CHAPTER 3 RECEIVER DESCRIPTION

CHAPTER CONTENTS

Refer to this chapter for the following:

- A simplified functional description of the operation of the Oncore receiver
- Antenna power and gain requirements
- Physical size and electrical connections of the Oncore receiver
- GT and UT Oncore receiver technical characteristics and operating features
- Installation precautions and considerations
- Oncore receiver mounting guidelines
- Interface protocol description
- Operational modes of the Oncore receiver
- Additional customizing capabilities and operation

OVERVIEW

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

A simplified functional block diagram of the Oncore receiver is shown in the following illustration.

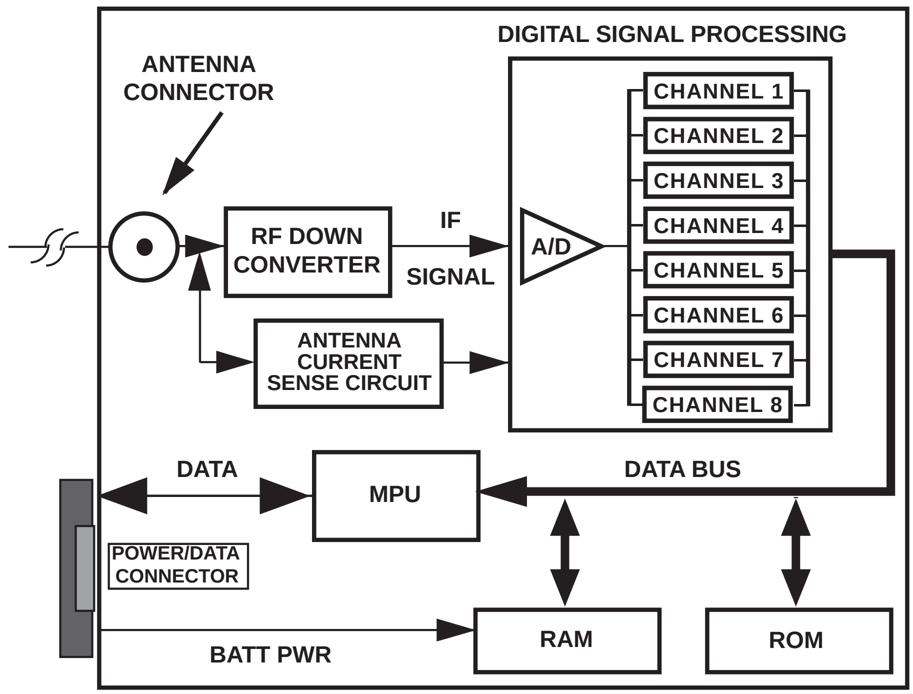


Figure 3.1: Oncore Receiver Functional Block Diagram

Simplified Block Diagram Description

OVERVIEW (CONTINUED)

The Oncore Receiver has an eight parallel channel design capable of tracking eight satellites simultaneously. 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. The Oncore receiver must be powered with regulated +5 V power. Time recovery capability is inherent in the architecture. The UT Oncore is designed specifically for precise timing applications.

The L1 band signals transmitted from GPS satellites are collected by a low-profile, microstrip patch antenna, passed through a narrow-band bandpass filter, and then amplified by a signal preamplifier contained within the antenna module. Filtered and amplified L1 band signals from the antenna module are then routed to the RF signal processing section of the receiver module via a single coaxial interconnecting cable. This interconnecting cable also provides the +5 V power required for signal preamplification in the antenna module.

The RF signal processing section of the Oncore receiver printed circuit board (PCB) contains the required circuitry for downconverting the GPS signals received from the antenna module. The resulting intermediate frequency (IF) signal is then passed to the eight channel code and carrier correlator section of the Oncore receiver PCB where a single, high-speed analog-to-digital (AD) converter converts the IF signal to a digital sequence prior to channel separation. This digitized IF signal is then routed to the digital signal processor (also contained within the eight channel code and carrier correlator section) where the signal is split into eight papallel 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 GPS receiver operating modes and decodes and processes satellite data and the pseudorange and delta range measurements used to compute position, velocity, and time. In addition, the position processor section contains the inverted TTL serial interface.

WARNING

Keep-alive random access memory (RAM) is provided for the retention of satellite ephemeris data, custom operating parameters, almanac information, and other information, as specified in Chapter 5. **To prevent loss of this information when the Oncore receiver is powered off, an external +5 V BATT voltage is required.** Retention of the real-time-clock (RTC) value also requires the external +5 V BATT signal when the Oncore receiver is powered off.

ANTENNA SENSE CIRCUIT

The Oncore receiver is capable of detecting the presence of an antenna. The receiver utilizes an antenna sense circuit which can detect under current (open condition), over current (shorted or exceeding maximum receiver limits), or a valid antenna connection. The antenna sense circuit was designed around the Motorola GPS antenna; therefore non Motorola antennas may exceed the threshold limits as listed below.

Under current circuit:
  Good indication: greater than 5 mA
  Bad indication: less than 5 mA

Over current circuit:
  80 mA maximum for normal operation
  45 mA maximum for short circuit

The above information is output in two of the I/O messages, @@Ea (Position/Status/Data Output Message) and @@Fa (Self-Test). Upon detecting an over current situation, the receiver will automatically shut down the RF section until the fault is cleared. Upon detecting an under current situation, the receiver will continue to operate as normal, but will flag the fault mode in the two I/O messages. An external power source must be used if the antenna circuit power requirements exceed the limits.

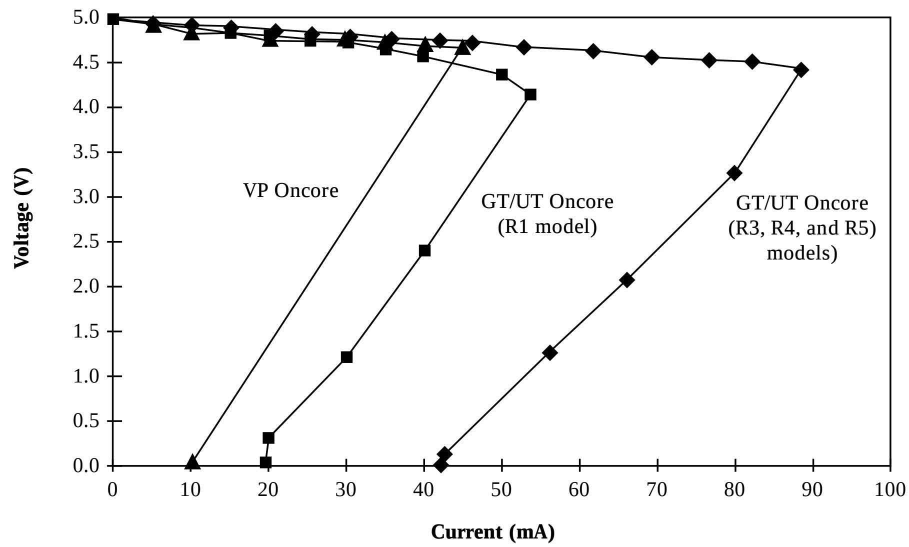
ANTENNA FEED CURRENT

The GT and UT Oncore receivers now provide up to 80 mA of current via the antenna power supply circuit. The circuit still has a 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 and 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, two rail to rail operational amplifiers, a pass transistor and a voltage divider to set the upper and lower limits of the under current and over current thresholds. The operational amplifiers compare the voltage developed across the current sense resistor with these thresholds. If the antenna is drawing 5 mA or more, the first operational amplifier will produce a logic level to the digital circuits where it is monitored by the firmware. If the signal is absent, indicating an under current condition, an alarm bit is set to alert the user.

Antenna Feed Circuit (Continued)

For the over current circuit, when the voltage drop across the current sense resistor is equal to the over current threshold (set at about 90 mA for room temperature) the output of the amplifier starts shutting down the pass transistor. At this point, the voltage to the antenna starts to decrease and a logic level is provided for the digital circuit to trigger an alarm bit that indicates an overcurrent condition.



Antenna Circuit Performance
Voltage vs. Current @ 25°C

Figure 3.2

An additional feed back path between this output voltage and the over current operational amplifier causes a further decrease in the output current depending on the output voltage level. This action results in folding back the current such that the short circuit amount is about 45 mA, which is less than the 90 mA threshold. This prevents the over heating of the series pass transistor should the shorted coax condition occur. A chart of the typical output voltage vs. the load current is shown in figure 3.2 above.

The output current limit is higher than previous versions of Oncore receivers. This is to support longer cable runs through the use of higher gain antennas or in-line amplifiers so that the signal does not drop below the tracking threshold when it reaches the GPS receiver.

External Gain Range

ACTIVE ANTENNA CONFIGURATION

The recommended external gain (antenna gain minus cable and connector losses) for the GT Oncore R3 model is 10 to 26 dB. The recommended external gain for the UT Oncore R5 model is 10 to 33 dB. A typical antenna system might have an active antenna with 24 dB of gain and six meters of cable with 6 dB of loss. The external gain would then be 18 dB, which is within the acceptable range. For more information, refer to the Active Antenna Applications Note.

On-Board LNA Option

PASSIVE ANTENNA CONFIGURATION

The GT Oncore now has an option that allows the use of passive antennas. The R4 model of the GT has an on-board low-noise amplifier (LNA). The LNA allows for a passive antenna with up to 2 dB of cable loss to be connected to the receiver.

The R4 module still provides 5.0 V power on the center pin of the RF connector for possible use with an active antenna. The external gain range for an active antenna with the R4 model is 8 to 15 dB. If the external gain is higher than 18 dB, there may be a drop in sensitivity at high temperature and high voltage.

