NOTE: Before Datum 50 may be used, the M48M must have the user datum information programmed into it using the @@Ap command. If this is not done, Datum 50 will contain WGS-84 coordinates, identical to Datum 49.*

Default datum: WGS-84 (ID code 49)

Legacy Code Compatibility: The @@Ao command has been implemented in an identical fashion on virtually all Oncore receivers. The main difference is that the VP receivers had sufficient memory to hold 48 of the most commonly used datums, whereas the M48M can store one.

DATUM SELECT COMMAND (@@Ao)

Binary Format

Query currently used **Datum ID**:

@@AoxC<CR><LF>

where:

x =1 out of range byte: 0xFF

Checksum = 0xD1

Message length: 8 bytes

Complete hex string to query current **Datum ID**:

0x40 40 41 6F FF D1 0D 0A

Change currently used **Datum ID**:

@@AodC<CR><LF>

where:

d = datum ID 49 or 50 *(0x31 or 0x32)*

C = checksum

Message length: 8 bytes

Response to either command:

@@AodsssffiiffffxxyyzzC<CR><LF>

where:

d = current datum ID: 49 or 50 *(0x31 or 0x32), default = 49 (0x31)*

sssff = semi-major axis (m)

where: sss = integer part 6,000,000..7,000,000 *(0x56 0x8D 0x80 .. 0x6A 0xCF 0xC0),* default = 6,378,137 (0x61 52 99)

ff = fractional part 0..999 (0.0..0.999m) *(0x00 .. 0x03 0xE7)*, default = 0 (0x00 00)

iiffff = inverse flattening constant

where: ii = integer part 285..305 *(0x01 0x1D .. 0x01 0x31)*, default = 298 (0x01 2A)

ffff = fractional part 0..999,999,999 (0.0..0.999999999), default = 257,223,563 (0x0F 54 EB 8B)

xx = delta X (0.1 m) -32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)

yy = delta Y (0.1 m) -32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)

zz = delta Z (0.1 m) -32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)

C = checksum

Message length: 25 bytes

DEFINE USER DATUM MESSAGE (@@Ap)

Applicability: M48M and M48M Timing receivers

The M48M can accommodate one user defined datum stored as ID number 50. The Define User Datum command allows the user to define the constants used for this datum.

A datum is defined by a semi-major axis, an inverse flattening constant, and an offset from the center of mass of the earth, given as delta-X, delta-Y, and delta-Z
parameters.

If the user has not supplied the receiver with custom datum parameters, Datum 50 will contain WGS-84 parameters, identical to those stored in the receiver's default datum, Datum 49.

Default value: WGS-84 parameters

Related command: Datum Select Message (@@Ao)

Legacy Code Compatibility: The @@Ap command has been implemented in an identical fashion on virtually all Oncore receivers.

DEFINE USER DATUM MESSAGE (@@Ap)

Binary Format

Query current **User Defined Datum Parameters:**

@@ApdxxxxxxxxxxxxxxxxxC<CR><LF>

where:

d = user datum ID:	50
xxxxxxxxxxxxxxxxx =	17 bytes, all 0x00
C = 0x31	

Message length: 25 bytes

Complete hex string to query current **User Defined Datum Parameters**:

0x40 40 41 70 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 31 0D 0A

Change current **User Defined Datum Parameters:**

@@ApdsssffiiffffxxyyzzC<CR><LF>

where:

d = datum ID	50
sssff = semi-major axis (m)	
sss = integer part	6,000,000..7,000,000 *(0x56 0x8D 0x80 .. 0x6A 0xCF 0xC0),* default = 6,378,137 (0x61 52 99)
ff = fractional part	0..999 (0.0..0.999), *(0x00 .. 0x03 0xE7)*, default = 0 (0x00 00)
iiffff = inverse flattening	
ii = integer part	285..305, default = 298 (0x01 2A)
ffff = fractional part	0..999,999,999 (0.0..0.999999999), default = 257,223,563 (0x0F 54 EB 8B)
xx = delta X (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)
yy = delta Y (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)
zz = delta Z (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7), default = 0 (0x00 00)
C = checksum	

Message length: 25 bytes

Response to either command:

@@ApdsssffiiffffxxyyzzC<CR><LF>

where:

d = datum ID	50
sssff = semi-major axis (m)	
sss = integer part	6,000,000..7,000,000
ff = fractional part	0..999 (0.0..0.999)
iiffff = inverse flattening	
ii = integer part 285..305	
ffff = fractional part	0..999,999,999 (0.0..0.999999999)
xx = delta X (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7)
yy = delta Y (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7)
zz = delta Z (0.1 m resolution)	-32,768..32,767 (-3276.8..3276.7)
C = checksum	

Message length: 25 bytes

IONOSPHERIC CORRECTION SELECT COMMAND (@@Aq)

Applicability: M48M Timing receivers

The user has the flexibility of turning the GPS ionospheric correction models on or off. The models do a reasonable job of taking out the range error induced by the earth's ionosphere by using algorithms and parameters transmitted to the users by the satellites.

Default modes: Ionospheric model enabled

IONOSPHERIC CORRECTION SELECT COMMAND (@@Aq)

Binary Format

Query current **Ionospheric Correction Selection:**

@@AqxC<CR><LF>

where:

x = 1 out of range byte: 0xFF

C = CF

Message length: 8 bytes

Complete hex string to query current **Ionospheric Correction Selection**:

0x40 40 41 71 FF CF 0D 0A

Change current Ionospheric Correction Selections:

@@AqsC<CR><LF>

where:

s = selection 0x00 = ionospheric model disabled
0x01 = ionospheric model enabled

C = checksum

Message length: 8 bytes

Response to either command:

@@AqsC<CR><LF>

where:

s = selection 0x00 = ionospheric models disabled
0x01 = ionospheric model enabled

C = checksum

Message length: 8 bytes

POSITION FILTER SELECT COMMAND (@@AQ)

Applicability: M48M Timing receivers

This message enables or disables the position filter.

Default mode: Enabled

POSITION FILTER SELECT COMMAND (@@AQ)

Binary Format

Query current **Position Filter Status:**

@@AQxC<CR><LF>

where:

x = 1 out of range byte 0xFF

C = 0xEF

Message length: 8 bytes

Complete hex string to query current **Position Filter Status:**

0x40 40 41 51 FF EF 0D 0A

Change current **Position Filter Status:**

@@AQsC<CR><LF>

where:

s = selection 0x00 = disabled
0x01 = enabled

C = checksum

Message length: 8 bytes

Response to either command:

@@AQsC<CR><LF>

where:

s = selection 0x00 = disabled
0x01 = enabled

C = checksum

Message length: 8 bytes

POSITION HOLD PARAMETERS MESSAGE (@@As)

Applicability: M48M Timing receivers

The user can specify Position Hold coordinates both for timing applications to increase the timing accuracy and when the receiver is used as a source of differential correction data. This command is used to enter the position to be held.

The position is specified in the same units and referenced to the same datum as the initial position coordinates of latitude, longitude and height (to the same resolution). The height parameter is referenced to the GPS reference ellipsoid. Note that all three parameters must be specified. The valid ranges of each parameter are the same as those specified in the Combined Position Message (@@Ga).

Note: This command will only be executed if Position Hold is disabled. Position Hold is controlled using the @@Gd message.

Default values: Latitude = 0° (Equator)
Longitude = 0° (Greenwich Meridian)
Height = 0 m (GPS Height)

Legacy Code Compatibility: The @@As command has been implemented in a similar fashion on the older VP and UT/UT+ Oncore receivers.

POSITION HOLD PARAMETERS (@@As)

Binary Format

Query current **Position Hold Parameters**:

@@AsxxxxxxxxxxxxxC<CR><LF>

where:

xxxxxxxxxxxxx = 13 out of range hex bytes: 0xFF
C = 0xCD

Message length: 20 bytes

Complete hex string to query current **Position Hold Parameters**:

0x40 40 41 73 FF FF FF FF FF FF FF FF FF FF FF FF FF CD 0D 0A

Change current **Position Hold Parameters**:

@@AsllllooohhhhtC<CR><LF>

where:

llll = latitude in mas	-324,000,000..324,000,000 (-90º..90º)
oooo = longitude in mas	-648,000,000..648,000,000 (-180º..180º)
hhhh = height in cm	-100,000..1,800,000 (-1,000.00..18,000.00 m)
t = height type	0 = GPS height
C = checksum	

Message length: 20 bytes

Response to either command:

@@AsllllooooohhhhtC<CR><LF>

where:

llll = latitude in mas	-324,000,000..324,000,000 (-90º..90º)
oooo = longitude in mas	-648,000,000..648,000,000 (-180º..180º)
hhhh = height in cm	-100000..1,800,000 (-1,000.00..18,000.00 m)
t = height type	0 = GPS height
C = checksum	

Message length: 20 bytes

TIME CORRECTION SELECT (@@Aw)

Applicability: M48M Timing receivers

This command selects the time reference (either GPS or UTC) used in the @@Ha 12 Channel Position/Status/Data and @@Hb Short Position Messages. This Time command is also used to determine the synchronization point for the 1PPS timing pulse.

Note: *If the receiver has not downloaded the UTC parameters portion of the almanac, the receiver will output time equal to GPS time and a flag denoting the lack of UTC parameters will be set in the @@Ha message. Once the receiver has downloaded the UTC parameters from the satellites the receiver will automatically switch the time reference to UTC if UTC mode is selected.*

Default mode: UTC

Legacy Code Compatibility: The @@Aw command has been implemented in an identical fashion on virtually all Oncore receivers.

TIME CORRECTION SELECT (@@Aw)

Binary Format

Query current UTC **Time Correction Option:**

@@AwxC<CR><LF>

where:

x = 1 out of range hex byte: 0xFF
C = 0xC9

Message length: 8 bytes

Complete hex string to query current **Time Correction Option:**

0x40 40 41 77 FF C9 0D 0A

Change current **UTC Time Correction Option:**

@@AwmC<CR><LF>

where:

m = time mode: 0x00 = GPS
0x01 = UTC

C = checksum
Message length: 8 bytes

Response to either command:

@@AwmC<CR><LF>

where:

m = time mode 0x00 = GPS
0x01 = UTC

C = checksum
Message length: 8 bytes

1PPS TIME OFFSET COMMAND (@@Ay)

Applicability: M48M Timing Receivers

The M48M outputs a one pulse-per second (1PPS) signal with the rising edge placed on top of the UTC or GPS one second tic mark, depending on which time reference has been selected by the user. The 1PPS Time Offset command allows the user of M48M Timing Receivers to offset the 1PPS time mark in one nanosecond increments. This offset can be used to place the 1PPS signal anywhere within the one second epoch.

The resolution of this parameter is one nanosecond. This does not imply that the 1PPS output by the M48M is accurate to this level. This command only allows the user to change the location of the average placement of the pulse.

The absolute accuracy of the signal is a function of GPS time accuracy, and is subject to degradation due to U.S. Department of Defense policy.

Range: 0.000000000 to 0.999999999 s

Default value: 0.000000000 s
Resolution: 1 ns

Legacy Code Compatibility: The @@Ay command was implemented in an identical fashion on UT+ and VP timing receivers.

