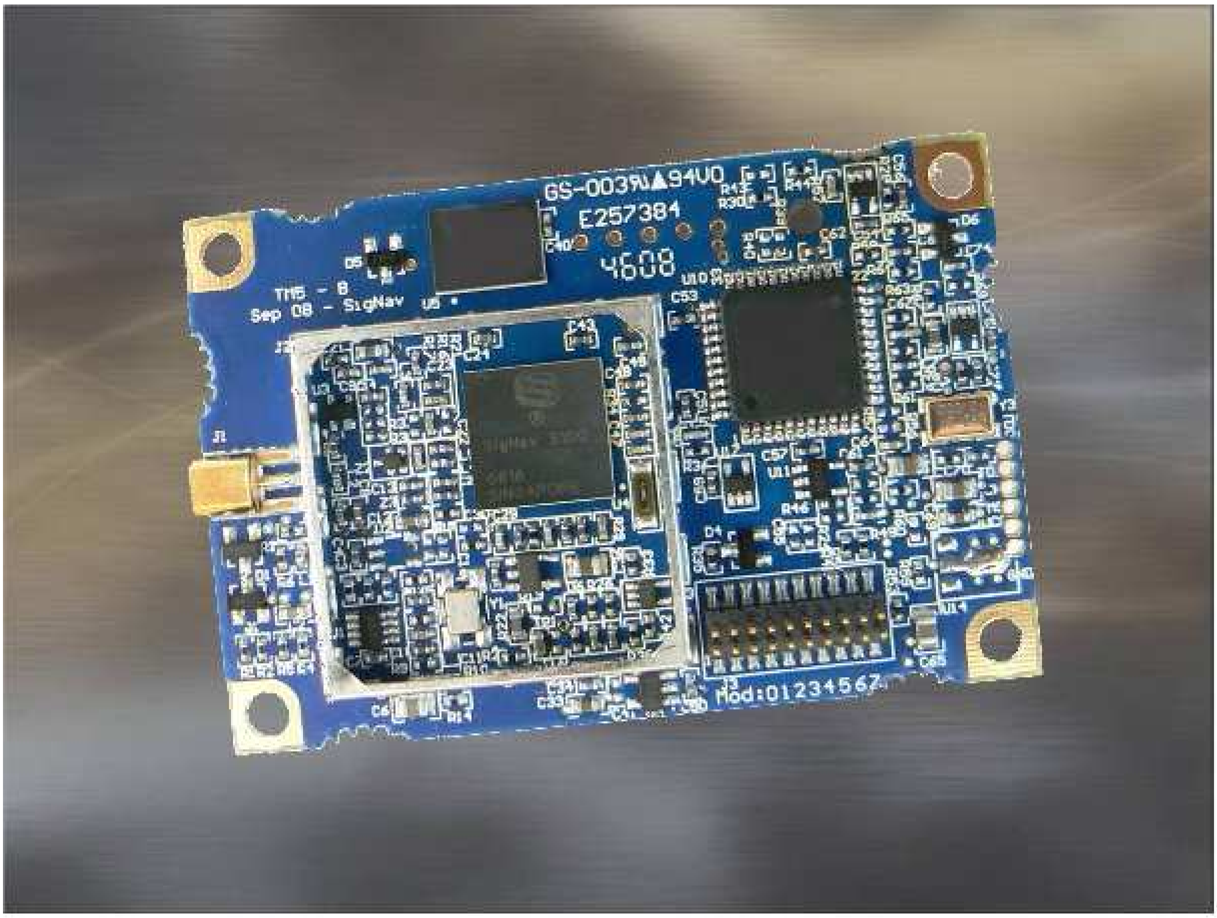

TM3-02EH Timing Module User Guide

TM3-0000-User Guide-V1.0
16th October 2009

Notice

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We reserve the right to change products, specifications, and installation data at any time, without notice.

This document describes SigNav's TM3-02EH Timing Module.

Trademarks

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Contents

About this manual

This manual is part of a documentation set that describes the features, performance, configuration, integration, operation and monitoring of the TM3-02EH Timing Module. The complete documentation set consists of:

TM3-02EH User Guide

This guide describes the mechanical and electrical characteristics of the modules as well as the supported features and performance, along with any specialised configuration protocols specific to the TM3-02EH.

Interface Control Document: NMEA Protocol

The Interface Control Document: NMEA Protocol describes the complete suite of standard NMEA messages supported by the TM3 along with any SigNav specific extensions.

Interface Control Document: Motorola Protocol

This document describes the Motorola M12 binary protocol implementation supported by SigNav's products for backward compatibility with M12+ and M12M applications.

Evaluation Unit User Guide

This guide describes the mechanical and electrical characteristics of a test system for the TM3-02EH. This unit is included in the TM3 Evaluation Unit forming an essential aid to developers incorporating the module into their systems. It empowers users to test the TM3's features and performance quickly and efficiently without the expense of developing a suitable test bed. The unit provides a complete evaluation environment.

Test Tool User Guide

The Test Tool provides the software interface for the TM3 Evaluation Unit. Amongst other things it can be used to:

- Monitor the GPS environment, displaying the number of visible satellites and signal strength,
- Provide Assistance under weak signal test conditions.

This guide is designed to minimise the time taken to set up an evaluation environment consisting of a TM3 Evaluation Unit and a TM-NMEA-EVAL AGPS Test Tool. The individual User Guides should be consulted for more in depth information.

Getting Started Guide

This guide is designed to minimise the time taken to set up an evaluation environment consisting of a TM3 Evaluation Unit and a TM-NMEA-EVAL AGPS Test Tool. The individual User Guides should be consulted for more in depth information.

TM3 Programming Tool

This document outlines the procedure to follow when upgrading the TM3-xxxx operating system.

To assist you to find the information you require the following overviews are provided for each major section of the manual:

Chapter 1: Introduction
This chapter provides an introduction to the terms and conventions used throughout this manual along with an overview the TM3 system architecture and a description of the features and functions of the product variants in the TM3 range.

Chapter 2: Features and Specifications
Chapter 2 provides an in depth specifications of the physical, electrical, operational and environmental performance of the TM3-02EH.

Chapter 3: Protocols
This chapter provides a brief outline of the command and control protocols supported by the TM3-02EH. Please refer to the Interface Control Document: NMEA Protocol and Interface Control Document: Motorola Protocol for detailed descriptions

Chapter 4: Operation and Systems Integration
Chapter 4 contains useful tips for integrating the TM3-02EH into a target system along with installation and handling procedures.

Appendices
These contain supplementary information that may be of use to a system designer, such as conversions between the various units used to measure GPS signal strengths, the product's warranty and a glossary of terms.

1 Introduction

1.1 Precision, Timing, Synchronisation & Clocking

GPS satellite clocks are calibrated to GPS Time which, in turn, is synchronised with the Universal Time Coordinated (UTC) to an accuracy of 50 nanoseconds by the US Naval Observatory (USNO). Satellite "timing" is used in a number of applications across a broad range of industries, many of which can be addressed by SigNav's GPS timing modules. Current GPS timing applications include:

Communications

- Conventional 2G, 2.5G and 3G mobile telecommunications networks at BSC or MSC level
- Emergent mobile femtocell applications
- Digital paging systems
- Wireless Local Loop (WLL) and Local Multipoint Distribution System (LMDS)
- Mobile Radio
- ATM/SDH/SONET networks
- Optical Transport Networks (e.g. DWDM)
- Mobile emergency location services (E911) until GPS-aided handsets are available

Power

- Synchronisation of power distribution equipment
- Location of power line faults

TV and Radio Broadcasting

- Synchronisation such as simulcasts or "syndicated" transmissions

Information Technology

- Network Time Protocol (NTP) Servers synchronise TCP/IP networks to UTC
- Database synchronisation

Financial

- Precise, UTC-traceable time stamping of e-business/e-commerce transactions and email

1.2 The TM3 Product Family

This manual predominately pertains to the TM3-02EH. The TM3-02EH is the only currently supported member of the TM3 family. Its predecessors are the TM3-01 and TM3-02.

1.2.1 TM3-02EH

The TM3-02EH is intended to be functionally, mechanically and electrically interchangeable with Motorola's M12+ and M12M timing modules. Exhibit 1 provides an overview of the TM3-02EH's I/O functions.

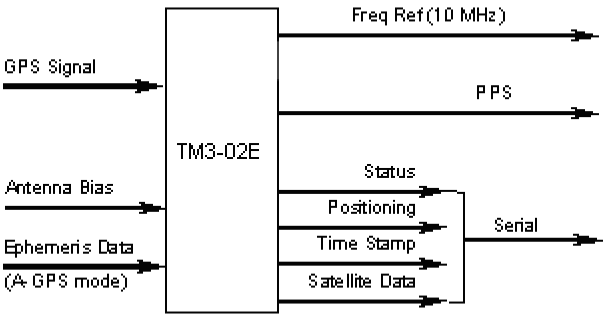


Exhibit 1 TM3-01 Functional Overview

For compatibility with the vast majority of M12+/M12M applications, the TM3-02EH implements the essential subset of Motorola's features and functions. Specifically optimised for timing applications, the TM3-02EH supports T-RAIM, Position Hold, Self Survey and Antenna/Cable Delay Compensation. Start up and extraction of synchronisation, or timing, can be achieved with signal strengths down to -142 dBm. Enhancements to Motorola's capabilities include:

Quantisation (a.k.a. Sawtooth) Error Elimination
The TM3 supports Sawtooth Error Elimination rather than Motorola's Sawtooth Error Correction. Sawtooth Errors occur in conventional GPS Timing receivers as a result of the fact that the system clock driving the GPS receiver is asynchronous with GPS time. In the Motorola M12 receiver this error was estimated and provided to the user via one of the binary messages in the Motorola Binary Protocol. It was then up to the user to make use of this knowledge but the error was still present in the 1PPS pulse synchronization to GPS time. In contrast, the TM3 system clock is precisely aligned to GPS time so that the sawtooth error is eliminated and is not present in the alignment of the PPS pulse to GPS time.

Flash Memory
The TM3 series employ flash memory relieving the need for a battery back-up facility. Firmware, configurations and operational data are held indefinitely without the need for a power source. Flash memory also enables the TM3 series to be easily upgraded in the field to support the latest version of code. Upgrading a ROM based product would be a significantly more difficult task requiring a physical rework of the module.

Ultra Stable Reference Oscillator Outputs
To further enhance the TM3-02EH functionality, a 10 MHz disciplined oscillator output is available for off-board use within the target system's circuitry. The 10 MHz output exhibits exceptionally low phase noise and spurious component levels. It could, for example, be used to drive synthesizers in wireless communications equipment. This reference oscillator output is not only exceptionally stable but also phase locked to the GPS or UTC second. The design shall be flexible to enable other "custom" frequencies to be supplied on request.