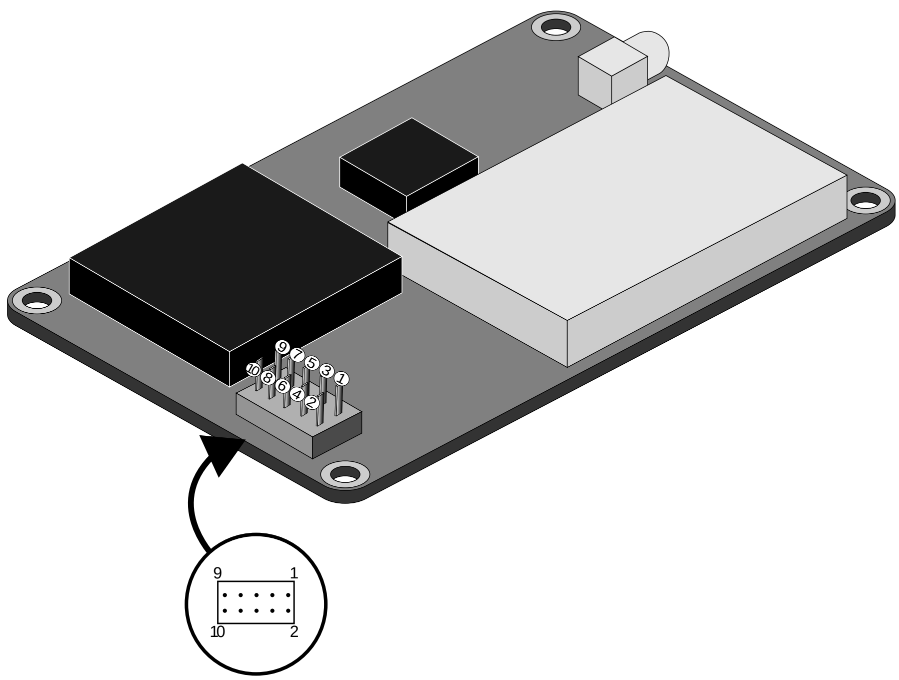


Figure 3.3: Oncore Receiver

ELECTRICAL CONNECTIONS

The Oncore receives electrical power and receives/transmits I/O signals through a 10-pin power/data connector mounted on the Oncore. Refer to Figure 3.3 for pin numbering.

The following table lists the assigned signal connections of the Oncore receiver's power/data connector.

Table 3.1: Oncore Power/Data Connector Pin Assignments

Pin #	Signal Name	Description
1	BATTERY	Externally applied backup power (≤ + 5 V)
2	+5V PWR	+5 V regulated main power
3	GROUND	Ground (receiver)
4	VPP	Flash memory programming voltage
5	RTCM IN	RTCM input
6	1PPS	One pulse per second signal
7	1PPS RTN	One pulse per second return
8	TTL TXD	Transmit 5V logic
9	TTL RXD	Receive 5V logic
10	TTL RTN	Transmit/receive return

Oncore Operation Voltage and Current Ranges

5V PWR (Main power)

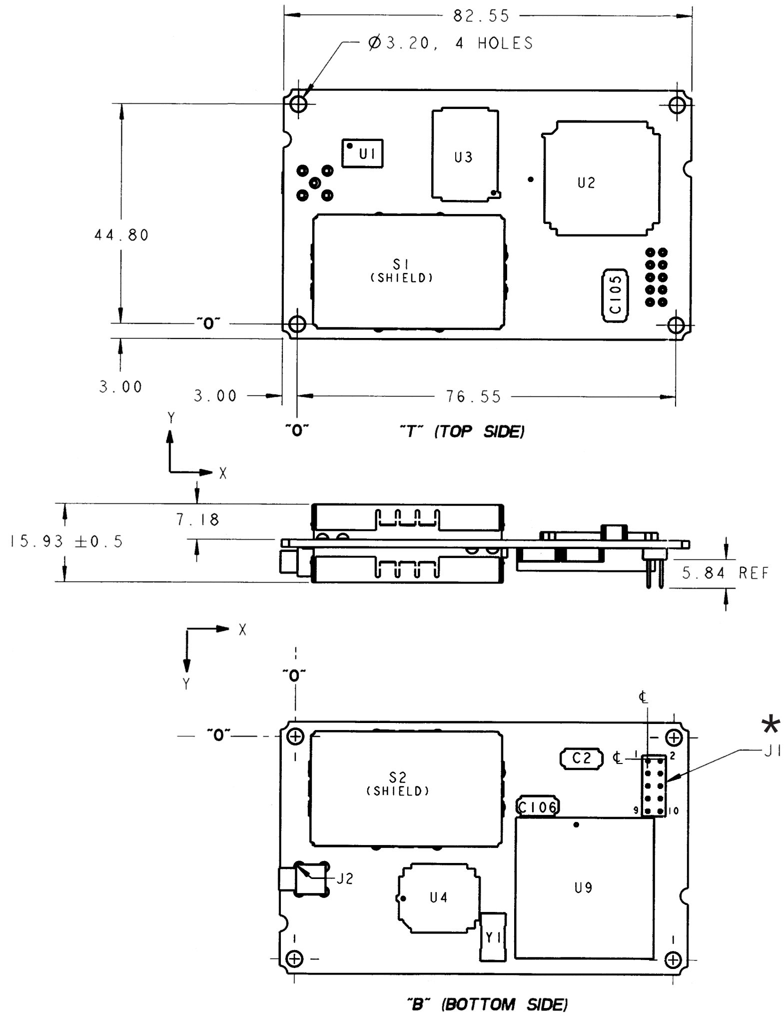
Voltage: 4.75 V to 5.25 V
50 mV peak-to-peak ripple

Current: < 0.9 W at 5 V at 25°C with active antenna drawing 20 mA

BATTERY (Externally applied backup power)

Voltage: 2.5 V to 5.25 V

Current: 5 µA typical @ 2.5 V
100 µA typical @ 5.0 V



REF DESIG	PCB SIDE	LOCATION (NOMINAL TO CENTER) "X"	"Y"	SIZE (NOMINAL) WIDTH "X"	LENGTH "Y"	HEIGHT
C2	B	57.8	4.4	5.7	3.3	2.6
C105	T	64.2	6.0	4.4	7.5	2.9
C106	B	49.1	13.9	5.7	3.3	2.6
* J1	B	71.2	4.4	4.9	12.3	8.2
J2	B	3.4	28.8	6.0	6.0	5.4
S1	T	10.6	22.6	39.3	23.8	6.9
S2	B	10.6	22.6	39.3	23.8	6.9
U1	T	13.0	34.9	3.8	5.0	1.6
U2	T	59.4	29.9	22.0	22.0	1.5
U3	T	33.8	34.7	8.4	17.8	2.5
U4	B	29.3	32.6	13.9	11.5	3.3
U9	B	58.6	30.4	24.0	24.0	4.4

* LOCATION MEASURED TO ℄ OF PIN #1

All dimensions in mm

NOTE: Power/Data Connector (J1):
MFR: AMP #104326-06 header, 10-pin W/2.54 centers
RF Connector (J2):
MFR: M/A-COM #5864-5002-10 (OSX) sub-miniature snap-on

Figure 3.5: Oncore Printed Circuit Board Layout

Table 3.2: Oncore Technical Characteristics – GT Model

General Characteristics	Receiver Architecture	• 8 parallel channel • L1 1575.42 MHz • C/A code (1.023 MHz chip rate) • Code plus carrier tracking (carrier aided tracking)
	Tracking Capability	• 8 simultaneous satellite vehicles
Performance Characteristics	Dynamics	• Velocity: 1000 knots (515 m/s); > 1000 knots at altitudes < 60,000 ft. • Acceleration: 4 g • Jerk: 5 m/s^3 • Vibration: 7.7G per Military Standard 810E
	Acquisition Time (Time To First Fix, TTFF) (Tested at -30 to +85°C)	• < 15 s typical TTFF-hot (with current almanac, position, time and ephemeris) • < 45 s typical TTFF-warm (with current almanac, position and time) • < 90 s typical TTFF-cold • < 1.0 s internal reacquisition (typical)
	Positioning Accuracy	• 100 m 2dRMS with SA as per DoD specification • Less than 25 m SEP without SA • 1-5 m typical in differential mode
	Timing Accuracy (1 Pulse Per Second, 1 PPS)	• < 500 ns (1 sigma) with SA on
	Antenna	• Active micro strip patch antenna module • Powered by receiver module (5-80 mA @ 5 V)
	Datum	• WGS-84 • One user definable datum
Serial Communication	I/O Messages	• Latitude, longitude, height, velocity, heading, time • Motorola binary protocol at 9600 baud • NMEA at 4800 baud: GGA, GLL, GSA, GSV, RMC, VTG, ZDA • Software selectable output rate (continuous or poll) • TTL interface (0 to 5 V) • Second COM port for RTCM input
Electrical Characteristics	Power Requirements	• 5 ± 0.25 V; 50 mVp-p ripple (max.)
	"Keep-Alive" BATT Power	• External 2.5 V to 5.25 V; 5 µA (typ.) @ 2.5 V
	Power Consumption	• < 0.9 W @ 5 V with active antenna drawing 20 mA
Physical Characteristics	Dimensions	• 2.00 x 3.25 x 0.64 in. [50.8 x 82.6 x 16.3 mm]
	Weight	• 1.8 oz. (51 g)
	Connectors	• Data/power: 10 pin (2x5) unshrouded header on 0.100 in. centers • RF: right angle OSX (subminiature snap-on)
	Antenna to Receiver Interconnection	• Single coaxial cable • Antenna sense circuit
Environmental Characteristics	Operating Temperature	• -40ºC to +85ºC
	Humidity	• 95% noncondensing +30ºC to +60ºC
	Altitude	• 60,000 ft. (18 km) (max.) • > 60,000 ft. (18 km) for velocities < 1000 knots
Miscellaneous	Standard Features	• Motorola DGPS input corrections at 9600 baud on COM port one • RTCM SC-104 input Type 1 and Type 9 messages for DGPS at 2400, 4800, or 9600 baud on COM port two. • NMEA 0183 output • Velocity filtering (user controlled)
	Optional Features	• Lithium battery • Right angle SMB RF connector • On-board LNA for passive antenna support • Low profile shields