1PPS TIME OFFSET COMMAND (@@Ay)

Binary Format

Query current **1PPS Time Offset:**

@@AyxxxxC<CR><LF>

where:

xxxx = 4 out of range hex bytes: 0xFF

C = 0x38

Message length: 11 bytes

Complete hex string to query current user specified **1PPS Time Offset:**

0x40 40 41 79 FF FF FF FF 38 0D 0A

Change current **1PPS Time Offset:**

@@AyttttC<CR><LF>

where:

tttt = time offset in ns 0..999,999,999 (0.0 to 0.999999999 s)

C = checksum

Message length: 11 bytes

Response to either command:

@@AyttttC<CR><LF>

where:

tttt = time offset in ns 0..999,999,999 (0.0 to 0.999999999 s)

C = checksum

Message length: 11 bytes

1PPS CABLE DELAY CORRECTION COMMAND (@@Az)

Applicability: M48M Timing Receivers

The M48M timing receiver outputs a 1PPS signal, the rising edge of which is placed at the top of the GPS or UTC one second time mark epoch as specified by the Time Mode command. The 1PPS Cable Delay Correction command allows the user to offset the 1PPS time mark in one nanosecond increments relative to the measurement epoch.

This parameter instructs the GPS receiver to output the 1PPS output pulse earlier in time to compensate for antenna cable delay. Up to one millisecond of equivalent
cable delay can be removed. Zero cable delay is set for a zero-length antenna cable. The user should consult a cable data book for the delay per unit length for the particular antenna cable used in order to compute the total cable delay needed for a particular installation.

This parameter may also be employed by the user to adjust the position of the 1PPS to compensate for other system delays.

Range: 0.000 to 0.000999999 s
Default value: 0.000 s
Resolution: 1 ns

Legacy Code Compatibility: The @@Az command was implemented in an identical fashion on UT+ and VP timing receivers.

1PPS CABLE DELAY CORRECTION (@@Az)

Binary Format

Query current **1PPS Cable Delay Correction:**

@@AzxxxxC<CR><LF>

where:

xxxx = 4 out of range hex bytes: 0xFF

Checksum = 0x3B

Message length: 11 bytes

Complete hex string to query current user specified **1PPS Cable Delay Correction:**

0x40 40 41 7A FF FF FF FF 3B 0D 0A

Change current **1PPS Cable Delay Correction:**

@@AzttttC<CR><LF>

where:

tttt = time offset in ns 0..999,999 ns (0.0 to 0.000999999 s)

C = checksum

Message length: 11 bytes

Response to either command:

@@AzttttC<CR><LF>

where:

tttt = time offset in ns 0..999,999 ns (0.0 to 0.000999999 s)

C = checksum

Message length: 11 bytes

VISIBLE SATELLITE DATA MESSAGE (@@Bb)

Applicability: M48M Timing Receivers

This command requests the results of the most current satellite visibility computation. The response message gives a summary of the satellite visibility status showing the number of visible satellites, the Doppler frequency and the location of the currently visible satellites. The reference position for the most recent satellite alert is the current position coordinates.

Note that these coordinates may not compare to the GPS receiver's actual position when initially turned on, since the GPS receiver may have moved a great distance since it was last used.

Note: Each @@Bb message from the M48M will contain information for a maximum of 12 satellites. If less than 12 satellites are visible, unneeded fields will be filled with zeros. If there are more than 12 visible SVs visible, then details (SVID, Doppler, Elevation, etc.) of ONLY the 12 highest SVs will be reported in the message.

Default mode: Polled

Legacy Code Compatibility: The @@Bb command has been implemented in an identical fashion on virtually all Oncore receivers.

VISIBLE SATELLITE DATA MESSAGE (@@Bb)

Binary Format

Query Current **Visible Satellite Data:**

@@BbmC<CR><LF>

where:

m = mode	0x00 = output response message once (polled)
	0x01 = output response message data when visibility data changes (approximately once every 5-7 seconds)
C = checksum	

Message length: 8 bytes

Response to above command:

@@Bbn iddeaas iddeaas iddeas iddeaas iddeaas iddeaas
iddeaas iddeaas iddeaas iddeaas iddeaas iddeaas C<CR><LF>

where:

n = number of visible sats 0 ..12

For each visible satellite, up to n fields contain the following valid data

i - satellite ID	1 .. 32
dd - Doppler in Hz	-5,000..5,000
e - elevation in degrees	0..90
aa - azimuth in degrees	0..359
s - satellite health	0 = healthy and not removed
	1 = unhealthy and removed
C = checksum	

Message length: 92 bytes

*NOTE: The spaces in the response message shown above have been added merely to increase readability. There are no embedded spaces in the actual message sent out by the M48M receiver.

ALMANAC STATUS MESSAGE (@@Bd)

Applicability: M48M Timing Receivers

This command requests almanac status information corresponding to the satellite almanac data currently stored in RAM. The GPS receiver continually captures a complete new almanac to internal RAM while tracking satellites. If an existing almanac is stored in RAM on power-up, satellite visibility information will be available immediately. If no almanac data is stored in RAM on power-up, the receiver will download a new almanac and then compute satellite visibility information.

Legacy Code Compatibility: The @@Bd command was implemented in an identical fashion on VP Oncore receivers.

ALMANAC STATUS MESSAGE (@@Bd)

Binary Format

Query **Current Almanac Status**:

@@BdmC<CR><LF>

where:

m = mode	0x00 = Output status once (polled)
	0x01 = Output status when RAM almanac data changes (continuous)
C = checksum	

Message length: 8 bytes

Response to above command:

@@BdvwtassssrrrrrrrrC<CR><LF>

where:

v = almanac valid flag	0x00 = no almanac in receiver
	0x01 = valid almanac in receiver
w = almanac week number (raw)	0x00..0xFF (ICD-GPS-200)
t = time of almanac (raw)	0x00..0x93 (ICD-GPS-200)
a = number of available SVs	0x00..0x20
ssss = SVs in almanac	32 bit (2 byte) binary field,
	each bit represents one SVID
	(msb = SVID 32; 1sb = SVID 1)
rrrrrrrr =	8 reserved bytes
C = checksum	

Message length: 23 bytes

LEAP SECOND STATUS MESSAGE (@@Bj)

Applicability: M48M Timing Positioning Receivers

This message polls the receiver for current leap second status information that has been decoded from the Navigation Data message received from the GPS satellites. The data sent back by the receiver provides specific date and time information pertaining to any future leap second addition or subtraction.

Leap seconds are occasionally inserted in UTC and generally occur on midnight UTC June 30th or midnight UTC December 31st. The GPS control segment typically notifies GPS users of pending leap second insertions to UTC several weeks before the event.

When a leap second is inserted, the time of day will show a value of '60' in the seconds field. When a leap second is removed, the date will roll over at 58 seconds.

The 'current UTC offset' will be zero if the receiver is set up to run in GPS time mode instead of UTC.

Default mode: Polled

Legacy Compatibility: The @@Bj message was used in an identical manner in virtually all receivers.

LEAP SECOND STATUS MESSAGE (@@Bj)

Binary Format

Query current Leap Second Pending information:

@@BjmC<CR><LF>
where:

m = mode	0x00
C = 0x28	

Message length: 8 bytes

Complete hex string to query current user specified **Leap Second Status:**

0x40 40 42 6A 00 28 0D 0A

Response to above command:

@@BjmC<CR><LF>
where:

m = leap second status	0x00 - no leap second pending
	0x01 - addition of one second pending
	0x02 - subtraction of one second pending
C = checksum	

Message length: 8 bytes

UTC OFFSET OUTPUT MESSAGE (@@Bo)

Applicability: M48M Timing Receivers

This message allows the user to request the UTC offset that is currently being used in the time solution. The value reported is the integer number of seconds between UTC and GPS time. If the offset reported by the receiver is zero and UTC is the selected time reference, the receiver does not currently have the portion of the almanac that contains the UTC parameters.

The UTC parameters are broadcast by the satellites as part of the almanac, which is repeated every 12.5 minutes. The message can be set to output either once (polled), or any time the UTC offset has been updated or changed from its previous value.

Default mode: Polled

Legacy Compatibility: The @@Bo message was used in an identical manner in the UT+ receiver.

UTC OFFSET OUTPUT MESSAGE (@@Bo)

Binary Format

Request Current UTC Offset:

@@BomC<CR><LF>

where:

m = mode	0 = output UTC offset once (polled)
	1 = output UTC offset every time it is updated
C = checksum	

Message length: 8 bytes

Response to above command:

@@BouC<CR><LF>

where:

u = UTC offset in seconds	-128..+127
C = checksum	

Message length: 8 bytes

REQUEST UTC/IONOSPHERIC DATA (@@Bp)

Applicability: M48M Timing Receivers

This message allows the user to request UTC and ionospheric data decoded from the Navigation Data Message.

Default mode: Polled

Legacy Compatibility: The @@Bp message was used in an identical manner in the M12 receiver.

REQUEST UTC/IONOSPHERIC DATA (@@Bp)

Binary Format

Request Current UTC/Ionospheric Data:

@@BpmC<CR><LF>

where:

m = mode	0 = output response once (polled) 1 = output response when either UTC or ionospheric data changes
C = checksum	

Message length: 8 bytes

Response to above command:

@@CoabcdefghAAAAaaaadtwWnDC<CR><LF>

where:

a, b, c, d, e, f, g, and h = Ionospheric Data (see ICD-GPS-200, Table 20-X for scale factors)

a = $\alpha 0$	Ionospheric cubic coefficient alpha0 -128…+127 seconds
b = $\alpha 1$	Ionospheric cubic coefficient alpha1 -128…+127 seconds/semi-circle
c = $\alpha 2$	Ionospheric cubic coefficient alpha2 -128…+127 seconds/(semi-circle)^2
d = $\alpha 3$	Ionospheric cubic coefficient alpha3 -128…+127 seconds/(semi-circle)^3
e = $\beta 0$	Ionospheric cubic coefficient beta0 -128…+127 seconds
f = $\beta 1$	Ionospheric cubic coefficient beta1 -128…+127 seconds/(semi-circle)
g = $\beta 2$	Ionospheric cubic coefficient beta2 -128…+127 seconds/(semi-circle)^2
h = $\beta 3$	Ionospheric cubic coefficient beta3 -128…+127 seconds/(semi-circle)^3

AAAA, aaaa, d, t, w, and W = UTC Data (see ICD-GPS-200, Table 20-IX for scale factors)

AAAA = A0	Constant terms of polynomial, -2,147,483,648…+2,147,483,647 seconds
aaaa = A1	First order term of polynomial, -8,388,608…+8,388,607 seconds/second
d = Δt_{LS}	Delta time due to leap seconds, -128…+127 seconds

$t = t_{ot}$ Reference time for UTC data,
0…602,112 seconds
$w = WN_t$ UTC reference week number,
0…255 weeks
$W = WN_{LSF}$ Current week number derived from subframe 1,
0…255 weeks
n = DN Day number of UTC change over,
1…7 days
$D = \Delta t_{LSF}$ Leap second value at change over,
-128…+127 seconds
C = checksum

Message length: 29 bytes

SET TO DEFAULTS COMMAND (@@Cf)

Applicability: M48M Timing Receivers

This command sets all of the GPS receiver parameters to their default values. Performance of this utility results in all continuous messages being reset to poll only output, and clears the almanac and ephemeris data. The time and date stored in the internal real-time clock are changed by the execution of this command except the year. The year will be remain as the last input or calculated year.

Legacy Code Compatibility: The @@Cf command has been implemented in an identical fashion on virtually all Oncore receivers.

SET-TO-DEFAULTS (@@Cf)

Binary Format

Set the GPS receiver to **Default** values:

@@CfC<CR><LF>

where:

C = 0x25

Message length: 7 bytes

Complete hex string to **Set to Defaults:**

0x40 40 43 66 25 0D 0A

Response to above command:

@@CfC<CR><LF>

where:

C = checksum

Message length: 7 bytes

NMEA PROTOCOL SELECT (@@Ci)

Applicability: M48M Positioning Receivers

This command causes the M48M positioning receiver to change the serial data format on the primary port from Binary to NMEA 0183. The baud rate of the port is switched from 9600 to 4800 and input commands are recognized in NMEA format only. Note that the default mode of all of the NMEA output messages is off. To initiate NMEA output, the NMEA input commands detailed in the following pages must be utilized.