***sub*ATTO - Advanced Ambiguity Resolution**

SigNav's unique patented scheme allows timing to be obtained from only one weak signal satellite when position is known to within 3km or 4 weak satellites ***even when no position assistance is provided***. This is achieved using an interlocking suite of signal processing algorithms. SigNav's competitors are unable to produce timing under the same conditions. This is an enormous advantage in applications where it is difficult or impossible to provide accurate assistance.

SigNav's unique scheme enables its products to operate in harsher indoor environments than its competitors, allowing equipment incorporating our products to be deployed deeper within buildings, in more buildings, more reliably and in a wider range of environments as depicted in Exhibit 2.

Extended Holdover

The TM3-02EH also provides Extended Holdover. In order to achieve this, SigNav has employed the SigNav S100 receiver chip, new oscillator circuitry and sophisticated new oscillator control algorithms to further enhance the inherent stability.

Terms and Conventions

The following Terms and Conventions are used in this specification.

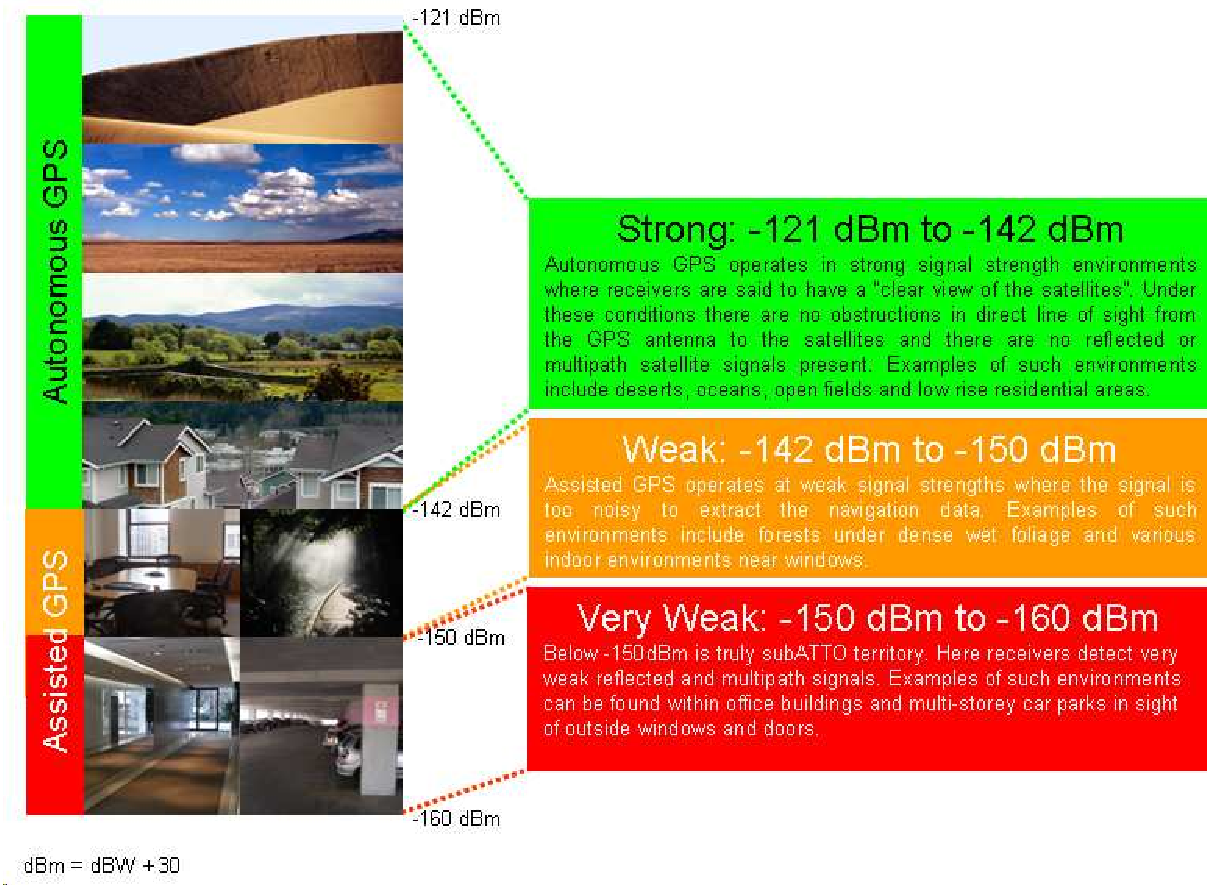
1.2.2 Product Nomenclature

TM3	This generic term refers to the TM3-01, TM3-02 or TM3-02EH.
TM3-01	Refers specifically to the TM3-01
TM3-02	Refers specifically to the TM3-02
TM3-02EH	Refers specifically to the TM3-02EH

1.2.3 GPS Satellite Signal Strengths

1.2.3.1 Strong, Weak or Very Weak Signals

Throughout this specification we refer to the behaviour of the module in the presence of satellites with various signal strengths. For simplicity, these are categorised as **strong**, **weak** or **very weak**. Each of these terms is defined in the next Exhibit.



Notes:

1. *The peak signal strength available from a strong satellite in ideal conditions is approximately -121 dBm.*
2. *Clear access to satellites refers to the GPS antenna having a full half hemisphere view of the sky without any obstructions by trees, buildings and such things that may attenuate or reflect the GPS signals.*

Exhibit 2 Satellite Signal Strength Definitions

1.2.3.2 Units of Measure

The GPS industry uses several units to measure satellite signal strength: dBW, dBm and dB.Hz. The latter, dB.Hz is the carrier to noise ratio as reported by the receiver. SigNav has standardised on the use of dBm.

1.3 TM3 System Architecture

The TM3's architecture is illustrated in the block diagram format in the following Exhibit.

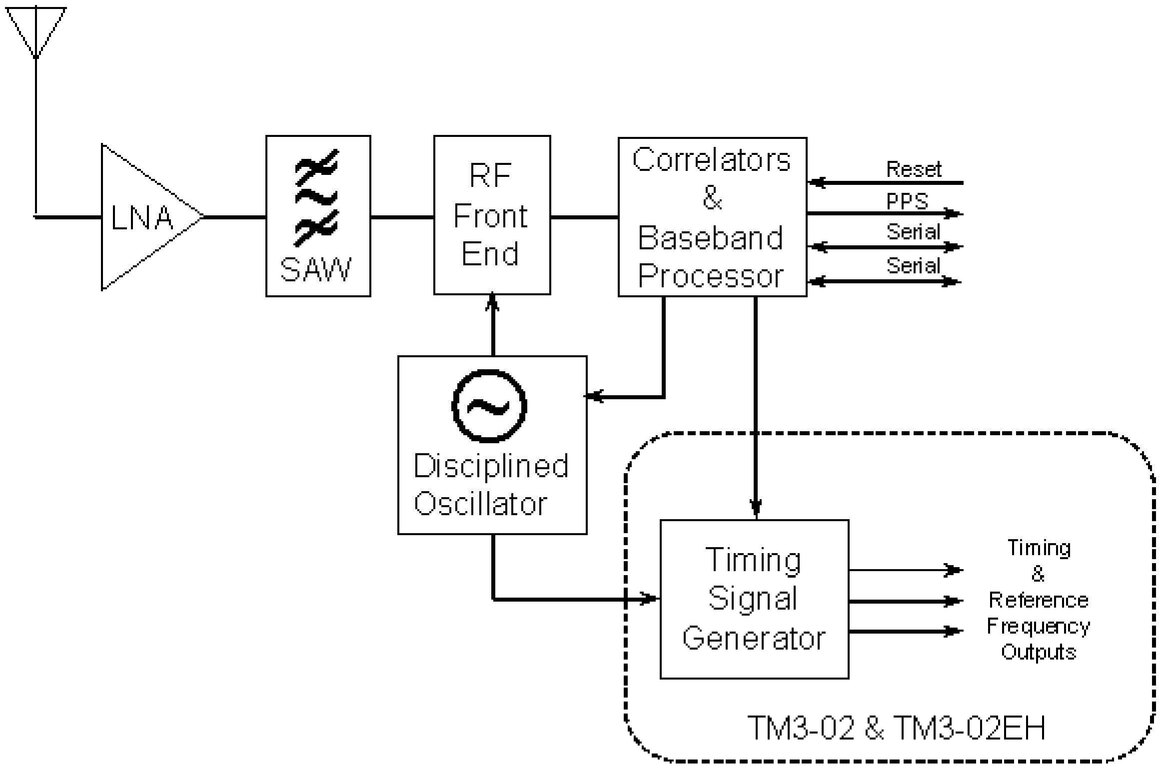


Exhibit 3 TM3 Block Diagram

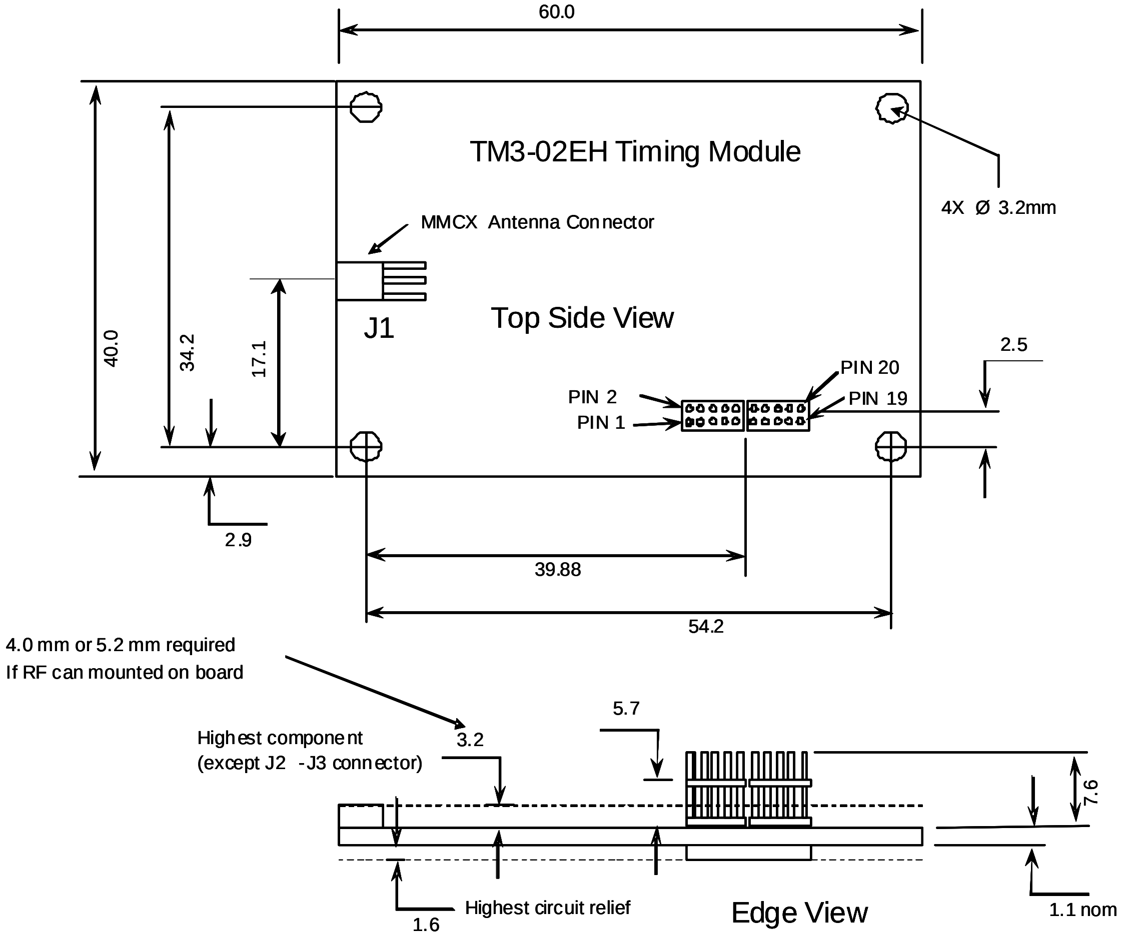
The flexible design of the Timing Signal Generator provides for easy customisation of the timing and frequency outputs. For the TM3-02EH these outputs are fixed as described in this document.