ONCORE GPS RECEIVER TECHNICAL CHARACTERISTICS

Table 3.3: Oncore Technical Characteristics – UT Model

General Characteristics	Receiver Architecture	• 8 parallel channel • L1 1575.42 MHz • C/A code (1.023 MHz chip rate) • Code plus carrier tracking (carrier aided tracking)
	Tracking Capability	• 8 simultaneous satellite vehicles
Performance Characteristics	Dynamics	• Velocity: 1000 knots (515 m/s); > 1000 knots at altitudes < 60,000 ft. • Acceleration: 4 g • Jerk: 5 m/s^3 • Vibration: 7.7G per Military Standard 810E
	Acquisition Time (Time To First Fix, TTFF) (Tested at -30 to +85°C)	• < 20 s typical TTFF-hot (with current almanac, position, time and ephemeris) • < 50 s typical TTFF-warm (with current almanac, position and time) • < 300 s typical TTFF-cold • < 1.0 s internal reacquisition (typical)
	Positioning Accuracy	• 100 m 2dRMS with SA as per DoD specification • Less than 25 m SEP without SA
	Timing Accuracy (1 Pulse Per Second, 1 PPS)	• Time RAIM algorithm • < 130 ns (1 sigma) with SA on • In position hold mode, < 50 ns (1 sigma) with SA on
	Jamming Immunity	• Immune to the following CW jamming signal levels measured at the input to the Oncore Active Antenna when the receiver is in position-hold mode. Values are typical. -50 dBm @ 1570 MHz -79 dBm @ 1575.42 MHz -56 dBm @ 1580 MHz
	Antenna	• Active micro strip patch antenna module • Powered by receiver module (5-80 mA @ 5 V)
	Datum	• WGS-84
Serial Communication	Output Messages	• Latitude, longitude, height, velocity, heading, time (Motorola binary protocol) • Software selectable output rate (continuous or poll) • TTL interface (0 to 5 V)
Electrical Characteristics	Power Requirements	• 5 ± 0.25 V; 50 mVp-p ripple (max.)
	"Keep-Alive" BATT Power	• External 2.5 V to 5.25 V; 5 µA (typ.) @ 2.5
	Power Consumption	• < 0.9 W @ 5 V with active antenna drawing 20 mA
Physical Characteristics	Dimensions	• 2.00 x 3.25 x 0.64 in. [50.8 x 82.6 x 16.3 mm]
	Weight	• 1.8 oz. (51 g)
	Connectors	• Data/power: 10 pin (2x5) unshrouded header on 0.100 in. centers • RF: right angle OSX (subminiature snap-on)
	Antenna to Receiver Interconnection	• Single coaxial cable • Antenna sense circuit
Environmental Characteristics	Operating Temperature	• -40ºC to +85ºC
	Humidity	• 95% noncondensing +30ºC to +60ºC
	Altitude	• 60,000 ft. (18 km) (max.) • > 60,000 ft. (18 km) for velocities < 1000 knots
Miscellaneous	Standard Features	• Time RAIM • 100PPS output • Automatic site survey • Jamming protection
	Optional Features	• Lithium battery • Straight OSX RF connector

1PPS SIGNAL DEFINITION

- 0 to 5 V live pulse
- 1 PPS time mark is synchronous with the mid point of the rising edge of the pulse rising from 0 V to 5 V
- Rise time is approximately 20 to 30 ns
- 5 V pulse width is approximately 200 ms ± 1 ms
- The falling edge will occur approximately 200 ms after the rising edge
- Accurate to < 500 ns (1 sigma) in stand alone mode (with SA on)
- UT Oncore accurate to < 130 ns (1 sigma) in stand alone mode (with SA on)
- UT Oncore accurate to < 50 ns (1 sigma) in position-hold mode (with SA on)

RF JAMMING IMMUNITY (UT MODEL ONLY)

Many precise timing GPS installations require locating the GPS antenna at close range to radiating antennas such as cellular telephone, paging, or other wireless communications systems. Some of these transmitters may randomly cause the GPS receivers 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.

The GPS signal is broadcast at 1575.42 MHz with a bandwidth of +/- 1 MHz. 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.

To reduce the risk of unintentional jamming from high power out-of-band signals causing dropouts, additional filtering has been added to the UT Oncore. The desired result was achieved by working with various GPS L-band filter suppliers to develop filters that were small, economical and had the desired characteristics.

The VP Oncore (the predecessor to the UT Oncore) with the best selectivity (B8 model) uses two L-band filters and a five pole first IF filter. Experience from this model was used to design the improved UT Oncore. Although the B8 design is effective, the band width of the input filter on this model is comparatively wide and the low side roll off is not very steep. The image filter and the first IF filter are very effective and have been retained for the R5 model of the UT Oncore. The first L-band filter has been replaced with one with a narrower band width and steeper low side roll off. In addition, a third L-band filter was added between the first filter and the image filter. The second IF filter has also been improved. The result is a GPS receiver with greatly improved selectivity, which is to say, better immunity to jamming signals.

RF Jamming Immunity (continued)

Figure 3.6 compares the selectivity of the R5 model of the UT Oncore with the B8 model of the VP Oncore. An additional 30 dB of rejection (an improvement of 1000:1 in power) has been achieved at the first image (J/S 110 dB). The improvement is 15 dB at the second image (J/S 87 dB). The jamming immunity of the GPS receiver and antenna system will be further improved with the additional margin provided by the filtering in the active antenna.

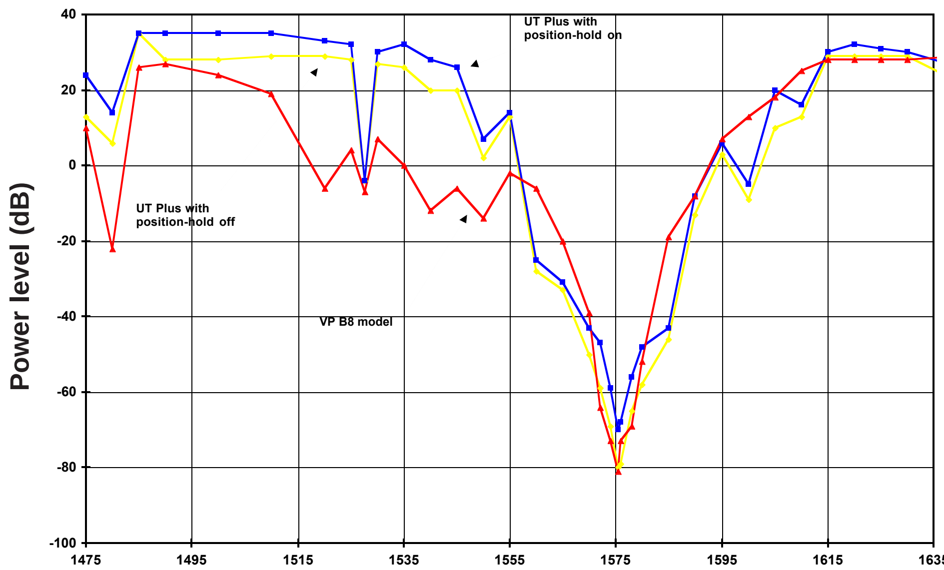


Figure 3.6 Jammer Frequency (MHz)
Immunity to Jamming Signals

Adaptive Tracking Loops

Motorola has developed an innovative software technique to further improve the jamming immunity of the UT Oncore receiver. The technique takes advantage of the fact that for precise timing applications, the receiver is not moving.

In mobile applications of GPS, the receivers 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 GPS receiver is stationary, the tracking loops do not need to be as wide in order to track the satellites.

In the UT Oncore 2.x 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 UT Oncore.

Test results have demonstrated that this approach is effective at providing an additional 10 dB of jamming immunity both in the GPS band and out-of-band.

RF Jamming Immunity (continued)

The combined results of the additional filtering and the adaptive tracking loops in the UT Oncore make it very effective at improving RF jamming immunity, thus making installation in timing applications more flexible and robust.

AUTOMATIC SITE SURVEY (UT MODEL ONLY)

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

The Automatic Site Survey averages a total of 10,000 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 5 of the DOP type field in the Position/Status/Data Message (@@Ea) is set. Once the position is surveyed, the UT Oncore 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 @@Ea message.

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

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

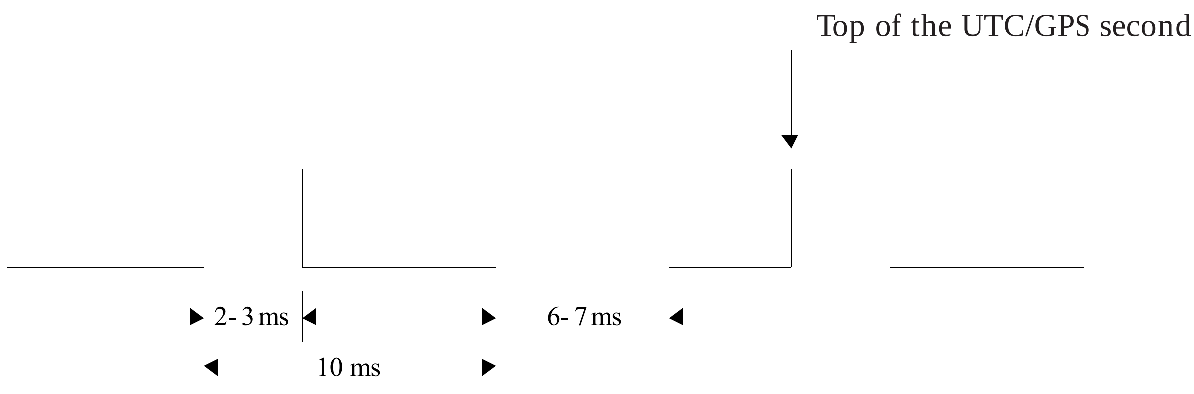
The status of the Automatic Site Survey and Position-Hold Mode is retained in RAM when the receiver is powered down only if battery backup power is provided.