NOTE: There is no binary response to this command by the receiver. The receiver immediately switches to NMEA protocol and awaits NMEA commands.

Legacy Code Compatibility: The @@Ci command has been implemented in an identical fashion on virtually all VP, GT+, and M12 Oncore positioning receivers.

SWITCH I/O FORMAT (@@Ci)

Binary Format

Switch to NMEA Format command:

@@CimC<CR><LF>

where:

m = format 0x01 = NMEA

C = 0x2B

Message length: 8 bytes

Complete hex string to **Switch to NMEA Format:**

0x40 40 43 69 01 2B 0D 0A

There is no response message to this command.

RECEIVER ID (@@Cj)

Applicability: M48M Timing and Positioning Receivers

The M48M outputs an ID message upon request. The information contained in the ID string is self-explanatory. The model number can be used to determine the type of receiver installed.

Legacy Code Compatibility: The @@Cj command has been implemented in an identical fashion on virtually all Oncore receivers.

RECEIVER ID (@@Cj)

Binary Format

Query **Receiver ID:**

@@CjC<CR><LF>

where:

C = checksum

Message length: 7 bytes

Complete hex string to query **Receiver ID:**

0x40 40 43 6A 29 0D 0A

Response to above command:

The response is output as a 25 column by 12 row array. General format is as shown below:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	@	@	C	j	cr	lf	C	O	P	Y	R	I	G	H	T		2	0	1	0	-	2	0	1	1
2		i	-	L	O	T	U	S	.						cr	lf	S	F	T	W		P	/	N	
3	#		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	cr	lf	S	O	F	T	W	A
4	R	E		V	E	R		#	X	X	X	X	X	X	X	X	X	X	X	X	cr	lf	S	O	F
5	T	W	A	R	E			R	E	V		#	X	X	X	X	X	X	X	X	X	X	X	cr	lf
6	S	O	F	T	W	A	R	E		D	A	T	E			X	X	X	X	X	X	X	X	X	X
7	X	cr	lf	M	O	D	E	L		#					X	X	X	X	X	X	X	X	X	X	X
8	X	X	X	X	cr	lf	H	D	W	R		P	/	N		#		X	X	X	X	X	X	X	X
9	X	X	X	X	X	X	X	cr	lf	S	E	R	I	A	L		#				X	X	X	X	X
10	X	X	X	X	X	X	X	X	X	X	cr	lf	M	A	N	U	F	A	C	T	U	R		D	A
11	T	E			X	X	X	X	X	X	X	X	X	cr	lf										
12																	C*	cr	lf						

*C = Hex checksum

Message Length 294 bytes

UTC/IONOSPHERIC DATA INPUT [Response to @@Bp or @@Co]

Applicability: M48M Timing Receivers

As well as being the response to the @@Bp message, this message allows the user to input UTC and ionospheric data into the receiver which is then echoed in the response.

UTC/IONOSPHERIC DATA INPUT [Response to @@Bp or @@Co]

Binary Format

Change **UTC/Ionospheric Data:**

@@CoabcdefghAAAAaaaadtwWnDC<CR><LF>

where:

Ionospheric Data (see ICD-GPS-200, Table 20-X for scale factors)

Parameters	Description	Bits	Units
a = $\alpha 0$	Ionospheric cubic coefficient alpha 0	8	-128…+127 seconds
b = $\alpha 1$	Ionospheric cubic coefficient alpha 1	8	-128…+127 seconds/semi-circle
c = $\alpha 2$	Ionospheric cubic coefficient alpha 2	8	-128…+127 seconds/(semi-circle)^2
d = $\alpha 3$	Ionospheric cubic coefficient alpha 3	8	-128…+127 seconds/(semi-circle)^3
e = $\beta 0$	Ionospheric cubic coefficient beta 0	8	-128…+127 seconds
f = $\beta 1$	Ionospheric cubic coefficient beta 1	8	-128…+127 seconds/semi-circle
g = $\beta 2$	Ionospheric cubic coefficient beta 2	8	-128…+127 seconds/(semi-circle)^2
h = $\beta 3$	Ionospheric cubic coefficient beta 3	8	-128…+127 seconds/(semi-circle)^3

UTC Data (see ICD-GPS-200, Table 20-IX for scale factors)

Parameters	Description	Bits	Units
AAAA = A_0	Constant terms of Polynomial	32	-2,147,483,648…+2,147,483,647 seconds
aaaa = A_1	First Order Term of Polynomial	32	-8,388,608…+8,388,607 seconds/second
d = Δt_{LS}	Delta Time due to Leap Second	8	-128…+127 seconds
t = t_{ot}	Reference Time for UTC Data	8	0…255 seconds
w = WN_t	UTC Reference Week Number	8	0…255 weeks
W = WN_{LSF}	Current Week Number derived from Subframe 1	8	0…255 weeks
n = DN	Day Number of UTC Change Over	8	1…7 days
D = Δt_{LSF}	Leap Second Value at Change Over	8	-128…+127 seconds

C = checksum

Message length: 29 bytes

Response to above command:

@@CoabcdefghAAAAaaaadtwWnDC<CR><LF>

where:

Ionospheric Data (see ICD-GPS-200, Table 20-X for scale factors)

Parameters	Description	Bits	Units
a = α0	Ionospheric cubic coefficient alpha 0	8	-128…+127 seconds
b = α1	Ionospheric cubic coefficient alpha 1	8	-128…+127 seconds/semi-circle
c = α2	Ionospheric cubic coefficient alpha 2	8	-128…+127 seconds/(semi-circle)^2
d = α3	Ionospheric cubic coefficient alpha 3	8	-128…+127 seconds/(semi-circle)^3
e = β0	Ionospheric cubic coefficient beta 0	8	-128…+127 seconds
f = β1	Ionospheric cubic coefficient beta 1	8	-128…+127 seconds/semi-circle
g = β2	Ionospheric cubic coefficient beta 2	8	-128…+127 seconds/(semi-circle)^2
h = β3	Ionospheric cubic coefficient beta 3	8	-128…+127 seconds/(semi-circle)^3

UTC Data (see ICD-GPS-200, Table 20-IX for scale factors)

Parameters	Description	Bits	Units
AAAA = A_0	Constant terms of Polynomial	32	-2,147,483,648…+2,147,483,647 seconds
aaaa = A_1	First Order Term of Polynomial	32	-8,388,608…+8,388,607 seconds/second
d = Δt_{LS}	Delta Time due to Leap Second	8	-128…+127 seconds
t = t_{ot}	Reference Time for UTC Data	8	0…255 seconds
w = WN_t	UTC Reference Week Number	8	0…255 weeks
W = WN_{LSF}	Current Week Number derived from Subframe 1	8	0…255 weeks
n = DN	Day Number of UTC Change Over	8	1…7 days
D = Δt_{LSF}	Leap Second Value at Change Over	8	-128…+127 seconds

C = checksum

Message length: 29 bytes

ASCII POSITION MESSAGE (@@Eq)

Applicability: M48M Timing Receivers

The ASCII position output message contains position, time and receiver status
Information similar in scope to the @@Hb binary Short Position message. The ASCII message may be a more convenient interface for certain applications where the ASCII output of NMEA is desired, but operation at 4800 baud is not desirable. The units and style of the data is similar to NMEA output.

Default mode: Polled

Legacy Code Compatibility: The @@Eq command has been implemented in an identical fashion on GT+, UT+, and M12 Oncore receivers.

ASCII POSITION MESSAGE (@@Eq)

Binary Format

Request **ASCII Position Message:**

@@EqmC<CR><LF>

where:

m = output mode	0x00 = output response message once (polled)
	0x01 .. 0xFF = response message output at indicated rate (continuous)
	1 (0x01)= once per second
	2 (0x02)= once every two seconds
	255 (0xFF) = once every 255 seconds
C = checksum	

Message length: 8 bytes

Response to above command:

@@Eq,mm,dd,yy,hh,mm,ss,dd,mm.mmmm,n,ddd,mm.mmmm,w,shhhh.h,sss.s,hhh.h,m,t,dd.d,
nn,rrrr,aa,CCC<CR><LF>

where:

Date:

mm = month	1..12
dd = day	1..31
yy = year	12..00 (2012..2100)

UTC Time:

hh =hours	0..23
mm = minutes	00..59
ss = seconds	00..60 (60 if leap second is inserted)

Latitude:

dd = degrees	00..90
mm.mmmm = minutes	00..59.9999
n = direction	N = North, S = South

Longitude

ddd = degrees	000..180
mm.mmmm = minutes	00..59.9999
w = direction	W = West, E = East

ASCII POSITION MESSAGE (@@Eq)

Binary Format

Response Message Continued

Height:

s = sign of height	+ or -
hhhhh.h = height in meters	-1000.0..18,000.0

Velocity:

sss.s = speed in knots	000.0..999.9
hhh.h = heading in degrees	000.0..359.9

Receiver status:

m = fix mode	0 = autonomous
	1 = differential
t = fix type	0 = no fix
	1 = 2D fix
	2 = 3D fix
	3 = Position Propagate Mode
dd.d = dilution of precision	00.0…99.9, HDOP if 2D, PDOP if 3D
nn = number of satellites in use	00..37
rrrr = reference station ID	0000..1023
aa = age of differential data in s	00..60
CCC = checksum	000 .. 255****

Message length: 96 bytes

****Note that unlike all other binary messages, the @@Eq response checksum consists of the three ASCII characters that make up the normal XOR'ed checksum of the hex values of the ASCII characters. For instance, if the hex value of the XOR'ed checksum = 0xC4, the receiver would report an ASCII checksum of 196.

COMBINED POSITION MESSAGE (@@Ga)

Applicability: M48M Timing Receivers

This message allows the user to enter an initial position estimate.

If the receiver is computing a 2D fix, the receiver will ignore any attempts to change the latitude and/or longitude using this command. If the receiver is computing a 3D fix, it will also ignore any attempts to change height with this command. Under these conditions the receiver will respond with coordinates of its currently calculated location.

Default Values:	Latitude = 0º
	Longitude = 0º
	Height = 0m (GPS Height)

Legacy Code Compatibility: The @@Ga command was implemented in an identical fashion on the M12 Oncore receiver.

Earlier ONCORE receivers such as the VP, GT+, SL, and UT+ utilized three different messages to convey this information:

@@Ad –	Latitude
@@Ae –	Longitude
@@Af -	Height

COMBINED POSITION MESSAGE (@@Ga)

Binary Format

Query Current Position Command**:**

@@GaxxxxxxxxxxxxxC<CR><LF>

where:

xxxxxxxxxxxxx = 13 hex bytes:	0xFF
C = 0xD9	

Message length: 20 bytes

Complete hex string to query current **Combined Position:**

0x40 40 47 61 FF FF FF FF FF FF FF FF FF FF FF FF FF D9 0D 0A

Change Current Position Command:

@@GaaaaaooooohhhhtC<CR><LF>

where:

aaaa = latitude in mas	-324,000,000..+324,000,000 (-90º to +90º)
oooo = longitude in mas	-648,000,000..+648,000,000 (-180º to +180º)
hhhh = height	-100,000..1,800,000cm (-1000 to 18000 m)
t = height type	0 = GPS, 1 = MSL (always 0 with M48M receivers)
C = checksum	

Message Length: 20 bytes

Response to above command:

@@GaaaaaooooohhhhtC<CR><LF>

where:

aaaa = latitude in mas	-324,000,000..+324,000,000 (-90º to +90º)
oooo = longitude in mas	-648,000,000..+648,000,000 (-180º to +180º)
hhhh = height	-100,000..1,800,000cm (-1000 to 18000 m)
t = height type	0 = GPS, 1 = MSL (always 0 with M48M receivers)
C = checksum	

Message Length: 20 bytes

COMBINED TIME MESSAGE (@@Gb)

Applicability: M48M Timing Receivers

This message allows the user to give the receiver an initial estimate of the current time and date.