2 Features and Specifications

2.1 Physical Specification

2.1.1 Module Dimensions

The following Exhibit illustrates the general physical attributes of the TM3 -02EH timing module. It depicts a TM3-02EH equipped with a 20 pin header/socket. All dimensions are in millimetres.



Notes:

1. *All components including connectors reside on a single side of the printed circuit board as shown in the plan view of the Exhibit. This is referred to as the top side of the board.*
2. *The component height does not exceed 3.2 mm (or 5.7 mm if an RF can (if fitted) above the top side of the board.*
3. *A clearance of 1.6 mm is required below the board.*
4. *J1 is a snap fit MMCX socket. The antenna lead accesses the socket on a plane parallel to the printed circuit board.*
5. *The 20 pin connector can accommodate 1.27 mm pitch pins headers. The total pin height from the top of the board is 7.6 mm.*

Exhibit 4 TM3-02EH Mechanical Drawing

2.1.2 Mounting Methods

The TM3's uses combined header/socket connectors which enable it to be mounted in one of two ways.

Scenario 1

The pins of the TM3's header are mated with a socket on the target system's motherboard. The TM3's "component side" facing the target system's motherboard (see Mounting Scenario 1 Exhibit 5).

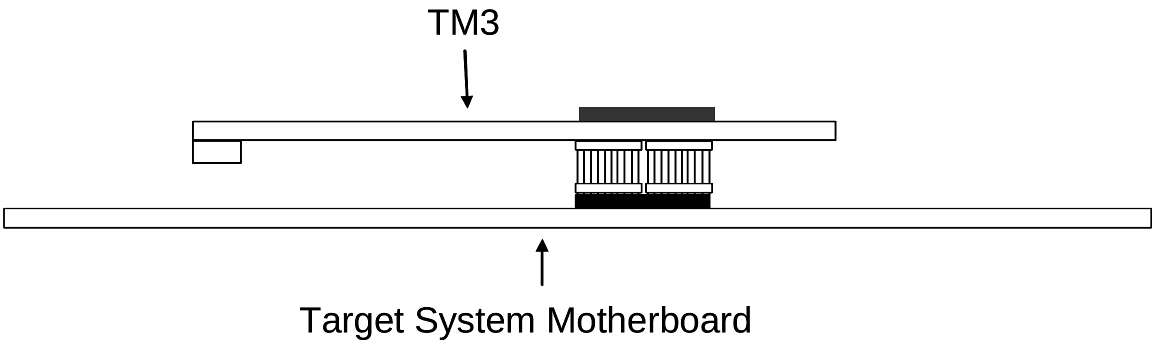


Exhibit 5 Mounting Scenario 1

Scenario 2

Pins on the target system's motherboard are mated the TM3's socket on the "underside" or "non- component side". In this scenario the TM3's non-component side is facing the motherboard (see Exhibit 6 Mounting Scenario 2)

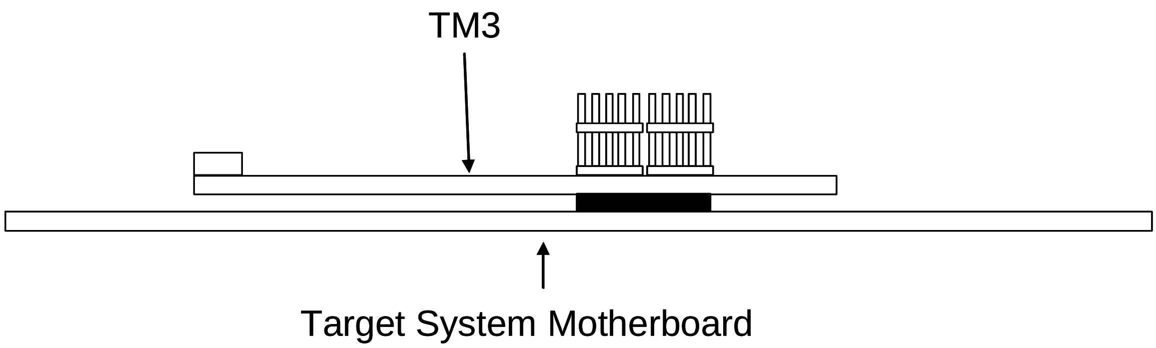


Exhibit 6 Mounting Scenario 2

2.1.3 Connectors

The header on the component side of the TM3 is physically compatible with Samtec's FW-10-03-G-D-225-074-A whilst the socket on the underside is physically compatible with their CLP-110-02-G-D-A. These part numbers are provided are provided for reference only and do not constitute a recommendation for use.

2.1.4 Module Weight

The TM3-02EH weighs 12g.

2.2 Electrical Specification

2.2.1 Module pin outs and signal functions

2.2.1.1 Connector pin outs

The definitions of the signals provided on the header of the Timing Module are shown in the following Exhibit.

Pin	Name	Signal Type	Voltage Level	Signal Description Summary
1	Freq Ref	Output	3 volt	10 MHz reference frequency output
2	Ground	Ground	0 volt	Power supply and signal reference, ground
3	Spare			Reserved for future use
4	Spare			Reserved for future use
5	Spare			Reserved for future use
6	Status 1	Output	3 volt	Status pin, used to indicate loss of lock
7	Status 2	Output	3 volt	Status pin, used to indicate within tolerance
8	Spare			Reserved for future use
9	Spare			Reserved for future use
10	Spare			Reserved for future use
11	Tx1	Output	3 volt	Serial data, UART1 transmit (out of timing module)
12	Rx1	Input	3 volt	Serial data, UART1 receive (into timing module)
13	+3V PWR	Supply	3 volt	Power supply input, 3 volt regulated
14	PPS	Output	3 volt	1PPS Output
15	Ground	Ground	0 volt	Power supply and signal reference, ground
16	Spare			Reserved for future use
17	$\overline{\text{ProgSelect}}$	Input	3 volt	Boot select pin, used for in-field programming
18	Spare			Reserved for future use
19	Vant-in	Supply	2.7 to 5.5 V	Supply for active antenna
20	$\overline{\text{Reset}}$	Input	3 volt	Reset pin. Also used only for in field programming

Notes:
1. Spare pins must be left open circuit.

Exhibit 7 TM3-02EH Connector Pin Out

Further information about the functions and use of each of the TM3-02EH's pins is provided in the following Exhibits.

2.2.1.2 Power supply and power control

Name	Connector Pin	Description
+ 3V PWR	13	Regulated supply voltage. Regulation to lower voltages is provided on the module.
Ground	15	Power supply return. Also connected to pin 2.
Ground	2	Power supply return. Also connected to pin 15.
Vant-in	19	Required antenna supply (2.7 V to 5.5 V).

Exhibit 8 Power supply and power control

2.2.1.3 Serial communications

Name	Connector Pin	Description
Rx1	12	This is used for the provision of a serial data stream into the Timing Module. This is a logic level signal with high representing a logical '1' and low a '0'. Start bit low, 8 data bits, stop bit high, no parity, bit rates are for Motorola 9600k and NMEA 115.2k
Tx1	11	Delivers the serial data stream from the Timing Module. This is a logic level signal with high representing a logical '1' and low a '0'. Start bit high, 8 data bits, stop bit low, bit rates as for Rx1.

Exhibit 9 Serial communications

2.2.1.4 Timing reference outputs

Name	Connector Pin	Description
PPS	14	1PPS Pulse width: The positive going pulse is set to a width of 200 ms.
Freq Ref	1	Presents a 10 MHz edge rate controlled LV-TTL wave.

Exhibit 10 Timing reference outputs

2.2.1.5 10 MHz, PPS and Timing Reference Alignment Relationships

In Mode 1 the alignment relationship between 10 MHz, PPS and the Timing Reference (either GPS or UTC second) is depicted in the following Exhibit. In this mode the rising edge of the PPS signal can be used as the sync source, which is conventional usage.