100PPS OUTPUT (UT MODEL ONLY)

With the UT Oncore 2.x firmware, the timing output can be selected between 1PPS and 100PPS. This is done using the Pulse Mode command (@@AP). See chapter 6 for information on the format of this command.

When selected, the 100PPS signal is output on the same pin as the 1PPS. The 100PPS signal has the same accuracy and stability characteristics as the 1PPS signal. Each pulse is approximately 2-3 ms in duration (the pulse width is not accurately controlled) so the 100PPS signal has a nominal duty cycle of approximately 25%. Every hundredth pulse is 6-7 ms in duration. The leading edge of the pulse following the long pulse corresponds to the top of the second (UTC or GPS, depending on the Time Mode). Figure 3.7 shows a diagram of the 100PPS output signal.

The 1PPS Offset and 1PPS Cable Delay features work the same in 100PPS mode as they do in 1PPS mode. In 100PPS mode, these commands are used to accurately control the placement of the pulse after the long pulse.



100PPS Signal Description

Figure 3.7

TIME RAIM ALGORITHM DESCRIPTION (UT MODEL ONLY)

Time Receiver Autonomous Integrity Monitoring (RAIM) is an algorithm in the Oncore timing GPS receivers (VP and UT) that uses redundant satellite measurements to confirm the integrity of the timing solution. The 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 Time 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, the time is the only remaining unknown. In order to compute the time, the GPS receiver only requires one satellite. 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 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 Table 3.4 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.

Table 3.4: 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	-1
Average	10.0125		10.000	

RECEIVER MODULE INSTALLATION

Your Oncore 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 Oncore receiver board into your housing system, special precautions need to be considered.

INSTALLATION PRECAUTIONS AND CONSIDERATIONS

Before you install an Oncore receiver, please review the following precautions and considerations.

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 wrist bands and anti-static bags are considered standard equipment in protecting against ESD damage.

Electromagnetic Considerations

The Oncore receiver PCBs contain a very sensitive RF receiver; 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, try moving the antenna away from the source of the interference.

Installer Caution (Continued)

RF Shielding

The RF circuitry sections on the Oncore GPS receiver board are protected with a tin plate shield to guard against potential interference from external sources. When a design calls for the Oncore to be near or around RF sources such as radios, it is recommended that the Oncore be tested and tried in the target environment to identify potential interference issues prior to final design.

In worst case situations, the Oncore receiver PCB may require an additional enclosure in a metal shield to eliminate electromagnetic compatibility (EMC) problems.

Real-Time Clock (RTC)

When powered up, the RTC in the Oncore receiver will have an incorrect time unless it was previously set and maintained by external backup power. To ensure a faster time to first fix, the time, date, and GMT offset should be input if both the main power and battery backup power have been disconnected.

Thermal Considerations

The receiver operating temperature range is -40°C to +85°C, and the storage temperature range is -40°C to +105°C. The antenna operating range is -40ºC to +100ºC. Before installation, you should perform a thermal analysis of the housing environment to ensure that temperatures do not exceed +85°C when operating (+105°C stored). This is particularly important if

- air circulation in the installation site is poor,
- other electronics are installed in the enclosure with the Oncore receiver PCB, or
- the Oncore receiver PCB is enclosed within a shielded container due to electromagnetic interference (EMI) requirements.

Grounding Considerations

The GT and UT Oncore receivers now have a different grounding scheme than previous Oncore receivers for improved EMI/EMC performance. The RF shields on both sides of the module are connected to ground at multiple points. 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 GPS receiver will still function properly if it is not grounded via the mounting holes, but the shields may be less effective.

PCB Mounting Hardware

ONCORE RECEIVER MOUNTING INSTRUCTIONS

Mounting Hardware Design Guidelines

For all the design validation and process validation tests that were conducted and completed successfully by Motorola, the Oncore PCBs were mounted on round or hex female threaded metal standoffs and screwed/tightened down with metal english or metric screws. The mounting standoffs are available with english or metric threads.

One of the key points in selecting the four standoffs that will mechanically hold and secure the Oncore PCB to the application PCB directly or indirectly is the diameter of the standoffs. Obviously the height of the standoff will be determined by the customers application. Recommended nominal diameter of the standoffs should be around 0.165 in. or 4.16 mm (See Figure 3.8).

These standoff should give ample space and clearance between

- the outside diameter of the standoff and the outside edge of the RF shields of the GT Oncore, and
- the outside diameter of the standoff and the outside edge of the 10 pin header of the GT Oncore.

If the recommended diameters of the standoff are not available, one can probably go higher with the next available diameter. See Table 3.5 for a suggested list of companies that carry standoffs equal or close to the recommended diameters. The maximum limit is around 0.212 in. or 5.38 mm diameter; at this point the standoffs are literally touching the RF shields of the Oncore.

Another important point to consider is the mating 10-pin receptacle on the application PCB. When choosing this mating connector, one must be aware that the outer diameter of the standoffs should not come too close to this connector.

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 3.9 and 3.10 for recommended layouts of the standoffs and

Mounting Hardware (Continued)

mating receptacles. Also see Figure 3.5 which is an outline drawing of the Oncore receiver. The drawing describes the overall placement and height of large components and connectors populated on both sides of the Oncore PCB.

The recommended screws for the standoffs that will secure the Oncore to the standoffs are metal screws with 4-40 threads or M3 threads. The nominal torque to assemble the Oncore PCB with screws to the standoffs is 6 in-lb each with a maximum of 7 and minimum of 5 in-lb. Washers are not required nor recommended for use with the Oncore PCB. All design and process validation testing was completed with metal screws mounted directly onto the PCB without washers.

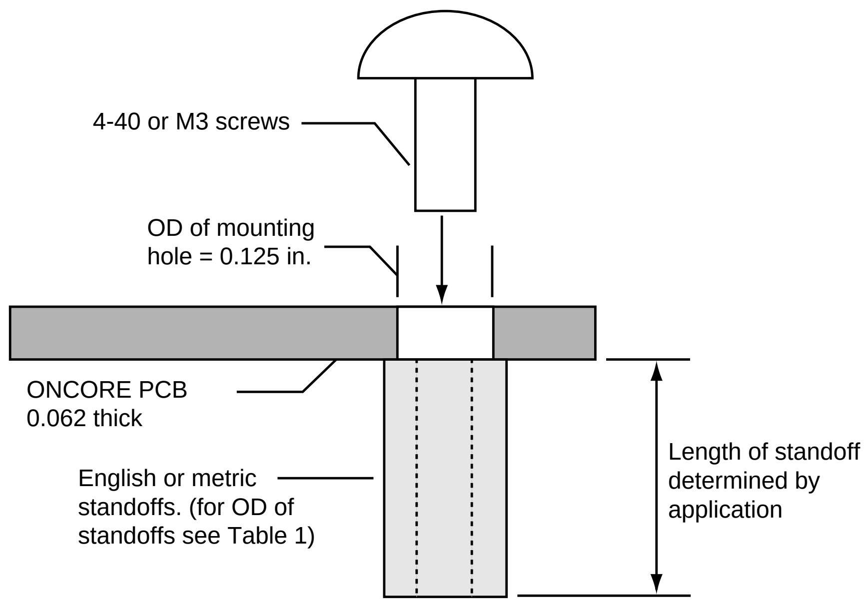


Figure 3.8: Layout of the Oncore PCB cross section with reference to the standoff and screw

Mounting Hardware (Continued)

MOUNTING HARDWARE (CONTINUED)

Table 3.5: List of Threaded Standoff Suppliers

No.	Company Name	Part description of metal standoffs	Outside diameter
1	Keystone Electronic Corp. Tel: 718-956-8900 Fax: 718-956-9040	• Plain female standoffs 4-40 threads available in lengths from 0.250 to 1.0 in. • Plain female standoffs M3x0.5 mm threads available in lengths from 5 to 25 mm	0.187 in. round or hex 5 mm hex
2	RAF Electronics Hardware Tel: 203-888-2133 Fax: 203-888-9860	• Plain female standoffs 4-40 threads available in lengths from 0.250 to 1.0 in. • Plain female standoffs M3x0.5 mm threads available in lengths from 5 to 25 mm	0.187 in. round 4.5 mm hex
3	PEM Engineering & Manufacturing Corp Tel: 215-766-8853 Fax: 215-766-0143	• Self clinching female standoffs 4-40 threads available in lengths from 0.250 to 1.0 in. • Self clinching female standoffs M3x0.5 mm threads available in lengths from 5 to 25 mm	0.165 in. round 4. 2 mm round

Design and Process Validation Test Information

Motorola has conducted numerous design and process validation tests for different versions of the Oncore. Mechanically, the Oncore dimensions are exactly the same for different versions (model numbers) of the Oncore PCB.

One of the key legs of the design validation is the thermal shock testing followed by vibration testing. In thermal shock testing the temperature cycles every hour from -40°C to +85°C . The units are put through anywhere from 300 to 500 cycles before going on to the vibration table where they are mounted on metal standoffs.

Sturdiness and Reliability of Metal Standoffs

The Oncore PCB mounted on standoffs 0.375 or 0.500 in. long passed the vibration test successfully. The mechanical test is conducted in three axes, one hour each, at 7.7 Gs random vibration. In the final analysis this is a severe military specification as per MIL-STD 810E. After the vibration test leg of the design validation, the screws lose about 60% to 80% torque, which is expected as per design. Also, all the parts populated on both sides of the Oncore PCB remain soldered to the PCB with no loose connections.

Mounting Hardware (Continued)

Sturdiness and Reliability of Metal Standoffs (Continued)

Motorola has also conducted independent vibration tests such as the SAE J1455 Truck Cab spec. (1.04 Gs for four hours per axis) and the SAE J1211 Car Chassis spec. (2.57 Gs for four hours per axis). Both of them passed successfully with the GT Oncore PCB mounted on 0.375 in. high standoffs.

Motorola conducted independent mechanical shock tests at the 30 G level (10 ms duration) at least 100 times, which also passed successfully.