If the receiver is tracking at least one satellite, the receiver will ignore any attempts to change the time and date parameters using this command. Rather, the receiver will respond with currently calculated time and date.

Default Values:	Time =	12:00:00
	Date =	1/1/99
	GMT offset =	0:00

Legacy Code Compatibility: The @@Gb message was implemented in an identical fashion on the M12 Oncore receiver.

Earlier ONCORE receivers such as the VP, GT+, SL, and UT+ utilized three different messages to convey this information:

@@Ac –	Date
@@Aa –	Time
@@Ab -	GMT Offset

COMBINED TIME MESSAGE (@@Gb)

Binary Format

Query Current Time Message:

@@GbxxxxxxxxxxC<CR><LF>

where:

xxxxxxxxxx = 10 hex bytes:	0xFF
C = 0x25	

Message length: 17 bytes

Complete hex string to query current date, time, and GMT offset**:**

0x40 40 47 62 FF FF FF FF FF FF FF FF FF FF 25 0D 0A

Change Current Time Message:

@@GbmdyyhmsshmC<CR>LF>

where:

Date:

m = month	1…12
d = day	1…31
yy = year	2012…2100

Time:

h = hours	0…23
m = minutes	0…59
s = seconds	0…59
s = signed byte of GMT offset	00 = positive 255 = negative
h = hour of GMT offset	0…+23
m = minutes of GMT offset	0…59
C = checksum	

Message Length: 17 bytes

Response to above command:

@@GbmdyyhmsshmC<CR>LF>

where:

Date:

m = month	1…12
d = day	1…31
yy = year	1982…2100

Time:

h = hours	0…23
m = minutes	0…59
s = seconds	0…59
s = signed byte of GMT offset	00 = positive 255 = negative
h = hour of GMT offset	0…11
m = minutes of GMT offset	0…59
C = checksum	

Message Length: 17 bytes

1PPS CONTROL MESSAGE (@@Gc)

Applicability: M48M Timing Receivers

This message allows the user to choose how the 1PPS output from the receiver will behave. Note that the allowable options are different depending upon whether the user is working with an M48M timing or positioning receiver.

Default mode: Continuous

Legacy Code Compatibility: The @@Gc command was implemented in a similar fashion on the M12 Oncore receivers.

On eight channel timing receivers such as the VP and UT+ this information was included in the @@En T-RAIM Setup and Status Message

1PPS CONTROL MESSAGE (@@Gc)

Binary Format

Query current **1PPS Mode**:

@@GcxC<CR><LF>

where:

x = 1 hex byte: 0xFF

Checksum = 0x24

Message length: 8 bytes

Complete hex string to query current **1PPS Mode:**

0x40 40 47 63 24 0D 0A

Change **1PPS Control** Command:

@@GcpC<CR>LF>

where:

p = 1PPS control
0x00 = 1PPS disabled
0x01 = 1PPS on continuously
0x02 = 1PPS active only when tracking at least one satellite
0x03 = 1PPS on when T-RAIM conditions are met *(timing receiver only)*

C = checksum

Message Length: 8 bytes

Response to above command:

@@GcpC<CR>LF>

where:

p = 1PPS control
0x00 = 1PPS disabled
0x01 = 1PPS on continuously
0x02 = pulse active only when tracking at least one satellite
0x03 = 1PPS on when T-RAIM conditions are met *(timing receiver only)*

C = checksum

Message Length: 8 bytes

POSITION CONTROL MESSAGE (@@Gd)

Applicability: M48M Timing Receivers

This message allows the user to choose the following position control mode the receiver will operate:

Mode 00 = Normal 3D positioning
Mode 01 = Position Hold
Mode 02 = 2D positioning (positioning receiver only)
Mode 03 = Auto-survey with 10,000 samples (timing receiver only)
Mode 04 = Auto-survey with 5,000 samples (timing receiver only)
Mode 05 = Auto-survey with 1,000 samples (timing receiver only)

Note that the allowable options are different depending upon whether the user is working with an M48M timing or positioning receiver.

Default mode: Normal 3D positioning

Legacy Code Compatibility: The @@Gd command was implemented in a similar fashion on the M12 Oncore receivers.

This message combines the functionality of the @@At and @@Av commands used on 8 channel positioning and timing receivers.

POSITION CONTROL MESSAGE (@@Gd)

Binary Format

Query Current Position Control Mode:

@@GdxC<CR><LF>

where:

x = 1 hex byte: 0xFF

C = 0xDC

Message length: 8 bytes

Complete hex string to query current **Position Control Mode:**

0x40 40 47 64 FF DC 0D 0A

Change Current **Position Control Mode** Message:

@@GdcC<CR>LF>

where:

c = control type
- 0x00 = enable normal 3D positioning
- 0x01 = enable position hold
- 0x02 = enable 2D positioning *(positioning receivers only)*
- 0x03 = enable auto-survey with 10,000 samples *(timing receivers only)*
- 0x04 = enable auto-survey with 5,000 samples *(timing receivers only)*
- 0x05 = enable auto-survey with 1,000 samples *(timing receivers only)*

C = checksum

Message Length: 8 bytes

Response to above command:

@@GdpC<CR>LF>

where:

c = control type
- 0x00 = enable normal 3D positioning
- 0x01 = enable position hold
- 0x02 = enable 2D positioning *(positioning receivers only)*
- 0x03 = enable auto-survey with 10,000 samples (*timing receivers only*
- 0x04 = enable auto-survey with 5,000 samples *(timing receivers only)*
- 0x05 = enable auto-survey with 1,000 samples *(timing receivers only)*

C = checksum

Message Length: 8 bytes

TIME RAIM SELECT MESSAGE (@@Ge)

Applicability: M48M timing receivers

This message allows the user to enable or disable the Time RAIM algorithm.

Default: T-RAIM off.

This command was part of the @@En message used on 8 channel UT+ and VP timing receivers.

TIME RAIM SELECT MESSAGE (@@Ge)

Binary Format

Query **Current Time RAIM Mode**

@@GexC<CR><LF>

where:

x = one hex byte: 0xFF

C = 0xDD

Message Length: 8 bytes

Complete hex string to query current **Time RAIM Mode:**

0x40 40 47 65 FF DD 0D 0A

Change Current Time RAIM Mode

@@GetC<CR><LF>

where:

t = mode 0x00 = disable
0x01 = enable

C = checksum

Message Length: 8 bytes

Response to either command:

@@GetC<CR><LF>

where:

t = mode 0x00 = disable
0x01 = enable

C = checksum

Message Length: 8 bytes

TIME RAIM ALARM MESSAGE (@@Gf)

Applicability: M48M timing receivers

This message allows the user to enter the Time RAIM alarm limit in multiples of 100 ns, or to query the receiver for the current setting. The default alarm limit is 1000 ns.

Default value: 1000 ns

This command was part of the @@En message used on 8 channel UT+ and VP timing receivers.

TIME RAIM ALARM MESSAGE (@@Gf)

Binary Format

Query current **T-RAIM Alarm Setting:**

@@GfxxC<CR><LF>

where:

xx = two hex bytes: 0xFF 0xFF

C = 0x21

Message Length: 9 bytes

Complete hex string to query current **T-RAIM Alarm Setting:**

0x40 40 47 66 FF FF21 0D 0A

Change T-RAIM Alarm Message:

@@GfaaC<CR><LF>

where:

aa = T-RAIM alarm limit (3 – 10,000 in 100s of nanoseconds)

C = checksum

Message Length: 9 bytes

Response to either command:

@@GfaaC<CR><LF>

where:

aa = T-RAIM alarm limit (3 – 10,000 in 100s of nanoseconds)

C = Checksum

Message Length: 9 bytes

LEAP SECOND PENDING MESSAGE (@@Gj)

This command polls the receiver for leap second status information decoded from the Navigation Data message. The output response provides specific date and time information pertaining to any future leap second addition or subtraction. Present and future leap second values are also output rounded to the nearest integer value.

This command only operates in a polled manner, thus it must be requested each time leap second information is desired.

The ‘present leap second value’ and ‘future leap second value’ are reported from the navigation data from the satellites. They do not change based on the leap second application time; they will be updated based on when the navigation data is updated.

Leap seconds are occasionally inserted in UTC and generally occur on midnight UTC June 30 or midnight UTC December 31. The GPS control segment typically notifies GPS users of pending leap second insertions to UTC several weeks before the event. When a leap second is inserted, the time of day will show a value of 60 in the seconds field. When a leap second is removed, the date will roll over at 58 seconds.

The ‘current UTC offset’ will be zero if UTC is disabled.

LEAP SECOND PENDING (@@Gj)

Binary Format

Query Current Leap Second Pending Status:

@@GjC<CR><LF>

where:

C = 0x2D

Message length: 7 bytes

Complete hex string to query current **Leap Second Pending Status:**

0x40 40 47 6A 2D 0D 0A

Response to above command:

@@GjpfyymdiffffhmsC<CR>LF>

where:

p = present leap second value
f = future leap second value
yy = year of the future leap second application 2012..2100
m = month of the future leap second application 1..12
d = day of the future leap second application 1.31
I = integer part of current UTC offset (seconds) 0..255
ffff = fractional part of current UTC offset (nanoseconds) 0..999,999,999
h = hour of the future leap second application 0…23
m = minute of the future leap second application 0…59
s = second of the future leap second application 0…60 (60 when leap second applies)
C = checksum

Message Length: 21 bytes

12 CHANNEL POSITION/STATUS/DATA MESSAGE (@@Ha)

This message is the ‘standard’ M48M binary position/status message. The @@Ha message provides position and channel related data to the user at a specified update rate.

Default mode: Polled

Note: *United States export laws prohibit commercial GPS receivers from outputting valid data if the calculated GPS height is greater than 18,000 meters (11 miles) and the calculated 3D velocity is greater than 514 meters/second (1135 miles/hour). If the receiver is used above both of these limits concurrently, the height and velocity outputs are clamped to the maximum values. In addition, the latitude and longitude information will be incorrect.*

12 CHANNEL POSITION/STATUS/DATA MESSAGE (@@Ha)

Binary Format

Request 12 Channel Position/Status/Data Message:

@@HarC<CR><LF>

where:

r = Output Rate	0x00 = output response message once (polled) 0x01 .. 0xFF = response message output at indicated rate: 0x01 = once per second 0x02 = once every two seconds - - 0xFF = once every 255 seconds
C = checksum	

Message length: 8 bytes

Response to above command.