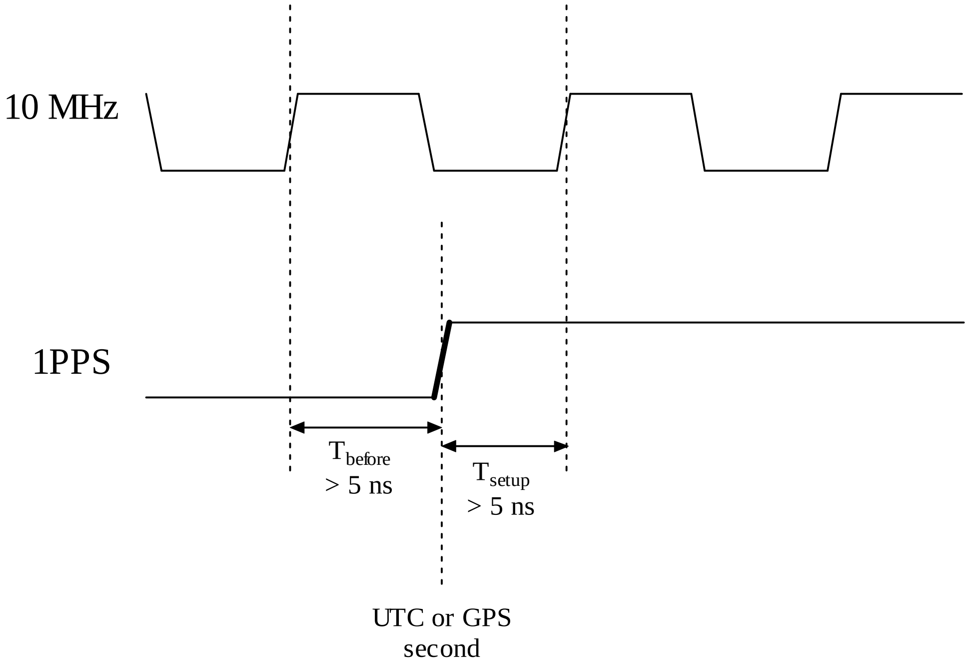
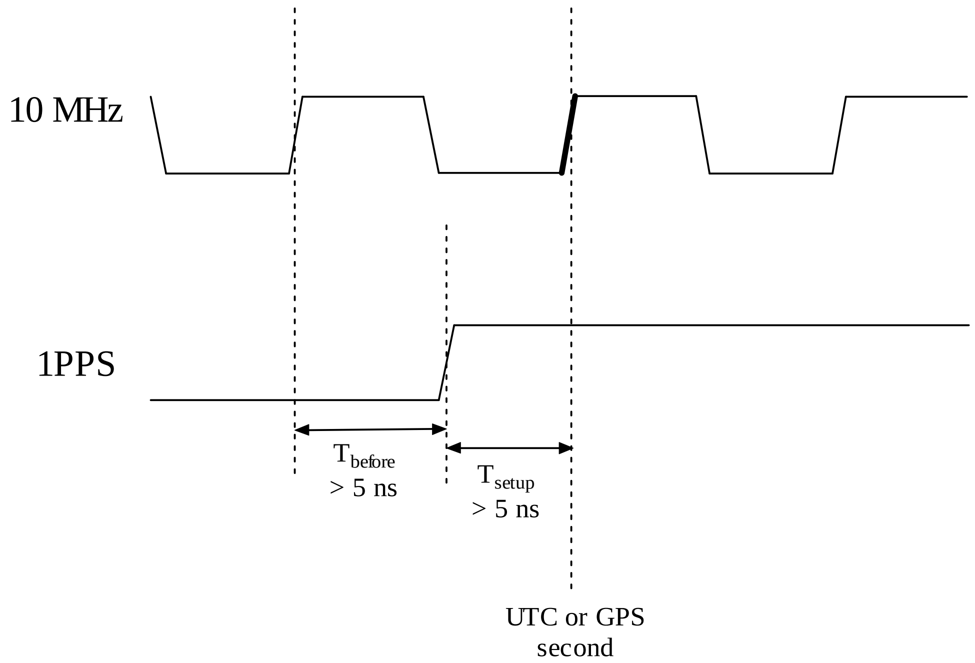


Exhibit 11 Alignment Relationship Mode 1



In Mode 2 (NMEA only) the alignment relationship between PPS, 10 MHz and the Timing Reference (either GPS or UTC second) is depicted in the following Exhibit. In this mode the rising edge of the PPS signal can be used to notify the host system that the next rising edge of the 10 MHz is to be used as the sync source.

Exhibit 12 Alignment Relationship Mode 2

2.2.1.6 In-field programming of GPS firmware

Name	Connector Pin	Description
$\overline{\text{ProgSelect}}$	17	This pin is set low to reprogram the onboard flash with a new version of the GPS firmware and held high during normal operation.
$\overline{\text{Reset}}$	20	This input is pulled low to initiate the programming cycle. As it is equipped with on-board pull up, it may be held high or left open circuit in normal operation.

Exhibit 13 In-field programming of GPS firmware

The TM3-02EH also supports an in-field upgrade mechanism that can be done entirely over the serial port without the need to toggle any pins directly. See run-time reprogramming in the NMEA documentation.

2.2.1.7 Spare or unused pins

Name	Connector Pin	Description
Spare	3,4,5,8,9,10,16,18	These pins are currently unused by the GPS firmware. It is strongly recommended that these be left open circuit so as not to cause a conflict with future versions of firmware.

Exhibit 14 Spare or unused pins

2.2.1.8 Status indicators

Name	Connector Pin	Description
Status1	6	Status1 provides a “Loss of Lock” indication. This signal is de-asserted (going low) after satellites are being tracked. The signal is re-asserted only when all satellites lose tracking.
Status2	7	Provides a “Within tolerance” indication. The signal is asserted when the firmware assesses that accurate GPS timing is achieved after satellites have been acquired and tracked. This indicates that the timing signals adhere to their specification. After loss of lock the signal is de-asserted (goes low).

Exhibit 15 Status Indicators

2.2.2 Power Consumption

State	Current	Voltage	Power	Condition
Typical Operation	66 mA	3 V	200 mW	During satellite tracking and time fixing
Max Consumption	100 mA	3 V	300 mW	Whilst actively acquiring satellites

Exhibit 16 Power Consumption

2.2.3 Signal electrical and timing properties

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Supply voltage	V_{DD}		2.85	3.0	3.15	V
Max Supply Ripple		1 Hz to 1 MHz			50	mV p-p
Output high voltage for pins, Status1, Status2 and Tx1	V_{OH}	I_{OH} = -1 mA, V_{IN}=3.0V	2.3		2.8	V
Output high voltage for pins PPS, FreqRef, Timing Output 1		I_{OH} = -8 mA, V_{IN}=3.0V	V_{IN} - 0.4			V
Output low voltage for pins, Status1, Status2 and Tx1	V_{OL}	I_{OL} = +1 mA , V_{IN}=3.0V	GND	0.2	0.45	V
Output low voltage for pins PPS, FreqRef, Timing Output 1		I_{OL} = +8 mA, V_{IN}=3.0V			0.4	V
Input leakage current	I_{IL}		-10.0	+/- 1	+10.0	µA
Input voltage range	V_{IN}	V_{IN} = 3.0 V	-0.3		V_{IN} + 0.3	V
Input high voltage	V_{IH}	V_{IN} = 3.0 V	0.7 x V_{IN}		V_{IN} + 0.3	V
Input low voltage	V_{IL}	V_{IN} = 3.0 V	-0.3		0.3 x V_{IN}	V
Input pin capacitance	C_{IN}	into 20 pF in parallel with 10 kΩ			10	pF
Output load capacitance	C_L				20	pF
PPS Period				1		s
PPS Pulse Width	t_{PULSE}			200		ms
Freq Ref Duty Cycle	t_{DUTY}		40	50	60	%
Freq Ref				10		MHz
Rise time all signals	t_{RISE}	12 pF load			12	ns
Fall time all signals	t_{FALL}	12 pF load			12	ns

Exhibit 17 TM3-02EH signal electrical and timing characteristics

2.3 GPS Features and Performance

2.3.1 GPS Receiver

The TM3 is an L1 (1575.42 MHz) GPS receiver. It incorporates a search engine for satellite acquisition. When a GPS signal is found, the code phase and frequency values are used to initialise one of the twelve tracking channels. Tracking twelve satellites simultaneously permits the smooth transition between satellites when they fall below the mask angle or are obscured from view.

2.3.2 Antenna

A TM3 operates with an active antenna, fixed or portable. Typical parameters for a suitable portable, active antenna can be found in the following Exhibit.

Antenna	
Frequency	1575.42 ± 2 MHz
VSWR	1.5 Max
Bandwidth	4 MHz Min
Axial Ratio	3 dB Typical
Impedance	50Ω
Peak Gain	4 dBic Min
Gain Coverage	> -4dBic at -90°~ 90° (over 75% volume)
DC Voltage	3 V
Polarization	RHCP

Amplifier Module	
Amplifier Gain without cable	27 dB Typical
Noise Figure	< 2.0 dB
Filtering	-25 dB (+100MHz)
Output VSWR	2.0 Max

Exhibit 18 Typical portable antenna characteristics

2.3.3 Antenna Sense

Suitable antennae can extract a power feed from the MMCX connector. The operating current ranges are displayed in the following exhibit. Antenna sense circuitry is used to detect and report normal operation, under current and over current conditions as well as the absence of an antenna bias voltage.

Parameter	Condition	Current
Operating Current Range	~3 V ≤ Vant-in ≤ ~5 V	5 to 80 mA
Under Current Condition	Vant-in ≈ 3V	< 3 mA ± 2.5 mA
	Vant-in ≈ 5V	< 5 mA ±2.5 mA
Over Current Condition	Vant-in ≈ 3V	> 50 mA ± 5 mA
	Vant-in ≈ 5V	> 85 mA ± 5 mA

Exhibit 19 Typical antenna current

Note: Where the antenna is capable of dual voltage and the cable length is long, consideration should be given to setting the antenna voltage to 5 V to compensate for the cable voltage drop.

2.3.4 External GPS L1 Signal Gain Required

The TM3 has been designed to operate with external active antenna and cabling that results in a net gain in the range 16 to 36 dB at the MMCX connector.

2.3.5 Acquisition Sensitivity

Parameter	Signal Strength
Acquisition Sensitivity	-155 dBm

Exhibit 20 TM3-02EH Acquisition Sensitivity

2.3.6 Time to First Fix

Time To First Fix or TTFF is the period between power up and the establishment of a position fix of sufficient accuracy to support the specified timing accuracies and not just the first geographic position fix of 300 metres.

Parameter	Signal Strength	TTFF (50%)	TTFF (90%)	Conditions
Cold Start TTFF	>-142 dBm	60 s	110 s	Clear access to satellites, no multipath, no initial position, no initial time estimate, almanac unavailable, ephemeris unavailable, tcxo error < 2.5 ppm,
Warm Start TTFF	>-142 dBm	60 s	100 s	Clear access to satellites, no multipath, initial position error ≤ 100 km, minimal initial time estimate, almanac ≤ 1 month old, ephemeris unavailable, tcxo error < 2.5 ppm,
Hot Start TTFF	>-142 dBm	32 s	45 s	Clear access to satellites, no multipath, initial position error ≤ 100 km, minimal initial time estimate, almanac ≤ 1 month old, ephemeris < 2 hrs old, tcxo error < 0.1 ppm
Hot Start TTFF	-142 dBm to -157 dBm	100 s	180 s	A spread of satellite signals strengths from -142 dBm to -157 dBm, no multipath, initial position error ≤ 1.5 km, initial time error ≤ 2 s, ephemeris < 2hrs old provided

Notes:

1. *Clear access to satellites refers to the GPS antenna having a full half hemisphere view of the sky without any obstructions by trees, buildings and such things that may attenuate or reflect the GPS signals. No TM3 movement*
2. *The TTFF specified will be achieved with a 90% probability*
3. *Assissted Hot Start TTFF Pertains to NMEA protocol.*

Exhibit 21 Time To First Fix with 90% probability

2.3.7 Reacquisition Time

Parameter	Typical 50 %	Typical 90 %
After 15 s obstruction	3.0 s	5 s
After 30 minute obstruction	30 s	70 s

Notes:

1. *For signal strengths > -142 dBm.*

Exhibit 22 Reacquisition Time

2.3.8 Time To Lock

Time To Lock or TTL is the period between power up and the establishment of time lock at the specified timing accuracies. When the uncertainty in the initial position is small enough to support the user-specified timing accuracy requirement, only a single satellite is needed to establish time lock. However, in all other cases, a position fix must precede time lock. When weak signals are used, time is taken up in resolving the millisecond ambiguities before time lock can be established.