Design Worksheets

Given below in figures 3.9 and 3.10 are sample worksheets which show the Oncore and the application PCB mounted in two different ways. The purpose of these worksheets is to provide the reader with recommended design guidelines.

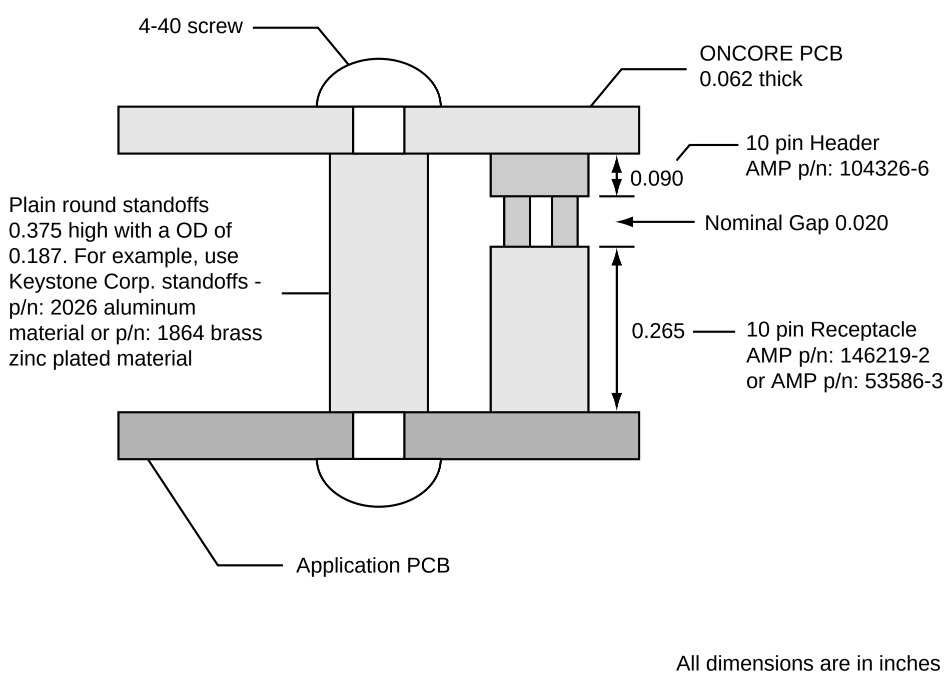


Figure 3.9: Sample layout of GPS Oncore PCB which is directly connected to the application PCB

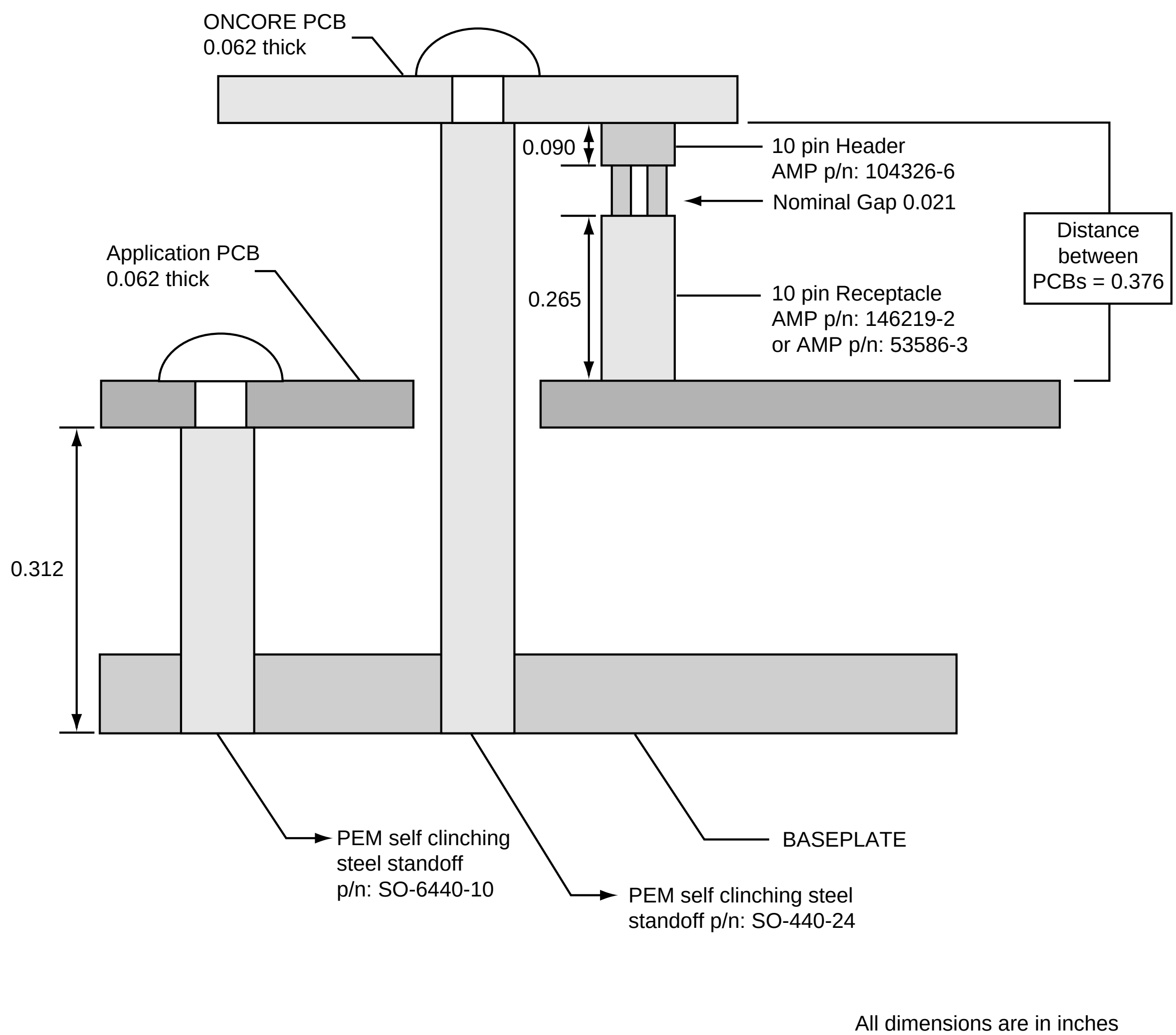


Figure 3.10: Sample layout of GPS Oncore PCB and the application PCB independently mounted on a baseplate

Mean Time Between Failure (MTBF)

The MTBFs for the Oncore family of GPS receivers have been computed using the methods, formulas, and database of MIL-HDBK-217.

Table 3.6: Oncore Receiver Mean Time Between Failure (MTBF)

Average temperature (ºC)	VP Oncore MTBF (hours)	GT/UT Oncore MTBF (hours)
40	596,921	1,114,077
35	777,404	1,285,262
30	927,386	1,467,496
25	1,164,043	1,649,656

The above information is computed assuming a static application in a benign environment at the given temperatures. These reliability predictions only provide broad estimates of the expected random failure rates of the electrical components during the useful life of the product, and are not to be used as absolute indications of true field failure rates. The above MTBF values may not correspond to actual field failure rates.

Operational Overview

SYSTEM INTEGRATION

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

Interface Protocol Description

INTERFACE PROTOCOL

The Motorola Oncore receiver has up to two TTL serial data ports. The first port is configured as a data communications equipment (DCE) port and provides the main control and data path between the Oncore receiver and the system controller. The second port is for RTCM DGPS correction input (GT only). Refer to Table 3.7 for the interface protocol parameters. To connect the Oncore to an RS-232 port, one must supply circuitry to convert TTL to RS-232 and RS-232 to TTL.

The I/O port operates under interrupt control. Incoming data is stored in a buffer that is serviced by the Oncore receiver's operating program. This buffer is serviced every 1.0 seconds.

Table 3.7: Oncore Interface Protocol

Format	Motorola	NMEA 0183	RTCM SC-104
Type	Binary	ASCII	1 & 9
Direction	In/out	In/out	In only
Port	1	1	2
Baud rate	9600	4800	2400, 4800, 9600
Parity	None	None	None
Data bits	8	8	8
Start/stop	1/1	1/1	1/1

TTL OUTPUT

The serial interface signals, RXD and TXD, are available for user connection. A ground signal is also required to complete the serial interface. There is no additional protection or signal conditioning besides the internal protection of the microprocessor since they are connected to the microprocessor directly. TXD and RXD are regular TTL signals with voltage ranges from 0 to 5 V. For input signals, minimum input high voltage is 2 V and the maximum input high voltage is 5 V. 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 connect to a PC (which are normally equipped with an RS-232 interface) directly. An RS-232 driver/receiver is required to make this connection. The driver/receiver provides a voltage shift from 0 to 5 V to a positive and negative voltage (for example, ±10 V), and also has an inversion process in it. Some RS-232 driver/receiver integrated circuits (ICs)—for example; Motorola's MC145407—will provide all these functions with only a +5 V supply.

TTL	0 V to 0.8 V	= logic 0
	2.4 V to 5.0 V	= logic 1
RS-232	-5 V to -15 V	= logic 1
	5 V to 15 V	= logic 0

NOTE: 50 pf maximum capacitance on TTL level output

Motorola Binary Format

The binary data messages used by the Oncore Receiver consist of a variable number of binary characters. These binary messages begin with the ASCII @@ characters and are terminated with the ASCII carriage return and line feed <CR><LF>. The first two bytes after the @@ characters are two ASCII characters that identify the particular structure and format of the remaining binary data. The byte preceding the termination <CR><LF> of all messages is a single byte checksum (the exclusive-or of all message bytes after the @@ and before the checksum). Every message has the following components:

- Message Start:
  @@ - (two hex 40s) denotes start of binary message.
- Message ID:
  (A..Z)(a..z, A..Z) - ASCII upper-case letter, followed by an ASCII lower-case or upper case letter. These two characters together identify the message type and imply the correct message length and format.
- Binary Data Sequence:
  Variable number of bytes of binary data dependent on the command type.
- Checksum:
  C - The exclusive-or of all bytes after the @@ and prior to the checksum.
- Message Terminator:
  <CR><LF> - carriage return and line feed denoting the end of the binary message.