@@Hamdyyhmsffffaaaaoooohhhhmmmmaaaaoooohhhh
mmmmVVvvhhddnt (repeat 'imsidd' series for 12 channels) ssrrccooooTTushmvvvvvvC<CR><LF>

Date

m = month	1..12
d = day	1..31
yy = year	2012..2100

Time

h = hours	0..23
m = minutes	0..59
s = seconds	0..60
ffff = fractional second	0..999,999,999 nanoseconds

Position (Filtered or Unfiltered following Filter Select)

aaaa = latitude in mas	-324,000,000..324,000,000 (-90º..+90º)
oooo = longitude in mas	-648,000,000..648,000,000 (-180º..+180º)
hhhh = GPS height in cm	-100,000..+1,800,000 (-1000..+18,000m)
mmmm MSL height in cm	-100,000..+1,800,000 (-1000..+18,000m)M48M

Position (Always Unfiltered)

aaaa = latitude in mas	-324,000,000..324,000,000 (-90º..+90º)
oooo = longitude in mas	-648,000,000..648,000,000 (-180º..+180º)
hhhh = GPS height in cm	-100,000..+1,800,000 (-1000..+18,000m)
mmmm = MSL height in cm	-100,000..+1,800,000 (-1000..+18,000m)M48M

Speed/Heading

VV = 3D speed in cm/s	0…51400 (0.0 to 514 m/s)
vv = 2D speed in cm/s	0…51400 (0.0 to 514 m/s)
hh = 2D heading	0….3599 tenths of degrees (0.0 to 359.9º)

Geometry

dd = current DOP	0 .. 999 tenths of degrees (0.0 to 99.9 DOP) (PDOP for 3D fix, HDOP for 2D fix,)

Satellite Data

n = number of visible satellites	0 ..12
t = number of tracked satellites	0 ..12

Channel Data

i = SVID		0…37	
m = mode		0…8	
where:		0 = Code Search	5 = Message Sync Detect
		1 = Code Acquire	6 = Satellite Time Available
		2 = AGC Set	7 = Ephemeris Acquire
		3 = Freq Acquire	8 = Available for Position
		4 = Bit Sync Detect	
s = signal strength		0…255	
I = IODE		0…255	
dd = channel status (16 bits)			
(msb)	Bit 15:	Reserved	
	Bit 14:	Reserved	
	Bit 13:	Reserved	
	Bit 12:	Narrow-band search mode (timing rx only)	
	Bit 11:	Channel used for time solution	
	Bit 10:	Differential Corrections Available	
	Bit 9:	Invalid Data	
	Bit 8:	Parity Error	
	Bit 7:	Channel used for position fix	
	Bit 6:	Satellite Momentum Alert Flag	
	Bit 5:	Satellite Anti-Spoof Flag Set	
	Bit 4:	Satellite Reported Unhealthy	
	Bits 3-0:	Satellite Accuracy per para 20.3.3.3.1.3 of ICD-GPS-200	
		0000 (0) 0.00m <URA<=2.40m	
		0001 (1) 2.40m <URA<=3.40m	
		0010 (2) 3.40 m<URA<=4.85m	
		0011 (3) 4.85m<URA<=6.85m	
		0100 (4) 6.85m<URA<=9.65m	
		0101 (5) 9.65m<URA<=13.65m	
		0110 (6) 13.65m <URA<=24.00m	
		0111 (7) 24.00m<URA<=48.00m	
		1000 (8) 48.00m<URA<=96.00m	
		1001 (9) 96.00m<URA<=192.00m	

(URA continued) 1010 (10) 192.00m <URA<=384.00m

1011 (11) 384.00m <URA<=768.00m
1100 (12) 768.00m <URA<=1536.00m
1101 (13) 1536.00m <URA<=3072.00m
1110 (14) 3072.00m <URA<=6144.00m
1111 (15) 6144.00m <URA*

*No accuracy prediction is available – unauthorized users are advised to use the SV at their own risk.

ss = receiver status

(msb)	Bit 15-13:	111 = 3D Fix 110 = 2D Fix 101 = Propagate Mode 100 = Position Hold 011 = Acquiring Satellites 010 = Bad Geometry 001 = Reserved 000 = Reserved
	Bit 12-11:	Reserved
	Bit 10:	Narrow band tracking mode (timing rx only)
	Bit 9:	Fast Acquisition Position
	Bit 8:	Filter Reset To Raw GPS Solution
	Bit 7:	Cold Start (no almanac, almanac out of date or have almanac but time or position unknown)
	Bit 6:	Differential Fix
	Bit 5:	Position Lock
	Bit 4:	Autosurvey Mode
	Bit 3:	Insufficient Visible Satellites
	Bit 2-1:	Antenna Sense 00 = OK 01 = Over current 10 = Under current 11 = No bias voltage
	Bit 0:	Code Location 0 = EXTERNAL 1 = INTERNAL

rr Reserved

Oscillator and Clock Parameters:

cc = clock bias	-32768…32767 ns
oooo = oscillator offset	0…250000 Hz
TT = oscillator temperature	-110…250 half degrees C (-55.0…+125.0°C)

Time mode/UTC Parameters:
u = time status

	Bit 7:	1 = UTC time mode enabled
		0 = GPS time mode enabled
	Bit 6:	1 = UTC offset decoded
		0 = UTC offset not decoded
	Bits 5-0:	Present UTC offset value, range
		–32…+31 seconds from GPS time* (ignore if Bit 6 = 0).

GMT Offset:

s = signed byte of GMT offset	0x00 = positive
	0xFF = negative
h = hours of GMT offset	0…23
m = minutes of GMT offset	0…59
vvvvvv = ID tag 6 characters	(0x20 to 0x7e)
C = checksum	

Message Length: 154 bytes

*Represents UTC time offset from GPS time. Offset is rounded to the nearest integer value.

12 CHANNEL SHORT POSITION MESSAGE (@@Hb)

Applicability: M48M timing receivers

This is a shortened version of the @@Ha position message provided to the user at a specified update rate.

Default mode: Polled

Note: *United States export laws prohibit commercial GPS receivers from outputting valid data if the calculated GPS height is greater than 18,000 meters (11 miles) and the calculated 3D velocity is greater than 514 meters/second (1135 miles/hour). If the receiver is used above both of these limits concurrently, the height and velocity outputs are clamped to the maximum values. In addition, the latitude and longitude information will be incorrect.*

SHORT POSITION MESSAGE (@@Hb)

Binary Format

Request Short Position Message:

@@HbrC<CR><LF>

where:

r = output rate	0 = output response message once (polled) 1..255 = response message output at indicated rate (continuous): 0x01= once per second 0x02= once every two seconds 0xFF = once every 255 seconds
C = checksum	

Message length: 8 bytes

Response to above command.

@@HbmdyyhmsffffaaaaoooohhhhmmmmVVvvhhddntssrr
vvvvvvC<CR><LF>

Date

m = month	1..12
d = day	1..31
yy = year	2012..2100

Time

h = hours	0..23
m = minutes	00..59
s = seconds	0..59
ffff = fractional second	0..999,999,999 nanoseconds

Position (Filtered or Unfiltered following Filter Select)

aaaa = latitude in mas	-324,000,000..324,000,000 (-90º..+90º)
oooo = longitude in mas	-648,000,000..648,000,000 (-180º..+180º)
hhhh = GPS height in cm	-100,000..+1,800,000 (-1000..+18,000m)*
mmmm MSL height in cm	-100,000..+1,800,000 (-1000..+18,000m)* always 0,000,000 with M48MM48M

Speed/Heading

VV = 3D speed in cm/s	0...51400 (0.0 to 514 m/s)
vv = 2D speed in cm/s	0...51400 (0.0 to 514 m/s)
hh = 2D heading	0....3599 tenths of degrees (0.0 to 359.9º)

Geometry		
dd =current DOP		0..999 (0.0 to 99.9 DOP) (PDOP for 3D fix, HDOP for 2D fix, 00.0 otherwise)
Satellite Data		
n = number of visible satellites		0…12
t = number of tracked satellites		0…12
ss receiver status		
(msb)	Bits 15-13:	111 = 3D Fix 110 = 2D Fix 101 = Propagate Mode 100 = Position Hold 011 = Acquiring Satellites 010 = Bad Geometry 001 = Reserved 000 = Reserved
	Bits 12-11:	Reserved
	Bit 10:	Receiver in narrow-band tracking mode (M48M timing receiver only)
	Bit 9:	Fast Acquisition Position
	Bit 8:	Filter Reset To Raw GPS Solution
	Bit 7:	Cold Start (no almanac, almanac out of date or have almanac but time or position unknown)
	Bit 6:	Differential Fix
	Bit 5:	Position Lock
	Bit 4:	Autosurvey Mode
	Bit 3:	Insufficient Visible Satellites
	Bits 2-1:	Antenna Sense 00 = OK 01 = Overcurrent 10 = Undercurrent 11 = No bias voltage
	Bit 0:	Code Location 0 = EXTERNAL 1 = INTERNAL
rr		Reserved
vvvvvv = ID tag		6 characters (0x20 to 0x7e)
C = checksum		

Message Length: 54 bytes .

12 CHANNEL TIME RAIM STATUS MESSAGE (@@Hn)

Applicability: M48M timing receivers

This message allows the user to request output of T-RAIM status information.

Legacy Compatibility: The information in the @@Hn message constitutes a portion of the data in the @@En message utilized by the UT+ and VP timing receivers.

TIME RAIM STATUS MESSAGE (@@Hn)

Binary Format

Request Current Time RAIM Status:

@@HnrC<CR><LF>

where:

r = output rate	0 =polled once 1 .. 255 = output at indicated rate: 0x01 = once per second 0x02 = once per every 2 seconds 0xFF = once per 255 seconds
C = checksum	

Message Length: 8 bytes

Response to above command:

@@Hnpysrvvvveen[12x{sffff}] C<CR><LF>

where:

p = pulse status	0 = off 1 = on
y = 1PPS pulse sync	0 = pulse referenced to UTC, 1 = pulse referenced to GPS time
s = Time RAIM Solution	0 = solution within alarm limits; 1 = ALARM, user-specified limit exceeded 2 = UNKNOWN, due to: a. alarm threshold set too low b. T-RAIM turned off c. insufficient tracked satellites
r = Time RAIM status	0 = detection and isolation possible; 1 = detection only possible; 2 = neither possible
vvvv =	32 bit field to indicate which svids were removed by T-RAIM
ee = time solution 1σ accuracy estimate	0..65,535 nsec
n = negative sawtooth time error of next pulse	–128..+127 ns

For each of 12 channels:

s = satellite id	1 .. 32
ffff = fractional GPS local time estimate of satellite	0..999,999,999 ns
C = checksum	

Message Length: 78 bytes

GPGGA (NMEA GPS FIX DATA)

This command enables the NMEA GPGGA GPS Fix Data message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously). Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs. The value of the periodic rate is retained through a power cycle only if battery backup power is applied.

If the receiver has just powered up and has yet to compute a position fix (GPS status field is '0'), then the time (hhmmss.ss) and HDOP (y.y) fields will be nulled. If the receiver is not currently computing a position fix sometime after the first fix, the time field (hhmmss.ss) will be frozen and the HDOP field (y.y) will be nulled. If the receiver is not currently receiving differential GPS corrections (GPS status field (q) is not '2'), then the age of differential data (t.t) and differential reference station ID (iiii) fields will also be nulled.
.

NOTE: *Height reported in the GPGGA message is GPS height, and the geoidal separation field (g.g) will always be nulled since the M12 Oncore does not calculate this information.*

Legacy Code Compatibility: The GPGGA message was output in a similar fashion by VP, GT+, and M12 Oncore receivers.

Note: *United States export laws prohibit commercial GPS receivers from outputting valid data if the calculated GPS height is greater than 18,000 meters (11 miles) and the calculated 3D velocity is greater than 514 meters/second (1135 miles/hour). If the receiver is used above both of these limits concurrently, the height and velocity outputs are clamped to the maximum values. In addition, the latitude and longitude information will be incorrect.*

GPGGA (NMEA GPS FIX DATA)

NMEA-0183 Format

Set GPGGA message rate:

$PMOTG, GGA, yyyy*CC<CR><LF>

where:

yyyy = update rate	0..9999 seconds
CC = optional checksum	

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPGGA, hhmmss.ss, ddmm.mmmm, n, dddmm.mmmm, e, q, ss, y.y, a.a, z, g.g, z, t.t, iiii*CC<CR><LF>

where:

hhmmss.ss = UTC of position fix	
hh = hours	00..24
mm = minutes	00..59
ss.ss = seconds	00.00..59.99
ddmm.mmmm, n = latitude	
dd = degrees	00..90
mm.mmmm = minutes	00.000..59.999
n = direction	N = North
	S = South
dddmm.mmmm, e = longitude	
dd = degrees	000..180
mm.mmm = minutes	00.000..59.999
e = direction	E = East
	W = West
q = GPS status indicator	0 = GPS not available
	1 = GPS available
	2 = GPS differential fix
ss = number of sats being used	0..12

y.y = HDOP

a.a, z = antenna height

a.a = height

z = units M = meters

g.g, z = geoidal separation

g.g = height

z = units M = meters

t.t = age of differential data

iiii = differential reference 0000..1023 station Id

CC = checksum

GPGLL (NMEA GEOGRAPHIC LATITUDE AND LONGITUDE)

This command enables the GPGLL Geographic Position-Latitude/Longitude message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously).

Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs. The value of the periodic rate is retained through a power cycle only if battery backup power is applied.

If the receiver has just powered up and has yet to compute a position fix (GPS status field is 'V'), then the time field (hhmmss.ss) will be nulled. If the receiver is not computing a position fix sometime after the first fix the time field (hhmmss.ss) will be frozen.

Legacy Code Compatibility: The GPGLL message was output in a similar fashion by VP, GT+, and M12 Oncore receivers.

Note: *United States export laws prohibit commercial GPS receivers from outputting valid data if the calculated GPS height is greater than 18,000 meters (11 miles) and the calculated 3D velocity is greater than 514 meters/second (1135 miles/hour). If the receiver is used above both of these limits concurrently, the height and velocity outputs are clamped to the maximum values. In addition, the latitude and longitude information will be incorrect.*

GPGLL (NMEA GEOGRAPHIC LATITUDE/LONGITUDE)

NMEA-0183 Format

Set response message rate:

$PMOTG, GLL, yyyy*CC<CR><LF>

where:

yyyy = update rate	0..9999 seconds
CC = optional checksum	

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPGLL, ddmm.mmmm, n, dddmm.mmmm, e,
hhmmss.ss,a*CC<CR><LF>

where:

ddmm.mmmm, n = latitude	
dd = degrees	00..90
mm.mmmm = minutes	00.000..59.999
n = direction	N = North
	S = South
dddmm.mmmm, e = longitude	
dd = degrees	00..180
mm.mmm = minutes	00.000..59.999
e = direction	E = East
	W = West
hhmmss.ss = UTC of position fix	
hh = hours	00..24
mm = minutes	00..59
a = status	A = valid
	V = invalid
CC = checksum	

GPGSA (GPS DOP AND ACTIVE SATELLITES)

This command enables the GPGSA DOP and Active Satellites message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously). Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs. The value of the periodic rate is retained through a power cycle only if battery backup power is applied.

If the receiver is not computing a position fix (mode field is '1'), then the xDOP fields (p.p, q.q, r.r) will be nulled. If the receiver is computing a 2-D position fix (mode field is '2'), then the PDOP field (p.p) and the VDOP field (r.r) will be nulled. Only satellite IDs used in the solution are output; the remaining satellite ID fields will be nulled.

GPGSA (GPS DOP AND ACTIVE SATELLITES)

NMEA-0183 Format

Set response message rate:

$PMOTG, GSA, yyyy*CC<CR><LF>

where:

yyyy = update rate	0..9999 seconds
CC = optional checksum	

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPGSA, a, b, cc, dd, ee, ff, gg, hh, ii, jj, kk, mm, nn, oo, p.p, q.q, r.r*CC<CR><LF>

where:

a = sat acquisition mode	M = manual (forced to operate in 2D or 3D mode) A = Automatic (auto switch 2D/3D)
b = positioning mode	1 = fix not available 2 = 2D 3 = 3D
cc,dd,ee,ff,gg,hh, = ii,jj,kk,mm,nn,oo	SVIDs used in solution (null for unused fields)
p.p = PDOP	1.0..9.9
q.q = HDOP	1.0..9.9
r.r = VDOP	1.0..9.9
CC = checksum	

GPGSV (NMEA GPS SATELLITES IN VIEW)

This command enables the GPGSV GPS Satellites in View message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously). Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs.

If the receiver is not tracking the satellite, the SNR field (ss) will be nulled. Further, an entire group — satellite ID field (ii), elevation field (ee), azimuth field (aaa), and SNR field (ss) — will be nulled if not needed.

NOTE: *The value shown in the SNR field (ss) is the same as the C/No value in the 12 Channel Position/Status/Data Message (@@Ha) and the 12 Channel Short Position Message (@@Hb).*

GPGSV (NMEA GPS SATELLITES IN VIEW)

NMEA-0183 Format

Set response message rate:

$PMOTG, GSV, yyyy*CC<CR><LF>

where:

yyyy = update rate	0..9999 seconds
CC = optional checksum	

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPGSV,t,m,n (4 x ,ii,ee,aaa,ss)*CC<CR><LF>

where:

t = number of messages	1..4
m = message number	1..4
n = number of satellites in message	1..4

For each visible satellite (four groups per message)

ii =	satellite PRN number
ee = elevation (degrees)	0 .. 90
aaa = azimuth (degrees True)	0 .. 359
ss = SNR (dB)	0..99
CC = checksum	

GPRMC (NMEA RECOMMENDED MINIMUM SPECIFIC GPS/TRANSIT DATA)

This command enables the GPRMC Recommended Minimum Specific GPS/Transit Data message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously). Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs. The value of the periodic rate is retained through a power cycle only if battery backup power is applied.

If the receiver has just powered up and has yet to compute a position fix (GPS status field (a) is 'V'), then the time (hhmmss.ss) and date (ddmmyy) fields will be nulled. If the receiver is not computing a position fix sometime after the first fix, the time (hhmmss.ss) and date (ddmmyy) fields will be frozen. If the receiver is not computing a position fix (status field is 'V'), then the speed over ground (z.z) and track made good (y.y) fields will be nulled.

Note 1*: The Magnetic Variation field (d.d) will always be nulled since the M12 Oncore does not have this information.*

Note 2: *United States export laws prohibit commercial GPS receivers from outputting valid data if the calculated GPS height is greater than 18,000 meters (11 miles) and the calculated 3D velocity is greater than 514 meters/second (1135 miles/hour). If the receiver is used above both of these limits concurrently, the height and velocity outputs are clamped to the maximum values. In addition, the latitude and longitude information will be incorrect.*

GPRMC (NMEA RECOMMENDED MINIMUM SPECIFIC GPS/TRANSIT DATA)

NMEA-0183 Format

Set message output rate:

$PMOTG, RMC, yyyy*CC<CR><LF>

where:

yyyy = update rate	0000 .. 9999 seconds
CC = optional checksum	

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPRMC, hhmmss.ss, a, ddmm.mmmm, n, dddmm.mmmm, w, z.z,y.y, ddmmyy,d.d, v*CC<CR><LF>

where:

hhmmss.ss =	Time of position fix (ref to UTC)
hh = hours	00..24
mm = minutes	00..59
ss.ss = seconds 00.00..59.99	
a = GPS status	A = valid
	V = invalid
ddmm.mmmm,n =	Latitude
dd = degrees	00..90
mm.mmmm = minutes	00.000..59.999
n = direction	N = North
	S = South
dddmm.mmmm, w =	Longitude
ddd = degrees	00..180
mm.mmmm = minutes	00.000..59.9999
w = direction	E = East
	W = West
z.z = speed over ground (knots)	0.0 ..
y.y = track made good (referenced to true north)	0.0..359.9
ddmmyy = UTC date of position fix	
dd = day	01..31
mm = month	01..12
yy = year	00..99
d.d magnetic variation (degrees)	Always nulled with M48M
v = variation sense	E = East
	W = West
CC = checksum	

GPVTG (NMEA TRACK MADE GOOD AND GROUND SPEED)

Applicability: M48M positioning receivers

This command enables the GPVTG Track Made Good and Ground Speed message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously).

Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs. If the receiver is not computing a position fix, all numeric fields (a.a, c.c, e.e, g.g) will be nulled.

NOTE: *The magnetic track field (c.c) will always be nulled since the M12 Oncore does not have this information.*

GPVTG (TRACK MADE GOOD AND GROUND SPEED)

NMEA-0183 Format

Set message output rate:

$PMOTG, VTG, yyyy*CC<CR><LF>

where:

yyyy = update rate 0000 .. 9999 seconds
CC = optional checksum

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPVTG, a.a, b, c.c, d, e.e, f, g.g, h*CC<CR><LF>

where:

a.a = Track (degrees true)
b = T (message formatting constant)
c.c = Track (degrees magnetic) ** always nulled with M48M
d = M (message formatting constant)
e.e = speed in knots
f = N (message formatting constant)
g.g = speed in km/hr
h = K (message formatting constant
CC checksum

GPZDA (NMEA TIME AND DATE)

This command enables the GPZDA Time and Date message and determines the rate at which the information is transmitted. The periodic rate field (yyyy) instructs the receiver either to output this message once (polled), or to output this message at the indicated update rate (continuously). Once the receiver is set to continuous output, the continuous flow can be stopped by sending a one-time (polled) output request. The receiver will output the response one final time, and then terminate any further message outputs.

Currently, there is no mechanism to set the local zone description in the NMEA I/O format, and the receiver operates as if the GMT offset is set to 00:00, reporting UTC time only.

GPZDA (NMEA TIME AND DATE)

NMEA-0183 Format

Set response message rate:

$PMOTG, ZDA, yyyy*CC<CR><LF>

where:

yyyy = update rate Once every 0..9999 seconds
CC = optional checksum

Note - the asterisk (*) is not present unless the optional checksum is present

Response to above command:

$GPDZA, hhmmss.ss, dd,mm, yyyy, xx, yy*CC<CR><LF>

where:

hhmmss.ss = UTC time
hh = hours 0..23
mm = minutes 0..59
ss.ss = seconds 0..59.99
dd = day 1..31
mm = month 1..12
yyyy = year
xx = local zone hours -13..13
yy = local zone minutes 0..59
CC checksum

SWITCH I/O FORMAT TO BINARY

This utility command switches the serial data format on the primary port from NMEA 0183 to Binary. The baud rate of the port is switched from 4800 to 9600 and input commands are recognized in Binary format only.

SWITCH TO BINARY

NMEA-0183 Format

Switch to Binary format:

$PMOTG, FOR, x*CC<CR><LF>

where:

x = format 0 = Binary
CC = optional checksum

Note - the asterisk (*) is not present unless the optional checksum is present

There is no response message to this input command.

APPENDIX 1 – GPS Terminology

This section provides definition of terms used in the M48M GPS Receiver User’s Guide

Almanac

Data transmitted by a GPS satellite which includes orbital information on all the satellites, clock correction, and atmospheric delay parameters. These data are used to facilitate rapid satellite acquisition. The orbital information in the almanac is less accurate than the ephemeris, but valid for a longer time (one to two years).

Ambiguity

The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite pass at a single receiver.

Argument of Latitude

The sum of the true anomaly and the argument of perigee.

Argument of Perigee

The angle or arc from the ascending node to the closest approach of the orbitingbody to the focus or perigee point, as measured at the focus of an elliptical orbit, in the orbital plane in the direction of motion of the orbiting body.

Ascending Node

The point at which an object's orbit crosses the reference plane (i.e., the equatorial plane) from south to north.

Azimuth

A horizontal direction expressed as the angular distance between a fixed direction, such as north, and the direction of the object.

Bandwidth

A measure of the information-carrying capacity of a signal, expressed as the width of the spectrum of that signal (frequency domain representation) in Hertz (Hz).

Baseline

The three-dimensional (3D) vector distance between a pair of stations for which simultaneous GPS data has been collected and processed with differential techniques.

Beat Frequency

Either of two additional frequencies obtained when signals of two frequencies are mixed. The beat frequencies are equal to the sum or difference of the original frequencies.