Exhibit 23 summarises the TTL performance. The first four rows of the table under the headings give the autonomous performance and the remaining six rows deal with assisted operation. The ambiguity resolution algorithms operate differently depending on the position uncertainty and this gives rise to the last 3 rows of the table.

Assisted	Parameter	Signal Strength	TTL 50%	TTL 90%	Initial Position Uncertainty	Conditions
No	Cold Start TTL	>-142 dBm	75 s	125 s	N/A	Clear access to satellites, minimal multipath, no initial time, estimate, almanac unavailable, ephemeris unavailable, tcxo error < 2.5 ppm,
No	Warm Start TTL	>-142 dBm	75 s	120 s	< 100 km	Clear access to satellites, minimal multipath, no initial time estimate, almanac ≤ 1 month old ephemeris unavailable, tcxo error < 2.5 ppm,
No	Hot Start TTL	>-142 dBm	50 s	65 s	≤1,500 km	Clear access to satellites, minimal multipath, no initial time estimate, almanac ≤ 1 month old ephemeris < 2 hrs old, tcxo error < 0.1 ppm

Notes:

1. *Clear access to satellites refers to the GPS antenna having a full half hemisphere view of the sky without any obstructions by trees, buildings and such things that may attenuate or reflect the GPS signals.*
2. *TTL is referenced to the time before which all assistance is provided*

Exhibit 23 Time To Lock

2.3.9 Extended Holdover Features

Parameter	Value
Holdover Period	5 minutes
Frequency Stability	20 ppb
Synchronization Accuracy:	1 µs
Max Temperature Rate	24 ℃/Hour
Temperature Range	0 ℃ to 60 ℃
GPS Signal Conditions	Strong

Exhibit 24 Holdover parameters

2.3.10 Datum

WGS-84[1] datum is supported.

2.3.11 Position Accuracy

Position Wander is defined as the magnitude of the horizontal distance between each position fix and the mean of the position fixes. The Position Wander performance is defined under the following conditions:

- Live GPS satellite signals > -142 dBm;
- Clear view of the sky;
- No TM3-02EH movement;
- Minimal multi-path.
- Mask Angle configured using the default value of 10°.

Position Accuracy is defined as the accuracy of the self survey position relative to the true position under the following conditions:

- Live GPS satellite signals greater than or equal to -142 dBm;
- Clear view of the sky;
- No TM3-02EH movement;
- Minimal multi-path.
- TM3-EH permitted to complete a position self survey.
- Mask Angle configured using the default value of 10º.

Parameter	50%	90%
Horizontal Position Wander	2.25 m	4.5 m
Vertical Position Wander	3.5 m	8 m
Horizontal Position Accuracy after 10,000 fix self survey	-	2.5 m
Vertical Position Accuracy after 10,000 fix self survey	-	10 m

Exhibit 25 Position Accuracy

[1] *World Geodetic System of 1984*

2.3.12 Assisted GPS

The TM3-02EH supports a SigNav proprietary Assisted GPS scheme for NMEA protocol.

To operate in weak and very weak signal environments, from -142 dBm to -157 dBm the TM3-02EH needs to be supplied with assistance data to compensate for the inability to extract the navigation message at these signal strengths. Assistance can be provided to the TM3 using various “out of band” schemes. These range from web based servers delivering assistance over the internet to data packet delivery over the mobile phone network.

The assistance data provided along with its error or validity is shown in the following Exhibit.

Assistance Data	Error/Validity
Time	Error < ±2 sec
Position	Error < ± 3000 m
Almanac	1 month valid
Almanac Health	1 month valid
UTC data	1 month valid
Ionosphere data	1 month valid
Ephemeris	2 hour valid

Exhibit 26 Assistance Data

2.3.13 GPS Timing Features

To provide superior GPS timing performance, the TM3 offers specialised features and modes of operation.

Position Hold Mode. In this mode the position estimate is not allowed to change, permitting the timing to be estimated with a single satellite in view. Normally, the receiver would solve for position and time using 4 or more satellites. The TM3 enters this mode after averaging 2D or 3D position fixes for a user defined period. After 10,000 position fixes the resulting accuracy in 2D is 2.5m (95%) and in 3D is 20m (95%).

Self-Survey Mode. Prior to entering the Position Hold Mode, the receiver averages its own position estimates over a user-configurable period. Adjustment of this period enables a user to determine the accuracy of the position used to estimate time as well as the time taken for the TM3 to synchronise. The averaged position is only used once the survey is complete.

Advanced Ambiguity Resolution - Single, Weak Satellite Signal Timing. This is a special case of the Position Hold Mode, whereby the TM3-02EH is able to start and synchronise (or extract timing) with only one satellite in view. This relies on having initial position accurate to a few kilometres depending on the timing accuracy required. The TM3-02EH is unique in that the single available signal may even be below data extraction level (i.e. -142 dBm < signal strength < -157 dBm) as long as suitable assistance is provided.

Advanced Ambiguity Resolution - Multiple Weak Satellite Signal Timing. TM3-02EH also incorporates a unique mode in which it is able to start and synchronize with 4 or more weak satellite signals (and no strong signals) even when the initial position is not known.

Time-specific Receiver Autonomous Integrity Monitoring (T-RAIM). T-RAIM is used to reject erroneous satellite measurements or data that might adversely affect the accuracy of the TM3. Satellite clock bias measurements are used to monitor satellite health and identify problems without relying on the speed of satellite health updates. The algorithm employed identifies satellites exhibiting clock bias deviations by examining error differences between individual satellites and mean/median values over time. The algorithm allows unhealthy satellites to be excluded from the solution and quarantined for a period of time before being re-evaluated.

Antenna Calibration. This facility enables the user to compensate for the latency introduced by the antenna, the antenna cable run and the module's RF front-end components.

Quantisation (also known as Sawtooth) Error Elimination. The TM3 supports Sawtooth Error Elimination rather than Motorola's Sawtooth Error Correction. The Sawtooth Errors in conventional GPS 1PPS outputs occur as a result of the fact that the GPS receiver's system clock to which the 1PPS output is necessarily aligned is asynchronous with GPS time. In the Motorola M12 receiver this error was estimated and provided to the user via one of the messages in the Motorola Binary Protocol. It was then up to the user to make use of this knowledge but the error was still present in the alignment of the 1PPS pulse to GPS time. In contrast, the TM3 system clock is precisely aligned to GPS time so that the sawtooth error is completely eliminated from the PPS signal.

2.4 Timing Specifications

This section provides the specifications for each of the timing parameters associated with the TM3-02EH.

2.4.1 Output Timing Relationships

The following Exhibit illustrates the timing relationships between the UTC second and the PPS output.

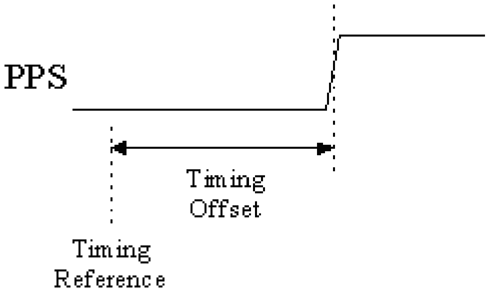


Exhibit 27 UTC Second and PPS timing relationship

Timing Offset is defined as the time difference between the UTC or GPS Second and the rising edge of the PPS output. This is programmable in the range +999,999,999 to -999,999,999 ns with a default setting of 0 ns. By convention the greater the positive value, the further to the right the PPS output occurs.

The Freq Ref output of the TM3 is phased locked to PPS.

2.4.2 Position Derived PPS Error

Any position error will result in timing biases that will change depending on the directions to the satellites whose signals are used for the timing measurements. The size of this position-derived bias error will be no more than 1 us for every 300 m of position error. Thus a 10 m error will contribute biases of less than 33 ns. The position derived bias error will generally be much less than this upper limit especially when several satellites are used.

With clear access to satellites and minimal multipath, the position error without averaging is less than 4 m 2DRMS. This means that 95% of the time the horizontal error will be less than 4 m. The vertical error is less than 4 m RMS which means that 67% of the time the vertical error will be less than 4 m. After averaging the total 3D error will typically be very much less than this depending on the averaging interval. Overall the error under these conditions should be well under 1 m giving rise to position-derived bias error of around 3 ns or less.

Under conditions of obscuration and multipath, the position-derived bias error will be much more significant. Under extreme conditions, errors of 300 m or more can be expected prior to averaging. Under these conditions, an averaging period of 24 hours should be used if possible since the errors occur in a diurnal pattern associated with the movements of the satellites in the sky. After averaging the position-derived bias error can be expected to be much less than 1 us.

2.4.3 Reference Frequency Deviation

The maximum deviation of the TM3-02EH's reference frequency is provided in the following Exhibit.

Deviation	Signal Strength	Comments
10 ppb	>-142 dBm	Clear access to satellites, no multipath and while "Within Tolerance" status is active.
30 ppb	-142 dBm to -157 dBm	Uniform spread of satellite signals in range -142 dBm to -157 dBm, no multipath and while "Within Tolerance" status is active.

Notes:

1. *"ppb" means "parts per billion" that is the value shown multiplied by 10^{-9}*
2. *Clear access to satellites refers to the GPS antenna having a full half hemisphere view of the sky without any obstructions by trees, buildings and such things that may attenuate or reflect the GPS signals.*

Exhibit 28 Reference Frequency Deviation

2.4.4 Reference Frequency Jitter

Jitter	Signal Strength	Comments
± 0.3 µs	>-142 dBm	Clear access to satellites, no multipath. This figure includes Jitter of both Ref Freq relative to PPS time and PPS relative to GPS second.
± 2 µs	-142 dBm to -157 dBm	Uniform spread of satellite signals in range -142 dBm to -157 dBm, no multipath, figure includes Jitter of both Ref Freq relative to PPS time and PPS relative to GPS second.

Notes:

1. *Clear access to satellites refers to the GPS antenna having a full half hemisphere view of the sky without any obstructions by trees, buildings and such things that may attenuate or reflect the GPS signals.*
2. *Valid while in tolerance flag is asserted.*

Exhibit 29 Reference Freq Jitter

2.5 Frequency Reference Stability and Purity

The Allan variance/deviation of the Frequency References is specified to be with the envelope defined in the following Exhibit along with the Maximum Time Interval Error (MTIE).