Every Oncore receiver input command has a corresponding response message so that you can determine whether the input commands have been accepted or rejected by the Oncore receiver. The message format descriptions in Chapter 6 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 format and text messages reside in its memory. This approach gives you complete control of the display format and language.

The Oncore receiver reads the input command string on the input buffer once per second. If a full command has been received, then it 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 received if

- it began with @@ and is terminated with a carriage return and a line feed,
- the message is the correct length for its type, and
- the checksum validates.

Motorola Binary Format (Continued)

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 Oncore receiver. For multiparameter input commands, the Oncore receiver will reject the entire command if one of the input parameters is out of range. Once the input command is detected, the Oncore 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 the data (positive or negative) is described via the two's complement presentation.

Input command messages can be stacked into the Oncore receiver input buffer, up to the depth of the message buffer (2048 characters long). The Oncore 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.

Every input command has a corresponding output response message. This enables you to verify that the Oncore receiver accepted the input command. The Oncore receiver response to properly formatted commands with at least one out-of-range parameter is to return the previous unchanged value(s) of the parameter(s) in the response message.

Input commands may be of the type that change a particular configuration parameter of the Oncore receiver. Examples of these input command types include commands to change the initial position, the Oncore receiver internal time and date, satellite almanac, etc. These input commands, when received and validated by the Oncore 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 has a corresponding response message showing the configuration parameter change. To request the current status of the Oncore receiver, enter an input command with at least one out-of-range parameter. 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.

Motorola Binary Format (Continued)

The rate at which the data is output in the continuous output mode is dependent on the type of data in the message. Table 3.8 shows the rates at which the data messages are output for each type of message, depending on the setting of the continuous/one-time option that is part of the input command.

Table 3.8: Data Message Output Rates

OUTPUT MESSAGE TYPE	MESSAGE ID	CONTINUOUS (m=1...255)	ONE TIME (m=0)
Position/Status/Data Output Message	Ea	At selected update rate	When requested
ASCII Position Output Message*	Eq	At selected update rate	When requested
Time Raim Setup and Status Message**	En	At selected update rate	When requested
Almanac Data Output	Cb	When new almanac available	When requested
Visible Satellite Status Message	Bb	When visibility data changes	When requested
UTC Offset Status**	Bo	When UTC offset data available or when it changes	When requested
Leap Second Pending Status	Bj	Not available	When requested

* GT Oncore receiver only
** UT Oncore receiver only

For the case where more than one output message is scheduled during the same one second interval, the GPS receiver will output all scheduled messages but will attempt to limit the total number of bytes transmitted each second to 750 bytes. For the case of multiple output messages, if the next message to be sent fits around the 750 byte length goal, then the message will be output. For example, if messages totaling 718 bytes are scheduled to be sent, and the user requests another 58 byte message, then 776 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.

If external battery power is applied during the power-off state, the polled or continuous option of each output message is remembered in the Oncore receiver RAM memory.

The UT Oncore timing receiver supports the timing capabilities via the Motorola binary I/O format. Non-timing receivers will not respond to, nor create, the timing I/O messages.

Motorola Binary Format Input/Output Processing Time

NMEA Support

The GT Oncore 2.x 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 an electronic navigation instrument that supports the specific output messages. 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. If back-up battery power is applied or if the receiver has the battery option, then the GT Oncore receiver retains the output settings when powered off and reconfigures itself to the same state when powered up again. If no back-up power is provided, the receiver will start up in the default state (Motorola binary format at 9600 baud) each time it is powered on.

All NMEA messages are formatted in sentences that begin with the ASCII $ (hex 24) and end with ASCII <CR><LF> (hex 0D and hex 0A). A five-character address occurs after the ASCII $. 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. Note that the NMEA messages are not fixed length. Fields within the message are delimited by the ASCII comma character. The maximum length of any NMEA message is 79 characters.

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.

The output of the above listed messages is controlled with a Motorola NMEA format message. Input messages follow the NMEA specification, and take the form $PMOTG,,,,,*CS<CR><LF>. All input parameters are separated with comma delimiters. The P character identifies the message as Proprietary format, the MOT is the manufacturer designator for Motorola, and the G is for GPS.

For the case where more than one output message is scheduled during the same one second interval, the GPS receiver will output all scheduled messages but will attempt to limit the number of bytes transmitted each second to 375 bytes. For

NMEA 0183 Format Overview (Continued)

the case of multiple output messages, if the next message to be sent fits into the 375 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 for transmitting messages is simply alphabetical.

The NMEA input and output are on the primary serial port. For details on the command formats see the Input/Output section of this document.

RTCM SC-104 Format Overview

RTCM Differential GPS Support

The GT Oncore 2.x firmware supports the RTCM SC-104 Version 2.0 format for differential corrections. The receiver employs a decoding algorithm that allows the unit to directly decode the RTCM Type 1 and Type 9 (6 of 8 type with two most significant bits always 01) differential correction messages from the secondary input serial port (pin 5). Having a separate port allows the GT Oncore to simultaneously accept the RTCM format data stream and other receiver input commands (in either Motorola binary format or in NMEA format).

Use with Motorola Evaluation Kits

The GT Oncore receiver now has an input port on a previously unused pin. Older Oncore evaluation kits do not have the ability to support the second comm port. The previous interface board and cable were not configured to support the second comm port. To easily use the interface board for testing, tie the input pins of port 1 and port 2 (pins 5 and 9) together and input the RTCM corrections on the main input port

EXCLUSIVE-OR CHECKSUM CREATION

This application note describes the procedure to calculate checksums used in the serial messages of the Oncore GPS receivers. An example message is used to illustrate the procedure.

Command name: Position/Status/Data Output Message (eight channel)

Command in Motorola binary format: @@EamC<CR><LF>

In this message, ‘m’ indicates the response message rate (ie. 1 = once per second, 2 = once every two seconds, etc.), and ‘C’ is the checksum. In calculating the checksum, only ‘Eam’ are used. The exclusive-or operation yields a one if only one of the bits is a one. Setting ‘m’ to ‘1’, we have the following:

Character	Hexadecimal	Binary
E	45	0 1 0 0 0 1 0 1
a	61	0 1 1 0 0 0 0 1
Xor	24	0 0 1 0 0 1 0 0
1	01	0 0 0 0 0 0 0 1
Xor	25	0 0 1 0 0 1 0 1

The final checksum would then be ‘25’ in hexadecimal. The complete command would then be as follows:

Message format	@	@	E	a	m	C	<CR>	<LF>
Hexadecimal	40	40	45	61	01	25	0d	0a
ASCII	@	@	E	a	^A	%	^M	^J

To enter this command using the PC controller software type:
@@Ea01

Within the PC controller software, the characters beyond the fourth character are treated as hexadecimal numbers and the checksum is computed automatically. The receiver will now report the eight channel position/status/data message every second. Note that this is equivalent to entering the ‘ps8 1’ controller command.

The checksum for the ASCII Position Message (@@Eq) is computed in a similar manner. The 8-bit checksum is converted to a decimal value between 0 and 255 and sent.

NMEA checksums, which are optional, are also calculated in a similar manner. The 8-bit representations of all the characters between but not including the starting ‘$’ and the ending ‘*’ are used. The high and low four bits of the eight bit checksum are converted to and sent as ASCII characters.

MILLISECOND TO DEGREE CONVERSION

The primary output message of Oncore receivers is the Position/Status/Data Message (@@Ea). In this message, the latitude and longitude are reported in milliarcseconds. This note describes how to convert milliarcseconds to degrees.

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 a conventional degrees, minutes, seconds format follow this procedure:

- Divide the milliarcsecond value by 3,600,000
- The integer portion of the quotient is the degrees
- Multiply the remaining decimal fraction of the quotient by 60
- The integer portion of the product is the minutes
- Multiply the remaining decimal fraction of the product by 60
- The integer portion of the product is the seconds
- The remaining decimal fraction of the product is the decimal seconds

CONVERSION EXAMPLE:

Michigan Avenue, Chicago, IL:

Latitude = 150748869 mas	Longitude=-315445441 mas
150748869 / 3600000 = 41.87468583	-315445441 / 3600000 = -87.62373361
Degrees = 41	Degrees = -87
0.87468583 * 60 = 52.48114980	-0.62373361 * 60 = 37.42401660
Minutes = 52	Minutes = 37
0.48114980 * 60 = 28.86898800	-0.42401660 * 60 = 25.44099600
Seconds = 28	Seconds = 25
Decimal seconds = 0.868988	Decimal seconds = 0.440996
Latitude = 41º 52' 28.869"	Longitude = -87º 37' 25.441"

INPUT/OUTPUT PROCESSING TIME

The Oncore receiver always operates in position fix mode and the input buffer data is serviced once a second. When powered on and available satellites are tracked, the current receiver position is available. If no satellite signals are received, 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 **GMT Offset** command:

BC time	=	shortest command input + command processing + shortest command output
	=	10 ms + 50 ms + 10 ms
	=	70 ms

Typical case:

TC time	=	input anywhere across one second period + command processing + output anywhere across one second period following command processing
	=	0.5 s + 0.05 s + 0.475 s
	=	1.025 s

Worst case:

WC time	=	input beginning of one second period + output end of one second period
	=	1 s + 1 s
	=	2 s

Note: The receiver **Self-Test** command takes 5-10 seconds to complete.