Bias

See Integer Bias Terms.

Binary Bi-phase Modulation

Phase changes of either zero or 180 degrees (representing a binary zero or one, respectively) on a constant frequency carrier. GPS signals are bi-phase modulated.

Binary Pulse Code Modulation

Pulse modulation using a string of binary numbers (codes). This coding is usually represented by ones and zeros with definite meanings assigned to them, such as changes in phase or direction of a wave.

Bluebook

A slang term derived from a blue NGS reference book. The book contains information and formats required by NGS for survey data that is submitted to be considered for use in the national network.

C/A Code

The Coarse/Acquisition (or Clear/Acquisition) code modulated onto the GPS L1 signal. This code is a sequence of 1023 pseudorandom binary bi-phase modulations on the GPS carrier at a chipping rate of 1.023 MHz, thus having a code repetition period of one millisecond. This code was selected to provide good acquisition properties.

Carrier

A radio wave having at least one characteristic (such as frequency, amplitude, phase) that may be varied from a known reference value by modulation.

Carrier Beat Phase

The phase of the signal that remains when the incoming Doppler-shifted satellite carrier signal is beat (the difference frequency signal is generated) with the nominally constant reference frequency generated in the receiver.

Carrier Frequency

The frequency of the unmodulated fundamental output of a radio transmitter. The GPS L1 carrier frequency is 1575.42 MHz.

Celestial Equator

The great circle that is the projection of the earth's geographical equator of rotation onto the celestial sphere. Its poles are the north and south celestial poles.

Celestial Meridian

The vertical great circle on the celestial sphere that passes through the celestial poles, the astronomical zenith, and the nadir.

Chip

The length of time required to transmit either a one or a zero in binary pulse code. One chip of the C/A code is about 977 ns long, which corresponds to a distance of 293m.

Chip Rate

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

Clock Offset

Constant difference in time readings between two clocks.

Code Division Multiple Access (CDMA)

A method of frequency reuse whereby many radios use the same frequency but with each one having a separate and unique code. GPS uses CDMA techniques with Gold codes for their unique cross-correlation properties.

Cold Start

Typical time a GPS receiver requires to develop a fix after application of power given that the receiver has no stored data. Cold starts times normally have a large standard deviation as the time depends heavily on satellite visibility at any given time.

Conventional International Origin (CIO)

Average position of the earth's rotation axis during the years 1900-1905.

Correlation-Type Channel

A GPS receiver channel that uses a delay-lock-loop (DLL) to maintain an alignment (correlation peak) between the replica of the GPS code generated in the receiver and the received code from the satellite.

Deflection of the Vertical

The angle between the normal to the ellipsoid and the vertical (true plumb-line). Since this angle has both a magnitude and a direction, it is usually resolved into two components: one in the meridian and the other perpendicular to it in the prime vertical.

Delay-Lock-Loop

The technique whereby the received code (generated by the satellite clock) is compared with the internal code generated by the receiver clock. The latter is shifted in time until the two codes match. Delay-lock-loops can be implemented in several ways, including *tau* dither and early-minuslate gating.

Delta Pseudorange

See Reconstructed Carrier Phase.

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 measurements are to first take differences between receivers (single difference), then between satellites (double difference), then between measurement epochs (triple difference).

A single-difference measurement between receivers is the instantaneous difference in phase of the signal from the same satellite, measured by two receivers simultaneously.

A double-difference measurement is obtained by differencing the single difference for one satellite with respect to the corresponding single difference for a chosen reference satellite.

A triple-difference measurement is the difference between a double difference at one epoch of time and the same double difference at the previous epoch of time.

Differential GPS solutions can be computed using either code phase or carrier phase measurements. In differential carrier phase solutions, the integer ambiguities must be resolved.

Differential (Relative) Positioning

Determination of relative coordinates of two or more receivers that are simultaneously tracking the same satellites. Dynamic differential positioning is a realtime technique achieved by sending code corrections to the roving receiver from one or more monitor stations. Static differential GPS involves determining baseline vectors between pairs of receivers.

Dilution of Precision

A description of the geometrical contribution to the uncertainty in a position fix, given by the expression DOP = SQRT TRACE (ATA), where A is the design matrix for the instantaneous position solution (dependent on satellite receiver geometry). The type of DOP factor depends on the parameters of the position fix solution. Standard terms for GPS applications include the following:

GDOP Geometric DOP – three coordinates plus clock offset in the solution.
PDOP Position DOP – three coordinates.
HDOP Horizontal DOP - two horizontal coordinates.
VDOP Vertical DOP - height only.
TDOP Time DOP - clock offset only.
RDOP Relative DOP - normalized to 60 seconds

DoD

United States Department of Defense. The government agency that led the development, deployment, and operation of GPS.

Doppler Aiding

The use of Doppler carrier phase measurements to smooth the code-phase measurements. Also referred to as carrier aided smoothing or carrier-aided tracking.

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. See Reconstructed Carrier Phase.

Double-Difference Ambiguity Resolution

A method to determine the set of ambiguity values which minimizes the variance of the solution for a receiver pair baseline vector.

Dynamic Positioning

Determination of a timed series of sets of coordinates for a moving receiver, each set of coordinates being determined from a single data sample, and usually computed in real time.

Earth-Centered Earth-Fixed (ECEF)

Usually refers to a coordinate system centered at the center of the earth that rotates with the earth. Cartesian coordinate system where the X direction is the intersection of the prime meridian (Greenwich) with the equator. The X and Y vectors rotate with the earth. Z is the direction of the spin axis.

Eccentric Anomaly 'E'

The regularizing variable in the two-body problem. E is related to the mean anomaly M by Kepler's equation. M = E esin(E), where e is the eccentricity.

Eccentricity 'e'

The ratio of the distance from the center of an ellipse to its focus to the semi-major axis. e = (1 - b2/a2) 1/2, where a and b are the semi-major and semi-minor axes of the ellipse.

Ecliptic

The earth-sun orbital plane. North is the direction of the system's angular momentum. Also called the ecliptic pole.

Elevation

Height above mean sea level or vertical distance above the reference geoid.

Elevation Mask Angle

The elevation angle below which satellites are ignored. Normally set to ten degrees to avoid interference problems caused by buildings, trees, multi-path, and atmospheric errors.

Ellipsoid Height

The measure of vertical distance above the ellipsoid. Not the same as elevation above sea level, because the ellipsoid does not agree exactly with the geoid. GPS receivers output position fix height referenced to the WGS-84 datum.

Ephemeris

A list of orbital parameters of a celestial object that can be used to compute accurate positions as a function of time. Available as broadcast ephemeris or as post-processed precise ephemeris.

Epoch

Measurement interval or data frequency. For example, if measurements are made and reported every five seconds, then we have five second epochs.

Fast Switching Channel

A switching channel with a sequence time short enough to recover (through software prediction) the integer part of the carrier beat phase.

Flattening

A parameter used to define the shape of an ellipsoid.

f = (a - b)/a = 1 - (1 - e2)1/2, where

a = semi-major axis

b = semi-minor axis

e = eccentricity

Frequency Band

A range of frequencies in a particular region of the electromagnetic spectrum.

Frequency Spectrum

The distribution of amplitudes as a function of frequency of the constituent waves in a signal.

Fundamental Frequency

The fundamental frequency used in GPS is 10.23 MHz. The carrier frequencies L1 and L2 are integer multiples of this fundamental frequency.

L1 = 154F = 1575.42 MHz

L2 = 120F = 1227.60 MHz

GDOP

Geometric dilution of precision. See Dilution of Precision.

$GDOP^2 = PDOP^2 + TDOP^2$

Geocenter

The center of mass of the earth.

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. The relationship can be defined by six quantities generally (but not necessarily) the geodetic latitude, longitude, and 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.

Geoid

The particular equi-potential surface which coincides with mean sea level, and which may be imagined to extend through the continents. This surface is perpendicular to the force of gravity at all points.

Geoid Height

The height above the geoid is often called elevation above mean sea level.

GPS

Global Positioning System, consisting of the space segment (up to 24 NAVSTAR satellites in six different orbital planes), the control segment (five monitor stations, one master control station and three uplink stations), and the user segment (GPS receivers). NAVSTAR satellites carry extremely accurate atomic clocks and broadcast coherent simultaneous signals.

GPS ICD-200

The GPS Interface Control Document is a government document that contains the full technical description of the interface between the satellites and the user. GPS receivers must comply with this specification if they are to receive and process GPS signals properly.

Gravitational Constant

The proportionality constant in Newton's Law of Gravitation.

$$G = 6.672 \times 10^{11} Nm^2/Kg^2.$$

Greenwich Mean Time (GMT)

See Universal Time.

HDOP

Horizontal dilution of precision. See Dilution of Precision.

Hot Start

Typical time a GPS receiver requires to develop a fix after application of power given that the receiver has stored time, position, almanac data, and ephemeris data.

HOW

Handover Word. The word in the GPS message that contains time synchronization information for the transfer from the C/A code to the P code. Refer to GPS ICD-200 for details.

Inclination

The angle between the orbital plane of a body and some reference plane (e.g. equatorial plane).

INS

Inertial Navigation System, which contains an Inertial Measurement Unit (IMU).

Integer Bias Terms

The receiver counts the radio waves from the satellite, as they pass its antenna, to a high degree of accuracy. However, it has no information on the number of waves to the satellite at the time it started counting. This unknown number of wavelengths between the satellite and the antenna is the integer bias term.

Integrated Doppler

A measurement of Doppler shift frequency or phase over time.

Ionospheric Delay

A wave experiences delay while propagating through the ionosphere, which is non-homogeneous in space and time and is a dispersive medium. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude, but opposite sign.

JPO

Joint Program Office for GPS located at the USAF Space Division at El Segundo, California. The JPO consists of the USAF Program Manager and Deputy Program Managers representing the Army, Navy, Marine Corps, Coast Guard, Defense Mapping Agency, and NATO.

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.

Kinematic Surveying

A form of continuous differential carrier- phase surveying requiring only short periods of data observations. Operational constants include starting from or determining a known baseline, and tracking a minimum of four satellites. One receiver is statically located at a control point, while others are moved between points to be measured.

Keplerian Orbital Elements

Allow description of any astronomical orbit. The six Keplerian orbital elements are as follows:

a = semi-major axis
e = eccentricity
w = argument of perigee
62 = right ascension of ascending node
i = inclination of orbital plane
To = epoch of perigee passage.

L1, L2

The L-band signals radiated by each NAVSTAR satellite. The L1 signal is a 1575.42-MHz carrier modulated with both the C/A and P codes and with the NAV message. The L2 signal is a 1227.60-MHz carrier modulated with the P code and the NAV message. Under anti-spoofing, the P code becomes the encrypted Y code for authorized users only.

Lane

The area (or volume) enclosed by adjacent lines (or surfaces) of zero phase of either the carrier beat phase signal, or of the difference between two carrier beat phase signals. On the earth's surface, a line of zero phase is the focus of all points for which the observed value would have an exact integer value for the complete instantaneous phase measurement. In three dimensions, this lane becomes a surface.

L Band

The radio frequency band extending from 390 MHz (nominally) to 1550 MHz.

Mean Anomaly

M = n(t - T), where n is the mean motion, t is the time, and T is the instant of perigee passage.

Mean Motion

n = 2/P, where P is the period of revolution.

Microstrip Antenna

A two-dimensional, flat, precisely-cut piece of metal foil glued to a substrate.

Monitor Station

Any of a worldwide group of stations used in the GPS control segment to monitor satellite clock and orbital parameters. Data collected at these sites are linked to a master station where corrections are calculated and controlled. These data are uploaded to each satellite at least once per day from an uplink station.