Parameter	Value
Allan variance	$<0.5 \times 10^{-8}$ (Locked to GPS, Measurement duration = 100 s)
Maximum Time Interval Error (MTIE)	< 80 nsec (Unlocked to GPS, Measurement duration = 1 s)

Exhibit 30 Allan Variance and MTIE

The phase noise (dBc/Hz) of the Frequency Reference with or without GPS is specified to be with the envelope defined in the following Exhibits. Freq Ref has been specifically designed to provide an ultra low phase noise suitable for mobile communications networks.

Frequency	Phase Noise
100 Hz	-100 dBc/Hz
1 KHz	-120 dBc/Hz
10 KHz	-135 dBc/Hz
100 KHz	-135 dBc/Hz

Exhibit 31 Freq Ref phase noise envelope

Spurious emissions (dBc) of the Freq Ref shall be within the envelope defined in the following Exhibit.

Frequency Bands	Phase Noise
1 KHz to 10 KHz	-115 dBc
10 KHz to 100 KHz	-100 dBc
100 KHz to 1 MHz	-70 dBc

Exhibit 32 Spurious emissions

2.6 Safety

The TM3 is compliant with

- UL 60950, Third Edition including CSA (Canadian Standards Association) CAN/CSA C22.2 No. 60950-00.
- EN 60950:2000 including national conditions and deviations in Annex ZB and ZC.

2.7 Shock and Vibration

2.7.1 Shock

The TM3 meets the drop test requirements identified in Section 4.3 of Telcordia GR-63-CORE.

2.7.2 Vibration

The TM3 meets the following vibration scenarios with the module securely located on a test fixture via its four mounting holes. This provides conditions consistent with those expected to be encountered in a target system.

2.7.2.1 Transportation Vibration

The TM3 meets or exceeds its specified operating parameters after being subjected to this vibration scenario. (i.e. the TM3 is not operational during this test)

Transport vibration is simulated using the power spectral density (PSD) versus frequency curve defined in the following Exhibit.

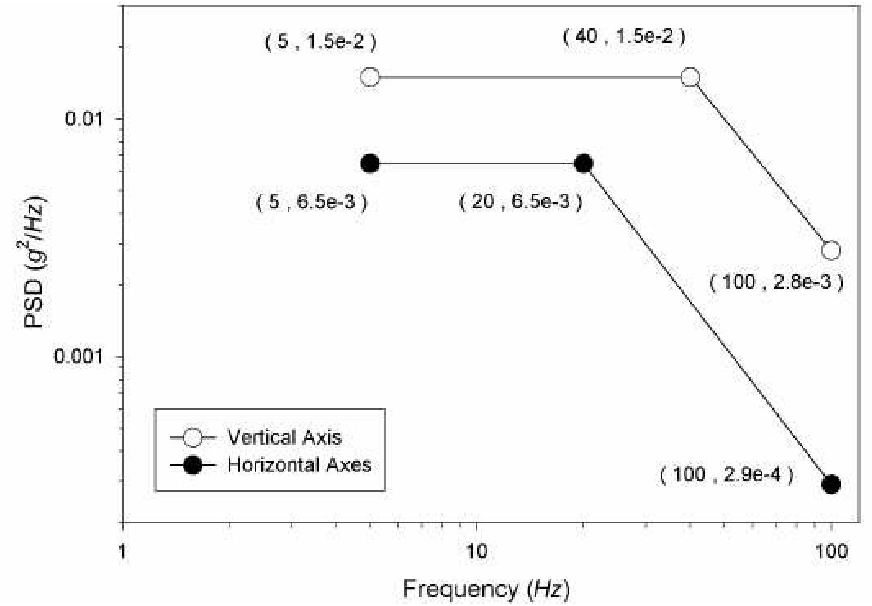


Exhibit 33 Transportation Vibration Spectrum: Shipping orientation established

2.7.2.2 Office Vibration

The TM3 meets or exceeds its specified operating parameters whilst subjected to this vibration scenario. (i.e. the TM3 is operational during this test).

Office vibration is simulated using the power spectral density (PSD) versus frequency curve defined in the following Exhibit. The PSD curve is defined by four straight lines on a log-log plot, connected by the points: (5 Hz, 9e-4 g2/Hz), (30 Hz, 4.2e-3 g2/Hz), (70 Hz, 5.3e-3 g2/Hz), (165 Hz, 9e-4 g2/Hz), (500 Hz, 9e-4 g2/Hz). A three-minute vibration dwell is to be performed in each axis at room temperature.

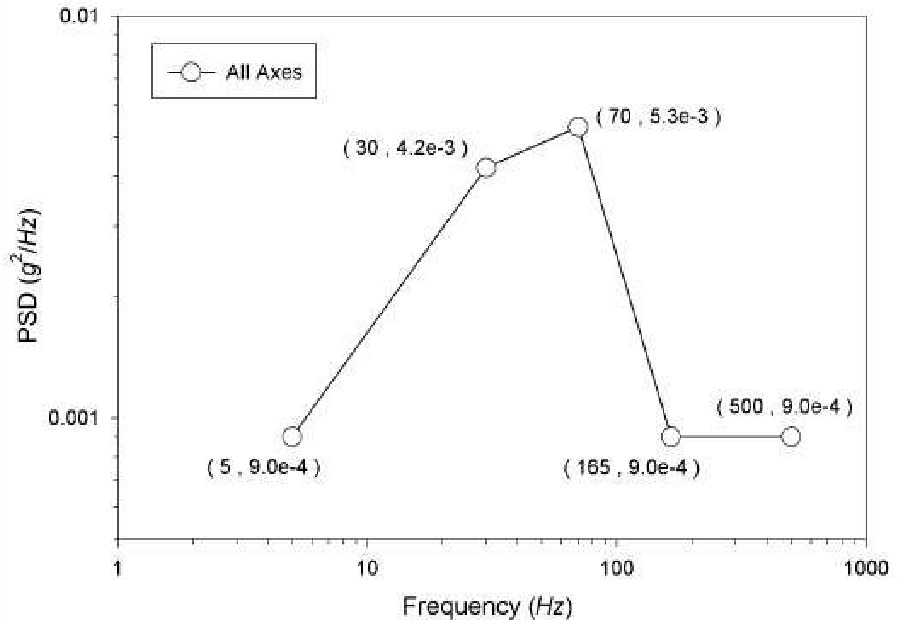


Exhibit 34 Office Vibration Spectrum

2.7.2.3 Earthquake Vibration

The TM3 meets or exceeds its specified operating parameters immediately before and after being subjected to this vibration scenario. Whilst the TM3 is not guaranteed to meet its specified operating parameters during this test, it will automatically return to a standard operating condition without operator intervention.

Earthquake conditions are simulated by performing a 30-second sinusoidal vibration dwell in each axis, at room temperature. The test consists of 5 g dwell at 10 Hz. The TM3 is attached to a test fixture at locations consistent with in-use conditions

2.8 Emissions

The TM3 complies with the following specifications when tested in an open air environment and mounted on a TM3 support board. This support board is the printed circuit board assembly provided as part of the TM3 Evaluation Unit. Emission tests were conducted without the metal enclosure usually provided to house the support board.

The specified limits apply to the E-Field intensity measured at 3 m with the unit placed, free standing, on a table 0.8 m above the reference ground plane.

The unit outputs are terminated with their normal interface impedances including the RF port (terminated with normal RF cable and impedances). An EM quite DC power source is used to supply the TM3. Measurements are made following the general procedures of EN 55022/CISPR 16 and ANSI C63.4

For frequencies below 1 GHz, measurements shall be made with a resolution bandwidth of 120 kHz and for frequencies above 1 GHz, the measuring bandwidth is 1 MHz.

Standard	Country
FCC Part15	America
GR-1089-CORE	America
CISPR	International

Exhibit 35 Emissions Compliance

Frequency Range	Limit
10 kHz to 30 MHz	46 dbV/m
30 MHz to 230 MHz	30 dbV/m
230 MHz to 1 GHz	36 dbV/m
1 GHz to 12.75 GHz	44 dbV/m

Exhibit 36 Radiated Emissions Limits

2.9 Immunity / Jamming Performance

The TM3's susceptibility to continuous wave jamming is defined in the following Exhibit.

CW Frequency	Comment	CW Power with respect to -140 dBW
1569.42 MHz	L1 - 6 MHz	66 dBc
1571.42 MHz	L1 – 4 MHz	51 dBc
1575.42 MHz	L1	25 dBc
1578.42 MHz	L1 + 3MHz	51 dBc
1582.42 MHz	L1 + 7 MHz	66 dBc

Exhibit 37 TM3 Jamming Susceptibility

The TM3 is immune to broadband jamming with jamming-to-signal power density ratio of 20 dB or less with an input signal strength of –130 dBm.

2.10 Environmental

2.10.1 Operational

The TM3 operates to the parameters specified in this document within a temperature band of -40℃ to +85˚C over a humidity range of 5% to 95%, n on-condensing.

2.10.2 Storage

The TM3 operates to the parameters specified in this document after being stored in a temperature range of -40℃ to +85˚C for a suitable p eriod of time.

2.10.3 Altitude

The TM3 operates within its specified parameters for an altitude range of -400 m to +8,000 m relative to sea level.

2.11 RoHS Compliance

RoHS (Restriction of Hazardous Substances) is the name given to the European Union's directive 2002/95/EC restricting the use of six hazardous substances (lead, mercury, cadmium, hexavalent chromium, PBBs [Polybrominated biphenyls] and PBDEs [Polybrominated diphenyl ethers]) in electrical and electronic equipment. The TM3 is compliant with the relevant sections of this directive.

2.12 Mean Time Between Failures (MTBF)

Reliability is calculated in accordance with Telcordia SR-332 for a unit operating at full power.

Product	MTBF (years)			
	@ 40degC	@ 50degC	@ 60degC	@ 70degC
TM3.02EH	224	134	80	49

3 Interface Control Protocols

Communications with the TM3 is achieved over the "Tx1/Rx1" serial interface. Essentially three interface control protocols can operate over this interface at the same time to change the configuration of the TM3 and request or receive status reports. The three protocols supported are:

1. Standard NMEA0183,
2. SigNav proprietary extensions which supplement the NMEA standard,
3. Motorola extensions necessary for compatibility with M12+ and M12M applications.

The proceeding sections outline the message set supported by the TM3 for each of these protocols. For such details as message contents, usage and syntax, the reader is referred to the companion documentation:

Interface Control Document: NMEA Protocol
Interface Control Document: Motorola Protocol

3.1 NMEA Protocol Support

The following Exhibits outline the NMEA commands, requests and reports supported by the TM3-02EH.