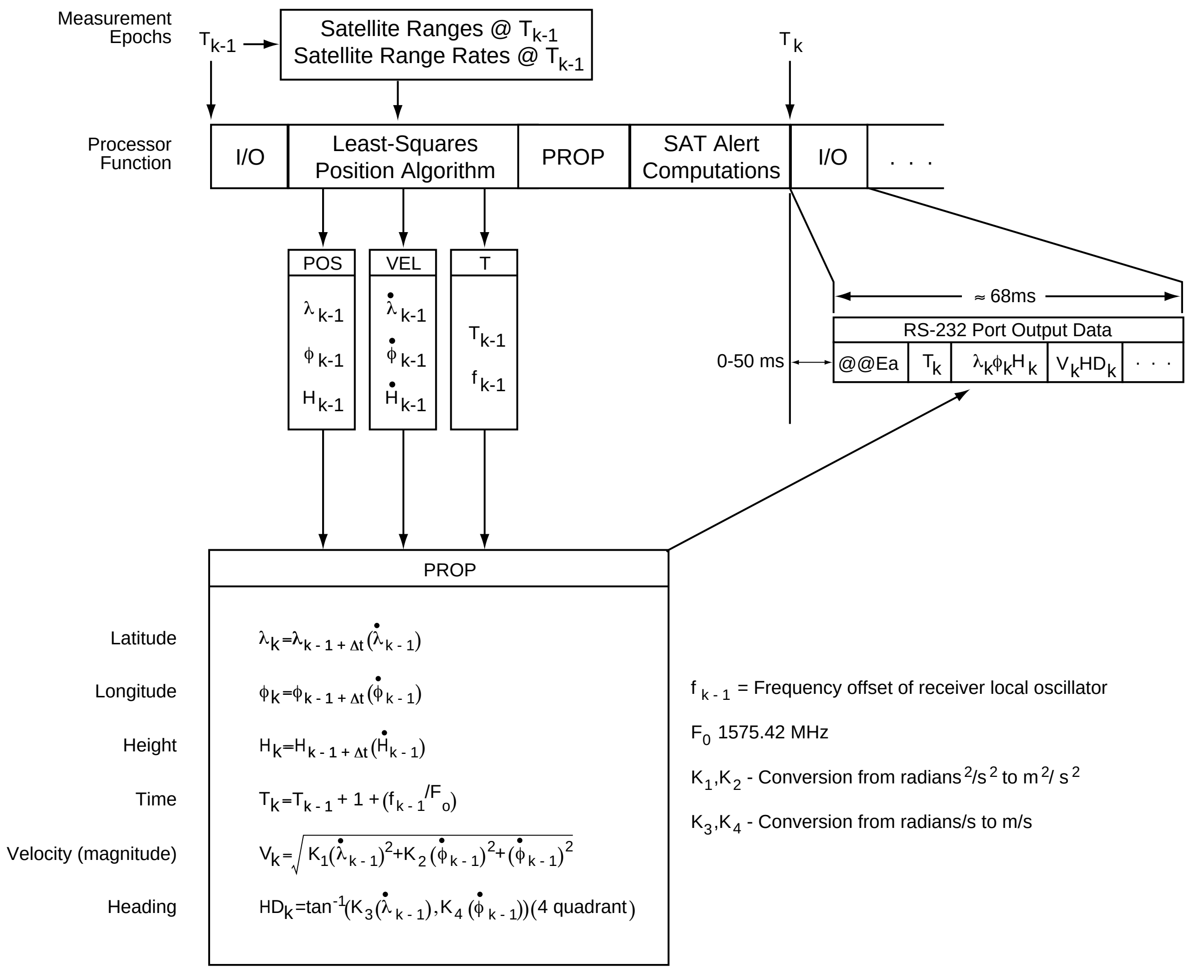
DATA LATENCY

The Oncore receiver can output position, velocity, and time data on the TTL port 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 TTL data in the position message is output between 0 and 50 ms after the most recent Oncore receiver measurement epoch.

Refer to Figure 3.11 for the discussions that follow.

Let T_k be the most recent measurement epoch. The Oncore Receiver takes about one second to compute data from the satellite range measurements. Consequently, the data 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 3.11: 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 TTL 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 T_{k-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 the 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 Oncore 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 +50 μs/s) and the oscillator's inherent instability (+/-30 ppm over specified temperature range).

When the Oncore processor computes receiver local time, this time corresponds to the time of the last receiver measurement epoch. This time is precisely known by the Oncore process to an accuracy of approximately 20 to 300 ns depending on satellite geometry and the effects of selective availability.

The computed time is relative to UTC or GPS time depending on the time type as specified by the user by the Time Mode.

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

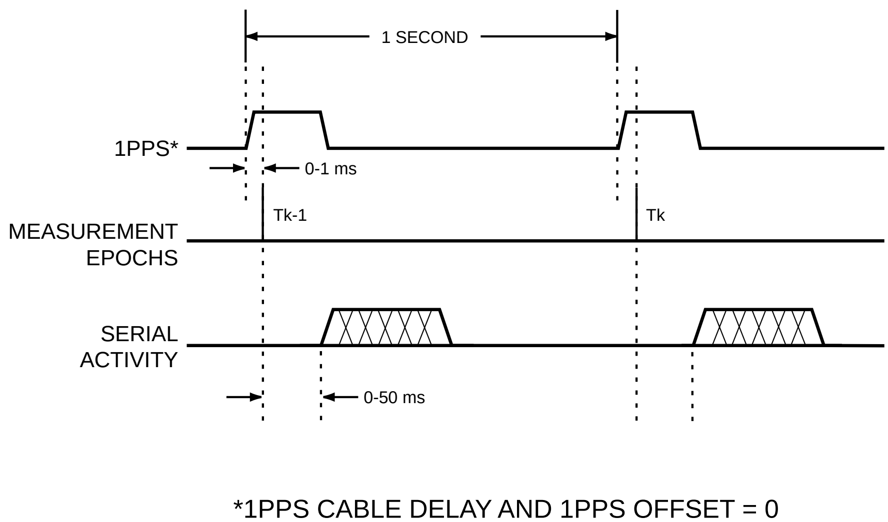


Figure 3.12: Output Signal Timing

Output Data Timing Relative to Measurement Epoch (Continued)

The Position/Status/Data Message and the Time RAIM Setup and Status Message 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 3.12.

1PPS Cable Delay and 1PPS Offset (UT Model Only)

Users can compensate for antenna cable length with the 1PPS Cable Delay command. The 1PPS can also be positioned anywhere in the one second window using the 1PPS Offset command. 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:

Top of second =	10.000000000 s
1PPS cable delay =	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 Oncore Receiver automatically acquires and tracks satellites; measures the pseudorange and phase data from each of up to eight satellites; decodes and collects satellite broadcast data; computes the Oncore receiver's position, velocity, and time; and outputs the results according to the current I/O configuration selected.

TTFF is a function of position uncertainty, time uncertainty, almanac age, and ephemeris age as shown in Table 3.9. The following information assumes that the antenna has full view of the sky when turned on.

Table 3.9: Oncore TTFF Information

POWER-UP STATE	INITIAL ERROR		AGE		TTFF (GT)	
	POS	TIME	ALMANAC	EPHEMERIS	TYPICAL	90%
Hot	100 km	3 min	1 month	< 4 hrs	15 s	30 s
Warm	100 km	3 min	1 month	U/A	45 s	65 s
Cold (default)	N/A	N/A	U/A	U/A	90 s	210 s

U/A – This parameter is assumed to be unavailable.
N/A – Not applicable. Knowledge of this parameter has no effect on TTFF in this configuration

Reacquisition time for all GPS satellite signals after signal obscuration is a function of the obscuration time, as shown in Table 3.10 below.

Table 3.10: Reacquisition Times

TIME OBSCURED	REACQUISITION TIME (Typical)
< 15 s	< 1.0 s internal
15 s	2.5 s
60 s	3.6 s
30 min	300 s

First Time On

When the Oncore receiver powers up for the first time after factory shipment, the initial date and time will be incorrect. This will force the Oncore 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 the satellite. When three or more satellites are tracked, automatic position computation is initiated. At power down, the Oncore receiver does not remember its current configuration unless external battery power is applied.

Initialization

When powered up, the Oncore receiver executes the satellite acquisition and tracking algorithms and will compute position when it acquires at least three satellites. For each of the user-requestable outputs, the receiver (if battery backed) remembers the previously requested message state (continuous or one-time) and rate. If no messages were requested continuously 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 possibly computing position fixes internally.

The Oncore receiver does not need to be initialized to its approximate user position coordinates to acquire satellites and output position, nor does it require a current satellite almanac. However, the TTFF will be considerably shorter if you help the Oncore receiver find satellites by setting the approximate initial position coordinates, setting the time and date correctly, and installing a recent satellite almanac.

If backup power is available, the Oncore receiver retrieves its last known position coordinates from RAM when main power is reapplied, and uses this information in the satellite acquisition algorithm. It also retrieves time and date information from the internal real-time clock so you do not have to initialize this information after you initially set the time or after it is obtained from the satellites. In addition, the receiver retains the almanac and last used satellite ephemeris as long as the backup power is applied. If you move the Oncore receiver a great distance before using it again, it will find and acquire satellites, but the TTFF will be longer than normal the first time you use the receiver. You can initialize the approximate position coordinates for faster TTFF if desired.

Each message in the I/O format description in Chapter 6 shows the default value for each parameter.

Shut Down

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

Keep Alive Power

If you disconnect the keep alive power (BATT power), then the real-time clock (RTC) and the battery backed RAM memory will be erased. In this scenario, date and time are lost and the Oncore receiver will enter the cold power-up state when power is reapplied. If the keep alive power is maintained during main power off, then the receiver will retain the last known position and time as well as the almanac, ephemeris, settings, and communications mode. If the receiver is turned on within four hours of power down, then a hot start condition may apply. Otherwise, a warm start condition will apply.

ROLLOVERS IN TIME

In August of 1999, the GPS week number will rollover from 1023 to 0 due to the limited length of the GPS week field in the navigation data stream. Motorola Oncore receivers (GT, UT, VP, XT, and Basic) have been designed and tested to properly distinguish the correct 20 year window (1024 weeks is just shy of 20 years). They will not need reprogramming or replacement come 1999. In fact, the transition will be completely transparent to users of Motorola Oncore GPS receivers. Motorola Oncore GPS receivers are also year 2000 compliant.