Multichannel Receiver

A receiver containing many independent channels. Such a receiver offers the highest signal-to-noise ratio (SNR) because each channel tracks one satellite continuously.

Multipath

Interference similar to ghosts on a television screen, which occurs when multiple signals arrive at an antenna after having traversed different paths. In GPS, the signal traversing the longer path will yield a larger pseudorange estimate and increase the error. Multiple paths may arise from reflections from structures near the antenna or the ground.

Multipath Error

A positioning error resulting from interference between radio waves that have traveled between the transmitter and the receiver by paths of different electrical lengths.

Multiplexing Channel

A receiver channel that is sequenced through several satellite channels (each from a specific satellite and at a specific frequency) at a rate which is synchronous with the satellite message bit rate (50 bits per second, or 20 milliseconds per bit). Thus, one complete sequence is completed in a multiple of 20 milliseconds.

NAD-83
North American Datum, 1983

NAVDATA
The 1500-bit navigation message broadcast by each satellite at 50 bps on both the L1 and L2 signals. The message contains system time, clock correction parameters,

ionospheric delay model parameters, and the satellite's ephemeris and health. This information is used by the GPS receiver in processing GPS signals to obtain user position, velocity, and time.

NAVSTAR
The acronym given to GPS satellites, which stands for **NAV**igation **S**atellite **T**iming **A**nd **R**anging.

Observation Session
The period of time over which simultaneous GPS data is collected by two or more receivers.

Outage
A point in time and space that the GPS receiver is unable to compute a position fix. This may be due to satellite signal blockage, unhealthy satellites, or a dilution of precision (DOP) value that exceeds a specified limit.

P-Code
The protected or precise code modulated on both the L1 and L2 GPS signals. The P-Code is a very long (about 1014 bits) sequence of pseudorandom binary bi-phase modulations on the GPS carrier at a chipping rate of 10.23 MHz that does not repeat itself for about 38 weeks. Each satellite uses its own unique one-week segment of this code, which is reset each week. Under anti-spoofing, the P-Code is encrypted to form Y code. The Y code is only accessible by authorized users, as controlled by the U.S. Department of Defense.

PDOP
Position dilution of precision, a unitless figure of merit expressing the relationship between the error in user position and the error in satellite ranges. Geometrically, PDOP is proportional to the inverse of the volume of the pyramid formed by lines running from the receiver to four observed satellites. Values considered good for positioning are small, such as 3 or less. Values greater than 7 are considered poor. Small PDOP is associated with many or widely separated satellites, and large PDOP is
associated with bunched up or few satellites. See Dilution of Precision.

Parity Error
A digital message consists of ones and zeros. Parity is an Exclusive-Or sum of these bits in a word unit. A parity error results when a bit (or bits) is changed during transmission, so that the parity calculated at reception is not the same as it was when the message was transmitted.

Perigee

That point in a geocentric orbit when the geometric distance is at a minimum. The closest approach of the orbiting body.

Phase-Lock-Loop

The technique of making the phase of an oscillator signal follow exactly the phase of a reference signal. This is accomplished by first comparing the phases of the two signals, and then using the resulting phase difference signal to adjust the reference oscillator frequency to eliminate phase difference when the two signals are next compared.

Phase Observable

See Reconstructed Carrier Phase.

Point Positioning

Geographic positions produced from one receiver in stand-alone mode. At best, position accuracy obtained from a standalone receiver is 15 to 25 meters (without SA), depending on the geometry of the satellites.

Polar Motion

Motion of the instantaneous axis of the rotation of the earth with respect to the solid body of the earth. This motion is irregular but more or less circular with an amplitude of about 15 miles and a main period of about 430 days (also called Chandler Wobble).

Precise Positioning Service (PPS)

The highest level of military dynamic positioning accuracy provided by GPS, based on the dual frequency P code and having high anti jam and anti-spoof qualities.

Prime Vertical

The vertical circle perpendicular to the celestial meridian.

PRN

Pseudorandom noise, a sequence of digital ones and zeros that appear to be randomly distributed like noise, but which can be exactly reproduced. The most significant property of PRN codes is that they have a low autocorrelation value for all delays or lags except when they are exactly coincident. Each NAVSTAR satellite has its own unique C/A and P pseudorandom noise codes.

Pseudolite

A ground-based GPS transmitter station that broadcasts a signal with a structure similar to that of an actual GPS satellite. Pseudolites are designed to improve the accuracy and integrity of GPS, particularly near airports.

Pseudorange

A measure of the apparent propagation time from satellite to receiver antenna, expressed as a distance. A pseudorange is obtained by multiplying the apparent signal propagation time by the speed of light. Pseudoranges differ from actual geometric ranges due to the satellite/receiver clock offset, propagation delays, and other errors. The apparent propagation time is determined from the time shift required to align (correlate) a replica of the GPS code generated in the receiver with the received GPS code. The time shift is the difference between the time of signal reception (measured in the receiver time frame) and the time of signal emission (measured in the satellite time frame).

Range Rate

The rate of change of range between the satellite and the receiver. The range to a satellite changes due to both satellite and receiver motion. Range rate (or pseudorange rate) is determined by measuring the Doppler shift of the satellite signal's carrier frequency.

RDOP

Relative dilution of precision. See Dilution of Precision.

Reconstructed Carrier Phase

The difference between the phase of the incoming Doppler shifted GPS carrier and the phase of a nominally constant reference frequency generated in the receiver. For static positioning, the reconstructed carrier phase is sampled at epochs determined by a clock in the receiver. The reconstructed carrier phase changes according to the continuously integrated Doppler shift of the incoming signal, biased by the integral of
the frequency offset between the satellite and receiver reference oscillators. The reconstructed carrier phase can be related to the satellite to receiver range, once the initial range (or phase ambiguity) has been determined. A change in the satellite to receiver range of one wavelength of the GPS carrier (19 cm for L1) will result in a one-cycle change in the phase of the reconstructed carrier.

Relative Navigation

A technique similar to relative positioning except that one or both of the points may be moving. The pilot of a ship or an aircraft may need to know the vehicle's position relative to a harbor or runway. A data link is used to relay the error terms to the moving vessel to allow real-time navigation.

Right Ascension

The angular distance measured from the vernal equinox, positive to the east, along the celestial equator to the ascending node. Typically denoted by a capital omega (Ω). Used to discriminate between orbital planes.

RTCM

Radio Technical Commission for Maritime Services. Commission set up to define a differential data link to relay GPS correction messages from a monitor station to a field user. RTCM SC-104 recommendations define the correction message format and 16 different correction message types.

SATNAV

A local term referring to use of the older TRANSIT system for satellite navigation. One major difference between TRANSIT and GPS is that the TRANSIT satellites are in low-altitude polar orbits with a 90-minute period.

Selective Availability (SA)

A DoD program to control the accuracy of pseudorange measurements, whereby civilian users receives a false pseudorange which is in error by a controlled amount. Differential GPS techniques can reduce these effects for local applications. Under SA, the DOD guarantees unauthorized users an accuracy of 100m 2DRMS at a 95% confidence level.
SA was deactivated in May of 2000 resulting in much better accuracies using standard commercial GPS receivers, but DoD has the capability to reactivate it at any time.

Semi-major Axis

One half of the major axis of an ellipse.

SEP

Spherical Error Probable, a statistical measure of precision defined as the 50th percentile value of the three-dimensional position error statistics. Thus, half of the results are within the 3D SEP value.

Sidereal Day

Time between two successive upper transits of the vernal equinox. One sidereal day is just under four minutes shorter than one solar day.

Simultaneous Measurements

Measurements referenced to time-frame epochs that are either exactly equal or so closely spaced in time that the time misalignment can be accommodated by correction terms in the observation equation rather than by parameter estimation.

Slope Distance

The three-dimensional vector distance from station one to station two. The shortest distance (a chord) between two points.

Slow Switching Channel

A switching channel with a sequencing period that is too long to allow recovery of the integer part of the carrier beat phase.

Solar Day

Time between two successive upper transits of the sun.

Speed of Light (SOL)

For GPS pseudorange calculations the speed of light is defined as $3x10^8$ m/S per GPS ICD-200.

Spheroid

See Ellipsoid.

Spread Spectrum

The received GPS signal is a wide bandwidth low-power signal (-160 dBw). This property results from modulating the L-band signal with a PRN code in order to spread the signal energy over a bandwidth that 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.

Spread Spectrum System

A system in which the transmitted signal is spread over a frequency band much wider than the minimum bandwidth needed to transmit the information being sent.

SPS

Standard Positioning Service, uses the C/A code to provide a minimum level of dynamic or static positioning capability. The accuracy of this service is set at a level consistent with national security. See Selective Availability.

Squaring-Type Channel

A GPS receiver that multiplies the received signal by itself to obtain a second harmonic of the carrier that does not contain the code modulation. Used in codeless receiver designs to obtain dual frequency measurements.

Static Positioning

Positioning applications in which the positions of static or near-static points are determined.

SV

Satellite vehicle or space vehicle.

Switching Channel

A receiver channel that is sequenced through a number of satellite signals (each from a specific satellite and at a specific frequency) at a rate which is slower than, and asynchronous with, the message data rate.

TDOP

Time Dilution of Precision. See Dilution of Precision.

Time to First Fix (TTFF)

Average time (usually expressed in seconds) required for a given GPS receiver to develop a position fix after power is applied. For receivers, first fix is defined as a 2D fix for positioning receivers and a3D fix for timing receivers. See Cold Start, Hot Start, and Warm Start.

TOW

Time of week, in seconds from midnight Saturday UTC.

T-RAIM

Time **R**eceiver **A**utonomous **I**ntegrity Monitoring. This is an algorithm that continuously monitors the integrity of the time solution by using redundant satellite measurements. This algorithm is only available on the M48M timing receiver. See the T-RAIM Setup and Status Message (@@Hn) in Chapter 5.

Translocation

A version of relative positioning that makes use of a known position, such as an NGS survey mark, to aid in accurately positioning a desired point. The position of the mark, determined using GPS, is compared with the accepted value. The three-dimensional differences are then used in the calculations for the second point.

Tropospheric correction

The correction applied to the measurement to account for tropospheric delay. This value is normally obtained from the modified Hopfield model, the parameters of which are broadcast by the satellites.

True Anomaly

The angular distance, measured in the orbital plane from the earth's center (occupied focus) from the perigee to the current location of the satellite (orbital body).

Universal Time

Local solar mean time at Greenwich Meridian. Some commonly used versions of universal time follow:

UTO - Universal time as deduced directly from observations of stars and the fixed numerical relationship between universal and sidereal time (3 minutes, 56.555 seconds per day).
UT1 - UTO corrected for polar motion.
UT2 -UTO corrected for seasonal variations in the earth's rotational rate.
UTC - Universal time coordinated; uniform atomic time system kept very close to UT2 by offsets. Maintained by the U.S. Naval Observatory (USNO).

GPS time is directly related to UTC by the following:

UTC - GPS = UTC offset (13 seconds in 2003)

User Range Accuracy (URA)

The contribution to the range measurement error from an individual error source (apparent clock and ephemeris prediction accuracies) converted into range units, assuming that the error source is uncorrelated with all other error sources.

UTM

Universal transverse mercator conformal map projection. A special case of the transverse mercator projection. Abbreviated as the UTM grid, it consists of 60 north-south zones, each six degrees wide in longitude.

VDOP

Vertical dilution of precision. See Dilution of Precision.

Vernal Equinox

One of two dates per year when the equator and ecliptic intersect along the line between the earth and sun. On these days, the day and night are each 12 hours long everywhere on earth, hence the term equinox, or "equal nights". The vernal equinox corresponds to the spring equinox in the Northern Hemisphere.

Warm Start

Typical time a GPS receiver requires to develop a fix after application of power, given that the receiver has stored time, position, and almanac data