Identifier	Function	Type
ALM	Configure/Report all current alamanac data	Command/Report
GGA	Report current position solution (Lat/Long/Alt radians)	Report
GLL	Report position & time	Report
GPQ	Immediately issue requested report	Request
GSA	Report SVs used in current position solution	Report
GSV	Report tracking status (SVNo, Az, Elv, Sig Str)	Report
RMC	Report position output report	Report
VTG	Report velocity	Report
ZDA	Configure/Report time and date	Command/Report

Exhibit 38 Standard NMEA Commands and Reports Supported

Identifier	Function	Type
CAR	Clears non-volatile memory and resets receiver	Command
CHL	Downloads/Reports constellation health for all SVs	Command/Report
CLR	Stops all periodic and scheduled reports	Command
CST	Time Set Command	Command
EPH	Downloads/Reports ephemeris data for a single SV	Command/Report
EPL	Reports ephemeris data for all visible SVs	Report
FIX	Configures/Reports fix mode used in position & time solutions	Command/Report
FOR	Switch to Motorola Protocol	Command
HLD	Hold Position Command and report	Command/Report
ION	Configures/Reports user provided ionospheric corrections	Command/Report
ITC	Configures/Reports Ionosphere and Troposhere models used	Command/Report
LLH	User provided latitude, longitude & height	Command
MSK	Sets/Reports the satellite mask angles	Command/Report
PPC	Configures/Reports PPS Parameter Configuration	Command/Report
REQ	Report on update report list	Report
RST	Resets receiver	Command
RQA	Request aiding from the host	Request
SAK	Signav acknowledgement of a command	Report
SAV	Save all current data to NV memory	Command
SCH	Requests/Declares reports scheduled for output (periodically/on update)	Request/Report
SNM	Serial number report	Report
SSR	SigNav Status Report for each TS pulse	Report
SUD	SigNav Upgrade Data command	Command
SUE	SigNav Upgrade End command	Command
SUR	SigNav Upgrade Report command	Command/Report
SUS	SigNav Upgrade Start command	Command
SVY	Configures/Reports self surveyed length	Command/Report
TAC	Grants permission to the TM3-02EH to perform a realignment event.	Command
TOL	Configures/Reports tolerance settings	Command/Report
TRS	Configures/Reports Time Transfer Filter RAIM settings	Command/Report
TZO	Time Zone Offset	Command
UNC	Accuracy of Time, Freq and Position	Report
UTC	UTC Parameters Report	Report
VER	Current Version	Report
XYZ	Configure\Report user provided XYZ position	Command/Report

Exhibit 39 SigNav Proprietary Commands and Reports

3.2 Motorola Protocol Support

The following Exhibit outlines the M12 binary protocol commands supported by the TM3.

Function	Receive Command	Transmit Command
Satellite Mask Angle	@@Ag	@@Ag
Ionospheric Correction Select	@@Aq	@@Aq
Position Hold Parameters	@@As	@@As
Time Correction Select	@@Aw	@@Aw
PPS Time Offset	@@Ay	@@Ay
PPS Cable Delay	@@Az	@@Az
Visible Satellite Data	@@Bb	@@Bb
Almanac Status	@@Bd	@@Bd
Almanac Data Request	@@Be	@@Cb
UTC Offset Output	@@Bo	@@Bo
Request UTC / Ionospheric Data	@@Bp	@@Co
Almanac Data Input	@@Cb	@@Ch
Set to Defaults	@@Cf	@@Cf
Switch to NMEA Protocol	@@Ci	@@Ci
Receiver ID	@@Cj	@@Cj
Current Position	@@Ga	@@Ga
Combined Time	@@Gb	@@Gb
PPS Control	@@Gc	@@Gc
Position Control	@@Gd	@@Gd
T-RAIM Mode	@@Ge	@@Ge
T-RAIM Alarm Control	@@Gf	@@Gf
Leap second pending	@@Gj	@@Gj
12 Channel Position/Status/Data	@@Ha	@@Ha
12 Channel Short Position	@@Hb	@@Hb
12 Channel T-RAIM Status	@@Hn	@@Hn
Self-Test	@@Ia	@@Ia

Exhibit 40 Motorola Commands Supported

Note:
Dialogue with the TM3 using Motorola commands may be achieved by using the WinOncore[2] package. At the time of writing, this is available from http://www.synergy-gps.com[3]

[2] *Copyright© Motorola*
[3] *Site owned and operated by Synergy Systems LLC*

4 Operation and System Integration

4.1 Target System Design Tips

When designing the target system to incorporate the TM3, it is important to observe the comments and instructions provided in this chapter to optimise performance.

4.1.1 Crisp Signal Edges

All signals generated on the TM3 and provided as outputs use standard logic signal levels and standard electrical drive from the gates on-board. As such no special electrical drive has been provided for long connection lines or signal line termination. The signal edges on the Timing and Frequency output need to be particularly clean. It is recommended that on the target system the PCB signal trace lengths be no longer than 100 mm leading to the TM3 connector. Signals should be routed over a multi layer board with an embedded ground or a separate ground wire running parallel and close to the signal from or to the TM3. This is standard practice for maintaining clean signal edges.

4.1.2 Electromagnetic Interference Guidelines

The frequencies or harmonics generated by the host system should provide sufficient guard band around the GPS frequency of 1575.42 MHz. Any interference in this band will degrade the TM3's sensitivity providing a lower signal to noise ratio. Potential sources of such "noise" are switch mode power supplies, clock signals and other RF sources such as radios etc. It is strongly recommended that during the design phase the host system be tested to identify potential interference issues.

Interference could manifest it self in the TM3 as a difficulty or inability to acquire (e.g. long Time To First Fix (TTFF)) and/or track satellites, restricting operation to only strong signal environments.

Where interferences sources are found, remedial design actions could include:

- Filtering
- Increasing rise times of clock edges
- Additional metal shielding

4.1.3 Grounding

The TM3 has been designed with four mounting holes. In addition to mounting, each hole also provides access to the TM3's ground plane. For optimal performance it is recommended that the TM3's ground plane be attached to the target system's ground plane. This should be achieved by using metal screws and metal spacers or posts to mount the TM3 in the target system. Any mounting arrangement should be tested to ensure ground plane continuity.

4.1.4 Mounting and Air Flow

Refer to Exhibit 4 for the mechanical envelope of the TM3. In addition to the clearances shown in this diagram, the designer should ensure that sufficient airflow is provided around the TM3 to prevent it exceeding its rated temperature through out the target system's rated operating environment.

4.2 Installation and Handling Precautions

4.2.1 Anti-static precautions

The TM3 is a static-sensitive device. To avoid damage, you must be grounded whenever you handle them.

Personal grounding can be achieved in a number of ways. The most common method is to wear a conductive wrist or ankle strap that is connected to a suitable earth point. Typically the straps are flexible bands with a minimum of a 1M resistor in the ground cords. These straps must be in contact with the skin to be effective. The use of anti-static floor matting and conductive footwear is an alternative however this method can only be used while standing. Any inspection operations or work performed on system modules must be carried out on a grounded conductive surface.

4.2.2 Antenna Placement

When mounting the antenna module, it is important to remember that GPS positioning performance will be most 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.

4.3 Firmware Downloading using the TM3 Programming Tool

Please read and follow the directions in the document accompanying the TM3-xxxx Programming Tool.

Do not interrupt the upgrade process.
Interruption to the upgrade process may result in the unit requiring a return to the factory for service.
If using the evaluation kit, it is recommended that the TM3 is powered by the supplied plug-pack even if the unit is connected via the USB. This is especially so during upgrade procedures.

Upgrading a TM3-02EH using the serial port method (see NMEA commands SUS, SUD and SUE) does not carry these risks.

4.4 Configuring TM3 Parameters

Once the TM3 has been loaded with operational firmware it is now ready to be configured for operation. Parameters such as T-RAIM selection, Self Survey Period and Antenna Calibration can be set over the **Tx1/Rx1** serial interface using a combination of Standard NMEA0183 commands, SigNav extensions and Motorola extensions. Please refer to Section 3 of this manual for further detail.

4.4.1 Settings saved to NV Memory

The following configuration settings are retained in the NV memory of the TM3 receiver on power down:

Parameter	Comments
NAV Data	The following NAV data decoded by the receiver is retained in NV memory: • Ephemeris • SV Clock Corrections • Almanac • Ionospheric corrections • UTC Parameters • Constellation health (each item is retained according to the timestamp/aging rules defined in IS-GPS-200)
• Fix Mode • Survey/hold position • Mask Angle • DOP Limits	The receiver will return to the previous fix mode, and restore a completed position survey/fixed position accordingly. **Note:** any restored positions are only trusted for a period of *15 minutes* from the time the record was saved.
Crystal data	Crystal offsets/aging properties etc
Serial configuration	Protocol in use (Motorola / NMEA)
Pulse configuration	Programmable pulse configuration
T-RAIM configuration	T-RAIM enable/disable, alarm limits etc
Scheduled reports	Scheduled/automatic output of Motorola binary and NMEA reports

During normal operation the receiver will update its NV memory record every 5 minutes, with the following exceptions:

1. Any settings changed using the Motorola binary protocol will immediately cause the NV record to be updated to reflect those changes.
2. An update to the NV record can be manually requested at any time using the SigNav NMEA extension *SAV* (see the Interface Control Document: NMEA Protocol).

4.4.2 TM3 configuration example

A typical TM3 standalone timing configuration is shown below:

Parameter	Setting
Fix Mode	Once an accurate position is obtained the receiver is able to provide a more accurate timing solution by constraining these unknowns and providing more observations for the time solution. Using one of the following Either: 1. Provide the receiver with an accurately surveyed position, and then set the position control mode to 'position hold'. OR 2. If an accurately surveyed position isn't available then allow the receiver to perform a self-survey by setting the position control mode to 'auto-survey'. Following a 10,000 fix survey the receiver will transition to 'position hold' mode using this surveyed position. (see the @@As and @@Gd Motorola binary commands)
T-RAIM configuration	T-RAIM - Enabled (see @@Ge Motorola binary command)
Delay corrections	Ionospheric & Tropospheric corrections – both Enabled (see @@Aq Motorola binary command)
Mask Angle	10 degrees [default] (see @@Ag Motorola binary command)

4.4.3 Operational Sequences and Modes

When a TM3-02EH is initialised upon the application of power or the instigation of a reset, the module can be subject to the following operational sequences and modes:

1 Processor initialisation

2 Acquisition assistance provided

3 Acquisition

4 Tracking leading to first fix (thus defining the Time-To-First-Fix, TTFF), after first fix Status 1 will go low

5 Stabilisation of timing outputs. Status 2 will go high

6 Continuous monitoring and control of timing accuracy during periods of tracking satellites and thus synchronisation with satellites transmissions

7 Periods of time when satellite tracking maybe temporarily lost but the timing accuracy is still good Status 1 will go high.. When the receiver cannot guarantee the quality of timing outputs **Status 2** pin will go low.

8 When satellite signals return and the timing outputs resettle Status will go low and **Status 2** pin will go high to indicate timing outputs are within tolerance.