Multichannel GPS satellite simulators have been used to test each rollover condition in GPS. For example, each week there is a rollover in the GPS seconds on midnight Saturday. The August 1999, year 2000, leap day, and leap second rollovers have all been successfully tested using simulators.

In order to handle the 1999 rollover, Motorola GT and UT Oncore GPS receivers use a date stored in flash memory. For example, if the firmware date is 1998, a defaulted receiver that does not have back-up power (or battery) will start with an internal time of 12:00 on 1/1/98 and begin acquiring satellites. Once the first satellite is acquired, the time and week number will be downloaded from the navigation data message. The receiver determines the current date by starting from the week number of 1/1/98 (week 938) and searching for the first occurrence of the current week number (week 964 for 7/1/98).

RECEIVED CARRIER TO NOISE DENSITY RATIO (C/NO)

The **Position/Status/Data Message** outputs C/No, which can be used to determine the relative signal levels of received satellite signals (refer to Figure 3.11 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 plot in Figure 3.13 is linear. The satellite signal strength is measured at the antenna input. Typically, the C/No is between 30 and 55 dB.

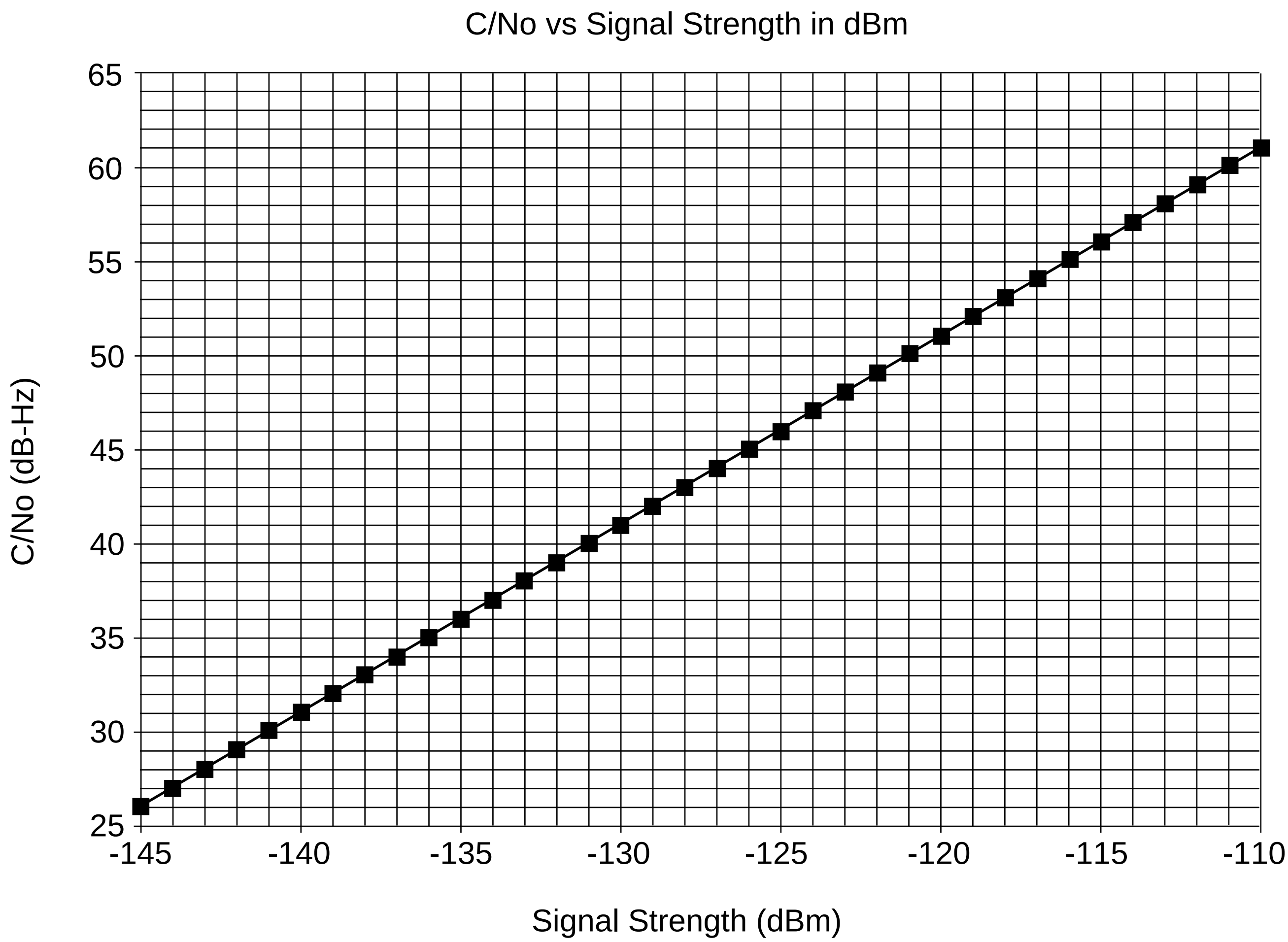


Figure 3.13

USING THE GT ONCORE IN DGPS MODE

The GT Oncore can be used in differential GPS (DGPS) mode for applications that require 1 - 5 meter accuracy. The GT Oncore uses corrections in the Motorola binary format or RTCM SC-104 Type 1 and Type 9 messages.

A VP Oncore GPS receiver must be used as a base station to generate corrections in the Motorola binary format; a GT Oncore cannot generate corrections. This section describes how to set up a differential system using a VP Oncore as a base and GT Oncore receivers as mobile units.

The VP Oncore should have firmware version 8.4 or newer in order to support all of the commands listed. The GT Oncore should have firmware version 1.6 or newer to support the Motorola binary differential mode.

VP Oncore Base Station Setup

In order to generate the best possible corrections, the VP Oncore must be put in position-hold mode with the known location of the antenna. The accuracy of the mobile receivers is limited by the accuracy of the known location. The following steps should be used:

1. Disable the ionospheric correction algorithm using the @@Aq command. Operating in differential mode will cancel out the ionospheric delay, whereas the ionospheric correction algorithm is not as effective.

2. Set the mask angle to 10 degrees using the @@Ag command. This will prevent the base station from tracking those satellites that are near the horizon, which tend to have the most error due to atmospheric delays and multipath.

3. Set the Satellite Selection Mode to Highest-In-The-Sky using the @@Ah command. This will cause the receiver to select the satellites that have the highest elevation angles, which are the satellites that will have the least amount of multipath. The GT Oncore always operates in the highest-in-sky mode. With the base and mobile receivers in the same mode, they will be most likely to select and track the same satellites.

4. Use the @@Ar command to set the receiver to N-In-View satellite selection, to disable the position filter, and to disable AFC tracking. This will force the receiver to use all possible satellites, disable the smoothing, and track with the phase-lock-loop only for the lowest receiver noise, respectively.

5. Set the correction threshold to 32 seconds using the @@AD command. This will require the receiver to track a satellite for 32 seconds before reporting a correction for that satellite. The delay will allow the carrier-aided-tracking filter to tighten up which reduces the receiver tracking noise to a minimum before sending out a correction.

6. Enter the position-hold position using the @@As command. The more accurate the position used is, the more accurate the corrected mobile fixes will be.
7. Enable the position-hold mode using the @@At command. This will force the receiver to solve for the satellite range errors rather than the receiver position.
8. Start the differential correction output using the @@Bh command. If more than six satellites are being tracked, then the response message @@Ce will be sent twice in order to output all of the corrections.

GT Oncore Mobile Setup

The GT Oncore must also be configured for optimum operation in differential mode, which is done as follows:

1. Initialize the receiver with date, time, position, and almanac if required. Entering these values may speed up the time to first fix (TTFF).
2. Disable the ionospheric correction algorithm using the @@Aq command. Operating in differential mode will cancel out the ionospheric delay, whereas the ionospheric correction algorithm is not as effective.
3. The GT Oncore is configured to accept the differential corrections using the @@Ce format. The corrections from the base station should be entered directly into the input port of the GT Oncore. The GT Oncore will automatically enter DGPS mode when enough corrections are available. If there are more than six satellite corrections, two of the messages will be required.

If the RAM is not backed up using a battery when the main power is down, the setup of the GT Oncore will not be retained. If this is the case, the ionospheric correction algorithm will be set to the default setting of on. For this reason, the ionospheric corrections should be disabled every time the unit is powered on if used in a differential system.

The GT Oncore receiver uses a position filter to smooth out the effects of constellation changes, multipath, receiver noise, and selective availability (SA). In differential mode, the position filter is disabled. Whenever the receiver switches from non-differential mode to differential mode, the position will ësnapí to the new position. When the receiver switches from differential mode to non-differential mode, the filter will make a smooth transition.

There are a few conditions that will cause the GT Oncore to compute a non-differential fix:

1. There are no differential corrections available.
2. The last differential corrections received are more than 90 seconds old.
3. There are three or fewer satellites being tracked that have corrections available.

One way of improving the differential performance in dense urban canyon areas is to send the satellite ephemeris information to the mobile units over the transmission link. This does not improve the accuracy of the DGPS solution; it only helps the mobile get started if it is subject to satellite blockage during startup. The base station can be used to output the satellite ephemerides on a regular basis. These ephemerides can be input to the GT Oncore using the @@Bf command. In this manner, the mobile will always have satellite ephemerides available. The GT Oncore will continue to download ephemerides from the satellites. The ephemerides in use will not change until the receiver decodes ephemerides with a new IODE number.

The GT Oncore will store up to eight satellite ephemerides in memory. It will only store the ephemerides that correspond to the satellites that are currently assigned to one of the eight tracking channels. When the GT Oncore is first powered on, the satellite assignments change frequently as the as the startup search algorithm is employed. For this reason, it may be best to hold off on inputting the satellite ephemerides until the receiver is in 2D or 3D fix mode and has a valid almanac. If the system is designed to send out the satellite ephemerides on a regular basis, then this is not an issue.