During these states of operation several outputs that may be observed as described in the following subsections

4.4.4 FreqRef signal

FreqRef will output a frequency that is approximately 10 MHz until good timing accuracy is established. After a period of time, the **Status 2** pin will go high to indicate the timing output is operating within specified tolerance. Once this occurs the output frequency will exhibit very high accuracy according to the specification and is synchronised to GPS or UTC time.

4.4.5 PPS signal

The **PPS** signal is a high going pulse (200ms in duration) whose leading (first) edge defines the accurate timing output from the TM3. The **PPS** signal will be established within 10 seconds of the power being applied. As acquisition, first fix and timing control converges, the leading edge of the **PPS** will be pulled in to close alignment with the absolute GPS or UTC second with characteristics and accuracy defined in the specification.

4.4.6 Status1: “Loss of Lock” signal

While the TM3 system boots up, the **Status1** pin is active (high) indicating no time fixes can be performed or “Loss of Lock”. While position or time fixes can be performed, “Loss of Lock” is inactive (low). “Loss of Lock” does not by itself indicate that the timing outputs are accurate.

4.4.7 Status2: “Within Tolerance” signal

After the first position fix the location of the receiver is known to the firmware and following an additional period of time (called settling time), the **Status2** pin will be set active (set high) to indicate accurate timing has been reached. The TM3 is now considered to be in the “Within Tolerance” mode. At initialisation time this signal is set to the non-active (low) state.
Timing synchronisation is assessed each one second (typically) with the aim of controlling the accuracy of the timing signals. This can only be done while tracking one or more satellites, having gone through both the full position fix cycle (of the TTFF time duration) followed by the settling period to reach synchronisation with GPS time. If the receiver is unable to perform timing updates because there are insufficient satellites to internally synchronise the time, then the **Status2** pin is deactivated (set low). At any time later if signals return and synchronisation is re-established, then the **Status2** pin will be re-activated (set high).

4.4.8 Output signal summary

The following Exhibits summarise and illustrate the conditions referred to previously in this section.

Execution Phase	“FreqRef ” (square wave)	“PPS” (1 ms high pulse)
Initialisation	~ 10 MHz	Off
Within 10 seconds of Initialisation	~ 10 MHz	On (not accurate)
Tracking first satellite	~ 10 MHz	On (not accurate)
First position fix (at TTFF secs)	~ 10 MHz	On (not accurate)
After settling time (at TTL secs)	Accurate 10 MHz	On (accurate)
Loss of timing synchronisation See Exhibit 25	~ 10 MHz	On (initially accurate but with increasing error)

Exhibit 41 Output Signal Summary

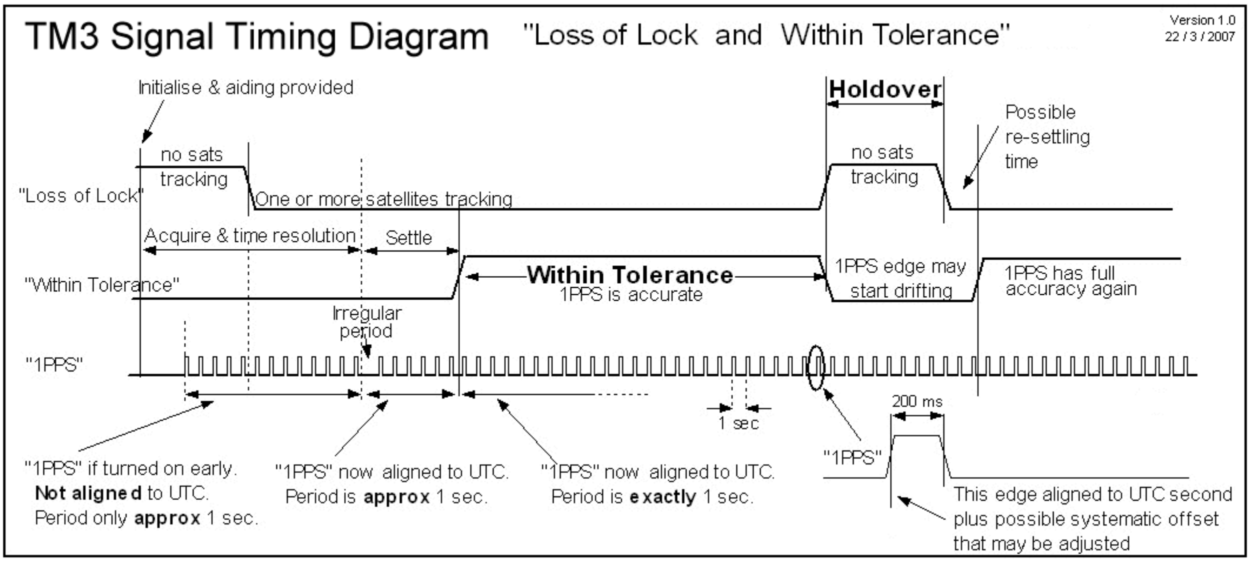


Exhibit 42 Start up Timing Diagram

Appendix 1: GPS Signal Strength Units of Measure

The GPS industry uses several units to measure satellite signal strength, dBW, dBm and dB.Hz. Conversions between each of these units of measure can be performed with the following relationships:

$$\text{dBm} = \text{dBW} + 30$$

$$\text{dB.Hz} \approx \text{dBW} + 200$$

Appendix 2: Identification of Firmware variants

Appendix 3: Warranty

SigNav Pty Limited warrants its hardware, firmware and software products against defective materials or workmanship for a period of 12 months commencing from the date of purchase.

Within the warranty period, at SigNav's discretion, SigNav may choose to repair or replace the defective product without charge for parts or labour. In repairing the product, new or reconditioned parts may be used. A replacement unit may be either a new or reconditioned unit of the same or similar design. Defective software or firmware will be replaced with either the same or a similar version of code providing the original functionality.

This warranty applies provided that the products are subject to normal use and operated and installed in accordance with the instructions given in the users manual, are not subject to damage by, but not limited to, accident (in transit or otherwise), misuse, abuse, fire, alteration, negligence, incorrect or incomplete installation or operation, tampering with or dismantling of the goods, Acts of God or foreign matter such as liquid, moisture or dirt, carry the original serial number applied at the time of manufacture, are not the subject of repairs or alteration in components or circuitry by persons other than SigNav or SigNav authorised maintenance or service personnel.

SigNav does not warrant that software and firmware products will be error free in all circumstances of their use and under all possible conditions and with all combinations of firmware, software and hardware whether it be firmware, software or hardware supplied by SigNav or by a third party. Defective goods must be returned to SigNav or a SigNav authorised service centre for repair or replacement. All transportation charges, either to or from SigNav or its service centres, will be at the customer's expense. The loss or damage of goods during said transit will be at the customer's risk.

This warranty in no way limits, varies or excludes the rights or remedies conferred by the Trade Practices Act.

Appendix 4: Glossary

2.5G	Generation of mobile/cell phone technology which enable high-speed data transfer over upgraded existing 2G networks
2G	Second generation mobile/cell telephony often referred to as s Personal Communications Service or PCS in the US.
3G	Third generation mobile/cell telephony designed to allow the transmission of very large quantities of data making is suitable for video applications
AGPS	Assisted GPS provides assistance data to receivers operating in weak to very weak signal strength environments where noise prevents the extraction of navigation data
A-GPS	See AGPS
ATM	Asynchronous Transfer Mode is a transport protocol that encapsulates voice and data traffic into small fixed-sized, 53 byte cells
BSC	Base Station Controller, a subsystem in a GSM mobile/cell phone network
CDMA	Code Division Multiple Access. A digital mobile/cell phone transmission technology
CR	Carriage Return a control character in ASCII code, unicode or EBCDIC that commands a device to move the position of the cursor to the first position on the same line
dB.Hz	Signal to Noise ratio expressed as relative power in a 1Hz bandwidth as reported by the GPS receiver
dBm	Strength of a signal expressed in decibels (dB) relative to one milliWatt (mW)
dBW	Strength of a signal expressed in decibels (dB) relative to one Watt (W)
E911	Refers to the U.S. Federal Communications Commission's Enhanced 911 mandate requiring mobile/cell phone location technology enabling emergency services to pinpoint the geographic position of a caller
EVT	SigNav's visual GPS evaluation tool
GPS	Global Positioning System
GSM	Global System for Mobile communications. A digital mobile/cell phone transmission technology
IP	Internet Protocol. A network layer protocol used in connectionless transport of information packets
LF	Line Feed a control character in ASCII code, unicode or EBCDIC that commands a device to move the position of the cursor to the next line
M12+	A Motorola GPS Module
M12M	A Motorola GPS Module
MMCX	A type of connector used in Radio Frequency (RF) applications
MSC	Mobile Switching Centre, a part of a GSM, TDMA, CDMA, or cellular network
MTBF	Mean Time Between Failures
NMEA	The National Marine Electronics Association (NMEA) is the unifying force behind the entire marine electronics industry
NTP	Network Time Protocol is used to synchronise device clocks over IP networks
PBB	Polybrominated biphenyls. A hazardous substance used in the fabrication of early electronics
PBDE	Polybrominated diphenyl ethers. A hazardous substance used in the fabrication of early electronics
PC	Personal Computer

PCB	Printed Circuit Board
PPS	Pulse Per Second. An output of a GPS timing module that delivers a pulse every second aligned to UTC
RoHS	Restriction of Hazardous Substances. An environmental mandate to reduce the use of hazardous materials in the electronics industry
SDH	Synchronous Digital Hierarchy is a European standard for high speed communications over optical fibre
SONET	Synchronous Optical NETwork is a standard for high speed communications over optical fibre
subATTO	SigNav's high sensitivity assisted GPS technology
TCP	Transmission Control Protocol. A transport layer protocol that provides reliable, full-duplex data transmission over IP networks
TDMA	Time Division Multiple Access is a second generation (2G) mobile/cell phone standard
TM3	A SigNav family of timing modules
TM3-01	Part code for a TM3 variant
TM3-02	Part code for a TM3 variant
TM3-02EH	Part code for a TM3 variant
T-RAIM	Time-specific Receiver Autonomous Integrity Monitoring a mechanism used to eliminate timing errors due to inaccurate satellites signals
TTFF	Time To First Fix is a measure of the elapsed time required for a receiver to acquire the satellite signals and navigation data, and calculate the first position solution. This is typically measured under various conditions such as cold start (GPS receiver has a valid almanac stored), warm start (GPS receiver has valid ephemeris and almanac data but not an accurate time) and hot start (GPS receiver has valid ephemeris, almanac and time)
USNO	US Naval Observatory
UTC	Universal Time Coordinate is a high-precision atomic time standard which is the basis for legal civil time all over the Earth. It is also referred to as Zulu time (Z), or using the term "Greenwich Mean Time" (GMT)
WLL	Wireless Local Loop a wireless communications technology used for the "last mile" delivery of telephony and internet services to customers